Subsurface Structure Interpretation Beneath of Mt. Pandan Based on Gravity Data

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Abstract. Mt. Pandan is one of the volcano that state as dormant volcano. On the other hand, Smyth et al. (2008) defined that Mt. Pandan is an active volcano. This volcano is apart a volcanic chain in Java island which is trending east-west along the island. This volcanic chain known as present day volcanic arc. Mt. Wilis is located in the south and it relatively much bigger compare to Mt. Pandan. There were earthquakes activity experienced in the surrounding Mt. Pandan area in the past several years. This event is interesting, because Mt. Pandan is not classify as the active volcano according to the list of volcanoes in Indonesia. On the otherhand Smyth et. al. (2008) mentioned that G. Pandan as modern volcanic which is located in Kendeng Zone of East Java. Gravity measurement around Mt. Pandan area was done in order to understand subsurface structure of Mt. Pandan. Gravity interpretation results shows that there is a low density structure beneath Mt. Pandan. It could be interpreted as existing of magma body below the surface. Some indication of submagmatic activities were found as hot spring and warm ground. Therefore it could be concluded that there is a possibility of magmatic activity below the Mt. Pandan.

1. Introduction
Mt. Pandan is a volcano with 897 meters high located in the Eastern part of Java Island. It is approximately 40 km northeast of Madiun town. Mt. Pandan is not listed as one of active volcanoes in Indonesia. However, Java Island as part of Indonesia Island Arc become an active region. In the Island a recent active volcanic chain trending east-west is developed. Is is related to active margin as formed by Indian-Australian plate subducted underneath Eurasian plate in the southern part of Java island. Subduction process has occurred along the Java Trench that located at the south of Java Island begin from Middle Eocene to present day [2]. Then, in the volcanic island contains the active volcanism is developed in Java Island since Early Cenozoic. Some volcanoes of the modern Sunda Arc are distributed along the Java island. A second older arc of Eocene to Miocene volcanoes in the East Java region formed the Southern Mountain [6].

The modern Sunda Arc volcanoes in East Java are built mainly in the Kendeng Zone. Mt Wilis is one of the active volcanic centre in East Java. Mt. Pandan in the north of Mt Wilis is defined as one of Modern Volcanic Centres [7] (Figure 1).
Smyth [7] defined that Mt. Pandan with conical morphology in the north of Mt. Wilis which has a modern volcanic centre. On the other hand CVGHM [1] defined as a dormant volcano. Mt. Pandan has a relatively little conical shape with approximately 300 meters high compare to the surrounding area. Some recent earthquake events were recorded in the area of Mt. Pandan. It could indicate an activity that may be related to magmatic process. Structurally, in the north of Mt. Pandan a thrust fault is found. 

Related to the occurrence of the earthquake there are two possibilities, first it was related to thrust fault activation and the second is related to submagmatic activation. There is also possibility that due to active fault movement may triggered upwelling magma.

Gravity measurement was conducted in the region in order to find an explanation relation to earthquake occurrence in the area of Mt. Pandan. By using Bouguer Anomaly Gravity data a subsurface structure beneath Mt. Pandan will be interpreted to explain the seismic activity in the area.

2. General Geology of East Java and important structural feature to Mt. Pandan

Physiographically, Java Island is divided into some region [8]. These zonations also reflect structural and stratigraphical features or tectonostratigraphy. By tectonostratigraphy, Smyth et al. [6] divided East Java into four zones, (Figure 1), they are (1) Southern Mountain Zone. The Eocene-Miocene volcanic arc are built on Mesozoic basement. Deposits include siliciclastic, volcaniclastic, volcanic and carbonate rocks which generally dip uniformly to the south, (2) Present-day Volcanic Arc, which active from the Late Miocene (3) Kendeng Zone as the main Eocene-Miocene depocenter in East Java contains thick sequences of volcanogenic and pelagic sediments. It is now an east-west trending thrust belt, and (4) Rembang Zone, the Eocene-Pliocene sequence includes shelf-edge deposits such as shallow marine clastic sediments and extensive carbonates. This zone contains one major ENE-WSW fault-bounded high (Rembang High) and many east-west orientated folds.

Figure 1 also shows Simplified Geological Map of Mt. Pandan and surrounding area in East Java included tectonostratigraphical zonation. Thrust Fault that trending east-west is the most important feature related to Mt. Pandan. It is become the boundary between Kendeng Zone and Rembang Zone.
3. Recent Seismic activity around Mt. Pandan
Some earthquakes happened in Madiun on June 25, 2015 in 7.73° S, 111.69° E with a depth of 10 km. The events were informed by Indonesian Agency for Meteorological, Climatological and Geophysical (MCG here in after we call BMKG). The earthquakes also caused some light to medium damages for several houses.

Nugraha et al. [4] studied hypocenter relocation of this earthquake by re-picking arrival of P wave and S wave phases, and then they done focal mechanism determination. The result showed that this earthquake was located in 7.6305°, 111.7529° E with 14.81 km focus depth and a strike-slip mechanism with strike direction of 163° around Madiun and also close to Mt. Pandan.

Some small earthquakes of Magnitude less than 3 was happened in February 2016. They were observed by BMKG network as shown in Figure 2. In order to study the wave form and source mechanism of the earthquakes, the Team of Geophysical Engineering, Institut Teknologi Bandung from March to May 2016 was operated two broad band seismometer station around Mt. Pandan.

By studied the wave form, there were observed fairly clear of small earthquake that has very short time different the arrival of S and P phase wave about 0.14 second with frequency dominant of 20 Hz to 45 Hz. This event could be interpreted as related to an activity of local tectonic (fault). It is suggested that additional geophysical and geological investigation are needed in order to determine the source of mechanism of these earthquake activities in surrounding Mt. Pandan.

4. Gravity around Mt. Pandan
The Geophysical Engineering, Institute Teknologi Bandung Team conducted gravity measurement on June 2016. The purpose of the survey is to understand the subsurface structure beneath Mt. Pandan. By the data the Complete Bouguer Anamaly Map was constructed as shown on Figure 3 (1). Based on Complete Bouguer Anomaly Map of Mt. Pandan, the Residual Bouguer Anomaly Map was developed.
The gravity anomaly in the map shows interesting results as an existing of low density value beneath Mt. Pandan.

Figure 3. The result of gravity survey in Mt. Padang shown as Complete Bouguer Anomaly Map of Mt. Pandan (1) and Residual Anomaly Map of Mt. Pandan (2). Note the existing of low gravity anomaly in the area of Mt Pandan. N-S line shows location section for forward anomaly density model.

Beside that it is found the trend less gravity anomaly value. The zone of less gravity anomaly is trending from north where Mt. Pandan located toward south where Mt. Wilis located. The density section was derived by Bouguer Residual Anomaly Map of Mt. Pandan can be seen in Figure 5. As the same an indication in the map low density anomaly is found underneath of Mt. Pandan. North south trending low density structure as shown in the map is identified also in the section. Anomaly density section derived from Residual Anomaly can be seen in Figure 5. According to the north-south section, it shows low density value in the area beneath Mt. Pandan (Figure 4).

5. Analysis

As mentioned before that the result of seismic wave data of earthquakes study in Mt. Pandan area, the events are occurred as earthquakes (Figure 2). Where as the focal mechanism of the earthquakes were as strike slip faults. They were indicating as shallow earthquakes. These findings indicated that they were not related to an upwelling of magma or movement of magma body.

On the contrary gravity data shows the indication the existing of low density value that could be interpreted related to existing of magma. The low density anomaly also formed a trend toward Mt. Wilis. There are also found a phenomena related to submagmatic activity such as hot springs and warm ground in the area. All the data could conclude that there is a possibility that both phenomena are related together. It could be explained that subduction process produced the fault movement and at the same time also triggered the upwelling magma to the surface.
6. Conclusions

According to available data on density structure beneath Mt. Pandan and supporting by earthquake data as well as submagmatic activity indication on the surface, Mt. Pandan could be determined as a modern volcano. Mt. Pandan volcano indicated has a relation of magma chamber to Wilis volcano. Both volcanoes are related to the same subduction process. The mechanism of tectonic process could be explained that the earthquakes may be triggered upwelling of the magma as they were happened due to subduction process.

As our experience before, the dynamic of subsurface condition could be studied by time lapse gravity study. Some examples of application the method was developed by [3, 5]. By using time lapse gravity method more clear understanding on subsurface change beneath of Mt. Pandan could be interpreted.

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