A FEATURES INVESTIGATION IN THE DEBRIS FLOW OF JIAOPINDU ALONG JINSHAJIANG RIVER

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ABSTRACT

A large amount of debris flow is developed along the lower reaches of Jinshajiang river, which gives raise to water loss and soil erosion. In order to understand features and mechanism of debris flow, GPS, GIS, RS were combined to be applied into the debris flow features study. Grain size distribution, mud balls etc. in natural profiles of accumulative fan were described. Mud traces, waterfalls and the stability of the slopes in the transportation zone were located. Geological structures, lithology, weathering intensity of bed rock in the source area were described. Image at a resolution of 2.5m of SPOT 5 combined with MapGis were applied to obtain the spatial parameters of the debris flow, such as, catchment area, gully erosion density of the catchment etc.. The histogram of grain size distribution and the normal probability plot of grain size were plotted to analysis the hydrokinetics of debris flow. The material composition and the microstructures of the phyllite in the source area have been studied by X-ray and scanning electronic microscope. Finally, the main features and mechanism of the debris flow was revealed.

Key Words: Debris flow, Field investigation, Normal probability plot, Mineral composition and micro structures, Features and mechanism

INTRODUCTION

Debris flow is one kind of geo-disasters which give rise to a lot of damages to cities and villages, recently, some of the detailed and profound study on debris flow was carried out by scholars, such as, simulating the damages of the debris flow in 1D or 2D(Nakatani K., Wada T., Satofuka Y, Mizuyama T., 2008), and in order to do the better job of simulation, the investigation of the case study is very important(Wan S., Lei T. C., Huang P. C., Chou T. Y., 2008), the assessment of magnitude and frequency of debris flow(Liu J. J., Li Y., Su P. C., Cheng Z. L., 2008) and assessing debris flow hazardous(Lin Ping-Sien, Lin Ji-yuan, Hung Jui-chi, Yang Ming-der, 2002), all of the detailed study is based on the field investigation to understand the geologic boundary condition of the debris flow.

There are three hundred twenty nine debris flows developed along the lower reaches of Jinhshajiang river which is the river section between the city of Panzhihua and Wudongde

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dam site, the meander length of the river section is 210km, strong intensity weathering of bedrock, concentrated precipitation of rain season, dry-hot season(xerothermic) last for about half a year, human beings activities ect., that gives rise to a lot of water lost and soils erosion, slope deformation, landslide and debris flow. Jiaopindu debris flow valley is one of the largest debris flow in this river section, for many years debris from this valley bring a lot of materials to Jinshajiang river which sometimes causes geological disasters to the facilities. A close attention to debris flow is paid by government for many years, the main question is that why, how much, how often the debris flow happened and what is the geological disasters will be caused in the near future, the aim of this paper is going to answer the questions above.

In order to answer the questions above, some of the basic knowledge is required, such as the material source condition, hydrometeorological condition, geomorphologic condition should be acquired, which makes the geology, hydrology, hydrogeology, meteorology, geomorphology and some modern techniques to be interdiscipline. based on remote sensing(RS), GIS and GPS techniques, at the very beginning the image data of remote sensing is interpreted under the software system of Mapgis, then a few days field geological investigation has been done, samples from natural profile of alluvial fan was used to be the material for sieving analysis, unit weight of the material is tested in situ, mineral composition and micro-structure for the samples from source area was studied, and the mechanisms of the debris flow is revealed.

FILED INVESTIGATION

Accumulation zone

A large scale of debris flow is located on the left bank of Jinshajiang river, the opposite bank is a small village named Jiapindu, hence the Jiaopindu debris flow is named, accumulated fan of Jiaopindu debris flow has a good fan shape as shown in fig.1, the fan has already intruded into Jinshajiang river, the width of the fan is about 670m, length is about 320m,the channel of the Jinshajiang river is obviously be squeezed by accumulated fan, the normal width of upper and down stream of the Jinshajiang river is about 175m,but it is only 84m wide in the accumulated fan section as shown in fig.4, the current of river is offset obviously, rapids formed at the accumulated fan section, main stream is drifted to the right side of the channel.

Fig. 1 Alluvial fan panorama of Jiaopindu debris flow

The main colour of the alluvial fan is grey black, and there is no vegetation even there is no grass on the fan, that means the fan is formed very new, fortunately, there is a gully developed on the fan,and a profile can be observed along the gully on which the colour of materials is dimgray, psephicity of gravel is very poor, and degree of sorting is also very poor, all of these are show in fig. 2.

Fig. 2 Psephicity & sorting very poor

Two samples are taken from the profile of gully, each sample weighted 10 kilograms, and the sieving analysis is accomplished in situ, the curves of accumulative percentage composition are shown in fig. 3, it is shows that curves are distributed in a large range of diameter, and the slope of curves are flat, the value of nonuniformity coefficient is 3.2, and the value of the curvature coefficient is 1.23, all of the information shows that grain size distribution is in a wide range.

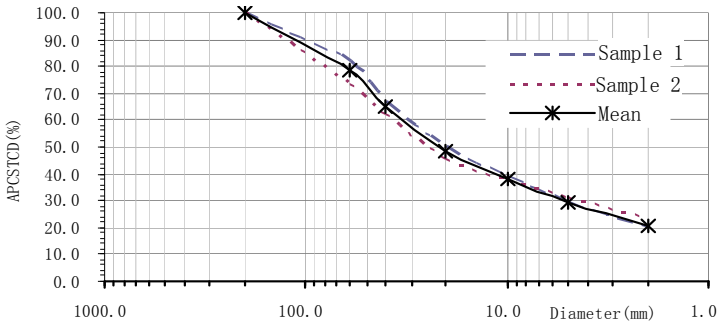

Fig. 3 Accumulative curves of percentage contents of alluvial fan

Notice: APCSTCD-Accumulative curves of percentage contents smaller than certain diameter

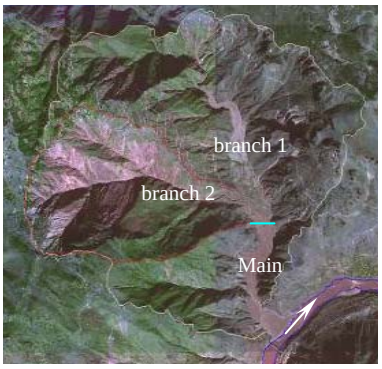

Fig. 4 Remote sensing data of Sport5

Transportation zone

Transportation zone can be recognized as a main transportation zone and two branches transportation zone, the accurate location of transportation zones is shown in figure 4, the length of the main transportation zone is about 2 km, it is in the direction of SSE flow into Jinshajiang river, the width of the main transportation zone is from 100 to 200m, and the shape in the plane is slightly curved. Branch transportation zone 1 is the extension of the main transportation zone; it has almost the same direction and features with main transportation zone. Branch transportation zone 2 is short and very narrow, and it is in the direction of SEE flow into main transportation zone.

Fig. 5 Collapse on the left bank

Fig. 6 Landslide on left bank of branch 1

Fig. 7 Mud traces on the left bank

There are many geologic features can be observed in transportation zone, fig. 5 shows that a very new collapse is located on the left bank of the main transportation zone, fig.6 shows that a landslide is located on the left bank of the branch transportation zone 2, in fact, the rock slope on both bank of the branch transportation zone 2 is strongly weathered and fractured, so the slope is extremely unstable. Fig. 7 shows that some mud is kept in a opened fissures, the location of this fissure is about 3m from the bottom, which is generally considered to be a mud trace that can be used as an important parameter to assess mud-carrying section.

Source zone

There are two branches according to remote sensing data from fig. 4 that means two source zones are existed for Jiaopindu debris flow. The features of two source zones is totally different, source zone 1 has the larger area, and the vegetations on the slope is very good, the slope is stable, and the degree of water lost and soils erosion is slightly as shown in the fig. 8, part of the slope has some loosen material that is man made due to road construction.

Fig. 8 Stable slope in the source zone 1 of Jiaopindu debris flow

The area of source zone 2 is about half the area of source zone 1, and the weathering intensity of bedrock is very strong, the geo-stress in rock slope is almost relaxed, according to phenomena in prospect tunnel the thickness of the strongly relaxed rock mass is about 20m, because 20m long from the adit is fully supported by log. Water lost and soil erosion is seriously, the surface of the slope is almost bare rock or soil, deformation and failure of large slope in the source zone 2 can be found almost everywhere, especially, many large scale of landslides is developed in this area as shown in fig. 9, in fact, the bared and unstable slope is about 300m high, local failure and the rock falling from this slope almost every day, so the local people named this area as Laokuashan that means failures and rock fallings always happened, people said that the sound of rock rolling can be heard clearly in every night, and fearfully sound of the rock rolling can be heard during heavy rain in the night.

Fig. 9 Landslides and bare rock soil in the source zone 2

REMOTE SENSING DATA INTERPRETATION

Debris flow is one kind of geo-hazardous that involved in a lot of influence factors, and a large area should be considered, such as source zone, transportation zone, accumulation zone, and some of the important spatial geometry data i.e. the catchment area, the maximum relative difference in elevation of the catchment, gully erosion density of the catchment, length of the main gully, drainage map etc., it is very difficult to get all of the parameters mentioned above by field investigation. Hence a higher resolution remote sensing data is used to obtain the parameters.

SPOT5 is the most advanced satellite of SPOT series launched by France, the capability of 3-D image is increased further, ground resolution of 2.5m is realized by new super-imaging mode, the panchromatic resolution is 2.5m and the multispectral resolution is 10m. Geodetic coordinates of Beijin 1954, and the Yellow sea datum are used in image data, the scale of the image data is 1:10000, imaging data as shown in fig. 4. The software of Mapgis is used to processing the image data, all of the params of Jiaopindu debris flow can be obtained as table 1 by remote sensing data interpretation. All of this param is important for the further study of Jiaopindu debris flow.

Table 1 Geometric params of Jiaopindu debris flow by remote sensing data interpretatiom

CA (km^2)	LMG (km)	MRDEC (km)	AGC	MSDSZ (°)	GEDC (km/km^2)	CCMG	PRLM ($\times 10^4 m^3$)	LRLMB
15.6	5.07	1.33	0.26	21.3	7.40	1.22	30305	0.56

Notice: CA-Catchment area; LMG-Length of main gulch; MRDEC-the maximum relative deference in elevation of the catchment; AGC-Average gradient of catchmaent; MSDSZ-Mean slope degree of source zone; GEDC-gully erosion density of the catchment, CCMG-Curving coefficient of main gulch; PRLM-Potential reserves of loose material; LRLMB-Length ratio of loosen material to bedrock.

GEOLOGICAL AND HYDROLOGICAL CONDITION

Geologic condition

Geological condition is involved in ages of the stratum, geological structure, lithology, mineral composition, intensity of weathering etc.. All of these params will influence the activities of debris flow; the following is brief information about geologic condition of Jiaopindu debris flow.

The age of the stratum is the Huili Group in the period of Mesoproterozoic Erathem(Pt_2), metamorphic rock is developed in Huili Group, such as, sericite phyllite, sericitization schist, metamorphic sandstone, and granitic gneiss, dolomite, the color of the phylite is generally dark gray, the sandstone and the dolomite is generally grey white.

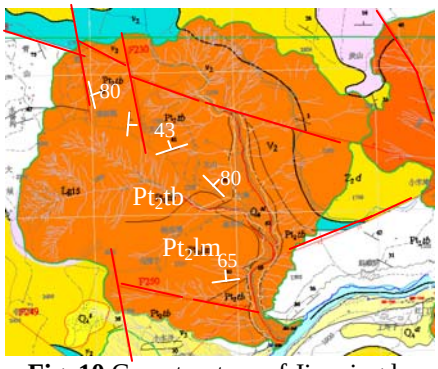

Fig. 10 Geo-structure of Jiaopingdu debris flow

The geological structure of the study area as show in fig.10, Pt_2tb is originated in the period of Mesoproterzoic Era, the faults is developed mainly in two directions, the strike of the faults is in NWW and NNW, respectively, and reverse faults is in the NWW direction, normal faults is in the NWW direction, due to the faults affection, the strike of the stratum is changed in many directions, and the dip angle is from 43° to 80°. The

stratum of sericite phyllite is strongly pressed by geo-stress, the rock mass is strongly fractured and weathered.

Hydrological condition

The location of Jiaopindu debris flow is at the elevation between 800 to 1500m in the Hengduanshan valley area, dry-hot valley is formed, due to foehn effect, typical meteorology and hydrology characteristics for dry-hot valley is plenteous sunshine, vigorous evaporation, concentrative precipitation, wet and dry season clearly, large daily range of temperature, dry half year, wet half year, four seasons sizzler along the valley.

According to local meteorological records in recent 50 years, average value of precipitation is 77.5～229.7mm from May to October, the maximum daily precipitation is 111.5mm, the maximum precipitation for one hours is 21.7mm, The lowest temperature is -5.9℃, the largest temperature difference is 40.6℃ in one year that make the weathering effect very strong along this valley.

LABORATORY TEST

Three items is important for analysing the mechanism of debris flow, they are mineral composition, microstructure of rock, and the grain size distribution of the accumulated fan. A sericite phyllite sample was taken from the branch source zone 2 as shown in fig. 11.

Fig 11 sericite phyllite

Mineral composition was tested by means of X-rays diffract with XD-3 diffractom, the test result is shown in table 2, it shows that the clay mineral of mica and chlorite in the composition is up to 86%, and only 14% is quartz and plagioclase.

Table 2 Mineral composition relative composition of sericite phyllite by XRD

Q	fs	Pl	Cc	Do	I/S	I-M	Ch	Am
13		1				70	16	

Notice: Q-Quartz; fs-Alkali feldspar; Pl-Plagioclase; Cc-Calcite; Do-Dolomite; I/S-Illite/smectite mixed layer; I-M-Illite or mica; Ch-Chlorite; Am-Hornblende.

Micro-structure photos of the sericite phyllite is scanned by electron scanning microscope, it is shown in fig. 12, the structure is amplified to 800X, schistose structure can be observed clearly in fig. 12, schistose minerals means the bedrock has been strongly subjected to geo-stresses.

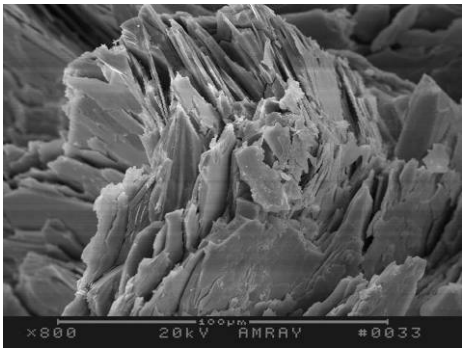

Fig. 12 Micro-structure of sericite phyllite

Grain size distribution curves of samples from the accumulative zone is shown in fig. 3 from fig. 3 some useful information can be obtained, but that is not enough to analysis the mechanism of the debris flow, normal probability paper is introduced to plot the accumulative grading contents on it, as shown in fig. 13, the horizontal axis is φ value, φ value can be calculated by equation 1, and the vertical axis is the accumulated percentage contents probability.

$$\varphi = -\log_2 d = -\frac{\lg d}{\lg 2} = -\frac{1}{0.3}\lg d \qquad (1)$$

In order to analysis fig. 13, the theory of sediment environment is applied, Moss suggested that for debris sediment environment analysis the diagram can be used as shown in fig. 14(A.T. Moss, 1962, 1964; Xie Yu-ping,1996). Moss's study proved that there are three kinds of the transportation manner, i.e. suspension, jumping, rolling or bed-load transportation, respectively, it is shown that three sections of line, i. e. suspension (B), jumping (A), rolling

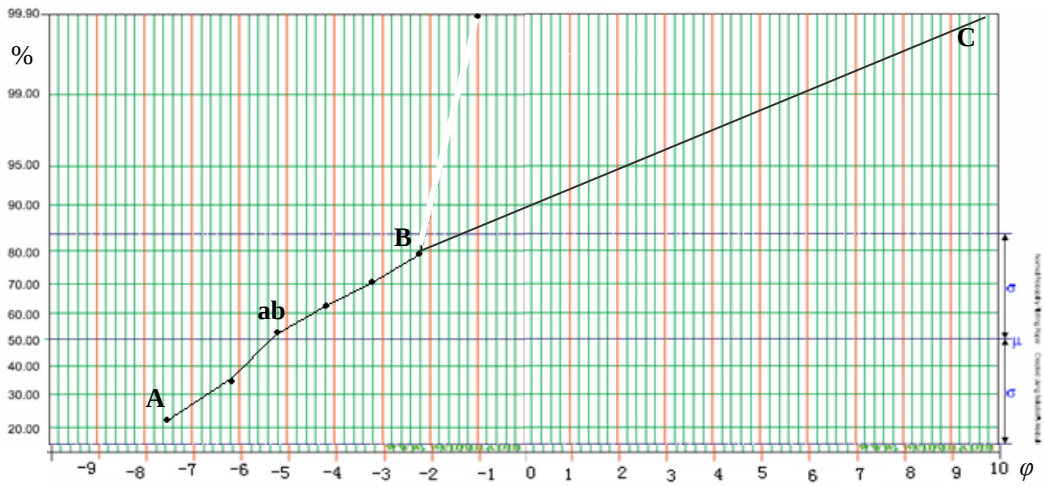

Fig. 13 Grain size distribution Plot on the normal probability paper

(C), respectively, appeared in fig. 14. Furthermore, the slope of each section of line reflects the degree of sorting, the smaller value of the slope, and the poorer degree of the sorting. even though, Moss's study is only concerned the grain size smaller than 2mm, but it is still a very good reference to the situation of Jiaopingdu debris flow.

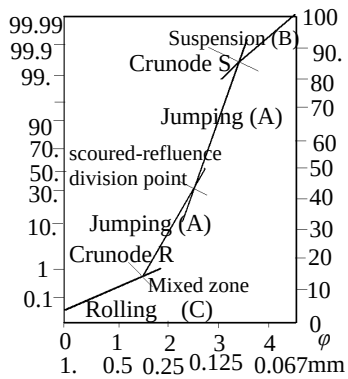

Fig.14 Probability cumulative curve segments

Comparing to fig. 14, the slope of the sections of line is flat in fig. 13, which means that the degree of sorting is very poor and the main transportation type is rolling or bed-load for grain size larger than 5mm, there is almost no jumping and for the very smaller grain maybe is suspension.

MECHANISM ANALYSIS

All of the information about Jiaopindu debris flow is mentioned above, typical accumulative zone, transportation zone and source zone is easily figured out by field work, some samples was taken and tested in situ and laboratory, one phenomenon need to be paid more attention is that source zone 1 and source zone 2 is quit a different, the fig. 15 shows the difference very clearly.

Fig. 15 is a bird view of main transportation zone, it is clearly shows that materials in the transportation zone with dark black colour which is from the source zone 2, and materials in accumulative fan with dark black colour from source zone 2 is obviously, furthermore, a small stream in yellow colour also can be seen in the main transportation zone, but it is almost

no material from source zone 1. What is the reason the debris flow is just take place in the source zone 2, the following is some explanations.

According to basic knowledge of debris flow, there are three very basic conditions have to be considered i. e. geologic condition, meteorological and hydrologic condition, geomorphologic condition, all of three conditions is already mentioned in previous paragraphs, here it is not just going to repeat again, but it is need to emphasized that the geological structure i. .e. faults, orientation of the stratum is very complicated. and the bed rock distribution is also complicated even the ages of the stratum is in the same group of the epoch which is more than 10000Ma from today, the characteristics of the rock mass is quit a different, because of the original rock type are mudstone, sandstone and limestone, after long term of geological structure movement affection which is including metamorphism, high geostress and then weathering, the type of the rock mass in the source zone is changed into metamorphic rock mass in a wide ranges that is from phyllite, schist, gneiss, dolostone, marble, the strength of rocks is totally different, and the capability of resistance to weathering is also very different, that is why the materials from source zone 1 and source zone 2 is so different.

Fig. 15 Bird view of transportation zone of Jiaopingdu debris flow

The bedrock in source zone 1 is mainly dolostone and marbles, the strength is strong, and the integrality of the rock type is from thick layer bedded blocky to intact, and the degree of weathering is from slightly to moderate, that is why there is almost no debris materials come down from source zone 1.

The bedrock in the source zone 2 is mainly phylitte and schist that is soft rock, the integrality of the rock type is from thin layer bedded fractured, dip angle of the rock layer is around 60° some of them is close to the vertical, the strength is very poor, faults and folds can be seen around the site, and the degree of weathering is very strong, the stability of the slope is very poor, many of large scale landslides is active right now as shown in fig. 9, that is why there is a lot of debris materials come down from the source zone 2.

Dark grey and schistose clay minerals is plenty in the phyllite of source zone 2, that is very important factor for phyllite weathering along dry-hot valley, half year dry and hot with plenty of sunshine, and large daily temperature difference that makes the phyllite absorbing a lot of heat in the day, and becoming cold in the night for all the half year, swell and shrinkage of phylitte takes place every day for half year, this kind of physical weathering causes a lot of new micro-fractures in the rock mass, it is a rain season for the another half year in this region, the air is humid, but the temperature is still hot that makes a lot of precipitation get into the micro fractures in phylitte, the moisture soften the strength of the rock mass, this kind of weathering cycled every year and every day in this special dry-hot valley that makes the slope

rock mass strong weathered and decomposed, furthermore, because of the slope in the source zone two is steep, so the collapse and landslide is very easy along the slope, a lot of debris materials from source zone 2 be produced, that is the mechanism explanation of Jiaopindu debris flow.

CONCLUSIONS

1, Field investigation, sampling and granular analysis in situ from accumulative zone is very important to get information of accumulative fan, in this way, not only the accumulative curves can be obtained, but also the accumulative probability curves can be obtained to analysis the hydrokinetic characteristics of debris flow.

2, Remote sensing data processing by Mapgis is a very useful method to calculate the geometry parameters of debris flow.

3, Geologic condition of source zone is the basic intrinsic factors, such as, geo-structure, lithology, mineral composition, micro-structure and intensity of weathered bedrock which can determine whether the debris materials could be produced or not.

4, A special climatic condition of dry-hot valley is the extrinsic factors, such as, temperature, higher temperature difference daily, plenty of sunshine, higher evaporation, concentrated precipitation which determine weathering velocity and hydrokinetic condition to control whether the debris flow occurred or not.

5, Comprehensive using RS, GIS, GPS and field investigation, laboratory test is a recommended method to study the characteristics of debris flow.

6, Debris material is mainly from source zone 2, and the debris flow will happened many time in the raining season every year, because the length of the main transportation zone is wide and long, but, the damage to the bridge is probably happened.

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