Study on the Microscopic Structure Characteristics of the Gray Matter Slate

Maolin Deng, Qiang Xu, Xing Zhu, Guojun Cai, and Guang Zheng

Abstract

The changes of the stress state and strength of the slip zone in a landslide are determined by the material composition, micro-structural feature, and formation mechanism of the slip zone. It affects the activities of the landslide. In this paper, the mineral composition of the slip zone, which is composed of soft rock of the gray matter slate, is identified by DMAX-3C X-ray diffractometer, polarizing microscope, and scanning electron microscope (SEM). Results show that the content of calcite reaches up to 68 %. There are no changes in the slickensides composition of the sliding surface material. The microscopic structure has been analyzed by different experiments. The results show that the weak zone is composed of the banded calcareous tuffaceous slate, and its structure is characterized by gray black striped fine grains, heterogranular and irregular, and cryptocrystal texture. There is clay on these surfaces, and can be cut into pieces, so it is easy to track and accommodate the shear failure surfaces.

Keywords

The gray matter slate • The slip zone soft rock • Microscopic structure • Mineral composition

Introduction

The tilted mountain constructed with thick limestone is widely distributed in the limestone territory of the southwestern China, including cities of Chongqing, Hubei, Guizhou, Yunnan and Sichuan. Most of the landslides occurred in those mountains caused large number of casualties and great loss of property. Liu et al. (1995), researched the dangerous rock mass whose weak zone was carbonaceous shale and mudstone took place in Lianzi cliff of Zigui county, Hubei province in 1964. Man (1991) studied the Zhongyang landslide that occurred on January 10, 1988, in Wuxi, Chongqing. The landslide volume was 7.65×10^6 m^3 and weak zone was on coal. The landslides caused the death of 26. The Jiguanling landslide is located in Wulong, Chongqing. Volume of landslide was 4.24 million m^3 and weak zone was located on shale. This landslide blocked the Yangtze River. Huang (2008) *mentioned that* the Yankou landslide, located in Yinjiang, Guizhou, killed five people and caused economic losses of 150 million Yuan. The slip zone was made of a thin layer of shale. Xu et al. (2009, 2010) described that the Jiweishan landslide, located in Wulong, Chongqing, produced a volume of 5 million m^3 and killed 74 people.

Liu et al. (2004) argued that the type, material composition, microstructural features, formation mechanism etc. of the slip zone determine the changes in its stress state and strength, which would affect the activities of a landslide. So, the research on the slip zone provides an in-depth knowledge pertinent to the development of landslide. The study on the mechanism of slip zone clay cracks presented were similar to the

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K. Sassa et al. (eds.), *Landslide Science for a Safer Geoenvironment*, Vol. 2,
DOI 10.1007/978-3-319-05050-8_5,

research of slip soil performed by Wang (2006). Li (2007) made in-depth studies on the formation, evolution process and mode of slip zone of the large bedrock bedding landslide. Gibo (2002) and others performed systematic and in-depth research about the strength properties of sliding zone soil. After the Jiweishan landslide in Wulong and Deng (2012), Feng et al. (2012a, b), Liu (2010), Xu et al. (2009, 2010), Yin (2010, 2011), Zhang et al. (2010), Zou et al. (2012) have rushed to the scene, carried out a detailed geological disaster research work and obtained a wealth of research information. Liu (2010), Xu et al. (2010), Yin (2010, 2011) made in-depth study on the formation mechanism of the landslide, and Zhang et al. (2010) analyzed the high-speed remote motion characteristics of the landslide. However, Deng et al. (2009) studied the microscopic structure of soft rock located in the slip zone, which is rare. In recent years, with the improvement of science and technology, the equipment in rock mechanics and the test technique have been greatly advanced, so the achievements in this regard are also increasingly high.

The research about the microscopic structure of soft rock of slip zone is of great significance to the disaster prevention and mitigation of geological disasters in the thick limestone regions of the southwestern China, where the mining, river, road and cities have been or are planned to be constructed. In the present paper, on the basis of the field macro geological survey of the Jiweishan landslide, the mineral composition, microscopic structure of soft rock of slip zone were studied by using DMAX-3C diffractometer (light filtering by CuKa, Ni), polarizing microscope, scanning electron microscope (SEM), and some valuable conclusions have been drawn.

Fig. 1 Image of the Jiweishan landslide

Fig. 2 Destruction of the samples and the observed slickensides

Overview of the Jiweishan Landslide

At 3 pm on June 5, 2009, a tremendous landslide occurred at the Jiweishan in Tiekuang Township, Wulong County, Chongqing City. The thick limestone slipped down along a low angle dip inter-bedded shale plane from 1,300 m cliffs (the height difference of about 200 m). Blocked by the opposite steep creek wall, the sliding rock mass changed its direction and travelled further along the 22,000 m along Tiejiang ditch (Fig. 1). The landslide body was mainly constituted by the Permian off-white thick-bedded micritic limestone, dark gray medium to thick bedded asphaltene-containing limestone, argillaceous limestone and limy-slate mezzanine etc. The area was about 84,000 m^2, and its volume was about 5×10^6 m^3.

The slip zone generally developed along the rock strata, with the occurrence of 30 ~ 355°∠22 ~ 30°. There are a large number of scratches on the slip surface along the sliding direction and a large number of white slickensides were developed on the slip surface, as can be seen in Fig. 2. The Jiweishan landslide with a dual structure in Wulong is a typical landslide located in tilted thick limestone territory. The soft rock of slip zone is the gray matter slate of 5 ~ 20 cm thickness. Under the combined effect of long-term mining activity in the lower part of the landslide and blocked sliding in the leading edge, the slope slowly creeped. This status has lasted for half a century, and therefore the structure of the soft rock of slip zone changed. The field landslide survey results show that microscopic structure of soft rock of slip zone plays an important role in accelerating the creep and eventually rapid starting of the landslide.

Test Equipment and Samples Preparation

The mineral composition is analyzed by the DMAX-3C diffractometer (light filtering by CuKa, Ni). Samples used in the micro tests of the rock were prepared according to the standard of the polarizing microscope and scanning electron microscope (SEM) powdered sample preparation. The powdered samples were then tested according to the polarizing microscope and scanning electron microscope (SEM) standards. To observe its microscopic characteristics, the micro testing of the sample was done with the polarizing microscope (OLYMPUS CX21P) and scanning electron microscope (SEM) S-3000 N/H manufactured by Hitachi. The test program was conducted in College of Materials

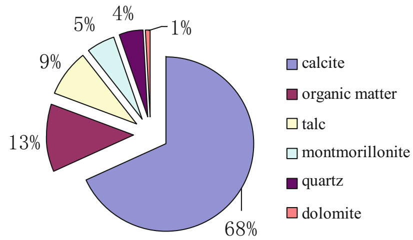

Fig. 3 Proportions of various minerals in the sliding zone materials

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Mineral Compositions

The mineral composition of the soft rock sample is analyzed by the DMAX-3C diffractometer (light filtering by CuKa, Ni). X-ray diffraction pattern is shown in Fig. 3. The identification result of the mineral compositions shows that the content of calcite reaches up to 68 %, whereas the proportion of the organic matter was 13 %, talcum was 9 %, montmorillonite was 5 %, quartz was 4 % and dolomite was 1 % (Fig. 4). With water dissolution and transportation, the calcite permeated and then stagnated in the striped calcareous gray matter slate. The high organic matter content reduces the compressive strength and shear strength of the layer of striped calcareous gray matter slate. The talcum is soft, delicate and smooth. It provides the conditions for the long creeping and rapid movement of the landslide after its initiation. There is a layer of slickensides covering the sliding surface, observed during the field investigation of soft rock of slip zone and shearing specimens. No changes were observed in the slickensides composition when they were analyzed by the DMAX-3C diffractometer (The red is X-ray diffraction of the slip zone slickensides, the light blue is X-ray diffraction of the slip zone soft rock) (Fig. 4).

Microstructure Features

The test results of the polarizing microscope structure show that the lithology of the weak zone is the striped calcareous gray matter slate, the structure is granular and aphanitic structure is gray-black inclusion off-white stripe fine-grained irregular inequi-granular. The slaty cleavage of the rock in weak zone is more significantly developed. The main rock components are off-white fine-grained carbonate and black carbonaceous mudstone.

The rock body is the dust-color inclusion of white stripes fine-grained lepidoblastic texture and a semi-directed bands-striped structure. The main rock components are carbonate, a lot of scaly calcite and a little fine-grained quartz, mainly calcite. The microstructure shows scaly aggregates often form in irregular pellet-group porphyritic. There is a little fine-grained irregular granular quartz between the particles, and sometimes there is fine-grained irregular granular or pellet carbonate, which is interpenetration symbiosis (Figs. 5 and 6).

Due to the effect of small granularity and impurities, the interference color tends to be less distinctive. The structural impact may lead to the slaty cleavage development along the bands or the edge of the group porphyritic. The organic gray matter is recrystallized and has formed the black aphanitic carbonaceous (Aphanitic graphite), and it can make hands dirty. The quartz disorderly intersperses between the calcite intergranular particles, and its distribution is ordinary, but its content is less. The slice is colorless. The interference color is gray, and it has much more developed wavy extinction. The quartz-carbonate veins in the rock is well developed. It macroly shows white zone and synchronous folding with the surrounding rock. Its locals contain black surrounding rock xenoliths, which are mainly constituted by band aggregates consisting of medium-grained irregular granular carbonate, and sometimes containing a relatively small amount of medium-grained irregular granular quartz, which are interpenetration symbiosis. The locals cut through the surrounding rock structure, but they are not affected by metamorphism structures. It may indicate that the formation of carbonate veins is mainly through the same structural development (Fig. 6). The structure and mineral composition of the gray matter slate are more complex. They experienced multi-phase deformation and metamorphic processes.

On the basis of the field macro geological survey of the Jiweishan landslide, the typical samples from 10 landslide sliding surfaces are tested by the scanning electron microscope (SEM). The samples at natural state and samples with 10-day water saturation were analyzed, and then the microstructure features of the landslide sliding surface were obtained. The lithology of the test's sliding surfaces is gray matter slate, dried naturally and plated, when the samples were observed by SEM. There are a large number of linear scratches, micropore, microfissure and the clay mineral directional arrangement (Figs. 7 and 8).

Under the rainfall condition, the situation where the water flowed into the interiors of the slip zone were simulated, and then the saturated-water tests were done. Five samples which were immersed in distilled water for 10 days were selected. They were soaked and then dried, and the microstructure were then examined by the SEM. The result shows that the micro-cracks expand, the porosity increases significantly, and new micro-cracks occur (Figs. 9 and 10). The water

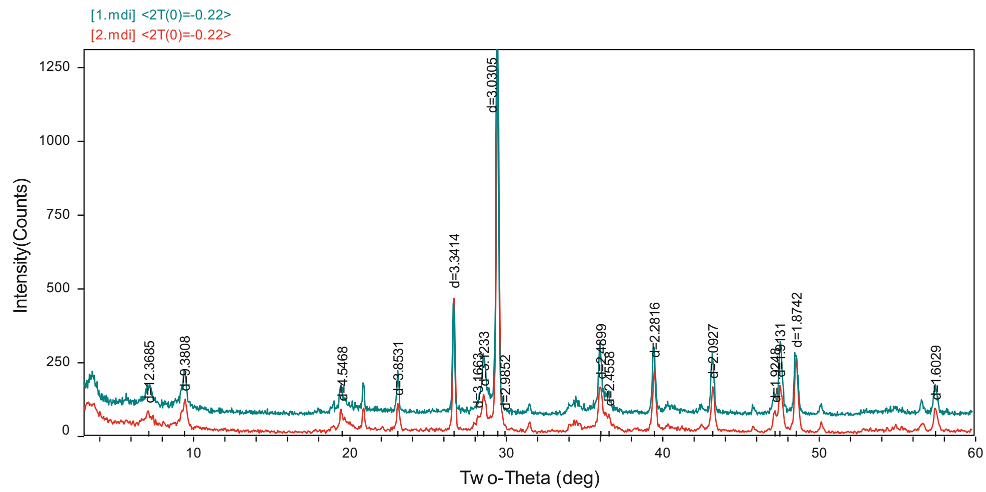

Fig. 4 X-ray diffraction of the Soft rock and specular materials

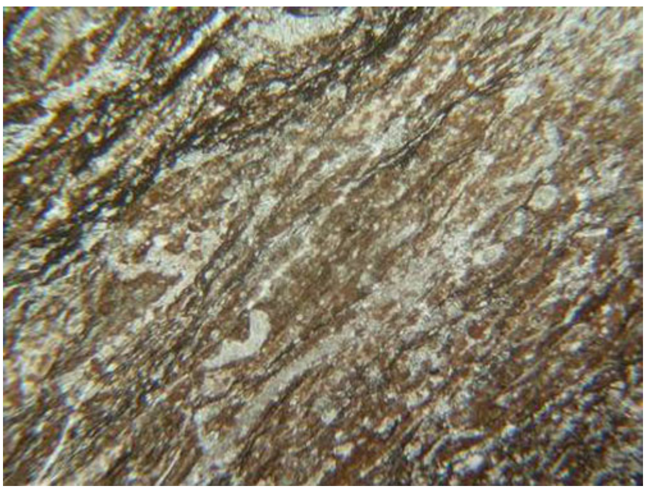

Fig. 5 Banded and perthitic structure (visual field diameter: 5.2 mm, parallelling to the polarization)

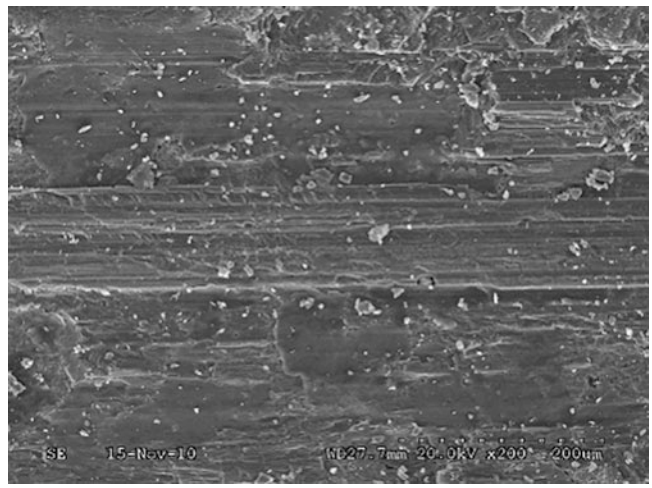

Fig. 7 Linear scratches in low magnification ×200 times

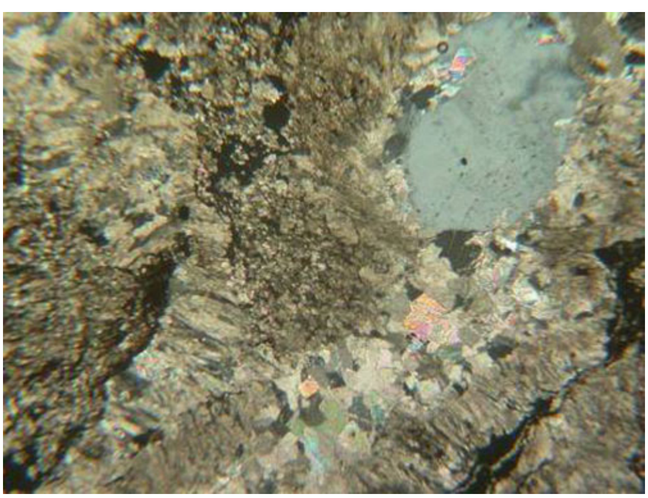

Fig. 6 Contact relationship between the carbonate aggregate and surrounding rock (visual field diameter: 1.0 mm, parallelling to the polarization)

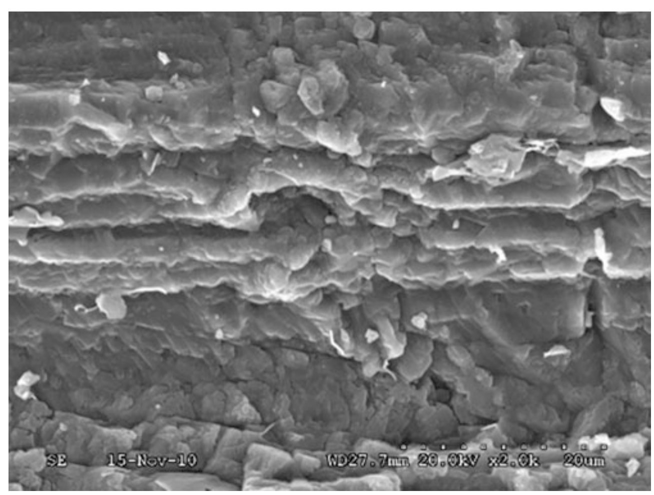

Fig. 8 Microcosmic linear scratches at high magnification x 2,000 times

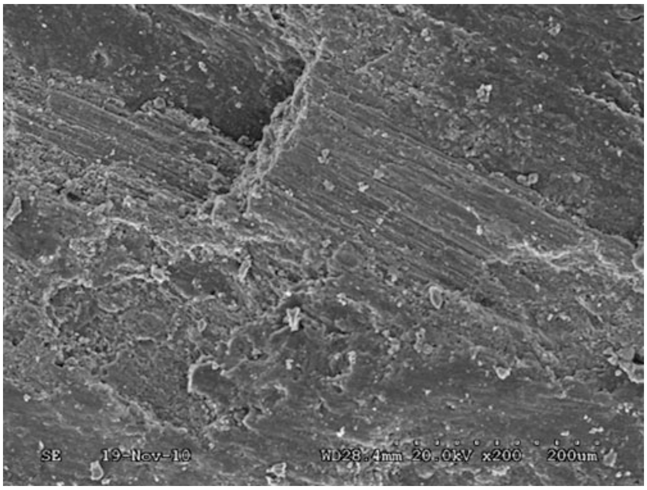

Fig. 9 Microporosity increases ×200 times

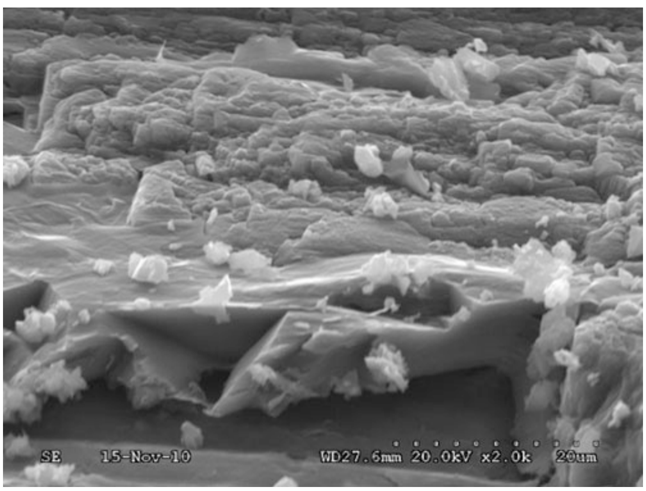

Fig. 10 Microporosity exists ×2,000 times

can lead to new micro-cracks of the soft zone, which become the main sources of continuous sliding cracks. The test results of the microstructure show that the structure and mineral composition of the gray matter slate are more complex. They have experienced multi-phase deformation and metamorphic processes. Some microscopic structures above the weak zone play an important role in the slow chain-styled catastrophe processes after the fast development, during which several stages have been experienced: the formation of landslide boundary in a long period → creeping along the weak surface → stress concentration and then shear collapse → disintegration impact → catastrophic failure occurrence. All these stages also coincide with the basic characteristics of the landslide movement.

Conclusion

The typical material composition, microstructural features, formation mechanism etc. of the landslide weak zone determine the changes in its stress state and strength, and these changes would affect the activities of a landslide. On the basis of the field geological survey of Jiweishan landslide (especially the slip zone), the slip zone characteristics of the Jiweishan landslide obtained much more detailed research through a series of laboratory tests.

1. The content of calcite reaches up to 68 %, whereas the organic matter about 13 %, talcum about 9 %, montmorillonite 5 %, quartz 4 % and dolomite 1 %. With water dissolution and transportation, the calcite permeated, and then stagnated in the striped calcareous gray matter slate. The high organic matter content reduces the compressive strength and shear strength of the layer of striped calcareous gray matter slate. The talcum is soft, delicate and smooth. There is a layer of slickensides covering the sliding surface in the investigation scene of the slip zone soft rock and shearing specimens. There are no changes in the slickensides composition when it is analyzed by the DMAX-3C diffractometer.
2. There are a variety of irregular granular or pellet minerals, and they are interpenetration symbiosis. The main rock components are off-white fine-grained carbonate and black carbonaceous mudstone. The former rock will produce bubbles when it meets cold HCl. The latter rock is soft and flexible, and it is mainly composed by mud, and it can make hands dirty. It hardly forms bubbles when it meets acid. Results before and after water saturation of the weak zone show that there are a large number of linear scratches, micropore, micro-fissure, and the clay mineral demonstrates directional arrangement in the natural dried samples in the scanning electron microscope. Besides, some micro-cracks and expansions occur in the fully water-saturated samples from the slip surfaces, the porosity increases significantly, and new micro-cracks emerge. These micro-cracks become the main sources of continuous sliding cracks. Some microscopic structures above the weak zone play an important role in the slow chain-styled catastrophe processes after the fast development.

Acknowledgments The research has been supported by the National Basic Research Program "973" Project of the Ministry of Science and Technology of the People's Republic of China (2013CB733200), by China National Science Fund for Distinguished Young Scholars (41225011), and by State Key Laboratory of Geodesy and Earth's Dynamics(SKLGED2013-1-1-EZ).

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