The relation of geochemical characteristics and landslide in Hungtsaiping area

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1. Introduction

The study area - Hungtsaiping is located at the south bank of Yonglu stream (upper stream of Jhangping Stream), Chungliao village of Nantou county, central Taiwan. Occurring on September 20, 1999 UTC, Hungtsaiping landslide was triggered by the Chi-Chi earthquake (Mw=7.6) which occurred fifteen kilometers away from the epicenter, near the town of Chi-Chi in Nantou County, central Taiwan (Fig. 1). Hungtsaiping area involves at least two huge landslides events in history with different mechanisms, triggered by strong earthquakes in 1916 and 1999 Chi-Chi earthquake (Lin et al., 2008). Wei and Lee (2006) defined the boundary of Hungtsaiping landslide by using digital aerial photogrammetric techniques. Hungtsaiping Landslide was divided into four zones: A, B, C, and D zone and two types which were provided by Lo et al. (2008). Coping with the geological and geomorphologic investigations, this study makes an attempt to find the relation between geochemical characteristics and landslide in Hungtsaiping area.

In the past, the methods of landslide research comprehend interpretation of aerial photos and topographic maps, field investigation, geophysical exploration, borehole logging, laboratory experiments and on-site monitoring such as water table, etc. According to the previous research studies, mass loading and slope gradient are two major factors affecting slope stability in the slide-prone area. Water also plays an important role for the mass movement in the slope region (Peng et al., 2007). Since 1990’s, a lot of research studies the characteristics of hydrogeochemistry and how to relate them to landslide. The hydrogeochemical information can unravel the hydrological process in landslide triggering (Bogaard et al., 2007), researchers considers hydrogeochemistry is an effective tool to interpret landslide study. Thus the focus of landslide research had shifted over the past few decades from emphasizing on the morphology to hydrogeochemical characteristics of landslide. Both isotopes and hydrochemistry can be used as characteristic indicators in landslide study. The purpose of this study is to apply information of hydrogeochemistry to landslide research. There are three aims in this study: (a) to use hydrogeochemical information
to unravel the hydrological processes in triggering landslide; (b) to set up a conceptual model of flow processes and water origin in Hungtsaiping landslide; and (c) to comprehend the relation of geochemical characteristics and landslide, particular index of landslide monitoring can thus be established.

2. Literature review

2.1 Landslides triggered by earthquakes

Landslides triggered by earthquakes are one of the most damaging calamities in nature. Past experience has shown that the most frequent damage after earthquakes in Taiwan is landslide. The size of area affected by earthquake-induced landslides depends on the magnitude and the focal depth of the earthquake, the topography and geologic conditions near the fault, as well as the frequency and duration of ground shaking (Hays, 1981). There were many examples about the landslide triggered by earthquakes in the past such as 1964 March 28 03:36 UTC Magnitude 9.2 Alaska, 1999 September 20 17:47 UTC Magnitude 7.6 Taiwan, and 2007 March 25 00:41 UTC Magnitude 6.7 Japan.

2.2 Regional geology of Hungtsaiping

The location of Hungtsaiping is to the west side of Jiufengershan, at Chungliao village of Nantou County, central Taiwan. Furthermore, Jiufengershan and Hungtsaiping are located at the east and west sides of Tsukeng anticline. This section summarizes the literature and the geological map of Taiwan - Puli sheet (Central Geological Survey, 2000) (Fig. 2).

2.3 Geochemical factors of landslide studies

Water plays a very significant role for landslide, especially in slope areas. In early days, landslide research workers put piezometers in boreholes to measure and record the data of water table, then used the data to monitor landslides. However, as for landslides with quick and large displacement, the monitoring instrument will easily be destroyed. Additionally, it is also a dangerous working environment for operators to monitor. Several studies (Epstein and Mayeda, 1953; Guglielmi et al., 2000; Wang et al., 2001; Guglielmi et al., 2002; Cappa et al., 2004; Peng et al., 2007; Monety et al., 2007) had noted that hydrogeochemistry is a useful tool which can be used to comprehend the triggered mechanism of landslide. Furthermore, Bogaard et al. (2007) provide an excellent review of the hydrogeochemical methods, results and issues related to landslide research.
3. Sampling and analytical methods

Water sampling was carried out from May 2008 to May 2009. Evenly distributed sampling locations were designed to be as representative as possible in Hungtsaiping landslide area. 19 groundwater samples were collected from the boreholes which were drilled in 2005 and 2008. 15 to 18 surface water samples contain creeks, ponds, spring waters and the Yonglu stream. Sampling sites are located by Global Positioning System - (GARMIN eTrex Vista Cx) as shown in Fig. 3. The experimental layout of this study is shown in Fig. 4. Electrical conductivity and pH value were determined. Otherwise, the specific ion concentrations (Cu$^{2+}$, Fe$^{2+}$, Mg$^{2+}$, Ca$^{2+}$, Na$^+$, K$^+$, SO$_4^{2-}$, and Cl$^-$) were determined by atomic absorption spectrometry (AA) and high-pressure ionic chromatography (IC); bicarbonate concentration was determined by titration. The total relative uncertainty, including the device accuracy and the repeatability error, is all less than 5 per cent. Nevertheless, for samples with unexpectedly high ion concentration, dilution up to a factor of ten to twenty times is needed. The mean total uncertainty due to this dilution procedure is estimated at 10 to 15 per cent for the dominant species (Na$^+$, Mg$^{2+}$, Ca$^{2+}$, SO$_4^{2-}$, and Cl$^-$) and less than 10 per cent for other compounds.

4. Results and discussions

This study yielded useful information about the relationship between geochemical characteristics and landslide. The oxygen and hydrogen isotopic compositions can display crucial information on climate conditions and hydro-geological processes in a specific area. Clearly, the findings indicate that precipitation has an effect on isotopic compositions in Hungtsaiping area. When precipitation increased by typhoons, the stable isotopic compositions decreased conspicuously and last for several months (Fig. 5). $\delta^{18}$O versus $\delta$D of samples can provide some information about the variation in water types, season, months, and sampling locations (Fig. 6). To summarize, several findings are of interest: it is quite obvious that the change in surface water was greater than that of groundwater, the stable isotopic compositions for groundwater were heavier than surface water, and the time-delay effect was common in groundwater.

The data of hydrochemistry were analyzed by software: Aqua Chem. v. 5.0, the monthly water characteristics for each sampling location were then shown on piper diagram. Their means are also presented graphically in Fig. 7. According to literature review, hydrogeochemistry had been taken notice of an effective feature to
comprehend the triggered mechanism and to monitor the velocity in landslide area. A more detailed understanding of this relationship can be gained from Fig. 8. The concentration of sulfate for samples can be expected to detect the movement of landslide. So far, the data and the observation on field investigations appear to be highly related in a sense that the concentration of sulfate can be an index in landslide studies.

5. Conclusions

The study provides some contributions to the development of using hydrogeochemistry on landslide studies, as well as it may lead to a better understanding of the relationship between geochemical characteristics and landslide. The implications are described as follows:

1. Precipitation has an effect on the oxygen and hydrogen isotopic compositions in Hungtsaiping area, as well as there are quite obvious features with in surface water and groundwater.
2. Piper diagram can classify each sample into four water types: Na-HCO₃⁻, Ca/Mg-HCO₃⁻, Ca/Mg-SO₄²⁻, and Na-Cl, the results can then be evaluated to understand the chemical processes between hydrology and geology.
3. The temporal and spatial evolutions of water with index substances maybe can be considered a useful tool in landslide studies.

6. Reference


Fig. 1 Location map of the study area (Google Earth).

Fig. 2 The Geological map of Taiwan - Puli sheet (Revised from Central Geological Survey, 2000).
Fig. 3 The sampling location of Hungtsaiping landslide.

Fig. 4 The procedures of study.
Fig. 5 Isotopic compositions of monthly mean and accumulated precipitation monthly during May to December 2008 in Hungtsaiping area (hollow symbols represent surface water, black symbols represent groundwater; circle represent $\delta^{18}$O, triangle represent $\delta$ D).

Fig. 6 The distribution of isotopic compositions for all samples, and the local meteoric water line (LMWL) represent the data of Peng et al. (2000).
Fig. 7 Hydrochemistry of Hungtsaiping landslide: piper diagram in November 2008.

Fig. 8 Isogram: the concentration of sulfate in July 2008 in Hungtsaiping area.