

## Application of Gravity Survey for Tin Exploration at Bongsu Granite, Kulim, Kedah, Malaysia

(Aplikasi Tinjauan Graviti untuk Penjelajahan Timah di Granit Bongsu, Kulim, Kedah, Malaysia)

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### ABSTRACT

*Alluvial tin mining in Karangan area was closely related to the mineralization of Bongsu Granite and its contact zone with sedimentary rocks of Semanggol Formation possibly through greisenization process. A gravity survey focusing on high tin anomaly area in Gunung Bongsu Forest Reserve was conducted to define the subsurface geology and structural patterns related to tin mineralization. The gravity data were corrected for drift, free air, Bouguer, latitude and terrain corrections to produce final gravity data of the study area. The data were processed and analyzed using Oasis Montaj to produce Bouguer, regional, residual, Total Horizontal Derivative (THD) regional and THD residual gravity maps for qualitative interpretations. Comparison of the produced gravity anomaly maps indicate occurrence of partial ring fractured-style model of granite emplacement initialized by laccolith development, doming of sedimentary bedrock, magmatic diking through ring fractures and finally sinking and melting of surrounded sedimentary rock before magma cooling and crystallizing to become granites bedrocks. Greisenization occurs within the inner ring granite as the bedrock developed at later phase.*

*Keywords: Greisenization; granite; gravity anomaly; ring fractures; tin mineralization*

### ABSTRAK

*Perlombongan bijih timah aluvium di kawasan Karangan adalah berkait rapat dengan pemineralan Granit Bongsu dan zon persentuhan antara granit dengan batuan sedimen Formasi Semanggol berkemungkinan melalui proses penggreisenan. Suatu kajian graviti telah dijalankan di kawasan Hutan Simpan Gunung Bongsu yang tertumpu kepada kawasan beranomali timah bagi menilai geologi subpermukaan dan corak berstruktur yang berkaitan dengan pemineralan timah. Data graviti dibuat pembetulan hanyutan udara bebas, Bouguer, latitud dan rupa bumi bagi menghasilkan data graviti akhir kawasan kajian. Data akhir diproses dan dianalisis menggunakan perisian Oasis Montaj bagi menghasilkan peta graviti Bouguer, rantau, baki, terbitan mendatar keseluruhan (THD) rantau dan THD baki bagi tujuan pentafsiran kualitatif. Perbandingan anomali antara peta graviti yang dihasilkan menunjukkan wujudnya model pembentukan granit melalui rekahan separa berbentuk cincin yang dimulakan dengan pembentukan lakolit, pembentukan struktur kubah pada batuan sedimen, rejahan magma secara daik melalui rekahan cincin dan akhirnya penenggelaman dan pencairan batuan sedimen sebelum penyjukan dan penghabluran magma untuk menjadi batuan dasar granit. Penggreisenan berlaku pada granit dalam struktur cincin kerana batuan tersebut terbentuk pada fasa lewat.*

*Kata kunci: Anomali graviti; granit; pemineralan timah; penggreisenan; rekahan cincin*

### INTRODUCTION

Karangan in Kedah was well-known for tin mining. The tin mining started since 1850 in this area which concentrated on placer deposits along Sungai Karangan and its main tributaries (Thow 1995; Willbourn 1926). Bongsu Granite is the main granite pluton in Karangan. It is late-magmatic, porphyritic biotite-muscovite typed with its grain size up to 2 cm consisting K-feldspar, plagioclase, quartz, biotite, muscovite, tourmaline, garnet, zircon and opaque minerals (Azman et al. 2000). Airborne regional gravity survey indicated the bedrock is connected to the Main Range Granite (Burley & Jamaluddin 1990). Aerial photo interpretation indicated appearances of three main circular features apart of lineaments trending in NNE-SSW directions

within the igneous bodies (Noor Bakri 2003; Figure 1). Argillaceous and arenaceous rocks of the Semanggol Formation also overlies the northern and within the granitic body as roof pendants (Jabatan Mineral dan Geosains Malaysia 2014).

The occurrences of the alluvial tin in Sungai Karangan were thought to be resulted from deep weathering of tin-mineralized contact zone between the Late Triassic granite and Early Permian to Late Triassic sedimentary rocks (Basir 1996, 1994; Courtier 1974). Recent study on high tin anomaly area from shallow soil geochemical indicated that the primary source of tin ore in this area came from the Bongsu Granite underlying the upstreams of the Sungai Karangan (Fakhrudin Afif 2018; Figure 2).

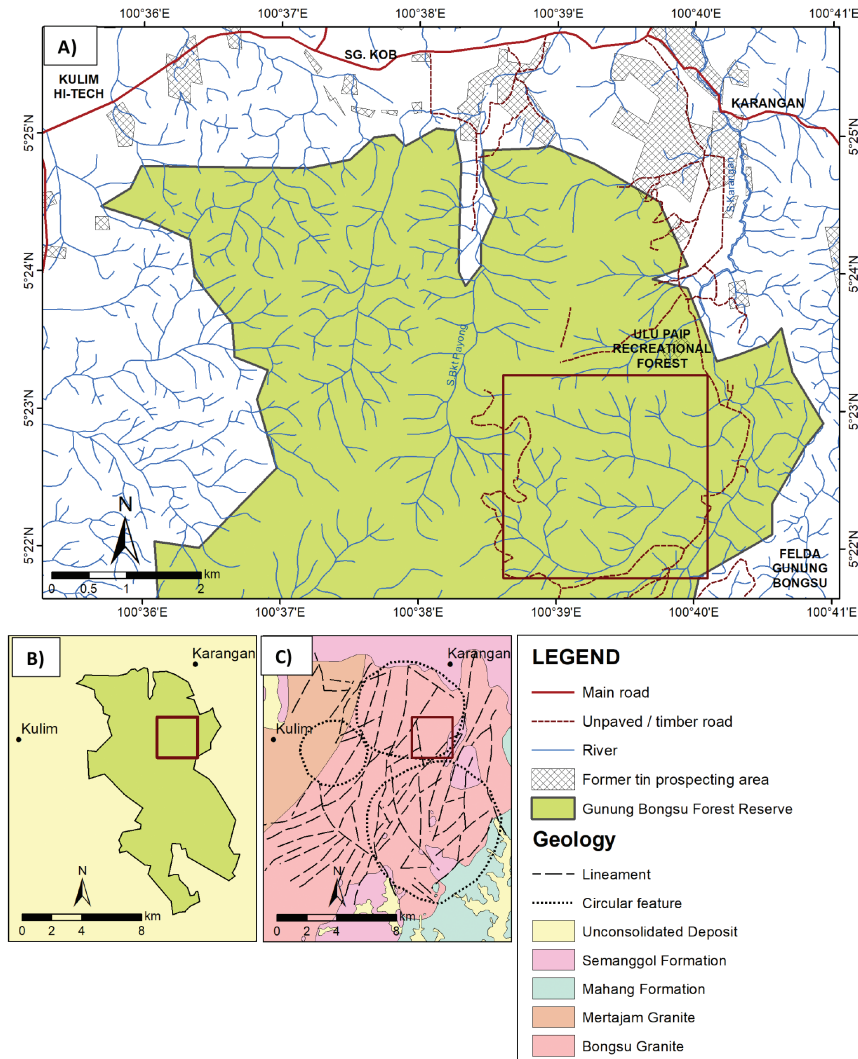


FIGURE 1. A) and B) Maps showing study area in Gunung Bongsu Forest Reserve near Karangan, Kulim, Kedah and C) its regional geology

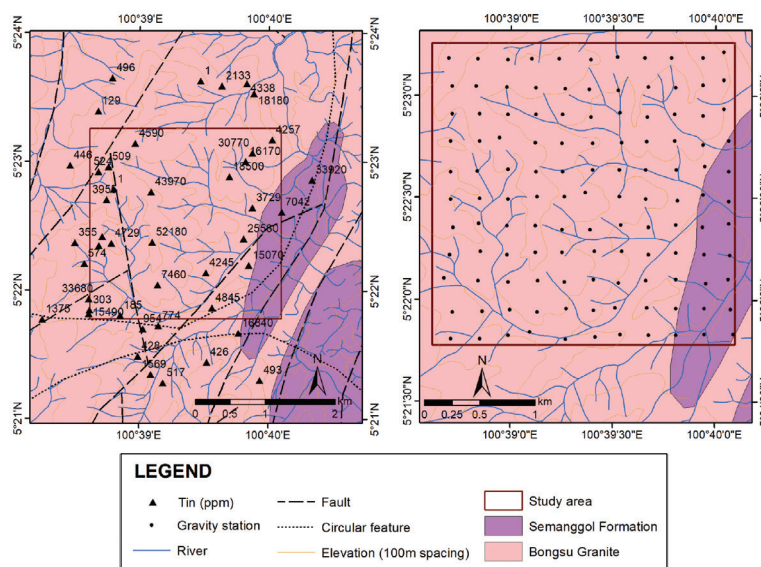


FIGURE 2. Subsurface tin concentration (in ppm) (left) and gravity station arrangement in the study area (right)

Theoretically, greisenization is an endogenic hydrothermal process which alters the upper part of dome-like cupola or ridge in granitic pluton (Ridley 2013). Tin mineralization occurred primarily in the altered zones within fractured bedrocks and contact zones between igneous and sedimentary rocks (Pirajno 2009). Greisen is one of the common types of tin deposits in Peninsular Malaysia which also consists of tourmaline, topaz, fluorite, beryl, wolframite and tantalite as accessory minerals (Yeap 2000).

Thus, the purpose of this geophysical study was to delineate different occurrences of bedrocks and structural patterns and their correlations with possible occurrence of greisen-type tin mineralization. The study area is located in the Gunung Bongsu Forest Reserve near Karangan. It is dominantly made of poorly outcropping of the Bongsu Granite while the southeastern area is overlain by roof pendant of the Semanggol Formation (Figure 2).

#### MATERIALS AND METHODS

The gravity survey was conducted at the southern part of Ulu Paip Recreational Forest area. A total of 121 gravity stations had been established with an approximately 250 m grid spacing, covering total area of 2.5 km<sup>2</sup> (Figure 2). The measurement was carried out by using Autograv CG-5 Scintrex gravimeter, through looping principal in order to monitor and eliminate the potential field drift effect. The observed gravity data were tied with the established gravity station (Loke et al. 1983). Every station elevation was

measured using Sunroad altimeter and Casio altimeter with resolution 1 m and 5 m, respectively, while the coordinates were determined by using global positioning system (GPS) Garmin 62 series.

The gravity data were corrected for drift, free air, Bouguer, latitude and terrain in order to produce corrected Bouguer data of the study area using reduction density of 2.67 g.cm<sup>-3</sup> as done by Abdul Rahim et al. (2012). The gravity data were then processed and analyzed using Oasis Montaj software to produce five gravity anomaly maps such as Bouguer, regional, residual, THD regional and THD residual for qualitative interpretation. The cut-off wavelength value of 2,000 is chosen in producing regional and residual maps as it generated the smoothest patterns of high to low regional anomaly.

#### RESULTS AND DISCUSSION

The geophysical data analyzed showed a significant Bouguer gravity (Figure 3) and regional gravity (Figure 4) anomalies maps. The Bouguer gravity anomaly map shows dominant negative anomalies in irregular pattern, whereas the regional gravity anomaly map also shows three highest anomalies from SW, NW and NE decreasing southeastward. As an example, the high anomaly area using similar studies was considered corresponds to igneous related bedrock in deep subsurface (Salem et al. 2015). Additionally, the residual gravity anomaly map (Figure 4) shows the three highest anomalies coincide within the areas of high Bouguer and regional anomalies. Therefore, the similarity

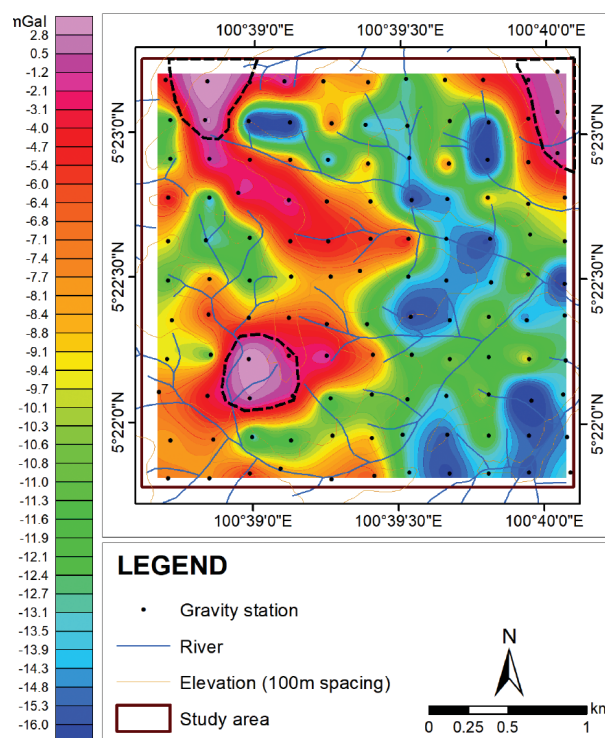


FIGURE 3. Bouguer gravity anomaly map. The dashed high anomalies are interpreted as the locations of multiple or massive igneous intrusions

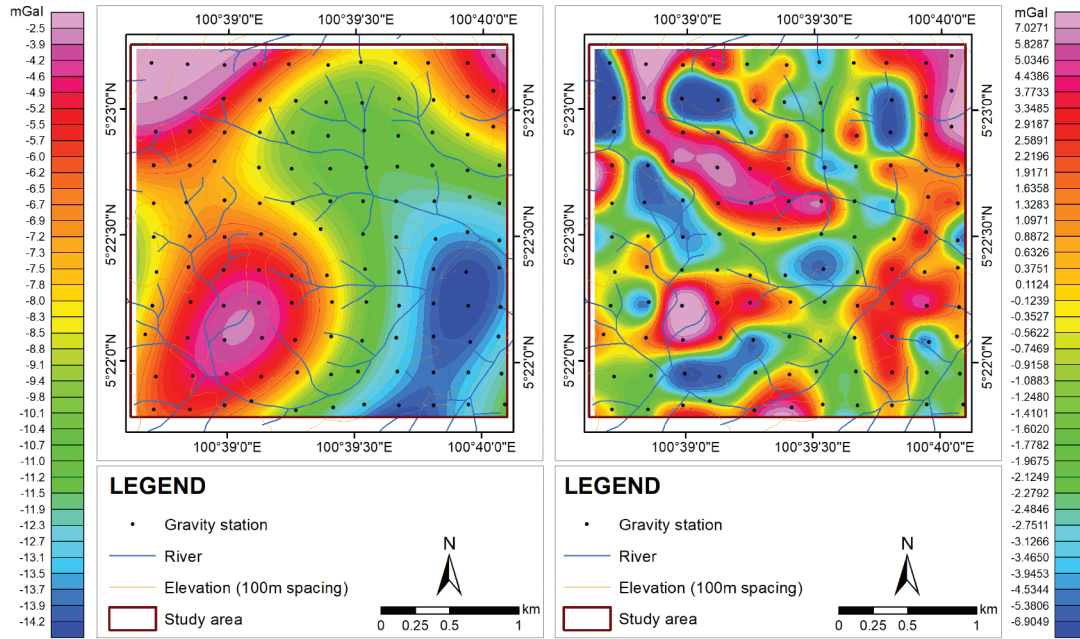


FIGURE 4. Regional gravity anomaly map (left) and residual gravity anomaly map (right)

of the results obtained by the gravity methods may represent the denser bedrocks in shallower environment.

The THD regional gravity anomaly map (Figure 5) shows dominantly three elliptical high anomalies which indicate either nearly vertical rock boundaries or faults in deep subsurface. These faults are considered as deep source of geothermal area including magma feeders (Hayes et al. 2015; Salem et al. 2005; Vigneresse et al. 1996). The THD residual gravity anomaly map (Figure 5) shows at

least two prominent bending lines tipping southeastward and three ring features of high anomalies. These lines and ring features initially due to density contrast of bedrocks in shallow subsurface.

Based on comparative studies on anomaly attributes from all produced gravity maps aided by geology and drainage pattern information, deductions on magmatic events towards the Bongsu Granite intrusions and alteration in the study area could be made as follows (Figure 6):

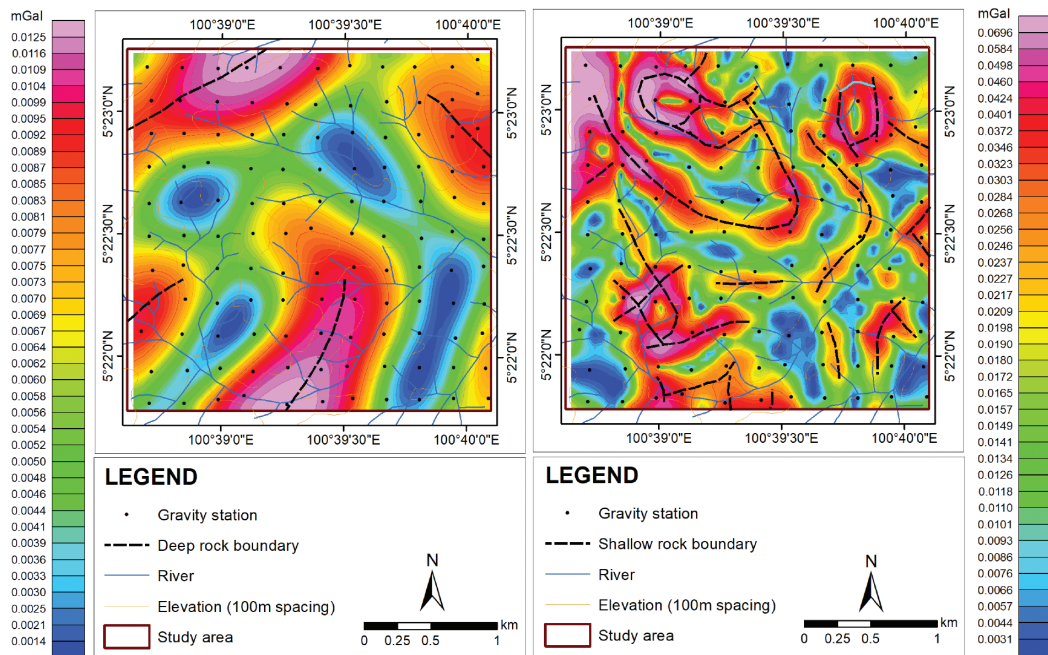


FIGURE 5. THD regional gravity anomaly map (left) and THD residual gravity anomaly map (right) with respective interpreted deep and shallow deep rock boundaries

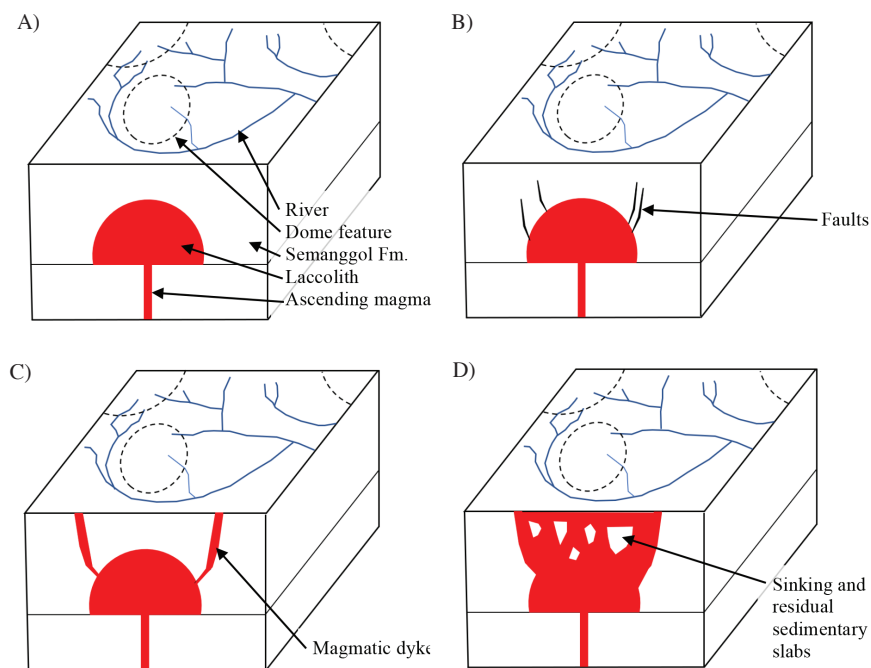


FIGURE 6. Schematic representation of magmatic events towards Bongsu Granite intrusion in study area

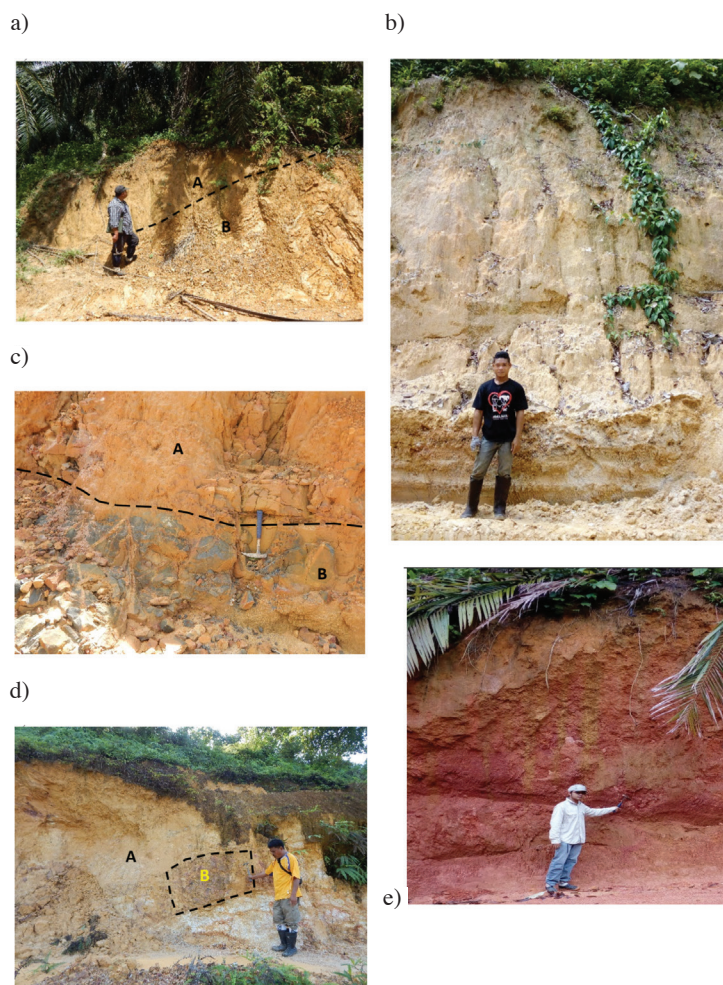


FIGURE 7. Photos of exposed outcrops in Bongsu Granite area. Photo a), b) and c) show occurrences of slightly metamorphosed sedimentary rocks (B) either beneath or as xenoliths in granitic bedrocks (A), while photo d) and e) show possibly greisenized, muscovite-sericite rich and feldspar-absent bedrocks exposed at timber road cutting near the granitic hilltops

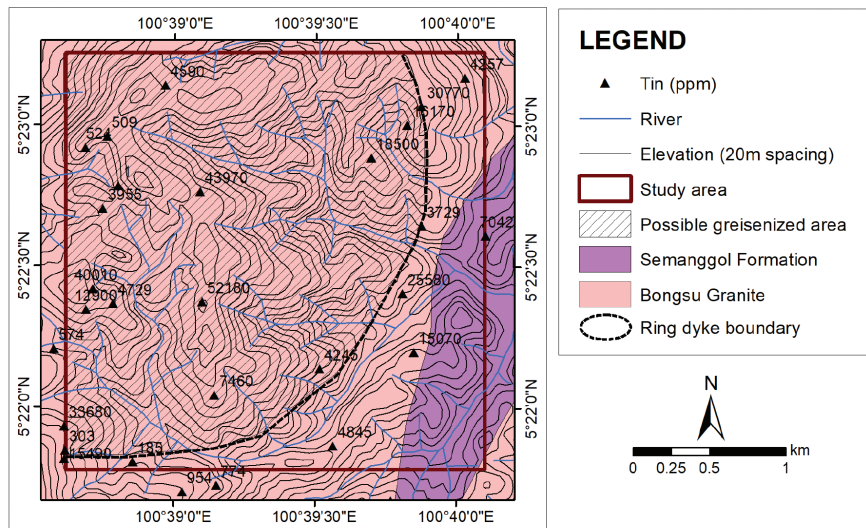


FIGURE 8. Ring dyke boundary and possible greisenized granite area

Magmatic ascends at SW, NW and SE deep area during Late Triassic, creating three individual laccoliths beneath the Triassic sedimentary bedrocks of the Semanggol Formation. The dome-like laccolith structures develop radial drainage patterns in the study area; The development of SW laccolith creates fractures around the edge of domes of overlying sedimentary rocks as interpreted in THD regional gravity anomaly map; Further magmatic upwelling partially melts the sedimentary rock on top and forming dykes through the ring-like fractures zone. The dykes are interpreted as ring feature of low anomalies in residual gravity anomaly map; As the diking magmas continue to rise up, the inner top sedimentary slab continues to melt and sink into underneath magma. Finally, magma intrudes above sinking slab, which causes the inner composition to be more felsic than the outer dykes. High anomalies in granitic area is due to effect by higher density of xenolith or metamorphism of the Semanggol Formation in residual gravity anomaly map.

Several outcrops within the study area showed the occurrence of granitic - sedimentary rock contacts which prone to indicate the appearance of xenolith due to slab sinking as the sedimentary rocks appear below the granitic bedrocks. Granitic bedrocks near hilltop area show greisenized pattern with lacking of feldspar but rich in muscovites and sericites (Fakhrudin Afif 2018; Figure 7).

Similar magmatic events occurred during emplacements of Götemar and Uthammar Granites in Sweden and Mount Givens pluton in California but no known study on any igneous bodies in Malaysia has been done (Cruden 2008; McNulty et al. 2000).

Based on the deductions, the ring dykes cools first as early phase granite followed by the inner ring as late phase granite. As hydrothermal fluids exsolve from earlier cooling magma and diffuse into later granitic phase, the inner ring granite is suggested to have undergone greisenization (Robb 2005) (Figure 8). The higher tin

distribution within the inner ring granite generally confirm the main greisenization area.

## CONCLUSION

The conducted gravity survey and analysis were successful to propose ring fractures to model magmatic ascend and emplacement to develop a part of the Bongsu Granite. Comparison studies on the produced Bouguer, regional, residual, THD regional and THD residual gravity maps correlate with the deduction of the model initialized by laccolith development, doming of sedimentary bedrock, magmatic diking through ring fractures and finally sinking and melting of surrounded sedimentary rock before magma cooling and crystallizing. Additional data including bedrock densities and geochemistry of subsurface and borehole are crucial to determine the zonation and to confirm the inner ring as having greisenization alteration.

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