Formation of, and preventative measures for, debris flow in Xide County, Xichang, China

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Abstract: Xide County lies in the mid-west part of the Xichang basin, China. Geohazards frequently occur. The geological structure of the basin is complex and neotectonic ground movements are strong. Earthquake movements are also frequent and the rock stratum has been broken by them. Landforms are rapidly formed and the relief is high. The area is subject to a monsoon climate and it rains frequently and strongly. These are the intrinsic factors that trigger debris flows. Human economic and engineering activities are environmentally unsustainable and have destroyed the ecological balance; this has contributed to the initiation of debris flows. Based on this understanding of the debris processes, the paper explains the hazards and the preventative measure for Xide county and presents methods for the prediction of debris flows there.

Résumé: Le comté de Xide se situe dans la pièce de Midwest du bassin de Xichang, Chine. Geohazards se produisent fréquemment. La structure géologique du bassin est complexe et les mouvements au sol néotectoniques sont forts. Les mouvements de tremblement de terre sont également fréquents et la strate de roche a été cassée par eux. Des formes de relief sont rapidement formées et le soulagement est haut. Le secteur est sujet à un climat de mousson et il pleut fréquemment et fortement. Ce sont les facteurs intrinsèques qui déclenchent des écoulements de débris. Les activités humaines économiques et de technologie sont ambiant insoutenables et ont détruit l'équilibre écologique ; ceci a contribué au déclenchement des écoulements de débris. Basé sur cet arrangement des procédés de débris, l'article explique les risques et la mesure préventive pour le comté de Xide et les méthodes actuelles pour la prévision des débris coule là.

Keywords: landslides, geological hazards, erosion, excavations, ecology, debris flow, prevention measurements

PREFACE

China is a mountainous country (Bang-Xing Tang, 1996), Particular mountain environments make China susceptible to many types of geohazards, such as, the formation of debris flows•landslides and avalanches•etc. They develop and distribute widely, occur frequently, and damage seriously. Since 1980s, the mountain hazards have caused huge damage. They have severely hampered the development of the country. According to the Chinese incomplete figures, there were more than three hundred fatalities and economic losses were more than ten billions during the end of 1980s and the early 1990s; there were more than one thousand fatalities and economic losses were more than twenty billions each year during the middle of 1990s.

Xide County lies in the mid-west part of the Xichang basin (Yun-Sheng Wang, 1996), Sunshui River runs through the county. The Heishui River and Xiaojiang Fault lie in its east part, the Anning River lies in its west part, the Zemu River lies in its south part, the Xiaojiang Fault lies in its north part (Figure 1). It lies in the high ground stress, the natural topography is high, it mainly consisted of mountainous region, the relief is steep, the geological structure of the basin is complex, environment is weak, and it rains frequently and strongly. Human economic and engineering activities are environmentally unsustainable and have destroyed the ecological balance; this has contributed to the initiation of debris flows. According to the survey, there are more than 78 debris flows gullies in the county. It has become an important factor that it severely blocks the economic development.

ANALYSIS OF THE DEBRIS-FLOW HAZARDS FORMATION

Debris flow or mudslides are one of natural geo-phenomenon. They are one of the most numerous and dangerous disasters in the world. They are a kind of special onrushes that are triggered by precipitation and consist of mud, sand and rock etc. They abruptly break out, and they are impermeable. The speeds and sheer destructive force are high, so they are particularly dangerous to live and properties. These flows are capable of destroying homes, washing out roads and bridges, sweeping away vehicles, knocking down trees, and obstructing streams and roadways with thick deposits of mud and rocks. Formation of debris flow is associated with many kinds of factors. The geological structure of the basin is complex and neotectonic ground movements are strong. Earthquake movements are also frequent and the rock stratum has been broken by them. Landforms are rapidly formed and the relief is high. The area is subject to a monsoon climate and it rains frequently and strongly. These are the intrinsic factors that trigger debris flows. Human

economic and engineering activities are environmentally unsustainable and have destroyed the ecological balance; this has contributed to the initiation of debris flows.

Geological Conditions

Geological conditions determine the frequency of geohazards in Xide County, especially in the Sunshui River drainage area.

Construction

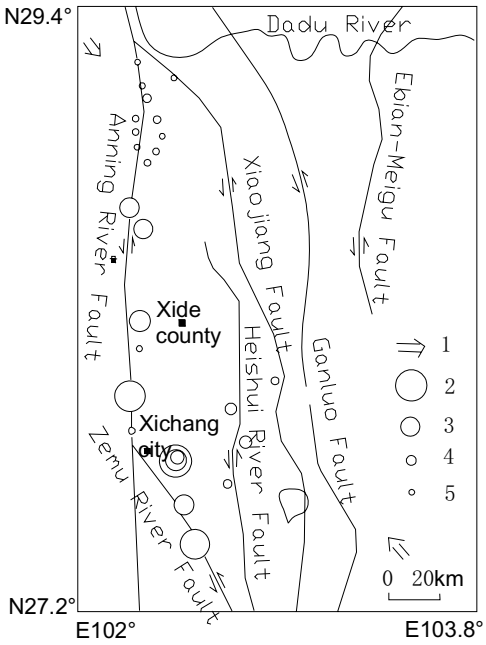

Figure 1. Seismic-tectonic map of Xichang (from Yue-Quan Shang, 1992) 1.σ1,2. seimicity >7, 3. seimicity=6~6.9, 4. seimicity =5~5.9, 5 seimicity <5

Debris flows mostly develop in the active tectonic zone. In different interjunctions of active tectonic zones, the frequency of earthquakes are larger, the strata distortion are strong, rock failure is also strong•so the debris flows occur very frequently in the area. Xide county lie in the stylolitic structure of the Indian plate and Eurasian plate•and it has multiperiodic activity characteristics. The geological structure of the basin is complex and neotectonic ground movements are strong. Earthquake movements are also frequent and the rock stratum has been broken by them. Landforms are rapidly formed the relief is high. So in the area, sliding and falling occur very frequently, and the formed a lot of loosening fragmentary material for debris flow.

The east of Zemo town lies in the Mishi syncline west wing of the Liangshan belt of folded strata, which consist of clasolite. The dip of strata is 10º~40º. The part between the Zemo town and Lianghekou belongs to the Lianhe town brachyanticline which is one of parts of the Mishi syncline. The Sunshuihe transects the fold of Mishi syncline, its side banks consisted of monocline V-shape valley, sub-first grade structures are tension-shear faults or compresso-shear faults whose strikes are NE, NNE and NWW, there are plenty of near EW strike tension joints and X shape joints in the area. The sand-shale sloping grounds that consist different tectonic association easily occurs collapses, slopes, and they directly supply a lot of loose solid matters for the debris flows, such as Machanggou, Donggou of the county, and Lianghekou. The west of Zemo town lies in the Anning River active fracture zone that consists of six main straightness faults. There are plenty of loose solid matters, so the debris flows also easily occur in the area, especially under duration of storm condition.

Lithologic characters

Rock and loose solid matters are matter condition of debris flows. The lithologic characters mainly consist of fragmentary rock, sand-shale and granite. Under a series of tectonic movements, regional metamorphism and groundwater action conditions, their resistance to weathering and denudation are decrease. The structures of the rock strata were destroyed so that the rock strata were broken up, their structures became loose and weak and weathering disintegration were intensive. They supplied plenty of loose fragmental matters. They also supplied kinetic energy for activities of debris flows.

Physiognomy Conditions

Physiognomy is the intrinsic factor of geo-hazards in the mountainous regions. It is one of important conditions for formation, movement and development of debris flows.

Since Neocene, Qinghai-Tibet Plateau was strongly uplifted, and formed a largest mountain. Not only did it affect the activities of monsoon wind and distributions of rain, but also it led to the formation and distribution of the geo-

hazards. Xichang city lies in the east of the Qinghai-Tibet Plateau, the difference of elevation is large, and its landform is also complex. The mountains' strikes are near North-south direction, most of the elevations are 2500~3700m. The difference of elevation between the mountain peak and mountain valley are 800~2000m. Sunshui River flows among the mountains. The degrees of slope are 30º~45º, some are more than 60º in the river basin. The density of cover is lower. Under all the mentioned above conditions, the debris flows frequently occur.

Atmospheric Precipitation

Atmospheric precipitation is also an important factor to the debris flow occurring. It is not only the liquid phase matters of debris flow occurring and hydrodynamic force condition, but also it is one of the triggering factors. So debris flows frequently occur during rainy year, especially the storm year.

There are rainwater debris flows in the region, so it is mainly affected by atmospheric precipitation. It is subtropics monsoonal climate. Its dry and rainy season is evident, atmospheric precipitation is abundant, yearly precipitation is more than 1000 mm, it mostly rains in summer and most of them are rainstorms. From May to October is the rainy season in a year, especially from June to September. So the debris flows frequently occur in the season. Furthermore, the densities of cover are medium and are very unbalance. The lower of the density of cover is, the more debris flows occur. Especially after excessive rain and meeting rainstorm, debris flows easily occur. For example, in 1981, debris flows occurred in the most of the valleys in the county.

Unreasonable Economic Activities

Debris flows frequently occurs that it is intimate relation with unreasonable human economic activities. Human economic activities are frequent in the region. Especially, since 1949, with the development of the economy and population growth in the mountain region, human economic activities are increasing, and the ecological balances are destroyed and gradually aggravated. So the natural disasters frequently occurred. They not only supply the source of matters•but also provides impetus condition for debris flow occurrence.

Irrational Exploitation and Management of Forests

The forest utilization was spoliatory in mountainous area in the past. Mountains turned into naked because of forcing cut. Forests are difficult to regenerate in the mountains. Additionally, poor management and transport lead to severe erosion and instability of the slopes. So the formation of debris flow becomes easy. The facts showed that most of the debris flows occurred in the region that forests were excessively cut.

Irrational Utilization of the Lands

The problem of foodstuff had brought about because of population growth. Unreasonable land utilization, such as deforestation, assart (The act or offence of grubbing up trees and bushes, and thus destroying the thickets or coverts of a forest) and land cultivation on the slopes etc. that leads to the naked mountains, rock and soil weathering, soil erosion and gully being formed. So they lead to the debris flow occurrence.

Mineral Exploitation and Irrational Dumping

Unreasonable mine exploitation not only destroyed vegetation and made the slope be unstable•but also dumped plenty of slag. Furthermore, there was not essential protection projects in the mines so that the mine dumps occur to debris flows and landslides. For instance, the slope whose foot was excavated was unstable in the mine in Lake Town several years ago, and it lead to debris flow occurring so that it had brought about heavily economic losses and casualties.

Irrational Road Construction Road and Hydraulic Engineering

The slopes were cut during the constructing roads in the mountains and became unsustainable. At the same time, the forest vegetations were destroyed. Both of them led to the debris flows occurrence. In the mountainous area, the hydro-energy utilization, such as constructing hydraulic engineering and ditch for diversion, also led to the slopes be destroyed and ditches leakage etc. Both of them also led to the debris flows occurrence. For instance, the slope was failure in the Lianghekou town because of the road be constructed. And it led to the railway which was from Chengdu to Kunmin moved backwards. In every rainy season, slopes and debris flows frequently occurred, and brought about huge economic losses.

DEBRIS FLOW PREVENTATIVE MEASURES

The scale of debris flows in the region is larger, the frequency is higher and the losses are larger, so it belongs to the most dangerous area (Peng Cui 2003). It heavy endangers to the properties and lives. For example, Donggou debris flow has occurred eight times since 1901.The extraordinarily serious debris flow which occurred on 27th May, 1974, led to serious loss of the properties and lives. So it is necessary to control it. But the formation of condition and environment of debris flow are different, so the principle of prevention is "The prevention is first and the controlling is secondary. The prevention accords with the controlling.

Preventative Measures

On one hand, most of the debris flow occurrences are relevant with the human economic and engineering activities, so it is a better measure to inhibit destroying the ecological balance and prevent the geohazards. Chinese government promulgated the rule of geologic hazard prevention and management in March, 1999. Since then, governments to all levels of Sichuan Province had promulgated the relevant rules.

On the other hand, on the base of geohazards investigation, we specially monitor the larger debris flows that may lead to serious loss of the properties and lives. And we success to predict many debris flows occurrence since the monitoring.

Controlling Measures

The formation, process and controlling purposes are different, so the controlling schemes are also different. The engineering controlling measures and bio-controlling measures are adopted together. And at the same time, under considering the different part of the slopes or the valleys conditions, we take the measure to control the soil, water and vegetation.

Drainage arrangement and tree planting are adopted in the formation area. Different kinds of dams and retaining walls are constructed in the flow area. Diversion dikes, draining dykes, sludging stops and barrages are constructed in the accumulation area.

Mentioned above measures were taken in the controlling the Donggou debris flow, and we benefited from it. Its benefit-cost was 20:1 to 50:1.

Predicting the Debris Flows

Predicting the debris flow is the most important part of reducing hazards and preventing hazards. On the base of knowing the debris flow, proper predicting the debris flow is an important method to protect the properties and lives.

The debris flows that are triggered by storm floods are random occurrences. There sizes are relevant with the magnitudes of the rainfall density and the loose solid matters. Gen-wei Cheng presented the equation of debris flow quasi-periodicity (Gen-Wei Cheng, 2002):

$$T_0 = \frac{\alpha - 1}{\ln(1 - P_s)}$$

where T_0 is debris flow quasi-periodicity in a, α is from 0.2 to 0.5 according to the local conditions, P_s is the frequency of debris flow occurring.

After the last debris flow breaking out about T_0 a, the frequency and size are bigger. According to the quasi-periodicity, we can predict the debris flow occurrence and protect the properties and lives.

CONCLUSIONS

The geological structure, neotectonic ground movements and rains are the intrinsic factors that trigger debris flows. Human economic and engineering activities are environmentally unsustainable and have destroyed the ecological balance; this has contributed to the initiation of debris flows. Based on this understanding of the debris processes, we take some preventative measures to decrease the debris flows occurrence. At present, the debris flows have rapidly decreased in the county.

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