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Ignimbrite Deposits Analysis to Understand of Paleovolcano Eruption Periods in Ngarai Sianok, Bukittinggi, West Sumatra

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ABSTRAK

Penelitian ini berlokasi di Cekungan Ombilin, Provinsi Sumatera Barat, yang merupakan salah satu cekungan yang berada pada jalur pegunungan (*intramountain)*. Cekungan Ombilin termasuk ke dalam struktur *full graben* yang merupakan hasil dari proses *tensional* pada Kala Eosen hingga Oligosen. Pada Kala Plio – Pleistosen terjadi perubahan regim gaya dari *tensional* menjadi *compressional* sehingga terjadi pengangkatan yang membentuk morfologi perbukitan hasil dari reaktivasi sesar-sesar Sumatera. Proses pengangkatan sangat dikontrol oleh reaktivasi sesar-sesar sebelumnya yang terus berkembang, kemudian dilanjutkan dengan adanya pergerakan sesar geser yang terjadi pada Kala Pliosen hingga Resen yang mengakibatkan terjadinya proses vulkanisme berupa letusan gunungapi, dengan material letusan yang menjadi sumber material endapan piroklastik ignimbrite di Ngarai Sianok. Sumber material endapan ignimbrite ini berasal dari Gunungapi Purba Maninjau yang berada pada arah Baratlaut dari Ngarai Sianok. Hal ini didasarkan atas arah kemiringan lapisan ignimbrite yang menunjukkan arah aliran lava. Kemudian berdasarkan keterdapatan kontak lapisan antara lapisan ignimbrite dengan lapisan endapan piroklastik dengan butiran yang semakin halus akan berperan sebagai pembatas periode letusan Gunungapi Purba Maninjau, sehingga dapat diketahui bahwa telah terjadi tiga kali periode letusan yang kemudian material letusan tersebut terendapkan di Ngarai Sianok, tepatnya pada cakupan wilayah lokasi penelitian.

Kata Kunci : Ignimbrite, Ngarai Sianok, Gunungapi Purba, Piroklastik

ABSTRACT

This research is located in Ombilin Basin, West Sumatra, which is one of the basins that were on the intramountain. Ombilin Basin is included in the full graben structure as the result of a tensional process in Eocene to Oligocene. In Plio - Pleistocene regime change from tensional into compressional resulting in the removal of which forms the hills morphology result of reactivation of the faults of Sumatra. The uplift process is largely controlled by the reactivation of the previous faults that keep evolving, then the process continues with the movement of the strike-slip fault that occurred in Pliocene to Resen that causes by volcanic eruptions, with the eruption material of the source material pyroclastic of deposits ignimbrite in Ngarai Sianok. The Source material of ignimbrite deposit is derived from Maninjau Paleovolcano which is located in the Northwest direction of Ngarai Sianok. It is based on the dip direction of ignimbrite layers that indicate the direction of lava flows. Then based on contact between ignimbrite layers and pyroclastic deposits with increasingly fine grains will act as a limitation period of Maninjau Paleovolcano eruption, so it is known that there have been three time periods of the eruption deposited in Ngarai Sianok, precisely on the location of the research.

Keywords: Ignimbrite, Ngarai Sianok, Paleo volcano, pyroclastic

INTRODUCTION

Ngarai Sianok is a geological phenomenon formed from the paleovolcano activity that has a very wide area coverage, with its constituent rock lithology that dominated by fine grained pyroclastic rocks known as ignimbrite deposit. Ignimbrite deposit have the characteristic of brittle and coherent, so that in some places this ignimbrite deposit was easy to crack and collapse then would form the valley with steep and deep walls (Poedjoprajitno, 2008). Verstappen (1973) says that Ignimbrite deposit in the research area which is derived from the Paleovolcano eruption activity of Maninjau is located approximately 20 km to the Northwest of the research area. The age of Ignimbrite deposit which is located in Ngarai Sianok is older than the age of the deposit in Merapi Volcano, Tandikat and Singgalang. It is based on the approach morphostratigraphy indicating that precipitated Merapi Volcano, Singgalang and Tandikat be a cover to partially ignimbrite deposit of Maninjau. In the research area, the presence of ignimbite deposit is expressed by plateau landscape which strongly scratch with steep and wide valley walls. The purpose and goal of this research was to determine the number of periods eruption that occurred in Sianok Valley, precisely at the coverage area of this research .

METHOD AND DATA

Based on the purpose of the research, the way to find out the period of explosion that happened is by study of the volcanic stratigraphy, sedimentology and geochronology of eruption product, it is based on literature review method and field observation about the stratigraphy of Maninjau Paleovolcano eruption product. Field data collection is done by the making of volcanic stratigraphy and the collection of Maninjau Paleovolcano eruption rocks.

Geo Volcanology

The research area is included in padang geological map with scale 1:250.000. The oldest rocks that is exposed in this area is phyllite, limestone, granodiorite, and diabast in range of Paleozoicum until Tertiary. There are some types of volcanic rock that's located in this area, like basalt, andesite, breccias tuff, breccias lahar, and tuff pumice. Tersier magma activity occurs sporadically identified by the tuff pumice deposition that arranged of acid, rocks intrusion, and lava that arranged from ryolite to dasite spread in almost of big fault sumatra zone. The quarter

volcano activity that arranged from acid in this research area is in big fault sumatra zone. The existance of pyroclastic flow that is in Padang Plateu, especially in research area is strongly connected with volcanical activity an big Fault Sumatra Zone (Van Bemmelen, 1949; Westerveld, 1953).

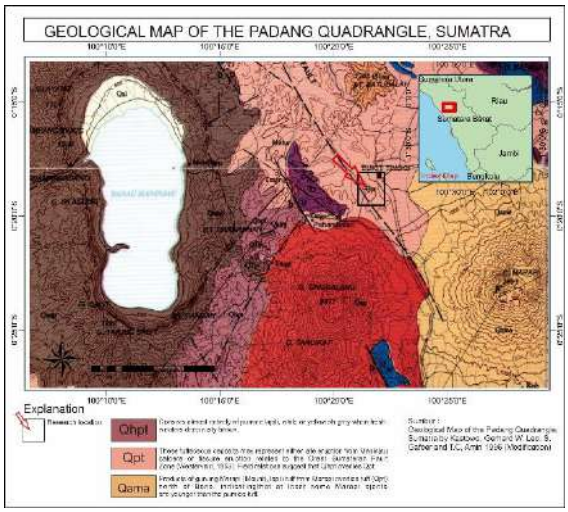

Figure 1. Geological Map of Research Area

The Result Data Of Observation Location

Based on the field data which obtained in 4 observation location with the stratigraphy sequencing which has the different characteristic. The following will be attached the trajectory map (figure 1) also with the data which obtained in every observation location.

Observation Location 1

Stratigraphically, the lithology which found in the first observation location is the tuff with really fine grain texture and composed by the biotite mineral, the thickness of tuff bedding which is exposed is 60 cm, then above of the tuff bedding there is a ingnimbrite bedding which is deposited parallel with the pumice fragment and basalt also composed of biotite, quartz, a little pyrite and also the trace of gas flow (figure 2), the thickness of this ignimbrite bedding is 5,9 m. in this ignimbrite lithology found the inset of lava flow with the coarse texture and reddish color (figure 3), the thickness of this lava flow bedding is 1,5 cm with the orientation of N 095^0 E/15^0 SW.

Figure 2. Gas Pipe Structure

Figure 3. Strata Contact between Tuff Layer and Ignimbrite with Lava Inset

Observation location 2

On this second observation location composed by the ignimbrite bedding (figure 4) with the pumice fragment and basalt which is lesser than the first observation location. The fragment whih is located in this ignimbrite bedding is having the different size, from smaller gravel into bigger gravel.

Figure 4. Stratigraphy of Observation location 2

The thickness of this bedding is 5,5 m, above this ignimbrite bedding deposit as parallel the tuff bedding with the fining up texture. The tuff bedding which is composed by the rhyolite fragment and basalt, the thickness of this tuff bedding is up to 10 m. around this observation location found some charred wood (figure 5). Below the cliff of this second observation location found the scree fan with the material source of tuff bedding which have been experienced landslides.

Figure 7. Charred Wood

Observation location 3

In this third observation location which done in the cliffs found the same characteristic. The first cliff in this observation location with the cliff in the second observation location separated by the big fracture which cleave the cliff into the west with the steep fracture plane (figure 8).

Figure 8. Normal Fault Structure

In the first cliff of third observation location composed by the tuff bedding with the inset of volcanoclastic deposit. The tuff bedding is having the fining up texture with the thickness up to 2,5 m which composed by the fragment of basalt and rhyolite. The volcanoclastic deposit which is located in the first cliff is conglomerate with the tuff matrix and the fragment of basalt with the vary diameter from the smaller gravel into the bigger one, the thickness of volcanoclastic deposit is up to 85 cm. the observation in the second cliff is having the same stratigraphy variable which is the tuff bedding with the inset of volcanoclastic deposit. The tuff deposit is having the fining upward texture with the thickness almost reach 20 m and having the same fragment as the first cliff which are basalt and rhyolite.

The volcanoclastic deposit which located in the second cliff found there is a geological structure which is the fracture in the tuff bedding and it is parallel with the cliff. Then based on the observation in the third cliff which having the same characteristic of stratigraphy variable as the cliffs before in the observation location three. The tuff bedding in the third cliff is having the same texture as the cliff before but it has the different thickness which is up to 4 m, with the basalt and rhyolite as their fragment. Volcanoclastic deposition in the third observation location is role as the scouring of tuff bedding because of the distribution of this deposit which is not distributed widely and also interrupted, then in the third observation location also found the sedimentary structure of lamination. Generally, the fragment size of volcanoclastic deposit from the first cliff to the third cliff is getting smaller with the bedding which also getting thinner and then disappear (figure 9).

Figure 9. Volcaniclastic Deposit with Small Volumetric in Tuff Layer

Observation location 4

In the fourth observation location as the stratigraphy variable, composed by the ignimbrite and tuff bedding (figure 10). The ignimbrite bedding in this observation location is composed by the pumice and basalt fragment with the thickness of ignimbrite bedding up to 2 m. in this ignimbrite bedding also has the relatively gentle in sloping but tend to have the great sloping, this thing also supports by the mineral alignment in the ignimbrite bedding which has the more appropriate alignment direction with the slope of ignimbrite bedding (figure 11).

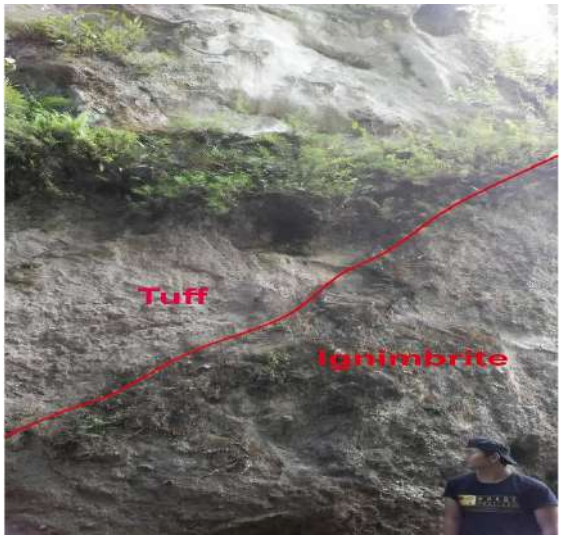

Figure 10. Contact Between Ignimbrite and Tuff Layer

Figure 11. Material Alignment

On the lower part of ignimbrite bedding there is a volcanoclastic deposit which formed by the deposition process from the river activity nowadays, the volcanoclastic deposit is consists of the basalt fragment which has the relatively small size and also contain the sedimentary structure which is the convolute lamination (figure 12). On the upper part of ignimbrite bedding laid a tuff bedding which is fine and compact with the thickness of bed up to 4 m.

Figure 12. Convolute Lamination

Volcanic Facies

Volcanic facies is rock deposition type that is resulted from volcano explosion arranged by explosion type, deposition, and erosional process. The difference of volcanic facies is based on litology, grain size, sedimentary structures, texture, and genesys. In volcanic facies, the main litology identification is lava, piroclastic, and epiklastik (figure 13).

- The Volcanic Core Facies

  The volcanic core facies is characterized by lava intercalation, ash fall, and colluvium. The composition of lava and ash is started from andesite until basalt olivin range, it is depend from eruption and volcano type. Very poor sorting and this deposition often contain lumps of angular size that is very diverse.

- Proximal Facies

  This facies is characterized by deposition result of volcanic eruption like breccias pyroclastic flow, pyroclastic fall, inset of lava flow, and medial facies intercalation with lahar presence.

- Medial Facies

  This facies is characterized by the abundance of lahar deposit and conglomerat, coarse sand with pyroclastic fall layers (medium to fine grain range). There is lava flow in volumetric small amount.

- Distal Facies

  This facies is characterized by domination of fluviatil epiklastik deposit, lahar deposit, and redeposit from volcanic product of medial facies, proximal, and core facies. Generally this rock facies shows the characteristic of epiklastik deposition with fluvial deposition dominated or swamp.

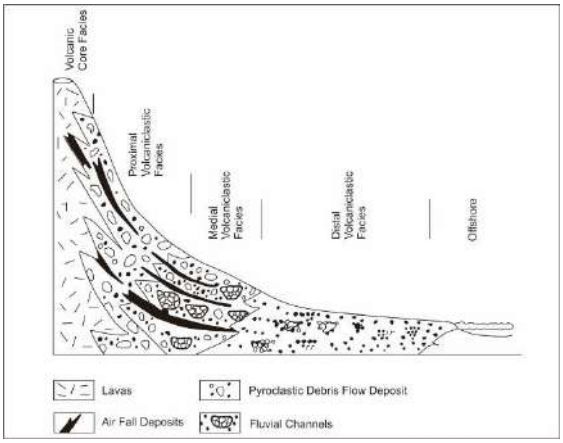

Figure 13. Sedimentary Facies with Difference Characteristic (Vessel and Davies , 1981)

RESULT AND DISCUSSION

The Period of Paleovolcano Eruption in Ngarai Sianok

The research zone which is located in Ngarai Sianok was composed mostly by the pyroclastic deposition which is the unit of tuff and ignimbrite and it is originally from the Ranau Formation, Ombilin Basin. Generally, the tuff in the research zone is having fining upward texture, sometime we can find the inset of volcaniclastic inside the tuff bed in the form of conglomerate with the fragment composition sometime originally from the igneous rock of basalt and rhyolite. After that, the ignimbrite in the research zone composing the pumice fragment and also basalt with the various size, from small gravel till the bigger gravel. In the volcaniclastic deposition of research zone can be find some of the sedimentary structures, namely parallel lamination, bedding, scouring and also the convolute lamination, the establishment of the structures are the result of sianok river current. Westerveld (1953) in Kastowo et al (1996), stated that the tuff deposit probably came from the last eruption of Maninjau caldera or the slit eruption in conjunction with the Sumatra Fault lines. The result of the observation in pyroclastic deposit in the research zone, can be obtained the three periods of paleovolcano eruption, based on the appearance of ignimbrite deposition which role as the beginning of

deposition process in one period, meanwhile the appearance of tuff deposit with fining up texture take the roll as the last of deposition process in one period (figure 14).

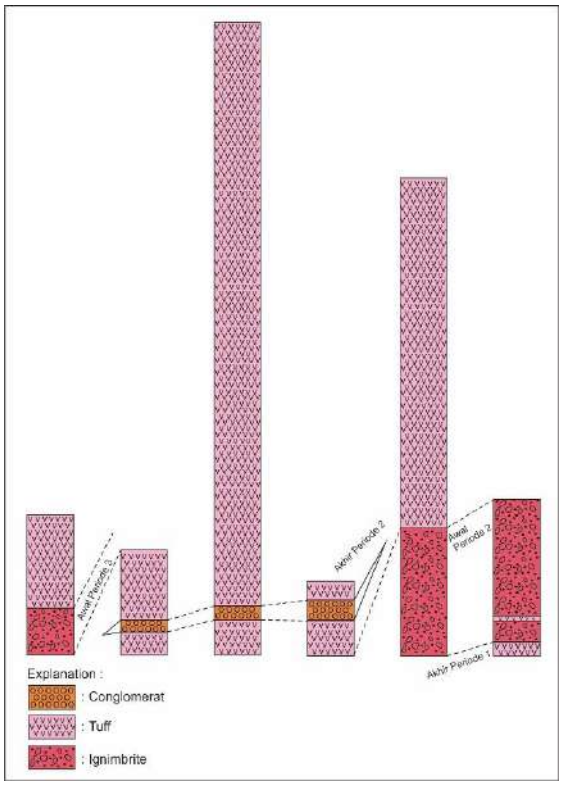

Figure 14. Stratigraphy Column and Depositional Periods in Ngarai Sianok

First Period

In this first period, we did not find the intact stratigraphy unit in one period, only the last deposition which characterized by the tuff with fine texture (figure..). The ignimbrite bedding as an initial limit of deposition process can't be found because the bedding is not exposed on the surface.

Second Period

In this second period found the intact stratigraphy unit in one period characterized by the ignimbrite bedding as the initial limit of sedimentation process which contact with the tuff bedding whis has the fining up texture as the lower limit of sedimentation process. The ignimbrite deposit has the pumice fragment which spread unevenly in the body of rocks and pumice which having the diameter size varying from the small gravel till the bigger gravel. The slope of ignimbrite deposition is relatively ramps, this thing is based on the appearance of lava flow which indicating the morphology of surface flow with the orientation of N 095^0 E/15^0 SW, based on that orientation, obtained the source of material is coming from the Maninjau Paleovolcano which located in the West area of research zone (figure 15) . The tuff bedding in this period is having the fining up texture. The tuff is originally from the paleovolcano which is Maninjau. Selby (1985), stated that the process of ignimbrite establishment is a part of the volcano eruption which produce the pyroclastic flow deposit with the type of nuees ardente and the flow of ash with pumice. The flow of heat gas which intruding from the crater with the high speed, transporting tepra to some kilometer inside the atmosphere. After that the heat flow which is trapped in the atmosphere forming the convection current, consequence the hot clouds which is continuing to soar. The part of the hot clouds which create the rocks fragment with the higher concentration than the air around which cause the loss of heat and the material in the cloud will fall, flowing with the high speed down the valley, as the lowest deposit in the whole ignimbrite unit. The continuity of ignimbrite bedding in this period is separated by the steep cliffs and controlled by the structure of geology such as normal fault, this thing is based on the condition of steep cliff, which interpret as the fault plane. In this period also found the volcaniclastic deposition such as conglomerate inset which nature as the grinder (scouring) against the tuff bedding, this thing is based on the spreaders of conglomerate bedding which is if we see from volumetric is experiencing the depletion layer.

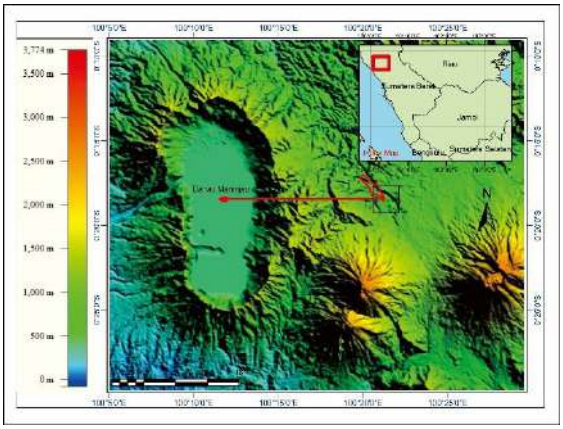

Figure 15. Research Area Location Based on DEM

Third Period

We found the stratigraphy unit in this third period but in incomplete condition in one periode, this thing be marked by the appearance of ignimbrite bedding as the initial limit of sedimentation process which followed by the deposition of tuff bedding with the coarse texture so there is no the lower limit of deposition in this period. The characteristic of ignimbrite in this period is much more similar with the ignimbrite in the second period, the difference is only at the slope which relatively more steep because the current product is truly controlled by the topography which follows the shape of valley and the spread of valley, beside controlled by the distance from its source, this thing also supported by the appearance of mineral alignment which has the most suitable direction of the alignment with the slope of ignimbrite bedding. The pyroclastic deposit in this period associated with the river deposition, at the lower part of ignimbrite bedding found a convolute lamination which caused by the pressure from the bedding layers above.

The Ignimbrite Characteristic of Ngarai Sianok

The distribution of ignimbrite in ngarai sianok located under 20 km from the Maninjau volcano. Ignimbrite

bedding separated by the steep cliffs which located in the Ngarai Sianok and then there is influence of normal fault so that the continuity of ignimbrite bedding in Ngarai Sianok is vary widely. The Maninjau ignimbrite characteristics more homogeny and composed by the pumice fragmen and the volcano stone (lytic) fragment from many grain size, in the mass basis of crystal and glass. The ignimbrite deposit differentiated by the characteristics when the eruption happens and also the typical of clastic sedimentary structure from the volcano. The condition of deposit is relatively different which influenced by the distance when the eruption happen. The observation of ignimbrite bedding in this research zone found the remnants of charcoal and the trace of gas flow (gas pipe structure) which form after the eruption and experience the deposition process. In the ignimbrite bedding found some inset of lava flow.

Volcanic Facies of Ngarai Sianok

Volcanic facies in ngarai sianok is a medial facies if we see from the location of ngarai sianok which around 20 km from the center of Maninjau Paleovolcano eruption. Pyroclastic deposit in Ngarai Sianok associated with the River Sianok deposit so that the sequence deposit exposed with the appearance of sedimentology structure such as convolute lamination, parallel lamination and the scouring. Beside of that, there is another characteristic which is the conglomerate with the thickness from 50 – 85 cm as the inset of pyroclastic deposit in Ngarai Sianok, but the appearance of conglomerate as volumetrically thinner. There is also in the research zone as the characteristic of medial facies that is the inset of lava flow with the slope relatively gentle. The thickness of pyroclastic deposition in this research zone are so varies which caused by the character of pyroclastic deposit which is fragile so it will easily eroded.

DISCUSSION

Based on the data in the research zone of Ngarai Sianok discovered the normal fault structure which shown by the cliff wall which is steep and with the parallel structure against the cliff it also cleave the cliff to the west, the fractures which located in this wall interpreted as the fault plane, this statement also support by the older research which done by Tjia (1977) and Katili (1967) in Poedjoprajitno (2008) which mention that the sumatera fault are consist of 18 segments, one of the segment was the sianok segment which is located in our research zone. But in the determination of fault type is only based on the geomorphology approaching whereas for the geological structure approaching can't be done because there is no any slickenside structure. After that in the research zone there is the volcaniclastic deposition which located in the second period as the inset (scouring) against the tuff bedding not as the period limit but this statement is not support by the Poedjaprajitno (2008) which stated that the volcaniclastic deposition as the limit of period which after that in the lower part of volcaniclastic deposition as the first period and the upper part of volcanoclastic deposition from the second period, but based on the our data, the volcaniclastic deposition only role as the scouring, this thing based on the distribution pattern of volcaniclastic deposition which volumetrically not really wide, and this also supported by the characteristic of tuff bedding which flanked the volcaniclastic deposition and having the same characteristic. Beside of that the determination of one period also based on the appearance of ignimbrite deposition as the initial limit of depositional process from the pyroclastic flow rocks and followed by the tuff deposition which has the fining up texture that role as the upper limit from the last of depositional process in one period.

CONCLUSIONS

Based on the results of data processing, it can be concluded that the research sites included in the Ombilin Basin with material sediment basin comes from Ranau Formation. Furthermore, based on stratigraphic studies obtained three times the period of the Ancient volcanic eruption that occurred at research sites, then material of the eruption deposited on the area of the research sites. The first period was marked by the presence of tuff which serves as the upper limit of the first period and the second period was marked by a sequence stratigraphy as a whole starting from the bottom up of ignimbirite layer to fining upwards of tuff layer, then in the second period found normal fault structure, so that the ignimbrite layer in this second period does not look constantly, found the presence of the matrix deposition volcaniclastic with tuff and basalt fragments with thinning the layer towards the Southeast. Furthermore, the third period is characterized by the presence of the ignimbrite layer in the bottom and then the layer of tuff deposited on top. Directions deposition of these three periods can be seen by the presence of lava flow contained in the unit of the second period, with the position of a layer of lava flows of N 095^0 E / 15^0 SW so that it can be seen that the direction of deposition of these three periods is derived from the West and if we make a straight line in map, we can be determined that the source material is derived from the Maninjau Paleovolcano.

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