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Basement Configuration of the Tomini Basin deduced from Marine Magnetic Interpretation

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Abstract

This paper presents the result of marine magnetic survey in Tomini Basin, Central Indonesia. On the basis of marine magnetic modeling, the main structural and geological elements of the basement of Tomini Basin are identified. At the centre of the basin, the up-doming feature points to an elevated magnetic susceptibility value. A geological model indicates that the entire basement of Tomini Basin is characterized by an oceanic-like crust with a basin axis at the centre nearly an east-west direction and suggests a rift-related graben.

Keywords: Tomini Basin, magnetic, susceptibility, basement

Sari

Tulisan ini memaparkan hasil survei magnetik kelautan di Cekungan Tomini, Indonesia Bagian Tengah. Berdasarkan model magnetik kelautan, struktur utama dan elemen geologi batuan alas Cekungan Tomini dapat teridentifikasi. Di bagian tengah cekungan, gejala pembubungan mengarah kepada adanya peningkatan nilai kerentanan magnetik. Model geologi menunjukkan bahwa seluruh batuan alas Cekungan Tomini dicirikan oleh kerak samudra dengan sumbu cekungan terletak di tengah-tengah berarah hampir timur - barat, serta menunjukan terban yang berhubungan dengan peregangan (pemberaian tektonik).

Kata kunci: *Cekungan Tomini, magnetik, kerentanan magnetik, batuan alas*

Introduction

In the framework of a deep-sea basin exploration in the frontier area particularly in the central and eastern Indonesia, Asikin and Safei (2008) proposed the application of polyhistory basin concept, which deals with basin classification formerly introduced by Kingston *et al.* (1983). However, there are three important parametres recognized in polyhistory basin concept that have to be considered in a sedimentary basin analysis. Those are type of basement underlying the basins (*continental, oceanicor transitional*), tectonic environment, and type of plate boundaries.

Different with on-land geology; offshore geology can not directly be examined as most information related to subsurface geology is resulted from marine geophysical investigations such as from marine magnetic surveys. According to Christopher *et al.* (1995), possible causes for strong magnetic highs are the presence of rock masses containing magnetite minerals such as gabbro, diorite, basalt, and other mafic rocks. In contrast, igneous rocks, such as granite or rhyolite, and most sedimentary rocks are notably non-magnetic and may show up as distinct magnetic lows which are also mapable. Advanced techniques and detailed analyses of magnetic data have been developed which can predict the depth, shape, and orientation of the basement below the seafloor as one of the important parameters required in the polyhistory basin concept as proposed by Kingston *et al.* (1983).

The Tomini Basin in Central Indonesia (Figure 1) so far remains relatively unknown and less studied in detail in the tectonic setting. On the basis of seismic reflection studies, two different opinions related to sediment fill in the Tomini Basin have been raised. Wijaya *et al.* (2007) defined that the sediment fill

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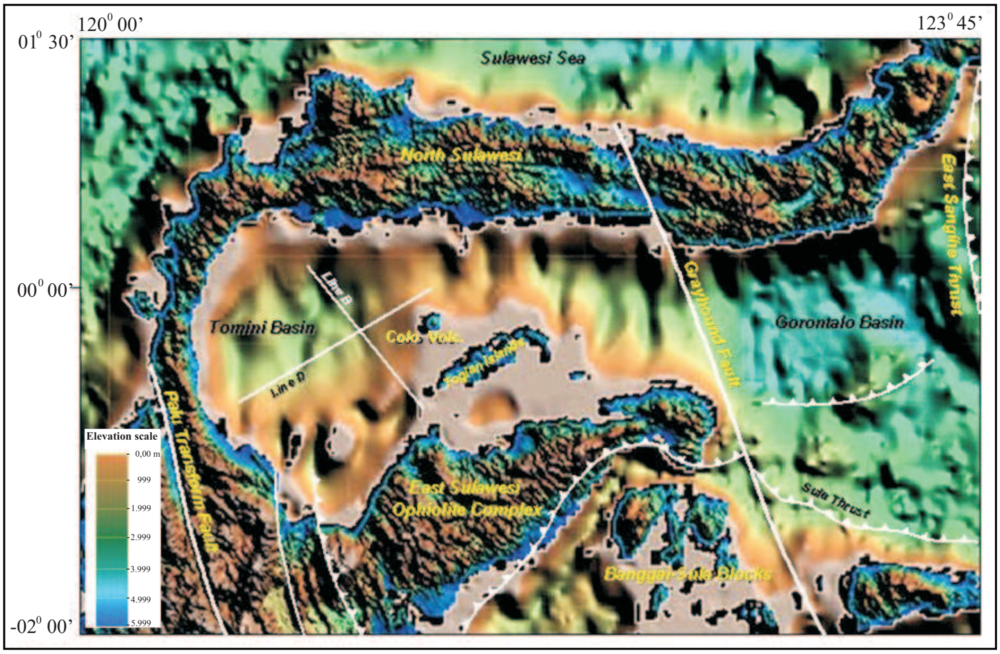

Figure 1. Map showing topographic and tectonic elements of the study area. Map modified from Silver *et al.* (1983); SRTM and DEM of NASA (2000). Line B and Line D indicate profiles produced in Figures 2 and 3.

in the Tomini Basin consists of shallow marine deposits such as sandstones and reefs forming a potential petroleum system. In contrast, Kusnida and Subarsyah (2008) indicate alternating pulses of terrigenous sediments in the form of deep-sea slump-turbidite-pelagic sediments that changed gradually into a deep-sea pelagic fill system toward the centre of the basins. These two different opinions may lead to the assumption that the Tomini Basin can possibly be underlain by continental or oceanic-like crust.

For these reasons, it was decided to conduct a marine magnetic interpretation from this area with the aim to portray the physical characteristics of the basement of Tomini Basin more clearly and to give a better understanding for scientific and economic purposes. The study is limited to delineation of the lateral and vertical variations of rocks underlay the Tomini Basin represented by the magnetic susceptibility distribution.

Setting of the Studied Area

The Gulf of Tomini (Figure 1) can be considered as a complex back arc basin of nearly east - west elongated-shaped depocentre, relating to the southward dipping subduction of Sulawesi Sea Plate in Paleogene to the north. The gulf is characterized by a bathymetric low of slightly below 1500 m in the Tomini Basin in the west, and a bathymetric low of a slightly below 4000 m in the Gorontalo Basin to the east. The island group of Togian characterizing the NE-SW traversed highs together with the Una-Una Islands, where the Colo Volcano is situated and separating the Tomini Basin from the Gorontalo Basin.

However, Silver *et al.* (1983) shows the presence of dunite in Colo volcanic products which may indicate that the magma source had through an oceanic material that is possibly part of East Sulawesi Ophiolite Complex. Permana *et al.* (2002) on the basis of seismological data shows two different patterns beneath the Colo Volcano which lead to the conclusion that the Tomini Basin was formed by the subduction of Sulawesi Sea Plate in the north and may be superimposed with the northwest trending collision of Banggai-Sula micro-continent with the Eastern Arm of Sulawesi in the east. These two tectonic settings of different entity together with the development of the Una-una - Colo Volcanoes may cause a unique setting of the Tomini Basin.

Method and Data Acquisition

The magnetometer used in this study was the *Sea Spy Marine Magnetometer* with the precision of 0.1 nT. Before magnetic recording was executed, several 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 were conducted. This data acquisition was run continuously within time interval of 1 second sampling. Fix point data from GPS had been integrated to the total magnetic data during recording.

The marine magnetometer sensor was towed some 150 m behind the vessel to avoid the noise resulted from the vessel body which could be induced by a magnetic field. The data show a good result with fluctuation values range from 0.1 - 1.0 nT during day and night. To obtain total magnetic data, all observed magnetic data were then corrected by *International Magnetic Reference Field* (*IGRF-2005*). As the earth's field corrections have been applied to the observed magnetic data, the total magnetic anomaly profile then is subsequently considered to be related to the geological structures below. The magnetic anomalies were calculated as the forward modeling with 2.5 dimensional bodies. The Magnetic modeling was done by using Mag2dc software introduced by Cooper (1996).

Results

Four lines of nearly 450 km long of a magnetic survey technique were resulted from the Tomini Basin. However, in this paper only two magnetic lines are performed and modeled (Figures 2 and 3). The positive and negative anomaly values portray the magnetic basement lineation and represent the highs and the lows. Magnetic profiles show the updoming like-feature in the centre of the basin, where the emerge anomalies vary from -284.0 to 171.1 nT in Line-B and from -68.8 to 149.3 nT in Line-D. The total magnetic anomaly at the southeastern flank of the basin is more complex due to the presence of Togian Islands where the Colo volcanism activity is located.

Profile Line-B and Line-D (Figures 2 and 3) both indicate the possible sedimentary cover of the basin as characterized by susceptibility values range from -0.005 to 0.001 cgs units. Magnetic model Line-B (Figure 2) shows that the high total magnetic anomaly in general occupies the centre of Tomini Basin, and in fact is characterized by -0.11 cgs units. The southeastern flank of the basement is characterized by susceptibility values ranging from 0.04 to 0.1 cgs units, while the northwestern flank is characterized by susceptibility values ranging from 0.01 to 0.04 cgs units. Line-D (Figure 3) indicates that the centre of the basin is characterized by -0.12 cgs units. To the northwest, the basement is characterized by -0.05 cgs units, while to the southeastern from the centre of the basin, the basement is characterized by susceptibility value of -0.013 cgs units.

Magnetic model Line-D (Figure 3) shows that the depth of basement rocks of the Tomini Basin laterally varis from 2500 to 3400 m below sea level, where each block of rock mass is bounded at its sides by a series of graben like-structures.

Discussion

Regionaly, the lower total magnetic anomaly values dominate the flanks of the Tomini Basin, except the centre of the basin where the anomaly tends to be high. Most of the elongation of negative values occupy the zone, which indicate the occurence of magnetic basement characterizing the flank areas of the basin, and it seems to be related to the magnetic basement setting which indicates the presence of the rift-related basement.

From the centre toward the northern flank of the basin, magnetic models indicate a major graben, and the total magnetic anomalies range between -284 to 171.1 nT. On model Line-B, the anomalies at the southeastern part of the basin vary with several lows and highs and it is possibly caused by the presence of Togian Islands representing an imbricate zone, where the Colo Volcano is also present. It can be assumed that even though the general trend of the total magnetic anomaly is slightly north - south, the occurrence of high closures toward the centre of the basin indicate the development of the east - west structural lineation in the form of horsts and grabens. Magnetic models portray that the centre of Tomini Basin is possibly underlain by basic rocks (possibly peridotites?) with susceptibility values ranging from

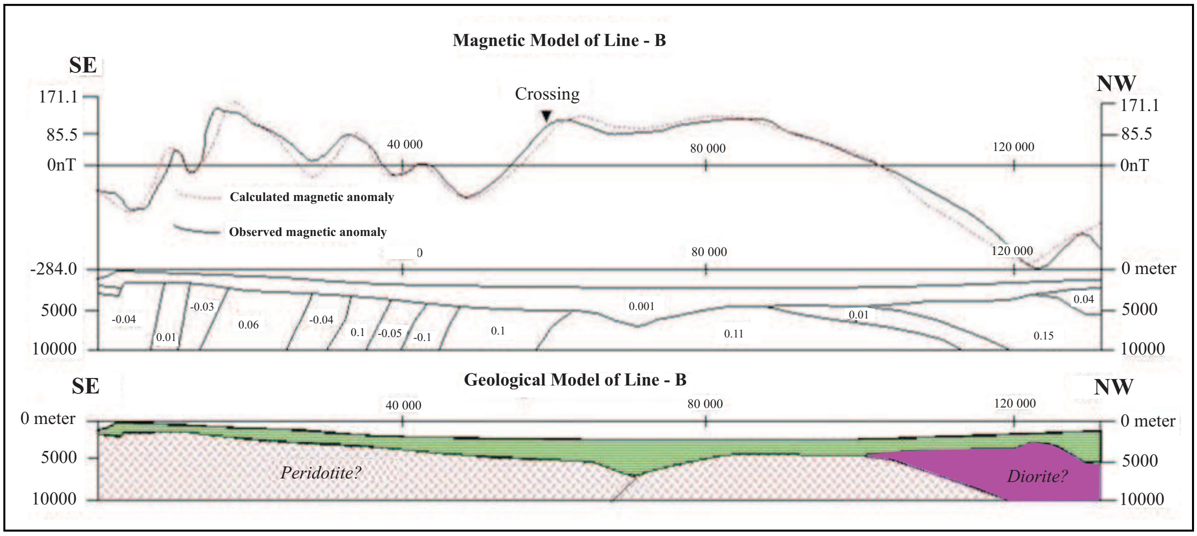

Figure 2. Magnetic and geological models of Line-B. Magnetic susceptibility in cgs unit.

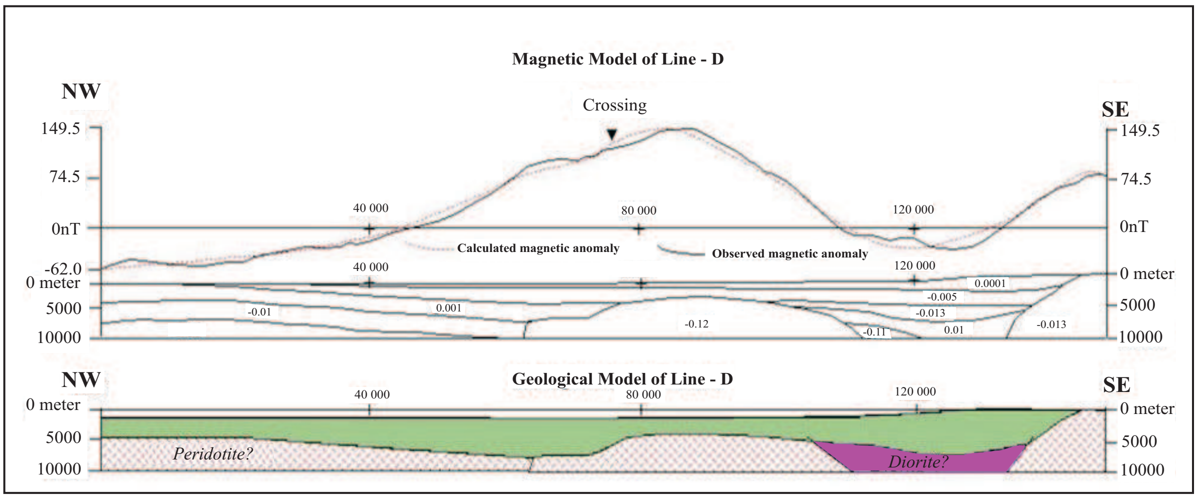

Figure 3. Magnetic and geological models of Line-D. Magnetic susceptibility in cgs unit.

0.11 to 0.12 cgs units and by intermediate rocks (diorites?) with susceptibility value of 0.013 cgs units toward the Togian Islands, where the Colo Volcano is situated (see Table 1).

A negative (-) symbol behind susceptibility values in the models possibly denotes a susceptibility contrast that is the relative susceptibility between two or more rocks composing the basement (Huang and Fraser, 2001), or it can also be caused by "magnetic reversal" during the basement rock formation (Christopher *et al.,* 1995). Geologically, the high magnetic susceptibilities of -0.11 to -0.12 cgs units characterize the interior under the centre of the basin, where the graben-like structures are in it. In contrast, the low magnetic intensity anomaly occupies the flanks of the basin, which is in general characterized by -0.01 - 0.05 cgs unit at both flanks.

Based on the susceptibility values, the basement of Tomini Basin is predicted to be equivalent to crystalline basement. Shallower susceptibility contrasts which occur toward the Colo Volcano is in contrast with host rocks, and may mask or complicate the interpretation of magnetic basement. Therefore, susceptibility variations within the magnetic basement in Tomini Basin are normal.

Table 1. Magnetic Susceptibility of selected Rocks (Christopher *et al.,* 1995)

Rock/Mineral	Density (10^3 kg m^{-3})	Volume k (10^{-6} SI) = cgs unit	Mass λ ($10^{-8}m^3kg^{-1}$)
Igneous Rocks			
Andesite	2.61	170,000	6,500
Basalt	2.99	250 - 180,000	8.4 - 6,100
Diabase	2.91	1,000 - 160,000	35-
Diorite	2.85	630 - 130,000	22 - 4,400
Gabbro	3.03	1,000 - 90,000	26 - 3,000
Granite	2.64	0 - 50,000	0 - 1,900
Peridotite	3.15	96,000 - 200,000	3,000 - 6,200
Porphyry	2.74	250 - 210,000	9.2 - 7,700
Pyroxenite	3.17	130,000	4,200-
Rhyolite	2.52	250 - 38,000	10 - 1,500
Igneous rocks	2.69	2,700 - 270,000	100 - 10,000
Average acidic igneous rocks	2.61	38 - 82,000	1.4 - 3,100
Average basic igneous rocks	2.79	550 - 120,000	20-
Sedimentary Rocks			
Clay	1.70	170 - 250	10-15
Coal	1.35	25	1,9
Dolomite	2.30	-10 - -940	-1 - - 41
Limestone	2.11	2 - 25,000	0.1 - 1,200
Red sediments	2.24	10-100	0.5-5
Sandstone	2.24	0 - 20,900	0 - 931
Shale	2.10	63 - 18,600	3-
Average sedimentary rocks	2.19	0 - 50,000	0 - 2,000

Conclusion

Marine magnetic method applied in the Tomini Basin provides a data information on magnetic intensity anomalies. The Tomini Basin is underlain by an oceanic-like crust and shows a nearly NE-SW symmetric lateral lineation of susceptibility values. The up-doming of slightly SE-NW structural style in the centre of the basin with susceptibility values of -0.11 to -0.12 cgs units possibly indicates a suspect thermal stretching, and an active tectonism is activated. It implies that the earlier basement in the basin is undergoing a thinning and differential subsidence.

The occurrences of relative susceptibilities among several rocks within the basement create susceptibility contrasts which are either positive or negative. In magnetic interpretations, the anomalies being studied are caused by susceptibility contrasts within the earth crust and subcrust.

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