REGIONAL LINEAMENT ANALYSIS AND ALTERATION MINERAL MAPPING FOR INTRUSIVE-RELATED COPPER EXPLORATION IN THE MYANMAR CENTRAL VOLCANIC BELT

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ABSTRACT: Lineament analysis by both LANDSAT ETM+ and RADARSAT and alteration mineral mapping by ASTER were carried out in Tertiary volcanic belt in Myanmar to identify new prospecting sites. N50-70E lineament is interpreted as old regional fracture controlling emplacement of Tertiary igneous bodies, while N10-40E is small local fracture where ore deposition is possibly induced. Alteration mineral map, limonite by VNIR, clay and alunite by SWIR, and silica content by TIR, were processed referring the Monywa deposit. Resultant images are informative for mineral exploration even semi-vegetated region. Integrated analysis identified 26 candidate sites to ground-truth survey. At least one site was new hydrothermal alteration which has not been reported.

1. OBJECTIVE

The Metal Mining Agency of Japan has been conducting a regional mineral-resource potential evaluation program, 'Indochina-Malay project' in the Central Myanmar region since 1999. The goal of the project is to delineate new prospecting sites targeting intrusive-related copper deposits from less studied but geologically suitable regions to facilitate metal mining investment. In the Myanmar Central Volcanic belt, present mining operations are limited to the Monywa deposit.

2. OUTLINE OF GEOLOGY AND MINERALIZATION

Intrusive-related copper mineralization is closely associated to Tertiary volcanism in Myanmar. Three Tertiary volcanic provinces have been identified and are referred to as eastern volcanic line, inner volcanic line, and western volcanic line from east (Franceschi, 1991; Fig. 1). Intrusive-related copper deposits, such as Monywa deposit, has been reported only from the inner volcanic line. The inner volcanic line extends from N26°to N18°oriented almost south to north, and is distributed in central portion of Central Lowlands (UN, 1996) which is considered as the Tertiary back-arc graben. Tertiary acidic to intermediate shallow level pluton intrudes both Mesozoic basement rock and Tertiary sedimentary rocks which buried the basin, i.e. Central Lowlands. Quaternary alluvium covers the area largely, thus Tertiary sequence shows limited outcrop.

The Monywa deposit situated N26° in the middle of western volcanic line is a world class copper deposits. Total ore reserve exceeding 800 million tons has been recognized by Ivanhoe Myanmar Holdings, Ltd. The Monywa copper mineralization can be observed closely related to biotite and hornblende-biotite porphyry, i.e. high-K dioritic composition. Thus, the mineralization style is considered similar to porphyry copper or gold system in island arc subduction regime such as the southwest Pacific region (e.g. Gustafson, 1978). K-Ar dating results indicate that igneous body intrudes in middle Miocene (18Ma: biotite) at Lepadaung ore body (MMAJ, 2001). Hypogene hydrothermal alteration is possibly subdivided into two stages: earlier parvassive sericite (muscovite) and pyrite alteration (17 to 14Ma) and later quartz-alunite-pyrite-(kaolinite) overprinting alteration (MMAJ, 2001). Multiple supergene oxidation process is significant. 'Sooty' oxide ore, enriched by very fine grained secondary chalcosite, produces major economic value at Sabedaung ore body.

3. METHODS

The survey, still in the reconnaissance stage, largely depends on satellite remote sensing. The methods employed are two; the one is lineament analysis by LANDSAT ETM+ and RADARSAT, the other is hydrothermal alteration mineral mapping with ASTER data. Survey area is shown in Fig. 1.

3.1 LINEAMENT MAPPING

Lineament analysis was undertaken to ascertain the regional structural elements at which emplacement of shallow level intrusions may have occurred, in addition to local minor structures that may have been important in controlling ore deposition. Imageries employed are eleven ETM+ RGB432 color infrared and three RADARSAT Scan SAR Narrow scenes. Lineament defined by O'leary et. al. (1976) is mapped on a display with a scale of 1:250,000 to 75,000 from appropriately enhanced imageries.

3.2 ALTERATION MINERAL MAPPING

The main survey region, central portion of the western volcanic line, is a sparsely vegetated semi-arid region. ASTER alteration mapping was therefore applied to know similar area of Monywa geology. Four consecutively obtained full mode ASTER L1B data is used for mapping. The data is geocoded to UTM. SWIR and TIR data are registered to VNIR by GCPs due to subtle inter-telescope mismatch. The darkest DN was then subtracted in VNIR and SWIR data to mitigate path radiance effect.

ASTER VNIR, SWIR, and TIR scenes were used for generating limonite, alteration clay minerals and alunite, and silica content images, respectively. The limonite image was processed by ratioing VNIR B2/B1, then density sliced into three classes.

The clay and alunite image was processed only by SWIR data. SWIR data were reduced to apparent reflectance by flat field method (Roberts et. al., 1985) using an scene internal object 'quarts hill' which is alluvium mainly consists of detrital quartz. The clay minerals (kaolinite, muscovite) and alunite image was generated by using spectral angle mapping method comparing to reference pixels (Kruse et. al., 1993). Reference pixels, alunite, kaolinite, and muscovite, were selected around the Monywa deposit verifying with field surveys and sample test. Fig. 2 shows ASTER convolved reflectance spectra of USGS spectral library data and each reference pixel data in this work. Although simple flat field method was employed, an acceptable similarity was achieved between the two spectra. Threshold of spectral angle mapping is decided as 0.025 radian by try-it-and-see process.

The silica content image was generated by TIR data. Emissivity in TIR was separated from temperature by alpha residual method (Hook et. al. 1992). Then silica content factor was calculated by MMAJ original 'K-value' method (MMAJ, 2000). The 'K-value' is derived by empirical approach based on a laboratory work on 194 samples including both fresh and weathered rocks, and minerals. Following silica content equation and related index K showed good linear approximation with respect to SiO2 content (wt%).

$$SiO_2(wt\%) = 57.11 - 286.88 \log((E[10]+E[11]+E[12])/3 / E[13])$$

where E[n] is emissivity on each ASTER band n. K-value is defined following term:

$$K = -\log((E[10]+E[11]+E[12])/3 / E[13])$$

Resultant K-value image was finally dencity sliced to highlight siliceous portions.

4. RESULTS

4.1 LINEAMENT MAPPING

Lineament distribution and its general orientation are shown in Fig. 3. Major lineament trend can be summarized as N-S, N50-70E, and N10-40E, under considering exaggeration due to imaging orientation.

N-S structure is the most dominant orientation, and is common to occur as longest lineaments more than 60km. This structure concentrates especially around the central portion close to N-S trending Sagaing fault. This fault is major active right-lateral strike-slip fault which movement started from late Miocene reflecting NE compressional tectonic regime.

N50-70E structure widely distributes in the Central Lowlands. This structure tends to occur exceeding 40km, especially around Monywa deposit and southern portion. According to image interpretation, this type of structure does not show any significant displacement in Tertiary lithology, on the other hand, accompanies significant deformation in Pre-Cambrian to Mesozoic lithology. Thus, N50-70E lineaments might be old structure before Tertiary sedimentation, and possibly then reworked. Considering the good correspondence to distribution of igneous rock, it might be possible to consider that this structure has controlled regional emplacement of Tertiary to present igneous activity.

N10-40E structure usually occurs as an aggregate of short lineaments less than 10km and tends to accompany with longer N-S trending lineament. Some of these structures can be identified as dilational fault jog related to strike-slip faulting. Dilational fault jog is an aggregate of open fissure and/or sheared fracture which behaves as good a structural preparation for epithermal ore deposition rather than major fault (Sibson, 1987).

4.2 ALTERATION MINERAL MAPPING

Fig. 4 shows a close up of alteration mapping results around the Monywa deposit because it is easier to examine mapping quality. Lepadaung ore deposits shows concentric alteration halo, from center to margin, vuggy quarts + alunite + limonite, then kaolinite dominant. However, such distribution is not directly recognizable on outcrop because higer topography, such as Lepadung hill, tends to be covered with dense vegetation. Alteration halo therefore can be only estimated from floating rock in less vegetated low topography.

Limonite, alunite, and silica enriched portion is observed in NE skirt in the Lepadaung hill. As NE skirt is close enough to the ore deposit, thus ore related debris directly accumulates. On the other hand, kaolinite pixel is mainly distributed in SW of Lepadaung hill where corresponds to distal site to ore deposit. Muscovite pixel seems not to be related to mineralization at the Lepadaung surface very well. Muscovite distribution envisages that this mineral is probably a product of diagenetic process of sedimentary rocks at Lapadaung and its vicinity except the Sabedaung open pit where deeper alteration is exposed.

These alteration mineral maps are informative enough to know general distribution of hydrothermal alteration minerals in this area even though the survey area is semi-vegetated region.

5. CONCLUSION

Integrated analysis including geological, lineament-related structural, and ASTER spectral mapping information, has identified 26 candidate areas of interest for groundtruth. Field checking has revealed that al least one area identified during analysis corresponds to paleo-hydrothermal activity which has not been previously reported.

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