Proceedings Indonesia International Geothermal Convention & Exhibition 2014
Jakarta Convention Center, Indonesia 4-6 June 2014

Young Dieng Volcanic Complex, Central Java, Indonesia: volcano stratigraphy and morphostructure analyses approached.

H. Permana, E.Z.Gaffar, Sudarsono, S. Indarto and A.F. Ismayanto

Research Center for Geotechnology LIPI, Bandung, Indonesia

Ph: +62 22 250 3654/Fax: +62 22 250 4593/e-mail: hpharper.permana@gmail.com

Keywords: *Dieng Volcanic Complex, craters, cones, stratovolcano, Young Dieng Volcanic Complex, regional and residual Bouguer anomaly, structural lineament, caldera collapse*

ABSTRACT

The Dieng Volcanic Complex, Banjarnegara, Central Java, Indonesia is complex volcanoes that build Dieng Plateau, 2565 m height. The relatively east-west Dieng Complex is stratovolcano type, composes more than 20 small craters and cones that grown in the two or more old stratovolcanoes or Old Dieng Complex, Prau-Rogojembangan. The younger cones or craters build the complex known as Young Dieng Volcanic complex.

Volcano stratigraphy analyses through DEM and topography map permits to identify the Old Dieng Complex, crescent moon like, open to SW that form during a caldera collapse. A successive younger volcanic cone grown follow the caldera collapse developed the Young Dieng Volcanic Complex and continuous active today.

The regional and residual Bouguer anomaly suggest the Central Java controlled by NW-SE structural lineament and less both of E-W and N-S structural lineament. The NW-SE structural lineament play main role in control Quaternary Volcanic activity such as Ungaran-Telomoyo-Merbabu-Merapi and Dieng Complex-Sundoro-Sumbing volcanic chains. The Dieng Complex present associated with low Bouguer anomaly and circular feature. The residual Bouguer anomaly could explain the Dieng Complex activity possibly controlled by dense NW-SE structural lineament and relatively thin crustal where the magma could reach to the surface.

Introduction

The Young Dieng Volcanic Complex grown in eastern part of Dieng Volcanic Complex crater that form crescent moon like opening to the southwest direction (Fig. 1). The Dieng Volcanic Complex was builded by some peak such as Mt. Juranggrawah (2468 ms msl), Mt. Prau (2559 ms msl), Mt. Kendalisodo (1699 ms msl) and Mt. Rogojembangan (1593 ms msl). The Young Dieng Volcanic Complex itself composes many craters and cones, both active (Sileri crater, Sikidang crater, or Sinila crater,) or inactive (Candradimuka crater, Bitingan crater, Siglagah crater, Pulosari crater, Prambanan-Sikunir crater and Pagerkandang crater). Some of the craters form a lake or pond that no longer activities such as Dringo pond, Merdada pond, Cebong pond, Pengilon pond and Silit pond.

Dieng volcanic complex is located in Dieng Plateau, Central Java, about 60 kms to the northeast of Banjarnegara, or 30 Km west of Wonosobo (Fig. 2). Dieng complex formed by volcanic products of Jembangan volcanic rocks (Qj), Pleistocene in age (Condon et al., 1996) composed by andesitic lavas and volcanoclastic. The volcanic rocks covered by lake sediments and alluvium (Qla) such as sand, silt, mud and clay and some cases tuffaceous. The Young Dieng Volcanic Complex (Qd), Holocene in age comprise andesite lavas, quartz andesite, and volcanoclastic material. Younger volcanic product is Sumbing volcano (Qsm) and Sundoro volcano (Qsu) (Condon et al., 1996).

Young Dieng Volcanic Complex, known as Dieng Geothermal Field, known as geothermal potential area lies in an area with low Bouguer anomaly and it was associated with circular feature (Ismayanto, 2007; un-pub). The similar condition was observed in Kamojang geothermal area, Garut (West Java) and Argopuro geothermal area, Probolinggo, East Java (Fig. 3). More specifically, Dieng geothermal field is located on the edge of a circular features with moderate Bouguer anomaly (Fig. 4).

Tectonically, the Central Java was controlled by normal subduction of the Australian Plate with southern part of Eurasian Plate or with Tertiary volcanic arc of Java forming east-west lineament of Bogor-Bandung-Majalengka cause the cessation of northwest-southeast trending fault activity (Gabon-Karangbolong lineament) since the Pliocene (Hamilton, 1979; Hall, 1996; Sribudiyani et al., 2003). The subduction has formed the Quaternary volcanic arc that covers most of the Tertiary volcanic products (Soeria Atmadja et al., 2005; van Bemmelen, 1949).

Objective of this paper is to formulate the relative volcanic stratigraphy (morphostratigraphy) of Young Dieng Volcanic complex that compiled by many volcanic body within craters or cones and ponds. While morphostructure and tectonic analysis intended to determine the geological structures that control the geothermal prospects in the Dieng area.

Methods

A morphostructure and morphostratygraphy analyses use DEM data (2006), scale 1:250.000 and topographic map scale 1:25.000; sheet 1408-432 (Kalibening); sheet 1408-441 (Batur) and sheet 1408-442 (Kejajar) (Bakosurtanal /BIG, 2001). Relative volcanic stratigraphy or volcanostratigraphy assembled by morphostratigraphy analyzes a way of comparing the relative age of volcanic products based on cross cut law and texture of topography. In this case, the relative young volcanic product cover or cut an older volcanic products or older rock layers or by looking at the relative distribution where younger rocks spread hindered or limited by older products. In addition it is also used a topography texture comparison where older products shows coarser texture due to more intensive erosion processes.

Geological structures pattern or morphostructure obtained through analyzing a structural lineament that interpreted manually ridge, valleys or river lineaments. These lineaments represent geological structures such as fault or fracture. Quantification lineament trend used rose diagrams with Simple Riedel shear analysis to formulate tectonic pattern that has occurred and controlled it.

Volcano stratigraphy Analyses

The large (Old) Dieng volcanic complex, extending nearly east-west trending formed around the Pliocene (3.6 Ma / million years ago). Around Pleistocene (0.5 Ma; Boedihardi et al., 1991), the volcanic complex experienced caldera collapse formed a crescent-shaped like opened toward the southwest (Fig. 1). Some higher place observe around Dieng caldera periphery like as Mt. Prau, Mt. Juranggrawah, Mt. Kendalisodo, Mt. Perbata, Mt. Rogojembangan and Mt. Condong. On the west side, present Mt. Beser, Mt. Kunting, Mt. Bromo, Mt. Kendeng, and Mt. Ragatembang. The caldera collapse followed by formation of volcanic bodies known as Young Dieng Volcanic Complex that builded by multi cone volcanic complex such as Mt. Bisma, Mt. Pakuwaja, Mt. Sikidang, Mt. Butak, Mt. Petarangan, Mt. Seroja, Mt. Sikunir and Mt. Pakuwaja. The volcanic activity in this area parallel to the southeast, with Mt. Sumbing and Mt. Sundoro (Fig. 4). Based on morphostratigraphy analysis, the Young Dieng Volcanic Complex could be separated into 11 different units that develops over Old Dieng complex as shown in Fig. 5. Relative volcanic stratigraphy of Young Dieng Volcanic Complex is shown in Table 1. The results suggest Mount Butak-Petarangan-Mountains Bisma interpreted as the oldest volcanic body in the Young Dieng Volcanic complex but refers to age obtained from Boedihardi (1991) shows a relatively younger age about 0.06 Ma.

Table 1. Volcanic stratigraphy of Young Dieng Volcanic Complex

	Morphostratigraphy	**Boedihardi et al. (1991)**
11	Sikidang Cone	
10	Merdada Cone	0,37 Ma
9	Pengilon-Warna Cone	
8	Mount Seroja	
7	Mount Sikunir-Telaga Cebong	
6	Pakuwaja-Prambanan Hills	
5	Candradimuka-Sinila-Jalatunda Cone	
4	Mount Jimat	
3	Kepakisan Hill	
2	Mount Pangamun-ngamun-Gajahmungkur-Sipandu	0,46
1	Mount Butak-Petarangan-Bisma	0.06 Ma
0	Old Dieng Volcanic Complex (Mt. Prau-Juranggrawah-Kendalisodo-Perbata-Rogojembangan-Condong)	3.6 Ma
T	Tertiary Rocks Unit	

Morphostructures Analyses

Geological structures describes in this study are structures lineaments represent fault or fracture developing in the Dieng Volcanic Complex (red line in Fig. 6). In general, structure lineament trend observed in the area is NW-SE, N-S and E-W trending. The northwest-southeast structural lineament trending are dominant in the study area especially in the northwestern area of Dieng Complex. This lineament expect to control the activity of the Mt. Dieng volcano-Mt. Sundoro and Mt. Sumbing and it was cut by N-S and E-W lineaments trending. The activities of Dieng Volcanic Complex was controlled and bordered by E-W trending lineaments that intersect with NW-SE lineaments trending structures.

The rose diagram (Fig. 7) of structures lineament shows the maxima lineament trend is N270^{o}E/N90^{o}E (WNW - ESE) with median azimuth is N297^{o}E. This result suggest that the old Sumatran structural pattern (N300^{o}E) still dominates in Dieng and surrounding area.

Bouguer Anomaly Analyses

The central of Java is characterized by high Bouguer anomaly (representing ridge) in the south (South Serayu Mountains) and lower Bouguer anomaly represent a basin of the northern side (Bogor basin) and North Serayu Mountains. Some anomalies such Tegal and Pekalongan highs separated a basins into 3 parts.

Structural lineament analysis showed that the Central Java controlled by the NW-SE structural lineaments, slightly E-W and rarely N-S and NE-SW trending lineaments (Fig. 8). The NW-SE structural lineaments play an important role in controlling the Quaternary volcanic activity as indicated by straightness of volcanic lineament such as Unggaran – Telomoyo; Merbabu - Merapi and Young Dieng Complex – Sundoro –Sumbing. A difference trend of activity is toward NW for Young Dieng Complex – Sundoro –Sumbing and opposing direction to SE for Merbabu – Merapi.

Residual Bouguer anomaly analysis represents a shallow geological structure provides similar lineament pattern and trend such as valley or ridge within shorter structure lineament (Fig. 9). Through the residual Bouguer anomaly analysis could be explained that of Dieng Complex activity may be influenced by dense NW-SE structure lineament on the edge of a basin that allowing magma liquid reach to the surface.

The structures lineament analysis of regional Bouguer anomaly of Central part of Java, showing maxima N315^{o}E/N135^{o}E (NW-SE) with median azimuth N311^{o}E (Fig. 10a). While lineament of the residual Bouguer anomaly, shows maxima similar direction N315^{o}E/N135^{o}E (NW-SE) with median azimuth about N320^{o}E but a slighty change in the median azimuth (Fig. 10b). These results suggest a deep seated structure pattern in Central Java has identical pattern with thin skinned structure. However, the thin skinned structure shows intensive N-S structure direction. Based on a common pattern azimuth, it can be indicated that the subsurface geological structures in central Java or Dieng in particular as well as the surrounding area is strongly influenced by the Old Sumatra pattern, N300^{o}E-N330^{o}E.

Refers to the result describe above, the initial postulation that the central part of Java strongly influenced by frontal subduction did not supported. The existing lineament structural pattern suggest more close to lineament pattern controlled by oblique subduction of Sumatra compared with the of Riedel Shear Model structure pattern as shown in

Fig.11. Based on Riedel Shear Model, N-S structural lineament patterns that develop in thin skinned structure classified as tension structures type or openings. It could be used as a basic assumption that these structures as a weak zone whereas a magma fluid raised to the surface in a geothermal system controlled by NS structural lineament.

Results and Discussion

The results of geological structure analysis obtain both subsurface structure (regional and residual Bouguer anomalies) and surface structure analysis based on morphostructural analysis. The surface structure pattern indicate E-W direction structural lineament in general, possibly represent folds, fault or normal faults (Fig. 12a). It could be assumed these structures as final product affected frontal subduction of Australian Plate. The tension structures model direction based on Riedel Shear Model (Fig. 12b) shows NNW - SSE direction in general for subsurface structure and N-S lineament direction commonly present on the surface (Fig. 12c). It is expected that the NNW - SSE structure pattern is a favorable zone for the geothermal system where the geothermal fluid can be trapped in the secondary permeability of the rock as well as interact with heat convection from a heat source. The N-S structure direction then bring the hot fluid to the surface. While, the E-W structure lineament is expected to be a seal for Dieng geothermal system. Fig. 12 shows structure analysis of Dieng and surrounding area.

Acknowledgment

This research was funded by national budget through the DIPA of LIPI. Special thanks to PT. Geodipa Energy who facilitates during fieldwork.

References:

Boedihardi, M., Suranto, and Sudarman, S. 1991. Evaluation of the Dieng Geothermal Field: Review of the Development Strategy. Proceedings, 20th Indonesian Petroleum Association Annual Convention, (1991), 347-361.

Bakosurtana/BIG, 2001. Topographic map, scale 1:25.000; sheet 1408-432 (Kalibening); sheet 1408-441 (Batur) and sheet 1408-442 (Kejajar); ed-1.

Condon, W.H., Pardiyanto, L., Ketner, K.B., Amin, T.C., Gafoer, S., and Samodra, H. 1996. Geological map of the Banjarnegara and Pekalongan Sheet, Jawa. Sec.Ed., GRDC, ESDM, Bandung

Hall, R. 1996. Reconstructing Cenozoic SE Asia. From Hall, R. & Blundell, D. (eds.) 1996. Tectonic Evolution of Southeast Asia, Geological Society of London Special Publication No. 106, pp. 153-184.

Hamilton, W., 1979. Tectonics of the Indonesian region, U.S.G.S. Professional Paper, 1078, 345 p.

A. F. Ismayanto, T.A.F Sumantri, I. Setiawan, Sudarsono, S. Indarto; Interpretasi Struktur Regional Jawa dari Peta Relief Shaded Gravity Regional Kaitannya dengan Lokasi Mineralisasi di Pulau Jawa, Oral presentation of Seminar Geoteknologi, Pusat Penelitian Geoteknologi LIPI, 2007

Setijadji, L.D., 2010, Segmented Volcanic Arc and its Association with Geothermal Fields in Java Island, Indonesia, Proceedings World Geothermal Congress.

Soeria-Atmadja, R. and D. Noeradi. 2005. Distribution of Early Tertiary volcanic rocks in south Sumatra and west Java. The Island Arc (2005) 14, 679–686

Sribudiyani, Prasetya, I., Muchsin, N., Sapiie, B., Ryacudu, R., Asikin, S., Kunto, T, Harsolumakso, A.H., Astono, P. and Yulianto, I. 2003. The Collision of the East Java Microplate and Its Implication for Hydrocarbon Occurences in the East Java Basin. Procc. IPA. Twenty-Ninth Annual Convention & Exhibition, October 2003

van Bemmelen, R. W., 1949, The Geology of Indonesia vol. IA : General Geology of Indonesia and Adjacent Archipelagoes, Martinus Nijhoff, Government Printing Office The Hague--

List of Figure:

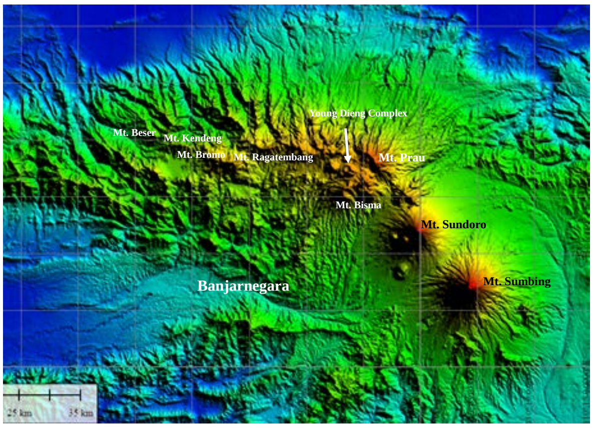

Figure 1. The crescent moon like opening to the southwest direction of Dieng Volcanic Complex.

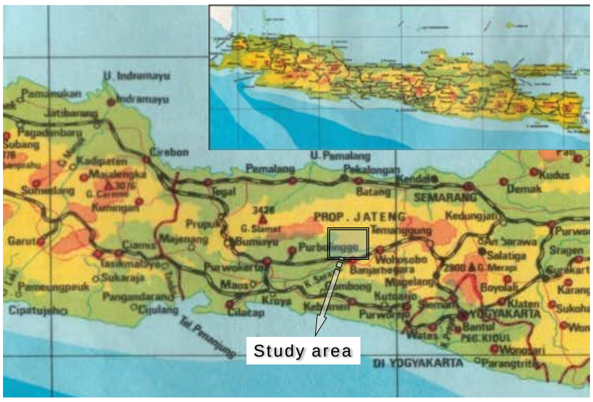

Figure 2. Map of study area.

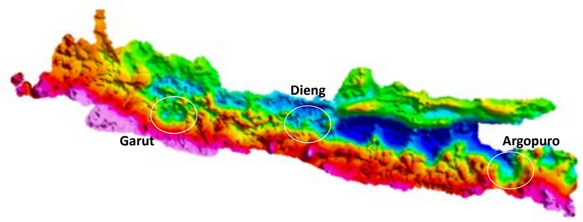

Figure 3. Dieng Complex present associated with circular feature and low Bouguer anomaly

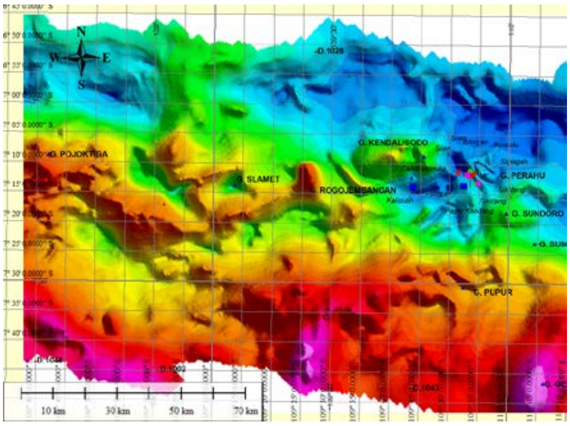

Figure 4. The Dieng geothermal field located at the edge of circular feature with medium bouguer anomaly.

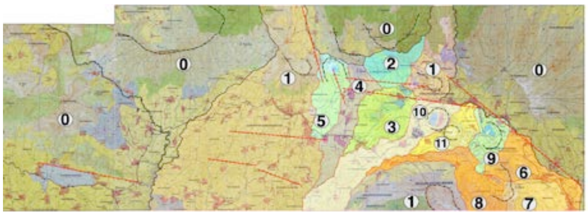

Figure 5. Result on morphostratigrapy analyses of Young Dieng Volcanic Complex. The numbers of explanation shows in Table 1.

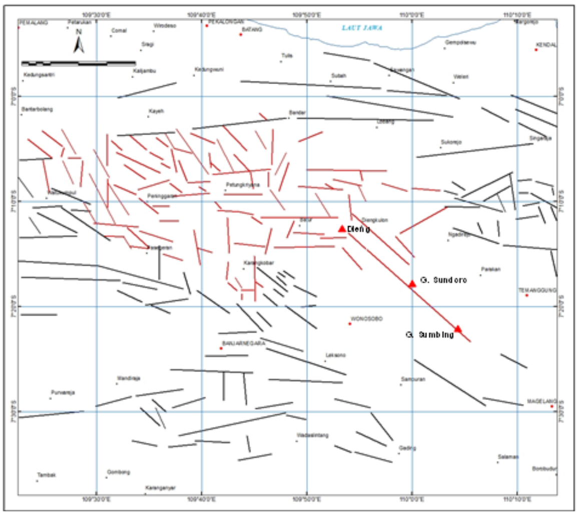

Figure 6. Geological structure pattern that developed in the study area (red line).

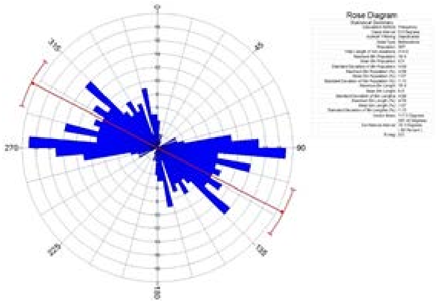

Figure 7. General trend of lineament obtain from morphostructure analyses.

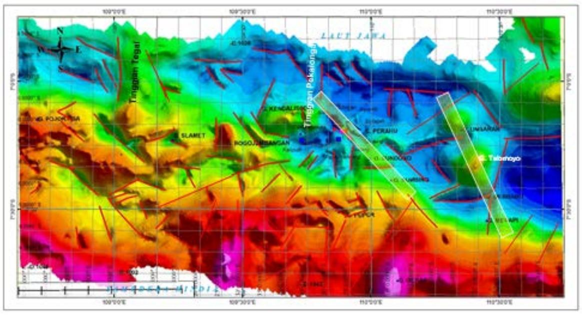

Figure 8. General structural lineament trend that developed in study area obtained from regional bouguer anomaly of Central Java.

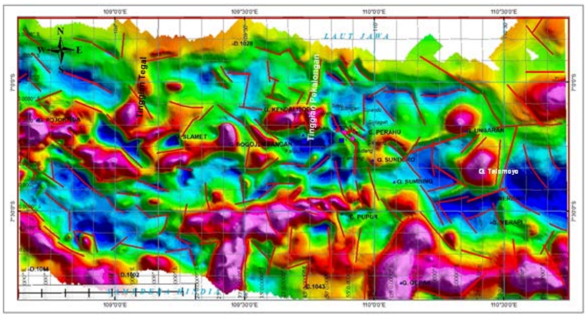

Figure 9. Shallow structural lineament that observed in study area based on residual bouguer anomaly analyses.

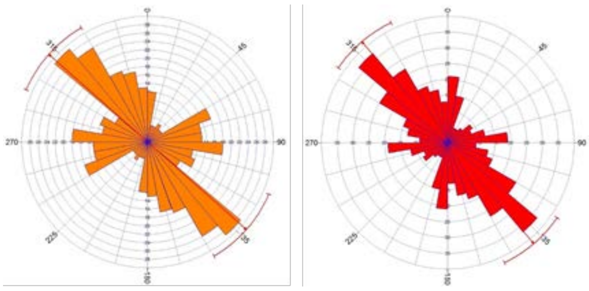

Figure 10a (left) shows maxima of lineament geological structure pattern based on the regional bouger anomaly analysis; Figure 10b (right) illustration of the geological structure lineament pattern based on residual bouger anomalies analysis.

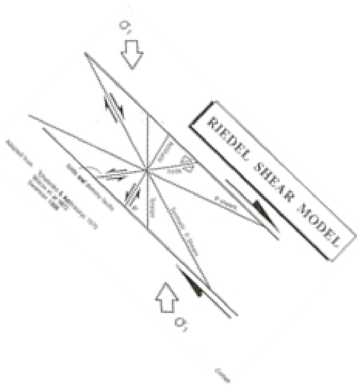

Figure 11. Riedel models used to describe the evolving pattern of the N-S trending structural lineament.

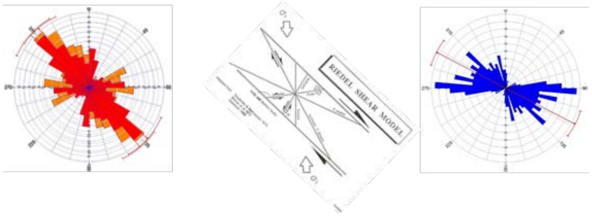

Figure 12. Comprehensive analysis of structural lineament pattern of Dieng. a) The gravity anomaly pattern of subsurface structure; b) middle: Riedel models and c) right, the surface lineament patterns.