

# Petrologic nature of the lower crust beneath the Japan arcs

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# 学 位 論 文 要 旨

## 学位論文題名

日本列島の下部地殻の岩石学的実体

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## 要約

Mafic xenoliths from two localities, Ichinomegata, Northeast Japan arc and Kurose, Southwest Japan arc, are investigated in this study to examine petrologic nature of the lower crust. Gabbroic xenoliths from Ichinomegata sometimes contain pyroxene-spinel symplectites between olivine and plagioclase as well as around plagioclase. Clinopyroxene and amphibole grains in symplectite show positive anomalies at Eu. These features, the mode of occurrence and chemical compositions, indicate that the symplectite minerals were formed by subsolidus reaction between olivine and plagioclase. In addition, these gabbros contain a large amount of amphiboles, some of which are obviously of secondary origin. In contrast, mafic-ultramafic xenoliths from Kurose do not contain any hydrous minerals and often contain a large amount of Al-rich spinel. Symplectic fine-grained mineral aggregates are found in one sample of spinel-rich websterite. All clinopyroxene grains in the spinel-rich mafic-ultramafic rocks exhibit positive spikes at Eu and Sr, which suggest that the clinopyroxene and Al-rich spinel were formed by subsolidus reaction between plagioclase and olivine. Some minerals (pyroxenes, spinel and amphibole) in mafic-ultramafic rocks from Ichinomegata and Kurose are of secondary origin. These mafic rocks originally contained larger amounts of olivine and plagioclase and were possibly olivine gabbros or troctolites before reaction and metasomatism.

## 学位論文要旨

There are a lot of localities of mafic-ultramafic xenoliths in Japan arcs. The information obtained from these xenoliths gives us petrologic constitute of the crust and the upper mantle beneath the Japan arcs. The mafic xenoliths from two localities, Ichinomegata, Northeast Japan arc and Kurose, Southwest Japan arc, are investigated in this study to understand petrologic nature of the lower crust beneath the Japan arcs. These mafic rocks have been metasomatized and/or metamorphosed at lower crustal conditions, which have changed their primary igneous properties.

I examined 10 samples of pyroxene-hornblende gabbros and one sample of pyroxene-hornblende gabbronorite. The pyroxene-hornblende gabbronorite is far less abundant pyroxene-hornblende gabbro, hornblende gabbro and other mafic rocks (e.g. hornblendite) in Ichinomegata. These gabbroic xenoliths contain pyroxene-spinel symplectites between olivine and plagioclase as well as around plagioclase. The symplectites consist of

clinopyroxene, amphibole, spinel and orthopyroxene, and their clinopyroxene and amphibole are different in composition from coarse-grained discrete ones; the former show lower  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$  and REE contents than the latter and show a positive anomaly at Eu. These features in the mode of occurrence and chemical compositions indicate that the symplectite minerals were formed by subsolidus reaction between olivine and plagioclase. Additionally, these gabbros contain a large amount of amphiboles, some of which are obviously of secondary origin, replacing discrete clinopyroxenes and constituting a part of symplectites. These secondary amphiboles are enriched in K, Rb and Ti relative to the other minerals, and their metasomatic formation was accompanied with addition of, at least, these elements. The metasomatism was caused by infiltration of fluid possibly released from hydrous arc magmas.

I also examined 13 samples of granulites and 7 samples of ultramafic rocks (3 websterites and 4 lherzolites). Mafic-ultramafic xenoliths from Kurose show granulose textures and do not contain any hydrous minerals. They often contain a large amount of Al-rich spinel. Fine-grained mineral aggregates composed of clinopyroxene and spinel similar to the symplectite in Ichinomegata gabbros, are observed around plagioclase in one sample of spinel-rich websterite. Clinopyroxenes in the symplectitic mineral aggregates show positive spikes at Eu and Sr, which suggest their formation by subsolidus reaction between olivine and plagioclase. It is noteworthy that all clinopyroxene grains in spinel-rich granulite and ultramafic rocks also show positive spikes at Eu and Sr. Modal amounts of pyroxenes and spinels are not in accordance hypothetical ones assuming model reaction ( $\text{Ol} + \text{Pl} = \text{Opx} + \text{Cpx} + \text{Spl}$ ) and some mineral compositions calculated with least-square method. This possibly means that not all pyroxenes and spinels were originated from olivine and plagioclase. These minerals originated from olivine and plagioclase in spinel-rich rocks have attained to equilibrium with relics of primary igneous minerals.

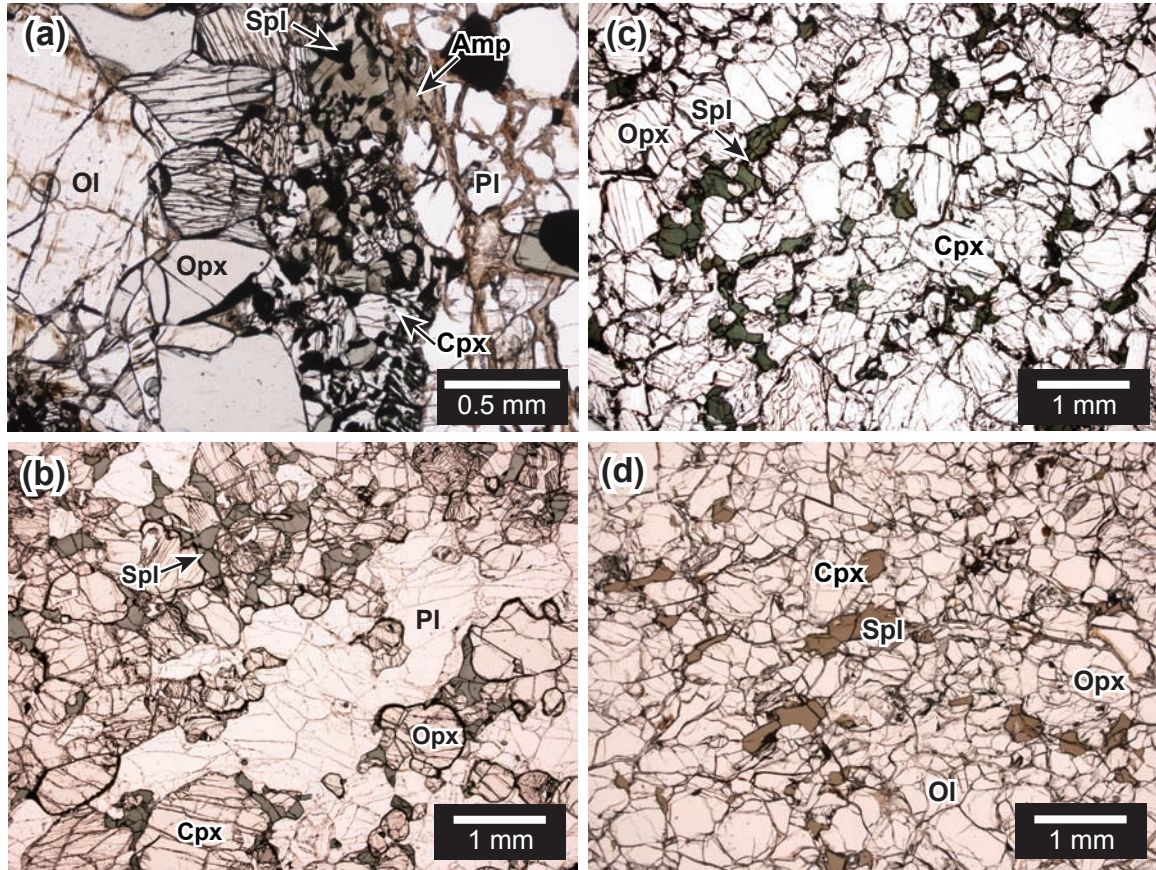
Some minerals (pyroxenes, spinel and amphibole) in the studied samples from Ichinomegata and Kurose are of secondary origin. These rocks have changed their primary igneous features (mineral assemblage and/or chemical composition), and originally contained larger amounts of plagioclase and olivine. They were possibly olivine-bearing (< 22 vol%) pyroxene-hornblende gabbros, hornblende-free olivine gabbros and troctolite in Ichinomegata before the subsolidus reaction and metasomatism. Spinel-rich mafic-ultramafic rocks from Kurose were probably olivine gabbros and troctolites before the metamorphism. It is difficult to specify details of the magma involved in formation of precursor rocks of the Kurose spinel-rich rocks, but it was possibly a MORB-like melt, which could commonly form troctolites and olivine gabbros.

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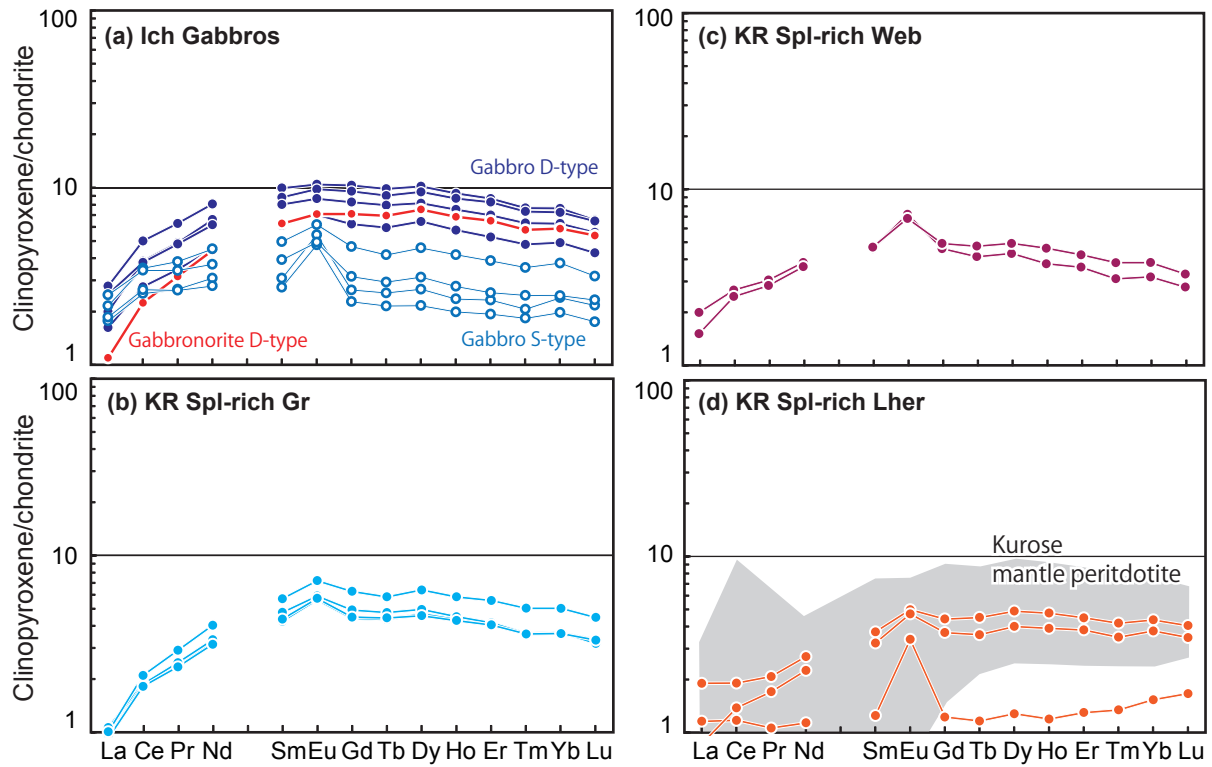
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**Figure 1.** Location of Ichinomegata, Northeast Japan arc and Kurose, Southwest Japan arc.



**Figure 2.** Photomicrographs of studied samples. Amp, amphibole; Cpx, clinopyroxene; Opx, orthopyroxene; Pl, plagioclase; Ol, olivine; Spl, spinel. (a) Pyroxene-spinel symplectite composed of orthopyroxene, clinopyroxene, spinel and amphibole in a pyroxene-hornblende gabbro from Ichinomegata (Ich-M031; plane-polarized light). It is characteristically observed between plagioclase and olivine. Minerals in symplectites are smaller in size than other minerals. (b) Granoblastic texture of a Spl-rich granulite from Kurose (KR-015; plane-polarized light). Note the large amount of green spinel. (c) Equigranular texture of a Spl-rich websterite from Kurose (KR-22; plane-polarized light). Note the large amount of green spinels. (d) Fine-grained Spl-rich lherzolite from Kurose (KR-P001; plane-polarized light). Note the difference in color of spinel between granulite and websterite (b,c).



**Figure 3.** Chondrite-normalized rare earth element patterns of clinopyroxene in the studied samples; gabbros from Ichinomegata (a), Spl-rich granulite from Kurose (b), Spl-rich websterite from Kurose (c) and Spl-rich lherzolite from Kurose (d). Data were averaged for each sample. (a) Discrete-type clinopyroxenes and symplectite-type ones show different patterns and levels of concentration. Chondrite values are from Sun and McDonough (1989). Data for mantle peridotites from Kurose (Abe et al. 1998; Yoshikawa et al. 2010) are shown for comparison.



## 学位論文審査報告書（甲）

## 1. 学位論文題目（外国語の場合は和訳を付けること。）

日本列島下部地殻の岩石学的実体

## 2. 論文提出者 (1) 所 属 環境科学 専攻

(2) 氏 名 武内 美佑紀

## 3. 審査結果の要旨（600～650字）

武内美佑紀氏は、島弧の下部地殻の岩石学的実体およびその成因を明らかにするために、東北日弧を代表する目潟、西南日本弧を代表する黒瀬の捕獲岩を詳細に検討し以下の結果を得た。前者ではウェブステライト～様々なガブロ類が下部地殻付近の岩石を代表している。ガブロ中ではかんらん石と斜長石の反応 および角閃石の形成が顕著に認められる。これらはほぼ同時に起きており、水とともに LIL 元素および鉄（特に三価）が付加され、比較的酸化的環境を示す。この下部地殻交代作用は上部マントルのそれと整合的である。一方黒瀬では、ウェブステライト～グラニュライトが下部地殻付近起源と考えられる。多くのものが緑色スピネルを含み、かんらん石と斜長石は共存しない。単斜輝石は Eu, Sr 等に正の異常が認められ、その傾向はスピネルに富む岩石ほど顕著となる。従ってこれらの岩石の特徴は、冷却に伴うかんらん石と斜長石の反応によって形成されたと考えられる。一部のレーゾライトもスピネルに富み、同様の鉱物化学的特徴を示す。従って、原岩はトロクトライト（一部は斜長石かんらん岩）と考えられる。この変成作用では元素の移動は認められない。これら両地域から読み取れる変成・交代作用は下部地殻の岩相を劇的に変化させ、モホを複雑化あるいは移動させた。これらの研究結果は島弧の下部地殻の岩石学的実体を明らかにしたものとして高く評価される。英語力も十分であると判断される。従って、本論文が武内美佑紀氏に博士（理学）の学位を与えるのにふさわしいものと判断する。

## 4. 審査結果 (1) 判 定 (いずれかに○印) 合 格 ・ 不合格

(2) 授与学位 博 士 ( 理 学 )