# METAULTRAMAFITES OF THE CRYSTALLINE BASEMENT OF THE CHUKCHI PENINSULA

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## ABSTRACT

On the Chukchi Peninsula, the crystalline basement crops out on the Koolen and Senyavin uplifts and is composed of gneiss, amphibolites and marbles; according to thermobarometric data, the metamorphism here occurred at T = 525-700°C, P = 5-7 kb. According to Rb-Sr isochronous dating, the Koolen uplift covers the timespan from 1990 Ma to 393 Ma (Zhulanova,1990). For the Senyavin uplift, there is only one date, 364 Ma, established by the same dating method. Both the Koolen and Senyavin uplifts host numerous small (< 0.2 $km^2$) ultramafite bodies subject to boudinage, which are reconstructed as Precarboniferous peridotite of ophiolites. They feature similar conditions of occurrence, that is they are conformable with the structure of hosting metamorphic sequences; they also are closely related by composition including cpx-free metamorphic paragenesis: ol + tr + en (without Ca), ol + ta, ol + tr, ± Crsp ± Crmgt[1], and the metamorphic grade: T = 600 = 750°C, P = 5-9 kb. Ultramafites of the Senyavin uplift feature jack-straw texture varieties close to olivine spinifex texture and related to regional metamorphism and contact bimetasomatism.

Some amphibolites and quartzite-gneiss are assumed to be metamorphic gabbroids, basalts and siliceous-clayish sedimentary rocks, which, in combination with ultramafites, are the counterparts of ophiolite assemblages. These ophiolites probably compose a young structural complex as compared with the early Pre-Cambrian basement.

## INTRODUCTION

High grade metamorphic domes in the Chukchi and Seward Peninsulas were originally assigned to the Eskimo massif (Bely,1964; Nedomolkin,1977). Nevertheless, even today, there is no reliable evidence for this correlation. There are differences in the known ages and metamorphic grade of both areas. The oldest isotopic data from the Seward Peninsula are late Precambrian, whereas in the Chukchi Peninsula there are early Precambrian ages (up to 1.9 Ga according to Rb/Sr method; Zhulanova,1990). Granulite grade gneisses occur in the Kigluaik Group of the Seward Peninsula (Moffit,1913; Lieberman and Till,1987), while in the Chukchi Peninsula occur metamorphic rocks not higher amphibolite grade. Ultrabasic rocks are known in the metamorphic domes along both sides of the Bering straits. Ultramafites, which are diagnostic of specific geodynamic environments, play an important role in the correlation of geologic events in these two regions.

## AGE AND METAMORPHISM OF THE BASEMENT OF THE CHUKCHI PENINSULA

There are three major uplifts on the Chukchi Peninsula: Koolen, Neshkan and Senyavin. A good example of a dome structure is in the vicinity of Koolen Lake. There are two series in the composition of this complex - lower, Ettelkhvyleut and upper, Lavrentyev (analogue to the Penkignei series of the Senyavin uplift) (Shuldiner and Nedomolkin, 1976). In the Ettelkhvyleut series, biotite gneisses and granitic gneisses prevail; biotite and hornblende-biotite schists occur rarely. The Lavrentyev series differs by the predominance of marbles. There are amphibolites and various schists - biotite, hornblende-biotite, clinopyroxene-hornblende, biotite-garnet, sillimanite-mica in this series. The metamorphic conditions, according to the amphibole-garnet (Powell, 1985), amphibole-plagioclase (Plyusnina, 1983), biotite-garnet and garnet-plagioclase thermometers (Perchuk et.al., 1983) and barometers, are T = 525-700°C, P = 5-7 kb. Smaller parameters of metamorphism - T = 525-625°C, P = 6-7 kb were found for amphibolite and biotite-garnet schist in Senyavin uplift. They correspond to the epidote-amphibolite facies and the low level of amphibolite facies (Akinin, 1990). There are the following ages of evolution of multistage rock metamorphism from the Koolen dome according to Rb-Sr isochronous dating: 1990 Ma (±150) for potassium granitization; 1770 (±80) and 782 (±55) Ma for endogenous activization of palingenous granitoids (Zhulanova, 1990). For metamorphic rocks of Penkignei series of Senyavin uplift we have obtained an isochron with the age of 364 (±5) Ma, $Sr^{87}/Sr^{86} = 0.70354$ by the same method at the same laboratory.

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[1] Abbreviation: ol- olivine, opx - orthopyroxene, en - enstatite, ta - talc, chl - chlorite, tr - tremolite, Cr-sp - chrome-spinel, Cr-mgt - chrome-magnetite, cc - calcite, dol - dolomite, bi - biotite, gr - garnet. Figure at simbol ($ol_{17}$) - Fe/(Fe + Mg) at.%.

Ultramafites, known both in Senyavin (Uskhetveem area) and in Koolen (Koolen area) uplifts, are very interesting. Inspite of the remoteness of these areas from each other (about 200 km), they are similar in structure and composition. We have not found their analogues elsewhere in northeastern Russia. Numerous small (not more than 300 m) ultramafite bodies are conformable with the structure of the host metamorphic strata. The ultramafites are composed of clinopyroxeneless metamorphic paragenesises: ol+en, ol+ta, ol+tr, ±Crsp, ±Crmgt. The Uskhetveem ultramafites are better studied, and we have found in them unique texture similar to spinifex komatiites.

## THE STRUCTURE OF THE PENKIGNEI SERIES IN THE SENYAVIN UPLIFT

Separate blocks of metamorphic rocks in the south - east of the Chukchi Peninsula are combined into the Senyavin uplift. The largest block is the Valkarvaam horst composed mainly of biotite plagiogneisses, schists, amphibolites and marbles of the Penkignei series. The 2nd Stratigraphic Meeting assigned an Archean age for this series. The horst extends for 80 km to the west of Senyavin Strait, with a width of 8-15 km. Analyzing the existing field data we have reinterpreted the structure of the Valkarvaam horst as the southwestern flank of a dome complicated by smaller scale folds.

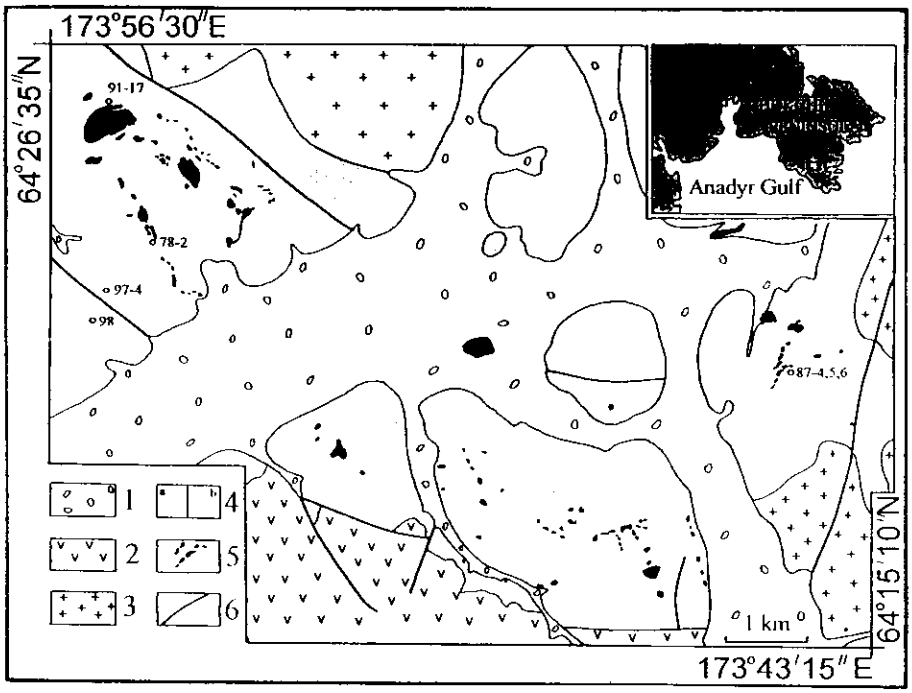


Fig. 1. A simplified geological map of Uskhetveem River area (Valkarvaam horst).
1 - alluvium; 2 - Cretaceous volcanic rocks of the Okhotsk-Chukotsk volcanic belt; 3 - Cretaceous granites; 4 - early Precambrian ? amphibolites (a) and biotite schists (b) of Penkignei series; 5 - ultramafites; 6 - faults. Circles with number is a location of the samples from which Rb/Sr age was obtained (see Fig. 2).

The Uskhetveen ultramafic bodies are located in the interflure of the Uskhetveen and Kurupka rivers. This area in the Penkignei series is composed of two strata. The upper stratum is steeply dipping marble, about 2.2 km thick, with rare lenses of schist and amphibolite. The second, lower stratum consists of biotite schists and amphibolites. The major part of these rocks extends northwestward. The chains of ultramafite bodies have the same direction. At some distance from the marble stratum the structure is complicated by a series of small discordant folds. On the left bank of the river schistose strata change its direction from the northwestern to submeridional one. A line of synclinal folds occurs there.

In the eastern part of the Senyavin dome there are gently folded Devonian and Carboniferous limestones, phyllites and sandstones. Paleozoic and early Precambrian sediments are overlain by the Albian calc-alkali volcanites of the Okhotsk-Chukotsk volcanic belt and intruded by Cretaceous granitoids.

## USKHETVEEM ULTRAMAFITE AREA

The ultramafites cover a 9.5 km x 2 km x 5.5 km area (Fig. 1). Its sickle-like form is concordant with the structure of Penkignei series. The total number of ultramafic bodies is 110. The size of the largest outcrop is not more than 300 m, the smallest one - several meters. The bodies are oval or elongated in shape and distributed like beads in a rosary. This is a result of boudinage. The planes of these outcrop contacts and sometimes the elements of the inner banding are concordant with the structure of the host schists; discordant foliation is found only in some sections of the largest bodies. A definite lithological control exists: ultramafites are often in contact with biotite schists and plagiogneises, but are absent among the marbles. Thus, the field observations show that ultramafites have mainly synkinematic character, i.e. have undergone the deformation together with amphibolites and schists. The age of their formation must be no younger than Lower Carboniferous according to the Rb/Sr

isochrone of 364 Ma from schists and amphibolites samples (Fig. 2, Table 1)). Most of the schists and amphibolites occur in the vicinity of the ultramafite bodies, i.e. in the zone of bimetasomatic changes.

The composition of the ultramafite rocks and minerals demonstrates that they belong to the alpinotype peridotites of dunite-harzburgite association. Most the rocks are similar to highly depleted harzburgites ($ol_{7-9}+en_{7-9}+$ tr+chl ±Crsp ±Crmgt) with Mg/Si=1, and orthopyroxenites (en+ta, en+ol). They have $Al_2O_3+CaO$=2-3%, $Cr_2O_3$=0.2-0.6%, NiO=0.2-0.4% with Mg/(Mg+Fe)=0.92-0.90. The contents of $TiO_2$, $Na_2O$, $K_2O$ are less than 0.1%. The average composition of Uskhetveem ultramafites was calculated according to the area occupied by various rocks (metadunites - 5.5%, metaharzburgites - 55%, metaenstatites - 26%, tremolitic metaperidotites - 10%, tremolitites - 3%, calc-silicate rocks - 0.5%). This composition corresponds to harzburgite, enriched by pyroxene: $SiO_2$=46.91, $TiO_2$=0.04, $Al_2O_3$=1.72, FeO=7.38, MnO=0.12, MgO=41.67, CaO=1.04, $Na_2O$=0.15, $K_2O$=0.07, $Cr_2O_3$=0.37, NiO=0.27 (wt.%).

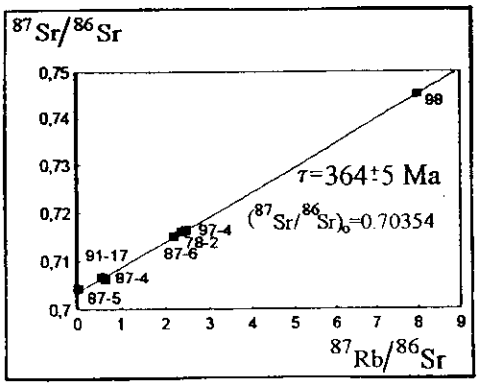


Fig. 2 Rb/Sr age of Penkignei series from the Senyavin uplift.

Because of metamorphism, the distribution of Si, Mg, Ca and Al among the minerals and rocks in Uskhetveem differs from that of magnesian island arc peridotites from ophiolite complexes. Allochemical exchanges are very well established by the redistribution of Al and Ca from orthopyroxene into chlorite and tremolite. In the metaharzburgites the quantity of talc is more than it would be during the isochemical enstatite replacement. Thus, we conclude that there was an increase of Si/(Mg+Fe) relative to the primordial one.

Besides metaharzburgites, orthopyroxenites and rare metadunites, we have established also the existence of tremolitic metaperidotites ($ol_{17-12}$ + $Tr_{2-5}$ ±Crsp, sometimes chl ±dol ±en 5%) which are more often located in the marginal parts of bodies, but sometimes compose the complete bodies and are similar in their chemical composition to lherzolites and harzburgites. Schlieren, veins and nodules of calc-silicate rocks (fo+cc+chl, tr+dol+mgt, accessory ones-chrome-spinel, pentlandit, graphite) similar to calciphyre, are associated with the rocks described.

Table 1. Rb and Sr isotopic composition of metamorphic rocks from Penkignei series

| Sample No | $^{87}Rb$ | $^{86}Sr$ | $^{87}Rb/^{86}Sr$ | $^{87}Sr/^{86}Sr$ | Rock Type |
|---|---|---|---|---|---|
| 87-5 | 0,9407 | 26,6900 | 0,03525 | 0,7042 | amphibolite |
| 87-4 | 10,3700 | 15,5900 | 0,66520 | 0,7062 | bi schist |
| 91-17 | 39,2100 | 66,3100 | 0,59130 | 0,7067 | amphibolite |
| 78-2 | 44,3701 | 18,5880 | 2,38800 | 0,7160 | bi schist |
| 87-6 | 30,0800 | 13,6200 | 2,20900 | 0,7152 | bi schist |
| 97-4 | 23,0800 | 9,3180 | 2,47600 | 0,7164 | bi-gr schist |
| 98 | 40,0100 | 4,9940 | 8,01200 | 0,7451 | bi schist |

Mass MI-1201 spectrometer, NEISRI, Magadan (Analysts: Korolkov A.V., Davidov I.A. and Magagin A.B.)

Most ultramafites are gigantic-grained and nonschistose but this does not contradict the suggestion on macrodeformations and can be the result of syn- or postkinematic recrystallization. The traces of deformation also may be hidden in the contact zones during the bimetasomatic processes.

They form the framework in interstices of which finegrained aggregates of talc or tremolite (±chl) are present. Sometimes, particularly in metapyroxenites, blade-like olivine intergrows the gigantic enstatite crystals. In all cases olivines are flattened along (100), stretched along the "*b*" axis and have a spotty zonation (Fig. 4). This distinguishes them from magmatic olivines in which crystals are mainly stretched along the "*a*" axis. The small ultramafic bodies are made entirely of jack-straw texture rock, but in the larger bodies they are developed only in schlieren or branching veins. There is no essential difference in the average composition of metaharzburgites with the allotriomorphic-granular and jack-straw textures. This fact distinguishes these rocks from komatiites.

The characteristics of the major minerals are the following: in many cases there is textural equilibrium of olivine with talc and tremolite, sometimes enstatite with chlorite and even talc; clinopyroxene is absent; and serpentinization is superimposed on the all assemblages. There are several features of the metamorphic re-equilibration of enstatite: the loss of Al, Ca, Cr and their redistribution into the hydrous minerals (chl, tr); and

the presence of two or more crystal generations of enstatite which differ in size, morphology, and texture relationships with talc. In all olivines the content of admixtures of CaO and $Cr_2O_3$ is very low (<0.01 wt.%), and this is not characteristic of magmatic rocks. The chrome-spinel composition is the same as in alpino-type peridotites. We consider the presence of spongy textures and crystal zonation uncharacteristic of magmatic process. In this type of zonation the contents of MgO and $Al_2O_3$ increase towards the margin.


3A 3B

Fig. 3 General textures of Uskhetveem ultramafites. A - allotriomorfic granular; B - jack-straw.

The size of olivine and enstatite is 1-2 cm, sometimes up to 30 cm; tremolite, chlorite and talc are usually smaller. We distinguish two types of ultramafite textures: 1) allotriomorphic-granular 2) jack-straw (Fig. 3). The jack-straw textures are found in all rock types, but mostly they are characteristic of the talc-olivine assemblage. In this texture elongate-laminated, blade-like serpentinized olivines are usually randomly priented, intergrown with, or sometimes parallel to, each other.

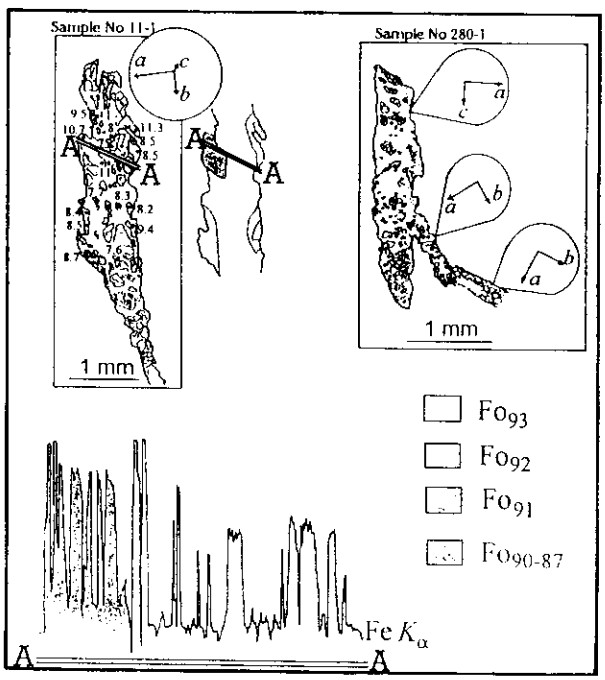


Fig. 4. Elongate serpentinous olivines with a spotty crystal zonation from jack-straw ultramafites.
a,b,c - crystallographic axes; Points with number - microprobe analyses and $Fe/(Fe+Mg)^{ol}$; **A-A** - location of the microprobe profile of roentgenogram radiation intension of Fe.

These characteristics make it possible to conclude that the Uskhetveem ultramafites are progressive recrystallized serpentinites similar to these described by Evans and Frost (1975). The distribution of Fe and Mg between the olivine and chrome-spinel depends on $Cr/(Cr+Al)^{sp}$ (Fig. 5). This distribution is approximated by a linear dependence close to the 700°C isotherm for all Uskhetveem ultramafites. The average temperature by the other geothermometres (Engi, 1978; Fabries, 1979) is 660°C, (st. divergence=45, n=38). The absence of clinopyroxene and anthophyllite, the stability of talc-forsterite assemblage, corrections for aluminous content of tremolite (Jenkins, 1983) and the correlation of fluid pressure with the lithostatic one (Marakushev, 1968) determine the equilibria of mineral assemblages of Uskhet-

veem ultramafites at the T=600-770°C, P=5-9 kb. Such parameters are close to the metamorphic conditions of host rocks of the Penkignei series.

In contact with the ultramafic bodies, and as xenoliths within the bodies, there are retrograded amphibolites, chloritites and rodingites. The protoliths of these rocks were probably gabbros, websterites, clinopyroxenites, lherzolites and plagioclase peridotites (taxitic ultramafic series of an ophiolites). The maximum desilicification zones of these rocks include paragenesis with corundum, pleonaste, phlogopite and tourmaline. In this case in ultramafites from the core of bodies towards the rim the ratio Si/Ca/(Mg+Fe) is increased.

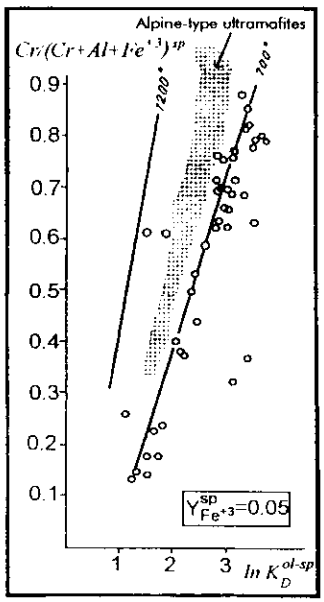


Fig. 5. ln $KD_{Mg\text{-}Fe}$ (olivine-spinel) vs. $Y_{Cr}$(spinel) from Uskhetveem ultramafites (circles). Isoterms by Evans and Frost (1975).

An analysis of literature and the author's data shows that elongate-lamellar forms of olivine are formed during various geological processes: volcanic (komatiites), intrusive (harrisite texture of allivalites of stratiform plutons), metamorphic (jack-straw textures of metaultramafites). Elongate-lamellar olivine crystals of metamorphic origin are described together with the primary ones in komatiites (Oliver et al.,1972), alpino-type ultramafites (Trommsdorf and Evans, 1972; Snoke and Calk, 1978), Precambrian layered intrusions (Collerson et al., 1976; Bakk, Cornelliusen, 1986), and bimetasomatic zones (Melyakhovetsky, 1982). Therefore this feature is not diagnostic of a unique geological environment.

## CONCLUSION

The Uskhetveem ultramafites are the products of interaction of acidic fluids with the solid ultramafic masses, probably, serpentinites. Ultramafites together with amphibolites and metasediments (biotite schists, marbles) may represent an ancient ophiolitic complex. This fact gives a new viewpoint on the history of development of Senyavin and Koolen domes.

According to aforesaid, it is important to compare them with the ultramafites from the foot of the Kigluaik Mountains in the Seward Peninsula (Lieberman and Till, 1987). Unfortunately, we have little information on these rocks, but it is clear that they are more metamorphosed (P=12±5 kb, T=900±150°C). The last fact is consistent with the higher level of metamorphism of the surrounding metapelitic association in comparison with the Chukchi Peninsula. Formation of garnet lherzolites of the Kigluaik Mountains is associated with the early phases of the Jur-K Brooks Range orogeny, simultaneously with the overlying Nome group blueschists. Perhaps the most important task now is to date directly the ultramafites from the Seward and Chukchi Peninsulas.

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