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Siberia - From Rodinia to Eurasia

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1. Introduction

The ancient Siberian continent and its Phanerozoic frame occupies the central position in the structure of Northern Asia (Fig. 1). The paleogeography of the Siberian plate attracts considerable interest, as an independent object of research which is throwing light on geographical conditions in the past, features of tectonic development of the region, legitimacies in the distribution of indicators of geological formations and other fundamental questions of geology.

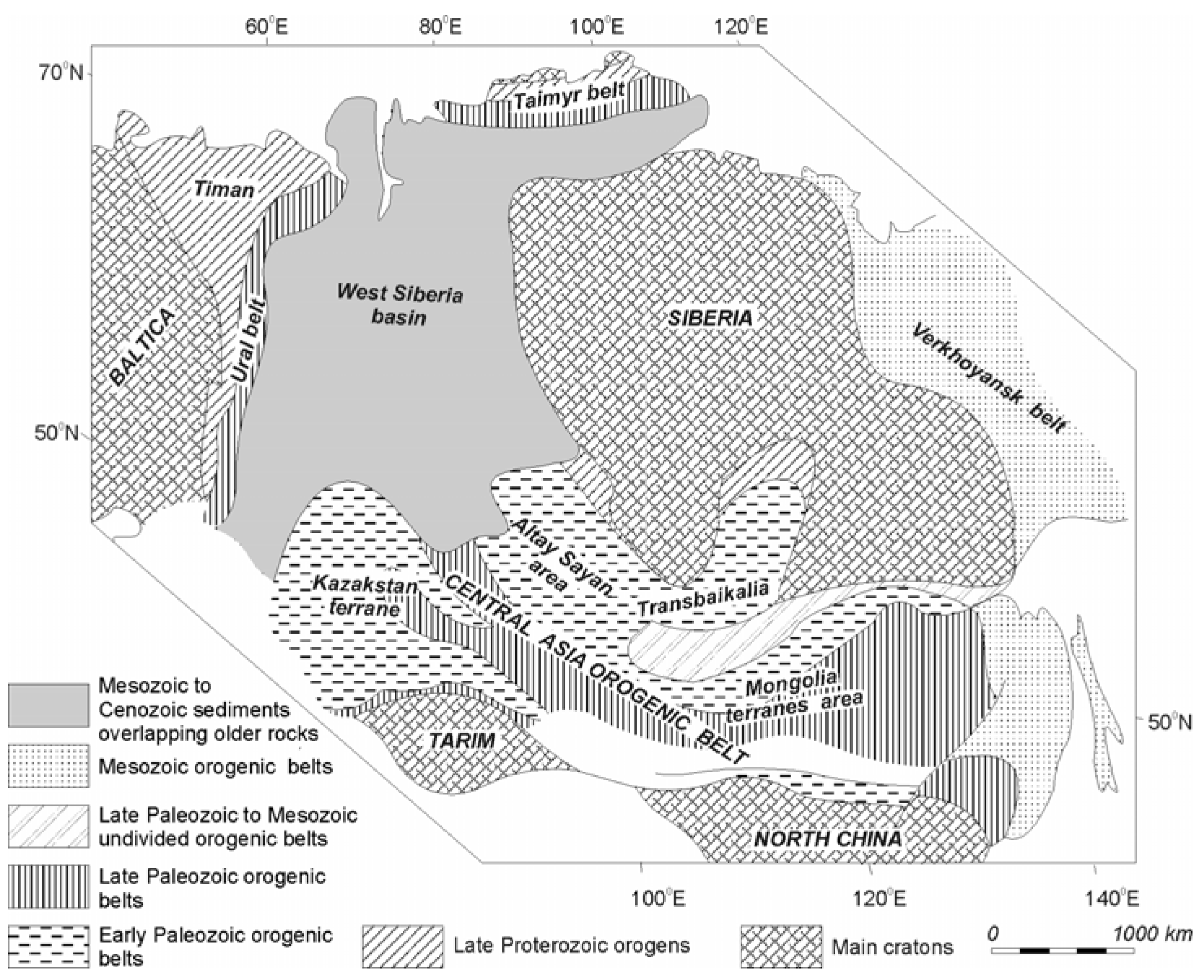

Fig. 1. Main tectonic units of the Northern Asia (adapted from Berzin et al., 1994).

Here we present the results of a short analysis of paleomagnetic data obtained during recent years over the territory of the Siberian Craton and some adjacent terrains. The new data allows us to propose a new version of the apparent polar wander path (APWP), uniting three large intervals of geological history: Neoproterozoic, Paleozoic and Mesozoic. This data allows a reconstruction of step-by-step tectonics of the Siberian continental plate for almost 1.0 Ga. It appears that large-scale long-living strike-slips were playing the major role in a tectonic history of the craton at all stages of development of the crust of its folded frame. Strike-slip motions defined the tectonic style of the evolution of folded systems as in the early stages of formation of oceanic basins, and during active subduction of oceanic crust and, undoubtedly, at the accretional-collisional stage. Intraplate deformations of the newly formed continental crust and accompanying active magmatism were also supervised by strike-slips motion of the fragments of different scale. The present work is an attempt to coordinate most of the paleomagnetic and geological information from different regions of Siberia forming a uniform picture in the context of a strike-slip hypothesis. Here we propose eight paleotectonic reconstructions corresponding to the key moments in the tectonic history of Siberia which describe a change of spatial position of the craton and support the leading role of strike-slip motions in the tectonic evolution of a continental crust of its frame on the base of paleomagnetic estimations. Those reconstructions are partly based on the author's tectonic models published earlier, but the central place here belongs to the Siberian Craton.

2. The tectonics of the Siberian Craton

2.1 The geology of the Siberian Craton

Siberian Craton occupies the central place in the structure of Northern Asia and is located between the largest rivers of Eastern Siberia - the Yenisey and Lena. The southeast boundary of the craton coincides with the Mongol-Okhotsk suture which separates the Early Paleozoic crystal complexes of Stanovoy block from the folded structures of the Mongol-Okhotsk belt developed at the end of Jurassic - Cretaceous (Zorin, 1999; Kravchinsky et al., 2002; Tomurtogoo et al., 2005; Metelkin et al., 2010a). Westward, the fields of Early Cambrian formations of Stanovoy block are "lost" among granitoid batholiths of the Baikal folded area. Here, the Zhuinsk system of faults is accepted as a boundary of the craton crystal complexes. Within the limits of Northern Transbaikalia, the boundary of the Siberian Craton is going inside a well expressed Baikal-Patom paleoisland arc. During Neoproterozoic and Paleozoic this territory was represented by a sedimentary basin on the margin of Siberian continent and was deformed as a result of accretional-collisional events (Parfenov et al., 2003; Khain et al., 2003; Zorin et al., 2009). The Sayan-Yenisey folded-napped structure forms the southwestern margin of the ancient continent. Further to the southwest, a mosaic of terrains of Altay-Sayan fragment of the Central-Asian mobile belt is located. At the western periphery the craton block is overlapped by Mesozoic-Cenozoic cover of the West Siberian plate and the boundary of the craton is conventionally traced over the Yenisey river valley. In the north, the platform deposits of Siberian Craton are buried under sediments of the Yenisey-Khatanga trough, which is considered as a branch of the West Siberia basin, and are limited the by structures of the Taimyr-Severnaya Zemelya folded-napped area. The eastern periphery of the Siberian Craton is formed by the deformed complexes of the Verkhoyansk folded-napped system. Here, predominantly sedimentary complexes deposited within the margin of the Siberian continent during the Paleozoic and Mesozoic, were detached and were broken from the crystal basement and pulled over the craton

(Parfenov et al., 1995; Oxman, 2003). The Verkhoyansk trough, developed at the frontal part of the napes, is accepted as a modern boundary of distribution of the low-deformed cover of the Siberian Craton. Thus, the most ancient crystal complexes of the craton are traced practically everywhere under the mountain ridges of the surrounding folded-napped belts, and the outlined boundaries represent the arbitrary contours used for paleotectonic reconstruction.

The Archean-Paleoproterozoic crystal basement is exposed in the limits of the Aldan-Stanovoy shield in the southeast and in the limits of Anabar-Olenek uplift in the north and also as relatively small missives among folded-napped structures of the cratonic margin in the south-west. Granulite-gneissic and granite-greenschist complexes undoubtedly are prevailing and form a number of terrains developed discretely between 3.3 and 2.5 billion years ago (Rozen et al., 1994; Rosen, 2003; Smelov, Timofeev, 2007). A collision of terrains and a build-up of the craton have taken place about 1.8 billion years ago (Rozen et al., 2005; Smelov, Timofeev, 2007).

The sedimentary cover is formed by Late Proterozoic and Phanerozoic deposits. Mesoproterozoic and Neoproterozoic geological complexes on the Siberian Craton are concentrated over its margins, forming both a sedimentary sequences comparable to conditions of shelf basins (Pisarevsky & Natapov, 2003), and magmatic (volcanic and the volcano-sedimentary) complexes connected with oceanic spreading and subduction processes on the continental margin. The last are included in Neoproterozoic folded belts surrounding the craton: the Central Taimyr, Pre-Yenisey and Baikal-Muya belts. Early Paleozoic sedimentary complexes are widespread and occupy all territory of the plate. Shallow sea and lacustrine terrigenous-carbonate and gypsum-dolomite deposits predominate (Kanygin et al., 2010). A new stage in the development of the plate complex began in the Devonian and has been connected with the continental rift event. Rifting has driven the generation of the Vilyui graben system and the extensive sedimentary basin in the east of the Siberian plate which was developed up to the end of the Mesozoic and resulted in the Vilyui syncline structure which is infilled mainly by terrigenous deposits (Parfenov & Kuzmin, 2001). The Permian-Triassic platobasaltic sequence and underlying Carboniferous- Permian terrigenous and the tuff deposit of the Tungus tectonic province is considered as an independent structural complex of the Siberian platform. The development of the depression here is connected with a stretching and thinning of the continental crust above an extensive hotspot in the mantle, so the thick trapp complex appears to be a direct reflection of the largest plum activity (Dobretsov & Vernikovsky, 2001). Moreover, the Permian-Triassic boundary coincides with rifting in the northwest frame of the Siberian Craton. The giant sedimentary basins of West Siberia, including the Yenisey-Khatanga trough, have occupied the adjusting, lowered margins of the platform. Late Mesozoic collisional processes in the east and the south of the craton have completed the development of the modern structure of the Siberian platform.

2.2 The paleomagnetic record

The apparent polar wander path (APWP) for Siberia is well known only for Paleozoic. Today, not less than four versions of this trend are proposed (Khramov, 1991; Pechersky & Didenko, 1995; Smethurst et al., 1998; Cocks & Torsvik, 2007). Distinctions between the paths are caused by different approaches in data selection, the non-uniform distribution of data over a time scale, and also by a “smoothing” technique during the construction of

APWP. Despite differences in details, the general character of the Paleozoic polar wander is co-coordinated and describes the northward drift of Siberia from the equator to high latitudes of the northern hemisphere with a prevailing clockwise rotation (Pechersky & Didenko, 1995; Cocks & Torsvik, 2007). The maximum drift velocity sometimes exceeded from 5 to 12 cm/year while the amplitude of rotation went up to 1 degree per million years, depending on an APWP version which was used.

We constructed the Neoproterozoic interval of APWP on the basis of a refined summary table of Precambrian poles (Metelkin et al., 2007a) where most of key poles (reliability index (Van der Voo, 1990) more than 3) from Siberia were obtained in resent years (Table 1).

In particular the analysis carried out (Metelkin et al., 2007a), proves nonconventional for the Siberia "eastern" drift (from outside the Indian ocean) of the poles comprising in Neoproterozoic a characteristic loop comparable with the well known "Grenville Loop" of APWP for Laurentia (McElchinny & McFadden, 2000). The similarity of the APWP shapes for Siberia and Laurentia not only quite unequivocally proves a tectonic connection of the cratons within the structure of Neoproterozoic, but also allows a reconstruction of the dynamics of its break-up (Metelkin et al., 2007a, Vernikovsky et al., 2009). The plate kinematics for the first third of the Neoproterozoic can be described by a southward drift with a counter-clockwise rotation from the equatorial to the moderate latitudes of the southern hemisphere. The second third of the Neoproterozoic is characterized by a reversed drift of the plate to the equator with a clockwise rotation. The calculated drift velocity as a rule does not exceed 10 cm/year, and the amplitude of rotation less than 1 degree per million years.

However, the Vendian (Ediacarian - from to 600 million years ago to 540 million years ago) APWP interval connecting the above mentioned Neoproterozoic and Paleozoic APWP trends (Fig. 2, Table 2) still remains ambiguous. For 560 million years we used the mean pole of the group which is concentrated near Madagascar Island (tab. 1). However, we also cannot exclude a more southern pole position for this time - which is near the coast of Antarctica (Shatsillo et al., 2005, 2006). Despite the essential progress in the study of Late Precambrian and a considerable quantity of new paleomagnetic data, the problem of the paleomagnetic pole position for the Vendian time is far from an unequivocal solution. A number of hypotheses were proposed and among them: a non-stationary, non-dipolar state of the geomagnetic field at this time, abnormaly high drift velocities and some others (Kirshvink et al., 1997; Meert et al., 1999; Kravchinsky et al., 2001; Kazansky, 2002; Pavlov et al., 2004; Shatsillo et al., 2005, 2006).

A serious problem whose solution can probably provide the answer to the majority of points of disagreement is the problem of the absolute age of the rocks studied and the age of magnetization preserved in them. Despite the described difficulties, the distribution of Vendian- Early Cambrian poles fits the expected trend between Neoproterozoic and Paleozoic APWP segments (Fig. 2).

Also there is unequivocal substantiation for the Early Mesozoic segment of the Siberian APWP due to the absence of authentic data for Middle and Late Triassic. A combination of Paleozoic and constructed Late Mesozoic segments (Fig. 2, Table 2) assumes the presence of a strongly pronounced casp (an interval with a sharp change in polar wander). The presence of the casp is basically not connected with the tectonic reasons, but is caused by a technique of APWP calculation during the smoothing of selected data over time intervals.

Object	age, Ma	Pole position			Reference
		(ºN)	(ºE)	A_{95}	
1050 - 640 Ma					
Malga Fm, , Uchur-Maya district	1045±20	25.4	50.4	2.6	Gallet et al., 2000
Lakhanda Group., Uchur-Maya district	1000-1030	13.3	23.2	10.7	Pavlov et al., 2000
Ui Group, including sills, Uchur-Maya district	950-1000	4.9	357.7	4.3	Pavlov et al., 2002
Karagass Group, Pre-Sayan trough	800-740	4.2	292.1	6.2	Metelkin et al., 2010b
Nersa Complex, Pre-Sayan trough	741±4 [1]	22.7	309.8	9.6	Metelkin et al., 2005a
Predivinsk Complex, Yenisei Ridge	637±5.7 [2]	-8.2	7.7	4.7	Metelkin et al., 2004a
600-530 Ma					
Aleshino Fm, , Yenisei Ridge	600-550	-28.3	24.3	7.7	Shatsillo et al., 2006
Carbonates, Igarka district	560-530	-33.4	45.6	12.7	Kazansky, 2002
Carbonates, Lena-Anabar district	560-530	-28.0	66.5	8.2	Kazansky, 2002
Aisin Fm., Pre-Sayan area	600-545	-39.9	75.1	12.1	Shatsillo et al., 2006
Taseevo supergroup Yenisei Ridge	600-545	-32.9	75.1	6.1	Shatsillo et al., 2006
Taseevo supergroup Yenisei Ridge	600-545	-41.0	91.0	15.4	Pavlov & Petrov, 1997
Ushakovka Fm., , Transbaikalia	600-545	-31.6	63.8	9.8	Shatsillo et al., 2005 [3]
Sediments, Pre-Sayan area and Yenisei Ridge	560-530	-29.5	74.1	4.5	Shatsillo et al., 2006 [3]
Kurtun Fm., Transbaikalia	560-530	-25.3	54.5	12.0	Shatsillo et al., 2005 [3]
Irkutsk Fm., Transbaikalia	560-530	-36.1	71.6	3.2	Shatsillo et al., 2005 [3]
Minua Fm., Transbaikalia	600-530	-33.7	37.2	11.2	Kravchinsky et al., 2001
Shaman Fm., Transbaikalia	600-530	-32.0	71.1	9.8	Kravchinsky et al., 2001
MEAN	~ 560	-33.9	62.2	8.9	
200-80 Ma					
Sediments, Lena River	175-245	47.0	129.0	9.0	* Pisarevsky, 1982
Basalts of Tungui depression, Transbaikalia	180-200	43.3	131.4	23.0	Cogné et al., 2005
Sediments, Verkhoynask trough	170-160	59.3	139.2	5.7	Metelkin et al., 2008
Badin Fm., Transbaikalia	150-160	64.4	161.0	7.0	Kravchinsky et al., 2002
Ichechui Fm., Transbaikalia	150-160	63.6	166.8	8.5	Metelkin et al., 2007b
Sediments, Verkhoyansk trough	140-120	67.2	183.8	7.8	Metelkin et al., 2008
Khilok Fm, , Transbaikalia	110-130	72.3	186.4	6.0	Metelkin et al., 2004b
Intrusions, Minusa trough	74-82	82.8	188.5	6.1	Metelkin et al., 2007c

Comment: [1] - age according to (Gladkochub et al., 2006); [2] - age according to (Vernikovsky et al., 1999); 3 - "anomalous" (non-dipolar) field according to the viewpoint of data authors; * Pisarevsky, 1982: pole #4417 from IAGA GPMDB. (http://www.ngu.no/geodynamics/gpmdb/).

Table 1. Selected paleomagnetic poles from Siberia used for calculation of the Neoproterozoic and Mesozoic intervals of the Siberian APWP.

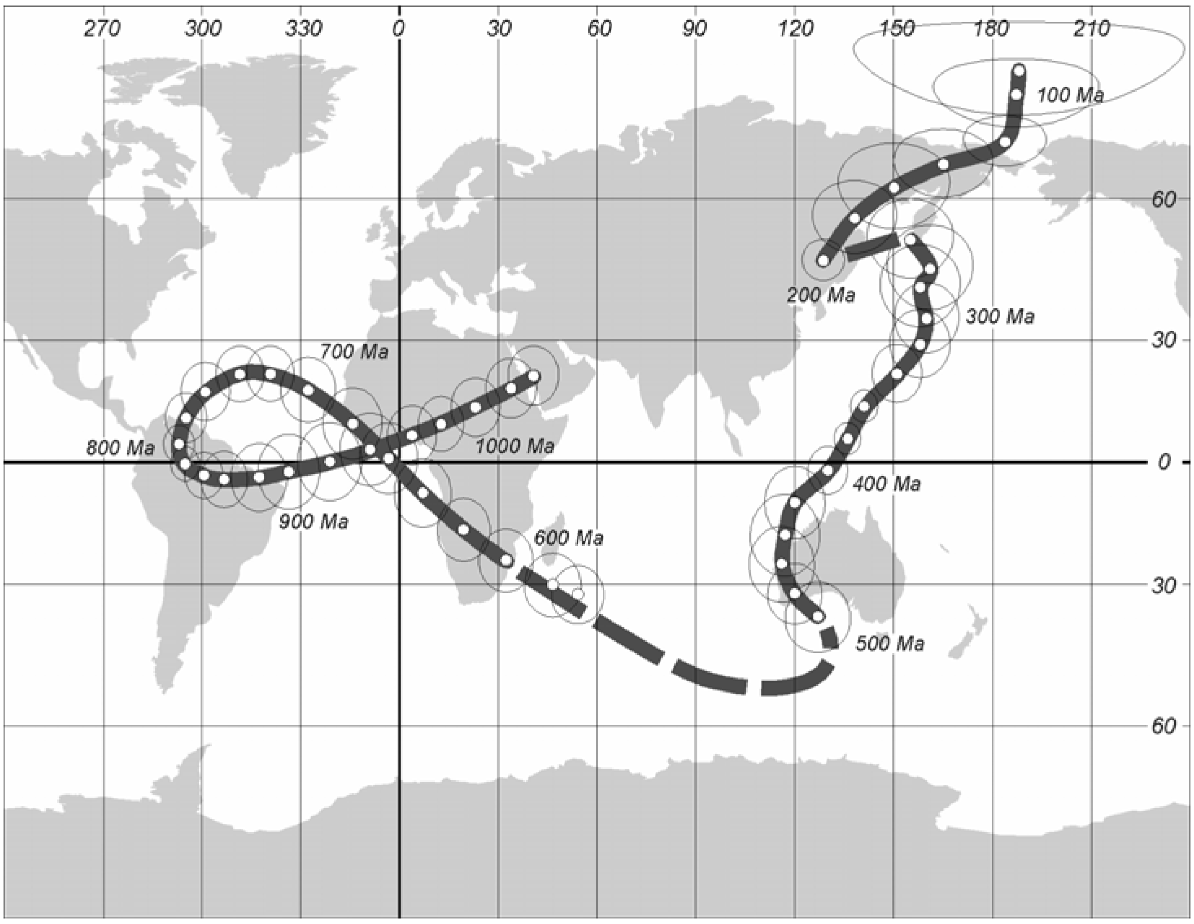

Fig. 2. The apparent polar wander path for Siberia. The pole co-ordinates are listed in the table 2. Dashed lines represent uncertain APWP intervals with poor data, which need verification.

Actually, the Late Mesozoic interval of the APW path is based on the paleomagnetic data obtained for the territory of the Verkhoyansk trough and the southwest periphery of the Siberian platform, generalized in (Metelkin et al., 2010a). We can see that the Late Mesozoic poles for Siberia have demonstrated a regular deviation from the reference poles for Europe (Besse & Courtillot, 2002). The angular distinction in Jurassic positions for Siberia and Europe reaches 45 degrees (Metelkin et al., 2010a) and gradually reduces by the end of Cretaceous. The possible reason of such distinctions appears to be the strike-slip motions between the Siberian and European tectonic domains. The scales of the motions can be estimated firstly as hundreds of kilometers. Under the term "domain", we understand the area with internal heterogeneous structure, but manifesting itself as a tectonicaly rigid block of the Earth's crust. Tectonic rigidity here is understood as the absence of deformations which have led to mutual motions or an essential rotation of blocks, composing the internal structure of the domain. According to the restored paleomagnetic trace, the Siberian domain during the Jurassic was a part of the Eurasian plate and was located in the high latitudes of the northern hemisphere. The whole structure has undergone a general drift in a southern direction (with a maximum velocity 10-12 cm/year) with a gradual clockwise rotation (an amplitude up to 2.5 degrees per million years). Up to the J-K boundary, Siberia has reached the modern co-ordinates and then demonstrates only a clockwise rotation with amplitudes not more than 0.5-1 degrees per million years (Metelkin et al., 2010a).

Mesozoic				Paleozoic				Neoproterozoic			
Age (Ma)	PLat	PLong	A_{95}	Age (Ma)	PLat	PLong	A_{95}	Age (Ma)	PLat	PLong	A_{95}
80	81.3	188.2	6.7	240	52	155	8	560	-32.2	54.3	6.7
100	77.8	187.4	5.2	260	46	161	9	580	-30.0	46.7	7.4
120	70.2	183.9	4.2	280	42	158	9	600	-24.1	32.5	7.5
140	66.3	165.2	6.0	300	35	160	8	620	-16.7	19.6	7.7
160	62.1	150.3	7.8	320	29	158	8	640	-7.6	7.2	8.6
180	56.3	138.3	7.1	340	22	151	7	660	1.0	356.8	8.9
200	47.7	128.8	4.3	360	14	141	4	680	9.7	345.9	8.9
				380	6	136	4	700	18.0	332.4	7.9
				400	-2	130	6	720	22.0	320.9	6.7
				420	-10	120	9	740	21.9	311.7	6.7
				440	-18	117	10	760	17.6	301.2	7.1
				460	-25	116	9	780	11.2	295.3	6.1
				480	-32	120	7	800	4.6	293.2	4.7
				500	-36	129	8	820	-0.4	295.1	4.3
								840	-3.3	300.8	5.8
								860	-4.2	306.9	7.1
								880	-3.7	317.5	8.5
								900	-2.3	326.5	9.4
								920	0.2	339.0	9.8
								940	3.2	351.2	9.1
								960	6.8	3.9	7.4
								980	9.6	12.7	6.8
								1000	13.8	23.2	7.2
								1020	18.4	34.0	7.3
								1040	21.5	40.8	7.2

Comment: The Paleozoic interval is taken from (Pechersky & Didenko, 1995); the Mesozoic and Neoproterozoic intervals are calculated of the basis of poles listed in table. 1. The data set was smoothed using the cubic spline (Torsvik & Smethurst, 1999) and then recalculated using a "sliding window" (window size - 50 Myr, poles through 20 Myr) (Besse & Courtillot, 2002); Plat, Plong - latitude and longitude of paleomagnetic pole; A_{95} - radius of 95% confidence oval.

Table 2. The final APW path for Siberia.

3. The structure of orogenic belts and terrains surrounding the Siberian Craton

3.1 Taimyr orogenic belt

The Late Paleozoic folded-napped structure of the Arctic part of Siberia (Fig. 3) can be divided into three large tectonic elements: the South Taimyr marginal-continental area, the Central Taimyr Neoproterozoic accretonal belt and Kara terrain separated by large thrusts, namely, the Major Taimyr and Pyasino-Faddey (Vernikovsky, 1996; Bogdanov et al., 1998).

3.1.1 South Taimyr area

The southern part of the Taimyr Peninsula is represented by a thick succession of shallow-sea sedimentary sequence with age ranging from Neoproterozoic to Permian. Towards the Siberian platform, the sequence plunges under Mesozoic-Cenozoic deposits of Yenisey-Khatanga trough and overlaps the Archean-Paleoproterozoic crystal basement of the Siberian Craton. The section is basically composed of carbonate and clay deposits and represents a typical sequence of the passive continental margin faced to the north (Ufland et al., 1991; Vernikovsky, 1996; Bogdanov et al., 1998). Development of the oceanic basin in the north of Siberia is assumed to be at the very beginning of the Mesoproterozoic, while in Neoproterozoic the region was developed in a mode of shelf margin of the continent (Pisarevsky & Natapov, 2003). The passive continental margin environment remained up to the Permian. The upper part of the section is sated by Early Triassic volcanic complexes of trapp formation. The formation of the complex has occurred under intraplate conditions under the influence of the North Asian superplum (Vernikovsky et al., 2003) and has probably been connected with the early stage of the opening of the Yenisey-Khatanga rift system and thus corresponds to the model of the forearc trough evolution in the north, in front of the growth of the Hercinian orogen.

3.1.2 Central Taimyr belt

The acrretional structure of the belt was formed during the Neoproterozoic (Vernikovsky & Vernikovskaya, 2001). The structure of the belt basically consists of paleoisland arc and paleoocean terrains which are represented by Neoproterozoic volcano-sedimentary and volcanic successions, alternating with Paleoprtoterosoic cratonic terrains, composed mainly from deeply metamorphosed rock associations (Vernikovsky & Vernikovskaya, 2001, Peace et al., 2001). According to U-Pb dating most of the ancient island arc associations were already developed in the beginning of the Neoproterozoic about 961±3 million years ago (Vernikovsky et al., in progress). Paleomagnetic data obtained for these complexes testifies that the ancient arc was located in the immediate proximity from the South Taimyr margin of Siberia (Vernikovsky et al., in progress). The paleomagnetic pole position (Plat=17.8, Plong=326.8 A95=4.0) is quite close to the one-age pole for the craton (Pavlov et al., 2002): the angular divergence is about 30°, while the latitudal one is less than 9°. Ophiolites and island arcs were developed in the northern margin of Siberia up to the end of the Neoproterozoic: their ages for Cheliuskin and Stanovoy belts are 750- 730 million years ago and 660 million years ago for the Ust-Taimyr belt (Khain et al., 1997; Vernikovsky & Vernikovskaya, 2001; Vernikovsky et al., 2004). The accretion time of the island arcs to Siberia is estimated as Late Neoproterozoic about 600 million years ago (Vernikovsky et al., 1997; 2004) and the overlapping Vendian-Paleozoic sedimentary complex, including characteristic molasse, forms a uniform margin-continental system with the South Taimyr territory (Ufljand et al., 1991; Vernikovsky, 1996; Vernikovsky Vernikovskaya, 2001). The sedimentary complex, along with Vendian coarse-grained molasse, contains siltstone, mudstone and black graptolite shale with layers of limestone and the dolomite, forming the main part of the section from the Lower Cambrian to the Devonian. The presence of graptolite shale proves a more deep-water sedimentary environment, rather than shelf complexes, typical for the South Taimyr area. The axis of a deep-water trough is reconstructed in the frontal part of Pyasino-Faddey thrust (Vernikovsky, 1996).

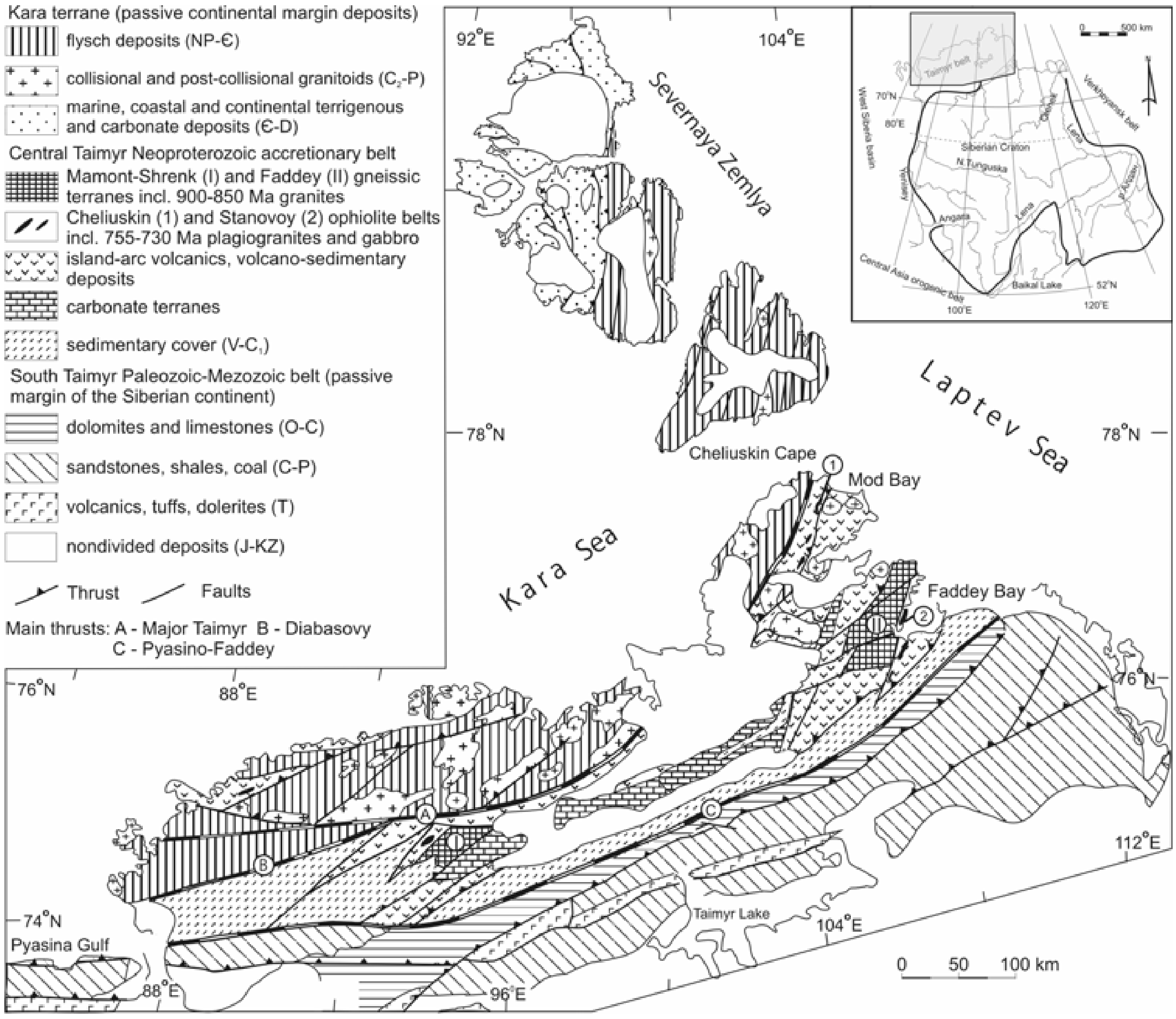

Fig. 3. Tectonic map of the Taimyr - Severnaya Zemlya fold-and-thrust belt (after Vernikovsky & Vernikovskaya, 2001).

3.1.3 Kara terrain

Kara terrain occupies the northern part of the territory, including the coastal part of the Taimyr Peninsula, the islands of the Severnaya Zemlya archipelago and the adjacent floor of the Kara Sea (Fig. 3). Three different rock associations can be distinguished here: i) Paleoproterozoic metamorphic complexes of the crystal basement is represented by palgiogneiss, amphibolite, and granitic gneiss (Ufland et al., 1991; Vernikovsky, 1996); ii) Neoproterozoic-Cambrian deposits of continental slope and slope front has an essential flysch structure and is represented by rhythmically alternating sandstone, siltstone and mudstone, partly metamorphosed from green-schist to amphibolite facies (Bogolepova et al., 2001; Lorenz et al., 2008); iii) relatively low deformed sequences of sedimentary cover with predominant coastal-sea and lagoon facies (limestone, marlstone, sandstone interbeded with gypsum), and also terrigenous continental strata which are often red beds (at the highest levels in the section) (Männik et al., 2002, 2009; Lorenz et al., 2008). The collision of the Kara microcontinent with the Siberian margin in the Carboniferous-Permian is reflected in the development of collisional granitoids and also in synchronous zonal metamorphism

(Vernikovsky, 1996; Vernikovsky et al., 1997). The Most ancient ages (more than 300 million years ago) are obtained for granitoids which are distributed northward and form the Major Taimyr thrust on Bolshevik island (Vernikovsky, 1996; Lorenz et al., 2007; 2008). The paleomagnetic data from the Kara terrain are available only for Early Paleozoic (Metelkin et al., 2005b). Despite the similarity of polar wander and comparable paleolatitudes, the APW trend for the Kara is considerably displaced to the east from the Siberian poles towards APWP for Baltica. Synthesis of the data and analysis of the restored kinematics of the Kara, Siberia and Baltica reveals a terrain history of Kara during the Paleozoic (Metelkin et al., 2005b). From the Ordovician up to the end of the Silurian, the terrain underwent a northern drift from 40°S to 10°N with an average velocity about 5 cm/year and counter-clockwise rotation with 1 degree per million years amplitude. Similar drift, but with outstripping rotation of the plate, is reconstructed for Baltica (Torsvik & Cocks, 2005). The main difference in kinematics of the Siberian plate consists in its clockwise rotation (Cocks & Torsvik, 2007). The opposite rotation of continental masses should provide a development of transform the zone between them and promote a strike-slip motion of the Kara microplate (Metelkin et al., 2005b).

3.2 The Verkhoyansk area

The Folded-napped structures of the Verkhoyansk belt frame the eastern margin of the Siberian platform and are separated by a system of frontal thrusts of the Verkhoyansk trough. Development of the orogen is a result of Late Mesozoic accretion-collision processes (Parfenov et al., 1995; Oxman, 2003). In plan from, the folded area forms a huge loop which in a fan shape extends to the north where it sinks down under the cover of the Arctic shelf. Rock complexes of the Verkhoyansk system are bending around the Olenek uplift and are joined with the South Taimyr, forming a uniform sedimentary paleobasin in the sense of composition, developed on an Early Precambrian crystal basement of the Siberian Craton. Composition and structure of the complex are relatively uniform. It is composed of a monotonous sequence of sandy-siltstone sediments of Carboniferous to Jurassic age which is underlain by more ancient carbonate deposits. The sequence is represented by genetically uniform sedimentary successions deposited under the conditions of passive margin (Parfenov & Kuz'min, 2001; Pisarevsky & Natapov, 2003). Basal horizons of the Mesoproterozoic - Neoproterozoic complex are abundant in the south of the area where they form Kyllakh and Sette-Daban uplifts. They are composed of shallow, lagoon-sea and sometimes continental deposits: dolomite, limestone, marlstone, sandstone, siltstone and shale (Khomentovsky, 2005). The southern part of the Kyllakh uplift (the Judoma-Maya zone) and adjacent Uchur-Maya plate in the west represent the stratotype district for the basic divisions of the Late Mesoproterozoic and Early Neoproterozoic of Siberia (Khomentovsky, 2005). The paleomagnetic data obtained from those strata (Gallet et al., 2000; Pavlov et al., 2000, 2002) give the background for paleotectonic reconstructions for Siberia at the Mesoproterozoic/Neoproterozoic boundary. The most important key poles are yielded from dolerites of subvolcanic intrusions, widely distributed among deposits of Ui group (Pavlov et al., 2002). Development of the intrusions along with the predominantly terrigenous sedimentary environment of the Ui group, distinguish it from the other strata of the Uchur-Maya region and may reflect the riftogenic processes within the craton margins at the boundary of 1 billion years (Rainbird et al., 1998; Khudoley et al., 2001).

3.3 The Baikal-Vitim fold-and-thrust belt

Geological complexes the Baikal-Vitim fold-and-thrust belt occupies an extensive territory to the east from the Baikal Lake up to the Vitim river basin. We consider three tectonic elements in its structure: the Bodajbo-Patom Neoproterozoic marginal-continental area; the Baikal-Muya Neoproterozoic accretional belt; the Barguzin-Vitim Early Caledonian orogenic area (Fig. 4).

3.3.1 Bodaibo-Patom area

The area is characterized mainly by Neoproterozoic sedimentary successions. Sections are usually represented by terrigenous-carbonate deposits but their geodynamic position is interpreted differently (Nemerov & Stanevich, 2001; Pisarevsky & Natapov, 2003; Zorin et al., 2009). The absolute age of the majority of startigraphic units is also under discussion (Stanevich et al., 2007). Nevertheless, the general structural plan does not cause any doubts: the strata represent a thick sedimentary wedge, thickening toward the folded area and overlapping the crystal complexes of the craton margin. The change of shallow-water faces to more deep-water, flysch-like and turbidity deposits, follow the same direction. Such features are inherent in marginal-continental sea basins. Ophiolites and subduction complexes overthrusted on the margin of the craton from the south and comprising the Baikal-Muya belt can be considered as indicators of the Neoproterozoic ocean.

3.3.2 Baikal-Muya belt

Three different units - the Muya cratonic terrain; Kilyan island arc terrain and Param oceanic terrain can be distinguished in the structure of the Neoproterozoic accretion belt (Parfenov et al., 1996; Khain, 2001). The most ancient ophiolite, according to Sm-Nd dates, correspond to the end of the Mesoproterozoic (Rytsk et al., 2001, 2007). The transformation of the continental margin into an active regime possibly occurred in the Middle Neoproterozoic 800-850 million years ago (Khain et al., 2003). Subductional volcano-plutonic associations are represented by the tuff and lava of rhyolite, andesite, basalt, and also gabbro and plagiogranite. The second peak of subduction magmatism corresponds to the interval 750-620 million years (Khain et al., 2003). However, according to some viewpoints the Kilyan island arc system was not connected directly with the margin of the Siberian Craton and the Baikal-Muya belt was a part of another superterrain, and has been developed far from the margin (Kuzmichev, 2005). Paleomagnetic data for this area are absent. It is supposed that just before the Vendian, the initial structure of the superterrain has been disrupted and the Bajkal-Muya fragment moved along the strike-slip and amalgamated to the Siberian Craton (Kuzmichev et al., 2005; Belichenko et al., 2006). The time of this event is supported by stratigraphic data. Acceretional complexes of the Baikal-Muya belt with angular and stratigraphic unconformity are overlapped by Vendian terrigenous deposits and Cambrian, predominantly carbonate deposits which have remained as isolated fragments and are probably the remains of former uniform sedimentary cover with Siberia (Belichenko et al., 2006).

3.3.3 Barguzin-Vitim area

Traditionally it is considered that Late the Precambrian orogenesis resulted from the accretion process between the Siberian Craton and the Barguzin microcontinent. The remains of the microcontinent are expected to be to the south of the Baikal-Muya belt within

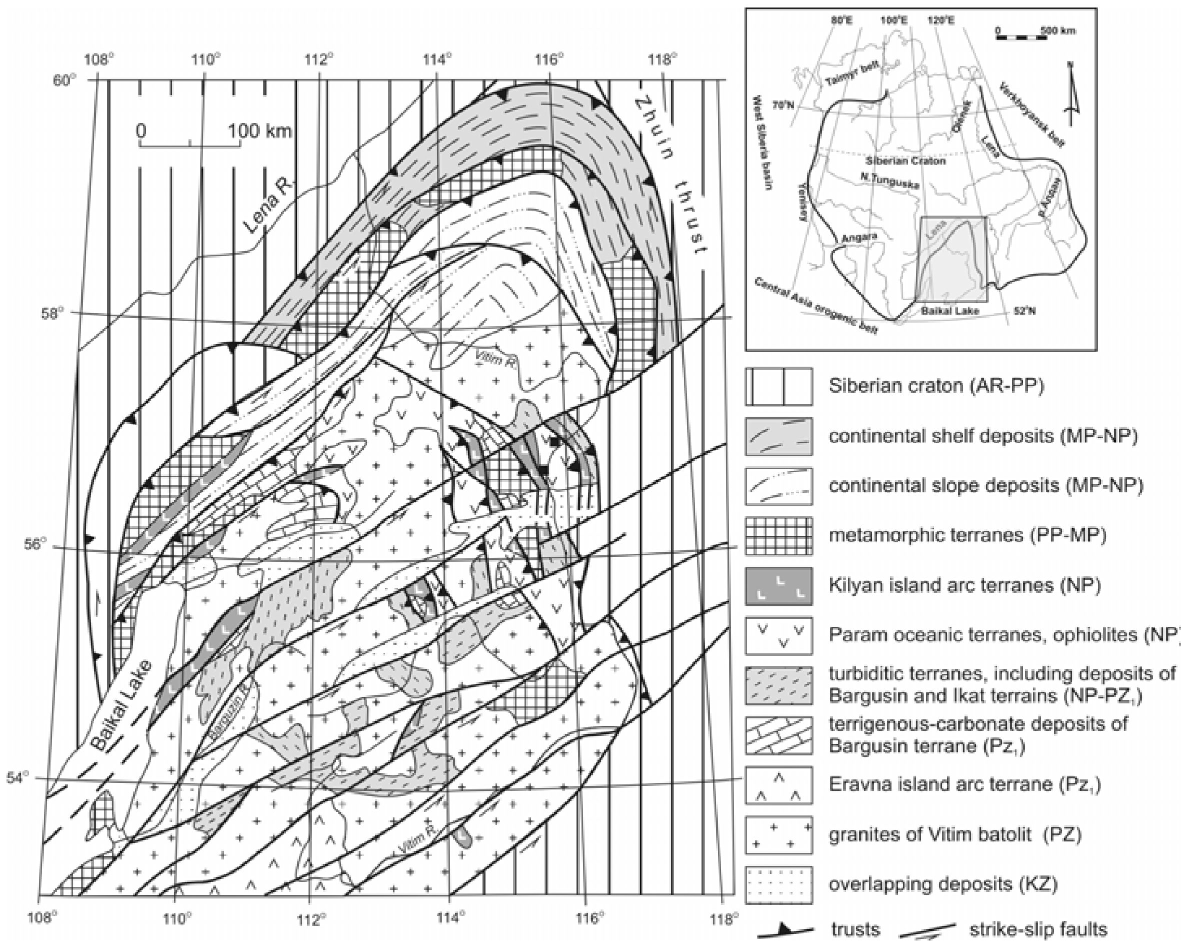

Fig. 4. Schematic geological map of the Baikal-Vitim fold-and-thrust belt (adapted from Parfenov et al., 1996; Vernikovsky et al., 2004)

the Barguzin-Vitim area (Zonenshain et al., 1990). Another point of view dominates now. It is possible to isolate two turbidite terrains within the limits of the area: Barguzin and Ikat terrains (Belichenko et al., 2006; Zorin et al., 2009). The structure of both terrains does not correspond to modern concepts of microcontinents. First of all, both terrains have no Precambrian crystal basement. Deeply metamorphosed deposits of the central part of the Barguzin ridge which were considered as Early Precambrian (Zonenshain et al., 1990) gradually change to weakly metamorphosed Vendian - Early Paleozoic deposits (Belichenko et al., 2006; Zorin et al., 2009), however, the age of metamorphism is not Precambrian but Ordovician-Silurian (Belichenko et al., 2006; Rytsk et al., 2007; Zorin et al., 2009).Cambrian volcanic complexes stretched by a chain along the River Uda in the northeast up to the River Vitim and united as a part of the Eravna terrain which can be considered the structures controlling island arc development (Gordienko, 2006). In the first, paleomagnetic data suggest a westward displaced position of the terrain in relation to its modern arrangement in the structure of the folded area. In the beginning of the Cambrian, the island arc was located about 5-10°N and had a submeridional orientation (Metelkin et al., 2009).

3.4 Sayan-Yenisey fold-and-thrust belt

The folded-napped structure of the Sayan-Yenisey area involves Early Precambrian complexes of southwestern margin of Siberian Craton (Fig. 5). The western boundary is well pronounced in the strike-slip zone - a branch of the Main Sayan deep fault with immediately adjacent Caledonian structures of Altai-Sayan fragment of the Central-Asian orogenic belt which is plunging in the north under Mesozoic-Cenozoic cover of the West Siberian plate. The zone of the deep fault is well traced by geophysical data under the deposits of Western Siberia along the left bank of Yenisey River up to the Turukhansk-Norilsk area (Vernikovsky et al., 2009).

3.4.1 Paleoproterozoic terrains of the craton margins (the Angara belt)

The structures of Sharyzhalgay and Birusa terrains constitute a distinct prominence of the Siberian Craton. They are composed of granulite-gneiss and granite-greenschist type rocks of the Archean-Paleoproterozoic age. Amalgamation of the terrains is associated with the boundary of 1.8 - 1.9 billion years ago which is reflected in the formation of collisional granites (Levitsky et al., 2002; Didenko et al., 2003; Turkina et al., 2007). Formation of similar complexes is also detected in the north (Nozhkin et al., 1999) where Paleoproterozoc structures are built up by granulite and amphibolites of the Angara-Kan terrain. It is supposed that this stage of crustal growth has occurred over the whole western margin of the Siberian Craton, and the resulting structure is united as a part of the Angara belt (Rozen, 2003). Further to the north, within the Yenisey range, the structure of the Angara belt is represented by the East Angara terrain. In the limits of the terrain, Early Precambrian crystal complexes are generally overlapped by low metamorphosed Mesoproterozoic and Neoproterozoic terrigenous-carbonate strata. Among them, to the south, in the limits of Pre-Sayan trough, deposits of the Karagas group are widespread. The group is characterized by a cyclic-constructed succession which was deposited in the coastal-marine environment. (Pisarevsky & Natapov, 2003; Stanevich et al., 2007; Metelkin et al., 2010b). The absolute age of the strata is hotly debated. Considering the available stratigraphic constraints and the indirect geochronological data, the group was deposited between 800 and 740 million years ago (Stanevich et al., 2007). Paleomagnetic data suggest a Middle Neoproterozoic age of the group and a high rate of its deposition (Metelkin et al., 2010b). Deposits of the Karagas group and the underlying Paleoproterozoic metamorphic complexes are saturated by subvolcanic intrusion of gabbro-dolerie, united in the Nersa complex. The age of that complex is estimated as 740 million years, and it has been formed in conditions similar to those of intercontinental riftogenesis (Sklyarov et al., 2003; Gladkochub et al., 2006). The results of paleomagnetic study of the Nersa complex are given in (Metelkin et al., 2005a).

3.4.2 Central Angara belt

The Central-Angara terrain occupies the central part of the Yenisey ridge. The structure of its basement corresponds to Paleoproterozoic metamorphic terrains of the Angara belt. In general, the Early Precambrian basement is overlaid by Mesoproterozoic and Neoproterozoic coastal-marine sedimentary complexes. However, it is separated from the East Angara terrain by the Panimba ophiolite belt accompanied with Ishimba thrust that allows us to consider a tectonic history of the Central-Angara terrain separately from the structures of the Angara belt. Argon-argon age of amphibolites and plagioclases from gabbro-amphibolites of the ophiolite belt is 1050-900 million years (Vernikovsky et al., 2003). Granitoids with 760-720 million years age appear to be indicators of a collisional event (Vernikovsky et al., 2003; Vernikovskaya et al., 2003, 2006).

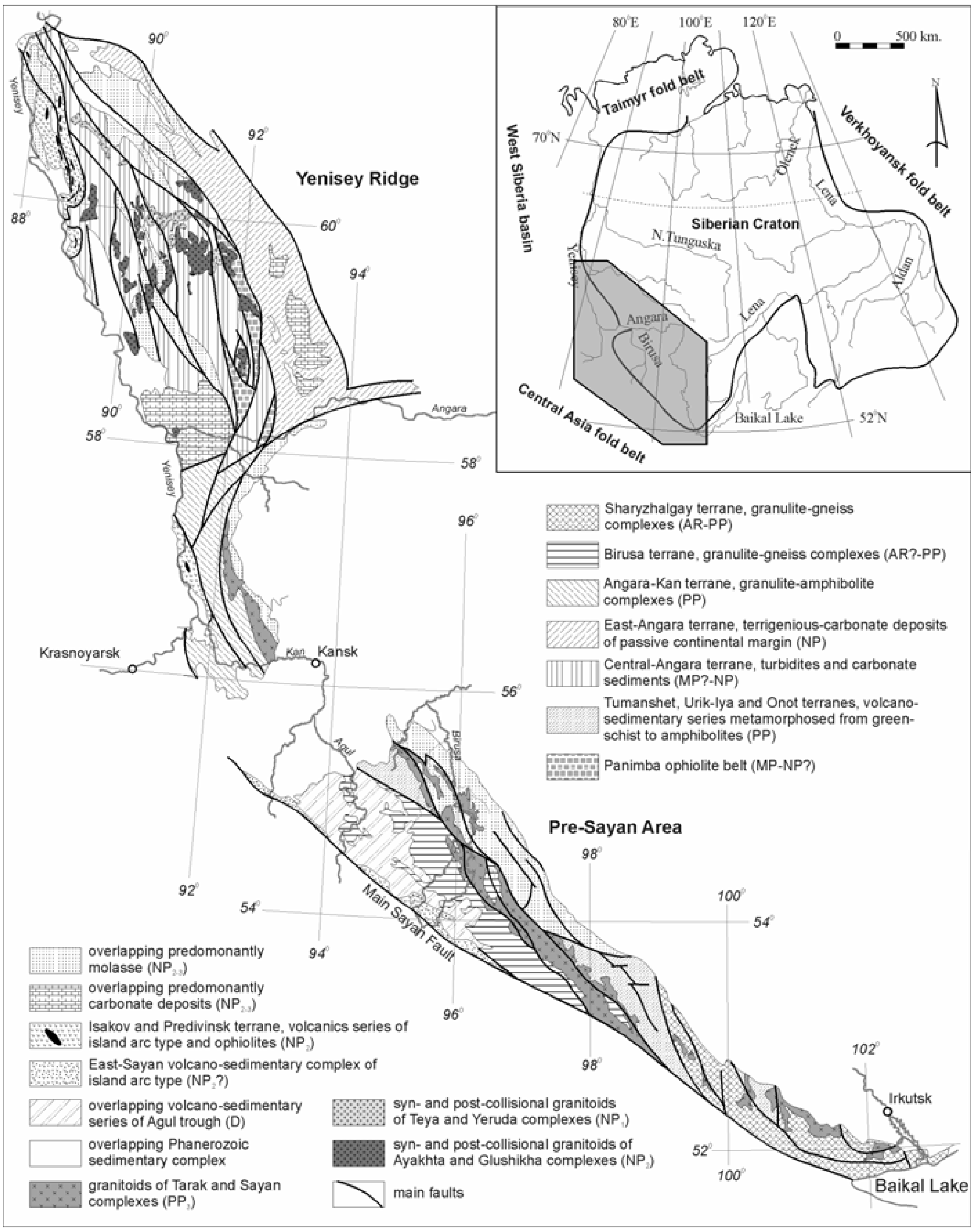

Fig. 5. Geological sketch-map of the Sayan-Yenisey fold-and-thrust area (after Metelkin et al., 2007a)

3.4.3 Pie-Yenisey accretional belt

The western periphery of the Yenisey ridge is occupied by Neoproterozoic accretional structures napped over crystal formations of the Central-Angara and Angara-Kan terrains. Isakov and Predivinsk island arc terrains can be distinguished in the area (Vernikovsky et al., 2003). Structures of the terrains contain subductional volcano-sedimentary complexes including ophiolite fragments, partly metamorphosed in green-schist conditions (Vernikovsky et al., 1999). Results of U-Pb, Ar-Ar, and Rb-Sr isotope study allow an estimate of the evolution time of an active volcanic arc between 700 and 640 million years ago, and the time of accretion as 600 million years ago (Vernikovsky et al., 2003). The time of accretion coordinates well with the Vendian age of overlapping molasse (Sovetov et al., 2000). A paleomagnetic study was carried out on the volcanic complexes of differentiated calc-alkaline series of the Predivinsk terrain with a U-Pb age 637± 5.7 million years ago (Metelkin et al., 2004a). Paleomagnetic pole positions correspond to the general trend of Vendian poles of Siberia (Pisarevsky al., 2000; Kravchinsky et al., 2001; Kazansky, 2002; Shatsillo et al., 2005, 2006). Taking into account that the development of the series has proceeded directly before accretion, the paleomagnetic data allows estimation of a spatial position not only for the arcs, but also as a first approximation for the craton (Metelkin et al., 2004a; Vernikovsky et al., 2009).

3.5 Altai-Sayan area

The Altai-Sayan area occupies the southwest frame of the Siberian Craton and is a fragment of the Central-Asian orogenic belt (Fig. 6). Terrains of island arc genesis compose the basic structure of the Early Caledonian folded area (Dobretsov et al., 2003). Among them are West Sayan, Kuznetsk Alatau, and Gorny Altai which are briefly characterized below. A number of publications describe these terrains as fragments of a formerly uniform island arc system supervising the Vendian-Cambrian subduction zone in the southwest of the Siberian continent (Şengör et al., 1993; Kungurtsev et al., 2001; Buslov et al., 2001; Gordienko, 2006). Accordingly the Early Paleozoic system of the Eravna arc and the Barguzin-Ikat back arc basin, we suggest as a natural continuation of the paleoisland arc system to the east. Accretion of the arcs to the craton started just at the beginning of the Ordovician and is manifested by the occurrence of numerous granite plutons of a collisional type (Dobretsov et al., 2003; Khain et al., 2003). The results of paleomagnetic study of the Altai-Sayan area can be obtained from a generalizing paper (Metelkin et al., 2009) or directly from the publications listed below for concrete regions. Particularly in (Metelkin et al., 2009) it is shown, that paleomagnetic poles for the second half of Cambrian and Ordovician are concentrated within a compact area to the south from Australia, while the Vendian-Early Cambrian poles are distributed along a great circle in the internal area of Africa. The circle center (approximately 61 N, 114° E) is close to the center of the Siberian Craton. On this basis we suggest that the terrains represented some fragments of a uniform island arc, and the deformation of the arc was connected with strike-slips resulting from rotation of those fragments at different angles (or strike-slipped at a different distance). Calculation of the angles leads to the paleoreconstruction which "straightens" the modern mosaic of terrains of the Altai-Transbaikalia area into a linear structure. On the other hand, to reach the coincidence of poles, it is possible to rotate each block around a corresponding sampling point. Actually, we used a series of great circles for the best fit of the pole positions. The average normal direction for all the circles corresponds to the center of the craton. However, a tectonic expression of this fact is an alternate idea and assumes a deformation of the island arc as a result of a rotation of its fragments round their own axes without a displacement from each other. The combination of the mechanism of the general strike-slip motion resulted in a segmentation, and relative displacements of fragments with their local rotations seem to be the most realistic.

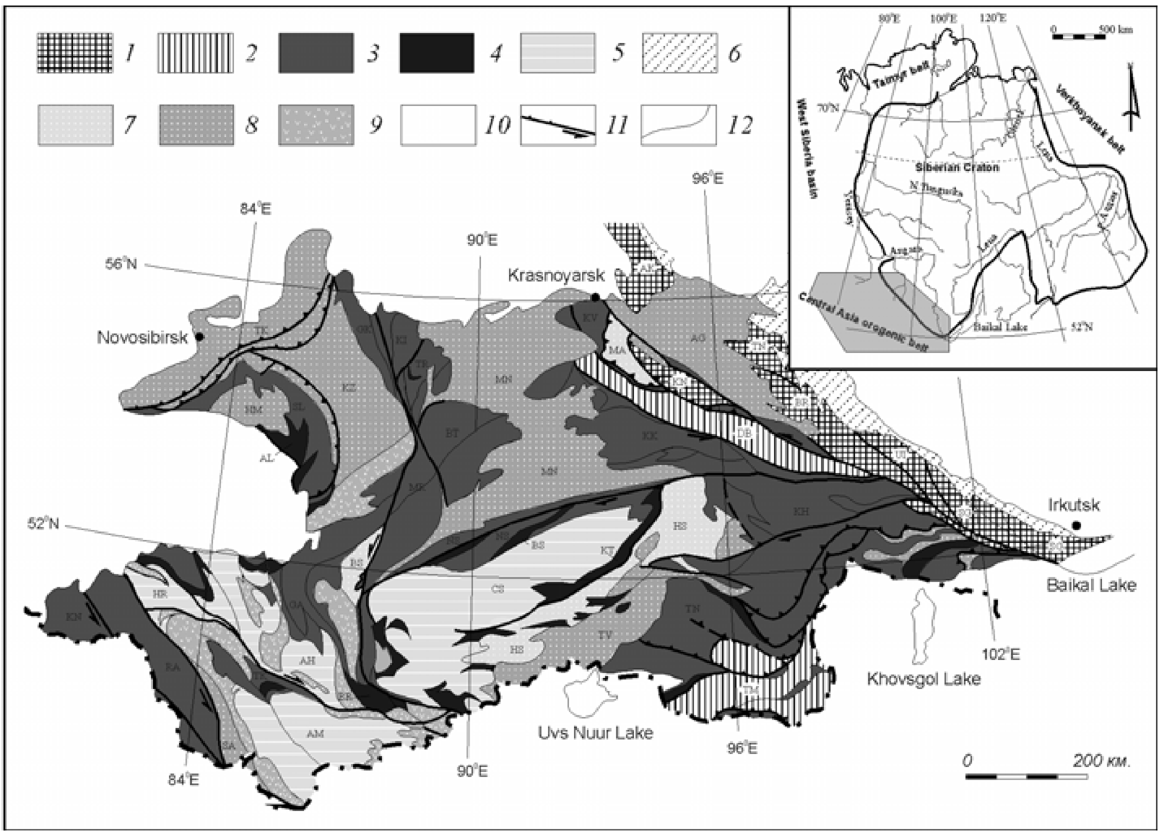

Fig. 6. The main structures of the Altai-Sayan area (modified from Kungurtsev et al., 2001).

Legend: 1-5 - tectonostratigraphic terranes: *1* - Siberian craton and cratonic terranes: BR - Birusa (granulite-gneiss, AR?-PP), SG - Sharyzhalgay (granulite-gneiss, AR-PP), AK - Angara-Kan (granulite-amphibolite, PP), UI - Urik-Iya (greenschist, PP), TN - Tumanshet (amphibolite, PP), KN - Kan (metamorphic, PP); *2* - miogeoclinal terranes (microcontinents): TM - Tuva-Mongolian (passive continental margin, NP), DB - Derba (passive continental margin, NP); *3* - island arc terranes (accretionary wedge, volcanic arc and back-arc basin complexes including): GK - Golden Kitat (accretionary wedge and volcanic arc, V-Є), KI - Kiya (volcanic arc, V-Є), TR - Ters (volcanic arc and back-arc basin, V-Є), BT - Bateni (back-arc basin, V-Є), MR - Mrass (volcanic arc and back-arc basin, V-Є), SL - Salair (island arc undivided, V-Є), NS - North Sayan (accretionary wedge and volcanic arc, V-Є) , GA - Gorny Altay (island arc undivided, V-Є), TK - Terekta (accretionary wedge, V-Є), TN - Tannuola (volcanic arc and back-arc basin, V-Є), KH - Khamsara (volcanic arc, V-Є), KK - Kizir-Kazir (island arc undivided, V-Є), KV - Kuvai (accretionary wedge, NP), RA - Rudny Altay (volcanic arc, D-C), KN - Kalba-Narim (accretionary wedge, D-C); *4* - oceanic terranes (seamounts and ophiolites including as a part of accretionary wedge, basement of island arc and as a product of back-arc spreading): KT - Kurtushiba (ophiolites in accretionary wedge, V-Є), BS - Borus (ophiolite,V- Є), AL - Alambai (ophiolite,V-Є), BR - Baratal (seamount, V-Є); *5* - continental margin turbidite terranes: CS – Central Sayan (Є-S), AH – Anui-Chuya (Є-S), HR – Charysh (Є-S), AM – Altai-Mongolian (NP-S); *6 - 9* – overlap assemblages: *6* – Siberian plate (NP - PZ), *7* – Early Paleozoic basins: HS - Khemchik-Sistigkhem (molasse, O-S), MA – Mana (sedimentary, V-Є), BS – Biya (molasse, O-S); *8* – Late Paleozoic – Early Mesozoic basins: MN – Minusa (volcano-sedimentary, molasse, D-P), KZ - Kuznetsk (molasse including trapps, D-T), AG – Agul (volcano-sedimentary, molasse, D-C), TK – Tom-Kolyvan (back-arc, volcano-sedimentary, D-P), HM – Khmelev (back-arc, volcano-sedimentary, D-C); TV – Tuva (volcano-sedimentary, molasses D-P), SA – South Altai (back-arc, volcano-sedimentary, D-C), *9* – Altai volcano-plutonic belt (D-C), *10* – Mesozoic-Cenozoic sedimentary basins; *11* –faults with specified napped or strike-slip kinematics of post-accretional displacement; *12* -other faults and geological boundaries. The inlay represents the location of the Altai-Sayan area relative to the Siberian Craton.

3.5.1 West Sayan terrain

The West Sayan terrain includes the Vendian-Cambrian complexes of the island arch which are composed of two large fragments. In the frontal part of North Sayan fragment the complexes of the accretionry wedge are represented by terrigenous deposits interbeded with basalt, tuff, marble, and also ophiolite units. The lateral succession to the north is supplemented by turbidities and then by complexes of the volcanic arc. The Vendian-Early Cambrian interval is characterized by tholiite magmatism which was replaced by a differentiated series at the boundary of 520 million years ago. This complex is overlapped by a multicolored terrigenous sequence formed as a result of an intensive washing of the volcanic series. The Kurtushiba fragment corresponds to the frontal part of the arc with widespread oceanic complexes. A paleomagnetic study of the above named complexes proves the preservation of a stable magnetic component which was acquired at the stage of rock formation (Kazansky et al., 1999). Generalization of the data reveals the following tectonic history of the terrain. Both fragments belonged to the uniform arc occupied in the subequatorial position in the Cambrian. The arc has undergone a prevailing submerideonal drift and strike-slip displacement of the Kurtushiba fragment to the southwest, in relation to the North Sayan (Metelkin et al., 2009).

3.5.2 Kuznetsk Alatau terrain

The Kuznetsk Alatau terrain consists of five units which possess the original tectonic style, but undoubtedly are fragments of the uniform paleoisland arc system (Metelkin et al., 2000; Kazansky et al., 2003). We studied four of them: Golden Kitat, Kiya, Ters and Bateni tectonic units, mainly composed of Cambrian subduction complexes with a typical set of rock associations.

The Vendian-Early Cambrian complex is represented by the tholeite series, the Middle-Late Cambrian complex is represented by a differentiated series with an expressed calc-alkaline composition and considerable concentration of pyroclasics. The development of the Late Cambrian-Early Ordovician molasse and alkaline volcano-plutonic complex corresponds to an accretion stage. The ages are proved by the isotope data (Vladimirov et al., 2001). Paleomagnetic data (Metelkin et al., 2000; Kazansky et al., 2003) shows that the structural plan of the region is determined by the strike-slip motions of its fragments. Analysis of APW trends (Kazansky et al., 2003; Metelkin & Koz'min, in progress) allows restoration of a southern drift of the arc with a 5-6 cm/year velocity which was accompanied by a clockwise rotation. The size of displacement of the forearc and back-arc parts were different which caused the strike-slip mechanism of transformation of the initial structure of the arc. The reconstructed position of the arc in the Cambrian corresponds to subequatorial latitudes.

3.5.3 Gorny Altai terrain.

The Gorny Altai terrain stands out because of its repeated alternation of blocks composed of island arc complexes, resulting from strike-slip tectonics which manifested both during Early Caledonian and Hercinian stages of the orogenesis (Buslov et al., 2003). The western part (the Anui-Chuya trough) is represented by terrigenous complexes of forearc basin with characteristic flysch and olistostrome composition. Complexes of accretionary wedge and volcanic arc are predominant in the central part. The basalts are typical representatives of the Kuray zone where the Vendian-Early Cambrian spreading and subduction complexes are widespread. The accretionary wedge is mainly composed of carbonate deposits overlapping pillow-basalts which are considered as seamounts (Safonova et al., 2008). The collision of the seamounts with the island arc occurred 520 million years ago, marking the beginning of the developed stage of subduction magmatism (Buslov et al., 2001). Typical calc-alkaline complexes of Middle-Late Cambrian are distributed in the east in the Ujmen-Lebed zone and volcano-sedimentary sequences of the back-arc basin are also present here. Paleomagnetic data (Pechersky & Didenko, 1995; Kazansky et al., 1998; Kazansky, 2002) testify that the Gorny Altai terrain constitutes a part of the Kuznetsk Alatau island arc and the transformation of its initial structure may be described by the same uniform strike-slip mechanism (Metelkin et al., 2009).

4. The tectonic and paleogeographical reconstructions of Siberia and surrounding terrains

4.1 The Neoproterozoic stage

The history of the Siberian paleocontinent actually begins at the moment of Rodinia break-up. The Neoproterozoic stage of tectonic history corresponds to this event (Li et al., 2008). The set of available geological and paleomagnetic data testifies that at the Mesoproterozoic-Neoproterozoic boundary the Siberian Craton was a part of Rodinia and could represent a large peninsula of the supercontinent in the northeast (Metelkin et al., 2007a; Pisarevsky et al., 2008). In modern co-ordinates, Siberia continued as Laurentia to the north so that the western margin of Siberia was a continuation of the western margin of Laurentia (Fig. 7). The review of geological data on structural position, structure, formation environments and age of the Late Mesoproterozoic and Early Neoproterozoic complexes distributed on the margins of the Siberian Craton shows that this stage of geological history practically in all the periphery of the continent is connected with the dominating conditions of a continental shelf (Pisarevsky & Natapov, 2003; Pisarevsky et al., 2008). The modern northwest margin of Siberia, also as the western and the eastern margins (Semikhatov et al., 2000; Petrov & Semikhatov, 2001), represented a passive continental margin with a typical complex of sedimentary rocks (Pisarevsky & Natapov, 2003). An active tectonic mode, possibly characterizes only the southern margin of Siberia (Rainbird et al., 1998; Pavlov et al., 2002; Yarmolyuk et al., 2005; Metelkin et al., 2007a). Geological complexes in this area can correspond to the mode of intracontinent riftung or an active stage of the development of the ocean. Among them dikes with an age of 950-1000 million years (Rainbird et al., 1998; Pavlov et al., 2002) in the sedimentary cover of Uchur-Maya region in the southeast of the craton, geological complexes of various geodynamic environments of the Baikal-Muya accretion system (Parfenovet al., 1996; Khain et al., 2003; Gordienko, 2006), the youngest at about 750 million years and younger and products of intraplate alkaline magmatism in Pre-Sayan and Baikal regions in the southwest of the craton (Yarmolyuk et al., 2005; Gladkochub et al., 2006) can be distinguished. Thus, the gradual rejuvenation of magmatism due to available isotope data is assumed to be from the east to the west. On the basis of a number of petrologic-geochemical evidences the direct link between the development of intrusive massifs subvolcanic intrusions of the basic composition with rifting processes, and the break-up of the Laurasian part of Rodinia is assumed (Yarmolyuk et al., 2005, Pisarevsky et al., 2008).
Paleomagnetic data suggest that break-up of the continental masses of Siberia and Laurentia during the Neoproterozoic passed gradually along the southern margin of Siberia from the east to the west under the defining role of strike-slips which have set the rotary motion to the Siberian Craton (Metelkin et al., 2007a). Following this model, it was possible to believe

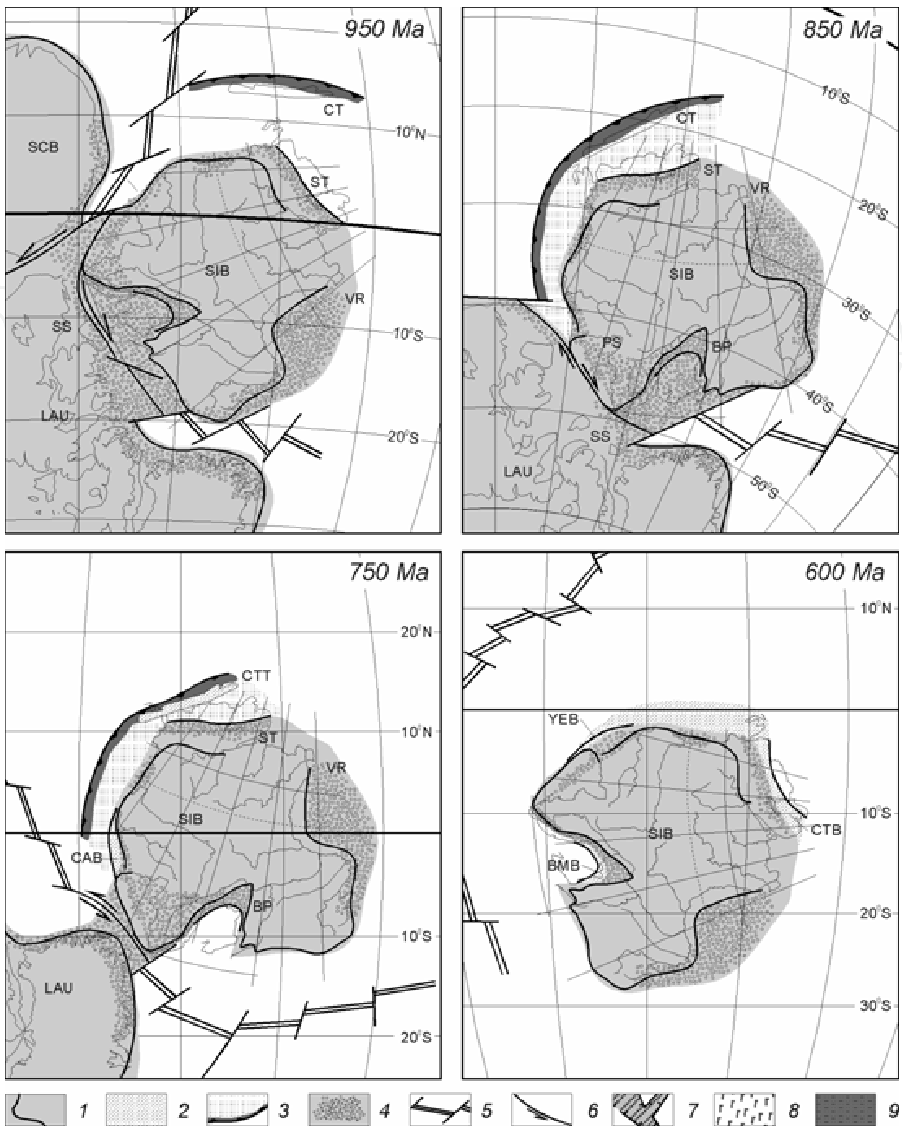

Fig. 7. Paleotectonic evolution of the Siberian Craton and its margins during the Neoproterozoic.

Legend: 1 – continental masses and most important block contours; *2* – accretionary structures, orogenic belts with corresponding age; *3* – subduction systems, including volcanic belts and back arc basins; *4* – marginal seas, shelf basins of passive margins; *5* – suggested spreading zones; *6* – general strike of transform-shear zones with their kinematic style; *7* – schematic area of crust thinning in limits of West-Siberian graben-rift system; *8* – schematic area of the development of the Permian-Triassic Siberian flood basalts; *9* – Mesozoic-Cenozoic cover of the West-Siberian sedimentary basin.

Abbreviations: continental blocks: SIB – Siberia, BAL – Baltica, KAR – Kara, KAZ – Kazakhstan, LAU – Laurentia, NCB – North China Block, TAR – Tarim, SCB – South China Block; basins of passive margins, marginal seas: VR – Verkhoyansk, BP – Bodajbo-Patom, PS – Pre-Sayan, SS – South Siberia (suggested), ST - South Taimyr; orogenic belts: ASB – Altay-Sayan Belt, BMB – Baikal-Muya Belt, VChB – Verkhoyansk-Chukcha Belt, MOB – Mongol-Okhotsk Belt, YEB – Pre-Yenisei belt, CAB – Central-Angara Belt, CAT – Central-Angara terrain, CTB - Central Taimyr Belt; island-arc terranins, fragments of active continental margin and volcano-plutonic belts: BT – Bateni, GA – Gorny Altai, ER – Eravna, GK – Golden Kitat, KI – Kiya, KT – Kurtushiba, NS – North Sayan, TS – Ters, CT – Central Taimyr, OChVB – Okhotsk-Chukcha volcano-plutonic belt; other structures: CPD – Caspian depression, WSB – West Siberian basin.

that at the boundary about 750 million years ago Siberia shifted along the northern margin of Laurentia along a distance of 2,000 km and its southwestern margin was located in the immediate vicinity of the northern margin of Greenland (Fig. 7). At this time, there was a transformation of the passive continental margin environment in the west, in the north (Vernikovsky et al., 2003) and probably in the south of Siberia (Khain et al., 2003) into an active one with the development of a Neoproterozoic system of island arcs. The active belt of the island arc magmatism has been probably separated from the continental margin by an extensive rear basin which provided a predominant quiet shelf sedimentary environment within all western and northwest margins of Siberia (Pisarevky & Natapov, 2003).

The stage of accretion of Neoproterozoic island arcs to the Siberian paleocontinent is manifested in Pre-Vendian - Vendian time (Dobretsov et al., 2003; Vernikovsky et al., 2004). The corresponding age of this accretion event in the west and in the north of Siberia is proved by the combined isotope-geochemical data (Vernikovsky & Vernikovskaya, 2006). Possibly, this stage of development of the active continental margin has resulted in marginal-continental riftogenesis and accompanying magmatism (Yarmolyuk & Kovalenko, 2001; Yarmolyuk et al., 2005; Vernikovsky et al., 2008).

Thus, complete separation of the Siberian continent from structures of Rodinia has occurred more than 100 million years later than the beginning of development of zones of crushing and local riftogenesis on the southern margin (Yarmolyuk & Kovalenko, 2001). The Neoproterozoic transform-strike-slip kinematics of development and transformation of ocean basins around Siberia at the stage of the break-up of Rodinia has predetermined the dynamics of the subsequent accretional-collisional events. From the end of the Neoproterozoic and up to the Mesozoic, Siberia was developed as an independent system of interaction of ocean and continental plates. During this time, the Siberian continental plate underwent a drift of mainly a northern direction from near equatorial latitudes of the southern hemisphere (~ 10°S) in the end of the Precambrian to high latitudes of the northern hemisphere (~60° N) in the end of the Paleozoic (Pechersky & Didenko, 1995; Cocks & Torsvik, 2007). According to paleomagnetic data, during this time the plate gradually rotated clockwise at an angle of about 180° and up to the beginning of the Triassic, the northern margin of Siberia has faced to the west (Fig. 7).

Late Proterozoic formations of the northwest margin of the Siberian Craton are overlapped by the Vendian-Paleozoic plate complex of passive continental margin with a peculiar platform mode of development (Vernikovsky & Vernikovskaya, 2001). The same geodynamic mode characterizes also the western marginal part of the Siberian paleocontinent (Sovetov et al., 2000; Vernikovsky et al., 2009). Against the accumulation of shallow sea carbonate and carbonate-slate deposits, a deep-water basin with distinct features of a linearly extended trough developed along the boundary between Central and South Taimyr. The basin as it was supposed by (Khain, 2001), was connected in the east with a similar basin of the internal areas of the Verkhoyansk system. The axis of this deep-water trough valley was located in the south of a zone of connection of the Central Taimyr accretional block with the continent, in a frontal part of the large Pyasino-Faddey thrust that allows consideration of its development as the foredeep trough (Vernikovsky, 1996).

4.2 The Paleozoic stage

The mode of active continental margin has been renewed, at least, in the southwest Siberian paleocontinent already at the end of the Vendian (Dobretsov et al., 2003). A large number of

Early Paleozoic island arc terrains form a tectonic collage of the Central-Asian belt on the western periphery of the Siberian Craton. Owing to the available paleomagnetic data, the Vendian-Cambrian subduction complexes reconstructed within the limits of the Altai-Sayan orogen represented fragments of a uniform system of island arcs which marked an extended zone of subduction of ocean plate along all the western periphery of the Siberian continent, similar to the modern Pacific margin of Eurasia (fig. 3). Deformation of this system at the stage of accretion to the Siberian Craton in the end of the Cambrian-Ordovician (and later in the Late Paleozoic and Mesozoic), was connected with strike-slip motions which are mainly caused by a clockwise rotation of Siberian continental plate. Such kinematics in the compression environment along the boundary between continental and oceanic plates led to the development of strike-slip zones along the continent periphery, and deformations of the Vendian-Early Cambrian island arc system. Displacements of fragments of this system could occur along strike-slips located both in back, and along zones of oblique subduction (Fig. 8). The rotation of periphery structures resulted in their "lagging behind" the continent forming individual tectonic blocks which interacting with each other have been displaced in a complex way (Kungurtsev et al., 2001; Metelkin et al., 2009).

After the accretion of the island arc system at the end of the Cambrian-Ordovician, a tectonic picture in the west and southwest of Siberia assumed a configuration close to the modern one. Paleomagnetic pole positions for Siberia and for terrains of the Altai-Sayan orogen are very close, though do not coincide completely (Metelkin et al., 2009). Small distinctions in pole positions specify that intensive deformation of paleoisland arc systems and back arc basins under the leading role of the strike-slips began in the Cambrian and proceeded during the whole Paleozoic (Buslov et al., 2003; Van der Voo et al., 2006; Metelkin et al., 2009).

In the north of Siberia, the Vendian to Devonian time interval is characterized by a growth of the Anabar uplift and the development of surrounding large synforms, occupied by epicontinental seas with carbonate sedimentation (Bogdanov et al., 1998). Also a deep-water trough formed at the beginning of Paleozoic along the location of the foredeep trough on the boundary of the South and Central Taimyr zones was still developed. The change of the tectonic mode was manifested in the Carboniferous, when carbonate deposits on the Taimyr shelf were superseded by terrigenous. The principal change in the sedimentary environment was an extremely important event in the tectonic history of the north of Siberia and was connected with the occurrence of a new source of terrigenous material (Zonenshain et al., 1990). Paleotectonic analysis, combined with available paleomagnetic data, shows that this event was caused by the beginning of interaction of the Siberian margin with the Kara microcontinent in the mode of oblique collision under the leading role of strike-slips (Metelkin et al., 2005b). The main role in tectonics of the Kara block belongs to transform zones connecting the Arctic margins of Siberia and Baltica within the limits of the uniform tectonic system which have caused the strike-slip motion of the Kara microplate in a northern direction, from a subtropical zone of the southern hemisphere to subequatorial latitudes of the northern hemisphere with a simultaneous counter-clockwise rotation. Strike-slip tectonics has completely defined the style of deformation of the Paleozoic margin in the north of Siberia during the collisional event in the Late Carboniferous-Permian (Vernikovsky, 1996, Metelkin et al., 2005b) which has also occurred against the contrastive rotation of the continental masses of the Kara and Siberian continents that fits well with the general paleotectonic picture (Fig. 8).

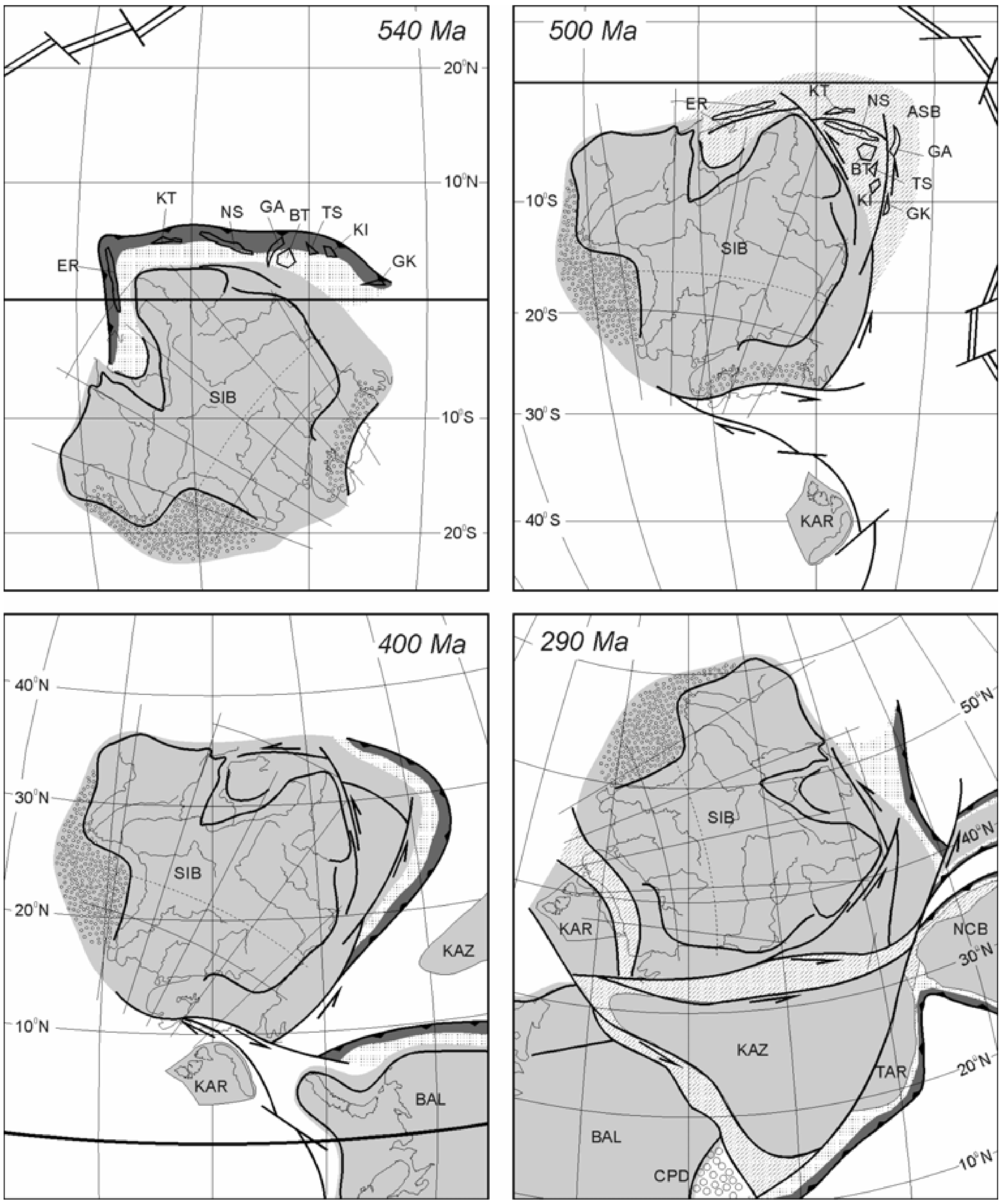

Fig. 8. Paleotectonic evolution of the Siberian Craton and its margins during the Paleozoic. For legend and abbreviations see Fig. 7.

A certain problem is represented by the absence of Paleozoic subduction complexes, which should be located within the Major Taimyr suture, if we assume a space with oceanic crust between Siberia and Kara. The obvious explanation, following from the proposed model, is a soft interaction of sialic masses with the predominating role of strike-slips, under conditions of oblique transform rapprochement and the subsequent collision. The final stages of the orogen the development at the Permian-Triassic boundary have led to development of large extension zones in the frontal part of the Taimyr folded structures and have predetermined the development of a large depression - the Yenisey-Khatanga trough in this segment of the belt.

4.3 The Mesozoic stage

Intracontinental rifting on the Permian-Triassic boundary is well pronounced in Western Siberia. Not only the folded-napped structure of Taimyr-Severnaya Zemlya area was formed up to the beginning of this stage. The closing of the Precambrian-Early Paleozoic oceans resulted in the general structure of the Central-Asian belt sewing the continental masses of the Siberian and East European cratons into a uniform Eurasian plate, which in turn has comprised the basic structure of the Laurasian part of Pangea. This key moment in the tectonic history of Siberia is marked by a giant trapp magmatic event, connected with the activity of the largest mantle plum (Dobretsov, 2005). Within the limits of Siberian platform, flood basalts are concentrated in the Tungus syneclise and continued under the Yenisey-Khatanga trough to South Taimyr. To the west, within the West Siberian plate, trapp basalts were found under the Mesozoic-Cenozoic cover of deposits and traced up to the East Ural trough. As a rule they distributed along rift zones of the Koltogor-Urengoy graben but also exposed in boreholes between rifts. Fields of flood basalts are stretched to the north, covering the bottoms of the Kara and Barents seas (Dobretsov & Vernikovsky, 2001; Dobretsov, 2005). The most southern satellite of Siberian trapps is present in the structure of the Kuznetsk trough (Dobretsov, 2005; Kazansky et al., 2005). Correlations on the basis of available paleomagntic and geochronological data testify that the development of the Siberian trapp province occurred extremely quickly. The duration of intensive magmatism in the different areas is estimated from 1 to 5 million years (Dobretsov, 2005; Kazansky et al., 2005).The magmatism was controlled in the south (the Kuznetsk trough), possibly in the west (West Siberia) and in the north (Yenisey-Khatanga trough), by large scale strike-slips (Fig. 9).

Analysis of paleomagnetic data for the Permian-Triassic boundary gives ground to the assertion that intraplate strike-slip deformation caused by a clockwise rotation of the Siberian tectonic domain of the Eurasian plate, appear to be a possible reason for the generation of submeridional systems of graben structures in the basement of West Siberia which resulted in the development of a large Mesozoic-Cenozoic sedimentary basin (Bazhenov & Mossakovsky, 1986; Voronov, 1997). The east branch of this strike-slip system which caused riftogenesis in West Siberia is an extension connected with the frontal thrust structures of Taimyr. The axial graben of the Yenisey-Khatanga trough and the single age Koltogor-Urengoy graben-rift system (Khain, 2001) form a resemblance to a triple junction that fits the strike-slip model.

Essential deformations in the compression environment, shown in the southwest of Siberia, within the limits of the Altai-Sayan folded area are correlated with the same strike-slip tectonics caused by a rotation of the Siberian domain of the Eurasian plate relative to the European one (Bazhenov & Mossakovsky, 1986; Metelkin et al., 2010a). Strike-slip motions of the described kinematics in the Eurasian continent proceeded up to the end of the Mesozoic (Fig. 9) which is supported by a regular deviation in Mesozoic positions for Siberia and Eastern Europe (Metelkin et al., 2010a). Thus, the crust deformation of the Central Asia in the Mesozoic, against the general clockwise rotation of the Eurasian plate as is shown in reconstruction (Fig. 9), is connected with the motions of separate components of its

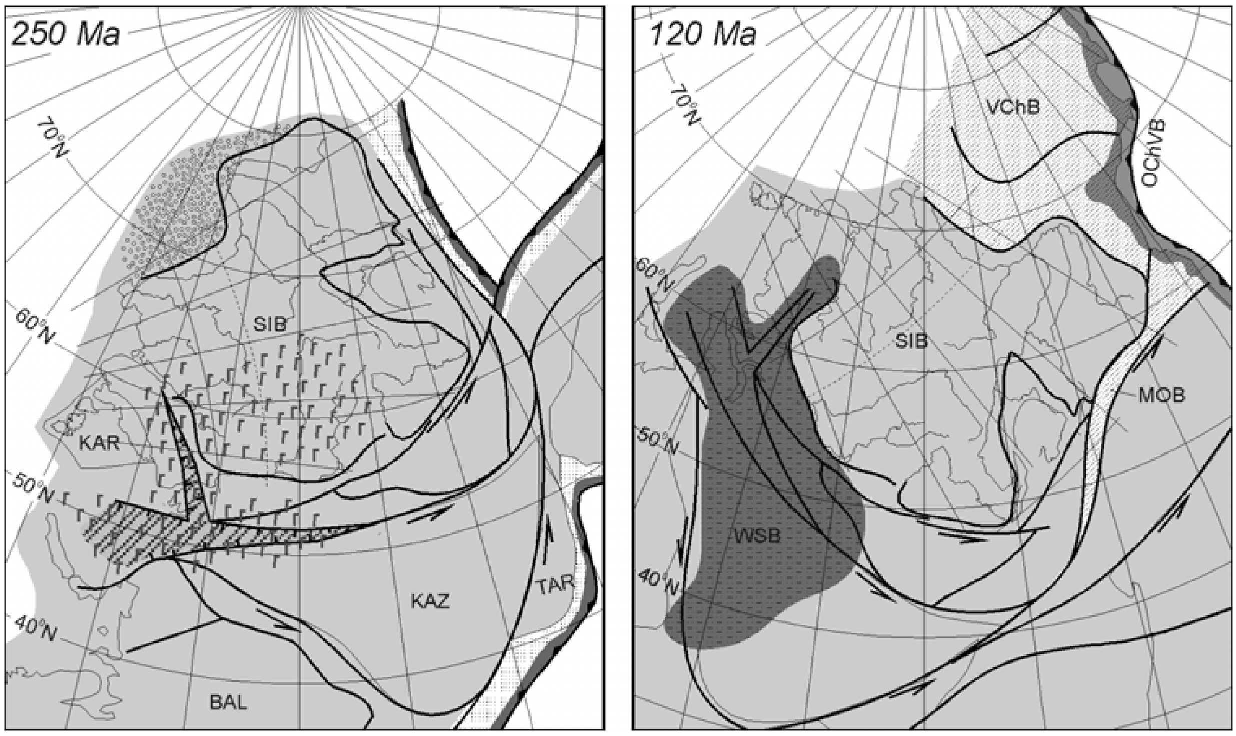

Fig.9. Paleotectonic evolution of the Siberian Craton and its margins during the Mesozoic. For legend and abbreviations see Fig. 7.

composite structure (the Siberian, European and Kazakhstan tectonic domains) along the system of large-scale strike-slip zones of the sinistral (Metelkin et al., 2010a). The deformation of the Mongol-Chinese territory of the plate is also described by a series of strike-slip zones responsible for fragmentation of the Earth's crust against a gradual propagation of the closure of the Mongol-Okhotsk gulf of Paleopacific from the west to the east (in modern co-ordinates), which separated the Siberian margin of Eurasia and the Paleozoic collage of terrains of the territory of Mongolia and China.

The geological consequences of such tectonics are consistent with a viewpoint given in (Bazhenov & Mossakovsky, 1986; Voronov, 1997; Natal'in & Sengör, 2005; Van der Voo et al., 2006). Strike-slip motions of the Siberian domain with a clockwise rotation, due to the configuration of the main structural boundaries, has caused a stable compression environment within the Central-Asian province (the southwestern frame of the Siberian Craton) and in the contrary extension environment within the limits of the north of the West Siberian province. Thus, those motions possibly, had a discrete character that is manifested in the reconstructed multistage character of the main orogenic epochs (De Grave et al., 2007; Buslov et al., 2008) and the correlation of strike-slips and other structural forms disturbing the initial integrity of the Mesozoic sedimentary complex of West Siberia to concrete time boundaries (Belyakov et al., 2000; Koronovsky et al., 2009).

5. Conclusions

The tectonic evolution of Siberia in the Neoproterozoic, Paleozoic and Mesozoic in the global scale can be correlated with the processes of the gathering and disintegrating of two supercontinents: Rodinia and Pangea. The transformation of one tectonic event within the margins of Siberia into another is often defined by the intensity and scale of strike-slip motions. The processes of strike-slip tectonics are presented practically everywhere and in all intervals of geological history of the Siberian plate. They defined the tectonic style of the evolution of the structures of the Siberian region in the early stages of development of the ocean basins, as well as during the active subduction of the oceanic crust and undoubtedly, at the accretion-collision stage. Intraplate deformations of the continental crust, accompanied with active magmatism, were also governed by strike-slip motions of fragments of different sizes. It is an important concept that reconstructed strike-slip zones very largely extended and as a rule correspond to the boundaries of the main tectonic elements that is they are connected with processes of at least regional, and more often of planetary scale.

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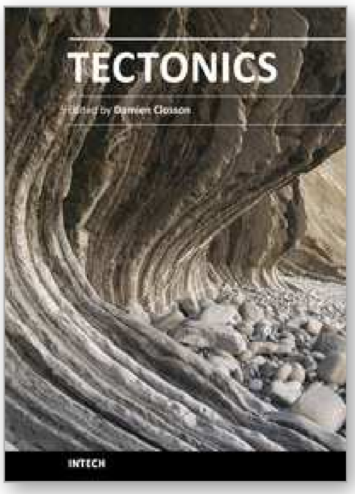

Tectonics

Edited by Dr. Damien Closson

ISBN 978-953-307-545-7
Hard cover, 358 pages
Publisher InTech
Published online 28, February, 2011
Published in print edition February, 2011

The term tectonics refers to the study dealing with the forces and displacements that have operated to create structures within the lithosphere. The deformations affecting the Earth's crust are result of the release and the redistribution of energy from Earth's core. The concept of plate tectonics is the chief working principle. Tectonics has application to lunar and planetary studies, whether or not those bodies have active tectonic plate systems. Petroleum and mineral prospecting uses this branch of knowledge as guide. The present book is restricted to the structure and evolution of the terrestrial lithosphere with dominant emphasis on the continents. Thirteen original scientific contributions highlight most recent developments in seven relevant domains: Gondwana history, the tectonics of Europe and the Near East; the tectonics of Siberia; the tectonics of China and its neighbourhood; advanced concepts on plate tectonics are discussed in two articles; in the frame of neotectonics, two investigation techniques are examined; finally, the relation between tectonics and petroleum researches is illustrated in one chapter.