Introduction to Rare – Earth Metal Resources in Thailand

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Abstract: Geochemistry and mineralogy of rare earth mineral deposits in Thailand were investigated. Monazite and xenotime are significant rare earth minerals occurring with tin ± tungsten deposits of primary and secondary types. The former is recognized in granites and pegmatites of southern Thailand and the latter are observed near the former and in Quaternary fluvial and beach deposits. Geochemical analyses on granites suggest that the ilmenite – series granites yield more rare earth minerals than the magnetite - series granites. The younger and strongly hydrothermally altered granites contain more rare earth minerals. Three rare earth provinces are identified – primary, secondary, and tertiary provinces. The tertiary province represents the weathering crust of granites and pegmatites and is of important economic significance to explore. In southern Thailand it yields the highest RE metal contents (0.092%). The most important secondary provinces are in Songkhla and Yala of southern Thailand and can yield up to 0.045 % monazite and 0.196 % xenotime contents.

Key Words: Rare earth, Thailand, Granites, Ilmenite series, Alteration

1. INTRODUCTION

There is an increase in demands of rare earth metals year by year; particularly those used for information technology (IT) industries, special magnets, petroleum catalysts, and ceramic/glass uses. It is anticipated that their life-span has been shortened dramatically. This is mainly due to the efforts made to discover, to develop new deposits, and to make them productive. Continuous efforts are made to extend its life-span. However, the present – day quantity of consumed resources is totally different from that of the earlier 30-year time. Therefore, it is very difficult to secure and to maintain rare earth metal resources of the same number, and the innovation is vital in exploration and development of resources.

In this study we define rare earth (RE) metals following the definition proposed by Shannon [1] as a group of 17 chemically similar metals that includes the elements scandium and yttrium (atomic numbers 21 and 39, respectively) and the lanthanide elements (atomic numbers 57 through 71).

The main purpose of this study is to evaluate preliminary potentials of RE metals in Thailand. Additional aims are to determine their sources and classifications of RE metals. Therefore, all the relevant and existing published and unpublished reports and maps were compiled and reviewed for the first step. Then field work was conducted for geologic syntheses and samplings of ores and granites. Selected samples of RE – bearing minerals, ores and rocks were analyzed geochemically and mineralogolically. Interpretation of the result was done in the last step for RE metal appraisal.

2. GEOLOGIC AND TECTONIC SETTINGS

It has been widely accepted that many of the RE metals in Thailand are always associated with granites and pegmatites [2] and that only some special types of granites can give rise to such mineralization [3]. In Thailand the granites form as the north – south trending batholiths and stocks in the long (> 2,000 km) and curvilinear zones or belts. In term of geographical distribution, these granites can be subdivided into 3 major belts, namely Eastern, Central, and Western Belts (Fig.1). These granite belts extend northern to southern Yunan and southward to Malaysia. Based on the classification by Ishihara [4] which is relatively similar to that of Chappel and White [5] , the granites of the Eastern Belt are mainly Triassic granites of I – type or magnetite – series whereas those of the Central and Western Belts belong to granites of both I – type or magnetite – series and S- type or ilmenite – series. The Central Belt granites occurred mainly in Triassic whereas those of the Western Belt are of Cretaceous to Tertiary. The S-type or ilmenite –series granites include fine – to coarse – grained biotite granites, biotite – muscovite granites, and tourmaline – muscovite granites. Only the biotite granites are usually porphyritic. Important accessory minerals include zircon, monazite, rutile, garnet, topaz and beryl.

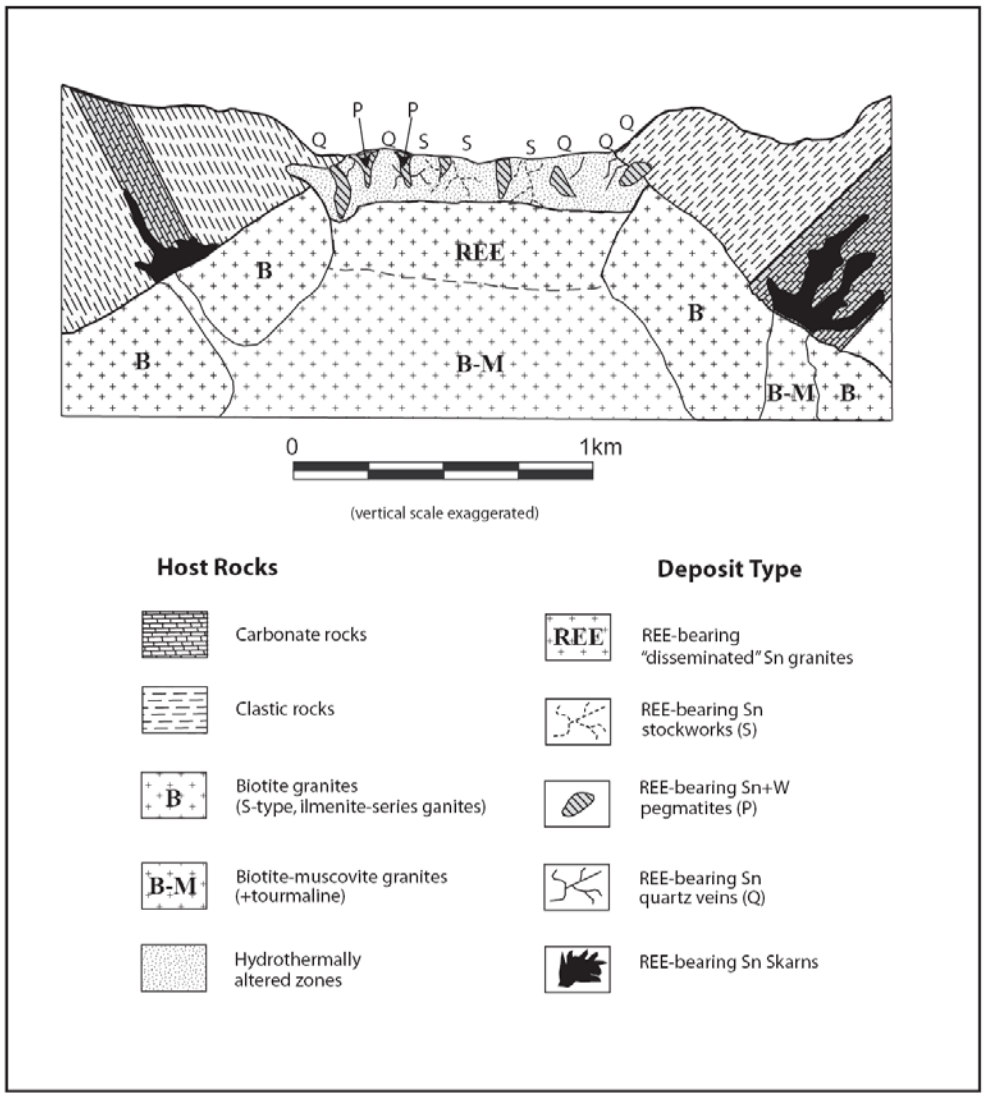

Fig. 1. Genetic model of the REE – bearing primary Sn± W deposits of Thailand (modified from Charusiri et al. [3]).

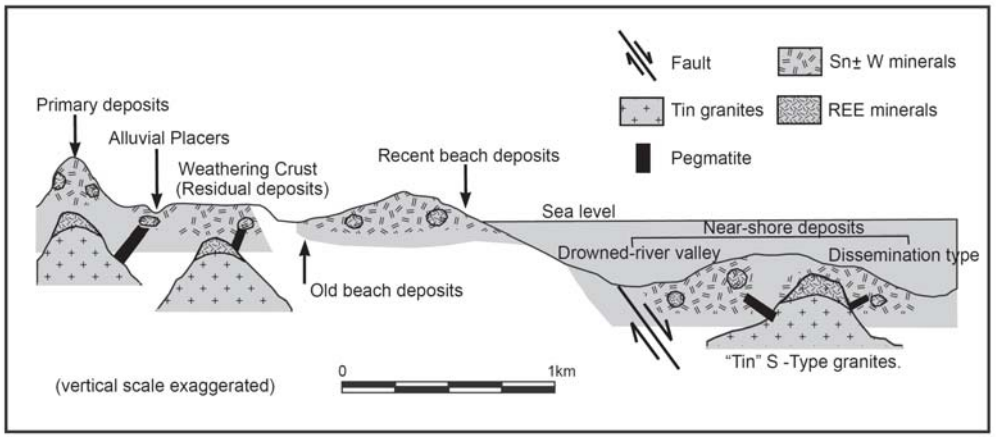

Fig. 2. Genetic model of the REE – bearing secondary Sn±W deposits of Thailand [3].

The magnetite - series granites include hornblende - biotite granites and biotite granites with strong to mild foliation and mainly porphyritic textures. Important accessory minerals are sphene, epidote and allanite (or orthite). In some places pyroxene are also present in minor amount. It is noted, based on our result, that the S-type or ilmenite – series granites with strong alteration can yield high REE contents (Figs. 1 and 2).

2. MINERALOGICAL INVESTIGATION

We compiled and reported RE metal contents from the analytical results of approximately 250 ore samples collected from various abandoned tin ± tungsten mines from both on land and sea beds. This also includes RE contents in ore samples collected from currently operated Au-Ag and Zn mines from various parts of the country. Mineral separation and processing were done to extract RE metal concentrates. XRD analysis and binocular microscopic determination were applied to evaluate their contents. Based upon our compiled data, particularly from the data by Praditwan [6] and Pungrassami [7], we found that both Zn and Au-Ag deposits contain no RE metals, and that only the tin ± tungsten alluvial and beach placer deposits host appreciable amounts of RE metals. Therefore unlike the other part of the world which bastnaesite is the most important ore for RE metals, in Thailand the most important RE ores are monazite and xenotime. Other RE minerals are samarskite, cassiterite, wolframite, zircon, microlite, columbite – tantalite, rutile, anatase, and ilmenite.

3. GEOCHEMICAL INVESTIGATION

In this study, results on the REE contents of about 150 granite and pegmatite samples from individual granite belts were reported. The analyses were performed using XRF, ICP OES and ICP MS methods [8]. It is quite likely that the granites of the Eastern Belt host small amounts of REE concentrations whereas those of the Central and Western Belts contain appreciable amounts of REE concentrations. We found that the granites of ilmenite – series granites, particularly those with the more evolved or differentiated melts can contain much more amounts of RE metal contents than the less evolved granites. Additionally, as very recently reported by Imai et al. [9], the weathering crust of the granites contain up to 1,000 ppm. It is quite likely that this kind of RE metal resources seems to be by far the most interesting one and requires detailed further detailed exploration for the commercial scale at present.

4. CLASSIFICATION OF RARE EARTH METAL RESOURCES

Based on the results reported above, we classify the RE metal resources into 3 provinces in Thailand, viz. primary, secondary and tertiary provinces (Fig. 3).

4.1 **Primary Province**

The primary RE metal province is the province where a group of RE metal deposits occurs principally in hard rocks, such as granites, pegmatites, and aplites. Charusiri et al. [3] and Imai et al. [9] recognized that the strongly differentiated or more evolved granites and the more altered granites and their minor intrusions contain more RE metal contents than the normal unaltered granites (Fig. 1). It is also found that the ilmenite – series (or S- type) granites contain more RE metal contents than the magnetite (or I – type) affinity for both of the altered and unaltered types. It is also recognized that the magnetite - series granites contain the varying total REE values from 512 to 778 ppm. Those of the more evolved granites vary from 634 to 997 ppm. The ilmenite-series granites have the total REE contents ranging from 712 to 887 ppm, and the more evolved granites show variation of total REE contents from 799 to 991ppm [8]. However, the strongly altered ilmenite – series granites have the total REE values from 832 to 1,092 ppm. However, as reported by Imai et al. [9], the REE value of the very strongly altered part of the ilmenite - series granites can be reached up to 1,525 ppm.

In addition, pegmatite can also be a host rock for RE metals. Geochemical analysis reveals that the altered pegmatite yields the RE metal contents of up to 0.02 and 0.05 % monazite and xenotime, respectively.

4.2 **Secondary Province**

Charusiri et al. [3] subdivided secondary RE metal deposits in Thailand into 3 groups; namely (1) alluvial placer deposits, (2) recent and old beach deposits, and (3) near – and off – shore deposits (Fig. 2). Particular interests are the Sn± W secondary deposit areas in the southern part of Thailand. Apart from cassiterite and wolframite, the other essential minerals are monazite, xenotime, zircon, columbite, tantalite, rutile, anatase, and ilmenite. The most important secondary provinces are alluvial placers in Songkhla and Yala of southern Thailand. The RE metal – bearing deposits contain up to 0.045 % monazite and 0.196 % xenotime contents [3].

4.3 **Tertiary Province**

A new type of rare earth elements (REEs) deposit has been discovered from the weathering crust of granites. Many of the deposits are located in southern Thailand. However, some of them are also found in the central part. In general this deposit type contains ΣRE_2O_3 within the range of 0.065% – 1.086% or at the average of 0.092% [9]. This type of REEs deposit was widely distributed with steady horizon and thickness of 3–4 m. The ore-bearing weathering crust (kaolinite) of the discovered REEs deposits belonged to the Cretaceous – Tertiary, S – type ilmenite – series granites. The new type of REEs deposit was suggested that chemical

weathering of the strongly evolved and altered granite weathering could lead to the enrichment of the rare earth elements. Therefore, it is of economic

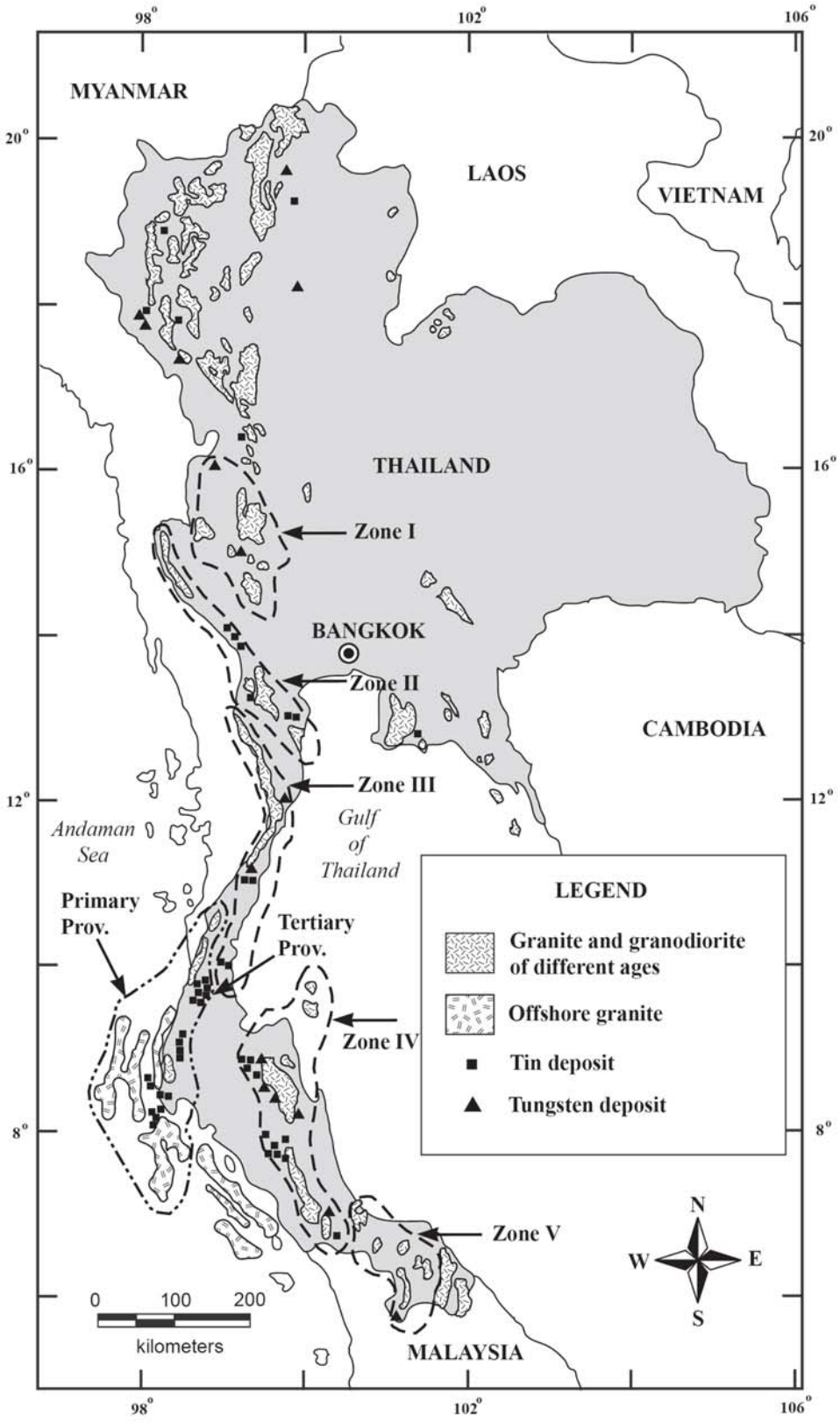

Fig. 3. Classification of REE provinces in association with Sn and W deposits and ilmenite – series granites in Thailand [3].

significance to explore REEs deposits in the in situ weathering zone of granites in Thailand.

5. DISCUSSION

Granites in Thailand show high REE contents in general. Total REE contents of weathered crust of granites in southern Thailand may reach 1,000 ppm. The total REE concentrations of weathering-crust granitic rocks appear higher than those of normal unaltered granitic rocks. However, REE contents of weathered crust of ilmenite – series granitic rocks are higher than those of the magnetite – series granites. The total REE contents of weathered crust of granitic rocks are elevated compared with the unweathered original granitic rocks.

In southern Thailand, Imai et al. [9] proposed that the total REE contents of weathered crust of granitic rocks are enriched at the lower part of the B zone in typical weathering profile. The chondrite-normalized REE patterns of the weathered crust of granitic rocks in southern Thailand are parallel to their unweathered part, while contents of each REE are higher in the weathered crust. This suggests that REE-bearing accessory minerals (monazite and xenotime) may be resistant against weathering, and may remain a residual phase. Thus, REE concentration should be elevated by removal of decomposed minerals.

Furthermore, it is observed that total REE contents are high in some hydrothermally altered granitic rocks through greisenization and argillization, and that kaolinite veinlets associated with hydrothermal Sn mineralization in the western granitic belt of southern Thailand. Some show HREE concentration higher than those of unweathered original granitic rocks in the western granitic belt of southern Thailand. Thus, the hydrothermally altered granitic rocks, and kaolinite veinlets associated with hydrothermal Sn mineralization in the western granitic belt of southern Thailand show relatively flat chondrite normalized REE pattern. According to Imai et al. [9], the REE pattern is similar to those of weathered crust of granitic rocks in Longnan area [10] [11] in China. The HREE concentration of greisens and hydrothermally altered granitic rocks, and kaolinized veinlets associated with Sn± W mineralization in the Western Granitic Belt are elevated compared with the unweathered original granitic rocks [10]. This is attributed to the leaching of LREE by hydrothermal solution, in addition to enrichment by removal of decomposed minerals. Furthermore, HREE is selectively enriched associated with clay minerals, such as kaolinite, most probably due to ion adsorption mechanism. The western granitic belt associated with Sn± W mineralization has a potential for the RE metal resources, particularly in hydrothermally altered granitic rocks and clay-enriched veinlets associated with hydrothermal deposits accompanied with ilmenite-series granitic rocks, in addition to REE-enriched weathered crust of granitic rocks and heavy mineral alluvium placers.

6. CONCLUSION

Monazite and xenotime are the most important RE metal minerals in Thailand. They are found more abundantly in ilmenite – series granites than magnetite – series granites. Secondary RE deposits yield high REE contents, as well as weathering crust of granites and altered ilmenite – series granites also contain high values of REE contents.

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