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Where does the South Anyui suture go in the New Siberian islands and Laptev Sea?: Implications for the Amerasia basin origin

Alexander B. Kuzmichev

Geological Institute of the Russian Academy of Sciences, Pyzhevsky 7, 119017 Moscow, Russia

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ABSTRACT

The South Anyui suture is a major tectonic boundary in NE Asia, believed to represent the remains of an ocean basin which separated Siberia from North America in Jurassic time. Its history also figures prominently in the Mesozoic reconstruction of the Arctic and the origin and evolution of the Amerasia basin. Three types of proposed trends of the South Anyui suture are evaluated. 1) The suture ends near the Kolyma River mouth where it meets the rotational transform. The paper, however, proves that the suture continues further westward up to Big Lyakhov Is. Consequently, a simple geometric rotational model for Amerasia basin origin must be rejected. 2) The suture trends from Big Lyakhov to the Anjou islands. The Anjou islands geology is examined, and it is concluded that the suture could not go through them. Hence, all proposed versions of the rotational hypothesis of the Amerasia basin opening are claimed to be invalid. 3) A proposed Taimyrian connection of the suture is examined, and it is concluded that this model must be rejected as well. The failure of all previously suggested models for the suture extent through the New Siberian islands and Laptev Sea means that in Early Mesozoic there was no oceanic basin that separated the New Siberian–Chukotka terrane from Siberia. Thus Siberia and North America formed a continuous continent in Jurassic time. This paper presents evidence that the South Anyui suture has instead turned back from Big Lyakhov island and followed a sinuous path designated as the Chroma Loop before connecting with the Kolyma Loop suture. On this model the South Anyui suture can be interpreted as a small segment of extensive boundary which separated the Amerasia Jurassic margin and terranes accreted to it from the Pacific. The modern boundary around the North Pacific is also quite sinuous. It was suggested that in Jurassic time it was straighter and the Amerasia ocean was originated as a common back-arc basin. Finally a new two-pole parallelogram hypothesis for the Amerasia basin opening is suggested and the approaches to its verification are outlined.

1. Introduction

The South Anyui suture is a key tectonic feature of the East Arctic region. It is believed to separate the major tectonic units of NE Asia including its submerged northern margin. The suture was first described in northern Chukotka, and geologists suggest that its eastern extension is the Angayucham belt in Alaska (Fig. 1) (e.g. Nokleberg et al., 2001). However its western continuation is still an outstanding problem in Arctic geology. The reconstruction of East Arctic Mesozoic tectonic evolution and ideas on the origin of the Amerasia basin depend on where this suture continues to.

The name South Anyui suture was introduced by Seslavinsky (1979) who regarded it as a trace of a Jurassic ocean that once separated two major landmasses now joined in Chukotka. South of the suture, there is a collage of Paleozoic and Mesozoic island arcs and continental terranes. Northwards there lies the Arctic continental terrane which comprises the East-Siberian shelf, Northern Chukotka, Wrangel island, the New Siberian islands and Arctic Alaska (Zonenshain et al., 1990; Natal'in, 1984; Parfenov, 1984; Bogdanov and Til'man, 1992; Natal'in et al., 1999) (Fig. 1). It is widely believed that the Arctic continental terrane is displaced with respect to Siberia and originated from Arctic Canada (e. g. Rowley and Lottes, 1988; Grantz et al., 1998; Lawver et al., 2002), forming the basis for the popular rotational model for the opening of the Amerasian basin. According to the model, this terrane was attached to Arctic Canada in the Early Mesozoic, then it rifted away at the end of Jurassic, rotated counter-clockwise and accreted to NE Asia in the Neocomian (the lower part of the Lower Cretaceous from Berriasian to Barremian) (Fig. 1). In the course of its drift the Amerasia basin opened behind it and the South-Anyui ocean closed south of it (Fig. 1). The rotational hypothesis suggests that the westward continuation of the South Anyui suture shall at some point meet a continental-scale arcuate transform fault that trends along the Amerasian basin side of the Lomonosov Ridge (Fig. 1). Where exactly this happens is controversial. Rowley and Lottes (1988) suggested a location near the Kolyma River mouth (Fig. 1). The idea that the South Anyui suture ends at this point has not been confirmed by geological or geophysical evidence. Other researchers

E-mail address: kuzmich@ilran.ru.

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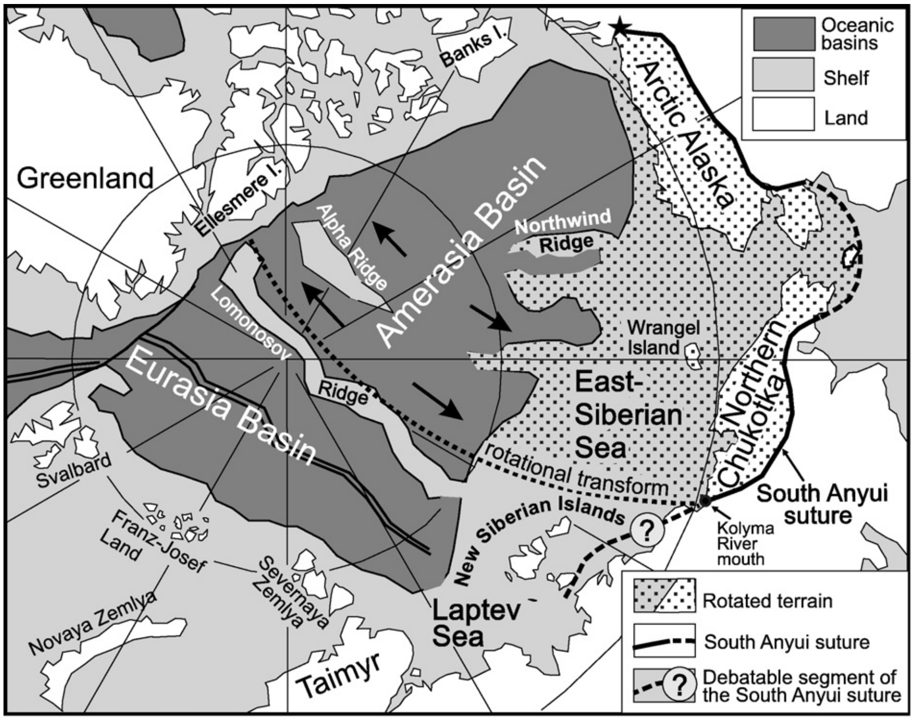

Fig. 1. A general view of the Arctic showing the location of the New Siberian islands and the South Anyui suture. The speckled area outlines the rotated terrane which has presumably drifted away from Arctic Canada in the course of the Amerasia basin opening. The pole of rotation is indicated by the star. The position of rotational transform is after Rowley and Lottes (1988). This transform is a principal terrane boundary which determines the East Arctic tectonic framework and a possible mode of Amerasia basin opening. The position of this boundary depends on whether the South Anyui suture ends at the Kolyma river mouth or goes to the New Siberian islands, and where it might continue from there.

place the location of the suture end more westerly (e. g. Parfenov et al., 1993; Layer et al., 2001 and many others), try to reconcile the rotational hypothesis with the postulated westward extension of the suture to Big Lyakhov island (e.g. Spektor et al., 1981) (Fig. 2). This assumption implies that from Big Lyakhov island, the suture turns north to the Anjou islands. However, there is no geological data in support of this idea either. Some workers imply that the South Anyui suture turns north at a point farther west (e.g. Drachev et al., 1998,

Fig. 2. General tectonic features of the New Siberian islands region and adjacent land.

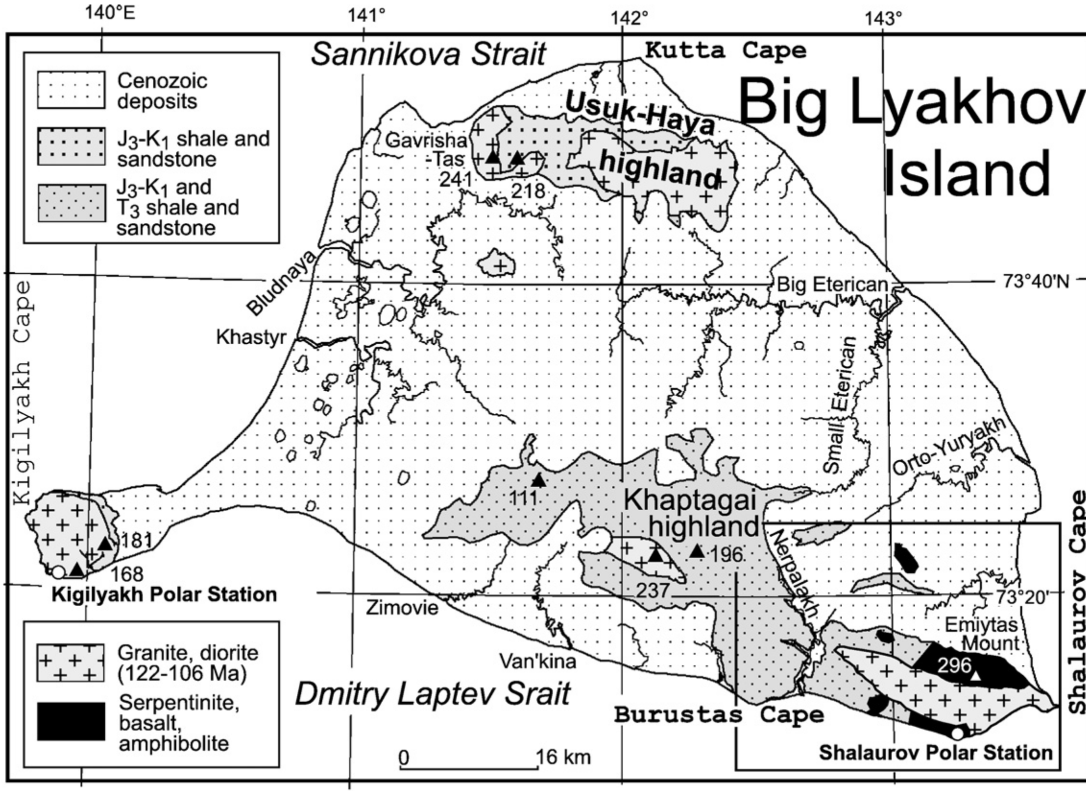

Fig. 3. A sketch geological map of Big Lyakhov island (simplified after Samusin, 1982). Rectangle shows the Fig. 4 area).

Natal'in et al., 1999). Others believe that it further continues to the Taimyr fold belt (e.g. Zonenshain et al., 1990; Sokolov et al., 2002). All these various ideas suggest different tectonic models for East Arctic evolution and imply different kinematics of the Amerasia basin opening.

On the vast shelf that occupies the territory between Taimyr and Chukotka foldbelts, the New Siberian islands have the only outcrops (Fig. 1). Thus, they are a key region to test different tectonic models of Early Mesozoic Arctic evolution, since each model suggests a different way the South Anyui suture trends through this area. The New Siberian archipelago includes three groups of islands (Fig. 2). The Lyakhov islands are composed of deformed Upper Jurassic–Lower Cretaceous terrigenous deposits which accumulated within a syncollision foreland basin (Kuzmichev et al., 2006; Miller et al., in press). The Anjou islands are covered with Late Mesozoic and Cenozoic continental deposits; while the two western islands have outcrops of shallow-marine Paleozoic and Early Mesozoic rocks: the New Siberian carbonate platform of Natal'in et al. (1999). The northernmost part of the archipelago (Zhannette and Henrietta islands or the entire territory of De Long islands) presumably represents a different terrane (Natal'in et al., 1999; Vol'nov et al., 1999; Kos'ko and Trufanov, 2002), which is not discussed here.

This paper is based on field investigations in the New Siberian islands conducted by the author in 2000, 2002–2004 and 2006–2007. The study was initiated by Nikita Bogdanov, former Director of the former Institute of Marginal Seas RAS. Several new discoveries and data allow the question of the location and continuation of the suture to be re-visited. 1) The South Anyui suture is exposed on Big Lyakhov island. 2) The possible continuations of the suture from the Lyakhov islands can be better evaluated. 3) It can be shown now that the suture extends neither west nor north, but must have connected with the Kolyma Loop of the Siberian margin to the south based on evidence that in Early Mesozoic time the New Siberian continental block was attached to the Siberian Platform. 4) This conclusion leads to a two-pole rotational model for opening of the Amerasia oceanic basin.

2. South Anyui suture on Big Lyakhov island

2.1. Objectives

Pillow-basalts and serpentinites have been known on Big Lyakhov island since 1932 (Ermolaev, 1932). Spektor et al. (1981) was the first who recognized their oceanic nature and that they marked the northwestern continuation of the South Anyui suture. This conclusion was based on tracing the magnetic anomalies through the unexposed lowland and shelf from Chukotka (Fig. 2). It later appeared that the position of this suture's western segment did not agree with the simplest version of rotational model for opening of the Amerasia ocean. According to the rotation hypothesis, the South Anyui suture did not extend to the New Siberian islands but instead merged with the rotational transform fault in the vicinity of the Kolyma River mouth (Rowley and Lottes, 1988; Embry, 2000, etc.) (Fig. 1). Based on this reasoning, the Big Lyakhov serpentinites were thought to be older and unrelated to the Cretaceous suture. Supporting this idea was the presence of Late Paleozoic ophiolites in the South Anyui zone (Natal'in, 1984; Sokolov et al., 2002) which are not directly related to the Mesozoic South Anyui ocean and to the problem of the Amerasia basin origin. This assumption seemed to be confirmed by Drachev who reported that oceanic rocks on Big Lyakhov island were Early to Mid-Paleozoic or Late Neoproterozoic in age (Drachev and Savostin, 1993). To clarify the situation, fieldwork was carried out in the southeastern Big Lyakhov island in 2000 and 2003 years and the results that support younger ophiolitic rocks are reviewed in brief.

2.2. Geological overview

Big Lyakhov island is poorly exposed. The bedrock crops out only in highlands and along the southeastern shore (Fig. 3). Most of the island is underlain by a flyschoid sequence which was folded, faulted and cleavaged. The clastic sequence was thought to be Late Jurassic on Kigilyakh and Usuk-Yuryakh uplands by analogy with fossiliferous

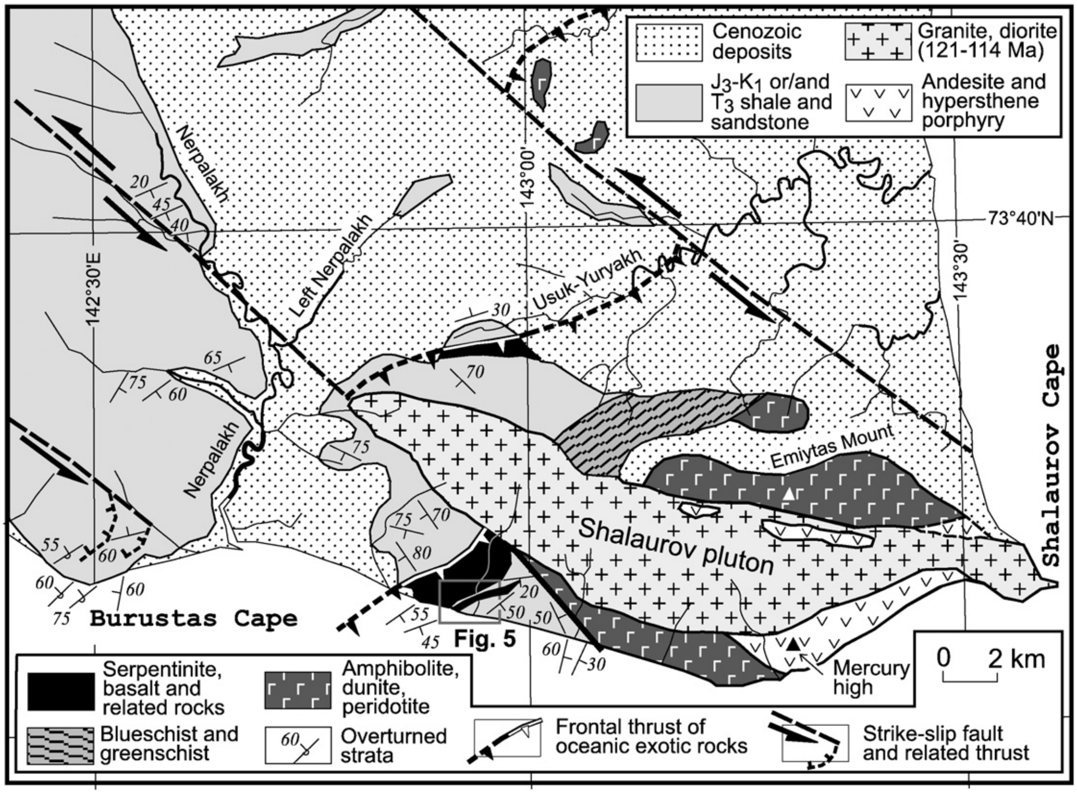

Fig. 4. Schematic geological map of southeastern Big Lyakhov island (on the basis of 2000 and 2003 fieldwork). The northern part, specifically the northern amphibolite exposures are shown after Samusin (Samusin, 1982).

deposits on Stolbovoi and Small Lyakhov islands. Similar deposits on the southeastern part of the island were defined as Permian and designated as the Burustas Fm. (Vinogradov et al., 1974; Samusin and Belousov, 1985). The Burustas Fm. contains tectonic nappes of exotic rocks of oceanic and island-arc origin (Fig. 3). These exotics are divided into three groups (from W to E): 1) pillow-basalt, serpentinite and associated rocks; 2) blueschist and greenschist nappe; 3) amphibolite unit, including ultramafic rocks (Fig. 4). All the above units and diorite–granite plutons which intrude them are described below.

2.3. The structure of SE island

The mapping indicates that the oceanic rocks were thrust onto the Burustas flyschoid sequence from SE to NW, a direction perpendicular to the general NW trend of the South Anyui suture (Fig. 2). NW thrusting is confirmed in the vicinity of Predmaysky brook where the Burustas strata dip SE, show minor concordant thrusts and are highly boudinaged near the contact with serpentinite body (Fig. 5). The general northwestern vergence is common for SE part of the island, though the Burustas strata strike is often discordant to the regional structural trend (Fig. 4). In places the strata trend northwest or westward. In Cape Burustas they show southeastern vergence which is reverse to regional thrusting (Fig. 4). All these phenomena can presumably be caused by strike-slip faulting as it is evident from the associated folds with steep axes. The presence of NW–SE strike-slip faults is clear from the mapping. If we prolong the nappes contours beyond the known outcrops, their segmentation by diagonal faults with left-lateral displacement is evident (Fig. 4). This system of NW strike-slip faults appears to be a major tectonic element, which determines the position and elongation of the granodiorite pluton (Fig. 4). The latter does not show any shearing indicating the upper age limit (121 Ma — see below) of this fault system.

2.4. Postorogenic granitoids and related rocks

In southern, western and northern Big Lyakhov island multiphase diorite–granite intrusions are exposed. A similar poorly exposed granite body presumably occurs in southern Small Lyakhov island as well (Dorofeev et al., 2001). The granites intrude Mesozoic sedimentary rocks (including Burustas Fm.) and nappes of oceanic rocks. Granodiorite at Cape Shalaurov contains numerous xenoliths of host rock which indicates a stopping mode for pluton emplacement. All the granitic bodies are postcollisional discordant shallow-level plutons which show hornfels at the contact with country rocks.

The most valid data on the age of granitoids have been obtained for the multiphase Shalaurov pluton in the southeastern part of the island (Fig. 4). The zircons from four phases have been analyzed with the SHRIMP-II ion microprobe at VSEGEI, SPb. These are: marginal gabbro–diorite; amphibole diorite; hypersthen diorite–porphyry, and the granite of central zone. The method's resolution was insufficient to determine the duration of intrusive process. The integrated age of the 14 points analyzed has yielded an age of 121.2±2.4 Ma (Fig. 6). Other data on the age of the Shalaurov plution have also been published: the $^{40}Ar/^{39}Ar$ biotite plateau age is 114.4±0.5, integrated age is 113.3±0.5 Ma (Layer et al., 2001); K–Ar age is 119±5, 120±6, 122±5 Ma (Dorofeev et al., 1999). The author has also studied the zircons extracted from andesite from Mercury high (Fig. 4) which are believed to be comagmatic with Shalaurov diorite. Twelve crystals have been analyzed. Six of them have yielded an age of 112.3±3.5 Ma, which indicates that the andesites are not comagmatic with the diorites (Fig. 7). The other six zircon crystals have turned out to be Neoproterozoic in age: 810±26 Ma (Fig. 8). All the zircons demonstrate magmatic habit and zoning. The Precambrian zircons are evidently entrapped from the granite–gneiss basement of the marginal part of the New Siberian Platform. The basement is thus Neoproterozoic in age.

The available age data for granitoids from the northern and western parts of the island are as follows: Kigilyakh pluton: K–Ar, biotite is 122±7 Ma (Dorofeev et al., 1999); $^{40}Ar/^{39}Ar$, biotite,

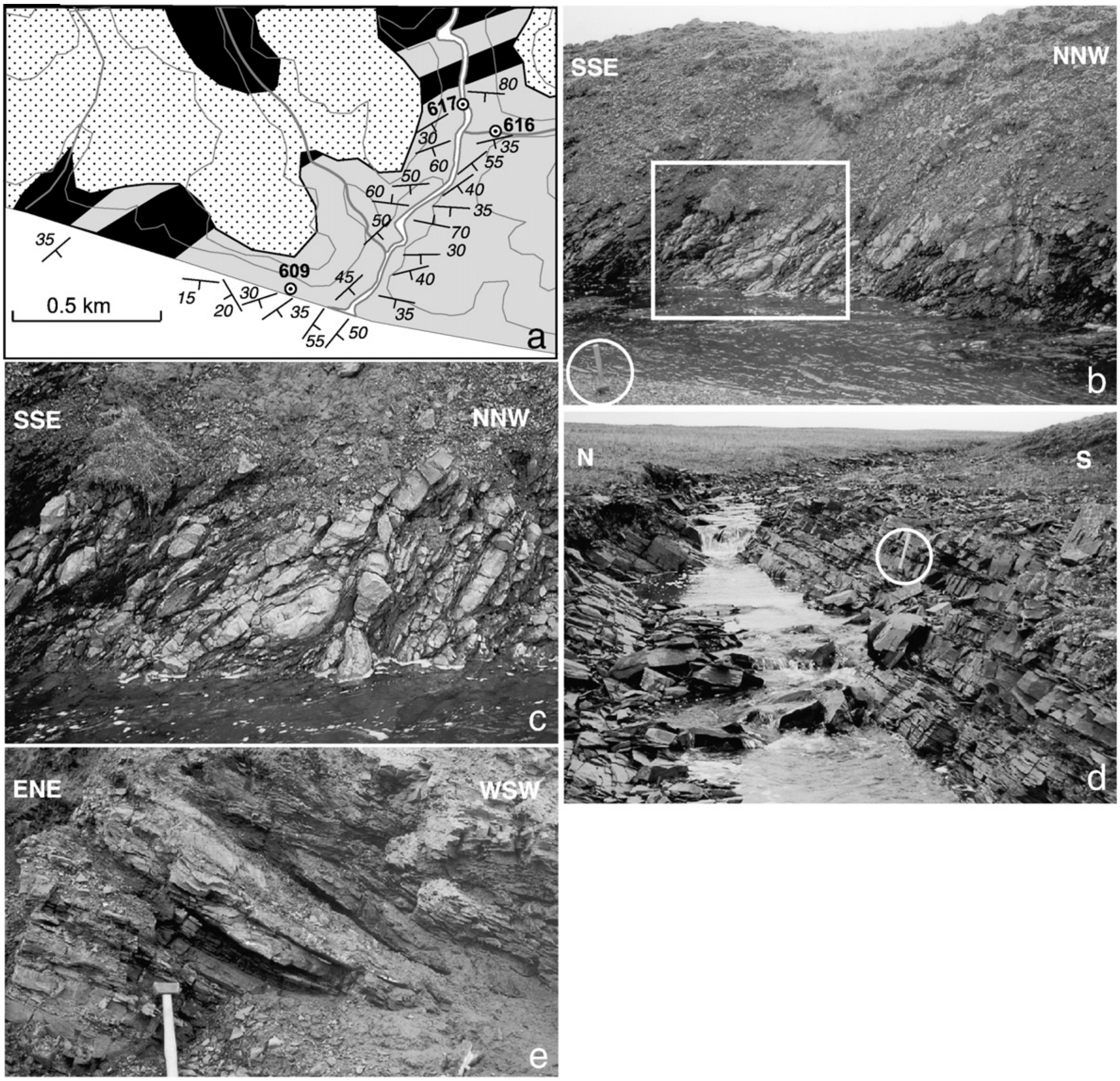

Fig. 5. Some structural features related to thrusting. (a) The scheme of serpentinite (black) nappes at the mouth of Predmaysky Brook (lower nappe also contains gabbro). The contour of Quaternary deposits (speckled) is shown arbitrarily: they actually cover the whole area. (b) Melanged flyschoid at 50 m from the serpentinite nappe (site 617).The frame shows the next photo. The hammer in a circle for scale. (c) The same photo, a detail. (d) Coherent flyschoid at 200 m from the contact for comparison (site 616). The hammer for scale (in a circle). Note the flat unexposed land at the background, typical of the area. (e) Local thrust in Burustas shales and sandstones, site 609.

integrated age is 104.7±0.5, plateau age is 106.4±0.5 (Layer et al., 2001). Northern plutons: K–Ar, biotite is 118±6 and 120±5; U–Pb, zircon is 118.0±04 Ma (Dorofeev et al., 2001). Analytical data and concordia plot for zircon ages are not available. The reason for the discrepancy between $^{40}Ar/^{39}Ar$ integrated age by Layer et al. (2001) and K–Ar age by Russian geochronologists is not clear. All the Big Lyakhov granitoids are more or less tin-bearing (Dorofeev et al., 2001). They were completely (Dorofeev et al., 2001) or partly (Layer et al., 2001) included into the north–south chain of tin–granites which trends for about 1000 km southwards from Big Lyakhov island to Cape Svyatoi Nos and further on. Otherwise, the Big Lyakhov intrusions can be treated as a northwestern extension of the Chukotka tin-bearing granite belt of the same age.

2.5. Pillow-basalts, serpentinites and associated rocks

This unit is exposed in the environs of Predmaisky Brook (Drachev and Savostin, 1993; Kuzmichev et al., 2005) (Figs. 4 and 5). Three types of rocks: pillow-basalt, serpentinite and gabbro-diabase were mapped (Kuzmichev et al., 2005). The pillow-basalt makes up a notable outcrop at the coast of Dmitry Laptev Strait. The basalt looks quite fresh and is unaffected by metamorphic or deformational events. The quartz and calcite veins indicate hydrothermal activity within hot oceanic crust. Ultramafic bodies are mainly harzburgitic serpentinites with bastite pseudomorphs. They also contain olivine–clinopyroxene cumulates, clinopyroxenite, and amphibolite. Gabbro–diabase shows gabbro–ophitic texture with laths of plagioclase and xenomorphic clinopyroxene.

Pillow-basalts are similar to mid-ocean ridge basalt (MORB) by most major and trace element concentrations. The rare earth elements (REE) patterns demonstrate the depletion in light REE (LREE). Almost all specimens are also heavy REE (HREE)-depleted to some extent. Pillow lavas show extremely low concentrations of some large-ion lithophile elements such as K (0.03–0.06% K_2O), Rb, and Sr. The rocks are characterized by Th/Nb ratio similar to that in N-MORB and by low Ce/Nb. Gabbro-dolerites exhibit the same geochemical characteristics as the above basalts and differ from them by reverse positive K and Rb anomalies. Both rock types show no signs of subduction-related fluid or melt effect. Though differing from typical N-MORB, they should be referred to oceanic-floor basalts. The amphibolites demonstrate a flat REE pattern, the large-ion lithophile elements (LILE) enrichment and a high Th/Nb and Ce/Nb ratio (Kuzmichev et al., 2005). These features may indicate a suprasubduction setting. Thus, a tectonic

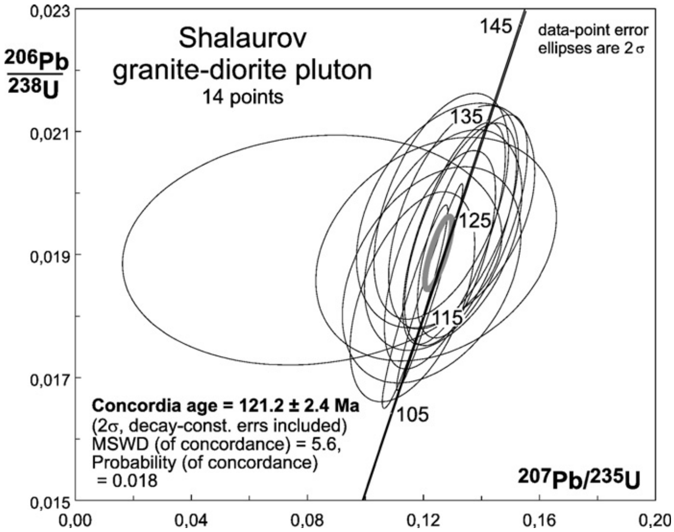

Fig. 6. U–Pb concordia diagram for the zircon SHRIMP ages of Shalaurov granite–diorite pluton.

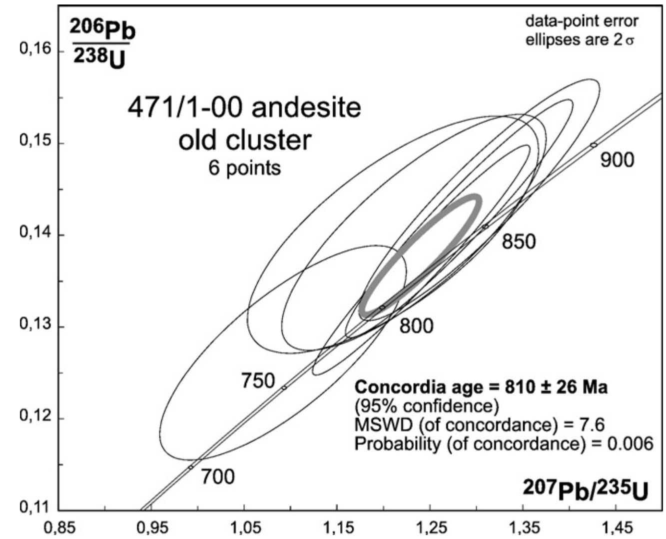

Fig. 8. U–Pb concordia diagram for the “old” zircons of the Mercury mount andesite.

mixture of igneous rocks of different origin crops out in Predmaisky area.

Pillow-basalts are most important for dating because they represent the crust of the oceanic basin that once lay southwards of the New Siberian terrane. Drachev and Savostin (1993) made an attempt to date the basalts using the Sm–Nd technique on six whole-rock samples, that yielded the age of 291 ± 62 Ma. However, their paper does not provide any analytical data nor isochron plot, MSWD and such like. It even remains unknown if the 2-sigma or 1-sigma intervals were reported. The author holds to the opinion that an attempt to determine a Sm–Nd isochron age for a single undifferentiated lava flow using whole-rock samples is obviously doomed to failure: the primary variations of Sm/Nd were insufficient for correct measurements.

We investigated numerous samples of interpillow matter in search for radiolaria, but with no success. This testing has not revealed any sedimentary components, which indicates rapid eruption. The only way to date these extremely low-K_basalts is to use celadonite — a K-rich hydrothermal mineral common for oceanic basalts.

Nine celadonite samples from the interpillow hyaloclastite were analyzed using the K–Ar method. The obtained age values range from 124 to 154 Ma and have different errors, varying from 3 to 10 Ma (Kuzmichev and Lebedev, 2008) (Fig. 9). The peak age is 145–140 Ma which is suggested to be the period of ophiolite obduction. As was shown in Staudigel et al. (1986), Gallahan and Duncan (1994), and Booij et al. (1995), the age of celadonite in oceanic basalts corresponds to the cessation of hydrothermal activity in the oceanic crust and is in general 10 or 20 Ma younger than the basalts extrusion. Therefore, the lower age limit of the Big Lyakhov pillow lavas is 160–170 Ma. Taking into account that the oceanic hydrothermal activity was stopped by the basalts obduction on the continental margin, we can confine the most probable age of the Big Lyakhov basalts to the Late Jurassic. Taking into account that celadonite is a very low-temperature mineral, this conclusion must be confirmed by other evidence like Rb–Sr ages.

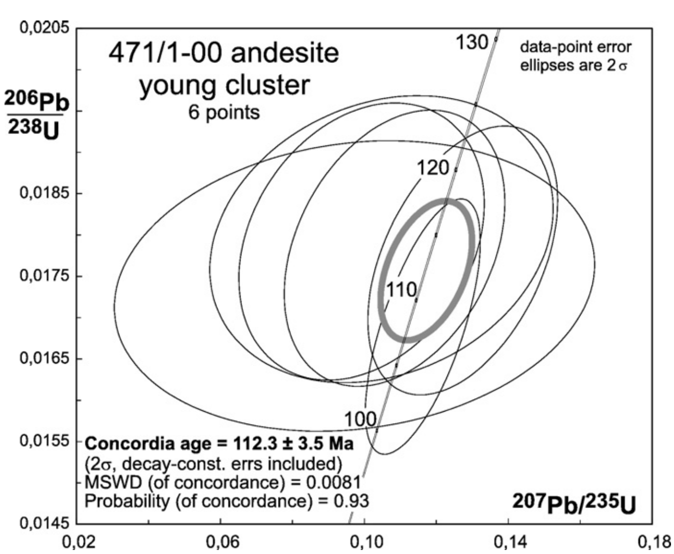

Fig. 7. U–Pb concordia diagram for the “young” zircons of the Mercury mount andesite.

2.6. Blueschists

Blueschists were found northwest of the Emiytas Mount in 2003 on a poorly exposed territory with rare bedrock outcrops (Kuzmichev et al., 2005). Most of exposed rocks are greenschists and hornblende–amphibolites, among which blueschists occupy a lens-shaped area of 1 × 5 km. Metabasalts and metagabbros of the unit are geochemically similar to the pillow-basalts described above except for the Rb–K

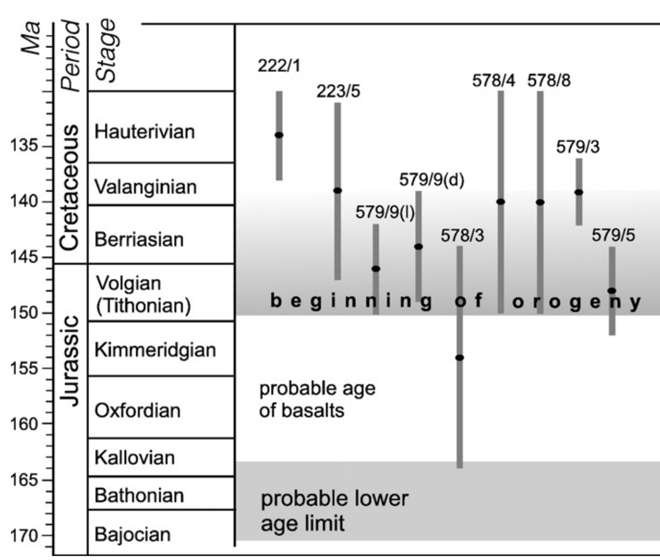

Fig. 9. K–Ar ages for celadonite samples of oceanic pillow-basalt (Kuzmichev and Lebedev, 2008).

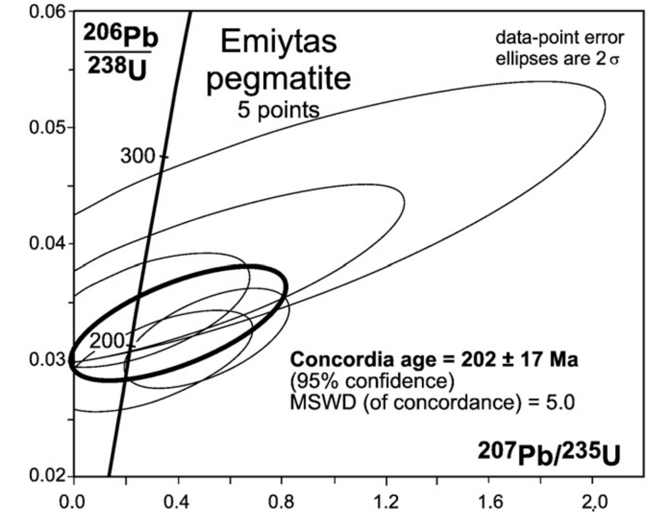

Fig. 10. U–Pb concordia diagram for the zircon SHRIMP ages of Emytas pegmatite.

anomalies. The rocks show depleted LREE and the same Th/Nb ratio as in N-MORB. They represent the oceanic crust rocks subducted beneath an island- or continental arc to a depth of 20–30 km (Kuzmichev et al., 2005). The garnet blueschists demonstrate an unusual counter-clockwise PT metamorphic trend that indicates pressure increasing on the regressive stage. We suggest that the increase in pressure was caused by 10 to 12 km-thick tectonic nappes piling over the zone of convergence (Kuzmichev et al., 2005). This orogenic crustal thickening may be caused by the Anyui-Svyatoi Nos arc–New Siberian terrane collision. No age data are yet available for the unit.

2.7. Emiytas mafic–ultramafic metamorphic complex

The Emiytas metamorphic complex crops out at the coast of Dmitry Laptev Strait and constitute the Emiytas Mount and surroundings (Fig. 4). Early investigators treated it as a Precambrian metamorphic basement (Samusin and Belousov, 1985; Voitsekhovskiy and Sorokov, 1957). Some geologists hold to this viewpoint up to now (Dorofeev et al., 1999). Drachev and Savostin (1993) interpreted the complex as a metamorphosed Late Neoproterozoic–Early Paleozoic ophiolite formed in mid-oceanic setting. Both viewpoints are not convincingly grounded.

We argue that the Emiytas unit is a deep-seated mafic–ultramafic suprasubduction layered intrusion. The rocks are sheared, with the primary layering occasionally preserved. In this nearly five-km thick succession, high-grade melanocratic rocks (including ultramafics) are irregularly replaced from bottom to top by shallower and more leucocratic varieties. The ultramafics are dominated by non-serpentinised dunite with schlieren of wehrlite and clinopyroxenite. The pyroxene is partly or completely replaced by amphibole. Gabbroic rocks do not preserve primary minerals and are predominantly epidote amphibolites. Some varieties contain garnet, rutile, corundum and sapphirine. Most of the gabbroic rocks are highly depleted with HFSE (Zr, Hf, Nb, Ta) and enriched with LILE, which may indicate the suprasubduction setting. At least two stages of gabbroic rock emplacement are visible. The first one is low Ti, low-REE cumulate rock turned into flaser-gabbro; the second is banded granoblastic high-Ti amphibolite or garnet–amphibolite. Two samples of such garnet–amphibolites from the lower part of the unit were studied by E. Sklyarov and produced the values of P=16–18 kbar, T=750–950 °C (Kuzmichev and Sklyarov, 2004).

Plagioclase-hornblende pegmatite veins are numerous in the lower half of the complex. The three thickest (up to several meters) veins exhibit zoning with quartz–feldspar cores and garnet-enriched rims. Such veins contain a rich mineral assemblage, including mica and zircon, allowing determinations of their age (see below) and PT conditions (T=650 C°, P=10 kbar). The initial $^{87}Sr/^{86}Sr$ ratio measured with apatite is 0.70282. The value is identical to that in host amphibolites and indicates the same depleted mantle source (Kuzmichev et al., in press).

Pegmatitic zircon shows clear colorless polyhedral crystals, sector zoning, an extremely low U content (2–8 ppm) and Th/U ratio (0.002–0.003), which indicate deep-level metamorphic crystallization (Corfu et al., 2003; Hoskin and Schaltegger, 2003). Up to now, only 5 zircon grains were analyzed by means of SHRIMP-II ion-probe at VSEGEI Analytical Centre (St. Petersburg) yielding a 202±17 Ma mean age (Fig. 10) (Kuzmichev et al., in press).

Amphibole, biotite and muscovite megacrysts were also studied using the $^{40}Ar/^{39}Ar$ technique. Biotite and amphibole show an excess ^{40}Ar, which is evident by typical graphs of step heating. This is common for high pressure metamorphics (Kelley, 2002). The muscovite sample showed no ^{40}Ar excess and its plateau age may correspond to reliable time for pegmatite cooling, which was 178.7±1.4 Ma (Kuzmichev et al., 2009). It is doubtful that the Ar isotopic system could have closed in the deep-level high-temperature conditions, and the age may indicate a certain stage of moving the unit to a more shallow level.

2.8. The Burustas flyschoid sediments

The terrigenous deposits that make up the base of Big Lyakhov island do not show any apparent difference throughout the island. They were originally described as a single stratigraphic unit referred to the Mesozoic due to *Inoceramus* shell found by K. Volossovich at the end of the XIX century (Ermolaev, 1932; Spizharsky, 1947). Subsequent investigators dated it as Upper Proterozoic by acritarchs (Voitsekhovskiy and Sorokov, 1957), and, finally, as Permian by the spores found in coal detritus at Cape Burustas (Vinogradov et al., 1974). Therefore, the Burustas Fm. in the central and eastern parts of the island was specified as Permian, while similar rocks in western and northern areas were attributed to Upper Jurassic (Samusin and Belousov, 1985). The latter interpetation was based on correlations with fossiliferous flysch in the neighboring Stolbovoy and Small Lyakhov islands, where Volgian–Early Neocomian *Buchia* species were recovered (Vinogradov and Yavshits, 1975). Later on, a fossil shell was found by Dorofeev on the marine coast near the Predmayski Brook (Fig. 5) that looked like *Monotis Okhotica* — an Upper Norian pelecypoda. After that, the Burustas Fm. was indexed as Permian–Triassic (Vol'nov et al., 1999).

In the studied area, the Burustas Formation is composed of graywacke sandstone and shale. The facies spatial and temporal changes remain unknown due to poor exposure. The section is partially composed of flysch that consists of typical turbidite couplets, common at Cape Burustas. In this outcrop, the flysch packets intercalate with mudstone and poorly sorted silty sandstone with storm-influenced hummocky cross-stratification. The latter indicates a comparatively shallow-level depositional environment, not more than several tens of meters deep (Dott and Bourgeois, 1982). Such combinations were attributed by Mutti et al. (2003) to flood-dominated fluvio-deltaic systems in marginal settings common for foreland basins. The Burustas foreland basin was fed with clastics from a collisional orogen. Green sandstone in the Burustas Cape includes chromium–chlorite flakes and cromium spinel which indicates the presence of serpentinite in a source area (Kuzmichev et al., 2005). If this was the same Late Jurassic ophiolite as crops out nearby, then the age of Burustas Fm. would be Volgian–Neokomian.

2.9. Discussion

The data on tectonic setting and age of sedimentary and igneous units exposed in Big Lyakhov island and the adjacent lands are

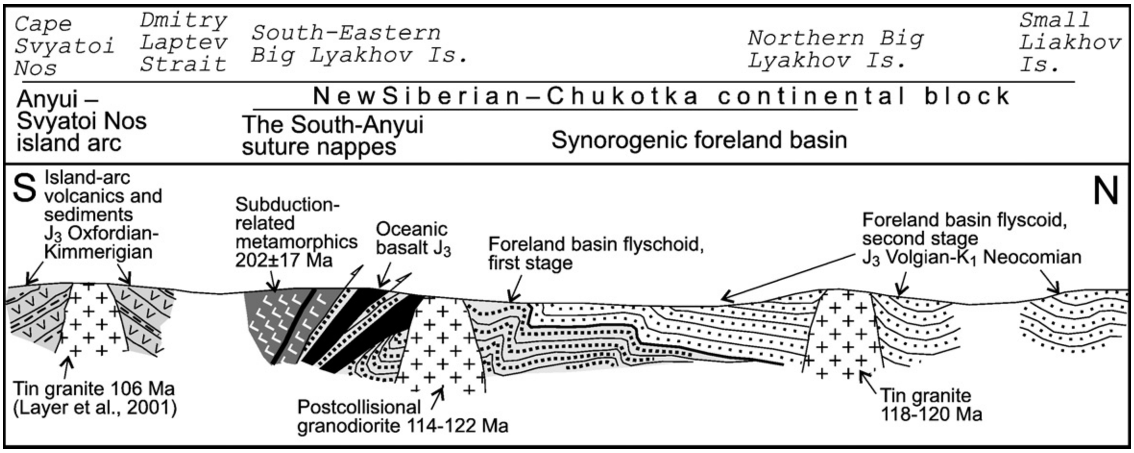

Fig. 11. Schematic N–S profile through the western end of the South Anyui suture in Big Lyakhov island with references to the available age data. These data in aggregate indicate that the suture has formed by mid-Neocomian time. Postcollisional granites emplaced ca. 20–30 Ma after the island arc–continent collision.

summarized in Fig. 11. These units are listed below (from south to north).

1) The Oxfordian to Kimmerigian volcanics and graywackes exposed at the Svyatoi Nos Cape are usually treated as belonging to the Anyui–Svyatoi Nos island-arc system (Natal'in, 1984; Parfenov, 1984; Zonenshain et al., 1990; Natal'in et al., 1999; Parfenov et al., 2001; Sokolov et al., 2002). These outcrops permit a connection of the Late Jurassic island-arc units in Chukotka and in the Big Lyakhov region to be establish.
2) Amphibolites and glaucophane schists were most likely related with the subduction zone beneath the same arc. The available data indicate an essentially older age (about 200 Ma) than that acknowledged for the island-arc volcanics. However, the lifetime of the arc may span the entire Jurassic.
3) Late Jurassic pillow-basalts are convincing evidence in favour of the Mesozoic South Anyui oceanic basin that lay south of the New Siberian terrane. There are similar oceanic pillow-basalts and cherts of the Oxfordian–Volgian age in Chukotka (Natal'in, 1984; Parfenov, 1984; Bogdanov and Til'man, 1992; Sokolov et al., 2002; Bondarenko et al., 2003).
4) The next zone is the Volgian–Neocomian foreland basin infilled with flysch. The Burustas Fm. is supposed to represent its earliest deposits though its assumed Late Jurassic age remains ungrounded. Previously reported fission-track data on the presence of Jurassic detrital zircon population in the Burustas sandstones (Kuzmichev et al., 2006) have been disproved. SHRIMP zircon dating has not revealed any Jurassic zircons. The youngest zircon population was about 250 Ma and the zircon age distribution was similar to that of Triassic rocks in Chukotka (Miller, 2006, personal communication). However, the author still believes that the Burustas Fm. belongs to the infilling of the Volgian–Early Neocomian foreland basin discussed earlier. In the studied part of Big Lyakhov island, the Burustas rocks are included in the nappe packets together with serpentinites and basalts. This is evidence that the rocks represent an earlier stage of the foreland basin evolution, whose deposits were buried under the propagating orogen. At that stage, the Jurassic granites may have not been yet exposed within the source area to provide zircons. The island-arc basalts on the Svyatoi Nos peninsula, which were first outwashed could have hardly supplied abundant zircon into the basin.
   The flysch deposits of Stolbovoi and Small Lyakhov islands represent the main stage of the foreland basin sedimentation. Abundant Buchia species that indicate the Late Volgian–Early Valanginian age interval were found by the author in these deposits in 2007 (Kuzmichev, A,B., Zakharov, V.A., Danukalova, M.K.. Pyatov, V.V. New data on the stratigraphy of Late Jurassic–Early Cretaceous deposits on Stolbovoi island. Stratigraphy and Geological Correlation, submitted). The Volgian–Neocomian flysch on Stolbovoi island can surely be correlated with the terrigenous unit of the same age, widespread in Northern Chukotka (Natal'in, 1984; Bondarenko et al., 2003). The age distribution of detrital zircons from Stolbovoi island sandstones is quite similar to that in Chukotka (Miller et al., in press).
5) Postcollisional discordant granitoids on Big Lyakhov island provide an upper age limit for the suture. This tectonic setting usually shows a lot of discordant plutons with quite varying geochemical features including those of A-type granites. Postcollisional magmatism may have lasted for 20 or even 30 Ma after collision. Similar tin-bearing granitoids are also known in Northern Chukotka (Sukhov et al., 1999; Miller and Verzhbitsky, in press).
   Thus the discussed data confirm the expected Mesozoic zoning and succession of events. The reconstructed Jurassic system includes (from south to north): 1) the Anyui–Svyatoi Nos volcanic arc with a subduction zone beneath it; 2) the South Anyui oceanic basin; 3) the margin of New Siberian–Chukotka terrane. By the end of Jurassic the oceanic basin was closed and fragments of its lithosphere were thrust onto the continental margin. A foreland basin with flysch sedimentation initiated in the forefront of the collisional orogen. This foredeep progressed through the first half of Neocomian or later and spread out throughout Lyakhov islands. By the Aptian, the orogen was disrupted by the WNW–ESE left-lateral strike-slip faults due to W–E compression.
   In the Aptian postcollision granitoids were emplaced. The intrusion of tin-bearing A-type granites continued in the Albian as well. The whole situation looks quite similar to that in the South Anyui zone. So its true extension is exposed on Big Lyakhov island. The next step is to find out its further course. The suture northward curving shall confirm the above rotational hypothesis, while the Taimyrian connection shall prove the Zonenshain model.

3. A proposed northward extension of the South Anyui suture towards the Anjou islands

3.1. Introduction

The northern trend of the suture seems to be the most popular: many geologists turn the South Anyui suture northwards from Big Lyakhov island in the direction of the Anjou islands (e.g. Spektor et al., 1981; Parfenov et al., 1993; Fujita et al., 1997; Greninger et al., 1999, etc.). The suture was delineated as a wide zone that is usually

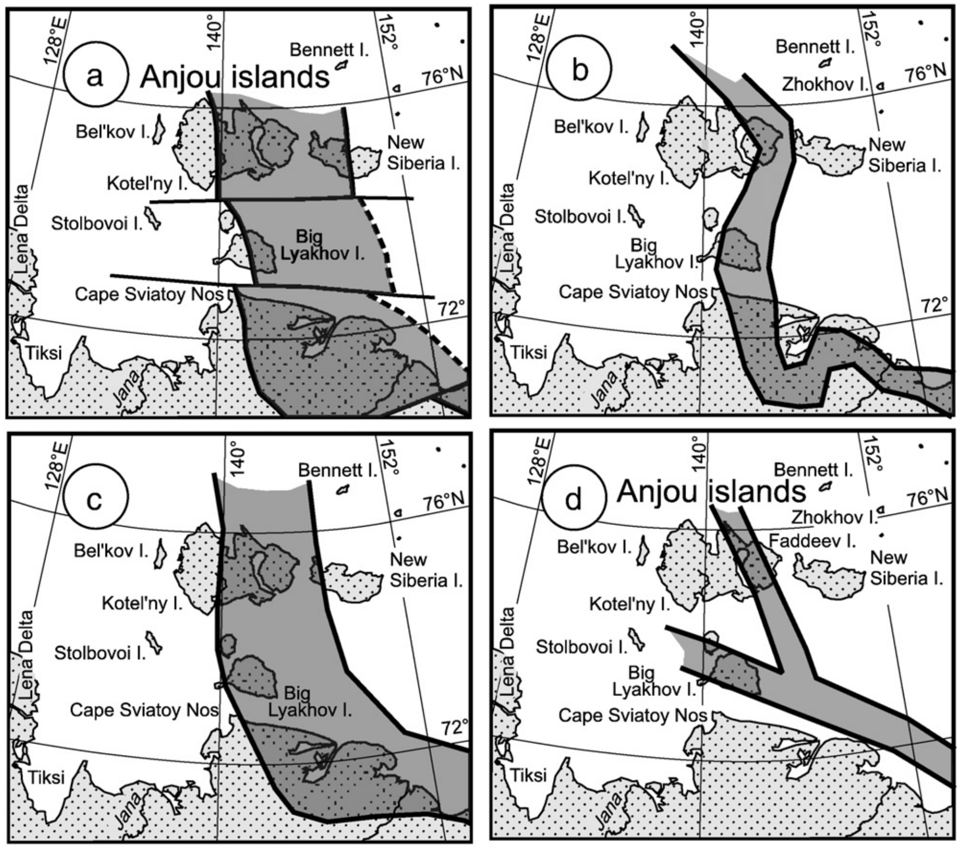

Fig. 12. Viewpoints on the northern trend of the South-Anjou suture (shaded) through the Anjou islands by: Spektor et al. (1981) (a); Parfenov et al. (1993) (b); Fujita et al. (1997) (c); Natal'in et al. (1999) (d).

directed towards Bunge Land or Faddeev island (Fig. 12). Spector, who was the first to turn this zone northwards (Spektor et al., 1981), noted that intensive magnetic anomalies, which could be caused by serpentinite bodies, were absent to the north of Big Lyakhov island. The study of Spector and his co-authors was only based on the geophysical data, he did not consider the background geology.

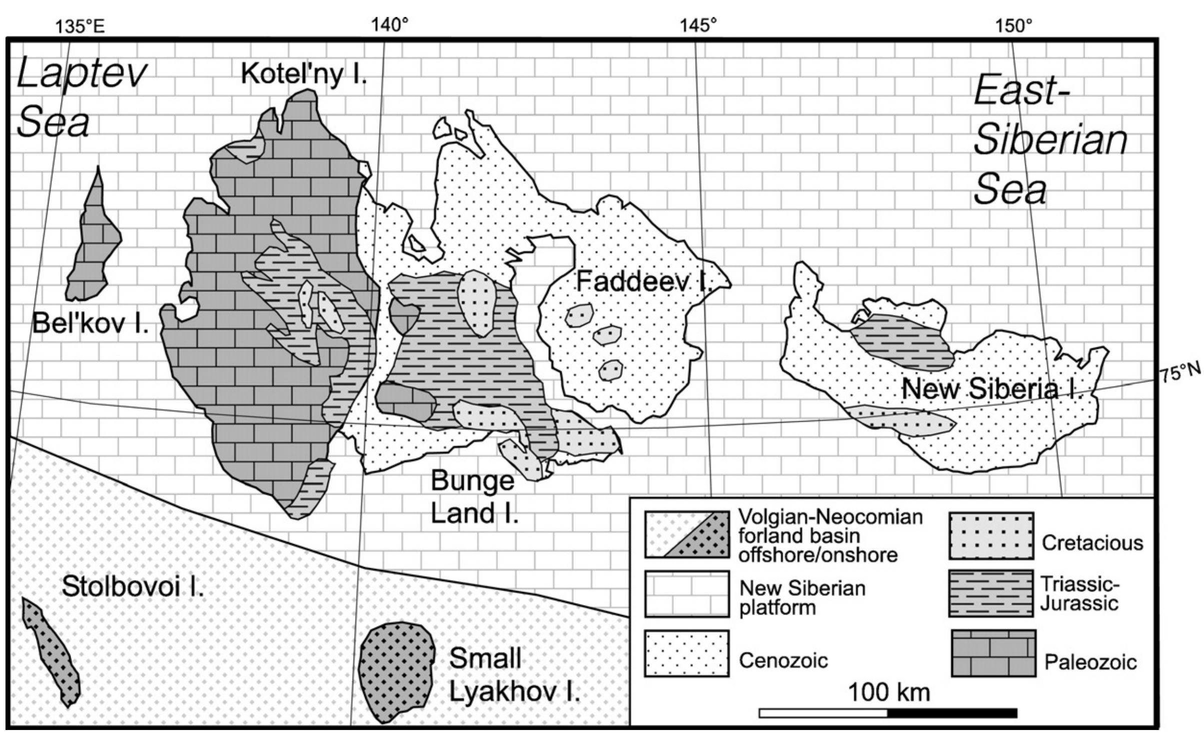

Fig. 13. The general geology of the Anjou islands (including drillhole data). Based on Kos'ko et al. (1985), Trufanov et al. (1986), Vol'nov et al., 1998.

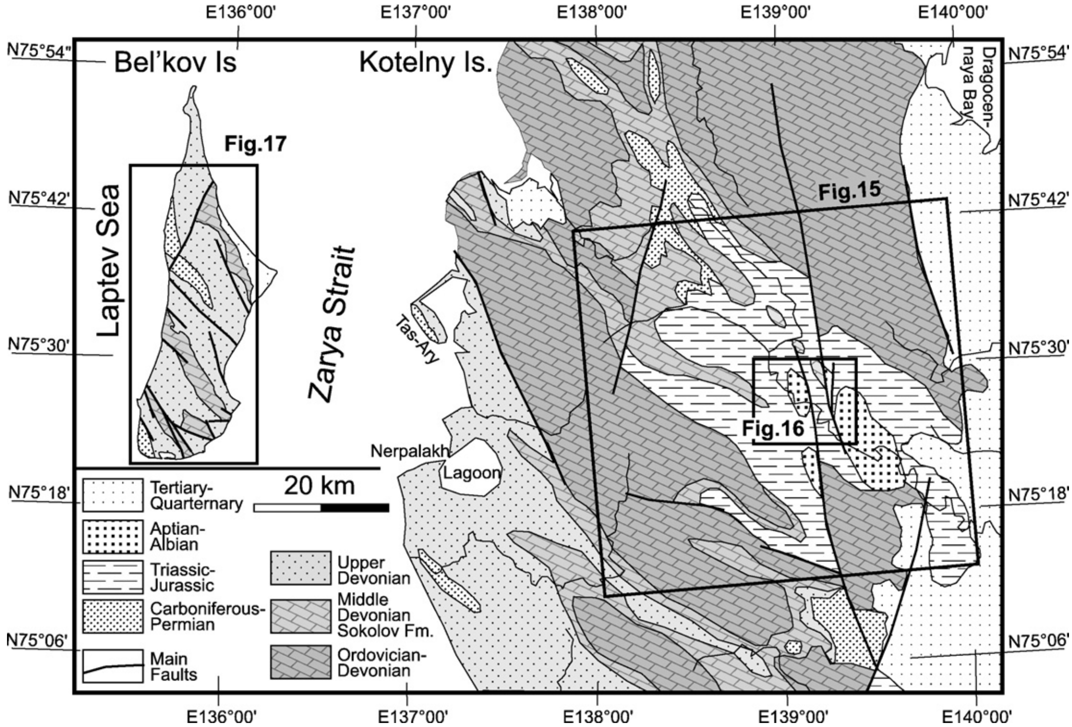

Fig. 14. Simplified geologic map of western Anjou islands (modified after Kos'ko and Nepomiluev, 1982). Locations for Figs. 15–17 are indicated.

Neither did other authors who suggested the suture's northward trend. However, if we examine the available information on the Anjou islands geology and tectonic evolution, it is clear that there is no room for the Mesozoic suture to pass through them. Four main stages can be distinguished in the Paleozoic–Mesozoic geologic history of the Anjou islands: 1) Lower Ordovician–Middle Devonian carbonate platform; 2) Late Devonian–Permian contrasting paleogeography including highlands and deep marine troughs; 3) Triassic–Jurassic shallow-marine basin neighboring the lowland; 4) Aptian–Late Cretaceous coaliferous onland sedimentation. Neocomian deposits are missing on the islands due to a high stand of the territory during the Anyui orogeny.

3.2. The Lower Ordovician to Middle Devonian carbonate platform

The Ordovician–Middle Devonian deposits are mainly presented by shallow-marine carbonate rocks named by Natal'in as the New Siberian carbonate platform (Natal'in et al., 1999). The deposits crop out on Kotel'ny and Bel'kov islands and are also known on Bunge Land island (Fig. 13). The latter is actually a lowland that had just recently risen above the sea level. However, due to rare natural outcrops and numerous mapping boreholes, its bedrock geology has been examined enough to state its similarity with that on Kotel'ny island. Comprehensive data on the Paleozoic rocks lithology and stratigraphy were obtained by Kos'ko, Nepomiluev and their colleagues who have shown that the North-Eastern part of the Paleozoic basin tends to get shallower throughout the entire stage (Kos'ko, 1977; Kos'ko and Nepomiluev, 1982; Kos'ko et al., 1985). A sharp facies zoning has been reconstructed for Silurian rocks represented by shallow-marine carbonates in NE Kotel'ny island and graptolyte shales in southeastern part of the island (Kos'ko, 1977). Breaks in the sedimentary record occurred at Silurian\Devonian boundary and in the Middle Devonian. The similarity of Devonian sedimentary and fossil record to the South Taimyr ones has been indicated by Cherkesova who participated in the geological survey in both regions (Cherkesova, 1975).

3.3. The Late Devonian–Permian stage

The main feature of the stage is rough topography. At the onset of Late Devonian there appeared to be a land area in the centre of Kotel'ny island and a deep trough on Bel'kov and SW Kotel'ny islands. The Upper Devonian sediments on Bel'kov island are represented by proximal turbidites including conglomerates and olistostrome with carbonate blocks up to several tens of meters long. Debris was derived from upslope reefs and from the older carbonate platform. In the course of Carboniferous and Permian time, there were local land areas and depressions on Kotel'ny island, while the Bel'kov island deposits continued to accumulate in a trough. Thus, in Late Devonian the paleogeography of western Anjou islands has changed from a stable carbonate platform to a highland rising above the sea level and to a deep trough in the SW bounded by an escarpment that supplied the olistostrome with carbonate blocks. These changes correspond to the rifting that occurred in Late Devonian time along the eastern edge of the Siberian Platform and the southern edge of the Chukotka microcontinent (Natal'in et al., 1999; Prokopiev et al., 2001).

3.4. The third stage: The trap magmatism and Triassic–Jurassic shallow-marine sedimentation

The Triassic–Jurassic succession begins with basalts and tuffs. They occur in a local area in the mid-Kotel'ny island and are known in several sites of west Bel'kov island. The comagmatic dykes, stocks and irregular plutonic bodies are more abundant. They are known in the western Kotel'ny island and are common in Bel'kov island especially in its western part, where at places they dominate Paleozoic host sediments. The chaotic orientation and irregular contours of intrusions indicate that host sediments provided a nearly isotropic soft substrate during the emplacement of basaltic magma. Mafic igneous rocks in the western New Siberian islands originated from the mantle-derived magma modified by crustal contamination. Their U–Pb zircon age of 252±2 Ma, petrographic features, and geochemical signature are the same as those in Siberian traps (Kuzmichev and

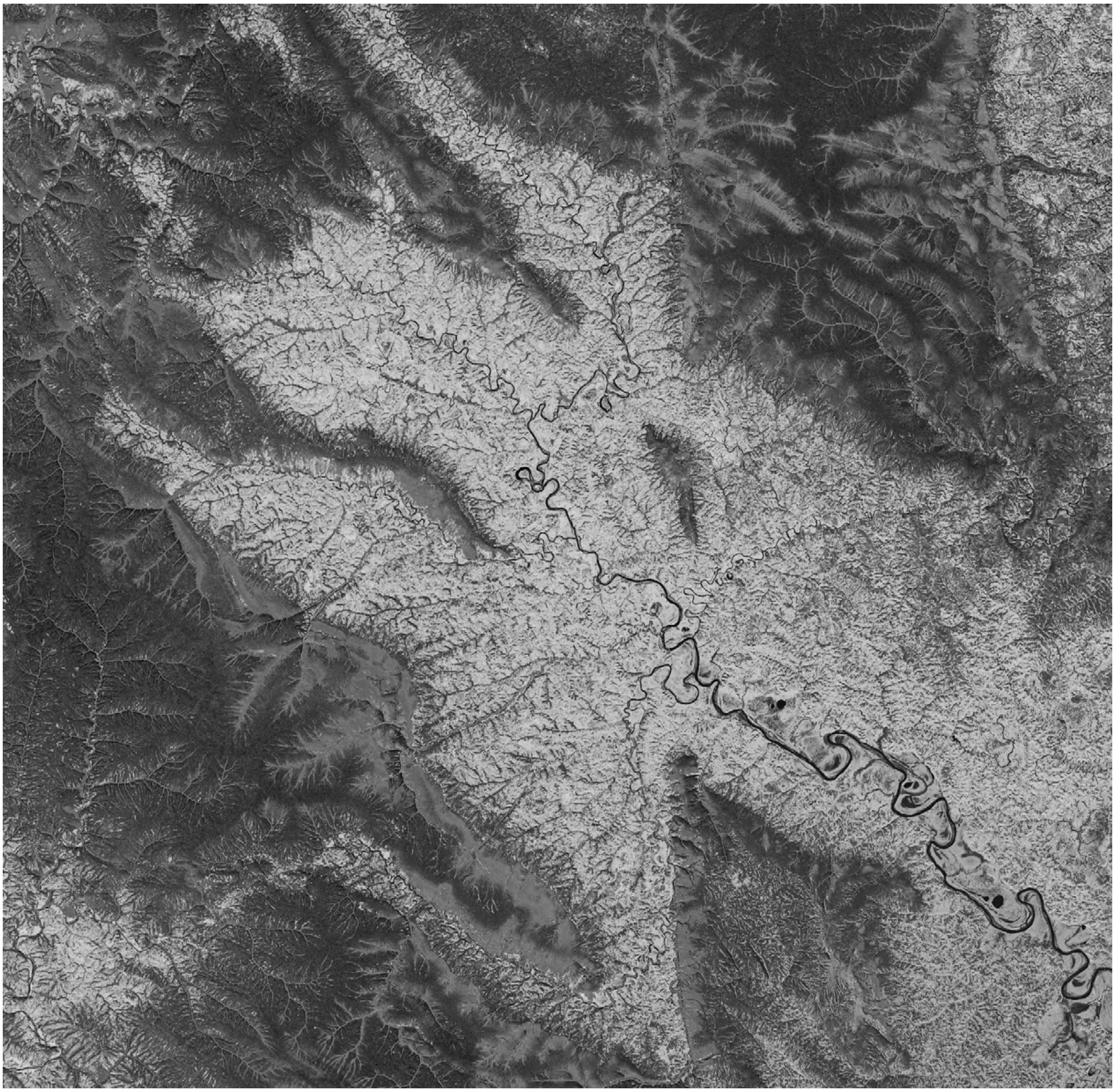

Fig. 15. Landsat 7 image of the middle of Kotel'ny island (see Fig. 14 for location). Dark highlands are Paleozoic carbonate rocks; light lowlands are Mesozoic and Cenozoic sediments. Note the fault across the middle of the image, the offset topography and sinuous path of some of Paleozoic ridges. The large river is Balyktakh.

Pease, 2007). Manifestation of the Bel'kov island mafic magmatism is similar to that in the southern Taimyr Peninsula and both lie within the northern limits of the Siberian trap province.

The Triassic–Jurassic sediments on Kotel'ny island form a continuous succession of shallow-marine poorly lithified mudstones. The lower part of the section is notable for oil shales. The Triassic rocks contain siderite concretions, abundant fossils (including *Mosozaurus*), and driftwood that indicate forest-covered lowland surrounding a marine basin. Rhetian and Jurassic deposits unlike Triassic ones contain rare sandstone layers. Upper Jurassic glauconite sandstone is known in a local area of the eastern Kotel'ny island (Kos'ko et al., 1985). Jurassic shallow-marine mudstone and siltstone were discovered by drilling on Bunge Lang, Faddeev and New Siberia islands (Trufanov et al., 1986; Vol'nov et al., 1999; Kos'ko and Trufanov, 2002) (Fig. 13). Volgian deposits were not found in the Anjou islands.

3.5. The Neocomian orogeny

Neocomian deposits are missing in the Anjou islands due to their highland position. The pre-Cretaceous strata on the Anjou islands were folded and faulted in the Neocomian. The author's field studies in mid-Kotelny island confirm the viewpoint of Kos'ko et al. (1985) that Aptian–Albian deposits lie unconformably upon Triassic rocks and contain conglomerate with debris of Paleozoic–Jurassic rocks. Cretaceous sediments show distinct contrast in the degree of lithification in comparison with the underlying Triassic–Jurassic ones: in practice Aptian–Albian clays and sands are not lithified. Thus, the recent structural pattern of pre-Cretaceous rocks is mainly due to Neocomian orogeny. As can be seen on mid-Kotel'ny island, the deformation was quite irregular: the rocks were steeply inclined and folded near the main faults and near the contacts of soft Triassic sediments with rigid Paleozoic carbonates. However both Paleozoic and Triassic strata lie almost horizontally over large areas. The folds strike NW–SE with vergence to both sides. Some folds are sinuos in plan view and show undulations (Figs. 14 and 15). This sinuosity is probably the result of overprinting of primarily NW–SE linear folds by the right-lateral north to south translation. Some of S–N faults of Bel'kov and Kotel'ny islands also show a right-lateral strike-slip component. These kinematics may somehow be related to results expected for the rotational hypothesis and are discussed at the end of section 3.

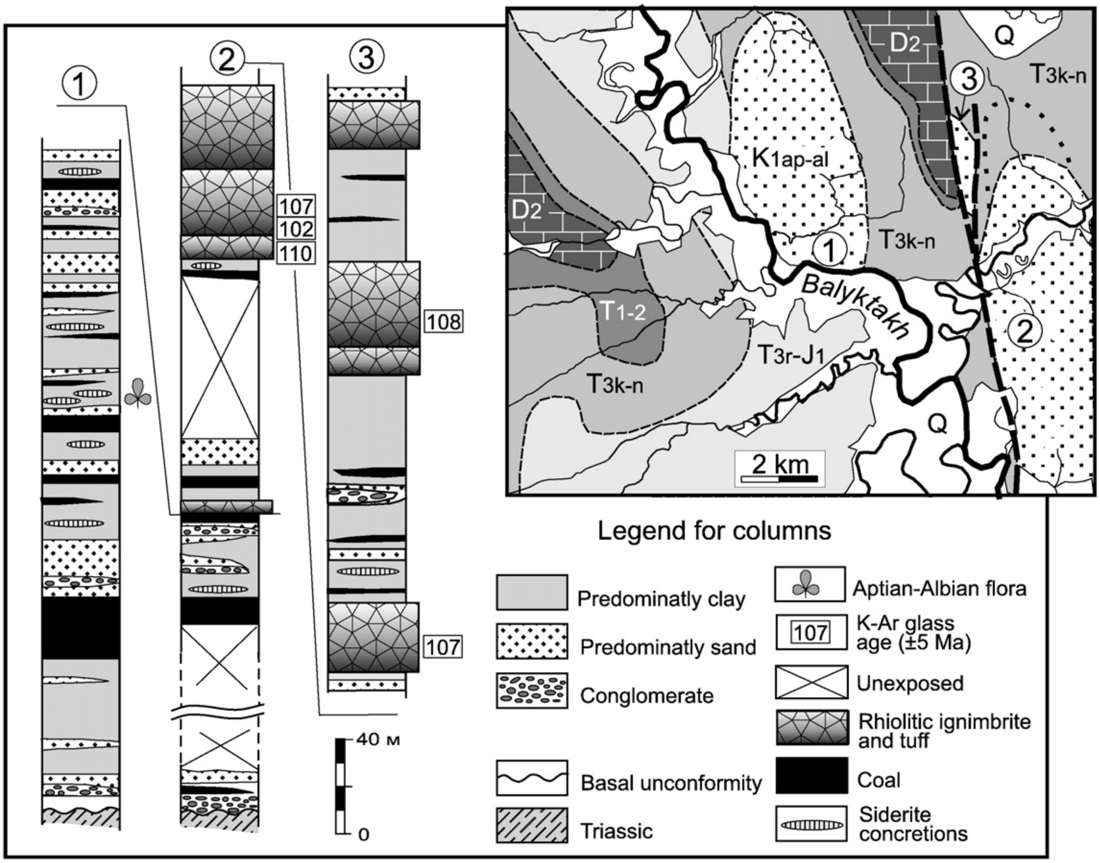

Fig. 16. Postorogenic Aptian–Albian coal-bearing deposits and ignimbrites in the eastern Kotel'ny island (after the 2006 fieldwork data) (see Fig. 14 for location). Stratigraphic columns on the left and map for their location on the right. All geological units on the map are marked with standard age indexes. Geological boundaries are shown with dashed lines due to poor exposure. Three spots locating Early Cretaceous rocks are numbered by circled figures. Dotted line in the map upper right is the boundary of the eroded Cretaceous basal conglomerate.

3.6. The postorogenic mid-Cretaceous coal-bearing deposits and ignimbrites

The postorogenic Cretaceous rocks in the Anjou islands did not form continuous cover, but rather filled the local onland depressions and half-grabens, whose position changed through time. The Aptian–Albian deposits are known in Kotel'ny, Bunge Land and Faddeev islands. The overlying Cenomanian–Turonian sediments were found in outcrops and boreholes in Faddeev and New Siberia islands (Vol'nov et al., 1999). The general composition of deposits was uniform through time and only the degree of coalification of peat and wood was changing from coal in Aptian–Albian to lignite in Upper Cretaceous. The felsic volcanics are common in the Albian portion, though tuffaceous sandstones occurred up to Turonian, indicating long-term igneous activity. Senonian rocks were not found on the New Siberian islands. The data on the Cretaceous–Tertiary deposits were published in English (Kos'ko and Trufanov, 2002) and this discussion mainly concerns their Aptian–Albian lower portion that contains felsic volcanics. They are the only rocks on the Anjou islands that could possibly be related to the South Anyui suture and was one of the reasons for the author's 2006 field study of mid-Kotel'ny island.

In the studied area Cretaceous deposits comprise three local fields numbered in Fig. 14. The western field contains the best exposures of the lower portion of the section. It is composed of clay, sand, crossbedded sandstone, coal beds up to 25 m thick and fluvial conglomerate at the base and on several higher levels. The pebble composition indicates that most detritus was supplied by the adjacent highlands. Plant fossils were attributed by Herman to Late Aptian (?)–mid-Albian (Kuzmichev A.B., Alexandrova G.N., Herman A.N. Apt-Albian coal-bearing deposits and ignimbrites on Kotel'ny island, New Siberian Archipelago. Stratigraphy and Geological Correlation, submitted). The same deposits also occur in the eastern field. The total thickness of prevolcanic strata exceeds 250 m. The pebble and heavy mineral composition show absence of volcanic material that means a sudden onset of volcanic activity.

The bigger upper part of the Kotel'ny Cretaceous section is composed of the same rocks but contains felsic volcanics, mostly tuffs of different fashion (Fig. 16). The most abundant are glassy ignimbrite flows changing to poorly welded tuff at the top. They form a caldera-like elongated syncline in the spot 2 (Fig. 16). Non-welded light-colored ash tuffs are not lithified. The only rhyolite flow up to 0.5 m thick was traced for a distance of about 4 km in the spot 2. Its surface was covered by the 2–7 cm large blisters both intact and burst, and the flow was actually bubbling while being effused. A visible thickness of this volcanic–sedimentary section exceeds 450 m (Fig. 16). The total incomplete thickness of Cretaceous in Kotel'ny island is about 700 m.

The glassy ignimbrites are classified as rhyolites by chemical composition: they contain 73.5–75.5% SiO_2 (recalculated to volatile-free rock). They show high amount of volatile components (4–4.8% LOI), high K_2O (4.4–5.8%), Rb (170–250 ppm); moderate Zr (110–200 ppm), Nb (10–16 ppm). Rare earth elements are moderately differentiated ($La/Yb(n)=4.5–10$) and show impressive negative Eu anomaly ($Eu/Eu^*=0.14–0.22$) (the authors unpublished data). The latter indicates extensive fractional crystallization.

The K–Ar age of ignimbrite glass corresponds to Albian (110–107 ± 2.5 Ma — see Fig. 16). A sample that yielded a younger age of 102 Ma had probably lost some radiogenic Ar. The Albian ignimbrites of Kotel'ny island show the same age as some of the Big Lyakhov island granitoids. The latter were classified as postcollisional intrusions and thus the Kotel'ny magmatism may also be regarded as related to the South Anyui suture collision processes. Nevertheless a more plausible explanation for this magmatism is an intraplate setting.

Welded ignimbrites on Kotel'ny island represent the explosions of overheated magma. It is very likely that the felsic magma resulted from fusion of mid-crustal rocks due to intrusions of hot basaltic magma and subsequent fractional crystallization that is quite typical for ignimbrites overall (e.g. Wark, 1991; Ferrari et al., 2002). The basaltic magma might be the same that constitutes Bennett island (Fig. 2). The Bennett island onland basalt flows make up a 350-m succession. It has the same stratigraphic position as felsic volcanics on Kotel'ny island lying upon the coal-bearing Aptian–Albian deposits (Vol'nov et al., 1999). The basalts show an intraplate geochemical signature (Masurenkov and Flerov, 1989). Their K–Ar whole-rock ages are as follows: 124±6, 110±5, 109±5, 106±4 Ma (Fedorov et al., 2005).

Thus, three igneous units on the New Siberian islands show the same Albian age. These are the Big Lyakhov island tin-bearing granites and andesites, the Kotelny island ignimbrites and Bennet island intraplate basalts. It is very likely that all the above units lie within a wide S–N trending zone (or two parallel zones) of Albian intraplate magmatism. This zone extends further south to the mainland, where it was first defined (Stavsky, 1982; Trunilina and Parfenov, 2001). On Big Lyakhov island it intersects a postcollisional granitic belt that goes in WNW direction along the South Anyui suture from Chukotka.

The reviewed features of preorogenic and postorogenic rock complexes on the Anjou islands leave no chance for the South-Anyui suture to pass through them. However, this conclusion does not concern the rotational transform fault which can be expressed only by structural features.

3.7. Seeking the South–North rotational transform

The proponents of the northward route for the suture do not seem to realize that such northward trending feature can hardly be the suture proper, but rather the rotational transform, implied by the rotational hypothesis of the Amerasia basin opening. It is more promising to seek the transform fault and related structures than the Mesozoic oceanic-related complexes located along its way.

The above overview has shown that in the Mesozoic the Anjou islands represented a single terrain and thus any significant tectonic boundaries should be located outside them. The only place where such transform zone may have passed is westward of the New Siberian islands. It was shown in Section 2 that all Lyakhov islands lie within the bounds of Neocomian foreland basin that originated in front of the South Anyui collisional orogen. So, the transform (if it exists) might joint the suture only west of Stolbovoi island and had therefore to pass westward of all the New Siberian islands. It can be expected that such a continental-scale fault zone must have left some supplementary structural features in the western New Siberian islands even if it did not cut them directly.

In fact some features which may indicate the right-lateral S–N displacement can be found in the western Anjou islands. Large-scale S–N and SSW–NNE strike-slip faults were mapped on Kotel'ny island (Kos'ko and Nepomiluev, 1980) (Fig. 14). Some of them are clearly seen to be cutting Paleozoic carbonates (Fig. 15), and anyone can examine them closely using the Google Earth program. This indicates the recent activation of the faults. However, the faulting probably began in the Neocomian, when Triassic–Jurassic deposits were unconsolidated. The N–S fault affected phosphorite concretions enclosed in Late Karnian deposits on the left bank of Balyktakh River near the point where it reaches the bottom of the inset map in Fig. 16. The concretions were cut into en-echelon slices being as soft as host clay. The later solidification protected concretions from deformation: they just rotated while the strain diffused in a relatively soft mudstone substrate. These faults in Kotel'ny island can be treated as subsidiary features of the main transform zone which lies westwards.

Bel'kov island is the closest place for the assumed transform. It is composed of Paleozoic carbonate (Middle Devonian) and terrigenous (Late Devonian – Permian) deposits. They were folded in Neocomian time to form a NW trending fold system in the same fashion as on Kotelny island but with a clearly expressed northern deviation (Fig. 17). The Bel'kov island Paleozoic strata were deformed to a greater extent and the strain increased toward the western side of the island. In the western cliff the rocks were in places cut to lensed blocks divided by numerous curved faults of differing attitudes. The results of structural studies of 2008 fieldwork are not yet processed and only general notes can be outlined. A notable structural feature of Bel'kov island is a penetrative NNW cleavage directed almost uniformly through the island (with some exceptions) and dipping steeply west. It can be interpreted either as the axial plane cleavage or as shear foliation. In places we observed the strike deviation of both cleavage and layering, which may be related with local horizontal rotation of blocks. The difference in the cleavage and bedding strikes (even up to perpendicular to each other) was observed in numerous sites. This can be accounted by either the blocks rotation in vertical plane or the occurrence of folds with inclined axes. Besides, we

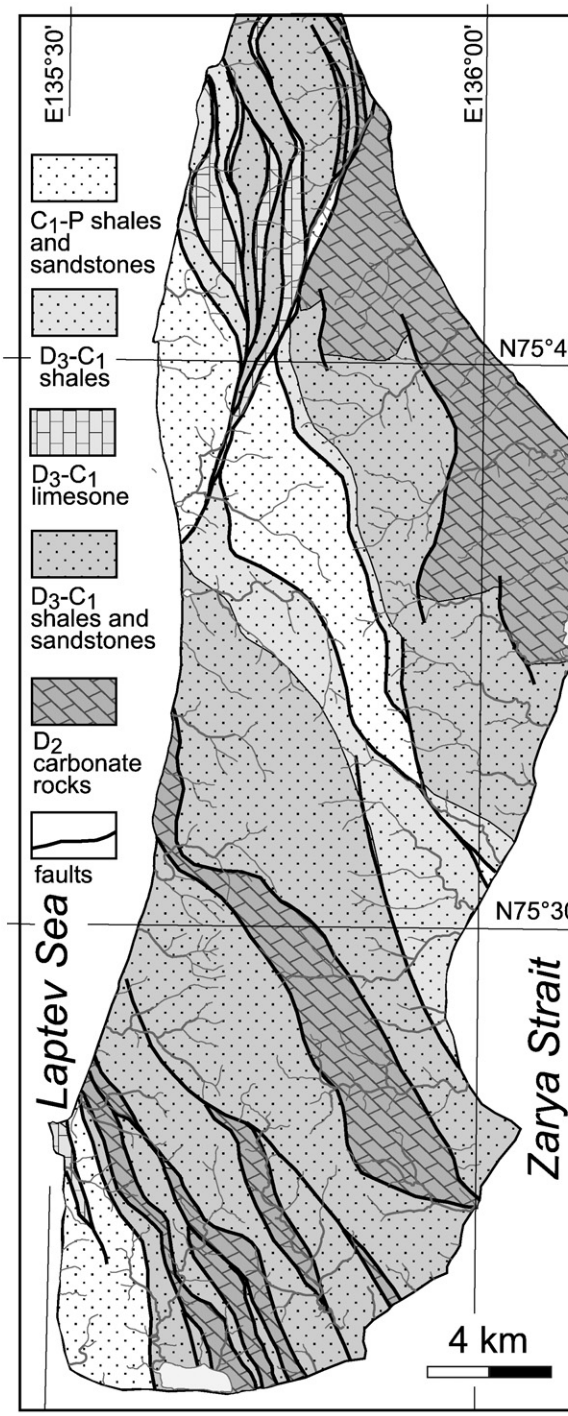

Fig. 17. Schematic field structural map of Bel'kov island (mapped by the author). See Fig. 14 for location.

actually observed a lot of minor faults that had a component of strike-slip combined with dip-slip. All these features can be related with strike-slip deformation. Reliable evidence in favour of strike-slip tectonics can be obtained only from map view (Woodcock and Fischer, 1986). The island is poorly exposed except cliffs. Only faults bounding different lithologies can actually be traced throughout the island. However, the results of mapping tentatively suggest that the NW linear fold structure of Paleozoic rock is overprinted with right-lateral N–S shearing (Fig. 17). These are, first, the mappable right-lateral N–S and NNE–SSW displacements. Second, these are imbricate faults that can be interpreted as strike-slip duplexes and horses (Woodcock and Fischer, 1986). The results of structural studies on Bel'kov Is. will be discussed in a separate paper. By now it is evident that the strain was strongly increasing toward the western Bel'kov island which may indicate a great N–S fault zone passing to the west of it. Some structural features can be interpreted as evidence of right-hand shearing along this zone which may satisfy the supporters of the rotational hypothesis. However the author does not think this zone is the looked-for rotational transform (see below).

3.8. Discussion

The above overview has shown that the pre-orogenic Triassic and Jurassic rocks on Kotel'ny, Bunge Land and New Siberia islands formed in stable shallow-marine environments. This contrasts significantly with the situation in the vicinity of the South Anyui suture with the evolving island arc, oceanic basin and continental edge. In Volgian–Neocomian time, the Anjou islands were a highland area, and the foreland basin lying to the south did not reach them. It was only in Aptian time that the fault-induced subsidence was initiated. So we can definitely conclude that no Mesozoic suture could pass through the Anjou islands. However, some geological features of the western Anjou islands indicate that the right-lateral south–north shearing strain has really affected the structure. Related deformations probably occurred in Neocomian and could in general be related to rotational transform that passed westward of Bel'kov island.

Nevertheless, some other features of Bel'kov and Kotel'ny islands geology contradict such assumption. Paleozoic carbonate rocks of the Anjou islands belong to the New Siberian platform which reaches North Alaska in the east (Natal'in et al., 1999) and Southern Taimyr in the west (Cherkesova, 1975). The Siberian trap province influenced by intraplate volcanic activity included the western New Siberian islands. This suggests that the New Siberian islands formed a continuous landmass with Southern Taimyr in Early Mesozoic time (Kuzmichev and Pease, 2007). Furthermore, by accepting a transform fault passing westward of the New Siberian islands we cannot save the rotational hypothesis, because this would enormously increase the geometric inconsistencies. With this boundaries the terrane that hypothetically detached from Arctic Canada is too long to fit in the space allowed. This permits the conclusion that neither the suture nor the continental-scale transform fault could go through the Anjou islands or separate them from Taimyr.

4. A proposed western continuation of the suture

4.1. A possible Taimyrian connection

A western or northwestern extension of the suture is the most plausible since in this case it just extends westward along strike (Fig. 18). The idea of a Taimyrian connection was presented by Zonenshain and Natapov (Zonenshain et al., 1990). The Taimyr fold belt is composed of three main terranes: Northern, Central and Southern ones divided by two large-scale thrust zones with southward vergence (Fig. 18) (Bezzubtsev et al., 1986; Zonenshain et al., 1990; Uflyand et al., 1991; Vernikovsky, 1996).

The northern fault zone (Main Taimyrian–Diabase thrusts) is actually a suture between two different terranes. This thrust zone formed at the end of Carboniferous through Permian time due to collision of the Kara continent with Siberia (Zonenshain et al., 1990). So it is much older than the South-Anyui suture. The age of syncollisional granites is about 300 Ma (Vernikovsky, 1996). Postcollisional granites dated mainly with K–Ar in 1960s–1970s provided a broad age interval with dominant values in the range of 280-240 Ma. The granite magmatism and metamorphism were the only witnesses of the terranes collision. No rock complexes which could be related to Paleozoic ocean are known in northern Taimyr possibly due to huge tectonic overthrusting.

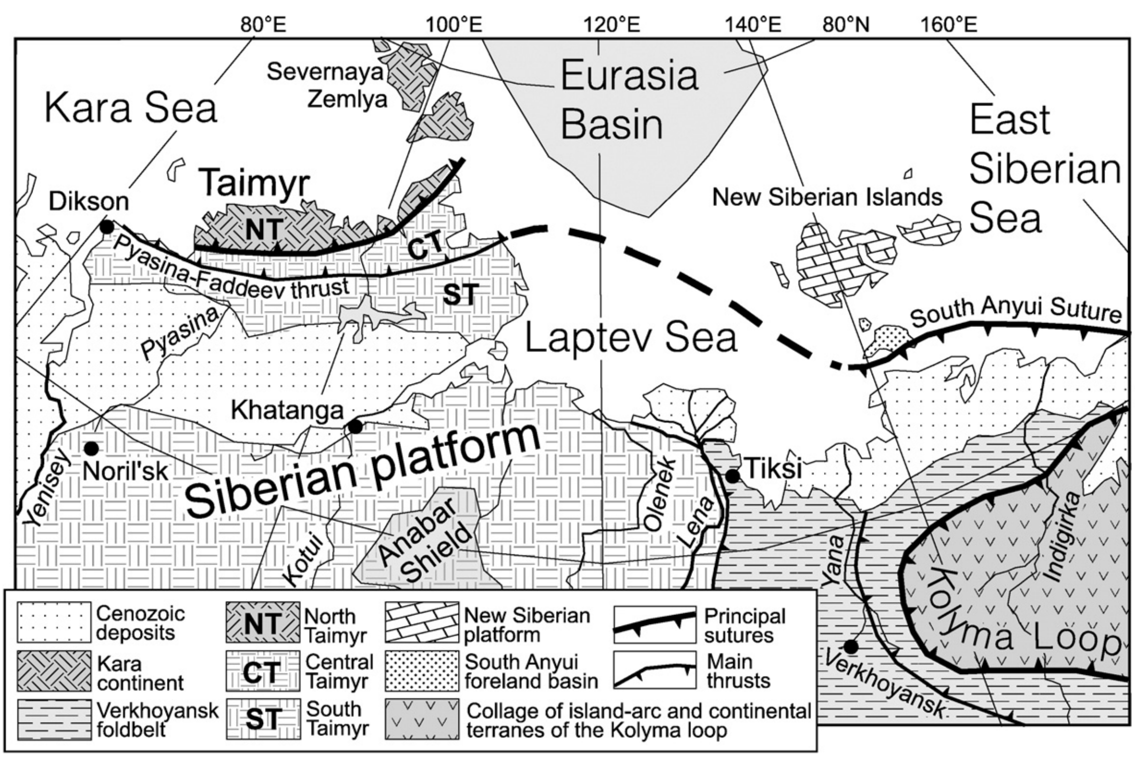

Fig. 18. Possible western continuation of the South Anyui suture (bold dashed line in the Laptev Sea) proposed by Zonenshain and Natapov (Zonenshain et al., 1990).

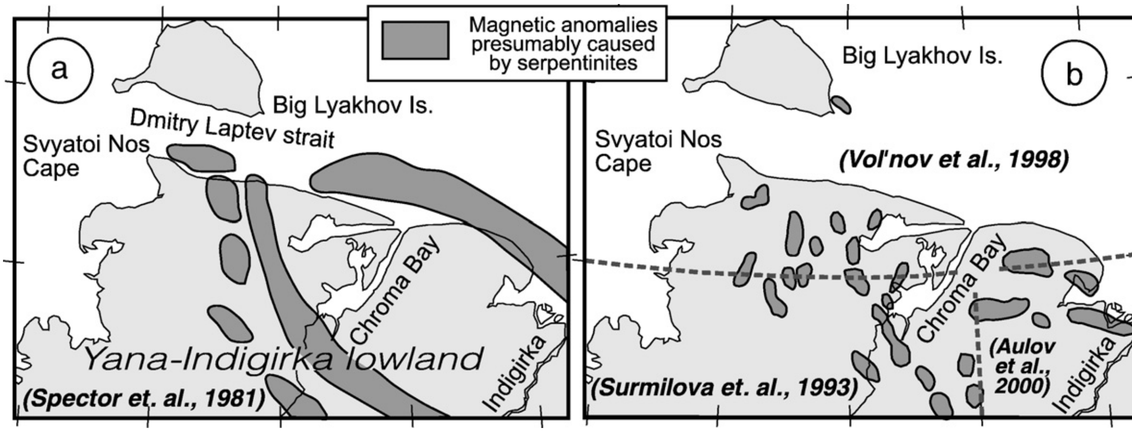

Fig. 19. Buried serpentinite bodies in the Yana–Indigirka lowland revealed by magnetic anomalies after Spektor et al. (1981) (a), and compilers of 1:1,000,000 scale geologic maps (Aulov et al., 2000; Surmilova et al., 1993; Vol'nov et al., 1998) (b). Thecorresponding references are indicated. Dashed lines in Fig. b show the borders of the map sheets. The serpentinite belts show the 180-degree turn which may indicate that the South-Anyui suture turns back at this place.

The southern Pyasina–Faddeev fault zone (Fig. 18) is a 30–40 km wide area of en-echelon thrusts dipping at 30–40° among tightly folded Paleozoic rocks (Bezzubtsev et al., 1983, 1986). It is impossible to delineate the exact border of Central Taimyr and South Taimyr terranes in this zone. The age of folding and thrusting is not well determined there. The entire sedimentary succession of the South Taimyrian terrane from the Lower Ordovician to Upper Triassic continues without any disconformity. Jurassic deposits are only known in western Taimyr, where they conformably overlie Triassic rocks (both are folded). The same region shows the exposed Cretaceous deposits. They are Valanginian sandstones with Ammonoidea and Belemnitella, that continue the Oxfordian–Kimmerigian succession without visible unconformity. Both lie horizontally in the southern outcrops and in the Yenisey–Khatanga depression (Bezzubtsev et al., 1986). Higher in the section there are Barremian–Aptian coal-bearing deposits. The latter occasionally occur in other parts of the central South Taimyr. In places this unit contains thick fluvial conglomerates with wood fragments that lie on Permian rocks with angular unconformity. Natapov recorded Paleozoic rocks thrust over Barremian-Aptian deposits (Zonenshain et al., 1990). Thus, the thrusting along the Pyasina–Faddev zone initiated as early as the Volgian and proceeded through the Neocomian simultaneously with the South Anyui collision.

4.2. Discussion

The Pyasina–Faddeev fault zone was interpreted by Zonenshain, Natapov and Uflyand as a principal suture formed after closure of an oceanic basin (Zonenshain et al., 1990; Uflyand et al., 1991). They considered the difference between the Paleozoic rocks composition in the South and Central Taimyr terranes to be the main indicator that they belonged to different continents. The Paleozoic (Ordovician–Middle Devonian) rocks in the Central Taimyr subbelt are represented by black graptolite shales with black limestones. In the South Taimyr deposits of the same age are represented by biogenic shallow-marine carbonates. This argument is not very convincing since graptolite shales and shallow-marine carbonates could be deposited in the same shelf basin (Bezzubtsev et al., 1986). Similar facies transition occur in Silurian deposits on Kotel'ny island where over a distance of 15–20 km the sublittoral biogenic limestones were gradually replaced from NE to SW by black graptolite shales (Kos'ko, 1977).

The following geological features testify against the interpretation of the Pyasina–Faddeev thrust zone as a suture.

1. Precollisional Late Paleozoic and Triassic–Jurassic deposits on both sides of the thrust zone are represented by shallow-marine and terrestrial sediments and do not contain any oceanic-related rocks. Though there is information on the poorly-studied serpentinite occurrences in three points in South Taimyr. All of them lie outside the Pyasina–Faddeev thrust zone at some distance south of it. Two localities were found in the areas composed of Devonian carbonate rocks (Bezzubtsev et al., 1986; Golionko, 2007, personal communication) and one in Permian sandstones (Gertseva and Samygin, 2005, personal communications). The most probable explanation is that they belong to Late Neoproterozoic ophiolites similar to those in Central Taimyr (Vernikovsky et al., 2004) which protruded through Paleozoic rocks.
2. There are no manifestations of collision-related magmatism or metamorphism or even hydrothermal veins neither along the thrust zone nor in its vicinity (Bezzubtsev et al., 1986). So it was hardly a zone of a two continents collision.
3. The fault zone shows no response in potential fields and cannot be found on gravity or magnetic maps (Bezzubtsev et al., 1986).
4. The presence of Siberian trap dikes which intrude both the Central and Southern Taimyr in the Permian/Triassic time, indicates that no oceanic basin existed between them in the Early Triassic.
5. The Jurassic deposits in Northern and Southern Taimyr show an identical shallow-marine fossil record (Zakharov, 2005, personal communication) which indicates a unified shallow-water basin.
6. The orogeny that occurred in Northern Taimyr at the end of Carboniferous and in the Permian is recorded in the sedimentary succession of Southern Taimyr. By Late Carboniferous, carbonate sedimentation in South Taimyr has been replaced by terrigenous deposits. The Upper Carboniferous sediments occasionally unconformably overlie older Paleozoic rocks. In Late Carboniferous and Permian time, a huge 7-km-thick succession of coal-bearing clastic rocks was deposited in South Taimyr. The clastics to all appearance were transported from the North Taimyrian orogen. This proves that no oceanic basin existed between the Northern and Southern Taimyr in the Permian.
7. In case we accept the Pyasina–Faddeev thrust as the continuation of the South Anyui suture, there must be some similarities in rock complexes lying on either side of the suture in Chukotka and Taimyr. Such similarites are missing. South of the South Anyui suture there occur Mesozoic volcanic arc complexes. Instead, the area on the south side of the Pyasina–Fadeev thrust is interpreted by most geologists as a deformed cover of the Siberian platform (e.g. Bogdanov and Khain, 1998). Contrarily, this South Taimyrian sedimentary succession resembles the complexes lying north of the South Anyui suture.

The Taimyrian direction for the South Anyui suture can be rejected by showing that the Anjou islands were a continuation of South Taimyr and the latter in its turn was a part of northern Siberia Platform. The Taimyr fold belt exhibited no trace of the Jurassic South Anyui ocean. Having rejected both the northward and westward

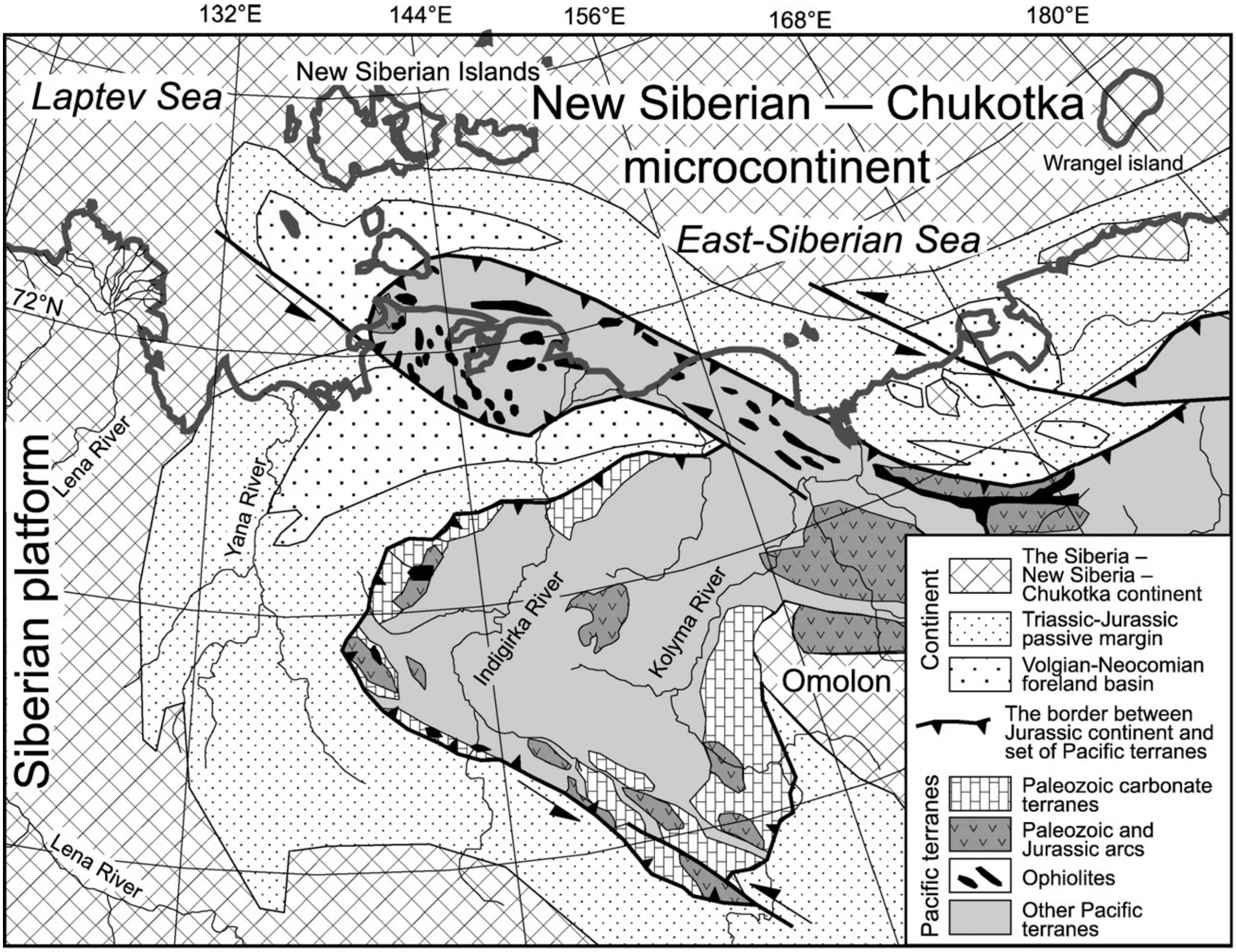

Fig. 20. Tectonic model for the linked South Anyui and Kolyma Loop sutures. Modified from (Kuzmichev, 2001, unpublished paper). Before making the connection with Kolyma Loop, the South Anyui suture curves to form Chroma Loop. Based on Zonenshain et al. (1990), Greninger et al. (1999), Natal'in et al. (1999) and others.

trends as possible routes for the South Anyui suture we have no other choice but to try a southward direction.

5. The third option: Kolyma Loop as a possible continuation of the South Anyui suture

5.1. The suture turns back

The South Anyui suture is a trace of a large Jurassic convergent system, comprising an island arc (or a set of arcs), an Arctic continental terrane margin and an oceanic basin that lies between them. This system could not have totally disappeared at some point, and the continuation of the suture must certainly exist. However, the chain of magnetic anomalies caused by serpentinite bodies extending from Chukotka to Big Lyakhov island has not been traced further neither northward nor westward. It could be expected that on the way to Big Lyakhov island this chain would gradually diminish, but instead it becomes wider in the Yana-Indigirka lowland. In this area the magnetic anomalies are arranged as two belts designated by Spector as West-Chroma and East-Chroma, which appear to join in the vicinity of Dmitry Laptev strait (Fig. 19a) (Spektor et al., 1981). This pattern implies that the serpentinite belt curves and turns back at this place. The interpretation of magnetic anomalies shown on the 1:1,000,000 State Geological Maps differs from that by Spector (Fig. 19b). However it also shows the serpentinite belts curving around the Chroma Bay. This may indicate that the entire South Anyui suture makes a U-turn and outlines a sigmoid that can be named the Chroma Loop by analogy with Zonenshain's Kolyma Loop. If we accept this idea, it will place the exposures of the suture on Big Lyakhov island on the northeastern segment of the Chroma Loop. This explains the SW–NE trend of the suture front there (Fig. 4). In case the suture actually turns back, its further continuation is be found onlyat the northeastern end of Kolyma Loop (Fig. 18). This leads to a new tectonic model of North-East Asia and adjacent shelf (Fig. 20).

5.2. The Kolyma Loop as a possible continuation of the South Anyui suture

In the previous sections we looked in vain for northern or eastern continuation of the South Anyui suture and adjacent terranes. The problem is believed to be really challenging for Arctic tectonics. It is astonishing that nobody ever tried to seek the northeastern continuation of the Kolyma Loop suture and adjacent terranes. This is no less important than the South Anyui problem and it seems quite natural to connect the sutures. However, to be joint the suture zones must curve quite intricately including two sigmoidal loops. Such complicated structure looks artificial and can hardly be expected to occur in nature. However, both loops are evident on magnetic maps (Fig. 21). The uniformity of the entire structure is emphasized by tracing the Cretaceous granitic belts and related gold and tin deposits that trend mostly along the suture's outer contour (e.g. Fujita et al., 1997; Greninger et al., 1999; Layer et al., 2001). An almost similar intricate structural pattern is inherent to Alaskan continuation of the suture zone as well (Johnston, 2001) and this appears to be a typical feature of the entire North Pacific region. The connection of the South Anyui suture with the Kolyma Loop (Fig. 20) is quite important for Arctic tectonics and suggests a new model for the Amerasia basin opening.

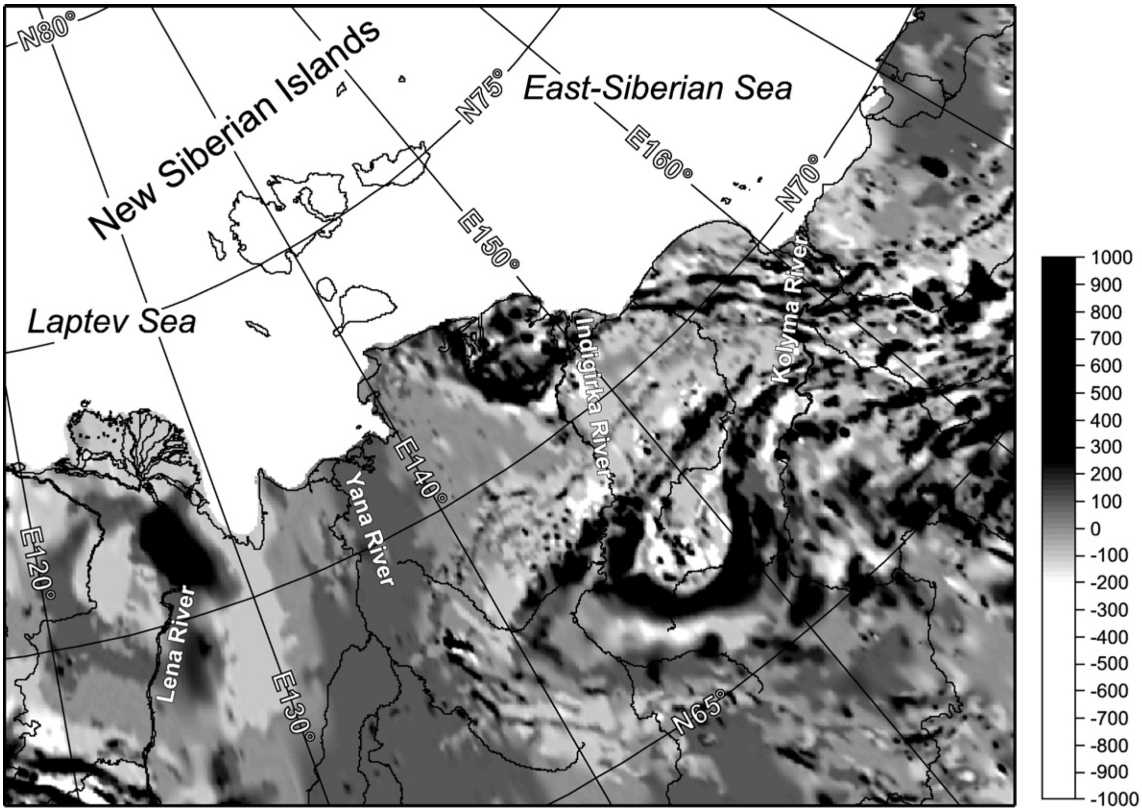

Fig. 21. Onshore magnetic map for the Kolyma–Western Chukotka region. Taken from: http://www.ngdc.noaa.gov.

The chart on Fig. 15 was demonstrated by the author at the Arctic Meeting in St. Petersburg in 2001 (International Conference: Polar Regions of the Earth: Geology, Tectonics, Resource Significance, Natural Environment, 1–3 Nov 2001) and a corresponding paper was soon prepared (in Russian). It was not published at that time being disapproved by experts in Arctic geology. A pioneering paper by Elizabeth Miller and her colleagues showed the Siberian connection to the Chukotka terrane in the Early Mesozoic on the basis of detrital zircon provenances (Miller et al., 2006). This precedent opened the way to discuss the connection of the loops and its consequences for the tectonic evolution of the Arctic.

5.3. The Kolyma Loop suture as compared with the South Anyui one

The Kolyma Loop forms an almost closed sigmoidal contour (Fig. 20). In general the inner ring of the Kolyma Loop is composed of Paleozoic carbonate terranes — former fragments of the Siberian margin; Late Paleozoic and Mesozoic arcs; ophiolites and postorogenic Cretaceous sediments and volcanics (e.g. Zonenshain et al., 1990; Oxman, 2003). The outer ring is the Verkhoyansk foldbelt composed of Carboniferous–Jurassic shallow-to-deep marine deposits accumulated at the Siberian Platform passive margin. Their boundary is a principal tectonic frontier. However it was not generally qualified as a suture. Seemingly, only Bogdanov and Til'man (1992) gave it a proper name (the Kolyma–Polousny) which however is not used. Hereinafter it is designated as the Kolyma Loop suture. Similarly to the South Anyui one, this suture outlines the front of Mesozoic island-arc rocks, ophiolites and Paleozoic terranes, thrusted over Triassic–Jurassic turbidites. The first phase of collision was previously dated as mid-Jurassic (e.g. Parfenov and Natal'in, 1986; Oxman et al., 1995) though later it was attributed only to the Omulevka microcontinent–Alazea arc collision. The resulting microcontinent began to accrete to Siberia at Oxfordian–Early Tithonian (Volgian) (Nokleberg et al., 2001; Oxman, 2003). The main phase of thrusting is the Late Volgian to Early Neocomian (Zonenshain et al., 1990; Prokopiev and Deykunenko, 2001; Oxman, 2003) that is the same as for the South-Anyui suture (e.g. Sokolov et al., 2002).

To justify the model in Fig. 20, the Kolyma loop suture and adjacent terranes on both sides of it must be compared with those of the South-Anyui suture. The author has never studied these regions and cannot provide a comprehensive compilation of a huge data array. Besides, the available data are incomplete, some of them are ambiguous and some papers lack clarity of narration. However there are enough papers on the subject published in English (e.g. Zonenshain et al., 1990; Parfenov, 1991; Oxman et al., 1995; Natal'in et al., 1999; Nokleberg et al., 2001; Sokolov et al., 2002; Oxman, 2003) and readers can make their own compilations. Some points however need comments. The following features of the integrated scheme are briefly discussed below, namely: 1) passive margin deposits on the continental side of the suture; 2) synorogenic clastic sediments; 3) island-arc terranes and ophiolites in the inner parts of the loops and 4) the system of left-lateral strike-slip faults that displaced the suture segments.

5.4. The Triassic–Jurassic passive margin deposits

The Triassic shales and sandstones both in Chukotka and Verkhoyansk regions evidently accumulated at passive margins (e.g. Parfenov et al., 2001; Prokopiev et al., 2001; Sokolov et al., 2002; Tuchkova et al., 2007) and their possible unification was already discussed on the basis of detrital zircon chronology (Miller et al., 2006). The setting of Jurassic deposits is not so clear.

Traditionally the entire Carboniferous–Jurassic succession of the Verkhoyansk belt was attributed to the Siberian Platform passive margin clastic wedge (Zonenshain et al., 1990 and references therein; Bogdanov and Til'man, 1992). Parfenov and his followers presented more sophisticated tectonic zoning of Verkhoyansk–Kolyma area by dividing it into several terranes. The eastern and northern ones that join the Kolyma Loop suture and are mainly composed of Jurassic

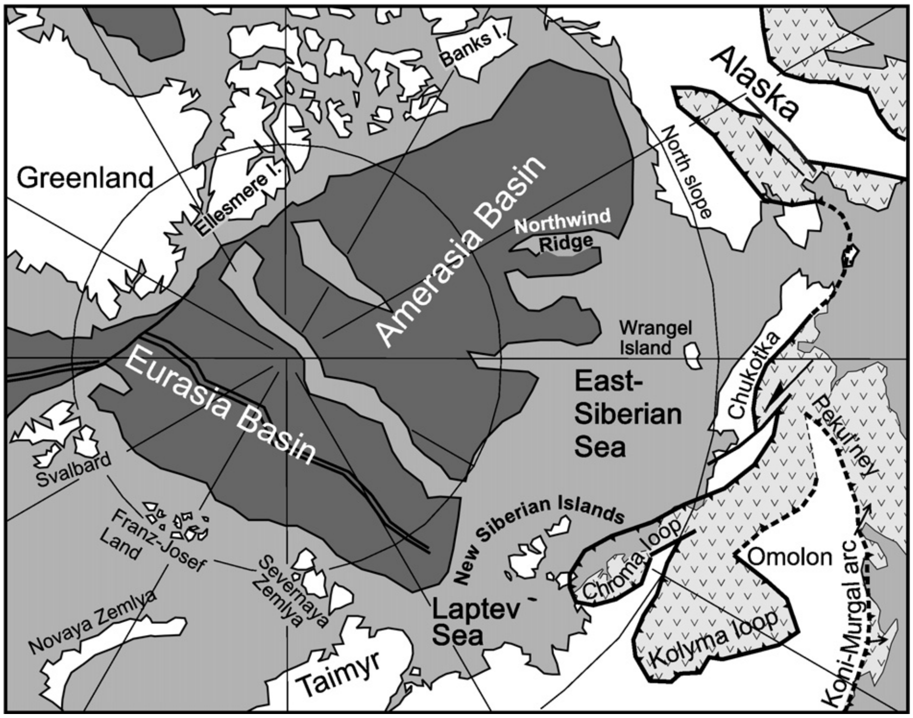

Fig. 22. The South Anyui suture and its possible continuations. Toothed line is the boundary between Amerasia continent and terranes accreted to it in Late Jurassic to Middle Cretaceous and later (speckled with V-pattern). The Alaskan suture meanders are shown after Johnston (2001); Chukotka — after Natal'in et al. (1999); Kolyma Loop — after Zonenshain et al. (1990), and Oxman (2003); Koni–Murgal arc after Zonenshain et al., and Nokleberg et al. (1998).

turbidites were attributed to forearc or back-arc basins or to an accretionary prism (Parfenov, 1984; Parfenov and Natal'in, 1986; Parfenov, 1991; Oxman et al., 1995; Nokleberg et al., 1998; Parfenov et al., 2001; Oxman, 2003). This means that the main suture, which separates the Siberian platform margin, on the one hand, and a set of terranes accreted to it in the Mesozoic, on the other hand, are placed within the former Verkhoyansk belt. It must be noted, that the above authors (with the exception of Oxman, 2003) do not consider this border to be a principal suture. No wonder: almost identical turbidite series lie on both sides of this border. The tectonic setting of Jurassic shale belts is actually somewhat ambiguous: the basins are assumed to be fed with clastics from the inner side of the Kolyma Loop instead of Siberia (e.g. Parfenov et al., 2001) or from both sides (e.g. Oxman et al., 2005). This assumption, however, has not ever been verified by sedimentological observations. At best, volcanic clasts were reported in the sediments which certainly could not be derived from Siberian platform. Even in that case, such Jurassic basins would be better interpreted as foreland basins initiated in the mid-Jurassic phase of collision. In the northern segment of the belt the collision seems to begin only in Volgian time, and the composition of Volgian (Tithonian) deposits really differs from the underlying Jurassic rocks (see the next section). For the purposes of this paper a more simple and obvious deduction by Zonenshain et al. (1990) is accepted. It places the suture to divide the shale belts — formerly a part of the Verkhoyansk belt, and the exotic terranes which include fragments of carbonate platforms, island arcs and ophiolites.

Pre-Triassic rocks of Siberia, Chukotka and adjacent shelf that are boldly unified in Fig. 20 under a single pattern are certainly not uniform throughout the territory (e.g. Natal'in et al., 1999; Prokopiev et al., 2001; Sokolov et al., 2002). Nevertheless, the known difference of Paleozoic rocks is not so significant to contradict the assumption that all of them were deposited at the margin of a single continent. The basement age of this united continent is also different. It is early Precambrian for Siberian Platform and Late Neoproterozoic for the East Siberia shelf, most of the New Siberian islands and Chukotka. This difference does not make a problem either. As was discussed earlier, the New Siberian–Chukotka terrane is probably a continuation of the Taimyrian edge of Siberian Platform whose basement contains Neoproterozoic blocks (Vernikovsky et al., 2004).

5.5. Volgian–Neocomian foreland basins

The basins that warped down in front of collisional orogens cannot be confidentially contoured in either Verkhoyansk–Kolyma or Chukotka regions, and their outlines are thus rather arbitrary (Fig. 20). In Northern Chukotka synorogenic clastic sedimentation began in Berriassian or in Volgian time (Natal'in, 1984; Sokolov et al., 2002; Bondarenko et al., 2003). The similarity of these sediments with the corresponding rocks in the Lyakhov islands is addressed in (Miller et al., in press).

Identification of synorogenic deposits along the outer contour of the Kolyma Loop is less evident. To the north of the Kolyma Loop, Volgian sandstones and shales are arbitrarily referred to such deposits (Fig. 20). In contrast to the underlying Jurassic sediments, they contain abundant volcanic clastics and probably tuffs (Surmilova et al., 1992) which may indicate the outwash of volcanic arc and the beginning of orogeny. This location is squeezed between the two loops and composed of imbricated thrust sheets that show southward vergence in the north and northward vergence in the south. Volgian rocks mostly occurred in the first area and may belong to the outer part of the Chroma Loop rather than to the Kolyma Loop. These deposits evidently differ from those in Stolbovoi island that contain few volcanic clasts.

5.6. Volcanic arcs and ophiolites

A lot of volcanic arc terranes were marked with proper names in the Kolyma and Chukotka regions (e.g. Parfenov, 1991; Oxman et al., 1995; Natal'in et al., 1999; Parfenov et al., 2001; Sokolov et al., 2002; Oxman, 2003). Most arcs have Paleozoic continental basement and can be united into one or two belts. Most popularized is the Late Jurassic Uyandina–Yasachnaya arc adjacent to the Kolyma Loop. At least two generations of oceanic ophiolites (mid-late Paleozoic and Jurassic) were found. Comprehensive data on the island-arc and ophiolitic terranes comprising the inner part of the Kolyma Loop and the South Anyui zone are published in English in the above mentioned papers.

The information on the rocks comprising the inner part of the Chroma Loop is quite scarce. Local exposures of the island-arc rocks are known in Cape Svyatoi Nos (Fig. 2) and in some places south of it. The lower unit (2150 m) of a visible Jurassic section is built up with shales and sandstones which contain Oxfordian–Volgian *Buchia* (Vol'nov et al., 1999). In southern locations the lower unit contains Oxfordian–Kimmeridgian ammonoidea. The upper unit (about 900 m) in the Svyatoi Nos features the island-arc basalt flows intercalated with shales, clastic lava and tuff. This unit also contains felsic and andesitic lavas in the southern areas. The whole-rock K–Ar ages for basalts are 148±5, 152±5, 157±5 Ma (Vol'nov et al., 1999) corresponding to Kimmeridgian. Thus the volcanic activity in the Svyatoi Nos arc was synchronous with that in Uyandina–Yasatchnaya arc and both might constitute a single arc system in Late Jurassic. The island-arc volcanics of similar age are also known in the South Anyui region (Natal'in, 1984; Sokolov et al., 2002).

5.7. Left-lateral strike-slip faults

Large-scale left-lateral NW–SE strike-slip faults are a major structural feature in Fig. 20. The easternmost fault is shown after Natal'in et al. (1999), who indicated en-echelon left-lateral displacement of adjacent Triassic rocks and a pre-Albian age as it does not displace the rocks of the Okhotsk–Chukotka volcanic belt (Natal'in, 2001, personal communication). The next location is the left-lateral strike-slip structural pattern known in south-east Big Lyakhov island (Fig. 3). The non-sheared early Aptian granitoids which intruded along these faults indicate the upper age limit for displacement. The southeastern and southwestern segments of the Chroma loop (Fig. 20) are rather straight (Figs. 20 and 21) and they may also represent strike-slip faults. The system of faults of similar significance is also shown at the southeastern edge of the Kolyma Loop (e.g. Nokleberg et al., 1998; Parfenov et al., 2001; Oxman, 2003).

This NW–SE strike-slip fault system further complicates the intricate course of sutures and may partly be responsible for the

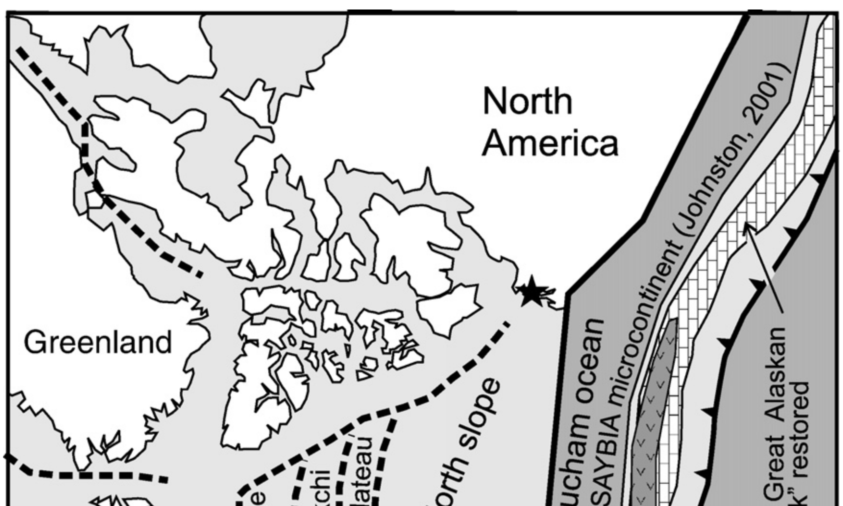

Fig. 23. Assumed Late Jurassic Arctic paleogeography prior to the Amerasia basin opening and after the Alazea arc accretion to form Omulevka microcontinent. Modern coastlines around Arctic are given for reference with paleogeography based on the reconstruction by Bullard, taken from Rowley and Lottes (1988).

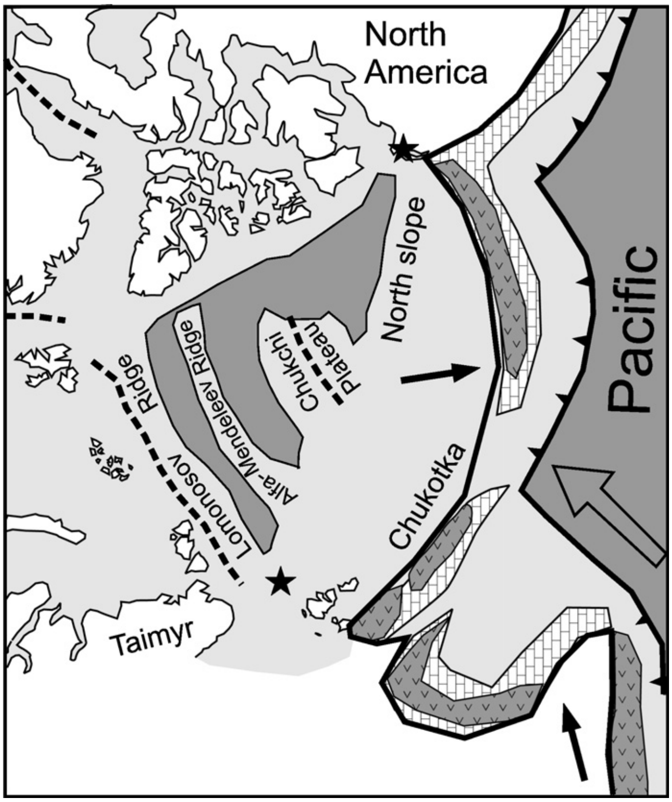

Fig. 24. A beginning of the Amerasia Ocean opening in mid-Neocomian. Note that the angle between the Lomonosov Ridge and Arctic Canada rifted foots is closer than at the previous stage (Fig. 23). The Amerasia ocean opened as a back-arc basin in a two-pole (stars) rotation.

eastward protuberance of the Chroma Loop. The system may indicate a W–E compression that affected the region in late Neocomian–early Aptian time.

5.8. Tectonic consequences of linking the sutures

Connecting the Kolyma Loop and South Anyui sutures leads to far-reaching implications for tectonic evolution of the entire North Pacific region and to the mode of the Amerasia basin opening in particular. The most essential points that must further be developed are indicated below.

6. The Late Jurassic–Neocomian tectonics of the North Pacific region and the Amerasia basin origin

6.1. The Late Jurassic–Early Cretaceous North Pacific paleogeography

Tracing of the South Anyui suture may extend beyond the Kolyma region. On passing along the Kolyma loop the trace of the suture disappears in the area where the Omolon massif – a former fragment of Siberian platform – is indented far northward (Fig. 20). The Pacific-facing side of the massif shows a discontinuous chain of Jurassic–Early Cretaceous and Paleozoic island-arc terranes and ophiolites. This chain begins at Pekul'ney Ridge (Fig. 22) and goes southwest to Taigonos Peninsula and farther on. Most of the Jurassic arc terranes used to be connected to the Kony–Murgal island-arc system (Parfenov and Natal'in, 1986; Zonenshain et al., 1990; Nokleberg et al., 2001). The southwestern part of Kony–Murgal arc was built up on the Siberian continental margin, while its northeastern tip formed the offshore island arc. The latter also had a Paleozoic basement just as the Uyandina–Yasachaya arc did (Nokleberg et al., 2001). Thus the dashed line in Fig. 22 with the exception of its southwestern end has similar meaning as the South Anyui suture marking the border between Late Jurassic continent and terranes accreted to it from the Pacific at the end of Jurassic and later.

The South Anyui suture can also be traced east of the Anyui region towards northern Alaska where its extension is known as the Angaucham suture (e.g. Nokleberg et al., 1998; Natal'in et al., 1999; Nokleberg et al., 2001; Miller et al., 2006). Further on it curves intricately back-and-forth through Alaska (Fig. 22). This line in Fig. 22 can also be defined as a border between the Jurassic North America continent and the terranes accreted to it. The latter include Paleozoic carbonate terranes crowned with arc volcanics similar to those in the Kolyma loop (Johnston, 2001). They form a Z-banded belt which actually composes most of Alaska. Being unbent this belt constitutes a ribbon microcontinent of 8000 km length called SAYBIAN (Johnston, 2001). In earlier times prior to 85 Ma it extended up to Mexico along the Pacific border of North America continent. Johnston believes it to be a narrow terrane that lay in the Pacific apart from North America up to the Late Cretaceous. According to Nokleberg et al. (2001), the Alaskan collage was built up with several individual arcs that collided with North America in Late Jurassic, at the beginning of Cretaceous and later. However, in Late Jurassic they also restore a rather straight Pacific edge of North America.

This leads to a continuous suture that goes around the north Pacific. Its northern portion is shown in Fig. 22. On the northern outer side of the suture is continent including northeastern Asia and northwestern North

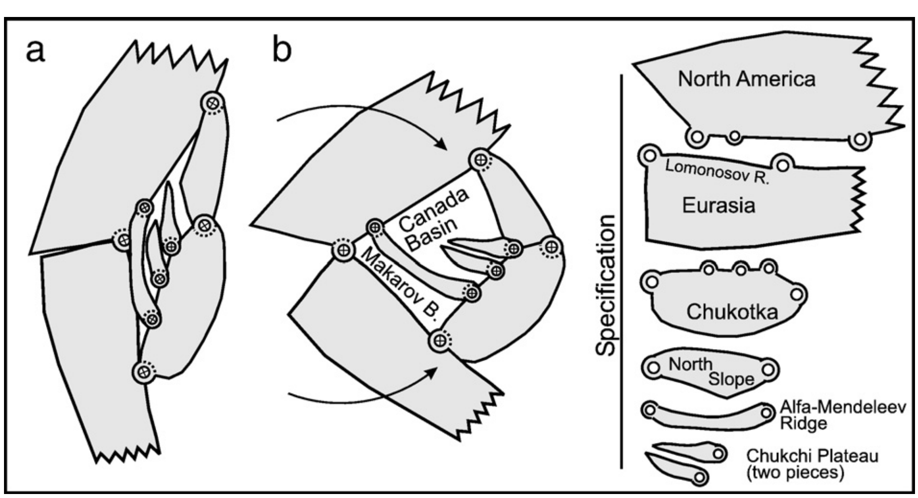

Fig. 25. The parallelogram model for Amerasia basin opening. Modified from Kuzmichev (2001, unpublished paper). A — Late Jurassic, B — recent. Chukotka and North Alaska in Fig. B are moderately compressed. Other terranes are taken as solid pieces.

America. On the southern inner side there is an ensemble of the island-arc and continental terranes that accreted to continental margin from the Pacific. The accretion began in Late Jurassic or Early Cretaceous and continued up to the Eocene. The complicated contour of this boundary is mainly due to the northward translation of the terranes on both Asian and American sides of the Pacific (Zonenshain et al., 1990; Johnston, 2001; Konstantinovskaya, 2003).

The northward translation and bending of the suture started in the Middle Jurassic on the Siberian side and was mostly completed in the Neocomian. Mid-Late Cretaceous volcanics of the Okhotsk–Chukotka belt spread flat upon the tangled structure. As for the American side, the "Alaskan terrane wreck" began in Late Cretaceous (Johnston, 2001; Nokleberg et al., 2001).

However that may be, in Late Jurassic much of Alaska and Kamchatka were not yet in place, the Omolon terrane was far south, the Kolyma and Chroma loops were not bent (or were not so much bent) and the continental margin facing the North Pacific was much straighter. In the case that the South Anyui suture is just the continuation of the Kolyma Loop then NW America and NE Asia were not divided by an ocean as most geologists believe (e.g. Zonenshain et al., 1990; Nokleberg et al., 2001; Sokolov et al., 2002) and formed the solid Amerasia continent with a joint margin. In Late Jurassic time the Atlantic ocean was much narrower and the Pacific one was noticeably wider. Thus, the North Pacific margin of the Amerasia continent was almost straight (Fig. 23). This Late Jurassic reconstruction is just a cartoon model that provides the basis for a more coherent and simple paleogeography than is commonly used. This scheme can be adapted to the comprehensive international North Pacific geological database (Nokleberg et al., 1998; Greninger et al., 1999) and in future may be redrawn for different Mesozoic stages in the manner similar to that of (Nokleberg et al., 2001). Microcontinents and volcanic arcs are shown in Fig. 23 as a single offshore sliver. Actually it may consist of several individual terranes, and some of them might be already attached to the continent in Late Jurassic time. The Oimyakon, South Anyui and Angaucham oceans are shown as a continuous back-arc basin while they might be individual basins. The closing of these basins mostly occurred in the Neocomian due to emergence of a new subduction zone inclined under Omulevka and SAYBIAN microcontinents from the side opposite to that shown in Fig. 23 (Natal'in, 1984; Nokleberg et al., 2001; Sokolov et al., 2002; Oxman, 2003). The assumed Late Jurassic paleogeography shown in Fig. 23 provides the basis for the discussion of the Amerasia basin origin.

6.2. Bipolar model for the Amerasia basin opening

Nikita Bogdanov noted that the Amerasia ocean is quite small and looks like the Japan Sea if both are drown to the same scale (2002, personal communication). This analogy can be extended. Both basins show similar structure with stretched continental ridges embedded in the oceanic crust and may share a similar origin: i.e. the Amerasia ocean may also be interpreted as a back-arc basin (Fig. 24). Its opening might follow the collision of continental and island-arc terranes to Amerasia continental margin in the beginning of Cretaceous. Common models for reorganization of the mantle convection and the oceanic slab roll back are applicable.

Thus, the Amerasia ocean can be treated as a common back-arc basin originated by rifting away of the marginal sliver of continental crust. However, the kinematics of rift-related opening cannot be simply outlined due to its recent triangular shape (Fig. 1). The rotational rifting of Alaska North slope to form the Canada basin is well substantiated (e.g. Rowley and Lottes, 1988; Lawver and Scotese, 1990; Grantz et al., 1998; Lawver et al., 2002). The point is what occurred at the basin's opposite corner that lies north of New Siberian islands (e.g. Rowley and Lottes, 1988; Lawver and Scotese, 1990; Lane, 1997; Lawver et al., 2002; Miller et al., 2006). This corner is the very place where this paper began and it can be discussed in more detail.

The pre-Cretaceous connection of New Siberian–Chukotka terrane with Siberian Platform (Fig. 20) and with its South Taimyrian part in particular (Sections 3, 4) leads to the assumption that the New Siberian corner of the Amerasia basin was also opened by rotation. It means that New Siberian–Chukotka continental sliver was rifted away from the Lomonosov ridge margin and rotated clockwise, just as Miller et al. (2006) suggested. The pole of rotation would lie in the recent Laptev Sea close to the recent corner of the Makarov basin (Fig. 24). Some structural features of the New Siberian islands and adjacent land support this hypothesis.

As was indicated earlier, the Anjou islands lie on the extension of South Taimyr belt and both demonstrate similar structural patterns of undulating linear synclines and anticlines. The South Taimyrian and Kotel'ny island structure mainly differs in having a different strike of the folds, NE in the first case and NW in the second. It may be due to a clockwise rotation of New Siberian terrane in the course of Amerasia basin opening. If the Kotel'ny island structure is rotated back (counter-clockwise) to its original position, it fits the strike of the South Taimyr folds quite well. The next testing point is the compression which has to occur on the opposite (Siberian) side of the pole of rotation. This area was really affected by compression which can be illustrated by any geological map of the lower Yana–lower Lena region. All the above points need specification. This is the task for another paper as well as an attempt to determine the age of Kotel'ny island rotation by paleomagnetics.

Thus both opposite corners of the Amerasia basin resulted from rotational rifting and the basin opening proceeded in the two-pole rotation mode. The variant of such model was already presented by Miller et al. (2006). The following idea is somewhat different. The main inconsistency of the two-pole model is the rather acute angle between the Lomonosov and Canada rifted margins (Fig. 1). If this angle was the same in Late Jurassic as Rowley and Lottes (1988) suggested, the two-pole model would not work. In Early Cretaceous time this angle had to be more obtuse and should grow closer in the course of the Amerasia basin opening (Figs. 18 and 19). The next inconsistency of the two-pole model is a straight and narrow Makarov basin which differs in shape from the Canada basin and suggests rather an orthogonal rifting than a rotational one. To escape both difficulties, a parallelogram model is presented (Fig. 25). Although this primitive mechanical model looks like a joke, the author believes that it provides the best available basis to explain the origin of Amerasia basin geographic features. The scheme in Fig. 25 is self-evident and does not require further elucidation.

7. Conclusions

The Neocomian South Anyui suture was recognized in Chukotka and interpreted as a principal tectonic boundary separating the terranes of North-American and Siberian origin. Its further tracing westward or northward from the reference area was regarded as a principal problem related to Arctic Mesozoic tectonic evolution and particularly to the origin of the Amerasia ocean basin. The New Siberian islands and Laptev Sea region are the key areas to test the current viewpoints of the suture route. Investigations on SE Big Lyakhov island have proved it to be the last point which the South Anyui suture reached on its way northwest. The previously proposed continuations of the suture to Anjou islands or to Taimyr peninsula were tested and rejected. This means that no oceanic basin separated the northwest America and northeast Asia in Jurassic time and they formed a single continuous continent. However, the South-Anyui suture did not stop at Big Lyakhov island but turned back making the Chroma Loop before it adjoined Zonenshain's Kolyma Loop. This newly established geography of the suture imparts a new meaning to it. Henceforth it is not the trace of the boundary between Jurassic America and Asia but a frontier of an Amerasian continent, separating it from a set of terranes that came from Pacific in late Jurassic and Cretaceous time. The meandering path of this frontier is the result of northward translation of terranes along both sides of the Pacific during

Cretaceous and Tertiary. When unbent to the Late Jurassic position, this convergent boundary between the Amerasia continent and Pacific became much straighter. If so, the Amerasia basin may have originated as a common back-arc basin by splitting away the continental sliver that included the East-Siberian shelf, Northern Chukotka and Alaska. This could occur only if the angle between the Lomonosov and Canada rifted margins was originally more obtuse than now. The articulated parallelogram model can explain the origin of Amerasia basin and its peculiar geographic features.

A considerable part of the above conclusions is geological speculation that requires further substantiation. The following points must be subjected to intensive investigation.

1) All the above speculative general schemes should be adapted to real geology using all published data and especially the database by Nokleberg et al. (1998). 2) The continental landmasses and shelf areas in the last figures are shown blank. They should be patterned in accordance with geology, and the general tectonic zoning must be traced from Taimyr and Severnaya Zemlya to Canada islands and North America. 3) Compressional deformations in the Laptev Sea region caused by rotation of New Siberian–Chukotka terrane must be specified and grounded by structural data. 4) Early Cretaceous clockwise rotation of the New Siberian terrane must be proved by paleomagnetic evidence. 5) The paper has revealed some phenomena that were not explained. The reason for N–S strike-slip faulting that affected the western New Siberian islands and the reason for the Neocomian orogeny in South Taimyr must be clarified. 6) Strong evidence must be sought for the declared obtuse angle between the Lomonosov and Canada margins in Jurassic. The list of further investigations introduced by the conclusions of this paper can be greatly extended. To gain success this future effort should be collaborative.

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