学　位　論　文　要　旨

学位論文題名

Along-ridge diversity of melt migration processes in the mantle:
implications from the northern Oman ophiolite

学位論文題名（邦訳）

マントルにおけるメルト輸送過程の海嶺方向の多様性：北部オマーンオフィオライトの例

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要約

The Oman ophiolite is the most extensively exposed ophiolite the world over, 500 km in NW-SE and 50-100 km in EW. It allows us to observe three-dimensional oceanic lithosphere on land, and provides information on the whole picture from its generation at the mid-ocean ridge to the end of magmatism when obducted on land. Dunite bands and dikes in the mantle section of the Oman ophiolite are interpreted as fossil melt channels within the suboceanic mantle. In particular, concordant dunite bands are of possible importance as the melt channels through which parental melts of MORB (mid-ocean ridge basalt) were transported to shallower mantle beneath the paleoridge axis. However, no comprehensive petrological data of concordant dunite bands and their ambient peridotites along a ridge segment have been published. I conducted sampling, field and microscopic observations, and chemical analysis of concordant dunite bands and their ambient peridotites from various “stratigraphic levels” in the mantle section along a paleoridge segment at the northern Oman ophiolite. I also conducted numerical modeling by using these data to clarify the diversity of melt-migration processes within suboceanic upper mantle beneath a fast spreading mid-ocean ridge. I took the segment structure into consideration because of difference in geotherm along the ridge segment, which possibly induces various melt migration processes.

学位論文要旨

Dunite bands and dikes in the ophiolitic mantle peridotite are interpreted as fossil melt channels within the suboceanic mantle. In particular, concordant dunite bands are of possible importance as the melt channels through which parental melts of MORB (mid-ocean ridge basalt) were transported to shallower mantle beneath the paleoridge axis. However, no comprehensive petrological data of concordant dunite bands and ambient peridotites along a ridge segment have been published. I conducted sampling of concordant dunite bands and their ambient peridotites from various “stratigraphic levels” in the mantle section along a paleoridge segment at the northern Oman ophiolite (Fig. 1). The Oman ophiolite is a fragment of Tethyan oceanic lithosphere formed at a fast spreading center. It allows us to observe three-dimensional oceanic lithosphere on land, and provides information on the whole picture from its generation at the mid-ocean ridge to the end of magmatism when obducted on land. The concordant dunite bands here are various both in thickness (few millimeters to few meters) and in frequency of appearance, and their boundaries with peridotites are sharp. The dunites are almost free from clinopyroxenes, which, if any, are tiny and interstitial to olivines and spinels.

I selected 28 outcrops from the mantle section of the northern Oman ophiolite (Fig. 1). I numbered them as T-1 ~ T-10 (Wadi Thuqbah), R-1 ~ R-3 (Wadi Rajmi), Z-1 (Wadi Zabin), F-1 ~ F-6 (Wadi Fizh), H-1 (Wadi Hilti), S-1 ~S-4 (Wadi Sarami), Ry-1 (Wadi Rayy), U-1 (Wadi Umm al Hasa) and K-1 (Wadi Khudayrah). The mantle section is classified into five subsets for simplicity; "uppermost mantle section" is within few tens of meters below the MTZ, "upper mantle section" is within up to 5 km-wide zone in plan to the west of the MTZ, "middle mantle section" is from 5 km to 10 km-wide zone in plan to the west of the MTZ, "lower mantle section" is from over 10 km-wide zone in plan to the west of the MTZ, and "basal section" is located at the base of the Oman ophiolite, which is above the metamorphic sole. I assume the outcrops along Wadi Thuqbah (T-1 ~ T-10) are derived from the center of a second-order paleoridge segmentation (segment center), whereas other outcrops (R-1 ~ R-3, Z-1, F-1 ~ F-6, H-1 and S-1 ~ S-4) are uncertain which part of the paleoridge segmentation they are derived from, although I regard them as having been derived from a distal part of a segment, possibly a segment end. In the other outcrops (Ry-1, U-1 and K-1), the MORB-related magmatism had been overprinted by off-ridge magmatism.

Most of the concordant dunite bands overlap in major-element compositions with their ambient peridotites, however some of them show rather lower Cr/(Cr + Al) atomic ratio (< 0.50) of chromian spinels (Figs. 2a and b), and higher Al_2O_3 (up to 4.0 wt%) and Cr_2O_3 (up to 1.3 wt%) of clinopyroxenes (Figs. 2c and d) in the uppermost mantle section than in the lower mantle section. In the ambient peridotites of dunite bands, trace-element (rare earth elements: REE with Sr, Zr, Ti and Y) patterns of clinopyroxene incline from heavy-REE (HREE) to light-REE (LREE) abruptly, whereas they show various shapes in dunites, depending on the stratigraphic levels along the paleoridge segment, most of them are gently to steeply declining from HREE to LREE (Figs, 3a, b and f), some are spoon-shaped at the lower to middle mantle section in the segment center (Figs. 3c and d), and those of the concordant dunite band at outcrop F-5 are heterogeneous in LREE to MREE contents even within a thin section (about 4 cm long by 2 cm) (Fig. 3e).

I suggest various melt migration processes in the mantle section based on different appearances of the dunite bands in the field and their mineral chemical characteristics along the paleoridge segment. I conducted numerical modeling (1-D steady state modeling) for clarifying a variety of the melt migration processes in the mantle section by using trace-element compositions of clinopyroxene. The modeling duplicates simple fractional melting and influx melting processes. The results indicate that LREE-enriched melt generated at higher pressure conditions flowed through a melt channel until shallower mantle section (less than 10 km to the MTZ), where such LREE-enriched melt mingled with highly depleted melts generated at lower pressure conditions, and N-MORB-like melts were generated as a consequence. Some melt channels mainly transported the highly depleted melts at the shallower mantle section, which occasionally precipitated orthopyroxene-rich rocks like orthopyroxenites along the melt channel. Another numerical modeling (plate model) suggests the fracture-related melt transport with chromatographic melt percolation into the wall peridotite in the uppermost mantle section at the paleoridge segment end. These variations in the melt migration process resulted from a difference in mantle geotherm along the paleoridge segment related to the active mantle upwelling, e.g., higher at the segment center and lower at the segment end at a given stratigraphic level.

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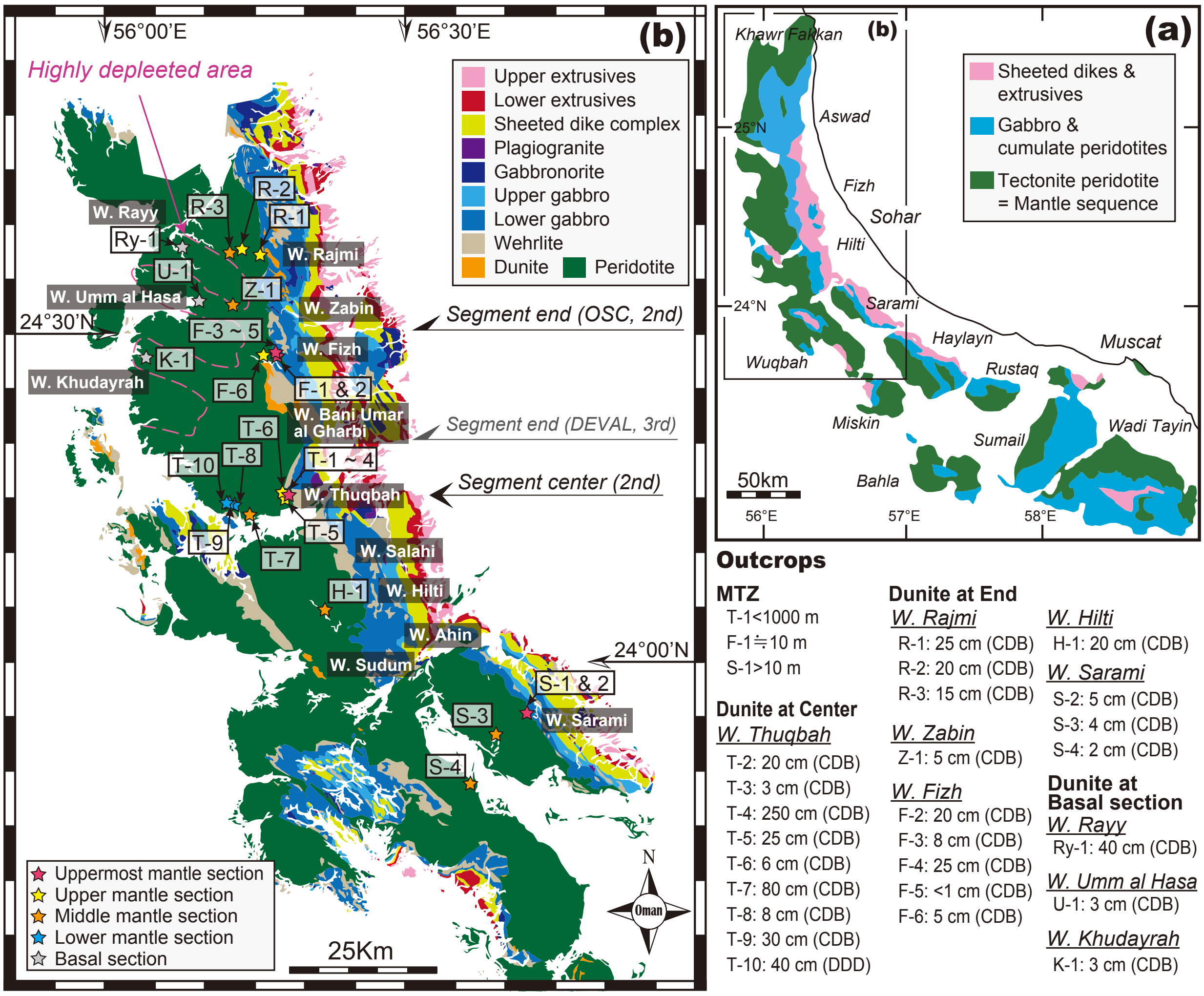

Figure 1

Geological maps. (a) Simplified geological map of the Oman ophiolite modified from Lippard et al. (1986). (b) Distribution of rocks in the northern Oman ophiolite with distribution of the outcrops that were examined here. Modified from the 1:250,000 geological maps of Buraymi and Ibri (Ministry of Petroleum and Minerals, 1992a, b). Paleoridge segment structures are quoted from Adachi & Miyashita (2003), Miyashita et al. (2003) and Umino et al. (2003). Area of highly depleted peridotites is enclosed by dashed line (Suetake & Takazawa, 2012). Abbreviations: Center = segment center, End = segment end, MTZ = Moho transition zone, CDB = concordant dunite band, and DDD = discordant dunite dike.

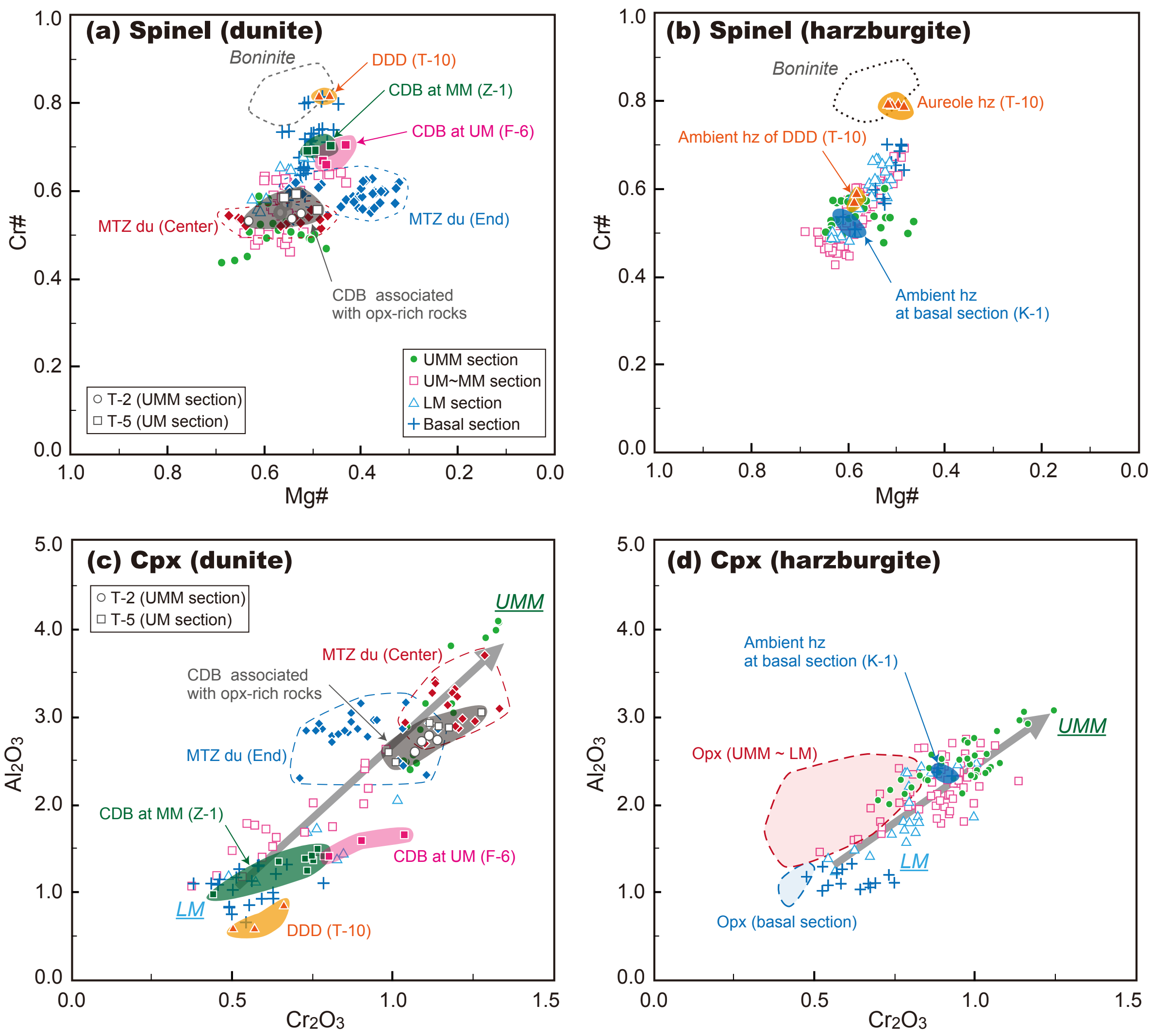

Figure 2

Mineral chemical characteristics of dunites (du) and their ambient harzburgites (hz). (a and b) Variations of Cr# [Cr/(Cr + Al) atomic ratio] and Mg# [Mg/(Mg + Fe) atomic ratio] in chromian spinel. The boninite fields are modified from Tamura and Arai (2006). (c and d) Variations of Al_2O_3 and Cr_2O_3 in clinopyroxene and orthopyroxene. The ranges of chemical composition of orthopyroxene are shown in red for the lower to uppermost mantle section, and in blue for the basal section. The arrowed thick lines show a systematic change in chemistry from the lower mantle (LM) section to the uppermost mantle (UMM) section through the middle mantle (MM) section and the upper mantle (UM) section of this study. Abbreviations are the same with Figure 1.

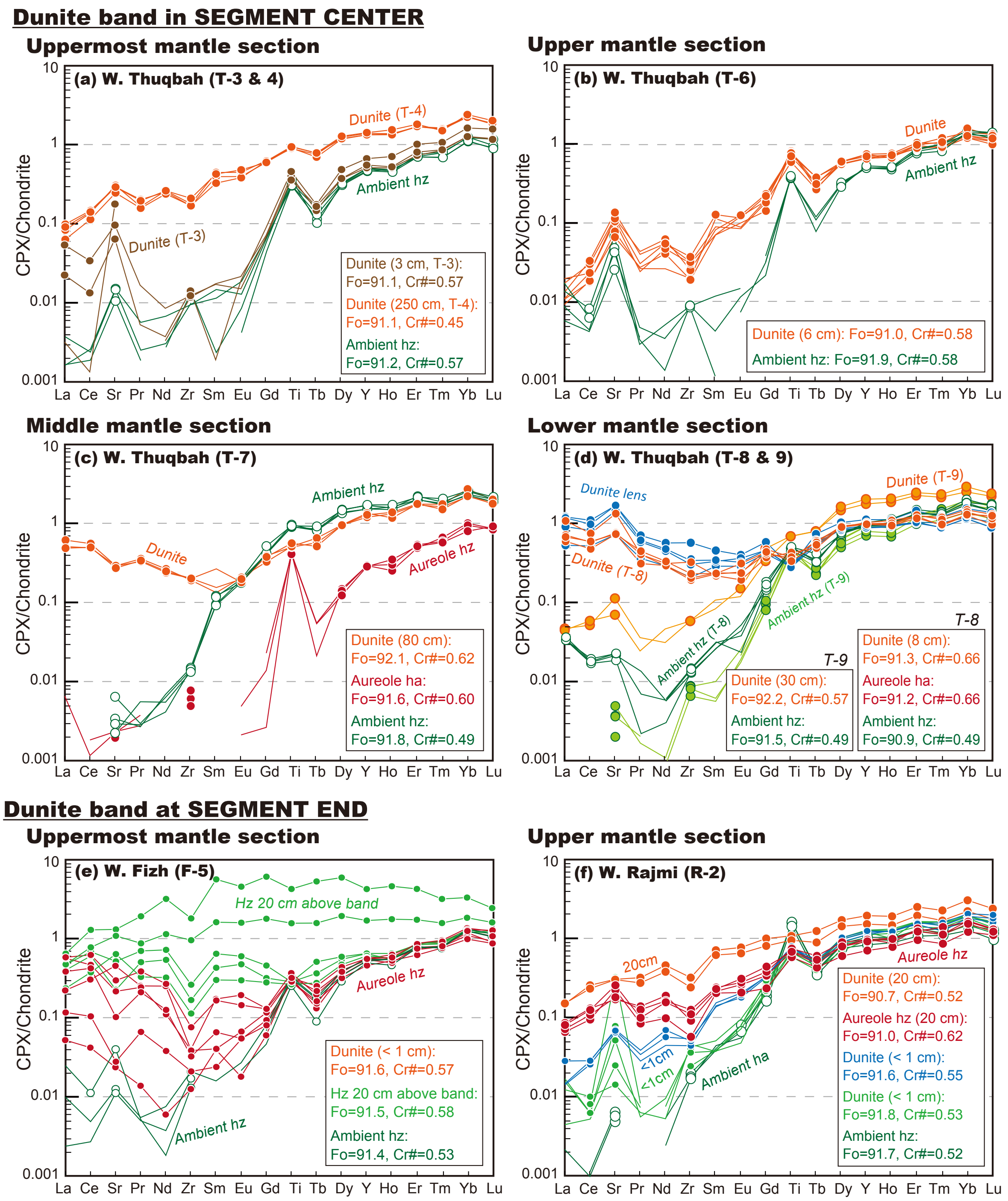

Figure 3

Chondrite-normalized trace-element patterns of clinopyroxene in dunites and their ambient harzburgites (hz). (a-d) Segment center. (e and f) Segment end. The harzburgite about 20 cm away from the dunite/harzburgite boundary (Hz 20 cm above band) is exceptionally enriched in trace elements of clinopyroxene at outcrop F-5 (e). Lithology and mineral chemistry are shown in rectangle boxes. Fo and Cr# are mean values. Chondrite values are from Sun and McDonough (1989). Symbols are not put for the data below the detection limits.

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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。）

Along-ridge diversity of melt migration processes in the mantle: implications from the northern Oman ophiolite（マントルにおけるメルト輸送過程の海嶺方向の多様性：北部オマーンオフィオライトの例）

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3．審査結果の要旨（600～650 字）

秋澤紀克氏は，海嶺方向のマントル中のマグマ輸送過程の多様性を知るために，オマーンオフィオライト北部のマントル部を調査研究した。特に，調和性ダナイトおよびその周囲のマントルかんらん岩を詳細に検討し，その産状（厚さや分布）および化学組成に、海嶺方向および深さ方向の変化があることを確認した。彼は，それを海嶺セグメントのマントル中の温度構造の違い（中心部では地温こう配が高く，末端部では低い）に起因するとした。秋澤氏はさらに，単斜輝石の REE（希土類元素）組成を使用した数値モデル計算を行った。その際にかんらん岩のモード組成，部分溶融度，流入するフラックスの組成，流入率等について妥当な仮定を行った。それにより，海嶺下における初生マグ生成およびマグマの輸送過程の多様性を説明するモデルを提出することに成功した。さらに，ダナイトの周囲のかんらん岩の単斜輝石の REE 組成を，メルト通路（ダナイト）からのメルトの浸入により説明することに成功した。以上により，60～70km 以浅のマントルにおけるマグマの振る舞いの全体像を示した。彼のモデルは複雑ではあるが，海嶺下におけるマントル岩石学に新たな知見を与えるものとして高く評価される。従って，本論文が秋澤紀克氏に博士（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　）