MAGNETIC SUSCEPTIBILITIES DISTRIBUTION AND ITS POSSIBLY GEOLOGICAL SIGNIFICANCE OF SUBMERGED BELITUNG GRANITE

Dida Kusnida, P. Astjario and B. Nirwana
Marine Geological Institute of Indonesia
Jalan Dr. Djundjunan 236, Bandung-41074 - Indonesia
e-mail: didakusnida@mgi.esdm.go.id

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ABSTRACT

An appraisal of the marine magnetic anomalies over the Belitung water provides information on the distribution of the magnetic susceptibility values. The 0.001 to 0.003 cgs unit contour values characterize the zone of submerged Belitung granite coincides with the zone of less than 50 nT total magnetic anomaly contour value. Susceptibilities distribution analyses reveal a strong correlation between magnetic susceptibility and type of granites. The nature of submerged Belitung intrusive is suggested to be granitic pluton of biotite-granite that is associated with cassiterite minerals.

Keywords: total magnetic anomaly, magnetic susceptibility, granite, Belitung, pluton

1. INTRODUCTION

Tin source in Indonesia is part of the South East Asia Tin Belt that is the richest tin belt in the world. It extends from South China, Thailand, Myanmar, and Malaysia to Indonesia. Tin is formed as primary deposits within granite and at the contact area within metamorphic rocks that are usually associated with tourmaline and tin quartz vein. According to Pamungkas (2006), two types of classic veins have been mined in Bangka-Belitung Islands. Those are fissure veins and bedding veins in which they are genetically derived from granite intrusion of the Upper Triassic (± 222 M years ago).

To delineate petrographic and geochemical variations of granitic plutons, previous authors (Tarling and Hrouda, 1993; Ishihara *et al*., 2000) have used magnetic susceptibility measurements as the tool. Magnetic susceptibility of rocks is determined by their bulk chemistry and magnetic mineralogy, in which the bulk magnetic susceptibility is possibly carried by ferromagnesian silicates (Gleizes *et al*., 1993), or on ferromagnetic granites in which susceptibility is carried mainly by magnetite (Ferré *et al*., 1999). Magnetic susceptibility measurements have also been widely used as lithologic indicator in granitic rocks or in the broad discrimination between paramagnetic (ilmenite-type granites) and ferromagnetic granitoids (magnetite-type granites), as mentioned by Sant'ovaia and Noronha, (2005). According to Aydin *et al.* (2007), based on petrographic observations and calculations of rock major element analyses within granite of Saruhan-Turkey, it indicates the presence of magnetite grains, where the zoning pattern of magnetic susceptibility across the pluton is concentric and reverses.

The aim of the study is to delineate the intrusive rock bodies of submerged Belitung pluton having susceptibility and separated from the regional anomalies of the extensive crystalline and sedimentary rocks on the basis of marine magnetic data. It is hoped that the study provides a better understanding of the study area with a considerable interest for scientific and economic purposes.

2. GEOLOGICAL SETTING

Belitung Island (Figure 1) lies between 107°35' - 108°18' E and between 02°30' - 03°15' S. To the north, it is limited by the South China Sea, by Java Sea to the south, and by Karimata Strait to the east. The Gaspar Strait separates Belitung and Bangka in the west. It is a residence of the Bangka-Belitung Province of Indonesia which is also includes several smaller islands that lie north-east of South Sumatra Province. Physiographically, Belitung is part of the Sunda Shelf and occurs as a tin belt that extends from Malaysia, Riau Islands, Bangka, and Tujuh Islands. In addition, the morphology of Belitung Island is wavy hills and plains.

According to Gafoer *et al.* (1992), the Bangka-Belitung islands consist of several rock formations such as metamorphic rocks (schist and gneiss) of pre-Carboniferous as the oldest rocks. The Cretaceous-Triassic granites and granodiorites intrusive occur as sources of tin. The Triassic sedimentary rocks consist of intercalation between metamorphosed sandstones and mudstones with limestone lenses and quartzite. The Quaternary deposits that consist of carbonaceous sediments, reefs, calcarenites, mud and Quaternary alluvium (sands and pebbles) are deposited unconformably on the older rocks.

On the basis of marine seismic reflection records and cores in Gaspar Strait, Batchelor and Bowden (1985) indicate four groups of sedimentary rocks that were deposited since Miocene. Those are young alluvium that consists of Holocene sedimentary cover and Upper Pleistocene alluvium complex, transitional units that consist of marine sediments of Upper Pleistocene and transitional unit of Middle Pleistocene, ancient sedimentary cover of Early-Upper Pleistocene and ancient alluvium plain facies interfingering with fan facies (granite boulders) and Sunda Plain regolith that consists

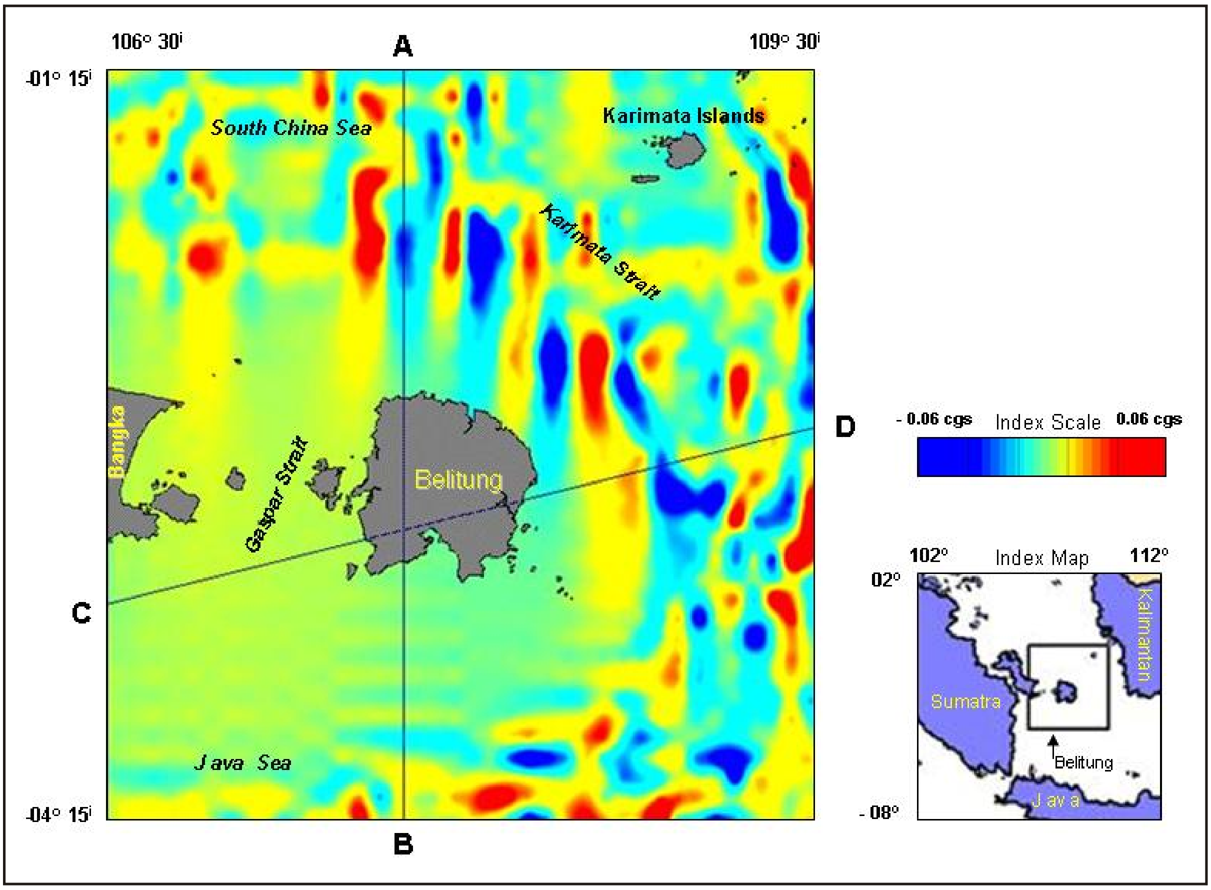

Figure 1. Susceptibilities distribution map of submerged Belitung pluton Profiles A-B and C-d are produced in Figure 4

of Pliocene colluvial deposits and fan materials and Upper Miocene latosol, laterites and bauxites derived from the weathering of granites and sedimentary rocks.

Batchelor and Bowden (1985) stated that the tin deposits in Belitung were initially sampled by vertical pits in areas where cassiterite could be recognized in overburden. In later years, magnetometer surveys, followed by pits, then diamond drilling located the tin lodes were carried out. Minerals present within tin ore in general are cassiterites while pyrites, quartz, zircons, ilmenites, plumbums, bismuths, arsenics, stibnite, chalcopyrite, cuprites, xenotimes and monazites are normally additional minerals.

3. METHOD

Data Acquisition and Database

To obtain geomagnetic data, the Marine Geometric G.813 Proton Magnetometer sensor was hauled some 100 meters behind the vessel. Recording of observed data with the precision of 0.1 nT was performed on the Soltec 3314 B-MF recorder. Diurnal variation was measured and recorded using a stationary ground Geometric G.866 and G.724 Magnetometer that were operated on land during the cruise. Navigation in the study area was carried out by means of the Global Positioning System (GPS). Marking of time and fixed point on recorder was plotted using an Annotator device.

Database for this study is the total magnetic anomaly map of Karimata Strait and surroundings (Figure 1). It was compiled and constructed by Kusnida *et al.* (2003) from marine geomagnetic data acquired by Marine Geological Institute of Indonesia since 1992 until 2003.

Data Correction

Magnetic field intensity measured at the observation point is a resultant of various variables, while in fact the aim of the geomagnetic survey is mainly to measure magnetic induction of geological body causing anomaly underneath (Peters, 1989). In a geomagnetic survey, the corrections applied are usually diurnal variations. The diurnal correction contributes the highest influence in the results of geomagnetic measurement. The amount of diurnal variation can be observed by measuring magnetic field intensity at the fixed observation point at a certain reading interval. Assuming that diurnal variation is a linear time function, then graphically the amount of diurnal variation correction can be determined during the measurement.

Technique

– Total Magnetic Anomaly Map

The total magnetic anomaly values were calculated based on equation:

$$F_{tot} = F_{obs} - F_{IGRF} \pm F_{var} \quad (1)$$

where:
(F_{obs}) : observed total magnetic field
(F_{IGRF}) : theoretical earth magnetic field
(F_{var}) : diurnal magnetic field correction

The diurnal and earth's field corrections have been applied to observed magnetic data, and then the total magnetic map, which is contoured, was constructed. This total magnetic intensity anomaly map is considered to be free from extraneous magnetic effect and primarily indicate the effects of geological features underneath.

– Moving Average Filtering

A residual magnetic anomaly studied in this paper is referred to intrusive rock bodies that have susceptibility and are separated from the regional anomalies of the extensive crystalline and sedimentary rocks. Such sedimentary rocks also have magnetic susceptibilities. Calculation to obtain a residual magnetic anomaly is directed to determine the susceptibility of causative sources underneath. Solution was emphasized on the basis of data filtering that indicates progressively effect of shallow anomaly bodies.

The residual anomaly differentiation by this method is an indirect process namely the output of the moving average of a regional anomaly. The moving average is a simple mathematical technique used primarily to eliminate aberrations and reveals the real trend in a collections data points. In cases where a given waveform is cluttered with noise, or where a mean needs to be extracted from a periodic signal, a moving average filter may be applied to achieve the desired result.

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According to Weimer (2003), moving average filter allows a great deal of flexibility in waveform filtering applications. It can be used as a low-pass filter to attenuate the noise inherent in many types of waveforms or as a high-pass filter to eliminate drifting baseline from higher frequency signal. General equation for upward continuation is:

$$Hz(x,y,-h) = \sum \bar{H}(r)b(r) = H(0)b_0 + H(1)b_1 + H(\sqrt{2})b_2 + H(\sqrt{5})b^3 + H(\sqrt{9})b_4 + \ldots + \quad (2)$$

Hz (x, y, $-h$) : general formula of upward continuation.
h : height of upward continuation with positive direction downward
$\bar{H}(r)$: mean upward continuation value at circle with radius of r
b(r) : coefficient factor of circle with radius r

Susceptibility values distribution of the study area was obtained by applying equation:

$$K = \frac{I}{H} \quad (3)$$

Where :
- k = susceptibility value (cgs unit)
- I = residual magnetic field intensity (nT)
- H = earth magnetic field (nT)

However, for detail concerning this technique, the reader is referred to Kusnida and Astawa (2003).

4. RESULTS

The total magnetic anomaly map of Karimata Strait (Figure 2) shows that this area consists of several distinct magnetic lineaments that reflect and correspond to rock units underneath and more or less seem to be relate with magnetic province (Figure 3) produced by Ben Avraham (1973). In general, except around Bangka-Belitung waters, it is characterized by a series of couples and shorts wavelengths of highs and lows anomalies. The high anomalies in general are characterized by the amplitudes (200 - 400 nT) while the lows are characterized by the amplitudes (-200 - -500 nT). This anomaly province also forms a shield that shows a general southwest - northeast trend crossing Java Sea, and swings to the north-northwest crossing Karimata Strait and into Riau Islands and Malaysia Peninsula as well. This total magnetic anomaly province seems to correspond and approximately parallel to the major structural elements in this area, which is the Jurassic-Triassic magmatic arc of Malaysia-Sumatra-SE Kalimantan (Soeria Atmadja *et al.*, 1998).

Southern waters of Kalimantan and eastern Java Sea are characterized by relatively high-level with isolated total magnetic anomalies that have short wavelengths, gradual and varied amplitudes of less than 200 nT. These small isolated anomalies possibly relate to small near-surface magnetic bodies. In central Java Sea, they occur on both sides of the Karimun Arch and probably indicate the presence of dike along the faulted flanks of the arch (Ben Avraham, 1973). The gradually and almost no significance change in total magnetic anomalies characteristics in the Java Sea suggest that the arch composes of rock with very low magnetic susceptibility, possibly granite and implies that the igneous rocks are deep as proven by the evident from the seismic profiles (Emery *et al.*, 1972).

The Bangka-Belitung plutonic massive seems to be clearly recognized by very broad low-positive magnetic anomalies (less than 50 nT) or no magnetic anomalies. This smooth magnetic province is the result of several different factors. It may be due to the great depth of burial of magnetic basement or to a regional metamorphism that decreased the magnetization of the basement rocks (Ben Avraham, 1973). Around the islands of Bangka and Belitung, smooth magnetic field is the results of low-positive susceptibilities of widespread granitic basement. Susceptibilities distribution map (Figure 1) indicates that contour values between 0.001 cgs unit and 0.003 cgs unit portray a magnetic bearing massive zone of the extension of submerge Belitung granite. In contrast, the surrounding susceptibilities distribution with contour values of <0.001 cgs unit and >0.003 cgs unit portray a magnetic bearing basement of regional magnetic anomalies. On the basis of magnetic susceptibilities distribution map mentioned above, the Belitung magnetic high is delineated by susceptibilities values between 0.001 cgs unit and 0.003 cgs unit (Figure 4).

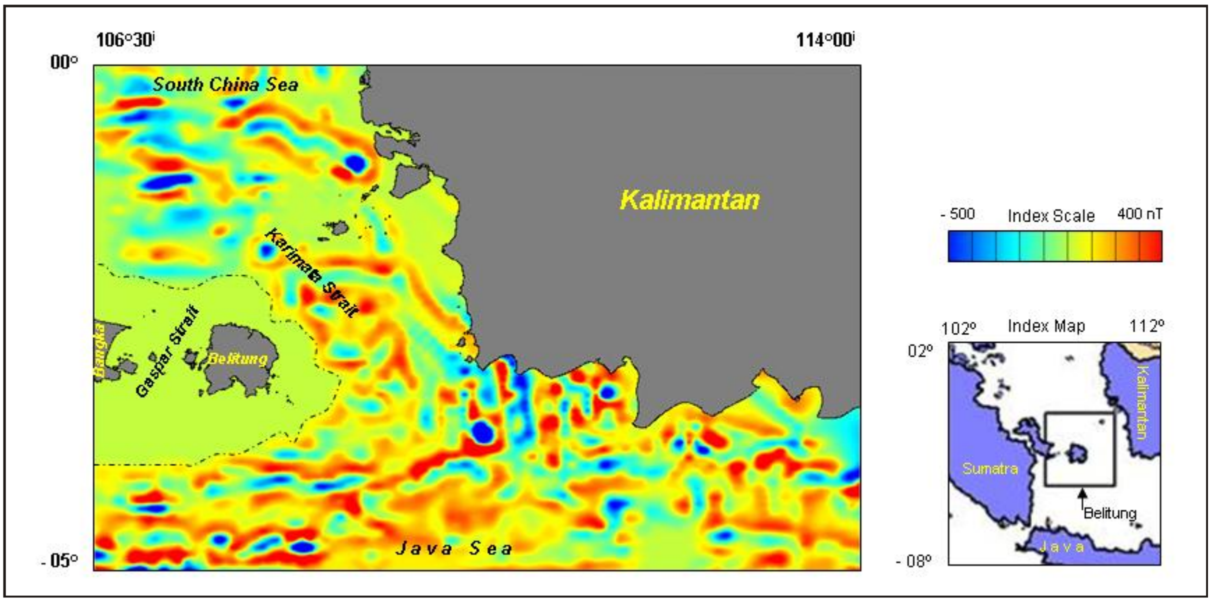

Figure 2. Total magnetic anomaly map of Karimata Strait and surrounding. The submerged Bangka-Belitung plutonic islands seem to be characterized by < 50 nT contour value indicated by dash line

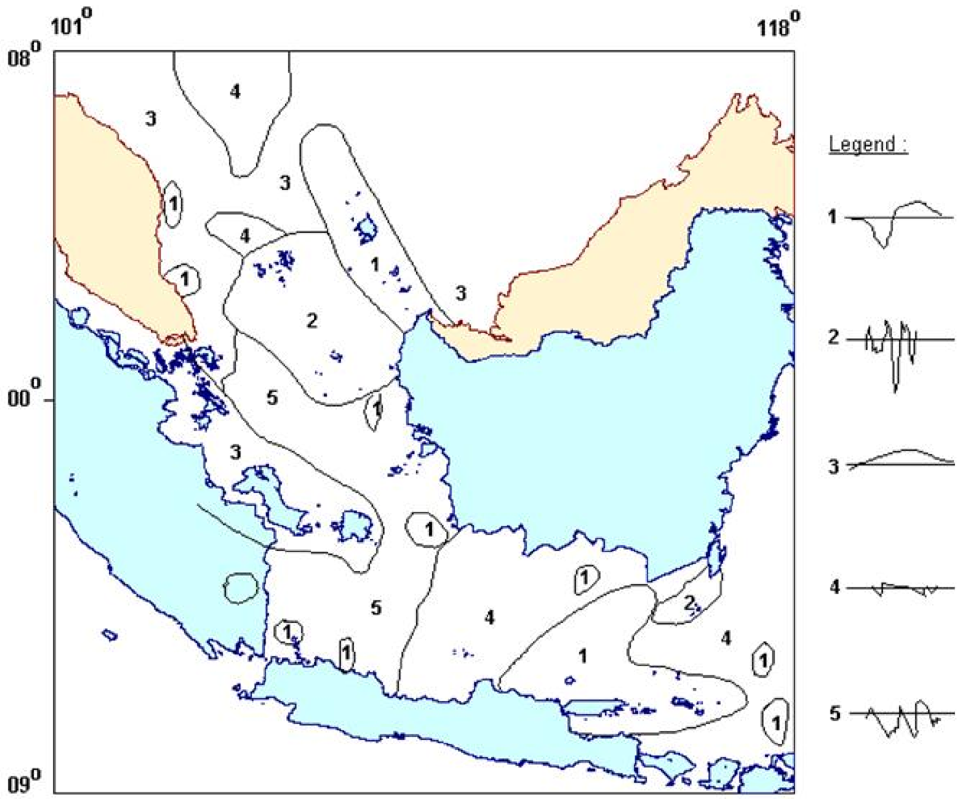

Figure 3. Magnetic provinces over the Sunda Shelf (Ben Avraham, 1973). A typical magnetic anomaly from each province is shown in the legend

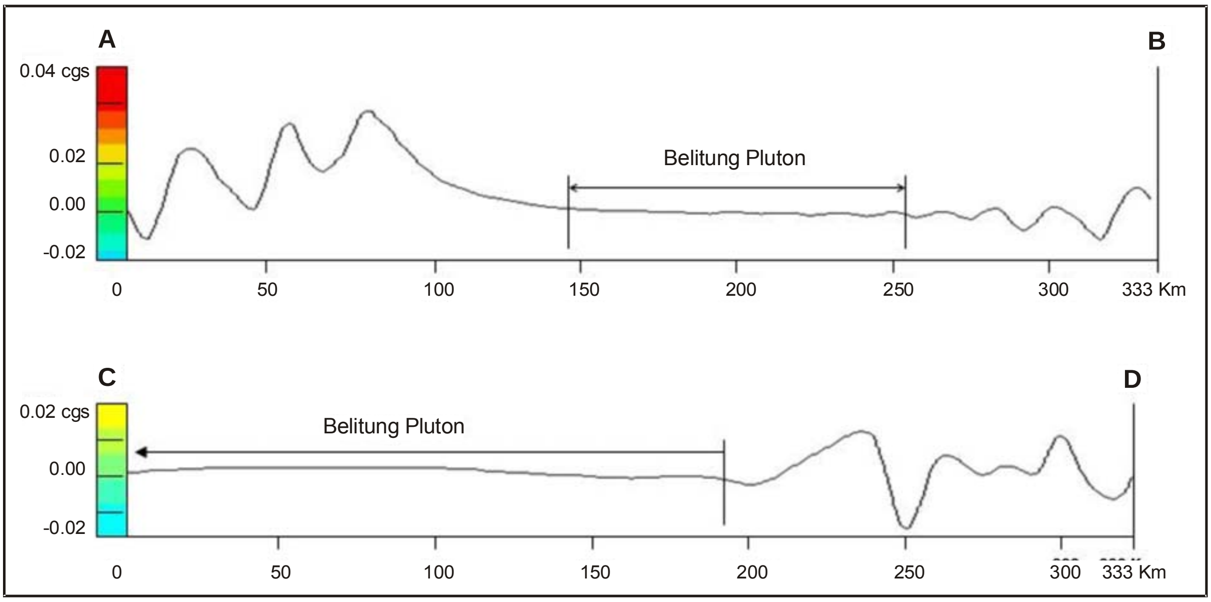

Figure 4. Profiles A-B (above) and C-D (below) show the range of susceptibilities values of the Belitung Pluton indicated by 0.001 - 0.003 cgs

5. DISCUSSION

Magnetic anomalies are caused by all of larger plutonic bodies and other magnetic anomalies may possibly be caused by granitic intrusive. Although each exposed intrusive bodies in Bangka-Belitung Islands have been known as granites, a distinguishing in the magnetic properties is shown by the variety of magnetic expression. A low-positive of total magnetic anomaly less than 50 nT with the susceptibility values range from 0.001 – 0.003 cgs unit occurs immediately within the Belitung waters, even tough hundreds of kilometers offshore the island, the magnetic field is depressed.

Susceptibility measurements on hard samples confirm that the granites are magnetic and susceptibility values vary from 0.001 to 0.05 cgs unit for granite in the eastern Lachlan fold-Australia (Connelly, 1979). The granites have been grouped by chemical criteria into I-types which are purely igneous origin and S-types which have been derived by partial melting of sedimentary rocks that was remained at depth as a large body and did not move laterally for any great distance. However, other study also indicates that all the granitic plutons are geochemicaly classified as calcalkaline I-type granitoids in volcanic arcs. They have a susceptibility values of 0.001 to 0.03 cgs unit such as Abukuma granites in Japan that correspond to magnetite-series and/or ilmenite series granites (Atsushi and Tetsuichi, 2003) and 0.03 – 0.06 cgs unit for Natuna granites (Ben Avraham, 1973).

According to Aryanto *et al.* (2005), based on their study in Kelumpang-Belitung Island, it indicates the granitic rocks type of the area is I-type of biotite-granite and is associated with cassiterite minerals. Therefore, this concludes that the magnetic properties of the Belitung waters can conceive because of the submersion of this granite type. However, a width estimate, determined from the delineating the pluton, indicates that the source of the low-positive magnetic anomaly is deep below the sea. The 0.001 to 0.003 cgs unit susceptibilities value of the submerged Belitung granitic pluton is confirmed with the general I-type granites in the world.

The most prominent positive magnetic features are located at the southwest corner and near the northwest boundary of the area of Figure 1. Schwartz and Surjono (1991), stated that the Pemali tin deposit of Bangka is located in a Triassic granite pluton, which is characterized by a decrease of compatible Ca, Mg, Ti, P and Zr in the sequence: medium to coarse-grained biotite granite, megacrystic medium-grained biotite granite, two-mica granite/muscovite granites. The tin mineralization is confined to the two-mica granite and consists of disseminated cassiterite as well as greisens-bordered veins. The highly evolved muscovite granite is tin-barren and is distinguished from the two-mica granite by its low mica content and low loss-on-ignition values.

6. CONCLUSION

Low-positive anomalies delineating submerged intrusive features occur around Belitung Island. An elliptical low-positive anomaly is superimposed on an elongate, 0.001- 0.003 cgs unit magnetic susceptibilities values. This submerged intrusive possible economic interest, and the nature of this intrusive is suggested to be granitic pluton of biotite-granite that is associated with cassiterite minerals. This low-positive anomaly may represent an intrusive similar to the granite with which the tin deposits are affiliated.

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