

CHRONOLOGY OF VOLCANIC AND HYDROTHERMAL EVENTS IN THE ALTO PEAK GEOTHERMAL FIELD BASED ON THERMOLUMINESCENCE DATING

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ABSTRACT

Ages of 5 volcanic rocks and 5 altered materials are obtained by thermoluminescence (TL) method for the Alto Peak geothermal area. The age range for volcanic rocks is 20ka to 82ka, and that for altered materials is 2.7ka to 65ka. These ages denote that both volcanic activities and hydrothermal events continue to Late Pleistocene to Recent. One fault cuts 82ka lava proves its movement after such age. It is also suggested that some volcanic formations must be re-check because the ages are not match to expected geologic column.

If the cosmic ray contributes fully to the samples, possible TL age shift to younger age side is 34% for the sample with the lowest radiogenic contents and 8% for that with the highest contents. Such figures reducing to 19% and 4% if 10m erosion was expected from deposition to present sampling time.

1. INTRODUCTION

The Alto Peak area is located southeast of Greater Tongonan geothermal field and is situated within the Philippine Fault zone in northcentral Leyte (Fig. 1). The Philippine Fault is a major left-lateral strike slip structure whose fractures are believed to provide most of the permeability in the hydrothermal system. Production drill holes with fracture targets have generally been successful in exploiting secondary permeability. Recently drilled injection wells with fracture targets, however, have not been so successful. The nature of the intersected formation in the injection wells may explain some of poor permeability.

The age of fracture formation may give the hints for identifying permeable zones. Thermoluminescence (TL) dating can get the age of fault movement directly. However, an age for recent faulting is not reliable because the resetting condition of TL signal is insufficient (Ito and Sawada, 1986). Ages of hydrothermal activity and host rock are more easily measured with high reliability, and these

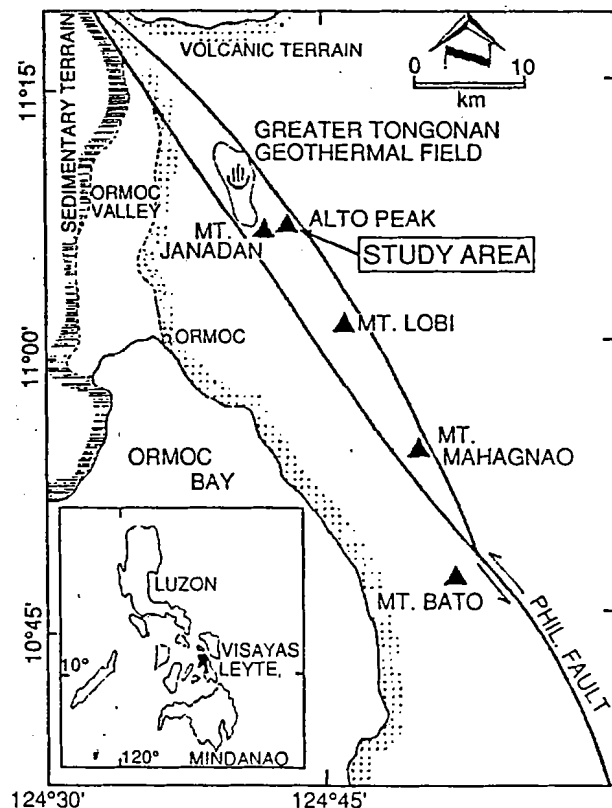


Fig. 1 Location and large scale geologic information of study area. (Compiled by PNOC-EDC)

age data give not only time of fault movement but also thermal history, heat source evaluation **and** geologic correlation.

In this paper, TL dating of volcanic rocks and alteration products (5 samples each) are carried out for giving the preliminary discussion to age of fracture movements and volcanic events. We also discussed some problems about TL dating method for obtaining reliable age.

2. OUTLINE OF GEOLOGY AND SAMPLES

The geology and structures are summarized by Reyes et al. (1993) based on the studies of Salonga and Pagado (1990) and Panem (1992). Figures 2 and 3 are the map and stratigraphy of this area in which our TL age data are added. The outline of geology and related data are described mainly by the study of Reyes et al. (1993).

The Cretaceous ultramafics and Late Miocene to Late Pleistocene sedimentary Binahaan Formation are base for volcanic rocks of Pliocene to Recent. These are andesitic volcanic complexes of Janagdan and Alto Peak, and their associated domes. The faces of them are lavas flows, pyroclastics, lahars, and epiclastic deposits originating from at least seven volcanoes and related four domes of varying ages (Fig. 3). Age of lava flows from Alto Peak 0.38Ma to 0.43Ma by K-Ar method (Bueza, 1983) and volcanism will extend to Recent by the geomorphology of Mt. Janagdan and Alto Peak.

Major fault systems are NW-SE trending which correspond to the direction of the Philippine Fault. Most of the volcanic centers and domes are located within a tensional block defined by the Alto Fault and Central Fault lines (Panem, 1992).

Samples for TL dating are collected from AP1 to AP3 lavas and altered ground (Fig. 2). Rocks are all hornblende andesite with small amount of quartz. Identification of sample formations is based on geologic map but the TL age data suggesting the different formations

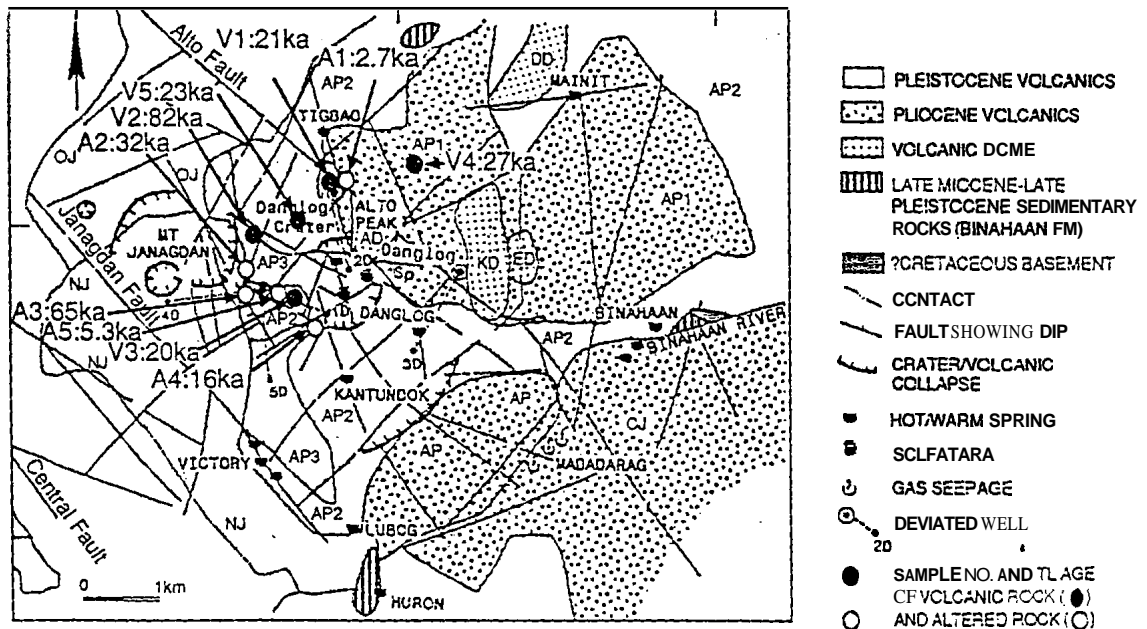


Fig. 2 Geologic map with TL dating results of Alto Peak area. (Compiled by Reyes et al. (1993) with the geologic data by Salonga and Pagado (1990) and significant structure data by Panem (1992)). The abbreviations used for formation correspond to those of Fig. 3.

FORMATION NAME	DESCRIPTION	AGE	INTRUSIVE EVENTS (TL age)	HYDROTHERMAL EVENTS (TL age)	SEDIMENTARY DEPOSITION
New Janagdan (NJ)	Hornblende andesite lavas, pyroclastics	Late Pleistocene	NJ, DD, AP2	NJ, DD, AP2	
Alto Peak dome (AD)	Hornblende andesite				
Dak-ai dome (DD)	Hornblende andesite				
New Alto Peak Volcanics 3 (AP3)	Hornblende andesite debris deposits				
New Alto Peak Volcanics 2 (AP2)	Hornblende andesite lavas, pyroclastics	Early to Late Pleistocene			
Old Janagdan Volcanics (OJ)	Hornblende andesite lavas, pyroclastics	Early Miocene	OJ	OJ	Formation
New Alto Peak Volcanics 1 (AP1)	Hornblende andesite lavas, pyroclastics	Pliocene	AP1, PD, CI, AP	AP1, PD, CI, AP	Binan Formation
Pasonaria dome (PD)	Hornblende andesite				
Abaga dome (KD)	Hornblende andesite				
Old Alto Peak Volcanics (AP)	Hydrothermally altered hornblende andesite lavas, pyroclastics				
Cancajanag Volcanics (CJ)	Hornblende two-pyroxene andesite often hydrothermally altered				
Binahaan Formation	Sedimentary breccias with fossiliferous and carbonaceous claystone, siltstone, sandstone and hyaloclastites. Upper, Middle and Lower members vary in relative amounts of hyaloclastites, organic materials and ultramafic clasts.	Late Miocene to Late Pleistocene			
Basement (Ultramafics)	Harzburgite and pyroxenite	Cretaceous			

Fig. 3 Summary of the stratigraphy, main geologic events and TL data of Alto Peak area. (After Reyes et al., 1993 except TL data)

as shown in Table 1. It is discussed later. The samples of altered ground are white colored silicified or argillic ones with one exception of AP1A which is collected from partly argillic fracture.

3. DATING PROCEDURE AND RESULTS

The experimental procedure of TL dating was described by Takashima and Honda (1988). Accordingly, their procedure is roughly explained. Mineral used for dating is quartz because it gives reliable age data. Samples are dried at room temperature in the dark. Then 320-4008 of the sample was crushed by a stainless mortar and/or ball mill, and sieved to pass 20 mesh. Then 290g of it was put in a plastic container for counting in a gamma ray spectrometer. A part of the 20 mesh sample was again crushed to get 60-200 mesh grains. After water washing, the grains were separated into magnetic and non magnetic portions by an isodynamic separator. The non-magnetic grains were treated by both 24% HF solution and HCl(1:1) for about 20 min. at 50°C each. The weight of sample was 10-50g in average, which was adjusted so as the final products becomes 0.5-1g. It is desirable to use aluminum sheets to keep the separated sample from exposure to light.

The TL emission was measured by the Hamamatsu Photonics C1230 Photon Counter and hand made heating devices. The emission of light of natural sample is very weak for most of measured samples. We try to get suitable condition and find that the N₂ gas introducing red color detection is the best. The main conditions for TL emission measurement are the heating rate of 150°C/min, sample weight of 15mg, R269 photomultiplier tube with 800V supply, two filter systems of infrared filter (Toshiba IRA-10) and long wave pass filter (ESCO Products OG-590), and 10 minutes of 300cc N₂ gas introduction. Gamma ray source of artificial irradiation is ⁶⁰Co of 1.11x10¹⁴Bq (=3000Ci).

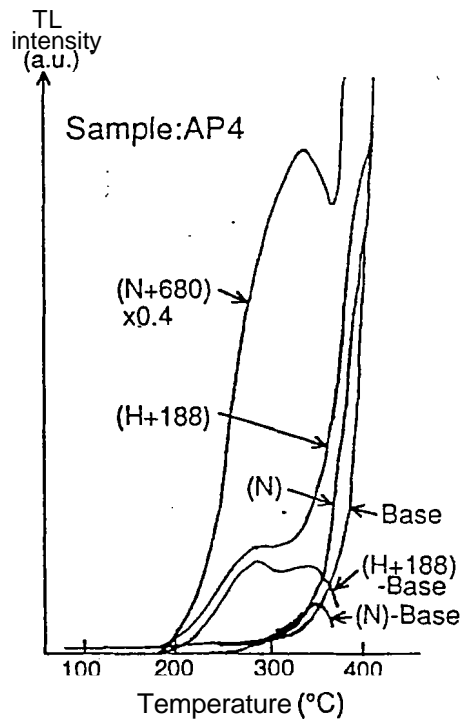


Fig. 4 TL glow curves of AP4 sample. TL glows of (N) and (H+188) are recalculated by subtraction of base signal.

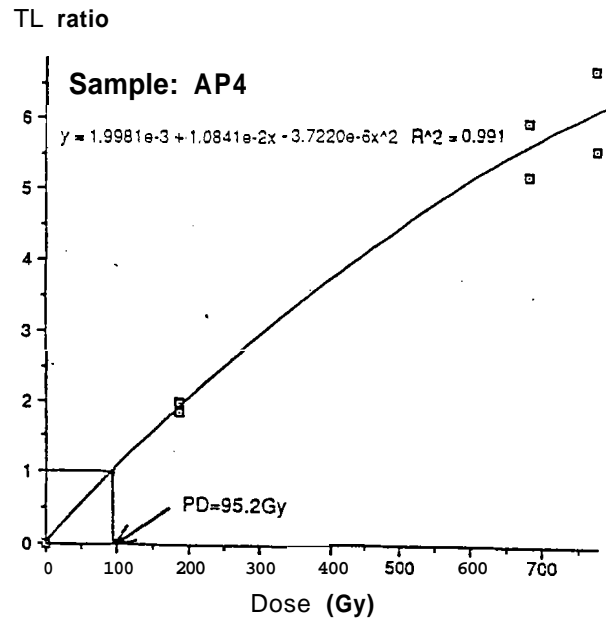


Fig. 5 TL growth curve of AP4 sample.

TL emission measurements were carried out for natural and gamma ray irradiated samples. Figure 4 is an example of TL glows of natural (N) and gamma ray irradiated samples (N+680 is the glow of 680Gy irradiation to natural sample and H+188 is the glow of 188Gy irradiation to 320°C pre-heat sample). The net signals of (N) and (H+188) are drawn in Fig. 4 which are obtained by subtraction of base signal. Based on these data, paleodose dose (PD) is calculated by the growth curve method (Fig. 5). The average number of measurements for each sample is two and an error in equivalent dose was 10 to 40%.

Chemical analyses were done by gamma ray spectrometry. The detector is a 76x76mm NaI scintillator crystal. Error of U and Th measurements is less than 10% and that of K is less than 3% in 24h operation and using NBS standards. Annual dose was calculated

Table 1 Summary of TL dating results of Alto Peak area.

No.	Sample No.	U (ppm)	Th (ppm)	K2O (%)	Annualdose (mGy/y)	Paleo-dose (Gy)	TL age (ka)	Remarks
Volcanic rocks								(Formation)
V1	AP1B	0.85	1.28	0.992	1.13	24.1	21±3	AP1(AD?)
V2	AP2	1.48	2.69	1.97	2.21	181	82±29	AP2
V3	AP6	1.42	2.81	2.14	2.34	46.1	20±5	AP2(AD?)
V4	AP8	0.98	2.45	1.96	2.06	56.5	27±12	AP1(AP3?)
V5	AP9	1.38	2.84	2.15	2.35	52.9	23±8	AP3
Altered rocks								(Alteration Mineral)
A1	APIA	1.02	1.63	1.28	1.44	3.9	2.7±0.4	Serisite
A2	AP3	1.05	1.74	0.01	0.389	12.6	32±10	Quartz
A3	AP4	1.58	1.86	1.14	1.47	95.2	65±12	Alunite
A4	AP5	1.90	3.34	0.524	1.14	18.3	16±2	Quartz,Alunite
A5	AP7	1.47	2.43	25	2.63	13.9	5.3±0.7	Quartz,Alunite

The abbreviations used for formations correspond to those of Figs.2 and 3

from the data proposed by Bell (1979) and water calibration introduced by Aitken (1985, p.75). Beta dose attenuation is roughly done for all Samples with the data of Mejdahl (1979). Contribution of cosmic ray is neglected because the sample was buried in deep part at almost all geologic time and it received very low cosmic ray. However, young aged samples must be counted cosmic ray contribution because they had few overburden. This effect is discussed later.

Table 1 shows the results of TL dating with the collected formations (and expected formation) of volcanic rock and alteration minerals. Obtained ages for volcanic rocks are range from 21ka to 82ka, and those for altered materials are 2.7ka to 65ka. All data of them are range in the Latest Pleistocene to Recent. The estimated TL errors are about 15-40%. Large amount of errors come from unstable TL emission.

4. DISCUSSION

Many factors control the TL age and they were discussed in previous papers (Takashima and Watanabe, 1994; Takashima, 1995). The results for correcting TL age to reliable side are used in this study but cosmic ray contribution is not discussed yet. The samples in this study are young and not so much overburden are expected. We calculate two cases of cosmic ray contribution.

First one is expecting samples keep at surface in all geologic time. The receiving cosmic ray must be about 0.2mGy/y which is expected value of latitude 10°. Then all TL ages are shifted to young side because annual dose of Table 1 increase 0.2mGy/y each. Re-calculated TL ages have large shift if original annual dose is small. Accordingly, a change of AP3 is the biggest and that of AP7 is the smallest. Obtained TL ages change of them are 32ka to 21ka (34% change) for AP3 and 5.3ka to 4.9ka (8% change) for AP7. Rest of samples shift their ages to young side at the rate between 34% to 8%.

Second one is estimation of erosion thickness from deposition to preset sampling point where is surface in normal case. It is quite difficult to evaluate precise erosion thickness but we can estimate rough value by use of topographic map. Figure 5 is example of such evaluation. The cosmic ray contribution increases with erosion. If a sampling point of AP3 was buried in 10m depth at the TL clock start (expected the time for end of alteration) and proportionally eroded to surface for sampling, receiving cosmic ray contribution changed from 0.04mGy/y to 0.2mGy/y and annual dose rate equalized to geologic time is 0.1mGy/y. In this case, TL age changes for AP3 is 32ka to 26ka (19%) and that for AP7 is 5.3ka to 5.1ka (4%). It is easy to calculate these cosmic ray contributions for different erosion thickness. Accordingly, correction must be done for young and low annual dose sample but not so important for old and high annual dose samples.

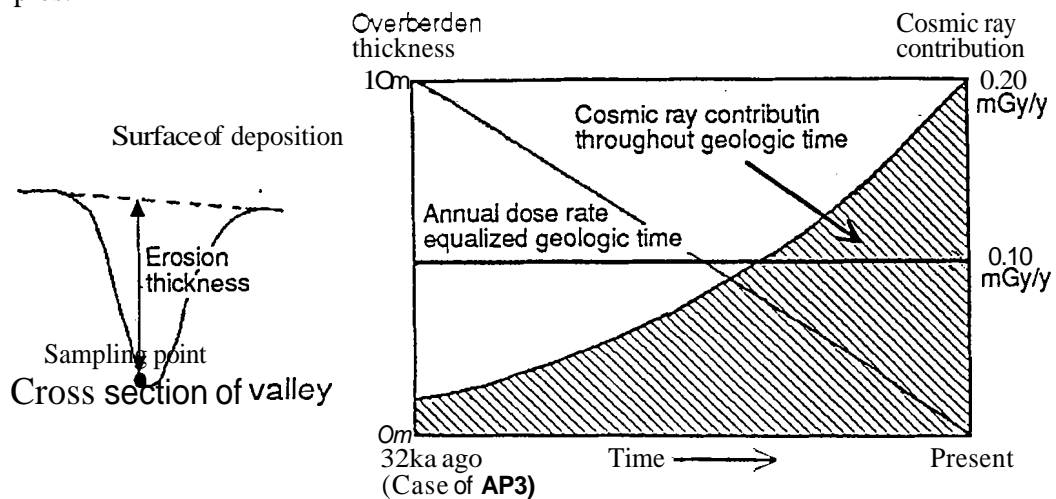


Fig. 6 Model of cosmic ray contribution with erosion process.

It is difficult to discuss for time of fault movement, thermal history, heat evaluation and volcanic stratigraphy from limited number of age data. However, a fault running to the AP2 point move after 82ka ago. Intrusive and hydrothermal events estimated by Reyes et al. (1993) shown in Fig.3 put to actual ages. Age data for volcanic rocks are roughly dividing two eruption stages around 20-30ka and 80ka. Age data for altered materials are not contradict to volcanic activity. Our limited survey carried out in this study can not reveal the precise volcano stratigraphy but some volcanic formation identified former study are not much for our age data (Table 1). Further research is required for this area in both field survey and TL dating.

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