# マントル溶融過程の多様性:特にメルト移動の場におけるメルト/マントル相互反応の重要性について

| | |
|---|---|
| 氏　　　　名 | 松　影　香　子 |
| 生　年　月　日 | |
| 本　　　　籍 | 京都府 |
| 学 位 の 種 類 | 博士（理学） |
| 学 位 記 番 号 | 博甲第255号 |
| 学位授与の日付 | 平成10年3月25日 |
| 学位授与の要件 | 課程博士（学位規則第4条第1項） |
| 学位授与の題目 | マントル溶融過程の多様性：特にメルト移動の場におけるメルト／マントル相互反応の重要性について |
| 論 文 審 査 委 員 | （主査）荒井　章司 |
| | （副査）田崎　和江，石渡　　明，寅丸　敦志，宮下　純夫 |

# 学位論文要旨


**Abstract**

This paper reports the igneous petrology and mineral chemistry of peridotite and/or coexisting gabbroic impregnations of the four peridotite complexes, the Ochiai-Hokubo peridotite complex, Horoman peridotite complex, Hess Deep and Moho transition zone of Oman ophiolite, to understand the mantle igneous prosesses. I concluded that the complexes were produced by two contrasting melting and crystallization processes during melt transport in the upper mantle. The first process is melting and melt extraction which forms the simple residual peridotites. The second process is the interaction between more primitive melt and peridotites of the uppermost mantle which produces the plutonic rocks with ﾒunusualﾓ chemical features. It is considered that the melt/mantle interaction is essential to understand the origin of the basaltic magma and residual plutonic rocks after melt migration, because the interaction process can extremely modify the primitive melt by partial melting of peridotite into ﾒunusualﾓ melt enriched with both Cr and some incompatible elements (e.g., Ti, Na, H2O), and make strange plutonic rocks.


Introduction

The chemical composition of magma which erupts at the Earthﾕs surface differs to various extent from that of the primary melt. The four peridotite complexes, the Ochiai-Hokubo peridotite complex, Horoman peridotite complex, Hess Deep peridotites and coexisting gabbros, Moho transition zone of Oman ophiolite are compared with one another, to understand the diversity of melting and melt migration processes in the upper mantle. The purpose of this paper is to present the description of the occurrence of the rocks (peridotites and/or coexisting gabbros) in the four peridotite complexes, and to demonstrate some examples of melt/mantle interaction. I especially discuss the petrographical diversity of reaction products and significance of melt/mantle interaction.

**Horoman peridotite complex**

The Horoman complex, the Hidaka Zone, Hokkaido, mainly consists of plagioclase lherzolite, spinel lherzolite, spinel harzburgite, dunite and wehrlite. Many studies have been done on this complex (e.g., Niida, 1984; Obata and Nagahara; Takahashi, 1991, 1992; Takazawa et. al., 1992; Ozawa and Takahashi, 1995). The complex has a well developed compositional layering which is made up of harzburgite-lherzolite and dunite-wehrlite. Harzburgite and lherzolite have the porphyroclastic texture, and the minerals usually have textures of deformation such as wavy extinction and kink band. In the harzburgite and lherzolite, Cr# (=Cr/(Cr + Al) atomic ratio) of spinel widely varies, from 0.08 to 0.68. The Cr# of spinel rapidly increases with an increase of Fo content of coexisting olivine (from 88.8 to 92.8). The Ti content of spinel and clinopyroxene is low ($TiO2 < 0.3wt\%$). The Cpx/(Cpx + Opx) ratio rapidly decreases with an increase of Cr# of spinel, and is around 0.1 when Cr#=0.5 and is almost nil when Cr#>0.6. The Horoman harzburgite and lherzolite is similar to ordinary mantle peridotite (e.g., Dick and Bullen, 1984; Arai, 1994) on texture, modal and chemical compositions.

**Ochiai-Hokubo peridotite complex**

The Ochiai-Hokubo complex, the Sangun zone, southwest Japan, is similar to Horoman complex in petrography, but have some important differences. The Ochiai-Hokubo complex mainly consists of spinel lherzolite, spinel harzburgite, dunite and wehrlite, which show alternation of harzburgite-lherzolite and dunite-wehrlite. In harzburgite-lherzolite, Cr# of spinel varies in the same way as Horoman, from 0.15 to 0.78. On the other hand, other mineral chemistry is different between the two complexes. In the Ochiai-Hokubo harzburgitelherzolite, Fo content of olivine (mostly 88-90) is not correlated with the Cr# of spinel, and Ti content of spinel and clinopyroxene is higher in rocks with Cr-rich spinel than lherzolite with Cr-poor one. Cr-rich spinel (Cr#>0.5) coexists with relatively coarse diopside (up to 1mm across). These observations indicate that the Ochiai-Hokubo harzburgite-lherzolite is different from ordinary mantle peridotite. In other words, ẋunusualŧ Cr-rich lherzolite (with Cr-rich spinel and coarse diopside) exists in this complex. The Cr-poor lherzolite is the only rock that has ordinary texture, modal and chemical compositions of the mantle in the Ochiai-Hokubo complex.

**Hess Deep**

Hess Deep is located just to the east of East Pacific Rise and on the western tip of NazcaCocos spreading center (e.g., Gillis, M思el, Allan et al., 1993). Various ultramafic-mafic pltonic rocks, spinel harzburgite, dunite, troctolite and olivine gabbro were drilled at Hess Deep during ODP Leg147. Olivine gabbro and troctolite are frequently accompanied by dunite in harzburgite. The feldspathic rocks are very heterogeneous: the lithology frequently changes from olivine gabbro to dunite through troctolite with gradual contacts in small distance. This relationship suggests that troctolite and olivine gabbro are similar to so-called indigenous dike with depletion aureole within harzburgite in some ophiolites (see below; e.g., Nicolas 1989). Harzburgite has weak porphyroclastic texture. Feldspathic rocks are composed of olivine, plagioclase, clinopyroxene and chromian spinel. Olivine is coarse and rounded in shape and often shows deformation texture. Plagioclase and clinopyroxene are anhedral and interstitial to olivine grain. A mini-pod of chromitite (about 2x3x10cm) was found in dunite. Numerous mineral inclusions, which consist a few grains of diopside, enstatite, jadeite, nepheline, albite, pargasite, K- and Na-phlogopites and olivine, are found in spinel in the chromitite and in troctolite. Harzburgite has olivine with Fo=91~91.5 and spinel with Cr#=0.5~0.6, $TiO_2 < 0.3$wt%, belonging to most refractory group of the ordinary abyssal peridotite from upper mantle. The dunite-troctolite-olivine gabbro are characterized by enigmatic chemical variations of clinopyroxene and spinel (Fig. 1). $TiO_2$ content of clinopyroxene, which is one of incompatible components, rapidly increases, from 0.2 to 2 wt%, while Mg# (=Mg/(Mg + $Fe^{2+}$) atomic ratio) and $Cr_2O_3$ content remain relatively constant, about 0.9 and 1.2wt% respectively. Spinel is also highly variable in $TiO_2$, from 0.4 to 2.8 wt%, while Cr# is constant or slightly increase. These rocks, enriched both in some incompatible elements such as Ti, Na and in compatible elements such as Cr and Mg, are "unusual" and quite different from the chemical trends expected for cumulate (e.g., Atkins, 1969) and mantle peridotite (see above, Horoman harzburgite-lherzolite).

**Moho transition zone of Oman ophiolite**

The Oman ophiolite has been known as one of the best exposed paleo-oceanic crustmantle slices (e.g., Coleman 1977; Nicolas, 1989). Lithology of the Moho transition zone (MTZ) of Oman ophiolite is highly variable. The MTZs at Wadi Hilti and Wadi Fizh consist of harzburgite, dunite and impregnations of olivine gabbro and troctolite. On the other hand, the MTZ at Wadi Farfar mainly consists of thick dunite and harzburgite, and feldspathic rocks are almost absent.

In the MTZ at Wadi Hilti, the dunite-troctolite-olivine gabbro suite in harzburgite is very similar in petrography to Hess Deep rocks except for the abundance of orthopyroxene. The feldspathic rocks are very heterogeneous: the litology gradually changes from olivine gabbro through troctolite to dunite. Troctolite and olivine gabbro sometimes exist as network of irregular sills and dikes with dunite aureole. The rocks from the MTZ of Wadi Hilti is also very similar in mineral chemistry to Hess Deep. Harzburgite has olivine with Fo=90.2~91.5 and spinel with Cr#=0.54~0.6, $TiO_2 < 0.5$wt%. In the dunite-troctolite-olivine gabbro suite, $TiO_2$ contents of spinel and clinopyroxene change from 0.2 to 2.0wt% and from 0 to 1.0wt%, while the content or ratio of compatible elements are rather constant. These observations suggest that the rocks from the MTZ at Wadi Hilti have the same origin as the Hess Deep rocks.

**Discussion and conclusion**

The lherzolite and harzburgite in the Horoman complex are simple residual peridotite which were formed by melting and melt extraction (Takahashi, 1992). On the other hand, the texture, mineral chemistry and modal compositions of Cr-rich lherzolite in Ochiai-Hokubo complex, and dunite-troctolite-olivine gabbro complexes in Hess Deep and in the MTZ at Wadi Hilti, can be hardly explained by both simple partial melting of mantle peridotite and simple crystal accumulation from a melt. The petrographical and chemical variations suggest that both the Cr-rich lherzolite and the dunite-troctolite-olivine gabbro complexes are the products of interaction between nearly anhydrous, infiltrating melts and wall rock peridotites at melt conduit in upper mantle. However, the interaction product of Ochiai-Hokubo peridotite complex is extremely different from those of Hess Deep and Wadi Hilti of Oman ophiolite. The difference between these complexes possibly reflects the differences of the wall rock and condition of the interaction. The Ochiai-Hokubo harzburgite-lherzolite is due to interaction between the melt and the lherzolite at spinel lherzolite stability conditions (about >8 kbre). On the other hand, the melts reacted with harzburgite at plagioclase lherzolite stability conditions (< 8kber) in Hess Deep and in MTZ of Oman ophiolite, because of the coexistence of plagioclase and Mg-rich olivine and of the evidence for reaction relation between orthopyroxene and melt in Hess Deep troctolite (Arai and Matsukage, 1996). The unusual mineral chemistry also can be explained by the interaction process. The content and ratio of compatible elements such as Cr and Mg# were buffered by the dissolution of pyroxene, especially orthopyroxene of wall peridotites, and Ti enrichment resulted from a kind of partial zone melting as the melt infiltration through wall peridotite (Fig. 1). The melt/mantle interaction may be more effective in failed melt channel, and produces the strange plutonic rocks in apparent disequilibrium with simultaneous effusive rocks.

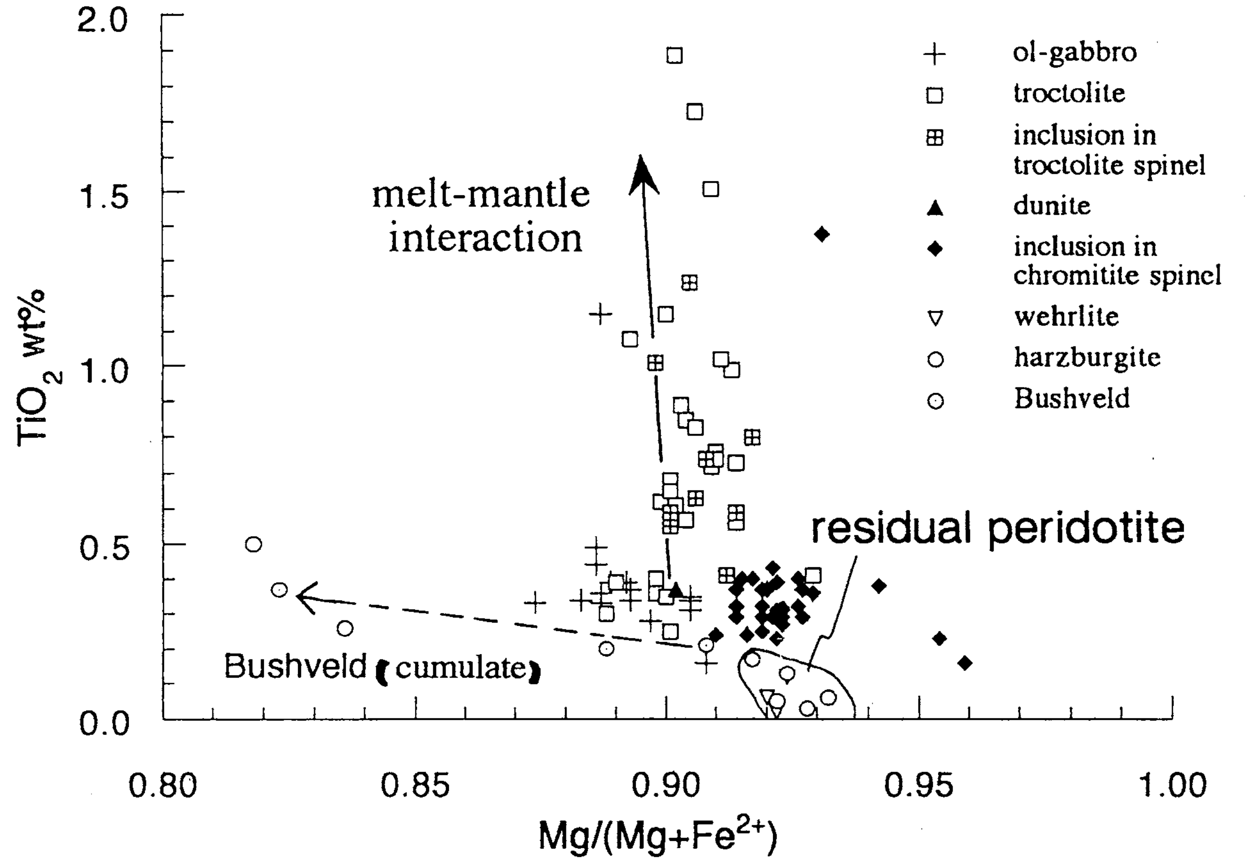


**Fig. 1** Relationship between $Mg/(Mg+Fe^{2+})$ atomic ratio and $TiO_2$wt% of diopsidic clinopyroxene in Hess Deep rocks. Hess Deep Data are after Arai and Matsukage (1996) and Matsukage and Arai (1998). Bushveld data arc after Atkins (1969). Bushveld trend is for cumulates by crystal fractionation. Solid arrow indicates the mantle-melt interaction trend which was deduced from the Hess Deep plutonic rocks by Arai and Matsukage (1996).

## 学位論文審査結果の要旨

2月3日に最終発表を行い，その後第2回審査委員会を開催した。1月27日の第1 回審査委員会の結果と合わせ，以下の結論を得た。
本研究は，上部マントル起源物質の多様性の解析をもとに，マントルにおける溶融作用の多様性を議論したものである。上部マントル起源物質としていくつかの異なった性質を有する固体貫入かんらん岩体を対象とした。それらは，落合－北房岩体（西南日本），ヘス・ディープ（太平洋の海底に露出），オマーン・オフィオライトのモホ遷移帯および幌満岩体（北海道）である。松影さんはまず，これらの野外調査，室内での綿密な解析を通して，共通点，相違点を洗い出した。そしてこれらの共通点はメルト成分の除去によることを明らかにした。また，相違点はメルトとかんらん岩の反応（メルト／マントル相互反応）の様態の違いにあるとし，それはメルトの移動速度に大きく依存することを予想した。これらの成果のうち，海洋底マントルでのメルト／マントル相互反応の重要性を明らかにした点，およびオフィオライトのモホ遷移帯の岩石学的性質を初めて明らかにした点が特に注目される。これらの成果のいくつかは，すでに学術誌に公表されている。多くの新事実を次々に明らかにした松影さんの野外，室内における観察眼の鋭さは特筆すべきものがある。また，論文では詳述されていないが，理論的考察にも優れたものがあり，記載結果に重みを与えている。したがって，本論文は博士（理学）を授与するのに十分な内容を有していると判断できる。