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# Analysis on the Formation Condition of Nanjiagou Debris Flow

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## Abstract

**In this paper, the formation conditions and development characteristics of nanjiagou debris flow are analyzed in detail through field investigation and collection of meteorological and rainfall data. The research results show that: ①The steep topography and landform, the loose and broken slope structure and the steep longitudinal slope of the channel in Nanjiagou valley provide the basic conditions for the formation of debris flow provenance, the convergence of water flow and the development of debris flow disaster.②Loose soil is formed continuously by weathering, and a large number of loose provenances are formed in the channel and at the edge of the channel under the continuous transportation of rainfall, which plays an important role in the development of the geological phenomenon of collapse and slip and the formation and evolution of debris flow provenances.③The large rainfall and catchment area in the study area are conducive to precipitation collection and runoff, and the short-time heavy rainfall is the most important cause of nanjiagou debris flow.**

## Keywords

**Debris flow; Rainfall; Formation condition.**

## 1. Introduction

Nanjia Gully is an old mud-rock flow gully, prone to occurrence degree is mild prone to occurrence, according to investigation and interview, the gully in the history of the 1990s large-scale mud-rock flow, resulting in a large number of farmland on both sides of the gully was silted, no casualties, 2012 rainy season small-scale mud-rock flow, flooded villages, farmland, no casualties.

At 1:30 on September 10, 2019, nanjiagou, Gujibaozi Group, Jiudin Village, Wanba Town, Jiulong County, Ganzi Prefecture, was hit by a sudden debris flow disaster due to heavy rainfall. Due to timely warning, 130 people from 30 households were evacuated to avoid danger and avoided serious damage caused by the debris flow. The debris flow rushed out the amount of about 23,000 square meters, debris flow accumulation range from the channel elevation of 2250m has been buried to the mouth of the trench, fanned distribution, accumulation area of 0.062km2, length of 1435m; Its disaster mode is silted along the gully, causing flood to the gully mouth residential area. As a result, farmland in Digjin Village was buried, roads, power lines and water supply networks were damaged, and the safety of life and property of 130 people in 30 households was threatened, resulting in economic losses of about 3.72 million yuan. The nanjiagou debris flow is determined to be a large-scale geological disaster in combination with the affected objects, the number of people affected and the economic loss, and its risk level is medium and the harmability level is medium.

According to the investigation and interviews, the starting section of debris flow in "9.10" is mainly the circulation area forming in the middle and upper reaches of the gully, and the main provenance points in the area are slope erosion provenance and gully accumulation

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provenance. Loose gully accumulation provenance starts to participate in debris flow activities under the action of upstream flood and rainfall erosion. In the process of discharging, debris flow material erodes and carries loose material along the gully bed and the two sides of the gully, forming debris flow disaster. According to villagers, the debris flow lasted about 1 hour, resulting in gukoukou houses, farmland was silted up, investigation of the mud level of about 0.5~3.0m, no casualties. According to the survey, it is estimated that the flow of debris flow in the lower reaches of the main gully is 140 $m^3/s$, and the solid material of debris flow is about $2.3\times10^4m^3$. Debris flow solid material mainly accumulated in the settlement area of the mountain pass, the original channel was full of silt after the overflow, silting township road, farmland, the height of the silting is about 0.5 ~1m.

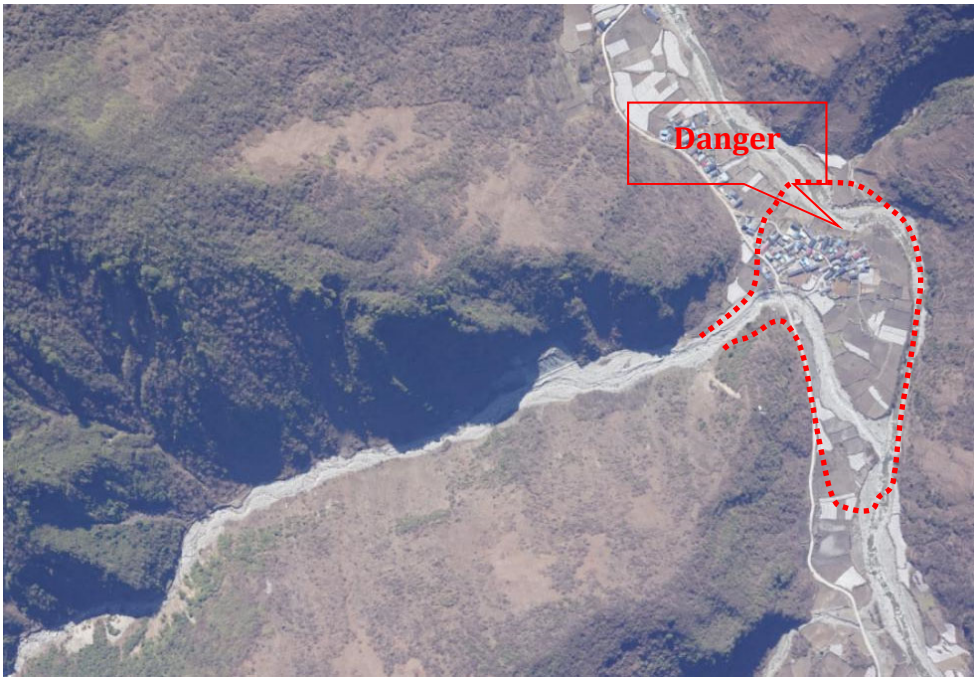


**Figure 1.** Debris flow threat Subject

## 2. Physical Geographical Conditions of the Study Area

### 2.1. Topography

Jiulong County is located in the west of Sichuan Province, the southeast of Ganzi Tibetan Autonomous Prefecture and the southwest of Gongga Mountain. It is at the junction of Ya 'an, Liangshan and Ganzi. Jiulong county is located in the southeastern margin of The Songpan geosyncline area, and belongs to the Deige-shaped structure system of Yunnan and Tibet. The territory of undulating terrain, north high south low, high difference. The elevation of the northern mountains is between 3,600-5,500 meters, with the highest reaching 6,010 meters; Valley is generally in 2000-3200 meters or so; In the southern xiaojin township, the junction of Luobuzigou and Yalong river is only 1440 meters, with an elevation difference of 4570 meters. Due to the large depth of river cutting, steep mountain, slope between 30° - 60°, most of the main river tributaries downstream cliff. The county is roughly divided into alpine plains and alpine valleys two major geomorphological areas, the main mountains in the territory of the big snow mountains, mountains are big snow mountain branches, mountains account for 65% of the total area, the altitude of 4000-5000 meters, mainly distributed in the central and southern; Extremely high mountains in the north, accounting for 34% of the total area, 5000 meters above sea level, year-round snow and ice cover. The whole country is divided into three sub-mountain

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systems according to the northeast, central and western regions. Its main ridge, a watershed for the Dadu and Yalong rivers, stretches 59 kilometers across the county.

The highest elevation is 5,800m, the lowest elevation is 1,540m, and the relative height difference is 4,260m. The topography in The valley is mainly steep, the cutting is intense, the mountain is high and the valley is deep, and the terrain is relatively developed. It provides favorable conditions for the development of bad geological phenomena such as landslide, unstable slope and slope surface erosion and the accumulation of loose solid source of debris flow.

## 2.2. Formation Lithology

The strata in the study area mainly belong to qinling area, Malkang subregion and Yajiang subregion of Bayan Khala, and the middle and Paleozoic Ordovician to Triassic strata are exposed. The ordovician, Silurian and Devonian strata are underdeveloped and the exposed area is small. The Permian is well developed and distributed in the southeast and west of the county. The upper middle and lower Triassic are fully developed and most widely distributed. Except for the Quaternary strata, the county is mainly composed of Marine carbonate-clastic rocks, which are intermingled with basic volcanic rocks in each age, and is mainly characterized by the shallow metamorphic rock series which is mainly exposed to sandy SLATE of Triassic Xikang Group in large area.

## 2.3. Meteorological

Jiulong County is located in the Kang-Dian plateau monsoon climate zone, with complex topography and large relative height difference. Influenced by the plateau airflow and monsoon, the climate is obviously vertically zoned, presenting a variety of climate types. The annual rainfall of Jiulong county is as follows.

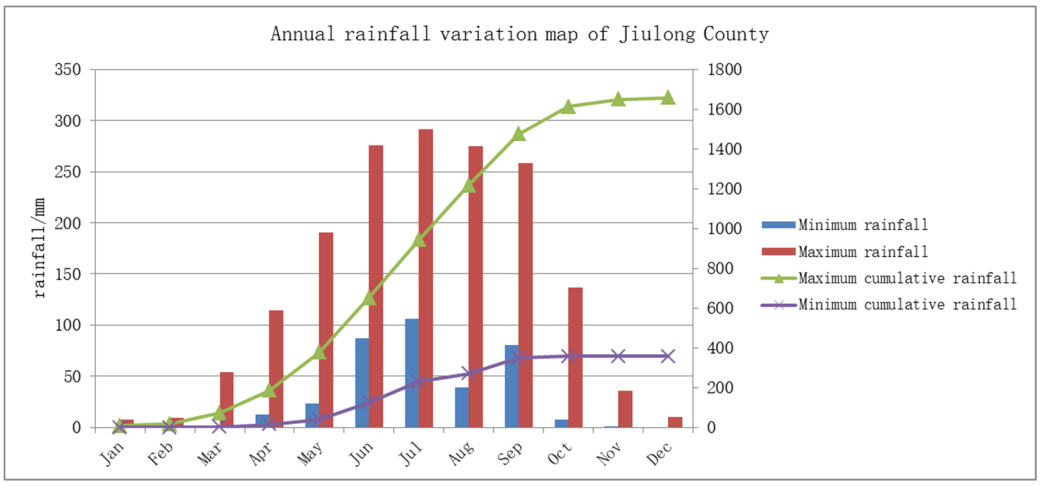


**Figure 2.** Annual rainfall variation map of Jiulong County

The distribution of rivers and gullies in Jiulong County is like leaf veins (Figure 2). To the big snow mountain as the boundary, the east is the Dadu River system, mainly have the Bay dam river and hongba River; The west is yalong River system, mainly jiulong River, Zier River, taka River, etc.

There is abundant groundwater in Jiulong County. According to the occurrence conditions of groundwater, it can be divided into two types: loose rock pore water and clastic rock pore fissure water.

The pore water of loose deposits is mainly distributed on both sides of river channels, first class terraces and river flats, and occurs in quaternary strata. Because of its high position, small

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distribution area and poor water content, it cannot form a single hydrogeological unit, so it has no hydrogeological significance.Clastic rock pore fissure water mainly occurs in bedrock fissure. The distribution of groundwater is controlled by lithology, structure, topography and geomorphology, and its water quantity is mainly replenished by meteoric precipitation and loose rock pore water. The fissure water is not easy to be enriched and this kind of groundwater is generally poor. It migrated down bedrock interfaces and fissures, eventually draining into the low-lying Jiulong River and flowing into the Yalong River.

Directly, and discharge of groundwater and the dynamic change law of formation lithology, geological structure and landform, and closely associated with rainfall and surface water, generally larger on the dynamic change of pore water, runoff way short, drainage condition is good, is a seasonal aquifer, in the rainy season, especially after the heavy rain, heavy rain, the water level increased significantly, dynamic water pressure, Can promote the occurrence of landslides, debris flow and other geological disasters.

### 2.4. Neotectonic Movement and Earthquakes

The county is controlled by the Qinghai-Tibet plate, and the neotectonic activity shows intermittent rise in large area. In terms of landform, the elevation of mountains in the area is generally between 3500-5500m, and peaks above 5500m are common, and the cutting depth is generally more than 1000m. From the perspective of glacier evolution, the origin of the glacier is often ice bucket lake, "U" shaped valley, "V" shaped valley, many of the middle and upper sections of the valley are open, the longitudinal gradient is small, but the lower section of the valley is usually narrow, cutting deeper before merging into the mainstream. In local sections of the county, there are beaded alluvial fans and spring points distributed in the mountain bed of tens of meters to more than 100 meters high, which becomes the evidence of crustal upward movement. In addition, the wide distribution of erosional terrace and base terrace in the region reflects that the depth of deep action exceeded the sedimentary action during the formation of the terrace, and the formation of some tuyere landforms also shows the characteristics of sharp rise of tectonic movement in the recent period.

Jiulong county has been observing earthquakes since January 1984. In the 1990s, small earthquakes with magnitudes of 2 to 4 occurred frequently in the county, with focal points centered on the core of the Dashixue Mountain in the east and the Yalong River in the west, while the Kowloon Valley in the central part of the county was relatively stable. February 23, 2003 yalong river - Jiulong - Kang (ding) three junction area 6.0 earthquake, resulting in the Yalong River area of Eight wo long, Shangtuan, Sanyanlong, Yandao and other villages, 1788 households, 7152 people affected, county xier town strong earthquake.

According to "Code for Seismic Design of Buildings" (GB50011-2010) (2016 edition) and the latest revised "Seismic Parameter Zoning Map of China" (GB18306-2015), the seismic fortification intensity of the survey area is 7 degrees, the design earthquake is grouped into the third group, the design earthquake acceleration value is 0.15g, and the characteristic period is 0.45s.

Jiulong County is located in the area of 7 degree intensity, so the earthquake in Jiulong county is a relatively major geological disaster inducing factor. It belongs to medium hard unstable field area, and the stability of the site area is poor.

## 3. Scouring and Silting Characteristics of Each Section of Debris Flow

### 3.1. Characteristics of Formation Region

The formation area is located in the upstream of the gully, mainly refers to the gully domain from the gully source to the gully elevation of 3050. There are many loose deposits in the gully

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domain, which are mainly the loose source on the slope surface. The overburden layer is thin, about 0.5-1.0 m thick.

The upstream rainfall collects to form slope scour, and the fine particles on the slope are carried down to the channel, and the debris flow is gathered in the channel to form small debris flow. The longitudinal slope of the channel in this section is large and the erosion and silting characteristics are mainly erosion.

### 3.2. Scouring and Silting Characteristics of Circulation Recharge Area

The length of the circulation recharge area is about 4.2km, and the loose provenances are mainly concentrated in the channel. Vegetation is developed on both sides of the channel, and local bedrock is exposed. The bank slope on both sides of the channel is v-shaped valley, and the channel is narrow, generally 8-15m wide, generally 30°-50° slope, locally steep, and slope deformation such as collapse and landslide is rare.

The gradual increase of gully makes the confluence capacity of surface water stronger, the hydrodynamic conditions gradually mature, and the anti erosion ability of surface soil is relatively poor, so that the gully beds in this area show strong downward erosion and lateral erosion, providing loose solid source for the Nanjiagou debris flow of Gujibaozi Formation in Zhejin Village, Wanba Town, Jiulong County.

### 3.3. Characteristics of Debris Flow Deposits

According to the site survey, the debris flow deposits are relatively large, and the content of fine particles is large.In small areas, heavy rain is frequent and rainfall is concentrated. The rainfall begins at the top of the mountain and expands to the foot of the mountain to form a large flood peak, which becomes the hydrodynamic condition for generating debris flow. Debris flow swept sand, mud, stone and other materials, from the broken rock collapse, landslide rock, gully accumulation of diluvial, slope deposits to; When the gully is cut, the height difference between the gully bed and the top of the mountain increases, and under the denudation of the storm, the solid material is easy to enter the gully bed. The main controlling factor of nanjiagou debris flow in Gujibaozi Formation is rainstorm, which is directly related to the occurrence of debris flow.

In conclusion, the solid materials, water source conditions and topographic conditions of nanjiagou debris flow in Gujibaozi Formation, Jiudin Village, Wanba Town, Jiulong County are all conducive to the occurrence and activity of debris flow. However, the occurrence of debris flow and its scale mainly depend on the intensity of rainfall, earthquake intensity and intensity of human engineering activities.

## 4. Conditions of Debris Flow Formation

### 4.1. Topography and Channel Conditions

The overall topography of nanjiagou debris flow in Gujibaozi Formation, Zhejin Village, Wanba Town, Jiulong County is high in the east and low in the west, and the longitudinal slope of the gully is large. The overall trend from gully source to gully mouth is steep up and slow down. The channels above the mountain pass are generally deep cut "V" shaped valleys, with narrow gullies, steep bank slopes, large cutting depth and large vertical gradient of the gullies.

Nanjiagou debris flow in Gujibaozi Formation, Digujin Village, Wanba Town, Jiulong County is located on the right bank of Wanba River. Geographical coordinates of the gully mouth are 29°1 '31.53 "N, 102°2' 19.96" e. The overall distribution of the basin is northwest-westward, with a length of 7.7km and a width of 1.2 ~ 4.2km. The inlet of the river is located on the right bank of the Wanba River. Nanjiagou debris flow basin covers an area of 14.5km2. The vegetation coverage rate of the whole basin is high, and the gullies are generally developed. There are two large gullies with large longitudinal slope, deep gullies, overall straight gullies and large local

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curvature. The main ditch is 7.42km long, the lowest point is 2120m above sea level, the highest point is 4600m above sea level, the relative height difference is 2480m, and the average longitudinal slope of the main ditch is 264‰.

According to the characteristics of gully domain, gully form and debris flow development, nanjiagou basin is divided into debris flow clear area, circulation area and accumulation area. Among them, the debris flow clear area is mainly distributed in the area above the altitude of 3050m, the circulation area is mainly distributed in the gully section between 2220 ~ 3050m and the exit pass, and the accumulation area is located in the section below the elevation of about 2004m at the exit pass of Nanjiagou.

The division of debris flow clear area, circulation area and accumulation area, as well as the topographic and geomorphological characteristics, and the characteristic parameters of the main branch valley are shown in figure below. Nanjiagou has two branch gullies, the watershed area is about 0.38km2, 1.25km2 respectively. The longitudinal slope of the gullies is large, the cutting is shallow, the development of the gullies is incomplete, and they are all clear gullies.

Water district is located in the source to the channel height 3050 m area, the mountain steep, average grade 418.7 ‰, the channel slope gradient generally 30 ° to 50 °, the local vertical, bedrock exposed, the low vegetation coverage, vegetation coverage rate < 60%, perennial affected by repeated freezing and thawing effect, rock weathering is strong, and in the rain and snow melt water slope surface erosion.

The circulation area is located in the section with an elevation of 2180-3050m of the channel, and the gully bank slope in this section is generally 25-45 °, with good vegetation coverage of more than 80%. The middle and upper reaches of the gully are generally 8-10m wide, while the middle and lower reaches are 10-15m wide, 20m in parts, with water drop. The average vertical slope of the gully is 185.11‰. This section is rich in provenance, providing material conditions for the occurrence of debris flow.

The accumulation area is located in the gully mouth section, and the elevation of the gully is 21020-2180m. The gully in this section is slow and wide, generally 20-30m wide, and the average longitudinal slope of the gully is 109.1‰. Debris flow accumulation fans (Figure 3) are distributed from the mountain pass. The fan length is about 300m. After the flood reconstruction of the main river along the river direction, the fan edge boundary shape is irregular, the top Angle of the fan is about 55°, the plane longitudinal slope is about 80-100‰, the top of the fan is slightly steep, and the middle part of the lateral pile fan is slightly inclined to both sides.

**Figure 3.** Orthophoto image of gully mouth of Nanjiagou debris flow in Gujibaozi Formation, Zhejin Village, Wanba Town, Jiulong County

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## 4.2. Source Conditions

Provenance is one of the important conditions for the formation of debris flow. The provenance of nanjiagou debris flow mainly comes from the slope erosion provenance (soil and water loss on the slope), collapse and slide provenance and gully accumulation provenance (loose accumulation body in gully bed) distributed on the gully bank slope body.

According to the field investigation, nanjiagou debris flow mainly has three provenance sources: collapse and sliding accumulation body, gully accumulation body and slope erosion accumulation. The total reserves of these three sources are 596.57×104m3 and 134.91×104m3, respectively. In addition, there are rich sources of dead and disorderly wood in the channel.

The first is the cave-slip accumulation body, which has nine cave-slip provenments (BH1-BH9), mainly distributed in the slope section of the banks on both sides of the main gully. The distribution height is 2150~2320 meters. The total provenments are about 13.07×10m3, accounting for 2.21% of the total provenments, and the dynamic reserves are 3.41×104m3. The main gully section of the cave-slip accumulation body is distributed in 9 places.

The second is the channel accumulation body, which consists of 4 sections (GD01~GD04). The total accumulation length of channel accumulation in the basin is 2997m, the accumulation area is 48.98×104 m2, and the total amount of source material is about 148.5×104m3, accounting for 24.89% of the total amount of source material, among which the mobile reserves that may participate in debris flow activities is 44.5×104m3.

The third is the slope erosion source, mainly distributed in the main gully and each branch gully circulation area on both sides of the slope. Nanjiagou debris flow gully basin covers an area of 14.5km2. As the slope provenance thickness ranges from 0.2 m to 0.4m, with an average thickness of 0.3m, the slope provenance reserves are 435×104m3, accounting for 72.9% of the total provenance, and the dynamic reserves that may be involved in debris flow activities are about 87×104m3.

From the current situation, once the continuous heavy rain or heavy rain, the upper trench trench cut, causing instability and destruction of high and steep accumulation bodies on both sides of the trench. Secondly, as the main gully is straight, it is easy to drive a large number of provenance to participate in debris flow activities in the rainstorm season, providing rich provenance conditions for debris flow development

## 4.3. Water Conditions

The water source of Nanjiagou mainly comes from meteoric precipitation and melting water of snow and ice, among which meteoric precipitation is the main driving factor of debris flow in Nanjiagou. [1] Since debris flows in this area occur in rainy season, melting water of snow and ice in spring generally does not become the source of debris flows. In addition, the inland water is not rich, does not constitute the main source of debris flow, there is no reservoir, lake and other concentrated surface water in the valley, through local visits and field investigations can be determined that short time, heavy precipitation is the most important cause of debris flow in the valley. Nanjiagou debris flow gully catchment area is large, both sides of the slope is steep, heavy precipitation in a short time can not form seepage, quickly form surface runoff, gathered into the gully, erosion of the gully and the solid loose material on both sides, debris flow. It can be seen that short - time heavy rainfall is the main cause of nanjiagou debris flow.

# 5. Mechanism of Debris Flow Formation

The topography of clear water area and circulation area of Nanjiagou debris flow gully of Gujibaozi Formation in Digin Village, Wanba Town, Jiulong County is relatively steep (400-500‰), the rainfall runoff coefficient is large, and the rainfall is easy to gather and form a flood, which forms a strong scouring effect on the loose soil of residual slope in the gully. The profile

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provenance is easy to be saturated, and the debris flow is easy to be started to form under the slope scour caused by rainfall. After the debris flow starts from the slope provenance of gully source and enters the main gully, the scour ability of the main gully increases, and the loose provenance in the gully is scoured to form the debris flow in the main gully. In the lower reaches of the gully area, the provenance is rich and the topographic slope is large (about 400%). The debris flow from the upper reaches is easy to scour the loose soil in this section and increase the scale of debris flow.

Jiulong county village coogee bay town to dig gold a great group of south Carolina gully is a rainstorm debris flow valleys type, main and gully debris flow scale domain loose solid source of accumulative and dynamic change and related to the case of rainstorm debris flow, when the channel in loose solid source domain accumulated more, and meet with concentrated rainstorm, large-scale debris flow disasters often occur. After the heavy rain, the soil in the gully becomes loose when saturated, and the bad geological phenomena such as collapse and landslide increase, and the local soil erosion is aggravated. The amount of loose solid provenance that can participate in debris flow activities also increases greatly. Once the heavy rain occurs, it is bound to cause large-scale debris flow disaster. Debris flow is easy to occur, and the urgency of governance is urgent [2].

A comprehensive analysis of the formation mechanism of debris flow mainly includes the following factors:

First, the steep topographic and geomographic conditions, loose and broken slope structure and steep longitudinal slope of the channel in the basin provide basic conditions for the formation of debris flow provenance, the convergence of water flow and the development of debris flow disaster [3].

Second, the weathering continuously forms loose soil, and under the continuous transportation of rainfall, a large number of loose provenance is formed in the channel and at the edge of the channel, which plays an important role in the development of the geological phenomenon of collapse and slip in the basin and the formation and evolution of debris flow provenance [4].

In conclusion, nanjiagou debris flow of Gujibaozi Formation in Zhejin Village, Wanba Town, Jiulong County is a rainstorm gully type debris flow. Under the conditions of current terrain, gully, provenance and water source, if the rainfall conditions are available, large-scale debris flow disaster may occur.

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