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Mapping of Subsurface Geological Structure and Land Cover Using Microgravity Techniques for Geography and Geophysic Surveys: A Case Study of Maluri Park, Malaysia

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Abstract

A microgravity investigation on bedrock topography was conducted at Maluri park reference level in Kuala Lumpur, Malaysia. The study aim to mapping the near-surface structure and soil and land cover distribution for geography and geophysics surveys. Two types of cross-section modeling of the residual anomaly generated the MaluriBouguer Anomaly model for site-1 and site-2 at Maluri Park. The 2D microgravity models produced the contour map, displaying the characterization due to density contrast in rock types while mapping the subsurface geological structure at different depths. Moreover, a synthetic model was initiated with the assumption of lateral distance on the left and right sides taken at 50 m and a depth of 60 m. The results of modeling confirmed that the soil and rock type composition on both models site tests are topsoil (1.1 to 1.92 g/cm^3), soil (1.8 g/cm^3), clay (1.63 g/cm^3), gravel (1.7 g/cm^3), sand (2.0 g/cm^3), shale (2.4 g/cm^3), sandstone (2.76 g/cm^3), and limestone (2.9 g/cm^3). The 2D gravity modeling using two model site tests obtained a correspondence with the observed microgravity data.

Keywords: Bouguer anomaly, limestone, microgravity, soil structure, topography.

1. Introduction

The survey area is underlain by limestones. The survey area in Maluri Park in eastern Kuala Lumpur, Malaysia, near Cheras. The survey location can be seen in the Fig.1. It is commonly understood that limestones pose a certain threat to soil structures. As limestones are generally easily dissolved by water, voids and cavities are common internal structures of this type of rock (Arisona et al., 2018). Identification of such structures can help to ensure sustainability, especially for land cover and strategic structures. The area under study is planned for both establishment of transportation facilities and an economic and urbanization projects. The motivation of the present work is to help reducing the threats to soil structures in the mentioned projects.

A significant application of geography and geophysical methods in mapping practice is to determine the bedrock and the characteristics of soil structure (Grandjean, 2009; Hiltunen, 2012). The gravity method is widely used for geography and geophysical surveys, especially in the detection of subsurface geological features and land covers. Gravity' anomalities controlled by the lateral variation of densities or other words, the lateral density contrast. Generally speaking, modeling of gravity data in 2D sections is useful for the determination of the depth of various features and can be done by either forward or inverse algorithms. In similarity with other geography and geophysical methods, the interpretation of gravity data is non-unique because many possible models could result in the same gravity anomaly. Constraints from borehole data can help to reduce the uncertainties greatly. The kind of useful information for this purpose in the depths of rock boundaries and rock densities. The irregular structure of limestones and land cover produces gravity anomalies, which are our target for gravity analysis and modeling. In other words, gravity anomalies are modeled to determine the subsurface structure and land cover problems.

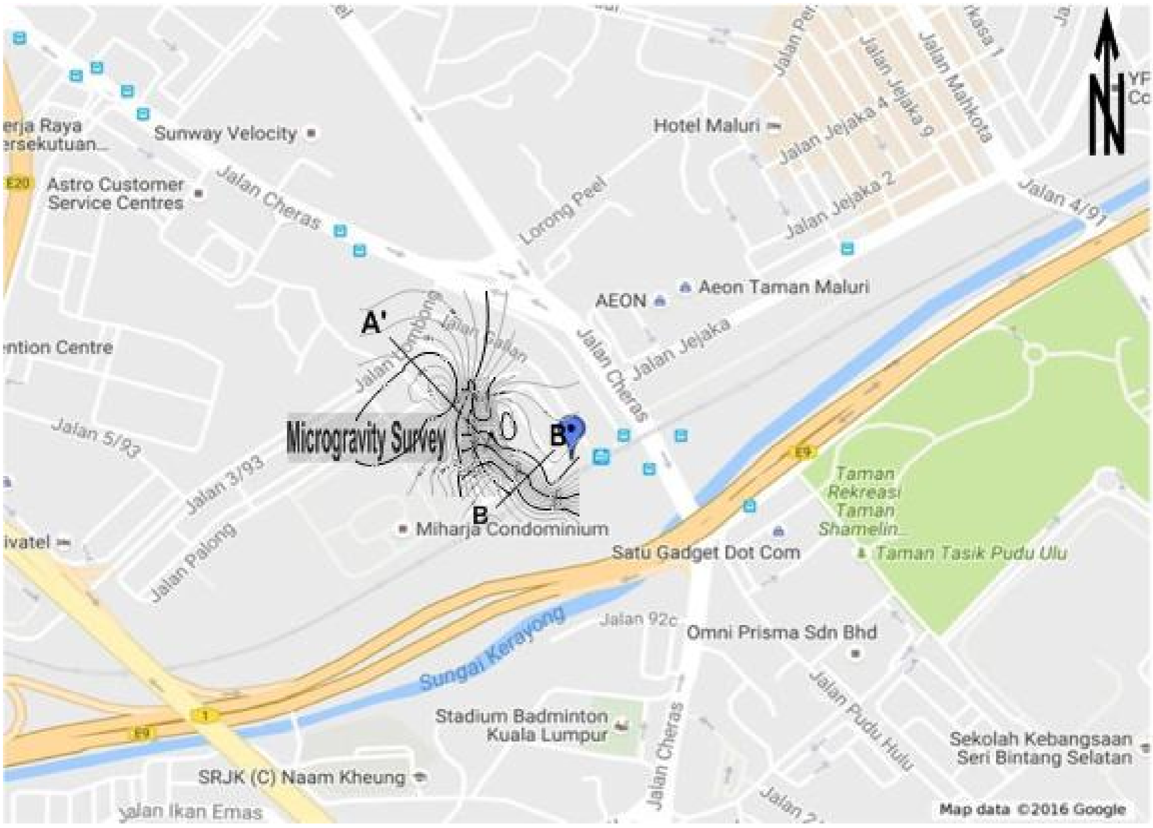


Figure1. Survey location: Maluri Park, Malaysia

As mentioned, the problem targeted by the present work is the presence of voids or cavities underneath the sites under the survey area. These cavities are either empty (i.e. filled with air or water) or filled with loose sediments. In both cases, the lateral density contrast is large, which favors the application of microgravity techniques. As the density of the cavities or voids is low compared to the surrounding host limestone bed, the anomalies will be negative. Hence, the analysis focusses on these negative anomalies for modeling their dimension and depth(Zabidi et al., 2011).

In this study, we perform microgravity modeling using physical parameters from real data that are robust. The bedrock within the survey area is a limestone formation. Limestone formations are well known for their highly unusual karstic features (Tan, 2005). As a consequence, the depth of the limestone bedrock is highly irregular. The overburden soils above limestone formation are mainly silty sands with significantly variable thickness due to the irregular topography of the limestone bedrock (Zabidi et al., 2011).

The soil thickness in the survey is that trends show variations of overburden soil between 3 m and 5 m. The soil is comprised mainly of sandy silt with embedded layers of soft clay. Moreover, the residual soil above the limestone bedrock is mainly loose fine-grained materials. The soil color in the survey area is light greyish-brown and mostly sandy. They are described and named according to the grain size classification as silty clay, clayey silt, silty sand, and sandy clay. Some are identified as fill and slime materials. They are essentially loose and soft material and are probably transported materials (Yusoff et al., 2016). The purpose of the research is mapping the near-surface structure and soil and land cover distribution for geography and geophysical surveys.

2. Methods

Microgravity data from the survey area were processed using Surfer ® 13 software , which reduced Bouguer anomaly values at each station of the microgravity survey. Fig.2 shows that the modeling has been well constrained because the parameters required to obtained the bedrock topography were well defined from the borehole data (Figure 3). According to Samsuddin (2003), modeling enables the determination of the presence of ridge and valley features. Additionally, the modeling indicates that there can be smaller features such as cracks or steep, narrow valleys within the ridges. This result explains the differences in the limestone depth in nearby boreholes.

The post-processing procedure checked the microgravity instrument corrections for latitude and longitude, diurnal variations, and instrument drift using base station polynomial drift values and relative elevation. This procedure is merged with the respective gravity station topographic survey data, which is being modeled. The same density value of 1.8 g⁄cm3 was used to calculate the Bouguer correction for all survey data sets. Table 1 presents the density of rock types that were reviewed in this study.

Table 1. Rock types density values

Rock Type	Density range (gr/cm^3)	Average (gr/cm^3)	Source
Sediment rock			
Overburden (Topsoil)	-	1.92	
Soil	1.20 to 2.40	1.92	
Clay	1.63 to 2.60	2.21	
Gravel	1.70 to 2.40	2.00	
Sand	1.70 to 2.30	2.00	Telford et al.,1990
Sandstone	1.61 to 2.76	2.35	
Shale	1.77 to 3.20	2.40	
Limestone	1.93 to 2.90	2.55	
Dolomite	2.28 to 2.90	2.70	

Subsequent processing was the elevation correction to address the variation in data points due to the topography. This evaluation is necessary for the 2D geotechnical modeling (Pringle,2012). Furthermore, the removal of regional values (low frequency and high amplitude) to express the residual anomalies (high frequency and low amplitude) was performed. The modeling of the residual anomaly was generated in Cooper ™ Grav2Dc v.2.10 software. However, qualitative interpretation using geological and geography maps are used only as additional information. According to (Amaluddin et al., 2019) geological formation or structure for instance can use the maps which poured in the data field or 2D.

The qualitative interpretation explains the anomaly by geological and geophysical information. On this basis, the geological structure and distribution of masses of different densities may be delineated. The gravity anomaly in the study area might be generated in the field due to the following factors; variations in the thickness, density differences of the subcrustal matter (crustal thickness), density variation within the basement rocks, thickness variations of the sedimentary rocks, and density variations within the sedimentary rocks. The difference in density values can be correlated to divergent material types such as soil, rock, and voids (Samsuddin,2003).

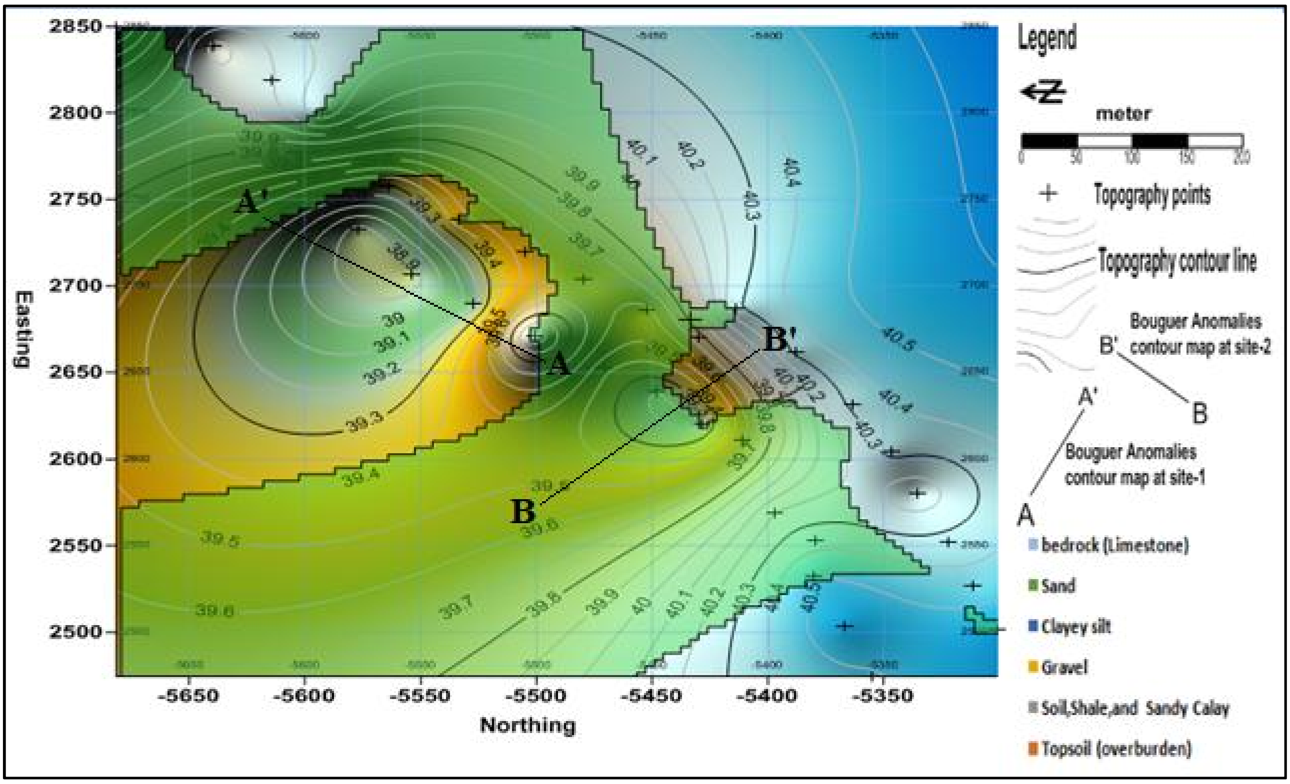


Figure 2.A 2D microgravity contour map at Maluri Station compiled from topography and Bouguer anomalies at site test-1 and site test-2. The microgravity countur color information above is on the right and adjusted the rock conditions in the study site.

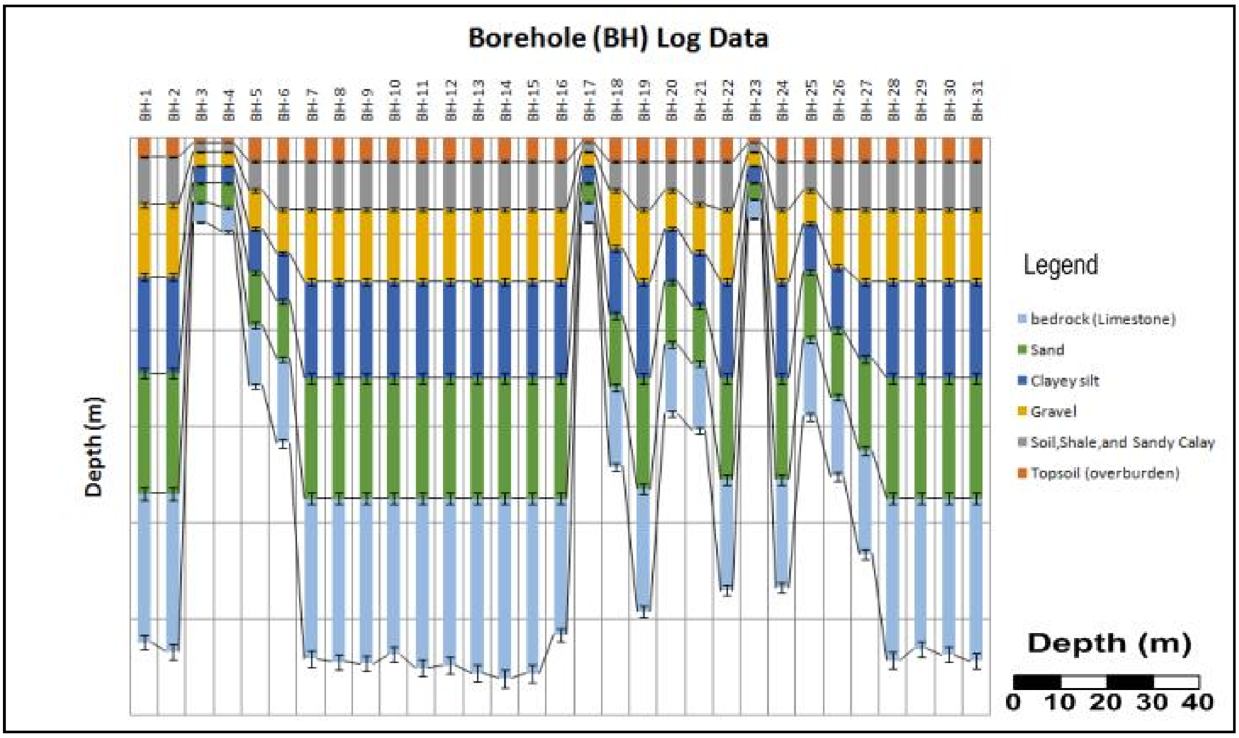


Figure 3. Borehole (BH) logs showing Bedrock RL at Maluri Station

3. Results and Discussion

The bedrock topography for the Maluri Station was compiled from BH results, secant bored piles (SBP) and Kingpost, and the gravity model. The density values were not uniform, which showed that some lines in the study area lack good control. The bedrock topography map is shown in Fig. 4was correlated with the 31boreholes, where the average topography height of about 39.91mwas determined (Figure 3).

Two sinkholes were detected in the study area in the southeast of the survey area. The sinkholes occurred near the LRT bridge, which might occur under the devotional of clay construction site tests. The cause of the sinkhole is attributed to the dissolution of the limestone bedrock and the subsequent raveling of the overburden soil cover.

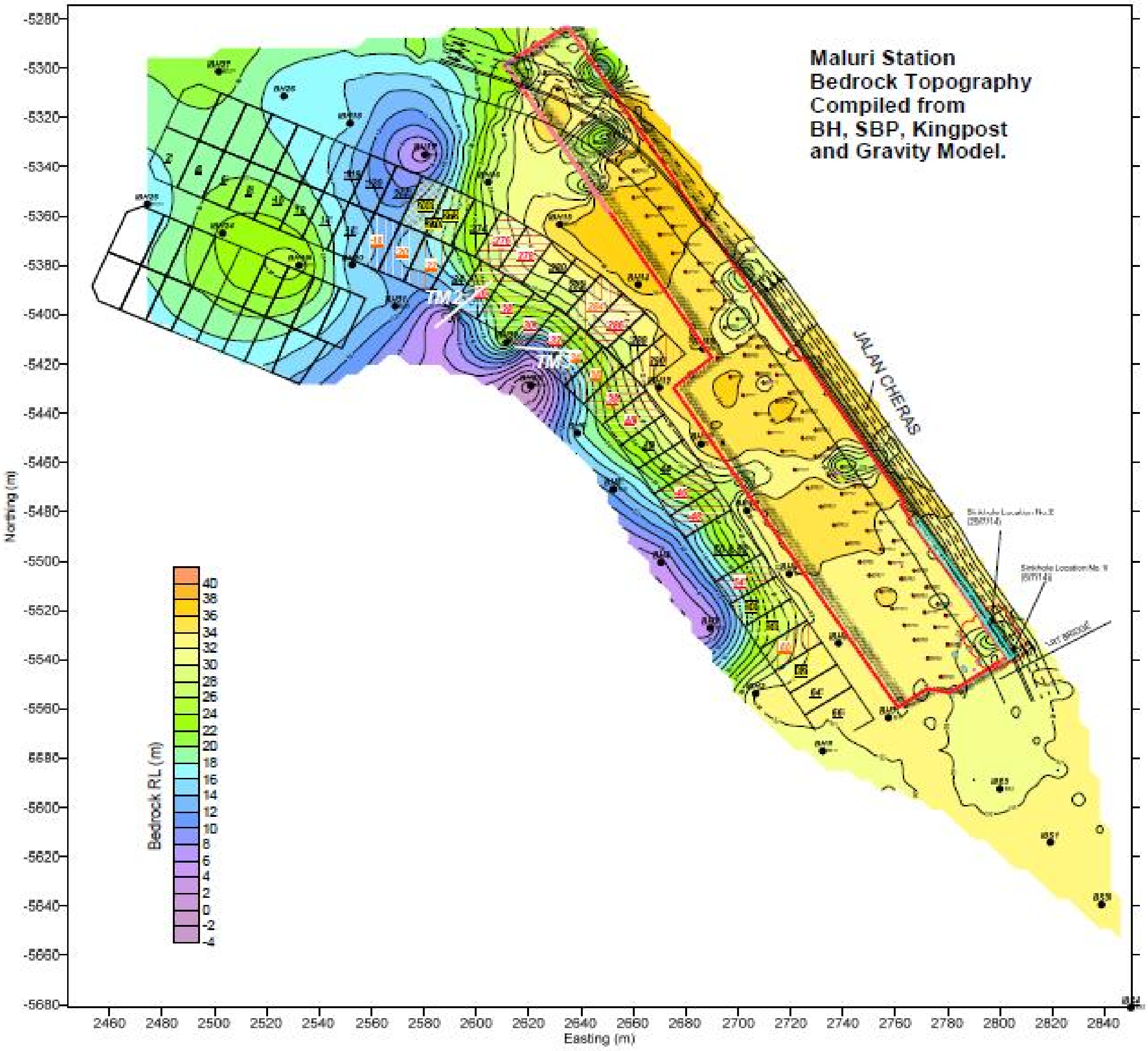
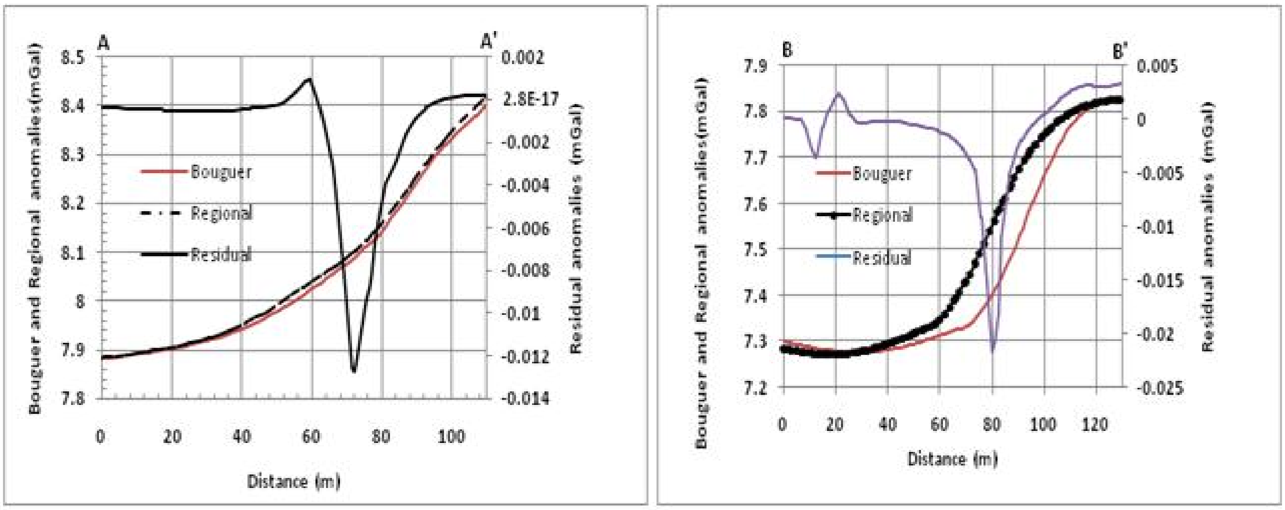


Figure 4.Maluri Station bedrock topography model.

The gravity pattern correlates subsurface topography of bedrock (Tajuddin and Lat, 2004). The results of this investigation confirmed earlier borehole results which indicated thepresence of the cavities (Samsudin, 2003). However, the uneven distribution and clustering of the data necessitate the use of an interpolation algorithm to create a uniformly spaced grid. All data processing in the contour map was generated with Cooper ™ Surfer ®13software. The survey results were represented in contour maps for delineating anomalies varying from negative to a positive value. According to Kamal et al. (2010), negative values are interpreted as low density subsurface layers and for the possibility of the existence of cavities. No density measurements were made during this work. The density values used are based on the investigations of Soils and Foundations Sdn. Bhd., employing a superficial deposit density of1.8 g/cm^3. Table 1presents the density of rock types that were reviewed in this study.

Fig 5 shows the results of the microgravity data of Maluri site for the Bouguer, regional, and residual anomalies. Fig. 5a displays the tendency of response towards positive anomalies, and yet it was not significant to influence the gravity anomaly around model site test-1. The small variation in gravity responses may be due to the effect of the distribution of rainwater around the area and the inhomogeneity in the soil types.

Fig.5b shows the gravity anomaly at model site test-2, characterized by negative values, probably due to the inhomogeneous geo-materials consisting of a mixture of clay and silt with grain sizes, which is from fine to medium. Additional geological and geography mapping showed that the complexity of the subsurface profile regarding the geomaterials, geological structure, and water seepage influences the contrast in the zones, thus resulting in some of the inconsistency of the gravity values.



a b

Figure 5. Results of gravity field measurements at Maluri Site for (a) profiles site test-1 and (b) profiles site test-2 using extracted techniques from anomaly contour maps.

Figs. 5a and 5b show results of the 2D geotechnical model generated with Cooper ™ Grav2Dc v.2.10 software. The two curves for the model at the sites confirmed the product of a misfit of4.44 % and 3.18 %between calculated curves with observed curves. Furthermore, model-calculated gravity confirmed density contrast at both model sites as shown in Table 2.

Table 2. Estimated density contrast from gravity field measurements at Maluri Site for (a) profiles site test-1 and (b) profiles site test-2

Model site test-1		Model site test-2	
Density (g/cm^3)	Rock Type	Density (g/cm^3)	Rock Type
1.80	Soil	1.10	Dry density
1.63	Clay	1.80	Clayey, Sandy Silt
2.00	Gravel	1.20	Clay
1.70	Sand	1.92	Overburden (Topsoil)
2.40	Shale		
2.76	Sandstone		
2.90	Limestone		
RMS Error = 4.44 %		RMS Error = 3.18 %	

Fig. 5 shows the zones associated with negative anomalies. An important to observation is the decrease of soil compactness due to the cavity and existence of groundwater around the area. In other words, the model site test encountered a unsewed soil at an adepth of about 5 to 10 m filled with water. Additionally, different factors include changes in gravity values caused by the dynamics around the observation points, such as variations in the depth of the groundwater level and land subsidence. The occurrence of strain and shear failure due to loading at the top layer of soil could be another reason.

In general, loading in the ground layers produces strain in the sediments (Fig.5), a decline in groundwater level at a depth of 15 m to 35 m). Strain observed in this area could be due to variation in the composition of the soil and water in the cavities. The loading effect is often referred to as consolidation.

As a result, regional anomalies when compared with Bouguer anomalies in a horizontal plane, the obtained residual anomalies are still significant. This difference is probably caused by the material homogeneity and similarity of the geological structure. The residual anomaly values are not affected by topography. Anomalies appear in the northeast and northwest. That result in line with the research (Arisona et al, 2018), difference assumed that this contrast is affected by density variations of the host rock and the possibility of rock density. The difference location implies that the anomaly is a result of different depth to the bedrock, different thickness of the overlying material

The Bouguer anomaly map result characterized the density contrast due to rock type and mapped subsurface geological structure and land cover at different depth. The research (Samsuddin, 2003) describes that the modeling enables the determination of the presence of ridge and valley features. Additionally, the modeling indicates that there can be smaller features such as cracks or steep, narrow valleys within the ridges.

The result is eight rock types from the profiling from different and depth. It is shown that the mapping for a geophysics survey can obtain information matching with the mapping aim. The research (Wanjohi, 2014) geophysical field mapping is the process in selecting the interest area, then identifying all geophysical aspect matching with the mapping aim. The mapping aim in the research (Wanjohi, 2014) is to understand all physical parameters of a geothermal field.

The survey results were represented in contour maps for delineating anomalies varying from negative to a positive value. Mapping in a geophysical method in the research (Georgsson, 2009) uses contouring to see the object interest phenomena. The contour or line data combined with other data like a polygon in the form of coloring.

Microgravity method solves problems targeted by the present work is the presence of voids or cavities underneath the sites under the survey area. According to the previous research (Tuckwell, Grossey, Owen, & Stearns, 2008) that micrografity establihed as technique for detection natural or man-made cavilities. In the case Mounchel Parkman on behalf of Herfordshire Country Council, a doline had opened up within a school playground. That example in the natural voids in the limestone bedrock.

4. Conclusion

The result obtained from the Grav2Dc v.2.10 software correlates the model-calculated gravity, and the corrected gravity data in site tests have minimal percentage errors. The results of modeling showed that there are eight rock types from the gravity profiles; topsoil (1.1 to 1.92 g/cm^3), soil (1.8 g/cm^3), clay (1.63 g/cm^3), gravel (1.7 g/cm^3), sand (2.0 g/cm^3), shale (2.4 g/cm^3), sandstone (2.76 g/cm^3) and limestone (2.9 g/cm^3). The utilization of extracted technique characterized the density contrast due to rock type and mapped subsurface geological structure and land cover for geography at different and depth. Models of microgravity distribution in the ground could be useful for the mapping of variations in soil composition. The changes in gravity anomaly observed throughout the sections were due to the heterogeneities in the composition of the subsurface materials and density contrasts in the study area. The information on the background lithology is paramount for an acceptable interpretation in a microgravity modeling of soil structure.

Conflict of Interest

The authors declare that there is no conflict of interest with any financial organization regarding the material discussed in the article.

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References

Amaluddin, L. O., Rahmat, R., Surdin, S., Ramadhan, M. I., Hidayat, D. N., Purwana, I. G., & Fayanto, S. (2019). The Effectiveness of Outdoor Learning in Improving Spatial Intelligence. *Journal for the Education of Gifted Young Scientists*, *7*(3), 667–680. https://doi.org/10.17478/jegys.613987

Arisona,A., Mohd N., Amin E.K., &Abdullahi, A.(2018).Assessment of microgravity anomalies of soil structure for geotechnical 2d models.*Journal of Geoscience, Engineering, Environment, and Technology (JGEET)3*(3), 151-154.

Georgsson, L.S. (2009). *Geophysical Methotds Used in Geothermal Exploration.* Presented at Exploration for Geothermal Resources, 1-22 November 2009, 1-16.

Grandjean, G. (2009). *From Geophysical Parameters to Soil Characteristics*.Florida: Report N°BRGM/FP7-DIGISOIL Project Deliverable 2.1, Final ReportDepartment of Civil and Coastal EngineeringUniversity of Florida.

Hiltunen, D.R., Hudyma,N.,Tran,K.T.,&Sarno,A.I. (2012).*Geophysical Testing of Rock and Its Relationthipsto Physical Properties*.Florida:Final ReportDepartment ofCivil and Coastal EngineeringUniversity ofFlorida.

Kirsch,R. (2006).*GroundwaterGeophysics, ATool for Hydrogeology*.New York: Springer.

Kamal,H.,Taha,M.,&Al-Sanad,S. (2010). Geoenvironmental Engineering and Geotechnics, GeoShanghai 2010 International Conference. (accessed 02.03.17)

Lilie, R.J. (1999).*Whole Earth Geophysics: An Introductory Textbook for Geologists and Geophysicists*. New Jersey:Prentice-HallInc.

Pringle, J.K., Styles, P., Howell, C.P.,Branston, M.W., Furner, R., &Toon,S.M. (2012). Long-term time-lapse microgravity and geotechnical monitoring of relict salt mines, marston, cheshire, uk. *Geophysic77*(6), 165-171.

Samsudin, H.T.(2003).A microgravity survey over deep limestone bedrock.*Bulletin of Geological Society of Malaysia4*(6), 201-208.

Tan, S.M. (2005). Karsticfeatures of kualalumpur limestone. *Bulletin of the Institution of EnginnerMalaysia 4*(7), 6-11.

Tajuddin, A.&Lat, C.N. (2004).Detecting subsurfacevoids using the microgravity method, a case study from kualalipis, pahang.*Bulletin of Geological Society of Malaysia 3*(48), 31-35.

Tuckwell, G., Grossey, T., Owen, S., & Stearns, P. (2008). The use of microgravity to detect small distributed voids and low-density ground. *Quarterly Journal of Engineering Geology and Hydrogeology*, *41*(3), 371–380. https://doi.org/10.1144/1470-9236/07-224

Wanjohi, A.W. (2014). *Geophysical Field Mapping.* Presented at Exploration for Geothermal Resources, 2-23 November 2014, 1-9.

Yusoff , Z.M., Raju,G. &Nahazanan, H.(2016).Static and dynamic behaviour of kualalumpur limestone. Malaysian Journal of Civil Engineering Special Issue Vol.28 (1), p.:18-25.

Zabidi, H. & De Freitas, M.H. (2011).Re-evaluation of rock core logging for the prediction of preferred orientations of karst in the kualalumpur limestone formation. *Engineering Geology*, 117(3-4), p.: 159–169.