Santonian to Palaeocene tectonics of the East-European craton and adjacent areas

by Anatoly M. NIKISHIN, Peter A. ZIEGLER, Randell A. STEPHENSON & Maria A. USTINOVA

Abstract

During the Senonian to Palaeocene times the East European Craton or Platform was affected by polyphase regional compression stresses. It led to different kind intracratonic compressional tectonics including gentle lithosphere folding (buckling) with spacing close to 500-600 km, origin (or reactivation) of inversion structures mainly along former rifted basins, syn-compressional rapid subsidence of some former rifted basins like Dnieper Basin, acceleration of salt diapirism in the Peri-Caspian Basin, possible compression-related (impactogen) rifting in the Ukrainian Shield. The compression related intracratonic tectonics coincided with collision events along Tethyan belt along Pontides and other zones. The Laramide orogeny was widespread round the Earth, and it could have led to global environmental changes at the Cretaceous/Palaeogene boundary.

Key-words. East-European Craton, Cretaceous/Palaeocene boundary, inversion tectonics, Laramide orogeny, deformations, palaeotectonic reconstructions.

Résumé

Du Sénonien au Paléocène, le Craton ou Plate-forme est-européen a subi des contraintes de compression régionale polyphasée. Il en est résulté différents types de tectoniques de compression intracratoniques incluant un plissement faible de la lithosphère ("buckling") à une distance proche de 500-600 km, l'origine (ou la réactivation) de structures d'inversion principalement le long d'anciens bassins d'effondrement, une subsidence *syncompressionaire* rapide de certains bassins d'effondrement anciens comme le Bassin du Dnieper, une accélération du diapirisme lié au sel dans le Bassin de la Caspienne (Peri-Caspian Basin), un effondrement possible lié à la compression (impactogène) dans le Bassin ukrainien. La compression liée aux tectoniques intracratoniques a coïncidé avec des collisions le long de la ceinture téthysienne, des Pontides et d'autres zones. L'orogenèse Laramide s'est fait largement ressentir sur la Terre et a pu conduire à des changements globaux d'environnements à la limite Crétacé/Paléogène.

Mots-clefs: Craton est-européen, limite Crétacé/Paléocène, tectonique d'inversion (inversion tectonique?), orogenèse Laramide, déformations, reconstructions paléotectoniques.

Резюме

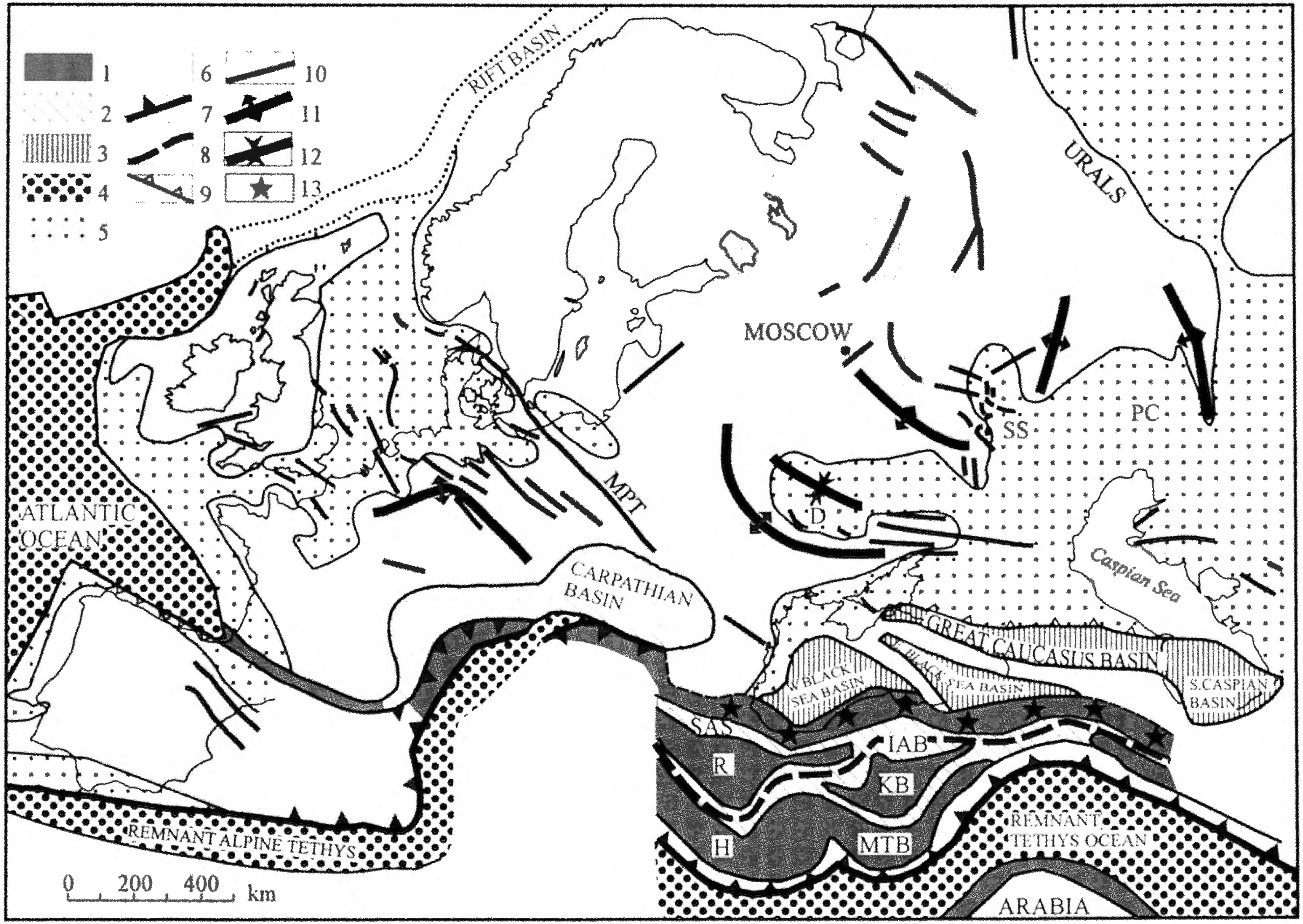
В сеноне-палеоцене Восточно-Европейский кратон испытал полифазное региональное сжатие. Это сжатие привело к разным типам компрессионной тектоники: к пологой литосферной складчатости с расстоянием между осями складок около 500-600 км; к формированию или активизации инверсионных структур в основном вдоль палеорифтов; к синкомпрессионному быстрому погружению некоторых рифтогенных бассейнов типа Днепровского; к активизации соляного диапиризма в Прикаспийской впадине; к вероятному импактогенному синкомпрессионному рифтогенезу на Украинском щите. Компрессионная тектоника внутри кратона была синхронна с коллизионными процессами вдоль пояса Тетис в Понтидах и других зонах. Ларамийская орогения имела глобальный характер и она могла привести к глобальным изменениям среды около мел-палеогеновой границы.

Ключевые слова: Восточно-Европейский кратон, мел/палеогеновая граница, инверсионная тектоника, ларамийская орогения, деформации, палеотектонические реконструкции.

Introduction

The Late Cretaceous to Palaeocene tectonic history of Western Europe has been described in detail by ZIEGLER (1990), but for Eastern Europe it was briefly discussed in ARKHANGELSKY (1922), SHATSKY (1964), GERASIMOV *et al.* (1962), E. V. MILANOVSKY (1940) and E. E. MILANOVSKY (1987), without detailed analysis of tectonic events. There is disagreement between authors on the palaeotectonic reconstruction of Europe at the Cretaceous/Palaeocene boundary (ZIEGLER, 1990; DERCOURT *et al.*, 1993; YILMAZ *et al.*, 1997, STAMPFLI *et al.*, 1998). In this paper we will try to combine all available data and reconstruct the tectonic history of Eastern Europe at the Cretaceous/Palaeocene (K/T) boundary in connection with regional tectonic events.

From the Senonian to the Palaeocene, Subhercynian and Laramide inversion tectonics affected large parts of the northern Alpine and Carpathian foreland of Europe (Fig. 1; ZIEGLER, 1990; ZIEGLER *et al.*, 1995; NIKISHIN *et al.*, 1997a) as well as the Alpine and Taurides foreland in Africa and Arabia, respectively (GUIRAUD & BOSWORTH, 1997). Subhercynian and Laramide inversion structures on the East-European Craton and its margins were described in detail by E. V. MILANOVSKY (1940) and are shown on the published maps of BOGDANOV & KHAIN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RIFT BASIN
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CARPATHIAN BASIN
Caspian Sea
GREAT CAUCASUS BASIN
BLACK SEA BASIN
SEA BASIN
S.CASPIAN BASIN
SAS
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KB
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MTB
REMNANT TETHYS OCEAN
REMNANT ALPINE TETHYS
ARABIA
0 200 400 km

(1981). Classical examples of tensional basins that were inverted during the latest Cretaceous and Palaeocene are the Donets Basin [Donbass] - that formed part of the Mid-Late Devonian Dnieper-Donets-Karpinsky rift belt (E. E. MILANOVSKY, 1987; STOVBA *et al.*, 1996), the Mid-Polish Trough (KUTEK, 1994; DADLEZ *et al.*, 1995), the Pre-Volga belt (e.g. Don-Medveditsa, Saratov dislocations; E. V. MILANOVSKY, 1940; E. E. MILANOVSKY, 1987), and the Pachelma aulacogen (Oka-Tsna, Kerensk-Chembar and Sura-Moksha swells; BOGDANOV & KHAIN, 1981; E. E. MILANOVSKY, 1987). Additional similar features, including the Soligalich, Sukhona and Vyatka swells, have also been described (BOGDANOV & KHAIN, 1981; E. E. MILANOVSKY, 1987; NIKISHIN *et al.*, 1997a; USTINOVA *et al.*, 1998). On the East-European Craton (EEC), the main problem is to precisely date the deformation age of these intraplate compressional features, since most of them were deeply truncated during Cenozoic times, and were deformed both in pre-Cretaceous times and during the Late Cenozoic Alpine orogeny. In any case, the European continent was affected by important phases of intraplate compression during Senonian to pre-Eocene times.

Late Cretaceous to Palaeocene inversion structures of the EEC and its margins

The *Mid-Polish Trough* is located along the western margin of the EEC (Fig. 2). For the history of this basin we follow data from ZIEGLER (1990), KUTEK (1994), DADLEZ *et al.*, (1995) and E. Gazdzicka (personal communication, 1998). The basin was formed as a rift belt during the Late Permian-Early-Middle Triassic. During the Late Triassic to Early Cretaceous the rifted basin underwent postrift subsidence accompanied by stress events. The Late Cretaceous history of the basin was very complicated (ZIEGLER, 1990; DADLEZ *et al.*, 1995; E. Gazdzicka, personal communication, 1998): during Cenomanian-Turonian times the basin underwent rapid syn-compressional subsidence which was followed by polyphase inversion of the basin. The timing of the inversion is not precisely known, but it has been suggested that the local uplift started in the Coniacian-Santonian, was more active in the Campanian, and that the main inversion phase with an amplitude of the uplift up to 2-3 km, took place in the Maastrichtian-early Palaeocene.

The Pripyat-Dnieper-Donets (PDD) Basin is located in the southern part of the EEC (Fig. 2). The history of this basin is discussed in E. E. MILANOVSKY (1987), NIKISHIN *et al.* (1996), STOVBA *et al.* (1996) and STOVBA & STEPHENSON (1999). The PDD Basin was a rift basin in the Late Devonian and underwent post-rift subsidence in the Carboniferous to Cenozoic times, complicated by numerous stress events. The PDD Basin has three segments: the Pripyat Basin, the Dnieper (or Dnieper-Donets) Basin, and the Donets Basin (or Donbass).

During the Early Cretaceous *the Dnieper Basin* in the Ukraine had a very low subsidence rate (GERASIMOV *et al.*, 1962; KAPTARENKO-CHERNOUSOVA, 1971; IVANNIKOV *et al.*, 1991). During the Late Cretaceous the subsidence rate was higher; we can recognize two epochs of subsidence: Cenomanian to Coniacian (relatively low subsidence rate with up to 280 meters sediment thickness), and Santonian to Maastrichtian (relatively high subsidence rate with 700 meters sediment thickness). As we will see below the Campanian-Maastrichtian (or even Cenomanian to Maastrichtian) subsidence took place in a regional compressional tectonic environment; and we suggest that the compressional stress caused the rapid subsidence [as was discussed for the Mid-Polish Trough in DADLEZ *et al.*, (1995)]. An erosional event took place in the Dnieper Basin at the Maastrichtian/ Palaeocene boundary: late Maastrichtian to early Danian deposits are missing (MORROZ, 1970; IVANNIKOV *et al.*, 1991), and late Danian(?)- Thanetian marine to continental deposits cover Maastrichtian sediments (MORROZ, 1970).

The Donbass in the Ukraine and Russia underwent a few inversion events between the Permian and earliest Jurassic times (E. E. MILANOVSKY, 1987; STEPHENSON, 1997; NIKISHIN *et al.*, 1998b; STOVBA & STEPHENSON, 1999). It was a relatively uplifted area mainly during the Early Cretaceous (GERASIMOV *et al.*, 1962). For the Late Cretaceous history of the Donbass we used data from GERASIMOV *et al.* (1962), NAIDIN (1960, 1969), BLANK & GORBENKO (1968), KAPTARENKO-CHERNOUSOVA (1971), SAVCHINSKAYA (1982), E. E. MILANOVSKY (1987), IVANNIKOV *et al.* (1991) and STOVBA *et al.* (1996). During the Cenomanian to Coniacian the Donbass was part of a large, shallow water to continental

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Fig. 1 — Tectonic scheme of Europe for the Senonian to Palaeocene time (mainly at the time close to the K/T boundary). Map of Western Europe is prepared after ZIEGLER (1990), mainly. 1 - active orogen, 2 - remnant deep-water mainly flysch basin, 3 - remnant deep-water back-arc basin, 4 - oceanic basin, 5 - Palaeocene intraplate sedimentary basin, 6 - Palaeocene eroded land in stable Europe, 7 - Palaeocene subduction zone, 8 - Late Cretaceous subduction zone, 9 - thrust belt of the Great Caucasus Basin, 10 - Senonian to Palaeocene inversional swell, 11 - intracontinental topographic arch (proposed gentle lithospheric anticline), 12 - intracontinental topographic depression (proposed gentle lithospheric syncline), 13 - Late Cretaceous magmatic arc. R - Rhodope Block, KB - Kirsehir Block, H - Hellenides, MTB - Menderes-Taurus Block, SAS - Srednogorie-Strandzha Basin (hypothetical), IAB - Izmir-Ankara Basin, MPT - Mid-Polish Trough, D - Dnieper Basin, SS - Simbirsk-Saratov Basin, PC - Peri-Caspian Basin. Remnant Tethys Ocean is shown not to scale.

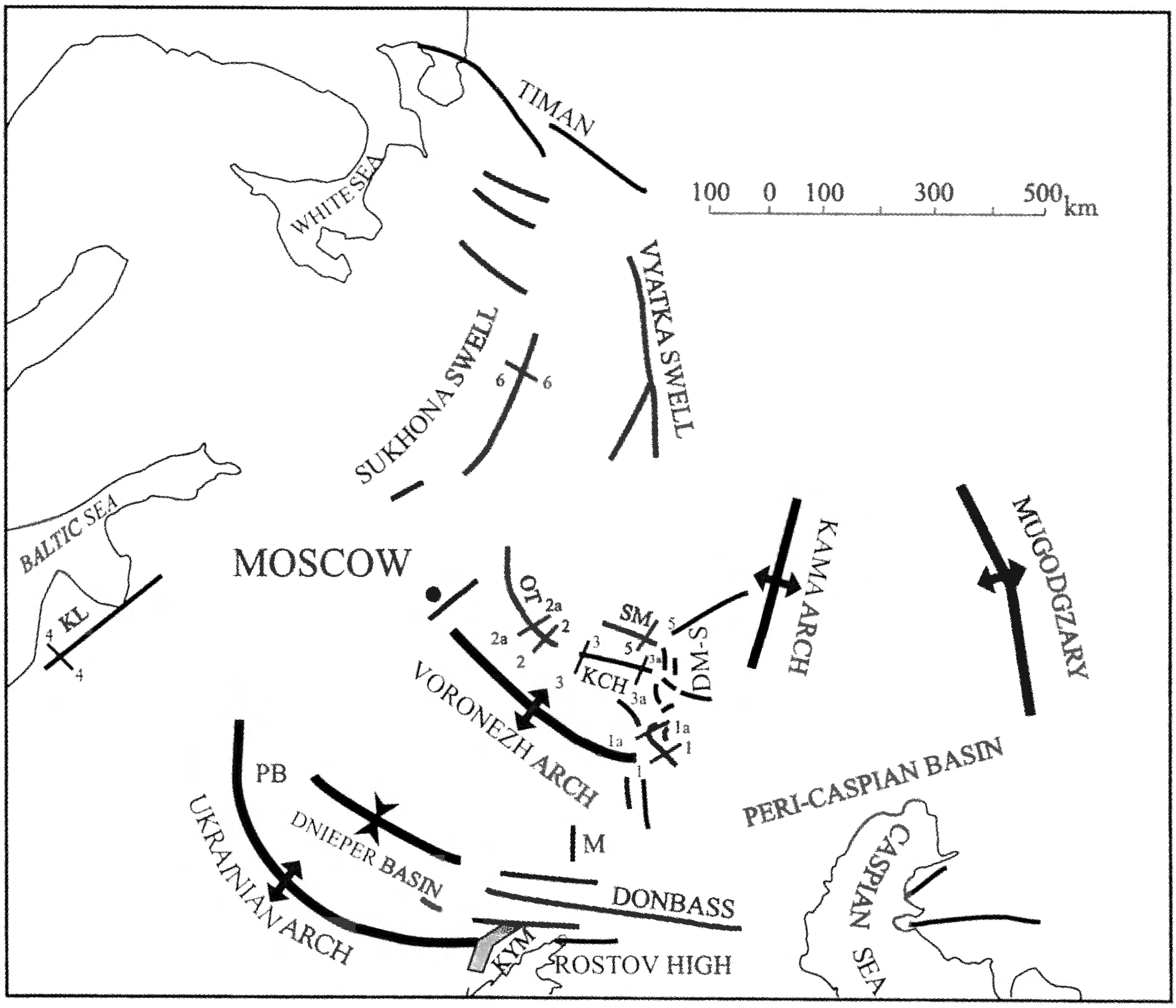

Fig. 2 — Location map for the main Late Cretaceous swells of the EEC and cross-sections for Fig. 3. 1-1 location of the cross section. KL - Klaypeda-Lokno Swell, OT - Oka-Tsna Swell, SM - Sura-Moksha Swell, KCH - Kerensk-Chembar Swell, DM-S - Don-Medveditsa-Saratov Swell belt, M - Millerovo Swell, KYM - Konka-Yaly-Molochnaya Basin, PB - Pripyat Basin.

sedimentary basin with minor evidence of local uplifting (in the Cenomanian). During the Santonian the Donbass started to uplift slowly: clastic sediments were supplied from the Donbass to the basin along the southern margin of the Donbass. An important change occurred in the Campanian (Naidin, 1960; Gerasimov *et al.*, 1962; Blank & Gorbenko, 1968; Savchinskaya, 1982; Ivannikov *et al.*, 1991): large scale clastic sediments were supplied by the uplifted Donbass both to the North and the South of the Donbass into the carbonate platforms. The maximum of this clastic supply was during the Late Campanian-Maastrichtian. Folding inside the Donbass and thrusting along its northern margins began at the Santonian/Campanian boundary with a maximum at the Cretaceous/Palaeocene transition; latest Maastrichtian deposits are missing along the northern margin of the Donbass (Blank & Gorbenko, 1968; E. E. Milanovsky, 1987; Ivannikov *et al.*, 1991; Stovba & Stephenson, 1999).

In the Pripyat Basin in Byelorussia only the youngest Turonian sediments are found. Post-Turonian Late Cretaceous marine sediments were eroded. Regional uplift of the Pripyat Basin region took place at the K/T boundary-Palaeocene (Gerasimov *et al.*, 1962; Beniamovsky, personal communication, 1998). At these times, minor reverse faulting occurred along some former rift faults (R. Garetsky, personal communication, 1998).

The Konka-Yaly Basin is located inside the Ukrainian Shield in the Ukraine to the South of the Donbass (Fig. 2) (Gerasimov *et al.*, 1962; Kaptarenko-Chernousova, 1971; Ivannikov *et al.*, 1991), and is oriented nearly orthogonally to the Donbass. *The Molochnaya* *(or Melitopol) Basin* lies directly to the South of the Konka-Yaly Basin. The Konka-Yaly and Molochnaya basins have a graben-like configuration (KAPTARENKO-CHERNOUSOVA, 1971; CHEKUNOV *et al.*, 1976); they were infilled by Cretaceous sediments (CHEKUNOV *et al.*, 1976; IVANNIKOV *et al.*, 1991). Using the data of CHEKUNOV *et al.* (1976) and IVANNIKOV *et al.* (1991) we can recognise two main minor rift events: an Albian (or Aptian-Albian) event with a subsidence close to 100 meters, and a Santonian-Maastrichtian event with a subsidence close to 200-350 meters. During these tectonic events mainly Precambrian faults were reactivated (KAPTARENKO-CHERNOUSOVA, 1971; CHEKUNOV *et al.*, 1976). The Aptian-Albian tension event could have been connected with a rifting related with the Black Sea Basin opening (NIKISHIN *et al.*, 1998b). We assume that during the Santonian-Maastrichtian times the Konka-Yaly-Molochnaya Basin was a graben-like tension structure of impactogen syn-compressional origin: it originated mainly along the axis of Late Cretaceous compressional stress, coinciding with the time of the Donbass uplift.

The Rostov High is located just to the south of the Donbass along the southern margin of the EEC. In this High the Early Eocene marine sediments cover gently folded Cretaceous strata including those of Maastrichtian age (ULANOVSKAYA, 1988). The Rostov High was part of the Donbass fold zone at the K/T boundary.

The Don-Medveditsa-Saratov Swell belt is located along the boundary between the Peri-Caspian Basin and the Russian Platform (Voronezh High), above the Devonian Don-Medveditsa rifted basin (E. V. MILANOVSKY, 1940; BOGDANOV & KHAIN, 1981; E. E. MILANOVSKY, 1987). The cross-section of this swell is shown on Figure 3. The swell underwent many inversion events since the Carboniferous. An important inversion took place during the Late Cretaceous. Data summarised in MORROZOV (1962), SENYUKOV (1949), SENCHENKO (1951) and IVANOV (1995) show that uplift inversion events took place in mid-Santonian, and at the Santonian-Campanian, Campanian/Maastrichtian, Maastrichtian/Danian boundaries. Sedimentological data show that in Campanian-Maastrichtian-Danian the Don-Medveditsa Swell was a source region for clastic sediments to the South and the East of the swell (MORROZOV, 1962), which means that the swell was an uplifted belt. Late Palaeocene deposits cover deformed Cretaceous strata (IVANOV, 1995).

The Millerovo Swell is parallel to the Don-Medveditsa Swell, 200 km to the west. It is a local anticline-like structure with an uplift of Late Cretaceous strata up to 40-50 meters (MORROZOV, 1962). It could have the same age as the Late Cretaceous deformations of the Don-Medveditsa Swell.

The Oka-Tsna Swell belt is located above the northern part and northern margin of the Riphean Pachelma aulacogen (rifted basin) in its northern prolongation (E. V. MILANOVSKY, 1940; BOGDANOV & KHAIN, 1981; E. E. MILANOVSKY, 1987) (Fig. 3). The swell had a long history, starting in the Carboniferous but its youngest deformed strata are of Santonian age (SAZONOV, 1953). An inversion phase took place possibly as early as the Santonian/Campanian transition, but it was definitely not younger than pre-Neogene.

The Kerensk-Chembar Swell is located along the northern margin of a central segment of the Riphean Pachelma rifted basin. *The Sura-Moksha Swell* is parallel to the Kerensk-Chembar Swell 70-100 km to the north, and it is not connected with a rifted basin (E. V. MILANOVSKY, 1940; BOGDANOV & KHAIN, 1981; E. E. MILANOVSKY, 1987) (Fig. 3). The swells have a polyphase deformation history. Late Cretaceous sediments are the youngest deformed strata. The available data show deformations at pre-Santonian, and also at the Santonian/Campanian and Campanian/Maastrichtian boundaries; they lasted until the Palaeocene (CHIBRIKOVA, 1951; SENCHENKO, 1951; SAZONOV, 1953; KHOKHLOV, 1955; DASHEVSKY, 1996). The main unconformity in the Sura-Moksha Swell is near the Santonian/Campanian boundary (A. Olferiev, personal communication, 1998).

The Vyatka Swell is located above the Vyatka (or Kirov, or Kazhim) Riphean and Devonian rifted basin in the eastern part of the EEC (E. V. MILANOVSKY, 1940; BOGDANOV & KHAIN, 1981; E. E. MILANOVSKY, 1987). The swell had a polyphase inversion history, but Albian strata are the youngest deformed ones. The deformations occurred in post-Albian times (ARKHIPOV & VYSOTSKY, 1996), and latest Cretaceous to Palaeocene ages are most likely. The *Sukhona Swell* is located above the Soligalich aulacogen in the Moscow Basin (BOGDANOV & KHAIN, 1981). The youngest deformed strata are of Albian age. And we assume as we did for the Vyatka Swell that the inversion occurred near the K/T boundary.

The Klaypeda - Lokno Swell belt trends in the Pre-Baltic region almost from Klaypeda (Lithuania), along the Lithuanian-Latvian boundary to the town of Pskov in Russia (BOGDANOV & KHAIN, 1981). This swell belt had a complicated inversion history. The Cretaceous strata are also deformed (Fig. 3). The swell belt is located not far from the Mid-Polish Trough and we suggest a Late Cretaceous to Palaeocene age for the inversion. New data show that compressional events took place in Lithuania at the Santonian/Campanian and Campanian/Maastrichtian boundaries at least (SLIAUPA, 1997, and personal communication, 1999).

The Timan Swell underwent many inversion events in pre-Cretaceous times (E. E. MILANOVSKY, 1987). It did not generally separate Early Cretaceous basins (E. Baraboshkin, personal communication, 1998) and was uplifted in post-early Cretaceous epochs. It is not excluded that an inversion event took place at the Cretaceous/Palaeogene boundary because some data show that compression deformations in the Polar Urals and Pay-Khoy lasted until the end of the Cretaceous (YUDIN, 1994).

The palaeogeography of *the Urals* is badly known for the time of the K/T boundary. Data for the Polar Urals show (ORESHKINA *et al.*, 1998) that Coniacian to Campanian shallow-water marine deposits are located along the western margin of the recent Urals and that they were formed in the former West Siberia Basin united with the Pechora Basin. Campanian deposits are covered with mid-Palaeocene marine sediments. An uplift of the Polar Urals could be suggested for the K/T transition. Detailed facial analysis demonstrates that the southern Urals (the Mugodzhary) were an uplifted area during Santonian to Danian (NAIDIN & KOTELNIKOV, 1998): sandstones and gravelites are found between Mugodzhary and the carbonate platform of the Peri-Caspian Basin. Generally we can assume that the Uralian foldbelt underwent uplift events near the K/T boundary, but an uplift event also took place at the Santonian/Campanian boundary (NAIDIN & KOTELNIKOV, 1998).

The Peri-Caspian Basin has numerous salt diapirs containing Kungurian salts (BOGDANOV & KHAIN, 1981; E. E. MILANOVSKY, 1987). Uplift of the diapirs occurred at irregular time intervals. Detailed data on the distribution of depositional thicknesses, facies and fossils show (BENIAMOVSKY *et al.*, 1973) that a rapid uplift of the diapirs took place in the Senonian to Palaeocene, mainly during regressive phases: at the Santonian/Campanian, the Campanian /Maastrichtian, the Maastrichtian/Danian, the Danian/Thanetian, and the Thanetian/Ypresian boundaries and also inside the Late Campanian; a maximum diapiric uplift took place at the Danian/Thanetian boundary. We can assume that the uplift events of the diapirs coincided with regional compressional events because similar compression events occur in the EEC.

Late Cretaceous to Palaeocene gentle lithosphere folds in the EEC

During the Senonian to Palaeocene times the EEC underwent long-wave deformations of its topography (Fig. 1). This can be seen mainly from palaeogeographical maps of NAIDIN *in* GERASIMOV *et al.* (1962) and from our own more recent data. During Cenomanian to Santonian times nearly the complete southern part of the EEC was a marine sedimentary basin; on the other hand from the Campanian to the Palaeocene an arching of the topography took place. Three main arches began to rise - the Ukrainian Shield together with the Byelorussian High (the Ukrainian-Byelorussian High), the Voronezh High, and the Kama High between the Simbirsk-Saratov and Peri-Caspian basins. These highs were separated by subsidence belts: the Dnieper Basin between the Ukrainian-Byelorussian and Voronezh highs, and the Simbirsk-Saratov Basin between the Voronezh and Kama highs. The amplitude of the arching was not more than 150-300 meters (today the top of the Cenomanian deposits is at the topographical level +220 meters on the Voronezh High, but the Dnieper Basin is at -500 to - 550 meters (BLANK *et al.*, 1992)). The distance between the axes of the arches (proposed lithospheric anticlines) is close to 500-600 km which is typical for intracratonic lithospheric folding (buckling) (ZIEGLER *et al.*, 1995; NIKISHIN *et al.*, 1997b)

Main types of the compression-related tectonics inside the EEC

As discussed above, the following compressional-related structures can be recognized inside the EEC from the Senonian to the Palaeocene: gentle lithosphere folding (buckling), origin of inversion structures, syn-compressional rapid subsidence of former rifted basins, acceleration of salt diapirism, compression-related (impactogen) rifting.

Late Cretaceous to Palaeocene tectonics in the Scythian Platform-Caucasus-Black Sea-Pontides-Moesian area

The Scythian Platform is located to the South of the EEC. Seismic profiling data show that minor inversion features developed on the Scythian Platform at the Cretaceous/Palaeocene boundary (NIKISHIN *et al.*, 1998a, b). In the Crimea, minor unconformities are evident at an intra-Santonian level, at the Maastrichtian/Danian boundary as well as at the transition from the Thanetian to the Danian and Ypresian to Thanetian (MURATOV, 1969; MAZAROVICH & MILEEV, 1989a, b). Relatively, the pre-Ypresian unconformity is the most important. The development of these unconformities is probably related to compression phases (NIKISHIN *et al.*, 1998b). Field data

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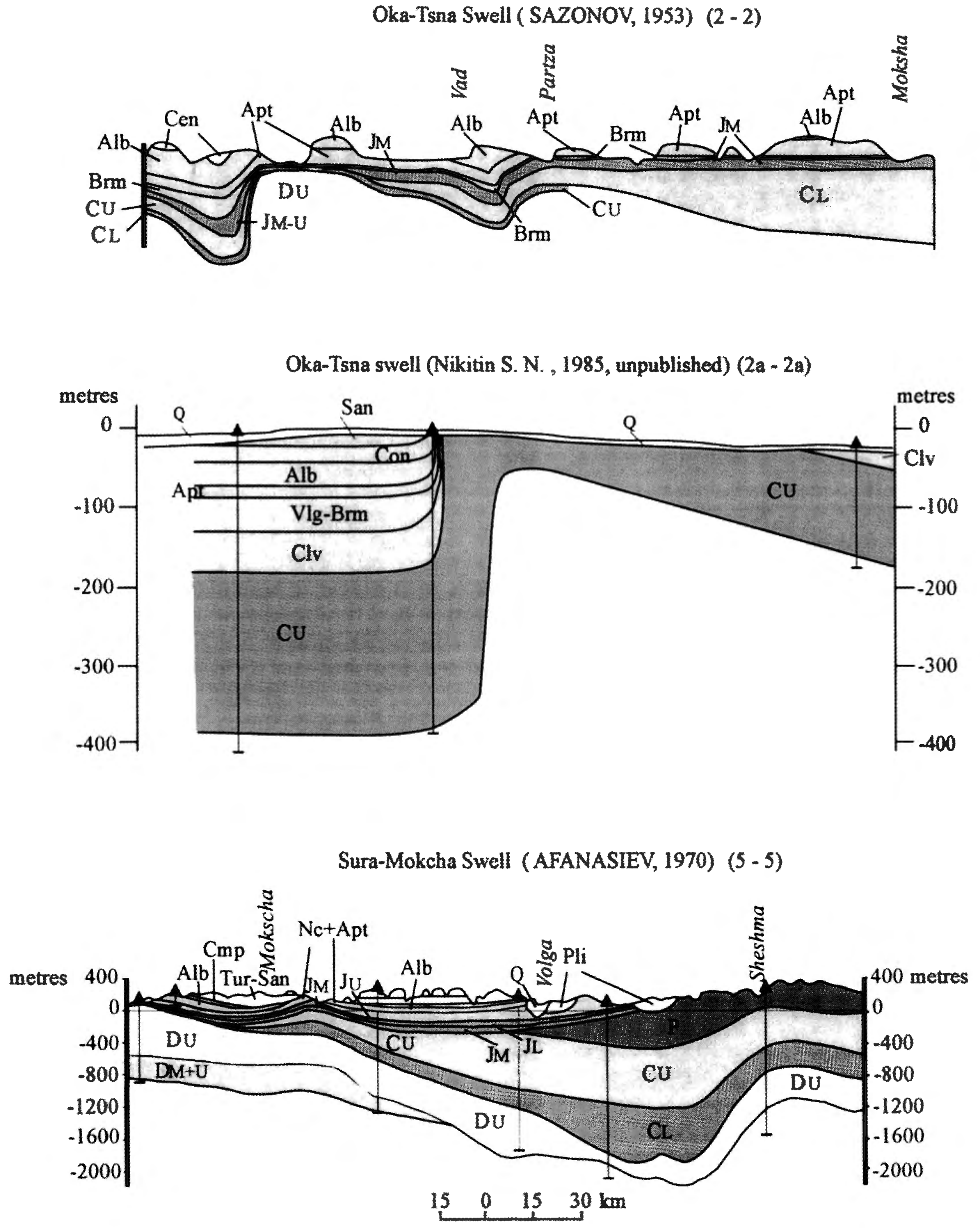
Figs 3a, 3b and 3c — Cross sections for some swells which were active during Senonian to Palaeocene times. Location of the cross-sections is shown on Fig. 2. Abbreviations: Q - Quaternary, Ne - Neogene, Pa - Palaeogene, K - Cretaceous, Ku - Upper Cretaceous, Kl - Lower Cretaceous, Cmp - Campanian, San - Santonian, Con - Coniacian, Tur - Turonian, Cen - Cenomanian, Alb - Albian, Apt - Aptian, Brm - Barremian, Nc - Neocomian, Vlg-Brm - Valanginian-Barremian, Ju - Upper Jurassic, Jm - Middle Jurassic, Jl - Lower Jurassic, Clv - Callovian, Bth - Bathonian, Baj - Bajocian, Tr - Triassic, Tl - Lower Triassic, Tat - Tatarian, P - Permian, Pu - Upper Permian, Pl - Lower Permian, C - Carboniferous, Cu - Upper Carboniferous, Cl - Lower Carboniferous, Fam - Famennian, Frs - Frasnian, Du - Upper Devonian, Dm - Middle Devonian, Ou+m - Middle and Upper Ordovician, Cmb - Cambrian, Vu - Upper Vendian, R - Riphean.


Oka-Tsna Swell (SAZONOV, 1953) (2 - 2)
Vad
Partza
Moksha
Alb
Cen
Apt
Alb
JM
Alb
Apt
Brm
Apt
JM
Apt
Alb
Brm
CU
CL
DU
JM-U
Brm
CU
CL
Oka-Tsna swell (Nikitin S. N. , 1985, unpublished) (2a - 2a)
metres
0
-100
-200
-300
-400
Q
San
Q
Con
Alb
Apt
Vlg-Brm
Clv
CU
CU
Clv
metres
0
-100
-200
-300
-400
Sura-Mokcha Swell (AFANASIEV, 1970) (5 - 5)
Mokscha
Nc+Apt
Cmp
Alb
Tur-San
JM
JU
Alb
Q
Volga
Pli
Sheshma
metres 400
0
-400
-800
-1200
-1600
-2000
DU
DM+U
CU
JM
JL
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CU
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400 metres
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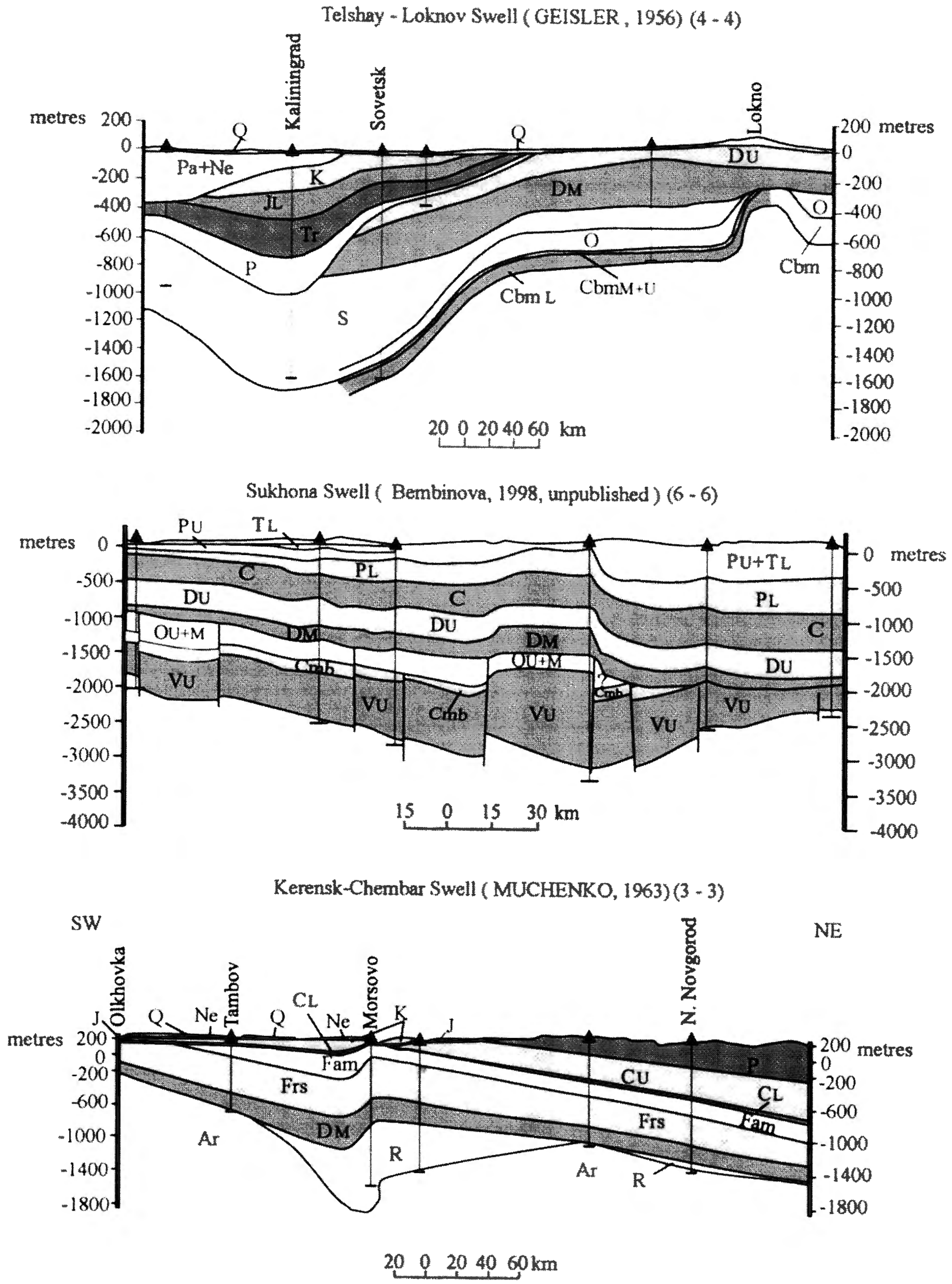
15 0 15 30 km

Fig. 3a


Telshay - Loknov Swell (GEISLER , 1956) (4 - 4)
Kaliningrad
Sovetsk
Lokno
metres
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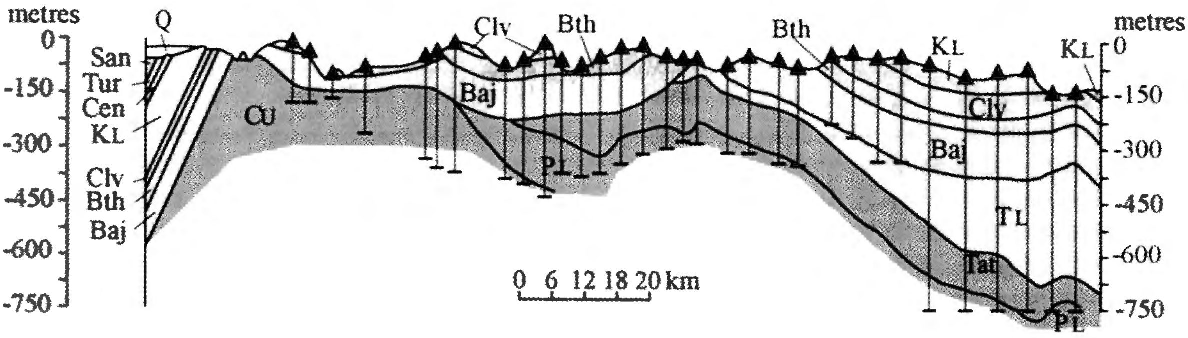
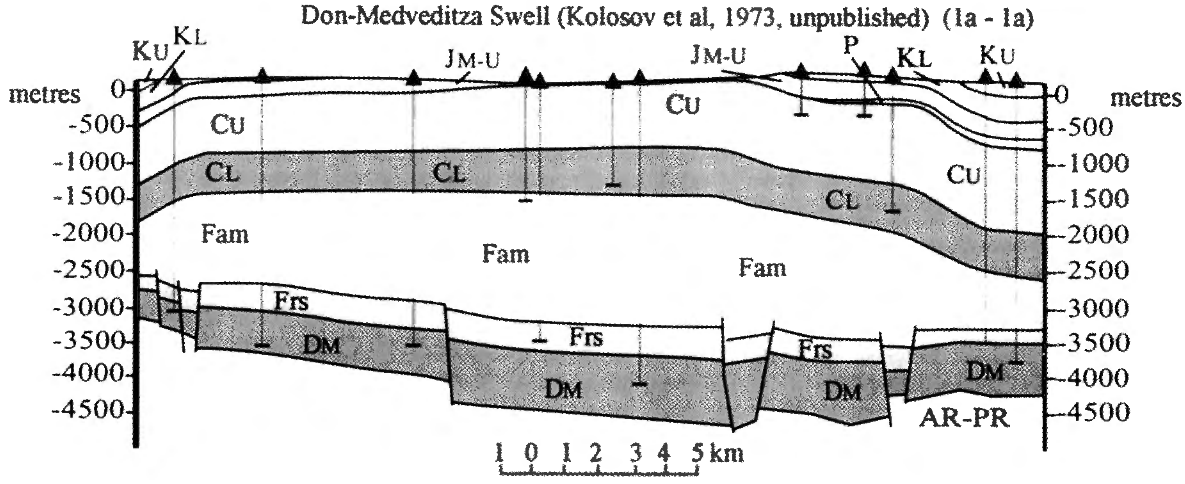
Cbm L
CbmM+U
20 0 20 40 60 km
Sukhona Swell (Bembinova, 1998, unpublished) (6 - 6)
metres
0 metres
PU
TL
PU+TL
PL
C
DU
DM
OU+M
Cmb
VU
15 0 15 30 km
Kerensk-Chembar Swell (MUCHENKO, 1963) (3 - 3)
SW
NE
Olkhovka
Tambov
Morsovo
N. Novgorod
metres
200 metres
J
Q
Ne
CL
K
Fam
Frs
DM
Ar
R
CU
P
20 0 20 40 60km

Fig. 3b

Ilovlinski height of Don-Medveditsa swell (SMIRNOV, 1962) (1 - 1)



Don-Medveditza Swell (Kolosov et al, 1973, unpublished) (1a - 1a)



Shorokopolski swell of the Kerensk-Tchembar system (Dashevskii et al. , 1996, unpublished) (3a - 3a)

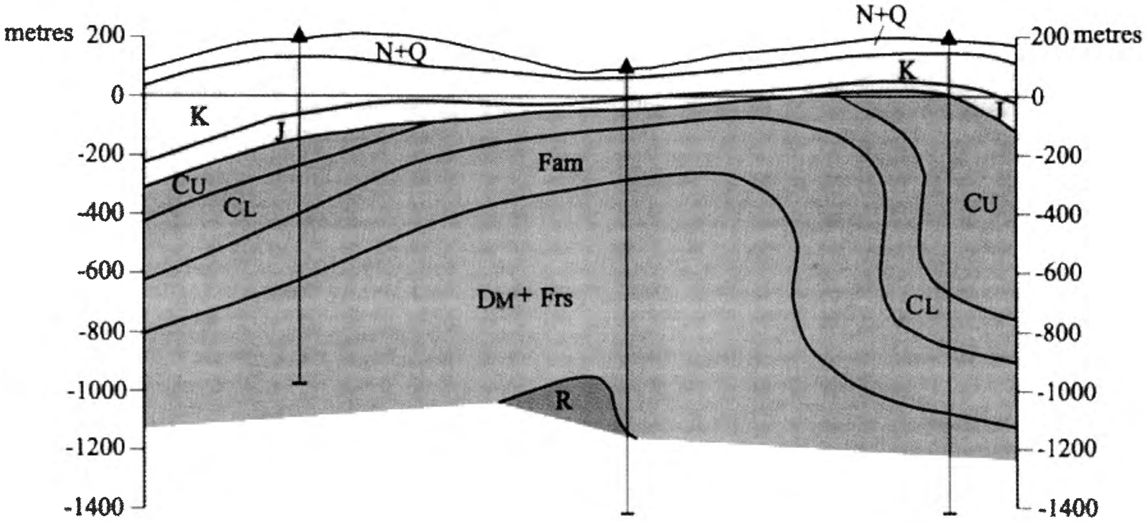


Fig. 3c

for the north-western part of the Alpine Great Caucasus (L. Rastsvetaev, 1998, personal communication) show that possible compression tectonism took place at the Maastrichtian to Palaeocene transition, because there are unconformities below the Eocene and inside(?) the Maastrichtian, and furthermore there are facial changes in the Maastrichtian deposits. In the north-eastern Caucasus in Dagestan gravitational olistostromes originated along the northern margin of the Great Caucasus Trough in Santonian to Maastrichtian times (MOSKVIN, 1962; MARKUS & SHARAFUTDINOV, 1989); their genesis could be connected with thrusting events and local inversion tectonics along the deep-water basin northern margin.

Data on the Pontides (OKAY & SAHINTURK, 1997; USTAOMER & ROBERTSON, 1997; YILMAZ *et al.*, 1997) show that collision tectonics occurred in Maastrichtian(?)-Palaeocene-pre-Lutetian times. The maximum collision took place in the Early Eocene, but the timing of these collision events is badly known. It was the collision of the Pontides and of the Gondwana-derived Kirsehir block-Menderes-Taurus Platform and the main closing of the Ankara-Erzincan suture (ophiolitic melange) (OKAY & SAHINTURK, 1997; YILMAZ *et al.*, 1997).

Data on the Lesser Caucasus region show that the Ankara-Erzincan ophiolite suture of Turkey reaches the Sevan-Akera suture in Armenia-Azerbaijan (LLORDKIPANIDZE, 1980; BOGDANOV & KHAIN, 1981; MONIN & ZONENSHAIN, 1987; E. E. MILANOVSKY, 1991). The geological structure of the region (KNIPPER & SOKOLOV, 1974; E. E. MILANOVSKY, 1991; GASANOV, 1996) shows that collision of the European continent with the South Armenian (Nakhichevan) Gondwana-derived terrane occurred in Late Cretaceous times; collision tectonics started in the Cenomanian-Coniacian and ended in mid-Santonian. A remnant flysch basin existed along the suture at the Cretaceous/Palaeocene transition.

Data on the Bulgarian shelf for the Balkan thrust wedge show (SINCLAIR *et al.*, 1997) that according to offshore seismic stratigraphy the first evidence of shortening was the reactivation of deep-level normal faults at the end of the Cretaceous. A regional uplift event took place, certainly at least in the eastern part of the Moesian Platform near the Cretaceous/Palaeogene boundary (mainly inside the Danian) (HARBURG & COHEN, 1997). It could have occurred in connection with a compression phase.

Data on the Scythian-Caucasus-Pontides-Moesian region demonstrate that Subhercynian and Laramide inversion tectonics in Europe were probably connected with collision tectonics and orogeny along the southern margins of the European continent (ZIEGLER *et al.*, 1998). We can add as further evidence that the inner Dinarides-Hellenides and Taurides started to collide with the European margin during the Senonian. With the final closure of the Vardar Ocean, this collision became important during Maastrichtian-Palaeocene times (STAMPFLI *et al.*, 1998).

Late Cretaceous to Palaeocene inversion structures in the Africa-Arabian and other areas

GUIRAUD & BOSWORTH (1997) discussed inversion structures in regions of Africa and Arabia. They recognised two main compressional events: in the Santonian (or Santonian/Campanian boundary) and at the Cretaceous/Palaeocene boundary. Close to the Santonian/Campanian boundary the inversion tectonics took place along the northern margin of the Africa-Arabia continent: Tellian Atlas, High Atlas, Tunisia, Egypt, Palmirides, Oman (start of emplacement of ophiolites); and also in rifted basins inside the continent - Benue, Termit, S. Chad, S. Sudan, Blue Nile Rift, Anza Rift, Lugh Mandera. At the Cretaceous/Palaeocene boundary, main inversion tectonics took place along the northern margin of the Africa-Arabia continent: Egypt, Palmirides, Oman (ophiolites). Generally the timing of inversion tectonic events in the Africa-Arabia continent and in Europe was very similar (ZIEGLER, 1990; GUIRAUD & BOSWORTH, 1997) but better stratigraphic control is needed for more precise conclusions. Numerous data show that inversion tectonics occurred also in the Tethys belt during the Senonian to Palaeocene (DERCOURT *et al.*, 1993; KHAIN & BALUKHOVSKY, 1993).

Recent investigations summarised in KHAIN & BALUKHOVSKY, (1993) show that near the K/T boundary orogeny affected many areas: the Laramide orogeny was very important f.i. in Northern and Southern America and in the Asian Far East.

Origin of the Late Cretaceous to Palaeocene compression stress in Eastern Europe

The origin of the Late Cretaceous to Palaeocene compression stress is a controversial problem. These important phases of intraplate compression of Senonian to Palaeocene age affected both the northern and southern Peri-Tethyan continents and were probably controlled by the accelerated counter-clockwise rotational convergence of Africa-Arabia with Eurasia (LIVERMORE & SMITH, 1985; WESTPHAL *et al.*, 1986; LE PICHON *et al.*, 1988). The Santonian/Campanian boundary coincided almost with a change of motion of Africa relative to Europe: oblique convergency was followed by more direct collision (GUIRAUD & BOSWORTH, 1997) with f.i. changes in subduction systems. We suggest three main reasons for such inversion tectonics: global plate kinematic reorganisation in the Senonian-Palaeocene, collisional tectonics along the Tethyan margins, and changes in subduction systems after accretions of new terranes.

Latest Cretaceous-Palaeocene global orogeny and biological crisis at the K/T boundary

New data show that the Laramide orogeny was very widely spread on the Earth. This led to changes in global topographical distribution of continents and oceans and f.i. also to changes in oceanic water currents and so on. In total, this could have led to a global environmental crisis. This could have been one of the main reasons for the biological crisis during the latest Cretaceous to Palaeocene with a climax at the K/T boundary.

Conclusions

1. Senonian to Palaeocene compressional polyphase regional stresses affected the East European Craton as well as the whole European palaeocontinent. This led to palaeogeographical changes and compressional tectonics inside the EEC.
2. We can recognise the following types of compressional tectonics inside the EEC: gentle lithospheric folding (buckling) with wave-length around 500-600 km; origin of inversion structures mainly above former rifted basins; syn-compressional rapid subsidence of former rifted basins; acceleration of salt diapirism; compression-related (impactogen) rifting.
3. The compression tectonics inside the EEC coincide with the orogenic epoch along the Tethyan belt.

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References

AFANASIEV, T.P. (ed.), 1970. Hydrogeology of the USSR, Nedra, Moscow, vol.13, 800 pp. (in Russian).

ARKHANGELSKY, A.D., 1922. A review of the geological structure of the European part of Russia, vol. 2, Central Russia. PG, Petrograd, 467 pp. (in Russian).

ARKHIPOV, Yu.V. , VYSOTSKY, K.A. & KALININ, A.T., 1996. About deformation of platform cover of the Volga-Ural Region. *Geotektonika*, **5:** 55-66 (in Russian).

BENIAMOVSKY, V.N., VOLCHEGURSKY, L.F., ZHURAVLEV, V.S., KOBLOVA, F.P., ROMASHEV, A.A., 1973. Peculiarities of tectonic movements in the eastern part of the Peri-Caspian Basin during Late Cretaceous times. *Byulleten Moskovskogo Obshchestva Ispytatelei Prirody, Geologia*, **48**, 3: 40-54. (in Russian).

BLANK, M., YA. & GORBENKO, V.F., 1968. Stratigraphy of the Upper Cretaceous deposits of the northern Donbass. *In*: Materials on the geology of the Donets Basin. Moscow, Nedra, p. 34-47. (in Russian).

BLANK, M., YA., NAIDIN, D.P. & OLFERIEV, A.G., 1992. Relief of Cenomanian root in Dniepr-Donets Trough, Voronezh Anteclyse and adjacent structures of the East-European Platform. *Byulleten Moskovskogo Obshchestva Ispytatelei Prirody, Geologia*, **67**, 6: 43-47. (in Russian).

BOGDANOV, A.A. & KHAIN, V.E., 1981. Tectonic map of Europe and adjacent areas, 1: 2.500.000, 2nd Ed. International Geological Congress, Commission of the Geological Map of the World, Subcommission of the Tectonic Map of the World. Academy of Sciences of the USSR.

CHEKUNOV, A.V., VESELOV, A.A. & GLIKMAN, A.I., 1976. Geological structure and history of the Peri-Black Sea basin. Kiev, Naukova Dumka, 164 pp. (in Russian).

CHIBRIKOVA, S.V., 1951. To the problem of connection of the Kerensk-Chembar and Saratov dislocations. *Scientific Notes of Saratov University, Geological Issue*, **23**; 36-46. (in Russian).

DADLEZ, R., NARKIEWICZ, M., STEPHENSON, R.A., VISSER, M.T.M., & VAN WEES, J.-D., 1995. Tectonic evolution of the Mid-Polish Trough: modelling implications and significance for central European geology. *Tectonophysics*, **252**: 179-195.

DERCOURT, J., RICOU, L.E. & VRIELYNCK, B. (eds.) 1993. Atlas Tethys, paleoenvironmental maps. Gauthier-Villars, Paris, 307 pp.

GASANOV, T. Ab., 1996. Geodynamics of ophiolites in the structure of the Lesser Caucasus and Iran. Baku, Elm, 454 pp. (in Russian).

GEISLER, A.M., 1956. New data on stratigraphy and tectonics of the Lower Palaeozoic of the North-Western part of the Russian Platform. *In*: Data on geology of the European part of the USSR. VSEGEI, Gosgeoltehizdat, Moscow, p. 174-185.

GERASIMOV, P.A., MIGACHEVA, E.E., NAIDIN, D.P. & STERLIN, B.P., 1962. Jurassic and Cretaceous deposits of the Russian Platform. Moscow University Press, 196 pp. (in Russian).

GUIRAUD, R. & BOSWORTH, W., 1997. Senonian basin inversion and rejuvenation of rifting in Africa and Arabia: synthesis and implications to plate-scale tectonics. *Tectonophysics*, **282**: 39-82.

HARBURY, N. & COHEN, M., 1997. Sedimentary history of the Late Jurassic-Paleogene of Northeast Bulgaria and the Bulgarian Sea. *In*: A.G. ROBINSON (ed.), Regional and Petroleum Geology of the Black Sea and surrounding areas. *American Association of Petroleum Geologists, Memoir,* **68**: 129-168.

IVANNIKOV, A.V., LIPNIK, E.S., PLOTNIKOVA, L.F., BLANK, M. YA., GAVRILISHIN, V.I., PASTERNAK, S.I., NERODENKO, V.M., KONASHOV, V.G., MATYUSHONOK, V.A., GONCHARUK, L.F., GUBKINA, T.B., ROZUMEYKO, S.V., KARELOV, M.I., & LYULIEVA, S.A., 1991. Regional stratigraphical scheme of the Late Cretaceous deposits of the platform region of the Ukraine. Institute of the Geological Sciences (preprint), Kiev, 31 pp. (in Russian).

KAPTARENKO-CHERNOUSOVA, O.K. (ed.), 1971. Stratigraphy of the Ukraine. Vol. 8, Cretaceous. Naukova Dumka, Kiev, 320 pp. (in Ukrainian).

KHAIN, V.E. & BALUKHOVSKY, A.N., 1993. Historical Geotectonics. Mesozoic and Cenozoic. INIAR, Moscow, 451 pp. (in Russian).

KHOKHLOV, P.S., 1955. Tectonics and history of development of the Kerensk-Chembar and Sura-Moksha dislocations. Moscow, Gostoptehizdat, 250 pp. (in Russian).

KNIPPER, A.L., & SOKOLOV, S.D., 1974. Pre-Senonian tectonic thrusts of the Lesser Caucasus. *Geotektonika*, **6**: 74-80. (in Russian).

KUTEK, J., 1994. Jurassic tectonic events in south-eastern cratonic Poland. *Acta Geologica Polonica*, **44**, 3-4: 167-221.

LE PICHON, X., BERGERAT, F. & ROULET, M-J., 1988. Plate kinematics and tectonics leading to the Alpine belt formation: a new analysis. *Geological Society of America. Special Paper*, **218**: 11-131.

LIVERMORE, R.A. & SMITH, A.G., 1995. Some boundary conditions for the evolution of the Mediterranean Region. *In*: D.J. STANLEY & F-C. WEZEL (eds.), Geological Evolution of the Mediterranean Basin. Springer-Verlag, New York, Berlin, Heidelberg, Tokyo, pp. 83-98.

LLORDKIPANIDZE, M.B. 1980. Alpine volcanism and geodynamics of the central segment of the Mediterranean fold belt. Tbilisi, Metsniereba, 162 pp. (in Russian).

MARKUS, M.A. & SHARAFUTDINOV, V.F., 1989. Oligocene olistostrome of the Eastern Caucasus and late Alpine tectonics. *Geotektonika*, **4**: 87-98. (in Russian).

MAZAROVICH, O.A. & MILEEV, V.S. (eds.), 1989 a. Geological structure of the Kacha Upland of Mountain Crimea. Stratigraphy of the Mesozoic. Moscow, Moscow State University Press, 168 pp. (in Russian).

MAZAROVICH, O.A. & MILEEV, V.S. (eds.), 1989 b. Geological structure of the Kacha Upland of Mountain Crimea. Stratigraphy of the Cenozoic, magmatism and metasomatism. Moscow, Moscow State University Press. 160 pp. (in Russian).

MILANOVSKY, E.V., 1940. Review of the geology of the Middle and Lower Pre-Volga region. Moscow-Leningrad, State Publishing House of Oil Literature, 301 pp. (in Russian).

MILANOVSKY, E.E., 1987. Geology of the USSR. Part 1. Moscow University Press. 416 pp. (in Russian).

MILANOVSKY, E.E., 1991. Geology of the USSR. Part 3. Moscow, Moscow University Press. 272 pp. (in Russian).

MORROZ, S.A., 1970. Palaeocene of the Dnieper-Donets Basin. Kiev University Press, Kiev, 190 pp. (in Russian).

MORROZOV, N.S., 1962. Upper Cretaceous deposits between the Don river and the Severnyi Donets river, and southern part of the Volga-Don area. Saratov University Press, 222 pp. (in Russian).

MOSKVIN, M. M., 1962. Upper Cretaceous sediments of the North Caucasus and Subcaucasia. *Acta Geologica Polonica*, **12**, 2: 159-199.(in Russian).

MONIN, A.S. & ZONENSHAIN, L.P., 1987 (eds.). Geological History of the Tethys Ocean. Moscow. Academy of Sciences of the USSR, P.P. Shirshov Institute of Oceanology, 155 pp. (in Russian).

MUSHENKO, A.I., 1963. About some peculiarities of the development of structures of the Russian Platform. *In*: Data on tectonics of the Lower Pre-Volga Region. Nauka, Moscow, p. 147-161.

MURATOV, M.V. (ed.), 1969. Geology of the USSR, Volume 8, Crimea. Part 1, Geology. Moscow, Nedra, 576 pp. (in Russian).

NAIDIN, D.P., 1960. The stratigraphy of the Upper Cretaceous of the Russian Platform. *Acta Universitatis Stockholmiensis. Stockholm Contributions in Geology*, **6**, 4: 39-61.

NAIDIN, D.P. & KOTELNIKOV, D.D., 1998. Palaeogeographical environments of deposition and clay minerals in the Lower Campanian of Aktyubinsk Pre-Mugodzhary region. *Izvestia Vysshikh Uchebnykh Zavedeniy, Geologia i Razvedka*, **4**: 23-34. (in Russian).

NAJDIN, D.P., 1969. Biostratigraphie und Paläogeographie der Oberen Kreide der Russischen Tafel. *Geologisches Jahrbuch*, **87**: 157-186.

NIKISHIN, A.M., ZIEGLER, P.A., CLOETINGH, S., STEPHENSON, R., FURNE, A.V., FOKIN, P.A., ERSHOV, A.V., BOLOTOV, S.N., KOROTAEV, M.V., ALEKSEEV, A.S., GORBACHEV, V.I., SHIPILOV, E.V., LANKREIJER, A., BEMBINOVA, E. YU, & SHALIMOV, I.V. , 1996. Late Precambrian to Triassic history of the East-European Craton: dynamics of sedimentary basin evolution. *Tectonophysics*, **268**: 23-63.

NIKISHIN, A.M., BOLOTOV, S.N., FOKIN, P.A., NAZAREVICH, B.P., PANOV, D.I., ALEKSEEV, A.S., BARABOSHKIN, E. YU, ERSHOV, A.V., KOPAEVICH, L.F., KOROTAEV, M.V., USTINOVA, M.A., BRUNET, M.-F., CLOETINGH, S. & STEPHENSON, R.A., 1997a. Devonian to Cenozoic geological history and dynamics of Scythian Platform-Donets Basin-South Russian Platform region. *In:* Intracratonic Rifting and Inversion. EUROPROBE GeoRift Workshop. ETH Zurich, October 16-19, 1997, p. 9-11.

NIKISHIN, A.M., BRUNET, M.-F., CLOETINGH, S. & ERSHOV, A.V., 1997b. Northern Peri-Tethyan Cenozoic intraplate deformations: influence of the Tethyan collision belt on the Eurasian continent from Paris to Tian-Shan. *Comptes-Rendus Académie Sciences Paris*, **324**, (II a): 49-57.

NIKISHIN, A. M., CLOETINGH, S., BOLOTOV, S.N., BARABOSHKIN, E. Y., KOPAEVICH, L.F., NAZAREVICH, B.P., PANOV, D.I., BRUNET, M-F., ERSHOV, A.V., IL'INA, V.V., KOSOVA S. S. & STEPHENSON, R.A., 1998a. Scythian platform: chronostratigraphy and polyphase stages of tectonic history. *In*: S. CRASQUIN-SOLEAU & E. BARRIER (eds.), Peri-Tethys Memoir 3. Stratigraphy and Evolution of Peri-Tethyan Platforms. *Mémoires Muséum national d'Histoire naturelle*, Paris, **177**: 151-162.

NIKISHIN, A. M., CLOETINGH, S, BRUNET, M. F., STEPHENSON, R., BOLOTOV, S.N. & ERSHOV, A.V., 1998b. Scythian Platform and Black Sea region: Mesozoic-Cenozoic tectonic and dynamics. *In*: S. CRASQUIN-SOLEAU & E. BARRIER (eds.), Peri-Tethys Memoir 3. Stratigraphy and Evolution of Peri-Tethyan Platforms. *Mémoires Muséum national d' Histoire naturelle*, Paris, **177**: 163-176.

OKAY, A.I. & SAHINTURK, O., 1997. Geology of the Eastern Pontides. *In*: A.G. ROBINSON (ed.), Regional and petroleum geology of the Black Sea and surrounding region, *American Association of Petroleum Geologists, Memoir*, **68**: 291-311.

ORESHKINA, T.V., ALEKSEEV, A.S. & SMIRNOVA, S.B., 1998. Cretaceous-Palaeogene deposits of the Polar Pre-Uralians: biostratigraphical and palaeogeographical aspects. *In*: A. KNIPPER, S. KURENKOV, & M. SEMIKHATOV (eds.), Urals: fundamental problems of geodynamics and stratigraphy. Moscow, Nauka, p. 183-192. (in Russian).

SAZONOV, N.T., 1951. Tectonic structure of Zhiguli and Borlinsk zones of dislocations. VNIGRI, Leningrad, vol. 2, p. 19-39. (in Russian).

SAZONOV, N.T., 1953. Tectonic structure of Ryazan and Penza regions and Mordovia ASSSR. *In*: Stratigraphy and Tectonics of the Russian Platform: Geochemistry and Regional Geology. Vol. 3, p. 65-84. (in Russian).

SAVCHINSKAYA, O.V., 1982. Life conditions of the Late Cretaceous fauna of the Donets Basin. Moscow, Nauka, 132 pp. (in Russian).

SHATSKY, N.S., 1964. Selected papers. Vol.2. Nauka, Moscow, 528 pp. (in Russian).

SENCHENKO G.S., 1951. About some peculiarities in changes of composition and thicknesses of Upper Cretaceous deposits in the eastern part of the Kerensk-Chembar Dislocations. *Scientific Notes of Saratov University, Geological Issue, 23*: 55-63. (in Russian).

SENYUKOV, V.M. & BAKIROV, A.A., 1949. The tasks of the oil geology in the solving of problems of oil and gas potential of the Russian Platform. Moscow, VNIGRI, vol. 1, p. 5-31. (in Russian).

SINCLAIR, H.D., JURANOV, S.G., GEORGIEV, G., BYRNE, P. & MOUNTNEY, N.P., 1997. The Balkan thrust wedge and foreland basin of Eastern Bulgaria: structural and stratigraphic development. *In*: A.G. ROBINSON (ed.), Regional and Petroleum Geology of the Black Sea and surrounding areas. *American Association of Petroleum Geologists, Memoir,* **68**: 91-114.

SLIAUPA, S., 1997. Tectonics of South Lithuania. PhD Thesis synopsis. Vilnius, 45 pp. (in Russian).

STAMPFLI, G.M., MOSAR, J., DE BONO, A. & VAVASIS, I., 1998 (in press). Late Paleozoic, Early Mesozoic plate tectonics of the Western Tethys. *Bulletin of the Geological Society of Greece.*

STEPHENSON, R.A., 1997. GeoRift project DOBRE: Late Palaeozoic peri-cratonic basin development in Ukraine and Russia. *In*: Intracratonic Rifting and Inversion. EUROPROBE GeoRift Workshop. ETH Zurich, October 16-19, 1997, p. 1-3.

STOVBA, S. M. & STEPHENSON, R. A., 1999. The Donbass Foldbelt: its relationship with the uninverted Donets segment of the Dniepr-Donets Basin, Ukraine. *Tectonophysics*, in press.

STOVBA, S.N., STEPHENSON, R.A. & KIVSHIK, M., 1996. Structural features and evolution of the Dnieper-Donets Basin, Ukraine, from regional seismic reflection profiles. *Tectonophysics*, **268**: 127-147.

ULANOVSKAYA, T.E., 1988. Paleogeographic reconstruction based on palaeoecology and its applications to palaeotectonic analysis (on the example of the Eocene of the Azov-Kuban Depression). *Izvestiya Vysshikh Uchebnykh Zavedeniy. Geologia i razvedka*, **1**:17-25. (in Russian).

USTAOMER, T., & ROBERTSON, A., 1997. Tectonic-sedimentary evolution of the North Tethyan margin in the Central Pontides of Northern Turkey. *In*: A.G. ROBINSON (ed.), Regional and petroleum geology of the Black Sea and surrounding region. *American Association Petroleum Geologists, Memoir*, **68**: 255-290.

USTINOVA, M.A., NIKISHIN, A.M., ALEKSEEV A.S., DASHEVSKY, V.V. & OLFERIEV, A.G., 1998. Deformational history of inversional structures of the Russian Platform. *In*: 6th Zonenshain Conference on Plate Tectonics (Moscow, February 17-20, 1998). Programme and Abstracts. Moscow, P.P. Shirshov Institute of Oceanology, p. 134-135.

VESELOVSKAYA, M.M., 1960. Issa deep well. VNIGRI, Leningrad, vol. 26. p. 176-226. (in Russian).

WESTPHAL, M., BAZHENOV, M.L., LAUER, J-P., PECHERSKY, D.M. & SIBUET, J.C., 1986. Paleomagnetic implications on the evolution of the Tethys Belt from the Atlantic Ocean to Pamir since Trias. *Tectonophysics*, **123**: 37-82.

YILMAZ, Y., TUYSUR, O., YIGITBAS, E., CAN GENC, S. & SENGOR, A.M.C., 1997. Geology and tectonic evolution of the Pontides. *In*: A.G. ROBINSON (ed.), Regional and petroleum geology of the Black Sea and surrounding region. *American Association Petroleum Geologists, Memoir*, **68**: 183-226.

YUDIN, V.V., 1994. Orogenes of the Northern Urals and Pay-Khoy. Ekaterinburg, Nauka, 284 pp. (in Russian).

ZIEGLER, P.A., 1990. Geological Atlas of Western and Central Europe - 2nd Ed., Shell Internationale Petroleum Maatschappij., Den Haag, Geological Society. Publishing House, Bath, 239 p.

ZIEGLER, P.A., CLOETINGH, S. & VAN WEES, J-D., 1995. Dynamics of intra-plate compressional deformations: the Alpine foreland and other examples. *Tectonophysics*, **252**: 7-59.

ZIEGLER, P.A., VAN WEES, J-D. & CLOETINGH, S., 1998. Mechanical controls on collision-related compressional intraplate deformation. *Tectonophysics*, **300:** 103-129.

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