

# The recharge characteristics in the highly geothermal potential area, Tatun Volcano Group, Taiwan

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## ABSTRACT

It has been long recognized that the Tatun Volcano Group is the most promising geothermal energy potential area, Taiwan. However, little attention has been paid in supply of water in terms of geothermal operations. This study provides a preliminary result from two adjacent catchments, Southern Sulfur and Northern Sulfur creeks, by analyzing geochemistry and water levels of surface water and shallow groundwater to learn the recharge characteristics of the region.

Two groups, Ca-Mg HCO<sub>3</sub> and Ca-Mg SO<sub>4</sub>, in both the surface water and shallow groundwater are identified by Piper Diagrams. It seems that groundwater reservoirs are affected by the precipitation exceed 500mm differently, 5-6 months for the Southern Sulfur and 3-4 months for the Northern Sulfur Creek catchments., HCO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>-2</sup>, Ca<sup>+2</sup> and Mg<sup>+2</sup> are the most closely related to the variations of precipitation and could be used as indicators for further investigations.

## 1. INTRODUCTION

It has been long recognized that the Tatun Volcano Group is the most promising geothermal energy potential area in Taiwan since it is the only region with volcanic activities. The investigation can be traced back to 1970s. Total 82 wells were drilled during 1966 to 1972 to investigate the potential geothermal energy in the TVG by Ministry of Economic Affairs. The reservoir temperature was estimated can be as high as 293°C with total capacity reach 500 MWe (Huang et al.,1973). However, little attention has been paid in supply of water in terms of geothermal operations.

As fluids move through rocks influenced by geothermal, they react chemically with the rocks, which themselves are usually chemically complex. Certain minerals in the reservoir rocks may be selectively dissolved by the fluids while other minerals may be precipitated from solution or certain chemical elements from the fluid may substitute for certain other elements within a mineral. These chemical/mineralogical changes in the reservoir rocks may also result in changes in fluid geochemical characteristics. We have collected water samples from creeks, wells and precipitation and analyzed their geochemical, water level fluctuations and isotopes properties since 2017. This study provides a preliminary result from two adjacent catchments, Southern Sulfur and Northern Sulfur creeks, by analyzing geochemistry and water levels of shallow groundwater to indicate the characteristics of groundwater recharge of the region with an attempt to provide the first hand information for the future exploration.

### 1.1 THE STUDY AREA

The study area (Figure 1) is located in the Tatun Volcano Group (TVG). It is mainly composed of pyroclastic deposit and andesitic bedrock belongs to the Northern Taiwan Volcanic Zone and is the most southwesterly part of the Okinawa Trough. Previously, the group was considered dormant; however, Chen and Lin (2002) reported recording some very young eruption products (less than 20 ka) in the Taipei Basin. Seismic observations also recorded some interesting volcanoseismic signals, which are considered to be most probably associated with the direct or indirect interaction between hydrothermal or magmatic fluids and solid rock in the upper crust. Compiling results from geothermal and seismic research, Song et al. (2000) concluded that the TVG could be still active. Based on helium isotopic data, Yang et al. (2003) suggested that a magma chamber may exist underneath Northern Taiwan, particularly in the area of Da-You-Keng (DYK) right in the neighbor of the proposed study area.

The Tatun Volcano Group (TVG), a typical multivalent volcano, containing at least twenty volcanic composites, cones and domes in an area of 20× 20 km<sup>2</sup> (400 km<sup>2</sup>), occupies the most volcanic areas in northern Taiwan. TVG is located in the north tip of Taiwan with the Kanjiao fault to the east and the Taipei basin is situated to its south. The study area (Fig. 1) is located in the TVG. It is mainly composed of pyroclastic deposit and andesitic bedrock belongs to the Northern Taiwan Volcanic Zone and is the most southwesterly part of the Okinawa Trough. Previously, the group was considered dormant; however, Chen and Lin (2002) reported recording some very young eruption products (less than 20 ka) in the Taipei Basin. Seismic observations also recorded some interesting volcano seismic signals, which are considered to be most probably associated with the direct or indirect interaction between hydrothermal or magmatic fluids and solid rock in the upper crust. Compiling results from geothermal and seismic research, Song et al. (2000) concluded that the TVG could be still active. Based on helium isotopic data, Yang et al. (2003) suggested that a magma chamber may exit underneath Northern Taiwan, particularly in the area of Da-You-Keng (DYK).

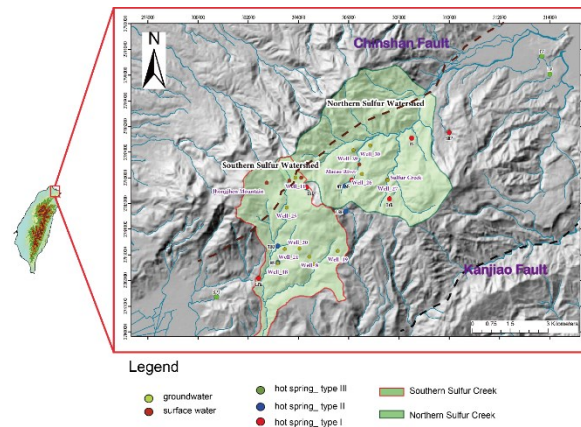


Figure 1: The study area with sampling locations.

There are two major fault systems, Chinshan fault and Kanjiao fault, in the study area. It is believed that these two faults dip southeast and extend into offshore (Chen et al., 2003).

The mean annual precipitation of the study area is about 5000mm. The precipitation days are average 211 day per year. The southwestern Monsoon dominates the study area during summer while the Northeastern Monsoon prevail during the winter time. The highest precipitation is recorded in October as 1607.3mm and the least precipitation is in May as 37.0mm.

Geothermal exploration can be traced back to 1970s. The Ministry of Economic Affairs initiated a project in order to cope with the first energy crisis. A total 82 wells drilled during 1966 to 1972 to investigate the potential geothermal energy in the study area. The reservoir temperature was estimated can be as high as 293°C with total capacity reached 500 MWe (Huang et al., 1973). Unfortunately, the project was terminated due to unable to cope with corrosion and the change of the energy policy. Taiwan has resumed to conduct geothermal exploration since 2009 in light of the new development of geothermal energy.

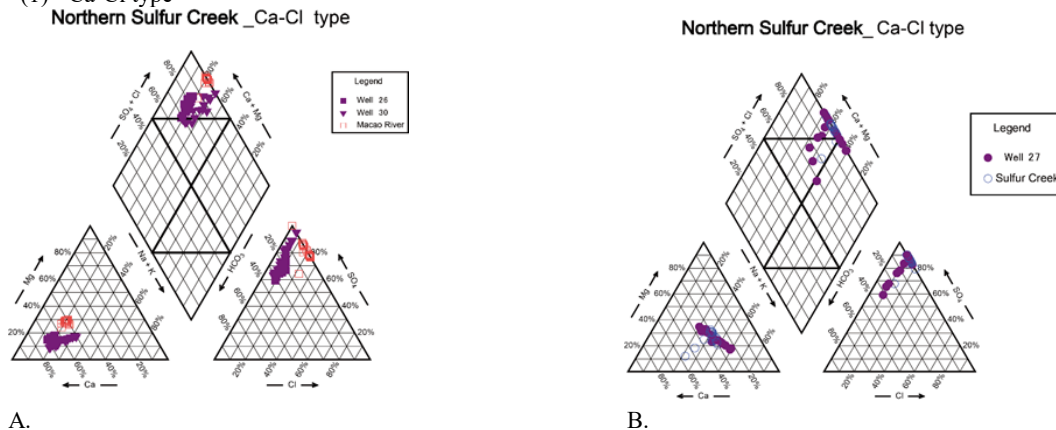
## 2. RESULTS AND DISCUSSION

Sampling sites includes three surface, Macao River, Sulfur Creek and Lujjiakeng, and 4 wells, Well 26, 27, 29 and 30, in the Northern sulfur creek catchment. In contrast, there are three surface sampling sites, Siaoyoukeng, Zhuzihu and Jhongjheng Mountain, and 8 wells, Well 8, 11, 17, 18, 19, 20, 21 and 25, in the Southern Sulfur Creek catchment.

### 2.1 The Northern Sulfur creek:

Two types of geochemical characteristics, Ca-Cl and Mg-HCO<sub>3</sub>, can be identified in the Northern Sulfur Creek catchment (Fig.2&3). Type Ca-Cl can further be divided into two different groups according to Ca<sup>2+</sup> percentage as shown in Fig.2.

#### (1) Ca-Cl type



A.

B.

Figure 2: Piper plots for the Northern Sulfur Creek catchment. Plot (A) indicates concentration percentage higher than 50% and (b) less than 50%.

The other type, Mg-HCO<sub>3</sub>, is found in Lujiakeng and Well 29. The dominant cation percentage are relative the same in both locations but Well 29 contain more anions than that of Lujiakeng (Figure 3).

(2) Mg-HCO<sub>3</sub> type  
Northern Sulfur Creek\_ Mg-HCO<sub>3</sub> type

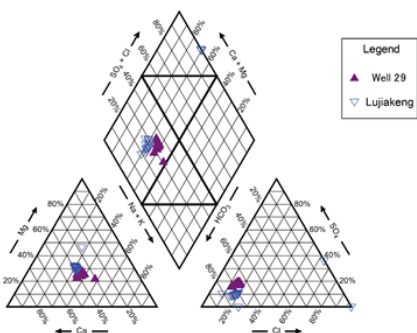


Figure 3: The Mg-HCO<sub>3</sub> piper diagram of the Northern Creek catchment.

Well 26 and 30 have the same geochemical properties with the Macao hot spring which indicates they may have come from the same recharge. This can also be confirmed by the pattern of groundwater level fluctuations (Fig.4). Two distinct react patterns to the major precipitation occurred in observation period. One is instant react to the major precipitation such as Well 26 and 30 while the others such as Well 27 and 29 take much more time to react implying two different recharge sources. In conjunction with isotopes data, water in Well 26 and 30 mainly comes from meteoric water while Well 27 and 29 may have mixed with other waters.

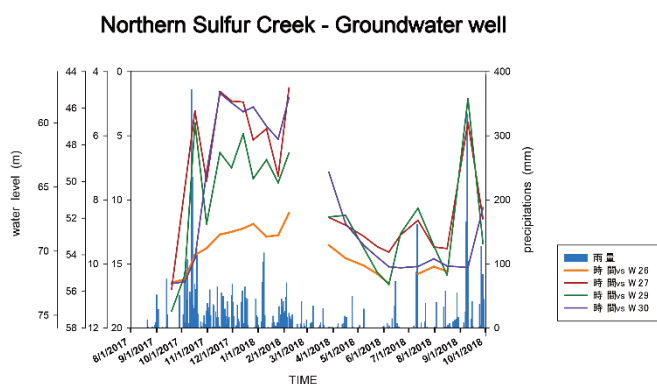


Figure 4: Groundwater level fluctuations of the Northern Sulfur Creek catchment.

2.2 The Southern Sulfur creek:

Two types of geochemical characteristics, Ca-Cl, Well 17, 20, and 8, (Fig.5) and Mg-HCO<sub>3</sub>, Well 11, 18, 19, 21, 25, can be identified in the Southern Creek catchment (Fig.6) based on piper diagrams. Well 20 has more SO<sub>4</sub> than that of Well 8 and 17.

(1) Ca-Cl type  
Southern Sulfur Creek\_ Ca-Cl type

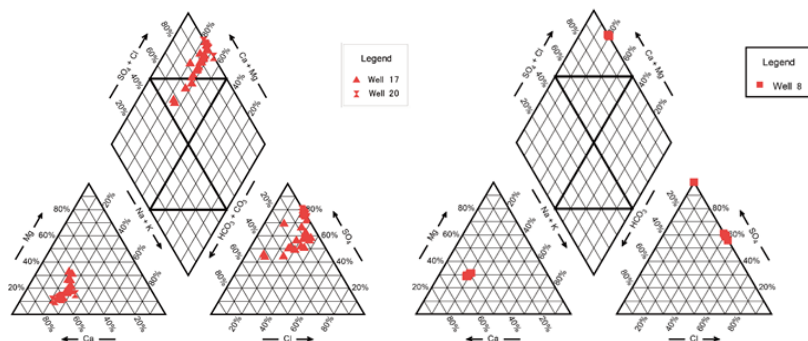


Figure 5: Ca-Cl type Piper plots for the Southern Sulfur Creek catchment.

(2) Mg-HCO<sub>3</sub> type  
Southern Sulfur Creek\_Mg-HCO<sub>3</sub> type

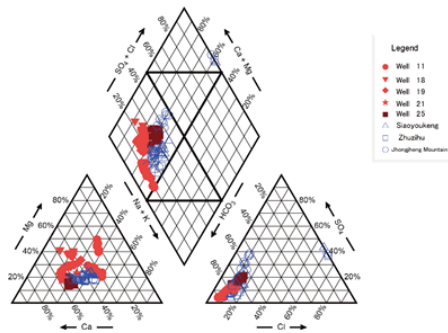


Figure 6: Mg-HCO<sub>3</sub> Piper plots for the Southern Sulfur Creek catchment.

There are also two distinct react patterns to the major precipitation occurred in observation period in the Southern Creek catchment in terms of response time. One is 2 months, Well 11、Well 20 and Well 21, and the other one is 4 months, Well 19 and Well 25, implying two different recharge sources(Fig.7).

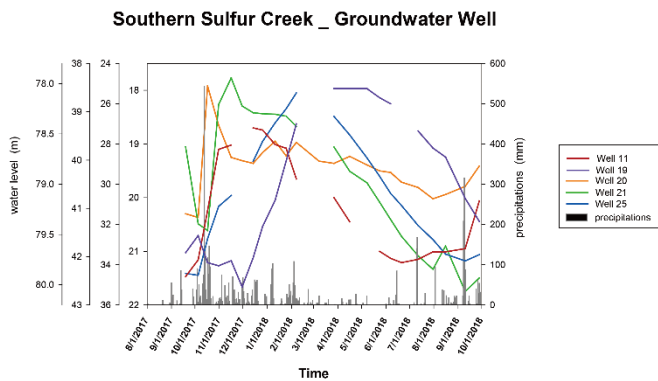


Figure 7: Groundwater level fluctuations of the Southern Sulfur Creek catchment.

**3. SUMMARY**

1. Two types of geochemical characteristics, Ca-Cl and Mg-HCO<sub>3</sub>, was identified in both the Northern Sulfur Creek and Southern Creek catchments.
2. In conjunction with isotopes data and groundwater level fluctuations, water in Well 26 and 30 mainly comes from meteoric water while Well 27 and 29 may have mixed with other waters in the Northern Sulfur Creek Catchment.
3. Two potential recharge areas can be identified in Southern Creek Catchment by integrated data as well
4. The preliminary results show the existence of different recharge mechanisms in the potential geothermal field, TVG.

**4. REFERENCES**

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