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Landslide-induced debris flow disaster in Biaoshuiyan Gully, Sichuan, China

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Селевая катастрофа, вызванная оползнем, в долине Биаошиян (провинция Сычуань, Китай)

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Долина р. Биаошиян находится в округе Пуге, провинция Сычуань, Китай. Река является притоком р. Земухе, относящейся с бассейну р. Жиншайианг. Водосбор начинается на восточных склонах горного массива Хенгдуаншан, где сезон дождей длится с июня по сентябрь и в этот период выпадает 67 процентов годовой нормы осадков, причем максимальное суточное количество осадков составляет 157,9 мм. Сочетание геоморфологического и геологического строения с характером осадков создает идеальные условия для формирования селей и оползней. 22 июня 1999 г. штормовой ливень с интенсивностью 75,9 мм/ч вызвал образование катастрофического селевого потока. Это был типичный сель, спровоцированный оползнем, то есть оползень в процессе движения трансформировался в селевой поток. В результате катастрофы погибли 2 чел., были разрушены 16 скотоводческих ферм, 8 домов, участок шоссе длиной 220 м, 150-метровый участок канала гидроэлектростанции. 23 га сельскохозяйственных угодий были завалены камнями, грязью и песком. Прямой экономический ущерб от селя составил 2,8 млн. юаней. Сель имел следующие характеристики: вязкая консистенция селевой массы; плотность 2,12 т/м^3; соотношение между твердой и жидкой составляющими около 7:3; скорость потока - значительная, максимальная скорость составила 14,55 м/с.

Biaoshuiyan Gully is located in Puge County, Sichuan Province, China. It is a tributary of the Zemuhe River of the Jinshajiang River system. The drainage develops in the eastern edge of the Hengduanshan Mountain area, where the precipitation is very concentrated from June to September (67% of yearly totals), the maximum daily precipitation is 157.9 mm. Therefore, the composition of landform, geology and rainstorm provides favourable conditions for debris flows and landslides. On June 22, 1999, torrential rain with 75.9 mm/h excited a disastrous debris flow in the gully. It is a typical landslide-induced debris flow, i.e., a landslide in the course of the movement changed into a debris flow. In the disaster, 2 persons died, 16 farm cattle went missing, 8 houses were destroyed, 220 m highway and 150 m draw water canal of a hydroelectric power station were damaged, 23 ha of farm land were covered with stone, mud and silt. The debris flow caused direct economic losses of 2.8 million Yuan (RMB). The characteristics of the debris flow are as follows: viscous fluid with the unit weight is 2.12 t/m^3; the ratio between solid and water in debris flow is about 7:3; the velocity of the flow is fast with maximum value of 14.55 m/sec.

1 Introduction

Biaoshuiyan Gully, 40 km away to the north of Puge County (nearby Xichang), Sichuan Province, China (Fig.1), is a tributary of the Zemuhe River of Jinshajiang River (the upper reaches of Changjiang River) System.

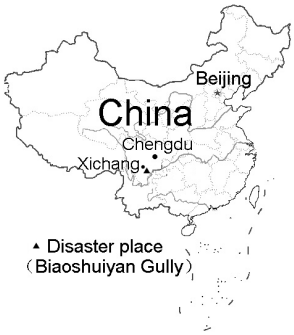

Fig. 1. The location of Biaoshuiyan Gully in China.

On 22 June, 1999, a disastrous landslide-debris flow (Fig.2, Fig.3) was excited by a torrential rain in the gully. It killed two persons, buried sixteen farm cattles, destroyed eight houses (1180 m^2); 220 m highway and 150 m draw water canal of a hydroelectric station, 23 hectare fertile farmland were buried, causing a direct economic loss amount to 2.8 million yuan (RMB).

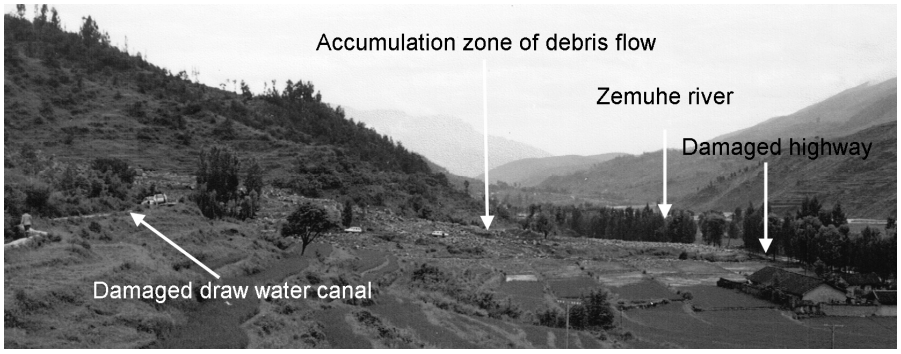

Fig. 2. A whole view of Biaoshuiyan Gully debris flow disaster. Photo by Xie Hong.

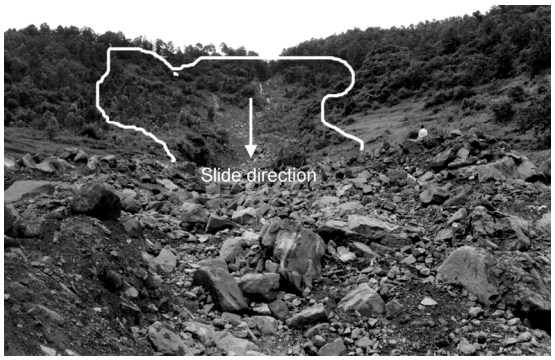

Fig. 3. Landslide-induced Debris Flow. Photo by Xie Hong.

The gully develops in the mountainous areas of the Southwestern China, where the mountains stretch and tower in large relief, with relative height difference over 1000 m in average between mountain ridges and valley bottoms and the maximum over 2000-3000 m. Geological conditions in the area are complex with deep and large faults developing, with strong affect of neotectonic movement, and frequent earthquake. The precipitation is abun-

dant and local rainstorm is more. Therefore, the composition of landform, geology and rainstorm provides favourable conditions for the form of debris flow and landslide.

The stratum in the gully consists of two units: the Cretaceous Lower Feitianshan Formation (K_{1f}) and the Quaternary loose deposit (Q_4^{dl}). Feitianshan Formation is composed of sedimentary rock including purplish-red sandstone, siltstone, mudstone and shale. It is a kind of semi-hard rock, with inferior diagenesis and cementation, containing much clay, with weak anti-weathering ability, and it is unhealthy engineering in geology; on the other hand, differential weathering is intense for weak rock alternating with the hard. Loose Quaternary deposit on slope is 10 m thick and sometimes rises to 15 m. Geologically, the gully is located on the west slope of the Jiaodingshan Syncline between two great regional faults, the Zemuhe Fault with N-W strike and the Zizhimo-Qiaowu Fault with near N-S strike, within 3 km in distance there, which have been in a strong influence. In addition, the gully is located to south section of the famous earthquake zone with N-S strike in China, the Zemuhe Fault is active and of responsibility for earthquake in the belt. By statistics, earthquake of magnitude ≥6.7 occurred five times since 624 A.D. in the belt (Tong Rongchang et al., 1993). The earthquake intensity is of VIII-IX in regionalization (The National…, 1990).

Geomorphologically, the Biaoshuiyan gully develops in the eastern edge of the Hengduanshan Mountain, which is a alpine and middle mountain area of tectonic denudation. It is a very small basin, with drainage area of only 0.78 km^2, length of 3.2 km, the gradient 228‰ (12.8°), altitude of the peak, 2100 m, and the relative height, 665 m. Landslide occurred in the lower reaches below altitude 1700 m (Fig. 4), the vertical section shows a 45°–60° gradient in the upper, and 20°–30° in the lower; thickness of loose deposit is 3-5 m.

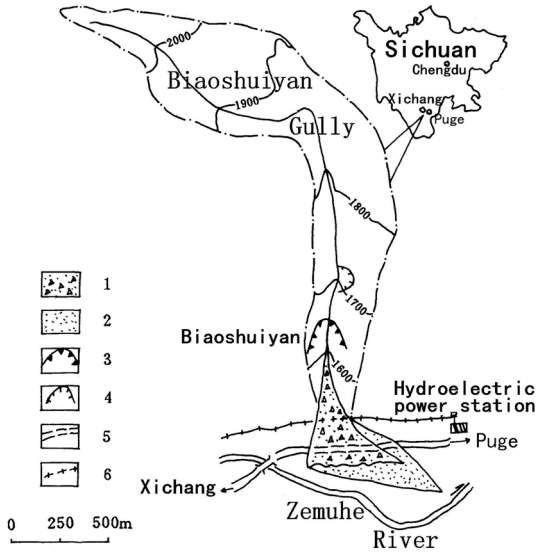

Fig. 4. Horizontal plan of Biaoshuiyan landslide – debris flow: 1 – main accumulation zone of debris flow; 2 – minor accumulation; 3 – landslide; 4 – collapse; 5 – damaged highway; 6 – damaged draw water canal.

The basin belongs to subtropical climate, perennial average temperature 16.0°C, with distinct wet (May-October, rainfall accounts for 88.5 percent of the annual) and drought (November-April, 11.5 percent) in the area. The area is a concentrated region of rainstorm-induced debris flow and landslide by having much local heavy rain in a small central zone and with great precipitation intensity. According to observations of local meteorological station, average annual rainfall in many years is 1518.2 mm, 67.1 percent of it concentrates in June-September, the daily maximum is 157.9 mm, rainstorm days is about 3.4 in a year.

2 Formation mechanism of debris flow

By 6 June, 1999, it had been raining for twelve days in the area. From 6 June to 22 June, it rained almost every day except 9, 15, 16, 18 and 19, amounted to 308.5 mm in the process (Table 1). Earth and stone had been saturated. Rainstorm running on 20-22, and especially on 22 June amounting to 84.5 mm, 9-10 P.M., with an intensity of 75.9 mm/h, stimulated landslide which at last transformed into debris flow in motion.

Apparently, the pre-storm conditions are the very crucial actions to ferment the debris flow that broke out at the final storm on 22.7 mm.

Table 1. Observation values for rainfall of June 6-22, 1999.

Date	6	7	8	9	10	11	12	13	14	15
Rainfall (mm)	0.6	10.8	3.1	0.0	0.1	11.1	10.4	23.2	0.2	0.0
Amount (mm)	0.6	11.4	14.5	14.5	14.6	25.7	36.1	59.3	59.5	59.5
Date	16	17	18	19	20	21	22			
Rainfall (mm)	0.0	62.4	0.0	0.0	52.0	50.1	84.5			
Amount (mm)	59.5	121.9	121.9	121.9	173.0	224.0	308.5			

3 Characteristics of debris flow

It is a typical landslide-debris flow because landslide in the course of the movement changed into debris flow directly.

It is a rainstorm-induced debris flow because rainstorm was both dynamical conditions of inducing debris flow and water composition of forming.

Investigation has shown that debris flow accumulation, with range of grain size from boulders to clay, has the appearance that mud was wrapping up stone; the slurry was dense and the buoyancy was great and therefore the fluid was asserted to be viscous.

At field site, volume ratio solid to water is about 7：3, and unit weight of the solid is 2.6, then the unit weight of debris flow is 2.12 t/m^3.

The velocity may be calculated by Manning's formula $V=KH^{2/3}I^{1/3}$. From the measured values at upper gully bed in accumulation zone of debris flow, H, 5 m; I, 0.284; and K, velocity, different values as 5.9 and 10 (Zhong Dunlun et al., 1989). It yields a velocity 15 m/s, showing the feature of high speed movement.

Area of the main accumulation zone, the fan of debris flow, is 2.99×10^4 m^2 and the average thickness of the fan is 3 m by survey; thereupon, the volume is 8.97×10^4 m^3. In addition, 5×10^3 m^3 of accumulation is outside to the fan. Therefore, two parts add up together, the volume amount of the deposited debris flow mass was about 9.5×10^4 m^3, or over 10^5 m^3, if water had not run off. Then, it is a debris flow of large scale by classified standard of accumulation volume (Zhong Dunlun et al., 1989).

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References

The National Seismological Bureau. Map of earthquake intensity regionalization in China (1:4 000 000). – Seismological Press, 1990. (In Chinese).

Tong Rongchang et al. Active fault and earthquakes in Sichuan Province. – Seismological Press, 1993, p. 102–103. (In Chinese).

Zhong Dunlun et al. Research and Prevention of Debris Flow. Sichuan Publishing House of Sciences and Technology, 1989. (In Chinese).