http://www.geojournals.cn/dzxbcn/ch/index.aspx

Surface Microtextures of Slipping Zone Soil of Some Landslides in the Three Gorges Reservoir District and Their Significance

YAN Chunjie[1], SUN Yunzhi[2] and TANG Huiming[1]

1 *Test Centre, China University of Geosciences, Wuhan 430074,Hubei*

2 *Institute of Yangtze River Exploring Technique, Ministry of Water Resources, Wuhan 430011, Hubei*

Abstract The mineral assemblage and content and surface microtextures of slipping zone soil of several landslides in the Three Gorges Reservoir District have been analyzed using the scanning electron microscope (SEM) and X-ray diffractometer (XRD). All the mineral assemblages are similar in these landslides. The main minerals are montmorillonite, illite, kaolinite, chlorite, quartz and feldspar. There are two kinds of surface microtexture in the slipping zone soil, i.e., linear scratches and arcuate scratches. Based on analyses of the changes of the microtextures, one can obtain information about the number, directions and stages of landslide movements. The authors have also studied the mechanism of landslide formation, evaluated the stability of landslides and revival possibility of ancient landslides and forecasted the activity of similar landslides in different districts. The surface microtexture features of stable landslides and mobile landslides are summarized and it is concluded that the existence of filamentous bacteria may result in or increase movements of landslides.

Key words: The Three Gorges Reservoir district, landslide, surface microtexture, scanning electron microscope (SEM)

1 Introduction

Landslide is a common geologic disaster. Just in 1998, 180000 unexpected geological hazards of different scales such as rockfalls and landslides took place in China, of which about 447 serious geological hazards caused 1157 deaths, over 10000 wounded and damage of more than 500000 houses, with the economic loss amounting to ca. 3.2 billion dollars. Slopes and slide masses in the reservoir district are easier to deform and lose stability in the construction and water-storing periods (Yang et al., 1997; Wu Shuren et al., 1999), and the construction of the Three Gorges project and safety of newly-built towns draw much attention from the public over the world, so it is of great significance to study the landslides in the Three Gorges Reservoir district.

Landslide is a moving mass, and its slip surfaces are the result of physical-mechanical environments (temperature and pressure) and keep and record the movement history of a landslide. They are actually mainly slipping zone soils (consist of montmorillomite, illite, kaolinite, chlorite, quartz, feldspar and calcite as well as micro-organisms), which are more easy to keep marks of landslides. The microtextures of slipping zone soils are the reflection of features of macro-deformation of landslides, and any changes of microtextures are a premonition for macro-deformation and instability of landslides. Therefore, through the determination of the material composition, contents and physical-mechanical properties of slipping zone soils and study and monitoring of the surface microtexture changes, we can obtain the information about the number, directions and stages of landslide movements, study the mechanism of landslide formation, evaluate the landslide stability and provide criteria for determining the revival possibility of ancient landslides and forecasting the activity of similar landslides in different districts (Wu Yixiang et al., 1992).

The scanning electron microscope (SEM) is an effective instrument in studying the microstructures of

landslides because of its high magnification, high resolution, simple sample preparation and powerful function in picture processing.

2 Sample Preparation

Firstly, oriented samples were taken from soils on slip surfaces at fixed sites, whether by drilling or by outcrop sampling. Then they were kept in a container (to avoid extension or compression by people) which was airtight to prevent textures from being destroyed by water losing and drying, and were taken back to the laboratory. From the premise that the surface textures were not hurt, slipping zone soils in different directions and on different slip surfaces were chosen and sticked on the SEM copper sample stage and let to be naturally dried. After gold spurting the soils were observed under the SEM. For the remaining samples, quantitative X-ray analyses and physical-mechanical tests were performed respectively.

3 Microtextures of Slipping Zone Soils and Their X-ray Analyses

3.1 Gaojiaolu landslide in the Chongqing steel plant

The landslide covers an area of 1020000 m^2 with 14200000 m^3 in volume. Its slide mass consists mainly of cataclastic rock masses whose maximum thickness is 40 m. During the overflow period in 1958, its eastern part revived and several ca. 5 cm high slip steps appeared on its front edge. The slipping zone soil was greenish grey clay, 3 cm thick, on which friction mirror planes and scratches are seen. Quantitative X-ray analysis showed that the slipping zone soil was mainly made up of montmorillonite, illite, kaolinite and quartz. Its microtexture features observed with the SEM are as follows: ① the clay minerals are oriented; ② arcuate scratches (Fig. 1-1) show a uniform wideness and are bent and their cutting relationships in different directions are clear; ③ linear scratches (Fig. 1-2 and 1-3) are straight, formed by friction of solid particles (quartz or feldspar or debris) (Fig. 1-2); early scratching marks of various directions cut by late ones are shown in Fig. 1-2 and 1-3.

Arcuate and disordered scratches are the main types in this soil formed by multiple creep slips of multiple directions. Linear scratches are scarcely seen. So it has the feature of multiple directions and frequent (at least 3 times) movements. Now it is in the creeping stage. But monitoring is necessary.

3.2 Wulongchi landslide in Wanzhou County

The front edge of the Wulongchi landslide is 151.0 m in height and the rear edge 215.0 m. The landslide has an average topographic gradient of 12°, a longitudinal length of 180.00 m, a lateral width of 150.00 m, a maximum thickness of 16.55 m and a volume of ca. 400000 m^3. Accidents of destroying residential houses lasted from 1993 till now because of ground rupture and deformation. Quantitative X-ray analysis shows that the slipping zone soil consists mainly of montmorillite, illite, kaolinite, quartz and feldspar. Its microtexture features are as follow: ① the clay minerals are oriented; ② linear scratches (Fig. 1-4 and 1-5) are deep and wide, continuous and unidirectional, without cutting relationships; ③ large quantities of micro-organisms are found, most of which are filamentous bacteria. As shown in Fig. 1-6 *hypomicrobium*; filamentous bacteria (Wanner, 1994; Zhou et al., 1999) are grossly large in specific surface area and grow rapidly with a bulking feature. When accumulated to a certain amount, filamentous bulking may also result in or increase landslide movements. Therefore it is considered that the landslide is just in its moving stage, and the existence of the filamentous bacteria may increase this movement. So the landslide should be monitored and tested most carefully to prevent accidents.

In addition, during the study of microtexture of a slide mass in Wanzhou county, we found typical oriented clay minerals (Fig. 1-7) and two sets of linear scratches of different directions (Fig. 1-8) as well as close-spaced continuous linear scratches (Fig. 1-9). Thus it may be inferred that the landslide has experienced at least two slide movements and is still in the moving stage now.

3.3 Huangtupo landslide in Badong County

The Huangtupo landslide (Wu Yongfeng, 1996) is located about 1 km upstream of old Badong town in Hubei province. It is a large old slide rock mass in the

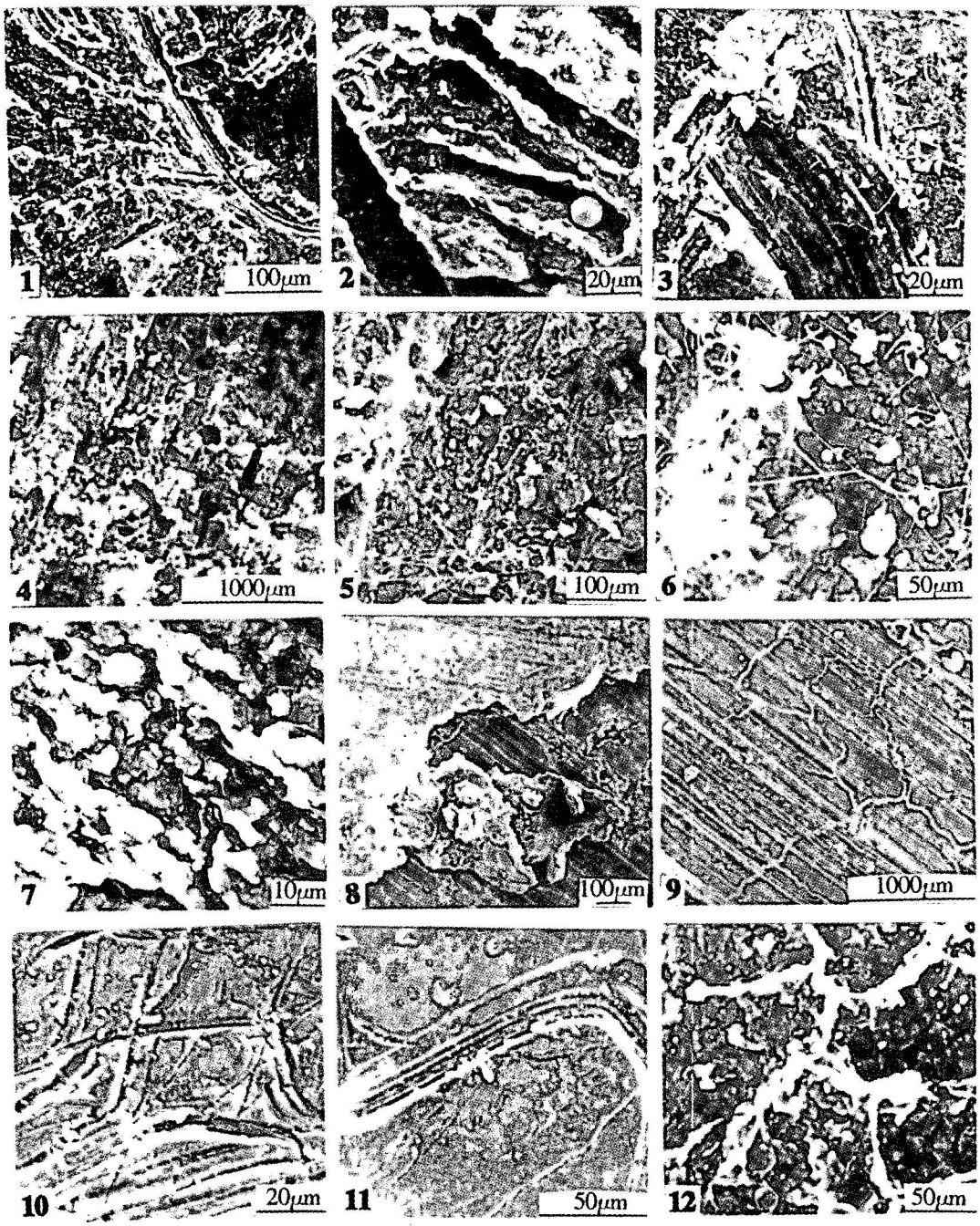

Fig. 1. Surface microtextures ot slipping zone soil of some landslides in the Three Gorges reservoir.
1. Arcuate scratches; 2. Linear scratches; 3. Early scratching marks of various directions cut by late ones; 4. Linear scratches; 5. Linear scratches; 6. Filamentous bacteria; 7. Oriented clay minerals; 8 Linear scratches of various directions; 9. Linear scratches; 10. Arcuate scratches; 11. Arcuate scratches; 12. Leached clay minerals.

Three Gorges Reservoir district. The landslide has an area of 1.38 km^2 and a total volume of about 40000000 m^3. The slipping zone soil consists mainly of quartz, montmorillite, illite and kaolinite.

The microtexture features of quartz are as follows: ① arcuate scratches (Fig. 1-10) can be clearly seen in many directions; ② in a single arcuate scratch (Fig. 1-11), wedge-shaped pits may be seen at its leading

edge, the scratch is wide and deep in its central segment and its trailing edge is shallow and thin which can indicate the direction of the slide movement. So the landslide experienced at least two sliding stage and now is in the creeping stage.

4 Conclusions

(1) Through analyses of the microtextures of slipping zone soils with the SEM, we can obtain information about the number, directions and stages of landslide movements and further judge the mechanism of landslide formation and its stability.

(2) The slipping zone soil shows the following features when the landslide is in a stable stage: the clay minerals are disorderly arranged and chaotically piled without scratches and dendritic clay minerals formed by leaching can be seen (Fig. 1-12). When the landslide is in the mobile stage, they are oriented with arcuate or linear scratches; filamentous forms are quite common.

(3) When closely spaced, straight and continuous linear scratches occur in the slipping zone soils of a landslide, they may be an omen of accelerated deformation of the landslide. Especially when there are large amounts of filamentous bacteria, the balance between the slide mass and the slide bed may be lost, thus causing an accelerated movement of the landslide. This offers criteria for determining the revival possibility of ancient landslides, and forecasting the activity of similar landslides in different districts.

Acknowledgements

This research was supported by National Natural Sciences foundation of China grant 49802028.

Manuscript received Dec. 1999
edited by Fei Zhenbi and Shi Hongyue

References

Wanner, J., 1994. The implementation of bulking control in the design of activated sludge system. *Wat. Sci. Tech.*, 29(11).

Wu Shuren and Wu Ganguo, 1999. Dynamic analysis of deformational structures of the xiannüfeng fault zone in the Three Gorges of the Yangtze River. *Acta Geologica Sinica* (Eng. ed.), 73(2): 163–172.

Wu Yixiang, Zhang Zonghu and Ling Zemin, 1992. A review of the present state of the research on soil microstructures. *Geological Review*, 38 (3): 250–259 (in Chinese with English abstract).

Wu Yongfeng, 1996. *The Huangtupo Landslide and Its Geolgical Problems*. Wuhan: China University of Geosciences Press, 93–97 (in Chinese).

Yang Sennan and Ren Jianye, 1997. The Shizikou gravitational gliding structure in the Yangzi River Gorge. *Acta Geological Sinica*, 71(1): 27–35 (in Chinese with English abstract).

Zhou Li, Peng Yongzhen, Huang Zhi et al., 1999. The factors of effects on filamentous bulking and the control of filamentous bulking. *Advances in Environmental Science*, 7(1): 88–93 (in Chinese).

About the first author

Yan Chunjie Male, born in 1963. He got a master degree for mineralogy in 1991. Now he is a senior engineer with the Test Centre of China University of Geosciences, and devotes himself to the study of geologic disasters and modern testing techniques and teaching work. E-mail: ChjYan@dnscug.edu.cn.