Indication of Hydrothermal Alteration Activities Based on Petrography of Volcanic Rocks in Abang Komba Submarine Volcano, East Flores Sea

Gejala Alterasi dari Kegiatan Hidrothermal Berdasarkan Petrografi Batuan Beku Volkanik di Gunungapi Bawah Laut Abang Komba, Laut Flores Timur, Indonesia

Lili Sarmili[1] and Johanes Hutabarat [2]

[1] Marine Geological Institute, Email: lsarmili@yahoo.com

[2] Department of Geology, Padjadjaran University

(Received 25 June 2014; in revised form 10 November 2014; accepted 04 December 2014)

ABSTRACT : The presence of mineral alteration or secondary processes to rocks on submarine volcano of Abang Komba was caused by an introduction of hydrothermal solutions. Those are indicated by the presence of a resembly of minerals alteration seen in their petrographic analyses. They are characterized by replacement partially surrounding of plagioclase phenocrysts, partially replacing plagioclase by sericite, carbonate and clay minerals. The replacement of pyroxene partly by chlorite, and the presence of albitisation (secondary albite) contained in fine rectangular plagioclase sized. Other fitures occasionally observed by the presence of partial oxidation of ore minerals and the presence of quartz, and epidote as an alteration from plagioclase and pyroxene.

Keywords : alteration, resembly of minerals alteration, oxidation, submarine vulcano of Abang Komba.

ABSTRAK : *Gejala alterasi atau proses-proses sekunder yang terjadi pada batuan di gunung bawah laut Abang Komba adalah disebabkan oleh introduksi larutan hidrotermal. Semua ini ditunjukkan dengan kehadiran kumpulan mineral ubahan yang terlihat dalam sayatan batuan. Kumpulan mineral ini dicirikan dengan adanya penggantian sebagian yang mengelilingi fenokris plagioklas, penggantian sebagian plagioklas oleh serisit, karbonat dan mineral lempung. Penggantian sebagian piroksen oleh klorit, dan adanya gejala albitisasi (albit sekunder) yang terdapat pada plagioklas berbentuk balokan yang berukuran halus. Gejala lainnya yang kadang-kadang teramati adanya oksidasi sebagian dari mineral bijih dan hadirnya kuarsa, serta epidot sebagai hasil ubahan plagioklas dan piroksen.*

Kata kunci *: alterasi, kumpulan mineral ubahan, oksidasi, gunung bawahlaut Abang Komba.*

INTRODUCTION

The study was based on the rocks samples which are described microscopically on the Abang Komba submarine volcano, Flores Sea, East Nusa Tenggara, Indonesia.

The aims of study is to determine the variation in texture and mineralogical composition, and also to obtain information about the secondary processes in each rocks. Rocks samples are generally taken from the coordinates between 123^{o} 43' 12 "- 123^{o} 54' 00" E and 07^{o} 55' 12 "- 08^{o}04' 48" S (Figure 1), within the territory of East Nusa Tenggara province.

From the results of the study in 2003 and subsequent years, based on bathymetric survey, we found 3 submarine volcanoes that extends to the southeast from the active Komba volcano island, i.e, Baruna, Abang and Ibu Komba (Sarmili et.al., 2004). The peaks of Baruna Komba has a depth of about 100 meters below sea water, Abang Komba has a minimum depth of 150 m, and Ibu Komba has a depth of 900 m.

Komba ridges is one of the underwater volcanoess in northeast Flores island which are known to have the hydrothermal potential. Many data of hydrothermal mineralization in the submarine volcano has been proven based on previous rock samples, especially in the Abang Komba volcano.

REGIONAL GEOLOGY

Eastern Indonesia is characterized by the presence of subduction-collision system of the Sunda-Banda island arc that produces the situation very complicated tectonic plate where the three main crust of the Indo-Australian-Eurasia-Pacific are collide together (Hamilton, 1979). Volcanic-plutonic belts are consists of 14 main complex of magmatic arc which spread along the edge of the crust Sundaland craton from Eurasian continent to the north edge of the Australian

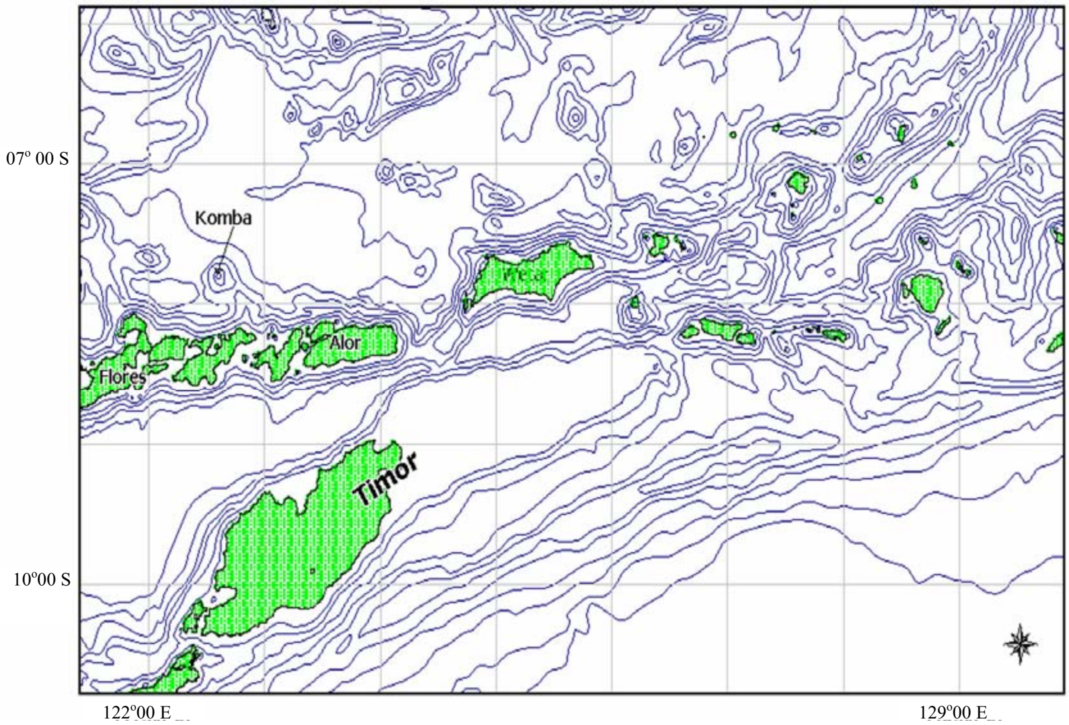

Figure 1. Location of the study area

continent. The magmatic arc formed continental crust and oceanic crust. The arc produce subduction, collision obduction, arcs-arc collision and arc-continent, rifting and transcurrent faults (Hamilton, 1979). The eastern part of the Sunda-Banda edge collisions is in the transition region starts from the Indian oceanic crust subduction system in Java trench up to the area of the collision between the thick Australian continental crust with southern Banda arc. Among these subduction and collision zones there is a transition zone whereas the Scott platform is a thin continental crust (McCaffrey, 1988). This transition zone is allegedly dominant with collisions compared to subduction system. Sunda-Banda island arc generated by the tectonic process also forms part of the southern and eastern edge of the Flores-Banda basin (Silver, et al; 1983) that geologically formed the back arc basin of younger age. In this area of the island arc of active volcanoes have been cut and shifted by a large shear fracture system.

Furthermore, according to Sarmili, et al., (2003) found that liniasi northwest-southeast trending dominate and characterized by the lineament of volcanic ridges from volcanic Komba (island of Batutara) to Ibu Komba submarine volcanoes.

The NW – SE directions of lineation is thought be older than other lineation around the area. This old lineation is estimated as a deep faults and open and eventually penetrated by volcanoes as well as Komba ridges.

Direction of northwest-southeast structure is interpreted has been cut by younger faults in the opposite direction, ie., NE-SW. Perhaps this fault system can be called transtension fault that is between the strike slip fault and the normal fault (extension). The existence of these structures were alleged that resulted in the emergence of mineralization and alteration of minerals.

Therefore, these two parts of southeast and eastern segment are productive magma chains and they are associated with rocks that have excellent water permeability so that a suitable place in the geological conditions for the development of hydrothermal mineralization potential.

METHODS

All materials research in relation to petrographic studies are in the form of igneous rocks samples where by using the method of dredging and grab sampler from Abang Komba submarine volcano. Map of sampling location of Abang Komba submarine volcano (Figure 2) at depths ranging from approximately 130 m or deeper below the sea water.

The problem solving is done through petrographic studies by examining the thin section of rock using a polarizing microscope (10 to 40 times scales). The main references used in the work of petrographic studies of

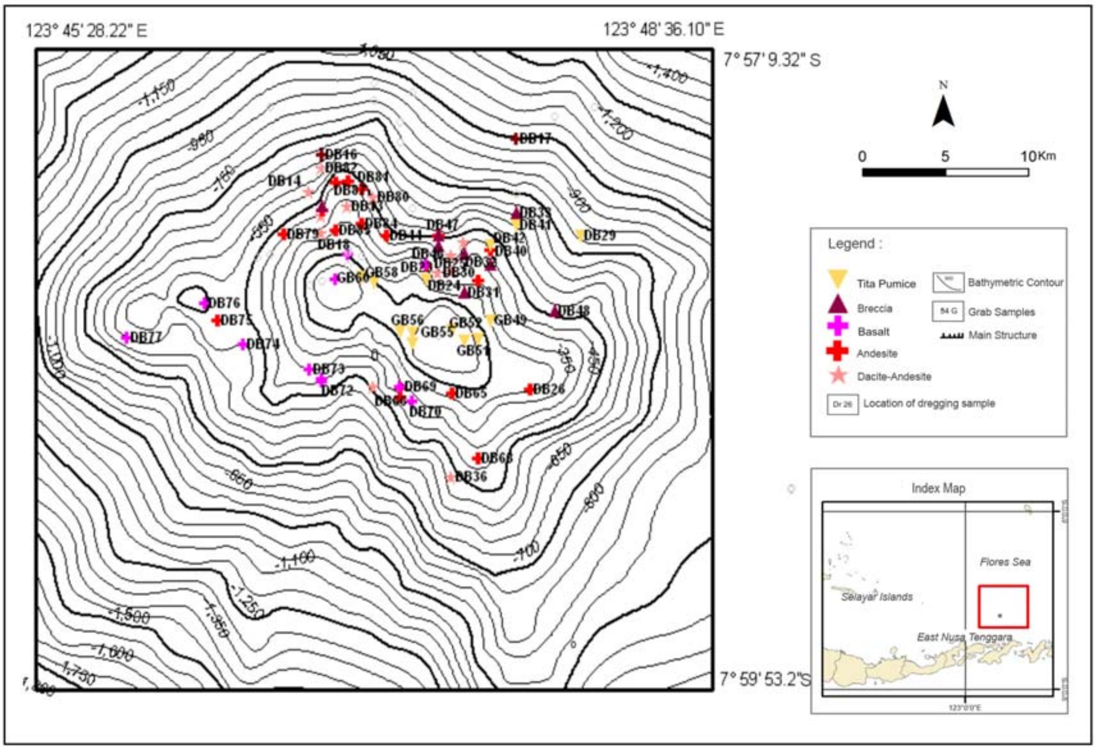

Figure 2. Map of sampling location of the study area

igneous rocks are Kerr (1979) and Mc. Kenzie, et al (1982) and Gill (1981) for descriptions of the optical properties of minerals as well as to the appearance of the texture.

RESULTS

Megascopically the rock is generally characterized by light grey to dark grey-brown with white spots and greenish-green or reddish in color, showing porphyritic texture with mafic and felsic minerals phenocrysts scattered in the form of fine microcrystalline. In some rocks samples are evident of dark brown to greeenish grey groundmass with dark greenish to pale patches as secondary minerals. Based on that megascopic appearance, then all samples in the study area can be grouped as andesitic, dacitic to basaltic lava.

Alteration

Generally, alteration minerals on Abang Komba summarine volcano is not too much different from other hydrothermal activity area, which according to Evans (1987), the rock is relative intermediate to basic, usually will indicate the type of alteration of chloritisation, carbonatisation, serisitisation, piritisation, and propilitisation. Most of these types are found in the study area, along with the type of alteration that is often found in the transition between the acid to intermediate rocks, namely argilitisation and silicification.

Results of Bandamin II expedition (Halbach et al., 2003), both northern and southern of Abang Komba showed concentrations of sulfide rocks with varying degrees of alteration. From the pattern of distribution of various alteration rock can eventually be made boundaries of minerals zoning system. In particular, the rocks that are propylitic (rich in green chlorite) in the north Abang Komba submarine volcano shows as the exterior of a hydrothermal alteration processes. Furthermore, the occurrence of barite mineral (Halbach et al., 2003), indicate a continuation of eastward hydrothermal deposit. The presence of anoxic mud stones rich in pyrite mineral clearly shows a rising hydrothermal emission center, which is located in the hole filled by rock fragments (detritus). They are also noticed that rock samples obtained indicate of epithermal temperatures ranging from 100^{o} to 200^{o} °C and is derived from the depth of between 400 and 600 meters.

The occurence of alteration or secondary process due to introduction of hydrothermal solution that occurs in rocks in the study area (Figure 3) are indicated by assemblage of minerals altered seen in thin section. They are characterized by the partial replacement of

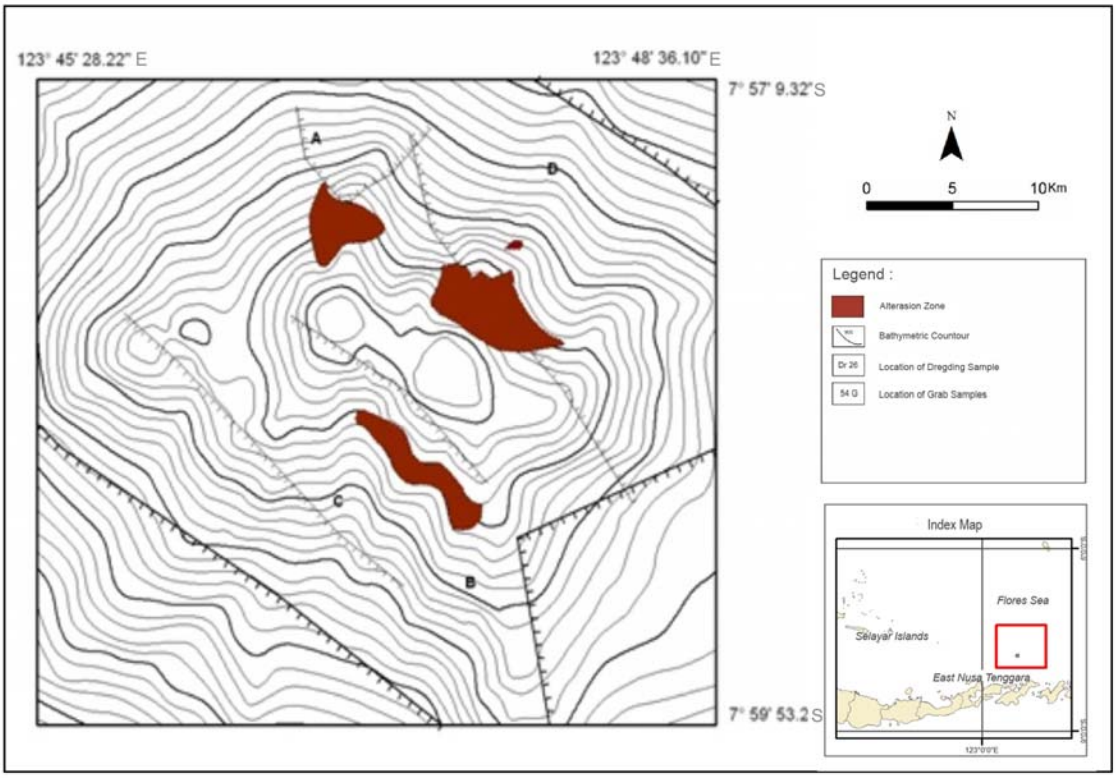

Figure 3. Map of indicated alteration zone.

most of the surrounding phenocrysts of plagioclase, partial replacement of plagioclase by sericite, carbonate and clay minerals; partial replacement of pyroxene by chlorite, and indication of albitatition (secondary albite) occured at rectangular shaped of plagioclase in fine size. Other indication observed is a partially oxidation of ores minerals and the presence of secondary quartz, and epidote as a result of alteration of plagioclase and pyroxene.

Based on petrographical analysis, which is more focused on alteration mineral occurrences, then the alteration minerals in Abang Komba in general can be divided into two groups, namely:

1. Group of chlorite-carbonate

Chlorite and carbonate alteration are the dominant mineral in andesite and dacite, in addition, there are also other secondary minerals such as clay minerals, sericite, and secondary quartz. These minerals are as a result from alteration from main/ primary components on the rocks.

At mostly chlorite from andesite and dacite are present as a result of alteration of pyroxene, biotite, and plagioclase, partially replacement of groundmass in form of microgranules of mafic minerals. While alteration on basalt, it is from pyroxene and biotite. Chlorite is found in colorless to green, low relief - medium, weak pleochroism, stringly and sometimes collected as aggregates (especially along clay minerals), in some places are clustered together with secondary quartz and sericite. Chlorite is a mineral that is often present in the hydrothermal alteration at neutral pH conditions and it is the result of alteration minerals containing Fe-Mg. Chlorite is expected as a result of the interaction of hydrothermal fluids at high temperature with cold sea water (Thompson and Thompson, 1996).

Carbonate is the result of alteration of plagioclase, biotite, pyroxene, and K-feldspar, in some samples shows a perfect replacement textures (pseudomorf) and as a groundmass.. Sometimes, it found as a vein, and it is also associated with sericite and secondary quartz. Carbonate presence with pale brown color, low relief and sometimes bumpy, with weak pleochroism, often associated with clay minerals as a groundmass. In type of VMS, carbonate varies from the type of siderite to dolomite, which reflects its alteration in host-rock, usually filled / associated with Fe-rich zone and interaction with sea water (Thompson and Thompson, 1996).

Secondary quartz is present as silica polymorphs that fills the space / cavity between minerals, bright to white in color, fine granular texture, moderate relief, sometimes there are together with K-feldspar, sericite and clay minerals, sometimes also as a groundmass. The presence of secondary quartz reflects the silicification process in Abang Komba submarine volcano, in response to a result of a decrease in the fluid temperature. Silicification is likely controlled by geological structures that exist in the study area.

2. Group carbonate-sericite-clay minerals

Characteristics of these alteration are relatively the same with the previous group, only can be differentiated in mineral dominance and their absence of chlorite. Carbonate, sericite and clay minerals are dominant in alteration mineral in this group. Carbonate primarily as a replacement of pyroxene, plagioclase, K-feldspar, and biotite and clay minerals are present as a result of alteration of pyroxene within groundmass of microlite plagioclase. Sericite is the result of alteration of plagioclase, K-feldspar and groundmass with a granular texture and collected as fine aggregate. In this group, alteration in carbonatisation, serisitisation, and argilitisation are more intensive, in addition to the absence of chlorite in this group, that it is characterized by sericite, indicating that there has been a change in the pH of the fluid, from neutral to acid (near-neutral to slightly acid) (Morrison, 1997b). With sericite reflects that there is also a rise in temperature, due to the crystallization of sericite evolve in parallel to the increase in temperature of the fluid.

A number of 10 rock samples were to be analyzed microscopically; in addition to observing the variations of texture and mineralogy composition, also to obtain information about the secondary processes experienced by each rock (Figure 4).

In the study area the igneous rocks generally show porphyritic - glomeroporphiritik texture. Plagioclase microlite on form lath-like within its groundmass often show trachytic or microlitic flow textures. On thin section (DB.64 and DB28) their groundmass are showing amorphous shape.

Glomeroporphiritic aggregate generally consists of phenocrysts and microphenocryst euhedral to subhedral from the mineral plagioclase, pyroxene, biotite and ore minerals, in which the spaces between the crystals of glomeroporphyritic clots is mostly filled by volcanic glass of brown to clear or slightly cloudy in color.

In some thin section (DB 65 and VG 50), there are veins of fine quartz and carbonate penetrates phenocrysts and microfenocrysts also groundmass, and also presence of phenocrysts compiled by mineral aggregate of feldspar, pyroxene, biotite, and opaq minerals those are interlocked to form phaneritic texture, or in the form of individual plagioclase crystals that have been altered entirely by sericite minerals, and associated with clay minerals and volcanic glass, exposing the "sieve textures".

Most of the thin section have been altered with weak to moderately strong intensity, characterized by the presence or resulting mineral assemblage sericite minerals, clay, carbonate, secondary albite, chlorite, epidote and ores minerals. These recrystallization are often accompanied by deformation (?), which is characterized by the presence of cracks in the mineral (their feonocrysts) are usually filled by secondary minerals.

Composition of mineralogy

Phenocrysts and Microphenocrysts.

The main phenocrysts phase is consist of plagioclase, pyroxene; biotite and hornblende and opaq minerals and are generally smaller than 3 mm, with a total contents ranged from 25-35%.

Plagioclase

Plagioclase is present dominated whether as component phenocrysts or microphenocrysts in form of

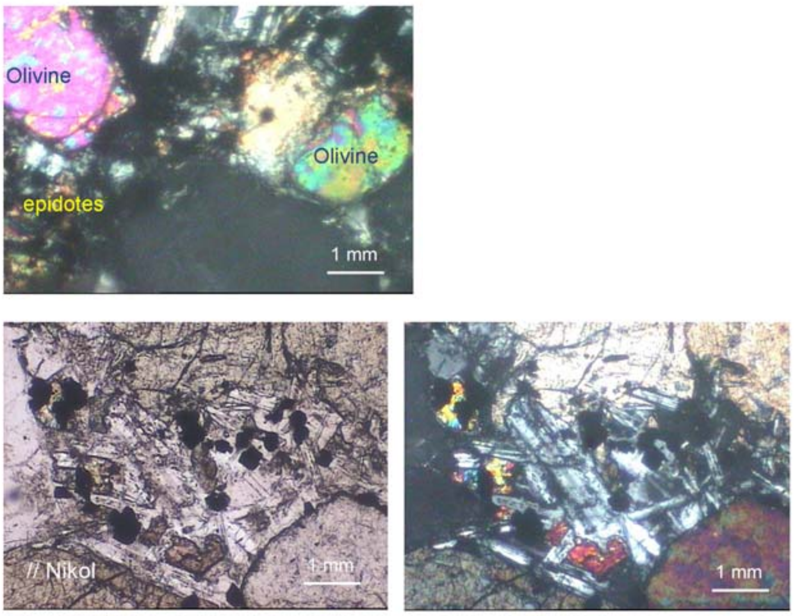

Figure 4. Thin Section of rocks samples taken from Abang Komba Submarine Volcano, ie., dyke (Basanite shows olivine, pyroxene and felsphatoids those are lying in between intergranular groundmass of plagioclase, opaque, pyroxene and olivine).

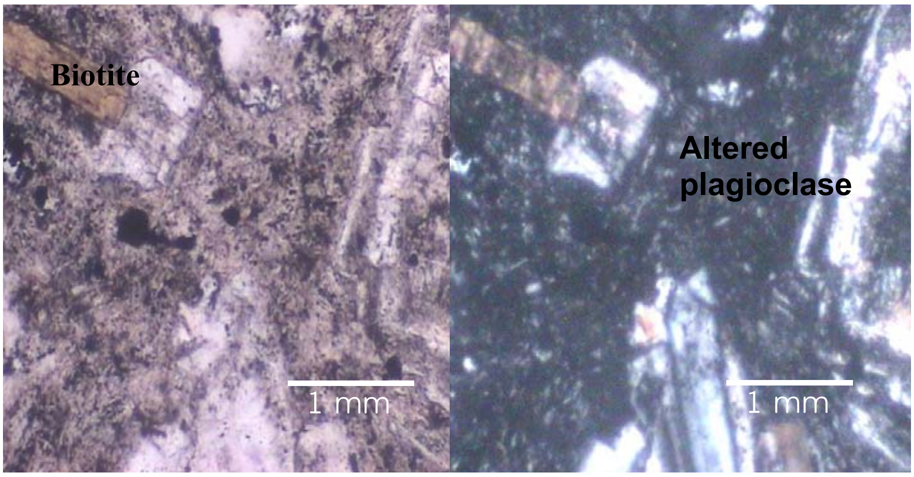

Figure 5. Thin section of andesite at sample number (DB.64 and DB28) showing an alteration on plagioclase with zoning structures.

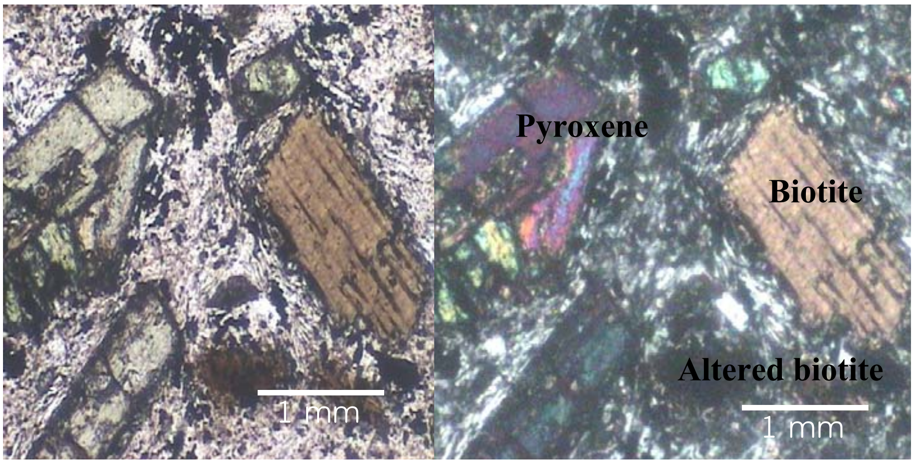

Figure 6. Thin section of an altered andesite at sample number (DB 65 and VG 50) especially on biote minerals.

a subhedral shaped crystals, prismatic or in form of elongated plates, showing twin albite, Carlsbad-albite and Carlsbad; interpreted as labradorite. Indication of zoning composition from the middle to the edges (oscillatory zoning) are common in plagioclase; besides several other individuals present in the form of a normal or reversed zoning (Figure 6) in the central part of the homogenous or patchily zoned. In some rock samples show a "sieve textures" with the inclusion of small-inclusion in groundmass constituent material, which often also be followed on the outside or the edge of the absorbed crystal. Similarly, indication of partial replacement in plagioclase by sericite, clay minerals, carbonate and epidote; and albitisation sometimes observed in some individuals plagioclase crystals. Plagioclase alteration process produces sericite, clay, carbonate and chlorite spotting.

Pyroxene

Pyroxene present represented by clinopiroxene and ortopiroxene as phenocrysts and microphenocrysts. Both are found in the form of crystals subhedral, short prismatic or tabular, colorless to pale greenish or brownish green in color. Clinopiroxene characterized by weak pleochroic from colorless to pale green, interpreted as diopsidic-augitic; while ortopyroxene characterized by moderate pleochroic of pink to green in color. Some pyroxene crystals showed groundmass corrosion characterized by bending the crystal boundary, and on the edges covered with ore mineral or iron oxide, and their spots in the crystal glasses. Other indication are often observed in twinning, zoning and opaque mineral inclusions and plagioclase. The alteration indicate pyroxene produce fibers green chlorite and carbonate.

Biotite

These minerals present in the form of long prismatic crystals, euhedral to subhedral, brown with dark brown pleochroic to light reddish brown or golden brown in color. Most of the crystal boundary has been corroded by groundmass and contains of grain inclusions opaque minerals. Some biotite crystals individuals seem of altered to green chlorite fibers and opaque minerals (Figure 5).

Hornblende

Found only in a few thin section, in the form of long prismatic crystals, brownish green to red-brown in color with strong pleochroic. There often shows as the membranes opaque mineral at the edge of the crystal and sometimes strongly altered to produce pseudomorf opaq minerals. Some of them contain grained inclusions opaque mineral and plagioclase.

Opaque Mineral

Opaque minerals always present in all thin sections and are represented by magnetite, and sometimes ilmenite, found as primary crystals in common form of subhedral to euhdral. Sometimes there are in aggregate of glomerophorphyritic along with phenocrysts and other microphenocrysts.

Groundmass

Rocks groundmass can be divided into two types, based on its content ranges from 65-75%. First groundmass type is having irregular, and that does not show the orientation. The irregular groundmass in general show trachytic orientation and flow banding generated by the presence of cleavage plane parallel to the flow surface, composed of prismatic plagioclase microlite or long and short rectangular form, needle-shaped structures and swallow-tailed; short prismatic pyroxene-shaped and granular; opaq mineral of octahedra shaped, and ligth brown to colorless glass volkanic, filling the above space crystalline of groundmass. The second type of form that does not indicate the direction of groundmass composed of acicular shape plagioclase, and rectangular form, or tabular or prismatic form in which the space between the crystals are filled by fine-grained anhedral pyroxene aggregates, octahedral shaped ore minerals and small amounts of glass volcanic, which forms intergranular to intersertal textures.

Descriptions of each secondary minerals, are described below :

Sericite (Figure 6a)

As an alteration of plagioclase and also as fine patches scattered on the surface of their origin. Together with clay minerals and carbonates occasionally replace their origin (DB1 sample).

Carbonate

As an alteration of plagioclase and pyroxene, or as individuals who are unevenly distributed. Sometimes found surroundings their origin or form elongated veins of rock fractures, along with quartz veins filling cracks forming rocks.

Clay minerals

Mainly as a result of alteration from palgioclase, pyroxene and biotite those are widespread and spotted in phenocrysts or mixcrophenocrysts surface, in the form of diffuse like clouds and brownish gray in color. Sometimes they found in the middle or at the edge their origin minerals and or surroundings plagioclase, or in the form of elongation lines.

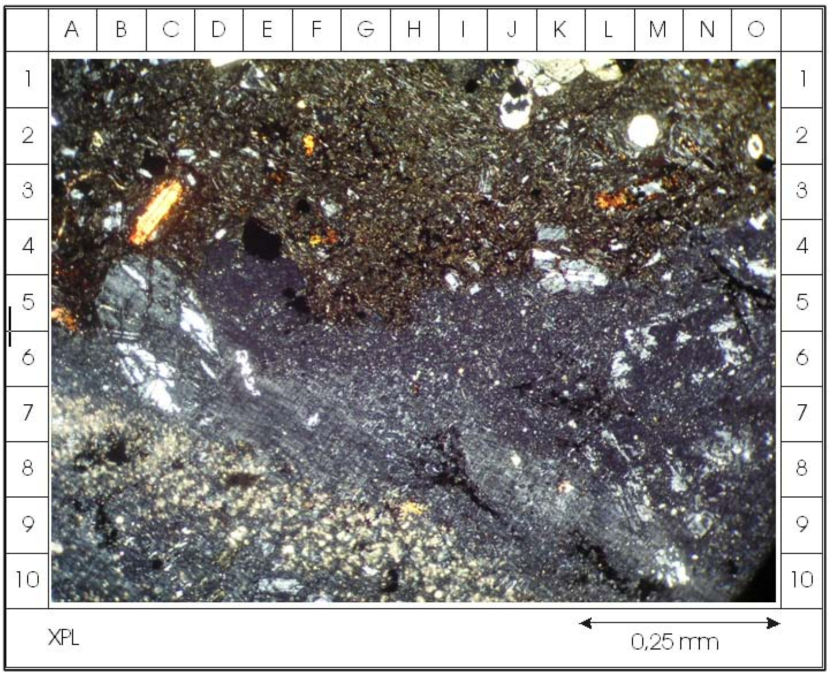

Figure 6a. "Sericite (From DB1 sample) : Alteration from plagiclase, colourless, bright, fine hairy, and irregular form, spread together with groundmass and carbonate.

Chlorite

As a result alteration from pyroxene, plagioclase, and hornblende and groundmass. As an alteration in phenocrysts and microphenocrysts usually found in the cracks and their cleavage. Sometimes found in the form of fine fibers or in the form of fine aggregates around the edge of their origin minerals.

Secondary albite

Albitisation are often found in plagioclase which is present as very fine aggregate, light brown color and sometimes contain patches of pale green chlorite aggregates.

Epidote

There is an alteration from plagioclase and pyroxene those are associated with chlorite or carbonate, sometimes as an aggregate of cavities filling in plagioclase; characterized by high relief, yellow and orange with interference colors of the rainbow.

DISCUSSION

From the composition of phenocrysts and microphenocrysts, where plagioclase and pyroxene are the first phase of crystallization, followed by biotite and ore minerals, the presence of the same of crystallization as well as observed.

They are often found some resorption and reaction textures, as seen in resorption in pyroxene phenocrysts and / or parts with smooth edges groundmass corroded by the aggregate, or there are the damaged rounded plagioclase forms or frittered caused by many small inclusions of groundmass materials, it indicates a combination process of fractional crystallization and magma mixing (Sakuyama, 1982).

The presence of biotite minerals (phlogophite) both as a phase of phenocrysts and microphenocrysts, as well as groundmass, it may related directly to crystallization of magma. While the presence of hornblende shows that the melt has been recrystallised under H_2O saturated conditions (Eggler & Burnham, 1973).

CONCLUSIONS

The phenocrysts on some rock samples, and supported also by the variation of unhomogeneous grain sizes and the presence of volcanic glass in groundmass, then it indicates that the possibility of contamination of the magma during its path to surounding crust (Stormer, 1972).

The indication of alteration or secondary processes were due to introduction hydrothermal solution that occurs in rocks are indicated by the presence of minerals alteration seen in the rock incisions are characterized by the partial replacement of most of the surrounding phenocrysts of plagioclase. These partial replacement of plagioclase by sericite, carbonate and clay minerals; and partial replacement pyroxene by chlorite, and the presence of albitisation (secondary albite) contained in rectangular shaped fine plagioclase sized. Other indications, are sometimes observed the presence of partial oxidation of the ore minerals and the presence of secondary quartz, while epidote as a result of alteration of plagioclase and pyroxene.

ACKNOWLEDGEMENTS

Acknowledgements to Dr. Susilohadi, Head of Marine Geological Institute at this time for his support and opportunity for authors to write this paper. Thanks to the Captain and his Crew of the Geomarin III RV., who had been helped by the completion of this study, friends researcher who helped and cooperation both on board and up to the completion of this paper. Also addressed to and other friends who have helped P3GL until the completion of this paper.

REFERENCES

[1] Eggler, D.H., and Burnham, C.W., 1973, Crystallization and fractionation trends in the system andesite-H2O-CO2-)2 at pressures to 10 kb, *Geological Society of American Bulletin* 84: 2517-2532.

[2] Evans, Anthony M. 1987, *An Introduction To Ore Geology*, Second Edition Geoscience Text; V.2. Blackwell Scientific Publications, London.

[3] Gill, J.B., 1981, *Orogenic Andesite and Plate Tectonics.* Berlin-Heidelberg; Springer-Verlag, 390.

[4] Halbach, P., Sarmili, L., Karg, N., Pracejus, B., Melkert, B., Post, J., Rahdens, E., and Haryadi, Y., 2003, The Break-up of a Submarine Volcano in the Flores-Wetar Basin (Indonesia) : Implication for Hydrothermal Mineral Deposition. *International Ridge News*, 121/ 1:18-22.

[5] Hamilton, W., 1979, *Tectonic of the Indonesian Region*, United States Geological Survey professional paper, 1078, U.S. Geological Survey

[6] Kerr, P., 1979, *Optical Mineralogy*, McGraw-Hill, New York, London, Toronto, 442.

[7] McCaffrey, Robert., 1988, Active Tectonics of the Eastern Sunda Arcs, *Journal of Geophysical Research*, 93 (B12) : 15,163-15, 182, December 10, 1988.

[8] Morrison, K. 1997b, *Important Hydrothermal Minerals And Their Significance*, Geothermal

And Mineral Services Division Kingston Morrison Limited. Seventh Edition. Jakarta.

[9] Silver, E.A., Reed, D., McCaffrey, R., 1983, Back-arc Thrusting in The Eastern Sunda Arc, Indonesia: A Consequence of Arc-continent Collision, *Journal of Geophysical Research,* 88.

[10] Sakuyama, 1981, Petrological study of the Myoko and Kurohime volcanoes, Japan: Crystallization Sequence And Evidence for Magma Mixing, *Journal of Petrology,* 22 : 553-583.

[11] Sarmili, L., Halbach, P., Pracejus, B., Rahders, E., Burhanuddin, S., Makarim, S., Purbani, D., Kusumah, G., Soesilo, J., dan Hutabarat, J., 2004, Mineralisasi Hidrotermal Temperatur rendah di Perairan Kompleks Gunung Komba, Laut Flores, Indonesia, Area in The Flores-Wetar Basin (Indonesia) and Associated Hydrothermal Mineralisation of Volkanic Rocks, *Bulletin of Marine Geology,* 18, (3).

[12] Stormer, J.C., Jr., 1972, Mineralogy and petrology of the Raton-Clayton volcanic field, northeastern New Mexico: *Geol. Soc. America Bull.,* 83 : 3299-3322.

[13] Thompson, A.J.B and Thompson, J.F.H. 1996, *Atlas Of Alteration, A Field and Petrographic Guide To Hydrothermal Alteration Minerals.* Mineral Deposits Division, Geological Association of Canada.