An examination on Tatun Volcano Group from seismic monitoring and geochemical observation

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Outline

Background of the studying area
- Geological background

Analysis
- Seismic Monitoring
- Geochemical analysis

Discussions and Conclusions
Geological Background

CF : Chinshan Fault
KF : Kanchiao Fault
★ : nuclear power plants
▲ : Chihsinshan
Geological Background

Eruption history (K-Ar dating)

Stage One 2.8–2.5 Ma
Stage Two 1.5–0.1 Ma

The presence of ash in sedimentary formations that are younger than about 20 ka in Taipei basin.
8 seismic stations with short period and broad-band are deployed since 2003.
Geochemical Sampling Sites

From 2003 to 2006
Basic analysis

Event classification

Volcanic tectonic
Regional tectonic

Locating events

Create velocity model

Relocating events

Events analyze
Basic analysis

Volcano seismic signal

High frequency earthquakes

Spasmodic bursts

no clear S wave
Basic analysis

- Volcano seismic signal
- Mixed frequency earthquakes
- Harmonic coda
- Low frequency earthquakes
Basic analysis

Volcanic gas composition

- H₂O
- N₂
- HCl
- Ar
- CH₄
- CO₂
- CO
- SO₂
- H₂S
- H₂
- S
- O₂
- He

Temperature
Basic analysis

Chemical composition

Arc type

Convergent plate gases

N$_2$/100

Divergent plate and hot spot gases

N$_2$/He

Groundwater

Mantle

Meteoric

10*He

N$_2$/Ar

Ar

He/Ar

Addition of air or groundwater

TRK
LHK-1
LHK-2
LFK
SYK
LSK
MS-1
MS-2
DYK
BY
SHP
DP
GZP
Helium isotopic

$^3$He/$^4$He ratios of samples from the TVG were much higher than $^3$He/$^4$He ratio in air. It suggested that He is predominantly of upper mantle origin in the TVG area.
Summary

Through seismic monitoring we have observed some volcano seismic events, such as spasmodic, mixed frequency and low frequency, around TVG area.

According to the sample from fumaroles the degassing sources for the TVG gases are closely related to the subducting process in NE Taiwan.

From the geochemical and geophysical studies, suggest that TVG may be a potentially active rather than an extinct volcano.
Seismicity Distribution

Location of seismic events

- ★: mixed frequency events
- ●: spasmodic events
- ▲: high frequency events
- ▲: seismic stations

Seismic stations:

- YM01
- YM02
- YM03
- YM04
- YM05
- YM06
- YM07
- YM08
Chemical Sample Distribution

$^{3}\text{He}/^{4}\text{He}$ ratio distribution

Dayoukeng
The fumarolic gas compositions of DYK started to vary since August 2004 (vertically dashed line).

An increase of outlet temperature of the fumaroles was observed at DYK.

Progressive increases of HCl concentrations and SO$_2$/H$_2$S ratios in DYK fumarolic gases were also observed.
HCl concentrations are generally low, except for some discharges affected by rapid heating (Giggenbach, 1996).

Almost all boiling-point fumaroles in the world have low HCl because most they are derived from a boiling aquifer beneath a fumarolic field.

HCl concentration is easily affected by water because of its high solubility. HCl may be lost or gained for the ascending gas due to a hydrothermal system.

The main Cl species in magmas are alkali chlorides, and HCl is released during shallow degassing.
Gas Sample in DYK Area

Seawater contributes a little part to the spring water of Chinshan and Dapu near the sea, it may be considered that the increase of HCl concentration in DYK area was caused by sea-water intrusion.

The probable intruded pathway of seawater could go along the Chinshan Fault.

But this anomaly of HCl was only observed in DYK area where is located in the middle part of the Chinshan Fault. On the other hand, sea-water intrusion cannot cause temperature rise.
Gas Sample in DYK Area

Increase of SO$_2$/H$_2$S ratio

At a given O$_2$ fugacity, sulfur occurs as SO$_2$ at high temperature and as H$_2$S at lower temperature. Giggenbach (1987) suggested that Eq. (1) is important for a degassing magma during its ascend towards the surface.

Thermodynamic modeling indicates that the reaction shifts to the right at high pressures (i.e. the magma degasses at great depths), thus H$_2$S is the dominant sulfur species in the gas. Conversely, hot gases escaping from a magma body emplaced at shallow levels in the crust will tend to be SO$_2$-dominated.

\[
\text{SO}_2 + 3\text{H}_2 \leftrightarrow \text{H}_2\text{S} + 2\text{H}_2\text{O} \quad (1)
\]

↑ temperature  temperature ↓

↓ pressure  pressure ↑
Gas Sample in DYK Area

Triangular plot for DYK area

CO₂–Stotal–HCl triangular plot for DYK gases, exhibiting more a magmatic signature than before.
Gas Sample in DYK Area

The ratio showed a **decreasing trend** during a few months after August 2004 (vertically dashed line) and returned to the previous values after approximately 6 months.
Gas Sample in DYK Area

Decrease of $^{3}$He/$^{4}$He ratio

The $^{3}$He/$^{4}$He ratio may increase if new magmatic material is added to the source, or it is decreased when more crustal material is added during the ascent of the gases.

The decrease of the $^{3}$He/$^{4}$He ratio in DYK was considered to be affected by crustal contamination when gases ascended to the surface. Consequently, the value returned to normal after the event stopped. However, the decreasing trend could also be caused by kinetic fractionation.

In isotope mass fractionation, the light mass ($^{3}$He) diffuses very fast into the gas phase and is depleted in the residual melt.
Seismicity in DYK Area

Seismic evidence 2004

Station not function
Seismicity in DYK Area

Seismic evidence 2006

(Rontogianni et al.)
Summary

(Rontogianni et al.)
The appearance of HCl and SO₂ in fumarolic gases in DYK could be related to the boiling of acidic sulfate–chloride water from the geothermal wells in the MT area, close to DYK. This deep aquifer (1250–1500 m deep) is assumed as the primary hydrothermal system (PHS) for the main source of the acid sulfate–chloride hot springs. The low concentration of HCl and SO₂ in gas compositions of fumaroles indicates that fumarolic gases cannot be generated from this acid sulfate–chloride water directly. The fumarolic gases could be produced by mixing meteoric water, the shallow aquifer (secondary hydrothermal system, SHS), with vapor phases generated by evaporation of primary hydrothermal system.
A zone of highly fractured and fluid-saturated rock may lie beneath Chihsinshan, extending to Dayoukeng, as evidenced by the occurrence of spasmodic bursts and elevated values of the $V_p/V_s$ ratio in the upper 3 km of the crust.
The Model

Chihsinshan

HYK

DYK

SP, HF events

PHS

magma chamber

0km

2km

4km

6km

8km
Conclusions

◆ Combining the helium isotopic ratios and volcano-seismic data, we suggest that a magma chamber might still exist beneath the TVG area, particularly in the area of DYK.

◆ According to the N2–He–Ar triangular plot for TVG gases. Most samples fall in the range of a mixing trend between convergent plate gases and air/groundwater. It suggests that the degassing sources for the TVG gases are closely related to the subducting process in NE Taiwan.

◆ We can not see any connection between geochemical and seismic observations in August, 2004 due to station break down. However there is a clear evidence shows that the variation of gas composition is related to seismic activities in April, 2006.

◆ The tectonics of northern Taiwan which is under a sustained extension due to the opening of the Okinawa Trough which could easily lead to opening of microcracks. The fluid and heat released through the opened fractures causing the variation of gas composition.
Thank you for your attention