A catastrophic debris flow near Gupis, Northern areas, Pakistan

Un écoulement des déchets catastrophique près de Gupis, Pakistan du Nord

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SYNOPSIS Debris flows, mudflows, landslides and rockfalls are a frequent occurrence in the Karakoram region of Northern Pakistan. Periodically these have been of such major proportions that they have dammed the river Indus or its tributaries. Sometimes when the dam has burst subsequently there has been serious flooding downstream. In July 1980 a catastrophic debris flow blocked the Ghizar river near Gupis, about 130 km west of Gilgit. Over a period of 30 hours waves of mud up to 5 metres high periodically surged down a side valley at estimated speeds of 100 km/hr, and formed a natural dam about 30 metres high. A lake quickly built up extending 5 km up-stream. The causes and nature of the debris flow are described together with the behaviour of the dam during the period following overtopping.

INTRODUCTION

In recent years there has been increasing attention to the causes and behaviour of debris flows so that their occurrence can be predicted and steps taken to prevent them or ameliorate their effects. (e.g. Johnson, 1970). Debris flows, landslides and rockfalls are a common occurrence in the remote high and mountainous terrain of the Karakoram region of Northern Pakistan, and a study of the geomorphological activity in the Hunza Valley was undertaken as part of the International Karakoram Project 1980 organised by the Royal Geographical Society (Goudie et al 1983). By chance a major debris flow was observed in the Ghizar Valley elsewhere in the region and this event is described here.

THE GHIZAR VALLEY

The Ghizar Valley (2000-2500m) is a deep steep-sided sediment-floored glaciated valley situated in the west of the Karakoram region (see Fig. 1a). On either side the barren mountains rise to 4500-5500m with some of the highest peaks snow covered even in summer. Near Gupis the valley floor consists of low angle fans which formed from outwash and debris flow deposits through which the river has cut a broad flood plain. In many places glacial deposits and scree slopes have formed above the fans. The valley floor is arid with a mean annual rain fall recorded at Gupis of only 117mm, and with diurnal temperatures ranging from +18°C to +32°C in July and August, and -5° to +5°C in January and February.

The Ghizar river drains a catchment of 4000 km^2, part of the Upper Indus Basin. Near its confluence with the Yasin river at Gupis it is about 50 metres wide and is a pale turquoise blue indicating a low concentration of suspended sediment, in contrast to the dirty grey of the Yasin river. As much of the flow is derived from snow and glacier melting, the discharge shows a minimum in winter and a maximum in July and August. Based on the records for the Gilgit river it is estimated that the summer discharge averages 170 cumec, and the annual discharge averages 70 cumec (equivalent to 550 mm annual precipitation).

PREVIOUS DEBRIS FLOWS IN THE REGION

The area is extremely arid, and storm generated precipitation falling on the steep poorly vegetated slopes results in rapid run off. As there is a plentiful supply of non-lithified superficial debris produced by weathering, slope degradation, and glacial and aeolian processes, there is a widespread occurrence of debris flows. These range in size from short narrow runnels on scree slopes to catastrophic events produced by flash flooding in storms or by sudden release of glacial melt-water (e.g. at Sheeshkat, Hunza 1976 (Goudie et al, 1983) and Gupis (this paper)). Such debris flows pose a major hazard to the local people, as they frequently destroy roads, housing, animals and agricultural land, and occasionally form natural dams.

Two types of natural dam are of relatively frequent occurrence in the Upper Indus Basin - landslide dams, and ice dams formed by the rapid advance of glaciers (Hewitt, 1982). Bursting of natural dams has often resulted in catastrophic flooding downstream. The principal landslide dams which have been recorded in historic times are shown in Table 1 but there is field evidence of the remains of many others.

TABLE 1

Some Landslide Dams in the Upper Indus Basin (Hewitt, 1982, Goudie et al, 1983)

Date	River	Cause	Details
1841	Indus	landslide/ rockslide	300m high 55km long lake drained in 24 hrs on overtopping. Major floods.
1858	Hunza	landslide/ rockslide	? 100m high 45km long lake drained suddenly on overtopping. Major floods.
1931	Indus	landslide	Drained slowly.
1976	Hunza	debris flow	20m high 12km long lake persisted despite attempts to breach dam.
1980	Ghizar	debris flow	30m high 5km long lake persisted.
1981	Gilgit	debris flow	5m high 0.5km long lake drained.

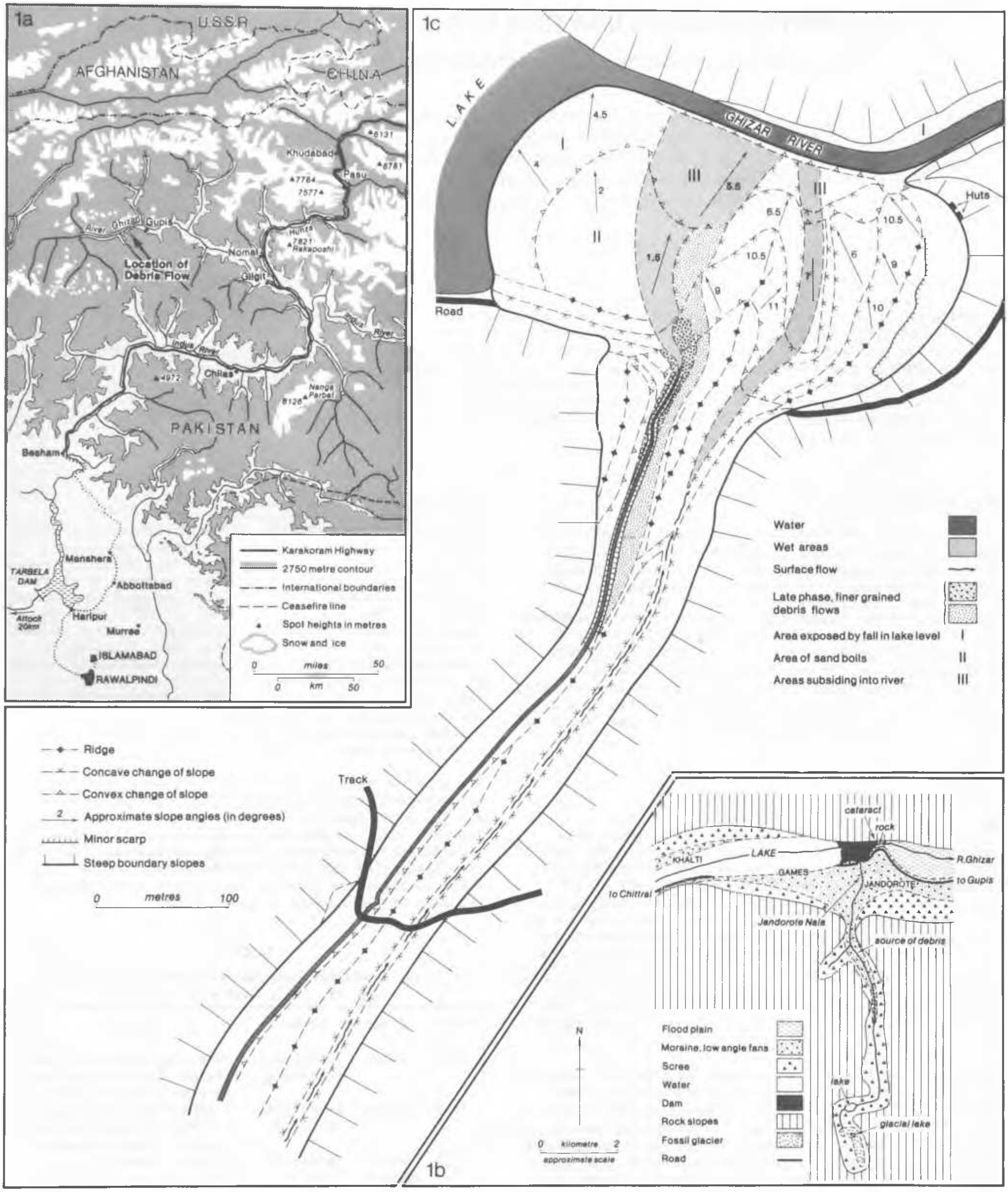

Fig 1: a) Location Plan. b) A sketch plan made before the overflow of the lake had taken place.

c) Detailed survey of the lower track, lobe and lake overflow, measured on 6th August 1980.

DESCRIPTION

The debris flow occurred about 5 km west of the confluence of the Yasin and Ghizar rivers, at a point where the Ghizar river flows through a narrow rocky cataract (see Fig. 1b). Upstream and downstream from the gorge the river crossed alluvial plains bounded by low angle fans to the south and rocky slopes to the north. Emerging from a side valley to the south, the Jandorote Nala joined the river just upstream of the cataract. With a normal summer flow similar to a mountain stream, the Nala flowed down a deep channel cut through the fan, approximately 80 metres wide at its base. Local people had constructed a dozen channels to tap the water for irrigation purposes. The road from Gilgit to Chittral crossed the Nala where it emerged into the main valley. At the time of the debris flow the weather was fine and there had been no significant rainfall in the area for some weeks previously. There were no earthquakes felt or recorded in the area that day.

At approximately 1630 hrs on 27 July 1980 a wave of mud and boulders swept down the Nala destroying crops, houses and livestock as well as the road, flowed across the alluvial plain and blocked the Ghizar river. Eyewitnesses said there was no warning and that thereafter waves of debris emerged very frequently so that the flow was almost continuous. By next morning (1100 hrs) when two authors (DN and REH) arrived the waves were arriving about four times per hour. The first indication of an approaching wave was aural giving 1½ to 2 minutes warning (the source was about 3 km away). Soon the wave could be seen slewing from side to side of the channel as it went round bends until with a deafening roar it reached the bottom of the Nala. At this point the wave was the full 80 metres width of the channel, up to 5 metres high and travelling at speeds of perhaps 100 km/hr, throwing up debris and boulders as it passed (see photos Figs. 2, 3). The wave then spread out when it reached the surface of the landslide dam which rose and fell like jelly. The scene closely resembled a breaking wave passing through the narrow entrance to a tidal inlet. When all the movement had ceased the surface of the fresh debris was firm enough for people to cross the Nala, and the debris had the consistency of a freshly mixed concrete.

By that evening the frequency and size of the waves had diminished and a flow of water and mud had started, eroding the surface of the debris track. At this time the dam was about 30 metres high, 200 metres along its axis with the downstream toe right through the rocky gorge. The maximum slopes of the dam were determined with an Abney level as 3.5 to 4° while the average slope of the debris track was 11.7°. A lake had formed which extended upstream about 5 km covering two villages and rendering 500 people homeless. At about midnight the dam was overtopped, but the level only dropped gradually at the dam eroded. There was no flooding downstream.

Over the following three days the river cut down the surface of the dam and the lake dropped by about 1 metre. During this time the topography of the dam changed significantly and the crest slope increased to 10° near the river. Standing water appeared on the surface of the

Figs 2a), 2b): General views of landslide dam and debris track.

Figs 3a), 3b): Views of debris waves emerging from Nala and spreading across dam.

dam and in places there were numerous sand boils. The surface of the dam and the lower part of the debris track was surveyed during the period 4 to 6 August and this survey is shown in Fig. 1c.

The day after the dam overtopped a reconnaissance was made up the side valley (see Fig. 1b). The lower part of the valley was inaccessible as a 30m deep gorge had been eroded in the moraine which formed the valley floor. At this point the average slope of the valley floor was about 20°. Further up the side valley the moraine was covered by scree and boulders and there had been little erosion. At the head of the valley there was a debris covered relic glacier within which was a lake estimated to be 80 metres in diameter. There were clear signs that the lake level had recently been 20 metres higher, at a level above the lowest part of its rim, suggesting the presence of a lake alongside the glacier. Shepherds who had been in the lower part of the side valley at the time spoke of a sudden flood which built up so quickly that people fled for their lives. They were only able to cross over again after 24 hours. By the time of the reconnaissance the Nala was back to its normal flow, which mostly came from melting of the glacier.

PROPERTIES OF DEBRIS

The debris was derived from the moraine that lined the base of the side valley. The geology of the area consists of two main units - the Rakaposhi volcanic complex forming the sides of the Ghizar valley, and the granodiorite of the Ladakh Intrusives up the side valley to the south (Tahirkheli, 1982). The moraine was derived mostly from the Ladakh granodiorites, and although the flow moved over the Rakaposhi volcanics, they were generally not incorporated.

The debris consisted of boulders cobbles and gravel in a silty micaceous sand matrix. The majority of the boulders were less than 0.5m in diameter but there were occasional boulders of at least 3m diameter. Particle size distribution analyses of samples of the matrix showed typically clay 1% silt 4-6%, sand 47-70%, gravel (<32mm) 25-47%. 100mm shear box tests on the fine fraction of the matrix (<6mm) placed wet showed a residual angle of shearing resistance at constant volume of 37°. Unfortunately it was not possible to determine the moisture content of the in-situ material, but from laboratory tests it may be inferred that the moisture content of the matrix lay in the range 15-20%.

DISCUSSION

This valley confined debris flow is similar to events described in many other arid mountain regions. Full summaries are given by Johnson (1970) and Brunsden (1979). The glacial lake at the head of the side valley appears to have burst quite suddenly with no obvious cause, the lake partially drained and then the burst closed again. Known in Iceland as a Jökulhlaup this phenomenon is thought to be caused by hydraulic fracture of the ice. Although there was no indication that it had happened before here, glacial lake bursts have recurred elsewhere causing successive debris flows. During the debris flow eyewitnesses indicated that the water flow in the side-valley was continuous for 24 hours, but there was no flow of water in the lower part of the Nala between the debris waves until the main flood higher up abated. It was not possible to observe the formation of the debris waves but at low moisture contents the debris is highly dilatent, and only when it reached a critical moisture content would it be sufficiently mobile to flow down the 20° channel. The pronounced pulsing is a characteristic of debris flows with high sediment concentration. It can be caused by the mobile debris suddenly bursting through a bouldery snout of a debris mass. During the period of observation each pulse passed in a few seconds with a pronounced breaking wave at the front, leaving the channel firm and motionless behind it. This contrasts with the extended laminar flow that has been observed in debris flows elsewhere, e.g. at Wrightwood (Johnson, 1970).

It is clear that high pore pressures were present in the landslide dam. The limiting slope of the dam during deposition was around 4° which implies an r_u value of 0.9 if an infinite slope analysis is applied. Once the dam was overtopped the river started to cut a channel down through it, but with high pore pressures still present the debris flowed in to the channel to choke the flow. This limited the rate at which the channel could be cut down, thus avoiding catastrophic flooding downstream. After three days the pore pressures had dissipated sufficiently that the limiting slope had increased to 10°, but the river still did not deepen its channel rapidly, presumably due to the presence of boulders from the debris in the channel bed. Recent reports (1984) indicate that the dam and lake still persist, in contrast to the landslide dams of 1841 and 1858.

CONCLUSIONS

This valley confined debris flow is similar to events described in many other arid mountain regions, although few have been attributed to glacial lake bursts. The serious consequences of such flows point the need for improved warning and control measures. A recurrence of debris flows at Gupis is possible, and warning could be given by monitoring the level of the glacial lake. Drainage could be installed to limit any future rise of lake level. In the Karakoram region a remote sensing survey could be undertaken to identify potentially hazardous areas, followed by field geomorphological surveys and the preparation of hazard maps. These could then be used as part of the input to future development programmes in the region.

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