THE GANKUVAYAM SECTION, KUYUL OPHIOLITIC TERRANE, AS A TYPE OPHIOLITE SECTION ON THE ARCTIC MARGIN OF THE RUSSIAN FAR EAST

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ABSTRACT

The Kuyul ophiolitic terrane of northeast Russia consists of ultramafic plutonic, volcaniclastic, and pelagic sedimentary rocks that were accreted to the Asian continent in Early Cretaceous. The latest Jurassic Gankuvayam ophiolite section of the Kuyul terrane consists of a sequence of harzburgite, gabbro-troctolite-wehrlite, plagiogranite, sheeted-dike, and pillow-lava units. This section corresponds to a secondary spreading center in the Triassic-Early Jurassic oceanic crust. The observed mineral assemblage is typical of ophiolites, but the mineral compositions have specific characteristics. The Gankuvayam ophiolite section is the most complete ophiolite, with respect to mineral assemblages, in Eastern Asia and could be a type section for studying the formation of ophiolites.

INTRODUCTION

The Kuyul ophiolite crops out northwest of the Kamchatka Peninsula in the Talovskie Mountains, where they form an allochthonous block 120 km long and 10 to 50 km wide, enclosed in an Early Cretaceous accretionary prism (Alekseev, 1991; Chekhov, 1982; Khanchuk, et al., 1990). The ophiolite consists of serpentinite melange, which includes blocks of harzburgite, gabbro, sheeted dikes, and basalts associated with pelagic sedimentary rocks. Middle Triassic and Norian-Lower Jurassic cherts are interbedded with limestones, and Norian-Rhaetian and Upper Jurassic cherts are found among sedimentary rocks. Dikes are aligned across the trend of the Kuyul massif. Judging by the regular pattern in the occurrence of the chill zones, the Gankuvayam thrust panel is an ancient spreading center, preserving major features of the oceanic hydrothermal metamorphism and hydrothermal sulphide mineralization (Khanchuk et al., 1990).

OUTLINE OF PETROGRAPHY

The Gankuvayam ophiolite panel forms the core of the synform (Fig.1), the limbs of which consist of serpentine harzburgite, and zones of serpentinite melange. Fig.2 shows the complete ophiolite cross-section of the Gankuvayam panel.

Serpentinized harzburgite predominates in the ultramafic part of the section. Heavily serpentinized dunites were observed near the gabbroic rocks. On the basis of their chemical composition, some clinopyroxene-bearing rocks could be attributed to lherzolite. Primary minerals of the harzburgite are olivine (70-80% of the rock), orthopyroxene (20-30%) clinopyroxene (0-5%),

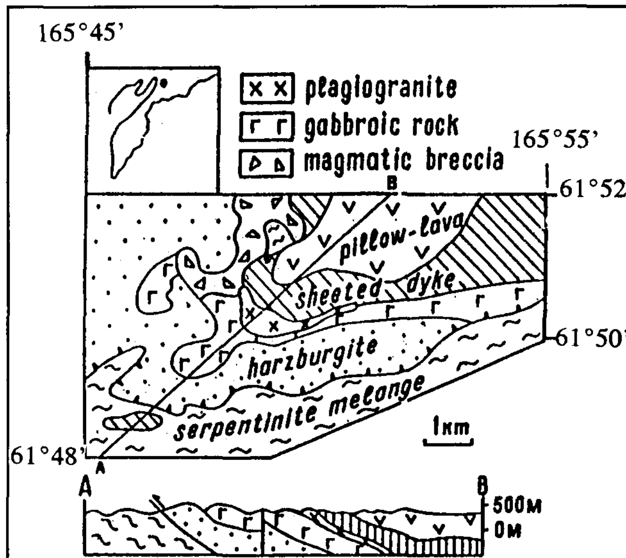

Fig.1. Geological scheme of the Gankuvayam ophiolitic section.

and chromium spinel (1-2%). Orthopyroxene, clinopyroxene, and chromium spinel form euhedral crystals among olivine grains, and the alteration of olivine and orthopyroxene produces a banded appearance. Some transformations due to dislocation metamorphism--like flexural cleavage cracks and cloudy crystal extinction--were observed.

Gabbro, troctolite, and wehrlite are interlayered. The modal classification of gabbro includes gabbro, gabbronorite, olivine gabbro, and olivine gabbronorite. Olivine gabbro predominates at the base and gabbronorite, commonly with olivine, in the upper part. Troctolites occur in the middle of a gabbro section. The troctolites consist of serpentinized olivine (40%), plagioclase (50%), and chromium spinel. Wehrlite consists of olivine (60-70%), clinopyroxene (20-30%), and chromium spinel. Little plagioclase or orthopyroxene was observed. Wehrlite beds vary in thickness from 0.5 to 15 m.

Veins of coarse-grained websterite and clinopyroxenite occur in the ultramafic part of the section. Their thickness varies from 10 to 30 cm to several meters. In the gabbroic section, veins are composed of fine-grained plagioclase-amphibole rocks.

Plagiogranites form lenses 40 to 60 m thick occurring between gabbroic rocks and dikes. Numerous inclusions of melanocratic rocks similar in composition to sheeted dikes were observed in the upper part of the plagiogranite bodies. Plagiogranite consists of granular quartz and plagioclase with normal zoning, amphibole, and a few clinopyroxene grains. Plagioclase and quartz intergrowths

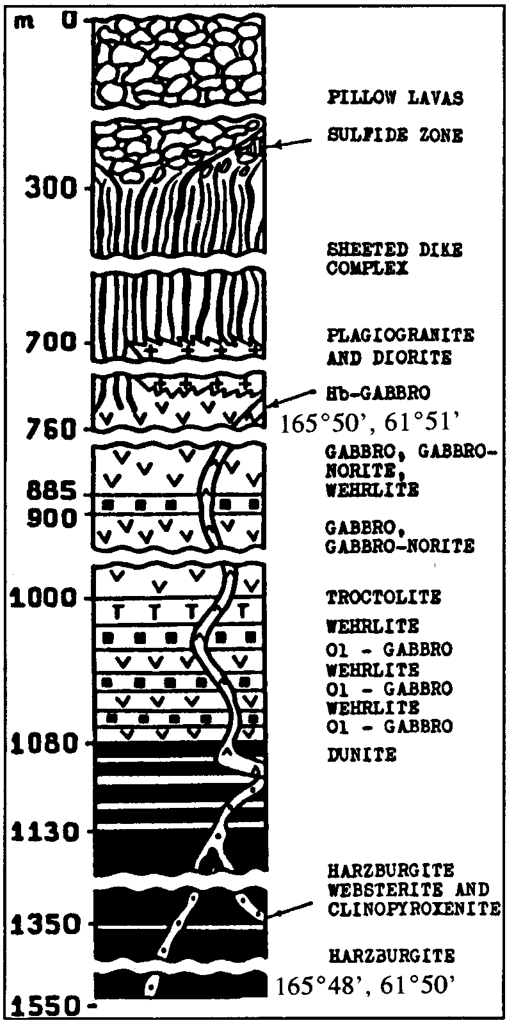

Fig.2. Stratigraphic column of the Gankuvayam section.

are characteristic.

Rocks with a doleritic texture predominate in dikes. Phenocrysts are andesine to labradorite, with minor pyroxene. The groundmass consists of plagioclase, augite, magnetite, and interstitial glass. Rocks with ophitic texture also occur (pyroxene dominates in microlithic mesostasis). There also are diabases containing quartz in phenocrysts. The extrusive portion of the cross-section consists mainly of spherulitic lava sheets with massive, rarely finely vesicular, structure, with beds of unsorted globular hyaloclastites in places. Petrographically, extrusive rocks are similar to dike rocks.

GEOCHEMISTRY

The major element composition and the contents of minor and rare elements in harzburgite, gabbro-troctolite-wehrlite, and plagiogranite rock complexes of the Gankuvayam section indicate that they are ophiolite assemblages. Compared with harzburgite, the gabbro-wehrlite portion of the section has lower XMg = 100 $Mg/(Mg+Fe^{+2})$ and high alkalinity. Gabbros contain very low TiO_2.

The chemical composition of basalt-dacite (icelandite) dikes and lavas indicates a common magmatic lineage and varies greatly from the typical oceanic basalts of Kuyul ophiolites. On the Ti-V diagram (Fig.3) they form isolated fields. Despite a high Na content in some, basalts generally fall into the field of the tholeiitic series. The geochemistry of the Gankuvayam pillow lavas is comparable to tholeiitic lavas of the supra-subduction zone. Chill-zone patterns indicate that the Gankuvayam thrust panel is an ancient spreading center preserving major oceanic hydrothermal metamorphic features and sulfide mineralization.

MINERAL CHEMISTRY

The chemical composition of minerals in 80 samples from the harzburgite, gabbro-wehrlite, plagiogranite, sheeted-dike, and pillow-lava portions of the section was studied using JXA-5A and Camebax microprobes. The results of the microprobe analyses are given in Table 1. In all cases the compositional trends of primary minerals in the Gankuvayam ophiolite are typical of those reported in residual mantle peridotite and cumulus ultramafic and gabbroic rocks of other ophiolite complexes (Coleman, 1977; Himmelberg and Loney, 1980; Pallister and Hopson, 1981; Loney and Himmelberg, 1984).

Chrome-aluminum spinel was analyzed in harzburgites, gabbros, and lavas. Spinel composition differs from alpine-type harzburgites in some lower magnesium content (Fig.4). On the $Cr-Al-Fe^{+3}$ diagram, spinel composition points align along the Cr-Al side, corresponding to the regular increase of alumina content from the center towards the grain edge (Fig.5). Relict spinel in gabbroids is similar in composition to that of harzburgites, but aluminous spinel also occurs here (Fig.5).

Olivine has high XMg in harzburgite (90-92%); it varies from 94 to 77 percent in the gabbro-wehrlite portion of the cross-section (Table 1). There is a direct relationship between XMg in coexisting olivine and chromium spinel.

The composition of ortho- and clinopyroxene is typical of ophiolite rocks. Crystallization temperatures calculated by use of the two pyroxene geothermometers (Wood and Banno, 1973; Wells, 1977) are similar and equal 977-1375°C for harzburgite, 1056-1230°C for wehrlite, and 918-1196°C for gabbro (Table 1). In dike and lava complexes, orthopyroxene is absent; and clinopyroxene has lower magnesium content in comparison with gabbro. Clinopyroxene compositions in the gabbroic and volcanic rocks plotted on discrimination diagrams of Leterrier et al. (1982) (not shown) indicate that the pyroxenes crystallized from a tholeiitic magma.

Plagioclase is represented by calcic varieties containing 70 to 90 percent anorthite. Grains are homogenous, indicating a slow cooling rate sufficient for chemical equilibrium.

DISCUSSION

The Late Jurassic-differentiated volcanic rocks of the Gankuvayam section differ sharply from typical oceanic basalts of the Triassic and Early Jurassic Kuyul ophiolites. Consequently, the Gankuvayam section represents a secondary spreading center in the oceanic crust. Geochemical data show that the Gankuvayam pillow lavas are comparable with tholeiitic lavas of a supra-subduction zone. Geological data suggest that the Gankuvayam spreading center developed accreted transversely to the Early Cretaceous active margin, and it is possible that the Gankuvayam spreading center compares favorably with the spreading centers of the Galapagos type (Khanchuk et al., 1990).

The Kuyul ophiolite is a roofless allochthon that can be regarded as a serpentinite melange underlying thrust panels composed of rocks belonging to the ophiolite assemblage and exotic fragments. The typical cross-section of the Kuyul ophiolite terrane is represented by interbedded siltstone, shale, volcaniclastic sandstone, conglomerate, limestone, and tuffite with a total thickness of approximately 10.5 km. Tithonian to Valanginian rocks that form part of the basement section crop out at lower structure levels. This complex underlier formed by the ophiolitic allochthon is represented by alevrolites and siltstone containing ammonitic fauna of Tithonian-Valanginian age. Hauterivian to Barremian deposits (turbidite-olistostrome units, including serpentinite melange) everywhere contain horizons of ophiolite-clastic olistostromes with *Buchia* and ammonite fossils, indicating intense accretion at that time. Olistostrome horizons within the Aptian to Albian part of the cross-section are very rare. Late Cretaceous and Paleogene marine to terrigenous deposits (molasse units) unconformably overlie basement rock of the ophiolitic allochthon.

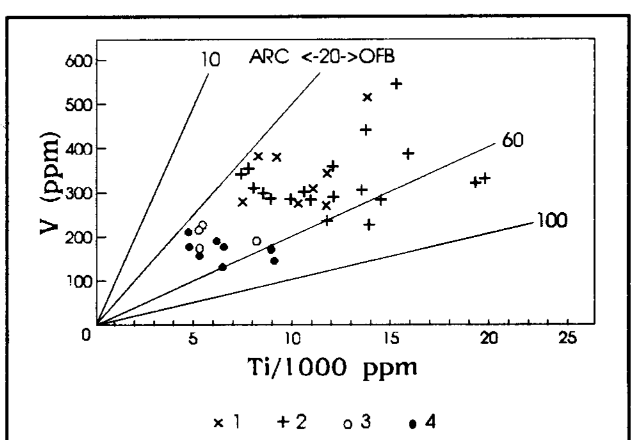

Fig. 3. Two types of basaltic rocks of the Kuyul terrane on the Ti-V diagram [Shervais, 1982]. 1-2 - Triassic-Early Jurassic basalts beyond the Gankuvayam section: 1 - to the north; and 2 - to the south; 3-4 - Late Jurassic Gankuvayam section: 3 - dikes, 4 - pillow-lavas.

The data obtained suggest a close genetic relationship causing a regular change of mineral assemblages upward in the Gankuvayam ophiolitic section. Gradual transitions between compositions of mineral assemblages in the ophiolite section are evidence for its unity. In the Gankuvayam section, high magnesium harzburgites, gabbro, and wehrlites associate with low magnesium-sheeted dikes and pillow lavas. Olivine and pyroxenes of harzburgites, gabbro, and wehrlites are notable for high magnesium content and chromium spinel for low magnesium content.

The lower part of the gabbro-wehrlite unit may be considered the basal cumulates corresponding to the solidified magma chamber at the crust-mantle boundary in the paleospreading zone; and higher levels of gabbro and plagiogranite appear to occur as simultaneous intrusions. The harzburgite is considered to represent the residium of partial melting and extraction of basaltic magma. The textures, limited mineral composition range, and general absence of mineral compositional zoning indicate that the layered gabbros are accumulates.

Table 1. Characteristic Major Minerals and Temperature of Crystallization of Ultramafic and Mafic Rocks from the Gankuvayam Section.

		XMG(%)			Spinel (%)		Temp
Sample Number	Rock Type	Olivine	Orthopyx	Clinopyx	XMg	XCr	Cryst(°)C
1. 8x42-4	Harzburgite	90	91	91	57	45	1058
2. 8x42-1	Harzburgite	91	92	92	59	53	1218
3. 8x47-1	Harzburgite	89	90	92	41	73	977
4. 9P82-3	Harzburgite	91	90	92	63	35	1010
5. 8x32-1	Harzburgite	92	90	94	31	62	1216
6. 8x32-4	Harzburgite	92	91	94	49	60	1375
7. 8x32-6	Harzburgite	92	92	94	55	57	1172
8. 9P75-7	Harzburgite	92	90	89	63	44	1015
9. 8x33-2	Dunite	92	92	90	50	65	1152
10. 8x33-4	Gabbro	75	79	86	35	69	1157
11. 8x33-6	Wehrlite	87	94	87	38	58	1056
12. 9P73-11	Wehrlite	86	87	91	34	48	1026
13. 9P77-1	Wehrlite	93	95	95	40	57	1048
14. 9P77-3	Dunite	89	92.	95	61	48	1093
15. 8x4-1-8	Gabbro	94	81	90	41	40	1152
16. 8x4-6	Wehrlite	91	82	90	28	57	1122
17. 8x4-9	Gabbro	89	90	89	78	8	995
18. 8x36-1	Troctolite	90	90	91	47	51	1034
19. 9P82-2	Gabbro-Norite	89	90	90	49	44	887
20. 9P83-2	Gabbro-Norite	87	68	89	33	56	849
21. 8x33-11	Gabbro-Norite	90	85	93	45	60	1156
22. 8x34-1	Gabbro	-	69	82	46	37	1016
23. 9P73-5	Wehrlite	92	93	94	73	34	1191
24. 9P73-9	Wehrlite	90	92	93	42	47	919
25. 9P73-12	Gabbro	87	88	89	35	54	957
26. 9P73-15	Wehrlite	90	92	89	37	46	948
27. 9P72-6A-1	Wehrlite	84	84	88	19	50	932
28. 8x34-4	Gabbro-Norite	-	91	91	67	35	1194
29. 8x35	Gabbro-Norite	-	87	81	56	47	1066
30. 9P74-3	Gabbro-Norite	-	85	86	47	62	989

Note: XMg = 100 Mg/(Mg+Fe^{+2}) XCr = 100 Cr/(Cr+Al). The temperature of crystallization was determined by two pyroxene geothermometers (Wood and Banno, 1973).

The full range of chromium spinel compositional data for Gankuvayam ophiolite is typical of peridotites that Dick and Bullen (1984) interpret as having complex multistage melting histories involving the development ofspreading centers on oceanic crust in the supra-subduction zones of ocean margins.

Thus, the Gankuvayam ophiolite section is the most complete, with respect to mineral assemblages, of ophiolite sections known in eastern Asia and could be recommended as a type section for studying the formation of ophiolites.

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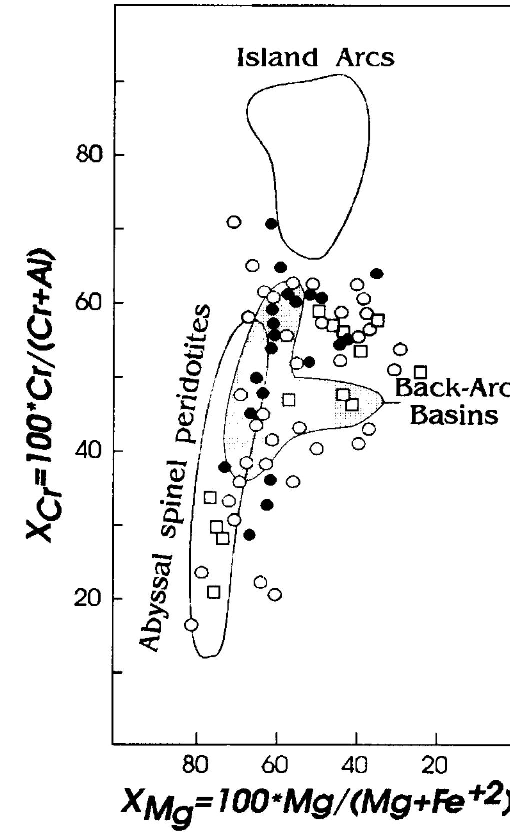

Fig.4. Composition of spinels from harzburgite and gabbro-wehrlite complexes (from Gankuvayam ophiolitic section). Dark circles - Harzburgites and dunites; Sguares - wehrlites; open circles - gabbros. Solid line - field of chrome-spinels of alpine-type peridotites. Dotted line - field of layered intrusives [Dick and Bullen, 1984].

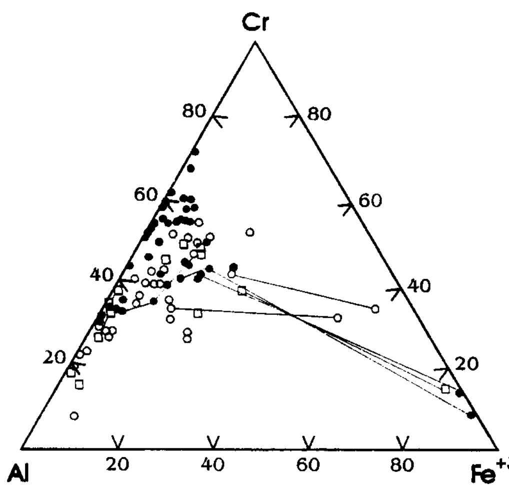

Fig.5. Composition of spinels from harzburgite and gabbro-wehrlite complexes on the Cr-Al-Fe+3 diagram. Dark circles - Harzburgites and dunites; squares - wehrlites; open circlrs - gabbros (From Gankuvajam ophiolitic section). Lines connect spinel compositions from the same sample.