AVALANCHE HAZARD IN KAGHAN VALLEY, HIMALAYA RANGE, PAKISTAN[1]

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Abstract.--Avalanche hazard in Kaghan Valley, Himalaya Range, Pakistan is being investigated. Long, steep slopes and heavy winter snowfall combine to produce frequent avalanche activity. Individual paths and events attain extremely large sizes by most recognized classifications. Usual approaches to hazard investigation such as mapping of paths is made difficult by landscape alteration by centuries of intensive agricultural land use. While local inhabitants have adjusted well to avalanches, including recognition of beneficial aspects, developments by outsiders are increasing the overall levels of risk in Kaghan.

INTRODUCTION

Avalanches have been under study in mountainous, developed countries since, in some cases, the eighteenth century, primarily in response to the hazard they pose to transportation, recreation, mining and habitation. However, with the exception of Chile (Atwater, 1968) there has been very little work on, or even awareness of, avalanche hazard in mountainous developing countries. Apart from the impact of avalanches on high altitude mountaineering, little has been written on this hazard in the Himalaya - Karakoram - Hindu Kush Mountains. Yet avalanches in this densely populated mountain region are a fact of life for human activity in some areas. The purpose of this paper is to describe the avalanche hazard in Kaghan Valley, in the Himalaya Mountains of northern Pakistan.

Avalanche hydrology and hazards are being investigated in Kaghan Valley as part of the Snow and Ice Hydrology Project, a joint undertaking between the International Development Research Centre (Canada), the Water and Power Development Authority (Pakistan), and Canadian Universities. While the study of avalanche hazards does not relate directly to the general aim of this large project, which is to create a better understanding of the glacial and nival sources of such major and vitally important rivers as the Indus, Jhelum and Chenab, it is becoming increasingly important to the Pakistani government because of interest in tourism and hydro power development in the mountainous areas and in strategic matters (with reference to the nearby Indian border).

RESEARCH AREA

Kaghan Valley extends in a northeasterly direction through the front ranges of the Himalaya to link the plains of Pakistan with the Gilgit area. Prior to the building of the Karakoram Highway through the Indus River gorge, Kaghan Valley provided the only vehicle access into the northern areas despite being closed every winter for up to six months by heavy snow and avalanche activity. The valley, which begins at the 4173-metre high Babusar Pass, forms along its 150-kilometre length the dividing line between the Indus gorge and mountains of Indus Kohistan to the west, and the mountains of Kashmir and the present border with India to the east (fig. 1).

Like much of the tectonically active Himalayan chain, the topography of Kaghan Valley is extremely rugged. This has been accentuated by glacial and fluvial erosion. Valley-side relief is on the order of 2000 metres. Valley bottom elevations range from 900 metres in Balakot to over 4000 metres at Babusar Pass, but most of the avalanche activity occurs between 2200 and 2900 metres. Peak elevations in the immediate vicinity of the valley attain 5260 metres.

Kaghan Valley is host to a wide variety of vegetation from extensive terrace cultivation of rice and wheat in the lower reaches where little natural vegetation remains, to alpine tundra in the upper reaches. In the middle valley where most of the avalanche paths are found, the valley bottom is heavily cultivated with potatoes and maize or used for pasture, with slopes above having a forest cover of various coniferous species. Above this are extensive areas of generally steep and heavily grazed alpine tundra.

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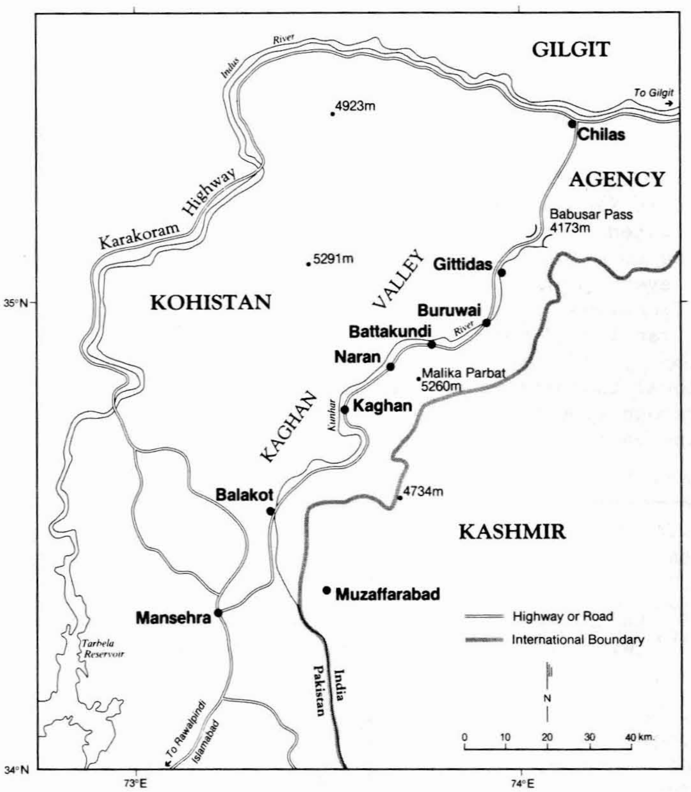

Figure 1. --General location of Kaghan Valley.

The elevation of the actual climatic treeline is difficult to determine because of extensive deforestation resulting from wood cutting and grazing. East- and southeast-facing slopes are generally much drier than west- and northwest-facing ones, and often have a sparse vegetation cover consisting of xeric species such as sage-brush.

Kaghan Valley, being located on the south slopes of the Himalaya Range, is well watered in contrast to the extremely arid valleys immediately to the north and west. Its climate can be divided into two main components on the basis of moisture supply. From June to October most precipitation is brought by the Indian monsoon, whereas the winter period from November to May sees most precipitation produced by disturbances associated with a high level westerly airstream (Binnie, Deacon and Gourley, 1958). These disturbances bring very heavy snowfalls to the valley above approximately 1000 metres. Unpublished snow survey reports dating as far back as 1920 describe heavy rain to be commonly associated with such snowfalls. Between storms the skies are generally very clear and large diurnal variations in temperature are common (Binnie, Deacon and Gourley, 1958)(fig. 2). During the winter winds are predominantly westerly, and result in snow accumulation patterns which follow the overall pattern of the topography (Binnie, Deacon and Gourley, 1958). This is reflected in large differences in snow water equivalents over elevation; data from 1961 to 1968 indicate a 150% increase in 800 metres of elevation gain (Water and Power Development Authority, 1969). Total November to April precipitation in the valley bottom averages 1060 mm in Naran (middle valley), with lowest totals recorded from November to January and a peak of 340 mm being reached in March (Water and Power Development Authority, 1969). The snowpack begins to develop in early November and reaches peak depths of anywhere from 26 to 160 cm water equivalent in the valley bottom at Naran (2400m) in March or April. At Lake Saiful Maluk (3200m) above Naran, peak depths of 205 cm water equivalent occur from early April to May. The snowmelt period is extremely rapid and by early May the entire snow cover has generally disappeared from the valley bottom. At higher elevations (3200 - 4000 m) snow can linger until June even though rapid melting also occurs.

GENERAL AVALANCHE PATH CHARACTERISTICS

Avalanche paths descend to the valley floor from the village of Kaghan to about as far north as Gittidas, where the valley widens (fig. 1). In May, 1986 more than thirty avalanche deposits lay across the road between Kaghan and the village of Battakundi. However, the largest concentration of paths is in the vicinity of Naran and, in fact, several parts of the village are threatened (fig. 3). Generally, the largest avalanche paths are located on east-facing slopes of the valley up to five kilometres north of Kaghan, and beyond this almost exclusively on the west-facing side. While this may be inconsistent with the prevailing winter winds (westerly), the answer probably lies in the steep altitudinal gradients of precipitation: north of Kaghan the west-facing slopes of the valley rise to a much greater height than the east-facing ones and thus receive greater amounts of snowfall. The exception is in Naran itself where a high ridge rises on the west side of the village. But in general the west-facing slopes show much evidence of a deeper snow cover and ensuing positive moisture balance, such as a lush and varied vegetation cover and numerous springs and streams. Observations in the spring of 1986 agree with this hypothesis that valley-side relief is a more important determinant of avalanche activity than exposure to wind; paths of all aspects that do not have a great relief had disproportionately small or a non-existent deposits on them.

Small avalanche paths in Kaghan Valley are either located on unconfined slopes or in shallow basins. Their starting zones are usually below the treeline if forest is present, with the starting zone composed of a variety of terrain ranging from bare rock to brush and immature conifers. The tracks are rarely gullied or very confined. The runouts generally extend only a short distance onto the valley bottom, or terminate in the Kunhar River. Large avalanche paths in Kaghan Valley are associated with a variety of other types of geomorphological activity, including streamflow, mudflows, landslides and debris torrents. Thus the

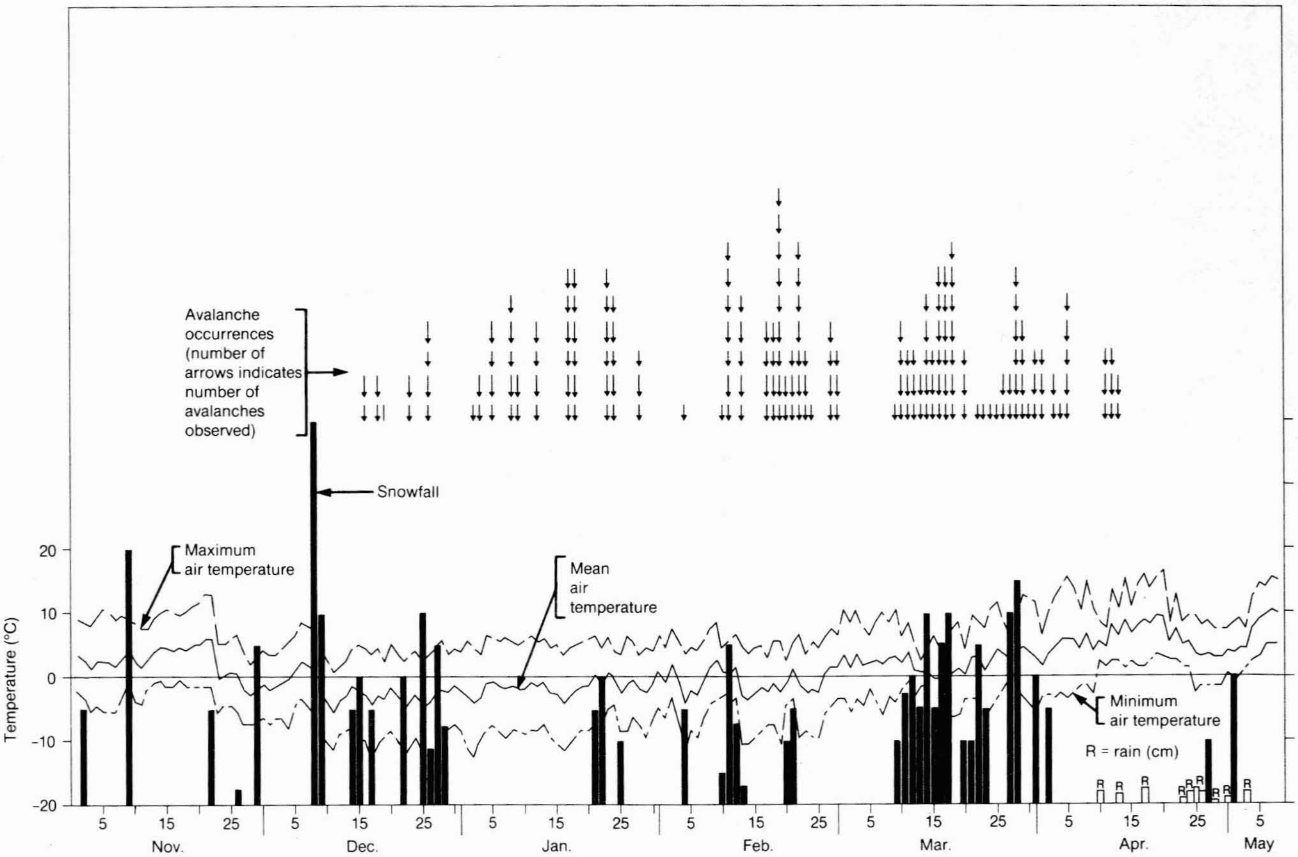

Figure 2. --Snowfall, daily air temperatures and avalanche activity, Naran/Battakundi area, Kaghan Valley, winter 1985-86.

winter period is not necessarily the only period of hazard at these locations. The starting zones are generally well above treeline and consist of numerous sub-basins for each path (fig. 4). They rarely have anything more significant than a heavily grazed alpine tundra for cover. The tracks are in all cases confined by deep gullies, which are often broken by cliffs. The runouts generally are on debris fans which have been formed by either floods or debris torrents. Because the Kaghan valley is very narrow in the middle reach, many of the large paths extend across its floor and up the opposite slope. Large avalanches frequently dam the river for up to two days. The boundary between the track and runout zones on paths of all sizes is often associated with a slope inflection, and in fact well developed impact pits or avalanche tarns such as described by Corner (1980) and FitzHarris and Owens (1984) are common.

Valleyside relief in the Naran area is in the order of 2000 metres (west-facing slopes) and as a consequence vertical falls on avalanche paths range up to about 1900 metres. Of the twenty-nine paths in Figure 3, nine have vertical falls greater than 1000 metres. Path gradients are generally steeper for small paths than for large ones; for twenty small paths measured in the Naran area, gradients range from 24^{o} to 38^{o}, with a mean of 33^{o}. For thirteen large paths, gradients range from 26^{o} to 34^{o}, with a mean of 29^{o}. For the very large, multi-branched paths, gradients are appreciably lower than this. As a consequence, they are able to build up larger masses of snow before release. Ten paths in the Naran and Battakundi area were surveyed in detail for purposes of avalanche hydrology investigations. Starting zone gradients on these paths range from 32^{o} to 43^{o} with a mean of 36^{o}; track gradients range from 22^{o} to 34^{o} with a mean of 29^{o}; and runout gradients range from 5^{o} to 17^{o} with a mean of 10^{o}. Runout zone gradients are difficult to measure accurately because these often terminate in an abrupt scarp and drop into the Kunhar River. The catchment areas (starting zone and track surface area) of these paths were also surveyed, and found to range from 51,000 m^2

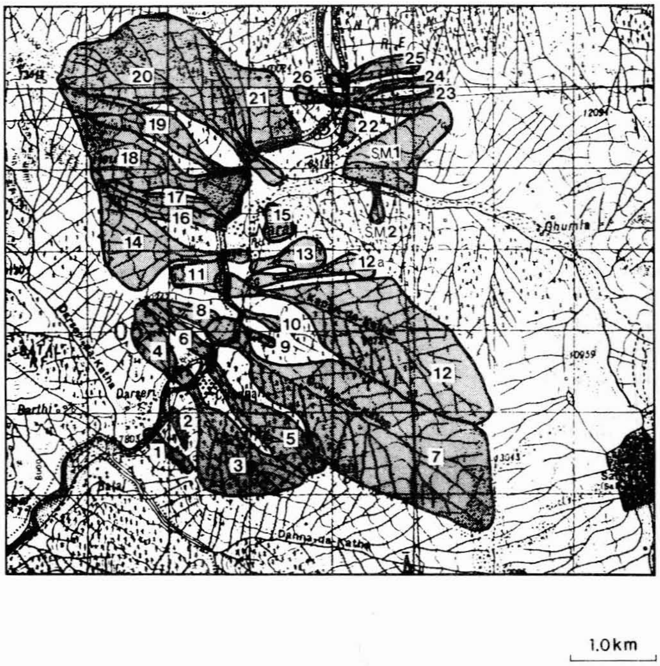

Figure 3.--Avalanche paths in the vicinity of Naran, Kaghan Valley. Paths with the prefix S.M. are located in the Saiful Maluk side valley.

to 5,324,000 m^2. Vertical falls on these paths range from 317 to 1715 metres. The catchments of the multi-branched paths were found to be particularly large; two of the largest, with respective vertical falls of 1715 metres and 1580 metres, were 5,324,000 m^2 and 4,403,000 m^2 in area (fig. 4). These compare with maximum catchment areas in the order of 560,000 m^2 at Rogers Pass, British Columbia (Schaerer, 1985).

PATH IDENTIFICATION AND MAPPING

Compared with European and North American experience (e.g. Martinelli, 1974), identification of avalanche paths and hazard zones in Kaghan Valley is extremely difficult. This is due in large part to the alteration of the landscape through centuries of intensive land use. Such identifiers as forest trimlines along avalanche paths are often missing due to deforestation or because the avalanche paths and hazard areas are situated above treeline. The runout zones are particularly difficult to delineate because of the intensity of human activity in the valley bottoms. Morphological identifiers such as boulder tongues, debris tails, and perched rocks in these areas are missing because they are cleared annually for potato and maize cultivation. Broken timber in tracks and runout zones is quickly gathered for firewood, a scarce commodity. Vegetative evidence of avalanche activity (snapped limbs, scarring etc.) is in general extremely difficult to distinguish from damage done by humans and grazing animals. In addition, many avalanches terminate in the Kunhar River which during spring flows, quickly disposes of avalanche deposits and other evidence. Thus avalanche path identification must rely largely on topographic characteristics such as slope gradients, the presence of open basins and gullies which act as starting zones and tracks, the presence of fans which serve as runout zones; on late-lying avalanche snow deposits; on local knowledge; and on the occasional damaged or destroyed buildings. The presence of undamaged buildings, however, does not always indicate an absence of even frequent avalanche activity, because indigenous dwellings built on avalanche paths in Kaghan Valley are constructed so that avalanches pass over them without damage.

While direct winter observations are the best means of obtaining information on avalanche activity in Kaghan Valley, they are highly impractical because the entire valley above Kaghan village is cut off and depopulated for the winter. Valuable observations can be carried out in spring as soon as the road is open to jeeps; such work was carried out in 1986. However, one serious problem of estimating avalanche travel distances came to light, and is the result of the rapid ablation which begins in March in the valley bottom. While mid-winter dry snow avalanches travel much greater distances than spring-time wet snow releases and in addition may be accompanied by destructive wind blasts, their deposits quickly melt owing to their spread-out nature and lower density. The wet snow avalanches on the other hand, which terminate much higher on the runout, leave thick, high density deposits which are slow to melt. The danger lies in basing avalanche travel distances on the wet snow deposits alone. A large path which descends into Naran provides a perfect example; while local people informed us that avalanches on this path during the 1985-86 winter had swept across the valley floor, any avalanche deposits remaining at the beginning of May were confined to the upper half of the runout. Avalanche information collected by a local observer who remained in the valley over the winter would be extremely valuable. In this study an inhabitant of Naran was hired to carry out such observations over the 1985-86 winter. Unfortunately, the resulting data cannot be regarded as highly accurate.

A great impediment to the surveying and mapping of avalanche paths and hazard areas is the lack of good large-scale topographic maps and aerial photographs. For this study the only available maps were photocopied Survey of India 1:63,360 sheets which were surveyed in 1930. While aerial photographs for Kaghan Valley undoubtedly exist, these are classified documents and are not readily available. Thus, without such basic sources of morphometric data, measurements of gradients, elevations, starting zone and track areas, runout distances etc. on identified paths must be done with laborious and time-consuming field surveys.

Figure 4.--Naran 7 avalanche path on 22 May 1986, with the deposit terminating in the Kunhar River. Note the Kaghan Valley road which crosses the deposit in the runout zone.

NATURE AND CAUSES OF AVALANCHES

As a result of the very large size of many avalanche paths in Kaghan Valley, the magnitude of individual releases can be very high, exceeding the upper limit (size 5) of the Canadian snow avalanche size classification. Size 5 releases in this system are described as the "largest snow avalanches known; could destroy a village or a forest of 40 hectares", and have typical masses of 100,000 tonnes and impact pressures of 1000 kPa (McClung and Schaerer, 1981). Compared to the typical path lengths for such major avalanches --3000 metres according to these authors -- the three largest paths investigated in the Naran area had path lengths of 3300 metres to 3900 metres (calculated by vertical fall over the sine of the path incline).

The ten paths on which hydrological investigations are being carried out were surveyed in the spring of 1986 for avalanche deposit masses, utilising a cross-section area method described by Schaerer.[4] The method involves establishing a number of deposit cross-sections, in this case by means of ground surveys using a compass, survey tape and Abney level. Each cross-section transect had to be surveyed twice, the first time to obtain the deposit surface profile and the second time to obtain the underlying ground profile after the deposit had melted. Many deposits, particularly those in the deep and confined track sections, had not melted at the time of the second survey, in which case the deposit depth has to be estimated. As well, rocks along the deposit boundaries were painted and this will allow the re-surveys to be carried out in the summer of 1987. Each cross-section is drawn on graph paper and its area measured with a planimeter. These cross-section areas are then combined with the cross-section spacing to obtain the deposit volume. An average density of 590 kg m^{-3}, which was obtained from measurements on various deposits in the Naran area, was used to obtain mass values. The resulting deposit masses for the ten paths range from 1195 to 920,807 tonnes, of which a significant proportion is located in the track zone if this is deeply gullied. The maximum measured mass is almost an order of magnitude higher than the typical mass for a size 5 release, and in fact four of the ten deposits have masses of over 100,000 tonnes. If one were to include the deposits remaining in the inaccessible upper track sections, the estimated maximum avalanche transport would exceed one million tonnes.

The measured avalanche masses were compared to calculated values based on Schaerer's (1984) formula for annual avalanche mass. In general the calculated masses exceed the actual masses, although a closer agreement is reached on the large paths (7.3% difference on average). For two paths the actual masses exceed the calculated masses, in one instance by a significant amount (110,608 tonnes versus 54,377 tonnes). The most likely source of error appears to be the yield ratios (percentage of snow in the catchment area that is avalanched down to the valley) that were utilised, which are based on Rogers Pass, B.C. data and which show a strong variation there from year to year and from path to path (Schaerer, 1984). The generally lower yield ratios in Kaghan Valley (on average 6.5% compared to 11% at Rogers Pass) may be the result of significantly gentler track gradients or the fact that many of the starting zones are composed of multiple sub-basins and it is unlikely that all of them would avalanche at once. Strangely enough, relatively good calculated values were obtained for large paths where the starting zones contain the largest number of such sub-basins. Another cause of error may be the winter precipitation parameter, which is difficult to calculate owing to the lack of records and the sharp increases with elevation in Kaghan.

The maximum potential mass of avalanches was also calculated for the ten paths, using formulae by Schaerer (1975) and Schaerer and FitzHarris (1984). Schaerer's (1975) formula assumes that all of the snow cover that builds up in the starting zone and track can potentially sweep into the valley during a maximum avalanche, and therefore the calculated values for Kaghan Valley are extremely high; from 104,427 to 10,913,175 tonnes. In fact, six of the ten paths have calculated maximum masses of over one million tonnes. Schaerer and FitzHarris' (1984) formula produces much more conservative estimates because of the inclusion of an avalanche mass

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4 Schaerer, P. 1985. Personal correspondence. Research Officer, Division of Building Research, National Research Council of Canada, Vancouver, B.C.

coefficient which is a function of the avalanche return period, and incline and wind exposure of the starting zone. The values of this coefficient obtained at Rogers Pass, B.C. were used for the Kaghan Valley paths, because the authors suspect regional variations to be weak. Our calculations for these paths produce masses ranging from 74,029 to 756,785 tonnes. For the largest path (fig. 4) the maximum avalanche mass that was calculated is actually less than the mass surveyed in the spring of 1986 (756,785 tonnes compared to 940,807 tonnes), indicating very severe avalanche activity during the 1985-86 winter. On these other large paths the surveyed masses closely approach the calculated maximums. In fact, there is significant evidence to indicate that 1985/86 was a severe avalanche season. For example, on some deeply confined paths the height of the track deposit in May closely concided with a 'trimline' separating heavily grazed brush and grass from bare slopes in the gully. This trimline presumably marks the limit of avalanche deposit heights. In addition, numerous avalanche deposits contained large quantities of destroyed mature timber, perhaps indicative of avalanche activity in areas which had not been disturbed for some time. A German scientist who has travelled through Kaghan Valley every spring since 1981 describes the 1985-86 avalanche season as the worst he has seen. Moreover, the local population has pointed out to us several paths which experienced avalanches for the first time in years. In Battakundi five people were killed in a dwelling when an avalanche descended a path for the first time in twenty years, while in other villages there was much evidence of damaged and destroyed houses.

While very little is known of the winter climate and snow conditions in Kaghan Valley, very cold conditions are probably rare. This, combined with a deep snowpack, has important implications for avalanche activity in the valley, namely that the snowpack is generally well settled and structurally stronger than a shallow snow cover in a colder climate. Most mid-winter avalanches in Kaghan Valley are probably of the "direct action" kind, produced by heavy snowfall. Rain is most likely an important triggering mechanism as well, occurring often in conjunction with the snowfalls. A third cause of avalanches is air temperature rises which destroy cohesion in the snowpack, and which are most significant in the spring time. Information collected from local inhabitants indicates that snowfall, rain and thaw triggered avalanches are indeed the most common. They also show that the avalanche season begins in Naran in December, or early January if the snowfall is light, and ends in mid-May. In 1986 a large number of wet snow avalanches were still descending to an elevation of 3300 metres on 8 June, triggered by very warm and sunny conditions.

Meteorological data are available from a potato research farm in Battakundi for the 1985-86 winter and these can be compared to avalanche observations carried out in Naran and Battakundi for a insight into avalanche causal mechanisms (fig. 2). While the avalanche data probably are not completely reliable, we are fairly confident that they at least reflect the general pattern and timing of avalanche activity. Figure 2 shows a strong relation between avalanche events and snowfalls; of the 196 avalanches recorded, 64 percent occur during or within twenty-four hours of a snowfall. The number triggered by rain cannot be determined because rain was unfortunately not recorded until April. However, judging by the fact that daily maximum temperatures always rise above $0^{o}C$, it probably is an important mechanism, at least in low elevation starting zones. Continuous snowfall totals before avalanche release range from approximately 10 cm to as much as 162 cm, recorded during an eight-day storm in March. The maximum daily snowfall that is associated with avalanche activity is 35 cm, but it is interesting to note that as much as 60 cm of snow fell in one day in December with no avalanches apparently being observed. A sharp rise in air temperatures occurs with 19 percent of the recorded avalanches. In 89 percent of such cases the mean daily temperature was above $0^{o}C$. A number of avalanches are associated both with snowfalls and rises in air temperature which could provide a combination trigger. However, it is difficult to identify rises in air temperature as a clear mechanism of avalanche triggering, because of the large diurnal variations in temperature which seem to be the norm. Lastly, it is worthwhile to note in Figure 2 that 23 percent of avalanche events were not related in any direct way with snowfall or a rise in air temperature.

AVALANCHES AND HUMAN ACTIVITY

As in much of the Himalaya Range, level or nearly-level land is intensively utilised. The pressure for agricultural land is so great that crops are grown on most tracts of ground which are gentle enough to hold topsoil. On steeper slopes, terraces are constructed in order to gain more level land; it is not unusual to see agriculture taking place on avalanche slopes at elevations of up to 3000 metres. Very often dwellings and other structures are constructed on hillsides so that the valuable level land can be utilised for growing crops.

As a consequence of this pressure for land, avalanche runout zones are scenes of considerable human activity. This activity is particularly concentrated on the same (east) side of the valley as the large avalanche paths, owing to a larger amount of level land and a more favourable moisture balance which is reflected in a reliable water supply, better developed soils, and timber. In addition, the single road in Kaghan Valley is located on this side of the valley. The avalanche hazard in Kaghan Valley is greatly minimised because most of the population, including both the nomadic Gujars with their livestock and the permanent inhabitants, migrates out in the winter. This out-migration is in response to not only the high degree of avalanche activity but also to the deep snow cover which persists for up to six months. Property damage is minimised because local knowledge of hazard areas and avalanche destructive effects is quite detailed for normal years. For example, houses that are constructed on avalanche paths have roofs that are level with the ground on the uphill side and allow avalanches to pass harmlessly overhead. As another example, houses in the Saiful Maluk side-valley are invariably built on the south side of debris fans which act as avalanche runouts. This presumably is the side from which any snow and avalanche deposits would disappear most rapidly during spring melt.

While the local population is reasonably adept at coping with the avalanche hazard under normal circumstances, exceptionally heavy snowfall years such as 1985-86 can cause serious problems. Most inhabitants' perception of the avalanche hazard seems to be relatively short-term; for example the avalanche fatalities in Battakundi, which were described earlier, were the result of the construction of a dwelling on an avalanche path which had been inactive for a period of twenty years.

The late-lying snow and avalanche deposits in the spring of 1986 also delayed the habitation of Kaghan Valley and the planting of crops by one month. Battakundi for example, was inaccessible for a month longer than usual. One outcome of this delay was reported famine among the inhabitants who had remained behind all winter. Most farmers waited impatiently for avalanche deposits to melt from their fields, which were then plowed and planted immediately. Cargo jeeps, which travel the length of Kaghan Valley and over Babusar Pass, experienced great difficulty all summer in negotiating the avalanche deposits which lay across the road (fig. 5).

Figure 5:--Cargo jeeps crossing a large avalanche deposit south of Naran on 10 May 1986. Note the large broken timber which was common in Kaghan Valley deposits in the spring of 1986, as a result of an unusually severe avalanche season.

As these melt out, their crossing by jeeps becomes at times very hazardous, because either the deposits are steeply inclined and terminate in the Kunhar River or large basal stream tunnels emerge as the deposit surface is lowered. A long-term visitor to the valley informs us that in some years (e.g. 1958) avalanche deposits still lay across the road in October.

It is clear that avalanches, while posing a hazard during winter and spring, serve as a resource to the local population during the intensive use period of summer. The most valuable resource is the broken timber carried by the avalanches to the valley bottom, which is a source of firewood for inhabitants (while there is a reasonable amount of forest left in Kaghan Valley it is protected by law). This harvesting is usually carried out by children, who are forced higher up the avalanche path as demand exceeds the rate at which wood is exposed by melting. Such wood is not only used locally but trucked as far as Balakot and further. The avalanche snow itself serves two useful purposes: for providing irrigation water for crops in the runout zone; and for keeping perishable food items cool. Irrigation water is directed to fields by means of small ditches which lead water off from the streams on larger avalanche paths. Avalanche snow for refrigeration purposes is quarried on a large scale and transported in large trucks out of the valley. In addition, avalanche runout zones for some reason are very suitable for potato cultivation, possibly as a result of fertilisation by avalanche-transported organic debris.

The avalanche hazard in Kaghan Valley is increasing primarily through developments by outsiders, related to such activities as tourism, hydro power development and a military presence. The local inhabitants are also interested in making the valley accessible as soon as possible after the winter in order to lengthen the tourist season and increase their income from this growing industry. However, given the scope of the avalanche phenomenon in Kaghan Valley, it will remain largely inaccessible in winter for a considerable time. Rather, it is the poor locational decisions for summer construction that are increasing the avalanche hazard and resulting in a great deal of property damage over the winter. For example, a large stone building was constructed by the Pakistan Meteorological Service in the middle of the runout zone of a large avalanche path in Naran, despite the warnings of local inhabitants. During the winter immediately following its construction the building was destroyed by an avalanche.

CONCLUSION

The physiography of Kaghan Valley is extremely rugged, which combined with a deep winter snow cover produces a high degree of avalanche activity. The size of individual paths and releases exceed in some cases the classification devised in Canada. The bulk of avalanche activity is caused by snowfalls, with rain and sudden rises in air temperature secondary mechanisms.

Traditional European and North American approaches to avalanche hazard investigation are to a great extent inapplicable because of the alteration of the landscape through centuries of intensive land use. Vegetative evidence is often absent as a result of a great demand for firewood, timber and as a result of grazing by livestock. Morphological identifiers in the runout zones are almost always missing because these areas are cleared annually for agriculture. Instead, identification and mapping of avalanche hazard in Kaghan Valley must rely on topographic clues, on late-lying avalanche deposits, on local knowledge, and on occasional damaged or destroyed buildings. An additional difficulty with such investigations in this area is the lack of basic morphometric data such as that provided by maps and aerial photographs.

The indigenous mountain population has a relatively good understanding of the avalanche phenomenon, and responds to the hazard by migrating out of the valley in winter. Unusually severe winters such as the one in 1985-86 create problems, however, because the small segment of the population that winters there is at risk, access into the valley in spring is delayed by avalanche-blocked roads, and grazing and planting of fields is delayed by late-lying avalanche deposits. After severe winters, local famine can be the result. Nevertheless, the avalanche hazard in Kaghan Valley is increasing primarily through developments by outsiders who have no intuitive knowledge of avalanches. While activity in the valley in winter is not increasing and likely will not in the foreseeable future due to the severity of avalanche activity and lack of development capital, summer construction projects by outsiders are increasingly being damaged or destroyed by avalanches. In most cases this is the result of poor locational decisions and ignoring the warnings of local inhabitants who appear to be aware of both the dangers posed by avalanches and some of the benefits provided by avalanche redistribution of snow.

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