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Temporal Changes of Complete Bougeuer Anomalies at Bromo Volcano, East Java, Indonesia

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Abstract

Bromo is one of the most active volcanoes located in Tengger Caldera, East Java, Indonesia. Historically, Bromo volcano was erupted about 50 times since 1775. Temporary gravity observation has been conducted at Bromo volcano in 1997, 2001 and 2014 to identified the temporal changes of Complete Bouguer Anomaly (CBA). The results of the research noted that for 17 years, subsurface conditions from Bromo volcano has changed. The changes in this period caused by volcanic activity from Bromo eruption, especially after eruption in 2000, 2004, 2010, and 2011. Based on the results of the gravity survey, Bromo volcano's structure has changed both in terms of morphology as well as geologically. This temporal changed was identified in the value of CBA around Bromo volcano. The CBA data is representative to determine the dynamic of magma chamber beneath Bromo volcano. In 1997, CBA obtained with range from 200 to 620 mGal and in 2001, the CBA contour's range is wider than 1997, that is from -320 to 120 mGal. The wide range affected by large distribution observed data with high vertical-horizontal topographic. The CBA 2014 distributed in the range of 454 to 496 mGal from 250 m and mean height as 350 m vertical topographic each datum.

Keywords: Bromo, Volcano, Gravity, Complete Bouguer Anomaly, Temporal Changes

INTRODUCTION

Indonesia has about 127 active volcanoes and 201 eruption points as the result of tectonic plate interactions. Bromo volcano is one of the most active volcanoes located inside Tengger Caldera, East Java, Indonesia. In its histories, this volcano has erupted at least about 50 times since 1775 and still active until present [1,2,3]. The last eruption which is the longest eruption period occurred in 2011. The biggest eruption at the end of last eruption caused destruction of the lava plug and as the consequence, the flames were seen on Bromo crater.

Bromo volcano located in 7°56.30'S and 112°57'E in geographical coordinates with elevation about 2329 meters above mean sea level (msl). This volcano included in Stromboli volcano type with freatomagmatic eruption [1]. Some monitoring technique has been applied in order to predict the volcanic activity that might be occurred. In order to identify the subsurface of Bromo volcano, some geophysical observation methods have been done. One of the preliminary surveys, known as gravity survey can provide information in detail through the measurement of gravity values differences caused by density contrast variations. Temporary gravity observation had been conducted at Bromo volcano in 1997, 2001 and 2014 to identify the temporal changes of Complete Bouguer Anomaly (CBA) along those periods. These changes can be associated with the dynamic of magma chamber beneath Bromo volcano. By combining the data and the geological information, the subsurface lithology can be interpreted. This information is so helpful for the monitoring technique of volcanic activities at the certain volcano.

GEOLOGICAL OF BROMO

Begin in 1,4 milions years ago, tengger Mountain have a long history. The expert name it Bromo-Tengger complex with the center of eruption shape like a bow and some volcano arround it. The Nongkojajar dome (1,4-0,2 milion years ago), Ngadisari dome (822-90 thousand years ago), Old Tengger dome (265-40 thousand years ago), Keciri dome (unknown age), Cemoro Lawang dome (144-30 thousand years ago) has formed because explosive activity. Some of that dome destroy because a big explosive acivity and formed Nongkojajar caldera, Ngadisari caldera, Keciri caldera, and Sea of Sand caldera. In present, the only active dome and still looking vulcanic activity after formation the Sea of Sand caldera is Bromo volcano.

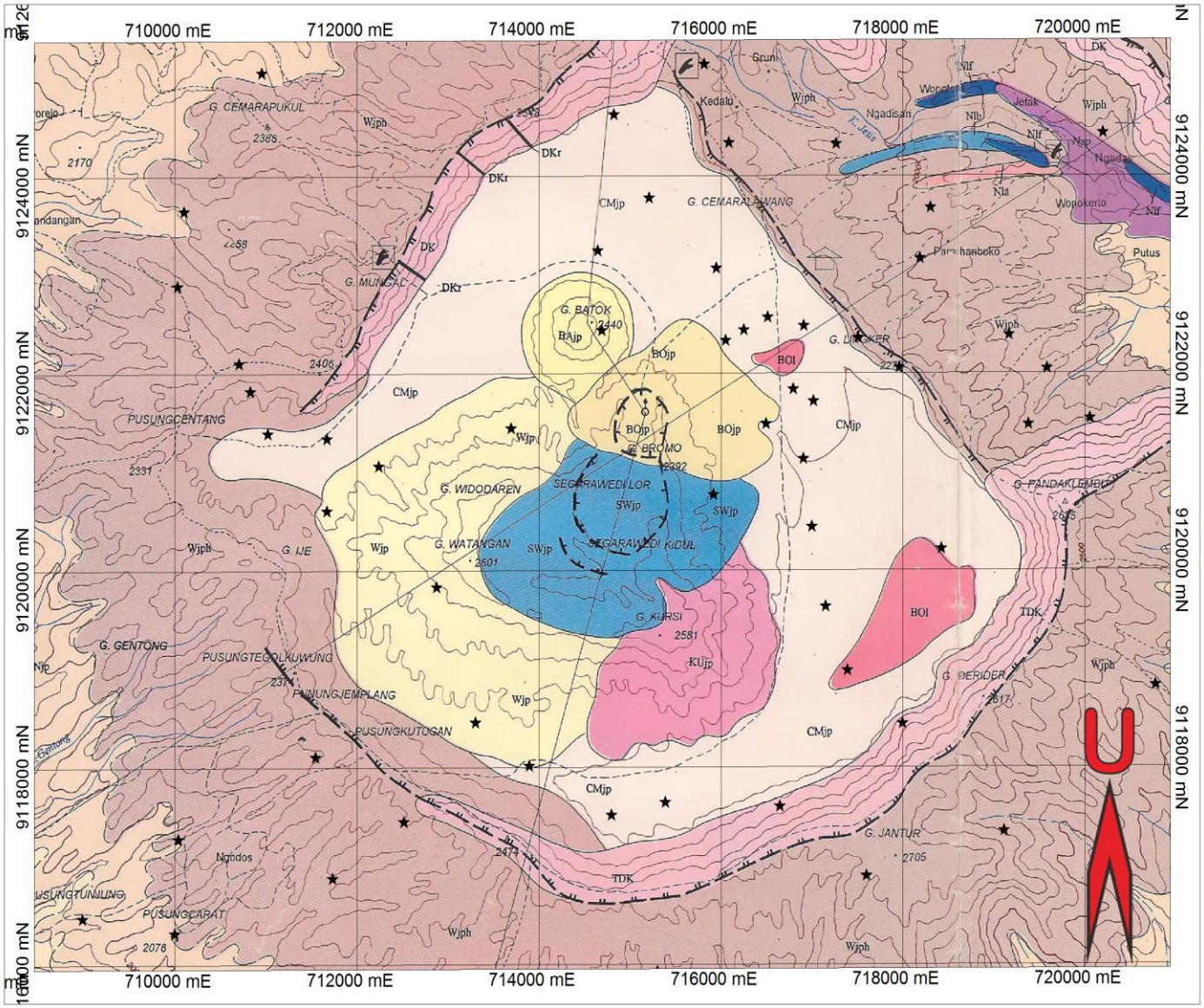


Figure 1. Geological map of Bromo Volcano Complex [2]

The geological map of Bromo volcano can be seen on figure 1. Bromo volcano is a quaternary volcano located inside Tengger Caldera, East Java, Indonesia [1]. Generally, Bromo volcano elevation is about 2392 m above mean sea level (msl) and 133 m above the base of Tengger Caldera with crater size about 600 m x 800 m. The crater always releases flue-gasses with high concentration of sulphur. Besides, Bromo volcano is a Stromboli volcano with some hazard potentials, they are tephra, heavy volcanic dust, poisoned gasses and pyroclastic falls [4]. The view at the edge of the crater shows that there are yellowish sulphur deposits spread unevenly [6]. Based on geological information, Caldera Tengger complex consist of some sedimentary formation. As explained by Zaenuddin, et al (1994) [6], they are: Bromo pyroclastic fall deposits (BOjp), Batok pyroclastic fall deposits (BAjp), Kursi pyroclastic fall deposits (Wjp), and Widodaren black rock deposits (WJph).

DATA AND GRAVITY OBSERVATION

This research involves 3 data, they are 2 secondary data obtained from previous research on 1997 and 2001, and 1 primary data obtained from gravity acquisition on 2014. These data contain differences of observation field both in wide and acquisition points. But all data represent the gravity surveys conducted in Bromo volcano and its surround. Each data consist the information of name, coordinate positions, elevations, times, terrain values and gravity value observed from each observation points. The data then processed to obtain the pattern of Complete Bouguer Anomalies (CBA) for each research. Processing steps done through the gravity data correction start whith tide correction to reduce the changes of gravity values as the effect of moon and sun movement which is depend on time and latitudes. Drift correction applied to reduce the effect from the shock of gravitymeter when acquisition done because spring was shift from its normal state.

Normal correction applied to correct the gravity value in different geographical location as the result from centrifugal forces which is maximum at the equator and minimum in poles and shape of the earth. Free-air correction applied to obtain values in topography, this correction used to correct the change of elevation by neglecting the masses between observation point and reference spheres. Bouguer correction is a first-order correction to account for the excess mass underlying observation points were on the plateau with uniform thickness, thickness, and density by summing up the value form acquisition, the slab between station and data. Terrain Correction is the last correction applied to the data to reduce the effect of topographic fluctuation or the existence of valleys and hills at observation field.

Research on 1997 carried out by Rangkudy [10] resulted 82 observation points and on 2001 carried out by Subekti [11] resulted 79 observation points. Whereas, the research conducted on 2014 had resulted 140 observation points. Research location is shown on figure 2.

RESULT AND DISCUSSION

Research on 2014 conducted with focusing on Bromo volcano and its surround. The observation points are shown on figure 4, which is the observation points plotted in geological map of the research area. These points selected by considering the geological information. Geological map of the area informs that the lava from Bromo volcano flows to North-East direction.

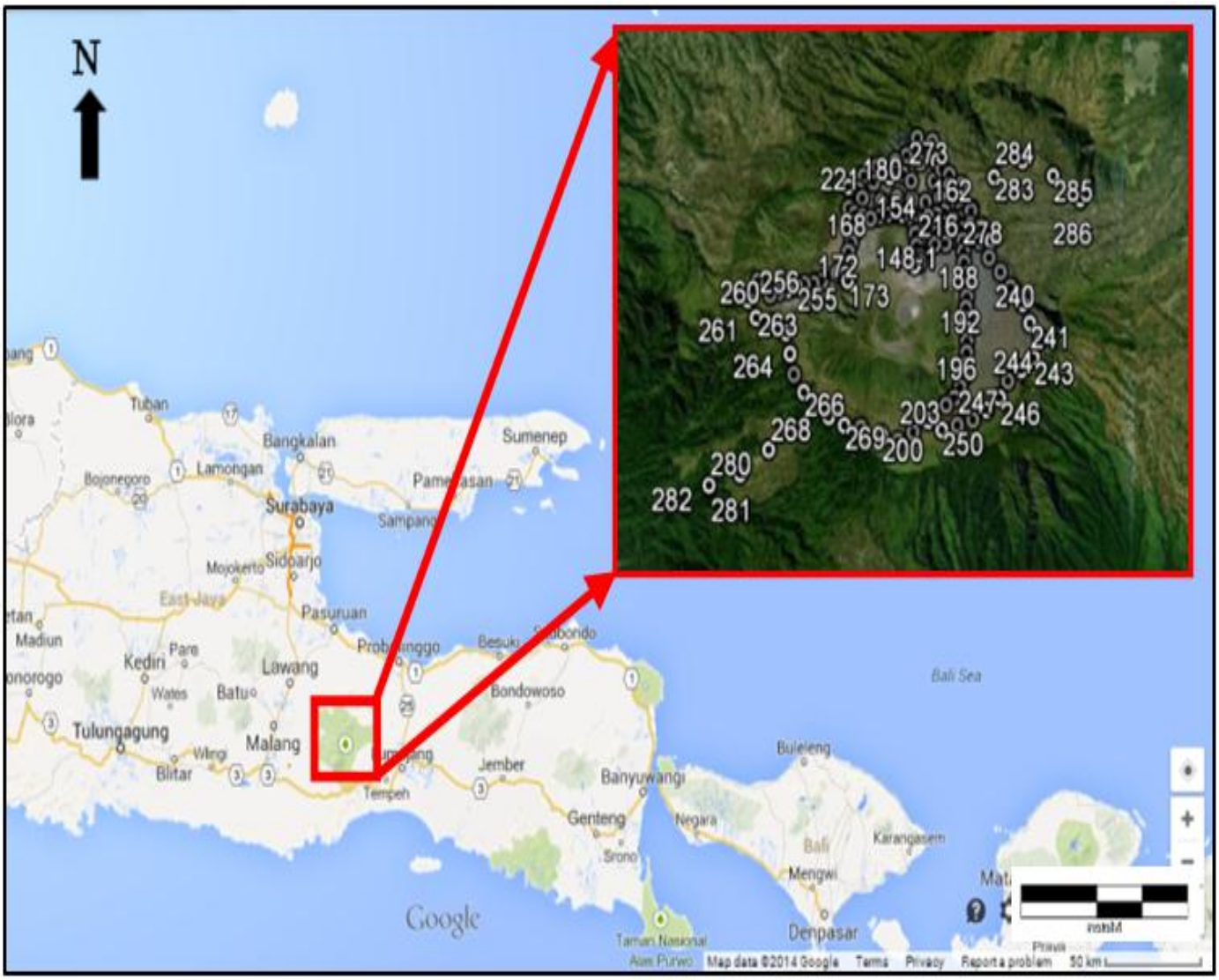


Figure 2. Map of the research location

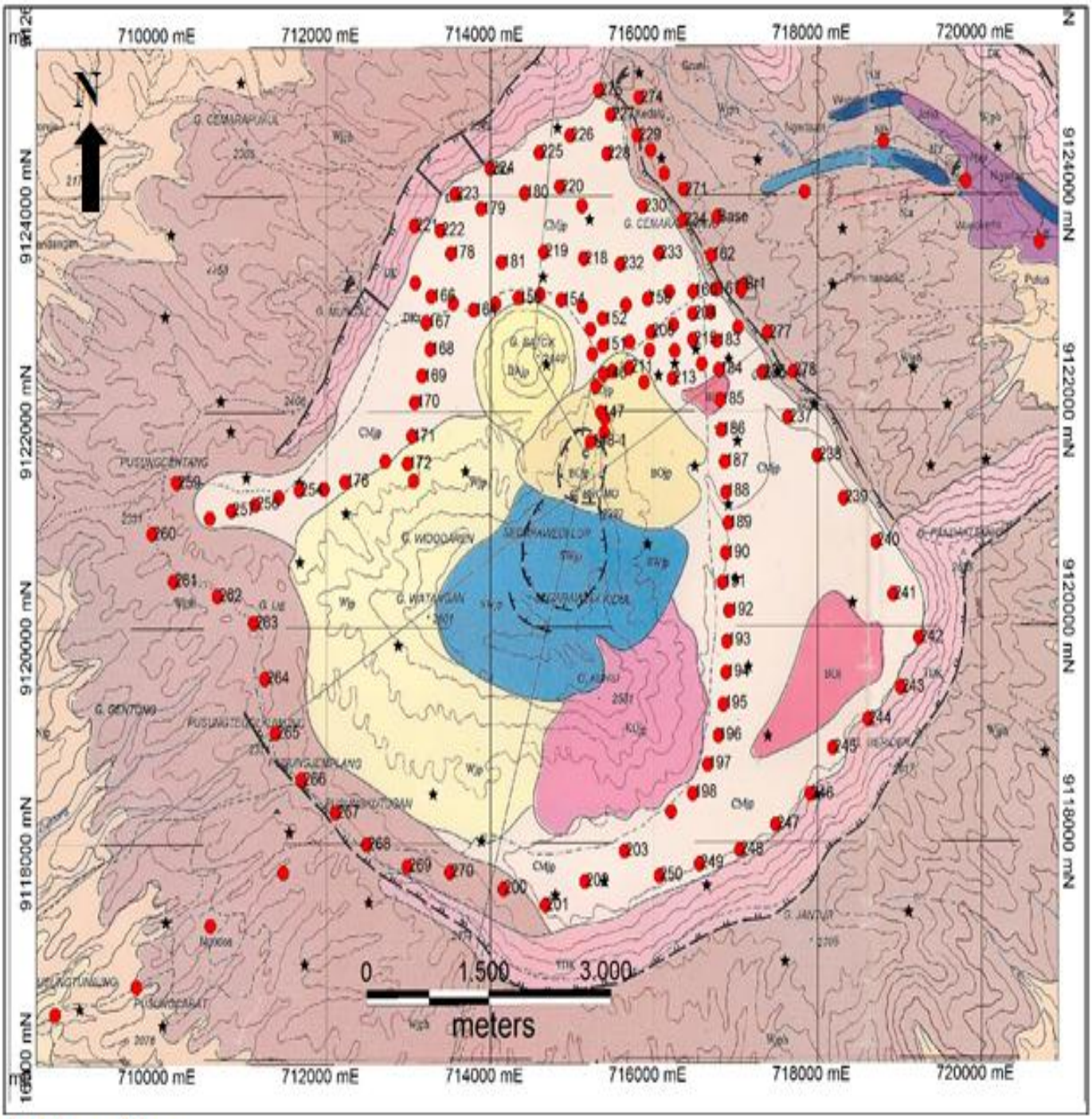
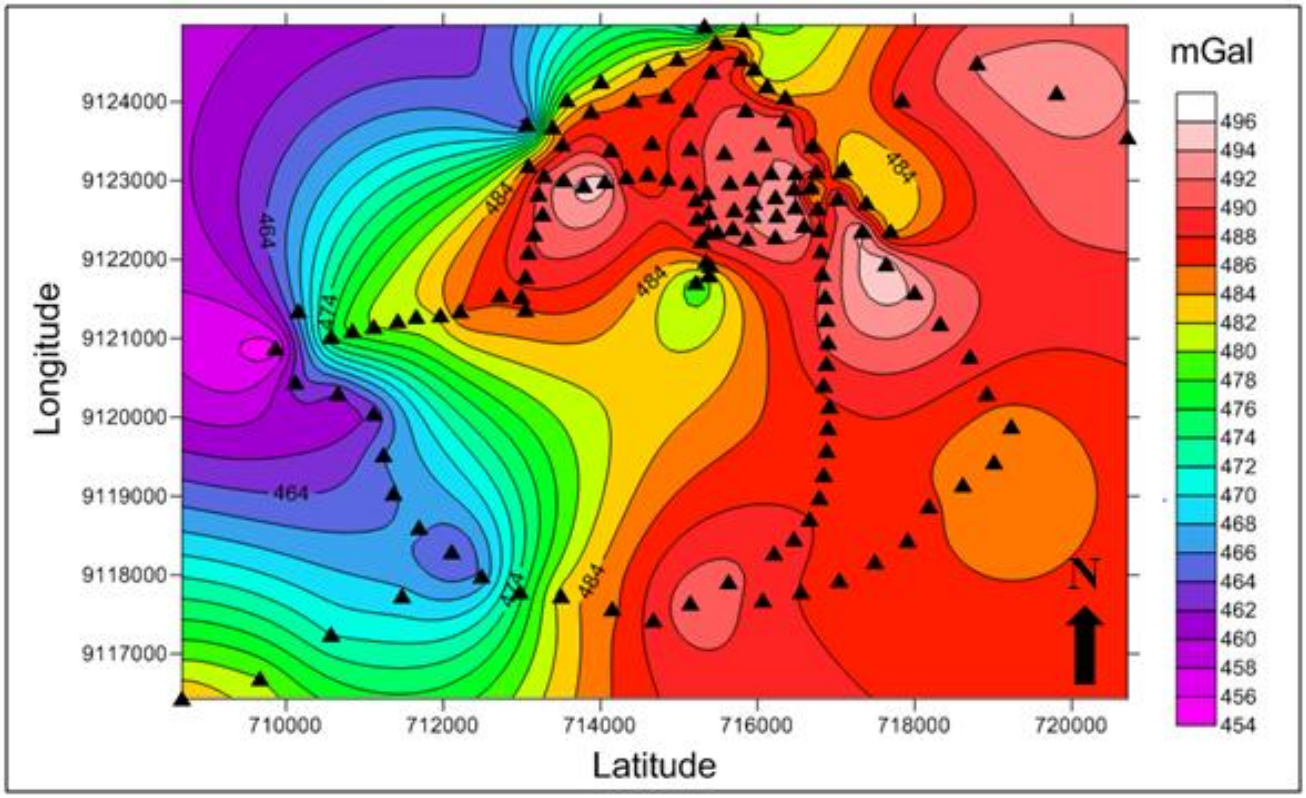
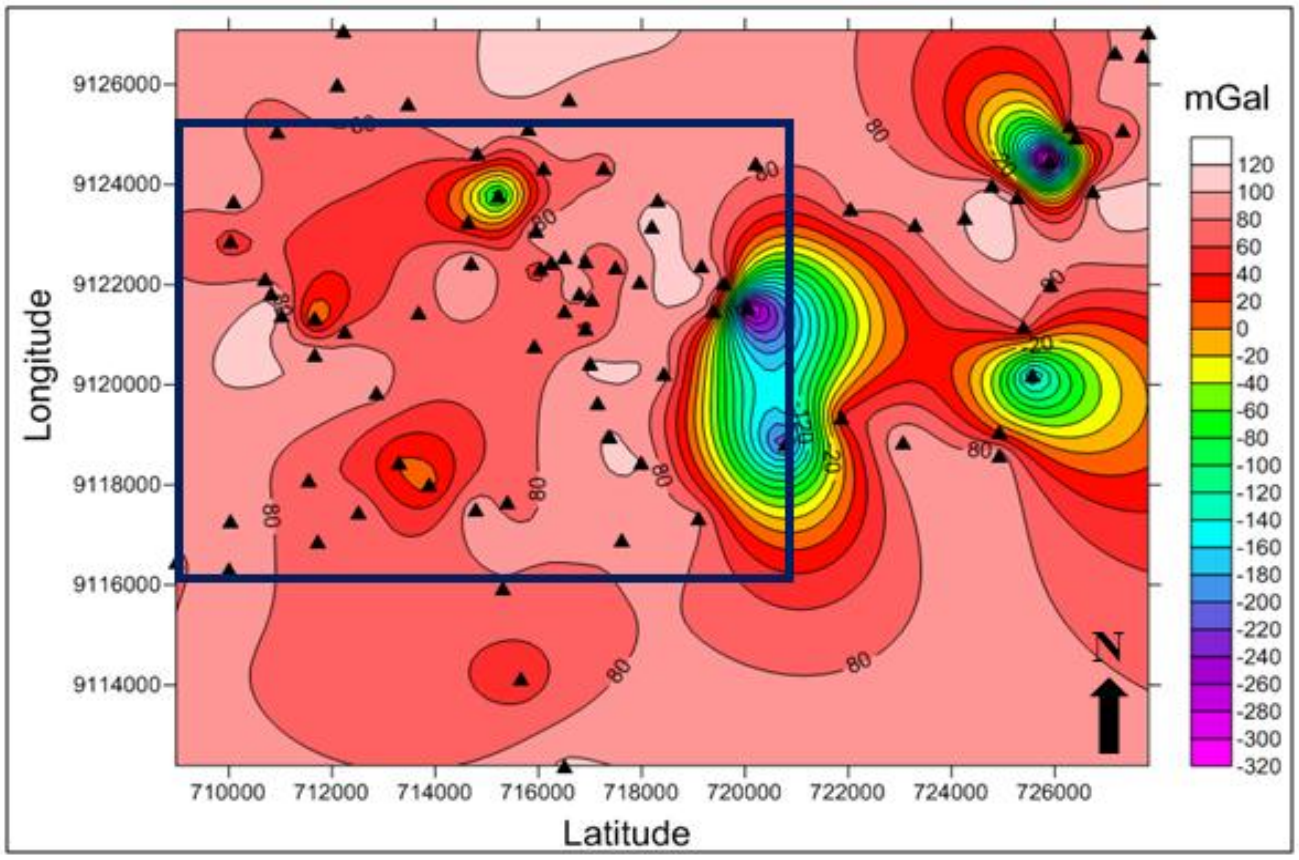


Figure 3. Observation point plotted at geological map from research on 2014.

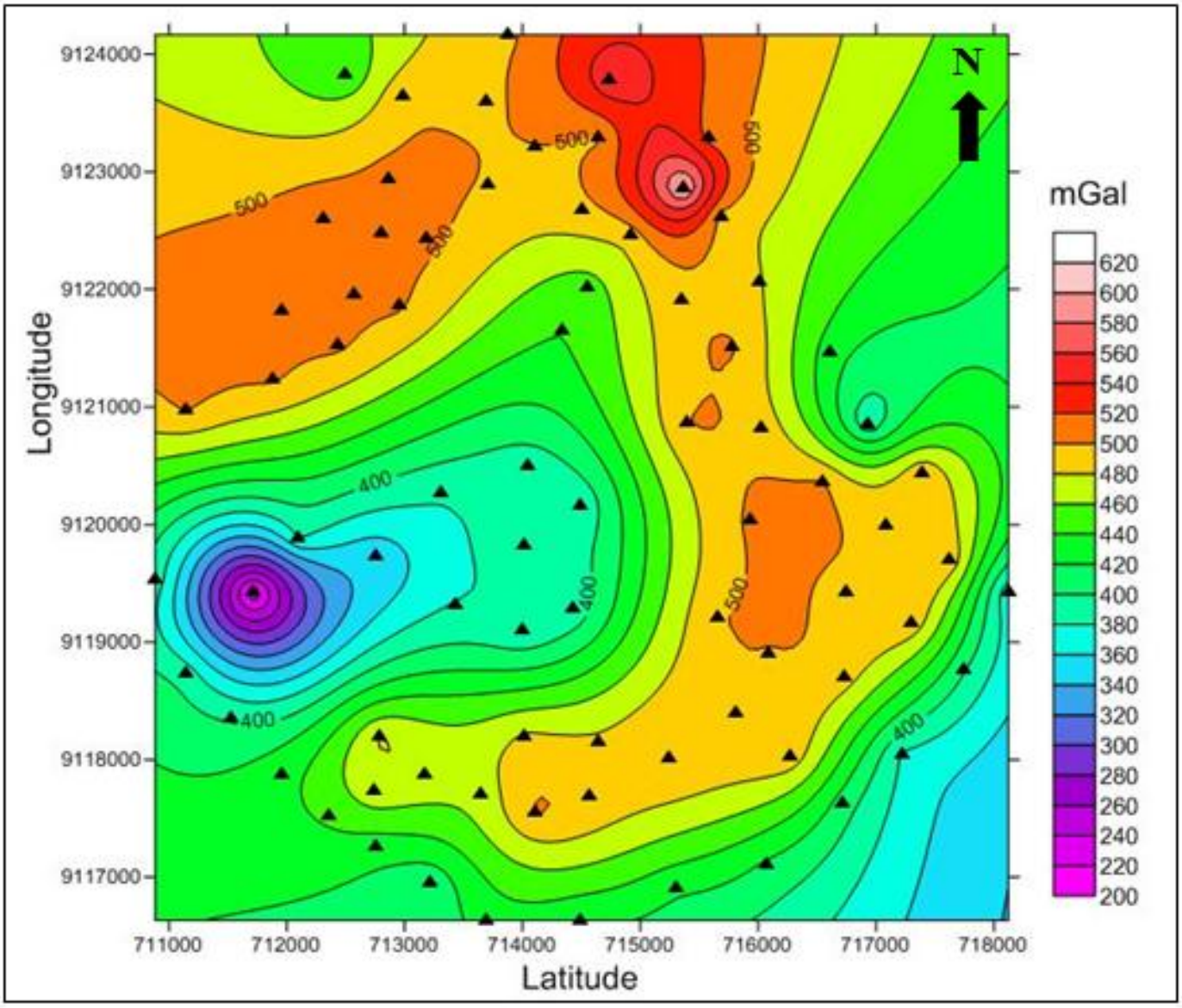
All of the data resulted 3 (three) different contours model of CBA values. Figure 5a, 5b and 5c shows the contour map of CBA from research on 2014, 2001 and 1997 respectively. The CBA data is representative to determine the dynamic of magma chamber beneath Bromo volcano.


mGal
496
494
492
490
488
486
484
482
480
478
476
474
472
470
468
466
464
462
460
458
456
454
Longitude
9124000
9123000
9122000
9121000
9120000
9119000
9118000
9117000
Latitude
710000
712000
714000
716000
718000
720000
N
464
474
484

(a)


mGal
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
Longitude
9126000
9124000
9122000
9120000
9118000
9116000
9114000
Latitude
710000
712000
714000
716000
718000
720000
722000
724000
726000
N
80
120
20

(b)



(c)

Figure 4. Contour map CBA from research conducted on 2014 (a), 2001 (b), and 1997 (c).

Qualitative interpretation by analizing geological information and CBA contour map shows that for 17 years (1997-2014), the CBA values changes. The change can be seen on the different CBA range for each contour. On 2014, the range is about 454 to 496 mGal. On 2001, the range is about -320 to 120 mGal. While for research on 1997, the range is about 200 to 620 mGal. The differences of the range value may occur due to the volcanic activity of Bromo volcano. The eruption was occurred on 2000, 2004 and 2011 which are cause many changes toward the subsurface. The wide range also affected by large distribution observed data with high vertical-horizontal topographic which each gravity observed datum affect the free-air and terrain correction largely.

CBA contour map from research on 2014 shows that the CBA values spread out with direction from North-West to South-East from higher to smaller value. The higher values are estimated as the volcanic product from Bromo activity. But this value is also corresponding to the elevation of the observation points.As the function of distance, the highest place will give the smallest gravity value. CBA contour map from research on 2001 gives different range because it has wider survey area. But by taking the same coordinates, the spread of the CBA value can be compared. This research informs that Bromo volcano complex dominated with high CBA value although the CBA range was different from the recent observation. CBA contour map from research on 1997 gives the closest range with the research on 2014 but it is wider. The highest value of CBA located in the North side of

the map. But the CBA values spread with similar pattern as recent observation. The high values are spread from North to South-East and the smaller values dominating in the West-Side to South-West and the East.

The different range in CBA contour map from each observation indicates that there are some differences in methods applied. The wider area observed the larger range of CBA value obtained. Those because there is more lithology identified. To reduce the large error, then the acquisition point must be denser by closing the space between them. In other word, the acquisition design influenced the result of CBA range.

CBA value related to the density contrast of the subsurface layers. High CBA value represents high density of the layer and vice versa. However, the change of these values identified from the temporal observation shows that there were some volcanic activity occurred during the certain period. When the eruption occurred, there must be some volcanic materials released from the crater of Bromo volcano. This will change the geological condition due to the material deposits around Bromo volcano.

CONCLUSION

Gravity survey is one of the geophysical preliminary methods, but this method can give us well enough information about subsurface condition. Gravity survey is also able to be applied to observing volcanic region. The research by using gravity methods conducted at Bromo volcano on 2014, 2001 and 1997, and give different result. The differences caused by the variation of acquisition design applied for each research.

The CBA data is representative to determine the dynamic of magma chamber beneath Bromo volcano. By analyzing the CBA data, then the subsurface condition can be estimated. The change of CBA range identified from the research probably caused by the volcanic activity along the certain period. The material released when the eruption occurred will change the geological condition around Bromo Volcano so that the density of the subsurface layers will also change.

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