U. S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPHIOLITIC COMPLEXES AND ASSOCIATED ROCKS IN THE UST-BELAYA MOUNTAINS AND ALGAN RIDGE, RUSSIAN FAR EAST

by

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Open-File Report
OF 92-20-I

1996

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INTRODUCTION

This report is part of a series of open-file reports on the ophiolitic complexes of northeast Russia and Alaska based on collaborative studies carried out between 1989 and 1993 by the Far Eastern Branch of Russian Academy of Sciences, the U.S. Geological Survey, and the Alaska Division of Geological and Geophysical Surveys. The following reports in this series are available in open-file from the U.S. Geological Survey:

OF 92-20A	Geologic map of the ophiolitic and associated volcanic arc and metamorphic terranes of Alaska (west of the 141st meridian) by Patton, W.W.,Jr., Murphy, J.M., Burns, L.E., Nelson, S.W., and Box, S.E., 1992
OF 92-20B	Ophiolitic and other mafic-ultramafic metallogenic provinces in Alaska (west of the 141st meridian) by Foley, J.Y., 1992
OF 92-20C	Ophiolitic complexes of the Gulf of Alaska by Nelson, S.W., 1992
OF 92-20D	Ophiolitic terrane of the western Brooks Range, Alaska, by Patton, W.W., Jr., 1992
OF 92-20E	Ophiolitic complexes and associated rocks near the Border Ranges fault zone, southcentral Alaska by Burns, L.E., 1992
OF 92-20F	Ophiolitic terrane bordering the Yukon-Koyukuk basin, Alaska, by Patton, W.W., Jr., 1992
OF 92-20G	Ophiolitic terranes of east-central and southwestern Alaska by Patton, W.W, Jr. and Box, S.E., 1992
OF 92-20H	Geologic map of ophiolite complexes and associated volcanic arc and metamorphic terranes of northeastern Russia by Khanchuk, A.I., Palandzhyan, S.A., and Panchenko, I.V., 1994

This report summarizes geological and geochemical information on the ophiolitic complexes and associated rocks of the Ust-Belaya Mountains and North Algan Ridge. For information on the location of specific geologic features mentioned in this report and on the geologic setting of the ophiolitic terranes of northeast Russia, the reader should consult Open-File Report 92-20H.

The ophiolite complexes described in this report, as well as other ophiolite complexes in the Koryak Highland, are underthrust by younger island-arc sequences and therefore belong to the Cordilleran-type as defined by E.M. Moores (1982). However, the Ust-Belaya Mountain and Algan Ridge ophiolite complexes have specific rock compositions, i.e. low depleted lherzolite abundance in the mantle sequence, which are more typical of the Tethyan-type ophiolites. For this reason, the ophiolite complexes of the

Koryak Highland may be unique among the ophiolites of the northern circum-Pacific fold belts.

TERRANES

This report provides data on outcrops of ophiolites situated on the south side of the Anadyr River in the Ust Belaya Mountains and on the Algan Ridge. The outcrops, which make up the largest exposure of ophiolites in the Koryak Highland, occupy an area 100 km in length and 35 km in width (Plate 1, col. F, fig. 8). Detailed study of geological structure and tectonic history of northeast Russia by S.G. Byalobzhesky, L.M. Parfenov, and S.D. Sokolov showed that tectonostratigraphic terranes of two different ages occur within the Ust-Belaya Mountains and Algan Ridge: the Penzhina-Anadyr terrane composed of oceanic and island arc complexes of Paleozoic and early Mesozoic (Middle Jurassic and older) age and the Mainits terrrane represented by an Early Cretaceous (Valanginian) island-arc sequence (Nokleberg and others, 1992). These workers further subdivide the Penzhina-Anadyr terrane into three subterranes: 1) the Ganychalan subterrane composed of early Paleozoic ophiolite and metaophiolite and Carboniferous-Triassic island-arc sequences, 2) the Main River subterrane composed of Ordovician-Silurian and Late Jurassic-Early Cretaceous sedimentary sequences and Carboniferous to Middle Jurassic island-arc sequences, and 3) the Ust-Belaya subterrane, which is described in detail below. All known outcrops of Ust-Belaya subterrane occur in the Ust-Belaya Mountains and on the north Algan Ridge. Small blocks of the Main River subterrane rocks composed of Late Triassic and Middle Jurassic terrigenous deposits covered by Late Cretaceous and Cenozoic molasse deposits crop out on west Algan Ridge and on the west bank of the Anadyr River. The Ganychalan subterrane crops out to the southwest of the Ust-Belaya area. In late Neocomian to Aptian time the different subterranes of Penzhina-Anadyr terrane were included in Kony-Murgal island-arc accretionary prism. Subsequently they were covered by marine terrigenous deposits of Albian and Late Cretaceous age in the forearc depression of Okhotsk-Chukotka continental-marginal arc and by late Senonian and Paleogene terrigenous and volcanic sequences of the Kamchatka-Koryak volcanic belt (Nokleberg and others, 1994).

TECTONIC STRUCTURE OF UST-BELAYA SUBTERRANE

A.A. Aleksandrov (1978) and G.E. Nekrasov (Markov and others, 1982) interpreted the structure of the Ust-Belaya Mountains and Algan Ridge to consist of five to seven individual nappe units. We subdivide the Ust-Belaya subterrane into four nappe units, each of which includes several thrust sheets. These nappe units are described below in structural order from bottom to top:

1. The Utyosiki unit consisting of tectonic slices and blocks of late Paleozoic to Early Cretaceous island-arc sequences separated by serpentinite and by melange with serpentinite matrix. The unit is not well-studied and the age of the magmatic and sedimentary rocks is uncertain.

The following two units are dismembered parts of the middle Paleozoic ophiolite assemblage that were separated during early stages of accretion when Devonian oceanic lithosphere was attached to a late Paleozoic arc.

2. The peridotite-gabbro unit is composed of a thick sequence of residual peridotite, ultramafic to mafic cumulate rocks of the transitional zone, and gabbro. The basement of the sequence is a tectonic melange with a serpentinite matrix. The blocks in the melange range in size from several tens of centimeters to 0.3 kilometers. They consist of rocks from the ophiolite assemblage and its sedimentary cover, from the island-arc complexes of late Paleozoic to early Mesozoic and Late Jurassic to Early Cretaceous age, and from metamorphic rocks of greenschist and amphibolite facies.

3. Otrozhny unit includes the upper part of the ophiolite assemblage and its sedimentary cover. The basement of this unit also contains a serpentinite melange similar to the peridotite-gabbro unit, but without blocks of metamorphic schists. The ophiolite sequence is intruded by dikes of plagiogranite porphyry and diabase that have chemical compositions suggesting island-arc affinities (Table 1, column E, fig. 2). K-Ar age of plagiogranite dikes (Table 1, col. C) and the presence of serpentinite and chromian spinel fragments in sandstones of Early Carboniferous age indicate that the Otrozhny ophiolite was a part of the basement of an island-arc since Carboniferous time.

4. The Udachny unit is composed of Late Jurassic to Valanginian sandy-clay deposits that formed in the forearc basin of Kony-Murgal island-arc (S.G. Byalobzhesky, oral communication).

The four tectonic units comprising Ust-Belaya subterrane are irregularly distributed across and along the strike of the regional structures. The subterrane is broken into several tectonic blocks that moved vertically and laterally along strike-slip faults relative to each other (Plate 1, column F, fig. 10). The largest of these tectonic blocks are described below:

The structurally highest *Northern* block is composed of ultramafic rocks, mainly of mantle affinities. Fragments of cumulate ultramafics are preserved along the east edge. Southwest of the *Northern* block, the ophiolite complex occurs at progressively lower levels and some units of the complex are locally underthrust in a northeast direction. The *Central* block is composed predominantly of gabbro that was thrust northeastward under the *Northern* block. To the southwest in the elevated part of the *Central* block, the section progresses downward from gabbro to mafic-ultramafic rocks of the transitional zone, to metamorphic peridotites, and then to serpentinite melange. The *Konachan-Mavrina* block, the structurally lowest part of the subterrane, is composed of the rocks of Otrozhny and Udachny units and is thrust under the southwest edge of the *Central* block. The *Eldenyr* block, which forms the elevated core of a horst structure, exposes deep levels of mantle peridotite. Strongly deformed ophiolites are also exposed in the *Eastern* block east of the main area of ophiolite outcrops. This block requires additional investigation to determine the age of the ophiolites. We tentatively correlate the ophiolites of the *Eastern* block with the Otrozhny ophiolite, but they may be Late Jurassic or Early Cretaceous in age and a fragment of the Mainits terrane, as suggested by G.E. Nekrasov (Markov and others, 1982).

LITHOLOGICAL UNITS OF OPHIOLITE ASSEMBLAGE

Petrographical and petrochemical data suggest that ultramafic and mafic rocks of the *Northern, Central, Konachan-Mavrina*, and *Eldenyr* tectonic blocks represent the same ophiolite assemblage. The main lithological units are not generally in direct contact and some units are represented in only one block. However, the observed relationships allow reconstruction of the structural sequence.

MANTLE SUITE

Petrography

The mantle suite of the tectonized peridotite is well-exposed in the *Northern, Central*, and *Eldenyr* blocks where two different sequences are recognized:

1) The first sequence is characterized by a zonal distribution of the peridotite facies. This sequence is found in the *Northern* block where the lineation and foliation of peridotite is predominantly north-south (Silkin and Sterligova, 1973; Smirnova, 1974). The peridotites are represented across strike from west to east by lherzolite, diopside-bearing harzburgite, minor barren harzburgite, and dunite. The end member of this zonation on the east is preserved in fragments composed of thinly banded alternations (1-3 cm) of dunite, cortlandite, wehrlite, pyroxenite, and hornblendite, intruded by dikes of microgabbro with MORB-type chemical composition (Plate 1, fig.1). The thinly banded ultramafic rocks are characterized by cumulate textures and higher iron contents, as compared with restite peridotites. They belong to the transitional zone, although their relationships with cumulate gabbro are not preserved.

2) The second sequence is composed of restite peridotite and crops out in the southern part of the *Central* block. The uppermost part of the mantle suite and the transitional zone to the crustal suite are exposed here. However, in contrast to *Northern* block, the lherzolite composition of peridotites persists up to highest level and a large dunite zone is absent. The thin (0.1-0.2 km) transitional zone is composed of dunite, wehrlite, and harrisite (plagioclase dunite) bands with schlieren and veins of pegmatoid gabbro. The peridotite massif of the *Eldenyr* block is composed almost entirely of lherzolite. Small areas of alternating dunite and websterite occur locally.

Textures

Textures in the peridotites are metamorphic and include protogranular textures, commonly preserved in the *Eldenyr* lherzolites. Porphyroclastic and mosaic textures and mylonites are typical in the fault zones and in the mantle suite basement. Antigoritization of peridotites, in addition to early serpentinization, is widely developed and makes the ultramafic rocks of Ust-Belaya subterrane distinct from other peridotite massifs of Koryak region.

Geochemistry

Figures 3, 4, and 5 (Plate 1, column E) show petrochemical properties of lherzolites and harzburgites. Though the compositional range is wide, most peridotites are represented by low and moderately depleted varieties (as indicated by pyroxene and chromian spinel composition), similar to peridotites of the modern oceanic passive margins and to very slow spreading centers. The least depleted lherzolites of the *Northern* and *Eldenyr* blocks are similar to subcontinental lherzolites, based upon their mineral composition. These data allow the interpretation (Palandzhyan, 1992) that the lherzolite unit of Ust-Belaya subterrane formed in a tectonic setting of an intracontinental oceanic basin opening. The more depleted peridotites occur only in the *Northern* block where the mantle sequence depletion rate increases toward the amphibole-bearing cumulate unit. This last factor suggests that intense depletion of mantle sequence is caused by melting in a water-saturated environment (see also Plate 1, column E, fig.4).

CRUSTAL SUITE

The large body of gabbro exposed within the *Central* block includes only the lower part of the crustal sequence. It is composed of banded olivine gabbro, troctolite, that in the lower part comprise lens-like bodies of plagioclase-bearing ultramafic rocks. In most outcrops, banded gabbro is metamorphosed to amphibolite. In the *Konachan-Mavrina* block higher horizons of the crustal sequence, represented by banded and isotropic gabbro and olivine gabbro, have been preserved. Petrographic features of mafic and ultramafic cumulates in these two blocks, namely, earlier plagioclase crystallization relative to clinopyroxene and absence of orthopyroxene, testify that the cumulates belong to the A-1 type in accordance with definition by M. Ohnenstetter (1985) and are indicative of the ophiolite formation in spreading centers of mid-oceanic ridges or pericontinental marginal basins.

Volcanic rocks of ophiolite assemblage crop out in the *Konachan-Mavrina* block. These are amigdaloidal basalt, diabase, spilite, and lava-breccia of diabase. Their petrochemical characteristics (Plate 1, fig.1) are similar to MOR-type basalts. Cherts and tuffaceous rocks occur in the upper part of the sequence. Geological relationships suggest that the age of volcanogenic-cherty sequence is pre-Middle Devonian, presumably Early Devonian (Markov and others, 1982).

METAMORPHIC ROCKS.

The basal tectonic melange of ophiolite allochthon includes the blocks of green-schist metamorphic rocks that are absent in the tectonic breccias within the ultramafic rocks. In contrast, amphibolites and garnet quartz-bearing amphibolites form tectonic inclusions in both the basal melange and in the peridotites of the *Central* block. In this block most banded gabbro are metamorphosed to metagabbro and amphibolites. According to available data (Plate 1, col. C), the amphibole alteration of mafic rocks occurred during Devonian.

Amphibolite facies metamorphism is also superimposed on the peridotites of the mantle sequence. Lherzolites in several large fault-bounded areas of the *Northern* and *Eldenyr* blocks have been metamorphosed to an olivine-antigorite rock composed of pseudomorphs of amphibole and chlorite after pyroxene, chromian spinel replaced by magnetite-like minerals, and chlorite (Silkin and Sterligova, 1973; Dmitrenko and others, 1990).

The metamorphic rocks of Ust-Belaya subterrane have been poorly studied. There are no data on the age of greenschists and therefore determination of their geodynamic history is impossible. One can assume, however, that amphibolite facies metamorphism of the lower and middle horizons of ophiolite assemblage closely followed formation of the ophiolites.

COVER COMPLEX

The cover complex is composed in the lower part of marine terrigenous deposits of late Albian to early Senonian age, correlative with the volcanic accumulations of Okhotsk-Chukotka continental arc. The upper part of the cover complex is composed of late Senonian to Paleogene coal-bearing nearshore and continental deposits, as well as of synchronous subaerial volcanic rocks that form the north flank of the Kamchatka-Koryak continental volcanic belt.

ACKNOWLEDGMENTS

This report was formatted, drafted, and edited by William W. Patton, Jr., and Judy Weathers of the U.S. Geological Survey, and Steven W. Nelson of the University of Alaska, Anchorage.

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