INDONESIAN REE, LITHIUM, AND GRAPHITE POTENCY

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Rare Earth Elements (REE)

The rare–earth elements are, by definition, group composed of seventeen elements consisting of scandium (Sc), yttrium (Y), La and the 14 lanthanides Ce–Lu (Figure 1). The term 'rare earth' has often been applied in the more restricted sense as a synonym for the lanthanides, thus excluding Sc, Y and La. From lanthanum (La) to europium (Eu) are grouped into Light REE (LREE) while from gadolinium (Gd) to lutetium (Lu) are classified as Heavy REE (HREE).

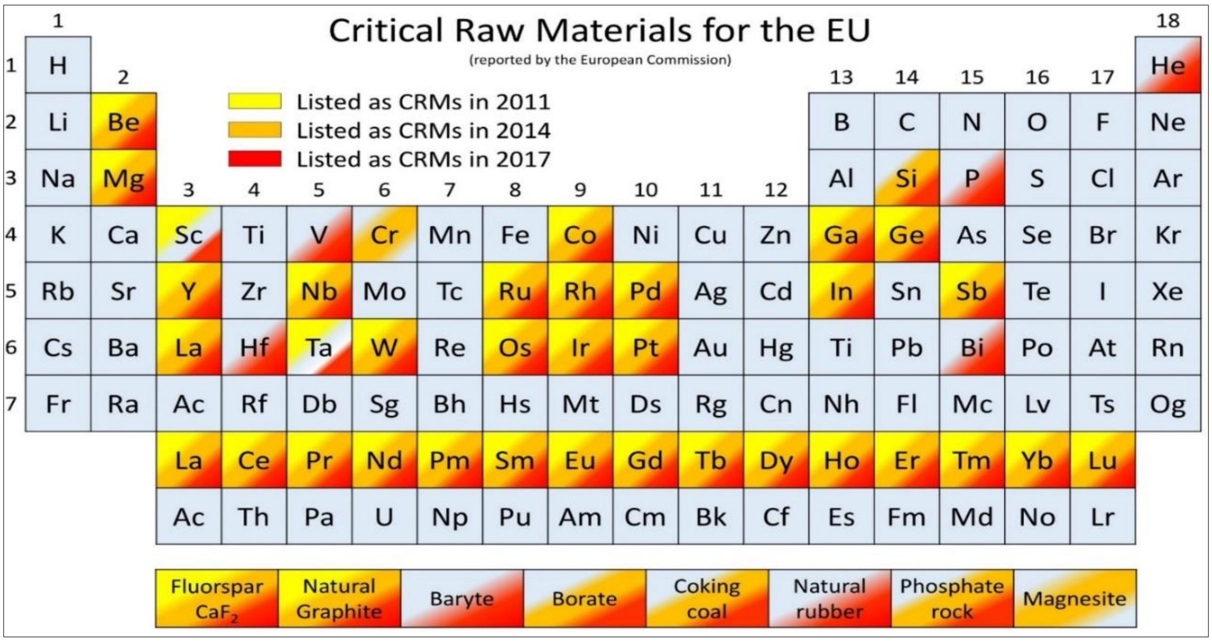

Figure 1. List of CRMs from periodic table (Rizzo, et al., 2020)

Occurrences

The majority of world REE deposits are hosted by carbonatite/alkaline rocks as firstly discovered in Bayan Obo, China. More than 550 carbonatite/alkaline complexes are distributed in the world which is confined to interior and marginal regions of continents especially Precambrian cratons and shield or related to large-scale rift structure. The other deposit of hydrothermal and supergene origin in carbonatites also represent a large REE resource. A small amount of REE-bearing minerals are accompanied by granite, alkaline granite, and alkaline suite rocks. REE was found to have formed as pegmatite-and skarn-stage, like in Indonesia but most of which are in the sub-economic margin.

Representative sedimentary deposits of REE are placer and conglomerate types. The detrital minerals originate from a wide variety of primary source rocks ranging from simple quartz veins to complexes of igneous and/or metamorphic origin. Economic concentrations occur where source rocks have produced sufficient quantities of valuable minerals and where geography and climate have provided suitable conditions for deposition. The placer deposits are widely distributed in the world. The major producing countries are Australia, India, Brazil, and Malaysia. Monazite and xenotime are the main RE minerals. They are associated with titanium minerals and zircon.

Weathered residual deposits have been formed under tropical and sub-tropical climates. Weathering processes concentrate REE in particular mineral-layer in the weathered crusts whose sources were originally REE-rich rocks like carbonatite and granite.

In Indonesia, REE placer deposits in form of monazite and xenotime together with rutile, ilmenite, and zirconium, monazite occurs as heavy sand deposits associated with tin ore. These originated from S-type granitic rocks due to weathering process where rock fragments and RE minerals were transported and deposited on low land, valley and beach. Monazite and xenotime also are found widespread in Asian Tin Belt passing through Riau Islands, Bangka Belitung, and West Kalimantan.

A new type of RE deposits is reported from Jiangxi province and its peripheral areas, South China, where granitoid containing comparatively much REE are perfectly weathered and almost the REE has been concentrated in the clay layer in the weathered crusts. Chinese geologists are regarded as a new type of deposit “ion adsorption-type". Similarly in Sibolga Granite of Indonesia, clay weathering products of tin-bearing granitic rocks show a significant value of Total Rare Earth Elements (TREE) up to 0.44%. These granitic rocks are also known to harbor small indications of uranium mineral deposits.

Most REE minerals occur in Indonesia are mainly of monazite and xenotime alluvial deposits together with tin minerals (cassiterite). Monazite is primarily found as mineral inclusions in granites, and pegmatites. During the weathering process, REE-bearing accessory minerals (monazite and xenotime) may be resistant or remain in residual soils.

Monazites secondary occurrence deposited as placer deposits by tin deposit, marine and beach sands which are largely found on Bangka Island. It can be seen that total REE contents are high in some hydrothermally altered granitic rocks through greisenization and kaolinization associated with hydrothermal Sn mineralization found in broadly areas of Bangka and Belitung in Indonesia.

Deposit types of REE as primary igneous, hydrothermal, and secondary/sedimentary, where some of those occurred in Indonesia areas are summarized in Table 1.

Table 1. Classification of REE Deposit Type (Weng et al., 2013)

Process	**Mineral deposit type**		**Key example**
Igneous	Silica undersaturated	Carbonatite	Bayan Obo (China), Araxá (Brazil), Karonge (Burundi), Mountain Pass (USA), Nolans Bore, (Australia), Steenkampskraal (South Africa)
		Alkaline complexes and alkaline pegmatites	Khibina and Lovozero (Russia), Norra Kärr (Sweden), Bokan (USA), Thor Lake (Canada) Kipawa Lake (Canada), Kola Peninsula (Russia)
	Silica saturated to oversaturated	Rhyolites Granites and granitic pegmatites	Round Top USA), Foxtrot (Canada) Khibina Massif (Russia), Motzfeldt (Greenland), Ytterby (Sweden)
Hydrothermal	IOCG		Olympic Dam (Australia), Milo (Australia)
	Skarn	Granite-related	Mary Kathleen (Australia)
		Carbonatite-related	Saima (China)
Secondary/	Heavy mineral sands		WIM150 (Australia)
sedimentary	Laterite		Tantalus (Madagascar)
	Tailings		Steenkampskraal (South Africa), Port Pirie, (Australia), Mary Kathleen (Australia)
	Shale-hosted		Buckton (Canada)
	Alluvial/placer		Charley Creek (Australia), India, Sri Lanka, FL (USA)

Future Plans

A total of 28 locations of REE mineralization were revealed, only 9 REE mineralization locations (30%) have been explored earlier such as Mamuju (West Sulawesi) with ∑REE 747,08 – 4.571,61 ppm in the soil sample (Figure 2) . Around 19 REE mineralization locations (70%) have not been explored optimally, this is the main target of the Geological Agency in the future (Figure 3 and Figure 4).

Figure 2. Soil Contains REE in Mamuju (West Sulawesi)

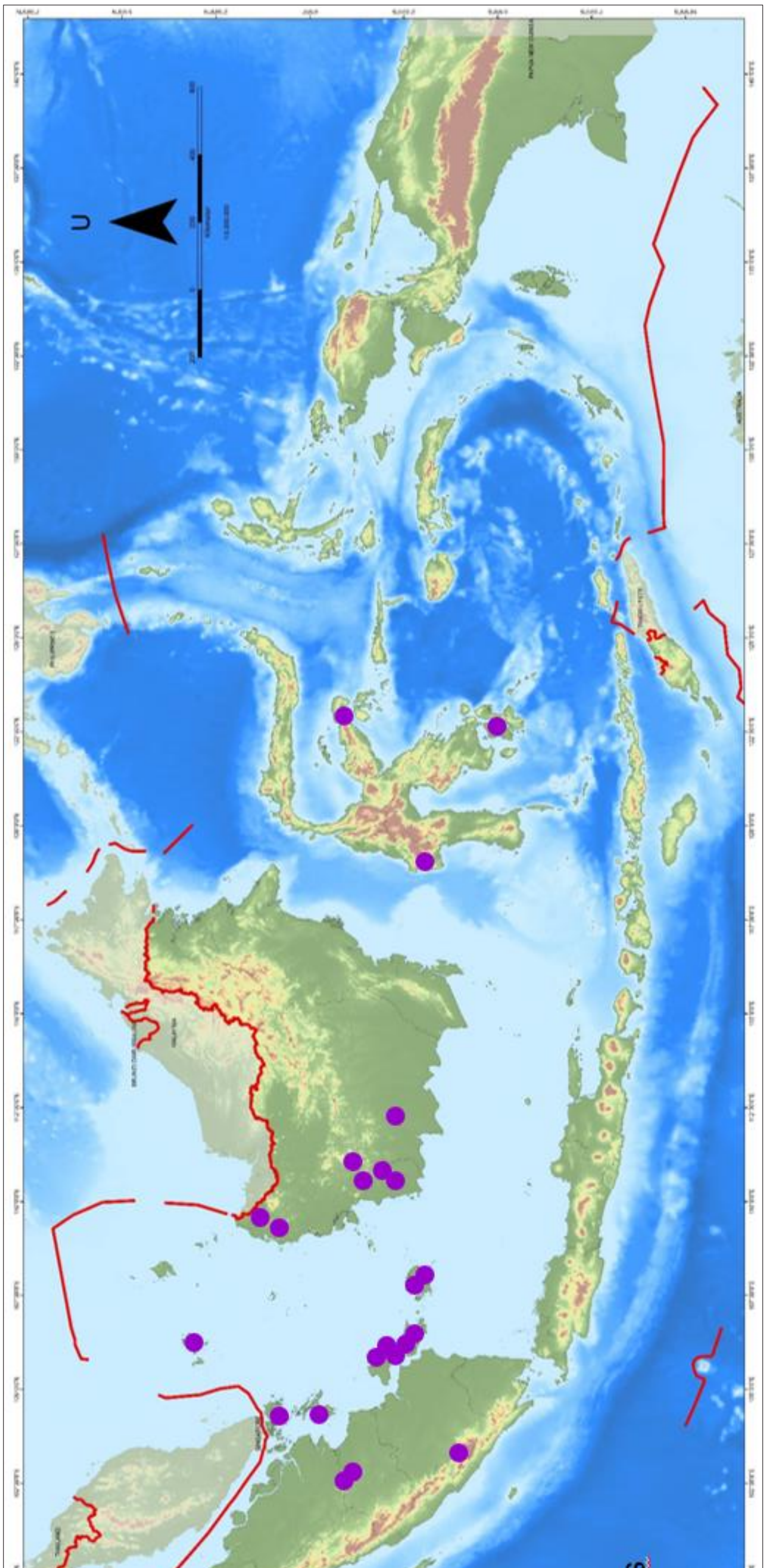

Figure 3. REE Occurrences Map in Indonesia

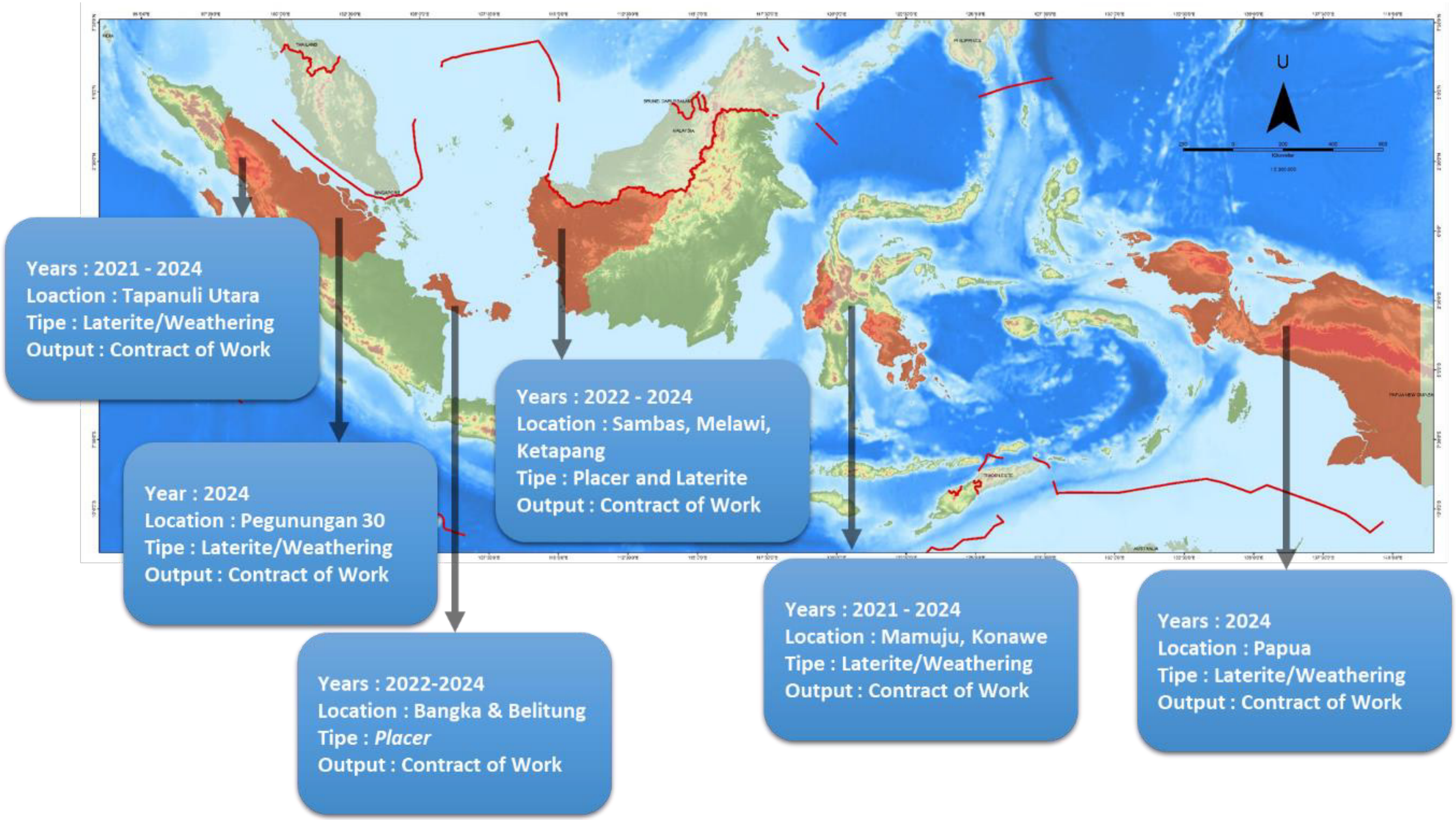

Figure 4. Future Plans Exploration Target

LITHIUM

Lithium with the symbol Li is the chemical element of Group I (1a) in the periodic table, the alkali metal group, and the lightest of the solid elements. The metal is soft, white, and lustrous. In nature, lithium is not present as a free element but as a compound in rocks. Granite and Pegmatite are referred to as the main sources of Lithium carrier. Lithium is also found in brine water or saltwater, on oil fields and from geothermal fluids. Lithium is mostly found in salt deposits or continental brine (Figure 5).

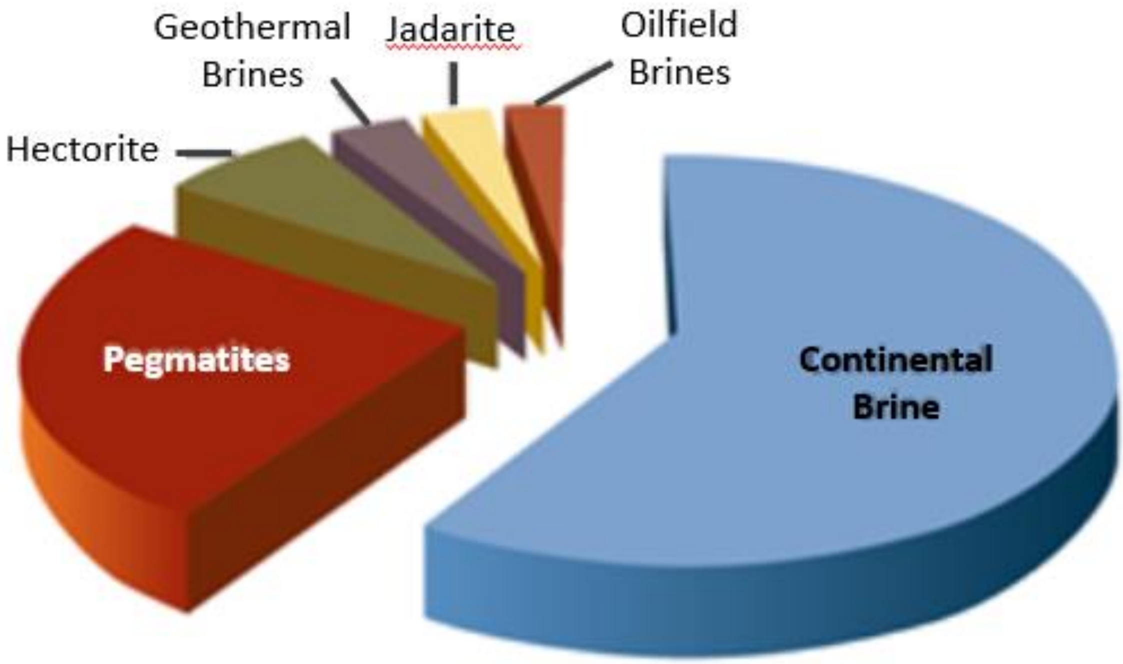

Figure 5. Lithium Existence in Nature (Evans, 2014)

Occurrences

In Indonesia, there are three main types of lithium sources that can be found: pegmatite deposit and granite, geothermal brine, and clay (mud volcano). Lithium analysis has been measured in three locations of granite by CMCGR: Hatapang Granite in North Sumatra, Akar Granite in Pegunungan Tiga Puluh, Riau, and Tanjung Pandan Granite in Belitung Island (Figure 6, Table 2). The lithium study in brine water was carried out in Dieng, Central Java, and Bledug Kuwu, Banggle, and Sidoarjo, East Java. In this study, the highest lithium contained in Brine is in Dieng geothermal field (Figure 6, Table 3). Lithium study in mud volcano or clay has been carried out in Sidoarjo mud volcano. The sample was taken with a hand auger with a maximum depth of 9.5 meters and a 250-meter grid. Li contains a range of 99 – 280 ppm.

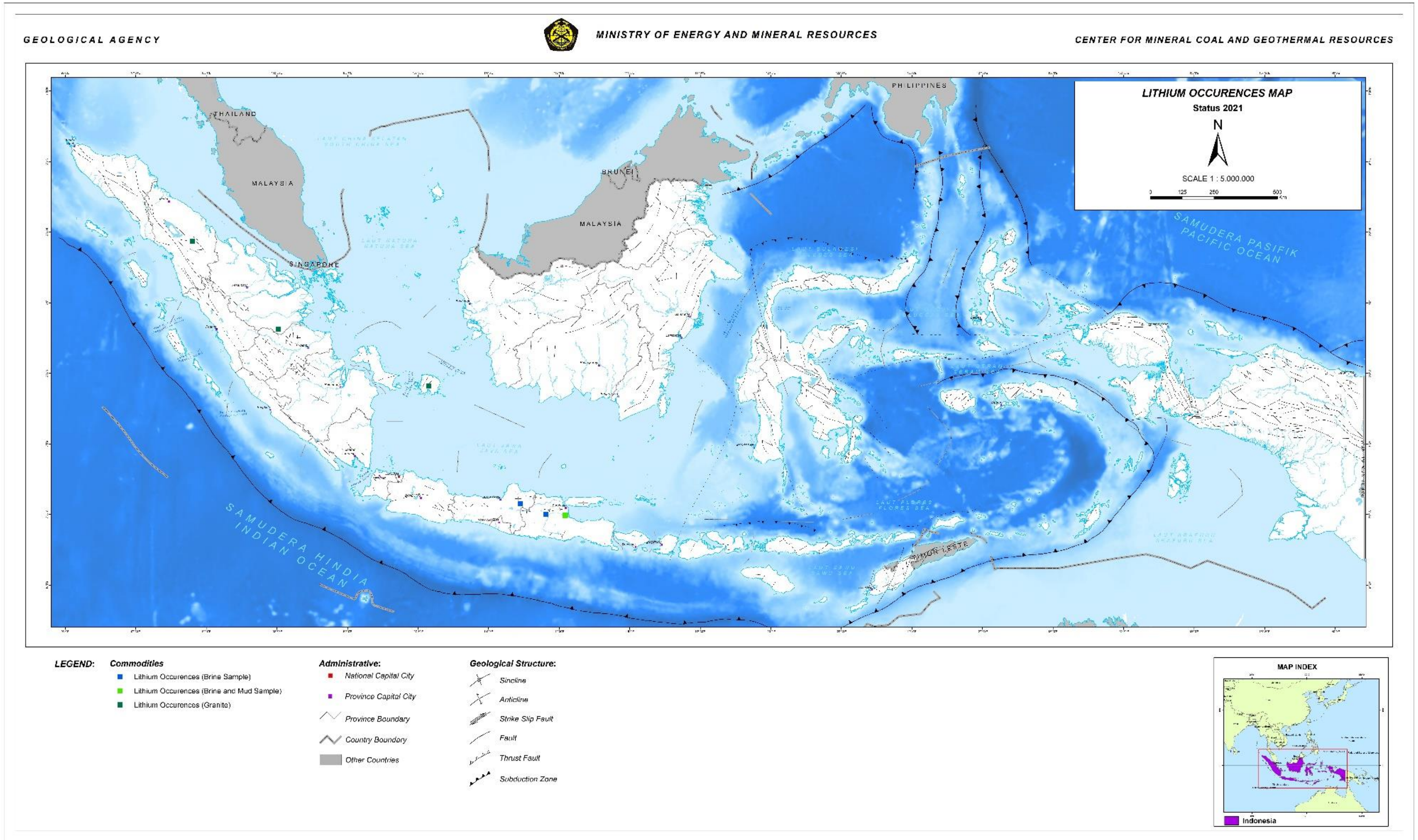

Figure 6. Lithium Occurences in Indonesia (study by CMCGR)

Table 2. Lithium Analysis by CMCGR in Granite

Formation	Location	Li (ppm)	Source
Hatapang Granite	North Sumatra	350	JICA-MMIJ, 1991
Akar Granite	Pegunungan Tiga Puluh, Riau	19 – 53 (Rock) 41 – 117 (Float)	CMCGR, 2018
Tanjung Pandan	Belitung Island	1 – 49	CMCGR, 2018

Table 3. Lithium analysis by CMCGR in brine water

No	Location	pH	DHL/ EC	Li^+
		-	(µS/cm)	(mg/L)
1	Dieng	6.34 - 6.98	28,100 – 41,400	28.9 - 53.9
2	Bledug Kuwu	7.93	113,300	7.66
3	Banggle	6.88 - 6.97	12,750 – 24,900	8.97 - 24.30
4	Sidoarjo	7.17 - 7.48	43,300 – 65,900	9.38 - 15.14

Future Plans

Indonesia has many occurrences of pegmatite, granite, and geothermal (Figure 7). However, the study of lithium in pegmatite, granite, and geothermal water is still lacking in Indonesia. Of the pegmatite and granite occurrences in Indonesia, the lithium analysis was only measured in 3 (three) granite. The lithium in geothermal water is also only measured in 4 (four) locations. Therefore, research on lithium sources in pegmatite, granite, and geothermal water still has to conduct in the future.

GRAPHITE

Graphite is an opaque, gray-black, and soft (1-2 on Mohs hardness scale) mineral with a metallic luster. It is characterized by a greasy feel, low density (2.09-2.23 g/cm), high resistance to thermal shock, and high electrical conductivity (Anthony et al., 2003). Inertness, compressibility, elasticity, and lubricity are other important physical properties (Wissler, 2006). The 2014 world natural graphite production was estimated at 1.17 million tonnes (Figure 8; Olson, 2015), with most of it originating in China (67%), India (15%), Brazil (7%), Canada (3%), Turkey (3%), and North Korea (3%). Globally, most natural graphite is used in electrodes, refractories, lubricants, foundries, batteries, graphite shapes, recarburising, steelmaking, and friction products such as brake linings.

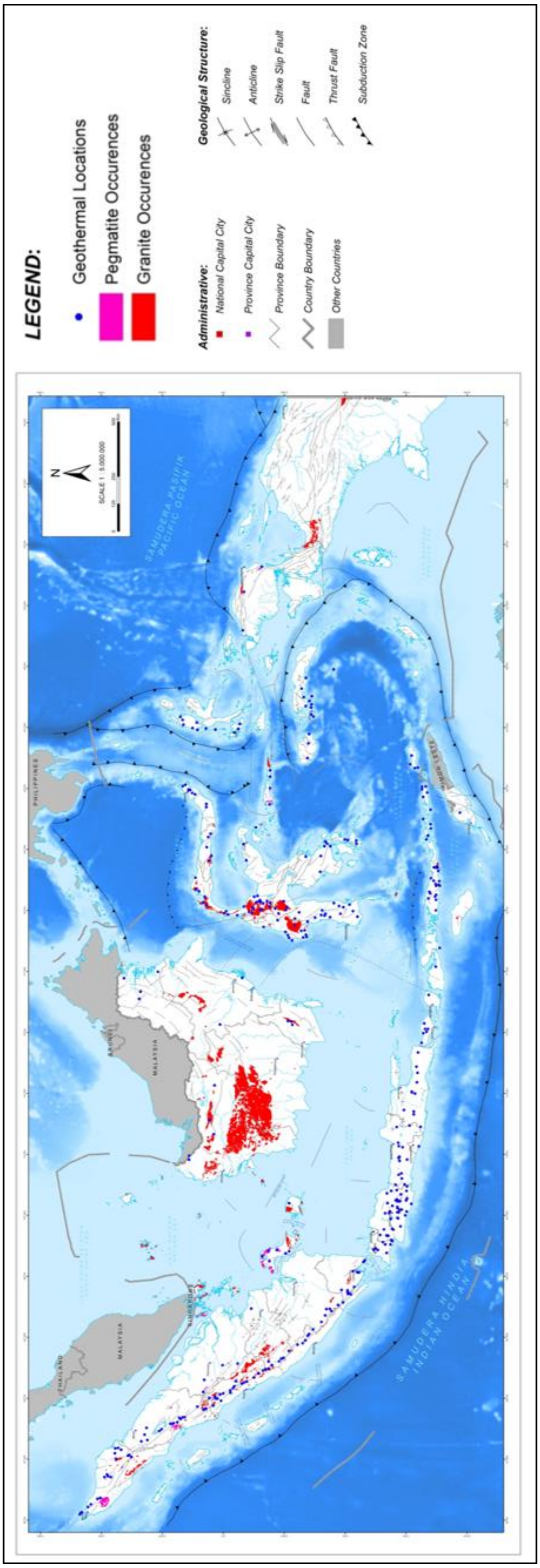

Figure 7. Pegmatite, Granite, and Geothermal Location in Indonesia

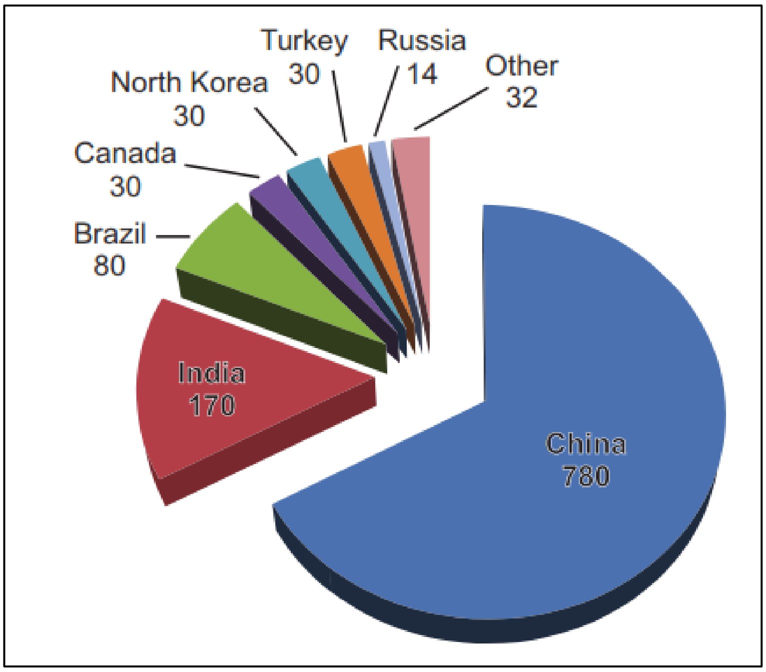

Figure 8. Global Graphite Production, in Thousands of Tonnes, Totalling 1.17 Million Tonnes, for 2014. Based on Data From Olson (2015). (George j. Simandl. 2015)

Refractory and high-technology applications make graphite a critical material in industrialized countries (Figure 9). High-technology uses of graphite represent a portion of the market with fastest forecasted growth. Examples of high-technology applications are: lithium-ion batteries for electric motor vehicles; large-scale electric energy storage devices; and graphite derivatives such as graphene (Sadasivuni et al., 2014; Dickson, 2014), spherical graphite, expanded graphite, and graphite foil.

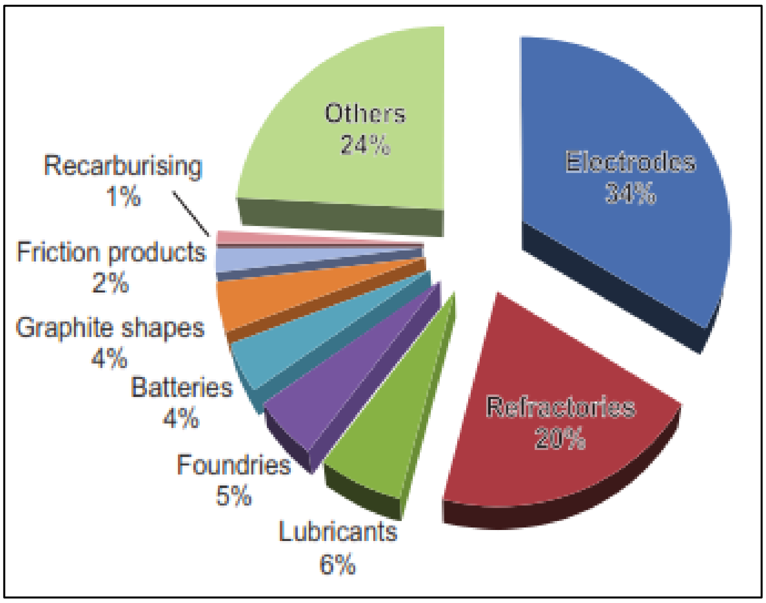

Figure 9. Main Uses of Graphite for 2012. Based on Data From Shaw (2013). (George J. Simandl. 2015)

Natural graphite deposits of economic interest are grouped into three main categories: 1) microcrystalline; 2) vein graphite (lump and chip); and 3) crystalline flake graphite (Figure 10). Deposit profiles by Simandl and Keenan (1998 a,b,c) provide an introduction to the main deposit types for exploration geologists and prospectors.

VEIN/LUMP GRAPHITE	CRYSTALLINE (FLAKE) GRAPHITE	MICROCRYSTALLINE (AMORPHOUS) GRAPHITE
		
• Origin: Hydrothermal Vein • Found in lump • Grade Graphite (C) > 98 % • Rare and tend to be expensive • Location : Sri Lanka	• Origin: Regional Metamorphic Rock • Found in flake • High-crystallinity • Grade Graphite (C): 80 – 95 % • Has lower price, inconsistency quality, contain impurity • Location: China, Australia, Mozambique, Brazil	• Origin: Coal deposit metamorphism • Lots of impurity and ash • Low-crystallinity • Grade Graphite (C) < 85 % • Most low price in market • Location: China, Mexico

Figure 10. Three Main Categories of Natural Graphite Deposit

Occurences

Thus far, there are 2 locations that are proven to have the occurrence of graphite based in our study. The rock-bearing graphite formation on the islands of Kalimantan and Sulawesi are metamorphic rocks. The metamorphic rock obtained from the sample is a phyllite-schist metamorphic rock type. It is based in our study that have been worked from 2017-2022 (Figure 11). There have been three studied group exploration regarding geological graphite deposit in Indonesia (Table 4).

Table 4. Graphite Study Result From 2017-2022 by Geological Agency

No	ACTIVITY	YEAR	RESULT
1	Prospectives Of Graphite Mineral On The Kalimantan And Sulawesi Islands	2017	• Graphite Deposit Characterization (Deskwork Study) • Analysis Method Trial For Graphite Identification • Prospective Rock Bearing Graphite Formation Evaluation
2	Prospecting Of Graphite In Sanggau Regency, West Kalimantan Province	2021	• Target Exploration Area On Sanggau Regency • Graphite Grade Test On Rock Bearing Sample
3	Preliminary Study Of Graphite In Kolaka Regency, Southeast Sulawesi Province	2022	(In Progress)

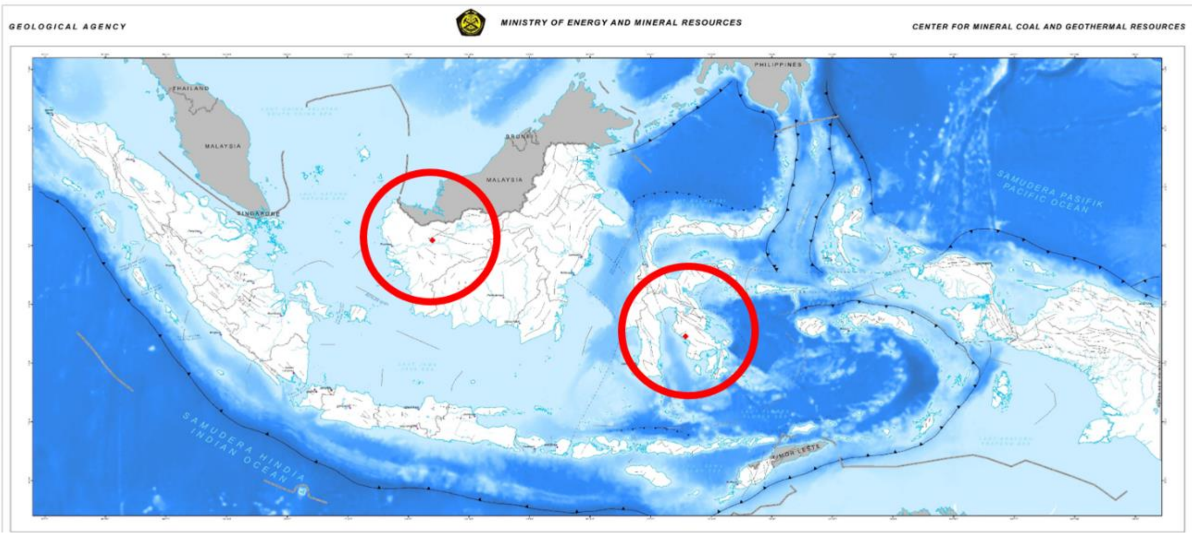

Figure 11. Graphite Occurences Map in Indonesia (*red circled*)

Future Plans

Graphite generally occurs as a result of metamorphism (regional or contact) of organic matter in sediments. Indonesia has a fairly wide distribution of metamorphic rocks, with a stretch from Aceh to Papua. Some of those were phyllite-schist types that have the potential to have graphite deposits. Based on the study, the team examined the presence and distribution of metamorphic rocks in Indonesia. The results of this study resulted in several groups of metamorphic formations suspected of having the potential for graphite deposits. Some areas that are proposed for further action are the North-Central region of Sumatra, Kalimantan (Sanggau and Melawi), Sulawesi (Pompangeo and Mekongga), and West Papua (Figure 12).

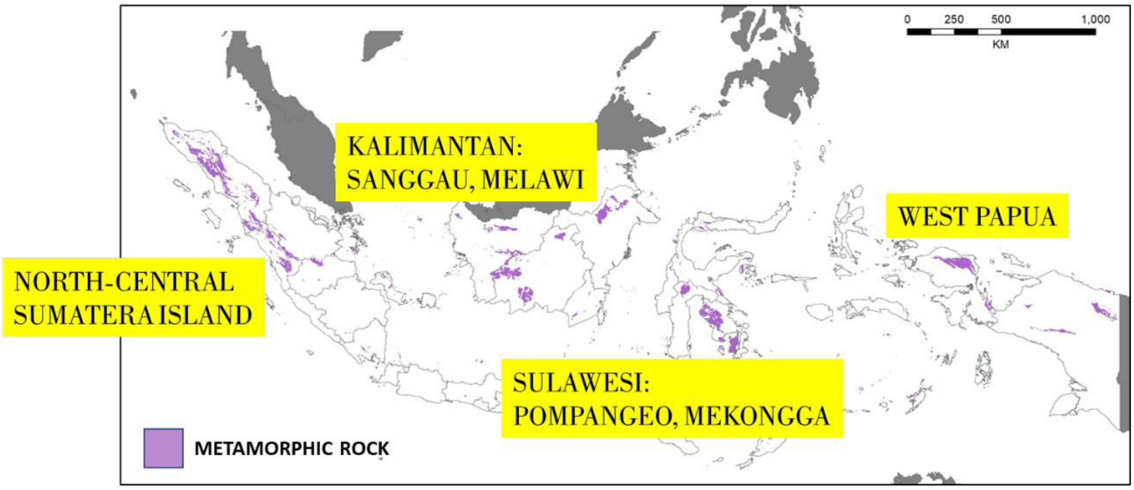

Figure 12. Future Plans Study of Graphite Deposit in Indonesia Based on The Metamorphic Belt Distribution

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