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Characteristics and Development of the Debris Flow Fan in Dalancha Gully, Beijing

GAO Jiarong, HU Fengbing, LIU Ying
(College of Soil and Water Conservation of Beijing Forestry University, Key Laboratory of Soil and Water Conservation and Desertification Combating of Ministry of Education, Beijing 100083, China)

Abstract Debris flows occur frequently in the mountain area of Beijing. Through detailed data collection and field investigation, this article studied the characteristics of the debris' deposition fan of Dalancha gully. It shows that the fan formation bears upon two debris-flow processes, the primary water-stone flow made the basic configuration of the fan, and the second viscous flow changed remarkably the morphology of the fan. The evolution of the fan in Dalancha gully is significantly influenced by the mainstreams of Dalancha gully and Xibianlian ravine; the exterior of the fan can be divided into four parts I, II, III and IV. Part I, II, III represent characteristics of the viscous debris flow, and part IV presents the primary water-stone flow. The manner, distance and erosion intensity of solid matters is different between the two debris-flow processes. The size, directions of array, and the roundness of gravels in different parts also reflect the characteristics of two debris-flow processes. The results will enrich theories on study of debris flow in Beijing Mountain and provide data to the mitigation of debris flow in Beijing Mountain.

Key words deposit fan, debris flow, water-stone flow, Beijing mountain
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1 Introduction

The geomorphology of piedmont changes greatly in the short-duration deposition processes of debris flow (Tang Chuan, 1991), and the dynamical process of debris flows can be deduced from morphological development and deposit feature of fans. The study of debris flow deposit fans attracts more international efforts, and especially in Jiangjia ravine, China is systematical, including triggering (Chen Jie, 2005; Tian Lianquan, 1991), physical and chemical composition of deposits (Luo Guisheng, 1987; Lei Xiangyi, 1987).

Debris flows occur frequently in west mountain area of Beijing, and fans are a prominent landform of debris flow deposits (Cui Zhijiu, 1996). Debris flow occurred in Dalancha gully, Fengjiayu Town, Miyun County, Beijing in 1939 (Zhang Kaiping, 2004), forming a typical fan at the intersection of the mouth of Dalancha Gully and the main channel of Xibailian ravine. we selected the deposit fan as the study object, through detailed data collection and investigation of the conditions of physical geography of the watershed Dalacha gully and the characteristics of the debris flow deposit fan, and try to explain the reasons of characteristics and the evolution of the deposit fan, which can

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作者简介 (Biography): Gao Jiarong, address: College of Water and Soil Conservation, Beijing Forestry University, No. 35, Qinghua East Road, Haidian District, Beijing 100083; telephone number: 010 - 62338040; fax: 010 - 82308012; email: jiaronggao@sohu.com
Hu Fengbing, address: 981 mail box, Beijing forestry university, No. 35, Qinghua east road, Haidian district, Beijing 10083; telephone number: 010 - 62338040; fax: 010 - 82308012; email: hufengbing@126.com

benefit the basic research of debris flow fan and the mitigation of debris flow hazard.

2 Study area

Dalancha gully, N40°39′ ~ 40°39′, E116°51′ ~ 116°52′, is located in Xibailian ravine, Fengjiayu Town, Miyun County, Beijing, and the fan in this study is at the mouth of Danlanch gully, which intersects with the main channel of Xibailian ravine.

Fig. 1 General view of the study area

2.1 Geomorphology of the watershed

Danlancha gully, a part of the mountain range Yanshan, is dominated by middle-low mountains, which is of single-inclined fault block and intense denudation. The absolute elevation of the highest point is 910 m, and the lowest point 522 m at the mouth of the gully. The average degree of the slope is 33.27°, and the average gradient of the channel is 18°. Controlled by the geological structure, lithology and exogenic forces, the slope of the mountain is characterized by steep slopes and cliffs. The formation area of debris flow is 0.58 km^2, and the flouling section area 0.09 km^2. The upstream channel is remarkably incised with the configuration of the transversal profile "V" shape, and the downstream channel is intense erode by debris flows which can be seen from traces and time of debris flow with the configuration of the transversal profile "U" shape. The whole shape of the watershed is leaf-like. Short channel of drainage basin make precipitation fast a confluence in the channel which can seriously scour the slope and transport solid matters including gravel, sand, grain, clay and prone to form debris flow.

2.2 Geological setting

The geological structure, on Shicheng fracture zone in the second belt of folded strata of New Cathaysian tectonic facture zone, with the trend to northeast 20°, dip-slip to east with the angle 6°. The activity of New Cathaysian tectonic facture is obvious. The fault block is uplifted with the comparison to the geological structure of Miyun reservoir. The strata layer of this region has a long history and was formed in Archean. Rock of this region is dominated by gneiss and schist, and metamorphic rock is quartzite and griotte.

The properties of lay up of the strata layer is better, with good extension, better processes of migmatitization, and belong to regional metamorphism, whose microscopic structure is bracky anticline.

2.3 Climatic conditions

The climate of the location is the typical semiarid subhumid monsoon climate in warm temperate zone. About 76.4% of precipitation, average amount 650 mm, falls in the summer, especially in July and August (Wu Zhenghua, 2001). Concentration and long duration of rainfalls are essential to the occurrence of debris flow. For example, the duration of precipitation was even about 40 days, which resulted in the occurrence of 1939 debris flow. And the average annual air temperature is 10.8℃. And the average annual earth temperature is 13℃, with the extreme highest 67.5℃ and lowest −7℃, resulting in high intensity weathering of rock, which can be a source of solid matter in debris flows.

2.4 Human activities

Before 1939, there was a village with a few houses at the mouth of Dalancha gully. Most of terraces along the main channel were growing Chinese chestnut and Walnut trees. For lacking of protection of bush and herb, the soil under trees was very fragile to be eroded by the water and the ecosystem of the watershed became worse and worse. The 1939 debris flow destroyed the village and terrace fields along the channel about 500 m from the mouth of the gully, but terrace in the upstream was survived. Now, no pepole lives in the gully, but the human activities still exist, which include fruit trees planting on the existing terrace, firewood cutting, pasturing, etc. Under the pressure of these existing activities, the stability of the watershed ecosystem is prone to collapse and the probability of debris-flow occurrence increases.

The gravel gradation, size, directions of array, and the roundness of gravels in different parts of debris flow deposition fan were measured. Several gravels in the Dalancha gully were selected randomly and those abc length and incline were measured. In the representative parts I and III of the fan a roundness hole were dug and 1 kg particle that the diameters beyond 10 mm were selected and analyzed in laboratory. Average particle diameter, sorting, skewness and kurtosis were measured by the Polk and Ward formula.

3 Characteristics of the fan

Characteristics of the fan reflect the property of debris flow, and so is the fan in Dalancha gully.

3.1 Cross section

The sketch map and surveyed slope-gradient drawing in cross-section of the fan are showed in figure 2. It shows that the deposit is characterized of typical debris-flow deposit, with the font, body, and tail. The length of the front is 10 m, and that of the body is 28 m. When the debris flow reached the accumulated position and its velocity decreased significantly, solid matter, such as gravels, sands, clays, began to deposit under gravitational force, gravels rolled, sided or leaped, and sands and clays suspended, rolled or crawled, which resulted in different forms of the fan. The midst of fan is protruding and the slope gradient of the body is 5°, and that of the front is 24°, higher than that of the former.

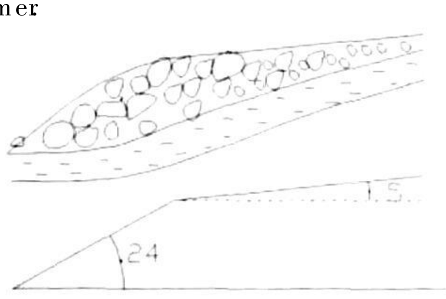

Fig. 2 Sketch map and surveyed slop-gradient drawing in cross-section of the fan

The fan has no apex, resulting from materials have been eroded and transported by water flows afterwards. It just presents the deposition of viscous debris flow, and we can not find the deposition of water-stone flow if just from the cross-section of the fan.

3.2 Morphology of the fan

The morphology of the fan can be divided into 4 parts named part I, II, III and IV (Fig. 3).

Part I lies in the midst of the fan, with its slope gradient is 5°. The deposit contains a large amount of sand and clay, where many shrubs grow. The average diameter of gravels is 0.28 m, and most of the gravel diameter are above 0.13 m, with the extremely largest 0.58 m. There are comparatively less deposits between the diameter 2 mm and 0.13 m. The trend of long axis arrangement of most gravel is directional, the diameters of gravels gradually become smaller from the upper to the brim of this part. The length of this part is 28 m from the starting point, and the largest width 7.5 m on the intersection with part II.

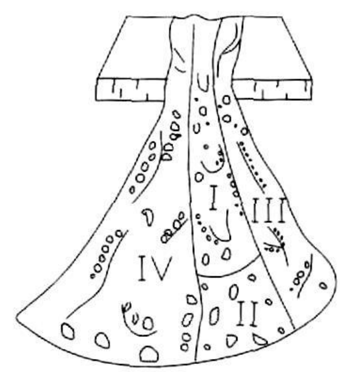

Fig. 3 Sketch map of the morphology of the fan

Part II is the front of the debris flow deposit. The slope gradient is 24°. This part has an isosceles-trapezoid-like shape, with the upper side 7.5 m, the bottom side 11 m, and the two symmetry sides 19 m. The average diameter of gravels is 0.21 m, with the largest 0.8 m. The trend of long axis arrangement of gravels presents no certain direction.

Part III lies in the right of the fan, with its slope gradient is 10°. Some herb and brush grow on the deposit. The average diameter of gravels is 0.20 mm, ranging from 1.2 mm to 0.34 mm. There are a lot of sands and clays in the gaps of gravel. The trend of long axis arrangement of most gravel is directional; the diameters of gravels gradually become smaller from the upper to the brim of the fan, which is like that of Part I, according to statistics. The bottom of this section is 19 m.

Part IV lies in the left of the fan, and its shape is sector-like. The gradient of the main slop is uniform, with the angle 8.5°, but the slope gradient where it meets part I and II is 10°, which has the same value with part III. The average diameter of gravels is 0.5 m, ranging from 1.76 m to 0.37 m, which is bigger than other part. The length of the bottom is 33 m, which is a little longer that the brim-length addition of part II and part III. The trend of long axis arrangement of most gravel is directional, the diameters of gravels gradually become smaller from the upper to the brim of this part. There are no sands and clays in the gaps between the gravels.

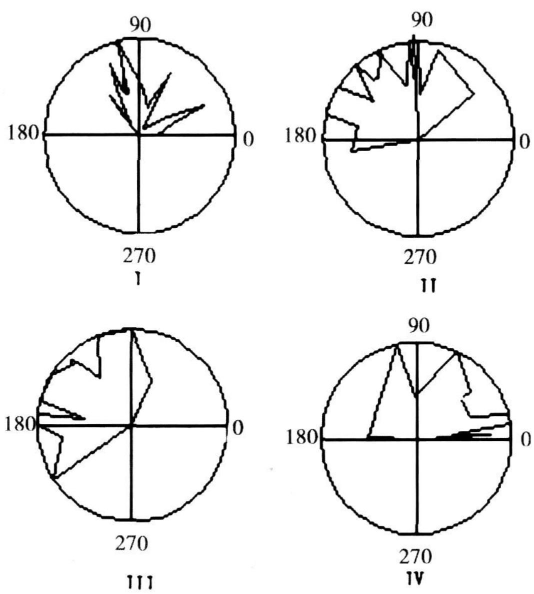

Fig. 4 Rose diagrams of the trend of long axis arrangement of gravels in part I, III, IV

Rose diagrams of the trend of long axis arrangement of gravels in part I, II, III, IV is shown in Fig. 4: (1) the trends of long axis arrangement of most gravels in part I, II and III belong to one certain direction and should result from one debris flow process, considering that part IV is on the front in cross-section analysis; (2) the trends of long axis arrangement of most gravels in part IV belong to another direction and should result from another debris process.

3.3 Size analysis

According to statistics, the average diameters of gravels in part I, II, III share similar and that of part IV is bigger than that of other three parts. It shows that the scale of debris flow resulting in part IV is bigger than that of debris flow resulting in part I, II, and III.

For the large amount of grain contained in the parts I and III than other parts, the granularity were measure in these two parts. The sorting is poor in part I and part III like 2.668 and 2.536. This has a well connection with the origination of deposition and reflect that the two parts deposition is from one debris flow process. The skewness of two deposition parts are −0.133 and −0.100, it show that the deposition were caused by the debris flow. The kurtosis is smooth in part I and part III like 0.771 and 0.75 and close to the normal distribution. It demonstrates the water power and debris flow are exist in the gully. Particle size analysis in part I and III (Fig. 5) shows that (1) particles in part I and II share common characteristics and they were formed in one debris-flow process; (2) the upper section of weigh cumulative curves is a continuum, smooth, and convex curve, which demonstrates the favorable sorting of particles; (3) There are multi-convexes in the frequency curves, which demonstrate that the debris flow was viscous and several different hydraulic phenomena occurred.

According to the roundness index classification index presented by Fork (Jiang Zaixing, 2003), the roundness value of most gravel in the part I, II, and III is 1 or 2, in another word, pointedness or sub-pointedness. And the roundness value of most gravels in part IV is 0 or 1, that to say, sharp-pointedness or pointedness.

There are obvious corrosion traces and pockmarks in surface of gravels. Corrosion traces were made when gravels scrubbed each other, and pockmarks were made when gravels stoke into each other during the transportation. Investigation shows that corrosion traces prevail on gravels in part IV, and pockmarks prevail in part I, II, and III. It is investigated that corrosion tra-

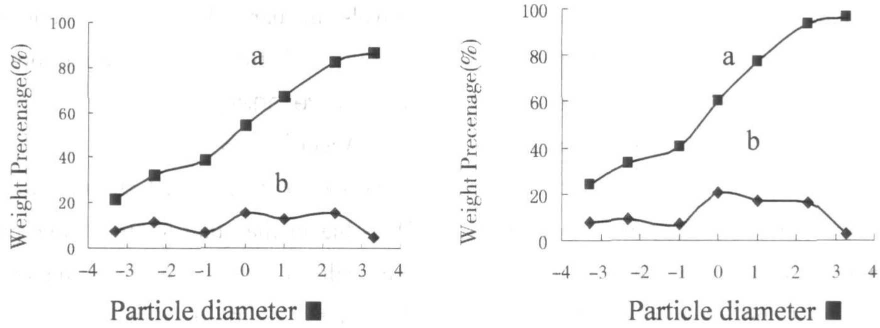

Fig. 5 Particle size curves in part I (left) and part III (right)
a weight cumulative curve b frequency curve

ces and pockmarks on gravels in part IV is more obvious than that of the other three parts, which also demonstrates the scale differences of debris flows.

Based on the analysis above, it can be concluded that (1) There were two debris flow processes, and the primary is water stone flow and the second is a viscous debris flow; (2) The formation of the fan resulted from the two debris-flow processes, and water-stone flow deposit formed the basement, the viscous debris flow deposited on the surface of the former, significantly change the morphology of the fan; (3) Part I, II, III exhibit characteristics of the viscous debris flow and part IV exhibits that of water-stone flow; (4) The scale of water-stone flow is greater than that of the viscous debris flow.

4 Development of the fan

4.1 Formation of the fan

The formation of the fan in Dalancha gully was closely related with the two processes of the water-stone flow and the viscous flow. The water-stone flow occurred in 1939. Because of 40 days long-duration precipitation, a huge amount of affluxion accumulated in the channel in the gully. The current remarkably eroded side slopes, resulting in slopes destabilization and caused landslide and slide, which supplied a great deal of solid matters. After the flux of flood reached a certain amount, gravels were transported greatly and began to slide or roll under the hydraulic power and gravitational force. And the current strongly eroded the matrix of the channel bed. About 200 m before reaching the mouth of the gully, the upper matrix was moved, thus the water-stone flow came into being. When reaching the mouth of the gully, the slope is slow, solid matters began to deposit as a form of fan. In the process of deposit, the deposition was influenced by the flood of the main channel of Xibailian ravine, the direction of deposition changed, and the fan shape became asymmetric (fig. 2). Also because of impediment of the deposit, the main channel of Xibailian ravin changed its course (Fig. 6). The viscous debris flow occurred afterwards, transporting many gravels, sands, and clays. When it arrives to the watershed mouth, solid matters deposit on the fan, resulting in a projection, and an increase of thickness of the fan. For it was not influenced by the flood in the main channel of Xibailian ravine, the deposition direction did not change, correspond to the flow direction of the main channel of Dalancha gully.

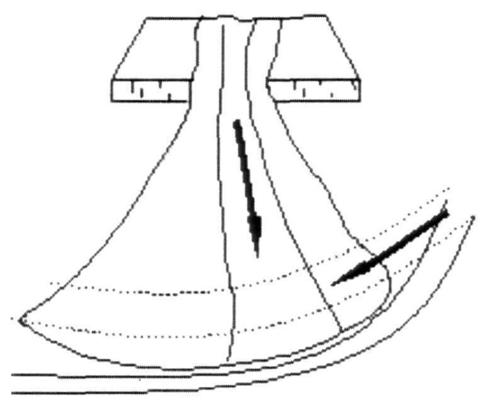

Fig. 6 Relationship between the fan and streams in Dalancha gully and Xibailian ravine

4.2 Evolution of the fan

The fan's evolution has a close relationship with the mainstream of Dalancha gully and the mainstream of Xibailian ravine. The base of the fan is composed by gravels, and the porosity ratio is great When arriving at the fan, the current becomes the underflow, eroding the matters in the inner part, thus changing the internal structure of the fan If floods occur in the gully, water current will overflow, eroding sands and clays on the upper part, changing the surface of the fan The main stream of Xibailian ravine flows along the brim of the fan, eroding the side, then changing the fan' s edge shape.

The protection of vegetations on the fan reduces the erosion intensity when overflows occur So it plays a negative role on the morphological change of the fan.

The probable debris flows afterwards and Earthquakes are also important factors influencing the evolution of the fan.

5 Conclusions

The investigation and data analysis of the debris flow formation progress and the fan deposition characteristics in Dalanshi gully has revealed some important baseline data

From the investigation and data analysis of the debris flow formation progress and the fan deposition characteristics in Dalanshi gully has revealed some important baseline data

(1) The morphology of the fan is divided into part I, II, III, IV. Part I, II, III result from the deposition process of a viscous debris flow, and part IV a water-stone flow, which can be seen from the analysis of size analysis, the trend of long axis arrangement of gravels and corrosion traces and pockmarks And the scale of the water-stone flow was greater than that of the viscous flow.

(2) The formation of the fan in Dalancha gully was closely related with the two processes of the water-stone flow and the viscous flow. The primary water-stone flow made the basic configuration of the fan, and the second viscous flow changed remarkably the exterior of the fan

(3) The fan' s evolution has a close relationship with the mainstream of Dalancha gully and the mainstream of Xibailian ravine After arriving at the fan, the current as a underflow in Dalancha gully erodes the solid matters in the inner part, changing the internal structure of the fan And the main stream of Xibailian ravine flows along the brim of the fan, eroding the side, changing the fan' s edge shape.

(4) Streams, floods, vegetarians, probable debris flows afterwards, earthquakes are important factors influencing the evolution of the fan

It is difficult to deduce changes in the inner of the fan because of underflow' s existing

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北京大烂碴沟泥石流堆积扇的特征及其演变过程

高甲荣, 胡封兵, 刘 瑛
(北京林业大学, 教育部水土保持与荒漠化防治重点实验室, 北京 100083)

摘 要: 北京山区由于山坡陡峻、构造发育、岩体破碎, 加上气候条件, 泥石流灾害的发生较为频繁。密云县是北京山区泥石流高发区, 冯家峪镇则是密云县泥石流发生最多的区域。密云县冯家峪镇西白莲峪历史上发生多次泥石流, 其流域自然地理条件复杂、泥石流堆积形态多样, 大烂碴沟泥石流堆积扇具有一定的代表性。研究泥石流堆积特征及其演变过程, 以期丰富北京山区泥石流基础资料, 同时对完善泥石流灾害防治的危险区区划有所裨益。

在收集当地泥石流发生历史资料的基础上, 详细的调查了西白莲峪大烂碴沟的自然地理状况和泥石流堆积物的特点。大烂碴沟上游沟谷剖面呈"V"形, 切割明显, 地形坡度一般在 32°以上, 而下游沟谷剖面呈"U"形。从泥石流形成的年代和冲刷痕迹推测, "U"形沟谷为泥石流冲刷形成。整个流域成扇形, 泥石流形成区面积为 0.58 km^2, 流通区面积为 0.09 km^2。大烂碴沟流通区沟道极短, 这样, 形成区汇集洪水到达流通区后, 严重冲刷沟谷坡脚, 破坏基岩的稳定性, 造成两岸岩石滑坡、崩塌和沟床岩石的整体性搬运, 从而形成泥石流。流域出口处有泥石流扇形堆积体, 砾石含量较多。

采用野外调查和室内实验结合的方法对大烂碴沟泥石流的堆积物特点进行研究, 具体如下: (1)地貌特征: 采用野外量测与填图的方法, 主要调查堆积扇的部位及其地形、沟道比降与宽度, 堆积物外部形态等。(2)结构组成: 主要有颗粒级配、岩性组成、砾石排列与分选性、堆积物的结构与构造特征, 以及粒态、擦痕、砾石包裹情况, 大漂砾粒径、堆积位置与排列等颗粒特征。砾石的调查通过在沟道内随机选取一定数量的砾石进行 abc长度和倾向调查。以上参数通过现场观测、测量取得。选定泥石流堆积区典型部位 I和 III, 通过挖圆形探坑, 取出全部颗粒。将颗粒直径大于 10 mm 的大颗粒筛出, 称重, 将剩余颗粒 1 kg左右带回实验室分析。粒度分析的主要方法为: 平均粒径比中值能更正确地反映碎屑颗粒的集中趋势, 按福克和沃德的平均粒径的表达式 $M_z = \frac{\phi_{16} + \phi_{50} + \phi_{80}}{3}$ 判别碎屑颗粒的集中趋势; 采用由福克和沃德提出的标准偏差公式 $\sigma = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$ 判别颗粒大小的均匀程度; 采用福克和沃德的偏度公式: $SK_1 = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$ 判别粒度分布的不对称程度; 峰度是用来衡量粒度频率曲线尖锐程度的, 也就是度量粒皮分布的中部与两尾端的展形之比, 采用福克和沃德提出的峰度公式 $K_G = \frac{\phi_{95} - \phi_5 + \phi_{80}}{2.44(\phi_{75} - \phi_{25})}$ 判别。在查阅历史资料和堆积物调查的基础上, 本文对大烂碴沟泥石流堆积扇的发育和演变过程进行了分析。

研究结果表明, 该区泥石流堆积扇的形成受到初次水石流和二次粘性泥石流两种泥石流形成过程的影响, 水石流形成堆积扇主体, 粘性泥石流则起到显著改变堆积扇形态特征的作用。大烂碴沟泥石流堆积扇的演变过程和特征明显受到大烂碴主沟和西白莲峪主沟水流的影响。从外部特征来看, 堆积扇可以分为 I, II, III和 IV四个区, 其中 I, II, III区表现为二次泥石流堆积特征, IV区表现为初次泥石流堆积特征。两次泥石流形成过程中固体物质的运动方式、搬运距离和侵蚀强度不同, 其堆积扇在不同分区的沙砾粒径、排列方向和圆度也反映出两次泥石流的形成特征。

该研究结果对今后进一步探讨北京山区泥石流形成机理和运动过程以及为北京山区泥石流防治制定有效措施提供了科学依据。

关键词: 堆积扇; 泥石流; 水石流; 北京山区