

The Hydrothermal Alteration of Andesite in Tatun Volcano Group Geothermal System, Taiwan

Chia-Mei Liu*, Yu-Wei Tsai, Ching-Huei Kuo, Ke-Hen Song,
55, Hwa-Kang Road, Yang-Ming-Shan, Taipei, Taiwan 11114, R. O. C.

E-mail: *jim12@ulive.pccu.edu.tw

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

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

E-mail: kevin258357@gmail.com

Keywords: Hydrothermal alteration, petrography, mineral assemblage, Tatun Volcano Group, Taiwan

ABSTRACT

In northern Taiwan, the Quaternary volcanoes consist of the Tatun and Chilung Volcano Groups, the Kuanyinshan Volcano and offshore volcanic islets, i.e., Chilungtao, Huapaingshu, Meinhuahsu, and Penghiahsu. These compositions of volcanic rocks are predominantly composed of andesite with a little basalt or dacite. The Tatun Volcano Group (TVG), a typical multivert volcano, containing at least twenty volcanic composites, cones and domes in an area of $20 \times 20 \text{ km}^2$ (400 km^2), occupies the most volcanic areas in northern Taiwan. The volcanic activities of the TVG, i.e., hot springs and gas fumaroles, are well developed now and are mainly distributed in the periphery of main volcanic composites and cones along the Chihshan Fault with an area $18 \times 3 \text{ km}^2$ from the south to the north of the TVG area.

The Liuhaungku and Longfengku are two of the most active volcanic activities areas of the region. The aim of this paper is to study the petrography and mineral assemblages under the influence of volcanic gases in the TVG. The preliminary results showed that it has no evident element been eroded with samples taken from brownish-covered weathered andesite. In contrast, it has a lot of elements been eroded away, such as alumina, iron, potassium, and calcium in white-covered weathered andesite. Silicon and titanium are the most stable and resistant elements in the process.

1. INTRODUCTION

In Taiwan, there are four high geothermal potential areas in Taiwan including the Tatun Volcano Group, Ilan, Lushan, and Hwalian-Taitung areas, according to the previous reports and studies (Figure 1a)(MRSO, 1973, 1975, 1977, 1978, 1979, 1980; Liu et al., 2011; Chang et al., 2013). In the TVG area, it has been identified an active volcano based on a large number of shallow micro-earthquakes, harmonic codas, seismic tremors (Lin et al., 2005; Konstantinou et al., 2007), and high heat flows with geothermal gradients higher than $100 \text{ }^\circ\text{C}/\text{km}$ were detected through geothermal exploration between 1960s and 1970s (MRSO, 1969, 1970, 1971, 1973). Meanwhile, recent measurements of volcanic gases and $^3\text{He}/^4\text{He}$ ratios also show that an active magma chamber might still exist underneath the TVG (Yang et al., 1999; Lee et al., 2008).

The Tahuangtsui geothermal area, Lihunagku and Longfenku areas, have significant volcanic gas and the artificial hot spring. The aim of this paper is to study the erodibility of individual element as the proxy for mineralogical facies transition under the influence of volcanic gases in the TVG.

2. GEOLOGICAL SETTING

In the Lihunagku and Longfenku areas, these compositions of volcanic rocks are predominantly composed of andesite with a little basalt or dacite (Juang and Chen, 1989; Song et al., 2000; Lai et al., 2010; Tsai et al., 2010). Late Tertiary sedimentary sequences, i.e., the Wuchishan and Mushan Formations, occur as basement rocks below the volcanic body of the TVG. In the Tatun volcanic area, most of the andesitic lavas in the region are compact and impermeable, the basement rock, the Wuchishan Formation, consists mainly of thick-bedded to massive sandstone that good reservoir rock. Most of the hot springs issue acid sulphate-chloride water with temperature lower than $200 \text{ }^\circ\text{C}$ and pH values less than 4 that are found in the Wuchihshan sandstone under the Tahuangtsui thermal area (Figure 1b).

3. METHODS

In this paper, sixteen samples were collected and these samples were analyzed by microscopy, x-ray diffraction and energy-dispersive x-ray spectroscopy.

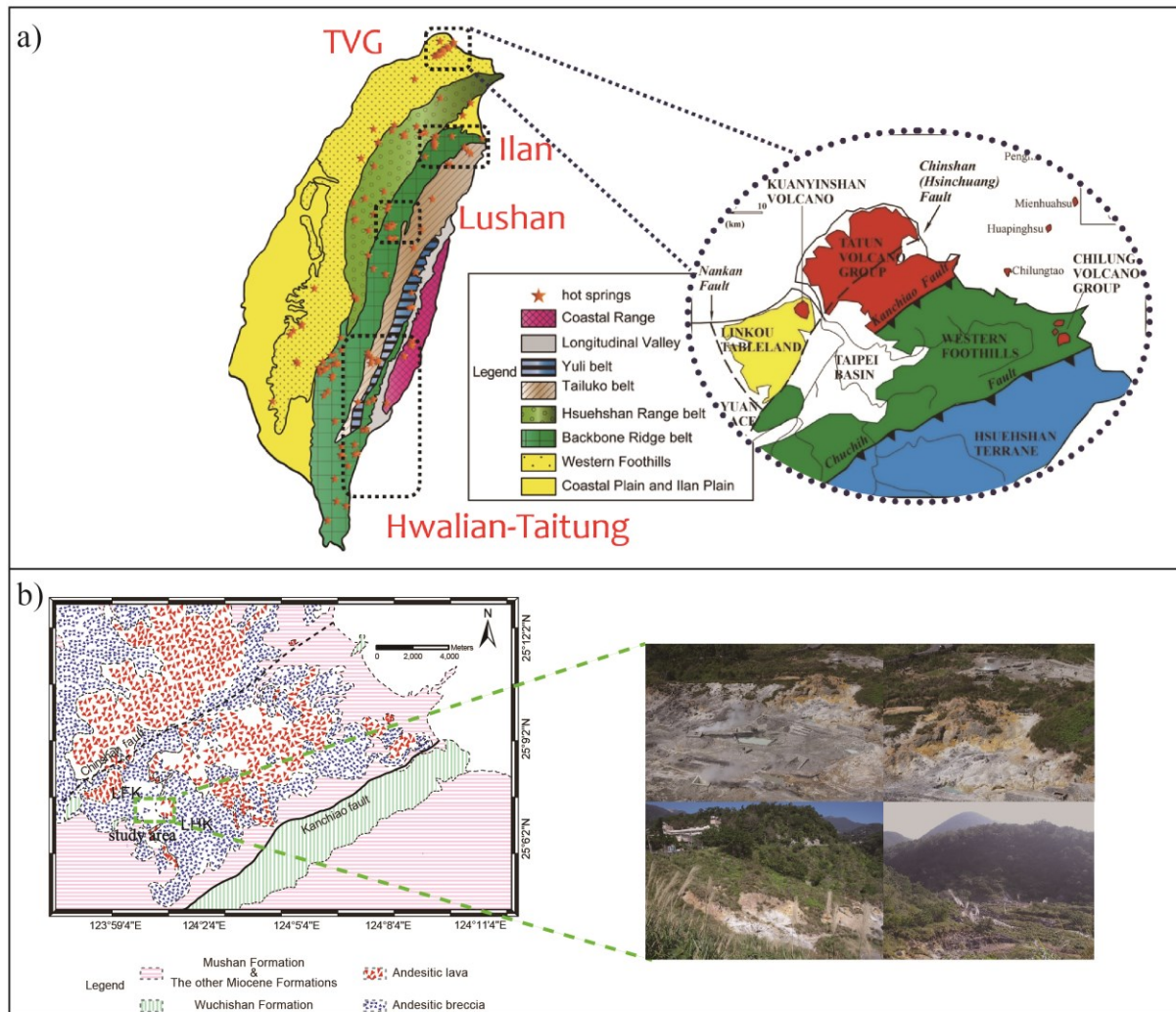


Figure 1: a) Four high potential geothermal area of Taiwan. b) The Liuhunagku and Longfenku areas have significant volcanic gas and hydrothermal alteration of andesite.

4. RESULTS AND DISCUSSION

4.1 Petrography

In this paper, the S02, S03, S07 samples are consistent of quartz, cristobalite, tridymite, and opal-A. The S01 sample is including quartz, cristobalite, tridymite, and opal-A, hypersthene, augite, hornblende and plagioclase. The other samples, S04-S06, S08-S16, are major composed of plagioclase, augite, hornblende, hypersthene and less consist of quartz, cristobalite, tridymite, and opal-A (Figure 2 and 3).

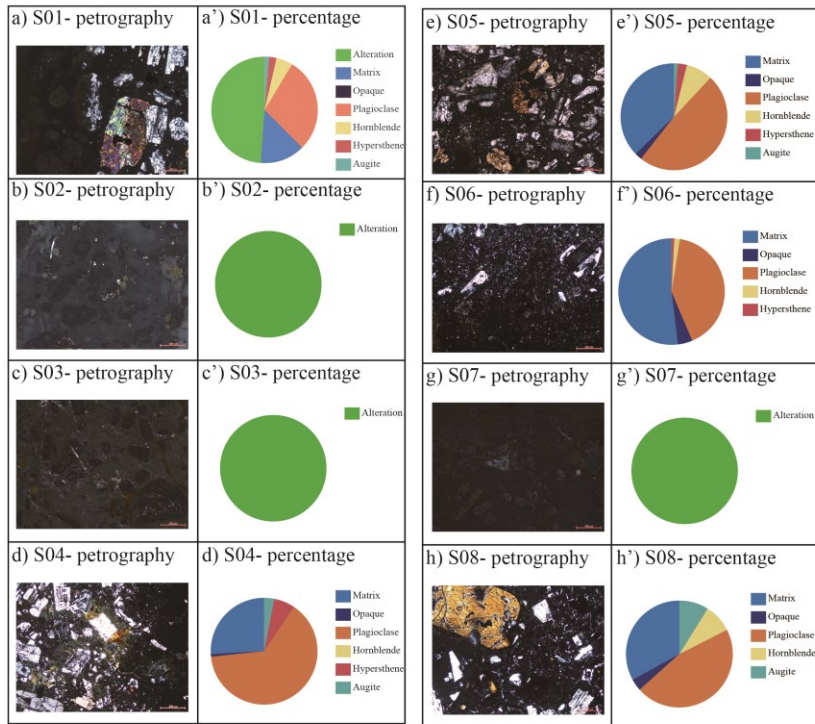


Figure 2: The petrography and mineral percentage of S01-S08 samples.

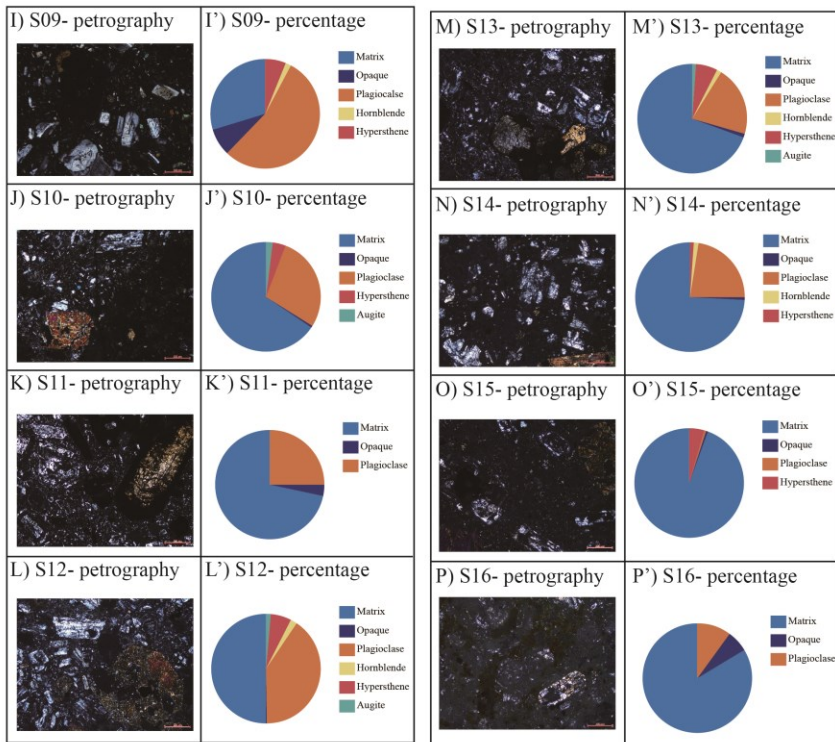


Figure 3: The petrography and mineral percentage of S09-S16 samples.

4.2 Major elements of brownish and white covered andesite

The silica concentration of white-covered andesite almost higher than brownish-covered andesite. The alumina, iron, potassium, and calcium are erode away in white-covered weathered andesite. However, the silicon and titanium are the most stable element in hydrothermal alteration process (Figure 4).

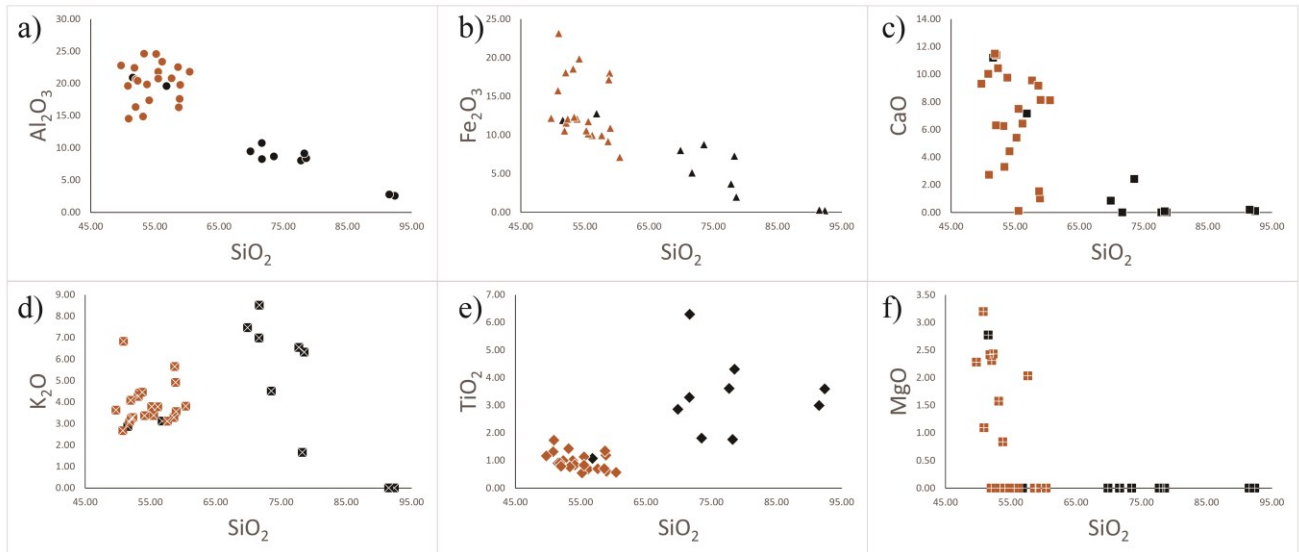


Figure 4: The different major elements v.s. silica. The fill black symbols indicate white-covered andesite, and the fill brown symbols display brownish-covered andesite.

4.3 Hydrothermal alteration

In Lihunagku and Longfenku areas, the XRD pattern results display that outer of white-covered andesite are major consist of tridymite, quartz, opal-A, and cristobalite, and inner of white-covered andesite are include tridymite and plagioclase. However, the XRD pattern results of brownish-covered andesite just are composed of tridymite and plagioclase from outer to inner.

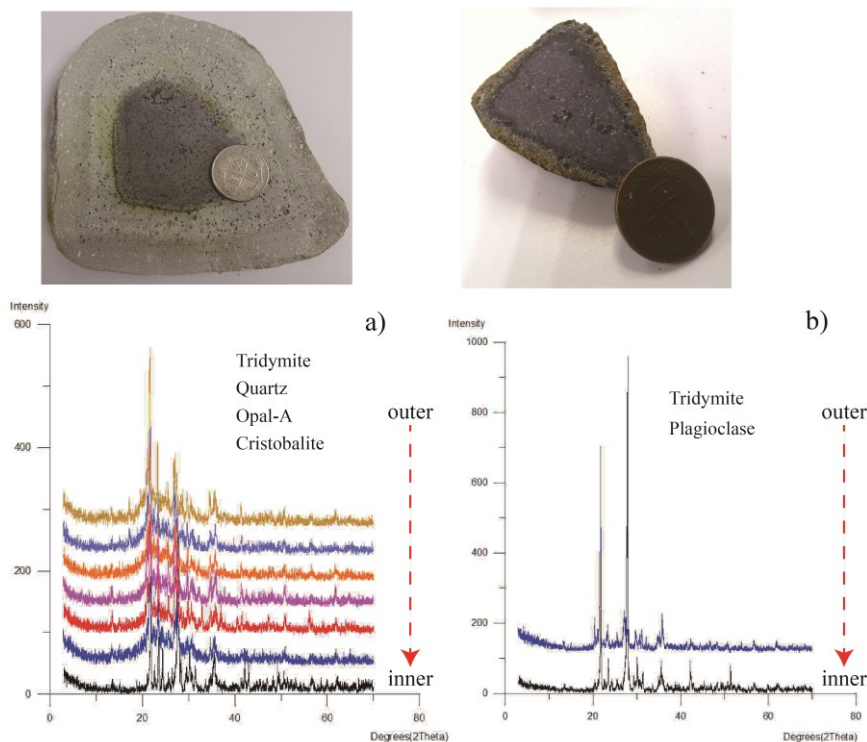


Figure 5: The XRD pattern in white-covered andesite (a) and brownish-covered andesite (b).

5. CONCLUSION

- (1) The S02, S03, S07 samples are consistent of quartz, cristobalite, tridymite, and opal-A. The S01 sample is including quartz, cristobalite, tridymite, and opal-A, hypersthene, augite, hornblende and plagioclase. The other samples, S04-S06, S08-S16, are major composed of plagioclase, augite, hornblende, hypersthene and less consist of quartz, cristobalite, tridymite, and opal-A.
- (2) The silicon and titanium are the most stable element in hydrothermal alteration process.
- (3) For the XRD results, the inner of white-covered and brown-covered andesite are included tridymite and plagioclase, the outer of white-covered andesite composed of quartz, cristobalite, tridymite, and opal-A.

REFERENCES

- Juang, W.S., and Chen, J.C.: Geochronology and geochemistry of volcanic rocks in northern Taiwan. *Bull. Geol. Survey*, **5**, (1989), 31-66. (in Chinese)
- Konstantinou, K.I., Lin, C.H., and Liang, W.T.: Seismicity characteristics of a potentially active Quaternary volcano: the Tatun Volcano Group, northern Taiwan. *J. Volcanol. Geotherm. Res.*, **160**, (2007), 300–318.
- Lai, Y.M., Lin, Y.J., Song, S.R., Tsai, Y.W., Hsieh, Y.C., and Lo, W.: Topography and Volcanology of the Huangtsuishan Volcano Subgroup, Northern Taiwan. *Terr. Atmos. Oceanic Sci.*, (2010), doi: 10.3319/TAO.2010.02.22.04.
- 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.
- Lin, C. H., Konstantinou, K.I., Liang, W.T., Pu, H.C., Lin, Y.M., You, S.H., and Huang, Y.P.: Preliminary analysis of volcano seismic signals recorded at the Tatun volcanic group, northern Taiwan. *Geophys. Res. Lett.*, **32**, (2005), L10313, doi:10.1029/2005GL022861.
- MRSO: The geothermal exploration of the Tatun Volcano Group (I). MRSO Report, **90**, (1969), 63 pp. (in Chinese)
- MRSO: The geothermal exploration of the Tatun Volcano Group (II). MRSO Report, **102**, (1970), 86 pp. (in Chinese)
- MRSO: The geothermal exploration of the Tatun Volcano Group (III). MRSO Report, **111**, (1971), 48 pp. (in Chinese)
- MRSO: The Report on Geothermal Exploration of TVG, IV. Mining Research and Service Organization, (1973), 78 pp. (in Chinese)
- Song, S.R., Tsao, S., and Lo, H.J.: Characteristics of the Tatun volcanic eruptions, north Taiwan: implications for a cauldron formation and volcanic evolution. *J. Geol. Soc. China*, **43**, (2000), 361-378.
- Tsai, Y.W., Song, S.R., Chen, H.F., Li, S.F., Lo, C.H., Lo, W., and Tsao, S.: Volcanic Stratigraphy and Potential Hazards of the Chihshingshan Volcano Subgroup in the Tatun Volcano Group, Northern Taiwan. *Terr. Atmos. Oceanic Sci.*, (2010), doi: 10.3319/TAO.2010.02.22.03.
- Yang, T. F., Sano, Y., and Song, S.R.: $^3\text{He}/^4\text{He}$ ratio of fumaroles and bubbling gases of hot spring in Tatun Volcano Group, North Taiwan. *Nuovo Cimento*, **22C**, (1999), 281-286.