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# Volcanic gas controls the alteration mineral assemblages in the Tatun Volcano Group, Taiwan

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**ABSTRACT**

This study firstly applies the petrography and alteration mineral assemblages of rocks to study mineralogical facies transition under the gas-water-rock interaction in Longfengku and Liuhaungku regions of the Tatun Volcano Group (TVG).

The results showed that the andesite consists of augite, hypersthene, hornblende, plagioclase and these samples far away from fumaroles?; a partial altered andesite composes of opal, cristobalite and less plagioclase; and an andesite includes opal and a little plagioclase in the closer fumaroles area. The sulfur does not exist in samples far away from fumaroles.

In addition, the results of SEM, EDS and ED-XRF showed that samples are texture intact with lower silica content, and higher aluminum and calcium elements in the area that distant fromfumaroles. Finally, this study suggests the sulfur component plays an important role during alteration process.

## 1. INTRODUCTION

The volcanic gas is a well agent for monitoring active volcanoes, and it can provide evidence that the magmatic gas how to scrub the rock between magma chamber and surface (Symonds et al., 2001; Napoli et al., 2016). The Tatun Volcano Group (TVG) has recently been identified as an active volcano in 2016 (Lin 2016). The TVG, a typical multivent volcano, containing at least twenty volcanic composites, cones and domes in an area of 20× 20 $km^2$ (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 ?and are mainly distributed in the periphery of main volcanic composites and cones along the Chihshan Fault with an area 18 × 3 $km^2$ from the south to the north of the TVG area (Chen and Wu, 1971; Lai et al., 2010; Tsai et al., 2010).

This study provides a new evidence how volcanic gas controls the alteration mineral assemblages of andesite. This study collected the andesite samples and analyzed the petrography, mineral assemblages, element concentration, morphology and element contents of rock by microscope, XRD, micro-XRF analyzer (XGT), SEM and EDS in the TVG.

## 2. GEOLOGICAL SETTING

Late Tertiary sedimentary sequences, i.e., the Wuchishan and Mushan Formations, occur as basement rocks below the volcanic body of the TVG. In addition, the volcanic rocks are predominantly composed of lava flows with subsidiary pyroclastic breccias, tuffs, lahars and reworked volcanic lastics (Figure 1) (Huang, 1998).

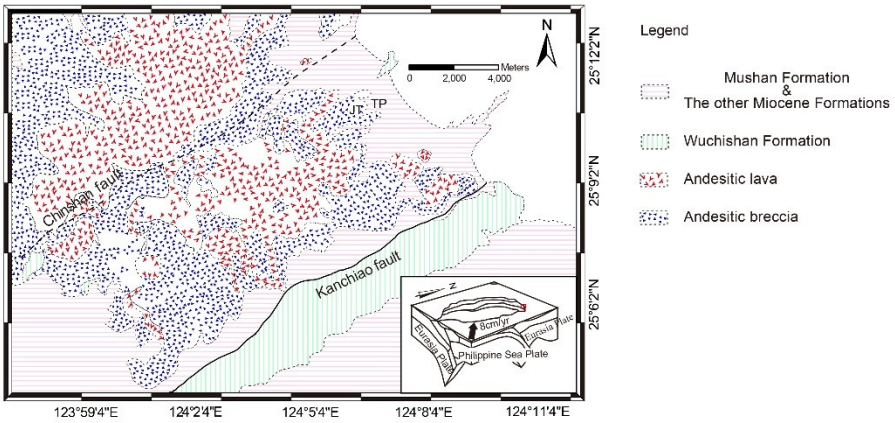


**Figure 1: Schematic geological map in the Tatun Volcano Group (modified from Huang, 1998).**

## 3. RESULTS AND DISCUSSION

### 3.1 Occurrence, Petrography and XRD pattern

The andesite sample of this study can be classified into six layers from inner to outer (Figure 2). The layer I is gray black in color with black minerals grains . The layer II is medium gray in color with grains of white minerals. The layer III is medium light gray in color with grains of black minerals. The layers IV and V are light gray color with the grains number of white minerals more than black minerals. The layer VI is very light gray in color with white minerals.

The petrography analusis showed that layer I has euhedral plagioclase, augite, hypersthene, hornblende, Opaque minerals and groundmass. The II, III, and IV layers contain less Fe-Mg minerals, and most minerals could not be observed in thin section under microscope. The applies to layers V and VI as well (Figure 3).

The figure 4 display mineral assemblages of the six layers by XRD. Except for the layer I, the other layers have bytownite, cristobalite, opal-A. The layer I just has bytownite.

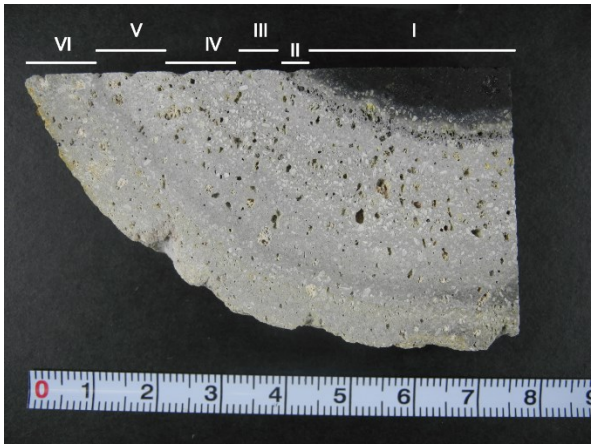


**Figure 2: The visible scale of andesite in TVG.**

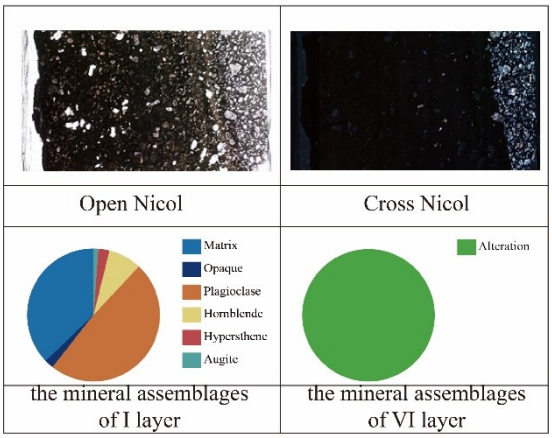


**Figure 3: The petrography of andesite in this study.**

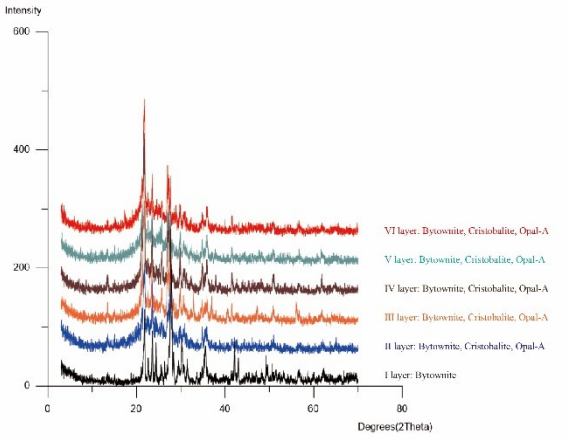


**Figure 4: The XRD pattern of andesite.**

### 3.2 The elements concentration, morphology and element contents of andesite

Figure 5 shows the elements concentration of andesite, the silicon and sulfur are positive correlation, however, the both of calcium and iron are negative relationship. The appearance of sulfur in andesites is an unusal case because the sulfur is enrich element in volcanic gas. We suggest the volcanic gas acting as an important agent for hydrothermal process.

Figure 6 shows the transition of morphology from inner to outer. The morphology of inner andesite shows massive, however, the morphology of outer andesite is similar to the process of leaching. However, inner layers have higher silicon, calcium and aluminum than that of the outer layers.

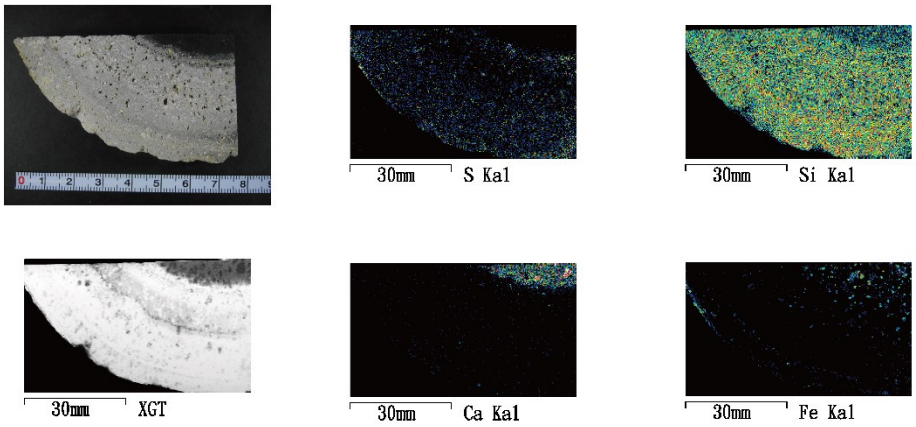


**Figure 5: The element pattern by micro-XRF analyzer (XGT).**

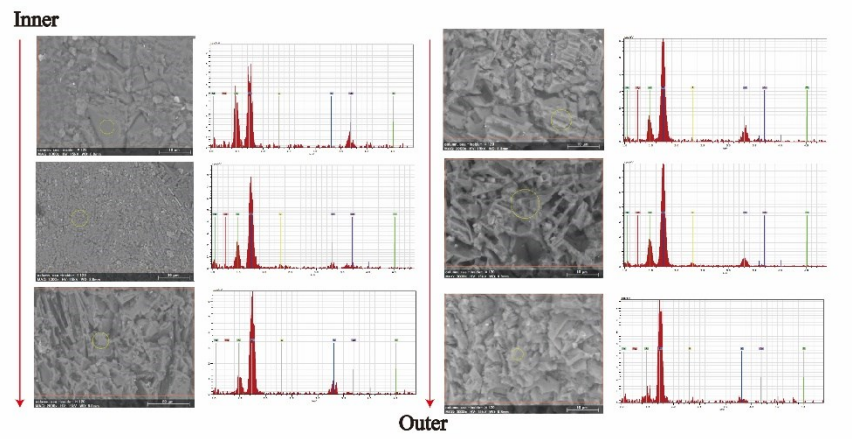


**Figure 6: The element contents distribution and morphology of andesite by SEM and EDS.**

## 4. CONCLUSION

(a) Petrography and x-ray pattern showed that andesite of blacky gray color includes augite, hypersthene, hornblende, plagioclase (outer andesite). The altered andesite is composed of opal-A, cristobalite and less plagioclasewhile the completely altered andesite consists almost of opal-A. The sulfur element does not exist in andesite of blacky gray color (inner andesite).

(b) SEM and EDS showed that the texture is intact with higher concentrations of silicon, aluminum and calcium elements in the inner layers. However, the outer layers exhibits leached texture with less concentrations of silicon, aluminum and calcium elements.

(c) Finally, this study suggests that the sulfur of gas fumaroles plays an important role in this unique hydrothermal alteration process.

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