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PETROLOGICAL AND GEOCHEMICAL STUDIES OF GRANITE HOSTED W-SN DEPOSIT IN TAGU TAUNG AREA, TANINTHARYI REGION

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Abstract

Tagu Taung area is situated about 59 km southeast of Myeik, Tanintharyi Region. In the study area, porphyritic granite intrudes the metasediments of the Carboniferous to Early Permian Mergui Group. Porphyritic granite is medium- to coarse-grained and characterized by the phenocrysts of feldspar. It is mainly composed of quartz, plagioclase, microcline, perthite, orthoclase, muscovite, biotite, chlorite and zircon. Geochemical data indicates that the granites from the study area have A/CNK ratio (1.2-1.4) is greater than 1.1 expressing peraluminous and S-type. When plotted in the (Y+Nb) / Rb discrimination diagram, Tagu Taung granites occupy syn-COLG (syncollisional granite) setting. Therefore, it can be said that these S-type granites are formed at syncollisional setting. The W-Sn mineralization is spatially and genetically associated with porphyritic granite. W-Sn ores are associated with sulfide bearing quartz veins that intrude the graywacke and granite. There are two stages of mineralization: namely greisen stage and vein stage. Molybdenite, chalcopyrite and sphalerite were deposited during the greisenization process (early stage). Successively, wolframite, cassiterite, arsenopyrite, pyrite, chalcopyrite, bismuth and sphalerite formed in the vein stage. The Sn-W mineralization is genetically related to the S-type granite emplacement that is resulted from the partial melting of the crust.

Keywords: Petrology, Geochemistry, S-type granite, Paragenetic sequence, W-Sn mineralization

Introduction

Tanintharyi Region is located at the southern part of Myanmar and it is geologically famous for its tin-tungsten mineral deposits. Tagu Taung is one of the famous mine in the region and situated about 59 km southeast of Myeik (Figure 1).

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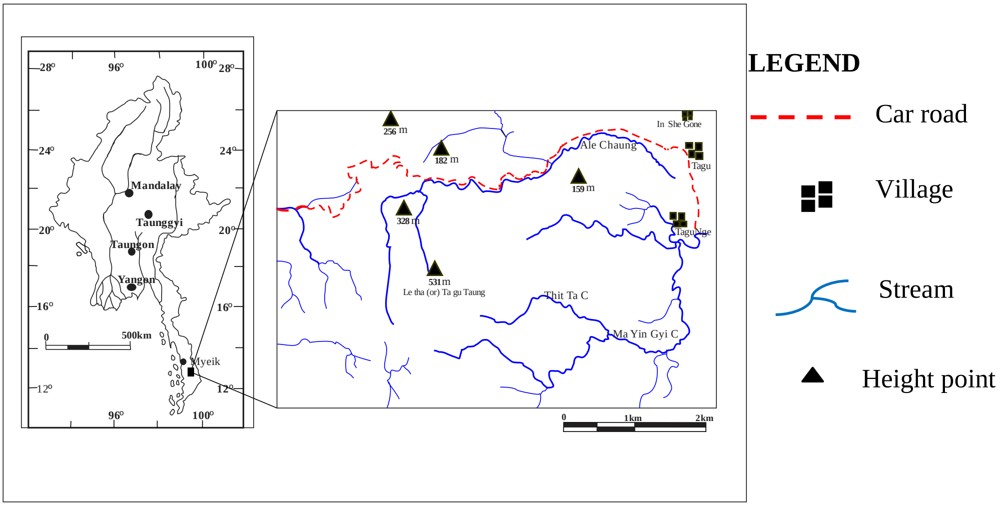


Figure 1: Location map of the study area

Regional Geologic Setting

Regionally, different stratigraphic units are exposed in the Tagu Taung and its environs (Figure 2). Mostly, Tertiary rocks occur along the Tanintharyi Valley. It is mainly composed of sandstone, slate, and conglomerate. Small belts or basins of non-marine sandstone, conglomerate and shale of Late Tertiary age, locally containing minor amount of oil shale and lignitic coal also occur.

The name of Mergui Series was given by Oldham (1956) to the unfossiliferous strata consisting of shales, agglomerates, limestones and quartzites which exposed within the Tanintharyi Region. It is redefined as Mergui group that is the oldest rock unit in this area. It is widely distributed unit in the study area. It is composed of a thick sequence of folded phyllites, argillites, greywackes and shales, with subordinate amount of conglomerates, sandstones, quartzites, limestone, tuffs and agglomerates. Tin-tungsten bearing granites intrude the Mergui Group.

Granitoids of this region are appeared as southern extension of granitoids from Dawei area and passes southward to Kawthaung. The granitoids intrude the metasedimentary rocks of Mergui group and they can be grouped into three ranges; the western frontier range, the central range and the eastern range. The Mergui pluton is elongate NNW-SSE and parallel trends to the country rocks which are affected by greenschist to lower amphibolite facies metamorphism. Biotite granite and biotite-muscovite granite are most abundant rocks with subordinate amount of porphyritic biotite, hornblende granite, granodiorite and tourmaline-muscovite granite.

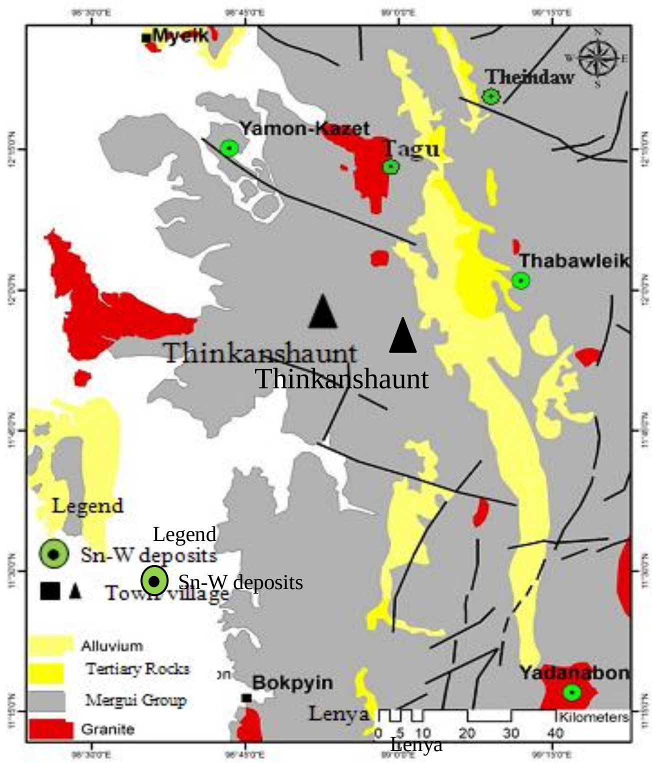


Figure 2: Regional geological map of Tagu Taung and its environs (Aung Zaw Myint, 2016)

Deposit Geology

The study area is composed of the metasedimentary rocks of Carboniferous - Permian Mergui Group and granitic rocks (Figure 3). The Mergui Group is widely distributed around the study area. In the study area, the prominent rock unit of the Mergui Group is greywacke, and Greywacke occurs as well exposed along the study area. Greywackes are dark grey, fine-grained, compact and highly jointed (Figure 4a). It strikes nearly east-west with north dipping between 70° to 80° inclination.

Porphyritic granite intrudes the metasediments of the Mergui Group. It is mainly composed of quartz, feldspar, biotite and minor amount of muscovite. Zoned feldspars occur as phenocrysts in the granite demonstrating the porphyritic texture (Figure 4b).

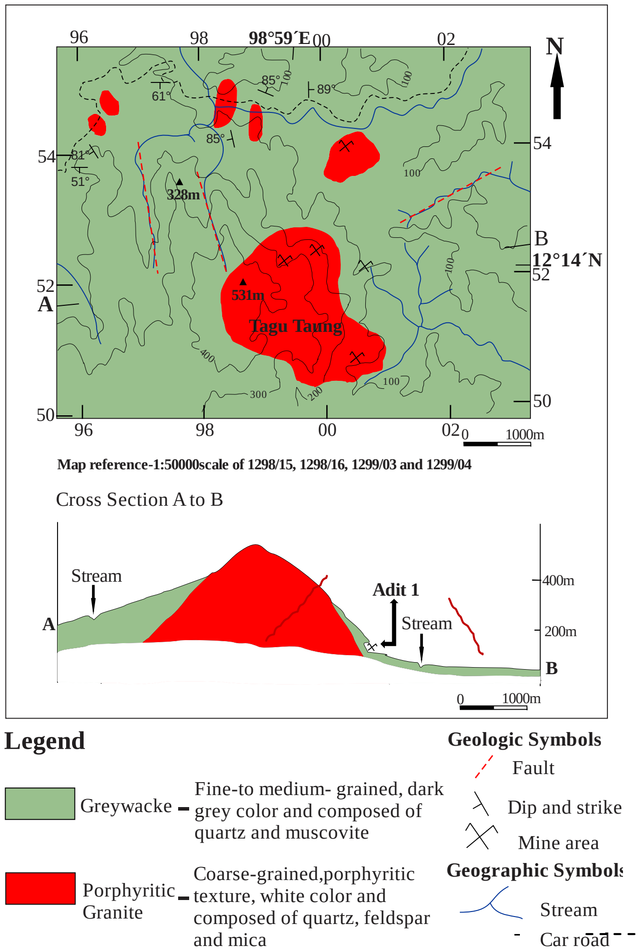


Figure 3: Geological map of the Tagu Taung area

Figure 4: Photographs showing (a) the greywacke unit of the Mergui Group and (b) the phenocrysts of zoned feldspar dispersed in the porphyritic granite

Petrography

Porphyritic granite

Megascopically, it is coarse-grained and porphyritic texture. The color is yellowish white on weathered surface and white on fresh surface. It is mainly composed of quartz, feldspar and mica which form an interlocking and equigranular matrix of feldspar and quartz with scattered muscovite and biotite mica. The feldspar is found as major phenocrysts of the rock and presents zoning (Figure 5).

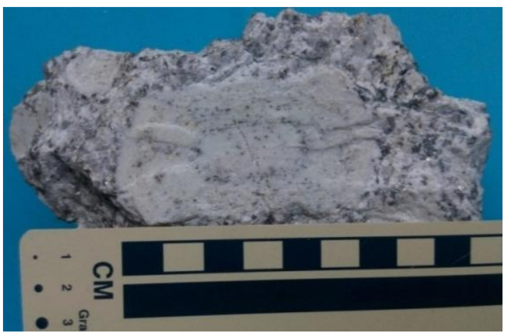


Figure 5: Hand specimen of porphyritic granite presenting feldspar phenocryst

Under Microscopic study, it shows medium- to coarse-grained texture and porphyritic texture. It is mainly composed of quartz, plagioclase, microcline, perthite, orthoclase, muscovite, biotite, chlorite and zircon. The proportion of quartz and feldspar (Plagioclase, microcline, prethite and orthoclase) is more than 75% of the whole rock. Quartz grains are found as bleb-like intergrowth in the microcline and perthite (Figure 6a). Subhedral plagioclase shows multiple twining and the grain size ranges from 0.4 mm to 1.2 mm. Plagioclase is slightly altered to saussurite and sericite (Figure 6b). Some fine-grained plagioclases are found as inclusions in the microcline. Alkali feldspars are microcline, perthite and orthoclase occurring as subhedral minerals and their grain size ranges from 0.55 to 1.3 mm. Microcline phenocryst often hosts microcline and plagioclase inclusions (Figure 6c).

Biotite is mostly altered to chlorite (Figure 7a), and also has the dark haloes where if hosts zircon inclusion (Figure 7b). Perthite is intergrowth texture of albite and orthoclase. The formation temperature of perthite may be nearly 590°C and it can be formed near the crust. So, according to petrographically, the study area of Tagu Taung's granite may be peraluminous and S type granite. Zircon inclusion can be observed in the orthoclase (Figure 7c).

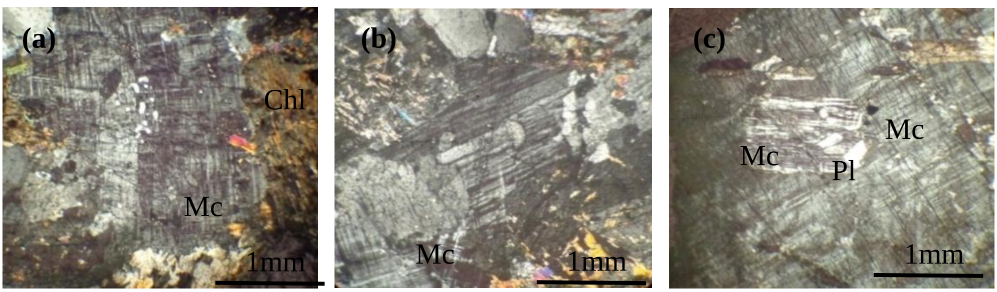


Figure 6: Photomicrographs showing (a) the bleb-like intergrowth of quartz in microcline and biotite altered to chlorite, (b) the microcline, perthite and plagioclase; the intensive sericitization occurs in the plagioclase and (c) microcline and plagioclase inclusions in microcline phenocryst (Mc-Microcline, Chl- Chlorite, Pl-Plagioclase)

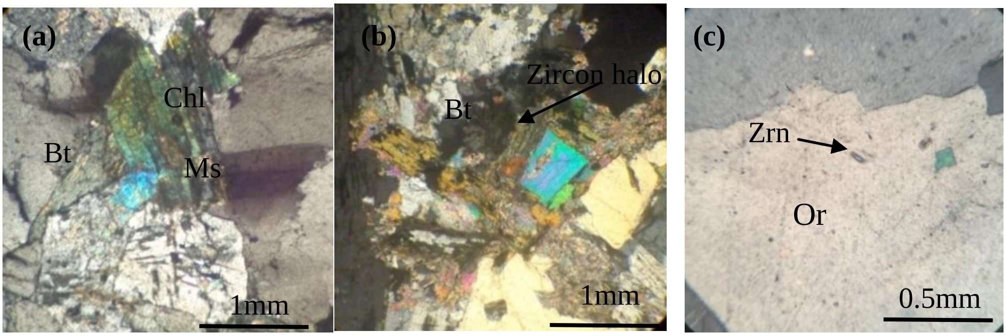


Figure 7: Photomicrographs showing (a) the muscovite, biotite and chlorite, (b) the zircon haloes in biotite and (c) the zircon in the orthoclase (Bt- Biotite, Ms- Muscovite, Chl- Chlorite, Zrn-Zircon)

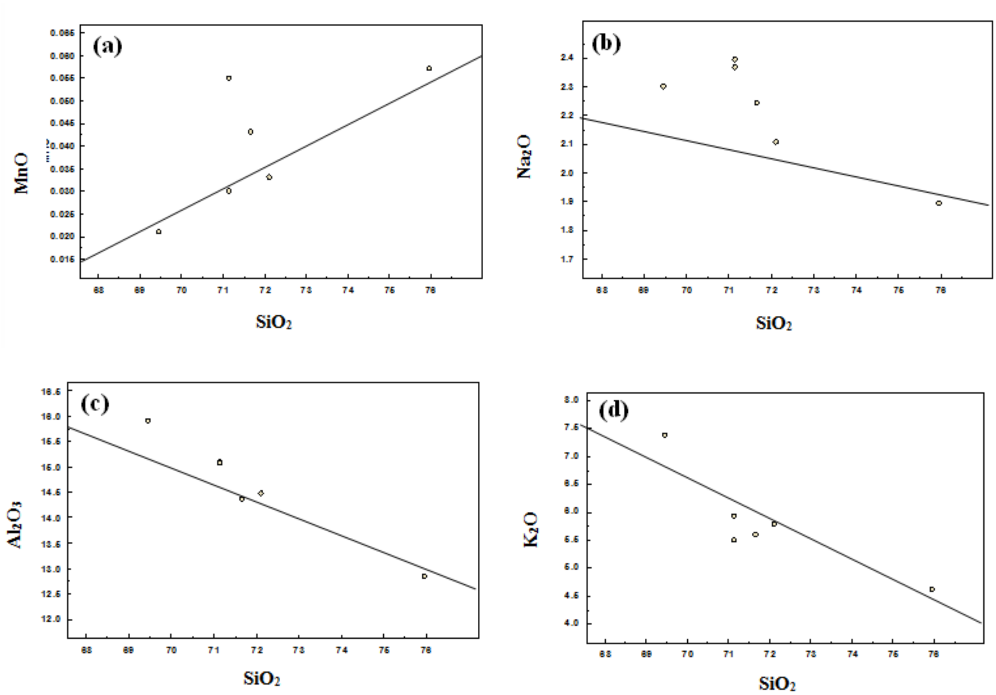
Geochemistry

Granite geochemistry

XRF geochemical data reveals that the granite samples contain SiO_2 (69-76%), Na_2O (1.89-2.39%), MgO (0.57-0.72%), Al_2O_3 (12.8-15.88%), P_2O_5 (0.14-0.18%), K_2O (4.6-7.3%), CaO (0.61-1.18%), TiO_2 (0.27-0.36%), MnO (0.02-0.06%) and FeO (1.58-2.18%). The concentrations of trace elements are V (17-31 ppm), Co (26 to 41 ppm), Ni (13-16 ppm), Cu (3-97 ppm), Zn (23-179 ppm), Pb (52-109 ppm), Mo (11-18 ppm), Rb (677-846 ppm), Sr (25-66 ppm), Y (31-40 ppm), Zr (158-214 ppm), Nb (23-36 ppm), Sn (47-152ppm), W (8-349ppm), Th (44-58ppm) and U(13-29ppm).

SiO_2 shows positive correlation with MnO and it means that the value of SiO_2 increases with the value of these major elements increase (Figure 8a). SiO_2 has the negative correlation with Na_2O, Al_2O_3 and K_2O, indicating that the value of SiO_2 increase with the value of these major elements decrease (Figures 8b, 8c & 8d). SiO_2 has positive correlation with W and Sn. It means that the value of SiO_2 increase with the value of these trace elements increase (Figures 8e & 8f). SiO_2 shows Negative correlation with Sr. It reveals that the value of SiO_2 increases with the value of these trace elements decrease (Figure 8g). The SiO_2 and the ratio of Rb/Sr concentration is also positive correlation (Figure 8h).

CIPW normative corundum contains 2.886 to 3.97 and this indicates that the granite of Tagu Taung area is S-type granite (Chappell and White, 1974 and 2001). The SiO_2 / (Na_2O+K_2O) diagram indicates that granite conditions (after Cox-Bell-Pank, 1979) (Figure 9a). According to alumina saturation index diagram, A/CNK ratio is greater than 1.1 and it can be said that the granite is peraluminous and S-type (Shand, 1943) (Figure 9b). These granites have high content of Rb (677-946 ppm) and Ba (234-437 ppm) with low content of Sr (25-66 ppm). The Rb-Sr-Ba triangular plot reveals the highly differentiated nature of the granite (EL Bouseily and El Sokkary, 1975) (Figure 10a). When plotted on the (Y+Nb) / Rb discrimination diagram, Tagu Taung granites occupy syn-COLG (syncollisional granite) setting (Pearce et.al, 1984) (Figure 10b). R1-R2 plot also indicate the syncollision tectonic setting (Batchelor and Bowden, 1985) (Figure 10c). Thus, it can be said that granite from Tagu Taung area are S-type granite which are formed at syncollisional setting.



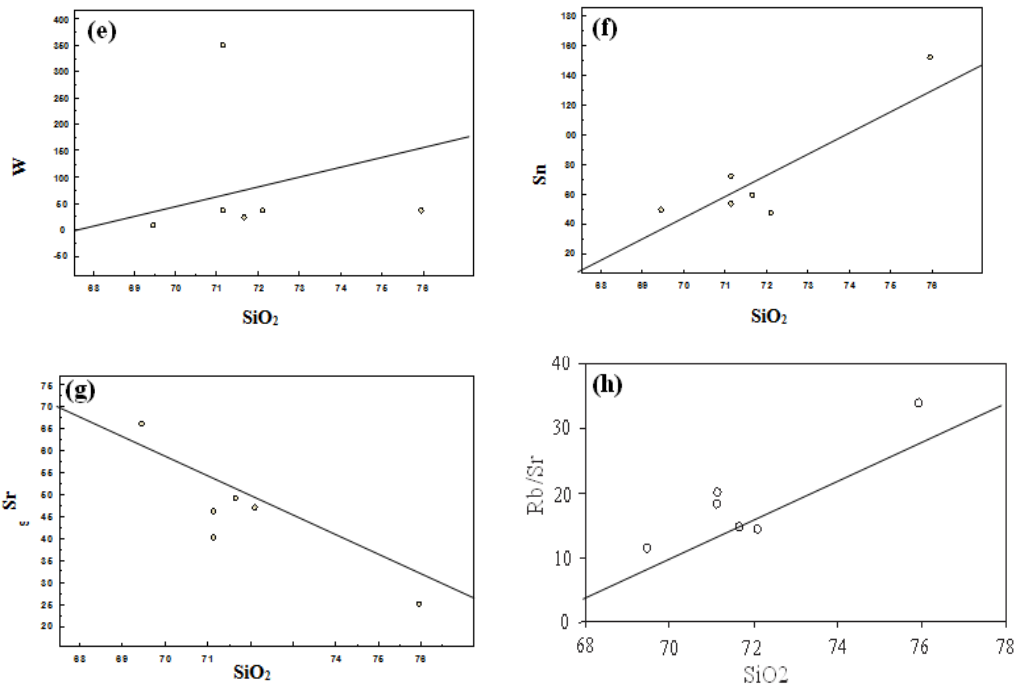


Figure 8: Variation diagram showing (a) the positive correlation between SiO_2 and MnO, (b,c,d) the negative correlation between SiO_2 and Na_2O, Al_2O_3, K_2O, (e.f,g) the positive correlation between SiO_2 and W, Sn and Sr and (h) positive correlation between SiO_2 and Rb/Sr

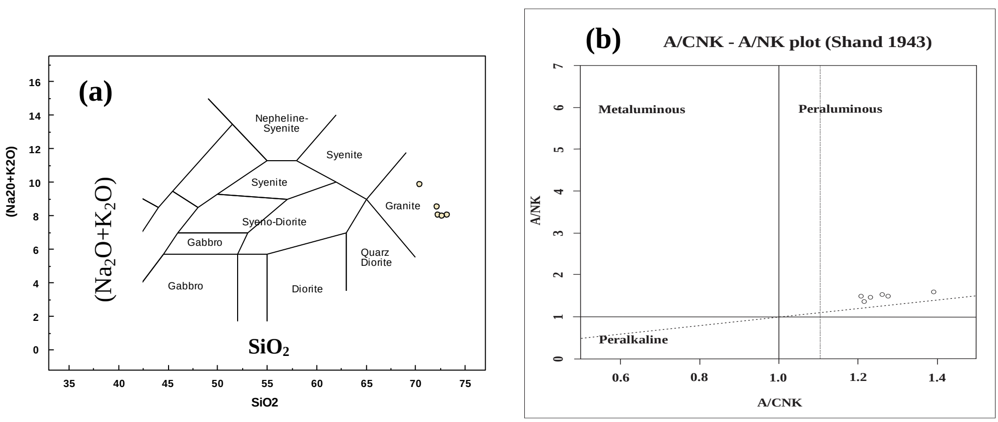


Figure 9: (a) SiO_2 / (Na_2O+K_2O) plot diagram data showing granite conditions of Tagu Taung area (Cox-Bell-Pank, 1979) and (b) Alumina saturation plot diagram showing Peraluminius nature of Tagu Taung area (Shand 1943)

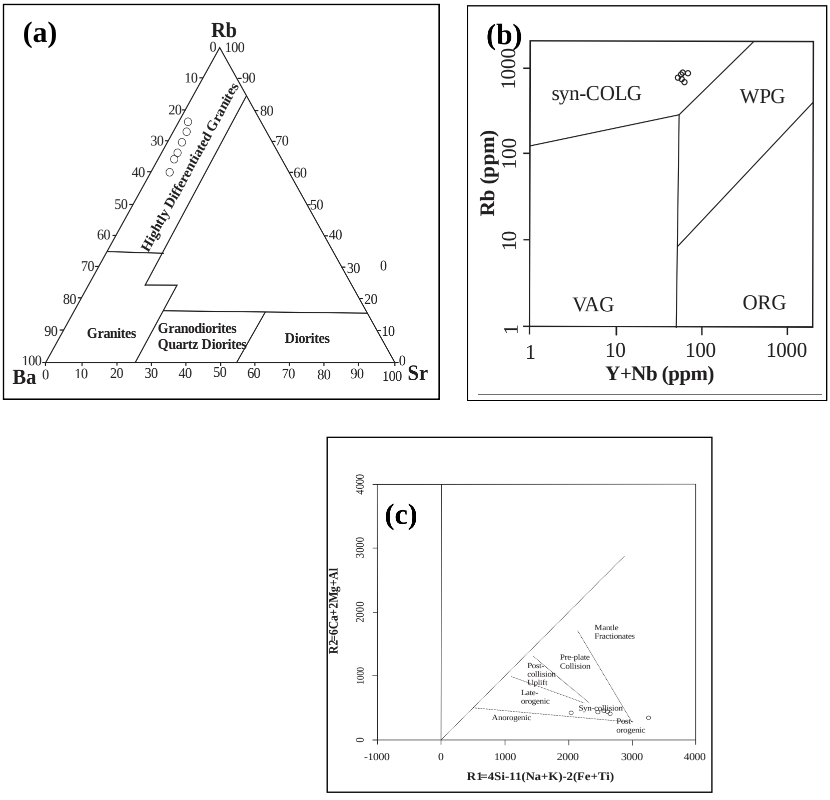


Figure 10: (a) Rb-Ba-Sr triangular plot of Tagu Taung granite (EL Bouseily and El Sokkary, 1975); (b) (Y+Nb)/Rb plot of (Pearce al, 1984) and (c) R1-R2 plot of (Batchelor and Bowden, 1985)

Alteration and Mineralization

Alteration

According to the field observation and microscopic studies, the common alterations associated with W-Sn mineralization are greisenization and silicification.

Greisen systems are resulted from complex and late- to post-magmatic metasomatic processes that affect and take place within a nearly consolidated granitic mass and the adjacent country rocks. Greisenization is typically linked with highly fractionated magmas (Pirajno, 2009). In Tagu deposit, greisenization occurs near the granite intrusion, especially at adit 2 and adit 3. Typically, greisen mainly consists of quartz and muscovite with accessories of tourmaline, topaz, apatite, fluorite, and iron oxide. In the study area, greisen is associated with quartz veins. Greisen is reddish grey with mica flakes (muscovite) in weathered surface and bluish grey color in fresh surface (Figure 11a). It is mainly composed of quartz, muscovite, apatite and the most common ore is molybdenite (Figure 11b). Under the microscopic study, quartz is prevalent. The quartz is anhedral and the edges of the quartz are jagged. It is associated with muscovite (Figure 12a). Muscovites is predominant and coarse-grained texture. The molybdenite is associated with mouscovite flakes (Figure 12b). The deformed and fractured apatite is also found within the coarse-grained mouscovite (Figure 12c).

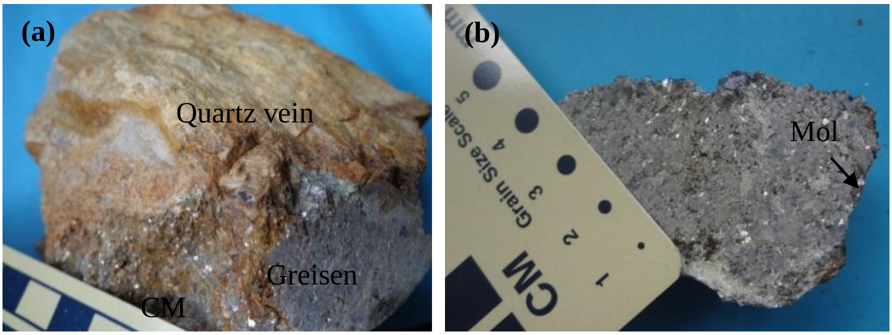


Figure 11: Hand specimen of (a) greisen and quartz vein at the Tagu deposit and (b) molybdenite bearing greisen surface at the Tagu deposit

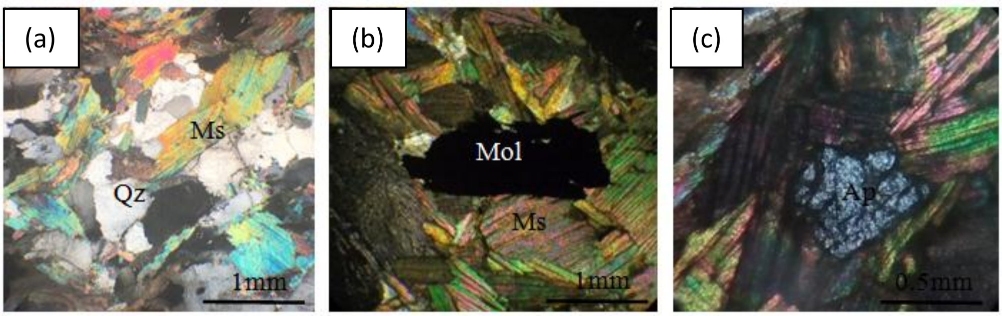


Figure 12: Photomicrograph showing (a) the nature of quartz and muscovite in the greisen, (b) the molybdenite with muscovite in the greisen and (c) the subhedral apatite in the greisen (Qz- quartz, Ms- muscovite, Mol- molybdenite, Ap- apatite)

Silicification is prominent alteration type in the study area and mainly occurs within the metasedimentary rocks intruded by quartz veins around the adit 1. Outcrop nature, it is red to pale brown color, hard and compact than other metasediment. Megascopically, it can be found more lighter color than other metasediment. Quartz veinlets occur at the surface. Under the microscopic study, quartzs are wavy extinction and mostly are irregular shape (Figure 13a). Silicification related by quartz veins intrusion. These veins intrude the metasediment and silica solution emplacement formed as silicification (Fig 13.b).

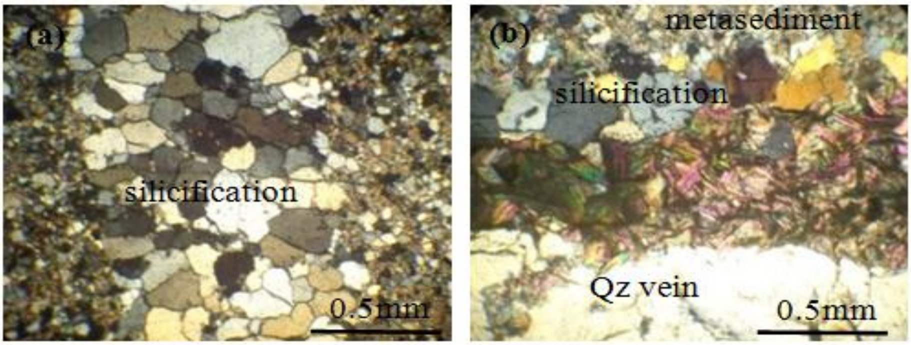


Figure 13: Photomicrograph showing the nature of silicification in the metasedimentary rock near the adit-1

Mineralization

The mineralization style of the Tagu (also known as Kontapin) deposit is designated as a vein type deposit which is hosted by the porphyritic granite and metasedimentary rocks. In mineralized area, veins can be sub-divided into three types as (i) quartz vein, (ii) mica-bordered quartz vein, (iii) sulfide bearing quartz vein. W-Sn mineralization is associated with the sulfide bearing quartz vein. Veins trend mostly east-west direction with nearly vertical to various amount of inclination.

The adit-1, parallel quartz veins cut into the metasediment (Figure 14a). These quartz veins are shifted by the minor faults and taper upwards. Adit-1 is located in the metasedimentary rocks while adit-2 is hosted within the granite. The elevation of adit-2 is 360 m height. The vertical quartz veins intruded by the granite and this quartz vein is adit-3. The elevation of adit-3 is

395m height. In (Figure 14b) is mica bearing quartz vein at the adit-1 are mica segregation occurs in the margin of quartz vein. In (Figure 14c) ore bearing sulfide-quartz vein intrude into the metasedimentary rocks. In (Figure 15a) is the ore bearing mineralized quartz veins and its width is 35cm. The two tunnels and one vertical shaft occur along this vein. All ore minerals occur as irregular patches and disseminated (Figure 15b). The ore bearing sulfide zone occurs in this vein. Ore productions are mostly extracted from this vein. Schematic diagrams of the adit location map of the Tagu Taung deposit is shown in Figure (16).

Figure 14: Outcrop showing (a) the quartz vein in the metasediment of the Mergui Group at the back of adit-1, (b) the mica segregation along the margin of quartz vein in the adit-1 and (c) the sulfide bearing quartz vein with wolframite

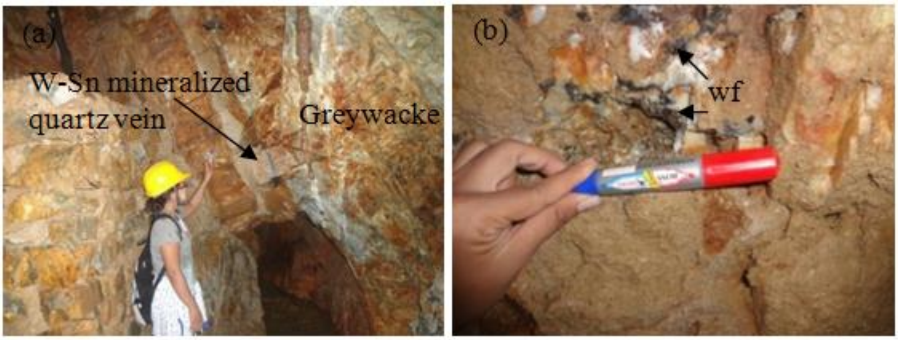


Figure 15: Outcrop showing (a) the W-Sn mineralized quartz vein in the adit-1 and (b) the patches of wolframite in the adit-1

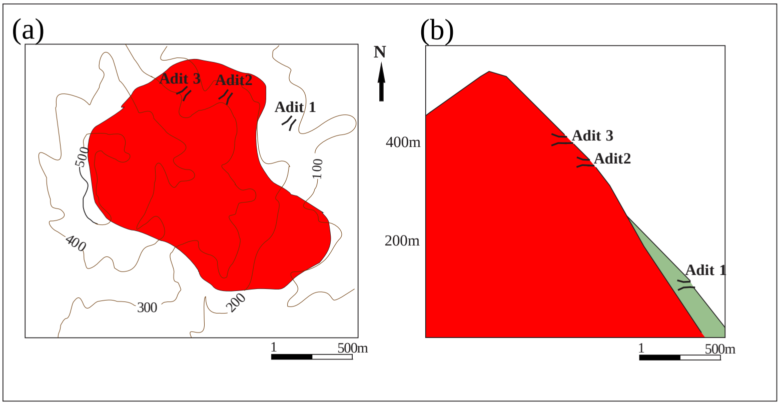


Figure 16: Schematic diagrams of the adits location map of the Tagu deposit (a) plan view and (b) vertical view

Thit Ta prospect

Thit Ta prospect area, W-Sn mineralization is hosted within the granite. The silicified and mineralized zone is well exposed in the Thit Ta area (Figure 17a). Pyrite veins of up to 5cm width cut the silicified body (Figure 17b). In the silicified body, arsenopyrite is widely disseminated and associated with pyrite in some places. Wolframite occurs as disseminated grains within the silicified body (Figure 17c).

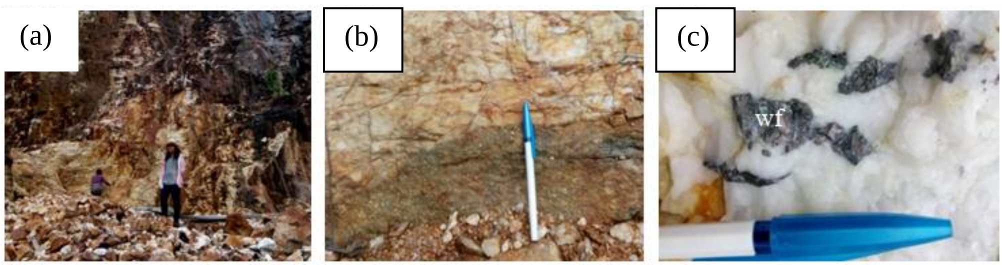


Figure 17: Outcrop showing (a) the Thit Ta prospect, (b) the contact line between silicified body and sulfide vein and (c) the disseminated wolframite in silicified body

Ore Mineralogy

Tagu deposit

In Tagu deposit, the main ore is wolframite which is associated with cassiterite, arsenopyrite and pyrite. In hand specimen, wolframite is dark brown to black color with brownish black streak and bladed form. In (Figure 18a), wolframite occurs within the vein boundary as bladed form. Cassiterite is the main tin mineral in in Tagu Taung deposit possessing brown and black color and short or slender prismatic or pyramidal form. Wolframite and cassiterite occur together along the margin of vein (Figure 18b).

Arsenopyrite is common sulfide ore mineral at the adit-1. The grain size of arsenopyrite is generally 1 cm in length. Arsenopyrite is associated with pyrite. Pyrite is major sulfide ore mineral in the Tagu Taung mine and molybdenite occurs near adit-3.

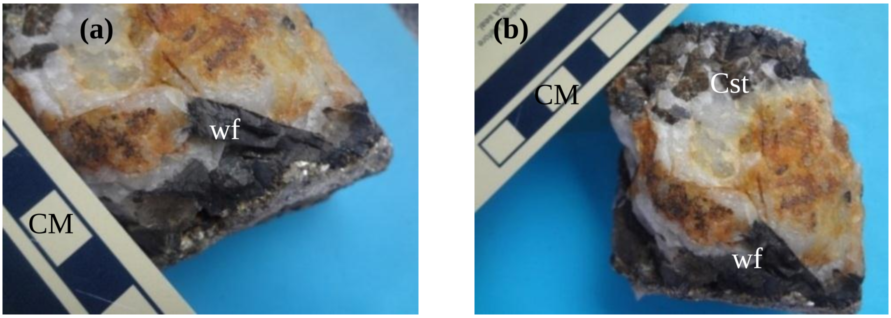


Figure 18: Hand specimen of wolframite and cassiterite in adit-1 of Tagu deposit

Ore microscopic description

Common ore mineral is wolframite which is associated with cassiterite and sulfides such as arsenopyrite, pyrite, chalcopyrite and sphalerite. Bismuth and molybdenite are also found as minor minerals. Common gangue minerals are quartz, and muscovite.

Wolframite is the principle ore mineral of tungsten-tin mineralization of the study area. Wolframite is found as massive, subhedral tabular lamellar form. Wolframite is closely associated with chalcopyrite, pyrite and sphalerite which marginally replaced by these sulfides (Figures 19a & b). Cassiterite is the major tin ore of the Tagu deposit and usually associated with wolframite. Unknown oxide minerals are enclosed in the cassiterite and they may be columbite (Figure 19c). Under transmitted light, cassiterite is brownish grey color with yellow to yellow brown internal reflection, distinct bireflectance, colorless to yellow pleochroism, color banding and two set of cleavages (Figure 20a). Cassiterite is rarely associated with sulfide minerals.

Arsenopyrite and pyrite common sulfides of the Tagu Taung deposit and Thit Ta prospect area. The color of arsenopyrite is white with pale yellow tint. Pyrite is yellowish white, lighter than chalcopyrite, high reflectance and usually isotropic. Bismuth is creamy white color, highly reflective and weak bireflectance. Chalcopyrite is yellow to brassy yellow color and usually occurs as anhedral grains. Sphalerite can be found as anhedral disseminated grains or associated with other sulfides as arsenopyrite, pyrite, chalcopyrite and molybdenite. In (Figure 20b) arsenopyrites are found as large crystals that host chalcopyrite, sphalerite and bismuth. In some places, chalcopyrite occurs as emulsoid texture in sphalerite (Figure 21a). Subhedral molybdenite can be found within the mica flakes. The size of molybdenite is about 10 mm (Figure 21b).

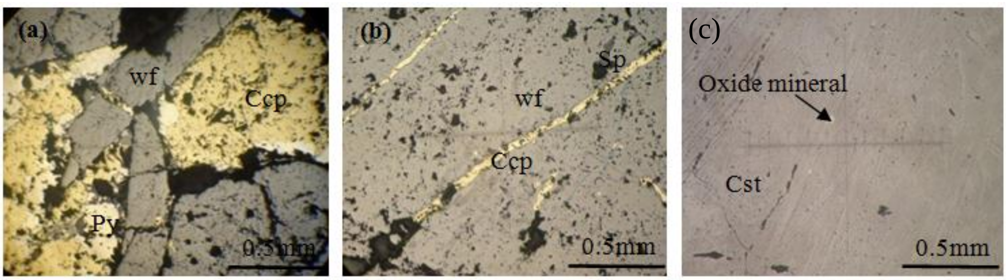


Figure 19: Photomicrographs showing (a) the nature of bladed, subhedral tabular wolframite replaced by chalcopyrite and pyrite, (b) the wolframite veined by chalcopyrite and replaced by disseminated sphalerite grains and (c) the oxide mineral inclusions (probably columbite) in cassiterite (under reflected light) (wf- wolframite, Ccp- chalcopyrite, Py- pyrite, Sp- sphalerite, Cst- cassiterite)

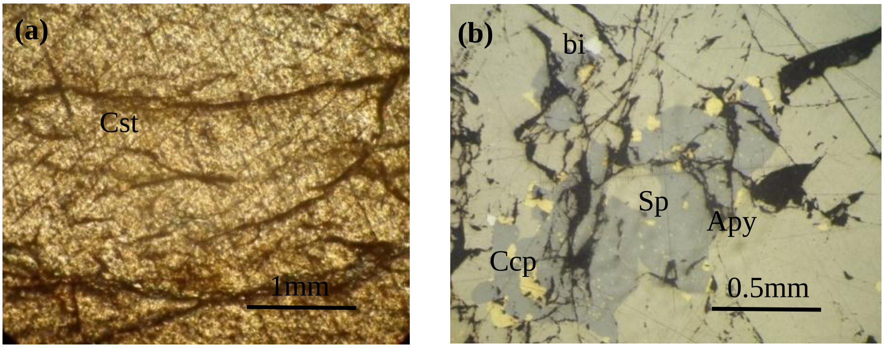


Figure 20: Photomicrographs showing (a) the two set of cleavage in cassiterite (under transmitted light), (b) the intergrowth texture of sphalerite and chalcopyrite; sphalerite, chalcopyrite and bismuth replaced the arsenopyrite (under reflected light) (Cst- cassiterite, Apy- arsenopyrite, Ccp- chalcopyrite, Sp- sphalerite, bi- bismuth)

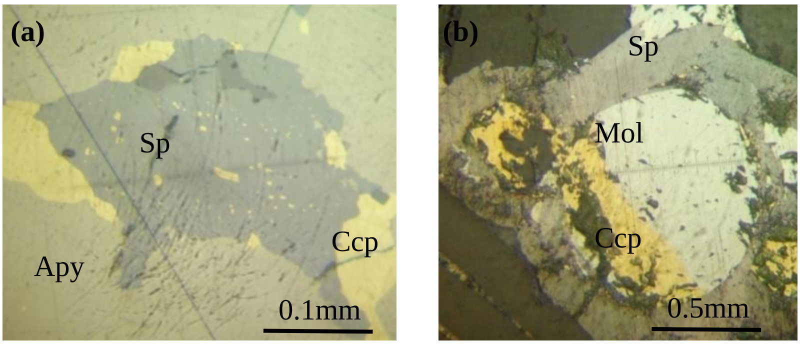


Figure 21: Photomicrographs showing (a) emulsion texture of the chalcopyrite and sphalerite and (b) the replacement texture of molybdenite, chalcopyrite and sphalerite in greisen (under reflected light) (Apy- Arsenopyrite, Ccp-Chalcopyrite, Sp-Sphalerite, Mol- Molybdenite)

Paragenetic sequence

By the study of ore microscopy, nature of ore minerals and their textural relationship, the minerals paragenetic sequence of ore minerals in Tagu deposit can be illustrated below (Figure 22). There are two major stages such as greisen stage and vein stage found in the Tagu deposit.

Minerals	**Greisen**	**Vein**	
		Early Stage	**Late Stage**
Wolframite		————————	
Cassiterite		————————	
Arsenopyrite		——————	
Pyrite		——————	
Bismuth		———	———
Chalcopyrite	——————	- - - - - - - - - - - -	——————
Sphalerite	——————	- - - - - - - - - - - -	——————
Molybdenite	——————		

Figure 22: Paragenetic sequence of the ore minerals at the Tagu deposit

Summary and Conclusions

According to petrological and geochemical studies, Tagu Taung granites are peraluminous and S-type. Rb-Sr-Ba triangular plot indicates Tagu Taung granite is highly fractionated. These granites are located in the field of syn-COLG (syncollisional granite) setting (Pearce al, 1984; Batchelor and Bowden, 1985). The Sn-W mineralization is genetically related to the S-type granite that is resulted from the partial melting of the crust.

The common alterations associated with W-Sn mineralization are greisenization and silicification. Greisen is mainly composed of quartz, muscovite, apatite and the most common ore is molybdenite. Silicification is the prominent alteration type in the study area. Silicification mainly occur within the metasediment rocks intruded by quartz veins. W-Sn mineralization is associated with the sulfide bearing quartz vein. Veins are trending mostly east-west with nearly vertical to highly inclined.

Vein ore mineralogical studies provide the paragenetic sequence demonstrating two stages of ore deposition. Greisen stage is presented by the deposition of molybdenite, chalcopyrite and sphalerite whereas quartz vein stage is characterized by wolframite, cassiterite, arsenopyrite, pyrite, chalcopyrite, bismuth and sphalerite.

According to field observation, wolframite is associated with cassiterite and/or sulfide minerals such as arsenopyrite, pyrite, chalcopyrite and sphalerite. However, cassiterite is not commonly associated with sulfide minerals and only associated with wolframite and oxides.

According to the granite petrological and geochemical data, mineralization style and ore mineralogy, W-Sn mineralization of Tagu Taung area can be termed as the granite-related hydrothermal system.

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References

Aung Zaw Myint., (2016). Sn-W Mineralization in the Central Granitoid Belt of Myanmar and presentation at RGS annual meeting 2016, Japan. (Unpublished)

Batchelor, R. A., Bowden, P. (1985) Petrogenetic interpretation of granitoid rock series using multicationic parameters. *Chem.Geol.*, 48, 43-55.

Cox, K.G., Bell, J.D. & Pankhurst, R.J (1979). *The Interpretation of Igneous rocks*.

Pearce, J. A., Harris, N. B. W., and Tindle, A, G., (1984). Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: *Journal of Petrology*, p-25, p-956-983.

Pirajno, F., (2009). *Hydrothermal Processes and Mineral Systems,* Geological survey of Western Australia, 100 Plain St. p-205-257.

Pracejus, B., (2008). *The Ore Minerals Under The Microscope, An Optical Guide,* Linacre House, Jordan Hill, Oxford, UK, 1st edn.

Shand, S. J., (1943). *Eruptive rocks.* T. Murby and Co., London, 444p.