

Towards the challenging REE exploration in Indonesia

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Abstract. Rare earth elements (REE) are the seventeen elements, including fifteen from $_{57}\text{La}$ to $_{71}\text{Lu}$, in addition to $_{21}\text{Sc}$ and $_{39}\text{Y}$. In rock-forming minerals, rare earth elements typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates. The REE occur in a wide range of rock types: igneous, sedimentary and metamorphic rocks. REE are one of the critical metals in the world. Their occurrences are important to supply the world needs on high technology materials. Indonesia has a lot of potential sources of REE that are mainly from residual tin mining processes in Bangka islands, which are associated with radioactive minerals e.g. monazite and xenotime. However, the REE from monazite and xenotime are difficult to extract and contain high radioactivity. Granitoids are widely distributed in Sumatra, Sulawesi, Kalimantan and Papua. They also have a very thick weathering crusts. Important REE-bearing minerals are allanite and titanite. Their low susceptibilities during weathering result an economically potential REE concentration. I-/A-type granitoids and their weathered crusts are important REE sources in Indonesia. Unfortunately, their distribution and genesis have not been deeply studied. Future REE explorations challenge are mainly of the granitoids their weathered crusts. Geochemical and mineralogical characterization of type of granitoids and their weathered crusts, the hydrothermally altered rocks, and clear REE regulation will help discover REE deposits in Indonesia.

1. Introduction

Rare earth elements (REE) are the seventeen elements in the Periodic Table, including fifteen from $_{57}\text{La}$ to $_{71}\text{Lu}$, in addition to $_{21}\text{Sc}$ and $_{39}\text{Y}$ [1-3]. In rock-forming minerals, rare earth elements typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates. Rare earth elements are classified into light rare earth elements (LREE) and heavy rare earth elements (HREE) [3].

The REE occur in a wide range of rock types: igneous, sedimentary and metamorphic rocks. REE deposit in igneous rocks are commonly associated with alkaline and peralkaline rocks, and they can also be formed in carbonatites [3-4]. They can also be enriched in the granitoids through the accumulation of REE-bearing minerals such as apatite, allanite, monazite, titanite and xenotime since they tend to remain in the melt until the late stages of magmatic differentiation [1,3].

Quite different from their name, rare earth elements are really not that rare; they are relatively plentiful in the earth crusts [2]. REE are very critical to support the development of future high technology, such as manufacturing catalytic converters, petroleum refining catalyst, magnets, hybrid cars, and electronics, making them economically important worldwide [5-6].

There are rare earth element reserves in about 34 countries. China is the largest producer, consumer and exporter of rare earth element products. But, China is definitely not the only supplier of the rare earth element products. There are abundant rare earth element deposits besides China. In Asia,



fourteen countries have rare earth element deposits, five of them are Vietnam, India, Mongolia, Kazakhstan and Kyrgyzstan [2].

Petrochemical, REE geochemistry on granitoids, and their weathered crusts and the granites are of particular importance. No detailed research on granitic rocks in Sumatra has ever been conducted.

Study of REE in Indonesia is very important to support not only world demand but also growing interests among the geologist and Indonesian researchers. The aim of this review is to elucidate the geology of granitoids and their association with the REE enrichment.

2. Geology and distribution of REE in indonesia

In Indonesia, there are three types of main exploration targets of REE deposits. They are primary REE deposits associated with alkaline-peralkaline igneous rocks, secondary lateritic deposits, and placer monazite (xenotime) as by-products of placer tin mining [7]. In addition, granitoids and their weathered crusts are identified as main source of REE in Indonesia, in particular of western part of North Sumatra [8-11]. A wide distribution of granitoids and their weathered crusts has a potential as main REE source. Thus, it is believed that more rare earth element deposits will be discovered. Suwargi et al., 2010 identified at least 15 locations which have been reported to have granitoids associated with REE in Indonesia[12] (Figure. 1).

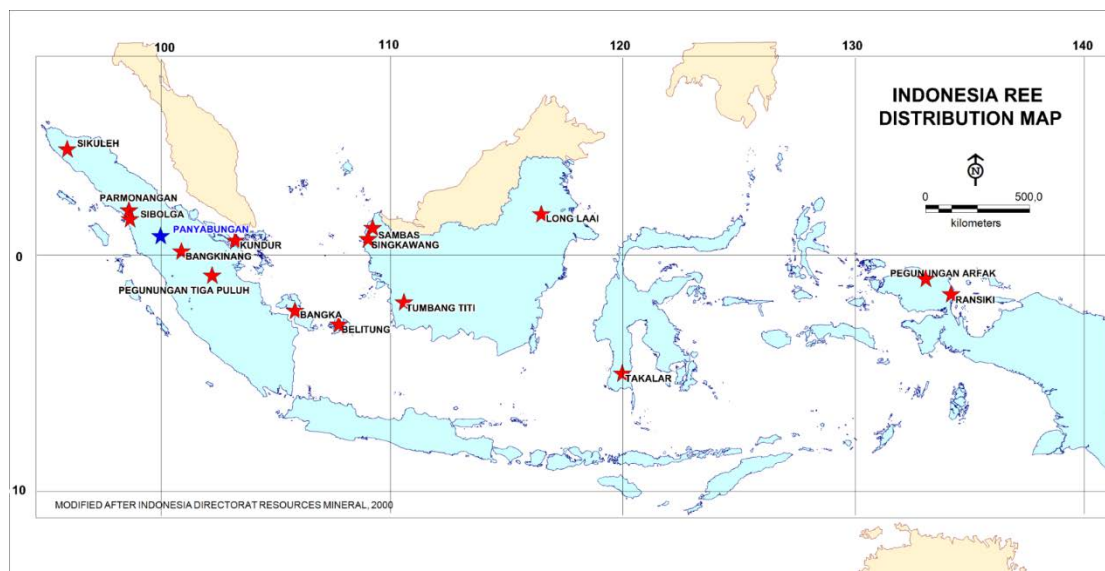


Figure 1. Distribution of granitoids in Indonesia modified after [12].

Tin has been produced mainly from placer deposits both onshore and offshore of Tin Islands such as Bangka, Belitung [13]. This tin mineralization is primarily associated with Main Range Belt granitoids, which are distributed in the Southeast Asian Tin Belt, a major metallogenic province of Sn deposits associated with ilmenite-series granitic rocks [14-15]. Besides Bangka and Belitung islands, placer tin occurrences with associated monazite have also been reported in many parts of Sumatra and Western Kalimantan [7]. On Sumatra Island, tin mineralization associated with Main Range Granites occurs in the plutons at Sungai Isahan and adjacent areas in the Tiga Puluh region of South Sumatra and the batholith at Sijunjung in the eastern flank of the Bukit Barisan to the northeast of Padang [15]. The Hatapang Granite, located at the south of Lake Toba and to the east of Sibolga associated with a tin prospect, belongs to the S-type Western Belt Granites ([15-16].

3. REE in the granitoids

REE are enriched in I-/A-type granitoids in Sibolga [10]. They are calc-alkaline, ilmenite-series, mainly peraluminous, and are classified into quartz alkali feldspar syenite, quartz syenite, alkali

feldspar syenite, alkali feldspar granite, syenogranite, and monzogranite. REE are not enriched in the S- and I- type granitoids of Panyabungan, Kotanopan and Muara Sipongi. The granitoids from Sibolga were formed at within-plate and orogenic setting, with characters of A-type and ilmenite-series.

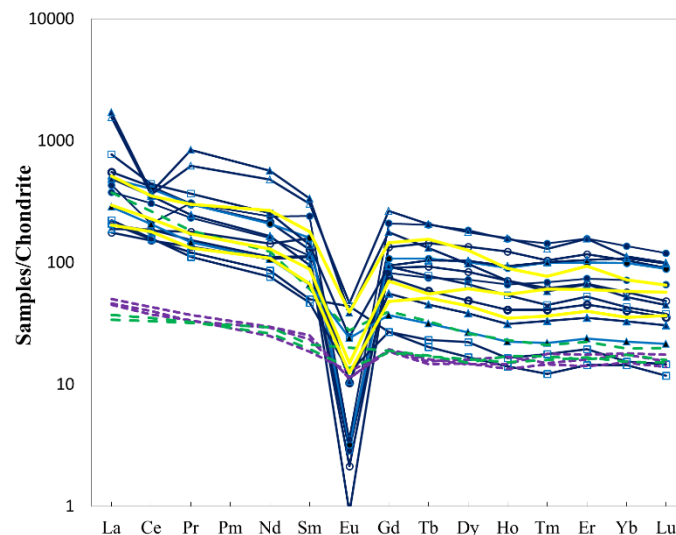


Figure 2. Chondrite normalized REE patterns (normalizing values of chondrite are from McDonough and Sun, 1995).

The alkali felspar granite, alkali felspar syenite, quartz syenite and diorite from Panyabungan were formed in volcanic arc setting, with characters of I-type, ilmenite-series and magnetite-series. On the other hand, granitoids at Kotanopan consist of syenogranites and tonalites, while granitoids at Muarasipongi are composed of quartz monzonite and quartz diorites which were formed in volcanic arc setting, with characters of I-type and magnetite-series [9].

4. REE in the weathered granitoids crusts

The weathered crusts of granitoids are the predominant source of REE in particular of HREE [9,17 - 18]. That type of deposits is called ion-adsorption-type REE deposits. The enrichment of REE in the lower horizon of the weathered profile occurred due to the accumulation of REE that was absorbed on to the clay minerals. The weatherable REE-bearing minerals, including fluorocarbonates, allanite, and titanite, are the source minerals for the ion adsorption ores [8-9,17-18].

The largest producer country of ion adsorption-type REE deposits is China. They produce about 20% of the world production in 2010 [19]. Indonesia is located in a tropical climate and consists of wide distribution of granitoids and their crusts, and therefore Indonesia has a potential as REE source of the ion adsorption-type REE deposits. Titanite and allanite occur in syenogranite at Sibolga. Allanite and titanite are likely decomposed to be the source of ion exchangeable REEs and control the elemental mobility of REE [8-9].

5. Toward exploration of REE

Exploration of REE in Indonesia is believed to reveal a big potential resource. It is not only associated with the tin belt, but also with another granitoids in Indonesia which are distributed from the western most of Sumatra Island to the eastern most of Papua Island.

This study suggests that the main exploration targets of REE deposits in Indonesia are the metaluminous-peraluminous, ilmenite-series, I- /A-type and highly differentiated granitoids, and their weathered crusts, in addition to the alkaline-peralkaline igneous rocks, secondary lateritic deposits, and placer monazite (xenotime). Indonesia has developed REE from placer deposits, but the REE-bearing minerals called as monazite is categorized as a radioactive mineral by the Mining Law No.

4/2009 that restricts its development by general mining companies. Furthermore, building a processing plant of the REE-bearing radioactive minerals will create the environmental problem.

The government needs to synchronize the regulation among the sectors i.e. the mining law (UU No. 4/2009), energy (UU No. 30/ 2007), and nuclear (UU No. 10/ 1997) to encourage the discovery and development of REE deposits in Indonesia.

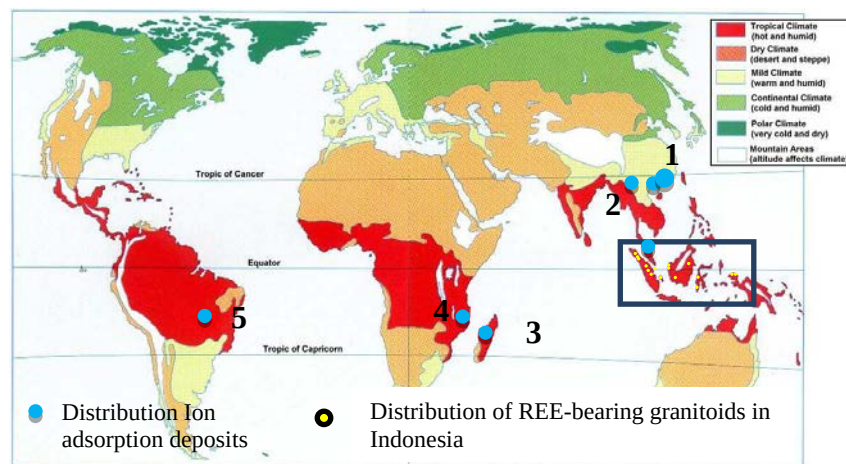


Figure 3. World map of the Koppen-Geiger climate classification (modified after [6]). Ion adsorption-type REE deposits and prospects are shown in the map.

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References

- [1] Wilson M. 1989 *Igneous Petrogenesis*. Unwin Hyman, London, 466 p.
- [2] Chen Zhanheng 2011 *Global Rare Earth Resources and Scenarios of Future Rare Earth*. Journal of rare Earth, Elsevier, Vol. 29, 1 p1-6.
- [3] Castor, S. B. and Hedrick, J. B. 2006 Rare earth elements. In J.E. Kogel, N. C. Trivedi, J. M. Barker, S. T. Krukowski (eds) *Industrial Minerals & Rocks: Commodities, Markets, and Uses*. Society for Mining, Metallurgy, and Exploration (U.S.), 769-792.
- [4] Long, K. R., Van Gosen, B. S., Foley, N. K. and Cordier, D. (2010) *The principal rare earth elements deposits of the United States—A summary of domestic deposits and a global perspective*. U.S. Geological Survey Scientific Investigations Report 2010–5220, 96p. <http://pubs.usgs.gov/sir/2010/5220/>.
- [5] Pecht, M. G., Kaczmarek, R. E., Song, X., Hazelwood, D. A., Kavetsky, R. A., and Anand, D. K. (2012) *Rare Earth Materials: Insights and Concerns*. Energetic Science and Technology Series, University of Maryland, CALCE ESPC Press, 125p.
- [6] Dickson, J. S. (2015) *Rare earth elements: Global market overview*. In: Simandl, G. J. and Neetz, M., (eds.), Symposium on Strategic and Critical Materials Proceedings, November 13-14, 2015, Victoria, British Columbia. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper, 5-11.
- [7] Setiadi L.D. (2015) *Geology of Rare Earth Elements Mineralization and Their Potential in The Indonesian Archipelago*, Proceeding of Seminar of REE
- [8] Setiawan I., Takahashi R., Imai A., 2015 *REE Enrichment in Granitoids and Their Weathered Crust at Sibolga, North Sumatra Province, Indonesia*. Akita Symposium 2015, Japan

- [9] Setiawan I 2017b *Geology and REE Geochemistry of Granitoids and Their Weathered Crusts in The Western Part of North Sumatra, Indonesia*. Dissertation report, Akita University (Unpublished)
- [10] Setiawan I., Takahashi R., Imai A., 2017a, *Petrochemistry of Granitoids in Sibolga and Its Surrounding Areas, North Sumatra, Indonesia*, Special Publication of Asia- Africa Mineral Resource, Resource Geology, 3, 254-278.
- [11] Maulana A., Yonezu K., Watanabe W 2014 *Geochemistry of rare earth elements in the weathered crusts from the granitic rocks in Sulawesi Island, Indonesia*. Journal of Earth Sciences, 3, 460-472
- [12] Suwargi, E., Pardianto, B. and Ishlah, T. 2010 *Potensi logam tanah jarang di Indonesia*. Buletin Sumberdaya Geologi, 5, 131-141. (in Indonesian)
- [13] Sainsbury, C.L. (1969) *Tin Resources of the World: A Description of the Types of Tin Deposits and Main Tin-producing Areas of the World*. Geological Survey Bulletin 1301, U.S. Govt. Printing Office, Washington, 53p.
- [14] Schwartz, M. O., Rajah, S. S., Askury, A. K., Putthapiban, P. and Djaswadi, S. (1995) *The Southeast Asian Tin Belt*. Earth-Science Reviews, 38, 95-293.
- [15] Cobbing, E. J. (2005) *Granites*. In : Barber, A. J., Crow, M. J. and Milsom, J. S., (eds.), *Sumatra- Geology, Resources and Tectonic Evolution*. Geol. Soc. London, Mem., 31, 54-62.
- [16] Clarke, M. C. G. and Beddoe-Stephens B. (1987) *Geochemistry, Mineralogy and Plate Tectonic Setting of a Late Cretaceous Sn-W Granite from Sumatra, Indonesia*. Mineralogical Magazine, 51, 371-387.
- [17] Sanematsu, K., Kon, Y., Imai, A., Watanabe, K. and Watanabe, Y. 2013 *Geochemical and mineralogical characteristics of ion-adsorption type REE mineralization in Phuket, Thailand*. Miner. Deposita, 48, 437-451.
- [18] Sanematsu K. And Watanabe Y. 2016 *Characteristics and Genesis of Ion Adsorption-Type Rare Earth Element Deposits*, Review in Economic Geology, v. 18, pp 55-79
- [19] Roskill, 2011, *Rare Earths & Yttrium: Market Outlook to 2015*, 14th edition, 2011: Roskill Information Services, Ltd., London, 492 p.