MARINE GEOMAGNETIC ANOMALY BELT AND ITS RELATIONSHIP TO THE REMNANT ARCS IN THE NORTHWESTERN JAVA SEA, INDONESIA

SABUK ANOMALI GEOMAGNETIK KELAUTAN DAN HUBUNGANNYA DENGAN JEJAK BUSUR DI LAUT JAWA BAGIAN BARAT LAUT, INDONESIA

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ABSTRACT : The continuous marine geomagnetic survey within a time interval of 1-second sampling and a precision of 0.1 nT was conducted in the northwestern Java Sea to identify and interpret the general trend of total marine magnetic anomalies and the possibility related to the geological resource potential. These magnetic data were then processed according to the formula corrected and applied to marine magnetic data. The total marine magnetic anomalies of the northwestern Java Sea indicate a well-defined lateral trend belt of anomaly contours. Anomalies are divided into four delineation zones: Zones I, II, III, and IV. A preliminary analysis of these anomalies led to the interpretation, reflecting the residual of a slightly east-west trending geological body underneath. Examination of magnetic anomalies suggests Zone I and IV characterize a basinal area, Zone II depicts a granitic belt, and Zone III describes a Cretaceous magmatic arc system in the east that extends from Middle Java across the Java Sea through Southern Kalimantan. These magnetic anomalies seem to coincide with the free air gravity anomalies data derived from TOPEX satellite data.

Keywords: the northwestern Java Sea, total magnetic anomaly, remnant arc, granite

ABSTRAK*: Survei magnetik kelautan berkesinambungan dengan interval waktu pengambilan sampel 1 detik dan ketelitian 0,1 nT dilaksanakan di baratlaut Laut Jawa untuk mengidentifikasi dan menafsirkan kecenderungan arah anomali magnetik total dan kemungkinan kaitannya dengan potensi sumber daya geologi. Data magnetik ini kemudian diproses sesuai dengan rumus dan koreksi yang umum diterapkan terhadap data magnetik kelautan. Sabuk anomali magnetik total baratlaut Laut Jawa menunjukkan kecenderungan arah lateral yang cukup jelas. Pola anomali magnetik ini dapat dibagi menjadi empat zona: Zona I, II, III, dan IV. Dugaan awal terhadap anomali ini mencerminkan adanya jejak tubuh geologi di bawahnya berarah agak timur-barat. Pengamatan anomali magnetik menunjukkan bahwa Zona I dan IV mencirikan daerah cekungan, Zona II menggambarkan sabuk granit, dan Zona III kemungkinan menggambarkan sistem busur magmatik berumur Kapur yang membentang dari Jawa Tengah melintasi Laut Jawa melalui Kalimantan Selatan. Anomali magnetik dari area studi ini tampak mirip dengan anomali udara bebas dari data satelit TOPEX.*

Kata Kunci: *: Laut Jawa bagian Baratlaut, anomali magnetik total, jejak busur, granit*

Contribution:
D.K. and L.A. conceived and planned the study and performed the marine geomagnetic data acquisition and processing. D.K. took the lead in writing the manuscript. All authors provided critical input, discussed the results, and completed the manuscript.

INTRODUCTION

From 1990 until 2020, systematic marine geomagnetic surveys and mapping in Indonesia were conducted by the Marine Geological Institute of Indonesia (MGI) using RV Geomarin I to cover 64 of 365 quadrangles. This paper discusses a result of ten marine geomagnetic quadrangles compiled by Kusnida et al. (2003), covering the South of Karimata Street and the northwestern Java Sea. Compilation of the total magnetic anomaly map results shows a unique distribution anomaly pattern, forming an arc with an east-west direction and curving to the northeast in the east. However, marine geomagnetic anomaly distribution in this area has never been studied in detail. Many geomagnetic studies confirmed that anomalous geomagnetic variations usually reflect the geological conditions and rock composition underneath (Connelly, 1979; Ferré et al., 1999; Aydin et al., 2007). In addition, many authors have used magnetic susceptibility measurements to delineate petrographic and geochemical variations of granitic plutons (Tarling and Hrouda, 1993, Ishihara et al., 2000, Kusnida et al., 2008).

This study aims to identify and interpret the general trend of total marine magnetic anomalies of the northwestern Java Sea and its surrounding. It is referred to as a remnant arc, such as depicted by the total magnetic anomaly of submerged Belitung Granite (Kusnida et al., 2008) and the marine free air gravity map of the study area (https://topex.ucsd.edu/marine_grav/mar_grav.html), as well as the possibility related to the geological resource potential. However, this paper is still preliminary because magnetic data is a dipole field that causes multiple interpretations of the subsurface geological objects, especially for areas with low magnetic latitudes. Further data processing can be conducted by reducing to poles (RTP) in the future to show a monopole magnetic anomaly.

Regional Settings

The Indonesian archipelago consists of seven orogenic collisions, namely Meratus, Sulawesi, Molucca Sea, Seram, Lengguru, Papua Central Mountains, and Timor Orogens (Satyana et al., 2007). Meratus Orogen in Southeast Kalimantan results from a collision between the continental shield of Schwaner (Southwest Kalimantan) and the continental fragment of Paternosfer. The Schwaner Mountains, the so-called part of Sundaland, is a complex of igneous and metamorphic rocks formed by magmatism due to various tectonic events. In this area, the formation of the A-type granitic rocks is related to the rifting of the Southwest Borneo Block from Northwest Australia during the Jurassic (Auliya et al., 2021).

Sundaland is a geological name to refer to areas in the Southeast Asia peninsula, including the Malacca peninsula, the island of Borneo, Sumatra, and Java. The tectonic evolution of Sundaland is a combination of fragments remnants from the Gondwana continent, which was separated due to the Late Jurassic to the Middle Miocene spreading (Hall et al., 2009; Metcalfe, 2011; Auliya et al., 2021). These parts then merged with part of the Eurasian continent, formed tectonic subduction in southern Eurasia, and changed its movement to what it is today (Figure 1). Tectonically, the study area is divided into the western and eastern parts. The east-west trending Bangka-Belitung controls the western to Schwaner Belt in West Kalimantan, which belongs to the magmatic arc system composed of acid to intermediate rocks. In contrast, the northeast-trending Meratus-Bobaris Complex in South Kalimantan controls the eastern part, consisting of the ophiolite. In the Java Sea, the Karimun Java Arc separates these ranges and the Meratus-Bobaris fault system, which correlated with the Lok-Ulo fault system in Middle Java (Sunarya and Simanjuntak, 1987).

The northern part of the Java Sea, where the study area is located, has an average water depth of 60 - 130 meters. It is a middle or transition zone that separates the South China Sea – the Strait of Karimata from the Banda Sea system. This transition zone is the gateway between West Indonesia and East Indonesia and physiographically covers offshore Bangka-Belitung-South Kalimantan.

DATA ACQUISITION AND METHOD

This study was derived from a geomagnetic survey of RV Geomarin in the northwestern Java Sea area (Figure 2). Magnetic intensity data were collected using the Geometric marine magnetometer. Following a standard operating procedure, before magnetic recording was executed, the parameters were set on a sonar-link acquisition software, such as magnetometer sensor offset to GPS (*Global Positioning System*), sensor cable length (*layback*), and data sampling interval. The marine Geometric G.813 proton magnetometer sensor was hauled 150 meters behind the vessel with the precision of 0.1 nT in each continuous marine magnetic survey within a time interval of 1-second sampling. Magnetic data were observed and recorded by using a Soltec 3314B-MF recorder. Diurnal variation was measured and recorded using a stationary Ground Geometric, G.866 and G.724 Magnetometer operated on land during the cruise. The diurnal and earth's field corrections (International Geomagnetic Reference Field 2005) have been applied to the observed magnetic data. The total magnetic anomaly map subsequently is free from extraneous magnetic effect and primarily indicates the impact of geological structures underneath. Positioning and navigation of the surveyed area using the Global Positioning System (GPS). The marking of time and a fixed point on the recorder were plotted using an Annotator device. The base maps used in marine geomagnetic surveys were 1:250,000 scale using Universal Transverse Mercator (UTM) and Datum WGS-84 at a 5-km traverse interval.

RESULTS AND DISCUSSION

The geomagnetic field intensity measured at the observation point results from various variables, while the geomagnetic survey aims to measure the magnetic

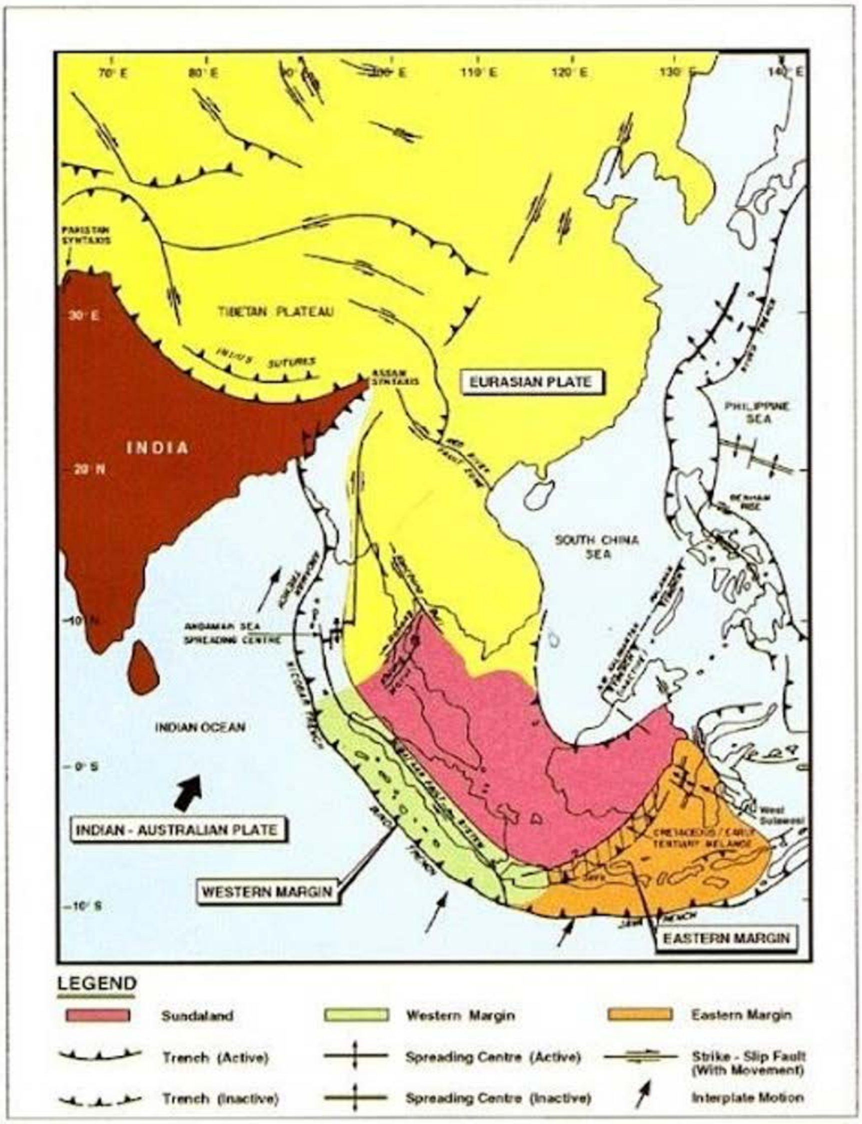

Figure 1. Location of Sundaland and its present developing tectonics (Modification from Davies 1984 in Sudarmono et al., 1997)

induction of the geological body, causing anomalies underneath. Therefore, it is necessary to reduce some variables that affect the measurement results. In a geomagnetic survey, the correction applied is primarily diurnal variations.

The value of the total magnetic anomaly contours in the study area varies between –500 to +400 nT, as described in Kusnida et al. (2003; 2008). The detailed interpretation was carried out from the anomaly values, resulting in the division of the study area into four zones (Figure 2): Zones I (- 50 nT to +400 nT), Zone II (< +50 nT), Zone III (closed by -200 nT), and Zone IV (-100 nT to -300 nT). A preliminary analysis of these anomalies led to the interpretation,which reflects the residual of a slightly east-west trending massive body underneath. Examination of magnetic anomalies suggests Zone I and IV characterize a basinal area, Zone II depicts a granitic belt, and Zone III describes a Cretaceous magmatic arc system in the east that extends from Middle Java across the Java Sea through Southern Kalimantan.

Zone I is characterized by a group of contour pair closures with values between -500 nT and +400 nT in an east-west direction. This pair of contour closures, in the southern part, is gradually adjacent to the homogeneous magnetic anomaly contour of Bangka-Belitung and characterizes the South China Sea and the Karimata Strait. Zone II is characterized by east-west arcuate far apart anomaly contours of <+50 nT representing the surrounding waters of the massive Bangka–Belitung islands. Zone III is characterized by many pairs of dense anomalous shapes trending west-east and then curving to the northeast to form a shield and is limited by a contour value of –200 nT on both sides. This contour pattern is a magnetic anomaly in the form of an arc approaching the island of Southwest Kalimantan. Finally, Zone IV is characterized by an

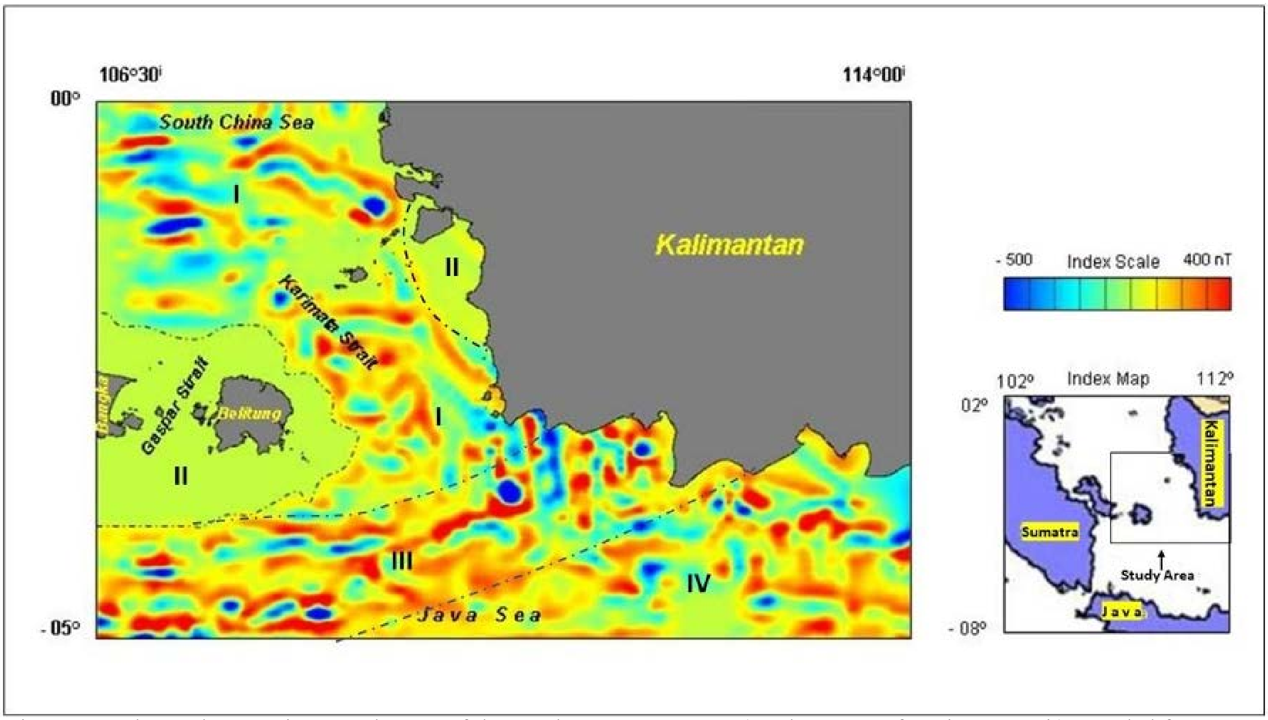

Figure 2. The total magnetic anomaly map of the Northwestern Java Sea (southern part of Karimata Strait) revealed four zones. The submerged Bangka-Belitung plutonic islands are classified as Zone II with magnetic anomaly < 50 nT. (Modified from Kusnida et al., 2008).

unorganized anomaly contours pattern of –100 to –300 nT. This anomaly pattern is believed to be the continuations of the melange-ophiolite complex in Lok Ulo in Middle Java and the Meratus Range of South Kalimantan. Therefore, it can be assumed that although the general trend of the four zones of the anomaly contours in the study area is slightly northeast, the occurrence of high and low closures in each zone indicates the control of the EW to NE structural lineation.

The distribution pattern of the total magnetic anomaly in the study area shows a massive homogeneous anomalous and predominate, expressing the submerged Bangka-Belitung plutonic, characterized by less than <+50 nT, which is also possibly related to the total magnetic anomaly that occurred in the West Kalimantan. Although each exposed intrusive body in Bangka-Belitung Islands has been known as granites, a distinction in the magnetic properties is shown by the variety of magnetic expressions. The susceptibility of submerged Bangka-Belitung is indicated by values ranging from 0.001– 0.003 cgs unit, as described by Kusnida et al. (2008).

The susceptibility values range from 0.001 - 0.05 cgs units confirmed to characterize granite in the eastern Lachlan Fold-Australia (Connelly, 1979). Petrographic study shows that granitic plutons in volcanic arcs are classified as calc-alkaline I-type granitoids with a susceptibility value of 0.001 - 0.03 cgs unit, such as Abukuma granites in Japan (Kamei and Takagi, 2003) and 0.03 – 0.06 cgs unit for Natuna granites (Ben Avraham, 1973). Based on its chemical criteria, granite is grouped into type I (igneous rock of origin), and type S is known to originate from partially melted sedimentary rocks. According to Aryanto et al. (2005), their study on Kelumpang-Belitung Island showed that the type of granite in the area is a biotite-granite type I and is associated with cassiterite minerals. Therefore, it is suspected that the magnetic anomalies of the submerged Bangka-Belitung pluton in West Kalimantan could be due to this type of granite.

Although the early tectonic history is poorly defined by magnetic dipole anomaly, the structural trend of basement rocks is well-exhibited by marine free-air gravity data (Figure 3). Free-air anomaly patterns in the east–northeast direction are expected to be geologically related to gently-cratonized Late Mesozoic (?) along ten to hundreds of kilometres. Compared with the magnetic dipole anomaly in the study area, the free-air gravity anomaly strengthens the dipole image's magnetic path. The positive free-air gravity anomaly with a value of >30 mGal is also distributed in the direction of E-W to NE-SW in pairs parallel to the free-air gravity anomaly with a value of <30 mGal. In general, the free-air anomaly contour pattern reflects the lineament of the rock mass distribution underneath with an almost uniform density, both in the form of height and low. A comparison of the free-air gravity anomaly distribution pattern with the magnetic dipole anomaly in the study area shows a unidirectional tendency in the form of the arcs.

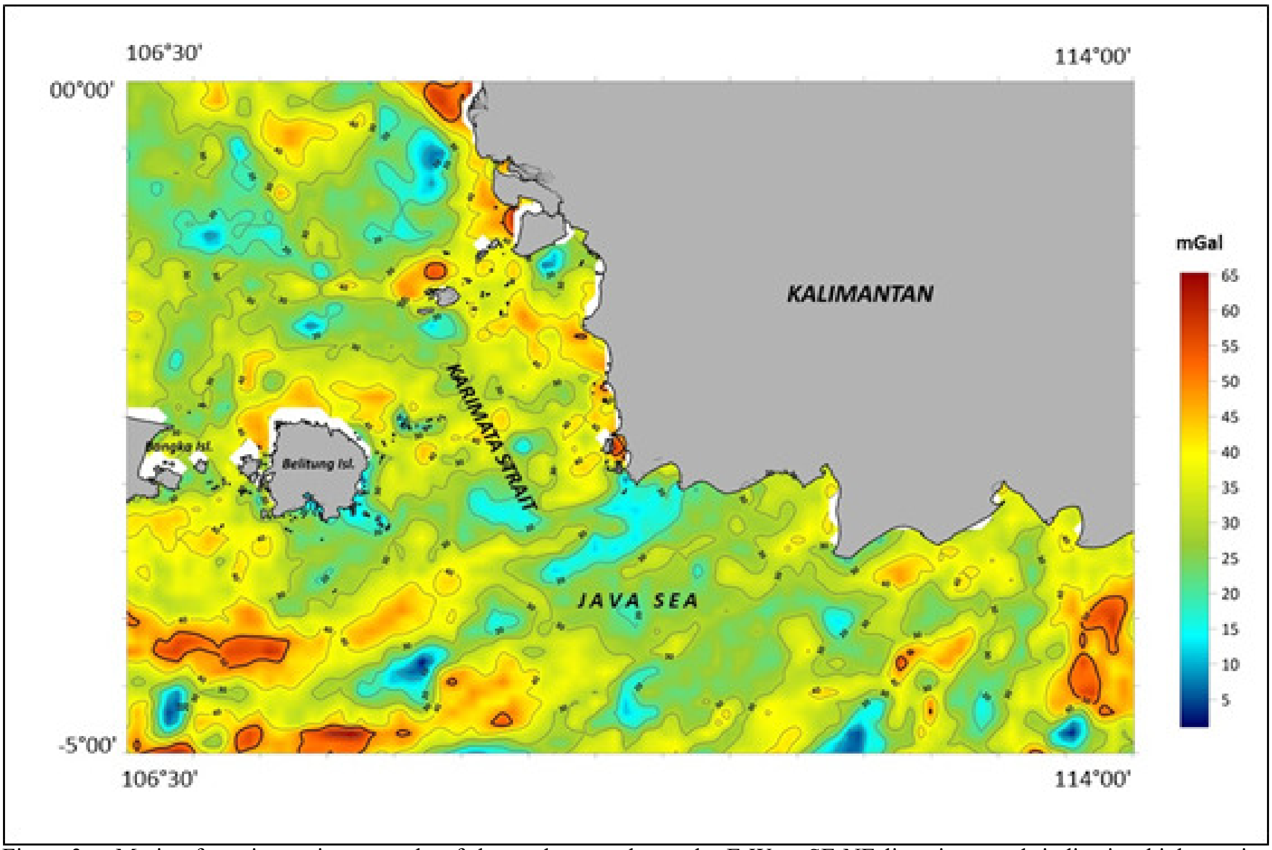

Figure 3. Marine free air gravity anomaly of the study area shows the E-W to SE-NE lineation trend, indicating high gravity anomaly lineation (>30 mGal) and low (<30 mGal) contour values (Source:https://topex.ucsd.edu/marine_grav/mar_grav.html).

CONCLUSIONS

The study area is characterized by magnetic anomaly values ranging from –500 nT to +400 nT. Regional negative values dominate the study area, except for the southwestern part near Sumatera Island; the anomaly tends to be positive. In general, the negative anomalies occupy the eastern and southern part of the study area and demonstrate only minor closures. The total marine geomagnetic anomalies of the northwestern Java Sea indicate a well-defined lateral trend belt of anomaly contours. They can be divided into four zones: zones I (- 50 nT to +400 nT), II (< +50 nT), III (closed by -200 nT), and IV (-100 nT to -300 nT). A preliminary evaluation of these anomalies led to the interpretation, reflecting the residual of a slightly east-west trending massive body underneath. Examination of magnetic anomalies suggests Zone I and IV characterize a basinal area, Zone II depicts a granitic belt, and Zone III describes a Cretaceous magmatic arc system in the east that extends from Middle Java across the Java Sea through Southern Kalimantan. A comparison of the free-air gravity anomaly distribution pattern with the magnetic dipole anomaly in the study area shows a coincides unidirectional anomaly contours tendency in the form of the arcs.

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