COMPLEX ENVIRONMENTAL STUDY OF CLAY MINERAL BEARING SEDIMENTS IN THE AREA OF KULCS, HUNGARY

Applied and methological study to reveal the sedimentological features of Kulcs landslides and to investigate the applicability of ATR FTIR in earth science studies

by

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Summary of the Ph.D. dissertation

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1. Introduction and objectives

Because of increasing human land use and urban expansion, several settlements have been built on loess bluff endangered by landslides in many parts of the world. In these areas, landslides and related surface movements develope by a combination of natural and anthropogenic factors. These factors especially depend on the spatial and temporal distribution of precipitation and on water-rock interactions (WEN & CHEN 2007, ÚJVÁRI ET AL. 2009, LI ET AL. 2011). For engineering slope stabilization works and monitoring systems of landslides, therefore, it is necessary to observe the environmental processes originated from water-rock interaction and mechanical-chemical alterations, as well as mineralogical and geochemical markers in sliding material (SUMMA et al. 2010). There are several laboratory experiment on time dependent alteration of minerals under different environmental conditions. Landslide, is a kind of natural laboratory in which those processes are intensified, however, is rarely studied (SHOAEI 2013). It is particularly important for the high banks of the river Danube where landslides have reactivated and developed new ones in stable and even remediated areas of populated regions in recent years.

The main objective of this research was to study the sedimentological features of landslide on Kulcs that is geomorphologically one of the most active area of the Danube bluff, Hungary. Furthermore, the mineralogical and geochemical factors was observed in terms of landslide formation. There have been very few studies that have investigated these factors in slip zone of loess bluffs (BORSY & SZÖŐR 1981, BIDLÓ 1983, WEN ET AL. 2007), therefore, mineralogical and geochemical measurements are an important result of this research. To discriminate the secondary alteration due to the sliding process, slipped sediments were compared with sediments of similar age and facies. In addition, the usefulness of the attenuated total reflectance Fourier-transform infrared spectrometry (ATR FTIR) for the classification of sediments in landslide deposit, as well as for the identification of weakness zones in landslide has been illustrated. Infrared band areas and wavenumber

shifts have been compared against estimated mineral compositions by X-ray powder diffraction and thermal analysis. Some typical particularities of the grain size and shifts in wavenumbers on ATR FTIR spectrum of sediments were revealed.

2. Studied area

A long term field observations and laboratory measurements were carried out on the southern part of Kulcs area, Hungary. It is one of the largest region in Hungary that is affected by slidings, and where landslides have been documented since 1964. Landslides are hazardous for buildings those are situated near the Danube riverbank (FTV, 1979). However, there has not yet been performed complete mitigation throught engineering works before the end of the observation period. Furthermore, the slip zone is close to the surface, therefore it is possible to sample the slip surface by shallow boreholes and excavations.

3. Methods

Sediment samples were taken from the surface of the landslide and from the excavation of the slope of the landslide, as well as from boreholes. In addition, samples were also collected from a borehole that was drilled out of the slipped area.

- Geotechnical/sedimentological features: grain size distribution (laser particle analysis), density (He-pycnometry), porosity (mercury intrusion porosimetry), pore surface and pore size distribution (mercury intrusion porosimetry, N_2 and CO_2 physisorption)
- Mineralogical composition: bulk mineral composition (X-ray powder diffraction, thermal analysis, infrared spectrometry), clay mineral composition (X-ray powder diffraction)
- Geochemical characterization: main and minor element composition (inductively coupled plasma atomic emission spectroscopy, inductively coupled plasma mass spectrometry), moisture content and loss of ignition

(gravimetric determination), CO_2 content (CO_2-volumetry), morphological and chemical study of carbonate concretions (scanning electron microscopy)

- Data processing: chemical index of alteration calculation, test of relationshis between mineral composition and infrared parameters of sediments by linear regression

4. Thesis

1. Based on the mineralogical and chemical analysis, similar sediments occur in the slipped area and in the non-slipped area at Kulcs. The two boreholes, drilled 15 m in distance from each other at the southern boundary of the landslide, show a gravelly layer that is two meters deeper in the stable area than in the landslide. Therefore, large scale vertical movements took place, outward and upward displacements from the bluff to the riverbank.
2. Field survey and geotechnical observations, mineralogical as well as geochemical studies highlight the importance of paleosol layers and red clay in the development of Kulcs landslides as these can act as potential sliding planes. It is concluded that fine grain size and large amount of sheet silicates in these sediments can facilitate the development of slides. It can be stated that elevated content of smecite and decreased amount of carbonate occur in the sliding surface of red clay. A few centimeters from the sliding surface, however, smectite content decrease and carbonate content inrease in the sediment.
3. My study confirmed by geochemical feature that the Kulcs landslide deposit is part of the Hungarian old loess-paleosol sequence. It is pointed out that the loess from Kulcs contains generally a higher potassium and a lower sodium content than Hungarian old loess. The reason for this is that the source area of Kulcs landslide deposit contain small amount of plagioclase and/or plagioclase have already weathered in the sediment. It

can be stated that red clay from Kulcs is similar to the „Tengelic Member of the Tengelic Red Clay Formation”.

4. Methodological observations by ATR FTIR show that ATR FTIR band areas characterize the different types of sediments. The infrared band areas and their ratios appear to be sensitive parameters to identify the sediments with high content of sheet silicates, especially smectitic type. Based on linear regression, the defined ATR FTIR band areas of minerals correlate with mineral composition measured by X-ray diffraction and thermal analysis. With the developed sample preparation and evalutaion for ATR FTIR spectra it is observed that the magnitude of the infrared band area largely related to the smectite content that was measured by X-ray diffraction and thermal analysis.
5. The amounts of minerals with small grain size, especially smectite, is underpredicted because their grain size is comparable or smaller than the penetration depth of the infrared light. As the grain size effect causes significant changes in the ATR absorbance, therefore, it can be taken into account during sample preparation and evaluation of ATR FTIR spectra.
6. It can be stated that infrared band shift in the ATR FTIR spectra depends on the quantity of minerals. The characteristic infrared bands of carbonates (~1400 cm^{-1}) and smectite (~1000 cm^{-1}) are shifted towards the lower wavenumbers with increasing amount of carbonate and smectite, of which was measured by X-ray diffraction and thermal analysis. It was also demonstrated on mechanical mixtures of minerals. As a consequence, peak position shift is caused by changes in modal proportion of minerals beside overlapped adjacent bands and changing bond strength in the mineral structure.

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