

- The sketch map of field investigations in Wenchuan earthquake hit region, Chengdu City.

1 Environmental and Geological Condition

1.1 Geomorphology

BaiSha River Basin is located in Dujiangyan County, and is a typical canyon landscape of intermediate elevation, with a maximum elevation of 4582 m, and a minimum elevation of 870 m. As shown in Fig.2, the area inside the watershed is approximately 363 km² with an averaged slope of 18°. The slopes on the two sides of the gullies have angles from 45~75°, and accordingly it is easy for slope failures to occur. In 2008, Wen Chuan Earthquake, landslides were triggered in the Basin (Fig.1), and it is still supplying source for the upcoming debris flow events.

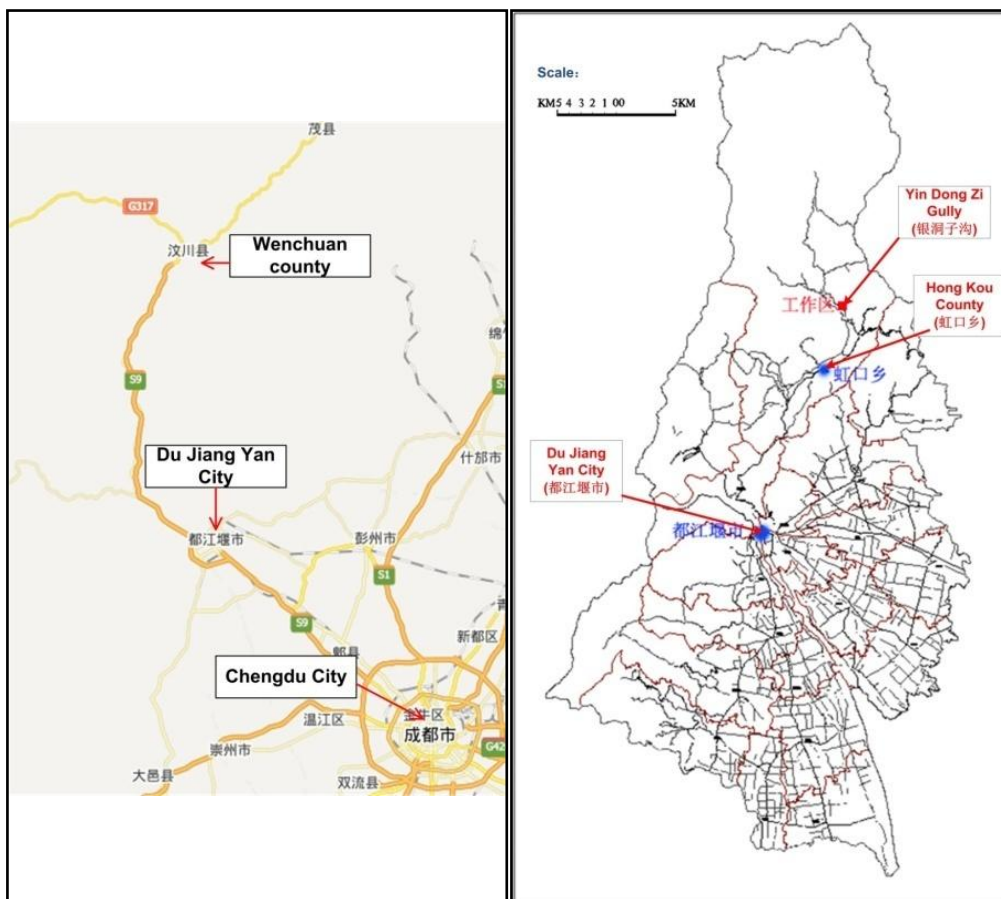


Fig. 1 Location of BaiSha River Basin

1.2 Meteorology

The weather in Dujiangyan city is always dominated by the subtropical humid climate, which is common in Sichuan basin. The characteristic weather is cloudy and frequent rainfall. From 1987 to 2008 the averaged

annual precipitation is 1134.8 mm; the minimum amount is 713.5 mm, while the maximum amount is 1605.4 mm. About 80% of the precipitation distributes from May to September. The maximum month precipitation is 592.9 mm, while for the precipitation of one day, it is 233.8 mm. However, in 8th, June, 2013, the record was overwritten to be 749.9 mm in one day.

1.3 Geology

The outcrop in the Yin Dong Zi Gully area is consisted of quaternary strata and bedrock. As shown in Fig.4, the bedrock consists of granite, andesite, diorite, tuff and some metamorphic rock; the quaternary strata is the deposition of $Q_{4el}+pl$, $Q_{4pl}+dl$, $Q_{4col}+dl$ and Q_{4sef} . The quaternary strata are mainly composed of gravel, with a thickness variation from 1 m to 20 m.

The tectonic structure in Du Jiang Yan City belongs to the middle and south part of LongMen Mountain tectonic belt. The tectonic structures include Hong Kou- Ying Xiu fault zone and Guan Xian fault zone. While Hong Kou- Ying Xiu fault zone is 40 km long, with an inclination of $300^{\circ} \sim 330^{\circ}$, direction of $50^{\circ} \sim 60^{\circ}$ from north to east; Guan Xian fault zone is 50 km long, with an inclination of $310^{\circ} \sim 330^{\circ}$, direction of $45^{\circ} \sim 53^{\circ}$ from north to east.

➤ Real-time monitoring and pre-warning system

Real-time monitoring and pre-warning system was constructed in 5 mountain hazards sites including 3 debris flows and 2 landslides along the Longmenshan fault in Dujiangyan and Pengzhou County, Chengdu City, where Wenchuan earthquake taking place. The system watches the behaviors of rainfall triggered mountain hazards with inexpensive and sophisticated sensors, such as inclinometers, a low-cost and simple monitoring method for precaution of rainfall-induced landslides, and Pluviometers, pore presser meters, water content meters, video monitoring system for both landslides and debris flows, and ultrasonic mud level meters, infrasound monitoring meters for debris flows. all the data is transferred through wireless network (Fig.2,3).

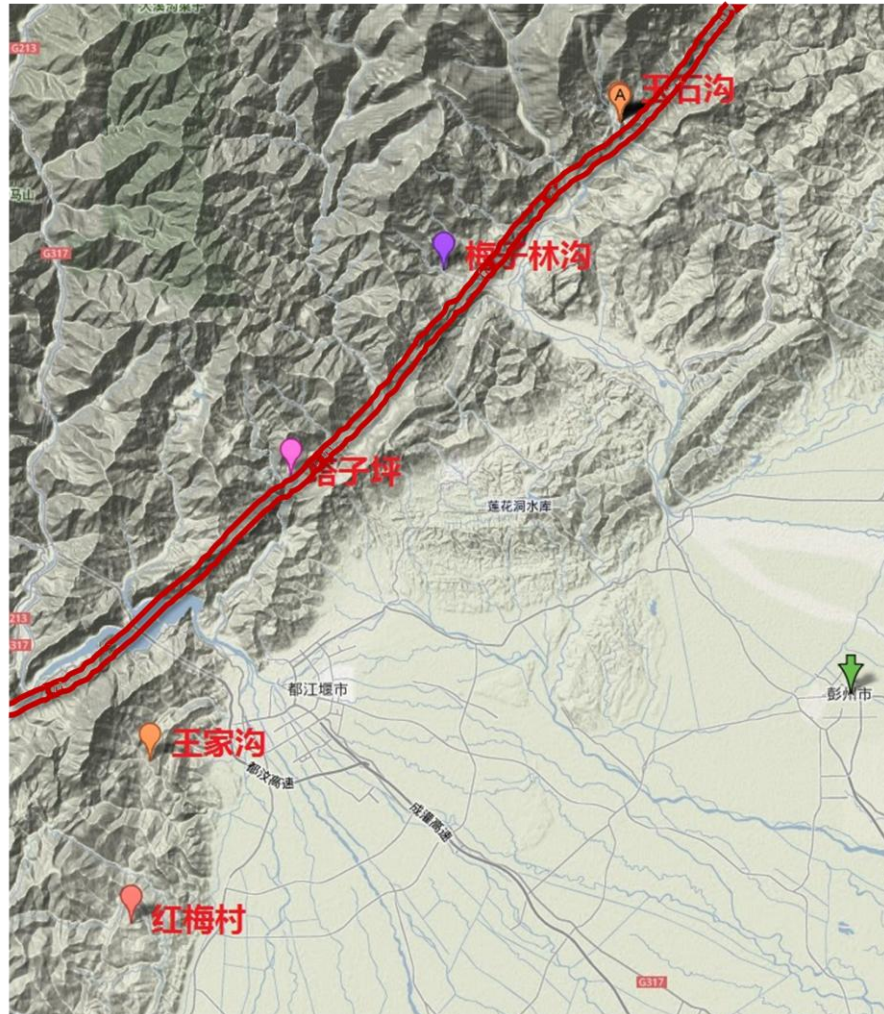


Fig.2 location of the Real-time monitoring and pre-warning disaster sites

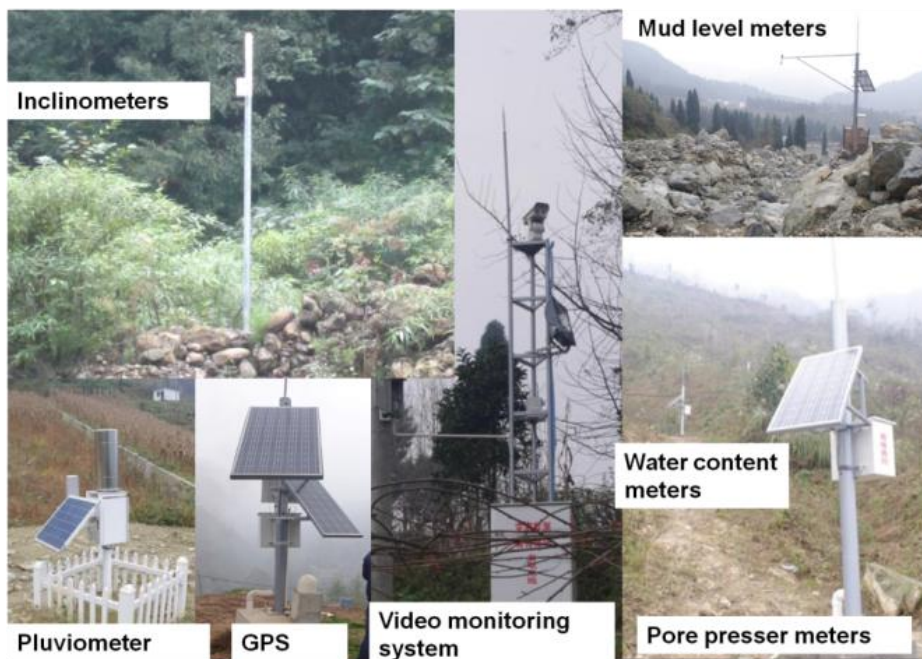


Fig.3 Photos of Site-specific real-time monitoring and pre-warning system

➤ Yin Dong Zi Gully

Yin Dong Zi Gully is located in the north of Du Jiang Yan city, 30km from the downtown; the coordinate is east longitude, $103^{\circ}40'19''$ and north latitude, $31^{\circ}9'46''$, as shown in Fig.1.

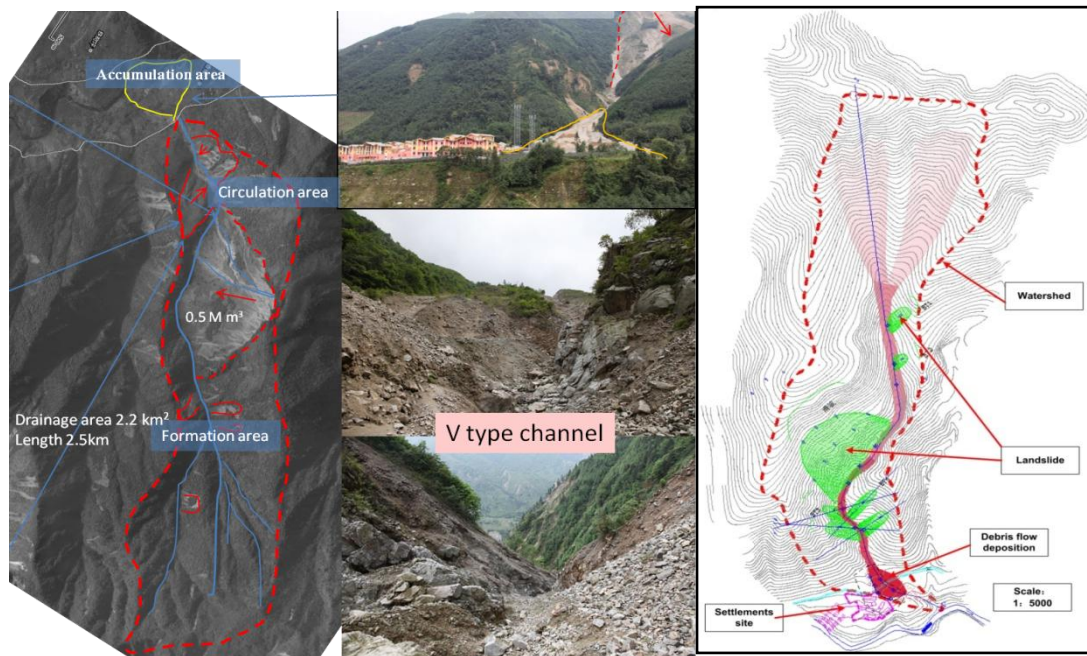


Fig. 4 Debris flow scope at Yin Dong Zi Gully

Debris flow events

In the history of Yin Dong Zi Gully, there was nearly no debris flow occurrences. However, after the Magnitude 8, Wen Chuan Earthquake in 2008, a lot of slope failures and landslides occurred, which supplied a great amount of source for the sequential debris flows. In the midnight of Jun. 17th, 2009, a heavy rainfall brought a precipitation of 219 mm in 6 hours. The main precipitation concentrated between 3 am to 6 am, with a rainfall intensity of 60 to 70 mm/h. This rainfall triggered the first big debris flow in this gully. The flow velocity at the gully mouth was approximately 2 to 3 m/s, while the height was about 3 m, and the maximum discharge was about 100 m³/s. The field investigation after the debris flow showed that the debris deposition beyond the gully mouth was about 3×10⁴m³, while the debris deposition inside the gully was about 5×10⁴m³. The particle in the debris deposition has an averaged diameter of 10-20 cm, while the maximum particle size is about 1.0 m. Most particles are of the angular shape.

The debris flow in 2009 caused the destructions of 5 residences, and the road in the front of the gully mouth. The total economical loss is 600,000 CNY. Fortunately, there was no casualty.

Starting from 2009, each year in Yin Dong Zi Gully some debris flows of big and small scales occurred frequently. The newest debris flow occurred in June, 2013, which has a greater scale than the one in 2009, see Fig4 and5. The debris flow in 2013 swallowed the newly constructed dam and drainage groove.

Currently, the settlements site is located on the right side of the gully mouth for 56 families, with a total number of 228 people.



Fig. 5 Location of Yin Dong Zi Gully

➤ Gangou Gully

Gangou Gully is located in the north of Hongse Village which is quite close to Taziping Landslide, Du Jiang Yan city, 14 km from the downtown. the area inside the watershed is approximately 1.2 km²; the length of the gully is about 1.9 km, with an averaged slope of 30- 40° .

Debris flow events

There was no debris flow record in the history of Gangou Gully. after Wenchuan Earthquake, 6 major slope failures occurred in the watershed, which supplied a great amount of source for the upcoming debris flows. In July. 17th, 2009, a heavy rainfall with a total rainfall of 219 mm triggered debris flow in this gully. The flow velocity at the gully mouth was

approximately 3.5 m/s, while the height was about 2.1 m, The field investigation after the debris flow showed that the debris deposition beyond the gully mouth was about $3.2 \times 10^4 \text{ m}^3$, while the debris deposition inside the gully was about $35 \times 10^4 \text{ m}^3$. The particle in the debris deposition has an averaged diameter of 8-30 cm, most particles are of the angular shape. The debris flow in 2009 caused 2 persons dead and the total economical loss is 30 m CNY.

Starting from 2009, each year in Gangou Gully debris flows of big and small scales occurred frequently. The newest debris flow occurred in July, 2013, the newly constructed sabo dam and the bridge cross the gully were completely buried by the debris. Fig6 -8.

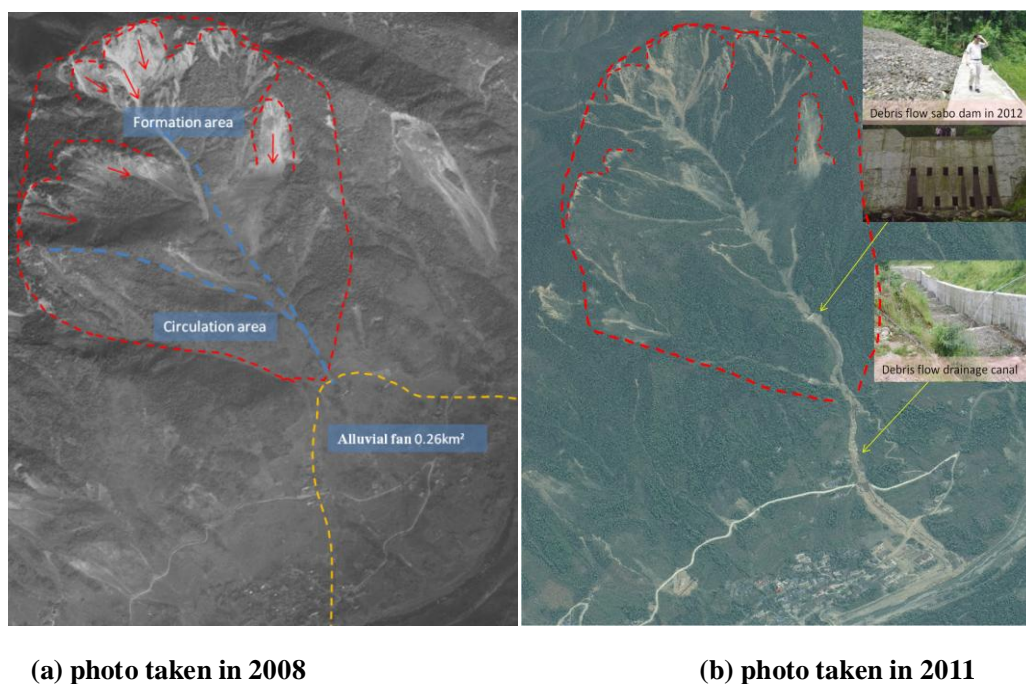


Fig.6 Debris flow in Gangou Gully



Fig.7 Debris flow occurred in Gangou Gully, August 18, 2010



Fig.6 Debris flow occurred in Gangou Gully,2009

➤ **Secondary Mountain Hazards Triggered by the 7 Ms Lushan Earthquake , 20 April 2013**

Ms 7.0 giant earthquake took place in Lushan County, Yaan City at 8:02, April 20th, 2013, which claimed 196 of lives, 21 of missing and effected 2M people, also induced large amount of secondary mountain hazards including collapses, landslides, etc. The most of secondary mountain disasters is collapses with small and median scale volume according to field investigation. Five principal types of secondary mountain disasters consisting of conglomerate collapses, sandstone collapses, carbonate stone collapses, landslides and long run-out landslide-avalanche were proposed. The regional geological environment and structure was regarded as the primary element and the large amount of loosen materials are easy for occurring debris flows and landslides triggering by the storm and continuous rainfall, which will seriously threat the reconstruction and lives in the rainy season for decades, therefore the post-earthquake effect as well as the monitoring and pre-warning strategy should be carry out in earthquake area and especially in reconstruction settlements.



Fig.7 Distribution map of mountain hazards in Lushan earthquake hit region

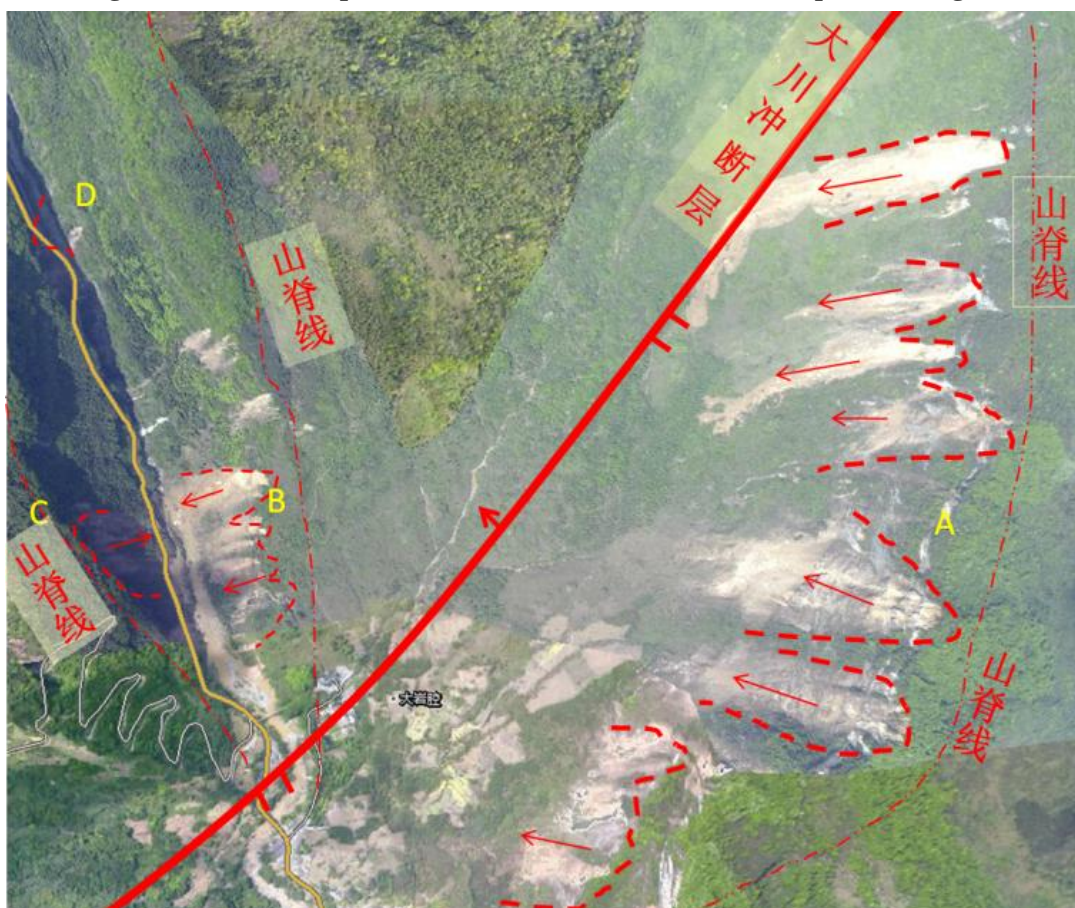


Fig.8 Collapses in Dayanqiang, Shuangshi County

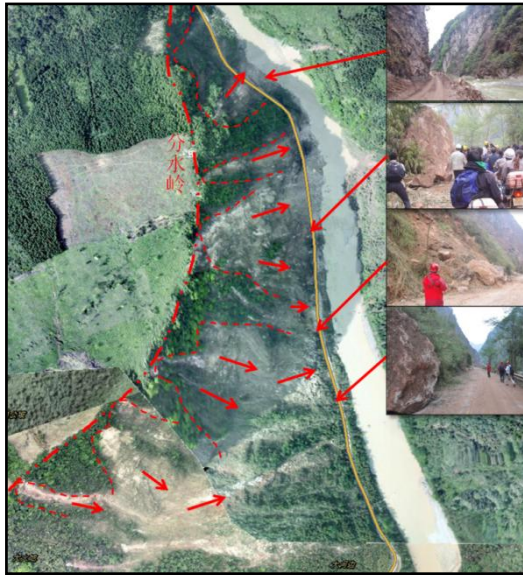


Fig.9 Collapses in Jinjiguan, Baosheng County

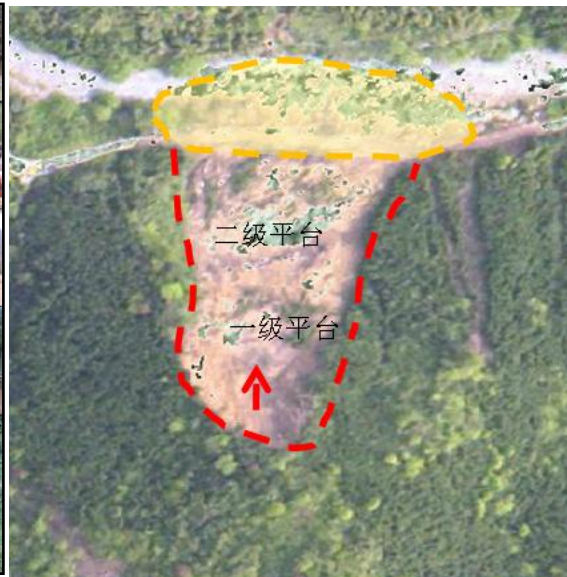


Fig.10 Qianshuigou landslide in Shuangshi County.

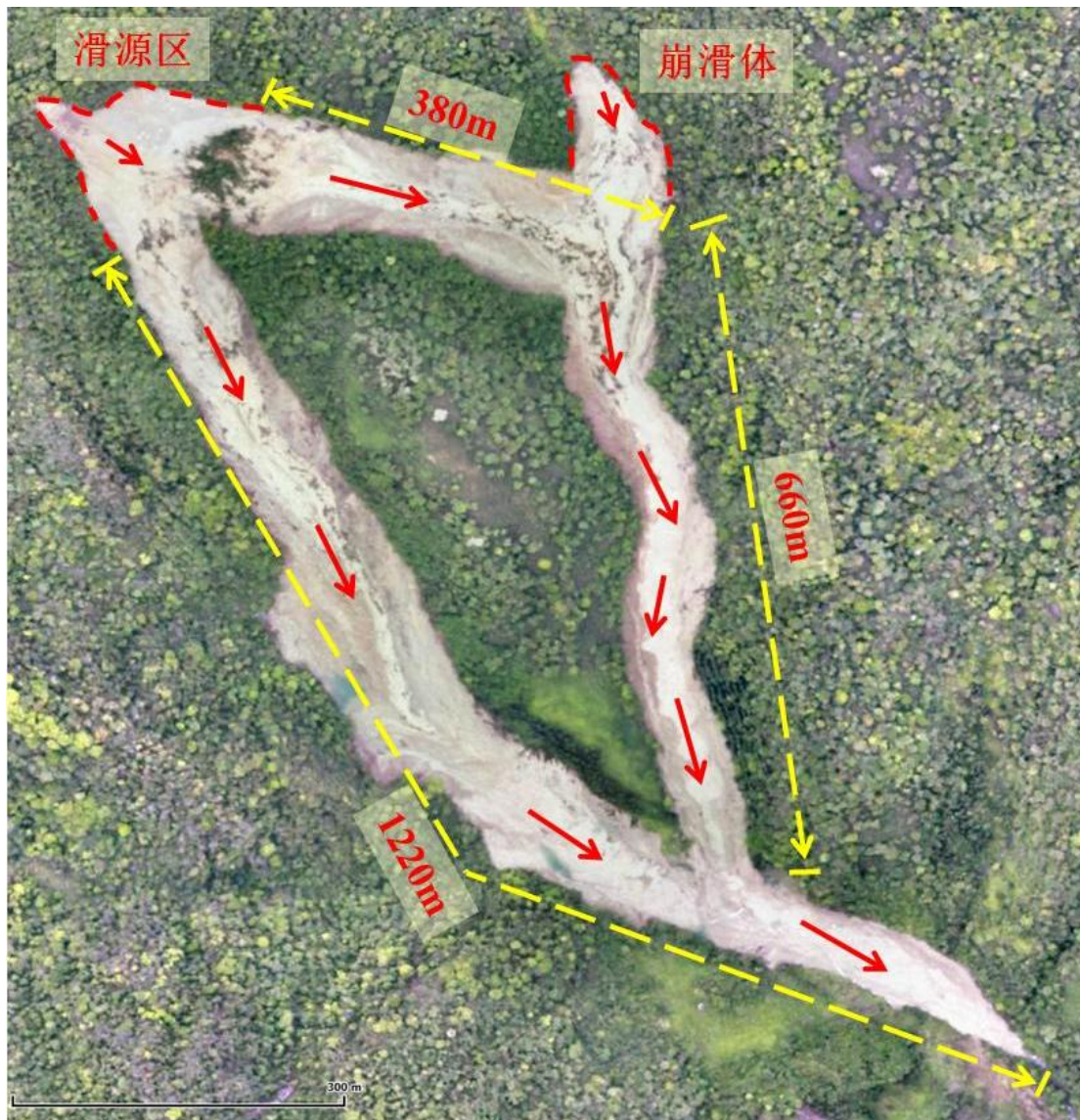


Fig.11 Tangjiagou long run-out landslide in Tianquan County.

Fig.11 illustrates one of a high-speed landslide and debris flow that occurred at the Tangjia gully in Tianquan County; location at (102.471_E, 30.091_N) in the Damiao Village, Laochang county. The Tangjia gully debris flow was triggered by the main shock of Ya'an earthquake. The elevation of debris flow ranges from 935m to 2060m. Under the influence of the landform, the landslide was split up into two suitable channel moving down on the left and right sides, and the slip mass changed into debris flow in the motion. Its length is about 80m, and the width is about 110m. The estimated volume of the debris flow is about $200 \times 10^4 \text{ m}^3$.



Photo.2 The top of Large collapse mountain



Photo.3 Dammed lake



Photo.4 deposit in the gully



Photo.5 deposit in the gully