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PETROGENESIS OF ANDESITE IN CISANGGARUNG AREA, CIMENYAN DISTRICT, BANDUNG REGENCY, WEST JAVA

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ABSTRAK

Daerah Cisanggarung terletak di Kecamatan Cimenyan, Kabupaten Bandung, merupakan daerah yang tersusun oleh hasil gunungapi sehingga ditemukan banyak singkapan batuan yang cukup tebal dan dimanfaatkan sebagai tambang andesit yang dikelola oleh masyarakat setempat. Penelitian ini mengkaji karakteristik batuan andesit daerah cisanggarung dengan menggunakan metode petrologi, petrografi, XRF dan ICP-MS sehingga dapat diinterpretasikan petrogenesanya. Batuan andesit daerah cisanggarung menunjukan struktur kekar berlembar dan secara mikroskopis memiliki tekstur porfiritik, trakitik, glomeroporfiritik, zoning, embayment, dan sieve. Komposisi mineral pada batuan yaitu plagioklas, piroksen, mineral opak, dan mineral sekunder berupa klorit dan mineral lempung. Magma pembentuk batuan andesit daerah cisanggarung merupakan seri calc-alkaline tepatnya pada tatanan tektonik island arc tholeiitic yang berkaitan dengan zona subduksi yang dicirikan dengan TiO2<1.3 wt.%. Magma diduga berasal dari lempeng kontinen pada kedalaman 127.87-136.92 km. Magma pembentuk batuan vulkanik daerah ini telah mengalami proses diferensiasi yaitu fraksinasi kristalisasi dan asimilasi. Proses magmatisme membentuk dua tahapan kristalisasi, yaitu dimulai dari tahap pendinginan magma yang lambat, kemudian diikuti oleh magma yang mendingin relatif cepat ke permukaan.

Kata kunci: Andesit, Petrografi, Geokimia, Petrogenesa, Cisanggarung

ABSTRACT

The Cisanggarung area is located in Cimenyan District, Bandung Regency, an area composed of volcanic products that many thick outcrops are found and used as andesite mines managed by local communities. This study examines the characteristics of andesite in the Cisanggarung area using petrology, petrography, XRF, and ICP-MS so that petrogenesis can be interpreted. Andesite rocks in the Cisanggarung area have a sheeting joint structure and microscopically have porphyritic, trachytic, glomeroporphyritic, zoning, embayment, and sieve textures. The composition of this rock was plagioclase, pyroxenes, opaque minerals with the less content of secondary minerals such as chlorite and clay minerals. The magmatic affinity of this rock shows calc-alkaline series, precisely in tholeiitic island arc tectonic setting associated with subduction, which is characterized by TiO_2<1.3 wt.%. Magma presumably comes from a continent plate with a depth of 127.87-136.92 km. Magma in this area undergoes a middle-stage differentiation process, namely assimilation and fractionation crystallization. The magmatism process forms two stages of crystallization, starting from the slow cooling stage, followed by relatively fast magma to the surface.

Keywords: Andesite, Petrography, Geochemistry, Petrogenesis, Cisanggarung

INTRODUCTION

The Cisanggarung area, Bandung Regency, is an area composed of volcanic activity from 3 periods of volcanism, namely the pre-Sunda eruption period, Sunda eruption period, and Tangkuban Parahu eruption period (Soetoyo and Hadisantono, 1992) (Fig. 1). One of the volcanic products in this area is many thick andesite outcrops. It is used as a mine managed by the local community. This study aims to interpret the petrogenesis of andesite rocks in the Cisanggarung area based on petrology, petrography, and geochemistry.

The stratigraphy of the study area is divided into nine units, which are the product of effusive, explosive eruptions and secondary volcanic deposits (Putra et al., 2021) (Fig. 2). The units are successively from old to young, namely: Cisanggarung Basement Lava Flow Unit (Cbs), Cisanggarung 1 Lava Flow Unit

(Cl1), Cisanggarung 2 Lava Flow Unit, Cisanggarung 3 Lava Flow Unit (Cl3), Cisanggarung 4 Lava Flow Unit (Cl4), Cisanggarung Pyroclastic Flow Unit (Cap), Cisanggarung Debris Fall Unit (Cgp), Cisanggarung Lava Unit (Clh), and Cisanggarung Pyroclastic Fall Unit (Cjp).
The volcanic facies of this area are Sunda proximal-medial facies and pre-Sunda medial facies.

METHOD

The research method includes field observation and taking rock samples in the field, which are then analyzed more detail in laboratory. The sample is a rock that is not weathered, not oxidized, and not altered.
The petrographic analysis was carried out on thin sections using a polarizing microscope at the Laboratory of Petrology and Mineralogy, Faculty of Geological Engineering, Padjadjaran University, to identify texture and mineral composition. For geochemical analysis, it uses XRF and ICP-MS methods. XRF (X-Ray Fluorescence) analysis was carried out at the Pusat Survey Geologi to obtain the major elements, and ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) analysis was carried out at the Intertek Jakarta Laboratory to obtain traces and rare earth elements (REE) of rocks. The analysis of various data compilations is used to interpret the petrogenesis of andesite in the study area.

RESULT AND DISCUSSION

Petrology

Generally, rocks in Cisanggarung are characterized by gray to brownish-gray color, and the amount of mafic minerals is 30%-60% so that it can be classified as mesocratic igneous rock (Fig. 3). The rock texture is aphanitic to porphyritic. The structure found in this rock is a sheeting joint. The identified minerals are plagioclase and pyroxene. Based on its mineral composition, this rock belongs to andesite igneous rock (Streckeisen, 1976).

Petrography

Microscopically, rocks in Cisanggarung has porphyritic, hypocrystalline, inequigranular and hipidiomorph texture. This rock consists of 35-45% phenocryst and 55-65% groundmass.
The phenocrysts are plagioclase and pyroxene, and secondary mineral in the form of clay mineral and chlorite. The groundmass is plagioclase microlites and volcanic glass. The groundmass is divided into two, namely those with a direction (trachytic texture) and those that do not have direction. This rock belongs to porphyry andesite based on its texture and mineral composition (Travis. 1955)

The mineral composition in the thin section of andesite rocks in general is: andesine (10-28%) exhibits transparent, low relief, euhedral-subhedral, zoning, sieve, and embayment texture (Fig. 4). Pyroxene (10-20%) has a brownish color, high relief, euhedral-subhedral, the visible texture is glomeroporphyritic (a texture in which plagioclase phenocrysts and pyroxene are clustered into aggregates). Opaque minerals (1-3%) have black color, anhedral, isotropic, and enclosed plagioclase and pyroxene. Clay minerals (1-2%) have a yellowish-brown color, found scattered, rarely as groundmass, and alteration product from plagioclase and pyroxene. Chlorite (1%) has a brownish-green color, fibrous, replaced plagioclase.

Geochemical

Rock geochemistry was obtained using XRF (X-Ray Fluorescent) test on three rock samples and ICP-MS on two rock samples (Fig. 2).

1. Major Element

Bas et al., (1986) divided the types of igneous rocks based on the total alkali (Na_2O + K_2O) and silica (SiO_2) (Fig. 5 a). The results of plotting the values on the diagram, the Cisanggarung area has andesite types.
Magma differentiation stage using Thornton and Tuttle (1960) diagram (Fig. 5 b). Based on the mafic index (MI) and felsic index (FI) elements, the sample of lava rock in the Cisanggarung area has undergone a middle-stage differentiation process, namely assimilation and crystallization fractionation.
To determine the origin of the magma series, Irvine and Baragar (1971) used the AFM triangle based on the content of Alkali (K_2O + Na_2O), Iron Oxide (FeO + Fe_2O_3), and Magnesium (MgO) (Fig. 5 d). Based on the plotting on the AFM diagram, it shows that the magma series in the Cisanggarung area is included in the Calc-Alkaline series.
The magma series can also use the Peccerillo and Taylor (1976) classification based on the content of potassium or potassium (K_2O) and silica (SiO_2) (Fig. 5 c). The plotting results show that the rock-forming magma in the Cisanggarung area comes from the Calc-Alkaline series. Calc-Alkaline is a magma with an oxidation state of the original magma. The calc-alkaline magma series can only form in subduction tectonic settings (Wilson, 2007).
The nature of magma shows what rock it originates from. Based on the origin of the rock formations, magma is divided into continents and oceans. Pearce et al. (1977) determined the origin of magma based on K_2O, TiO_2, and P_2O_5 (Fig. 5 f). Based on the plotting results in the diagram, the rock in the Cisangarung area comes from the continental crust.

Mullen (1983) divides magma sources based on the tectonic setting of the origin of the magma that forms the originating rock, namely Island Arc Calc-Alkaline Basalt, Island Arc Thoeliite, Mid Oceanic Ridge Basalt, Oceanic Island Thoeliite, and Oceanic Island Alkaline Basalt (Fig. 5 e). Based on the triangle diagram, it can be seen that the origin of the magma that forms the rock in the Cisanggarung area is the Island Arc Thoeliite.

The depth of magma originating from the rock formed at a depth of the Benioff zone. The Benioff zone is a planar area that is seismically associated with subduction zones. The depth of the original magma can be obtained using the Hutchison (1975) formula as follows:

$$h = [320-(3.65 \times \%SiO_2)] + (25,52 \times \%K_2O)$$

Based on these calculations, it is known that the depth of the original magma formed at a depth of 127.87 – 136.92 km.

2. Trace Element

Rock samples are assumed to be rocks from the earth's mantle so that the results of the analysis of trace elements of rocks are normalized with Primitive Mantle (Sun and McDonough, 1989), which is the composition of the earth's crust and mantle so that they are considered close to magma and then plotted into a spider diagram to see the pattern was compared with NMORB (Sun and McDonough, 1989), Oceanic Island Basalt (OIB) (Sun and McDonough, 1989), and Island Arc Basalt (IAB) (Dirk, 2008). The rock sample spider diagram shows a relatively similar pattern to island arc basalt (IAB). The diagram shows the enrichment of the elements Rb, K, Th, Pb and the low abundance of the elements Nb, Zr, Ti. This is a characteristic of calc-alkaline magma (Wilson, 2007). A sudden decrease in Nb levels characterizes the type of magma that erupts in a tectonic environment associated with subduction (Wilson, 2007) (Fig. 6 a).

3. Rare Earth Element

Determination of the tectonic environment is carried out using rare earth elements (REE), which are plotted on a spider diagram normalized to chondrite (Sun and McDonough, 1989). The diagram shows that CB 1 has lower LREE and HREE content than ST 32. The pattern shows LREE enrichment and decreases towards HREE gradually but not significantly. The pattern that shows LREE enrichment is the pattern of calc-alkaline. A weak Eu depletion towards Sm and Gd indicates that the rock originates from the island arc (Wilson, 2007) (Fig. 6 b).

Discussion

Magma undergoes a differentiation process starting from the magma chamber, which will later come out to the surface. The magma differentiation occurs due to contamination from the crust. In the spider diagram, there is a negative Eu anomaly which is a characteristic of the crust that undergoes partial melting, or magma differentiation is influenced by plagioclase fractionation (McLennan et al., 1993)

The assimilation process is indicated by an increase in trace elements' low field strength and the appearance of a zoning texture on plagioclase. It is also supported by geochemical data, where the K2O content is more than 1% (Ismail and Hendratno, 2016).

There is a difference in the rate of cooling of magma so that there are two stages of cooling, magma that cooling slowly and followed by relatively rapid cooling to the surface. When it cools slowly, the crystal growth rate is high, and the crystal growth becomes concentrated in the formed crystal core, so that the crystals formed are relatively coarse. When magma moves upward rapidly, the rate of crystal growth is so low that the crystals formed are relatively fine. At a very fast cooling, the degree of crystal core formation and crystal growth becomes zero, resulting in glass (Gill, 2010). The andesite rock indicates the difference in the cooling rate of this magma with a porphyritic texture, and the sheeting joint structure shows a rapid cooling. It is proved by petrographic and geochemical analysis, included andesite.

Based on the AFM diagram (Irvine and Baragar, 1971) the magmatic affinity included a calc-alkaline magma series. This is supported by the spider diagram pattern of enrichment of elements Rb, K, Th, Pb and low abundance of elements Nb, Zr, Ti. This is a characteristic of calc-alkaline magma (Wilson, 2007).

Theoretically, the normal development of an orogenic zone will produce a series of magmas with potassium content increasing as they move away from the trough. Andesite is formed in a convergent tectonic setting, the calc-alkaline magma series is only formed in a convergent tectonic setting in the subduction zone (Wilson, 2007).

According to Gill (1981), rocks formed in the subduction zone have a TiO_2 value of <1.3 wt%, rocks in the Cisanggarung area have a TiO_2 content of 0.72-0.84 wt% so that these rocks are formed in the subduction zone. These data are supported by the sudden decrease in Nb levels characterizing the type of magma that erupts in a tectonic environment associated with subduction (Wilson, 2007). The spider diagram pattern shows a weak Eu depletion towards Sm and

Gd indicating that the rock originates from island arc (Wilson, 2007).
Based on Mullen (1983), the rocks of the Cisanggarung area are associated with the tholeiitic island arc tectonic setting.
The rock-forming magma of the Cisanggarung area is produced in a subduction zone from the continent plate (Pearce et al., 1977) with a depth of 127.87 km – 136.92 km (Hutchison, 1975) and has undergone intermediate magma differentiation (Thornton and Tuttle, 1960).

CONCLUSION

Andesite in Cisanggarung area, as a result of volcanic activity, generally shows a sheeting joint structure and porphyritic, glomeroporphyritic, trachytic, zoning, and sieve textures.
The calc-alkaline series type of this rock in the research area is a product of eruption related to subduction, precisely in the tectonic setting of the tholeiitic island arc with magma source come from the continent plate at a depth of 127.87 km – 136.92 km in the Benioff zone.
Magma undergoes a middle-stage differentiation process, namely assimilation and crystallization fractionation. The magma cooling process occurs in two stages, starting from cooling characterized by a coarse texture (presence of phenocrysts), followed by relatively rapid cooling to the surface characterized by a fine texture.

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Table 1. Major oxides in wt% of Cisanggarung rocks.

Oxide	ST 32	CB 1	ST 36
	wt%		
SiO_2	58.53	60.94	60.43
Al_2O_3	19.84	17.04	18.15
Fe_2O_3	5.15	4.84	4.8
MgO	1.87	3.07	2.53
CaO	7.46	6.88	7.39
Na_2O	2.86	2.96	2.8
K_2O	1.33	1.33	1.47
TiO_2	0.84	0.74	0.72
P_2O_5	0.16	0.16	0.18
MnO	0.1	0.11	0.09
SO_3	0.01	0.04	0.02
LOI	1.79	1.26	1.4

Table 2. Trace elements of Cisanggarung rocks.

Trace Element	CB 1	ST 32
	(ppm)	
Rb	63.4	59.3
Ba	388	358
Th	11.2	11
U	1.89	1.78
Nb	5	4.7
K	13700	14200
La	24.4	29.8
Ce	40.7	46.6
Pb	7	8
Pr	4.81	6.21
Sr	338	373
P	770	940
Nd	19.4	27.6
Zr	93.4	132
Sm	3.8	5.6
Eu	1	1.6
Ti	3740	4000
Dy	3.3	5
Y	16.5	27.5
Yb	1.7	2.9
Lu	0.31	0.43

Table 3 Trace elements concentration of Cisanggarung rocks.

REE	CB 1	ST 32
	(ppm)	
La	24.4	29.8
Ce	40.7	46.6
Pr	4.81	6.21
Nd	19.4	27.6
Sm	3.8	5.6
Eu	1	1.6
Gd	3.9	5.9
Tb	0.52	0.77
Dy	3.3	5
Ho	0.6	1
Er	1.8	3
Yb	1.7	2.9
Lu	0.31	0.43

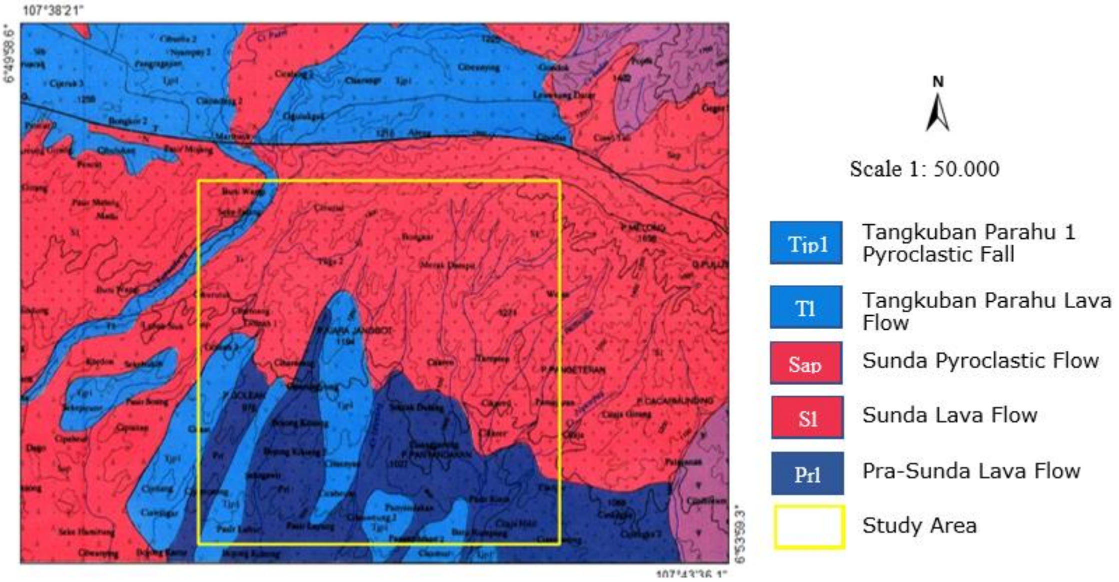


Fig 1. Part of Geological Map Tangkuban Parahu/Sunda Volcano Complex (Soetoyo and Hadisantono, 1992)

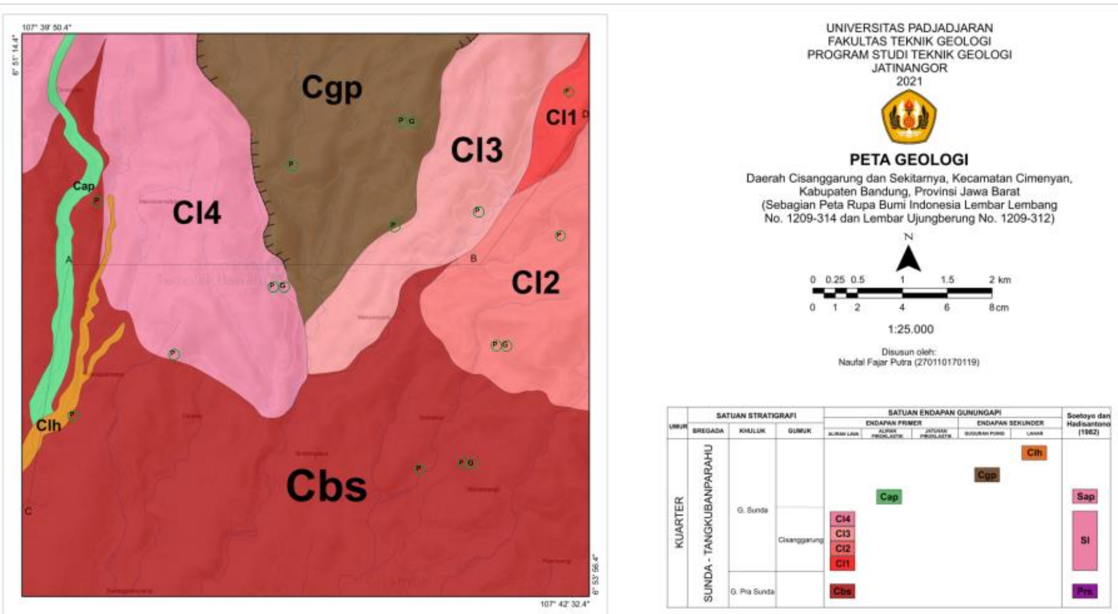


Fig 2 Geological map of study area (Putra, 2021)

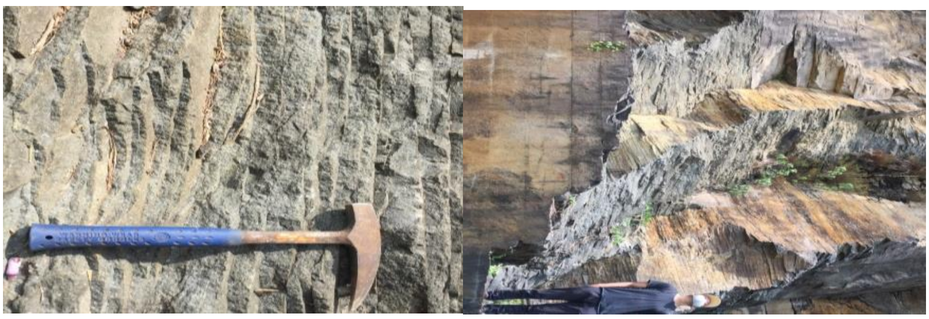


Fig 3 Andesite outcrop in study area

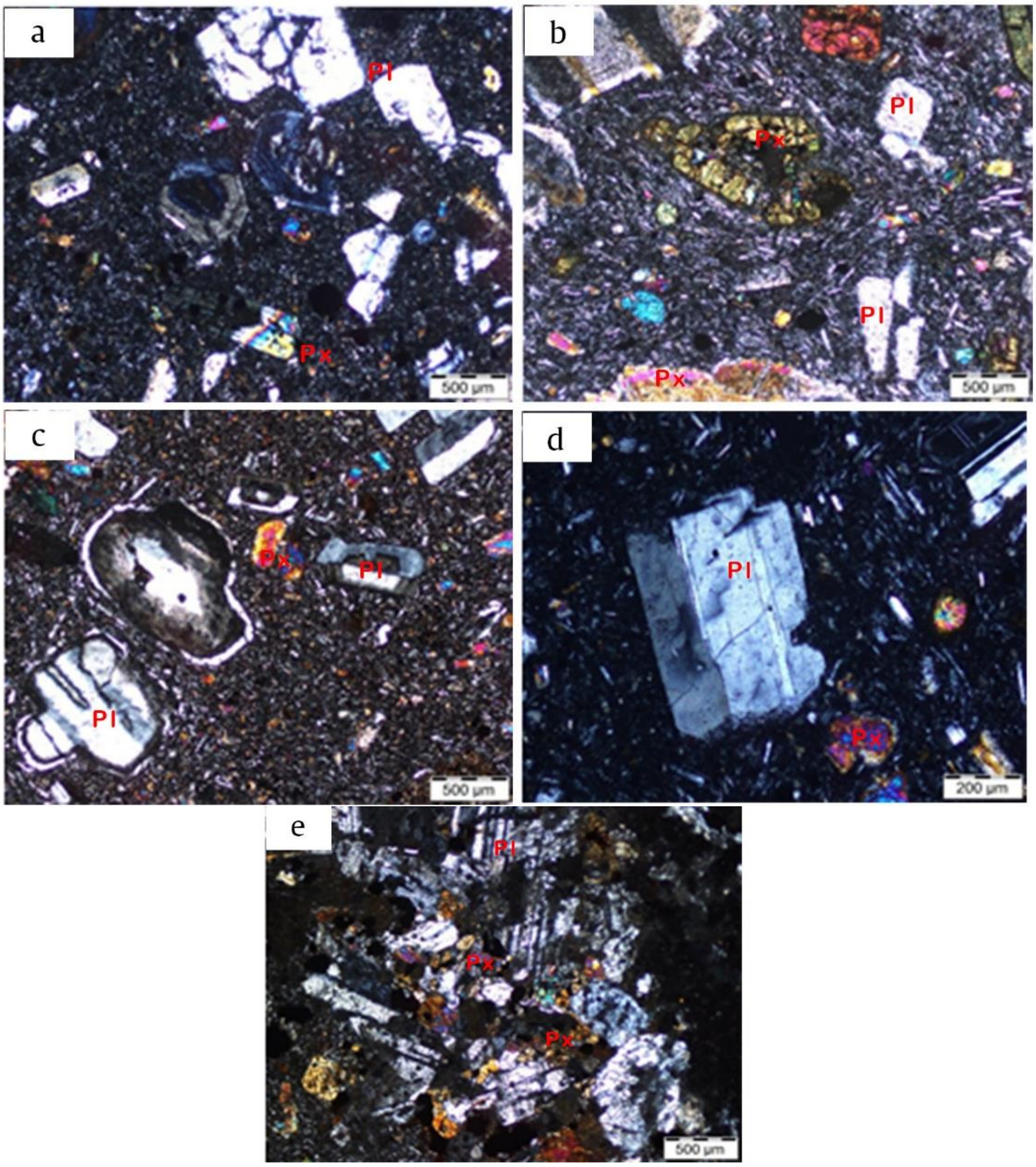


Fig 4. (a) zoning texture. (b) Trachytic texture. (c) sieve texture. (d) embayment texture. (e) glomeroporphyritic texture

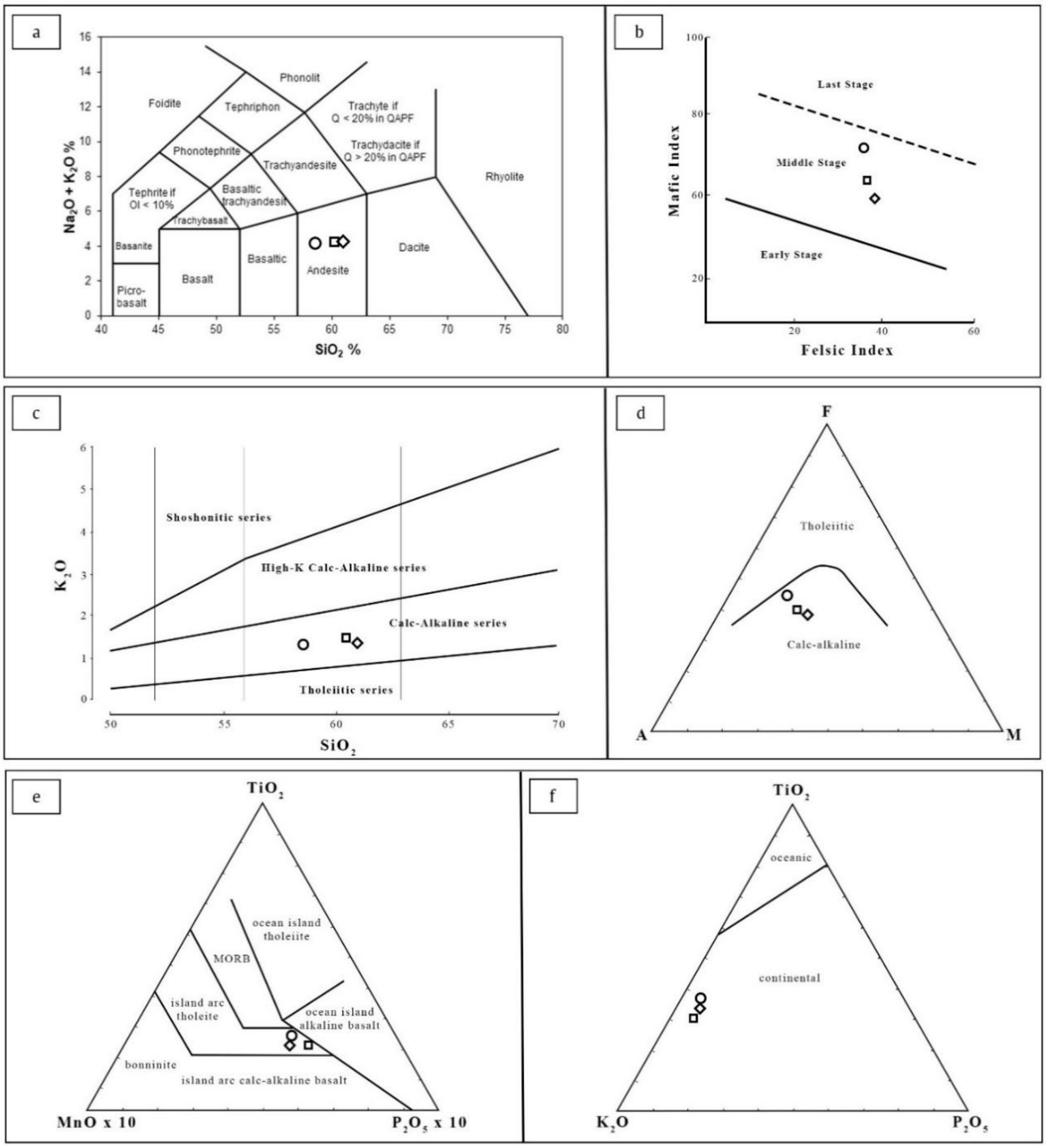
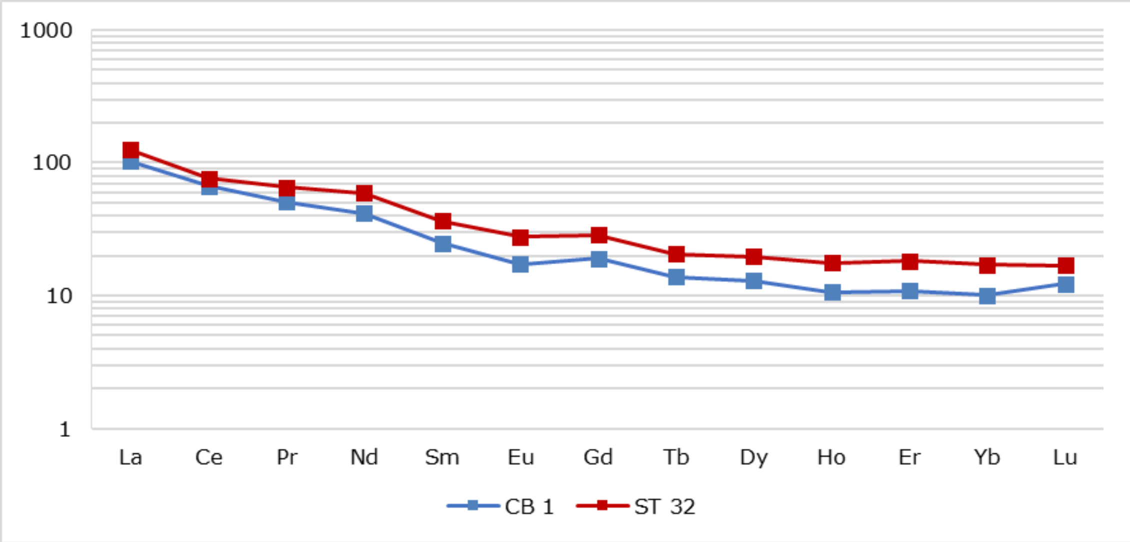


Fig 5 (a) TAS diagram (Bas et al., 1986). (b) Mafic Index vs Felsic Index diagram (Thornton and Tuttle, 1960). (c) K2O vs SiO2 diagram (Peccerillo and Taylor, 1976). (d) AFM diagram (Irvine and Baragar, 1971). (e) Tectonic setting diagram (Mullen, 1983). (f) Rock origin diagram (Pearce et al., 1977)



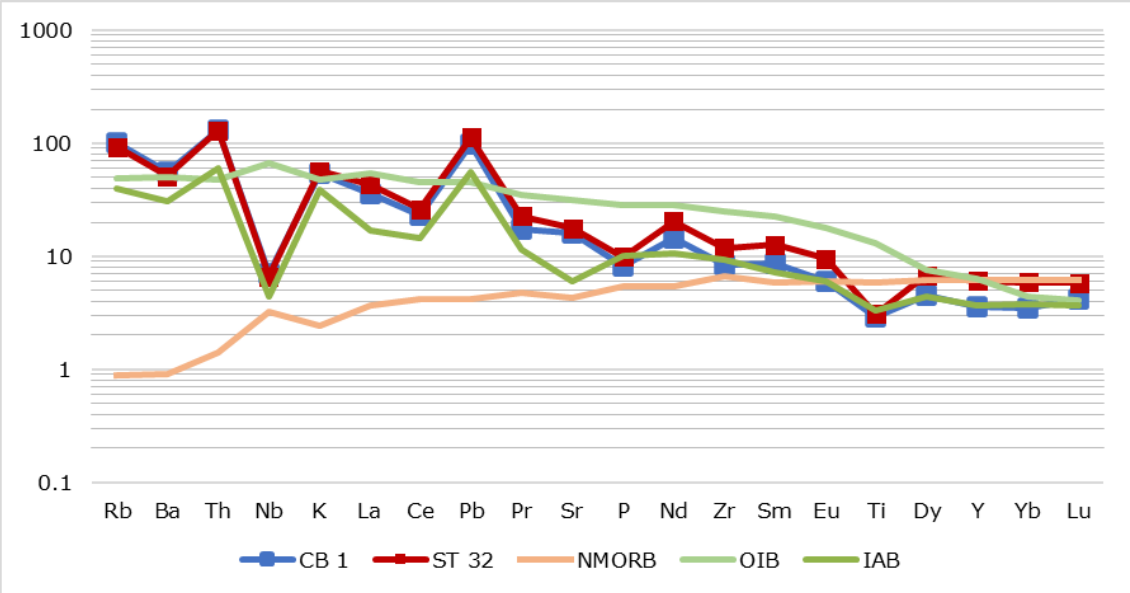


Fig 6 (a) spider diagram trace element. (b) spider diagram rare earth element