Volcano Tourism of Mt. Rinjani in West Nusa Tenggara Province, Indonesia: a Volcanological and Ecotourism Perspective

Heryadi Rachmat
Geological Agency, Ministry of Energy and Mineral Resources of the Republic of Indonesia
Corresponding Author: **hery_rachmat@yahoo.com**

Abstract

Indonesia has nearly 500 volcanoes and 129 of them are currently active. The active volcanoes are spread out along a 7000 km volcanic belt from Sumatra to Java, Bali, Nusa Tenggara, Banda, Halmahera and Sulawesi. Each volcano possesses its own natural characteristics that usually include beautiful landscapes and sceneries, fresh air and fertile lands. One of the volcanoes is Mount (Mt.) Rinjani (+3726 m) in Lombok island, West Nusa Tenggara. It is the second highest volcano in Indonesia after Mt. Kerinci (+3800 m) in Sumatra. Mt. Rinjani is situated at latitude 8°25' S and longitude 116°28' E. The Rinjani volcano complex has potential to be developed for volcano tourism and natural volcanic museum.

Currently, vulcano tourism in Indonesia is still poorly developed and it relies on resources-based tourism only, not on knowledge-based tourism. Now is the moment for volcano tourism stakeholders, including travel guides, to prepare themselves by gaining more knowledge, specifically in term of scientific knowledge of a volcano and its environment. By doing so, they can make volcano more interesting as a tourist attraction and more appealing to both domestic and foreign tourists. The tourists eventually can have better understanding of a volcano including the landscapes, sceneries and panoramas, calderas, lakes, hotsprings, waterfalls, caves, etc.

This paper discusses the volcano-tourism potential of Mt. Rinjani, focusing on volcanic and geological aspects as the main tourist attraction, and environmental aspect as a secondary attraction. The volcano-tourism attractions can include specific or general activities, depending on a visitor's interest, for examples for recreation, adventure or cultural activities.

Introduction

West Nusa Tenggara is a province that has three A-type active volcanoes, which include Rinjani in the Lombok Island, Tambora in the Sumbawa island and Sangeangapi in the Sangeang Island. Mt. Rinjani (+3726 m) lies at the northern part of Lombok Island, administratively within the East Lombok District.

Mt. Rinjani National Park, one of 39 national parks in Indonesia (Figure 1), is a representative of the best areas in natural landscape and wildlife biodiversity. National parks are important tourist attractions and can significantly contribute to regional and national economies. The parks are managed nationally by the Ministry of Agriculture and Forestry, Directorate General of Nature Conservation and Protection from its central office in Bogor, West Java.

The Rinjani Park includes calderas, a lake, cones and a crater. The calderas include three cones of A-type volcanoes, which consist of Barujari (+2376 m), Rombongan (+ 2110 m) and Anak Barujari (+2112 m), with a lake called Segara Anak (Baby Sea). The Rinjani belongs to B-type active volcano in the form of strato in the eastern part of the calderas. Over its top, there is a crater of 860m x 650m in size and 300m deep, whose explosion history has never been recorded. Its last explosion was in 1994, when the Barujari crater produced lava flows and volcanic materials of ashes up to bomb size (Rachmat, 1994).

Approximately 1175m to the west of the top of Barujari, there is a small hill that was a product of flank eruption, with a height of more than 2112 m. To get to the top of Barujari and the 1994 lava flows, trackers can walk it up through the Putih (White) river head and walk up the cliff/northern part of the lake for approximately three hours. The 1994 eruption produced a piling up of volcanic materials, such as ashes and rocks over the southeastern part. A rainy season in November 1994 cause a large flood and led to 31 deaths and 7 injuries, as well as destroying agricultural fields, mills, a small shop and irrigation channels.

In 1994, the Mt. Rinjani observatory post was built at Sembalun Lawang. The observatory is now furnished with a seismograph, a thermometer and a telescope. The volcano is being continously monitored by two persons working on shift, who have been specially trained in volcanic observation. These people would monitor Mt. Rinjani's volcanic activities persistently, visually and seismographically. Assuming an eruption occurred at Mt. Barujari, the danger zone from the eruption extends over an area of 196 km^2, which is populated by people living in Bayan (eight villages), Aikmel (three villages) and Sambelia subdistricts (five villages). Mt. Rinjani can throw out disastrous materials, which primarily include glowing cloud, blazing lava flows, stone rains, ash rains and poisonous gas. Secondary disastrous materials include lahar flows, stone flood and large flood. However, the volcano can also bring advantages, such as for geotourism and volcano tourism attractions and flora and fauna development.

Historically, the eruption of Mt. Rinjani often came from Mt. Barujari and Mt. Rombongan, which form the northern chain of Mt. Rinjani. There were no fatalities in the last eruption, however lahar flood as a secondary impact of the eruption claimed some victims.

Ecotourism development cannot be separated from conservation. The joint partnership concept is essentially an example of pure ecotourism, developing styles of tourism that benefit local communities and strengthen conservation objectives of a protected area. The Rinjani Trek has the potential of becoming an ecotourism model in Indonesia.

There are some interesting locations on Mt. Rinjani, which are scattered from its slope up to the summit, that can become the main tourist attraction and potentially support tourist attractions in the area. These include the crater/caldera at Mt. Rinjani and Mt. Barujari. The crater/caldera and its walls consist of alternating and cross cut of lava flows and pyroclastic layers including lava product of the Mt. Barujari's latest eruption, creating an amazing scenic view. Other objects to the upstream of Kokok Putih, Susu cave and at the foothills of Mt. Barujari are calderas with beautiful views and hotsprings, while in the Segara Anak Lake, people can do fishing. When this area is developed into a volcano tourism destination in the future, activities can include cross country, travelling around the lake, wall climbing, tracing calderas walls to watch the lava flows and visitting hot springs and the new crater hole produced after the Mt. Barujari's eruption in June 1994.

Geological Setting

Geology

Van Bemmelen (1949) suggested that the northern part of Lombok Island is a continuation of the Solo Zone of Java Island. This zone represents the former top part of a geanticlinal belt, which broke off the south flank (represented by the Southern Mountains) and slipped northward. At the top part of the geanticline, granodioritic plutonic rocks were emplaced during the intra-Miocene phase of diastrophism. The basic roof part of such an intrusion is exposed on Java Island in the Jiwo Hills (west of Surakarta, Central Java), but farther eastward this older basement of the Solo Zone is not exposed anywhere. It appears in the western part of North Lombok, where the basic roof part of a plutonic intrusion is also exposed.

Geomorphology

According to van Paddang in Data Dasar *Gunungapi* (Kusumadinata, 1979), Rinjani is a composite volcano protruding high up at the northern part of Lombok. It is mostly composed of young volcanic rocks. The Rinjani cone (3726 m asl) is the steepest and highest peak in the area, consisting of mostly loose materials with a crater on its summit. To the west of this volcano, there is a caldera containing water which is elliptical in shape and is called Segara (Figure 2).

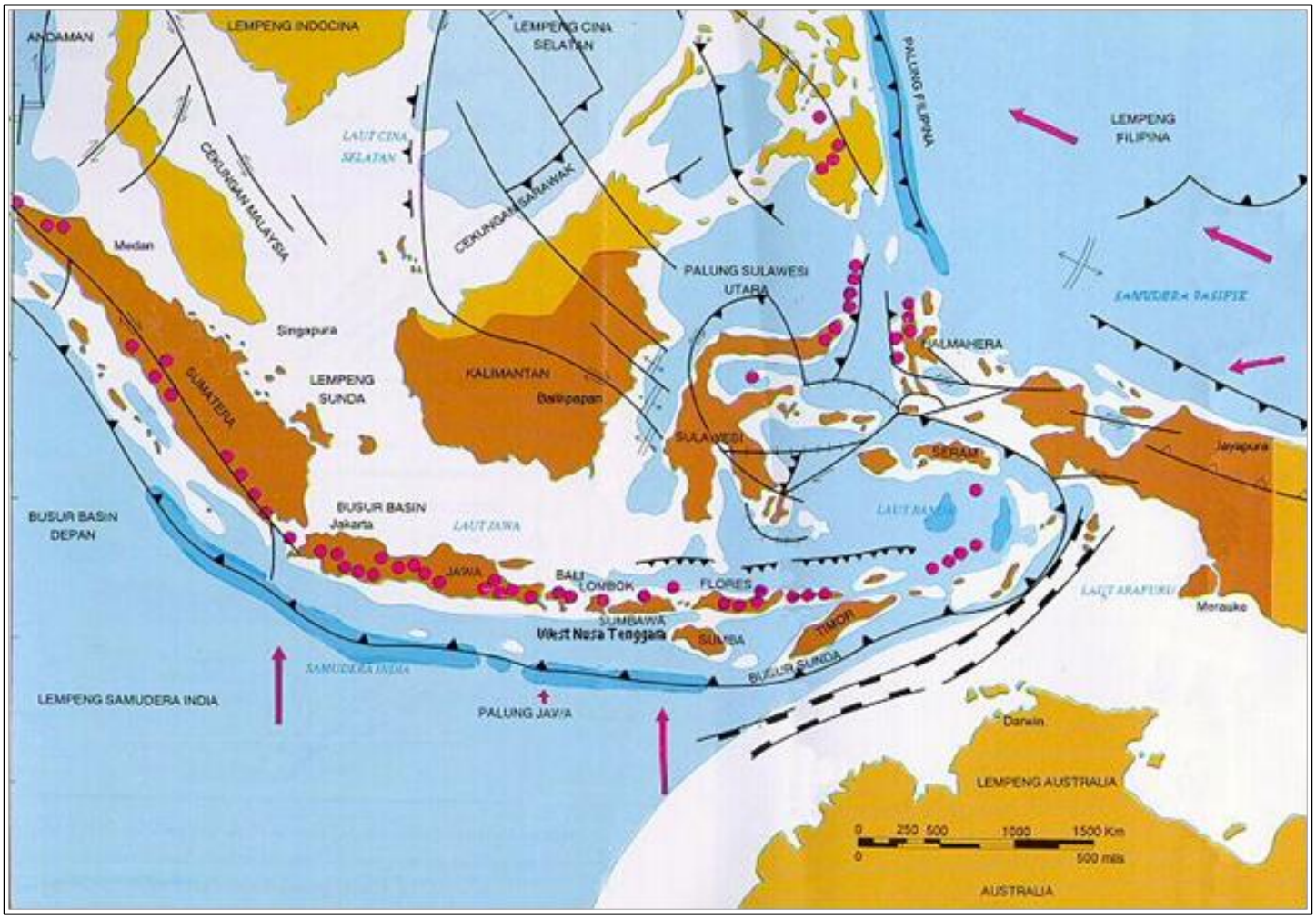


Figure 1. *Volcanoes in Indonesia*



Figure 2. *Calderas morphological unit of the volcano complex*

At the eastern part of Segara Anak Lake, there is a new volcanic cone called Barujari (2376m. asl), whereas to the west of it, there is another volcanic cone called Gunung Rombongan (2110 m asl). Both young volcanic cones are composed of lava flows and loose materials resulted from strombolian eruptions.

Other volcanic cones in the surrounding area are Mt. Kondo (2914 m asl) at the SW part of the calderas, Mt. Sangkareang (2914 m asl.) at the NW part of the calderas, and Mt. Plawangan (2658 m asl.) at the NNE rim of the calderas. In the northeast flank of Rinjani, there is a plateau called Sembalun Lawang, which is located at an elevation of 1000 m above sea level. Compared to the northern flank, the southern flank of Rinjani is more perfectly developed, while at the eastern and western flanks other old volcanic bodies bound the developments of Rinjani.

Stratigraphy

The stratigraphy of the Rinjani complex can be subdivided into units of eruption products that consist of several eruption sources, namely: Old Rinjani, Mt. Kondo, Mt. Sangkareang, Mt. Rinjani, Mt. Barujari, Mt. Mas and Mt. Manuk. Some of them, such as Old Rinjani, Kondo, and Sangkareang, no longer have craters because they were blown off during caldera formation. But, there are still indications showing that there used to be eruption sources, for example the eruption products, dykes, hot spring and alteration of the surrounding rocks (Hendrasto et al., 1990). In general, the eruption products are distributed to the northern and southern flanks, while to the east and western flanks the distribution is bounded by older Punikan and Anak Dare volcanic complexes.

Determination of the stratigraphic succession is based on lithological contact and super position of rock units. But, when a contact cannot be observed, the stratigraphy is determined by comparing lithology types and the degree of weathering and erosion. Distribution of the rock units was determined by using aerial photograph analysis.

Tectonics

Van Bemmelen (1949) interpreted the older basement of Solo Zone as the geanticline of East Java which re-appears in the western part of North Lombok. He suggested that the pattern of Java seems to end in this Island. The development of tectonic activity of Lombok was the result of an uplift, volcanic activity and intrusion.

It is inferred that the oldest tectonic activity in Lombok took place in the Oligocene and was later followed by submarine volcanic activity of basaltic andesite composition, resulting in deposition of volcaniclastic rocks of Pengulung and Kawangan Formations. These two formations interfinger each other. The volcanic activity took place until Early Miocene and during Middle Miocene, a postmagmatic-activity occurred in the form of dacite intrusion into the Pengulung and Kawangan Formations.

Petrology and Geochemistry

Based on petrographic and chemical analysis of some lava flows of Rinjani caried out by Santosa and Sinulingga (1994), there are some similarities between lava flows of Rinjani and those from the Java Island. Generally, these lava flows are porphyritic and have intergranular texture with plagioclase, pyroxene and olivine phenocrysts. For those that have intergranular texture, the pyroxene and olivine minerals are frequently found amongst the irregular and elongated plagioclase minerals. Apart from phenocryst, the plagioclase is also found as ground mass in microlite forms. This plagioclase is also often associated with opaque minerals, pyroxene and glassy ground mass. The crystals are generally subhedral to euhedral shaped. Based on the extinction angle of the albite twin and lots of zoning, they are mostly labradorite.

The pyroxene of Rinjani lava flows is mostly found as phenocrysts (20%), subhedral-euhedral crystals with prismatic shaped, simple twinning and poly synthetic, varing from ortho- to clino- pyroxene. The olivine minerals are subhedral-anhedral, and they are found as phenocrysts (in relatively small amounts ranging between 1-5 %). The olivine minerals are usually found between plagioclase minerals. The opaque minerals are found almost in all thin sections as the ground mass in anhedral crystals. From the thin sections it is found that the lava flows of Rinjani range between basalt-to basaltic andesite.

Chemical analysis of some rock samples of Rinjani volcano shows that silica content varies from 48.95 %-56.86 %. The TiO content is less than 1 % and there are only 2 samples sowing 1.02 % and 1.04 %, which indicate that the lava flows are characteristic of an island-arc lava (Santosa and Sinulingga, 1994).

Geothermal Energy

A geothermal field occurs at the Sembalun Lawang area, east-northeastern part of the Rinjani Volcano. The geothermal manifestation of Sembalun area is shown by the presence of hot springs and an altered volcanic zone. There are three hot springs found in the outer side of Sembalun calderas, while an alteration of volcanic rocks is found in the Sembalun lava flow unit, named Aik Orok altered zone. These three hot springs are Aik Kukusan, Aik Kalak and Aik Sebau.

The geothermal field is part of a volcano depression that resulted from calderas forming eruption of Sembalun volcano during pre-historic time/Early Quaternary (Sundhoro, 1992). This big eruption was characterized by its big volume of andesite pyroclastic flows associated with andesite-dacite pumice fall.

The collapse of the roof of magma chamber resulted in calderas structures that formed a ring fracture system. The Sembalun calderas have an elliptical shape which is 7km x 4 km in size, facing northwestward.

History of Mt. Rinjani Complex

Various reconstructions of the paleo-Mt. Rinjani Complex indicate that an old Rinjani volcano situated to the west of the present Mt. Rinjani, had existed with the height of 5000 m above mean sea level (Figure 3).

In the Pre-Quaternary time (>1.6 my), Rinjani area consisted of sedimentary rocks, then when volcanic activities occured in the Pleistocene time (<1.6 my), the mountain underwent volcano tectonic activities. As a result of intense activitiy in the form of huge and strong explosions (paroxysmal explosion) followed by the collapse of the mountain body, the mountain lost most of its body and the rest was left in the form of Segara Anak calderas. This was followed by the forming of Mt. Barujari, Mt. Rombongan, and the emergence of Anak Barujari Hill.

Mt. Barujari is 170m x 200m in size, with the height of 2296 - 2376 m, or appears approximately 600m over the calderas base. The latest eruption of this mount was in June 1994, which resulted in ash rain, lahar, lake water surface declined to 4 m and an increase in the water temperature from 18°C to 40°C for 3 months. As a result of heavy rain over its top part, the pile of ash and sand caused a lahar flood along the Tanggik River and approximately 31 people died, 7 people were badly injured, agriculture fields and dam were destroyed and irrigation ways were silted up.

There were eight eruptions since 1847, all of them in Rinjani (Segara Anak) calderas. Based on its history record, Mt. Rinjani has never erupted, so Mt. Rinjani belongs to the B-type of active volcanos. The types of eruption in Rinjani calderas were effusive (lava flows) and explosive (pyroclastic falls) which formed strato type volcano. Eruptions were recorded 8 times, i.e in 1847; 1884; 1901; 1905; 1915; 1944; 1966 and 1994 (Figure 4).

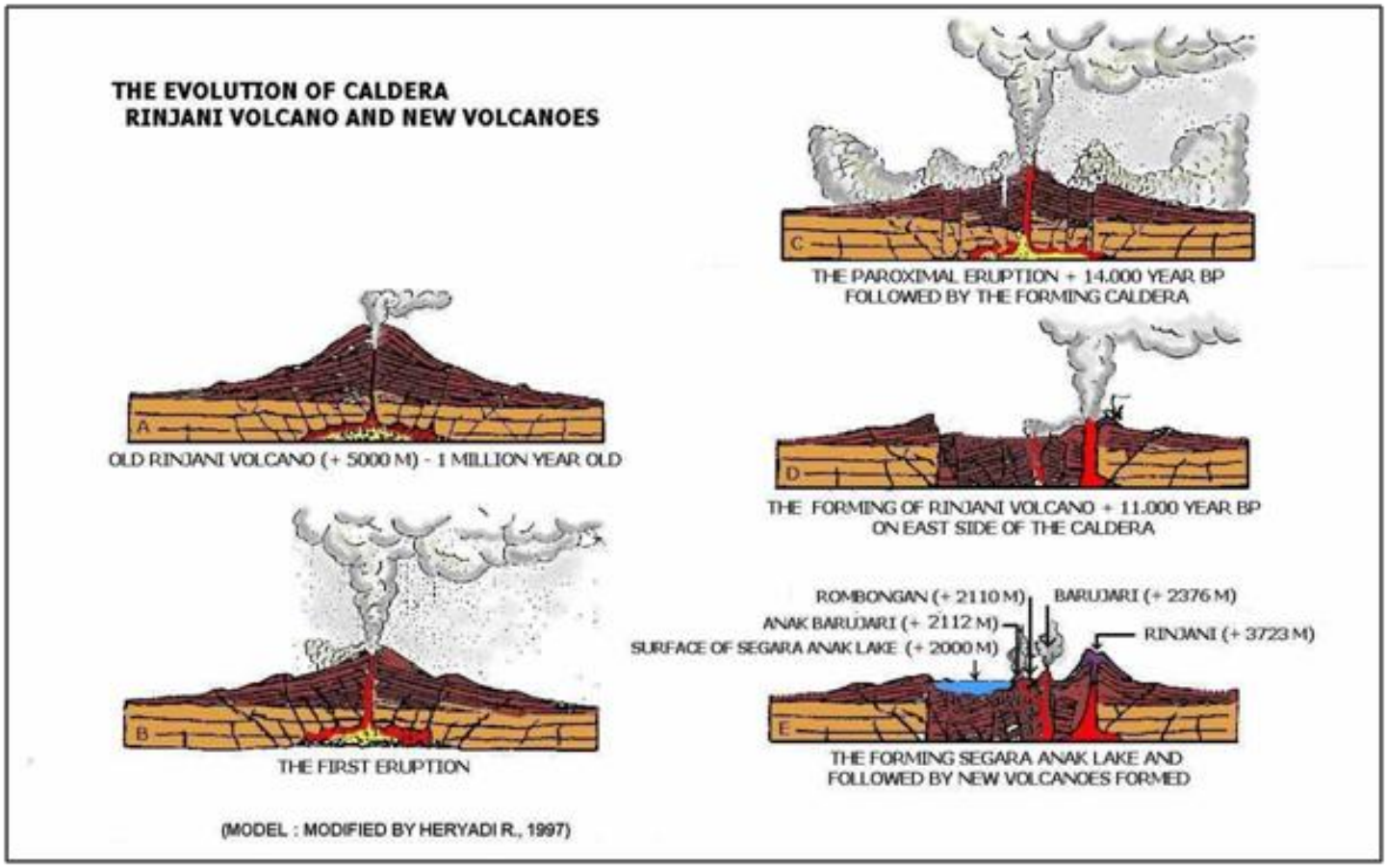


Figure 3. *Evolution of Mt. Rinjani*

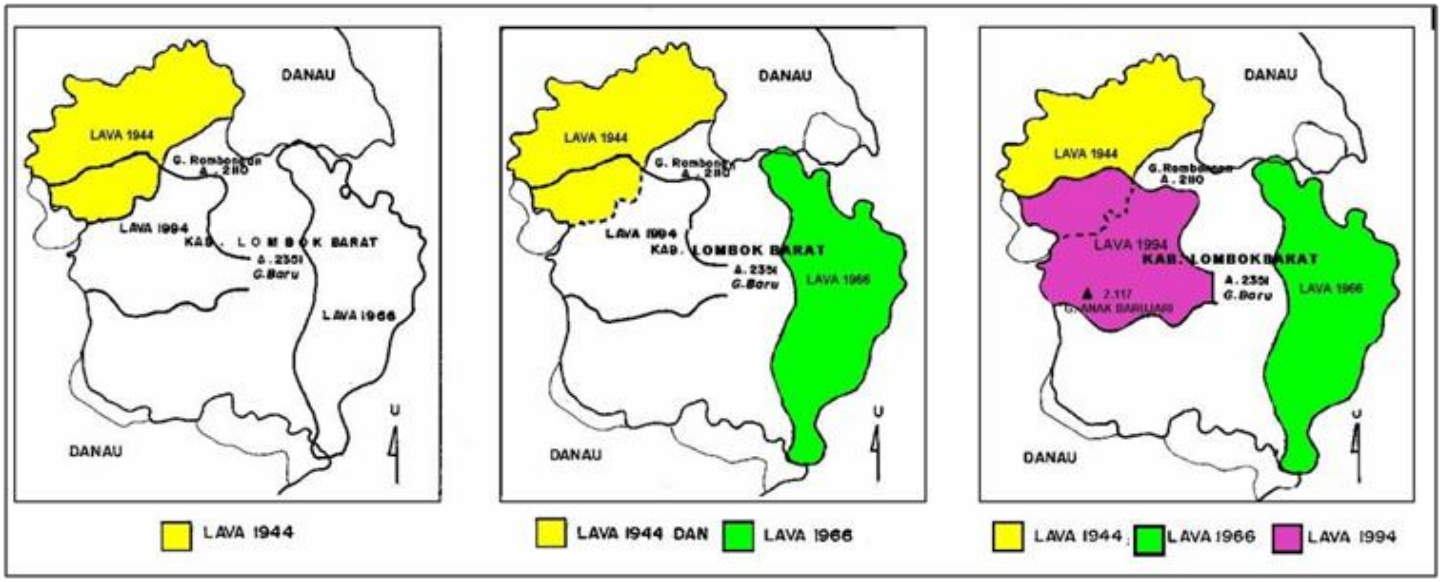


Figure 4. *Lava flows in Segara Anak Caldera in 1944-1994*

Only three explosions were recorded, *i.e.* in 1944, 1966, and 1994. The first explosion in 1944 formed the new cone of Mt. Rombongan, which emerged from the caldera's lake situated in northwest part of Mt. Barujari feet, which became wider to the north and west. The second explosion in 1966 produced lava, which came out from the eastern part of Mt. Barujari slope and reached the lake in the north and south. The last explosion in 1994 also came from Mt. Barujari, which produced lava in the west through the lake and caused the emergence of the Mount Anak Barujari and also resulted in the increasing of Mt. Barujari activities.

Volcano Tourism Potential

There are three relevant potential resources for volcano tourism in Mt. Rinjani that can be developed to be tourist destinations, that is geotourism/volcano tourism, flora/fauna and community development (Rachmat, 1998; 2001).

The Top/Calderas of Mt. Rinjani and Mt. Barujari

The highest point in the Mt. Rinjani area is situated in the eastern side of the elliptical Rinjani calderas (4.8 km and 3.5 km in diameters). When this point is seen from the distance, it appears as the top of Mt. Rinjani. The beautiful scene of Mt. Rinjani crater can be clearly seen from this point and a beautiful sea view can also be seen to the northern and eastern side.

Segara Anak Lake

The present crescent-shape of Segara Anak Lake lies at the height of ± 2008 m asl, which has an area of ± 11,126 ha and depth 160 up to 230 m, eventhough data measured in 1925 yields ± 250 m in depth. After the explosion in 1944, the lake depth measured in 1951 was 200 m, with the area of 11,000 ha as a result of silting of the lake (Figure 4). It is deduced that this occured because of sedimentation of rock erosion from the upper part of the crater and the other products of explosion. This lake/caldera historically occurred as a recent of huge explosion that formed a big hole and rain for a period of time filled the hole with water creating a lake called Segara Anak. Fishing activities are carried out in this Lake, because there is a huge number of fresh water fish like mujair and karper. The weight of a single karper can reach 4 kg. Residents and tourists travel around the lake by rowboat.

Waterfalls and Caves

There are three main waterfalls in the Kokok Putih River stream, *i.e.* near Goa Susu (Susu Cave), in Mayung Putih, and in the proximity to Segara Anak Lake (Figure 5). Another waterfall in Sendang Gile comes from Mt. Rinjani hills indirectly. The waterfalls along Kokok Putih stream are a result of stopped lava flow, and the height of these waterfalls depend on the thickness of the lava flow when it stopped. All of these places attract many tourists, particularly on holiday.

The 1944, 1966, and 1994 Lava Flows

The new lava flows that can become another tourist objects are the lava flow from Mt. Barujari which erupted in 1944, the lava flow of the 1966 Mt. Rombongan eruption, and the lava flow of the 1994 Mt. Barujari eruption. The lava shapes are sharp corners in blocks with deep holes with lava flows which have become and harden. It occured as a result of accumulation of gas pressure with magmas from the depth, which came out to the surface through weak zones or crater holes. Theoretically, if the gas pressure is very high, it will be accompanied by a huge explosion which throws out hot materials of ash with a size of about 12 m in diameter. If the gas pressure is weak, the lava just flows with temperature around 800°C.



Figure 5. *Susu Cave and Hot Spring*

Hot Springs
Hot springs are formed by surface water that flows deep down in the earth through cracks and contacts with magma, then the water rises to the surface as hot springs.

- Susu cave hot spring. This hotspring is situated at ± 1750 m msl with temperature of 52-45°C in ambient air temperature at 19°C and pH 6-7. The water is clear, steamy and has a bad smell like H_1S with spots of yellow sediments and sinters.

- Foot of Mt. Barujari. This spring has a temperature from 42.4-44°C and pH 7.6 with clear and bubbly water.

- Payung cave Pengekereman Umar Maya. This spring is found along the Kokok Putih River with a temperature of 50°C in 12°C ambient air temperature and pH 6-7. The water of the spring is clear, very steamy, with continuous and large amount of bubbles, and has orange and yellow colours of sediments (iron oxide) that might have arisen from basaltic andesite of lava blocks (Figure 6).



Figure 6. *Payung cave hot spring and small waterfall of Kokok Putih*

Cross Country/Wall Climbing/Glider Flying
The Rinjani complex can be reached from Mataram (the main city of Lombok) by car to Senaru (2.5 hours) or to Sembalun Lawang (3.5 hours) and continued on foot through several tracks from Senaru to Segara Anak Lake (9.5 hours) or from Sembalun Lawang to Segara Anak Lake (10.5 hours). The top of Mt. Rinjani can be reached out from two locations, i.e. from Plawangan Sembalun, which needs t 2.5 hrs, climbing and directly from Aikmel. However, the second one is very hard because this route is longer and people will not find any water. Other activities in Mt. Rinjani area can be wall climbing along calderas walls, which surround the Segara Anak Lake and glider flying from the top of Mt. Rinjani to Sembalun Lawang.

There are several routes when people want to tracking around the Mount Rinjani to get some experiences and enjoy the view of Mt. Rinjani and Segara Anak Lake. Some routes can be described as follows (Figure 7) :

North Route: Bayan - Senaru
Senaru - Pelawangan (north side of calderas edge) - Kokok Putih needs around 9.5 hrs. This is the easiest route with smooth slope and the best view of a new stream of lava of Babanan.

North northeast Route: Bayan - Torean
This more difficult route can be completed in a day from Bayan to the caldera base.

Southeast Route: Sembalun Lawang
There are two routes: Sembalun Lawang-Pelawangan-Summit; and Sembalun Lawang-Plawangan-Kokok Putih. These two routes need the same length of time to complete, which is around 10.5 hrs. Even though the second route is more difficult, people prefer to use this route because it is easier to reach the top of Mt. Rinjani.

Sajang Route
This route is similar to the Sembalun Lawang Route because the footsteps meet the Sembalun Lawang Route on the western side.

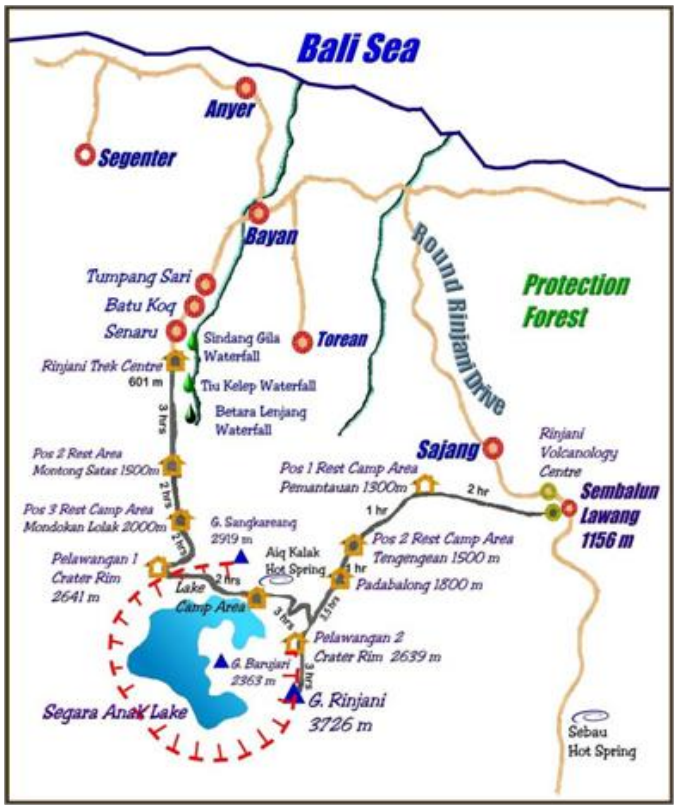


Figure 7. *The Rinjani Mountain Track*

Geothermal

A geothermal is formed by near surface magma sources that, due to the magma heat, reaching the surface through the weakness of the cracked earth. The heat can appear as steam, gas or a hot spring. There are five potential geothermal fields in Mt. Rinjani, all of them situated in Sembalun sub-regency East Lombok Regency. The fields appear as hot watersprings and fumaroles, *i.e.* in Sambelia, Aek Sebau, slope of Mt. Anakdare, and Putih River of Segara Anak Lake. All these five geothermal fields located between 1500 and 2500 m asl, an have temperatures ranging from 41°C to 47°C, debit 0,3 to 2 1/s and pH6 to 7.

The Geology and Volcano Information

The Volcano Observatory Station has been built in Mt. Rinjani area, situated in Sembalun Lawang. There are two guards in this post everyday in the shift of 24 hour. Their task is to monitor volcano activities visually and seismically (Figure 8). The station has been equipped with several monitoring and communication tools which are connected to the Directorate of Volcanology and Geological Hazard Mitigation in Bandung twice a day. This station also has been equipped with information, photos and maps such as the Dangerous Zone Maps of Mt. Rinjani, posters, and some photos related to the activities of Mt. Rinjani. This station is very important as supporting volcanotourism objective in which the tourists can get more detailed information about many things that relate to volcanoes.



Figure 8. *Rinjani volcano observatory and seismograph*

Flora and Fauna

Mount Rinjani National Park covers an area of 41.330 ha. The park is surrounded by a further 66.000 ha of Protected Forest. Mount Rinjani is rich in the variety of flora, fauna and vegetation types (Figure 9).



Figure 9. *Types of flora and fauna around Gunung Rinjani National Park*

Notable flora include the everlasting edelweiss flower *(Anaphalis viscida),* tiger orchid *(Vanda sp),* alang-alang grass *(Imperata cylindrica),* cemara tress *(Casuarina trifolia and Casuarina).* Wildlife found in the Park includes deer *(Cervus timorensis)* although they are hard to spot. Other mammals include black silver leafed monkeys or lutung *(Presbytis cristata).* Birds recorded in the park include eagles *(Spizaetus cerhatus) and white* cockatoos with yellow crests *(Cacatua sulphurea ocidentale).*

Community Development
The main objective of the Mt. Rinjani Management is to foster community development on park boundaries bringing about benefits to rural women and men, in recognition of the link between national conservation and local development goals. There are other objectives of the Mt. Rinjani Management.

Firstly, to improve park management through training, developing management techniques and improving infrastructure, secondly to develop responsible park tourism by encouraging ecotourism based on trekking and Sasak culture.

Because of its geographic position which is close to each other, Lombok and Bali have similar culture and arts, nevertheless, there are still differences either in arts, culture or the life of Lombok people. The *traditional house, music, earth wear, art pattern, traditional clothes and handy crafts of* Lombok are also different from Bali (Figure 10).

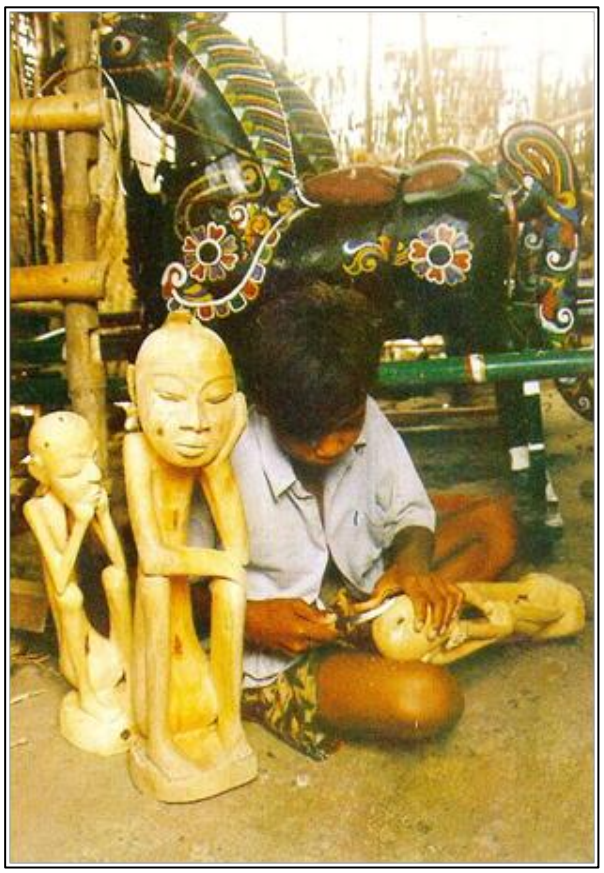


Figure 10. *Traditional Handicrafts and Art Patterns*

Conclusion

Mount Rinjani is the second highest volcano in Indonesia belonging to The `Ring *of* Fire'. The dramatic landscape has been created over millions of years *of* cone-building and violent explosions. Eroded forested slopes rising directly from the sea create their own weather patterns and become a catchment area for the whole Lombok.

Mount Rinjani complex has variations in its natural resources (natural heritage) such as various types of flora and fauna. It also has other enticing charms, the uniqueness and beauty of nature known as geotourism or volcanotourism. The combination of all these makes Mount Rinjani a fascinating potential for volcanotourism and a specific vulcanotourism and specific uniqe type of nature tourism which stresses on its volcanological and geological elements. Over twenty villages surround Rinjani and there are many routes up to the mountain, but the main acceses are from Senaru in the north and Sembalun Lawang in the east. The challenging three-day Rinjani track route from Senaru to the crater rim (Plawangan), down to the stunning crater lake then on to Sembalun Lawang, is considered as one of the best track in Soth East Asia. Those heading for the summit usually prefer to start in Sembalun Lawang. If you want to know one of the fantastic volcanos in the world, come to the Rinjani volcanoes in Lombok Island, and West Nusa Tenggara Province, Indonesia. I believe you will find something new about this volcano.

The main objective of Mt. Rinjani Management is to foster community development on park boundaries bringing about benefits to rural women and men, in recognition of the link between national'conservation goals and local development goal, based on an ecotourism programme.

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