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The Mineral Assemblages of Hydrothermal Alteration in Slate Formation Area-Chingshui Geothermal Field, Taiwan

Ching-Huei Kuo, Chia-Mei Liu, Chun-Fa Huang, Yu-Wei Tsai

Department of Geology, 55, Hwa-Kang Road, Yang-Ming-Shan, Taipei, Taiwan 11114, R. O. C.

E-mail: ckuo@faculty.pccu.edu.tw

E-mail: ljm12@ulive.pccu.edu.tw

E-mail: Henry4823@gmail.com

E-mail: tsayyw@faculty.pccu.edu.tw

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ABSTRACT

The exploration of geothermal resource in Taiwan can be traced back to the 1970s. A 3-MWe geothermal energy power plant was installed in Chingshui Geothermal Field, Ilan of Taiwan in 1981. The geothermal energy power plant of Chingshui Geothermal Field is one of few metamorphic geothermal fields in the world. The majority of bedrocks are argillites, slate and metasandstone. We have systematically analyzed samples taken along the two creeks, Chishui and Chilukeng, of the region to understand the spatial distribution of mineral assemblages under the influence of alterations by using XRD. The recognition of alteration mineral zoning can help identify hydrothermal fluid channel ways. We have found the existence of montmorillonites, a typical product of hydrothermal alteration, is tightly associated with surface hot springs. Kaolinite, Illite and quartz are observed in argillites areas while Kaolinite, Illite, Chlorite and quartz are found in slate formation.

1. INTRODUCTION

The geothermal energy power plant of Chingshui Geothermal Field is one of few metamorphic geothermal fields in the world. A 3-MWe geothermal energy power plant was installed in Chingshui Geothermal Field, Ilan of Taiwan in 1981, the first of its kind (Figure 1 and Table 1) (Bertani, 2012). The heat source of the area was first studied by using $^{3}He/^{4}He$ isotope ratio (Yang et al., 2005). A 1.39R_A ratio indicates the mantle plumes as the heat source of the area. The heat sources of the Chingshui Geothermal Field was identified as magmatic origin by isotopes of sulfur from hot springs water (Lu et al., 2017). The Chingshui Geothermal Field is situated in the Backbone Ridge belt that is mainly composited of Miocene slate, metasandstone, and argillite. We have observed some unique mineral assemblage spatial distributions in field, so we believe that the chemistry and structure of alteration minerals are a response to their conditions of formation. The minerals and mineral assemblages, especial clay minerals, would provide information on hydrothermal conditions. The minerals typically occur in zones/sections in field that reflect changing conditions of formation. The recognition of alteration mineral zoning can help identify hydrothermal fluid channel ways. It could further provide the linkage between mineral assemblages with geothermal activities and could be served as indicators, particularly in metamorphic regions. We have systematically analyzed samples taken along the two creeks, Chingshui and Chilukeng, of the region by using XRD to understand the spatial distribution of mineral assemblages under the influence of heat produced by geothermal activities.

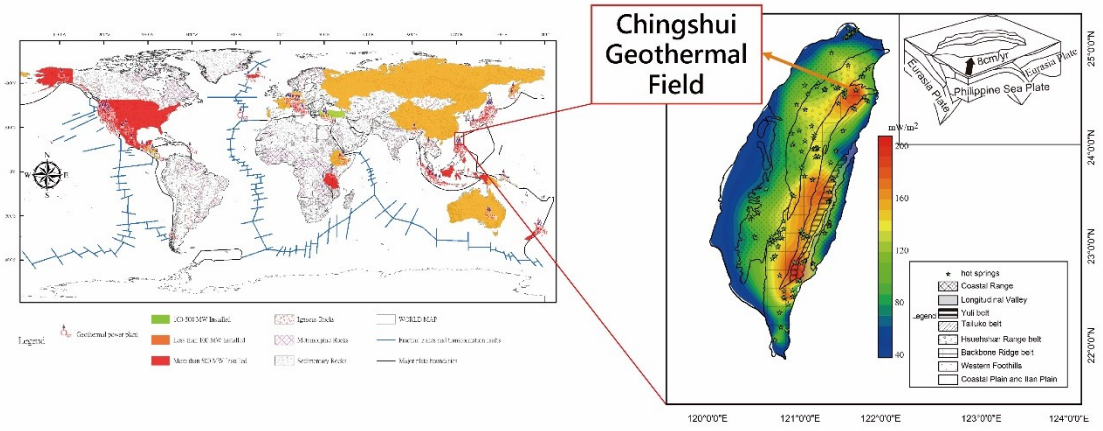

Figure 1: The map of geothermal power plants worldwide and the heat flow map of Taiwan.

Table 2: The list of geothermal electricity development by country (taken from Bertani, 2012).

Country	COD	Country	COD
Italy	1914	Taiwan	1981
Japan	1925	Nicaragua	1983
New Zealand	1958	France	1984
USA	1960	Australia	1987
Russia	1966	Greece	1987
Iceland	1969	Argentina	1988
China	1970	Thailand	1989
Mexico	1973	Costa Rica	1994
Turkey	1974	Guatemala	1998
El Salvador	1975	Ethiopia	1999
Philippines	1977	Austria	2001
Indonesia	1978	Papua New Guinea	2001
Portugal	1980	Germmany	2003
Kenya	1981		

2. METHODOLOGY

Rock samples were taken along the two creeks, Chingshui and Chilukenga, and then smashed and grinded for XRD analysis. Model XRD-6000 made by Shimadzu was used to analyze samples with the following parameters: scan velocity at (2θ Rate) =1°/min, divergence slit at 1.00°, scatter slit at 1.00°, receiving slit at 0.3mm. Clay mineral samples were analyzed by X-rays diffracted at a scan range of 3 ° to 40 °and other mineral specimens were at a scan range of 3 ° -70 °.

3. RESULTS AND DISCUSSION

3.1 The surface geological survey in Chingshui Geothermal Field

Precipitation of gypsum, calcite and aragonite are found wherever the fumarole presents in the field in all geologic sections including metamorphic sandstone with slate interbedded (CSs2), slate inter-metamorphic sandstone section (CSs3) along Chingshui Creek and Slate section (CSs4) argillite with slate intebedded (CSarg) along Chilukeng creek. In addition, fissures are often found with calcite filling veins. There are three types of patterns were found in the field. They are near parallel, parallel, and perpendicular to slaty cleavages. There are a large quantity of quartz veins were found in the field as well. They all appears almost vertical to the bedding but limits by metasandstone indicating quartz veins forms during the diagenesis of meatsandstone (Figure 2) instead of geothermal activities.

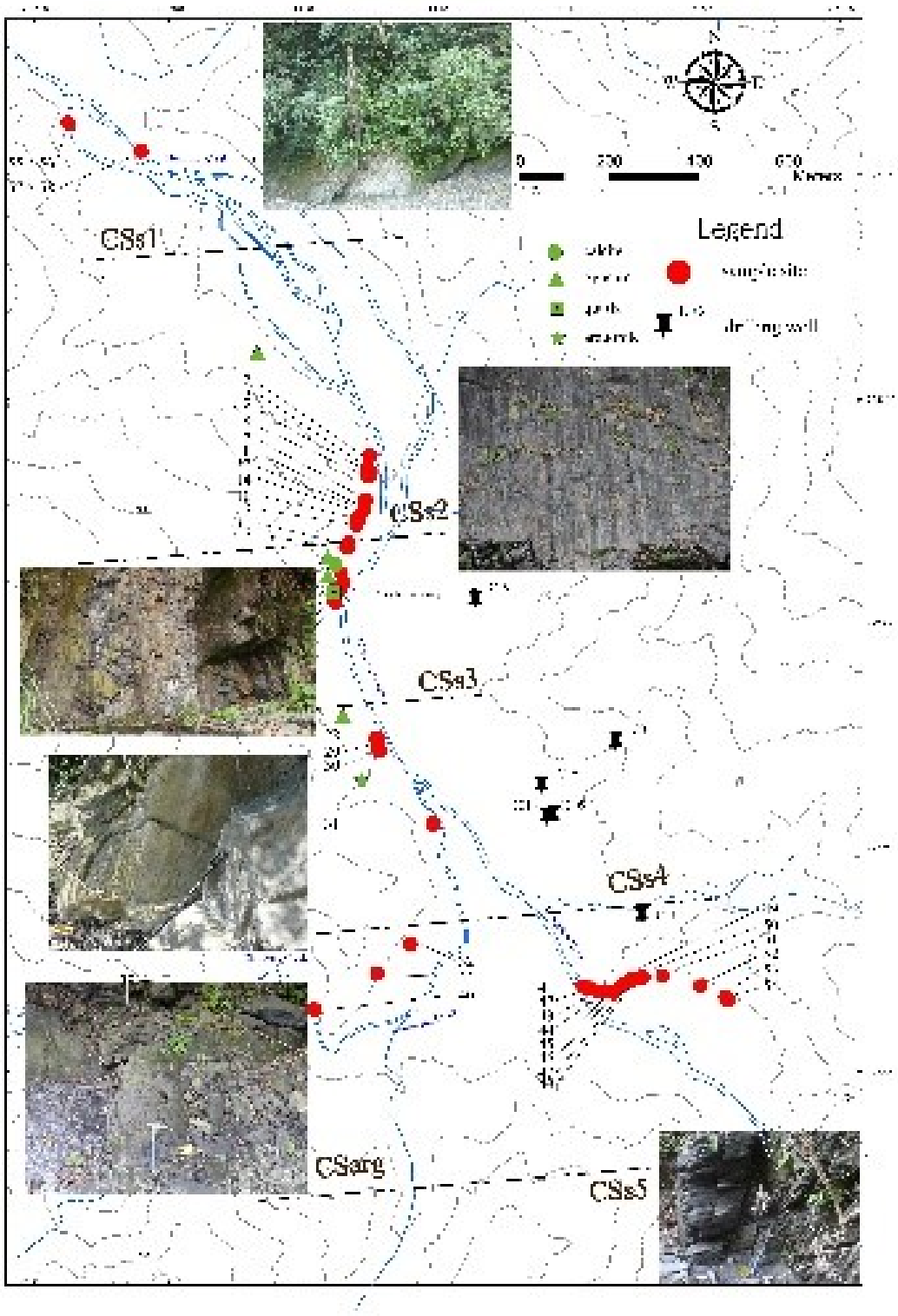

Figure 2: The lithological map and geothermal phenomena distribution of Chingshui Geothermal Field.

3.2 The mineral assemblages of Chingshui Geothermal Field

Total 58 samples were collected and systematically analyzed along the along the two creeks, Chishui and Chilukeng.

Kaolinite and chlorite were commonly found in sections of CSs3, CSs4, CSs2, and CSarg (Figure 3). However, the spatial distribution shows interesting patterns. Kaolinite was found along Chilukeng creek and the north of Chingshui Creek (Figure 3) while small amount

of chlorite appeared with Kaolinite along Chingshui Creek. Interestingly, a large amount of montmorillonite appeared in CSs3 (Figure 3). The distribution of smectite coincides with gypsum, calcite and aragonite indicating that is associated with geothermal activities (Figure 4a). We believe that smectite is resulted from the hydrothermal alteration of Illite under the influence of h (Figure 4a and 4b). Therefore, smectite can be used as the indicator for geothermal activities.

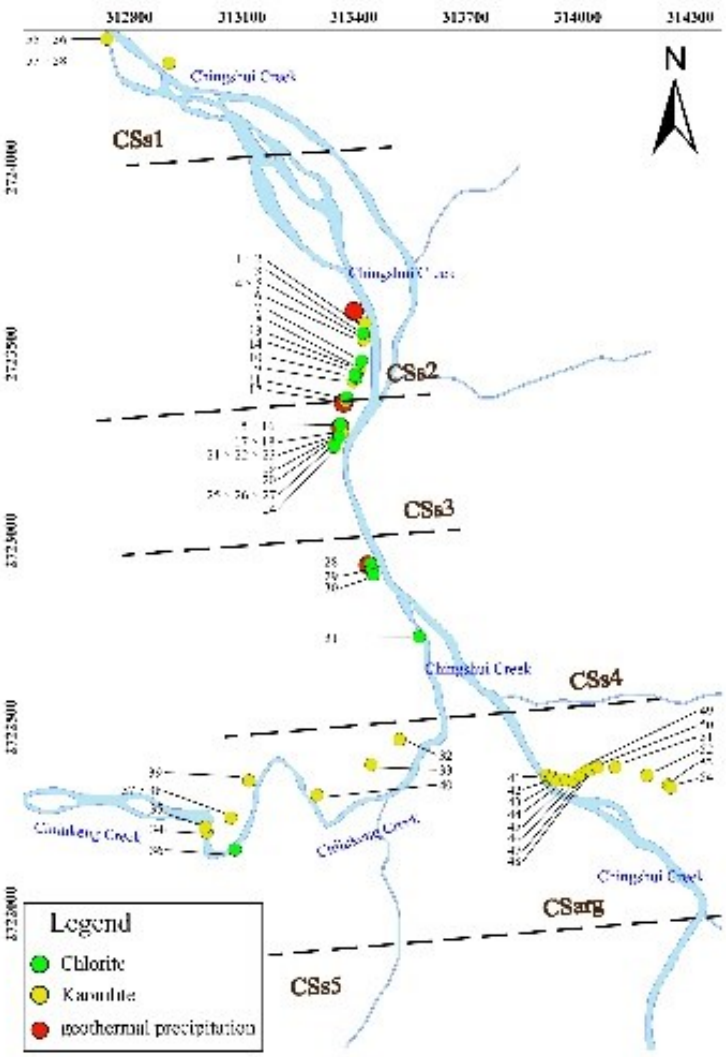

Figure 3: The location map of mineral assemblages in Chingshui Geothermal Field.

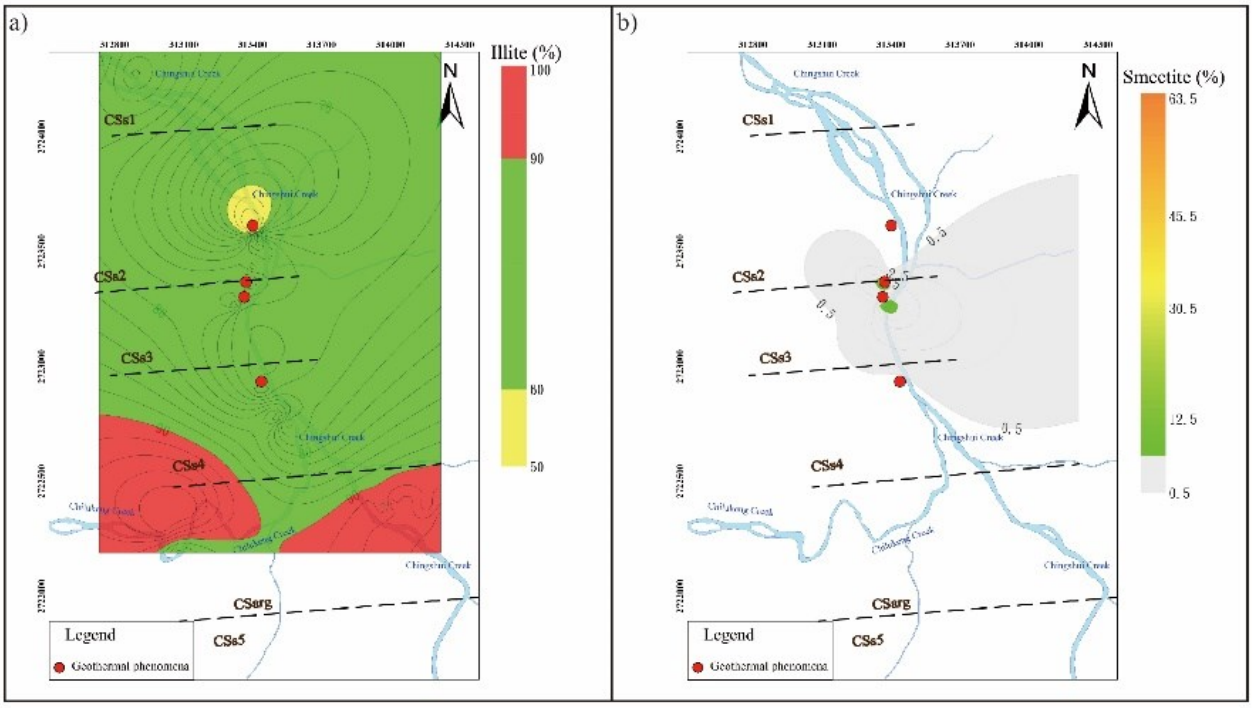

Figure 4: (a) The spatial distribution of Illite in percentage. (b) The spatial distribution of smectite in percentage.

4. CONCLUSION

a. Kaolinite was found along Chilukeng creek and the north of Chingshui Creek.

b. Kaolinite and chlorite were commonly found in sections of slate.

c. Montmorillonite is the product of hydrothermal alteration and it is resulted from the alteration of Illite under the influence of hydrothermal.

d. The distribution of clay minerals assemblages in Chingshui Geothermal Field proved to be linked to hydrothermal conditions.

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