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The Evidence of Neutral Thermal Water by Petrography and Mineral Assemblages of Andesite in Tatun Volcano Group, Taiwan

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ABSTRACT

In Taiwan, the neutral thermal water of Tatun Volcano Group has seen increased attention in the last several decades, due to the neutral thermal water causes corrosion of pipeline less than acidic thermal water during developing geothermal resource. This research focused on the characteristics of core of neutral thermal water area, and applied the petrography, and X-ray diffraction to interpret water-rock interaction in the neutral thermal water area of Tatun Volcano Group (TVG).

In the TVG, the pH value of neutral thermal water is between 5.5 and 6.5, and their stable isotopic values of hydrogen and oxygen range from -24.8 ‰ to -35.5 ‰ and from -6.5 ‰ to -2.5 ‰, respectively. According to the petrography phenomenon, there shown the significant alteration zone between lava and pyroclastic rock, and existed a lot of iron oxide-limonite and montmorillonite. Furthermore, the alteration mineral has iron oxide-limonite and montmorillonite. This study inferred to the neutral thermal water was caused by mixing surface water with volcanic gas based on the evidence of iron oxide-limonite. Finally, this study interpreted that the process of the petrography and minerals transformation of andesite by water-rock interaction. First stage, it was fresh rock that is gray andesite. Second stage, it was medium gray andesite with empty space, and calcite has replaced part of plagioclase and groundmass. Third stage, it was dark gray andesite, had cristobalite, with iron oxide-limonite precipitated in empty space, and montmorillonite produced from plagioclase by hydrothermal alteration. Finally, it was brown andesite, had montmorillonite and cristobalite, with a lot of iron oxide-limonite precipitated in empty space and groundmass.

1. INTRODUCTION

In Taiwan, it can be divided to three stages from 1962 until now for the geothermal development. First stage, those results shown that there are a lot of thermal water distribution in the meta-clastic rock, and fist geothermal power plant was sat up in the Chingshui Geothermal Field, which belongs to low-grade meta-clastic rock, at 1982. At that time, the Tatun Volcano Group was recognized a highest geothermal potential area but it had serious corrosion problem. Second stage, we were re-build up the geothermal power plant of the Chingshui Geothermal Field, found higher geothermal potential area in Ilan Plain, which has thick alluvium from 100 m to 1,000 m, and detected the resistance time of thermal water, and providing the conceptual model in the acidic and neutral thermal water of TVG. Now, we focus four sites to prepare geothermal power plant setting which include Tatun Volcano Group (Chen, 1970; Liu et al., 2011; Chen and Liu, 2013).

Therefore, this study collected the samples from outcrop and core that are situated near alteration zone and site of neutral thermal water, respectively. We applied the petrography, X-ray diffraction, and energy dispersive X-ray fluorescence spectrometer on texture, mineral assemblages, and geochemistry, respectively. First, we analyzed and compared the characteristics of andesite samples of outcrop and core. Second, we provided the process of water-gas-rock interaction in the neutral thermal water of Tatun Volcano Group. Finally, we construct the renew model and supply the monitoring items for geothermal power plant setting.

2.METHODOLOGY

This study takes photos of the whole thin section by microscope (Type: Olympus BX51) and by digital camera at 40X with parallel and cross polarizations, respectively. Splice all 40X photos to become one picture, which call it “Full Detail Picture” (Figure 1). This picture can provide detailed information about grain size, roundness, sorting, mineral assemblages and their percentages in the sample.

For alteration mineral, this study prepares clay slide. Deposit clay water onto glass slide and air-dry. This step is to orient the clay mineral. And we glycol sample in the oven at 60 °C for 4 h. This step will help identify the montmorillonite. Finally, analyze the samples by X-

ray diffraction (SHIMADZU TYPE: XRD-6000). This procedure uses Cukα radiation at 30 KV, 30 mA with 2°/min scanning speed under the angle ranging between 3° and 40°.

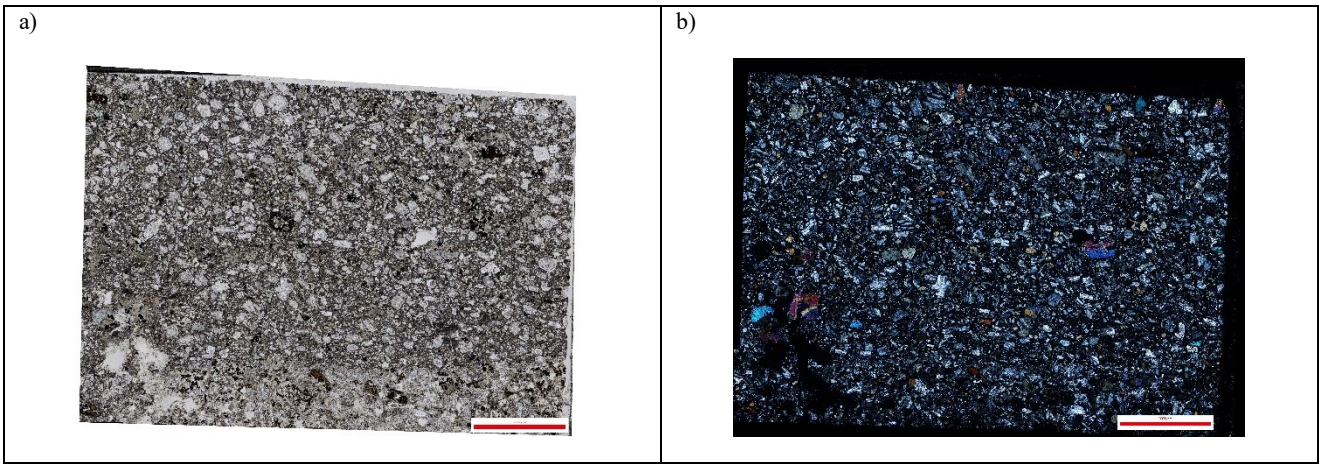

Figure 1: The Full Detail Picture in parallel and cross polarizations.

3. RESULTS AND DISCUSSION

3.1 Sampling sites and named rock

This study collected pyroclastic rock, lava and core samples near and far away alteration zone that shown in the Figure 2a. The Figure 2b displayed the rock type and lava samples are andesite and basaltic andesite by TAS classification.

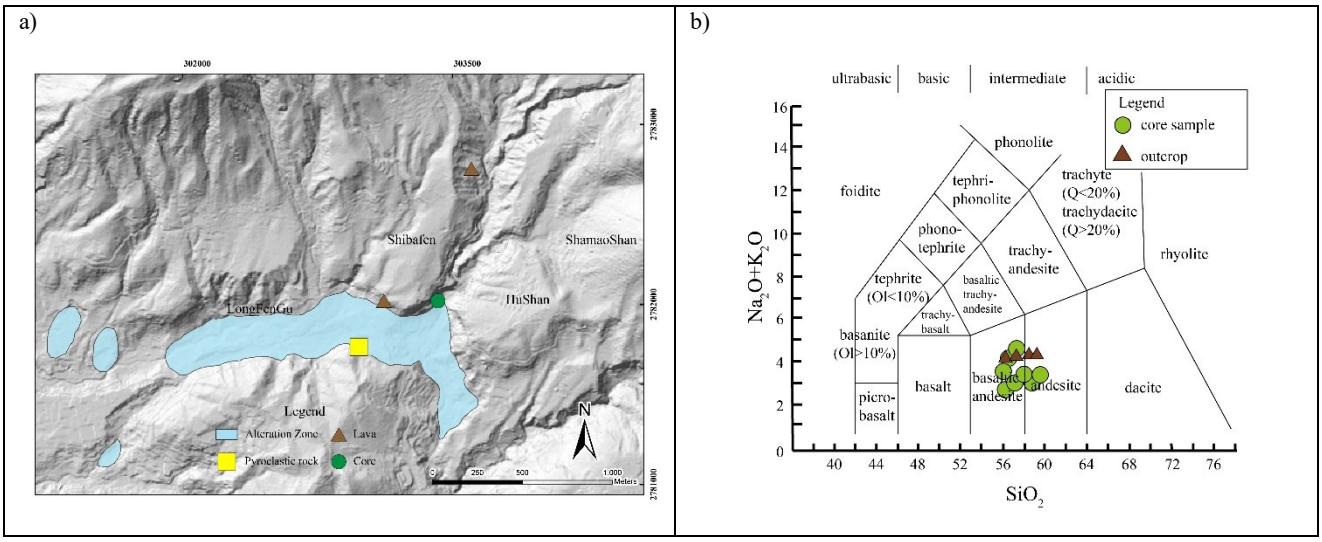

Figure 2: (a) This study sampling sites and alteration zone. (b) The sample type is named by TAS classification (total alkali and silica contents).

3.2 Hand specimen and petrography descriptions of lava and pyroclastic rock near alteration zone of outcrop

The Figure 3 shown the hand specimen and petrography results of lava and pyroclastic samples. For hand specimen, the pyroclastic rock presented many layers, but lava only displayed two layers and the alteration crust of lava is thin less than 0.5 cm. Either pyroclastic rock or lava sample, they consist of matrix (groundmass), opaque minerals, plagioclase, hypersthene, augite. However, the lava sample has iron oxide-limonite.

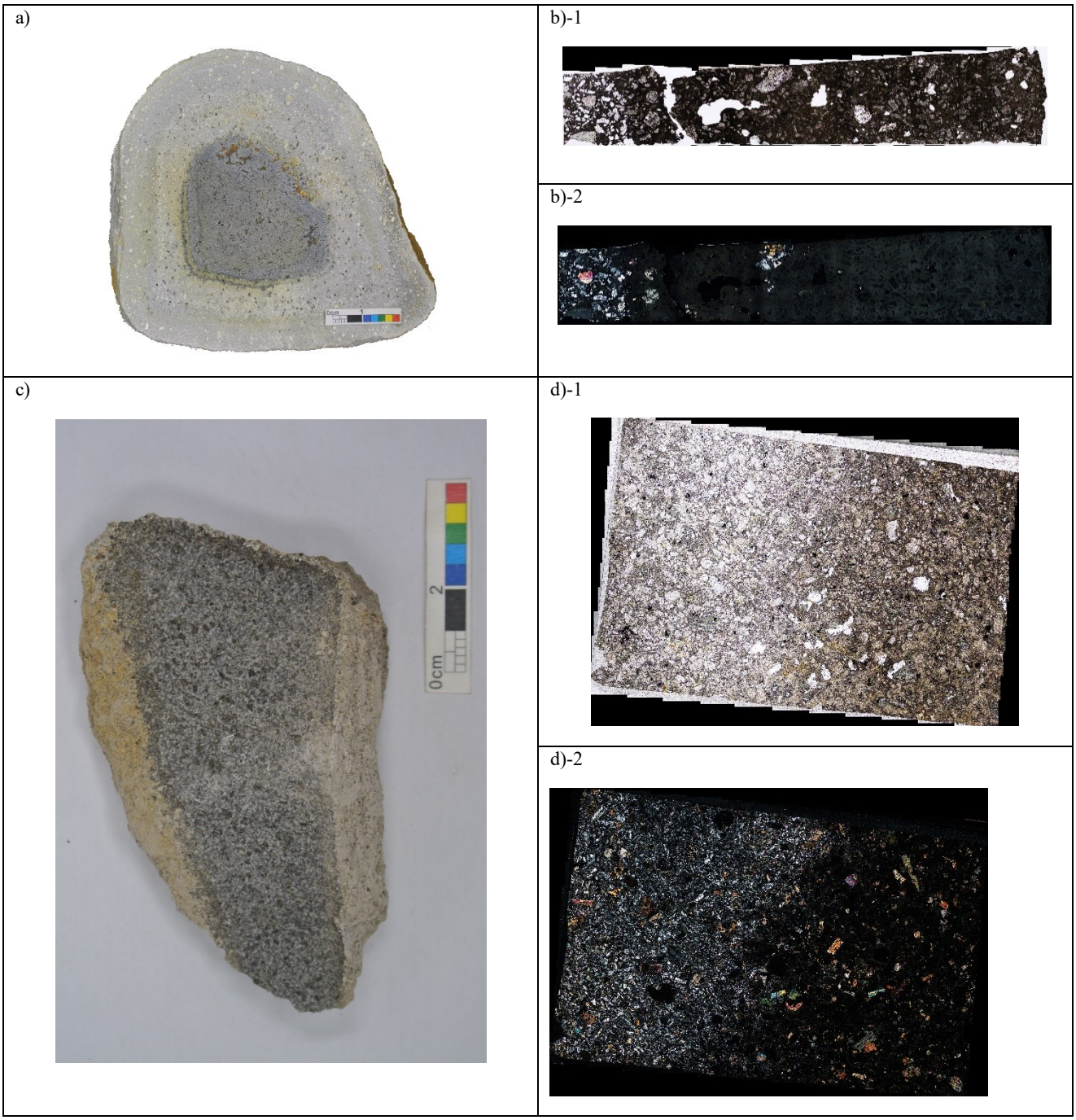

Figure 3: The hand specimens of lava and pyroclastic rock. (a) The pyroclastic rock has many layers. (b)-1 and (b)-2 shown the thin section of pyroclastic rock. (c) The lava sample is two layers. (c)-1 and (c)-2 displayed the thin section of lava sample.

3.3 Alteration mineral assemblages and geochemistry by XRD and ED-XRF

The Figure 4 shown the X-ray pattern and sulfur concentration. The pyroclastic rock has cristobalite, opal-A and significantly sulfur signal, which arrived more than 6 % (Figure 4a and 4b). And then, the lava samples consist of halloysite and cristobalite, and they have minor sulfur concentration, if they are far away alteration zone (Figure 4c).

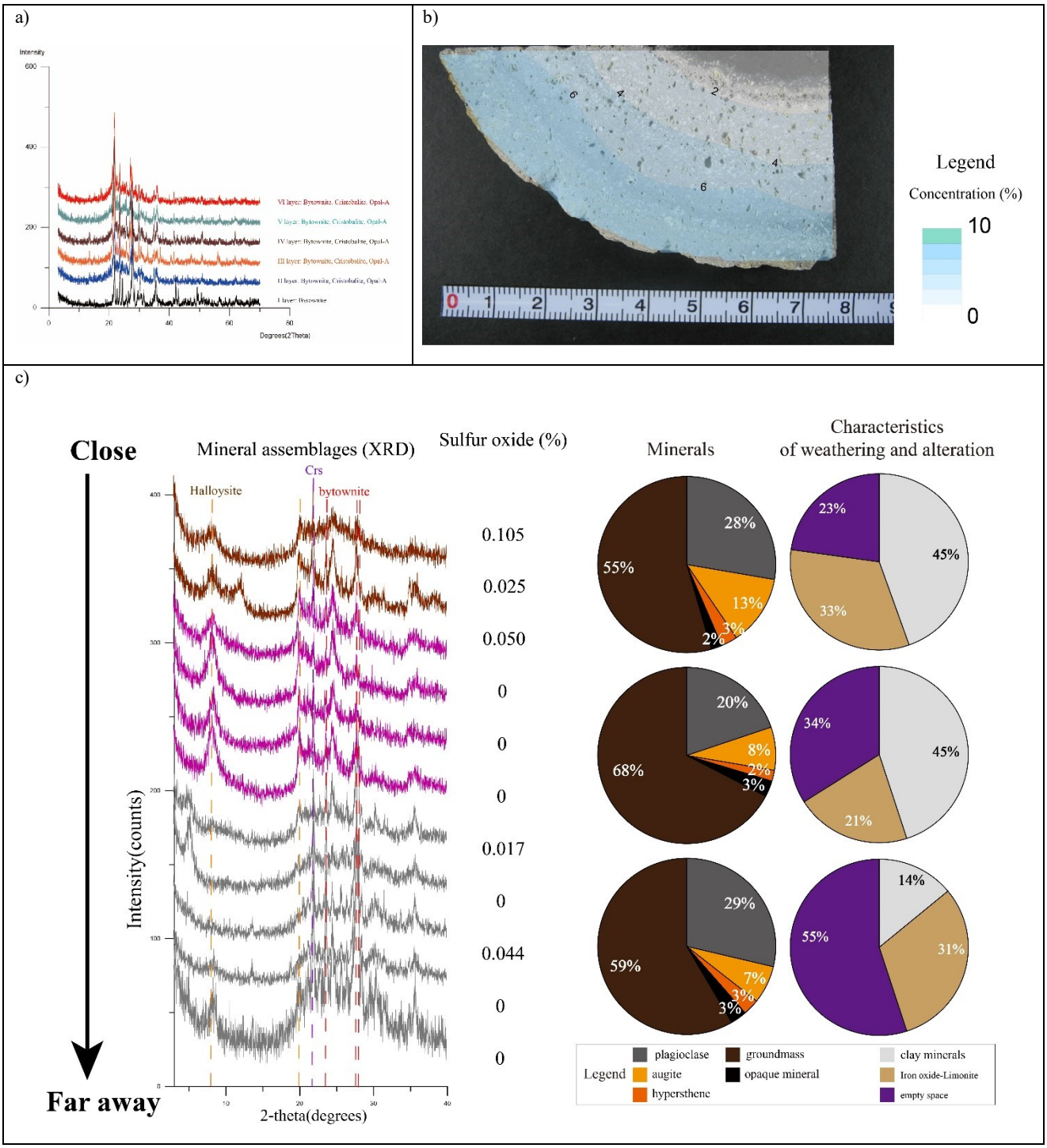

Figure 4: The alteration mineral and sulfur concentration. (a) The X-ray patterns of pyroclastic rock. (b) The sulfur concentration of pyroclastic rock from core to ring. (c) The X-ray patterns and sulfur contents of lava sample near and far away alteration zone.

3.4 The characteristics of core samples in the neutral thermal water

The core samples didn't detect sulfur signal. The iron oxide-limonite, montmorillonite are widely distribution in lava and pyroclastic rock, however, the calcite only shown lava sample near the boundary of lava and pyroclastic rock (Figure 5).

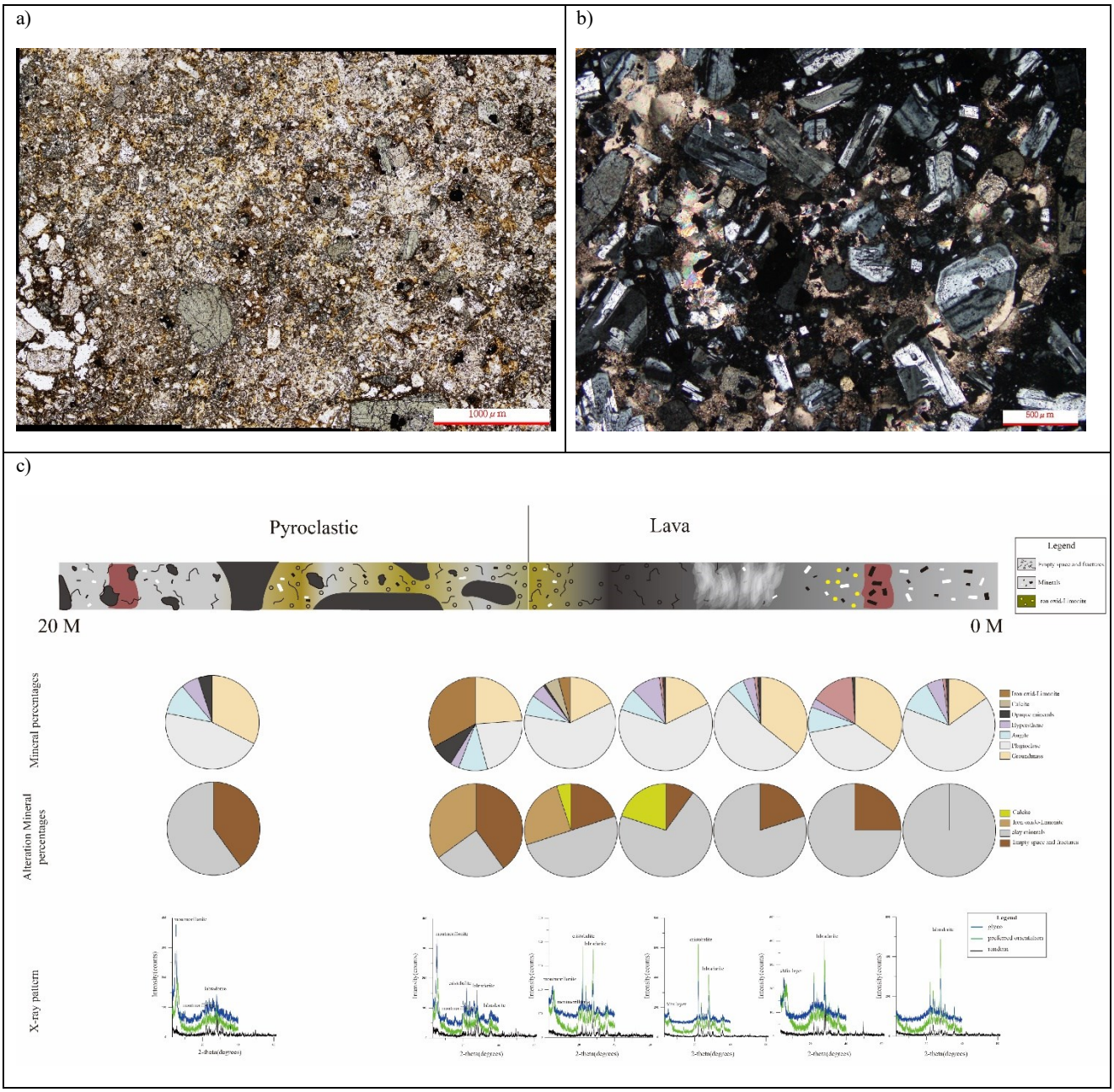

Figure 5: The percentage of minerals and alteration minerals with depth. (a) The iron oxide-limonite in core sample. (b) A few calcite display in lava sample.

3.5 The renew conceptual model in the neutral thermal water of Tatun Volcano Group

Based on the sulfur concentration, calcite, cristobalite, halloysite, iron oxide-limonite and montmorillonite, this study provides that the process of water-gas rock interaction of Tatun Volcano Group has three stage. First, the acidic water dissolves minerals and produce the empty space. Second, the huge surface water injection. And finally, precipitated the iron oxide-limonite (Figure 6).

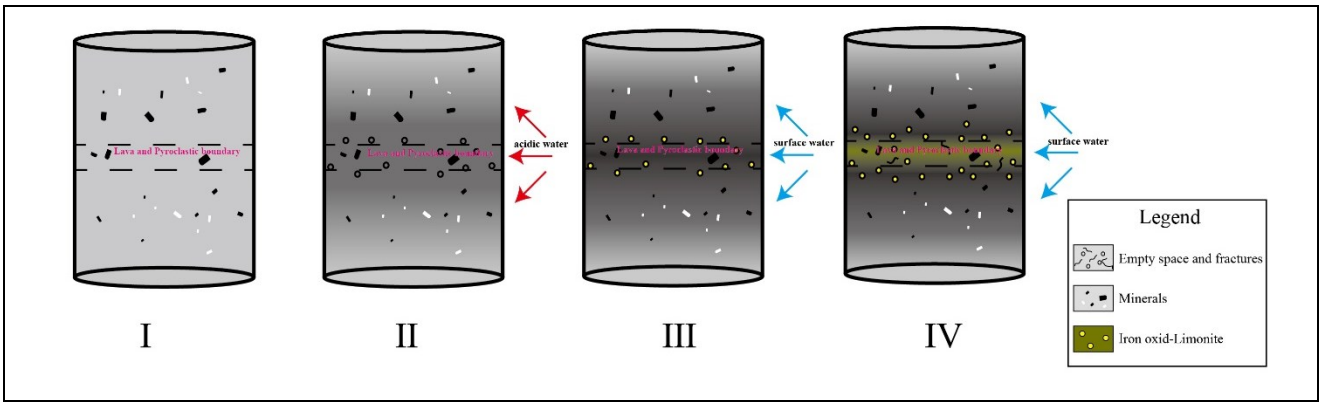

Figure 6: The process of water-gas-rock interaction in neutral thermal water of Tatun Volcano Group.

4. CONCLUSIONS

These findings are worth summarizing as below:

(1) In this study, all samples belong to basaltic andesite and andesite by TAS classification.

(2) The pyroclastic rock is altered more than lava either outcrop or core sample.

(3) The alteration minerals have opal-A, cristobalite, halloysite, kaolinite, limonite, calcite, and montmorillonite. The opal-A only exits in pyroclastic rock of outcrop, the calcite and montmorillonite present in core sample. The limonite shows in lava of outcrop and core sample.

(4) The sulfur just exists in pyroclastic rock and lava of outcrop. In the core sample, we didn't detect any sulfur signal.

(5) The renew conceptual model infers to the surface water is a key point that let the acidic thermal water change to neutral thermal water.

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