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INTERPRETATION OF TECTONIC SETTING AND MAGMATISM FOR EDUCATION AND GEOTOURISM IN IJEN UNESCO GLOBAL GEOPARK, EAST JAVA, INDONESIA

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Abstract - *Indonesia's tectonic conditions are quite interesting, especially discussing about the boundary conditions of the western and eastern parts of Indonesia's tectonic areas which have very different characteristics. One of the things that results from tectonic activity is magmatism that produces volcanoes. The Sunda Arc in the western part of Indonesia is a subduction tectonic zone that produces arc volcanoes. One of the volcanoes that grows in the area is the Ijen Volcano Complex which is in a very interesting position. It is located at the boundary or transition between the Sundaland part in the west and the crust that thinner in the eastern part. Its volcanism is also quite interesting because it produces a caldera formed by an explosive eruption. The Ijen Complex grows on top of Tertiary sedimentary rocks. The magmatism is also affected by the assimilation process between sedimentary rocks and magma that comes from partial melting in the subduction zone. Knowledge regarding the interpretation of tectonic conditions and magmatism at Ijen is important as educational material. By studying the Ijen Volcano Complex, we can get data that the surface carried by magma rises and erupts so that we can obtain information about what is happening at the bottom beneath the surface there and its tectonic configuration. The results of this research are used for educational and geotourism activities in the Ijen Geopark area which are used to complete geological stories from existing sites.*

Key words*: Interpretation, geopark, Ijen, volcano, geotourism*

Sari – Kondisi tektonik Indonesia cukup menarik, terutama membahas tentang kondisi batas wilayah tektonik Indonesia bagian barat dan timur yang memiliki karakteristik yang sangat berbeda. Salah satu hasil dari aktivitas tektonik adalah magmatisme yang menghasilkan gunung api. Busur Sunda di Indonesia bagian barat merupakan zona tektonik subduksi yang menghasilkan busur gunung api. Salah satu gunung api yang tumbuh di sana adalah Komplek Gunung Api Ijen yang berada pada posisi yang sangat menarik karena terletak pada batas atau peralihan antara Sundaland di bagian barat dan kerak yang lebih tipis di bagian timur. Vulkanismenya juga cukup menarik karena menghasilkan kaldera yang terbentuk akibat letusan eksplosif. Komplek Ijen tumbuh di atas batuan sedimen Tersier. Magmatisme juga dipengaruhi oleh proses asimilasi antara batuan sedimen dan magma yang berasal dari pencairan sebagian di zona subduksi. Pengetahuan mengenai interpretasi kondisi tektonik dan magmatisme di Ijen menjadi yang penting sebagai bahan edukasi. Dengan mempelajari Komplek Gunung Api Ijen, kita dapat memperoleh data bahwa permukaan yang dibawa oleh magma naik dan meletus sehingga kita dapat memperoleh informasi tentang apa yang terjadi di bawah permukaan sana dan konfigurasi tektoniknya. Hasil riset ini digunakan untuk kegiatan edukasi dan geowisata di Kawasan Geopark Ijen yang digunakan untuk melengkapi cerita geologi dari situs- situs yang ada.

Kata kunci: Interpretasi, geopark, ijen, gunung api, geowisata

1. INTRODUCTION

Understanding magma genesis and evolution in subduction zone environments is crucial to understanding the formation of the continents and crustal recycling in the mantle. The relationship between tectonics and magmatism processes is very close. One of the sources of magma that fills volcanoes is plate subduction activity. The oceanic plate that enters then releases H_2O and causes a decrease in the boiling point of magma and results in partial melting. This magma source is important in understanding the magmatism that occurs in a volcano. The island of Java has the most active volcanoes in Indonesia. The growth of this volcano cannot be separated from the subduction activity of

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the Indo-Australian plate against the Eurasian plate at an average speed of 7cm/year (De Mets et al., 1994). The movement of the subducting oceanic plate may be a factor in the birth of magma in the subduction zone, but variations in the conditions of the overriding plate affect the type of volcanism present and provide clues about the character of the plate below. The tectonics of the eastern part of the island of Java is very unique and interesting, as the change between the thicker crust in the west and the thinner crust in the east can be observed in the area (Hamilton, 1979). Therefore, studying the volcanoes in the east of the island of Java is key in understanding the tectonic phenomena beneath, which become important educational aspect of geopark.

This paper will describe the geological aspect of Ijen Geopark and how this information is disseminated for educational purpose, especially for early educational institutions.

2. DATA AND METHODOLOGY

A systematic literature review was carried out on several publication related with regional geological setting of Ijen Volcanic Complex (Fig. 1). The geological data includes tectonic, stratigraphy, and magmatism. We also describe our approach to disseminate this information to public and in educational institutions.

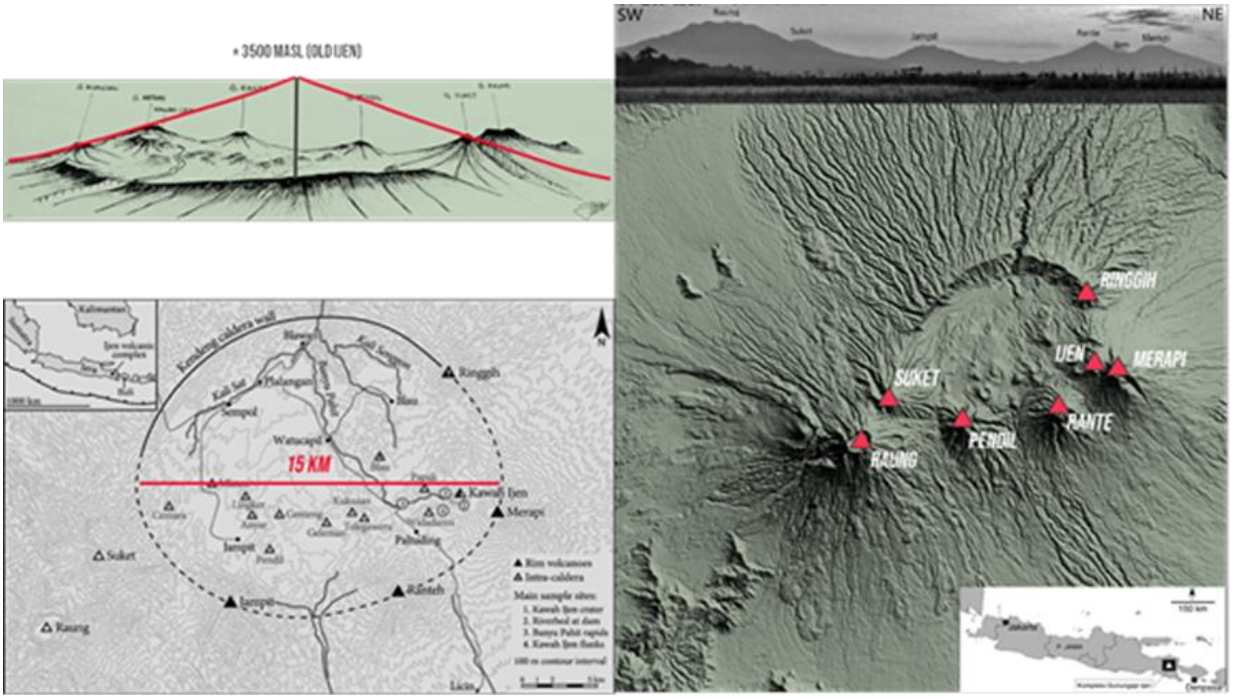

Figure 1 The location of caldera Ijen Unesco Global Geopark in Bondowoso and Banyuwangi Regencies, East Java, Indonesia (Sitorus,1990).

3. GEOLOGICAL SETTING

Tectonic Settings

Ijen volcanic complex is located on the eastern edge of Java within the Quaternary volcanic front of the Sunda Arc (Fig. 2). The arc forms the western part of the Indonesian subduction zone system, which extends over 3000 km from the Andaman Islands north of Sumatra to Flores in the Banda Sea. It formed as a result of the northward subduction of the Indo-Australian Plate beneath the Eurasian Plate at a rate of around 6-7 cm/year (Fig. 3) (DeMets et al., 1990; Tregoning et al., 1994). despite this apparently simple tectonic setting, understanding magma genesis and evolution at the Sunda arc is complicated by the variable nature of the arc crust, the changing age of the subducting oceanic crust, which increases eastwards from 80 to 130 Ma

BULLETIN OF GEOLOGY, VOL. 7, NO. 3, 2023
DOI: 10.5614/bull.geol.2023.7.3.4

(Plank and Langmuir, 1998). Along the length of the arc the composition and thickness of the overriding Eurasian plate is also thought to change, from continental in the west to oceanic in the east (Hamilton, 1979). Beneath Java, the crust is 20 km thick and has a seismic velocity structure intermediate between continental and oceanic (Whitford, 1975). The Java crust is said to consist of ophiolite slivers, melange and older volcanic rocks (Hamilton, 1979). The Sunda Land (SE Asian continental part of the Sunda block-Eurasian plate with pre-Tertiary basement) boundary shown in Fig. 1 suggests that in western Java the island arc is built on continental material. In eastern Java beneath the (outside the hypothesized Sunda Land boundary) the overriding plate comprises thickened oceanic crust. However, recent research on inherited zircons (Smyth, 2005) provides evidence for old continental basement beneath the Southern Mountains Arc (south of the active volcanic axis) in East Java.

Ijen Volcanic Complex is a typical strato volcano with average height of more than 2000 meters above sea level that belongs to the Quaternary volcanic zone in Java (van Bemmelen, 1949). According to van Bemmelen (1949, Fig. 4) this volcanic complex grows on granite rocks that form part of the southern mountain zone. This was later confirmed by Smyth et al. (2007) who proposed the existence of granitic rocks from Gondwana as a constituent of continental crust under the mountains of southern Java and continuously to South Sulawesi (Fig. 5). The bending to Sulawesi is right past the bottom of, indicating that Mount Raung and Ijen is on top of a continental crust. The existence of gondwana fragments is also estimated continuously to the southern mountains in western Java (Abdurrachman and Yamamoto, 2012). Geochemically, the complex is an active continental type (Siddiq, 2015). Analysis of petrogenesis by Sabila (2018) shows that is tectonically an active continental edge (Fig. 6) in the Subduction of the Indo-Australian Plate against fragments of the continental crust. This, geochemically, has confirmed the presence of a continental crust from Gondwana as the basement of Ijen.

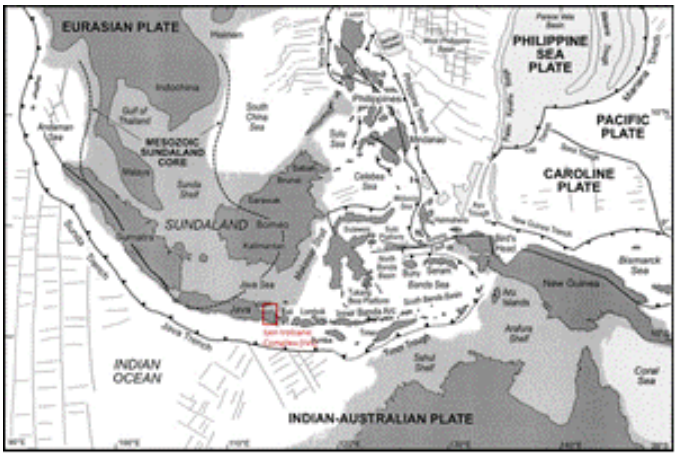

Figure 2. Ijen tectonic configuration and relation with the Ijen Volcanic Complex location (Smyth et al., 2007).

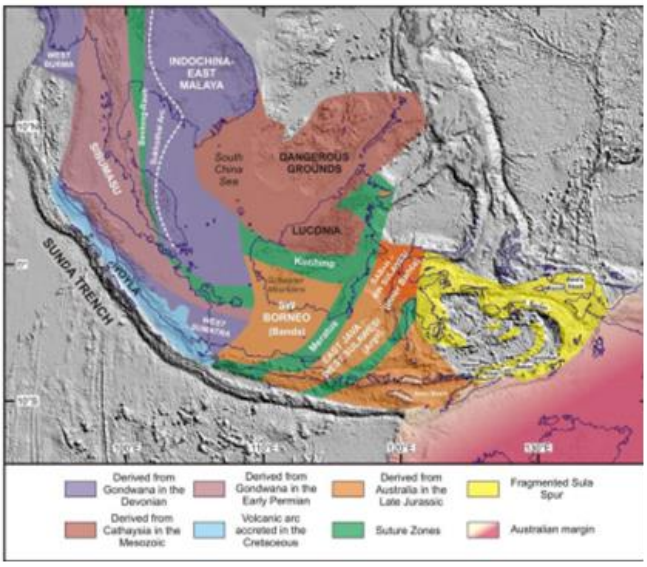

Figure 3. Southeast Asia microplate map (Hall, 2014).

Regional Stratigraphy

Stratigraphically, the edifices of Ijen (Fig. 3) are composed by Quaternary volcanic rocks that are grow above Tertiary-aged sedimentary rocks. According to regional geological map of Banyuwangi (Sidarto et al., 1993), regional geological map of Jember (Sapei et al., 1992), regional geological map of Besuki (Pendowo and Samodra, 1997), regional geological map of Situbondo (Agustiyanto and Santosa, 1993), and Kamid (1984) sedimentary rocks under Mount

BULLETIN OF GEOLOGY, VOL. 7, NO. 3, 2023
DOI: 10.5614/bull.geol.2023.7.3.4

Raung are carbonaceous, which also contain volcanic material. The Batuampar Formation (Oligo-Miosen) consists of volcanic breccia, tuff breccia composed andesite, tuff, and basalt. The Punung Formation (Miocene) consists of reef limestone, tuffacoeus limestone, and marls. The Menuran Formation (Miocene to Late-Pliocene) with a thickness of more than 300 m consists of marl and limestone, alternated with tuff. The outcrops around Menuran indicates that the local marl contains the components of limestone. Limestone with a thickness of up to 150 m is referred as the Pacalan Member is light gray to yellowish, fine-grained-medium, fossil-rich and well-layered. The thick Leprak (Pliocene) Formation is estimated to be about 300 m thick and tends to thicken eastwards consisting of limestone and sandstones. Limestone is grayish yellow or brownish, generally fine-grained and contains a lot of foraminifera. Before it was covered by young volcanic rocks, sedimentary rocks had been covered by older volcanic rocks. Ringgit Volcano (Late Pliocene) consists of lava, volcanic breccia and tuff, alternating tuffaceous sandstone. Lava is black or blackish gray, consisting of basalt, basalt leucite, pyroxene andesite and andesite hornblende. Argopuro Volcano and Ijen Tua Volcano (Quaternary) consist of volcanic breccia with lithic components.

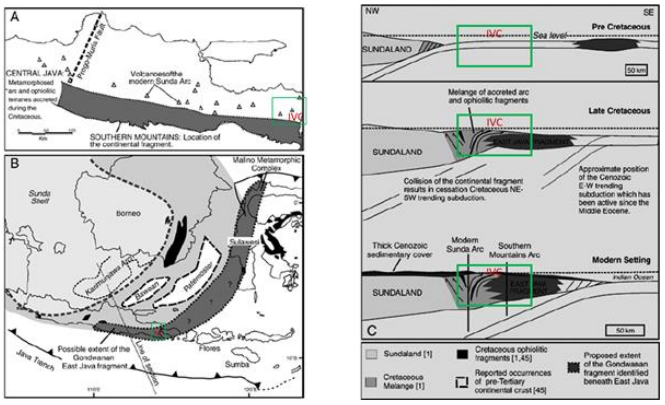

Figure 4. Arc evolution in eastern margin of Sundaland (Smyth et. al., 2008).

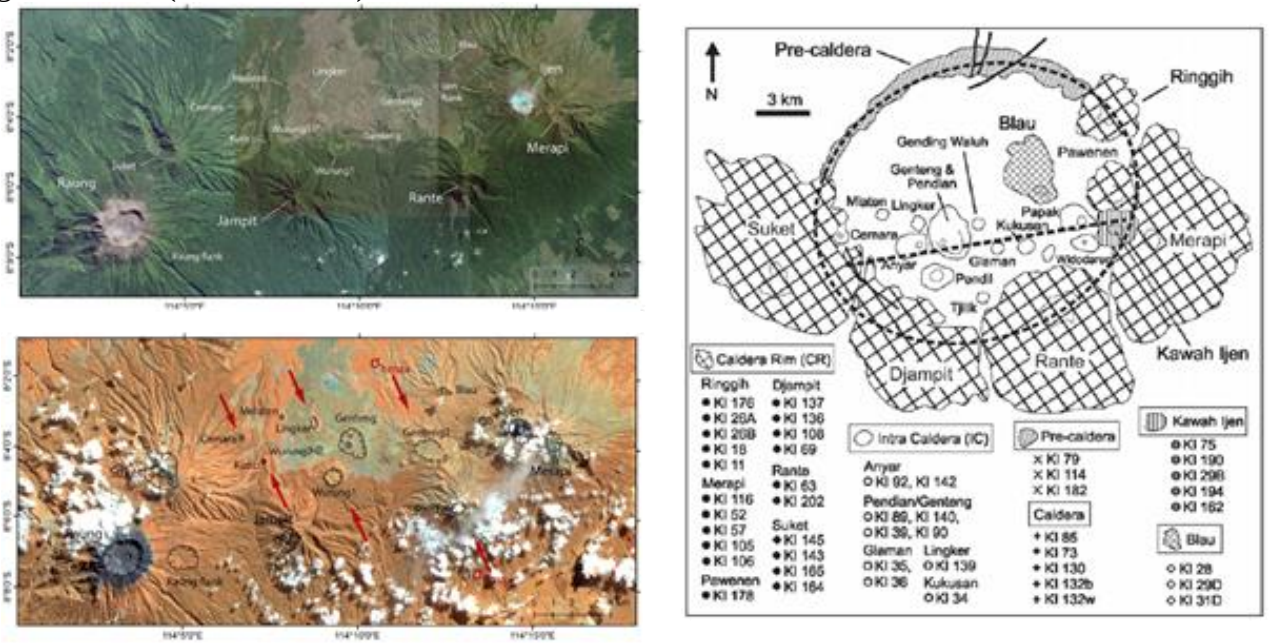

Figure 5. Geomorphology and volcano distribution (Marliyani et. al., 2020).

Magmatism

Mount Raung is the youngest volcano cone in gunungapi Ijen Complex (Sabila, 2018; Sutawidjaja et al., 1996). The mountain produces volcanic products in the form of pyroclastic and basaltic lava (Sabila, 2018; Sutawidjaja et al., 1996) with characteristics of high potassium calc-alkaline magma series (Sabila, 2018). Based on the source,

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lithology and eruption period, volcanostratigraphy of Mount Raung from old to young is divided into four crowns (khuluk), namely Khuluk Ijen Tua, Khuluk Suket, Khuluk Gadung, and Khuluk Raung (Sabila, 2018). The four crowns volcanism activities formed volcanic products such as basalt, andesite, and pyroclastic breccia, which are divided into 19 lithological units (Sabila, 2018). The magmatism activity of Mount Raung and its surroundings is divided into 5 phases namely phase I (Old Ijen period), phase II (Suket period), phase III (Gadung pre-escalator period), phase IV (Gadung post-caldera period), and phase V (Raung pre-chastening period) (Sabila, 2018). Magmatism that occurs in each phase is the differentiation of magma in the form of crystal fractionation and mixing of magma with different depth (Fig. 5). During phase V (Raung pre-caldera period) there is an additional process of assimilation with side rocks (Sabila, 2018).

4. DISSEMINATION PROGRAM

There are information panels in simple language, brochures, and websites containing Geopark content intended to easily inform people about tectonic setting and magmatism in Ijen Geopark area (Fig. 6). Not only information panels and brochures, but also an existence of education and research programs are helpful in spreading information and developing the Geopark. Ijen Geopark has several educational programs that coordinated by the Education Office and then socialized and applied in schools from kindergarten to junior high school levels. The Geopark goes to School program is an introduction program about Ijen Geopark for students and teachers at the junior high school level where the Ijen Geopark Management Body visits schools (Fig. 7). Besides that, the Ijen Geopark team also designed a program namely School goes to Geopark with students coming to the site to learn directly about Ijen Geopark. Junior high schools located around the Ijen Geopark area provide a Geopark Corner room containing Ijen Geopark content like replicas, books, magazines, or newspapers, etc. Geopark Corner will be used as a place to study for early childhood to elementary school student by visiting the Geopark Corner, junior high school students at their own school are in charge of informing about Ijen Geopark to them. The managers of the Ijen Geopark and the Education Office created learning modules for the kindergarten, elementary, and junior high school levels that aim to streamline the distribution of information about Ijen Geopark to schools. Research in the area is carried out directly at the Ijen Geopark sites conducted with university partners around the Ijen Geopark area.

Figure 6. Infographic panel about tectonic history in Ijen area.

Figure 7. In class activity about education of magmatism and volcanism.

The Ijen volcano complex is quite interesting because it has a basement that comes from Gondwana with the characteristics of a continental

crust. This is quite interesting because the existence of the continent beneath it definitely affects the magmatism process that occurs there. Assimilation between magma originating from the subduction zone and the continent will certainly increase magma contamination so that it can produce magma conditions that cause explosive eruptions. This can be seen from the presence of a fairly large caldera with a diameter of 15 km and is the largest caldera on the island of Java. This knowledge is very helpful if we can integrate to educational and geotourism program. Some panels and activities can be upgraded with tectonic and magmatism information (Fig. 8). If we look at the Ijen Volcano Complex, we can explain the tectonic conditions or configurations that exist on the southeastern edge of Sundaland which are different from what is in the east, this condition may be able to answer why East Java is rich in oil and gas and economical minerals while in The part of Bali and its east is starting to be found a little because the crust in the East Java part is continental crust that can be detected from the volcano.

Figure 8. Education and geotourism activity in Ijen Unesco Global Geopark.

Under the Ijen Volcanic Complex, we can also find Tertiary-aged sedimentary rocks that are the basement of this volcano. This is quite interesting because by studying this volcano we can understand how the interaction between magma and sedimentary rocks and their effect on explosive eruptions in a volcano. Another thing we can learn is that we can use volcanic research to map the distribution of sedimentary rock beneath which has been covered by young volcanic products.

All of this scientific based information is used in the development of Geotourism in Ijen Geopark as imtrepetation panels and other educational publication media. Apart from that, it is explained in educational activities, such as School goes to Geopark, which is routinely carried out (Fig. 9).

Figure 9. An effort to integrate tectonic and magmatism knowledge in education.

5. CONCLUSION

The conclusion from this literature study is that the Ijen Volcano Complex is a volcano that grows in the subduction zone between the Indo-Australian plate and the Eurasian plate which has unique characteristics. Its position is in the east of the island of Java, which is a transition zone between the continental crust which is quite thick, Sundaland in the west and thinner crust in the east, it is estimated that under the Ijen Volcano Complex, there is the southeastern edge of Sundaland. Then by studying magmatism processes and their interactions with rocks beneath the volcano, we can study the tectonic processes or configurations and distributions that can complete the understanding of regional tectonics in the Ijen Complex.

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