Gravity data of porong regions, sidoarjo in the interpretation geology structure and deformation of the subsurface

Eddy Supriyana¹, Tatang Padmawidjaja²

¹Department of Geophysics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Jalan Raya Bandung-Sumedang Km 21, Sumedang 45363, Indonesia
²Geology Survey Center, KESDM, Diponegoro Street no. 57, Bandung 40115, Indonesia

*E-mail: e.supriyana@geophys.unpad.ac.id

Abstract. Patterns of regional geological structure Sidoarjo has performed detailed interpretation of gravity data is controlled by the data of surface deformation via GPS. Indication of field data is not obtained a description pattern shallow geological structure being covered by sediment aluviumnya. Gas effluent or subsidence in the Siringbarat and Tanggulangin area is field evidence as controls in the estimation of interpretation of gravity changes and pattern density shallow geological structure. Regional and detailed gravity data interpreted that as an anomaly patterns are trending fault structures with the location of the gas effluent south southwest - north northeast. South trending regional fault structure of the southwest - north north-east to the surface to form a continuous fracture and amblasan as a medium in which the effluent gas is formed. Negative changes in the value of gravity is interpreted as a weak zone or zones shown as mass loss as subsidence located in Siringbarat and Tanggulangin. While positive changes in microgravity, as the removal of the zone located in the southern part of the Sidoarjo Mud pond.

1. Introduction

The gravity study in Porong area obtained 136 points of measurement at 1000 meter intervals for random observation, and a 500 meter interval for track observation (figure 2). The gravity measurements were carried out in 3 priods at the same point, ie June, September and November 2010. The gravity measurements were obtained by gravity changes and allegedly as mass or mass density changes, with observations in the field as subsidence or gas and water permeation. Alluvium sediments with thicknesses greater than 330 meters or 1000 ft as shallow sea deposits occupy the Porong area and around, where the young sediments are disrupted both from shallow structures that form fractures or horizontal forces of mud activity Sidoarjo. Impact on the outside of the pond area that formed subsidence and gas breaks around Siringbarat, Tanggulangin and Candipari [1].

The gravity change is thought to be a change of density of alluvium sediment mass from the horizontal force of the dry mud pond load. The mass assembly turns low due to a mixture of water (fluid), as a subsidence. The field data of subsidence are shown in the form of cracks, buildings, breaks and gas bursts, as well as soil surface degradation, whereas on gravity measurements there are instability instances of readings in the galvanometer. and also related to the fault zone through this region.
Surface deformation with GPS Geological Agency as well as breakdown and gas emission data as controls in interpretation and modeling [1]. The Porong Sorong area of Sidoarjo is located in the southern part of the decline of the gravity anomaly basin (Figure 1) bordering Mount Penggungan and Mount Welirang from the southern mountain range [1]. While tectonically located on the Lane Kendeng and Lane Solo-Gunungapi Quaternary [2]. The regional regional anomaly patterns of Malang and Surabaya, form a curved north-western curve pattern as a regional structure [3,4]. Geologically, the Watukosek Fault passes through the western part of the mud pool, which is part of the Kendeng and Rembang Lane, and southwest-northeast direction.

2. Methodology
The gravity data indicates the location of the mud pond located at the intersection of two fault zones i.e east-westward trending faults, southwest-northwestern quarterly fault, referred to as the Watukosek Fault [1,5]. The joint two fault is causing of impacts in addition to the horizontal forces that incubate the alluvial sediment (Qa), and a detailed gravity study was conducted in the western part of the mud pond starting from porong river area to Tanggulangin. While impact to drilling process causing mudflow in Porong area, the disturbance of land stability and structural process become more active East Java Regional Structure [5].

![Figure 1](image_url)  
**Figure 1.** (a) Patterns of regional geological structures based on Porong regional gravity data; (b) East Java Regional Structure [1]

2.1 Location
The location of the gravity study is located outside the Sidoarjo mud area, administratively located in three Districts of Porong, District Tanggulangin, District of Jabon, Sidoarjo Regency, East Java Province (figure 2). The geographically located on the coordinate between 70 30 ‘ - 70 34’LS and 1120 39’ - 112045 ‘BT.

2.2 Geological overview
Fault occurs in Quaternary volcano rocks, consisting of several shear faults and cesareous fault in various directions. The congestion fault with the south-western direction occurs on the Gender Rocks and cuts the steep escarp, estimated at the end of the Middle Plistosen.

The shear fault with the northeast-northwest and northwest-southeast direction occurs in Tengger Volcano Rock, estimated to be directly at the end of the Late Plistosen and cut the Tengger Crater, so that the eastern crater ridge becomes lower than the other escarpment. Weak folds occur in the Kabuh Formation and Jombang Formation, with the direction of the axis almost south-west with a sloping wing slope.
The alignment contained in the Malang Sheet is the result of the interpretation of the distant sensory image of the Landsat and the aerial portrait. In general, the alignment reflects the west-east, northeast-southwest, northwest-southeast and north-south directions in the Arapija-Wellirang and Tengger Volcanoes.

Stratigraphy of rocks found in the area of Sidoarjo is the rock deposits in this region begins with the formation of limestone Kujung Formation at the time of the Miocene which is then covered in a synchronized by the upper Pliocene volcanic sandstone deposits, bluish stone clay, alternating sandstone and lower Plistosen shale flakes – Middle. The rock groups (figure 3) were then overlaid by the non-harmonized Notopuro volcanic rocks of Upper Plistocene and alluvial delta Brantas aged Resen. The volcanic sandstone found in the Banjar panji-I well has a thickness of about 962 m, which is thinning eastward (Porong well).

This rock layer is volcanic rock deposits of volcanic eruptions in the western or westernmost of the upper Pliocene are the result of Plio-Plistocene orogenesis. The bluish-colored stone topped over it is the bottom of the Lower Plistocene Pale Formation. Bemmelen (1949) states that in the Lower Pliocene era there are many volcanoes located around Surakarta are still active and suspected at the same time in the eastern region there are other volcanic activities as the eastern end of the Solo Zone is a complex of volcanoes Old Wilis and Old Anjasmoro. The eruptions of the volcano complex produce lava deposits, pyroclastic flows, and / or "reworked" fluvial deposits of pyroclastic deposits. The layers of volcanic sandstone found in the Porong region and surrounding areas are the rock layers of the volcano eruption.
3. Gravity anomaly analysis

Based on the anomaly (figure 4), the high anomalous area occupying the southwest to Mount Penanggungan and Mount Welirang, with its pattern forming a circle rising towards the mountains. The high anomalous anomalies show that the rocks that occupy them are Arjuno-Welirang volcanoes composed of breccia, tuff, lava, agglomerates and lava, with high mass densities.

The basis of Arjuno Rock formation Arjuno - Welirang at the same time the removal of bedding base, should be obtained contour pattern of ideal anomaly is straight and no sub surface dynamics. However, it turns out that the geology of the East Java region has been deformed, causing a subsurface geological structure that developed in the area. Based on the anomaly pattern of parallel curves of north-trending north and repetition curves to the west. The anomalous curves of the north-south direction, as the Watukosek Fault. Watukosek fault is the name of a village where in the Watukosek region there is a difference in elevation that leads southwest - northeast.

![Figure 4](image)

Figure 4. The interpretation of gravity anomalies in the Porong area

The separation of gravity anomaly to regional gravity anomaly has been obtained by residual gravity anomaly, then the residual gravity anomaly is interpreted to obtain sub-surface geology of superficial geology. The distribution of residual gravity anomaly values ranges from -3.5 mGal to 4 mGal (figure 5). Based on the pattern of residual anomalies are divided into two groups, the lower anoretic group is smaller than 0 mGal and the anomaly height group is greater than 0 mGal. The group of residual gravity anomalies (B) that form anomalous ridges and occupy the middle through the Sidoarjo mud pool, this group lies between anomalous lows in the west (C) and anomalous lows in the east (A). Lower anomaly groups in both western and eastern parts form an anomalous basin directed northwest-southeast and in the direction of anomalous ridge. The anomalous ridge in the middle through the mud ponds reflects that the mudflow is located in the landing zone of the bedrock. In the gravity anomaly contour map obtained three anomalous basins separated by the height of the anomaly, the three anomalous basins are southwest-southeast and located in the west of mud pond of Sidoarjo, this interpretes the possible instability of subsurface structures. The gravity anomaly cross section to be used for modeling is done to cut the location of Sidoarjo Mud that is southwest-southeast direction. On the section of the gravity anomaly cross section through the Toll Road (BPLS) plan, Siring Barat and the west and east dikes.

Correlation between shallow geological structures and mass density changes, has been measured for 3 times, ie July 2009, November 2009 and March 2010. Gravity measurements have been compared in July 2009 and November as the first prizes and measurements between the months November 2009 and March 2010 as the second prize. The gravity difference in the first prize shows the zone of negative gravity change as negative zone (Figure 6) and positive gravity change zone as positive zone (Figure 6).
Negative zones or weak zones located in the western Siring area during ambulance occur about 500 meters of the mud embankment with gravity readings unstable (Figure 6). Monitoring GPS (Zaenudin, 2007) shows the elevation of elevation values with eastward slope located on the western part of the mud embankment. This shows that the change in negative gravity values in the assumption of mass density changes or mass density decreases.

Positive zone occupying Kalitengah Village in the northern part of the mud pond geologically, possibly because of the strengthening of mass density or removal of the base rock. GPS monitoring shows elevation elevation with changing slope in measurement interval. One of the observations on the ground was the wall of a cracked house north of a mud pond around Kalitengah road.
The second period of measurement in November 2009 and March 2010 (Figure 7), we have obtained gravity change contour map. Negative and positive zones affect position change, where negative zone or weak zone move towards Kampung Kalisawah, Ketapang Village and Kebakalan Village reach -1.6 mGal. Negative zones are correlated as weak zones, meaning there is a reduction in mass or a decrease in mass density at these locations to facilitate the occurrence of fractures that cause the existence of amblasan and indicated the emergence of gas bubbles. While a positive zone or strong zone indicates as an uplift area, the location is not found gas bubbles.

4. Conclusion
The results of gravity measurements in 3 periods can show substantially increasing downward deformation towards the north indicated by the presence of gas bubbles and the intensification of subsurface changes with an unstable gravimeter reading, with the direction of such instability along the western route to the toll road and alternative plan. This indicates a lack of mass occurring beneath the surface of the site causing unstable land or mass flow from south to north through the western Siring road. If compared with BMG measurement results (2007), also changes the pull of the mass to the north, the union of high density masses in the northern part of Sidoarjo Mud. While in the vicinity of Siring Barat and eastern part of Sidoarjo mud there is a decrease in gravity values that relate as a deterrent mass meeting or as a subsidence area. The decline in anomalous values in Siring Barat will greatly affect infrastructure and toll road plans or arterial roads. Based on the analysis of the three cross sections of the gravity value changes measured from the three different times indicates a change in gravity values that causes subsurface subsidence. While the gravity anomaly cross section illustrates the existence of geological structures such as inner faults that work on the zone causing the zone to be unstable and also reflected from the residual gravity anomaly pattern. The fractures appearing on the surface with the presence of methane gas bubbles indicate the area of the inner structure acting on the site shown in the geological model of the gravity anomaly cross section. Also controlled by cross-section of seismic data through Banjar Panji 1 well [1].

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