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LANDSLIDES EVALUATION AND STABILIZATION BETWEEN GILGIT AND THAKOT ALONG THE KARAKORAM HIGHWAY

By

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ABSTRACT

Ten major landslides and a few unstable zone s in a road strip of 350 km long from Thakot to Gilgit along the Karakoram Highway (KKH) are discussed in this report.

Study of slides include plotting of location of the landslide on road log map with respect to their distances from Thakot, types of rock/material involved in the affected area, origin and mode of their occurrences and remedial measures.

Proper execution and implementation of the recommendations proposed in this report may help a great deal in reducing the man-power and maintenance cost of the KKH.

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INTRODUCTION

Purpose and Scope :

The Karakoram Highway (KKH) is one of the most important roads of the country as it provides all weather communication facilities to the Northern Areas of Pakistan and also served as a trade link between Pakistan and the Peoples' Republic of China.

During the construction of the KKH, natural stability of the slopes was disturbed which caused large scale landslidings. Some other hazards such as avalanches, river erosion, and earthquakes have added to the problems of the area. At some places, slides are due to extensive and unscrupulous blasting without using modern techniques of controlled blasting.

The construction and maintenance of this road has been the prime responsibility of the Frontier Works Organization, However, the Geological Survey of Pakistan has been associated with the construction of this road since the project started in 1967. In view of the perpetual danger of land-sliding and other related hazards, the Committee on the Karakoram Research Cell, under the auspices of the University Grants Commission requested the Geological Survey of Pakistan to undertake this project and submit a detailed report on the problems and their remedies.

During the field season of 1983-84, detailed engineering geological investigations were carried out along the KKH to determine the causes of various type of mass movement phenomenon and remedial measures for each occurrences.

All the slides in road strip of 350 km long from Thakot to Gilgit were investigated, however, 10 major landslides are discussed in detail and other minor slides are described at the end of the report under the heading of non localized mass movements.

Continuous maintenance of the KKH requires considerable efforts in terms of time and money. It is estimated that slides will continue for another 15 to 20 years until the strata disturbed by blasting settle. KKH maintenance crews will be hard at work for years to come. Even in 1984 two Engineers Battalions are deputed for maintenance of the KKH. Proper execution and implementation of the recommendations proposed in this report may help a great deal in reducing the manpower and maintenance cost of the KKH.

Method of Investigation :

The method of investigations included plotting of location of each landslide on the road log map with respect to its distance from Thakot bridge. The landslides have been mapped on suitable scales considering the bed rocks and the composition of material involved. Reasons of occurrence of slides and their possible remedial measures to control or minimize the mass movement phenomenon are also discussed.

Tatta Pani slide due to its crucial position on the KKH was checked in detail and a geological profile on the scale of 1:10 m was prepared with tape and brunton method.

Location & Accessibility:

The portion of the Karakoram Highway from Gilgit to Thakot discussed in this report stretches for about 350 km. This part includes Survey of Pakistan toposheets 43 I/9, I/10, I/11, I/3; 43 E/6, E/14, E/7, E/10, E/4, E/3; 43 A/16; 43 B/13; 43 F/1 on the scale of 1:50,000

The KKH from Gilgit bridge runs along the right bank of Gilgit river which is joined by the Indus at Jaglot. The road crosses over to the left bank of Indus river at Rhakhiot, a place about 78 km south of Gilgit under the foothills of Nanga Parbat. It enters the Frontier Province near Basha and then passes through the Hazara and Swat Kohistan regions of the NWFP. At Kamilla the road again crosses over to the right bank and follows the Indus river upto Thakot. (Fig. 1).

Relief and Topography:

The terrain along the KKH is quite rugged and relief is moderate to high. The Indus valley is characterised by high precipitous cliffs, steep slopes, narrow gorges, and with frequent scree cones and alluvial fans.

The valley widens considerably at certain places to provide habitation and crop cultivation for the local population. The soil at these places is fertile and cultivation is done on the slopes in the form of terraced fields. The soil is mostly derived from the glacial till, deposited at higher reaches and also due to the natural process of disintegration of the country rocks..

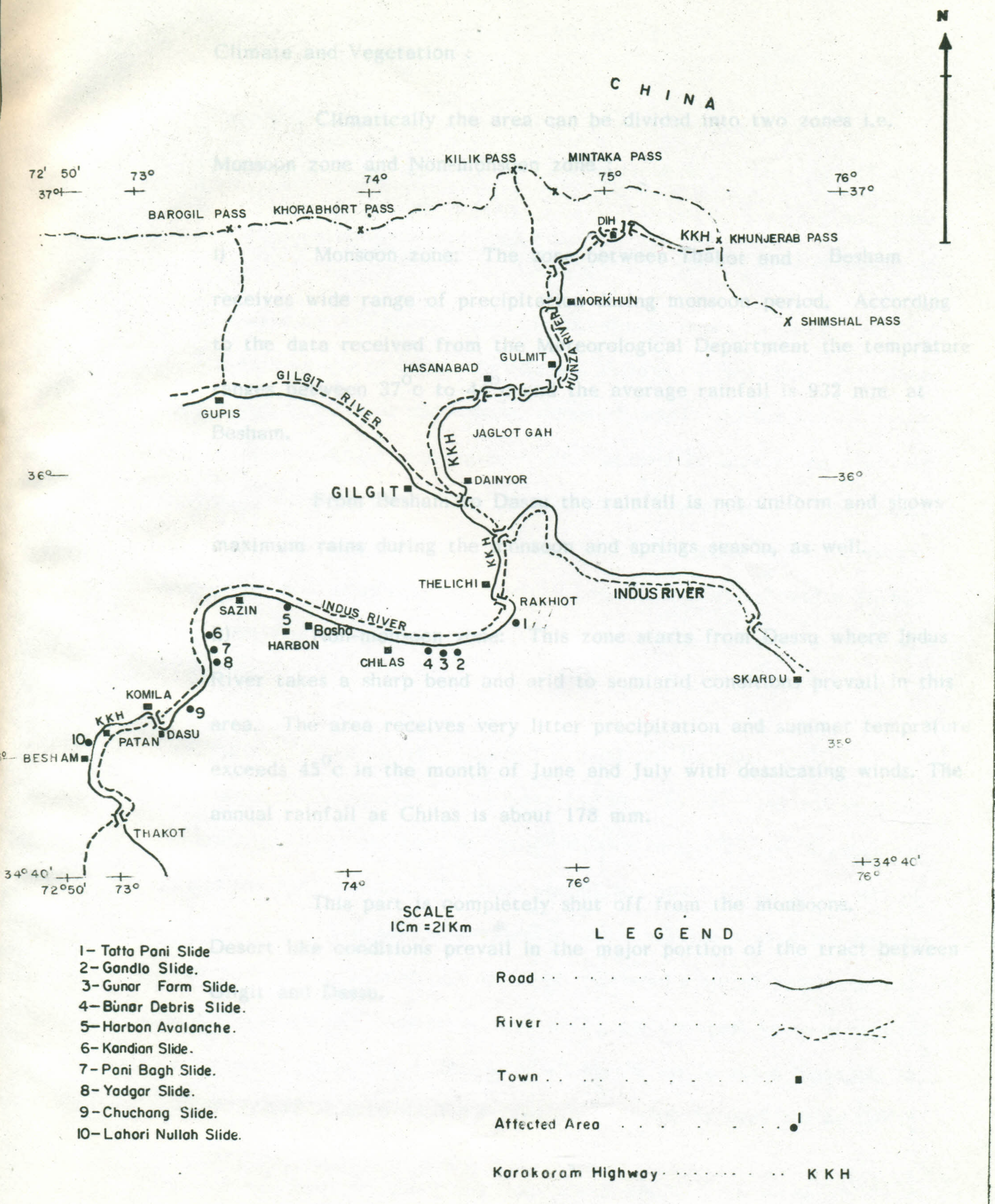

Figure.1- Map showing location of major affected areas along the Karakoram Highway between Gilgit and Thakot.

Climate and Vegetation :

Climatically the area can be divided into two zones i.e. Monsoon zone and Non-monsoon zone :

i) Monsoon zone: The zone between Thakot and Besham receives wide range of precipitation during monsoon period. According to the data received from the Meteorological Department the temprature ranges between $37^{o}c$ to $44^{o}c$ and the average rainfall is 932 mm at Besham.

From Besham to Dassu the rainfall is not uniform and shows maximum rains during the monsoon and springs season, as well.

ii) Non-monsoon zone: This zone starts from Dassu where Indus River takes a sharp bend and arid to semiarid conditions prevail in this area. The area receives very litter precipitation and summer temprature exceeds $45^{o}c$ in the month of June and July with dessicating winds. The annual rainfall at Chilas is about 178 mm.

This part is completely shut off from the monsoons. Desert like conditions prevail in the major portion of the tract between Gilgit and Dassu.

TATTA PANI SLIDE

Tatta Pani slide zone is located on KKH between KM 275 to 276 from Thakot, near the Rakhiot bridge, about 80 km south of Gilgit. Tatta Pani lies in Survey of Pakistan toposheet No.43 I/11 (Scale 1:50,000) with co-ordinates Lat. 35^{O} 29' N and long 74^{O}.35'.20" E(Fig.2).

The rock types exposed in the slide consist of gneisses and quartzite. Holocene fan gravels are also developed at the foot of the Nanga Parbat massif. These Holocene gravels are affected by the recent tectonics and a zone of breccia 5 to 10 m thick is present along the KKH. Slickensides are developed in this breccia zone. Most of these slickensides appear to plunge along the dip of fault surfaces on which they are found. Locally a fault scarp is developed in these fan gravels in association with the breccia zone. It appears to reflect a steeply dipping fault downthrown to the north.

The trace of the fault is delineated by a line of hot springs, some on the east side of road and some on the western flank towards the Indus River. The ones located along the road can be easily spotted by the rising steam. The hot springs south of Rakhiot Bridge are closely spaced and have a definite linear arrangement. The young fault scarp and associated features have cut these fan and terrace gravels and thus appear to be of Recent time. This fault is probably the surface expression of the rapid uplift of the Nanga Parbat Massif reported by Zeitler et al (1982) on the basis of fission track evidence (Lawrence & Ghauri, 1983).

It has been observed that at Tatta Pani, the road subsides about 10 to 15 cm per day along the fault scarp and the down thrown block on the west has moved down more than 3 meters from the original road level.

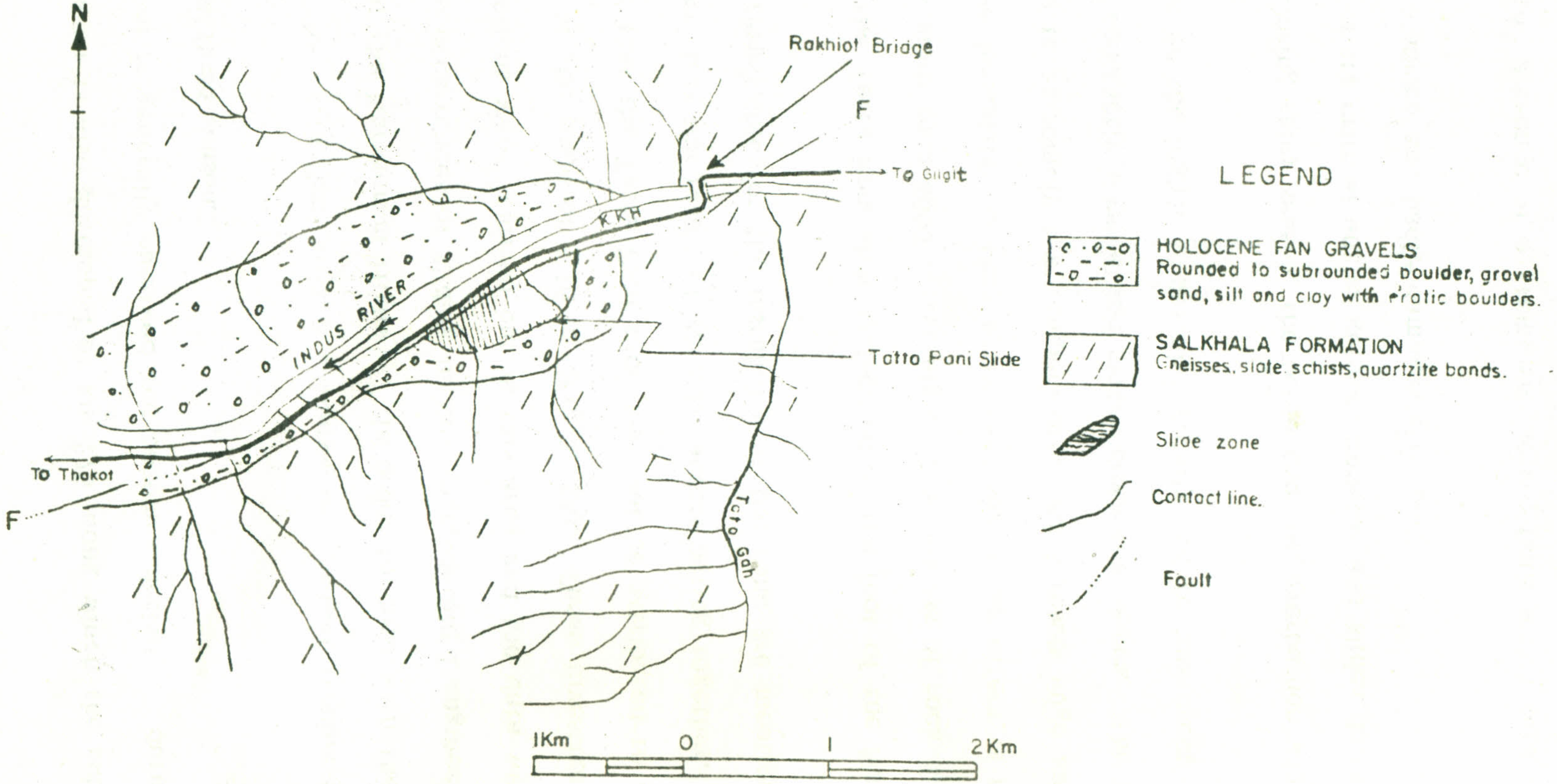

Figure 2 – Generalised geological map showing location of Tatta Pani Slide at Km 275 on the KKH.

A big shear is also developed at km 275 along which the subsidence movement is generally observed and becomes active during the rain and high flood season.

The Tatta Pani area is a source of constant trouble for the maintenance of the Karakoram Highway. In order to cope with the problem of repeated occurrences of sliding in this zone, detailed engineering geological investigations were carried out in this area and the data were plotted on profiles at the scale of 1:10 m. (Fig 3, 3A). These investigations revealed that the Tatta Pani slide may not be attributed to a single cause but it is the result of various factors acting together. The main factors responsible for the instability of the zone are mentioned below :

1. The Tatta Pani slide is located at the foot of the Nanga Parbat which is more than 8000 meter high. The process of rock disintegration and scree formation is very active and shattering effect is most prominent due to extremely low temperature. As a result huge amount of scree is constantly formed and moves down the slopes. The morains deposited on the higher slopes also greatly add to this creep movement.

During rainy season, the scree and the overburden which is exposed at its critical angle, gets an impetus and slides down in an abrupt and rapid action and badly damages the road.

2. Due to presence of a prominent active fault which runs in almost NE-SW direction the older formations have been pushed over the younger Holocene gravels. The movement takes place along the fault plane and activates sliding.

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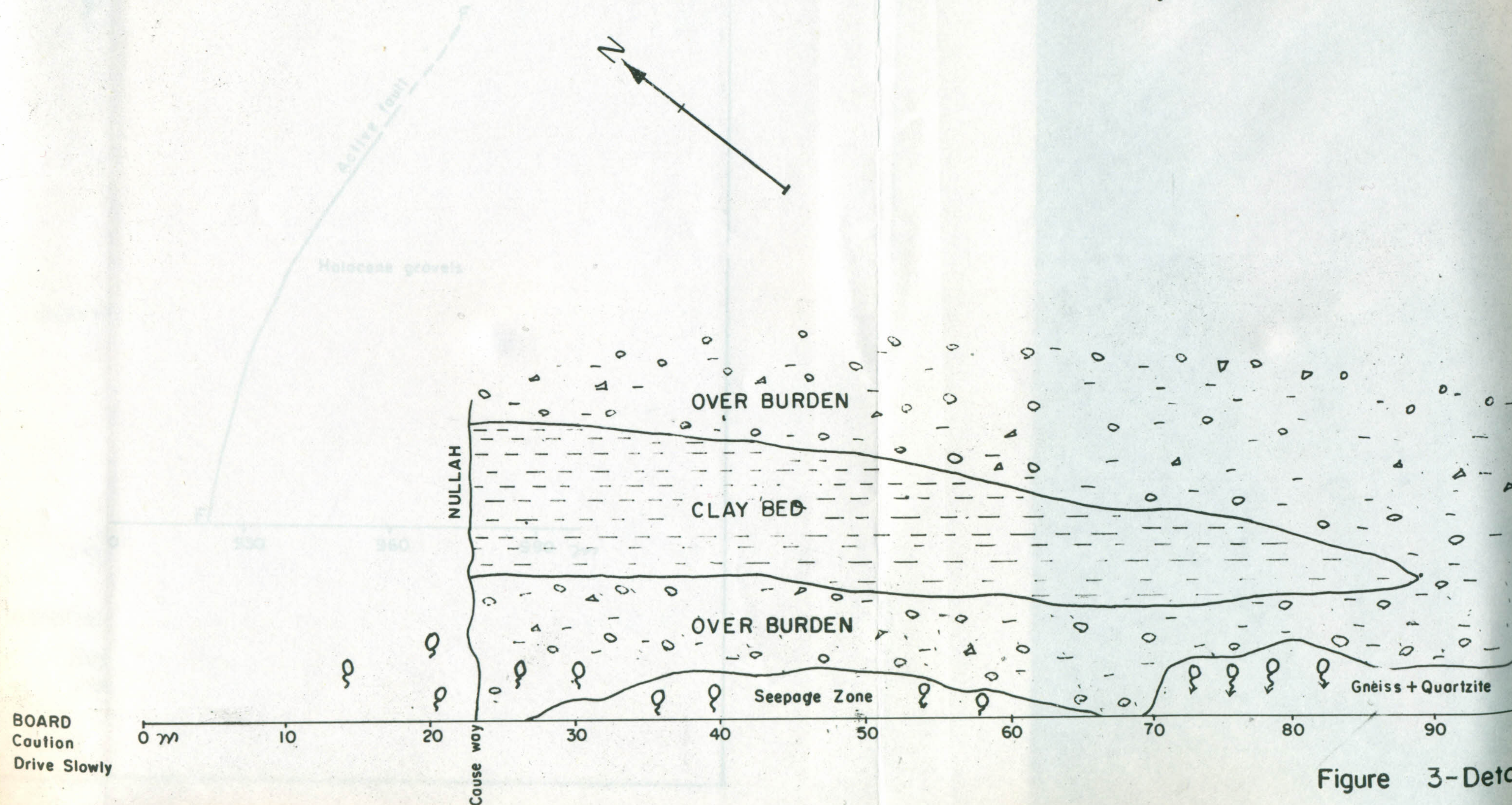
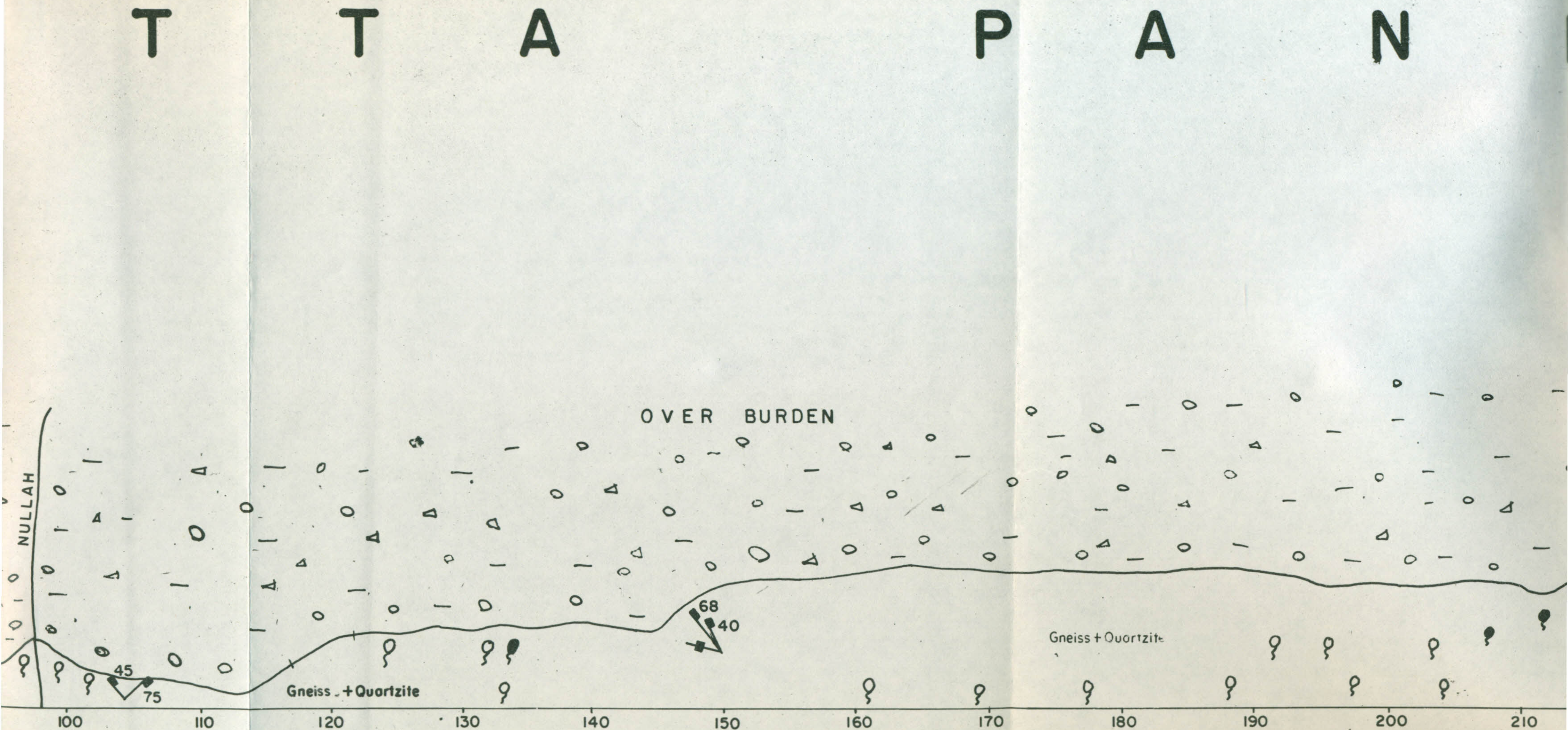
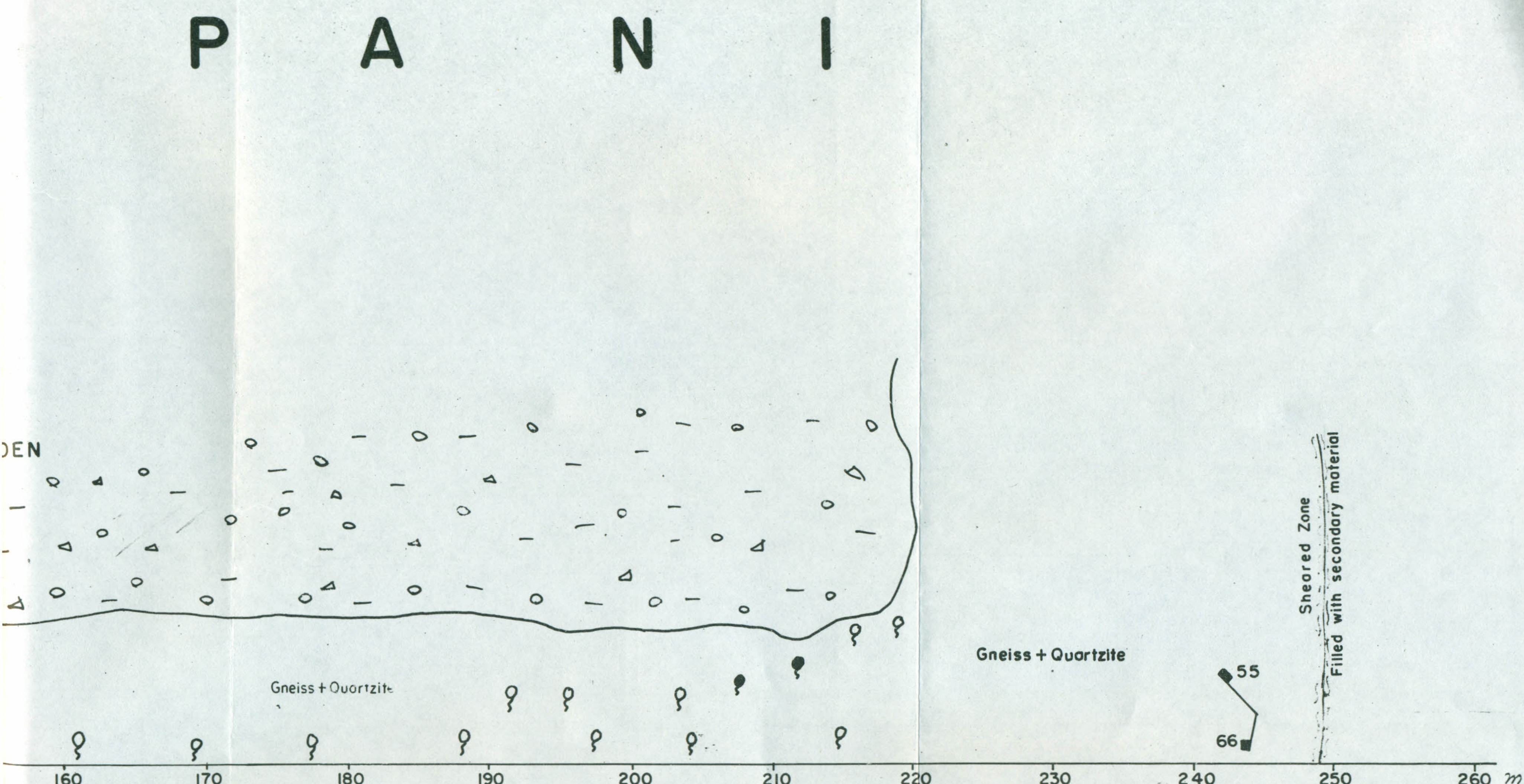


Figure 3-Deta



ailed geological profile of Tatta Pani Slide on the KKH. Symbols as shown in figure 3B

Scale. Horizantal 1: 10 m.
Vertical. Not to scale.



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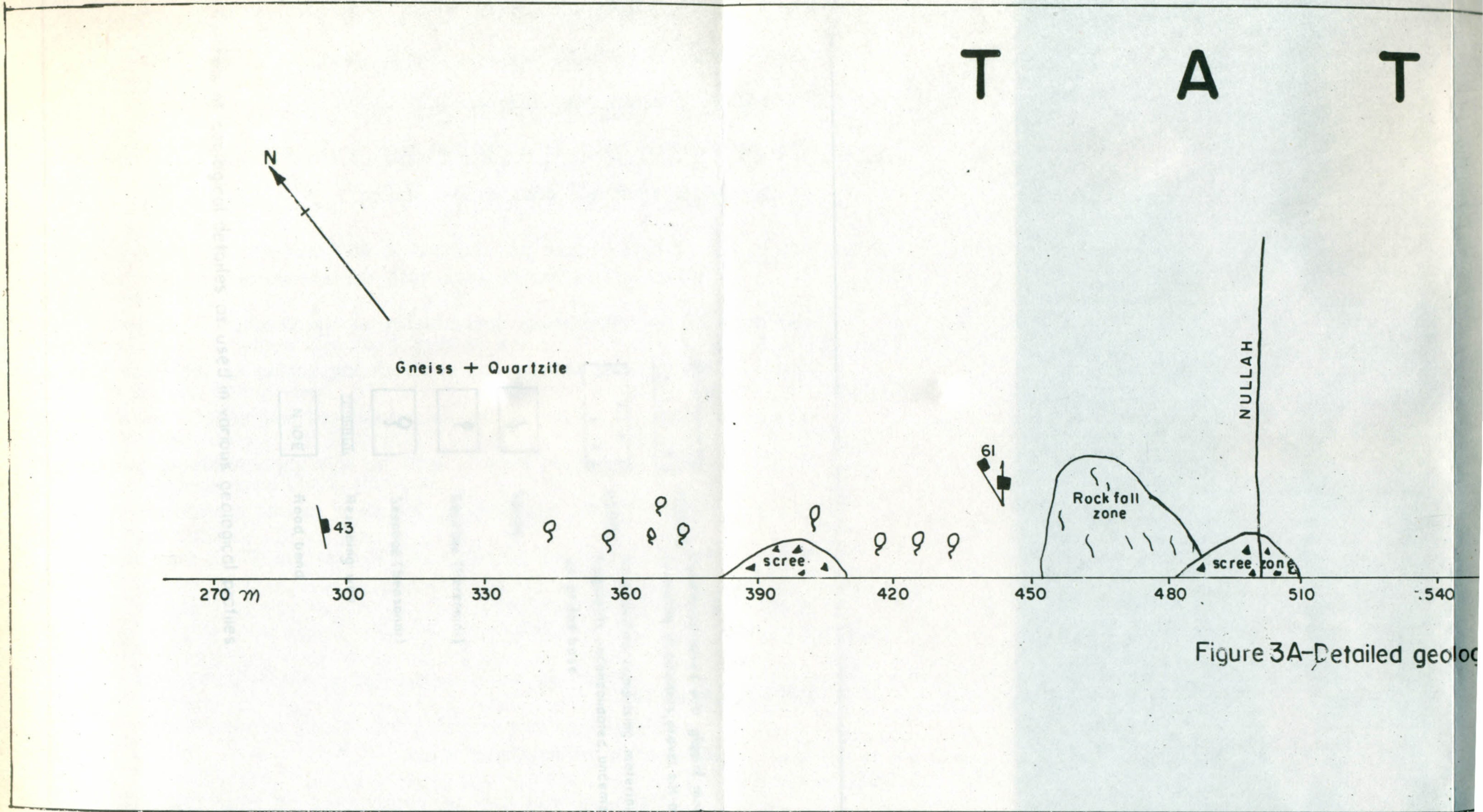


Figure 3A-Detailed geolog

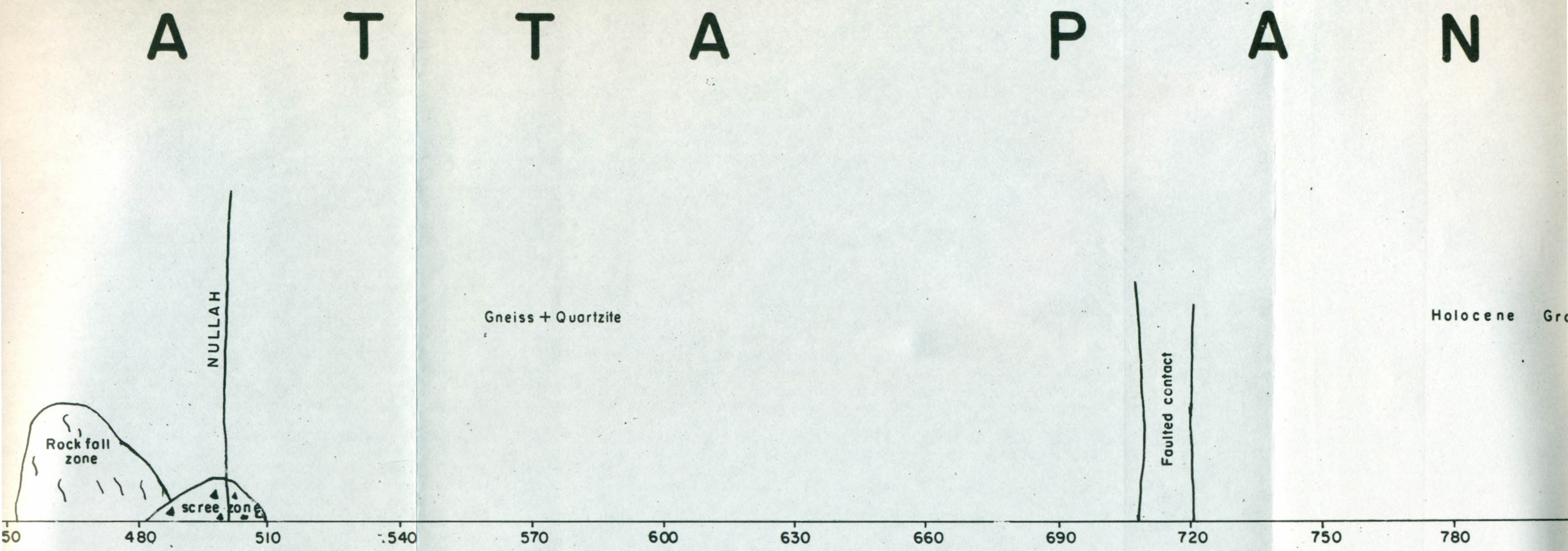
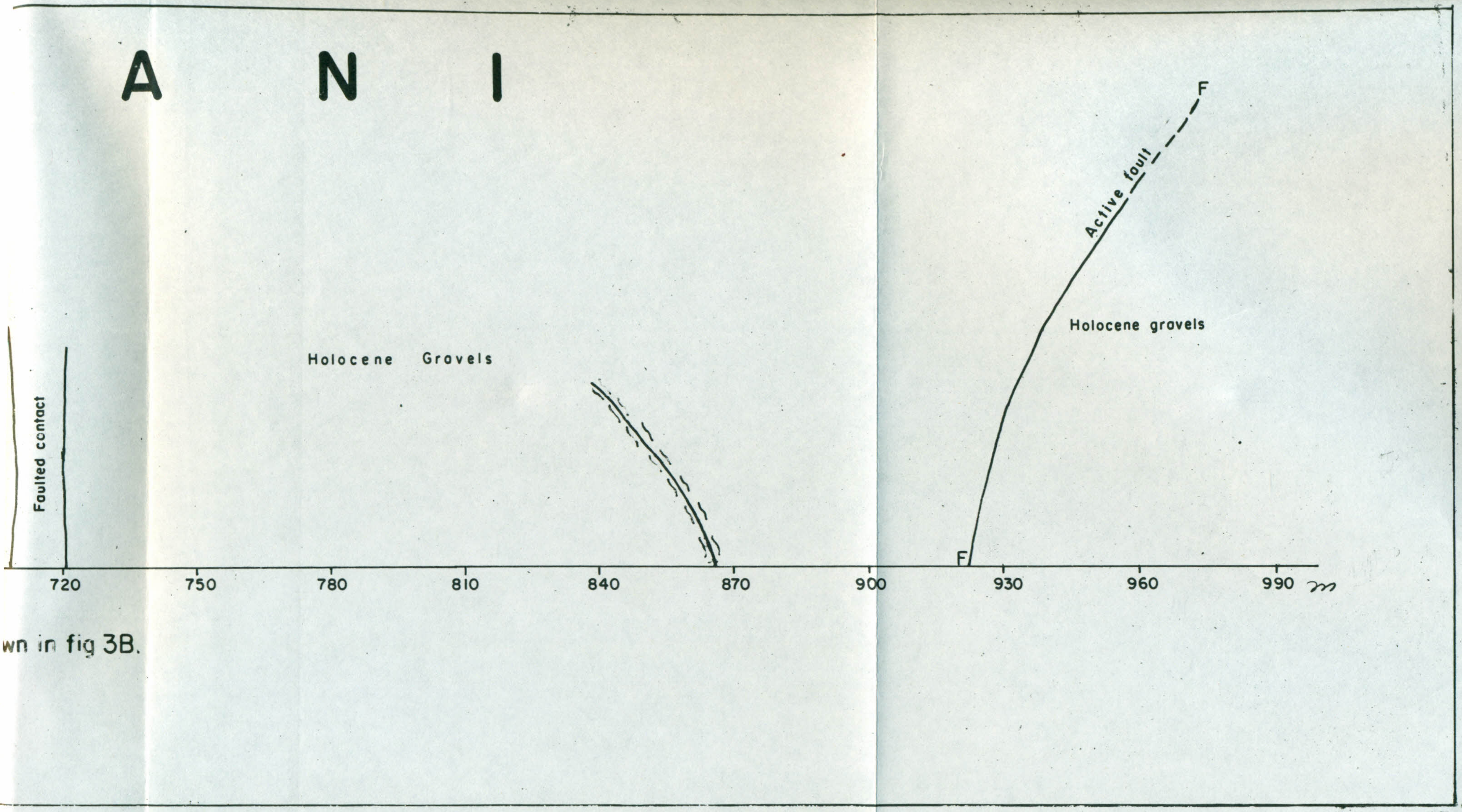


Figure 3A–Detailed geological profile of the Tatta Pani Slide on the KKH. Symbol as shown in fig 3B.

Scale. Horizontal 1: 30 m.
Vertical. Not to scale.



A N I
Faulted contact
Holocene Gravels
Active fault
F
F
Holocene gravels
720
750
780
810
840
870
900
930
960
990
m

wn in fig 3B.

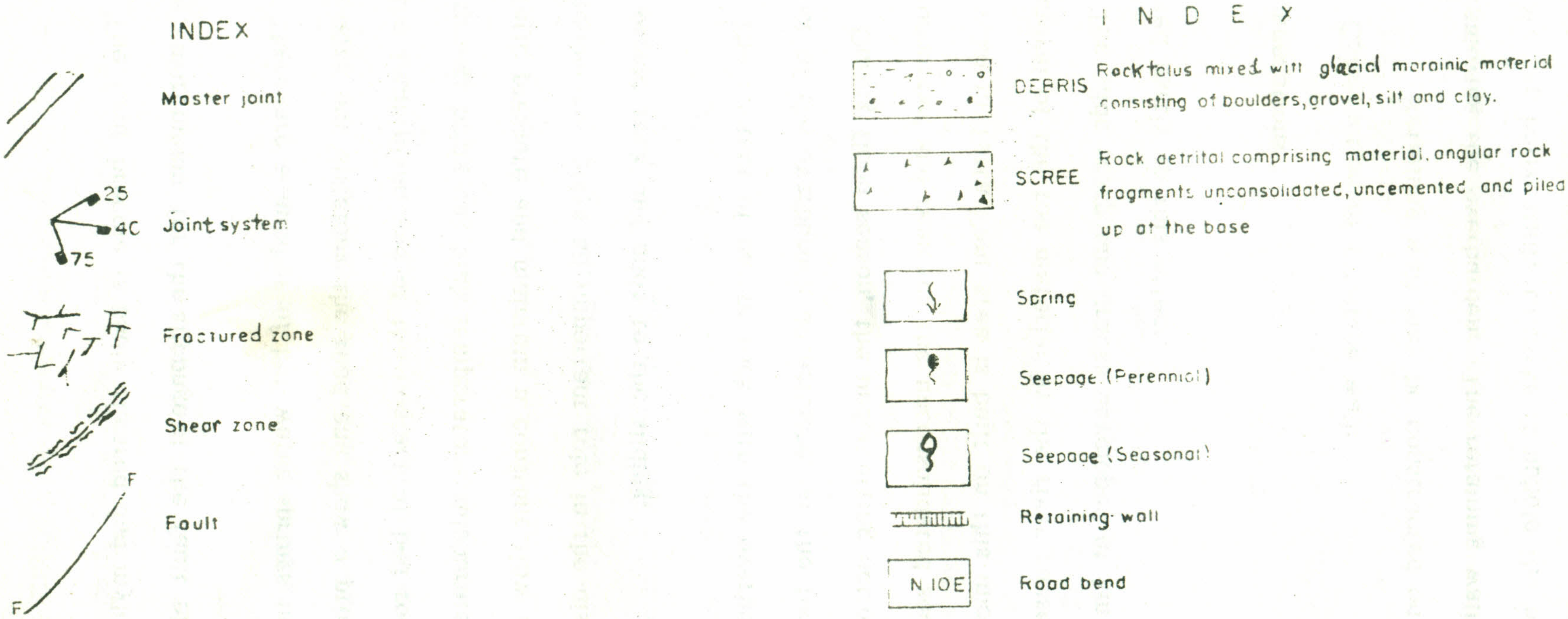


Figure 3B-Symbols of geological detailes as used in various geological profiles.

3. The fault breccia is badly sheared and mylonised and provide suitable environment for the slippage of the fault blocks.

4. There are a number of hot water springs in this zone. These springs ooze out all along the road and show a prominent alignment along the fault plane and at the contact of bed rock and overburden. These springs bring out high temperature sulphurated water under hydrostatic pressure and maintain a constant flow throughout the year. This phenomenon plays an important role in the disintegration and decay of the parent rock and adds to the sliding.

5. The contact of parent rock with the overburden is very steep, and most of the overburden accumulates at the foothill or at lower levels. During flood season, the undercutting action of the river becomes most pronounced and removes the unconsolidated sediments. As a portion of the road in Tatta Pani area is built on this unconsolidated material, the removal of the toe material by the river causes subsidence of the road. The slide scarp and cracks developed at km 275.2 may also be attributed partly to this effect.

Recommendations :

1. Construction of retaining wall:

Retaining wall may be constructed on fresh bedrock surface after removing the overburden. The retaining wall should be anchored vertically and horizontally to make it uphold the maximum load. The gap between bedrock and retaining wall may be filled with pervious material. Downward anchoring can be provided after drilling a hole upto the depth of 4 meters and filling it by grouting and constructing the foundations on these anchorage footings. The same procedure can be adopted horizontally.

2. Internal drainage:

The area is saturated with hot water, the source of which is persumed to be located at considerable depth. Seepage in the slide area can partly be controlled by providing holes below the contacts of bedrock and overburden and also below the road level.

Horizontal holes at 1 m intervals upto the length of 3 m. may be drilled and P.V.C. pipes be inserted to provide the channel for hot water. These holes should be inclined slightly downward and inter-connected to provide free passage in the major drain to let it pass the road safely.

Below the road level a series of horizontal holes should also be drilled by the same procedure to stop the water to go upto the contact and channelize it by connecting the pipes with each other. The pipes will also reduce hydrostatic pressure.

3. Slide at 275.2 k.m. :

This slide is located close to an active fault which is crossing the road at this point. This slide is so active that road slumps downward 15 cm per day. Army bulldozers constantly work on the road to make it trafficable by filling and levelling the road gradient.

The slide may be controlled by removing the overburden and blasting out the west portion of the fault which is already displaced. Eastern part of the fault block is stable and does not pose any danger of rock fall.

4. Permanent solution :

Road stretch from 275.5 to 276.2 km may be realized by excavating the road at a lower level where bedrock is exposed. Reinforced retaining structure may be erected to hold the realized road structure against the lateral thrust of the overburden. After the construction of the new road present road will only act as a plateform to hold the overburden for some time. Slides coming on the new road can be cleared and no damage to road structure will occur.

GANDLO SLIDE

Gandlo slide is located on KKH at km 260 from Thakot, and 107 km south of Gilgit. This slide extends for about 4 to 5 k.m. Gandlo slide lies on Survey of Pakistan toposheet No. 43 I/7 (1:50,000) with Co-ordinates Lat. 35^{o}.24' .30"N and Long. 74^{o} .23' .35"E.

The material in the slide area consists of Quaternary deposits of boulders, gravels, and coarse sand of alluvial origin (Fig. 4). The percentage of sand is about 90% with boulders upto 2m. in diameter. The sand is loosely cemented and can be plucked with fingers very easily. The sand is coarse grained, partly stratified and semiconsolidated. The boulder gravels occur in partially cemented sand matrix and have become conglomeratic at the base. The area is unstable because the Quaternary deposits form almost vertical cliffs which are hanging at certain places along the slide affected zone.

After the rains the boulders gravel collapse more easily because the large boulders are loosely held by the smaller rock fragments and also the sand is readily let free by the incoherent soil and as a result debris slide takes place. The bedded silt and sand below the gravel is

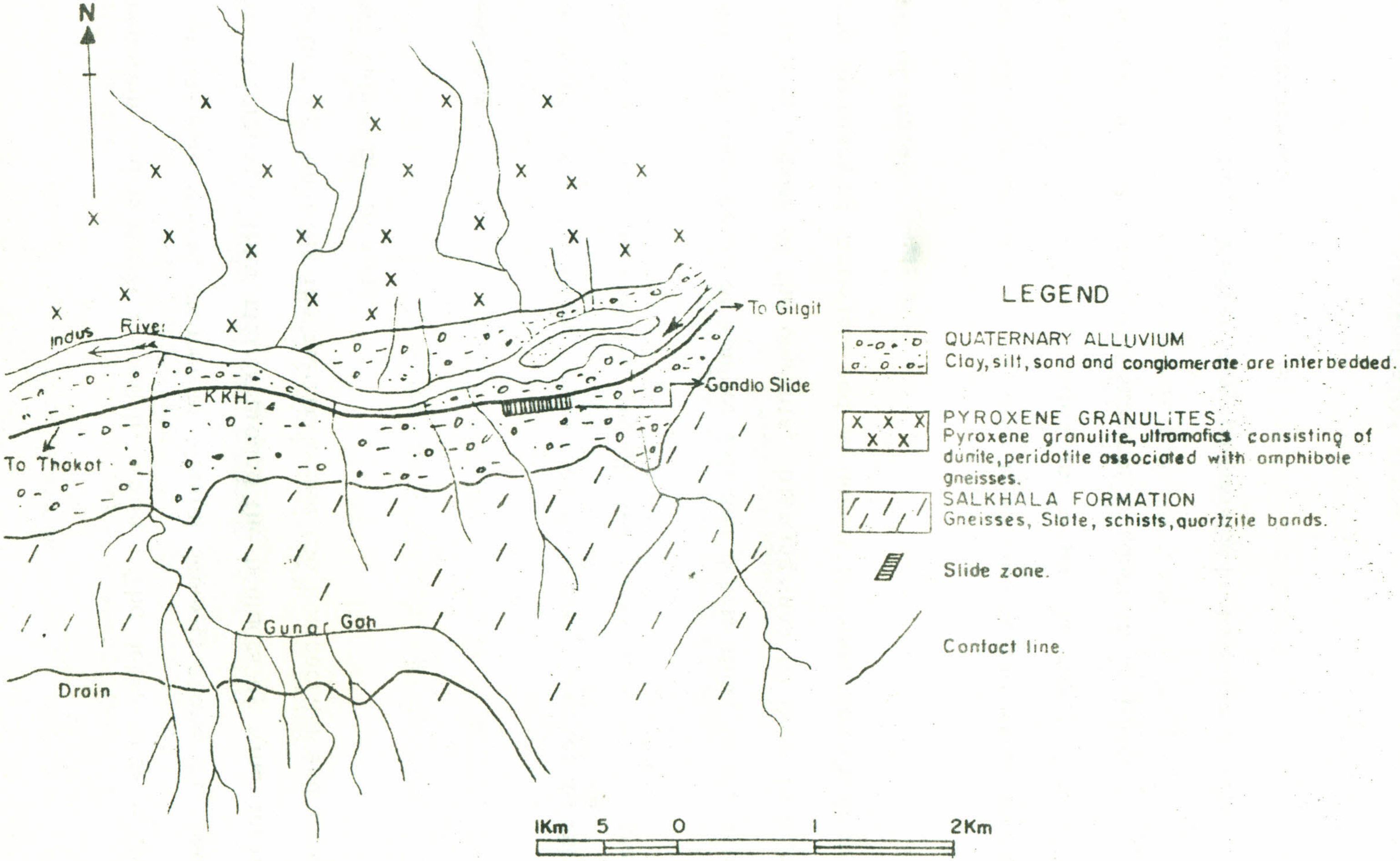


Figure 4-Generalised geological map showing location of Gandlo Slide at Km 261 on the KKH.

quite incompetent and is easily eroded by water. The debris slide is thus the result of unstable slopes, incoherent alluvial deposits above the road and erosion of relatively finer matrix around the boulders by wind action. The wind action by removing the matrix loosen the compaction and makes the boulders vulnerable to slide.

Recommendations :

1) The seepage of rain water cannot be efficiently checked in this area because of the looseness of the gravely sediments all over the area.

2) Since the main cause of boulder fall and debris slide, is the acute vertical angle of repose of the deposits, blasting may be done to bring down all the overhanging materials and to impart a comparatively more stable angle of repose.

3) One effective solution of the area is to reslope the whole stretch with berms and risers at suitable heights and widen the road. This will however, involve huge expenses and substantial quantum of work.

4) Effective surface drainage may be provided to serve as a temporary arrangement.

GUNER FARM SLIDE

Guner Farm slide is located on KKH. at km 257 from Thakot. The Guner village is located on a big terrace gently sloping towards the River Indus. This slide lies on Survey of Pakistan toposheet No.43 I/7 (1:50,000) with Co-ordinates Lat. 35^{o}.24'.15"N and Long. 74^{o}.22'.

The rock types encountered in the vicinity of the slide area comprises gneisses. The material involved in sliding mostly consists of reworked alluvial deposits comprising silt, sand, gravel and boulders. The finer material is predominantly silty clay. These alluvial deposits are partly stratified and compacted. (Fig.5).

It has been observed that the village terrace is cultivated and is irrigated by small fresh water channel connected to the nullahs upstream. The surplus water from these channels flows over the terrace and falls down on the road below the terrace. The rain water also attains the same flow direction and after passing over the road, finds its way into the river. This process of over flow removes the finer sediments as well as the binding cement from the coarse material and makes them loose and vulnerable to sliding. A part of this run-off water infiltrates into the ground and produces subsurface channels which further loosen the alluvial cover; this flow thus aggravates the debris fall.

Recommendations :

Guner Farm slide may be effectively controlled by channelising the flow of run off water and surface drainage. The surplus water may be diverted to proper culverts to check the ingress of water.

Although surface drainage itself is seldom sufficient for the stabilization of the slope, it can contribute substantially to the drying and thus, also controlling of the land slide. Nullah feeding the fields of Guner village should be channelized and at the top towards the roadside a concrete drainage should be provided to collect all excess water from other minor nullahs. This water can be easily diverted towards the west into the Lichi Gah to save the road. This distributary will also help in rainy season when almost all the water coming on top will pass through it and only direct hit of rain on the deposits will remain the problem. As the rains are not very common in this area, rest of the problems can be solved by providing road side drains to safely pass the water.

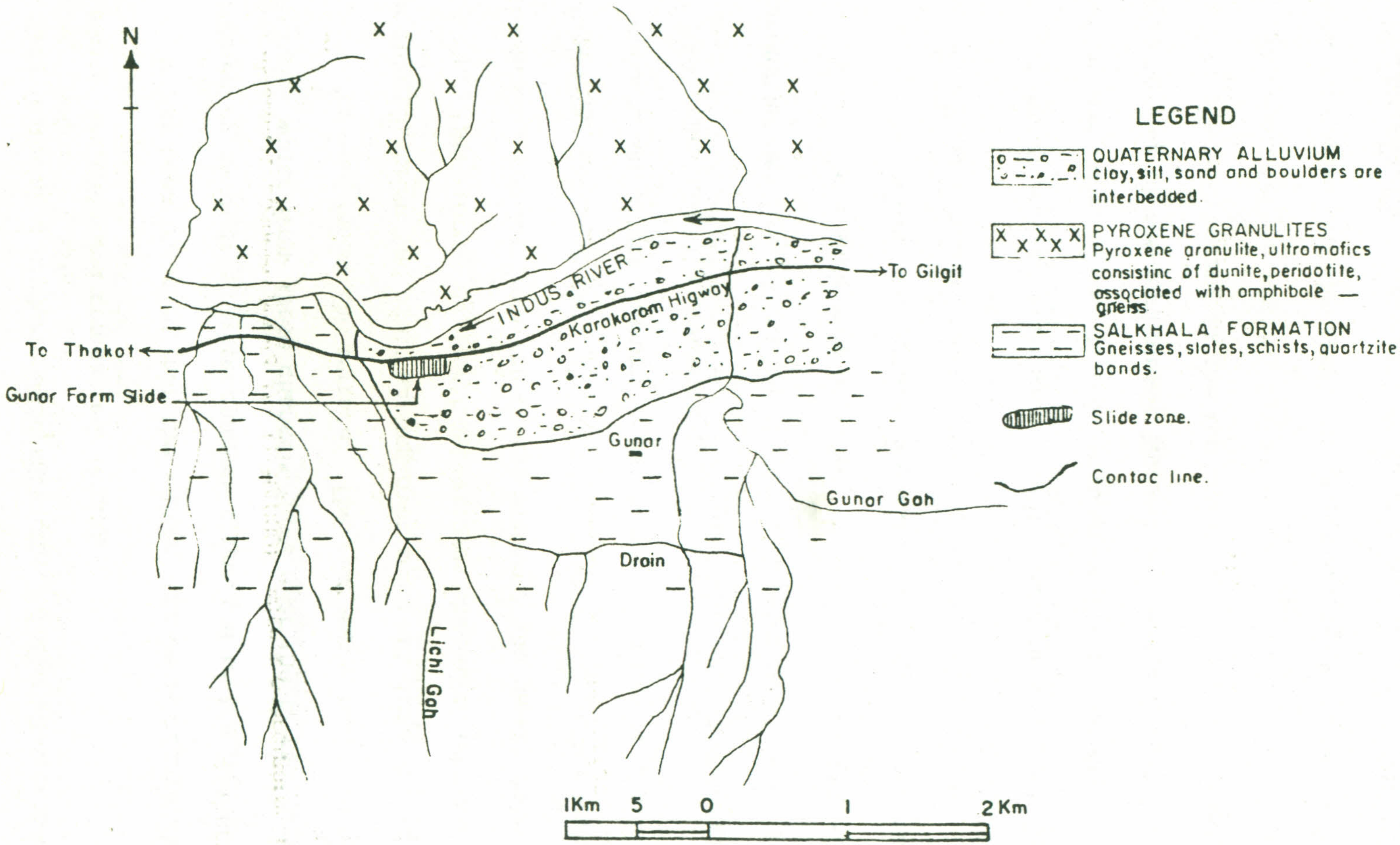


Figure 5— Generalised geological map showing location of Gunar Farm Slide on Km 257 on the KKH.

BUNAR DEBRIS SLIDE

Bunar debris slide is located on KKH at km 255 from Thakot approximately 18 km north of Chilas. This slide lies on Survey of Pakistan toposheet No.43 I/7 (1:50,000) with Co-ordinates Lat. 35^{O}.24'.15"N and Long. 74^{O}.18'.E. (Fig. 6).

Rock type exposed at the site is diorite. Jointing is very regular and three sets of joints were noted (1) N 55 W, 37 SW (2) N 80 W, 80 NE. (3) N 45 W, vertical. At the height of 65 m from the road level a shear plane is developed and slip surface is formed. Relatively finer material is lying in between the crown of shear plane and road, scree is piling up at the lower level near the road. Almost half of the road is covered by scree, which is lying at 40^{O} i.e. the critical angle. The rain, facilitates the material to slide down. In situ debris are partly cemented and roughly stratified. With the variation of temprature, scree material on loosening, fall under gravitational action.

Recommendations :

1) Retaining wall of about 3 m. high may be constructed at the base of the slide to retain material.

2) Ditch may be provided at the toe of the retaining wall to drain water.

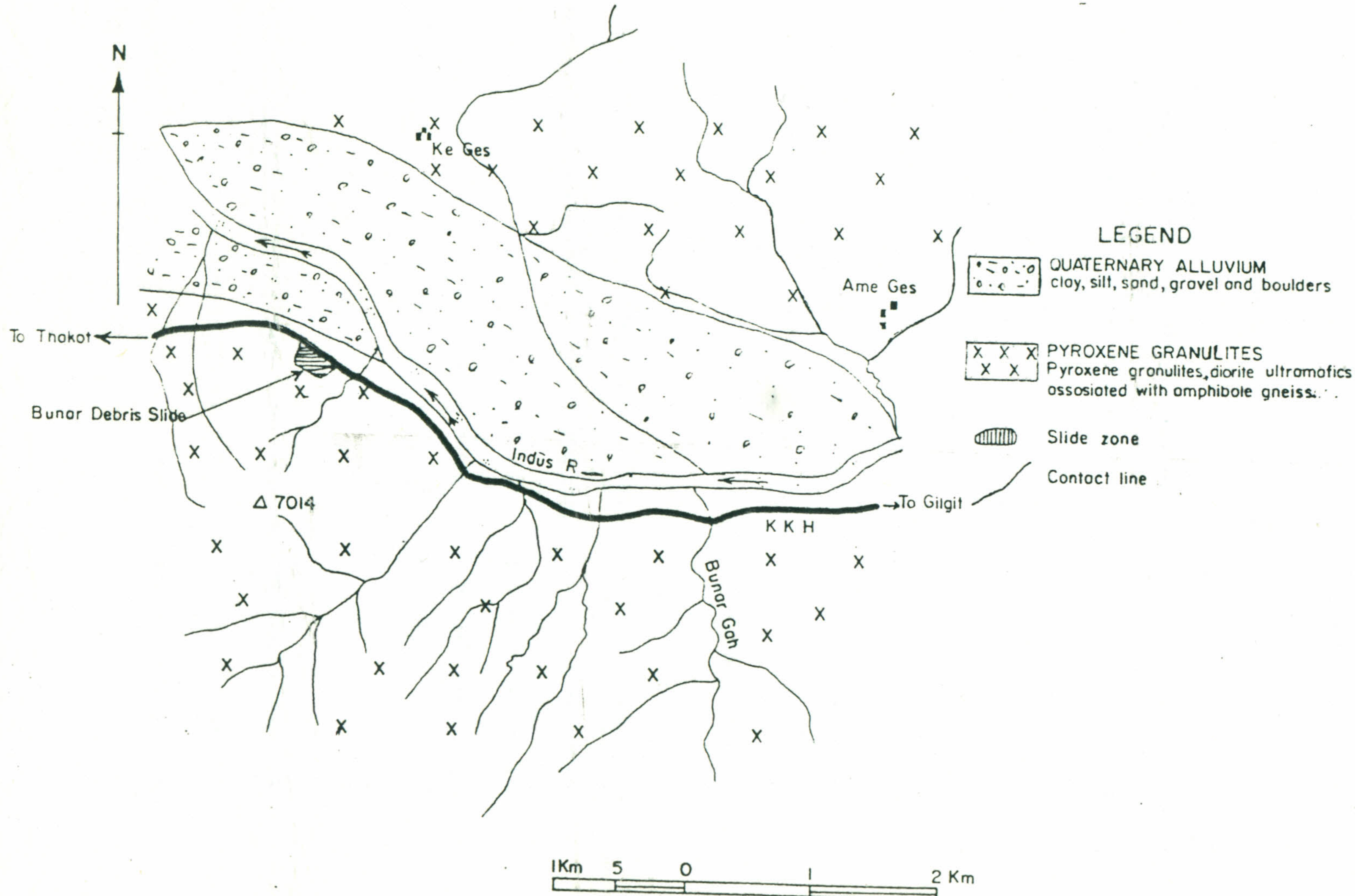


Figure 6- Generalised geological map showing location of Bunar Debris Slide at Km 255 on the KKH.

HARBON AVALANCHE

Harbon Avalanche is located on KKH at km 172 from Thakot approximately 3 km north of Shutial village. This avalanche lies on Survey of Pakistan toposheet No. 43 E/10 (Scale 1:50,000) with Co-ordinates Lat. 35^{o}, 32'.10" N and Long. 73^{o}.35' E. (Fig. 7).

Important aspect of the Harbon avalanche is the almost vertical scar which may be the result of removal of the surfacial terrace deposits and thus exposing the primary valley in the gabbro terrain. The material of the avalanche is composed of soils and rock fragments almost in equal amount.

A traverse was made upto the top of the Harbon hill to know the exact nature of the slide. At a height of approximately 900 m there is almost a flat terrace consisting of boulders pebbles, gravels and clayey silt with thin blanket of soil developed on this unstratified deposits. Near the top of the slide the terrace is subjected to vertical sinking and breaking of the landmass into blocks. Six major east-west trending cracks, alsmost parallel to each other, with a parting distance of 6 to 9 m. were noted (Fig. 8). From the crown of already developed shear plane first crack is 30 m. inside which is 15 to 30 cm. wide and fairly deep. Cuts or cracks made on the top of the terrace created depressions in which water accumulates. This water subsequently penetrates into the residual material, thereby loosening the soil mass and allowing it to slide down in the form of an avalanche. Other factors which support slide are:

1. Vertical movements of terrace material along these cracks in the form of slumps and sinks.

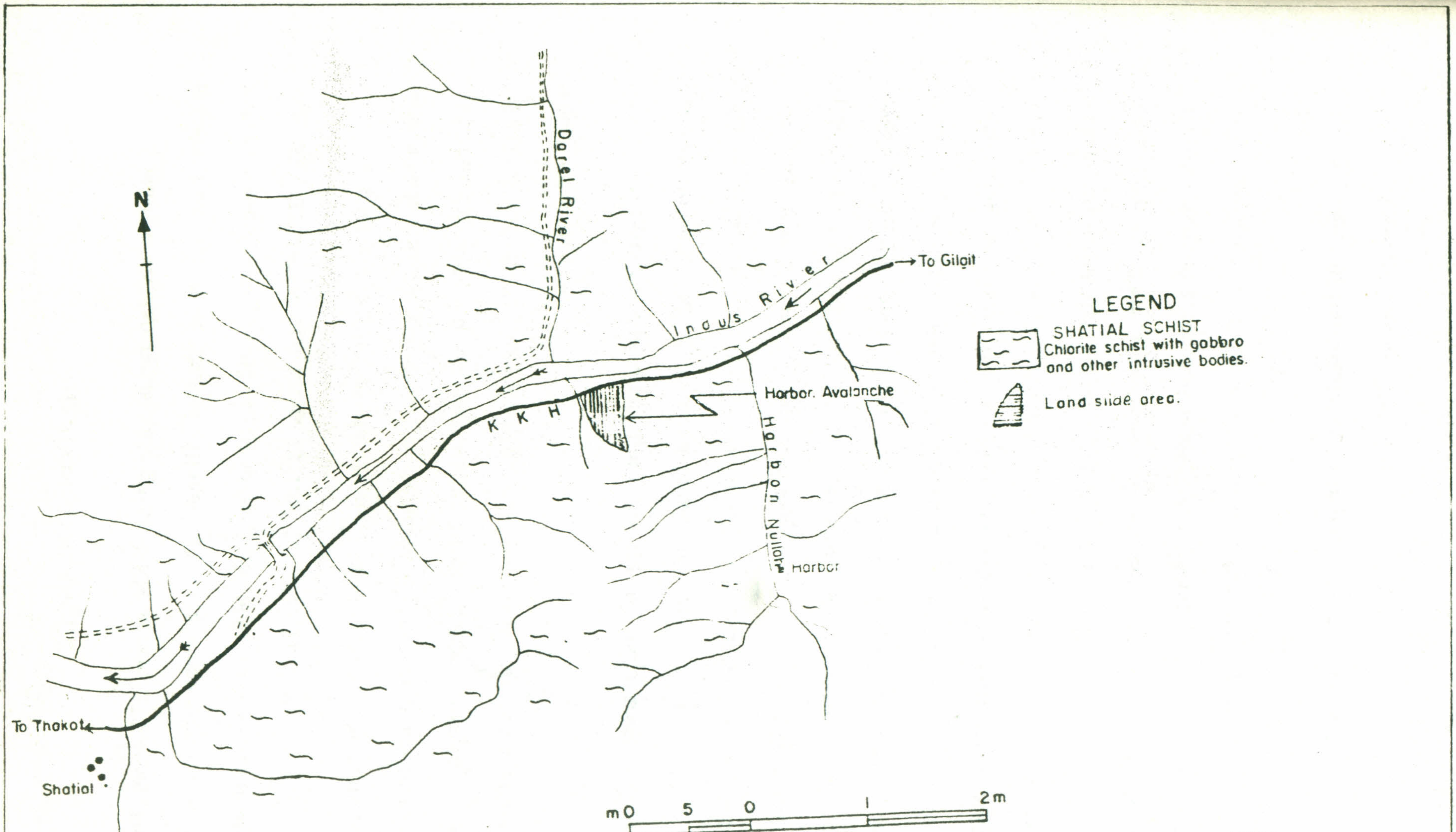


Figure 7- Generalised geological map showing location of Harbon Avalanche Area at Km 170 on the KKH.

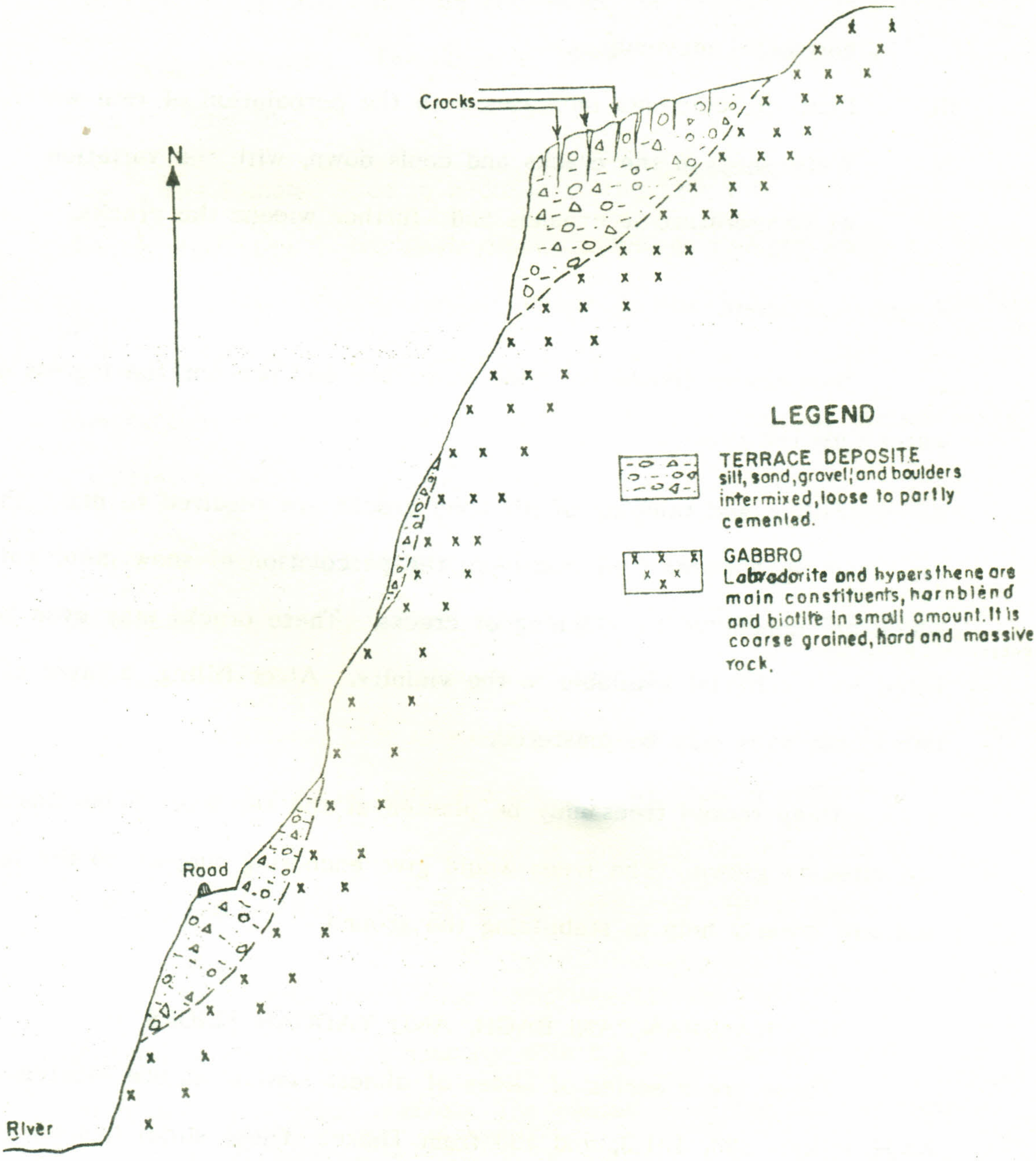


Figure 8- Geological cross section of Harbon Avalanche showing vertical scar above the road level and pattern of cracks on a flat terrace.

II. Water sinking through continuous water action prompted horizontal movements.

III. Load of sediments increases with the percolation of rain water.

IV. Water seeps in the cracks and cools down, with the variation of temperature it expands and further widens the cracks.

Recommendations :

1. Side drains should be made to reduce and prevent the ingress of water into the cracks.

2. Filling and tamping of all open cracks are required to make them safe from such water flow and from the percolation of snow melt water which are conducive to widening of cracks. These cracks may even be filled with material available in the vicinity. After filling, a layer of impervious soils may be plastered.

3. Deep rooted trees may be planted at the terrace. Some bushes are alrealdy grown. The trees would give enchoring support to the mass and will greatly help in stabilizing the ground.

KANDIAN,PANI BAGH, AND YADGAR SLIDES

These are a series of slides of almost similar nature located on KKH at kms 130, 131.3, and 133 from Thakot. These slides lies on Survey of Pakistan toposheet No.43 E/10 (1:50,000). Kandian lies with Co-ordinates Lat. 35^{O}.25'.45" N and Long. 73^{O}.13'.30" E. Pani Bagh lies with Co-ordinates Lat. 35^{O}.26'.41" N and Long. 73^{O}.12'.20" E. Yadgar Slide lies with co-ordinates Lat. 35^{O}.27'.45" N and Long. 73^{O}.13'.30" E.

The material involved comprises big boulders embedded in a fine silty clayey matrix chiefly derived from the decomposed rocks at higher levels. The material slides down in the form of mudflows in huge quantity after the heavy rains or some localised cloudburst. It is highly slippery and sticky under wet condition and on drying becomes loose and attains a greyish colouration. The material moves enmass and sweeps the road along it. (Fig. 9).

The Kandian slide in addition to the factor of heavy rains, may also be attributed to the environmental changes brought about by the human activities. The activities include cutting and grazing of trees and vegetation, disturbance of natural angle of repose as a result of construction activity on the road, and inadequate drainage system along the affected section.

The Pani Bagh slide has similar type of material exposed at steep angles upto a height of about 100m. The slide zone derives its material from higher catchment areas through a couple of streams which are 2 to 3 km long. Due to steep gradient of the nullahs, the rain water comes like a torrential flow and brings down load of sediments in large quantity and force. The road section opposite the torrential streams is damaged and washed away under the impact of falling debris.

The Yadgar debris slide comprises mixture of coarse and fine material in almost equal quantity with big erratic boulders embedded within the silty-clayey matrix. The causes of sliding are the same as described above i.e. over saturated debris material wash downhill due to the flash floods in the hill torrents. The debris on drying attain a very steep slope angle. The finer material is removed by strong wind action and makes the coarser sediments and big boulders susceptible to sliding in dry season as well. Three tributaries join the main nullah which aggravate the problem of debris flow.

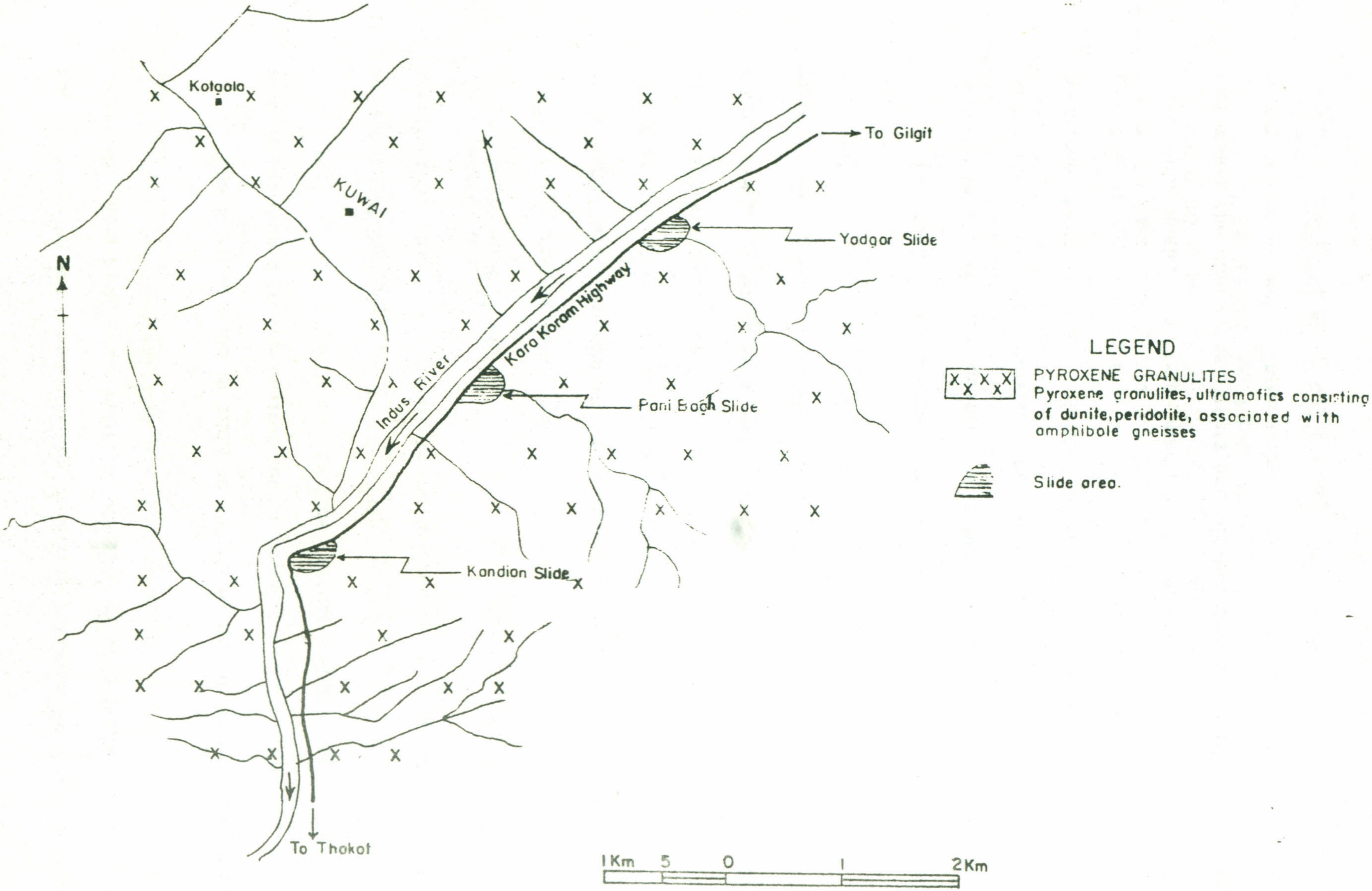


Figure 9- Generalised geological map showing locations of Kandian, Pani Bagh and Yadgar Debris Slides on Km 130, 131, and 132, respectively on the KKH

Recommendations :

1. At Kandian, the run-off water falls from height and causes slope failure and damages the road. This water may be channelized and make to fall over a suitably designed stone - pitched water fall at an angle of 10^{o}- 15^{o} less than the original slope angle. A drain may also be provided at the base of the slope at road level to divert the water properly into the river on the other side of the road.

2. At Pani Bagh, the flow of nullah could also be controlled with similar type of structure as described in the case of Kandian slide.

3. The mudflow at Yadgar Slide may be checked to some extent by diverting the potential flow of three nullahs. It would involve considerable quantum of work. A strong retaining wall may impart additional support to the slope.

CHUCHANG SLIDE

Chuchang slide is located on KKH at KM 110 from Thakot. This slide lies on Survey of Pakistan toposheet No.43 E/3 with Co-ordinates Lat. 35^{o}.18'N and Long 73^{o}.12' .35".E. (Fig. 10).

In the surrounding of Chuchang slide area pyroxene granulites are exposed where as at the slide Quaternary alluvium is present making the vertical cliff which is 30m high to its maximum. The deposition is stratified and consist in general of the following sequence from road level to top :

(a) Coarse loosely cemented sand about 3 m thick.

(b) Rounded boulders and gravel with sand 13 m thick.

(c) Sand loosely cemented 13 m thick.

(d) Clay with angular boulders and gravel 3 m thick.

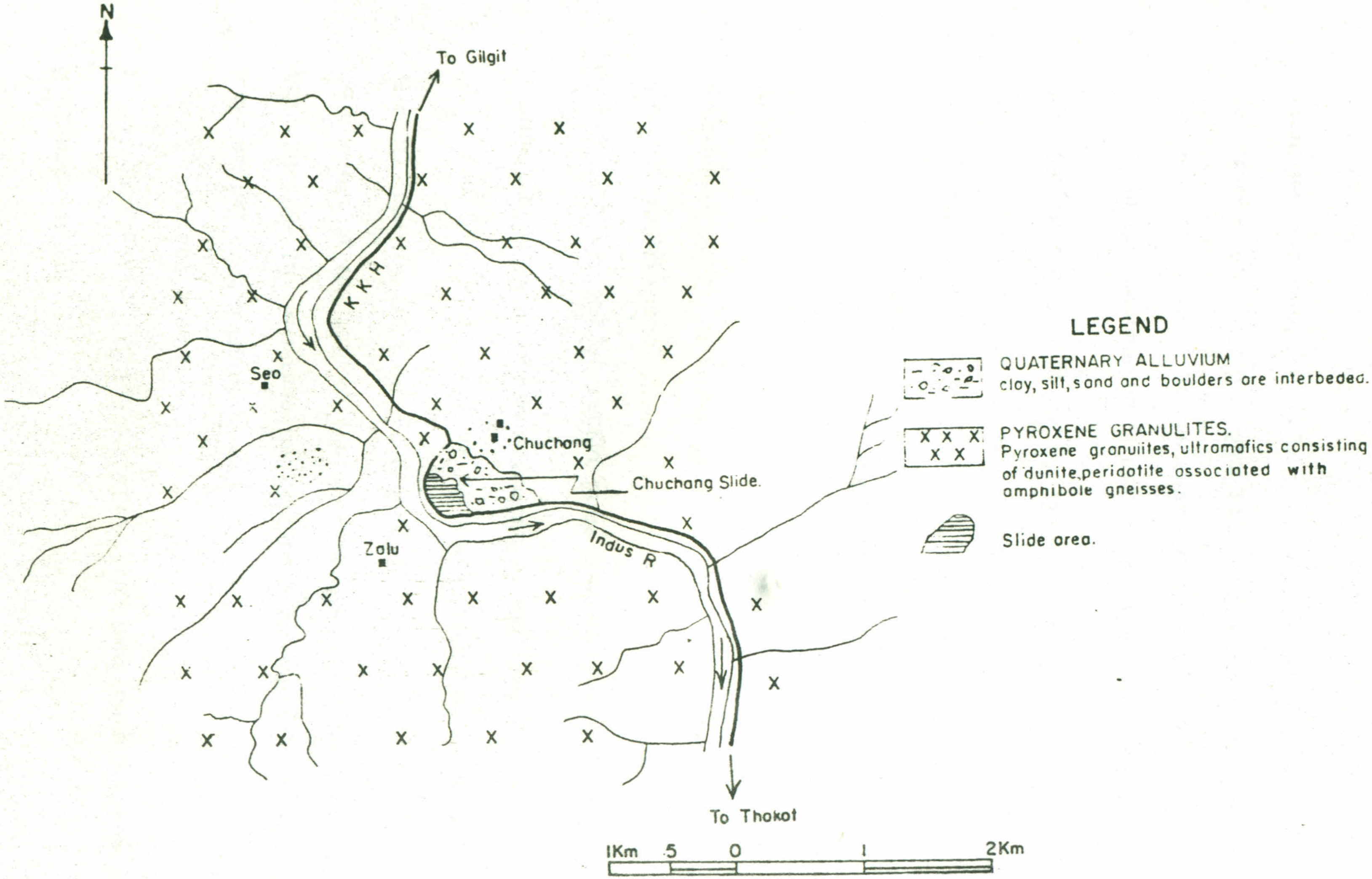


Figure 10 - Generalised geological map showing location of Chuchang Slide Area at Km 110 on the KKH.

The above strata normally stable at 50^{o} to 60^{o}. The sand is standing vertically but keeps on falling with the slightest vibrations from wind and vehicular movement. At one place overbreak of 2 m depth has taken place.

In the section between road and River Indus the material is similar as described above with silt and sand somewhat cemented.

The affected area is drained by a seasonal nullah which causes considerable undercutting and erosion of the side walls and causes large scale sliding.

Recommendations :

1) The nullah passing through Chuchang slide area should be properly protected from erosion by leading water on pitched stone with cement mortar and lead to the river through culverts and channels.

2) Road side drains may be provided to check the flow of rain and nullah water.

LAHORI NULLAH SLIDE

Lahori nullah slide is located at 32 km from Thakot. The rocks exposed in the area comprise schists and gneisses which are soft to medium hard. (Fig. 11).

The material involved in the slide is derived from decomposed and highly weathered schist rocks and is in the form of fine clayey soil with big slabs of broken parent rock. The process of soil formation is quick due to the soft and incompetent nature of the parent rock and considerably thick weathered soil cover is formed on the bedrock surface. This thick soil is used for crop cultivation where narrow long strips of terraced fields are developed on the hill slopes.

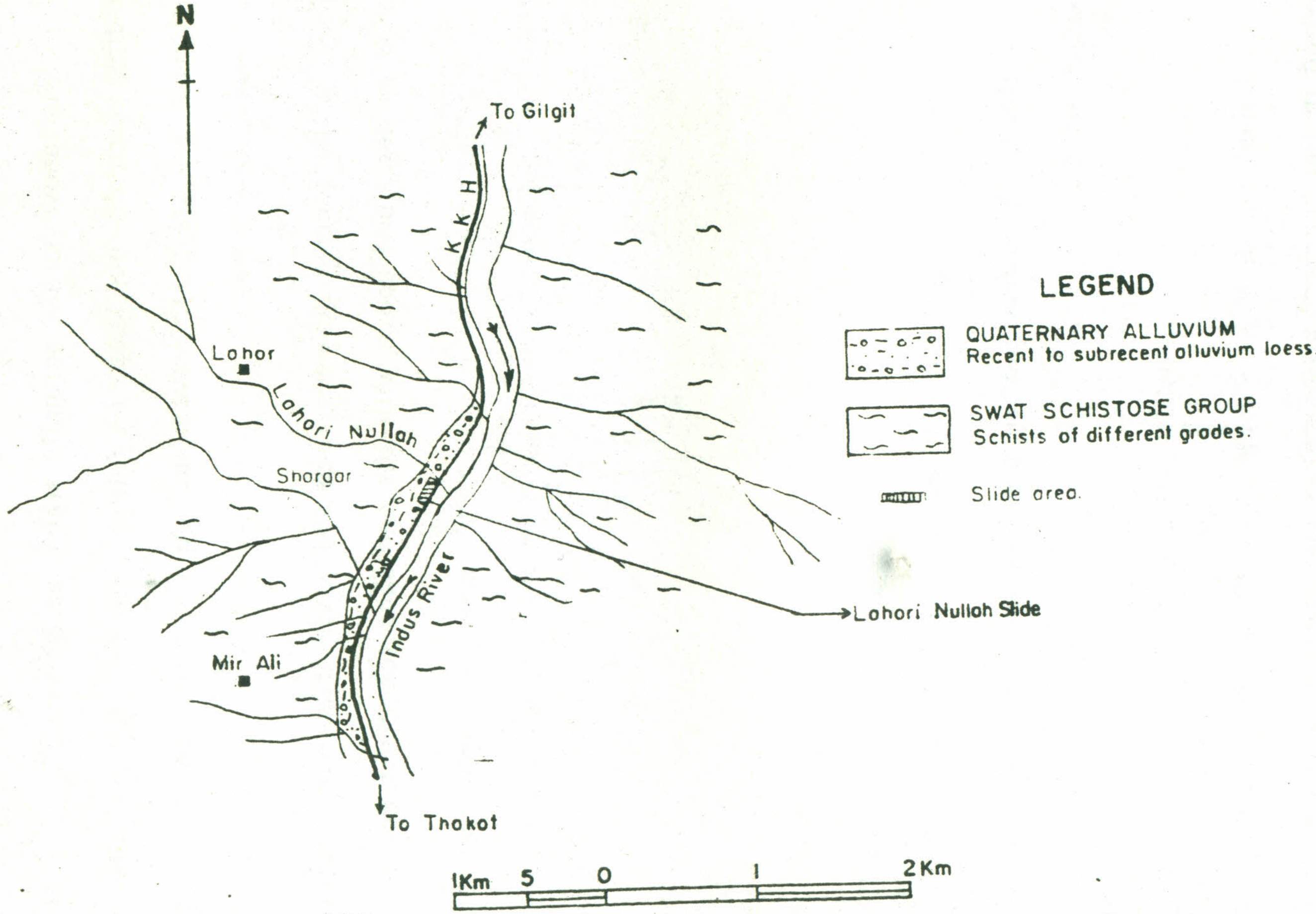


Figure 11- -Generalised geological map showing location of Lahori Nullah Slide at Km 32 on the KKH.

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The Lahori nullah slide occures in the form of a debris slide which is 110 m wide and the scar of the slide is distinctly visible at the height of about 100 m above the road. This slide most probably initiated due to the disturbance of its angle of repose during widening and construction of the road. The toe support was removed leaving the overhead material unsupported, making it vulnerable to sliding.

As these hill slopes are highly cultivated the infiltration rate is comparatively more which enhances the process of rock decay. The clayey contents get lubricated and start sliding down under the impact of gravity. Contact of terrace deposits with the rocks after receiving continuous moisture from the cultivated fields gets lubricated and start falling down.

Recommendations :

1) The slide may be effectively checked by the construction of a breast wall at the road level and a retaining wall below the road.

2) Stone-pitched drain may be constructed at the road side to divert the rain water and pass it down the road through a culvert.

3) Excessive infiltration of water may be checked in the terraced fields above the slide zone by limiting the supply of crop water.

NON LOCALISED MASS MOVEMENTS

The geological context, environmental hazards, and climatic effects can cause landslides at any place along the Karakoram Highway. We in the preceeding pages have discussed those areas which are worst affected. However, many areas along the KKH. are such that movements varying from hill side creep to huge slide scars can occur sporadically. The causes of such sporadic occurrances are local in nature such as :-

(1) Construction activity that cuts into a slope.

(2) removal of protective vegetation.

(3) worsen natural drainage conditions.

Therefore it is almost impossible to forewarn with the danger potential of such areas.

Appendix-1,2 gives a detailed inventory of the mass movements occured in various stretches of the Karakoram Highway on different dates particularly after the torrential rains which has been collected with the courtesy of Frontier Works Organisation. It was observed that on 26th October, 1982, at least 12 slides occured in 13 kilometer between 47 to 60 km from Thakot (Fig. 12). The nature of the mass movement phenomenon comprised rock falls, mudflows and debris slides and involved about 36,900 cubic meter of rock and talus debris (Appendix 1).

It may be mentioned here that the geology played an important role in the stability of this area. In the 13 km stretch of the road described above, the major rock formations include Pyroxene Granulites, Jijal Ultramafics and Swat Schistose group(Fig. 12). These rocks with the exception of pyroxene granulites are highly incompetent and susceptible to weathering and mass movements.

On 11th March, 1983, the phenomenon reactivated in the same road stretch from km 53.6 to 62.5 where at least 10 slides were recorded after the rains and involved 4,700 cubic meter of rock and debris. (Fig. 13, Appendix 1).

Another landsliding incident on 26th March 1983, affected a much larger area and nearly 14 places were recorded with heavy debries in a zone of 27 km between km 31.7 to 58.3 from Thakot. The rock and debris involved ranged in volume to approximately 6,234 cubic meters

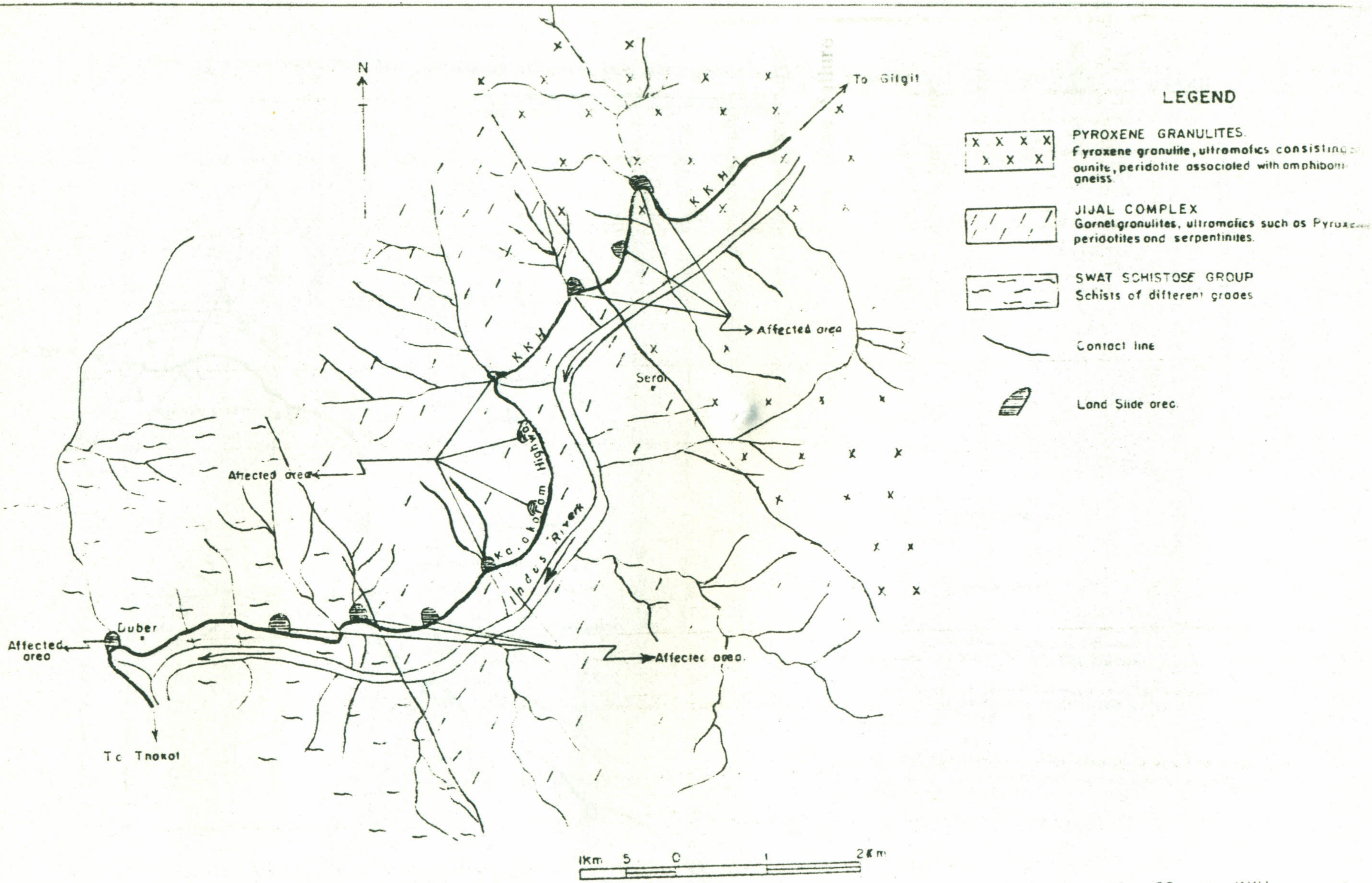

Figure 12 · Generalised geological map showing locations of land Slide effected areas on 26 October 1982 at Km 47 to 60 on the KKH.

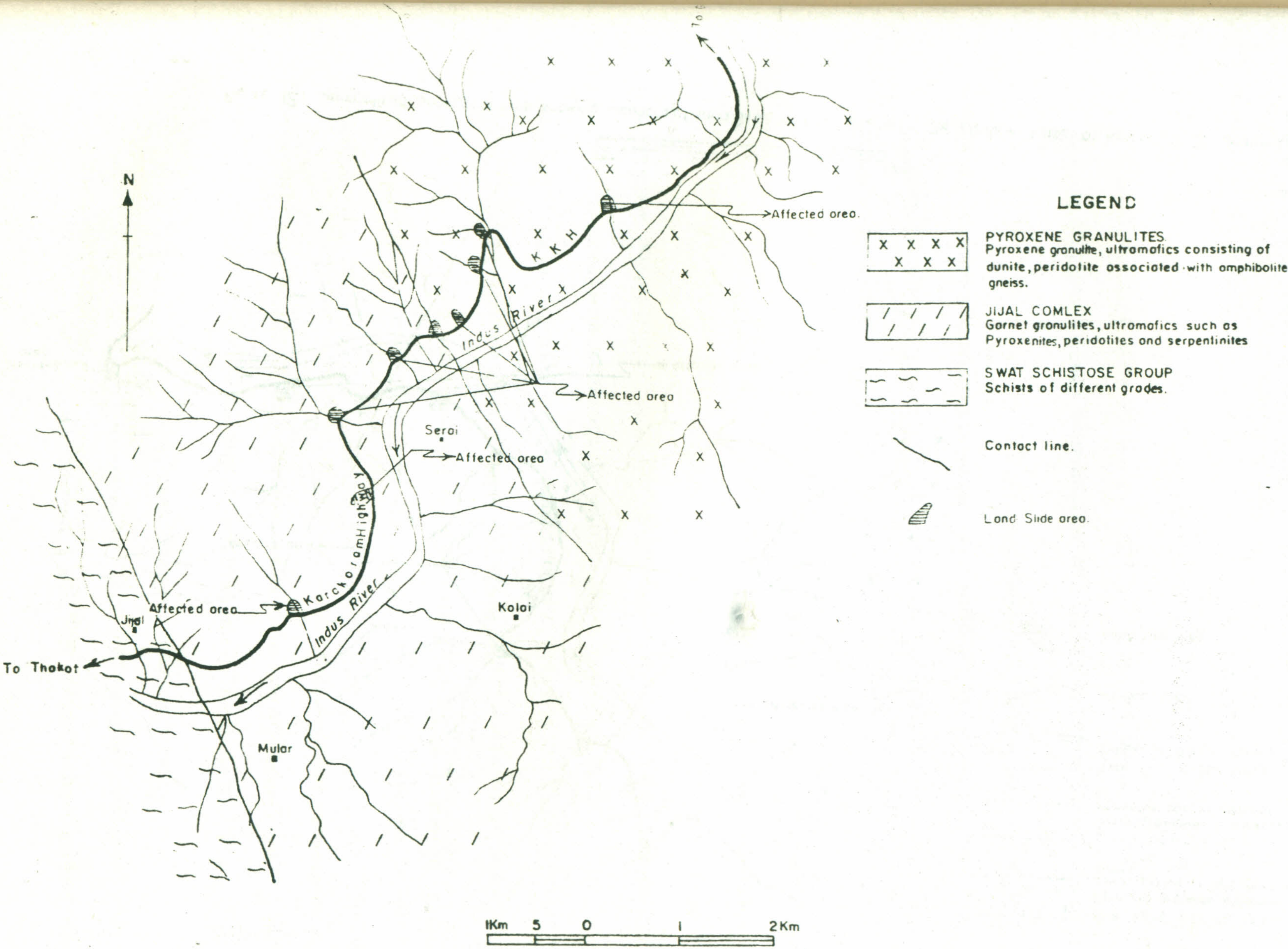

Figure 13 :- Generalised geological map showing locations of land slide affected areas on the 11, March 1983 betwen Km 53–63 on the KKH.

Similar occurrances were noticed on the same date between Thakot and Shawar (0 km to 12.6 km). It involved 1,115 cubic meter of material (Fig. 14).

The statistics regarding the road section between km 111.2 to 130.1 and km 147 to 149 has also been recorded (Appendix 1). Some mass movement of occasional nature were also recorded at various places, along the Karakoram Highway.

The maintenance and clearance of road blocks required tremendous amount of efforts of both men and material.

Recommendations :

The problem areas described above are of varied nature and intensity and are attributed to different causes. Their controlling and remedial measures depend upon the local geological, geomorphological, and environmental conditions. Therefore, the following measures of general application are suggested to control or retard the slope failure and mass movement activities :-

1) The most effective and practicable method to check the slope failure particularly in rain affected areas is to provide efficient drainage system in the form of longitudinal and horizontal catchwater drains to reduce infiltration and ingress of surface water run off. The road drains play an important role in the stability of a slope. These drains may be stone-pitched and efforts should be made to keep them clean from debris so as to provide efficient flow of water to its point of disposal.

2) In fractured rocks, under-pinning may be done to control loose blocks and ledges.

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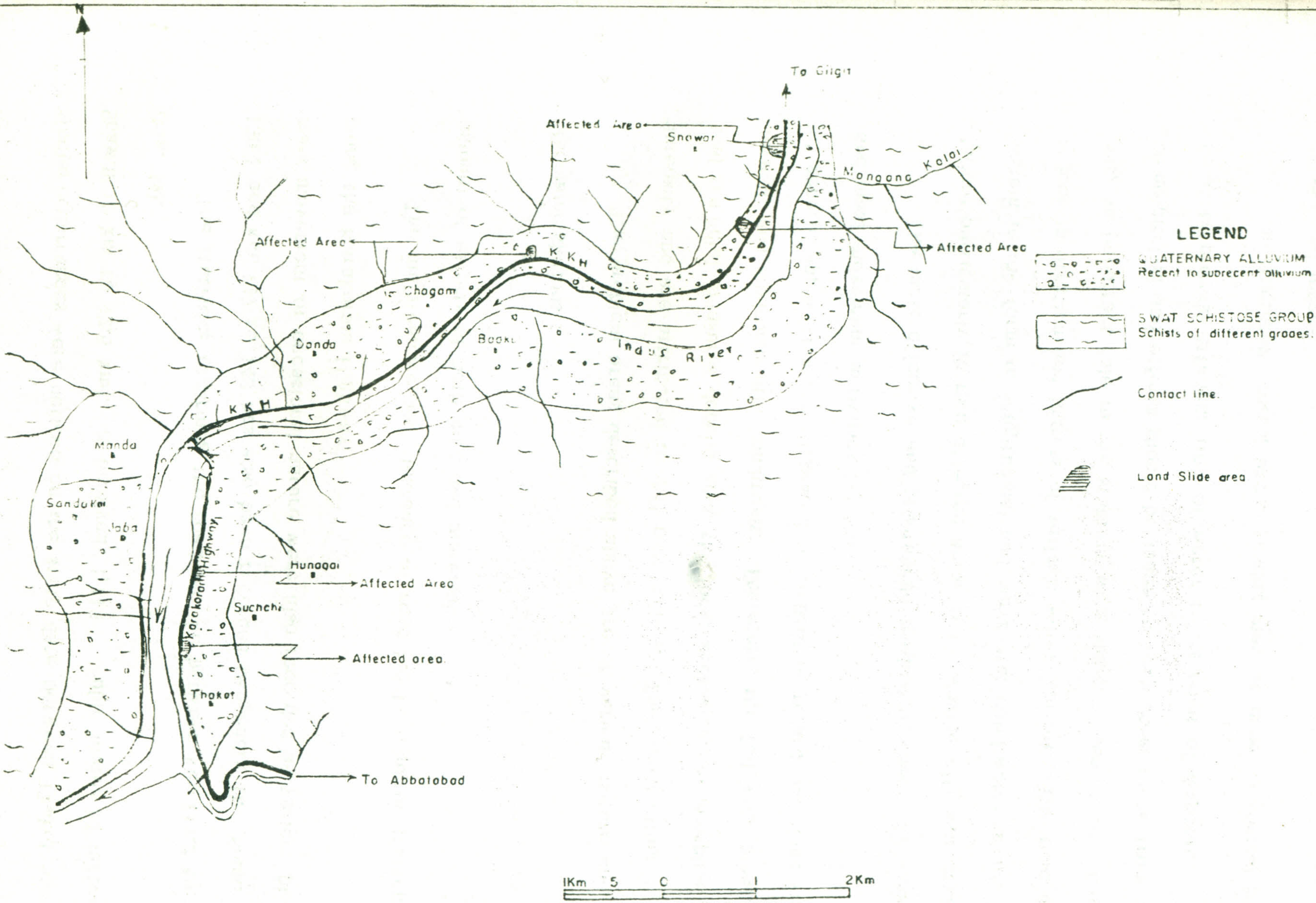

Figure 14– Generalised geological map showing locations of land Slide Affected areas on 26 March 1983, Thakot and Shawar at Km, 0 to 13, on the KKH.

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3) The over hanging blocks may be brought down by scaling to avoid danger of rock boulder fall due to vibrations.

4) A few places may be safeguarded by providing wire mesh net work to check the stones falling directly on the road.

5) Impact walls may be constructed for protection in scree areas.

6) Strong retaining walls in the cut slopes of talus and scree zones would greatly retard creep movement.

7) Some slopes may be gunited to retard weathering of parent rock.

APPENDIX - 1 : ROAD BLOCK-LOG OF KARAKORAM HIGHWAY FROM THAKOT BRIDGE TO RAKHIOT BRIDGE DURING FEBRUARY 1982 TO AUGUST 1983.

Date	K.M.	Volume: Length x width x height (m) (m) (m)	Reason
February, 1982			
1) 3-2-82	72.3	12 x 8 x 2	Rock fall.
2) 3-2-82	55.	10 x 6 x 2	"
3) 25-2-82	92 k.m.	25 x 8 x 5	"
4) 28-2-82	69	20 x 8 x 4	"
March, 1982:			
5) 22-3-82	80	10 x 8 x 5	"
6) 22-3-82	169	100 x 8 x	Mudflow.
7) 31-3-82	30	30 x 8 x 6	Landslide.
8) 31-3-82	116	50 Meter road washed away.	Flood.
April, 1982:			
9) 4-4-82	BARASIN 116 k.m.	30 x 8 x 5	Rock fall.
10) 9-4-82	Komila 100 k.m.	8 x 8 x 3	Landslide
11) 30-5-82	Tatta Pani 276	20 x 15 x 4	"
June, 1982:			
12) 15-6-82	Dubair	35 x 6 x 2	Landslide Debris.
	45.8	17 x 4 x 2	"
	46.046.1,	60 x 6 x 2	"
	48.4 k.m.	8 x 4 x 2	"
J u l y, 1982:			
13) 30-6-82	260.5	50 x 8 x 5	Rainfall.
14) 1-7-82	257.	30 x 8 x 2	"
15) 2-7-82	Chuchang 108	150 x 8 x 2	"
16) 2-7-82	105.7	150 x 8 x 2	Landslide
17) 7-7-82	55.4	25 x 8 x 2.5	"
18) 7-7-82	57.1	15 x 6 x 3	"
19) 7-7-82	57.2	20 x 7 x 4	

August, 1982: Date	K.M.	Volume Lengthxwidth x height	Reason
20) 10-8-82	Gandlo Br. 256	Glaciated with debris	Mudflow Boulders.
21) 11-8-82	Ghani Hotel 237.	Mudflow.	
22) 25-8-82	55.	50 x 6 x 6	Landslide.
September, 82:			
23) 28-9-82	45	15 x 8 x 1	Rock fall due to rain.
October, 82:			
24) 26-10-82	46.	8 x 6 x 3	Mudflow Boulder. Landslide.
25) 16-10-82	47.	8 x 6 x 2	Rock fall.
26) 26-10-82	92	12 x 6 x 3	"
27) 26-10-82	115	20 x 6 x 1.5	"
29) 26-10-82	56	300 x 5 x 3.	Mudflow.
30) 26-10-82	57	17 x 7 x 5	Rock fall Hill slide.
31) 26-10-82	58	30 x 8 x 5	Mudflow.
32) 26-10-82	60	6 x 30 x 1	"
33) 26-10-82	49	20 x 8 x 1	"
34) 26-10-82	51	20 x 8 x 1	"
35) 26-10-82	52	50 x 8 x 6	"
36) 26-10-82	53	35 x 8 x 2	"
37) 26-10-82	54	12 x 6 x 2	"
38) 26-10-82	55	25 x 8 x 6	"
39) 26-10-82	56	23 x 7 x 5	"
40) 26-10-82	170	1300 x 6 x 3	"
November, 82:			
41) 8-11-82	114	50 x 5 x 8	Hill slide.
42) 16-11-82	47	8 x 3 x 5	Mudflow due to rain.
43) 16-11-82	51	15 x 6 x 3	Hill slide due to rain.
44) 16-11-82	171	10 x 5 x 6	Mudflow.
45) 17-11-82	124	8 x 3 x 5	Rock slide, stone fall due to rain.

Dates:	K. M.	Lengthxwidthxheight	Reason
46) 17-11-82	125	8 x 6 x 5	Rock slide stone fall due to rain.
47) 17.11.82	128	6 x 3 x 1	"
48) 17-11-82	130	6 x 1 x 1	"
49) 17-11-82	132	8 x 4 x 1	"
50) 18.11.82	65.1	8 x 6 x 5	Landslide with boulder.
December, 82:			
51) 3-12-82	80.5	15 x 8 x 6	Boulder slide.
52) 3-12-82	81.	20 x 5 x 10	Hill slide with boulder.
53) 3.12.82	83	15 x 6 x 8	Landslide.
54) 3-12-82	78	18 x 6 x 8	"
55) 4-12-82	129	100x 10 x 10	Hill slide.
56) 4-12-82	52	50 x 10 x 20	Landslide.
57) 9-12-82	78.5	25 x 8 x 5	"
58) 9-12-82	79.	15 x 8 x 4	"
59) 9-12-82	80.5	100x 30 x 6	Rock fall.
60) 9-12-82	137.25	30 x 6 x 2	Rock slide.
61) 9-12-82	139.50	15 x 6 x 2x2	Landslide.
62) 9-12-82	142.	3 x 2 x 2	"
63) 9-12-82	154.	10 x 3 x 1.5.	"
64) 10-12-82	115	30 x 6 x 5	Rock slide
65) 13-12-82	104.50	10 x 10 x 5	Landslide.
66) 13-12-82	104.2.	20 x 10 x 3	Rock slide.
67) 13-12-82	104.9.	20 x 10 x 5	20 meter retaining wall washed away.
68) 13-12-82	164	7 x 4 x 3	Rock slide.
69) 13-12-82	149	30 x 3 x 3	"
70) 15-12-82	54	15 x 10 x 3	"
71) 18-12-82	52	15 x 10 x 3	"
72) 19-12-82	132	20 x 6 x 2.5	"
73) 19.12.82	54	2 x 8 x 3	"
74) 29-12-82	129	30 x 10 x 3	"

January,1983:	K.M.	Volume length x width x height	Reason
1) 9-1-83	96.8	35 x 6 x 1	Rock slide
2) 11-1-83	275	30 x 8 x 2	Hill slide.
3) 17-1-83	97	80 x 15 x 6	Rock fall.
4) 27-1-83	8.3	10 x 6 x 112	"
5). 27-1-83	109	20 x 6 x 2	"
6) 29-1-83	68.4	10 x 8 x 1.5	Rock fall
February,83:			
7) 2-2-83	71.2	6 x 8 x 1	Rock fall
8) 3-2-83	85.6	25 x 8 x 25.5	"
9) 24-2-83	89.5	16 x 8 x 1.5	"
10) 25-2-83	108	16 x 4 x 3	"
March, 1983:			
11) 1-3-83	53	30 x 6 x 3	Rock fall
12) 1-3-83	65	20 x 6 x 2	"
13) 1-3-83	103	50 x 6 x 8	"
14) 2-3-83	160.3	22 x 6 x 4	"
15) 5-3-83	117	15 x 4 x 6	Rock fall due to heavy rain.
16) 8-3-83	96.7	30 x 8 x 6	"
17) 9.3.83	46.1	50 x 8 x 5	"
18) 9-3-83	57.9	10 x 8 x 3	"
19) 9-3-83	141.5	4 x 3 x 3	Boulders fall due to heavy rain.
20) 9-3-83	151	8 x 4 x 3	Rock fall due to heavy rain.
21) 9-3-83	136	10 x 4 x 4	"
22) 9-3-83	275.5	35 x 8 x 115	Hill slide due to heavy rain.
23) 9-3-83	133	25 x 12 x 6	Rock fall " "
24) 10-3-83	166	4 x 5 x 6	Rock fall due to heavy rain.
25) 10-3-83	56.3	3 x 8 x 5	" " "
26) 10-3-83	133.5	60 x 18 x 6	Rock fall.
27) 10-3-83	149	30 x 10 x 4	Boulder fall
28) 10-3-83	123	30 x 10 x 4	Rock fall
29) 10-3-83	108	15 x 3 x 4½	"

March, 1983 :	K. M.	Volume Length x width x height	Reason
31) 11-3-83	100.4	35 x 8 x 6	Boulders fall
32) 11-3-83	159.75	35 x 4 x 6	"
33) 10-3-83	133.5	60 x 18 x 6	"
34) 11-3-83	60.3	15 x 8 x 2	"
35) 11-3-83	53.6	20 x 8 x 2	"
36) -do-	55.3	15 x 8 x 1	"
37) -do-	57.1	40 x 8 x 3	"
38) -do-	58.3	25 x 2 x 2	"
39) -do-	59.5	25 x 8 x 3	"
40) -do-	60.1	20 x 8 x 2	"
41) 11-3-83	59.1	20 x 8 x 3	Rock fall.
42) -do-	60.	25 x 8 x 3	"
43) -do-	62.50	30 x 8 x 4	"
44) ni 11/12	182.	16 x 22 x 8	"
45) ni 11/12	Harbon 170	17 x 1 x 6	"
46) 12-3-83	Sazin 158.3	15 x 4 x 6	"
47) 12-3-83	153.00	15 x 2 x 6	"
48) 12-3-83	151.1	60 x 5 x 6	"
49) 12-3-83	151.	60 x 10 x 1	Glacier
50) 12-3-83	159.8.	35 x 4 x 5	Rock fall.
51) -do-	106.	50 x 12 x 6	
52) -			Glacier
53) 12.3.83	127	3 x 10 x 5	Snowfall
54) ni 18.3.83	110. Chuchang area.	20 x 8 x 5	Rock fall.
55) ni 30-3-83	49.5	9 x 8 x 3	Rock fall
56) 21-3-83	52.5. near Jijal	25 x 29 x 4	"
57) 22-3-83	275.2	40 x 8 x 8	Rock fall
58) 25-3-83	55.5.	20 x 8 x 2	Rock fall due rain.
59) ni 25.3.83	170.	170 x 8 x 2	Boulders & Mudflow.
60) 26-3-83	275.5.	30 x 8 x 3	Due to heavey rain.
61) -do-	85.5	20 x 8 x 7	Rock fall.
62) -do-	147.50	7 x 1 x 6	Rock fall due to rain.

March, 1983.	K.M.	Lengthxwidthxheight	Reason
63) 26-3-83	147.	15 x 1 x 6	Rock fall due to rain.
64) "	149.	15 x 4 x 8	Boulder & Mud-flow.
65) "	6 k.m.	17 x 7 x 7.7	Rock fall due to heavy rain.
66) "	31.7.	38.8x8 x 12	"
67) "	1.5.	7.7 x 5.4x 1	"
68) "	47.8	12.2.x4 x 3	"
69) "	119.5	12 x 4 x 2	"
70) "	35.4	17 x 4 x 1	"
71) "	35.5	10. x 6 x 3	"
72) "	48.7	14 x 4 x 2	
73) "	58.3	18 x 6 x 1	"
74) "	111.2	12.2x 4 x 3	"
75) "	113.6	9 x 5 x 1	"
76) "	118.7	27 x 7 x 1	"
77) "	112.3	14 x 4 x 1	"
78) "	129.2	23 x 5 x 1	"
79) "	130.1	23 x 8 x 10	"
80) "	223.5	20 x 4 x 1	"
81) "	162.4	18 x 6 x 4	"
82) "	129.9	23 x 6 x 7	"
83) "	11.4	13 x 5 x 2,5	"
84) "	12.6	7.5 x 4 x 1	"
85) "	32.2	13 x 4 x 5	"
86) "	51	25 x 9 x 3	"
87) "	39	30 x 8 x 4	"
88) 27-3-83	51	35 x 8 x 10	"
89) 26-3-83	128	40 x 7 x 8	"
90) ni 29.3.	7.5	8 x 4 x 4	"
91) "	32.5.	12 x 8 x 5	"
92) "	37.6.	6 x 8 x 5	"
93) "	41.5	6 x 7 x 4	"
94) "	39.6	15 x 8 x 4	"
95) 31.3.83	108	25 x 8 x 3	Heavy boulders fell.

April, 1983:	K.M.	Length x width x height	Reason.
96) 8-4-83	32.2	30 x 10 x 7	Rock fall due to rain.
97) 8-4-83	32.3	60 x 10 x 15	"
98) 10-4-83	32.3	85 x 10 x 18	"
99) 14-4-83	51.6	20 x 8 . 10	"
100) 14-4-83	32.6	200 x 200 x 20	Rock fall.
May, 1983:			
101) 19-5-83	4.5.	14 x 8 x 6	Rock fall due to rain.
102) 21-5-83	261.8	24 x 8 x 1	Hill slide due to rain.
June, 1983:			
103) 27-6-83	24.5	25 x 8 x 3	Mud flow due to rain.
104) 27-6-83	24.75	28 x 8 x 3	"
July, 1983 :			
105) 2-7-83	32.2	35 x 8 x 5	"
August, 1983:			
106) 8.8.83	32	15 x 8 x 6	Rock fall due to rain.
107) 5.8.83	241	100 x 8 x 2	Glacier.
108) 19.8.83	275	75 x 9 x 10	Mud flow.

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APPENDIX - 2 : DEBRIS CLEARANCE RECORD OF SELECTED SLIDES FROM THAKOT BRIDGE TO RAKHIOT BRIDGE DURING 1981 TO 1983

(Year 1981 - 83)

S.No.	Area	Loc. K.M.	Length K.M.	Quantum of work cu. meter Jan. 81	82	83
1.	Gloze Banda	54	4.0	2,862	1,560	8,56,728
2.	Keru	83	6.0	1,893	949	29,544
3.	Chuchang Area	109	4.0	740	1,820	12,793
4.	Pani Bagh	128	10.0	18,624	5,858	39,922
5.	Harbon	172	4.0	12,146	8,975	7,324
6.	Basha Area	182	135	648	800	1,677
7.	Thak Area	234	8.0	5,506	4,050	-
8.	Gandlo Area	260	4	1,856	6,724	956
9.	Tatta Pani	275	5.0	12,638	6,954	9,640
10.	Misc. slides Debris Clearance			5,69,718	1,22,828	
11.	Lahori Nullah					
		Total :-		6,16,790	1,60,509	97,535

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