Terranes, Synaccretionary, and Postaccretionary Complexes of the Transbaikalia and Southeastern part of Eastern Sayn Regions, Siberia

By A.N. Bulgatov and I.V.Gordienko
(Geological Institute, Siberian Branch, the Russian Academy of Sciences, Ulan-Ude, Russia)

INTRODUCTION

The southern margin of the North-Asian Craton in the Eastern Sayn and Transbaikalia regions is bordered by various-age fold belts. The fold belts consist of a collage of terranes that were successively accreted to the craton at the end of Riphean and early Paleozoic, and in the Permian and Early Triassic. This paper describes and interprets the map of Transbaikalia tectonostratigraphic terranes and overlap complexes (assemblages) that is compiled and published at a scale of 1:5,000,000 in this volume (Gordienko and Bulgatov, this volume). Previous preliminary terrane analyses of the fold belts in this region have been published by Parfenov and others (1995), Bozhko (1995), Gusev and Khain (1995), and Gordienko (1997). The terranes are classified according to the following actualistic principles (i.e., tectonic environments): cratonal, metamorphic, ophiolite (oceanic), island-arc, turbidite basin, and accretionary wedge with a predominance of oceanic rocks. In addition, the passive continental margin of the North Asian Craton is distinguished.

PASSIVE CONTINENTAL MARGIN OF NORTH ASIAN CRATON

The passive continental margin of the North Asian Craton, named the Patom fold-thrust belt, consists of a sequence of thick (up 15 km), Riphean terrigenous and carbonate sedimentary rocks that accumulated on the depressed passive margin of the pre-Riphean basement of the North Asian Craton (Parfenov and others, 1995). These sedimentary rocks thin towards the craton. The western, northern, and eastern boundaries of the belt form the frontal zone of an orogenic belt. To the south, the orogenic belt is bounded by a variable-age, late Riphean and Paleozoic granite batholith. The formation of the Patom fold-thrust belt commenced with the deposition of the Anangr suite of the Bodaibin series during the Anangr stage of the late Riphean. Petrographic, petrochemical, and geochemical studies of the terrigenous deposits in the belt indicate that a number of Riphean terranes with different geodynamic natures (tectonic origins) were

accreted to the craton. Subsequently, various postaccretion collisions formed the Baikal-Patom fold and thrust belt during the Vendian, Early Paleozoic, Middle Paleozoic, and Late Paleozoic.

TECTONOSTRATIGRAPHIC TERRANES

Cratonal Terranes

Cratonal terranes (fragments of craton) that occur in the orogenic collage are composed of early Precambrian gneiss and granite, and stratified complexes that are regionally metamorphosed to granulite and amphibolite facies. The Muya cratonal terrane, consisting of the Kindikan series, Ileir and Lunkut suites, and a protoplatformal complex are characteristic examples. The Kindikan series forms the lowest part of the terrane (Bulgatov, 1983) and consists of lower and upper parts. The lower part consists of amphibole and biotite-amphibole gneiss. The upper part consists of garnet-amphibole and garnet-pyroxene-amphibole gneiss with minor amounts of amphibole-pyroxene gneiss with interlayered amphibolite, and biotite and garnet-biotite gneiss. The upper part of the Kindikan series consists of biotite and garnet-biotite (sometimes with hypersthene, kyanite, and sillimanite) gneiss with interlayered garnet-pyroxene and amphibole gneiss and amphibolite. Amphibolite facies retrogressive metamorphism resulted in hypersthene replacement by amphiboles. On the basis of composition and metamorphism, the Kindikan series is correlated with Kurultin series of the Aldan shield of the North Asian Craton.

The younger Muya terrane consists of the Ileir and Lunkut suites. The Ileir suite is composed of gneiss and schist composed of garnet-mica-amphibole, biotite-amphibole, garnet-biotite, mica, biotite that form interlayered amphibolite, amphibole schist, and marble. The Lunkut suite is a gneiss-carbonate-schist unit that occurs as a slice conformably on the Ileir suite. This slice consists of schist and gneiss composed of mica, garnet, amphibole, and carbonate minerals that form interlayered marble, dolomite, amphibolite, and quartzite. The Ileir and Lunkut suites are metamorphosed to amphibolite facies and are assumed to be Late Archean. Also part of the Muya craton terrane is an Early Proterozoic carbonate terrigenous protoplatform complex (Param series) that occurs unconformably on the Lunkut suite.

Geological-geophysical data indicate the Muya craton terrane forms a large plate, about 20 km long, that dips gently eastwards (Bulgatov, 1988). The inner structure, although complicated, consists of a series of tectonic plates separated by thrusts that contain lenticular bodies of eclogite (Dobretsov and Bulgatov, 1991) with an age of 653 ± 21 Ma (as determined by Sm-Nd whole-rock and mineral isochron analysis). These data indicate a Vendian age of deformation and collision (Shatskiy and others, 1996). Also occurring in the Muya terrane are Late Riphean and Paleozoic granitoid massifs that indicate the terrane was subjected to structural, thermal, and igneous events in the Riphean, Vendian, and early Paleozoic.

Metamorphic Terranes

In this area, metamorphic terranes are mainly derived from cratonal terranes that were extensively deformed in the Phanerozoic. For a example, the Olkhon metamorphic terrane contains a banded structure with the main bands consisting of various structural plates (Fedorovskiy and others, 1995). Several endogenic events affected this terrane (Letnikov and others, 1995, 1996): (1) granulite faces metamorphism at 1,900 to 1,800 Ma and formation of granite; (2) intrusion of potassium-sodic granite massifs at 1200 Ma; (3) formation of gabbroic massifs, pegmatites, and alkaline metasomatism associated with syenite formation at 570-530 Ma; (4) occurrence of high-pressure, fractured, regional, granulite facies metasomatism at 500-445 Ma; (5) formation of small bodies of gabbro, pegmatite, and microcline granite at 410-386 Ma; and (6) formation of a nepheline syenite massif at 397-386 Ma.

Early and Middle Riphean Oceanic Terranes

The Param, Ilchir, and Kulindin oceanic terranes consist of Early and Middle Riphean ophiolites that occur in tectonic plates and wedges that are 60 km wide by 300 km long. The ophiolites consist of peridotite, dunite, gabbro, basalt, and deep-water chert and shale. The mafic volcanic rock units in the ophiolites are N-, T-, P- MORB island-arc type basalt (Parfenov and others, 1995). The basement of the ophiolites is interpreted as a oceanic crust (Bulgatov, 1988). The ophiolite terranes are interpreted as basements of island arcs.

Middle and Late Riphean Island Arc Terranes

The Kilyan island arc terrane, of Middle and Late Riphean age, consists of tuff, tuffite, rhyolite, andesite, and basalt, and also contains gabbro and plagiogranite. The rhyolites are dated at 923 Ma and the plagiogranite is dated at 850-900 Ma (Konnikov and others, 1994). The Oka island-arc terrane in the Eastern Sayn region, of Late Riphean age, consists of the terrigenous-volcanogenic complexes of the Sarkhoij and Oka series, and the Ospa and Barungol suites.

Oka Island Arc Terrane

The Sarkhoij series of the Oka island arc terrane consists mostly of terrigenous and volcanic formations. The volcanic rocks, of mafic, intermediate, and siliceous composition, form an uninterrupted, differentiated sequence. The basalts are subalkalic potassium-sodic and sodic, low- and moderate titaniferous, tholeiite, and low alkaline and sodic, calc-alkali dacite and rhyolite (Kuzmichev, 1990). The age of the volcanic rocks in Sarkhoij series is 718±30 Ma as determined by Rb-Sr isochron studies (Buyakaite and others, 1989).

The lower part of the Oka series consists of volcanogenic rocks, including siliceous to mafic tuff and flows, gabbro-diabase sills and dikes, and the upper part consists of mostly rudaceous flysch (Kuzmichev, 1997) composed of sandstones and siltstone with interlayered conglomerate and breccia. The fragmental volcanic rocks in both slices formed on steep slopes. The upper flysh part is composed of siltstone, argillite, and sandstone up to 50 m thick. The clasts in the sandstone are derived from volcanic rocks in the lower part. Sedimentary structures indicate the flysch slice formed at the base and away from the base of a volcanic uplift. This series is characterized by glaucophane schist with ages of 825 ± 25 and 645 ± 52 Ma as determined by Rb-Sr isochron studies. The older age corresponds to the time of high-pressure metamorphism, and the younger age corresponds to the time of superposed low-pressure greenschist facies metamorphism (Konnikov and others, 1994).

Sills and gently transverse dikes occur in the Oka series and range from a few meters to several tens of meters thick, and are mainly composed of gabbro and diabase. Some thick bodies range from gabbro-diabase to granophyre. Rhyolite and andesite comprise up to 10% such bodies by volume (Kuzmichev, 1997). The gabbro and diabase are moderately titaniferous, low-potassic and low-phosphatic. These and REE data indicate a N-MORB type origin (Gladkochub, Sklyarov, 1996). Their age is 756 ± 43 Ma (as determined by a Sm-Nd isochron) (Kuzmichev, 1997).

The island-arc (sedimentary-volcanogenic complexes) of the Ospin and Barungol suites, also part of the Oka island arc terrane, are tectonically bounded units that occur adjacent to the Gargan cratonal terrane. The volcanic rocks in these suites consist of rhyolite, andesite, and basalts. The basalts are tholeiitic and calc-alkalic. The sedimentary rocks are mainly terrigenous (interlayered carbonaceous shale, siltstone, and sandstone, and conglomerate, often with graded bedding). Rare limestones occur in these suites. The suites also contains high titaniferous and subalkalic gabbro-diabase and diabase sills that are abundant to the northwest near the adjacent The sills of gabbro-diabase and diabase are abundant in the southeast part of this terrane and also are of subalkalic high-titaniferous, high-potassium, and high-phosphate composition, and are enriched in LREE (Gladkochub, Sklyarov, 1996).

Early-Middle Riphean Turbidite Basin Terranes

Turbidite basin terranes, mainly of Early-Middle Riphean age, consist of the Barguzin, Verkhnevitim, Bambuy, Delunuran, Shaman, Olokit, Kunaley, Bitudzhidin and Argun terranes. These terranes are composed mainly of metamorphosed carbonate, sandstone, and shale deposits that overlay a basement of continental crust (Bulgatov, 1988). The sedimentary rocks in these terranes sometimes contain volcanic rocks and subvolcanic bodies. The Barguzin terrane contains high-titaniferous and high-phosphate basalt, and diabase and gabbro-diabase enriched with LREE, with compositions similar to T-MORB basalt. The volcanic rocks of the Verkhnevitim terrane are mainly moderate titaniferous, low alkaline and tholeiitic (Bulgatov, 1983). In the Argun terrane, the volcanic rocks consist of basalt that is either moderately titaniferous, N-, T-MORB type, or high-titaniferous, P-MORB type (Gusev, Peskov, 1996).

Vendian and Cambrian Ophiolite, Island Arc, and Turbidite Basin Terranes

The Vendian-Cambrian oceanic and island arc terranes are the Khasurta ophiolite terrane, the Khamsarin, Verkhnekhasurta, Eravna island-arc terranes, and the Dzhida turbidite basin terrane.

The Khasurta ophiolite terrane consists of several tectonic plates (Kuzmin and others, 1995) composed of hyperbasites, gabbro and gabbro-pyroxenite, high-Cr basalt, high-titaniferous, subalkalic basalt with lenses and interlayered limestone. The ophiolites ages range in age from Vendian to the beginning of the Early Cambrian. These tectonic plates dip steeply (50-80 degrees) northward (present-day coordinates). The ophiolites exhibit no positive gravimetric anomalies. These data indication obduction of the Khasurta oceanic terrane over the Kupchin cratonal terrane.

The Khamsars island-arc terrane occurs in the southeastern part of the Eastern Sayn region and is the northeastern part of the same terrane that occurs mainly in Eastern Tuva. The Khamsars terrane consists mainly (about 90%) of Early and Middle Paleozoic granitoids. Stratified island-arc formations occur as large xenoliths or roof pendants in the granitoids, and consist of metamorphosed andesite, dacite, and rhyolite with interlayered lenses of carbonate, shale, reef limestone, and sandstone with Early Cambrian fauna (Gordienko, 1987).

The Verkhnekhasurta island-arc terrane occurs on the right bank of the Dzhida River. It is obducted over the Kupchin cratonal terrane. At the confluence of the Tsakirka and the Dzhida Rivers, the sedimentary-volcanogenic island-arc complex occurs as a great xenolith among granitoids and forms several tectonic plates that dip northward. This terrane contains low-Cr basalt and andesite basalt, associated tuff, and interlayered lenses of chert, plagiorhyolite, andesite, and associated tuff, tuffite. Also occurring is a tuff-turbidite slice composed of volcanogenic-terrigenous turbidite and tuff with interlayered lenses of andesite-basalt, carboniferous shale, and limestone with Early Cambrian fauna (Kuzmin and others, 1995; Belichenko, 1969).

The Early Cambrian Eravna island-arc terrane is composed of differentiated volcanic rocks and various age granitoids. The Eravna xenolith, that occupies 150 km^2, contains the large Ozernoye pyrite-polymetallic deposit. This xenolith is composed of plagiorhyolite, dacite, andesite, basalt, tuff, turbidite tuff (siltstone, mudstone, sandstone) with interlayered lenses of reef limestone with Early Cambrian fauna. The zenolith also contains stocks and dikes of mafic, intermediate and siliceous composition (Gordienko, 1987; Postnikov and others, 1997). The terrane also contains terrigenous and clastic-carbonate deposits formed in back-arc and inter-arc basins. In addition, the xenolith contains hyperbasites bodies near the northwest margin. These bodies were intruded into the upper crustal units and are clearly derived from the Vendian ophiolitic terranes that underlie the Eravna island-arc terrane.

The Vendian and Cambrian Dzhida turbidite basin terrane occurs between the Riphean Bitudzhida turbidite and Vendian and Early Cambrian oceanic and Early Cambrian island-arc terranes. The Dzhida turbidite basin terrane contains carbonate-terrigenous and turbidite deposits that formed on slopes and basin floors. The terrane occurs in tectonic plates that dip north. The margins of the terrane are olistromal zones of serpentinized melange and thrust zones (Bulgatov, Klimuk, 1998).

Paleozoic and Early Mesozoic Ophiolite, Island Arc, Turbidite Basin, and Accretionary Wedge Terranes

The middle Paleozoic turbidite basin terranes in the region are the Daur and Aga terranes.

The Daur terrane is composed of Late Devonian-Early Carboniferous sandstone and shale turbidites with interlayered andesite-basalt, jasper, siliceous shale, conglomerate, and gritstone. Small blocks of early Precambrian metamorphic rocks and granitoids occur in the terrane (Fomin and others, 1985). The terrane is characterized by a gravitational minimum (Menaker, 1972), indicating a continental crust for the Daur terrane.

The Devonian and Early Carboniferous sandstone-shale turbidites of the Aga terrane consist of interlayered lenses of gritstone, conglomerate, reef limestone with Devonian and Early Carboniferous fauna, jasper, siliceous shale, basalt, dacite, and rhyolite (Gordienko, 1987). The basalts are either (1) high-titaniferous, high-phosphate and enriched with LREE, Ta, Nb, Zr, Hf, Y; or (2) low-titaniferous, low-phosphate, with low concentrations of Nb, Ta, Zr, Hf, Y, REE, and especially LREE. The first type is similar to P-MORB basalt; the second is similar to N-MORB basalt (Gusev and Peskov, 1996). The Middle Carboniferous to Early Triassic terrigenous turbidites in the terrane are regressive and accumulated in relict basins separated by local uplifts (Amantov, 1975). The terrigenous turbidites consist of conglomerate, gritstone, argillite, siltsone, and sandstone. The Early Triassic units are more rudaceous. The stratified units of the Aga terrane range up to 20 km thick. The composition and thickness of Middle Carboniferous and Early Triassic turbidites indicate rapid and thick sedimentation. Tectonic plates and wedges of the Kulindin Riphean ophiolite terrane occur in the Devonian through Early Triassic turbidite deposits of the Aga turbidite basin terrane, indicating an ophiolitic (oceanic) crust for the Aga terrane. The Devonian through Early Triassic Aga terrane is characterized by a gravitational maximum that differs from the Daur terrane (Menaker, 1972). The Aga terrane contains Middle Carboniferous and Permian avalanche deposits that are interpreted as forming during "gentle" collision, and Early Triassic deposits that formed during "hard" collision with the final accretion of the Daur, Aga, and Argun terranes.

The Shilka ophiolite terrane consists of accreted wedges and plates composed mainly of Riphean ophiolites. The terrane extends along the Mongol-Okhotsk suture zone and unites fragments of Riphean ophiolites that are occur as tectonic plates and wedges among older and younger terranes. To the north-east, the Shilka terrane is named Tukuringra-Dzhagdin ophiolite terrane (Nokleberg and others, 1994, 1997). The ophiolites are composed of serpentinite, metagabbro, metabasalt, greenschist orthoschist, sericite-siliceous and carbonate-chlorite-sericite-siliceous schist, microquartzite, and jasper with interlayered sandstone and siltstone. The terrane also includes melange, containing serpentinite and blueschist derived from the basalt. Basalts and gabbro are subalkalic, moderate-titaniferous and high-titaniferous, and are similar to N-, and T-MORB basalt (Gusev, Peskov, 1996). Blocks of early Precambrian metamorphic rocks and granitoids also occur within the Shilka terrane. From older to younger, the blocks consist of Riphean psammitic schist and granitoid complexes, lower Paleozoic granitoids, Middle Paleozoic carbonate-terrigenous deposits, and Late Carboniferous granitoids.

ASSOCIATED OROGENIC BELTS

Associated orogenic belts consist of synaccretionary molasse that occurs in intermontane troughs and basins, and stitching calc-alkali granitoids.

Synaccretionary Molasse

Synaccretionary molasse of Late Riphean age occurs in the Padrin and Sinnir troughs. The Padrin trough occurs along the Vitim River and overlies eroded island-arc plagiogranite (Bulgatov, 1983). From older to younger, the molasse, consists of a basal unit of sedimentary breccia with angular fragments of underlying plagiogranite; interstratified, motley sandstone and siltstone; sedimentary breccia; and gritstone and conglomerate. The sedimentary rocks are 55 m thick. Alternating, motley tuff, rhyolite, dacite, basalt and siltstone, sandy-gritstone, and conglomerate layers occurs above the basal unit. The volcanogenic molasse of the Padrin trough is 3.2 to 4.5 km thick and is interpreted as forming under subaerial conditions associated with centralized volcanism and sedimentation in a lake basin that was 35 km long by10 km wide. The volcanic rocks are mainly basalt (mafic), and dacite and rhyolite (siliceous) and constitute a differentiated bimodal series. The basalt is high-titaniferous, high-phosphate, LREE-enriched, theoleiitic and calc-alkalic. The dacite and rhyolite are potassium-sodic, subalkalic, and normal. Gabbro and diabase constitute comagmatic intrusions and occur in fractured, steeply-dipping bodies. Associated leucogranite and granite-porphyry form large bodies up to 60 km^2. The age of the volcanic rocks is 765 Ma as determined by Rb-Sr isochron methods (Mitrofanov, 1978).

The Sinnir trough is about 150 km long and 12 to 15 km wide. The basal unit in the trough consists of green and violet basalt and tuff about 1000 m thick. Overlapping units are: an argillite and sandy dolomite unit about 650-750 m thick; conglomerate and argillaceous sandstone about 2,600 to 2,700 m thick; volcanoclastic andesite-basalt about 700-800 m thick; and kalirhyolitesand kalidacite. Comagmatic mafic intrusions include dunite-peridotite-troctolite, and gabbro-norite with an age of 700-750 Ma (Konnikov and others, 1994).

Stitching Calc-Alkalic Granitoids

The formation of calc-alkalic granites is related to the accretion of terranes to the North-Asian Craton. Late Riphean calc-alkali granites occur within the Argun terrane. They intrude Riphean deposits that are metamorphosed to amphibolite facies. The granites are overlapped by Vendian and Cambrian sandy-shale and carbonate deposits. Zircon U-Pb isochron ages of granoblastic granite gneiss are 850 ± 20 Ma and 500 ± 20 Ma. The latter age is interpreted as a later, superposed thermal event (Bibikova and others, 1979). This complex contains granite gneiss, plagiogranite gneiss, and coarse porphyroblastic granite gneiss. Migmatite occurs at the contact of granite massifs.

Late Riphean granitoids also occur in the northern part of the Barguzin turbidite basin terrane where volcanogenic-sedimentary deposits are regionally metamorphosed from greenschist to amphibolite facies, and where migmatites occur along the contacts of the granite batholith. Regional metamorphism and granite magmatism are interpreted as forming from an intense heat flux (Bolonev and others, 1983; Bulgatov, 1983). Vendian and Cambrian deposits, including basal conglomerate that overlap the Riphean regionally metamorphosed complex, are non-metamorphozed. They exhibit sericite and chlorite epigenetic recrystallization. Local biotite and garnet-bearing schist form conglomerate clasts, indicating that a major unconformity occurs between Riphean and Vendian and Cambrian complexes.

The absolute age of granites intruding the Barguzin terrane is 1,014 ± 80 Ma and 326 ± 27 Ma for granite veins, as determined by Rb-Sr isochron methods (Shergina and others, 1981). The granites are also dated by U-Pb zircon method as 301 to 314 Ma with inherited zircon with an age 1,190 Ma (Neimark and others, 1993). Isotopic data for alkaline-earth granites intruding other terranes to the north and northeast of the Eravna island-arc terrane (Parfenov and others, 1995; Jarmoluk and others, 1997) indicate the granitoids incorporate continental crustal material with ages of: 2,100 to 1,700 Ma; 1,600 to 1,560 Ma; 1,375 Ma; 1,200 Ma; and 503 Ma . The age of granite intrusion was variable and occurred at 1,014 Ma, 1,190 Ma, 556 to 537 Ma, 470 to 426 Ma, 387 to 320 Ma, and 320 to 270 Ma . The first and the last three intervals define tectonically active periods of the Transbaikalia region. The interval from 556 to 537 Ma is interpreted as a time of decreased tectonism during which carbonate rocks formed with magmstism.

Collisional-origin, calc-alkali granites of the Eastern Sayn region are dated at 463 Ma. A similar Ordovician age for the same granites intruding the Argun terrane, and a Late Carboniferous age for granites intruding the Daur terrane are collaborated by field geologic data.

OVERLAPPING ASSEMBLAGES

Riphean terranes of the northern regions of Transbaikalia and Eastern Sayan region accreted to the craton at the end of Late Riphean and are overlapped with angular unconformity by Vendian terrigenous and Cambrian carbonate deposits. These overlapping units are similar to coeval deposits of the Siberian platform, but differ in being greatly thicker, and also lack evaporite deposits. They comprise isolated fields represented by outliers of much larger sedimentary covers that were preserved after erosion. The structure and composition of Vendian-Cambrian slices indicate that they formed as part of the passive margin of the Siberian continent.

The Daur and Aga terranes of Eastern Transbaikalia accreted to the craton in Early Triassic. Overlapping these terranes are Late Triassic to Early Jurassic terrigenous deposits. The lack of volcanic rocks in these deposits indicates they formed along a passive margin, in the Mongol-Okhotsk marine bay adjacent to the ancestral Pacific ocean.

ASSOCIATION OF ACTIVE CONTINENTAL MARGINS: THE SAYN-TRANSBAIKALIA AND SELENGA-VITIM VOLCANIC-PLUTONIC BELTS

The Devonian and Early Carboniferous Sayn-Transbaikalia volcanic-plutonic belt extends for about 2,500 km from the Altai-Sayn region and Northern Mongolia into the central and northern parts of the Transbaikalia region (Gordienko, 1987). The belt is composed of subalkalic and alkalic volcanic rocks, granite, and gabbroic rocks. The occurrence of this volcanic-plutonic belt is tectonically linked to the turbidite deposits of the Daur, Aga, and Argun terranes. The marine turbidite basin deposits of these terranes and the Sayn-Transbaikalia volcanic-plutonic belt are interpreted as forming in an active continental margins.

In the Transbaikalia region, the Selenga-Vitim volcanic-plutonic belt formed in the Middle Carboniferous to Early Triassic as a continental arc. The belt extended for about 2,000 km from western Mongolia to the Olekma River basin (Gordienko, 1987; Jarmoluk, Kovalenko, 1991; Gordienko and others, 1998). The belt is composed of bimodal trachyrhyolite and trachybasalt volcanic flows, alkalic and subalkalic granite, nepheline and pseudo-leucite syenite, and ultramafic-alkaline rocks. At the same time, associated turbidite deposits were accumulating in the Aga terrane

INNERCONTINENTAL ASSOCIATIONS. THE SAYN-STANOVAYA AND MONGOL-TRANSBAIKAL RIFT SYSTEMS

Sayn-Stanovaya Rift System

The Sayn-Stanovaya rift system consists of regionally-extensive continental troughs that were with Late Triassic and Early and Middle Jurassic deposits. The deposits consist of volcanogenic, volcanogenic-rudaceous, and rudaceous units. A typical volcanogenic trough is Malo-Khamardaban (with dimensions of 100 by 18 km) which is bounded by the Khamardaban metamorphic terrane on the southeast. Most of the volcanic rocks consist of trachybasalt and trachyte in a proportion 10:1. Trachyandesite-basalts comprise less than 2 percent of the volcanic section by volume, and the terrigenous constituent, that forms separate, thin layers, comprises about two percent of the section. Numerous subvolcanic bodies occur and are composed of trachydolerite, syenite-porphyries, and comendite with syenite being dominate. Isotopic ages range 167 to 150 Ma (as determined by Rb-Sr and K-Ar methods) (Litvinovskiy and others, 1996).

The volcanogenic-rudaceous structure is best displayed in the great Tugnuiy trough (dimensions of 140 by 35 to 40 km) that occurs between the Zagan metamorphic and Eravna island-arc terranes. The trough is started to form in the Late Paleozoic (Gordienko, Klimuk, 1995). It contains: (1) Late Triassic limnetic deposits, trachybasalt, trachyandesite-basalt, subvolcanic bodies of trachyte and syenite-porphyry; and (2) Early and Middle Jurassic rudaceous deposits, trachyrhyolite and trachybasalt, and lesser trachybasalt-trachyandesite, subvolcanic trachyte bodies, syenite-porphyrie, and trachydacite. Also associated were small, coeval, Late Triassic to Middle Jurassic sedimentary troughs that were filled with small- to medium-size, angular, fragmental debris. Most of the Late Triassic to Middle Jurassic troughs were this type. A few troughs contain rudaceous sediments. As an example, the Naringol trough, that occurs in the Eastern Sayan region, on the northeastern side of the Khamsara island-arc terrane, has a triangular shape and formed between two fractures, the Main Sayan and associated fractures. These trough deposits consist of rubble and pebble conglomerate, gritstone, sandstone, and siltstones with interlayered coal-clay shale and coal beds. Thin-terrigenous sediments with coal beds occur in the upper part of the section. Flora indicate an Early-Middle Jurassic age; the thickness ranges up to 2,000 m. Numerous bodies of subalkalic and alkalic granites formed in a Late Triassic to Middle Jurassic period of tectonism in the eastern Transbaikalia region. The extensive granitoids in the Daur terrane. occupy an area of several hundred km^2.

Mongol-Transbaikalia Rift System

The Late Jurassic and Early Cretaceous Mongol-Transbaikalia rift system consists of numerous continental troughs filled with sedimentary graben and volcanogenic graben units. The volcanic rocks occur in the lower parts of section and consist of subalkalic rhyolite-basalt and trachybasalt. Formation of the rift system was followed by intrusion of subalkalic and alkalic granitoids and gabbros. Most rifts are longitudinal and are controlled by fault zones. The troughs form a system of narrow (1 by 15 km) and elongate (up to tens and hundreds km) grabens that are bounded by strike-slip faults on one or both sides. Cross troughs, oriented transversely to folds and faults, are relatively few. Unlike longitudinal troughs, cross troughs are wider, and are sometimes isometric and syncline-shaped. Faults occur along some, but not all of their boundaries. The longitudinal troughs consist of shift and cross-thrust types (Bulgatov, Turunkhajev, 1996).

CONCLUSIONS

The terranes that make up orogenic belts in the Transbaikalia region and in the southeastern part of the Eastern Sayan region consist of fragments of: (1) cratonal and metamorphic terranes' (2) Early and Middle Riphean, and Vendian and Early Cambrian ophiolite terranes; (3) Middle-Late Riphean and Early Cambrian island-arc terranes; and (4) Early-Middle and Riphean, Vendian and Cambrian, and Middle and Late Paleozoic turbidite basin terranes.

In the late Riphean, collision and accretion of Riphean terranes to the North Asian Craton occurred. Associated, synaccretionary stratificated units consist a volcanogenic molasse complex and stitching calc-alkali granites. The accreted terranes are overlapped by Vendian and Cambrian terrigenous and carbonate deposits that form part of the passive continental margin of the Siberian platform. The late Riphean collision and accretion was followed by large-scale displacement of the accreted units along northwest- and northeast-striking faults (present-day coordinates), and by folding and thrusting. As a result, a single island arc was separated into the Oka and Kilyan terranes (Parfenov and others, 1995).

An early Paleozoic collision consisted of: (1) intrusion of calc-alkali granite massifs; (2) fault displacement of blocks, folding and thrusting; (3) accretion of Vendian and Cambrian terranes to the North Asian Craton; (4) greater separation of the Riphean Oka and Kilyan island-arc terranes; and (5) fragmentation and displacement of an interpreted single Early Cambrian island arc into the Khamsara, Verkhnekhasurta, and Eravna island arc terranes. Kinematics of the terranes displacements in Late Riphean and Early Paleozoic consisted of southward movement (present-day coordinates) of the Angara-Anabar block of the North Asian Craton (Bulgatov and Klimuk, 1998).

Various middle Paleozoic terranes were accreted at the end of Early Triassic and were overlapped by Late Triassic to Middle Jurassic terrigenous deposits of the Mongol-Okhotsk ocean which was part of a passive continental margin.

In the Devonian and Early Carboniferous, and in the Middle Carboniferous to Early Triassic, the Sayan-Transbaikalia and Selenga-Vitim volcanic-plutonic belts formed and overlapped previously-accreted terranes. Middle and late Paleozoic great deformations took place to the north of the Eravna island-arc terrane and consisted of additional movement of the mountain masses to the north (present-day coordinates) and final formation of nappe-forming thrusts in the frontal parts of the following orogenic belts: Sredne-Vitim (Bulgatov, 1983); Akitkan (Bulgatov, Zaitsev, 1994); and Patom (Ivanov, Ryazanov, 1992). This process was followed by multi-staged formation of collision granites and high-temperature regional metamorphism.

The following continental rift systems formed in the region: (1) the Sayan-Stanovaya rift system in the Late Triassic to Middle Jurassic; (2) the Mongol-Transbaikalia rift system in the Late Jurassic-Early Cretaceous; and (3) the Baikal rift system in the late Cenozoic. The southward movement (present-day coordinates) of the Angara-Anabar megablock of the North-Asian Craton formed the Khamardaban nappe-fold system in the Mesozoic.

ACKNOWLEDGEMENTS

The authors have discussed the geology and tectonics of the Transbaikalia region with L.M. Parfenov and W.J. Nokleberg. The studies were sponsored by the Russian Fund of Fundamental Research (Grants 96-05-64361 and 97-05-96416).

REFERENCES CITED

Amantov, V.A., 1975, Tectonics and formations of Transbaikalia and Northern Mongolia: Nedra, Leningrad. 224 p. (in Russian).

Belichenko, V.G., 1969, Lower Paleozoic of Western Transbaikalia: Nauka, Moscow, 207 p. (in Russian).

Bibikova, E.V., Gracheva, T.V., and Motorina, Z.M., 1979, Geochronological boundaries of the southern part of Eastern Transbaikalia according to U-Pb data: Geochemistry, no. 2. p. 20-29.

Bolonev, V.U., Doronina, N.A., Kushev, V.G., Markov, E.I., Rudenko, V.E., Rudenko, J.L. and Semushin, V.N., 1983, Metamorphic types and facies of the northern part of the Baikal mountain area: Nauka, Novosibirsk, 152 p. (in Russian).

Bozhko, N.A., 1995, Riphean accretion of tectonostratigraphic terranes in the tectonic evolution of the Baikal Mountains: Doklady Russian Academy of Sciences, v. 341, no. 5. p. 654-657 (in Russian).

Bulgatov, A.N., and Klimuk, V.S., 1998, Structural features of the Dzhida Zone, Caledonides: Geotectonics, no. 1. p. 45-55 (in Russian).

Bulgatov, A.N., 1988, Geologic-geophysical model of the upper part of the crust of the northern Transbaikalian region: Russian Geology and Geophysics, no. 9. p. 62-68.

Bulgatov, A.N., 1983, Tectonotype of Baikalids: Nauka, Novosibirsk, 193 p (in Russian).

Bulgatov, A.N., Turunkhaev, V.I., 1996, Geodynamics of Central Asia in Late Mesozoic: Doklady Russian Academy of Sciences, v. 349, no. 6. p. 783-785 (in Russian).

Bulgatov, A.N., Zaitsev, P.F., 1994, Akitkan nappefold arc (Prebaikalie) and prospects of oil-gas bearings rocks: Doklady Russian Academy of Sciences, v. 336, no. 5. p. 639-642 (in Russian).

Buyakaite, M.I., Kuzmichev, A.B., and Sokolov, D.D. 1989, 718 Ma-Pb-Sr isochron for the Sarkhoij series of the Eastern Sayn: Doklady USSR Academy of Sciences, v. 309, no. 1. p. 150-154 (in Russian).

Dobretsov, N.L., and Bulgatov A.N., 1991, Geodynamic map of Transbaikalia (concepts of preparation and legend): Novosibirsk: United Institute of Geology, Geophysics and Mineralogy and the Buryat Geological Institute, Siberian Branch, Russian Academy of Sciences, no. 8. 51 p. (in Russian).

Dobretsov, N.L., and Ignatovich, V.I., eds., 1988, Geology and metamorphism of the Eastern Sayan, Novosibirsk: Nauka, 192 p. (in Russian).

Fedorovskiy, V.S., Vladimirov, A.G., Khain, E.V., Kargapolov, S.A., Gibsher, A.S., and Izokh A.E., 1995, Tectonics and metamorphism of collision zones of central Asian caledonides: Geotectonics, no. 3. p. 3-22 (in Russian).

Fomin, I.N., Sizich I.V., Cherednichenko, V.P., and Falkin, E.M. 1985, Transbaikalian tectonic complexes and their analogues in the adjacent regions: Tectonics of Siberia, v. 12: Nauka, Novosibirsk, p. 42-52 (in Russian).

Gladkochub D.P., and Sklyarov, E.V., 1996, Sill complexes of the south-eastern part of the East Sayan region: Doklady Russian Academy of Sciences, v. 349, no. 4. p. 520-524 (in Russian).

Gordienko, I.V., and Klimuk, V.S., 1995, Bimodal volcanism of the Tugnui rift depression (Transbaikalia): Russian Geology and Geophysics, v. 36, no. 5. p. 22-36.

Gordienko, I.V., 1997, Major terranes of the Transbaikalian region: Tectonic evolution of the East Asian continent. Short papers for the International Symposium. Seoul, Korea, p. 17-19.

Gordienko, I.V., 1987, Paleozoic magmatism and geodynamics of the Central Asian fold belt: Nauka, Moscow, 240 p. (in Russian).

Gordienko, I.V., Bayanov, V.D., Zhamoitsina, L.G., Klimuk, V.S., and Pakholchenko, Ju.A., 1998, Late Paleozoic bimodal volcanic-plutonic associations of Transbaikalia and geodynamic conditions of their formation: Russian Geology and Geophysics, v. 39, no. 2. p. 190-203.

Gusev, G.G. and Peskov, A.I., 1996, Ophiolites of Eastern Transbaikalia: Geochemistry and origin: Geochemistry. no. 8. p. 723-737 (in Russian).

Gusev, G.S., and Khain, V.E., 1995, On relations between the Baikal-Vitim, Aldan-Stanovoy and Mongol-Okhotsk terranes (south of central Siberia): Geotectonics, no. 5. p. 68-82 (in Russian).

Ivanov, A.I., and Ryazanov, G.V., 1992, Structural-kinematic analysis of the Patom trough: Nauka, Novosibirsk, 88 p. (in Russian).

Jarmoluk, V.V., Budnikov, S.V., Kovalenko, V.I., Antipin, V.S., Goreglyad, A.V., Salnikov, E.A., Kotov, A.B., Kozakov, I.K., Kovach, V.P., Jakovleva, S.Z., and Berezhnaja, N.G., 1997, Geochronology and geodynamic position of the Angara-Vitim batholith: Petrology. v. 3, no. 5. p. 451-466 (in Russian).

Jarmoluk, V.V., and Kovalenko, V.I., 1991, Rift magmatism of active continental margins and its ore-bearing. Nauka, Moscow, 263 p. (in Russian).

Konnikov, E.G., Gibsher, A.S., Izokh, A.E., Sklyarov, E.V., and Khain, E.V., 1994, Late Proterozoic evolution of the northern segment of the Paleoasian Ocean: New radiological and geochemical data: Russian Geology and Geophysics, v. 35, p. 7-8, p. 152-168.

Kuzmichev, A.B, 1990, Sarkhoiy series of the stratotypical area (stratigraphy, structural position, age): Late Pre-Cambrian and Early Paleozoic of Siberia, Problems of regional stratigraphy: Novosibirsk, Institute of Geology and Geophysics Siberian Branch, USSR Academy of Sciences, p. 104-123 (in Russian).

Kuzmichev, A.V., 1997, Structure of the Upper-Riphean Oka group at the right side of the Tustuk River (East Sayan): Russian Higher Schools Report, Geology and Prospect. no. 3, p. 21-36 (in Russian).

Kuzmin, M.I., Gordienko, I.V., Almukhamedov, A.I., Antipin, V., Baynov, V.D., and Filimonov A., 1995, Paleo-oceanic complexes: the Dzhida zone of caledonides (Southwestern Transbaikalia): Russian Geology and Geophysics, v. 36, no. 1. p. 1-16.

Letnikov, F.A., Khalilov, V.A., and Saveljeva, V.B., 1995, Isotopic dating of endogenetic processes in Preolkhonje: Doklady Russian Academy of Sciences, v.344, no. 1, p. 96-100 (in Russian).

Letnikov, F.A., Saveljeva, V.B., Gorevanov, D.E., and Khalilov, V.A. 1996, Metamorphism and metasomatism in deep-seated faults of the continental crust: Geotectonics, v. 30, no. 5, p. 15-26 (in Russian).

Litvinovskij, B.A., Zanvilevich, A.N., Shadajev, M.G., and Lyapukhov S.M., 1996, Role of fractional crystallization in the formation of a bimodal trachybasalt-trachyte series: Malo-Khamardabanskaya volcano-tectonic structure, Transbaikalia: Petrology, v. 4, no. 1. p. 26-45 (in Russian).

Menaker, G.I., 1972, Ore deposits in Central and Eastern Transbaikalia: structure of the Earth crust and regularities of their spatial distribution: Russian Geology of Ore Deposits, no. 6, p. 3-16 (in Russian).

Mitrofanov, G.L., 1978, Evolution of tectonic structures and stages of the continental crust formation of North-Western Transbaikalia: Tectonics and Metallogeny of Eastern Siberia, Irkutsk, Irkutsk State University, p. 38-56 (in Russian).

Neimark, L.A., Ritsk, E.Yu, and Rizvanova, N.G., 1993, Hercynian age and Precambrian crustal protolith for the Barguzin granitoids of the Angara-Vitim batholith: U-Pb and Sm-Nd isotopic data: Doklady Russian Academy of Sciences., v. 331, no. 6. p. 726-729 (in Russian).

Nokleberg, W.J., Parfenov, L.M., and Monger, J.W.H., and Baranov, B.V., Byalobzhesky, S.G., Bundtzen, T.K., Feeney, T.D., Fujita, Kazuya, Gordey, S.P., Grantz, Arthur, Khanchuk, A.I., Natal'in, B.A., Natapov, L.M., Norton, I.O., Patton, W.W., Jr., Plafker, George, Scholl, D.W., Sokolov, S.D., Sosunov, G.M., Stone, D.B., Tabor, R.W., Tsukanov, N.V., Vallier, T.L. and Wakita, Koji, 1994a, Circum-North Pacific tectono-stratigraphic terrane map: U.S. Geological Survey Open-File Report 94-714, 433 manuscript pages, 2 sheets, scale 1:5,000,000; 2 sheets, scale 1:10,000,000.

Nokleberg, W.J., Parfenov, L.M., and Monger, J.W.H., and Baranov, B.V., Byalobzhesky, S.G., Bundtzen, T.K., Feeney, T.D., Fujita, Kazuya, Gordey, S.P., Grantz, Arthur, Khanchuk, A.I., Natal'in, B.A., Natapov, L.M., Norton, I.O., Patton, W.W., Jr., Plafker, George, Scholl, D.W., Sokolov, S.D., Sosunov, G.M., Stone, D.B., Tabor, R.W., Tsukanov, N.V., and Vallier, T.L., 1997, Summary Circum-North Pacific tectono-stratigraphic terrane map: Geological Survey of Open-File 3428, scale 1:10,000,000.

Parfenov, L.M., Bulgatov, A.N., and Gordienko, I.V., 1995, Terranes and accretionary history of the Transbaikalian orogenic belts: International Geology Review, v. 37, no. 8. p. 73-751.

Postnikov, A.A., Zhuravleva, I.I., and Terlejev, A.A., 1997, Stratigraphy of Cambrian deposits in the Ozerny ore cluster (Western Transbaikalia): Russian Geology and Geophysics. v. 38, no. 3. p. 608-619.

Shatskii, V.S., Jagouts, E., Piboshlikov, Ju.I., Kozmenko, O.A., and Vavilov, M.A. 1996, Eclogites of the North-Muya Block: Evidence of Vendian Collision in the Baikal-Muya ophiolite belt: Doklady Russian Academy of Sciences, v. 350, no. 5. p. 677-680 (in Russian).

Shergina, Ju.P., Murina, G.A., and Kozubova, L.A., 1981, The Barguzin complex: on age granites on Rb-Sr evidence: Doklady USSR Academy of Sciences, v. 261, no. 4, p. 946-949 (in Russian).