PROCEEDINGS, 46th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 15-17, 2021
SGP-TR-218

The Characteristics of Andesite Under Weathering and Alteration in Tatun Volcano Group, Taiwan

Chia-Mei LIU[1], Ruo-Pin LI[1], Ke-Han SONG[2], Yu-Wei TSAI[1]

[1]Department of Geology, 55, Hwa-Kang Road, Yang-Ming-Shan, Taipei, Taiwan 11114, R. O. C.

E-mail: ljm12@g.pccu.edu.tw

E-mail: a7100526@g.pccu.edu.tw

E-mail: tsayyw@faculty.pccu.edu.tw

[2]Faculty of Science and Graduate School of Engineering and Science, 1 banchi, Sembaru, Nakagami Gun Nishihara Cho, Okinawa Ken, 903-0129, Japan

E-mail: k198601@eve.u-ryukyu.ac.jp

Keywords: weathering, alteration, petrography, mineral assemblages, geochemistry, Tatun Volcano Group, Taiwan

ABSTRACT

The weathering and hydrothermal alteration affect rock, and rock would record two processes. The Tatun Vaocano Group (TVG) is located in monsoon zone and active volcano phenomenon area, it belongs two pyroxenes basaltic andesite. This study major aim is to find what is kind of factor would affect the two pyroxenes basaltic andesite, and provides the information of corrosion process for geothermal power plant. This study analyzed the petrography, mineral assemblages, geochemistry of andesite by microscope, x-ray diffraction, and energy dispersive x-ray fluorescence spectrometer.

This study presents that the predominant mineral assemblages are augite, hypersthene, and bytownite, and the alteration mineral assemblages are cristobalite, halloysite and limonite. The two pyroxenes basaltic andesite is distinguished four stages by degrees of rock mass weathering based on the petrography, mineral assemblages, and geochemistry data in TVG. The two pyroxenes basaltic andesite has higher sulfur concentration near the active fumarole area, and that indicates the hydrothermal alteration influence two pyroxenes basaltic andesite more than weathering in Tatun Volcano Group of Taiwan.

1. INTRODUCTION

The Tatun Volcano Group is located in the monsoon zone, and there are widely hot springs distribution and significantly fumaroles (Yang et al., 1999; Lee et al., 2008; Liu et al., 2011). The rock is a well recorder that can record the source of rock and influence of weathering and hydrothermal alteration on the rock properties. The andesite has ring and different colour, which are common phenomenon, present in the Shibafen lava flow that is affected by chemical weathering and hydrothermal alteration.

The aim of this study analyzed petrography, mineral assemblages, geochemistry and weathering index for providing the conceptual model of minerals assemblages change under the processes of weathering and alteration.

2. METHODOLOGY AND SAMPLING SITES

This study applies microscope, X-ray diffraction, Energy Dispersive X-ray fluorescence spectrometer on the petrography, mineral assemblages, and geochemistry of andesite. In addition, this study calculates the weathering indexes of andesite by chemical index of alteration (CIA), chemical index of weathering (CIW), plagioclase index of alteration (PIA), weathering index (WIP) (Nesbitt and Young, 1982; Harnois, 1988; Fedo et al, 1995; Parker, 1970).

The equations as below:

$$CIA = [Al_2O_3*100/Al_2O_3+CaO+Na_2O+K_2O]$$

$$CIW = [Al_2O_3/(Al_2O_3+CaO^*+Na_2O)*100]$$

$$PIA = (Al_2O_3-K_2O)/(Al_2O_3-K_2O+CaO^*+Na_2O-K_2O)*100$$

$$WIP= [(2Na_2O/0.35) + (MgO/0.9) + (2K_2O/0.25) + (CaO/0.7)]*100$$

The sampling sites locate on the Shibafen lava flow of Tatun Volcano Group of Taiwan (Figure 1a). This study collects ring samples and medium gray, grayish red purple and brown andesite from Shibafen lava flow (Figure 1b to Figure 1d).

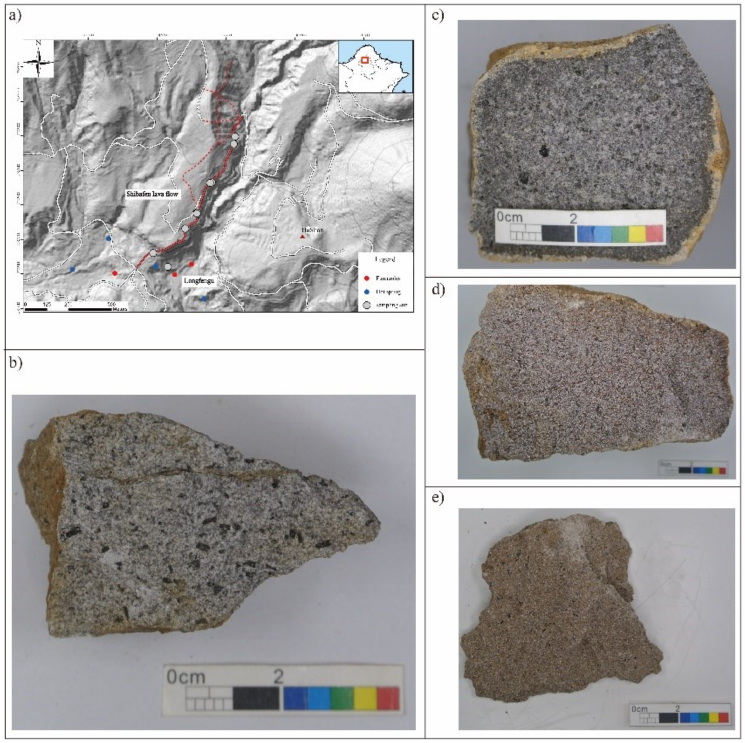

Figure 1: The sampling location and hand specimen. (a) The sampling locations in the Shibafen lava flow of TVG, (b) medium gray andesite, (c) ring andesite, (d) grayish red purple andesite, (e) brown andesite.

3. RESULTS AND DISCUSSION

3.1 The characteristics of fresh andesite

In the figure 2, it presents basaltic andesite, which is medium gray sample. The basaltic andesite consists of plagioclase (20 %-35 %), augite (2 %-12 %), hypersthene (2 %-5 %), opaque (1 %-3 %) and groundmass (47 %-72 %). Finally, the medium gray sample is named two pyroxenes basaltic andesite.

The results of geochemistry of medium gray two pyroxenes basaltic andesite show that silica are about 53.7%-55.4%, aluminum oxide are about 21.8%-24.6%, iron oxide are about 5.8%-7.3%, calcium oxide are about 8.2%-8.7%, magnesium oxide are about 1.7%-2.9%, potassium oxide are about 2.5%-3.1%, titanium oxide are about 0.6%-0.7%, sulfur oxide are about 0%-0.044% (Figure 3).

Based on methodologies of the different weathering indexes, the CIA, CIW, PIA, and WIP are 52.9-56.8, 57.4-62.1, 43.4-58.6, and 49.1-57.3 for the medium gray two pyroxenes basaltic andesite, respectively.

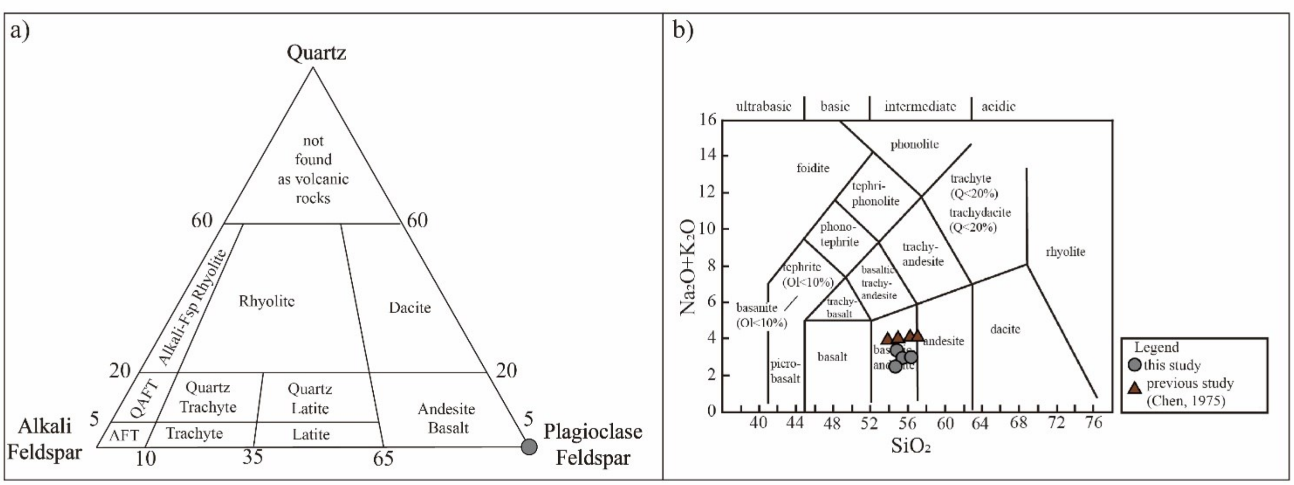

Figure 2: The classification by QAP and TAS diagrams in this study.

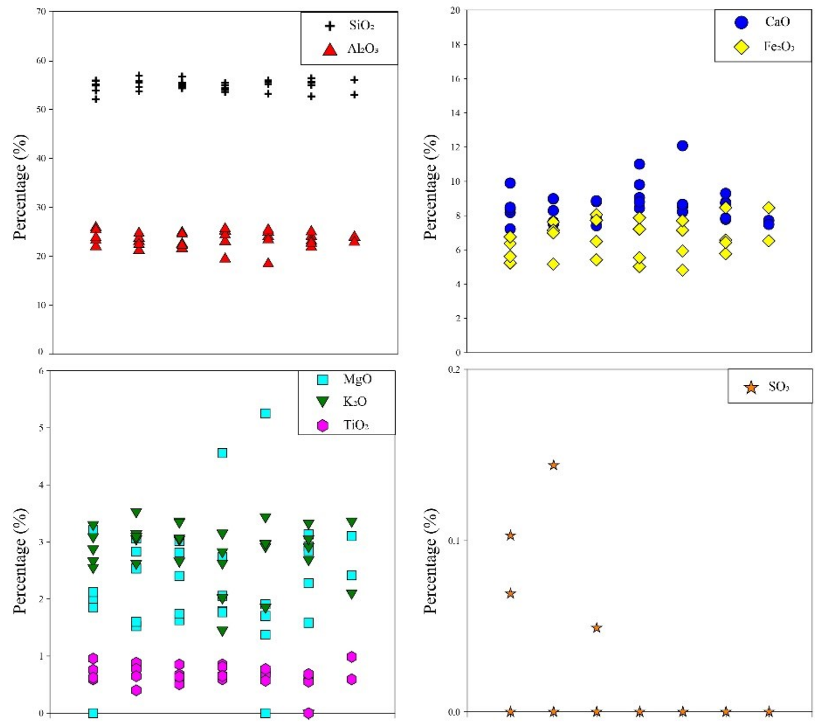

Figure 3: The geochemistry data of medium gray two pyroxenes basaltic andesite.

3.2 The characteristics of weathering and alteration andesite

The core part of ring two pyroxenes basaltic andesite consists of plagioclase (25%-35%), augite (4%-12%), hypersthene (1%-4%), opaque (1%-5%) and groundmass (49%-69%). In the figure 4, the results of geochemistry of core part of ring two pyroxenes basaltic andesite show that silica are about 54.9%-55.7%, aluminum oxide are about 18.1%-24.7%, iron oxide are about 5.0%-10.9%, calcium oxide are about 4.4%-8.9%, magnesium oxide are about 1.9%-3.1%, potassium oxide are about 3.8%-7.3%, titanium oxide are about 0.8%-1.8%, sulfur oxide are about 0%-1.937%.

Based on methodologies of the different weathering indexes, the CIA, CIW, PIA, and WIP are 54.6-57.8, 59.0-69.4, 55.4-61.7, and 51.8-60.0 for the core part of ring two pyroxenes basaltic andesite, respectively.

The ring part of ring two pyroxenes basaltic andesite consists of plagioclase (15%-30%), augite (1%-6%), hypersthene (0.5%-1%), opaque (0.5%-3%) and groundmass (59%-83%). In the figure 4, the results of geochemistry of ring part of ring two pyroxenes basaltic andesite show that silica are about 48.1%-57.6%, aluminum oxide are about 10.4%-23.2%, iron oxide are about 9.7%-18.4%, calcium oxide are about 2.2%-5.2%, magnesium oxide are about 0%-4.7%, potassium oxide are about 3.8%-7.3%, titanium oxide are about 0.8%-1.8%, sulfur oxide are about 0%-1.937%.

Based on methodologies of the different weathering indexes, the CIA, CIW, PIA, and WIP are44.1-69.0, 60.7-78.6, 37.0-75.1, and 49.4-67.2 for the ring part of ring two pyroxenes basaltic andesite, respectively.

The grayish red purple two pyroxenes basaltic andesite consists of plagioclase (15%-25%), augite (4%-13%), hypersthene (1%-3%), opaque (0.5%-3%) and groundmass (55%-73.5%). In the figure 5, the results of geochemistry of grayish red purple two pyroxenes basaltic andesite show that silica are about 50.9%-54.5%, aluminum oxide are about 25.4%-29.2%, iron oxide are about 6.5%-8.7%, calcium oxide are about 5.1%-6.6%, magnesium oxide are about 1.5%-2.6%, potassium oxide are about 0.8%-2.8%, titanium oxide are about 0.7%-3.6%, sulfur oxide are about 0%-0.050%.

Based on methodologies of the different weathering indexes, the CIA, CIW, PIA, and WIP are 63.0-70.9, 68.1-74.9, 65.3-72.6, and 33.2-47.6 for the grayish red purple two pyroxenes basaltic andesite, respectively.

The brown two pyroxenes basaltic andesite consists of plagioclase (25%-30%), augite (9%-16%), hypersthene (1%-4%), opaque (1.5%-3%) and groundmass (53.5%-57%). In the figure 6, the results of geochemistry of brown two pyroxenes basaltic andesite show that silica are about 47.5%-56.2%, aluminum oxide are about 25.9%-32.8%, iron oxide are about 5.5%-9.3%, calcium oxide are about 5.3%-9.3%, magnesium oxide are about 2.2%-2.7%, potassium oxide are about 0.7%-2.4%, titanium oxide are about 0.7%-0.9%, sulfur oxide are about 0.025%-0.105%.

Based on methodologies of the different weathering indexes, the CIA, CIW, PIA, and WIP are 64.7-76.0, 69.3-77.4, 66.9-77.0, and 27.0-42.9 for the brown two pyroxenes basaltic andesite, respectively.

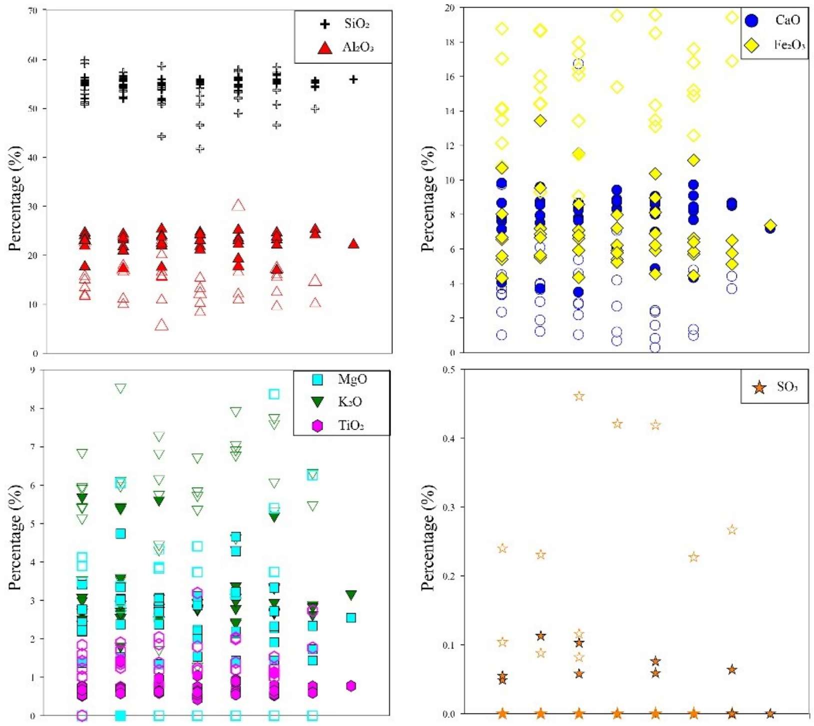

Figure 4: The geochemistry data of two pyroxenes basaltic andesite with ring (solid and hollow symbols display core and ring parts of ring andesite, respectively).

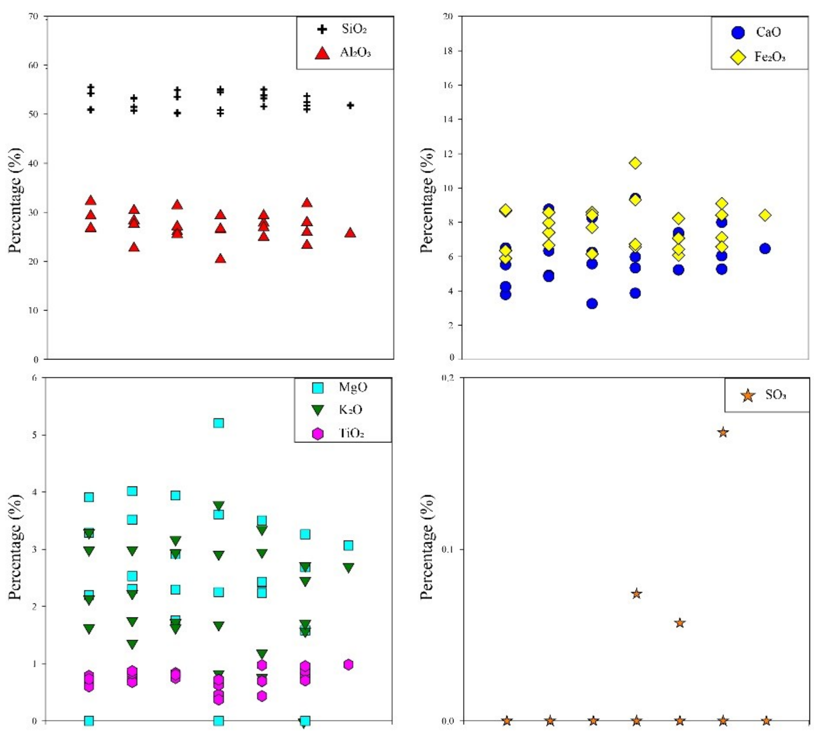

Figure 5: The geochemistry data of grayish red purple two pyroxenes basaltic andesite.

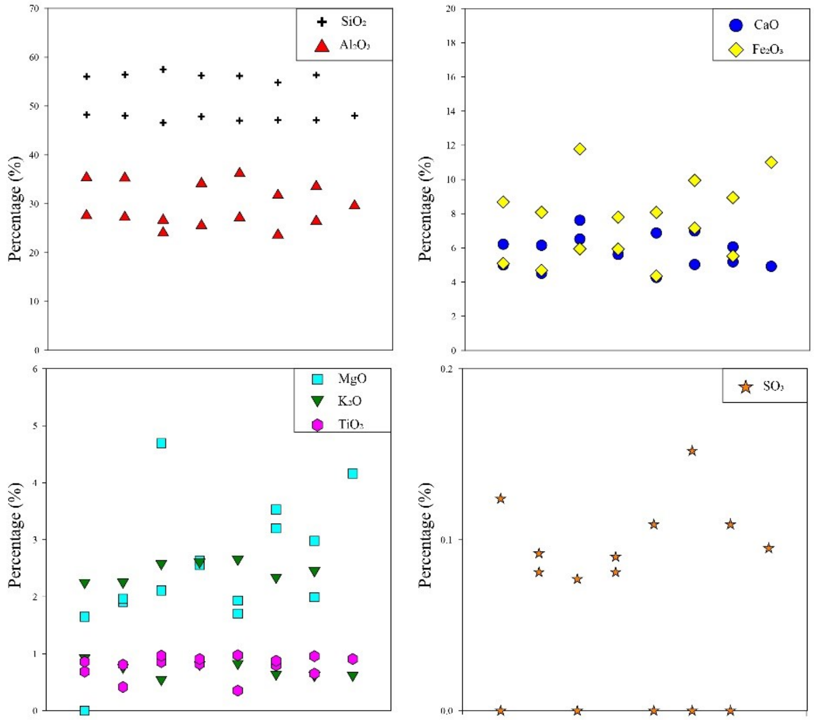

Figure 6: The geochemistry data of brown two pyroxenes basaltic andesite.

3.3 The conceptual model of two pyroxenes basaltic andesite under weathering and alteration

The figure 7 presents the conceptual model of two pyroxenes basaltic andesite under weathering and hydrothermal alteration. According to the results of petrography, geochemistry, mineral assemblages, and weathering index, the medium gray two pyroxenes basaltic andesite is fresh sample, the ring sample belongs to slightly weathered, grayish red purple andesite is moderately weathered, and brown andesite has highly weathered (Figure 8 and Figure 9).

The table 1 shows the weathering indexes of Shibafen lava flow. The Stage I is fresh sample, and CIA, CIW and PIA of Stage I are lower than the other stages. However, the Stage IV is brown two pyroxenes basaltic andesite, and WIP of Stage I are lower than the other stages.

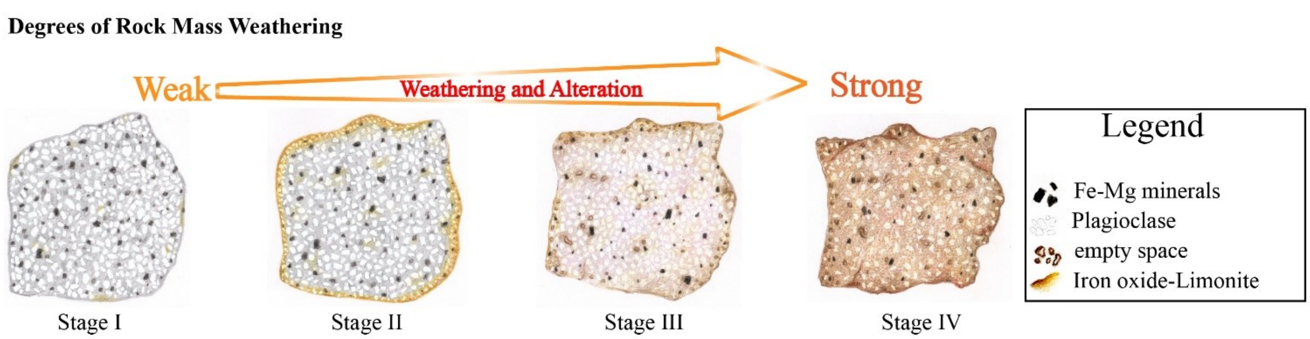

Figure 7: Degrees of rock mass weathering in the Shibafen lava flow of TVG.

Table 1: The weathering indexes of Shibafen lava flow in TVG.

	CIA	CIW	PIA	WIP
Stage I	52.9-56.8	57.4-62.1	43.4-58.6	49.1-57.3
Stage II Core	54.6-57.8	59.0-69.4	55.4-61.7	51.8-60.0
Stage II Ring	44.1-69.0	60.7-78.6	37.0-75.1	49.4-67.2
Stage III	63.0-70.9	65.1-74.9	65.6-72.6	33.2-47.6
Stage IV	64.7-76.0	69.3-77.4	66.9-77.0	27.0-42.9

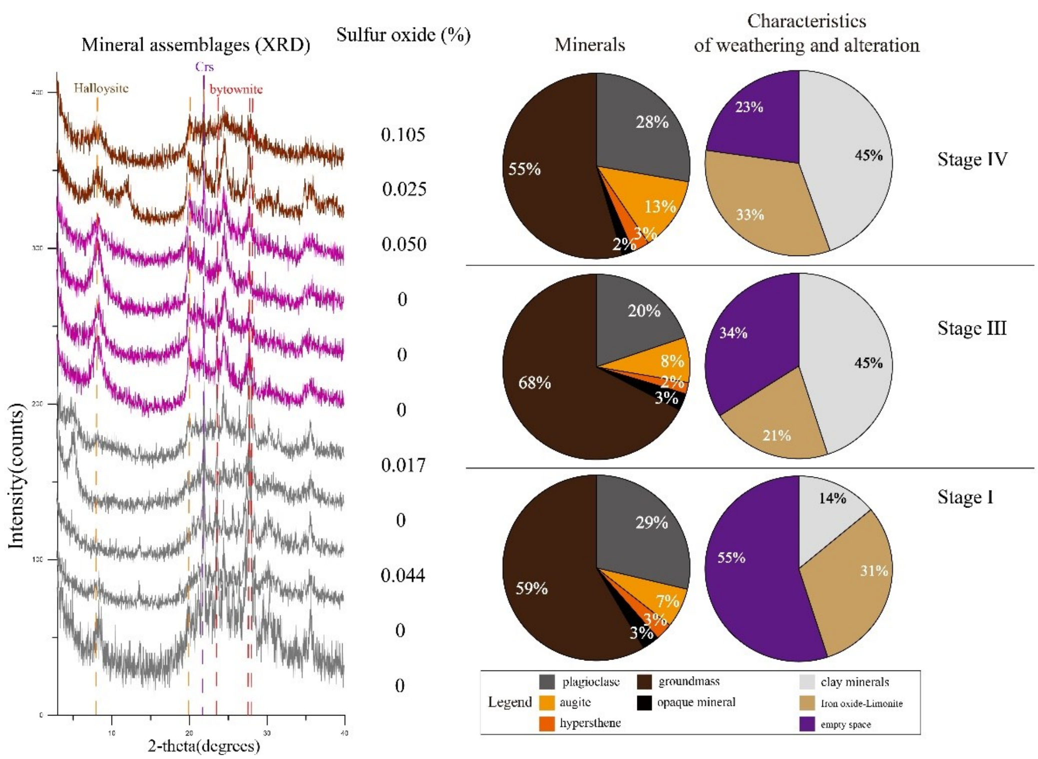

Figure 8: In the Stage I, III and IV, the mineral assemblages by X-ray diffraction, sulfur oxides, mineral percentages and characteristics of weathering and hydrothermal alteration by microscope.

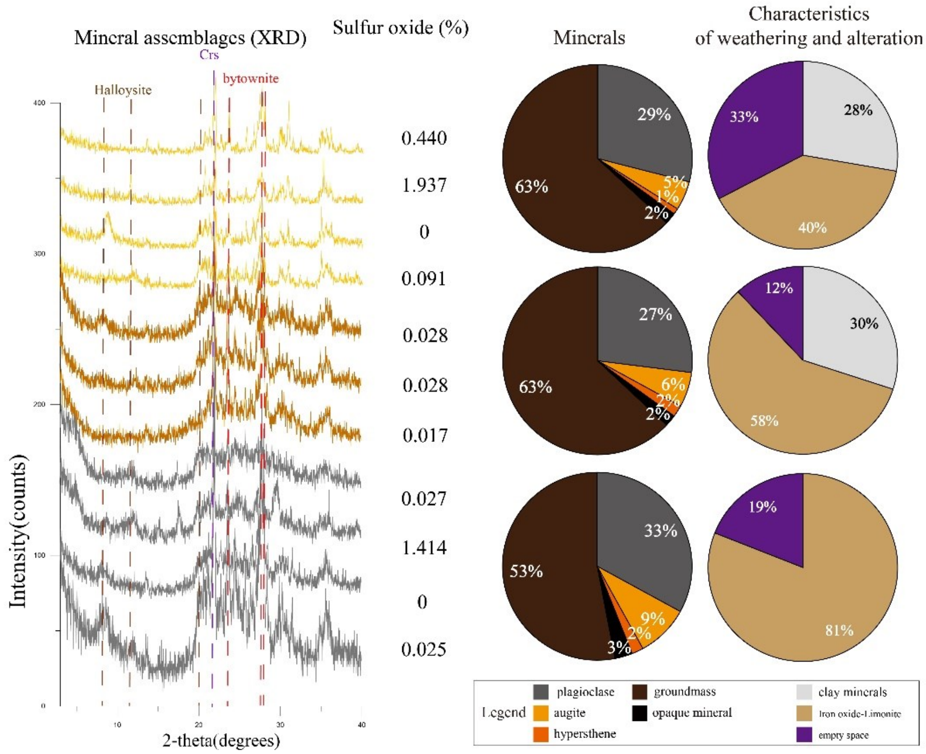

Figure 9: In the Stage II, the mineral assemblages by X-ray diffraction, sulfur oxides, mineral percentages and characteristics of weathering and hydrothermal alteration by microscope.

4. CONCLUSIONS

In this study has three of these findings which are worth summarizing:

(1) In Shibafen lava flow of TVG, the fresh andesite belongs to two pyroxenes basaltic andesite by QAP and TAS diagram, their mineral assemblages major consists of augite, hypersthene, and bytownite.

(2) According to the results of petrography, geochemistry, mineral assemblages, and weathering index, the two pyroxenes basaltic andesite of Shibafen lava flow can be classified to four stages by degree of rock mass weathering. Stage I is medium gray two pyroxenes basaltic andesite. Stage II belongs to slightly weathered degree that is ring sample. Stage III is grayish red purple andesite that belongs to moderately weathered degree. Stage IV is brown andesite that has highly weathered degree. Except for Stage I, the mineral assemblages of the other stages consist of augite, hypersthene, bytownite, cristobalite, halloysite and limonite.

(3) This study points out that the hydrothermal alteration influence two pyroxenes basaltic andesite more than weathering which evidence is provided from sulfur concentration of rock in Shibafen lava flow of TVG.

REFERENCES

Fedo, C. M., Nesbitt, H. W., and Young, G. M.: Unraveling the effects of potassium metasomatism in sedimentary rocks and paleosols, with implications for paleoweathering conditions and provenance. *Geology*, 23, (1995), 921–924.

Harnois, L.: The CIW index: a new Chemical Index of Weathering. *Sedimentary Geology*, 55, (1988), 319-322.

Lee, H. F., Yang, T. F., Lan, T. F., Chen, C. H., Song, S. R., and Tsao, S.: Temporal variations of gas compositions of fumaroles in the Tatun Volcano Group, northern Taiwan. *J. Volcanol. Geotherm. Res.*, 178, (2008), 642-635.

Liu, C.M., Song, S.R., Chen, Y.L., and Tsao, S.: Characteristics and Origins of Hot Springs in the Tatun Volcano Group in Northern Taiwan, *Terr. Atmos. Ocean. Sci.*, **22**, (2011), 475-489.

Nesbitt, H.W. and Young, G.M.: Early Proterozoic climates and plate motions inferred from major element chemistry of lutites. *Nature*, 299, (1982), 715-717.

Parker, A.: An index of weathering for silicate rocks. *Geological Magazine*, 107, (1970), 501–504.

Yang, T. F., Sano, Y. and Song, S. R.: $^3He/^4He$ ratio of fumaroles and bubbling gases of hot spring in Tatun Volcano Group, North Taiwan. *Nuovo Cimento*, 22, (1999), 281-286.