

Identifying Potential Geothermal Area Beneath Thick Alluvium Sediments of Ilan Plain, Taiwan by Clay Mineral Assemblages and Petrography

Chia-Mei LIU¹, Yu-Kai HU², Ching-Huei KUO³

^{1,2,3}Department of Geology, 55, Hwa-Kang Road, Yang-Ming-Shan, Taipei, Taiwan 11114, R. O. C.

lim12@ulive.pccu.edu.tw

pollynismo@gmail.com

ckuo@faculty.pccu.edu.tw

Keywords: low-grade metamorphic rock, montmorillonite, geothermal area, Ilan Plain, Taiwan

ABSTRACT

The study area, Ilan Plain of Taiwan, is covered by Holocene alluvium sediments, ranging from 100 to 1200 meters. This study collected samples from four boreholes, the SanXin-BH01 (602m), JeiYuan-BH01 (1438m), HTL01 (2200m) and HTL02 (2800m), under the project of Taiwan National Energy Program-Phase II.

JeiYuan-BH01, HTL01 and HTL02, mainly consist of slate, meta-sandstone, and meta-sandstone with cleavages, while SanXin-BH01 that only consists of slate. Illite, kaolinite, and chlorite are found in all samples. The montmorillonite, however, exists in SanXin-BH01, JeiYuan-BH01, and HTL02 except HTL01. According to the results of previous studies, the montmorillonite may serve as an indication of geothermal potential area particularly in the low-grade metamorphic rock. With it we have identify the existence of geothermal potential in the area of SanXin-BH01, JeiYuan-BH01, and HTL02.

1. INTRODUCTION

The Ilan Plain has higher potential geothermal area that located at Sanxing, Dongshan and Wujie. Based on the reports of temperature distribution, fluid inclusion, and geophysical data (Figure 1a, b, and c) (Chiang et al., 2008; Liu et al., 2015; Chen, 2016). Especially, for the data of fluid inclusion in JeiYuan-BH01. The results show that the veins are consist of quartz and calcite and formed along cleavage. Quartz and calcite are commonly mosaic deposited that is first stage geothermal fluid, and the deposit of second stage is calcite that cut the quartz grain of first stage. In the first stage, the homogenized temperature and salinity of geothermal fluid are 240°C -260°C and 2~6 wt.% NaCl eq., respectively. However, the secondary stage, the homogenized temperature and salinity of geothermal fluid are 280°C - 290°C and 2~6 wt.% NaCl eq., respectively. Finally, it infers to the veins are produced by meteoric water with anomaly heating, and the temperature value of geothermal fluid is about to 280°C -290°C (Liu et al., 2017).

However, it has thickness alluvium sediments cover the rock formation of the Ilan Plain. Is the rock formation associated with Hsuehshan Range belt which locates in the northern Ilan Plain or with the Backbone Range belt which is lies in southern part? This study utilizes the cores and cuttings from 4 wells, SanXin-BH01 (602m), JeiYuan-BH01 (1438m), HTL01 (2200m) and HTL02 (2800m), performs the petrographic analysis and mineral composition, and compares with that off the foothills surrounding the Ilan Plain, in order characterize the basement rocks in the Sanxing area and intent to identify the origin of the stratum (Figure 1d). This study analyzes the petrography and clay mineral assemblages of cutting, core to understand the characteristics of rock formation beneath Ilan Plain.

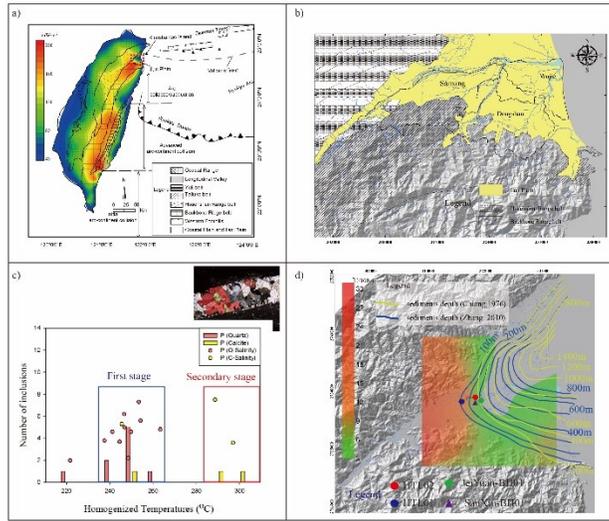


Figure 1: (a) The heat flow map in Taiwan (this study situates in the red area). (b) The Ilan Plain suits between the Hsuehshan Range and Backbone Range belts. (c) The report of fluid inclusion in JeiYuan-BH01. (d) Four cores location sites in the Ilan Plain.

2. GEOLOGICAL SETTING

The study area, the Ilan geothermal field, is located in the northeastern Taiwan with a triangular in shape (Figure 2). The Hsuehshan Range belt lies in the north of the plain and the south is situated the Backbone Range belt. The upper most part of the plain is covered by Holocene alluvium sediments ranging from 100 to 1000 meters including gravel, sand and mud. The Backbone Range belt is composed of mainly slate with a well-developed cleavage, and argillite and sandstones. The formations of Kangkou Fm., Hsitsun Fm., and Szeleng Ss that belong to the Hsuehshan Range belt. In addition, the formations of Lushan Fm., and Suao Fm. that are part of the Backbone Range belt (Ho, 1975).

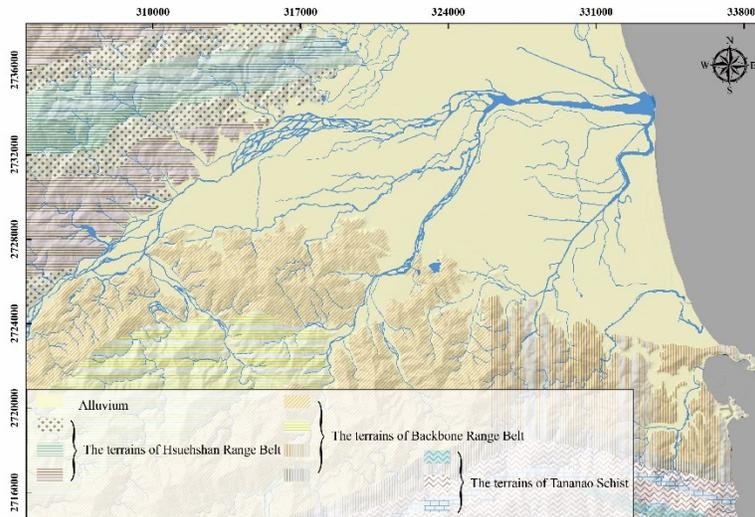


Figure 2: The geological setting in this study.

3. RESULTS AND DISCUSSION

3.1 Results of SanXin-BH01

For petrography of SanXin-BH01, it shows the parallel disjunctive cleavage between 469m and 539m, and the anastomosing disjunctive cleavage from 539m to 59 m. For clay mineral assemblages and their percentages, it has montmorillonite, illite, kaonilite+chlorite, 0.36%-20%, 75%-85% and 15%-25%, respectively. The illite crystallinity values are 0.26-0.38Δ°2θ.

3.2 Results of JeiYuan-BH01

For petrography of JeiYuan-BH01, it shows the parallel disjunctive cleavage between 732m and 759m, and from 771m to 908m, respectively, and the anastomosing disjunctive cleavage from 762 m to 770 m. For clay mineral assemblages and their percentages, it has montmorillonite, illite, kaonilite-chlorite, and 2.83%-12.8%, 72%-90% and 10%-28%, respectively. The illite crystallinity values are 0.22-0.39Δ°2θ.

3.3 Results of HTL-BH01

For petrography of HTL-BH01, it displays the anastomosing disjunctive cleavage from 450 m to 850 m, and the parallel disjunctive cleavage between 850m and 2,050m, and from 771m to 908m, respectively. For clay mineral assemblages and their percentages, it has illite, chlorite+chlorite chlorite and 75%-86% and 14%-25%, respectively. The illite crystallinity values are 0.23-0.33 $\Delta^{\circ}2\theta$.

3.4 Results of HTL-BH02

For petrography of HTL-BH02, it only displays the anastomosing disjunctive cleavage between 900 m to 900 m, and the samples of the other depth that show disjunctive cleavage. For clay mineral assemblages, it has montmorillonite, illite, kaonilite+chlorite. It reports clay mineral assemblage of different type, the percentages of clay minerals, and illite crystallinity value from 500 m to 2800 m. That montmorillonite only exists between 900 m and 1,100 m. For illite, it has 80%-90% from 500 m to 1,000 m, 91%-99% between 1,000 m and 1,800 m, and 82%-88% from 1,800 to 2,800 m. For kaonilite+chlorite, they are 10%-20% from 500 m to 1,000 m, 0%-9% between 1,000 m and 1,800 m, and 12%-18% from 1,800 to 2,800 m.

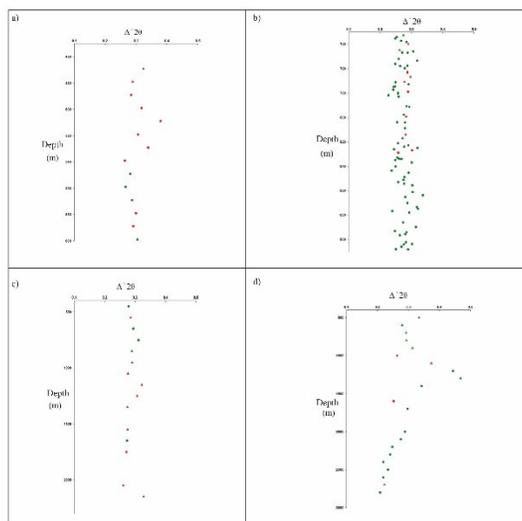


Figure 3: The illite crystallinity value verse depth in SanXin-BH01(a), JeiYuan-BH01(b), HTL-BH01(c) and HTL-BH02(d).

3.5 Results of Hsuehshan Range and Backbone Range belts

This study collects samples of Hsuehshan Range and Backbone Range belts. The slate of Hsitsun Fm shows the anastomosing disjunctive cleavage. The content ratios of the illite is 80%-87%, and the kaolinite+chlorite are 13%-20%, and illite crystallinity values are 0.25-0.28 $\Delta^{\circ}2\theta$. The metamorphic sandstone of the Szeleng Ss shows no cleavage, the content ratio of illite is 99%-100%, the kaolinite+chlorite are account 1%, and illite crystallinity values are 0.25-0.50 $\Delta^{\circ}2\theta$. The slate of Kankou Fm shows the parallel disjunctive cleavage, the illite content is 71%-81%, and the kaolinite+chlorite have 19%-29%, and illite crystallinity values are 0.25-0.35 $\Delta^{\circ}2\theta$. The metamorphic sandstone of Lushan Fm shows no cleavage, with 99%-100% of the illite, 0%-2% of the kaolinite+chlorite, and illite crystallinity values are 0.32 -0.45 $\Delta^{\circ}2\theta$. The slate of Lushan Fm shows the anastomosing disjunctive cleavage, the illite content is 75%-89%, and the kaolinite+chlorite account 11%-25%. The illite crystallinity values are 0.42-0.58 $\Delta^{\circ}2\theta$. The slate of Suao Fm shows the parallel disjunctive cleavage, the content ratio of illite is 67%-76%, the content of kaolinite+chlorite have 24%- 33%, and the illite crystallinity values are 0.25-0.35 $\Delta^{\circ}2\theta$.

4. CONCLUSION

This study proved that the combination of the petrography and clay mineral assemblages is a useful tool to identify the degree of low grade metamorphic rock. There have three rock types including slate, meta-sandstone, and meta-sandstone with cleavage beneath Ilan Plain.

Finally, this study compares samples of the cores, cutting and outcrop. The samples of four boreholes belong to Kankou Formation and Szeleng Ss of Hsuehshan Range belt.

REFERENCES

- Chen, Y.H.: Fluid inclusions of the vein from drilling core in Sanxing area Ilan, Taiwan, *Master thesis*, (2016), 140p.
- Chiang, H.T., Shyu, C.T. and Chang, H.I.: A study of shallow geothermal resources in Ilan Plain, Northeastern Taiwan, *Mining and Metallurgy*, **52**, (2008), 112-121.
- Ho, Chung-Sun: An Introduction to the Geology of Taiwan explanatory text of the geologic map of Taiwan, Central Geological Survey, MOEA, 2nd edition, (1988), 1-192. (in Chinese)

Liu et al.

Liu, C.M., Chiang, H.T., Kuo, C.H., Song, S.R., Tsai, Y.W.: Integrating Geothermometer and High Resolution Thermometer to Characterize the Geothermal Characteristics of Ilan Plain, Taiwan, *Proceedings, 40th Workshop on Geothermal Reservoir Engineering* Stanford University, Stanford, CA, (2015), 836-841.

Liu, C.M., Kuo, C.H., Chen, Y.H., Tsai, Y.W., Chen, H.F., Song, S.R: The Characteristics of Petrography and Fluid inclusions of Vein in Geothermal System of Ilan Plain, Taiwan, *Proceedings, 42th Workshop on Geothermal Reservoir Engineering* Stanford University, Stanford, CA, (2017), 883-886.