Tectonostratigraphy-volcanic of Gajah-Ijo-Menoreh Tertiary volcanic formations in Kulon Progo mountain area, Yogyakarta-Indonesia

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Abstract. Kulon Progo Mountains areas are formed by three Tertiary volcanic bodies that formed during Oligocene-Miocene times. Each volcano shows different tectonic control and stratigraphic result. This research conducted through interpretations of volcanic bodies, construction of stratigraphic columns, construction of geological cross-sections, supported by lithological-structural data from the field and some previous researchs. There are four volcanism periods in Kulon Progo Mountains, namely Late Eocene Volcanism, Early Oligocene Volcanism/Gajah, Late Oligocene Volcanism/Ijo and Late Miocene Volcanism/Menoreh. Gajah shape shows there are collaps volcano at the southern part and it was happened before Ijo emerge. Volcanism of the Eocene-Gajah-Ijo period is related to the Palaeogene extensional rifting period. Ijo volcano covers the southern part of Gajah Volcano. Menoreh volcano emerges at Late Miocene and covers Gajah volcano and Jonggrangan Formation. Menoreh Volcanism is related to the period of Neogene Compressional Wrench that produces a sinistral fault with left-stepping left lateral fault pattern.

Keywords: volcano, tectonic, fault, volcanism, stratigraphic.

1. Introduction

Kulon Progo is a mountainous area in southern Central Java (Figure 1) that is formed by a series of Tertiary volcanoes [1,2,3,4]. Three known Tertiary volcanoes are Gajah, Ijo and Menoreh volcano. These mountains are part of the Tertiary volcanic arc in southern Java. The three volcanoes aged are Oligocene-Miocene above on Eocene bedrock. At these times there are activities of superimposed volcanism in Kulon Progo Mountains.

Based on the study of other researchers, mentioned the existence of older volcanic rocks in the southern part of Java Island including Kulon Progo region. Publication by [5] describes the arc of Eocene magmatism /volcanism in southern Java. The presence of Eocene volcanic rocks is determined by the results of [6]. These rocks are located in the central part to the north of the body of Mount Ijo.

Reference [7] mentions the existence of volcanic components in quartz sandstone of Nanggulan Formation, in addition to metamorphic and plutonic materials. Basal rock fragments are found in the quartz sandstone of Nanggulan Formation, which are Eocene-aged [8] with a large percentage. The

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research resulted by [9] also mentions the existence of igneous rock fragments, on the quartz sandstone of Nanggulan Formation.

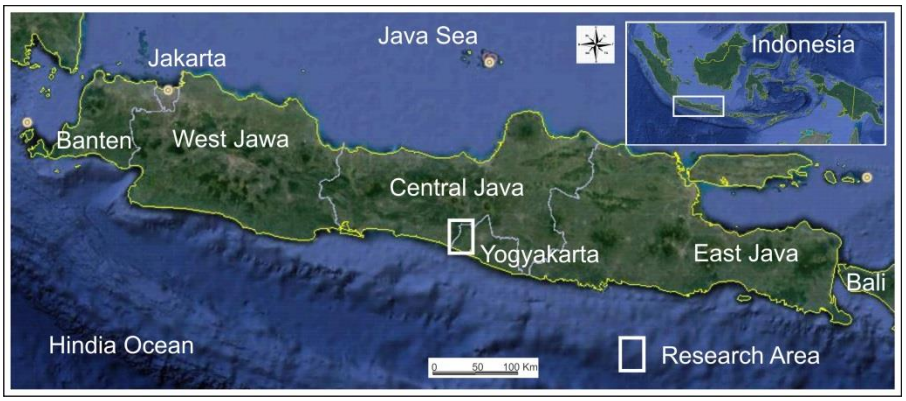


Figure 1. Location of research area in Java island constellation.

2. Regional Stratigraphy

The stratigraphy of Kulon Progo is included in the Old Volcanic Group, which is composed by Nanggulan Formation Rocks and volcanic rocks of Kebo-Butak Formation. The Nanggulan and Kebo-Butak formations are intruded by shallow intrusions of microdiorite, andesite and dacite [10, 11], which generally have alteration [4, 12, 13]. Some publications [4, 10, 11] state that these volcano groups are covered unconformitycally, by shallow marine deposits of the Jonggrangan and Sentolo limestone Formations.

2.1. Metamorphic Rock

So far, it is mentioned that the base rock of Kulon Progo mountains is Nanggulan Formation [1, 4, 10, 11, 14], but [15] mentions the presence of metamorphic rocks on the eastern side of Menoreh Mountain. This rock is in the form of schist and phyllite found on volcanic andesite breccia and xenolith in andesite lava. Thus, it can be ascertained that the base-rock of Kulon Progo mountains are metamorphic rocks. This is similar to the southern mountains area on the east side and the Serayu Mountains on the west side, which is above the metamorphic rocks.

2.2. Nanggulan Formation

Nanggulan Formation has an area with hilly morphology in Nanggulan area (east of Kulon Progo Mountain). Locally this formation is also found in the Sermo-Kokap area in the form of lenses or xenolite blocks in igneous andesite rocks. Research by [1] explains that this formation is the oldest rock in Kulon Progo Mountains. The deposition environment is lithoral in the transgression phase. Its constituent lithology consists of sandstones, lignite [16, 17, 18], marl, claystone, limestones, sandstones, tuffs rich in foraminifera and molluscs, estimated to be 350 m thick. Based on the study of planktonic foraminifera, the Nanggulan Formation has an age range between the Middle Eocene to the Oligocene [1, 2, 16, 19, 20, 21]. This formation is formed in a shallow marine environment to transition [8].

2.3. Old Andesite Formation/Kebo-Butak Formation

The Old Andesite Formation [1] or Kebo-Butak Formation [10, 11] is deposited unconformity over Nanggulan Formation. Its lithologies is volcanic breccia with andesite fragments [14], andesite [4, 10, 11, 14, 22], dacite intrusion [4, 10, 11], basal intrusion [14], lapilli tuff [14], lapilli breccia, andesite lava [14], agglomerates, and volcanic sandstones exposed in many locations in the area Kulon Progo. This formation is exposed in both the central, northern, and southwestern regions of the Kulon Progo Mountains that form a moderate to steep ridge of morphology. The thickness of this formation

is approximately 600 meters. Age of the Old Andesite Formation is Upper Oligocene [5, 23, 24, 25, 26], to Miocene [26, 27].

2.4. Jonggrangan Formation

Above the Old Andesite Formation there is a Jonggrangan Formation dposited unconformable on volcanic heights [28, 29]. This formation in general, the lower part consists of conglomerates, tuffaceous marl, and calcareous sandstone with molluscs content, as well as claystone with lignite. At the top, the composition of this formation is layered limestone and reefal limestone [30]. The thickness of the constituent rock formation is 200-500 meters [1] and has an Early-Midle Miocene age. The bottom of this formation is inter-fingering with the bottom of the Sentolo Formation. The morphology formed from this rock formation are mountains and conical hills and scattered in the middle of the Kulon Progo Mountains [1].

2.5. Sentolo Formation

Above the Old Andesite Formation, in addition to the Jonggrangan Formation, is also deposited the Sentolo Formation. The relationship between the Sentolo Formation and Jonggrangan Formation is inter-fingered. Sentolo Formation consists of limestone and marl. The bottom consists of a conglomerate piled by tuffaceous marl with tuff. These rocks upward gradually change, becoming a nice layered limestone rich in foraminifera. The thickness of this formation is about 950 meters. According to [31], the age of this formation is the Early Miocene to Pliocene.

3. Research Method

This study combines the results of field research with several other previous research results by several authors, interpretation of volcanic bodies distribution, construction of stratigraphic column, construction of geological sections, and lithological-structural data obtained during field observations. Through the delineation of volcanic bodies distribution can be known sequence of volcanic formations and relationships with the geological structure which is formed.

4. Volcanism

4.1. Late Eocene Volcanism

Results of the dating conducted by Ngkoimani et al., 2006, in [6] to the Eocene igneous rocks resulted in age 47.42 + 3.19 or Midle Eocene. This rock is in the body of Mount Ijo volcano. The types of rocks in these area are lava andesite and basal. This Eocene volcanic rock is within the circle of Mount Ijo's body, as the bedrock of Mount Ijo's body. This rock is above the Naggulan Formation in the southeast.

The basal rock fragments encountered in the quartz sandstone of the Nanggulan Formation are most likely derived from the Eocene volcano in this area. At the bottom of the Nanggulan Formation present the tuffaceous material and andesite / basaltic rock fragments in quartz sandstone. Also found in the field, mixing of claystone (Nanggulan Formation) and andesitic rock fragments, at the top of the Nanggulan Formation (as sedimentary melange). These igneous andesitic rocks were originally lava, which is flow above the black clays of Nanggulan Formation, which was still not compacted. Due to a disturbance, these igneous rocks then enter into the clay material that has not been consolidated. (Figure 7. Part a).

4.2. Early Oligocene Volcanism

Gajah Volcano is located in the middle of the Kulon Progo Mountains and some researchers claim to be the oldest volcano in this area [1, 3]. This volcanic eruption is centered in the west and spreads far to the east, north and slightly westward. The far facies of the west and south sides of this mountain have been broken and missing covered by younger volcanic materials or sediments. The rocks present in the proximal facies close to the center are basaltic andesitic intrusive rocks, andesite lava (Fig. 7

Part b) and andesitic breccia. While the rocks far from the center are laharic andesite breccia, conglomerate, tuffaceous sandstone, siltstone and lava still can be found.

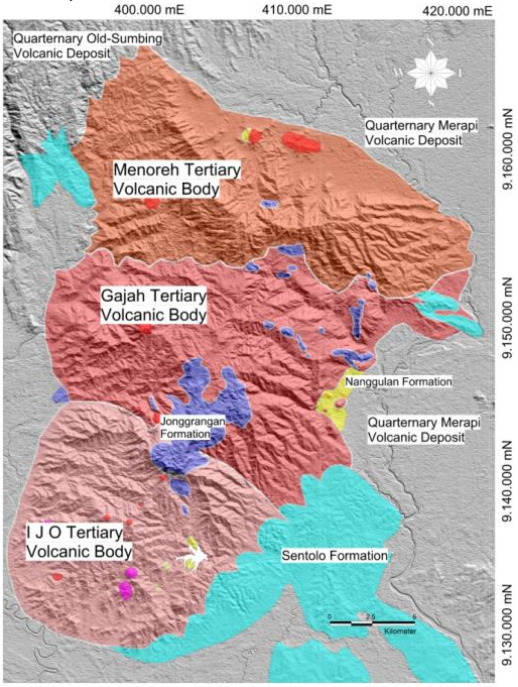


Figure 2. Distribution of the three volcanics in Kulon Progo.

The southern side of Gajah Volcano is cut by the fault or collapsed at the end of its active period. These normal faults have trend at northwest-southeast (NW-SE) directions. These faults then become the boundary with Mount Ijo which is present later in the south. So the relatively complete Gajah Volcanic stratigraphic record is from the volcanic centre to the eastern side, until it is limited by the Naggulan Formation (Figure 2).

4.3. Late Oligocene Volcanism

The intact circular pattern of the Ijo volcano in the south of Gajah mountain, indicates that this mountain is still younger than Mount Gajah (Figure 2). This intact circular pattern covers the body of Gajah volcano in the middle of Kulon Progo Mountains. Mount Ijo more shows a circular pattern (circular features) which is still intact, while Mount Gajah no longer shows this structure. This cross-cutting relationship shows that Mount Gajah comes first and then Mount Ijo comes to close some parts of Mount Gajah (Figure 3).

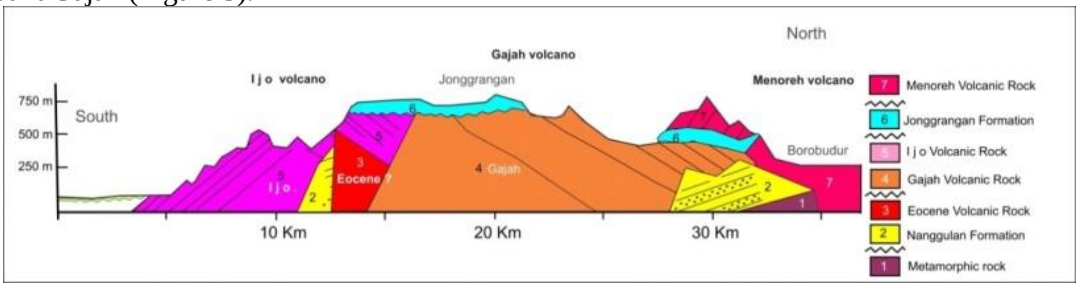


Figure 3. North-South cross section (N-S) of Kulon Progo Mountains.

4.4. Late Miocene Volcanism

In the Late Miosen age, volcanic activity appears on the northern side of Kulon Progo Mountains. This volcano is Mount Menoreh at the northern end of Kulon Progo Mountains which is now encountered with a semi-circular pattern (Figure 2). This volcano has collapsed and now only half of it. The rest of

the volcano's body opens to the north. This volcano foot is above the body of Mount Gajah and Jonggrangan Formation.

Menoreh volcano is the youngest volcano in the Kulon Progo Mountain range. Menoreh volcano that was formed at the age of Late Miocene, separated from volcanism of Mount Gajah and Ijo by a long time span, covering the post-Ijo erosional period, the settling period of Jonggrangan and the post-Jonggrangan erosional period. [27] conducted an absolute age analysis by K-Ar method of a rock taken from a volcanic centre near Borobudur Temple (north side of Kulon Progo Mountains). Hornblende age analysis showed age of 12.4 ± 0.7 Million years ago or Late Miocene.

According to regional geological maps, Menoreh volcanic rocks are above the Nanggulan Formation. However, based on this study the Menoreh volcano is also above the medial-distal facies, on the north side of Mount Gajah and also above the Jonggrangan Formation (Figure 3 and 4). Metamorphic rocks of schist and phyllite are also passed by the magma of Menoreh Mountain. These are shown by the encounter of schist and phyllite in the area of Sileng River, south of Borobudur Temple (east side of Menoreh Mountain) and in Menoreh Village, Salaman-Magelang Sub-district (west side of Menoreh Mountain).

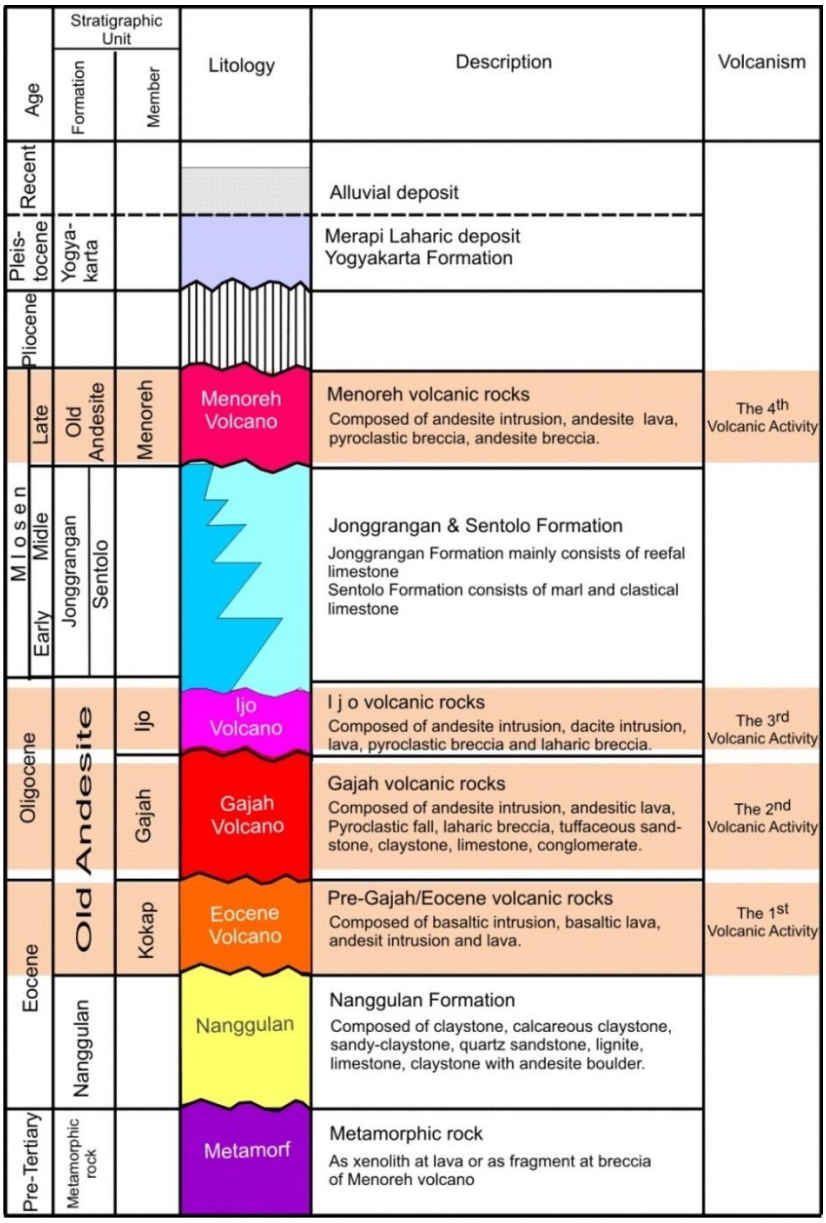


Figure 4. Stratigraphic column of Kulon Progo Mountainous Area.

5. Tectonism

[4] suggests that the Kulonprogo region and its surroundings belong to the South Serayu Mountain Range, which is regionally a transition, which lies between the northeast-southwest (NE-SW) Mesozoic palaeo-subduction and the west-east (W-E) Early Tertiary-Quarter subduction trend. Thus it can be expected that both patterns of the structure will be the dominant feature in the Kulonprogo area. In addition, the Kulonprogo area is also suspected to be formed by deformation of at least 2 times the tectonic phase periods, the first occurring in the Late Oligocene-Early Miocene and second on the Late Miocene-Quarter which produces a magmatic arc.

At Late Oligocene-Early Miocene tectonic activity reaches its peak, which is marked by the uplift of Kebo Butak Formation. The existence of north-south trending (NS) to northeast-southwest (NE-SW) compression stresses led to the formation of strike slip fault, folding and formation of joints in Kebo Butak Formation which was then filled by dyke andesite, dacite and quartz veins [5]. As the intensity of compression energy decreases, some of the normal faults occur in the same direction as the

tensile and extension build-up, followed by acid-intermediate intrusions and hydrothermal alteration followed by mineralization [4].

At the Late Miocene - Quarter, tectonic activity occurs again, resulting in fault and lifting in the Kebo-Butak Formation and the rocks above it. Locally there is a reorientation of the originally north-south (N-S), north-south-east (NE-SW) stress. The formation of fault, brecciation and fracture appear more dominant, while the filling of the fracture by hydrothermal solution becomes less prominent [4].

The compression stress that works since the Midle Miocene to Plio-Pleistocene is generally almost perpendicular to the island of Java. The stress corresponds to the major compression period, which occurs due to the encounter of the Indian-Australian ocean plate with the Southeast Asian continental plate. Thus the island of Java is controlled by a 3-way structure that is northwest-southeast, northeast-southwest and north-south. In the Kulon Progo area, the northeast-southwest direction, in general, has controlled the occurrence of shallow intrusions that produce mineralization [4].

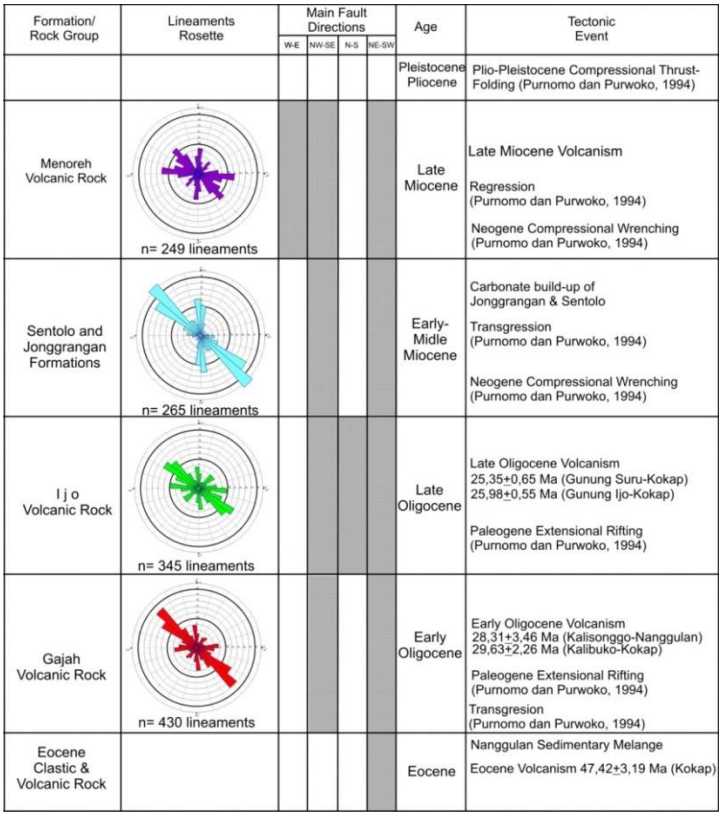


Figure 5. Tectonostratigraphy of Kulon Progo Mountains.

6. Discussion

Kulon Progo is a part of the transition area, between the Mesozoic, northeast-southwest (NE-SW) palaeo-subducsion, and the Early Tertiary-Quarterly west-east (E-W) subduction. Both structural patterns are expected to be the dominant feature in the Kulon Progo area. The northwest-southeast trending structure (NW-SE) present at all layers of rock (Figure 5) is probably an old, activated structure. Kulon Progo is also suspected to be formed by deformation of at least 2 times the tectonic phase periods, the first occurring in the Late Oligocene-Early Miocene and second on the Late Miocene-Quarter. The Late Oligocene Period - Early Miocene controls the emergence of Gajah and Ijo volcanisms, while the Late Miocene period forms Menoreh volcanism (Figure 5).

Publication by [32] states that the process of Tertiary structure formation in Java can be divided into 3 periods namely (1) Palaeogene Extensional Rifting, (2) Neogene Compressional Wrenching and (3) Plio-Pleistocene Compressing Trust-Folding. The Period of Palaeogene Extensional Rifting is

characterized by a rifting process on Eocene-Oligocene that initiates the formation of Tertiary basins in Java [32]. In general, the rifting process in each region forms the orientation of the graben and half graben structures (half graben) in certain directions, indicating the existence of tectonic order controls on the early formation of basins [32]. Research resulted by [8] mentions the formation of normal faults and grabens as the forming of the basin for Nanggulann Formation in this period. In the Kulon Progo Mountains, this period resulted in Eocene magmatism and volcanism (47.42±319 Mya), Gajah volcanism (28.31±3.46 Mya / Early Oligocene data from Kalisonggo-Nanggulan) and Ijo Volcanism (25.98±0,55 Mya / Late Oligocene (Data from Mount Ijo-Kokap). The extension of this period also causes instability of the basin resulting in sedimentary melange Eocene at the top of the Nanggulan Formation.

The Neogene Compressional Wrench period is characterized by the formation of shear faults, which mainly result from the compressive stress of the Indian Ocean plate collision. The resulting shear faults have a particular orientation, which corresponds to the main compression direction. Most of the fault movement is the reactivation of normal faults formed in the Palaeogene period [32]. Publication by [33] mentions the presence of a sinistral fault due to the north-south compression stress employed in the Kulon Progo Mountains. This sinistral fault is better known as Progo-Muria fault according to Smyth et al (2005), [6, 7, 34]. This compressional period also produces Menoreh volcanism at 12.4 ± 0.7 Mya / Late Miocene [27]. This compression phase is capable of producing volcanism because of a sinistral fault formed by left stepping sinistral fault, to produce transtensional zones.

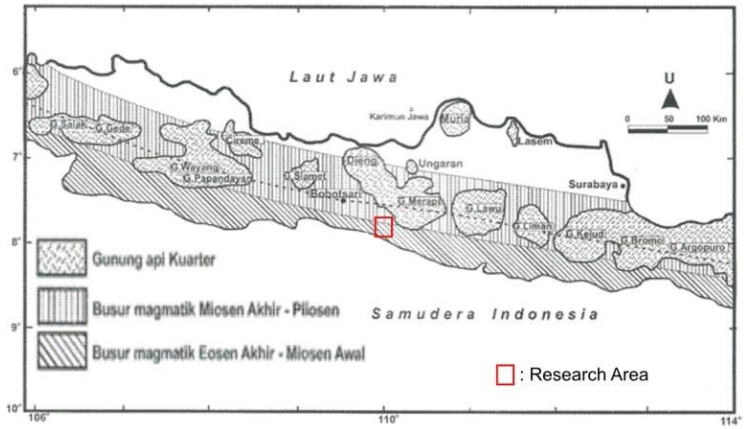


Figure 6. Distribution of Palaeogene to Quaternary volcanic rocks in Java [5].

The Plio-Pleistocene Compressional Thrust-Folding Period is characterized by the formation of folds, which continues in the formation of thrust fault. Anticlinorium and thrust-belt that have a certain orientation, they are associated with the direction of compressions and kinematics formation [32]. Thrust fault and folding on the eastern side of the Kulon Progo Mountains were generated during this period as a result of interaction with the southern Mountains of Java in the southeast part.

Publication by [19] argues that the geological history of southern central Java, at the time of the Palaeogene was ended by regional tectonic events on the Late Oligocene. During this period there is strong faulting and subsequent subsidence followed. In Kulonprogo this period is influenced by tectonic blocks, due to fault movement and volcanic activity. The Old Andesite Formation (Gajah and Ijo) was present due to this phase.

Java Island is as part of the Sunda Arc, which is a Tertiary arc of Tertiary to Quaternary volcano. This volcanic arc, formed as a result of subduction in the south of Java. Although the position of the subduction path develops or changes closer and away from the mainland of Java Island, but the location of volcanic arc on the island of Java is relatively at fixed position. This results in the occurrence of superimposed volcanism over time. This can be seen from the spread of volcanic rock in

Java, as stated by [5], as in Figure 6. Four periods of volcanism namely Eocene, Early Oligocene, Late Oligocene and Late Miocene are in one area, and the young cover the old.

Research by [26] suggests two Tertiary magmatic events that have occurred in Central Java. Both are characterized by an increase in potassium to time (transition from low-K to K-medium and sometimes K-rich calc-alkaline series). The first magmatic episode occurred during the Eocene-Early Miocene (40-19 Ma) with the E-W volcanic axis trend, located 50 km of the active Sunda arc axis. The second volcanic episode is as part of the base of Quaternary volcanism. This episode occurs within the age range 11-3 Ma (Late Midle Miocene - Late Pliocene). This second event shows the early presence of the modern Sunda arc. In the Kulon Progo Mountains, the three Eocene-Gajah-Ijo volcanisms are in the first volcanic episode, while Menoreh volcanism is in the second volcanic episode.



Figure 7. Field appearance of rocks from the 4 volcanic bodies in Kulon Progo Mountain.

Conclussions

Some conclussions of the study of tectonostratigraphy-volcanic of Gajah-Ijo-Menoreh Tertiary volcanic formations in Kulon Progo Mountain area are as follow :

1. There are four periods of volcanism in the Kulon Progo Mountains, namely Late Eocene Volcanism, Early Oligocene, Late Oligocene and Late Miocene volcanism.
2. Volcanism of the Eocene-Gajah-Ijo period is related to the Palaeogene extensional rifting period.
3. Menoreh Volcanism is related to the period of Neogene Compressional Wrench that produces a sinistral fault with left-stepping left lateral fault pattern.
4. Kulon Progo mountains are located on 2 zones of magmatic arc, namely Late Eocene - Early Miocene magmatic arc, and Late Miosen - Pliocene Magmatic arc.

References

[1] Van Bemmelen R W 1949 *The Geology of Indonesia* Vol. **IA** General Geology of Indonesia and Adjacent Archipelago (The Hague: Government Printing Office)

[2] Smyth H R, Hall R, Hamilton J and Kinny P 2005 *East Java : Cenozoic basins, Volcanoes and Ancient Basement*, Proceedings Indonesian Petroleum Association

[3] Barianto D H, Abboud E and Setijadji L D 2009 S*tructural Analysis using Landsat TM, Gravity Data, and Paleontological Data from Tertiary Rocks in Yogyakarta, Indonesia* Memoirs of the Faculty of Engineering, Kyushu University, Vol.**69**, No.2

[4] Harjanto A 2011 *Vulkanostratigrafi di Daerah Kulon Progo dan Sekitarnya, Daerah Istimewa Yogyakarta*. Jurnal Ilmiah MTG, Vol. **4** No. 2, Yogyakarta

[5] Soeria-Atmadja R, Maury R C, Bellon H, Pringgopawir H, Polves M, and Priadi B 1994 *Tertiary Magmatic Belts In Java*, Journal of Southeast Asian Earth Sciences. Vol **9**, No.1

[6] Husein S and Nukman M 2015 *Rekonstruksi Tektonik Mikrokontinen Pegunungan Selatan Jawa Timur: Sebuah Hipotesis berdasarkan Analisis Kemagnetan Purba.* Proseding Seminar Nasional Kebumian Ke-8, FT-UGM
[7] Smyth H R, Hall R, and Nichols G J 2008 *Significant Volcanic Contribution to Some Quartz-Rich Sandstone, East Java, Indonesia* Journal of Sedimentary Research, v. **78** pp 335–356
[8] Prasetyadi C 2008 *Provenan Batupasir Eosen Jawa Bagian Timur*. Proseding Pertemuan Ilmiah Tahunan IAGI ke 37, IAGI, Bandung
[9] Rahmad B and Maha M 2010 *Endapan Batubara Palaeogene Formasi Nanggulan-Kulon Progo: Kajian Geologi Batubara dan Fasies Batubara*. Proceedings PIT IAGI Lombok, The 39th AGI Annual Convention and Exhibition
[10] Rahardjo W, Sukandarrumidi and Rosidi HMD 1995 *Peta Geologi Lembar Yogyakarta* (Bandung: Pusat Penelitian dan Pengembangan Geologi)
[11] Rahardjo W, Sukandarrumidi and Rosidi HMD 2012 *Peta Geologi Lembar Yogyakarta*. Pusat Survey Geologi-Badan Geologi-Kementrian Energi dan Sumberdaya Mineral.
[12] Purnamawati D I, and Tapilatu S R 2012 *Genesa dan Kelimpahan Mineral Logam Emas dan Asosiasinya Berdasarkan Analisis Petrografi dan Atomic Absorbsion Spectophotometri (AAS) di Daerah Sangon, Kabupaten Kulon Progo, Propinsi DIY*. Jurnal Teknologi Vol. **5** No.2
[13] Ansori C and Hastria D 2013 *Studi Alterasi dan Mineralisasi di Sekitar Gunung Agung Kabupaten Kulon Progo-Purworejo*. Buletin Sumberdaya Geologi Volume **8** no 2.
[14] Suroso Rodhi A and Sutanto 1987 *Usulan Penyesuaian Tata Nama Litostratigrafi Kulon Progo, DIY.* Kumpulan Makalah Pertemuan Ilmiah Tahunan XV IAGI, Volume **1**, Yogyakarta
[15] Utama H W and Sutanto 2013 *Arti Penting Fragmen Breksi Sebagai Identifikasi Basement Perbukitan Menoreh Daerah Kaliduren serta Kesebandingannya Terhadap Fragmen Batuan Metamorf di Daerah Selogiri, Jawa Tengah.* Proseiding Seminar Nasional Kebumian Ke-6, T. Geologi UGM, Yogyakarta
[16] Harley M M and Morley R J 1995 *Ultrastructural studies of some fossil and extant palm pollen, and the reconstruction of the biogeographical history of subtribes Iguanurinae and Calaminae, Review of Palaeobotany and Palynology*, Elsevier Science pp 153-182
[17] Rahmad B, Maha M and Rodhi A 2008 *Reflektan Vitrinit dan Komposisi Maseral Seam Batubara Eosen Formasi Nanggulan Daerah Kalisonggo, Kecamatan Girimulyo, kabupaten Kulon Progo, DIY.* Prosiding PIT IAGI Ke-37, Bandung
[18] Ansori A Z L, Stefano A D, Jyalita J and Amijaya D H 2015 *Relationships of Depositional Environment and Mineralogy on Rock Fracturability (Brittleness): Case Studdy of Eocene Nanggulan Shale, Kulon Progo, Yogyakarta*. Proceedings Indonesian Petroleum Association, 39th Annual Convention & Exhibition
[19] Bolliger W and De Ruiter P A C 1975 *Geology of The South Central Java Offshore Area.* Proceedings Indonesian Petroleum Association, 4th Annual Convention
[20] Premonowati 1994 *Informasi Paleobatimetri Asosiasi Fosil Moluska*. Preceedings Geologi dan Geotektonik Pulau Jawa Sejak Akhir Mesozoik Hingga Kuarter, Yogyakarta
[21] Saputra R and Akmaluddin 2015 *Biostratigrafi Nannofosil Gampingan Formasi Nanggulan Bagian Bawah Berdasarkan Batuan Inti dari Kec. Girimulyo dan Kec. Nanggulan, Kab. Kulon Progo, D.I. Yogyakarta*. Proseding Sem. Nas. Kebumian Ke-8, FT-UGM
[22] Hartono H G and Pambudi S 2015 *Gunung Api Purba Mujil, Kulon Progo, Yogyakarta: Suatu Bukti dan Pemikiran*. Seminar Nasional ReTII Ke-10 Tahun 2015, STTNAS, Yogyakarta
[23] Widiasmoro 1994 *Evolusi Magma pada Kala Oligosen di Daerah Prambanan-Patuk-Imogiri-Parangtritis DIY.* Preceedings Geologi dan Geotektonik P. Jawa Sejak Akhir Mesozoik-Kuarter.
[24] Sutanto, Soeria-Atmadja R, Maury R C and Bellon H 1994 *Geochronology of Tertiary Volcanism in Java.* Proceedings Geologi & Geotektonik P. Jawa sejak Akhir Mesozoik-Kuarter, Yogyakarta

[25] Barianto D H, Kuncoro P and Watanabe K 2010 *The Use of Foraminifera Fossils for Reconstructing the Yogyakarta Graben, Yogyakarta, Indonesia*. Journal of South East Asian Applied Geology, May-August 2010, Vol 2(2), pp 138-143.
[26] Bellon H, Maury C, Soeria-Atmadja R, Polve M, Pringgoprawiro H and Priadi B 1989 *Chronologie 40K- 40Ar Du Volcanisme Tertiaire De Java Central (Indonesie): Mise En Evidence De Deux Episodes Distincts De Magmatisme D'Arc*
[27] Akmaluddin, Setijadji D L, Watanabe K, and Itaya T 2005 *New Interpretation on Magmatic Belts Evolution During the Neogenee-Quarternary Periods as Revealed from Newly Collected K-Ar Ages from Central-East Java, Indone*sia. Proceedings Joint Convention Surabaya-HAGI-IAGI-PERHAPI, Annual Conference and Exhibition, Surabaya
[28] Satyana A H and Purwaningsih M E M 2003 *Oligo-Miocene Carbonates of Java: Tectonic setting and effects of Vulcanism.* Proceedings of Joint Convention Jakarta 2003, The 32nd IAGI and 28th HAGI Annual Convention and Exhibition
[29] Satyana A H 2005 *Oligo-Miocene Carbonates of Java, Indonesia : Tectonic-Volcanic Setting and Petroleum Implications.* Proceedings Indonesian Petroleum Association The 13 th Annual Convention and Exhibition
[30] Sulistyoningrum D and Rahardjo W 2010 *Identification and Paleoecology of Coraline Fossil (Cnidaria: Anthozoa) from Jonggrangan Limestone, Western Slope of Kucir Hill, West Progo Area, Yogyakarta Special Province*. Proceedings PIT IAGI Lombok 2010
[31] Riandari B L and Wijono S 2013 *Biostratigrafi Foraminifera Plangtonik dan Lingkungan Sedimentasi Formasi Sentolo Jalur Sungai Niten, Sungai Serang dan Dusun Ngramang-Kulon Progo.* Proseding Sem. Nas. Kebumian Ke-6, T. Geo UGM
[32] Purnomo J and Purwoko 1994 *Kerangka Tektonik dan Stratigrafi Pulau Jawa Secara Regional dan Kaitannya dengan Potensi Hidrokarbon*, Preceedings Geologi dan Geotektonik Pulau Jawa Sejak Akhir Mesozoik Hingga Kuarter, Yogyakarta
[33] Widagdo A, Pramumijojo S and Harijoko A 2017 *Rekonstruksi Struktur Geologi Daerah Gunung Ijo di Pegunungan Kulon Progo-Yogyakarta Berdasarkan Sebaran Kekar dan Urat Kuarsa.* Proseiding Sem. Nas. Kebumian Ke-10, T. Geologi UGM, Yogyakarta
[34] Hall R, Clements B, Smyth H R and Cottam M A 2007 *A New Interpretation Of Java's Structure*. Proceedings, Indonesian Petroleum Association, May, 2007.