# Analysis of Formation Conditions of a Debris Flow

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**Abstract: This paper describes the basin characteristics of a debris flow in detail, analyzes the formation conditions of the debris flow, and finally expounds the internal and external factors of the starting conditions of the debris flow.**

**Keywords: Formation Conditions of Debris Flow; Internal Factors; Extrinsic Factor**

## 1. Engineering Background

Debris flow is located in the southwest of Sichuan, and geological disasters such as debris flow, collapse and landslide are relatively developed within the administrative area. In recent years, under extreme working conditions such as rainstorm and earthquake in flood season, debris flow gullies are prone to occur again. In order to maintain the safety of local people, the debris flow was designed to eliminate dangers.

## 2. Analysis of Debris Flow Formation Conditions

1) Topographic characteristics of gully region

Topography is the internal cause and necessary condition for the formation of debris flow, which restricts the formation and movement of debris flow and affects the scale and characteristics of debris flow, mainly including gully shape and relative height difference, hillside slope, gully bed gradient and so on.

Debris flow develops on the right bank of Quding River, and the plane shape of debris flow gully region is leaf-like. There is a large branch gully and six small slope debris flow gullies in the whole basin, with a total basin area of 2.04km$^2$ and a main gully length of 2617m. The landform type is alpine landform cut by erosion. The highest point of gully region is located at the northeast watershed, with an elevation of 3850m, and the lowest point of gully mouth is located at the right side of Quding River, with an elevation of 3090m, and the relative elevation difference of the whole basin is 760m. Debris flow gullies are generally V-shaped valley landforms, with steep bank slopes, with an average slope of more than 20°. The average longitudinal slope of the whole gullies is small, but the longitudinal slope in the upstream area is large, with a slope gradient of 30° ~ 50°, which is beneficial to the collection of rainfall and provides a foundation for the collection of debris flow water sources. See Figure 1 for the debris flow pattern.

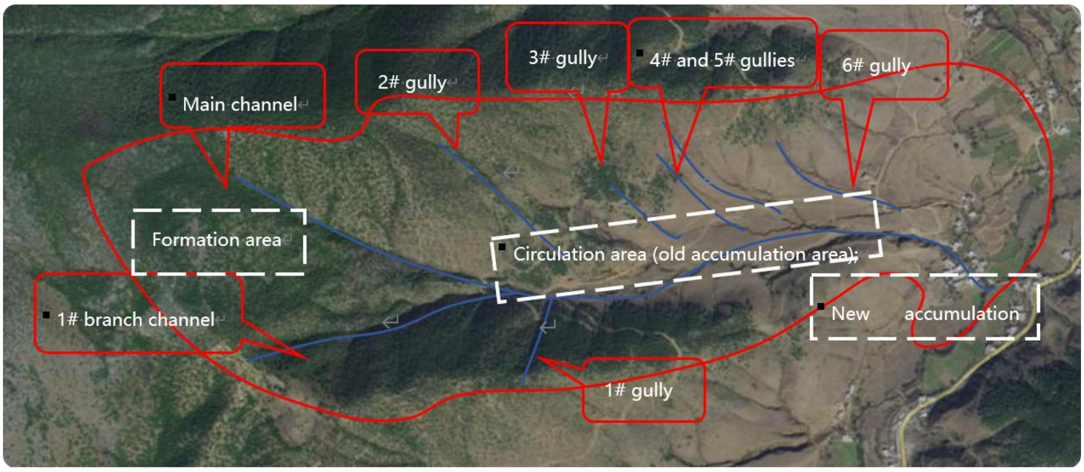


**Figure 1. Debris Flow Satellite Map**

(1) Degree of watershed development

Watershed development degree reflects the evolution stage of watershed topography, and can be judged by the relative cutting degree of watershed. The smaller the relative cutting degree, the higher the maturity of watershed development; conversely, the larger the relative cutting degree, the lower the maturity of watershed development. The relative cut value of a watershed is determined by:

 

$h' = h_{max}/L_{weeks}$

Where: h ′-relative cutting degree of watershed (expressed in decimals, dimensionless);

$h_{max}$-maximum relative height of the basin (m);

$L_{perimeter}$-watershed perimeter length (m).

The maximum relative height of debris flow gully is 960 m, the watershed perimeter is 6 762 m, and the watershed relative cutting degree h′= 0.14, which indicates that the newly formed gully has low maturity and serious gully erosion.

(2) Division of debris flow gully

According to the formation conditions, movement mechanism and distribution of loose solid sources of debris flow, the gully can be divided into three areas: formation area, circulation area (old accumulation area) and new accumulation area.

① Characteristics of formation area

The formation area is mainly distributed in the upper reaches of the main channel, with an area of 1.4km$^2$. The main channel in this area is 1150km long. The main geomorphological characteristics are steep terrain and the slope gradient on both banks is relatively consistent. The upper mouth of the main channel in this section is wide and gentle, and the lower mouth is sharp and thin, showing a wide "v" valley. The longitudinal slope is relatively large, with an average of 290 ‰. According to the investigation, there are few channel deposits in this area, mainly frozen and thawed erosion slope residues, and vegetation is shrubs. When debris flow occurs, this section starts to participate in debris flow activities in the form of trenching erosion. Due to the great longitudinal slope, although the animal source quantity is not much, the kinetic energy formed by its transformation is strong, and the converging fluid has strong erosion and destruction ability in the convection passage (formation) area.

② Topographic characteristics of circulation area (old accumulation body)

The circulation area is mainly located at the altitude of 3250 m~3100 m, the drainage area is 0.4 km$^2$, the accumulated length of the main ditch is about 1.1 km, accounting for 32% of the accumulated length of the main ditch of debris flow; the current circulation area is mainly the old accumulation body formed by the early debris flow, and new debris flow channels are formed due to the diversion and silting of debris flow. Besides the longer main channel, many channels are also developed on the old accumulation body. The circulation area is rich in material sources, mainly early accumulated gravel soil, with a gravel content of about 55%-60%. It is angular and sub-angular in shape, with a general particle size of 0.2 - 0.5m and a maximum of 1 m. The parent rock composition is limestone., filled with silty clay.

The vegetation in the circulation area is mainly composed of weeds, and a small amount of shrubs can be seen in the ditch, with a vegetation coverage rate of about 20%-30%. Many small gullies are developed on both sides of the circulation area. Flood and a small amount of sediment are continuously washed out of the small gullies in rainy season, which has siltation and erosion effects on the current circulation area.

③ Characteristics of accumulation area

Debris flow deposit area is located at the mouth of ditch, left bank of Quding River, elevation 3100 m~3090 m, deposit area is close to Quding River, new deposit area is mainly residential area of Yalang Village. Debris flow erupts from village roads into Dingqu River.

2) Source conditions

(1) Source type and distribution

Debris flow sources are rich, mainly distributed in circulation areas, elevation 3250 m~3100 m. The source types include channel deposit and slope erosion. These sources provide debris flow with a total amount of 2.7 × 10$^4$m$^3$, of which the dynamic reserve that can participate in debris flow activities is 0.11×10$^4$m$^3$.

The source of channel is mainly silty clay containing gravel, occasionally block stone, and the rest is filled with medium coarse sand and silty clay, which mainly participates in debris flow activity in the form of bank slope side erosion.

In the process of debris flow formation, the flood formed in the upper reaches washed the old accumulation layer, carried the loose materials of the slope body to the gentle zone in the middle and lower reaches, and formed the old accumulation body. The tectonic movement in this area is intense, and a large number of alluvial and diluvial deposits are stacked on both banks of the valley slope, forming the source of debris flow under the side erosion of debris flow. According to the investigation, the depth of deposit source is about 5~15 m, the area is about 0.25 × 10$^4$m$^2$, and the calculation shows that the cubic volume is about 2.5×10$^4$m3, and the dynamic reserve that can participate in debris flow is $0.09\times10^4$m.

The erosion source of slope is mainly gravel soil, occasionally block stone, parent rock is limestone, the rest is medium coarse sand and silty clay filling, the slope source area can reach $0.3\times10^4$m, once heavy rainfall occurs, debris flow is replenished by surface erosion, the maximum scouring recharge depth can reach 0.05m, providing a large amount of slope loose material source for debris flow; the slope soil layer on both sides of other sections is thin, human damage is small, and the loose material supply of large area slope is small.

The calculation formula of slope erosion dynamic reserves and sources:

$W= S\cdot d$

Where: W-loose material storage on slope ($m^3$)

S-recharge area ($m^2$) d-maximum scour depth (m)

(2) Grading characteristics of source particles

The investigation and analysis of particle composition of each source point distributed in the accessible area are carried out in this exploration work. Among the loose solid sources of debris flow, 3~12% of the total sources have particle sizes larger than 1 m, 15~27% of the total sources have particle sizes of 0.2~1 m, 54~67% of the total sources have particle sizes of 0.05~0.2 m, and 12~23% of the total sources have particle sizes smaller than 0.05 m. Generally speaking, the gully materials are mainly block gravel soil, and the proportion of block stone is relatively large, but the total amount of block less than 0.2m is relatively large, which is easy to start.

(3) Source startup conditions and methods

The starting conditions and modes of source mainly depend on the type, structure and granularity of source point, the relationship with channel and the degree of channel blockage, etc., and the starting modes control the number of possible starting of each source point and the harm of debris flow.

3) Water source conditions

(1) Influence of drainage system and topographical factors on catchment

Debris flow gully watershed is mainly deep cut low-middle erosion terrain, generally steep terrain, conducive to the convergence of rainfall. The main and branch gullies in the basin are all "V" type valleys, showing the characteristics of narrow and large longitudinal slope in the upstream and gradually widening and gentle longitudinal slope in the downstream. Under the control of this characteristic, the hydrodynamic conditions of the basin are strong and the sediment transport capacity is strong.

In addition, the basin shape is similar to fan shape, branch ditches are distributed in tree shape, and the length, longitudinal slope and channel shape characteristics of each branch ditch show certain differences, so the time when the peak of each branch ditch reaches the ditch mouth also presents the characteristics of staggered peak arrival, which also determines the superposition characteristics of peak discharge of main branch ditch in the process of debris flow movement.

(2) Influence of stratigraphic lithology distribution on catchment

According to the distribution of strata lithology in debris flow valley, the debris flow valley is dominated by slate of Qugasi Formation of Upper Triassic System, with thin overburden, and there are landslide deposits and channel deposits distributed in slope foot and valley. Bedrock outcropping area is generally favorable for rainfall to form surface runoff, while loose accumulation layer distribution area has strong water retention effect, and accumulation body is easy to saturate. Therefore, the upper and middle reaches of debris flow gullies are easy to collect water, forming strong hydrodynamic conditions, which are conducive to triggering debris flow.

(3) Influence of vegetation distribution on catchment

Debris flow gully: forest vegetation in the basin is mainly weeds, vegetation coverage is low, surface vegetation has low water retention effect, which is conducive to precipitation convergence to form surface runoff and debris flow start-up, which is also one of the important reasons for frequent debris flow in rainy season.

## 3. Debris Flow Initiation Conditions

According to the analysis of source start condition during debris flow outbreak in the past, source start (instability) is generally controlled by two factors, one is internal condition, the other is inducing condition, specifically including: ① stability of source status; ② cementation and compaction of source itself; ③ slope where source is located; ④ current washing; and ④ rainfall condition.

1) Internal factors

① Source stability

Through investigation, the landslide accumulation material in valley basin is not completely consolidated or compacted, loose and unconsolidated, and its overall stability is poor. Once triggered by rainfall, it will lose stability again. Part of fine particle matter first participates in debris flow activity, and then drives large particle matter to occur debris flow. Therefore, the poor or poor stability of the source status is another important condition for its start-up.

② Cementation and compaction of source material itself

Field investigation shows that under rainfall conditions, loose and uncemented fine particles deposited near the gully are most likely to lose stability and participate in debris flow activities, because their strength parameters are generally low, especially without cohesion. In the Gongba debris flow gully basin of Niangzhong, the collapse deposit sources near the gully generally have the characteristics of unconsolidated and loose. Under the action of rainstorm and concentrated flow, they are easy to lose stability and collapse and become debris flow sources.

③ Slope terrain slope where the source is located

Obviously, the steeper the terrain is, the more unfavorable it is to the stability of loose material. The slope of provenance in Gongba debris flow gully in Niangzhong is generally large, and most of provenance may participate in debris flow activities under the action of rainstorm.

2) External factors

① Water flow flushing

Water flushing actually refers to the positional relationship between loose material sources and water gullies. Concretely speaking, the closer the source of loose matter is to the current gully, the greater the influence of current scouring on it, and the more unfavorable to its stability.

The field investigation shows that the source of debris flow in Gongba gully is channel source, which is washed by main and branch gully flow directly and replenished by debris flow directly.

② Rainfall conditions

In fact, the outbreak of debris flow is related to rainfall in rainy season, so rainfall is the primary factor inducing debris flow, and the above-mentioned current scouring is generally accompanied by rainfall. According to the fact that the rainfall induced by debris flow in mountainous areas of Sichuan Province is generally about 48~50 mm or 8~12. 2 mm in 10 minutes, and the rainfall intensity in 1 minute is about 0. 8~1. 2 mm, when the intensity of rainfall required for debris flow outbreak in the whole basin is greater than 12 mm/10 minutes, on the one hand, the instability of unconsolidated, loose and fine particle sources will be induced due to the reduction of intensity parameters, on the other hand, the slope water flow can be rapidly accumulated in the gully to form floods, Debris flow recharge is initiated by erosion of sediments at the bottom and edge of the gully by further current erosion, resulting in instability of loose sources at the edge of the gully. The maximum average rainfall intensity of 1/6 h, 1 h and 6 h in Ciwu Town of Derong County can reach 7 mm, 13 mm and 26 mm respectively. The rainfall is rich, which basically has the conditions for debris flow outbreak.

## 4. Conclusions

To sum up, there are two controlling factors for the initiation (instability) of debris flow source: one is internal condition, the other is inducing condition, both of which lead to the occurrence of debris flow.

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