TO GEODYNAMIC EVOLUTION OF THE TAIMYR FOLDED AREA

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ABSTRACT

The tectonic scheme and main structures of the Taimyr folded area are shown. We characterize metamorphic and igneous complexes of the North-Taimyr zone of the Kara microcontinent and the Central-Taimyr zone, which represents a Precambrian accretionary belt. The latter includes the Mamont-Shrenk and Faddey terranes composed mainly of granite-metamorphic complexes, island arc fragments, and ophiolites. The features and types of metamorphic rocks from different terranes are found while studying mineral assemblages and composition, and calculating pressure-temperature (P-T) parameters metamorphism. A compositional comparison of metapelites, metabasites, and granites from different terranes was carried out. To distinguish the main formation stages of the Taimyr geodynamic complexes, we used new U-Pb, Sm-Nd, Rb-Sr and K-Ar isotopic data.

The first significant tectonic event was the formation of an accretionary block and its collision with the Siberian continent in Riphean time, which resulted in thrusting, metamorphism, granitization, and uplift of oceanic complexes. The age of this event corresponds to the age of ophiolitic plagiogranite (740-720 Ma), collisional granite (Mamont-Shrenk and Faddey terranes), and the age of metamorphism for garnet amphibolites of the Stanovoy belt (580-560 Ma). The Late Carboniferous-Permian collision of the Kara microcontinent and Siberian continent is responsible for one more event that is recorded by volumes of regionally metamorphosed rocks, collisional granites, and transformations of the Siberian continental margin. A late Paleozoic age for this event is defined by the age of granites, regional metamorphism (306-275 Ma), and folding of Paleozoic deposits, including the Permian (South Taimyr zone).

INTRODUCTION

The problem of the formation of the Taimyr fold area still attracts high interest among many investigators. It is traced along the Kara Sea for a thousand kilometers and has an importanty place among the main structures of the Arctic. South-Taimyr foldbelt (mainly of Paleozoic age), is situated between the Ural-Novozemelsky foldbelt and the Verkhoyansk-Chukotka fold area. The northern Precambrian part of Taimyr is considered by some authors as a block, which together with similar structures of Novosibirsk Islands, Chukotka Peninsula, Seward Peninsula, Canadian Archipelago, and North Greenland, composed the Arctida paleocontinent (Zonenshain and Natapov, 1987; Zonenshain et al., 1990; Uflyand et al., 1991; Zonenshain et al., 1991). In addition, study of the formation of the Taimyr fold area is significant to the explanation of the geological evolution of the Siberian Platform, which outlines Taimyr structures from the north.

Up to now, a large number of concepts about the tectonic nature of the Taimyr area have appeared. Some involve schemes for ancient geosynclinal evolution (from the Archean to Paleozoic), others are based on plate tectonic theory and involve geodynamic maps, which have provoked consideration of the North Taimyr as a foreign block in respect to the Siberian continent. The main investigations that significantly formed concepts on the geology and evolution of the Taimyr area are as follows: Urvantsev, 1949; Daminova, 1957; Ravich and Pogrebitsky, 1965; Pogrebitsky, 1971; Makhlayev and Korobova, 1972; Zabiyaka, 1974; Zakharov et al., 1977; Makhlayev, 1988; Bezzubtsev et al., 1986; Zabiyaka et al., 1986; Uflyand et al., 1991.

We accept a tectonic scheme similar those proposed by L.P. Zonenshain, L.M. Natapov, and A.K. Uflyan and others (Zonenshain et al., 1990; Uflyand et al., 1991), according to which the Taimyr fold area is divided into three zones: 1. Paleozoic-Mesozoic South-Taimyr zone, 2. Late Precambrian accretionary Central Taimyr zone and 3. North-Taimyr zone (the Kara microcontinent) separated by the giant Pyasino-Faddey and Main Taimyr thrusts (Fig. 1). The South-Taimyr fold area is composed of non-metamorphosed Paleozoic sedimentary rocks and Upper Permian and Triassic sedimentary and volcanic rocks and dikes. We will focus on the two other zones generally composed of Precambrian rocks;the Central and the North Taimyr zones. There are various metamorphic complexes whose formation is directly related to the major tectonic events of Taimyr evolution.

CENTRAL TAIMYR ZONE (PRECAMBRIAN ACCRETIONARY BELT)

This zone includes Precambrian metamorphosed island-arc and fore-arc complexes, sheets of oceanic crust (ophiolites), and continental crust fragments. These rocks extend from Pyasin Bay in the west, to the Laptev Sea in the east. They are part of a microcontinent related to Paleozoic structures formed by Late Riphean accretion and overlapped by Late Riphean-Vendian-Early Carboniferous sedimentary cover. The accretionary belt involves

Mamont-Shrenk, Faddey and island-arc terranes, which have tectonic thrust contacts. The first two are similar to each other but differ from the last compositionally and grade of metamorphism. Boundaries between blocks are traced by zones of cataclasis, mylonitization, and autoclastic melange (Makhlayev, 1978; Bezzubtsev et al., 1986; Uflyand et al., 1991). In addition, nappe-thrust structures were established inside terranes. In the western part of the North-Taimyr zone, volcanic blocks are exposed within tectonic windows among the Kara microcontinent sheets.

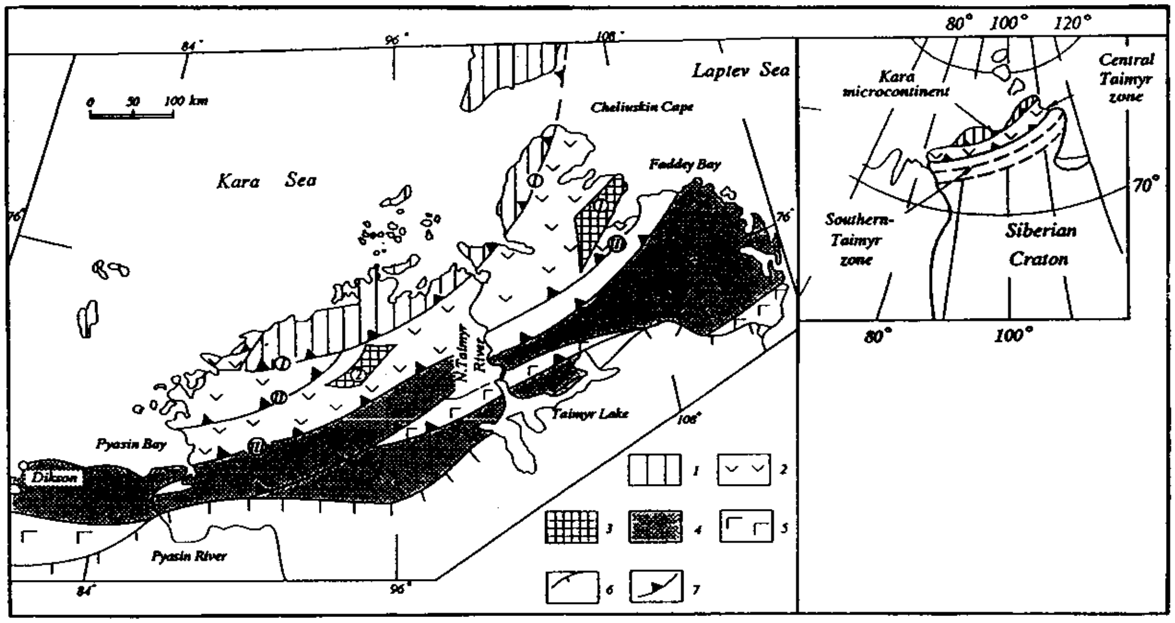

Fig 1. The scheme of main structures of Taimyr area.
1 - Kara microcontinent (Northern-Taimyr zone): Riphean flysch-like deposits and Late Paleozoic collisional orogenic granites; 2 - Riphean accretionary belt (Central-Taimyr zone): ophiolites, island arc complexes and Vendian-Middle Paleozoic carbonate-terrigenous cover; 3 - Late Riphean-Vendian granites, gneisses and amphibolites (1 - Faddey terrain, 2 - Mamont-Shrenk terrain); 4 - Ordovician-Permian deposits of passiv continental margin; 5 - Permian-Triassic volcanic-terrigenous deposits; 6 - Yenisey-Khatanga Mesozoic-Cenozoic depression; 7 - main thrusts (I - Main Taimyr thrust; II - Diabase thrust; III - Pysin-Faddey thrust)

Mamont-Shrenk and Faddey terrains

The Mamont-Shrenk and Faddey terranes are separated by a distance of 200 km, the first located between the Shrenk and Mamont Rivers, and the second near Faddey Bay, North Taimyr. These together are considered by most investigators as blocks of the oldest rocks in the region (Archean or Early Proterozoic). Recently, these structures are more commonly thought to be overlap sheets (Makhlayev (1988). The terranes are mainly composed of highly metamorphosed (epidote-amphibolite and amphibolite facies), metaterrigenous plagiogneisses, crystalline schists, biotite-amphibole schists, amphibolites, and garnet amphibolites. There are also dikes of amphibolized gabbro, granites, granite-gneisses and migmatites with minor quartzites, and marbles. Often the rocks carry the signs of cataclasis, mylonites and diaphthoresis, mainly at the periphery.

Metapelites are commonly biotite-sillimanite and garnet-biotite gneisses and, according to many components are compositionally close (Vernikovsky, 1995). There are some differences in Hf and Zr, REE contents and their normalized distributions (Fig. 2). Mamont-Shrenk metapelites are significantly enriched in light lantanoids and have a clear Eu negative anomaly, whereas the content of heavy lantanoids in both terranes is close.

Study of garnet composition from metapelites of the northern part of Mamont-Shrenk terrane and central part of Faddey terrane, allowed us to estimate their typical compositional change (Vernikovsky, 1988, 1995). Garnet zonation is characterized by low MnO, MgO, and FeO, and high CaO in the rim, relative to the core. Thus, grossular varies from 3-4 to 13-17 mol. percent. After Dobretsov and others (1972, 1974) and Miyashiro (1973), such a tendency indicates a pressure increase during mineral formation and\or change in fluid composition.

Metabasic rocks of both terranes are similar. There are green-brown and green hornblende and actinolite, and basic plagioclases, after which, epidote-zoisite aggregate and acid plagioclase are formed. Often, migmatites are displayed. Within the Mamont-Shrenk terranes, the degree of migmatization increases northwestwards

(Makhlayev, 1988). Within the Faddey terrane, zones of migmatization and small autochthonous granite bodies occur in the southeastern part and become larger northward.

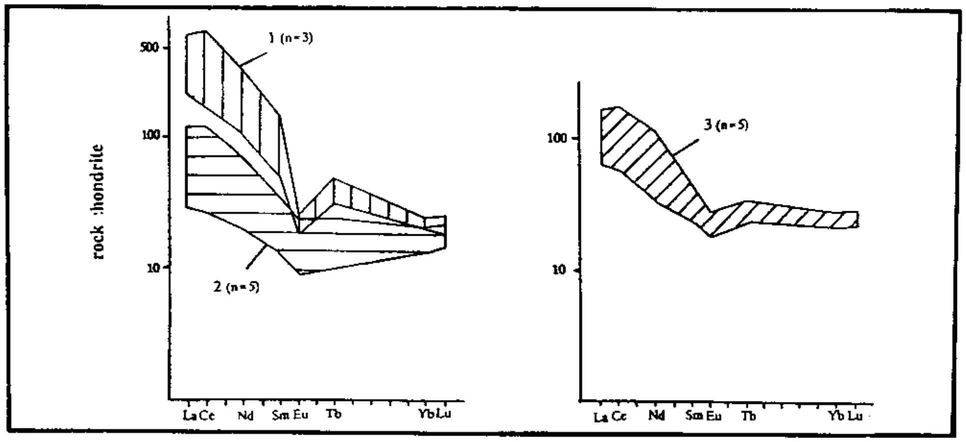

Fig 2. REE distribution for metapelites of Mamont-Shrenk (1) and Faddey (2) terrains and Kara microcontinent (3).
Normal values after Evensen, 1978

Specific high pressure minerals are found in the southeastern marginal parts of the blocks. In the Mamont-Shrenk terrane, they consist of garnet with an elevated pyrope component from high-alumina gneisses, rare occurrences of garnet-biotite gneisses, and sodium amphiboles and pyroxenes (glaucophane and omphacite), in cataclastic diopside-bearing rocks.

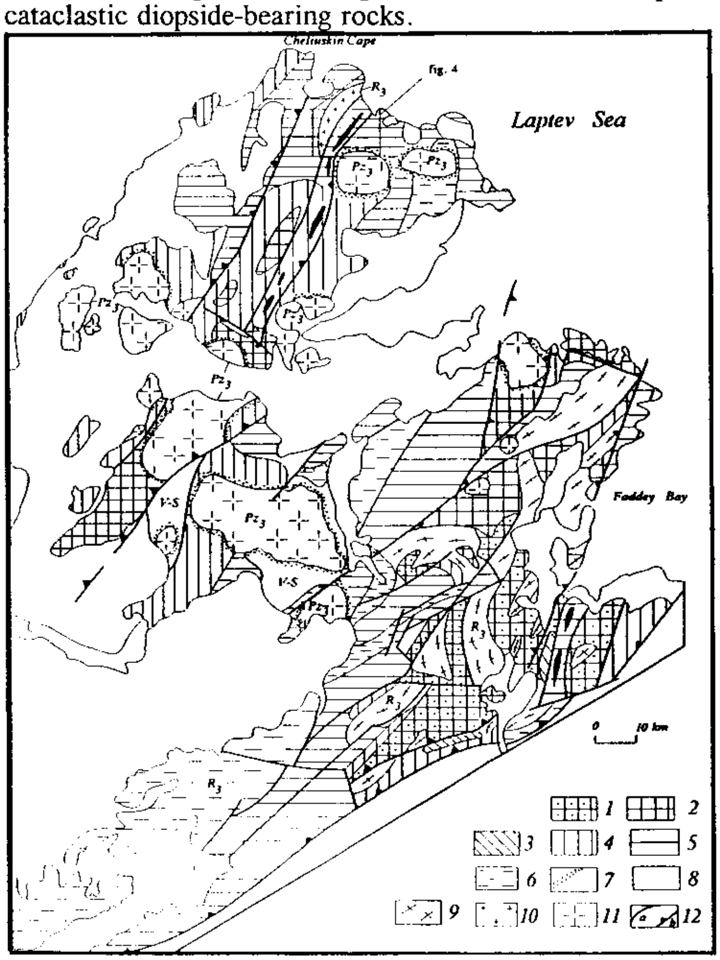

Fig. 3. The scheme of metamorphic facies of North-Eastern Taimyr, modified from Vernikovsky, Zabiyaka, 1985
Metamorphic facies: 1 - amphibolite and epidote-amphibolite; 2 - epidote-amphibolite; 3 - kyanite schist; greenschist: 4 - biotite zone, 5 - chlorite zone; 6 - low-temperature zone of greenschist facies and not-metamorphosed deposits; 7 - contact metamorphism zones; 8 - not-metamorphosed deposits; 9 - Late-Riphean-Vendian collisional orogenic migmatite-granite and granite; 10 - Late-Riphean trondhjemite-tonalite; 11 - Late Paleozoic collisional granites; 12 - disjunctives (a), thrusts (b)

Eclogite-like rocks were found on the left bank of Shrenk River (Bezzubtsev et al., 1986). In the Faddey terrane, there is a narrow zone with kyanite-bearing schists with muscovite, quartz, sillimanite, and sapphirine (Vernikovsky and Zabiyaka, 1985). To the northeast, this assemblage changes to kyanite schists with garnet, biotite, amphibole, albite, quartz, and epidote (Belov and Demina, 1980). These rocks occur within the block adjacent to the Stanovaya River ophiolites (Faddey Bay shore). Here, garnet amphibolites are related to the thrust sole. Garnet is also zoned (like metapelites) with high grossular in the rim of grains (up to 53%). Green-brown and green amphibole from these zones is replaced by blue-green amphibole; N_2O increases to 2 percent. P-T estimations using Aranovich and Podlessky (1980) and Perchuk (1989) geothermobarometers, show relatively low temperatures (500-650°C) and elevated pressure (5.5-8 kbar) for mineral formation (Belov and Demina, 1980; Vernikovsky, 1988).

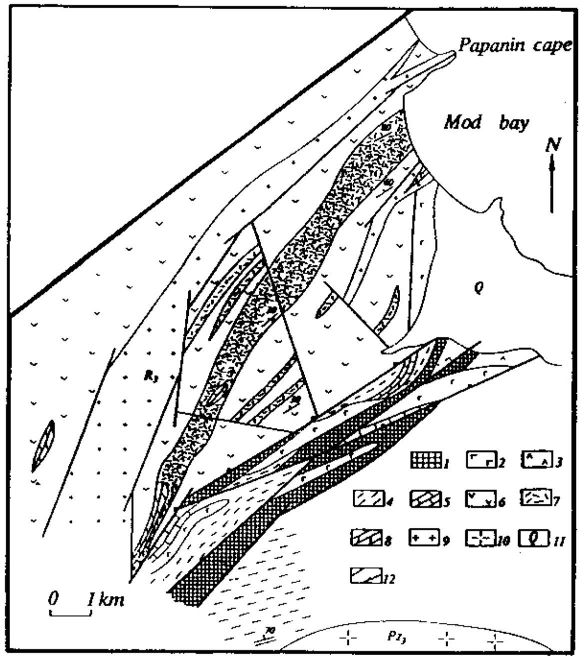

Fig 4. The geological map of north-eastern part of the Cheliuskin ophiolitic belt.
1 - serpentinized ultramafic rocks (mainly harzburgites); 2 - metagabbro; 3 - metabasalts with gabbro-diabase dikes; 4 - black quartz-chloritemica schists; 5 - limestones; 6 - meta-andesite-basaltic porphyrites, basic tuffs; 8 - metarhyolite-dacite lavas, acid tuffs; 9 - plagiogranites of tonalite-trondhjemite series (Rf_3); 10 - subalkali granites (Pz_3); 11 - Quaternary deposits; 12 - faults and thrusts.

Thus, available data prove that Mamont-Shrenk and Faddey metamorphism was multi-stage and P-T parameters changed due to tectonic movements. The adjacent position of these rocks with ophiolites and island-arc blocks (see below) and their mineral assemblages confirm the subduction-type of metamorphic transformations.

As for the age of the rocks considered there are preliminary U-Pb isotopic dates from zircon of 560-580 Ma for the Zhdanov massif granites (Faddey terrane). But the ancient zircon core provided a 1400 Ma mean age. The modeled 1800-1900 Ma age calculated using Sm-Nd data, shows that these granites were formed in the Late Riphean - Vendian from Early Proterozoic continental crust. Therefore, age dates for the Zhdanov granites may correlate with isotopic dates for granites on the right bank of the Mamont River (Zakharov et al., 1993).

Island-arc terrains and ophiolites

Rocks of this group occupy most of the Central Taimyr zone. Island-arc complexes and ophiolites are best displayed in the northeast area, and less well displayed in the western part of the region due to overlap by Late Riphean to Paleozoic terrigenous-carbonate deposits. In addition, they are exposed within tectonic and erosional "windows" in Kara microcontinent blocks. The complexes described are composed mainly of tholeiite and calc-alkali volcanics - acid, andesite and basic lavas (Bezzubtsev et al., 1986; Uflyand et al., 1991; Vernikovsky, 1992). Terrigenous-carbonate rocks are subordinate. Metamorphism is predominantly of the greenschist grade. However, garnet amphibolites are formed from basic volcanics only in the sole of thrusts (e.g. Stanovaya ophiolite zone). Greenschist island-arc and oceanic rock complexes occur near Mod Bay (Figs. 3 and 4). There are serpentinized ultramafics, metagabbro, and tholeiitic basalts within the southeastern sheet. Ultramafics are mostly harzburgites, with less dunites, lhezolites, and pyroxenites. Pyroxenes from gabbro are replaced by amphibole or, together with plagioclase, by actinolite-chlorite aggregate with minor epidote and zoisite. Basic plagioclase is also replaced by albite. Moreover, ultramafics and mafics are extremely disseminated within mylonitization zones and often recrystallized to form serpentinitic melange with blastomylonite inclusions. From the northwest, an andesite-basaltic nappe is thrusted onto the ophiolite sheet. Bulk composition for oceanic and island-arc rock complexes is shown in an AFM diagram (Fig. 5).

The Kunar complex plagiogranites of tonalite-trondhjemite series have a specific position (Fig. 4) and they appear as stratum-like bodies. Compositionally, they correspond to oceanic plagiogranites (Coleman and Peterman, 1975; Coleman, 1977) and are composed mainly of quartz and plagioclase with minor amphibole and biotite, usually replaced by actinolite, epidote, chlorite, and albite. The rocks were even more disseminated than gabbro. Such plagiogranites, associated with ultramafics and gabbro, are also exposed at the mouth of the Nizhnyaya Taimyra River (Proskurnin, 1991) and left bank of the Lenivaya River (Bezzubtsev et al., 1986), thus tracing a unified Cheluskin ophiolite belt for 500 km. Zircon and U-Rb dating of Kunar trondhjemites allowed estimation of its age - 740-700 Ma (Vernikovsky et al., 1993). Model age estimations obtained for the same samples with Sm-Nd method correspond to 850-785 Ma range. According to the data present the upper boundary to formation of the whole ophiolite belt can be marked.

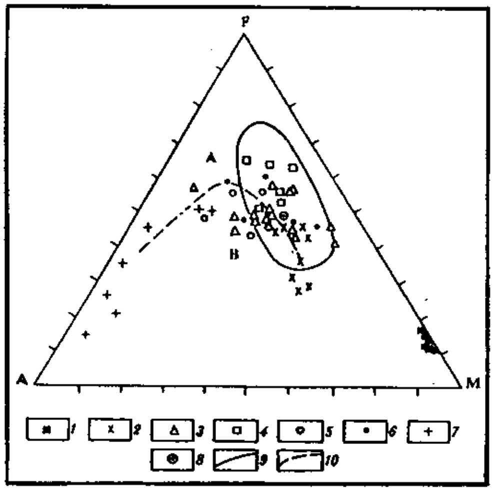

Fig 5. AFM diagram for ophiolitic and island arc complexes. 1 - serpentinized harzburgites, dunites; 2 - metagabbro; 3-6 - meta-andesite-basalts and amphibolites; 3 - metaandesite-basalts of the Cheliuskin belt; 4 - garnet amphibolites of the Stanovoy belt; 5 - amphibolites of Mamonta River; 6 - Kharitone Laptev Shore amphibolites; 7 - tonalites, trondhjemites; 8,9 - mean MORB composition (8) and a field of oceanic basalts (9) after Coleman 1977; 10 - boundary between of tholeiitic (A) and calc-alcaline (B) series fields.

Finally, it should be noted that various metamorphic conditions for andesite-basic volcanics from greenschist to amphibolite facies took place, and many investigators related the same rocks to different ages. Thus, metabasalts represented by garnet amphibolites were considered as the most ancient rock of the region of the Archean (Ravich and Pogrebitsky, 1965; Zabiyaka et al., 1986) or Early Proterozoic (Bezzubtsev et al., 1986). A large number of geological and geochemical data (Makhlayev, 1978; Vernikovsky, 1995) evidence that these volcanics are a single Riphean complex. Particularly, there is no significant compositional differences between metabasalts of different terranes as is seen in diagrams (Fig. 5,6).

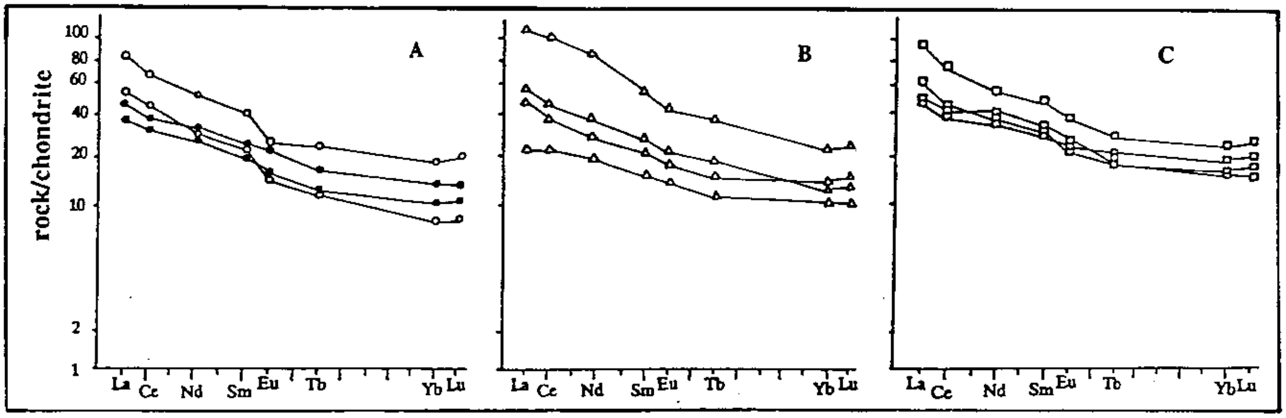

Fig. 6. REE distribution for metaandesite-basalts and metaamphibolites, Mamont-Shrenk terraine (A), Cheliuskin (B) and Stanovoy (C) ophiolitic belts.

NORTH TAIMYR ZONE (KARA MICROCONTINENT)

The Kara microcontinent is mainly composed of flysch-like deposits (sandstones, mudstones and pelites) which are interpreted as continental slope sediments (Zonenshain et al., 1990; Uflyand et al., 1991). The age of this sequences is defined by pre-Riphean and Riphean acritarches. Flysch-like deposits have been zonally metamorphosed from low greenschist to moderate amphibolite facies (Fig. 7). Successive character of their metamorphic transformations described by Makhlayev and Korobova (1972), Zabiyaka (1974) and Demina and Belov (1979) is noted while studying the metamorphic minerals composition, especially garnet (Vernikovsky, 1995). Spessartine component decrease from low temperature to high temperature zones from 15-16 to 3-4 mol. percent correlates with pyrope component increase from 8-9 to 19-21 mol. percent. Unlike Mamont-Shrenk and Faddey garnets these garnets have a progressive zonation or their homogeneity. Rims are enriched in FeO, sometimes MgO, depleted in MnO and CaO to prove their single-stage formation. Grossular component variations are not clear, commonly. P-T metamorphism estimations using Aranovich and Podlessky (1980) and Perchuk (1989) mineralogical geothermometers and geobarometers showed that the temperature from garnet to sillimanite zone changed from 490-520 to 620-660°C, pressure from 1.5-2 to 3.5-4.9 kbar, i.g. epidote-amphibolite or amphibolite facies (Dobretsov et al., 1972).

Amphibolite metamorphism is accompanied by migmatization resulting in formation of small bodies of authochthonous amphibole-biotite, biotite, and two-mica porphyroblastic gneiss-granites. Such a zonation is recorded in the western part of Kara microcontinent (Fig. 7) where the lower horizons of flysch-like deposits and underlying amphibolites and biotite-amphibole schists (metavolcanics of Riphean island arc) are exposed. To the east and north-east amphibolite zones are replaced by epidote-amphibolite and greenschist zones, autochthonous granites being replaced by larger paraautochthonous and allochthonous massifs which have discordant position and more isometric shape. Hornfelses with a clear zonation (amphibole and pyroxene facies) are associated with allochthonous granites of the Kara microcontinent (Vernikovsky and Zabiyaka, 1985).

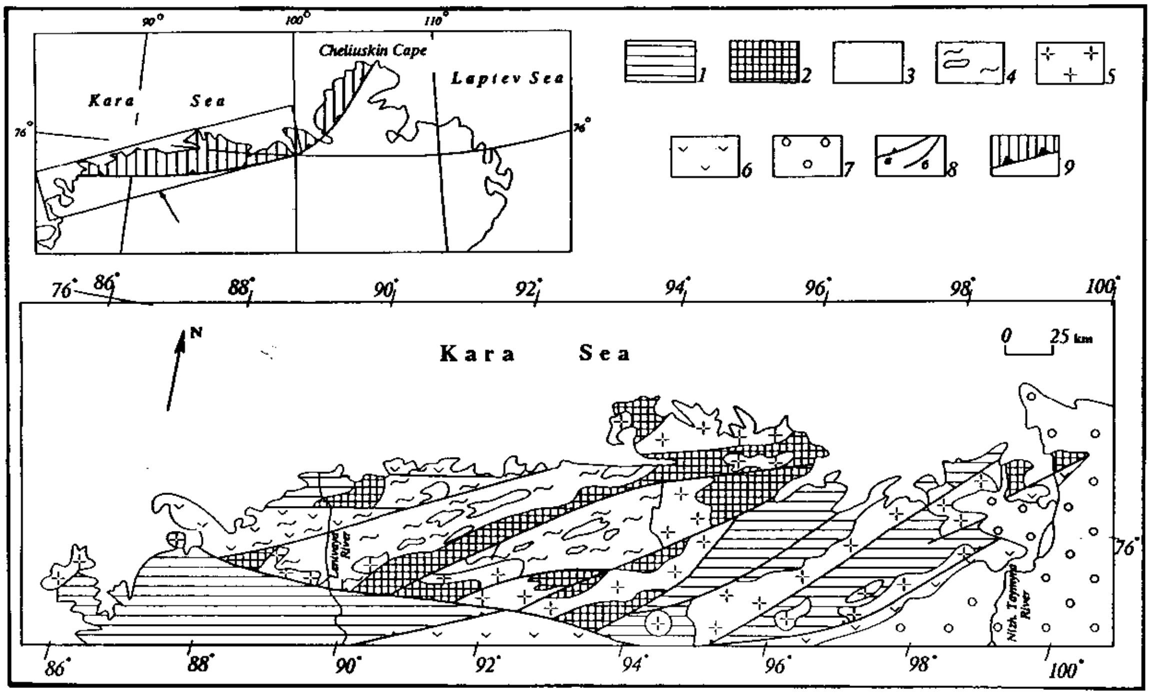

Fig. 7. The scheme for metamorphic facies rocks between Lenivaya and Nizhnyay Taimyra Rivers (compiled by the author using Makhlayev & Korobova, 1972; Zabiyaka, 1974; Zakharov et al., 1977).
1 - greenshist facies; 2 - epidote-amphibolite; 3 - amphibolite; 4 - migmatites and autochthonous granites; 5 - allochthonous granites; 6 - the Central Taimyr accretionary belt amphibolites; 7 - Meso-Cenozoic deposits; 8 - thrusts (a) and faults (b)

Compositionally the Kara microcontinent granites vary from granodiorites to subalkalic granites. Total alkalii exceed 7.5-8.1 percent, Na_2O/K_2O ratio ranges from 0.6 to 1.4. Along with rare-element composition the above data permit to consider them as S- and J-type granites (White and Chappell, 1977).

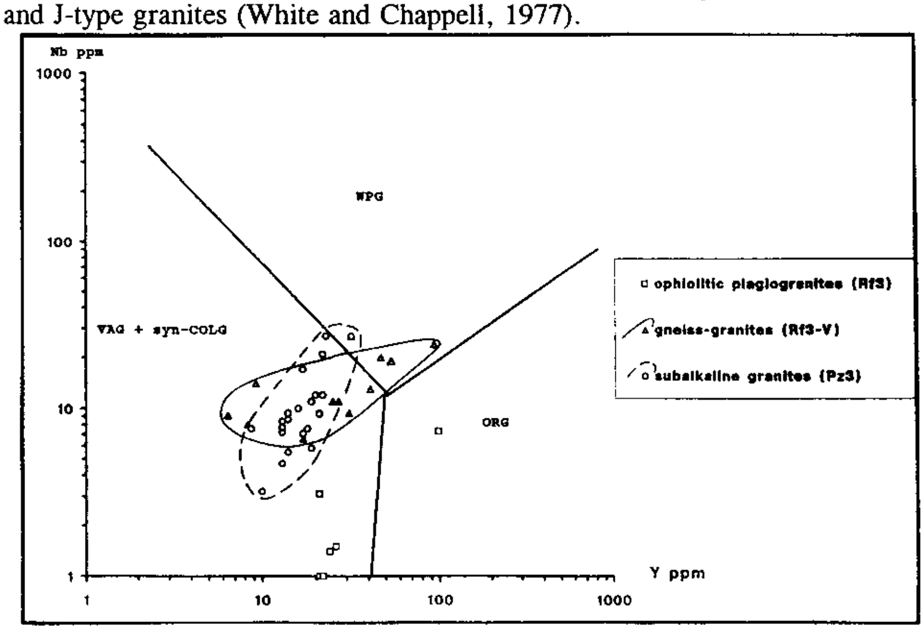

Fig. 8. Nb-Y discriminant diagram for Northern- and Central-Taimyr zone granites. Boundaries between syn-collision granites (syn-COLG), volcanic-arc granites (VAG), withinplate granites (WPG) and oceanic rige granites (ORG) after Pearce et al. (1984).

In the Pearce diagrams (Pearce et al., 1984) the Kara microcontinent granites fall on the field of syncollisional granites as the granites of Faddey and Mamont-Shrenk terranes (Fig. 8). But their trends are different. To estimate the age of formation for Kara granites and metamorphic rocks we carried out U-Pb, Sm-Nd, Rb-Sr, and K-Ar isotopic-geochemical and geochronological investigations (Vernikovsky, 1995). Two zircon varieties of very different age were established (U-Pb and Pb-Pb ratios). It can be referred to the age of substratum and its remobilization during granite formation with some amount of ancient radiogenic Pb inherited by newly formed zircon. This ancient zircon 2200 Ma age corresponds to the age of detrite zircons from flysh psammites obtained also with U-Pb method (Bibikova et al., 1968). To estimate the age for granites formation in this case the monacite dating can be used which does not contain the inherited Pb component. The monacite U-Pb dates fall onto concordia curve to be 306$\pm$2 Ma. The whole rock Sm-Nd model age from the same granites confirm them to be originated out from Riphean continental crust rocks. Isochronic Rb-Sr and K-Ar dating for granites and their host amphibolites and gneisses showed close 275 and 279 Ma values after amphibole, biotite, feldspar and whole rock. It reveals the close time of formation for migmatite-granites, migmatized amphibolites, and zonal regional metamorphic complex after flysch-like deposits.

CONCLUSIONS

Only the key questions concerning the problem of Taimyr folded area formation were touched in this paper to correlate major metamorphic and magmatic events with tectonic ones. Available information and own data permit to evidence of two major events of the Taimyr folded area formation in the Late Riphean and Late Paleozoic.

1. The first big tectonic event is formation of accretionary block and its possible collision with the Siberian continent in the Late Riphean. It resulted in formation of thrusts, metamorphism, granitization and uplift of oceanic complexes at the surface. This event age relates to the age of ophiolitic plagiogranites on one hand (740-720 Ma) and age of Mamont-Shrenk and Faddey collisional granites, and metamorphism age for Stanovoy garnet amphibolites (580-560 Ma) on other hand.

2. Collision of the Kara microcontinent and Siberian continent in the Late Carboniferous - Permian is responsible for one more event illustrated by the volumes of regionally metamorphosed rocks and collisional granites and tectonically affected on the Siberian continent margin.

This stage autochthonous granites have formed beneath sedimentary cover during crust thickening. Allochthonous granites have formed in the upper levels (mainly "greenschist"). This Late Paleozoic event age is determined by the age of autochthonous granites and regional metamorphism 306-275 Ma on one hand, and the age of folding all South Taimyr Paleozoic deposits on other hand.

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