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Types and Space Distribution Characteristics of Debris Flow Disasters Along China-Pakistan Highway

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ABSTRACT

According to water source category, debris flow disasters along China-Pakistan highway can be divided into four types from north to south: freeze-thaw debris flows, glacial-glacial lake outburst debris flows, rainfall-glacial debris flows and rainfall debris flows. What is more, based on their some basic space distribution parameters, such as, latitude and altitude in the valley mouth and corresponding valley strikes et al, space distribution characteristics of debris flows disasters along China-Pakistan highway are researched. Therefore, research results may play theoretical guiding roles and some practical application values in appropriate choose and rational design of debris flow prevention and control engineering along China-Pakistan highway and route selection of China-Pakistan railway which may be built in the future.

KEYWORDS: China-Pakistan highway; debris flows; types; space distribution

INTRODUCTION

China-Pakistan highway (also known as the Karakoram highway, KKH or Pamir highway) is an international highway between China and Pakistan. It connects Thakot, the northern city of Pakistan, and Kash in the Xinjiang, China and runs approximately 1038 km, of which 618 km is in Pakistan. China-Pakistan Highway can not only be constituent part of Pakistan's national highway network, but also may be a part of the Asian highway network and the only overland passage from China to Pakistan, subcontinent of south Asia and middle east. Therefore, China-Pakistan Highway has important strategic and military significance.

REGIONAL ENVIRONMENT OF CHINA-PAKISTAN HIGHWAY

China-Pakistan highway is an international mountain highway of the highest altitude in the world. It locates in the inland of the Pamirs plateau and passes through Hindu Kush, Karakorum and Himalaya, which are the highest three mountain ranges.

Regions along China-Pakistan highway have very unique terrain and geological conditions. On the one hand, topographies are with north high and south low, high mountain peaks, deep canyons, active glaciers and torrential rivers in these areas; on the other hand, China-Pakistan highway is located in the Himalayan seismic zone, belonging to one of the world's three largest seismic zones, so tectonic activities are very strong and earthquakes often occur. According to incomplete statistics, there are 317 times earthquakes of more than 5 magnitude in the areas of China-Pakistan highway, including more than 7 magnitude earthquakes of 9 times, especially 7.6 magnitude earthquake happened on October 8, 2005, directly causing a large number of coseismal geological disasters, such as, landslides and collapses[1].Therefore, because of strong tectonic movements, folds and joints have being developed, and rocks are with damage structure, easy weathering and low shear strength, so rich loose solid materials are prone to produce and accumulate on the slope surfaces and deep valleys in the regions along China-Pakistan highway.

There are complex and changeable climate conditions in the study areas. Climates have vertical distribution characteristics along north-south direction. Climate in the south regions of Honza river valley is subtropical climate, whose annual precipitation concentrates in summer and changes commonly between 600mm and 1000 mm, and the maximum temperature is 46°C; while north areas of Honza river valley belong to typical inland mountain plateau climate zone with rarefied air, small rainfall, strong solar radiation and low temperature(the minimum temperature can reach minus 30°C)[2].

Partial sections of China-Pakistan highway have being suffered frequently by modern glacial activities, especially K550~K800.Lots of modern glaciers have being developed in the west Himalaya-Karakorum areas, such as, Batura glacier, Passu glacier, Gulmit glacier, Gulkin, and so on. Many geological disasters (glacial flood, glacial lake outburst, debris flows and dammed lakes) resulted from these glaciers activities may not only can seriously damage China-Pakistan highway, but also may cause huge property loss and casualties to local residents[3].

Complex and unique geology, geomorphology, climate and hydrology conditions make China-Pakistan highway as the very complicated geo-hazard collection site. Therefore, a lot of geological disasters have being distributed extensively along China-Pakistan highway, such as, debris flows, landslides, rock-falls, avalanches and gravel-sliding slopes, et al, and damaged disastrously highway and affected its normal operation[4-7].

Debris flows types along China-Pakistan highway

Debris flows along China-Pakistan highway is the most frequent and most serious type of geological disasters. According to water source category, debris flows disasters along China-Pakistan highway can be divided into four types from north to south: freeze-thaw debris flows, glacial-glacial lake outburst debris flows, rainfall-glacial debris flows and rainfall debris flows. Their distribution along China-Pakistan highway can be shown in the Table 1 and Fig.1.

Table1: Distribution of four types debris flows along China-Pakistan highway

debris flows types	distribution areas
rainfall debris flows	between Raikot bridge (K470 +500) and Daynore town (K538)
rainfall-glacial debris flows	from Daynore town (K538) to Hasnabard (K623)
glacial-glacial lake outburst debris flows	between Hasanabad (K623) and Gosghil (K796)
freeze-thaw debris flows	from Gosghil（K796）to Khongjirap (K811）

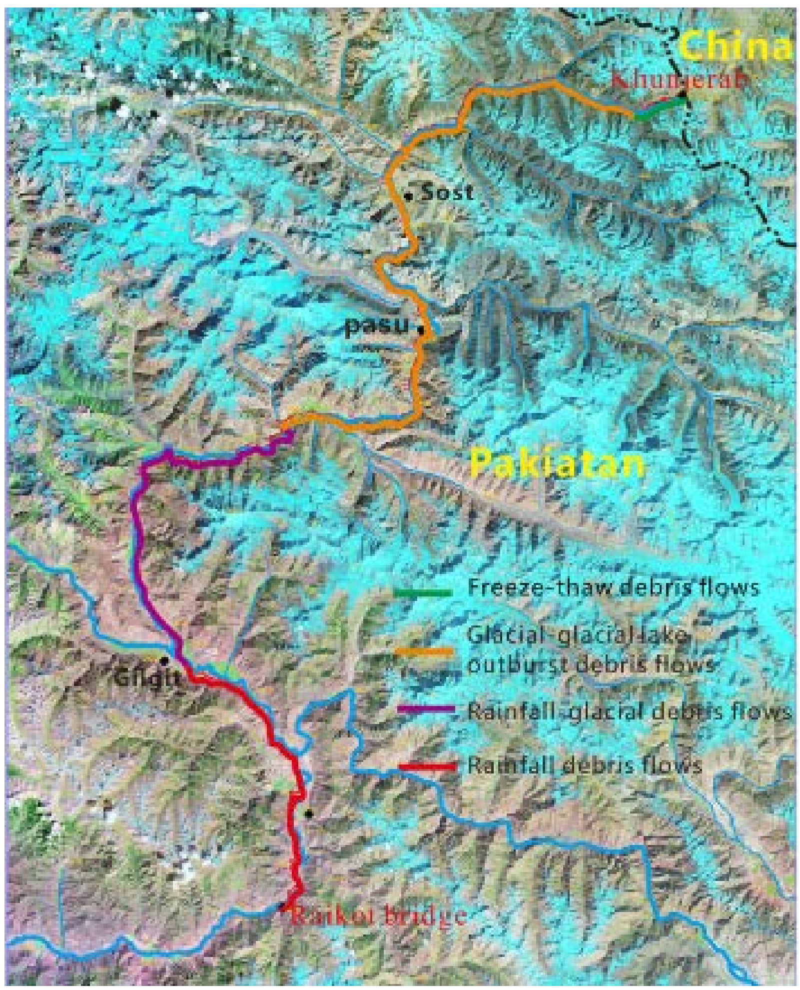


Figure 1: Distribution schematic diagram of four types debris flows along China-Pakistan highway

SPACE DISTRIBUTION CHARACTERISTICS OF DEBRIS FLOWS DISASTERS ALONG CHINA-PAKISTAN HIGHWAY

Obtaining basic primary data

Basic primary data on space distribution of debris flows disasters along China-Pakistan highway were obtained by the mean value on the basis of at least 3 measurement values measured with high accuracy instruments. Latitude and altitude in the debris flows valley mouth were get by GPSmap60CSx, while their corresponding valley strikes data were measured with the compass, which may be seen in the Table 2.

Table 2: Basic primary data on space distribution of four types debris flows along China-Pakistan highway

DFT	VN	ADFVM/m	VS/°	DFT	VN	ADFVM /m	VS/°	DFT	VN	ADFVM/m	VS/°
	1	1243	23		42	1438	216		83	1651	24
	2	1249	320		43	1441	205		84	1668	38
	3	1264	313		44	1430	166		85	1723	107
	4	1261	313		45	1443	186		86	1743	44
	5	1292	300		46	1440	234		87	1755	60
	6	1254	233		47	1450	196		88	1751	100
	7	1295	275		48	1431	236		89	1844	215
	8	1318	229	rainfall debris flows	49	1460	160	rainfall-glacial debris flows	90	1962	145
	9	1331	284		50	1485	231		91	1980	145
	10	1341	290		51	1522	334		92	1986	171
	11	1376	264		52	1524	226		93	1913	267
	12	1308	272		53	1527	174		94	1960	170
	13	1281	238		54	1474	233		95	2006	189
	14	1296	226		55	4341	329		96	1979	25
	15	1303	285		56	4385	15		97	2113	259
	16	1281	275	freeze-thaw debris flows	57	4405	159		98	2118	275
	17	1339	308		58	4422	330		99	2120	329
	18	1319	282		59	4443	11		100	2112	332
	19	1320	240		60	4568	334		101	2222	348
	20	1334	7		61	4718	328		102	2375	180
	21	1331	231		62	1512	76		103	2513	135
	22	1373	269		63	1507	18		104	2660	260
	23	1378	291		64	1507	49		105	2688	310
rainfall debris flows	24	1379	295		65	1515	38		106	2692	95
	25	1379	258		66	1517	48		107	2735	135
	26	1383	267		67	1518	26		108	2763	70
	27	1376	246		68	1517	30		109	2736	75
	28	1364	217		69	1513	37		110	2776	245
	29	----	244		70	1519	27		111	2841	309
	30	1365	205		71	1532	13	glacial-glacial lake outburst debris flows	112	2998	12
	31	1374	244	rainfall-glacial debris flows	72	1539	75		113	3052	123
	32	1378	265		73	1541	35		114	3274	85
	33	1416	228		74	1552	70		115	3341	220
	34	----	228		75	1547	70		116	3422	182
	35	1423	262		76	1575	75		117	3515	345
	36	1426	203		77	1582	95		118	3561	25
	37	1429	223		78	1575	65		119	3624	35
	38	1437	204		79	1600	90		120	----	36
	39	1432	210		80	1612	95		121	3853	311
	40	1443	241		81	1674	95				
	41	1450	216		82	1715	100				

Note: DFT--debris flows types, VN--valley number, ADFVM--altitude of debris flows valley mouth, VS--valley strike.

Distribution characteristics of latitude and altitude in the debris flows valley mouth along China-Pakistan highway

Distribution ranges of latitude and altitude in the valley mouth of four types debris flows along China-Pakistan highway can be shown in the Table 3.

Table 3: Distribution ranges of latitude and altitude in the valley mouth of four types debris flows along China-Pakistan highway

debris flows types	latitude distribution ranges in the valley mouth	altitude distribution ranges in the valley mouth
rainfall debris flows	N35°29′30″—N35°52′45″	1200-1500
rainfall-glacial debris flows	N35°55′30″—N36°16′30″	1500-2200
glacial-glacial lake outburst debris flows	N36°17′45″—N36°52′45″	2200-4000
freeze-thaw debris flows	N36°49′30″—N36°51′15″	4000-4800

From the Table 3, the following conclusions may be obtained:

(1) Freeze-thaw debris flows along China-Pakistan highway are mainly distributed in the regions of N36°49′~N36°52′ in latitude and above 4000 meters in altitude, which have typical high latitude and high altitude characteristic. Freeze-thaw actions are very obvious and frequent in summer; while in winter, the minimum temperature may reach -30°C, maximum snow thickness and maximum frozen soil depth were respective 1.5 and 0.5 meters. Thus, these regions are conducive to the development of freeze-thaw debris flows.

(2) Glacial-glacial lake outburst debris flows are commonly developed in the section with altitude range from 2200 to 4000 meters and latitude range between N36°17′ and N36°53′.The area belongs to inland plateau mountain climate zone, whose temperature is low and the annual average annual rainfall is less than 200 mm. What is more, rocks are bare and sparse vegetation in two sides of highway. On the one hand, many modern glaciers have being distributed in the summit and valley, such as, Batura glacier, Passu glacier, Gulkin, et al, and their precipitation increase rapidly with the increase of altitude[8-9]; on the other hand, there are many glacial lakes in the glacier. Therefore, abundant precipitation and outburst glacial lakes in glacier areas may provide adequate water supply conditions for debris flow disaster in this highway section.

(3) Rainfall-glacial debris flows are mostly induced in the areas of N35°55′~N36°17′ in latitude and 1500~2200 meters in altitude. Because of influence of the southwest monsoon in summer, rainfall is more concentrated. Moreover, some modern glaciers have being also distributed in the summit and valley on both sides of highway, such as, Kukuar glacier, Sat Marao glacier, Toltar glacier, and so on. As a result, water sources of debris flow disaster in this highway section have being mainly provided by mixed supply of rainfall, groundwater and snow melting.

(4) Rainfall debris flows generally occur in the section with altitude range between N35°29′ and N35°53′ and below 1500 meters in altitude. These regions belong to typical subtropical climate zone with more sufficient precipitation and higher temperature. So, debris flow disasters in these areas are mainly triggered by heavy rainstorms in summer.

Valley strikes distribution characteristics of debris flows disasters along China-Pakistan highway

Valley strikes distribution of four types debris flows disasters along China-Pakistan highway can be seen in the Fig.2.

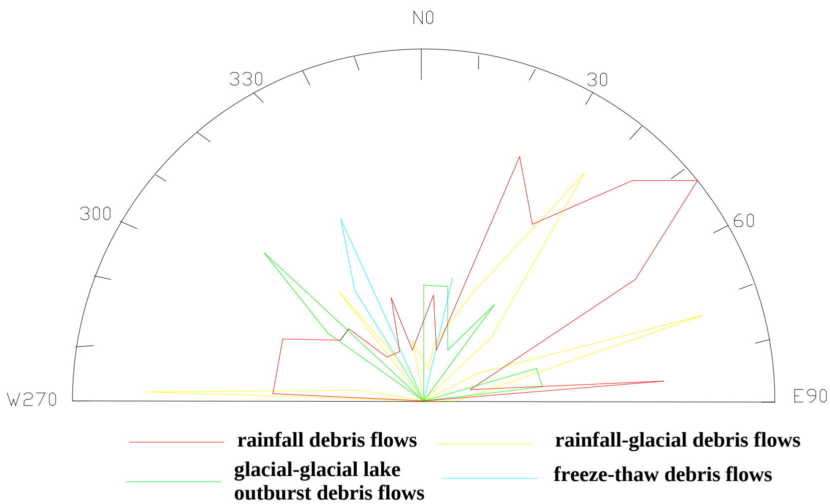
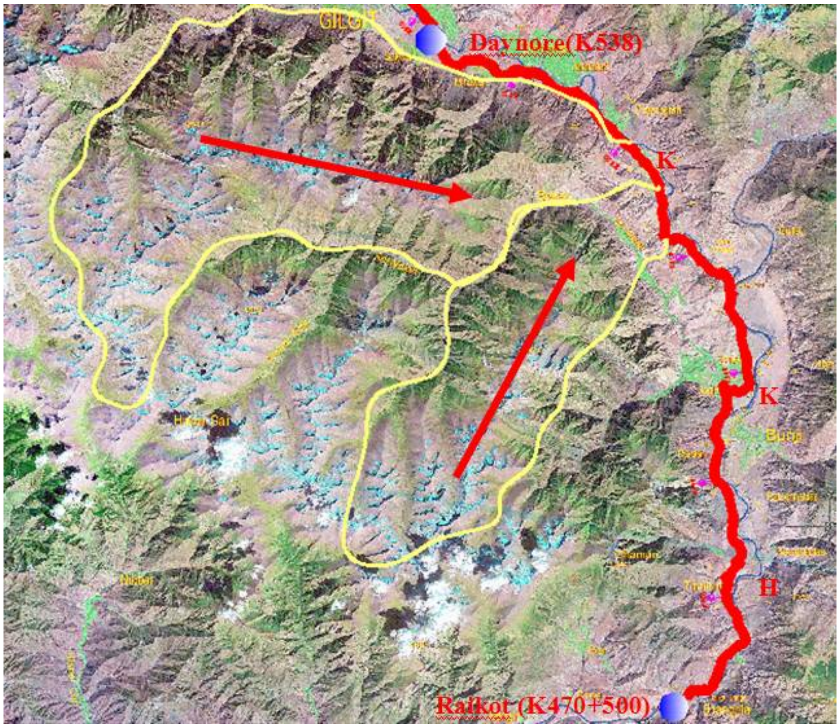


Figure 2: Valley strikes distribution of four types debris flows along China-Pakistan highway

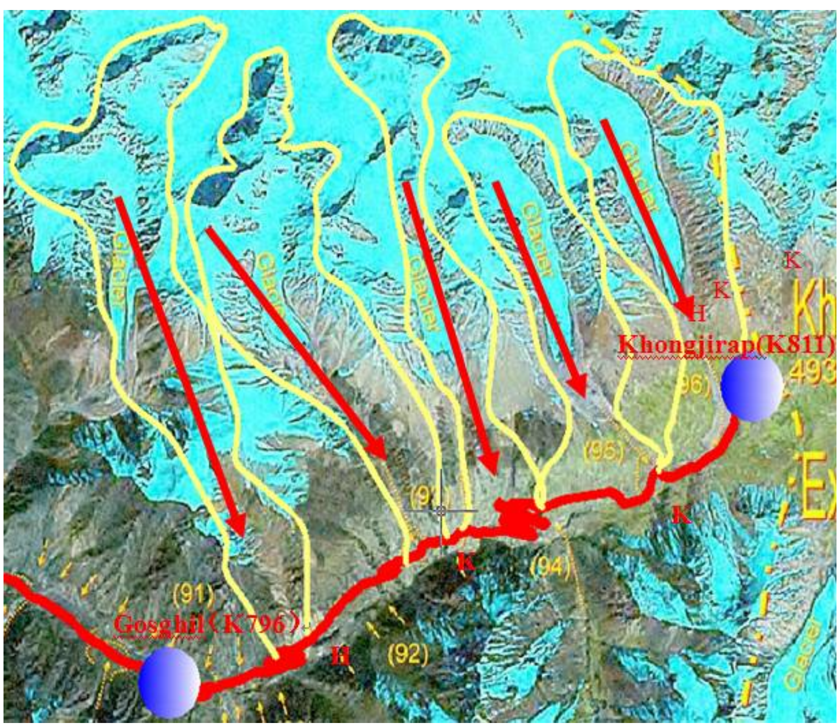
From Fig.2, it can be found following conclusions:

(1) Valley strikes of rainfall debris flows along China-Pakistan highway are mostly distributed in the range of north by east 20°~65° and north by west 45°~90°, while the vast majority of freeze-thaw debris flows valleys are developed along north by west 20°~35°. Valley strikes of these two types debris flows are commonly determined by catchments strikes of debris flows. According to the Fig.3, catchments strikes of debris flows between Raikot bridge (K470 +500) and Daynore town (K538) are both distributed in the direction of north by east and north by west, while debris flow catchments from Gosghil（K796）to Khongjirap (K811) are usually developed in the strike zones of north by west.

(2) Rainfall-glacial debris flows along China-Pakistan highway are mainly induced in the valley with strikes of north by east 20°~40° and 65°~80° and north by west 80°~90°, while valley strikes of glacial-glacial lake outburst debris flows are popularly distributed in the range of north by east 70°~85° and north by west 40°~60°.In general, their valley strikes are together determined by catchments strikes of debris flows and glacier strikes along China-Pakistan highway. From the Fig.4, most of glaciers strikes are distributed in the range of north by west, such as, Batura glacier, Passu glacier, Gulkin glacier, Gulmit glacier, Muchuhar glacier, et al; while a small amount of glaciers are developed along strikes zones of north by east, such as, E.Kukuar glacier, Sat Marao glacier, Toltar glacier, Baltar glacier, and so on.

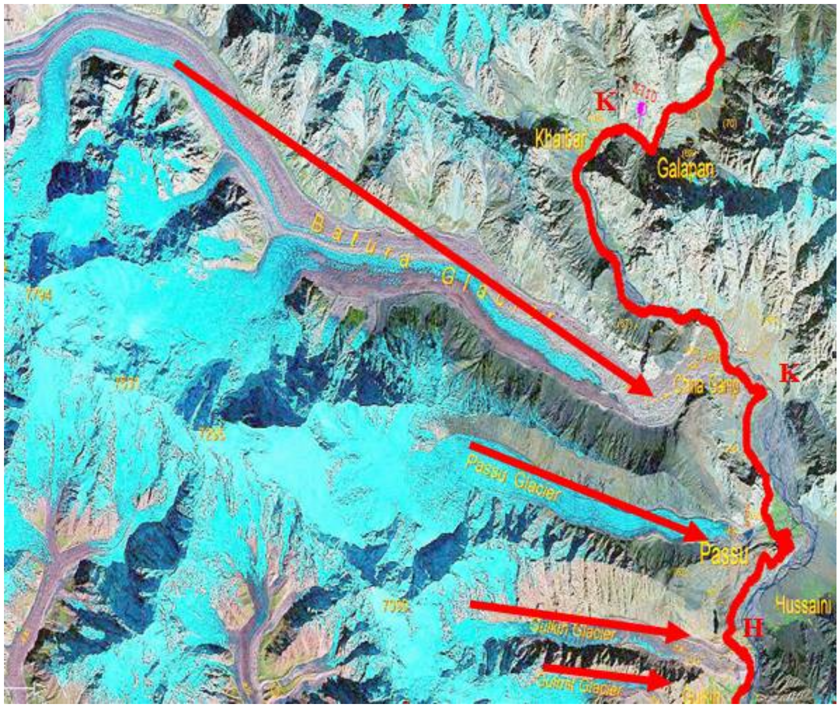


(a) Section between Raikot bridge (K470 +500) and Daynore town (K538)

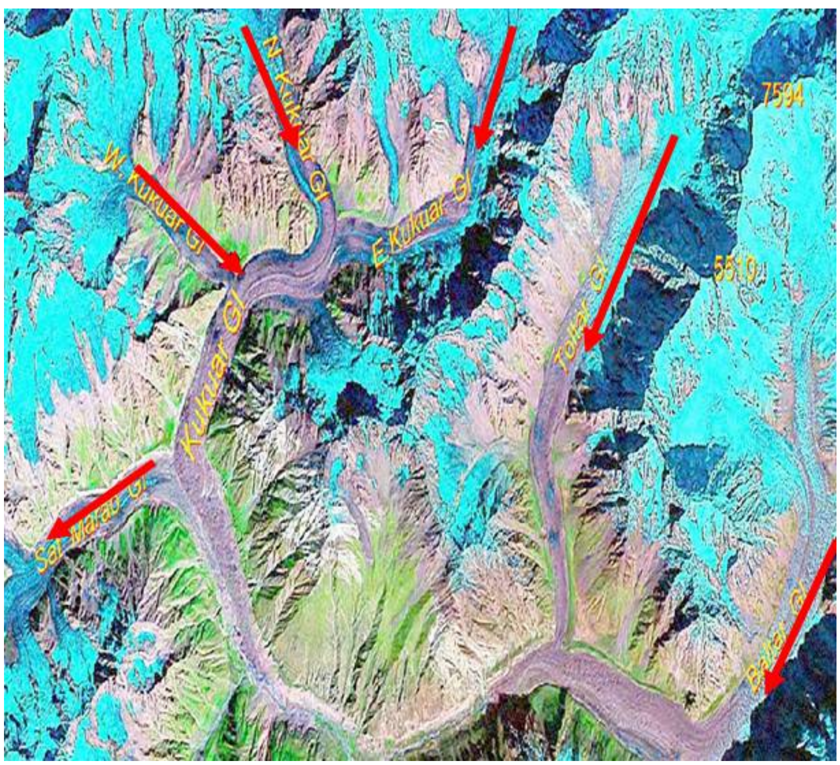


(b) Section from Gosghil（K796）to Khongjirap (K811)

Figure 3: Valley strikes distribution of debris flows along China-Pakistan highway



(a) Section between Hasanabad (K623) and Gosghil (K796)



(a) Section from Daynore town (K538) to Hasnabard(K623)

Figure 4: Glacier strikes distribution along China-Pakistan highway

CONCLUSIONS

In this study, the following conclusions are obtained:

(1) According to water source category, debris flows disasters along China-Pakistan highway can be divided into four types from north to south: freeze-thaw debris flows, glacial-glacial lake outburst debris flows, rainfall-glacial debris flows and rainfall debris flows.

(2) Freeze-thaw debris flows along China-Pakistan highway are mainly distributed in the regions of N36°49′~N36°52′ in latitude and above 4000 meters in altitude, glacial-glacial lake outburst debris flows and rainfall-glacial debris flows are commonly respectively developed in the section with altitude ranges of 2200~4000 meters and 1500~2200 meters, and latitude ranges of N36°17′~ N36°53′ and N35°55′~N36°17′, while rainfall debris flows generally occur in the areas with altitude range between N35°29′ and N35°53′ and below 1500 meters in altitude.

(3) Valley strikes of rainfall debris flows and freeze-thaw debris flows along China-Pakistan highway are mostly distributed in the range of north by east 20°~65° and north by west 45°~90° and 20°~35° respectively, which are commonly determined by catchments strikes of debris flows; while rainfall-glacial debris flows and glacial-glacial lake outburst debris flows are mainly induced in the valley with strikes of north by east 20°~40° and 65°~85° and north by west 40°~60°and 80°~90°, and then their valley strikes are together determined generally by catchments strikes of debris flows and glacier strikes along China-Pakistan highway.

Research results of this thesis may play theoretical guiding roles and some practical application values in appropriate choose and rational design of debris flow prevention and control engineering along China-Pakistan highway and route selection of China-Pakistan railway which may be built in the future.

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