

## GRANITE-RELATED Sn-W-REE MINERALIZATION OF MAWCHI AND DAWEI AREAS, MYANMAR

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## 論 文 要 旨

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論文題名 GRANITE-RELATED Sn-W-REE MINERALIZATION OF MAWCHI AND DAWEI AREAS, MYANMAR (ミャンマー, モーチおよびダウェイ地域の花こう岩に伴う錫-タングステン-希土類鉱化作用)			

## 論 文 内 容 の 要 旨

Myanmar is endowed with abundant occurrences of Sn-W mineral resources. The world class Mawchi Sn-W deposits and Mosakhee prospect in Mawchi area and the Wagone and Bawapin Sn-W deposits in Dawei area were studied. This study investigates the tectonic setting, geochemistry and petrogenesis of Sn-W deposits and their associated granites from the Mawchi and Dawei areas by comprehensive studies of the granites and Sn-W-REE mineralization, integrating traditional methods with novel geochemical tools, including U-Pb zircon and Ar-Ar geochronology, fluid inclusion microthermometry and stable isotope geochemistry.

Chapter I outlines the background, problem definition and purposes of this study.

Chapter II describes the regional and local geological settings of ore deposits in the Mawchi and Dawei areas.

Chapter III deals with the petrography and geochemistry of the granites in Mawchi and Dawei areas. The Mawchi granites consist of biotite granites (BG) and tourmaline granites (TG), with Sn-W mineralization hosted in the latter. They consist of peraluminous, strongly fractionated, with enrichment in Rb, Ta, Nb and Y and depletion in Ti, Hf and Zr. All studied samples are characterized by strong negative Eu anomalies on relatively flat REE tetrad patterns. BG fall in the fields of syn-collision and highly fractionated melt system with enrichment of HREE and Y, indicating TG possessing within-plate granite affinity. Nb-Hf-Pb isotopic signatures of BG and TG indicate that they originated from partial melting of upper crustal block during the post-collisional event of Sibumasu and the Sub-Myanmar plate. The Wagone granites from the Dawei area are also peraluminous, highly fractionated, with high contents of Rb, Ta, Nb and Y coupled with low contents of Ti, Hf and Zr. Clear negative correlation of  $P_2O_5$  with  $SiO_2$  and other geochemical signatures indicate differentiation of I-type magma. All samples are characterized by strong negative Eu anomalies on relatively flat REE patterns. The low  $I_{sr}$  values indicate that the parental magmas originated from the mantle and experienced extensive differentiation. Furthermore, Wagone granites fall in the fields of syn-collision, which confirms their tectonomagmatic origin from the collision event of Sibumasu and Sub-Myanmar plate during the Paleocene.

Chapter IV discusses the geochronology of the granites from the Mawchi and Dawei areas. LA-ICP-MS U-Pb zircon dating reveals that the ages of BG and TG of the Mawchi area are  $42.7 \pm 0.94$  Ma and  $43.7 \pm 0.4$  Ma. Moreover,  $^{40}Ar$ - $^{39}Ar$  biotite plateau age of BG is  $41.50 \pm 0.16$  Ma, which is interpreted as the cooling age of the magmatism and is consistent with the zircon age. Hydrothermal muscovites from TG and quartz vein define the coeval timing of hydrothermal activity and ore formation at  $\sim 40$  Ma. The  $^{40}Ar$ - $^{39}Ar$  biotite  $60 \pm 0.17$  Ma age of Wagone granite indicates that large-scale tin granite magmatism of Paleocene age occurred in the Tanintharyi Region. The results indicate that two large tin provinces of Myanmar have different origins (crustal-derived and mantle-derived) and tectonic settings (collisional and post-collisional).

Chapter V focuses on the mineralization and paragenesis of Sn-W-REE mineralization of Mawchi and Dawei areas. In Mawchi deposit of Mawchi area, the N-S trending vertical or steeply dipping quartz veins define three stages of ore forming process; (i) tourmaline-cassiterite stage (ii) main ore stage and (iii) polymetallic stage. Tourmaline,

cassiterite, pyrite I and muscovite are early-formed minerals that are representative of tourmaline-cassiterite stage. They continued to deposit together with wolframite, molybdenite, arsenopyrite, pyrite II, scheelite, fluorite and danalite forming the main ore stage. This was followed by the successive deposition of polymetallic minerals such as chalcopyrite, sphalerite, galena, Pb-Bi minerals and Nb-Ta-REE minerals. In Mosakhee prospect of Mawchi area, Sn-W mineralization is mainly characterized by stannite, wolframite, sphalerite and galena with trace amounts of cassiterite, pyrite, raspite and hematite. In Dawei area, Sn-W mineralization is associated with pegmatite veins at the Bawapin mine, whereas it occurs as greisen and quartz vein systems at Wagone mine. Bawapin pegmatite consists of quartz, feldspar, muscovite, calcite, cassiterite, wolframite, sphalerite, and other accessories. The quartz vein system of Wagone mine contains wolframite, cassiterite and molybdenite while the greisen zone is enriched in cassiterite and magnetite.

Chapter VI presents the Nb-Ta-REE minerals of Mawchi mine. Wolframoixiolite is the major scandium-host mineral whereas fergusonite contains high contents of U and HREE. The results have found that substitution of  $\text{Nb}^{5+}$  into  $\text{W}^{6+}$  is the main mechanism through which Nb-Ta minerals form in the mineralization system. Additionally, their formation was strongly controlled by the F- rich hydrothermal fluid. Textures and evolutionary trends of Nb-Ta minerals allowed for the identification of two types of genesis: replacement and exsolution.

Chapter VII explicates the fluid inclusion and stable isotopic studies of Sn-W-REE mineralization in the Mawchi and Dawei areas. The  $\delta^{34}\text{S}$  values of pyrite and arsenopyrite range from 2.9 to 6.2‰ and from 2.5 to 5.2‰ respectively, indicating a relatively homogeneous source of sulfur. The similarity of  $\delta^{34}\text{S}$  values in galena and Pb-Bi minerals may indicate that Pb and Bi were transported by a common fluid of likely pure magmatic origin. Assuming ranges of depositional temperature of 350 to 260°C for the main ore formation stage, possible  $\delta^{34}\text{S}_{\text{H}_2\text{S}}$  values of pyrite are 1.6 to 5.2 ‰. The  $\delta^{34}\text{S}_{\text{H}_2\text{S}}$  values of galena are 1.6 to 4.7 ‰ at 200 °C, which indicates that the source of sulfur for the whole mineralization is uniform and is very likely magmatic in origin. Calculated  $\delta^{18}\text{O}_{\text{H}_2\text{O}}$  data of cassiterite (7.3 to 8.4 ‰), tourmaline (7.8 to 8.2 ‰) and wolframite (4.1 to 6.4 ‰) suggests a magmatic source of ore fluid. At lower temperature conditions,  $\delta^{18}\text{O}_{\text{H}_2\text{O}}$  data of scheelite and quartz ( $\delta^{18}\text{O}_{\text{H}_2\text{O}}$  2.1 to 4.2 ‰ and 3.0 to 4.9 ‰, respectively) indicate that the ore fluid might be mixed with another source of water, which is likely meteoric in origin. Hydrogen isotope data of cassiterites suggest that  $\delta\text{D}_{\text{H}_2\text{O}}$  values decrease towards shallower depth during the degassing process. Origin of ore fluid is magmatic but the  $\delta\text{D}_{\text{H}_2\text{O}}$  value of ( $\sim -120\text{‰}$ ) is suggestive of meteoric contamination in the hydrothermal fluids responsible for the late stage of vein deposition. In the Mosakhee prospect, the vein filling temperatures range between 215 and 300°C, corresponding to salinities of less than 10 wt% NaCl. The  $\delta^{34}\text{S}$  values of stannite (3.6 to 4.0 ‰) and galena (4.6 to 6.0 ‰) indicate a homogeneous source for sulfur and calculated  $\delta^{34}\text{S}_{\text{H}_2\text{S}}$  values for galena at 280°C are 5.7 to 6.1‰. These values are heavier than those of Mawchi deposit, which implies a relative enrichment of  $\delta^{34}\text{S}$  in the sulfur source. Preliminary results from oxygen isotopes indicate the source of ore fluid, with  $\delta^{18}\text{O}_{\text{H}_2\text{O}}$  values of 2.9 to 4.8 ‰, was likely a mixture of magmatic and meteoric water. The vein filling temperature of Bawapin pegmatites ranges from 180 to 360°C, whereas that of Wagone quartz vein ranges from 270 to 340°C. Except for the cassiterite from Bawapin mine, the  $\delta^{18}\text{O}_{\text{H}_2\text{O}}$  values of oxide minerals are lower than that of pure magmatic water (i.e. 5.5 to 8.5 ‰) and indicate contamination of fluid from another source. A decreasing of  $\delta^{18}\text{O}_{\text{H}_2\text{O}}$  values corresponds to a drop in vein forming temperature, which indicates mixing of magmatic and meteoric waters in the ore fluid.

Ultimately, Chapter VIII summarizes the results and achievements of the whole study that were described and discoursed in the previous chapters. Comparative study with other famous Sn-W deposits from the other countries is also detailed in this chapter. These studies contribute to provide important insights not only into the Sn-W-REE mineralization in Myanmar but also into the Southeast Asian tin belt.