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陇南山区斜坡重力地质作用特征研究

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摘要

位于地质构造、地层、地貌、气候和植被五位一体叠加脆弱带的陇南地区是我国主要滑坡、泥石流、崩塌等斜坡重力地质作用区之一。本文简述了斜坡重力地质作用的概念和类型，着重分析了其垂直分带性、区域性、季节性、周期性、阶段性、继承性和共生性等作用特征，揭示了斜坡重力地质作用的活动规律。

主题词： 甘肃 重力 滑坡 泥石流

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SOME FEATURES OF SLOPE GRAVITATIONAL PROCESS (SGP) IN LONGNAN REGION OF GANSU PROVINCE, CHINA

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Abstract

Longnan region lies in the translational area among Qinghai—Tibet Plateau, Loess Plateau and Sichuan Basin and belongs to the superimposed weak belt in geological structure, stratigraphic properties, geomorphology, climate and vegetation, so the slope gravitational process, such as debris flow, landslide, rockfall, etc. are most conspicuous in this region. It is one of the four main gravitational disaster areas in China. Based on predecessors works and field investigation, this paper studies the definition and types of slope gravitational processes (SGP), especially analyzes their features, such as vertical zonality, regionality, seasonal variation, periodicity, inheritability, paragenesis, etc., thus brings to light their activity laws.

Subject words: Gansu, Gravity, Landslide, Mud-rock flow

1 INTRODUCTION

Longnan region is located in the southeast of Gansu Province, which belongs to the upper reaches of Changjiang River. Its total area is 38,434.33 km^2. Controlled by Qinghai—Tibet tectonic zone and Wudu arc-like structure and influenced by the up-lift of Qinghai—Tibet Plateau, neotectonic movements and earthquake are quite active, 15 larger earthquakes occurred in this region since Han Dynasty(Li Yulong, 1982). The 1879's earthquake triggered a great deal of landslides and debris flow in the area of 16,000 km^2 in 5 counties and caused serious losses (Li Honglian, 1991). In 1976, an earthquake occurred with rainstorm and resulted in tremendous landslide and debris flow. If great earthquakes break out, they will generate house collapses, landslide and debris flow disasters, block up roads and bring huge difficulties to the outside emergency squads. The terrace Ⅲ developed in Bailongjiang River valley. Faults and folds are broadly distributed, so rock layers are broken and loosened, the weathered layer reaches about 50 m deep.

The climate in Longnan belongs to monsoon climate type and is in the intermediate zone from subtropical monsoon climate to temperate subarid climate, so the climatic fluctuation is strong. The annual precipitation is 500—600mm, the rainfall from June to September occupies more than 60% of the year precipitation. The annual average temperature is 11 C. Since 1950s, the temperature has increased 0.5 C, but rainstorm increased from 7 times in 1950s to 37 times in 1970s(Li Honglian, Ma Dongtao, 1991). Meanwhile, ecosystem becomes worsened tremendously. The forest cover reduced to nowaday 29% from 50% in 1950. The lower

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forest line retreated 1,000m in vertical elevation. Desertification of land is very serious.

2 THE DEFINITION OF SLOPE GRAVITATIONAL PROCESS

Slopes are the most basic landform factor. Slope gravitational process (SGP) is one widespread form of slope process or slope movement. Slope process is the whole process of some small rock and soil mass or layered rock mass down-movement along slope. According to its exogenetic forces, slope process can be classified into 3 types: (1)process of slope materials erosion and transportation by flow water; (2) process of slope materials sorting and displacement by heaving, such as solifluction, stone-ring and stone-river etc.; (3) creep, falls, toppling and slide caused by slope deformation and failure under the gravity and all sorts of deformations generated by artificial cutting and digging activity on slope. In this paper, SGP is only discussed, because it has enormous effects on human activity and widely distributes on the slope.

SGP is the slope process under the influence of gravity or sometimes accompanied by other exogenetic forces. Different experts give it various terms according to their study specification: The Soviet scientists call it slope gravitational action (E. P. Yemiliyahnova, 1972); European and American experts call it mass movement or mass wasting (Brain Finlayson, Ian Statham, 1980; N. j. Kirkoy, 1972; N. J. Sselby, 1982); Chinese scholars name it loading process (Li Shuda, 1983). Mass movement is the movement of rock and soil debris down slope under the influence of gravity without the aid of flowing water, wind or glacier ice. Loading process is defined as the geologic process of the surficial loose materials and rock mass movement under their gravity and other triggering exogenetic forces.

3 TYPES OF SGP

3.1 Simple introduction to classification of SGP

The classification of SGP mainly depends on the deformation and failure forms of slope, slope material sorts, movement speed, surficial shape, age, causes, and other factors. E. P. Yemiliyahnova (1972) divided SGP into two types on basis of its forces: one is pure gravitational process type, another is complicated gravitational process type. On engineering geology field, rock mass mechanics classification is often used according to the inner stress distribution and deformation of rock and soil. Zhang Xiangong (1983) adopted this method and divided SGP into deformation and failure types. Either natural or artificial slope has slope and height. Thus, during the SGP course, slope height will be reduced and gradient will become smooth gradually. Through the deformation and failure process, slope extends to planation at last. Relying on the movement forms and materials, D. J. Varnes (1958) suggested a comprehensive classification method. SGP was divided into fall, toppling, slide, lateral spread, flows and complex types. At present, this is the best classification method of SGP, so it is used in this paper.

3.2 Types of SGP in Longnan Region

Through the field investigation and room study, it is clear that in Longnan region, landslide and debris flow are the major types because of their wide distribution, serious disasters and damage.

It is inspected that there are about 20,000 landslides in Longnan mountain region, in which there are 229 larger slides of volume exceeding 500,000m^3. The sliding area is 9,067 km^2, in which soil slide, debris slide and rock slide areas are 1,524.5 km^2, 2,811.5 km^2 and 4,731 km^2 respectively. If including the potential slide area, the total will be 15,000 km^2. Now, about 6,260 mud flow and debris flow gullies develop in Longnan, the total drainage area is 5,944.52 km^2. On May 22,1987, a debris flow broke out from Anping gully and formed a 80m long, 80m wide and 60m high natural rockfill dam, the dam blocked Beiyuhe River and submerged 8,000 mu (1 mu=667m^2) field, 19 people were killed. The maximum discharge of debris flow was 1,216m^3/s,however, the main river s discharge is only 250 m^3/s. During the process, one big stone of 4,000 m^3 which was fallen down slope by an earthquake in 1879 was displaced and carried by the flow about 100m. Statistics show that in near 20 years, 243 people died due to landsilde and debris flow disasters, the total damage reached 2.5 billion RMB¥ (about 400 million US $).

4 SOME FEATURES OF SGP

SGP results from interaction between endogenetic and exogenetic forces, it is also the product of climate evolution and long-term geological environment change. It is not only a product of gravity, but also an important and special dynamic action on the crust. Consequently, it presents some features in spatial and regional distribution, period and so on.

4.1 Vertical zonality

Vertical zonality refers to the features of the forms and intensity of SGP changing with elevation. These phenomena extensively exist in the Alps area (N. J. Selby, 1982; Michael Clark and John Small, 1982), Urumqi River source of Tianshan Mt. in Xinjiang and Maxianshan Mt. in central Gansu (Fang Xiaomin, 1988), but the vertical zonality appears more typically in Longnan.

Vertical zonality of SGP results from the multiple effects of all sorts of factors on a slope, particularly the effects of topographic conditions (height, slope degree), rock properties, geological structure, gravity, climate (rainfall, temperature) and surficial run-off conditions on a slope. On the whole slope from drainage divide to the valley bottom, SGP can be divided into four belts (Fig. 1). Ⅰ Fall-toppling belt: authors found that many drainage divides are always the landslide scarp in Longnan. Slope is often between 30° and 35° with high elevation, so has full potential energy for falling and toppling of steep soil and rock mass. Ⅱ Slide-flow belt: the slope wash just accumulates under the scarp and middle part of slope. Here, the slope is smooth and gentle, ground water is active, so rock and soil often slide along soft contact plane of Quaternary loess and Tertiary red layers (sandstone, conglomerate rock and clay). Sometimes, surficial debris flow can be formed under powerful rainfall. Ⅲ Fall-toppling-slide belt:

widely distributed and extensively active. More often, SGP occurs at the places where the lithosphere, hydrosphere, atmosphere and biosphere metamorphose greatly, for example Longnan in Gansu, Xiaojiang in Yunnan, Xichang in Sichuan and Bomi in the southeast of Tibet in China, California and Alaska in U. S. A., high mountains of British Columbia in Canada, the Alps in Europe, Huasaran in North Peru and Japan Islands. In these regions, the geologic structures are always complicated, neotectonic movements are quite violent, layers are fractured and topographies are steep, vegetations become decay and human activities are frequent. Pu Qingyu (1990) put forward the concept of Serious Disaster Belt of Central China. Longnan, Xiaojiang and Xichang are all located on the second terrace of this belt. The concept of SGPR can help us to understand the regionality of SGP, to divide SGP disaster regions and non-disaster regions, to classify disaster scale and intensity, and to make the preventive countermeasures against SGP disaster.

4.3 Seasonal feature

SGP always breaks at the certain time, in other word, it has the seasonal feature. The statistics show that more than 80% of SGP occurs during the time from June to September, particularly in July and August. Authors also find that earthquakes always meet with powerful rainstorm in Longnan and trigger a great deal of SGP disaster. For instance, the earthquakes coincided with rainstorms on July 1, 1879, July 20, 1883, July 1973 and June 1976, the trails of these catastrophes appeared very clear up till now. In the rain season of 1984, more than 1,000 landslides and landfalls occurred in the 8 counties of Longnan region.

4.4 Evolutional stages

The stage features of SGP depend on the factors of neotectonic movements, climate fluctuation, etc. According to the evolutional process, SGP can be divideu into three stages of occurrence, development and decline, namely, initial, mature and decay stages (Li Honglian, 1986). The cycle of three stages makes up the period of SGP (Table 1).

4.5 Periodic feature

The pluvial age and interpluvial age, loess depositional period and intermittent period, ice age and interglacial epoch have been recognized. Li Honglian (1986), Zhang Linyuan (1989), Shi Yafeng (1989) researched the debris flow period in China. R. Craig Kochel (1987) studied three debris flow stages since 11,000 B. C in Pavis Valley, middle Virginia. D. Higaki (1986) studied the two mass movement periods in the Central Kitakami mountains of Japan, he considered that one period was in the early Last Glacial Stage, perhaps around 50,000 yrs. B. P., and another is in the late Glacial Stage, between 30,000 and 10,000 yrs. B. P. Based on comparison and study, it is considered that there exist three SGP periods and two intermittent periods during Quaternary in Longnan region: the first is the later period of the Middle-Pleistocene, the second is the early and later period of Late-Pleistocene, the last one is the recent period since Holocene, among which the SGP in Late-Pleistocene was most widespread and strongest.

4.6 Differences of scale, movement speed and frequency

Table 1 The stage classification of SGP in Longnan region, Gansu Province

Evolutional stages	Features	Typical regions
Initial stage	Neotectonics become intensive gradually, gullies begin downcutting, slopes lose their stability. The rock falls and earth falls begin to form. The original alluvial fans are cut down and form the new fans. The eco-environment worsened.	Eastern part of Wenxian county and northern part of Tanchang county
Mature stage	Mountains uplift and valleys are downcut strongly. The earthquakes become very active. landslides and falls occur in large area, and a lot of debris flows are triggered, the debris flow fans are enlarged to the maximum limit. The slopes retreat quickly. Desertification of the land is very serious.	The middle reach of Bailongjiang River, Beiyuhe River basin, Yangtanghe River basin, the upper and middle reaches of Baishuijiang River and Xihanshui River
Decline stage	Neotectonic movements are in stable period, valleys become wider and are U-shaped. The downcutting of valleys and gullies stops. Landslide and fall activities become decline, debris flow processes get weaker and disappear at last. Slopes are all in stable state, vegetation and eco-environment get recovered.	The above-mentioned regions and other fragmentary areas

The scale, movement speed and frequency of SGP have obvious differences among various types. Generally speaking, the volume of landslide is from several hundred thousands to several ten millions m^3. In Fanjiashan, the volume of the largest landslide reaches about 300 million m^3. The average volume of landfall and rock fall is several hundred m^3. The velocity of debris flow is from 4m/s to 7m/s and its density is form 1.4t/m^3 to 2.2t/m^3 in Longnan. The movement speed of rockfall and toppling is from 10m/s to 100m/s. Because there are many and complex effect factors of landslide and debris flow, the frequency is far less than that of fall and toppling (Fig. 2).

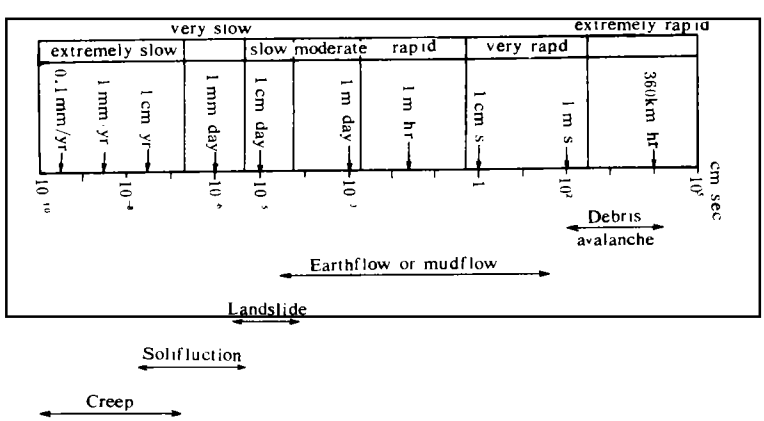

Fig. 2 The velocity ranges of SGP (after Michael Clark, 1982).

4.7 Inheritance feature

The SGP has the inheritance features in Longnan and other places in China. Almost all of the new SGP generate from the old SGP distributive area. The inheritance of long-term series and continuity in broad area of SGP depend on its main control factors, especially neotectonic movement. Usually, neotectonic movement appears as revival of old structure, generation of new structure, the differential uplift and subsidence of crust and great earthquakes, which supply advantageous topography and materials for SGP. Meanwhile, the climate changes. especially the synchronous changes of climate and tectonics, have the significant effects on the inheritance of SGP.

4.8 Paragenesis feature

Each type of SGP has the same or similar causes, therefore, affects each other and always occurs together, sometimes forms disaster chain. In Longnan region, debris flows often wash and erode slope, and form the overhanging planes, thus fall, toppling, landslide, landfall and rock-fall often occur and block the valley and river, which supply materials for debris flow. In Huasaran, north part of Peru, an ice avalanche broke out, mixed with water and formed debris flow, moved 14km from a peak of 5,700 masl along a 0.22 gradient valley to a city of 2,570 masl, the maximum speed reached 110m/s.

5 CONCLUSION

SGP is one slope process which depends completely or mainly on the influence of gravity. All of six types of SGP exist in Longnan region, they have the vertical zonality, regionality, seasonal variation, periodicity, inheritability, paragenesis. etc. features. The understanding of these features can help us to recognize the development, distribution and movement regularity of SGP, thus to make the countermeasures to prevent and reduce SGP disaster.

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