ENGINEERING GEOLOGY
INF. RELEASE NO. 272

IR-272.

GEOLOGICAL SURVEY OF PAKISTAN
MINISTRY OF PETROLEUM & NATURAL RESOURCES

GEOLOGICAL SURVEYS
MINERAL EXPLORATION

GEOPHYSICAL SURVEYS
GEOCHEMICAL SURVEYS
ENERGY RESOURCES SURVEYS

ENGINEERING GEOLOGICAL
SURVEYS. DRILLING FOR
EXPLORATION & EVALUATION

ROCK AND DEBRIS SLIDES BETWEEN KHUNJERAB PASS AND GILGIT ALONG THE KARAKORAM HIGHWAY

By

KANWAR SABIR ALI KHAN
ARSHAD FAYAZ
MOHAMMAD LATIF &
AMIR KHAN WAZIR

ENGINEERING GEOLOGY
INF. RELEASE NO. 272

GOVERNMENT OF PAKISTAN
GEOLOGICAL SURVEY OF PAKISTAN

INFORMATION RELEASE NO.272

ROCK AND DEBRIS SLIDES BETWEEN KHUNJERAB PASS AND GILGIT ALONG THE KARAKORAM HIGHWAY

By

KANWAR SABIR ALI KHAN
ARSHAD FAYAZ
MOHAMMAD LATIF &
AMIR KHAN WAZIR

Engineering Geology Branch, Northern Areas Directorate,
ISLAMABAD.

Issued by the Director General, Geological Survey of Pakistan, Quetta.
1986.

ABSTRACT

Rock, debris and scree slides from Gilgit to Khunjerab Pass along the Karakoram Highway (KKH) are discussed in this report. Study of slides include type of rock/material involved in the affected area, reason of their occurrences and remedial measures to check the mass movement phenomenon.

Kafir Pahar slide zone, Notorious Killing Zone and Shitan Pari slide are studied in detail due to their critical position on the KKH; and the magnitude and repeated occurrences involving large amount of material fall. Specific recommendations for the stabilization of slopes have been proposed for each of the affected areas.

Continuous maintenance of the KKH requires considerable efforts in terms of time and money. 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.

ACKNOWLEDGEMENT

The authors are indebted to Dr. S. Mahmood Raza, Deputy Director, GSP for his critical review and wise counsel in the final editing of this report. Thanks are also due to Mr.M. Saeed-uz-Zafar Khan,Director for providing every assistance and guidance in the accomplishment of this project.

The authors express their gratitude to the Frontier Works Organization for providing accommodation facilities in the field.

Last but not the least, the untiring efforts by late Manzoor Hussain, Stenographer and Mr. Ghulam Safdar, Stenographer for typing of this report and Mr. Mohammad Shafi, Geological Illustrator for preparation of diagrams is deeply appreciated.

CONTENTS

LIST OF FIGURES

TABLE AND APPENDIX

INTRODUCTION

Purpose and Scope.

On the request of University Grants Commission and the Frontier Works Organization, landslide investigations were carried out along the Karakoram Highway during the field season of 1983-84. These investigations were aimed at determining the causes of frequest incidents of slope failures all along the Karakoram Highway. These slope failures in the form of rock and debris slides, avalanches, mud flows and soil creep have posed serious threats to the communication links of the Northern Areas and are highly detrimental on the socio-economic life of the people of these areas.

The causes of these slides have been viewed in the perspective of disturbances of the slopes with regard to their natural angle of repose during the construction of the KKH. The environmental, topographic and geological factors have equally contributed to the occurrences of slope failures and are given due consideration in the proposed remedial measures.

Method of Investigations.

The conventional techniques of engineering geological mapping were used vis-a-viz the location and identification of the slides, their extent and magnitude and the type of rock and soil involved. Due to non-availability of large scale maps, road logs on suitable scales were prepared by tape and brunton method and each slide was mapped in detail.

Location and Accessibility.

The problem areas discussed in this report pertain to the road section between Gilgit bridge and Khunjerab Pass which is 266 km in length. This section of the Karakoram Highway passes through toposheet numbers 43 I, 42 L and 42 P. (Fig. 1).

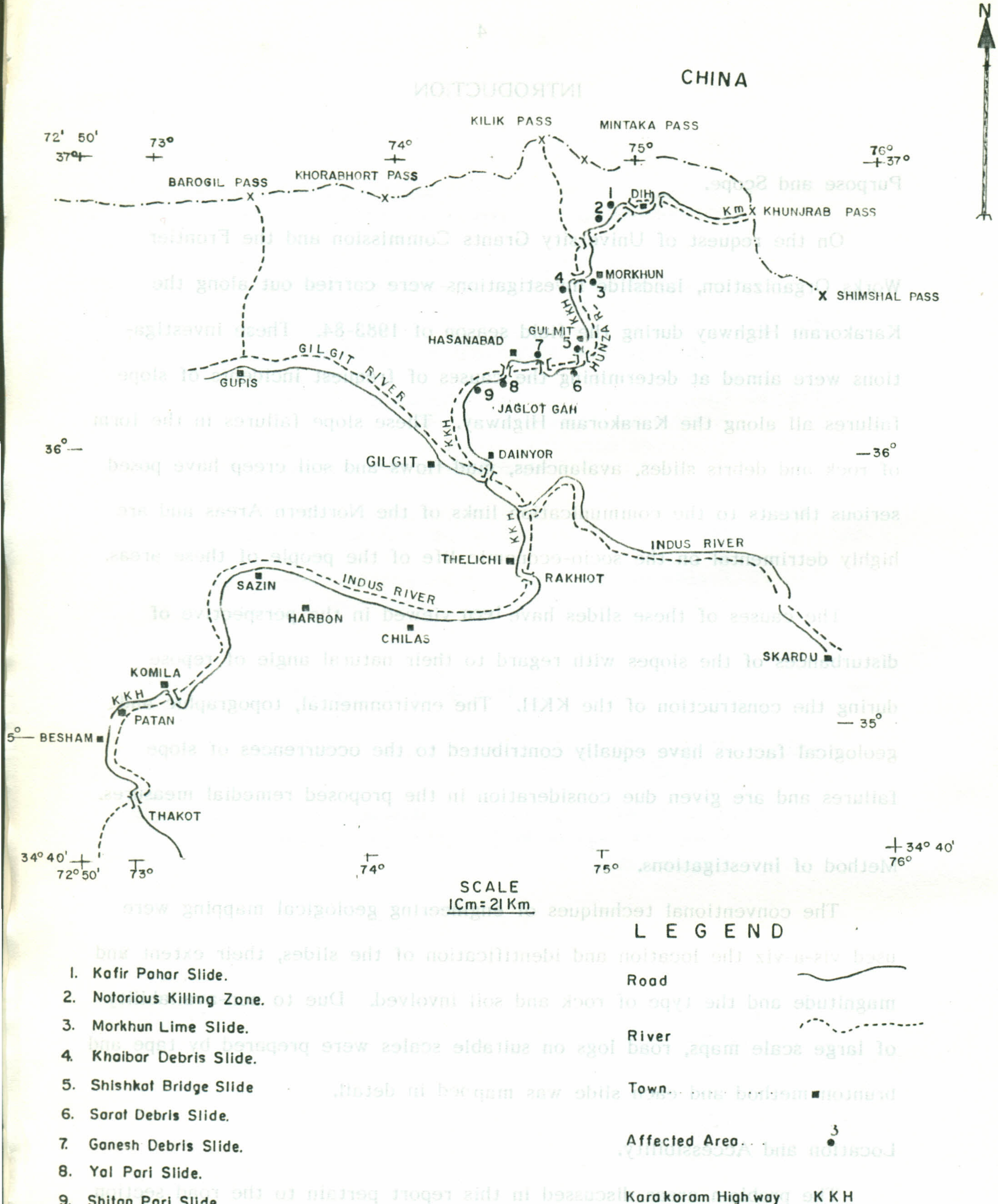


Fig 1: Generalized location map of the Slides along the Karakoram Highway.

The KKH crosses the Gilgit river at Dainyor, a few kilometer downstream of the confluence of Gilgit and Hunza rivers, and follows the left bank of Hunza river upto Hini village. The Jaglot Gah and Yal Pari slides are located in this part of the road. Between Hini and Ganesh, the road enters the main Hunza valley and runs over wide alluvial terraces. This area is free of any serious slope stability problem. At Ganesh near Karimabad, the road again follows the left bank of the Hunza river upto Gulmit and passes through Ganesh, Sarat and Shishkat debris slide zones. Between Gulmit and Morkhun, the Khaiber and Morkhun slides are encountered. The road section north of Morkhun enters into two very big problem areas hitherto, described as Notorious killing zone and the Kafir Pahar slide. This zone is about 12 km long and shows sudden and frequent occurrances of large scale sliding. The area between Dih and Khunjerab Pass is mostly a scree zone but other mass movement phenomenonsuch as rock falls, snow avalanches, mud flows and formation of ice crystals are also commonly encountered.

Relief and Topography.

The area between Gilgit and Khunjerab represents a rugged topography. The relief is moderate to high with elevation difference of approximately 3450 m. betweer Gilgit and Khunjerab Pass. The Hunza valley between Gilgit and Karimabad is wide but becomes narrower in the upper part particularly along the Khunjerab river. The road has been constructed at a ruling gradient of 1 in 16 and it has been a tremendous effort to attain this gradient below over-hanging cliffs, vertical rock faces, steep slopes and advancing glaciers.

Climate and Vegetation.

Climatically the area falls in the colder regions of Pakistan with a pleasant summer and a very extreme winter. The summer temperature ranges between 30 to 35°C and during winter the temperature sometimes falls down to -20°C in the upper Hunza valley. The rainfall is scanty and the precipitation occurs in the form of snow.

The lower Hunza valley is green and cultivation is done on wide alluvial terraces. The glacier water is used for irrigating the valley fields. In upper Hunza valley, the cultivation is restricted to small patches of land along major nullahs. The rest of the area has natural growth of grass and shrubs and is used as grazing lands.

GEOLOGY

The geology of the area in the upper Hunza valley north of Gilgit is very complex and the formations are highly tectonised. Based upon the work of Desio (1963, 72) Hayden (1961) and Schneider (1957), the following rock units may be described in their chronological order along the road section from Gilgit to Khunjerab:-

Alluvial deposits and talus	Recent
Glacial and fluvio-glacial deposits	Pleistocene
Axial Karakoram batholith	Pliocene
Migmatic plagioclase gneiss	Miocene-Pliocene
Chalt group	Cretaceous-Eocene
Greenstone complex	Cretaceous
Giraf Syenite	Eocene
Gujhal dolomite	Triassic-Jurrasic
Dumordo Formation	Permo-Triassic
Gircha Formation	Early Permian
Pasu Slates	Carboniferous
Kilik Formation	Lower Carboniferous or Devonian

Misgar Slates

It is a fine grained, greenish and black schistose rock with intercalations of greyish arenaceous quartzite. The Misgar slates are repeatedly folded with the fold axes striking west northwest. The rock unit is exposed in the upper Hunza valley north of misgar and are intruded by granite near Khunjerab Pass.

Kilik Formation

Dark, thick bedded limestone and dolomite separated by dark-grey arenaceous slate and shale associated with brown quartz-sandstone and red arenaceous slate. This formation is strongly tectonised and the beds are sub-vertical with an east-west strike. However, at the confluence of Kilik and Khunjerab rivers the beds dip moderately to the northwest and the formation is overturned. The Kilik formation outcrops as an elongated belt between the Misgar slates to the northeast and the Gircha formation to the south-west.

Pasu Slates.

These are black, phyllitic, arenaceous slates intercalated with black limestone and few grey quartzite beds. The largest outcrop is located between the granodiorite of the axial batholith and the Gujhal dolomite but the contacts are tectonic. It is exposed along the road section between Ghulkin and Pasu village.

Gircha Formation.

It consists of dark argillites with intercalations of dolomitic limestone in the upper part and light coloured sandstone in the lower part. The beds dip south-southwest. This formation is exposed over a large area along the KKH near the villages of Gircha, Khudabad and Tok Jengal.

Dumordo Formation.

It is a complex of white and grey, well bedded marble intercalated with thick beds of grey, often garnetiferous calc-schist, plagiocalse-biotite-gneiss, biotite-amphibole-garnet-gneiss, garnetiferous mica schist and kyanite-mica-schist. The marble is the predominant rock type in the central part of the formation. In the lower and upper parts it is less frequent and is gradually replaced by mica-schist and gneiss. This formation is several thousand meters thick and is exposed between Hini and Sarat. Its age is unknown and hypothetically can be refered to the Permo-Triassic (Desio 1963).

Gujhal dolomite.

It consists of a thick sequence of dolomites, dolomitic limestone and limestone with some intercalations of dark arenaceous slate and shale. It is about 500 meters thick and is exposed between the villages of Pasu and Morkhun.

Giraf Syenite.

It is a pink quartz-syenite rock with potassic felspar, medium grained, frequently with porphyritic texture; exposed north of Misgar and have thermally metamorphosed the Misgar slates.

Green stone complex.

This rock unit is exposed betwen Jaglot Gah and Shitan Pari for a distance of about 10 km along the KKH. It consists of lava, tuff, agglomerate, schists, gneiss, quartzite and limestone. At some places it is intruded by granodiorite, serpertinized dolerite and basaltic lava.

Chalt group.

It is exposed in the area of Shitan Pari to Hini village. It consists of Chlorite mica schist, quartz-biotite schist, talc schist, graphitic schist, quartzite, marble and phyllite with conglomerate bed. The sulpher smells out from schistose rock unit by the chemical action on pyrite present in the rock.

Migmatic plagioclase-gneiss.

In the upper Hunza valley, between the metamorphic rocks of the Dumordo Formation and the igneous rocks of the Karakoram axial batholith, outcrops a belt of migmatic gneiss which have a width of some hundred meters.

Axial Karakoram batholith.

Fine grained biotite-granodiorite, and locally hornblende-granite crosses the Hunza valley in a north-south direction betwen Sarat and Ghulkin.

The axial batholith and the Dumordo formations show frequent occurrences of granite stocks, pegmatite and aplite dykes in the upper Hunza valley. In addition to it some porphyrite dykes are seen crossing the Misgar Slate, the Gircha Formation and the Gujhal dolomite.

Glacial and Fluvioglacial deposits.

The glacial deposits (drift) are very extensive in all the upper Hunza valley and in the lateral valleys. Near the valley-floor they generally form more or less wide terraces having an undulating surface near the mountainous slopes. Younger and also terraced alluvial deposits are leaning against these tills which, in turn, overlie the rock-outcrops. Bedded alluvial deposits are frequently observed underlying the glacial deposits and, therefore, their age predates the last glaciation.

Alluvial deposits and talus.

These alluvial deposits consist mostly of reworked till which the present day glaciers amass at their fronts. The steepness of the mountain slopes does not favour the accumulation of large talus deposits of the friable rocks and the detrital material is rapidly brought down to the river bed by sheet-wash erosion.

ENGINEERING GEOLOGY

A detailed investigations regading the stability of slopes along the Karakoram Highway between Khunjerab pass and Gilgit provided an opportunity to study some of the natural hazards associated with the construction of a road in high mountainous areas. These hazards included the problem of slope failure due to rock/debris slides, rapid flow of scree material, soil creep and related phenomenon. These problems are identified and described here in detail:

Kafir Pahar Slide

Kafir Pahar slide zone is located on KKH between KM 555 to 560 from Thakot, near the confluence of Indra Nullah with the Khunjrab River approximately 10 km east of Dih. Kafir Pahar lies in Survey of Pakistan toposheet No. 42 L. (Scale 1:2,50,000) with co-ordinates Lat. 36^{o} 51'N, and Long. 74^{o} 49' E. Due to its unpredictable behaviour a board with the following caption has been erected by the Army Engineers to warn the travellers:-

"KAFIR PAHAR

Our Worst Enemy,

can Assault in Bad Weather"

The length of this danger zone is about 3.130 km. The Kafir Pahar slide zone, because of its extent and magnitude, warranted detailed investigations to determine the causes of large scale sliding and mass movement. In view of the type of problems encountered, large scale mapping on a longitudinal profile of 1":10 m was carried out in the zone of rock-fall and at a scale of 1":100 m in the scree zone. The rock exposed in this zone are slates and quartzite (Fig. 2). The dominant rock type is slate whereas quartzite occurs as lenticular bodies; and noted five such quartzite bodies in this zone. The slate is highly jointed and fissile. The quartzite is hard and competent and may stand at steep angles except the parts where it is highly jointed and fractured. The contact of slate and quartzite are highlysheared. In a zone of 450 m there are 2 faults and 6 shear zones. At the faulted contact of slate and quartzite, secondary carbonates have been deposited along the seepage lines. The rocks are tightly folded and faulted. Quartzite breaks into big blocks whereas the individual blocks in slate vary in size depending upon the joint system in the area. At least two to four sets of joints have developed among which the set No.1 with attitude N 60°W and southward dip is the master joint and extends continously in the slate body. Due to this intense jointing and structural disturbances, the whole 450 m zone has become unstable and poses problem of rock and boulder fall.

The slate due to its fissility and close jointing system coupled with intense shearing has been badly crumbled and weathers into fine scree material. Wide scree zones have developed all along the Kafir Pahar zone and problem of scree fall is frequently encountered. These scree zones range in width upto 600 m and form scree cones, with their apex located approximately 150 m high from the road level. The process of scree formation is further intensified by extremes of diurnal and seasonal variations in temperature. The scree slopes are formed at critical angle of repose and creep enmasse due to the undercutting river action and vibration caused by the movement of heavy traffic.

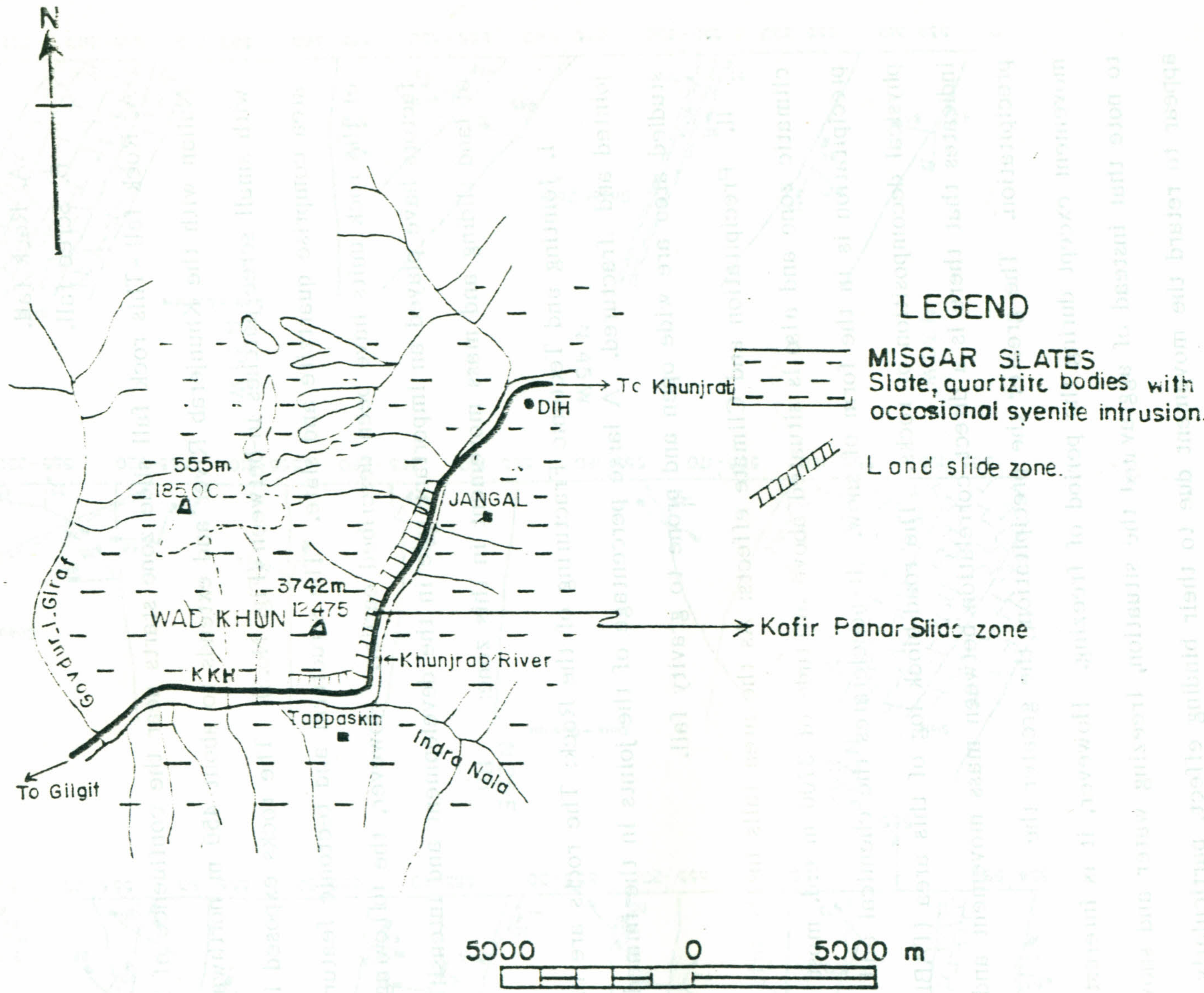


Figure 2– Generalised geological map showing location of Kafir Pahar Slide zone at Km 555 to 560 on the KKH.

The following two types of problem were identified in the Kafir Pahar zone:-

A. Rock fall.

B. Scree fall.

A. Rock fall - This rock fall slide zone starts near the confluence of Indira Nullah with the Khunjerab River and extends to about 450 m northwards with small scree patches in-between (Fig. No.3). The rocks exposed in the area comprise quartzite and slate. The structural and tectonic features of the rock units have been described earlier. However, the following factors have played an important role in the development and intensification of land sliding and mass movement in this zone:

I. Jointing and Tectonic Fracturing of the Rock: The rocks are highly jointed and fractured. A large percentage of the joints in the immediate studied area are wide open and prone to gravity fall.

II. Precipitation and Climate effects: As the area falls in the arid climatic zone and also is situated above altitude of 3700 m o.d. most of the precipitation is in the form of snow. It accelerates the chemical and physical decomposition of rocks. The road-block log of this area (TABLE 1) indicates that there is a direct correlation between mass movement and precipitation. The greater the precipitation, the greater the movement except during the period of freezing. However, it is interesting to note that instead of aggravated the situation, freezing water and snowfall appear to retard the movement due to their binding effect, particularly during the winter months.

The phenomenon may well be demonstrated by the fact that during winter months which are the peak months of precipitation, minimum movement

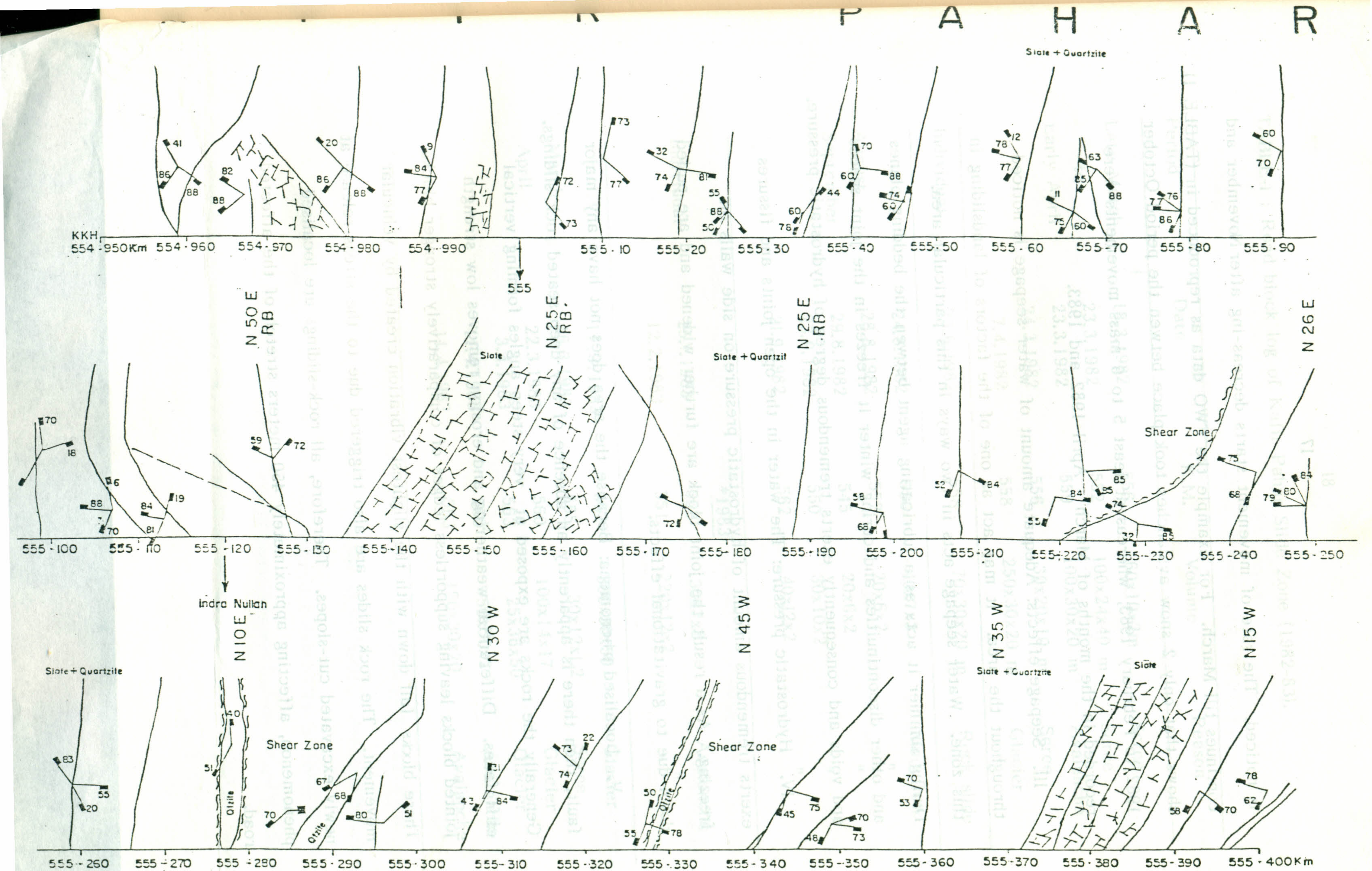


Figure 3 – Detailed Geological profile of the Kafir Pahar Slide between 554·95 Km to 555·4 on the KKH. Symbols as shown in figure 1A.
Scale. Horizontal . 1:10
Vertical not to scale.

B. Scree fall - The other major problem of the area is encountered in the form of creep of scree and debris material. It extends for about 2.6 km with small rock outcrops in the Kafir Pahar zone (Fig. 4). The process of scree formation is comparatively quick due to the peculiar lithology and structural behaviour of slates and also due to climatic effects and geomorphology of the area.

The slate breaks into smaller and angular rock fragments and finally changes into clayey soil. The scree formed as a result of disintegration of the rocks which are loose to partly compacted and form steep cones with critical slope angles. The scree cones contain various sized blocks of rock at the base which decrease in size upwards changing into finer material at the top. This rubble of rocks start flowing down with the slightest vibration created by wind or vehicular movement.

The movement of loose scree and debris downslope is mainly due to temperature changes (expansion by heat and shrinkage on cooling). During the winter months it is facilitated by frost action thereby loosening the rock fragments and causing upheaval of surface layers. On thawing during spring, the particles do not fall back to their original position but under the influence of gravity slide down the hill.

Recommendations.

A - Rock fall: The following recommendations are made for the control and stabilization of rockfall in the Kafir Pahar area:

i) Removal of Unstable Blocks and Overhangs: The most obvious measure would be to remove loose blocks of rock by scaling with steel bars. Controlled blasting may be done to bring down rest of the overhanging loose rocks to get a comparatively more stable rock at the face. Obviously care must be taken to avoid damaging the slope when it is being trimmed by further blasting.

ii) Rock Bolting: Rock bolting may be done at a few selected places in this zone. It would provide strength to the rock mass in two ways. Firstly the fall of loose blocks will be checked and secondly tensioning of the bolts would enhance the rock friction and minimize the movement.

iii) Shot Creting: Attempts were made to ascertain the relationship betwen the various climatic factors and movements. A shot-crete cover on the slope to prevent water infiltration, and retard weathering, is proposed to stablised the slope.

iv) Drainage: Drain holes drilled to the deep joints and along the contacts, (where seepage and carbonates are present) would probably enhance the stability by providing exits for any water that might accumulate from runoff on the slope. However, the effectiveness of this method of channelization is limited because runoff water does not form a major factor of sliding in this case.

B - Scree fall: The scree mostly poses the problem of creep and may be checked as suggested below:

i) Benching and Flattening of Slopes: At least 2 to 3 benches may be constructed in the lower half of the scree slope to trap the falling debris from coming down the road directly. There are at least 7 major patches of scree zones ranging from 140 to 450 m wide each (Fig. 4). The individual

K A F I R   P A H A R

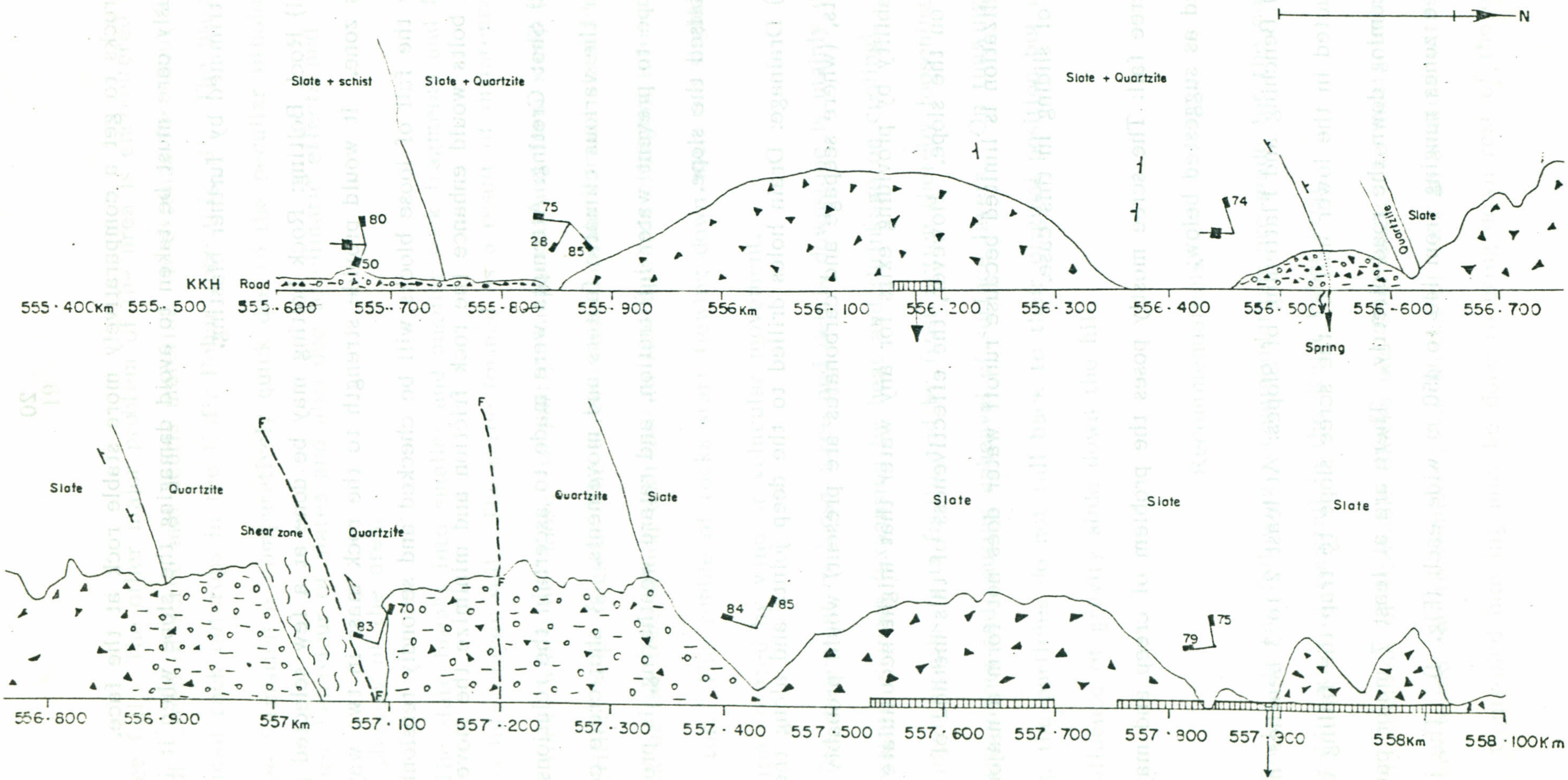


Figure 4 -Detaild geological profile of the Kafir Pahar Slide between 555·6 Km to 558 Km on the KKH. Symbols as shown in figure I.A.
Scale. Horizontal 1: 100 Vertical not to scale

bench may be constructed at 20 m vertical interval and 6 m wide with a drainage channel at the back slope. Impact wall may also be constructed at the edge of each bench.

ii) Diversion Spurs: Stone-pitched diversion spurs may be constructed to channelize the flow of scree to a suitable ravine or gully within the slide zone.

iii) Retaining Walls: These should be constructed with horizontal and vertical anchorage to uphold the scree. At present some retaining walls exist which are in a delapidated form and require proper repair and maintenance.

Notorious Killing Zone.

Notorious Killing Slide Zone is located on KKH at KM 549 from Thakot, approximately 5 km east of Dih. This zone lies on Survey of Pakistan toposheet No.42 L (Scale 1:2,50,000) with coordinates Lat 36^{o}, 47'N, and Long 74^{o},51'E. (Fig. 5). At the site the following wooden post to warn the travellers is erected by the army engineers:

"NOTORIOUS KILLING ZONE"
Stones Fall Without Notice"

This slide zone stretches for about 450 m and the name given to this slide indicates the seriousness of the situation. The Notorious Killing Zone was mapped on large scale by making longitudinal profiles on a scale of 1"=10m. The first 200 m from the starting point is rocky and problem of rock and boulder fall is encountered (Fig. 6). Proceeding north of the zone between 200 m to 450 m, the area comprises loose scree lying at critical angle of which particularly the scree patch betwen 320 to

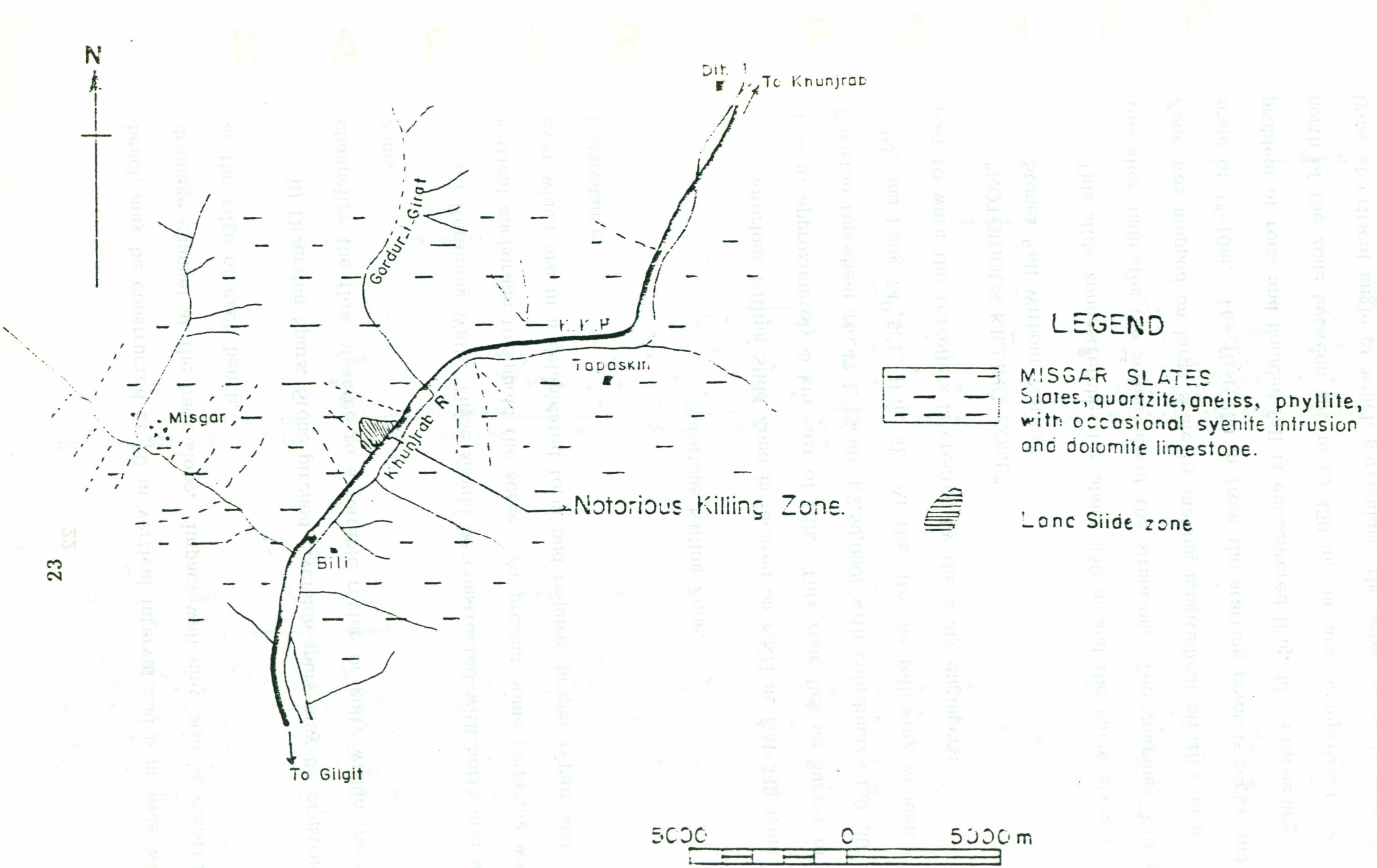


Figure 5_ Generalised geological map showing location of Notorious Killing Zone at Km 549 on the KKH.

NOTORIOUS KILLING ZONE

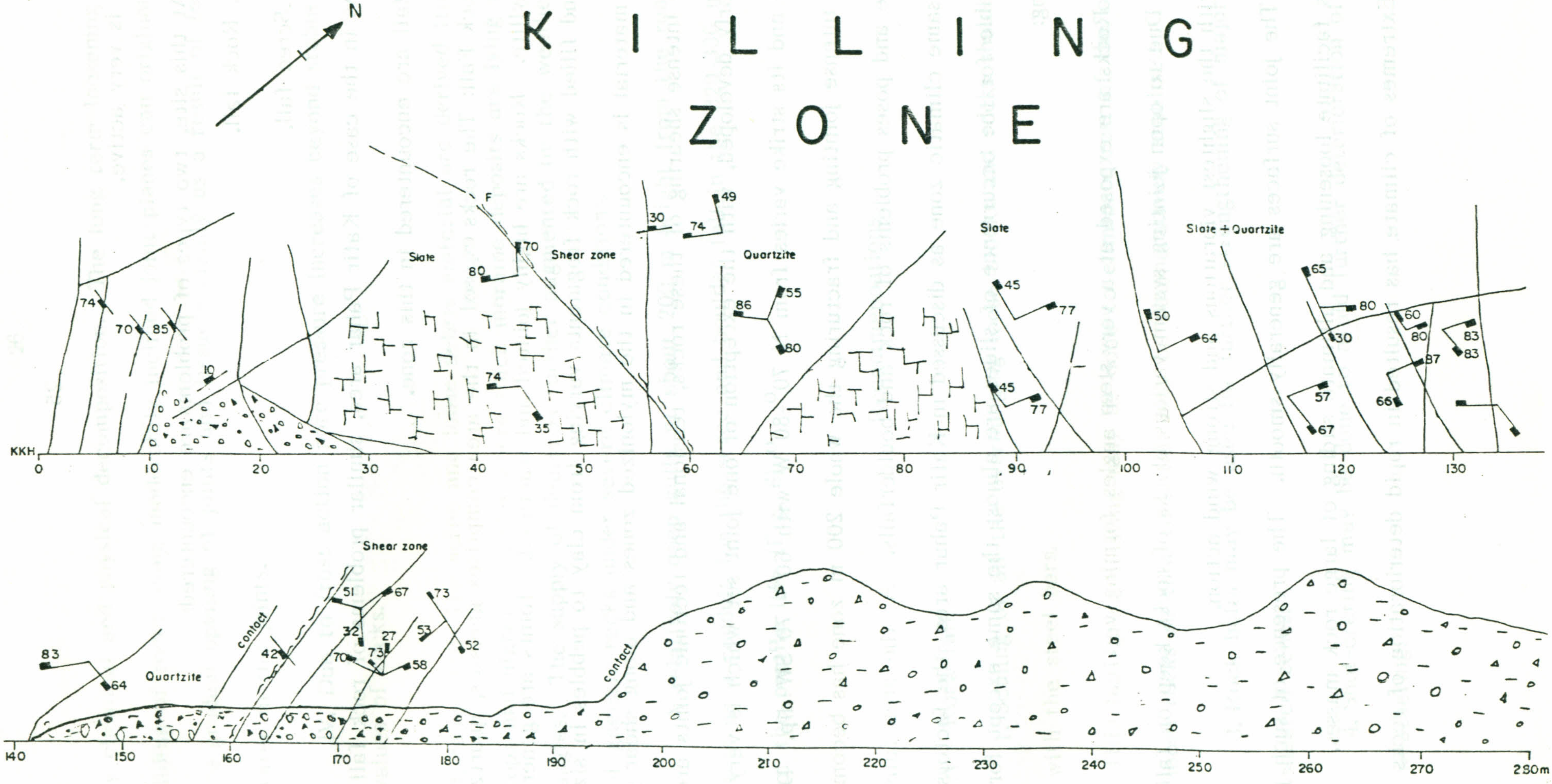


Figure 6- Detailed geological profile of Notoriou Killing Zone between 549-280 Km on the KKH. Symbols as shown in figure I.A.
Scale. Horizontal 1:10m
Vertical not to scale.

330 m is very active.

At this site, two types of problemsare encountered:

A. Rock fall.

B .Scree fall.

As in the case of Kafir Pahar area, similar problems of rock fall and scree fall are encountered in this zone.

A - Rock Fall: The rocks exposed in the area comprises gneisses, quartzite, and phyllite. Rocks are highly jointed and fractured. Joints are generally open and filled with rock fragments varying from clay to pebbles in size. Gouge material is encountered in the mylonized zones and along shear plane.s. Due to intense shearing of these rocks, tensional and tectonic joints are irregularly developed, with the exception of one joint set which is very regular and its strike varies from N 70^{o}-80^{o}W with 60^{o}- 70^{o}SW dip. Due to this intense jointing and fracturing the whole 200 m zone has become very unstable and poses problems of rock and boulderfalls. As the area falls in the same climatic zone as discussed in Kafir Pahar area, the factors responsible for the occurrence of slides are almost the same except for the following:

I. Rocks are exposed at a very steep angles forming vertical cliff faces. Due to open jointing system various blocks of rocks keep on falling down with the slightest vibrations and strong wind action.

II. The joint surfaces are generally smooth. The presence of such joint surfaces facilitate loosening and ultimate sliding of large rock masses.

III. Extremes of climate has resulted in rapid deterioration of rocks by chemical and physical decomposition. The long term loosening and sliding of rocks along moderately inclined joint planes can originate with the gradual opening of joints and fissures mainly as a result of feezing water in the joints.

IV. Due to frost action pore pressure increases beyond stable values of rocks.

B.-Scree fall: The scree and loose debris material are derived from ridge tops and higher altitudes where thick moraine deposits are lying at steep angles. The supply of debris is further augmented by the weathering of gneissic rocks under severe climate conditions.

A relatively deep gully at about 200 m height from the road elevation acts as a conduit for the scree and boulder fall in the 320-330 m stretch of the profile line (Fig. 6).

Recommendations

A - Rock fall:

1. Scaling of all the overhanging loose blocks and rocks should be done with the steel bars.

2. Controlled blasting may be done to eliminate rest of the overhanging loose rocks so that rock fall may be comparatively stablised.

3. Rock bolts may be used for further strengthening of major joints and sheared zones.

4. Shot-creting may be done to avoid further deterioration of rocks from weathering.

B - Scree fall: Removal of unstable parts from 330 m to 450 m: Scree is not very active and stones and pebbles keep on falling. The following methods are recommended:

1. Construction of retaining walls.
2. Benching at various intervals. (Multiple benching system).
3. Removal of unstable parts, and resloping of scree at low angle.
4. Plantation at suitable sites along the slope.

In addition to the above proposed recommendations, for the worst affected area between 320 m to 330 m stretch, the following corrective measures should immediately be undertaken:

i. diversion of scree towards the south of slide by providing diversion spurs.

ii. benching at 2-3 sites at various intervals.

iii. re-construction of already damaged retaining walls.

Morkhun Lime Slide

Morkhun lime slide is located on KKH at km 521 from Thakot at about 1.6 km downstream of Morkhun Camp. This slide lies on Survey of Pakistan toposheet No. 42 L (1:2,50,000) with co-ordinates Lat. 36^{O} 36' 20"N and Long. 74^{O}52' E.(Fig. 7).

At this site thick monotonous sequence of Gujal dolomite is exposed with minor dolomitic limestone interbeds. The dolomitic limestone at certain places is badly decomposed in the form of powdry lime with some unaltered boulders of the parent rock. The process of decomposition is very rapid and the weathered product of dolomitic limestone occupies the

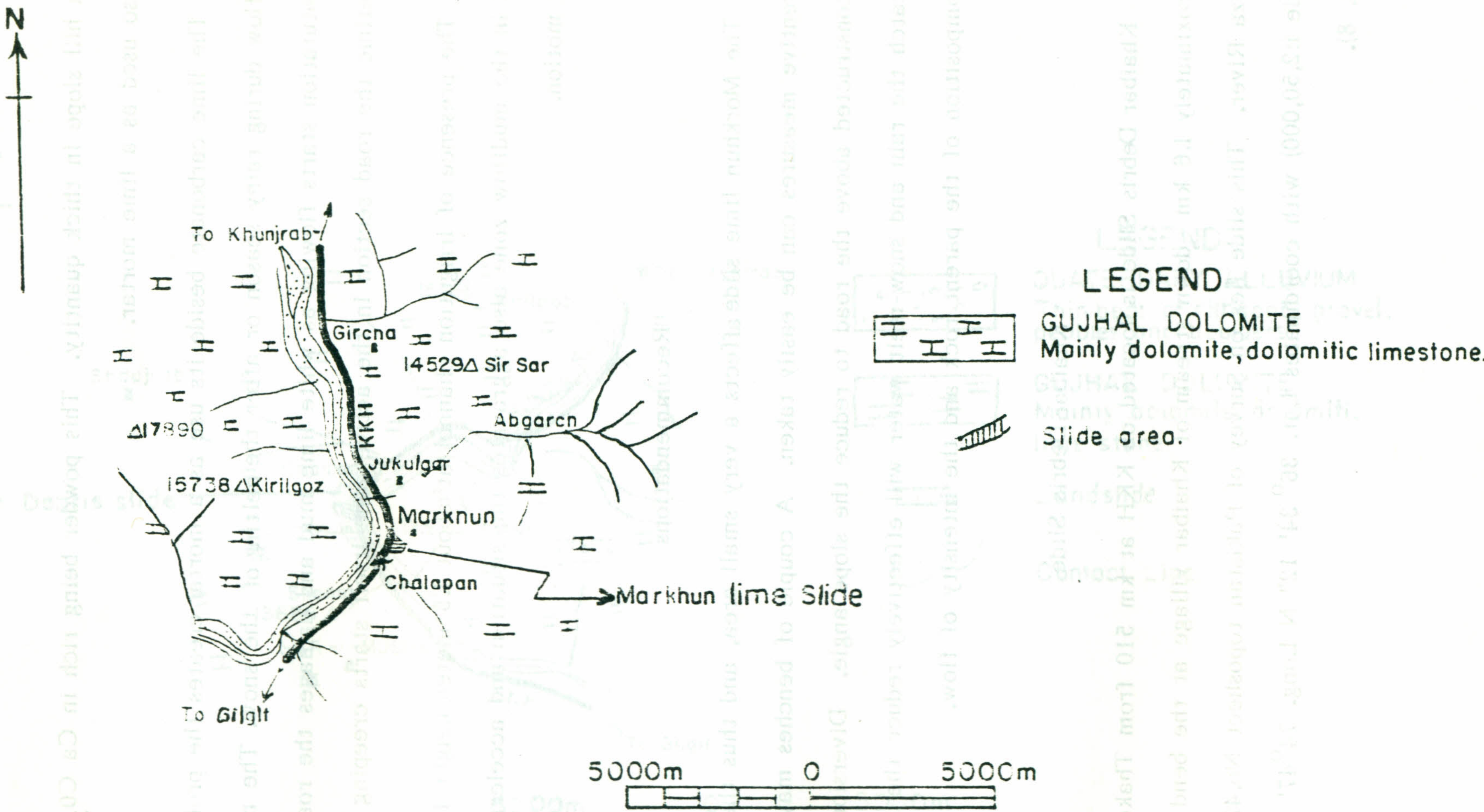


Figure 7 - Generalised geological map showing location of MarKhun lime Slide area at Km 521 on the KKH.

down hill slope in thick quantity. This powder being rich in Ca CO_3 is also used as a lime mortar.

The lime carbonate beside its use as a mortar creates the problem of mudflow during rainy season or after the melting of the snow. The material on saturation starts flowing as white lime mud and damages the road. Sometime the road section in the active zone itself starts creeping down.

The presence of irrigation channel at about 1.5 meter height from the road in the mudflow zone also aggravates the situation and accelerates the flow motion.

Recommendations

The Morkhun lime slide affects a very small area, and thus the preventive measures can be easily taken. A couple of benches may be constructed above the road to reduce the slope angle. Diversion channels to catch the rain and snow-melt water will effectively reduce the rate of decomposition of the parent rock and the intensity of flow.

Khaibar Debris Slide

Khaibar Debris Slide is located on KKH at km 510 from Thakot, approximately 1.6 km down stream of Khaibar village at the bend of Hunza River. This slide lies on Survey of Pakistan toposheet No.42 L (scale 1:2,50,000) with coordinates Lat. 36^{O} 34' 12" N Long. 74^{O}47' 30"E. (Fig. 8).

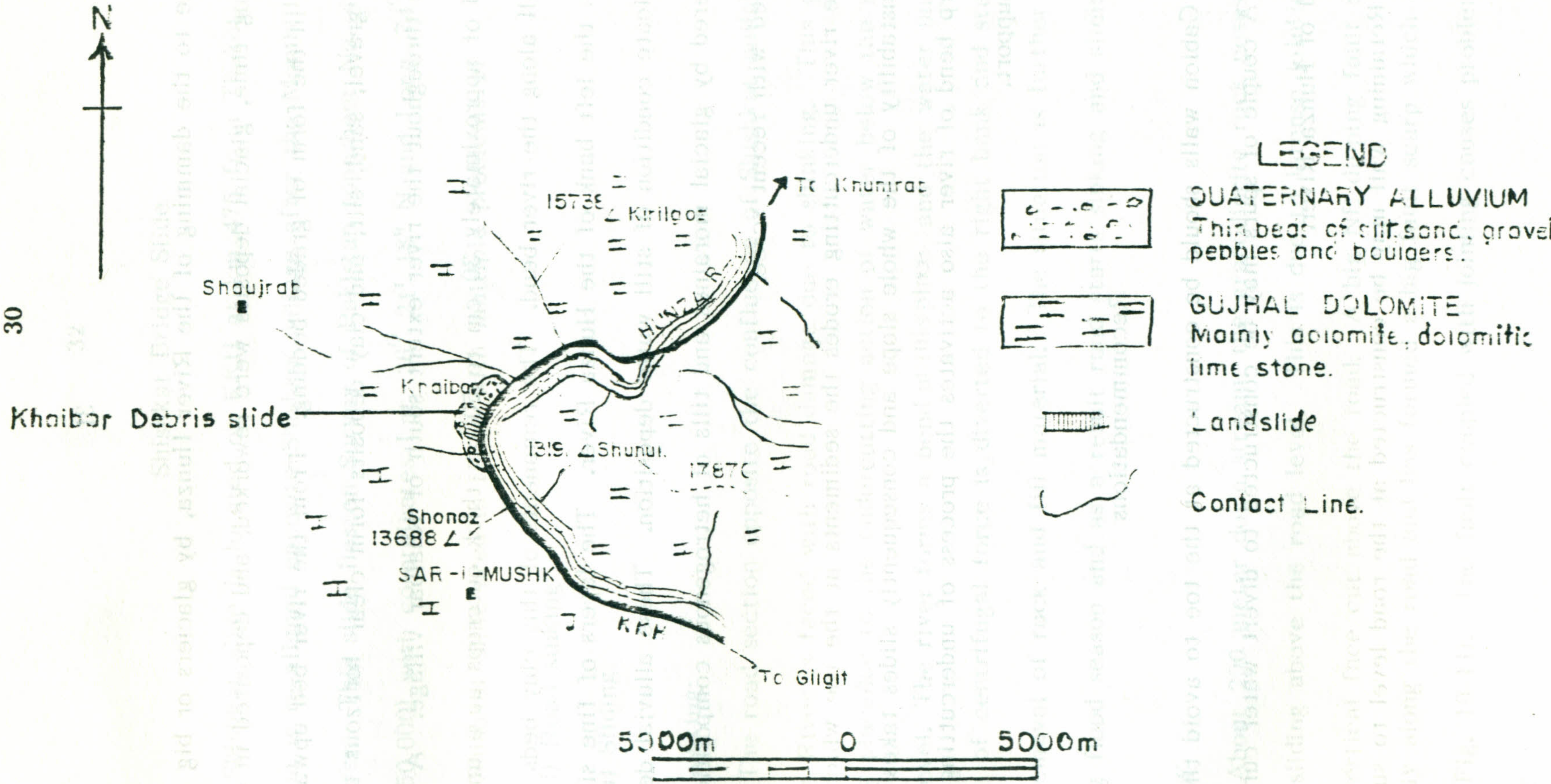


Figure 8— Generalised geological map showing location of Khaibar Debris Slide at Km 510 on the KKH.

Due to the damming of the River Hunza, by glaciers or big avalanches, for a long time, glacial deposits were reworked, and deposited in clear layering in the form of graded bedding. From the river bed upward alluvial gravel, sand, silt, and clay deposits form clear horizons and continue throughout the river extent south of Khaibar village. A buff coloured clay bed of approximately 30 cm to 50 cm thick outcrops at a uniform height all along the river bend. The remanents of this clay beds are also found on the left bank of the Hunza River. The layers of fine silt and clay indicate condition of still water deposition. These alluvial deposits are covered by glacial moraines and tills of hetrogenous composition which is intermixed with recent scree.

The river undercutting erodes the sediments at the toe which results in the instability of the whole slope and consequently slides takes place. The sharp bend of river also activates the process of undercutting and removal of toe support.

Recommendations

1. Gabion walls should be constructed at the toe to avoid the undercutting.

2. A couple of spurs may be constructed to divert water currents at the bend of Hunza River.

3. Retaining wall may be constructed at the road level to support the slope.

Shishkat Bridge Slide

Shishkat slide is located on KKH at km 475 from Thakot. This road section is re-aligned opposite Shishkat village after the Momhill glacial outburst. This slide lies on Survey of Pakistan toposheet No. 42 L. (l: 2,50,000) with co-ordinates Lat. 36° 21' 18" N and Long. 74°52'E.(Fig.9).

Shishkat slide area is faced with multiple problems of

i) Road sinking

ii) Sliding

Road sinking:

The road section opposite the confluence of Shishkat nullah with Hunza River is faced with road damage due to shinking. This problem is taking place due to the undercutting action of water below the road at the bed level. The river forms a bend at this place and the water under the action of centrifugal force is diverted to the right bank and starts scouring and removal of rock and fill material. The situation is further aggravated during flood season and as a result road starts sinking and sliding.

Sliding:

About 200 meter down stream, the granodiorite rock poses problem of rock sliding above the road level. This is due to intense jointing at the place and vertical face cut above the road. A big NE dipping fault also runs roughly along the road and has formed a big fault scarp which dips valley side (Fig. 10-11). The fault coupled with jointing causes problems of rock sliding.

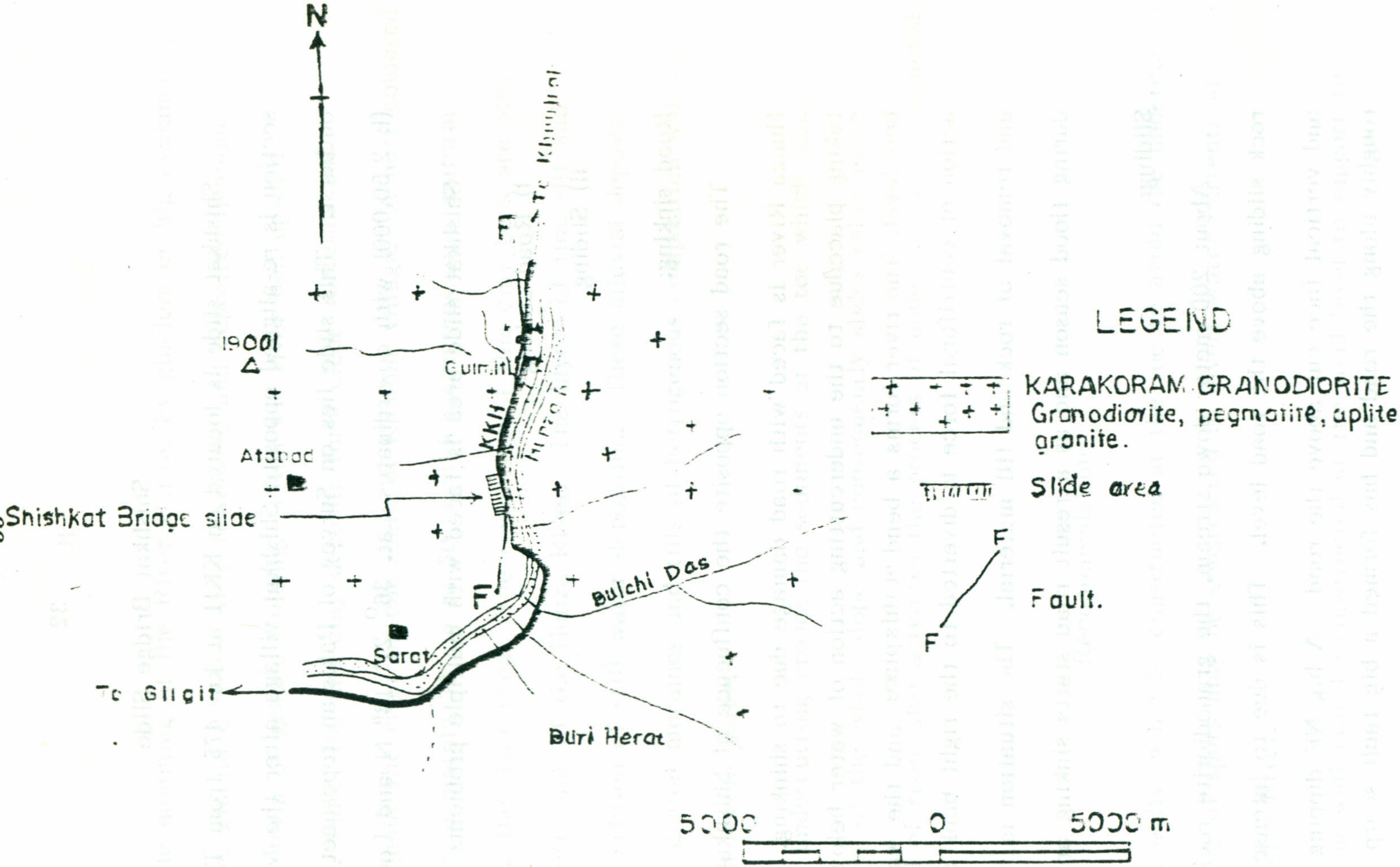


Figure 9 - Generalised geological map showing location of Shishkat Bridge Slide and road sinking area at Km 475 on the KKH.

SHISHKAT BRIDGE AREA

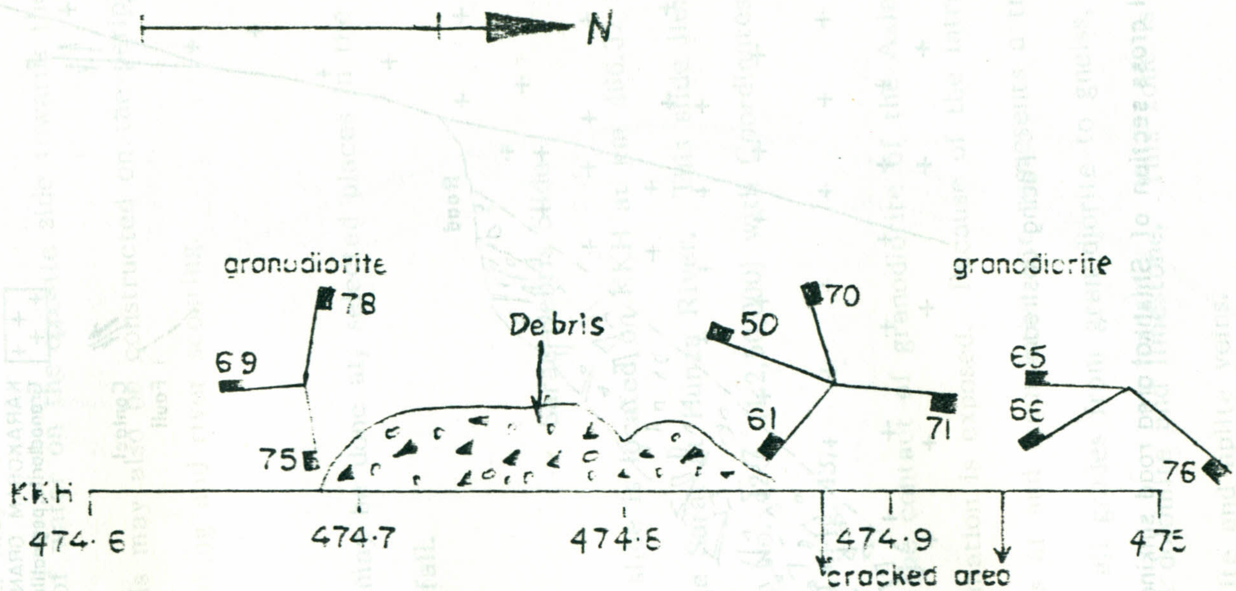


Figure 10-Geological Profile of the Shishkat Bridge Slide between 474·6 Km to 475 Km on the KKH. The details of the debris on the Road side. Joint pattern of the bed rock are shown, vertical scale is approximate where as horizontal scale is

1 = 100 Meters.

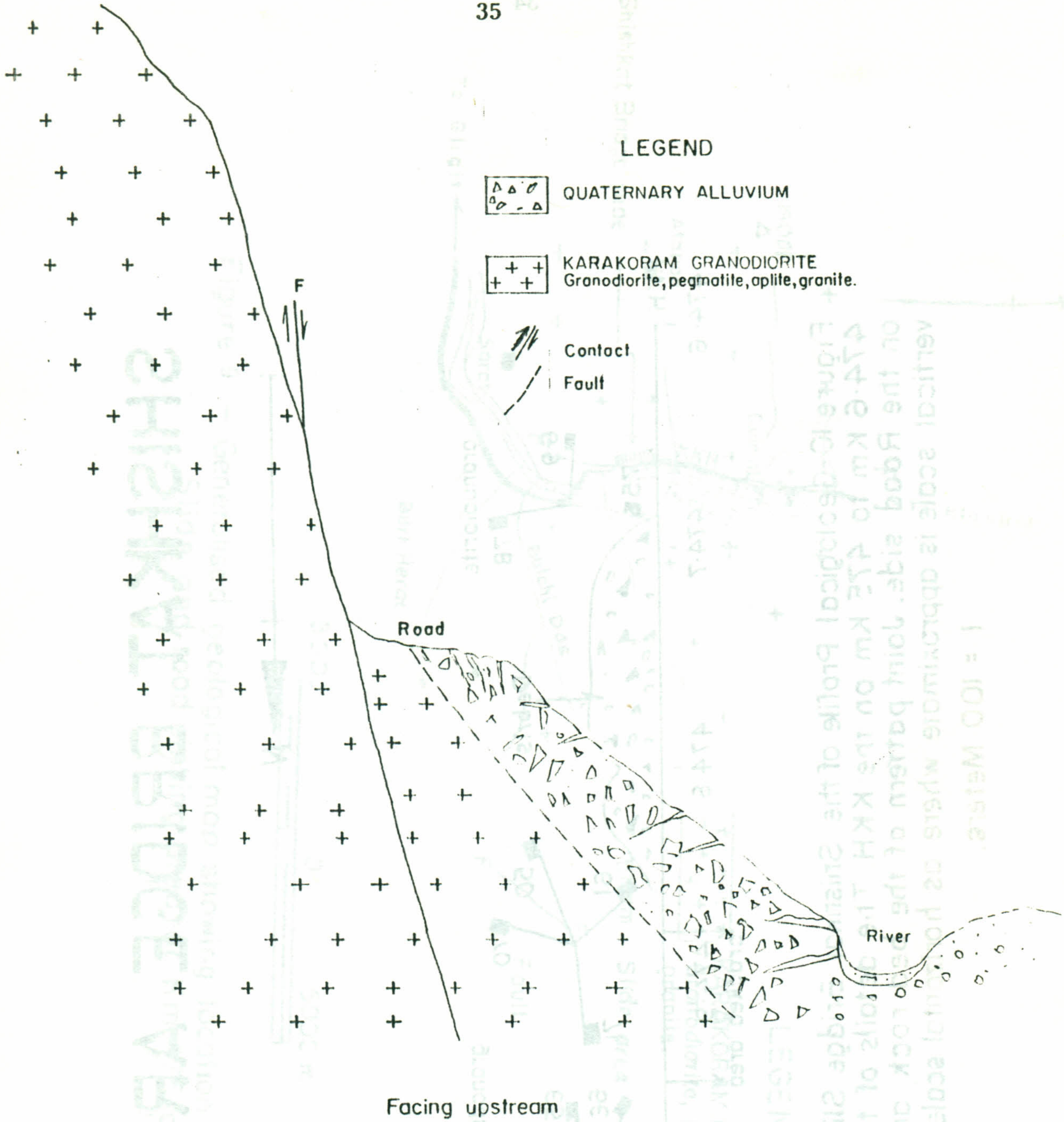


Figure II-Geological cross section of Shishkat area road sinking problem.

Recommendations

Road sinking:

1. This problem may be checked by making a series of strong spurs to divert the flow of water on the opposite side towards the west(Fig. 12).

2. Gabion walls may also be constructed on the periphery to support the road against sinking and river scouring.

Sliding:

Rock bolting may be done at, selected places in the affected area to check the boulder fall.

Sarat Debris Slide

Sarat Debris slide is located on KKH at km 466.32 from Thakot, opposite the village Sarat at Hunza River. This slide lies on Survey of Pakistan toposheet No. 42 L (1:2,50,000) with Coordinates Lat. $36^{O}18'13''$N and Long. $74^{O}51'$E. (Fig. 13).

At this site the contact of granodiorite of the Axial Batholith and Dumordo Formation is exposed. Because of the intrusive nature of contact, the rocks at and around the site represents a transitional zone which consists of all grades from granodiorite to gneiss, and of schist, coarse crystalline dolomite and limestone. This zone is also intruded by numerous pegmatite and aplite veins.

These rocks are irregularly jointed and individual block size ranges from 0.5 to 1 cubic meter. Gneiss and schists . because of their peculiar structure and texture are prone to much quicker weathering and decay. As

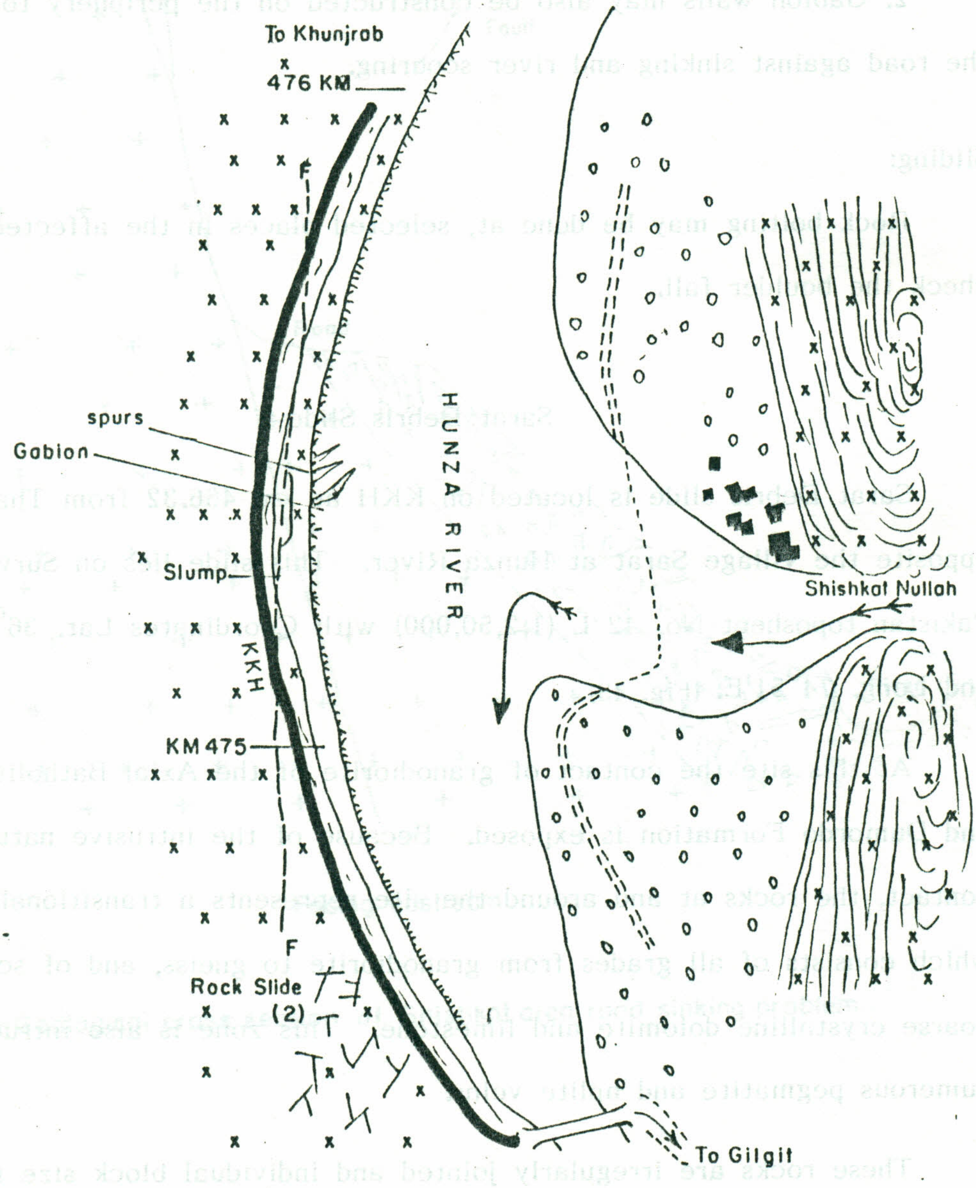


Figure 12 - Plane view of Shishkat Road sinking area showing the position of spurs and gabion walls to control the problem.

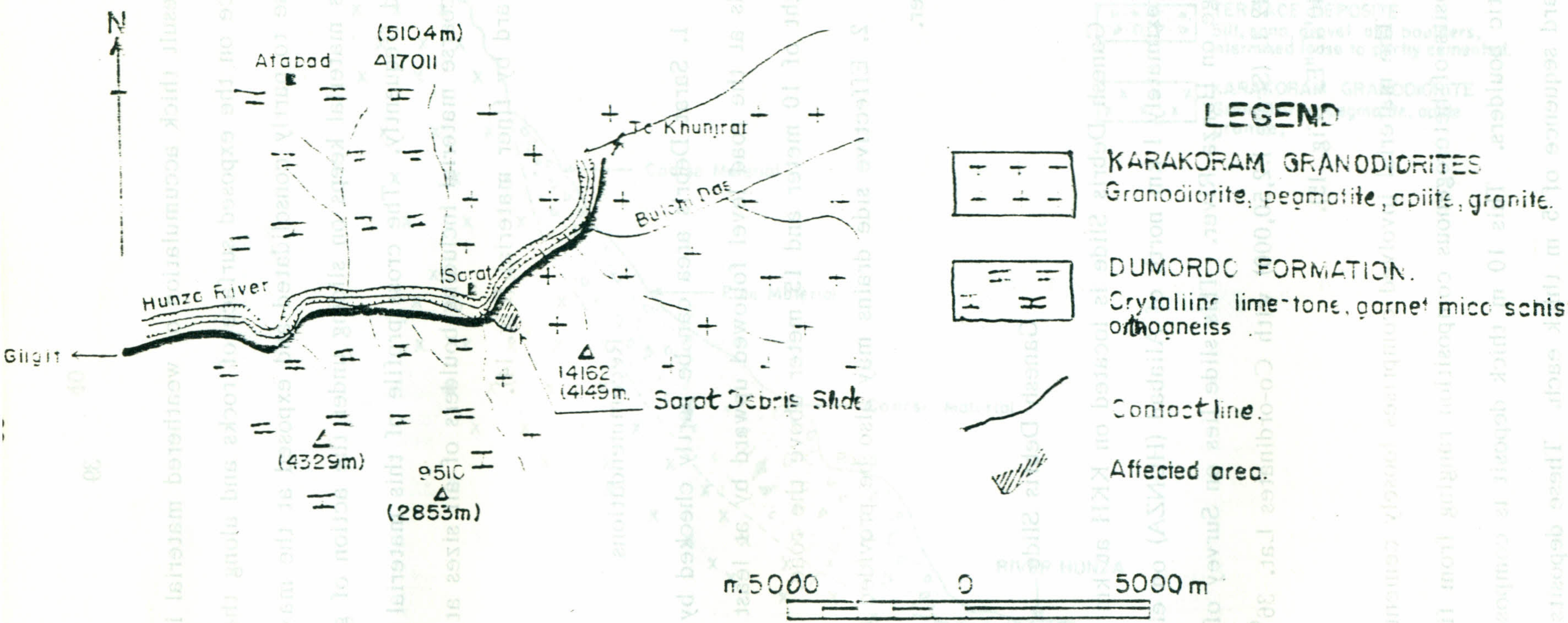


Figure 13— Generalised geological map showing location of Sarat Debris Slide area at Km 466 on the KKH.

a result thick accumulation of weathered material in the form of scree t place on the exposed surface of rocks and along the valley slopes. Scree loose to partly consolidated and exposed at the maximum angle of repose This material keeps on sliding under the action of gravity and blocks t road frequently. The cross profile of this material shows greater percent of coarse material including boulders of all sizes at the road level follow upward by finer material (Fig. 14).

Recommendations

1. Sarat Debris area can be partly checked by constructing retaining walls at the road level followed upward by at least two berms at the height of 10 meter and 15 meter above the road.

2. Effective side drains may also be provided to check the flow of water.

Ganesh Debris Slide

Ganesh Debris Slide is located on KKH at km 444 from Thakot, approximately 1 km north of Aliabad (HUNZA) on either sides of Ganesh bridge on Hunza River. This slide lies on Survey of Pakistan toposheet No.42 L (Scale 1:2,50,000) with Co-ordinates Lat. $36^{O}19'$ 57"N and Long. $74^{O}40'42''$E. (Fig. 15).

The material involved comprises loosely cemented fluvioglacial deposits of heterogenous composition ranging from fine clayey silt to big erratic boulders. This 10 m thick deposit is composed of two coarsening upward sequence of 5 m thick each. These deposits are interbedded with

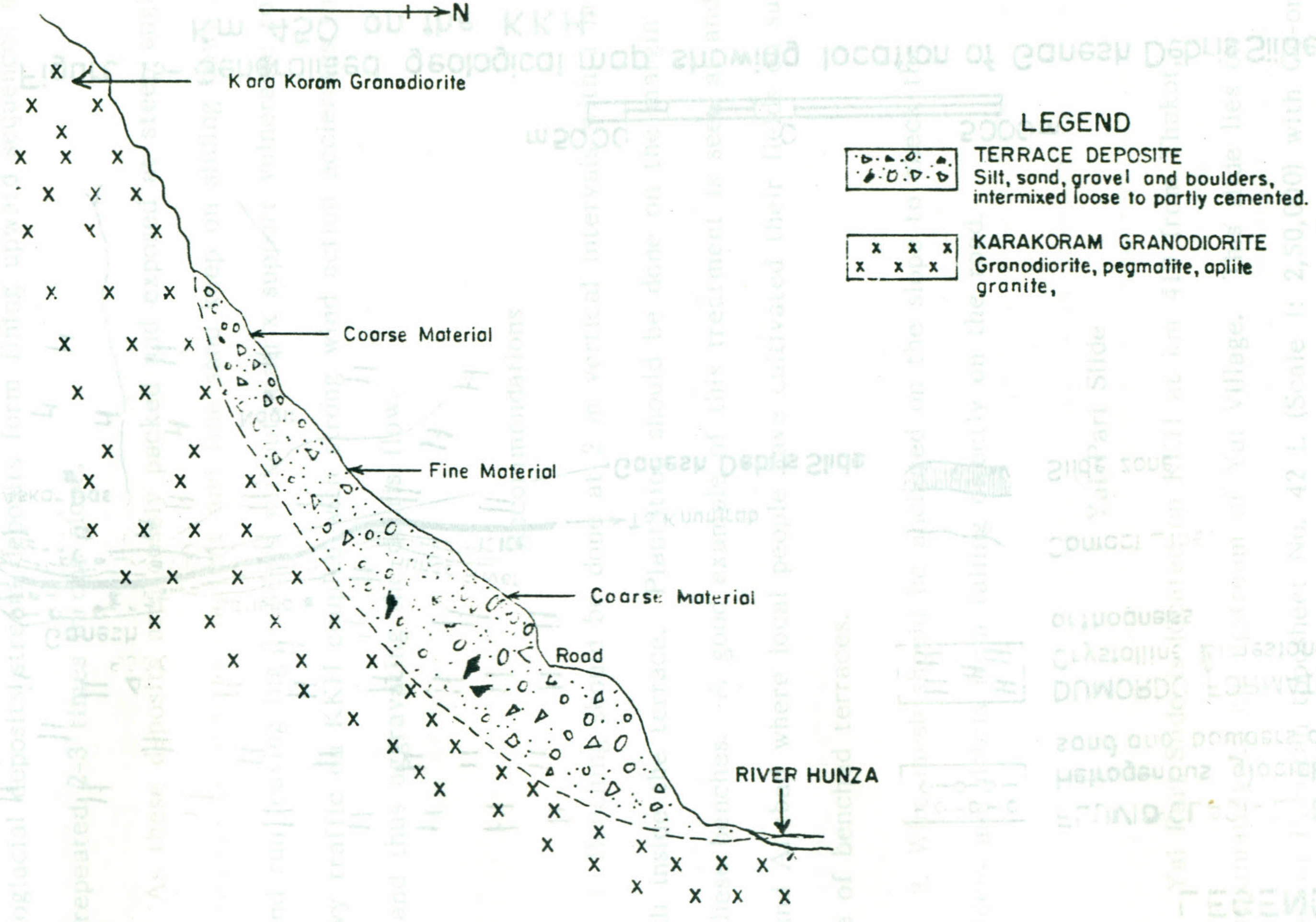


Figure 14 – Generalised cross section of Sarat Dabris Slide showing the position of various type of material.

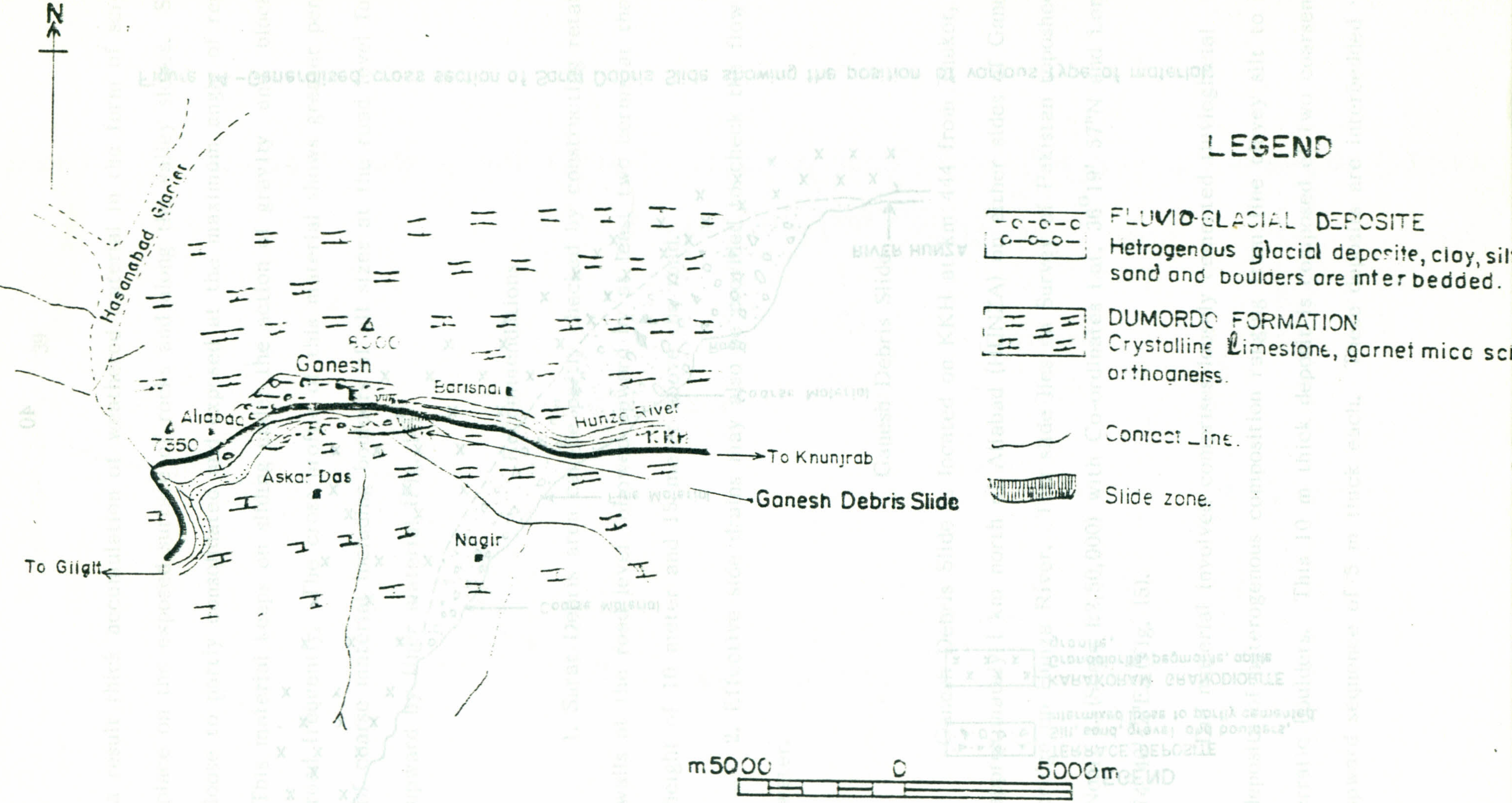


Figure 15- Generalised geological map showing location of Ganesh Debris Slide at Km 450 on the KKH.

reworked and well stratified stream bed deposits. The stream bed deposits are well sorted and show graded bedding ranging in grain size from fine sand to big boulders and are exposed at vertical slope angle. Unlike that of fluvioglacial deposits stream deposits form fining upward sequences and are repeated 2-3 times in one slope.

As these deposits are loosely packed and exposed at steep angles, the fine sediments such as clay silt and fine sand keep on sliding down like a sand run leaving big boulders without matrix support vulnerable to slide. Heavy traffic on KKH coupled with strong wind action acclerates the sand run and thus aggravating the debris flow.

Recommendations

1. Benching should be done at 2 m vertical intervals with 1 m width inside the terrace. Plantation should be done on the margin of these benches. A good example of this treatment is seen at and around Aliabad where local people have cultivated their fields on such type of benched terraces.

2. Wire mesh should be anchored on the slope to check the boulders and debris from falling directly on the road.

Yal Pari Slide

Yal Pari Slide is located on KKH at km 410 from Thakot, approximately 1.5 km upstream of Yal Village. This slide lies on Survey of Pakistan toposheet No. 42 L (Scale 1: 2,50,000) with Co-ordinates Lat. 36^{O} 15' N and Long. 74^{O}31' 10" E. The Hunza River near Yal Pari slide bends forming an "S" shaped curve and cuts deeply through the metasedimentary rocks.(Fig.16).

The formations exposed in the Yal Pari area belong to Chalt Schist comprising slate, schists, quartzite and some recent unconsolidated sediments of fluvio-glacial orgin. These rocks have a general north-south trend and dip at steeper angles ranging from 75^{o} to 85^{o} to the west. The rocks are badly weathered, highly jointed and fractured. The difference in the diurnal temperature being high, the effect of weathering is very much pronounced and the shattering of rocks results in the formation of huge amount of scree. It is accumulated in the form of talus and scree cones and comprise unstratified, poorly sorted angular pebble sized to huge blocks of rocks and clays. The rock fragments are usually splintry due to the shistose types of rocks.

The Yal Pari scree slope is very unstable because its angle of repose ranges between 45^{o}-48^{o} degrees below & above the level of the present KKH. The slide is preceeded by a flow or steady falling of rock fragments and it generally continuous throughout the day. The condition is further deteriorated by the undercutting action of the Hunza River. Another factor which has a detrimental effect on the movement of schistose rocks, is the presence of carbonaceous and slightly graphitic material in the main rock body. This material under wet condition acts as a lubricating agent and activates the movement of rock blocks.

Due to the absence of any bedrock at shallow depth the scree has no firm base to get consolidated, and is poised for sliding at the slightest disturbance. During the high flood period, the conditions become even

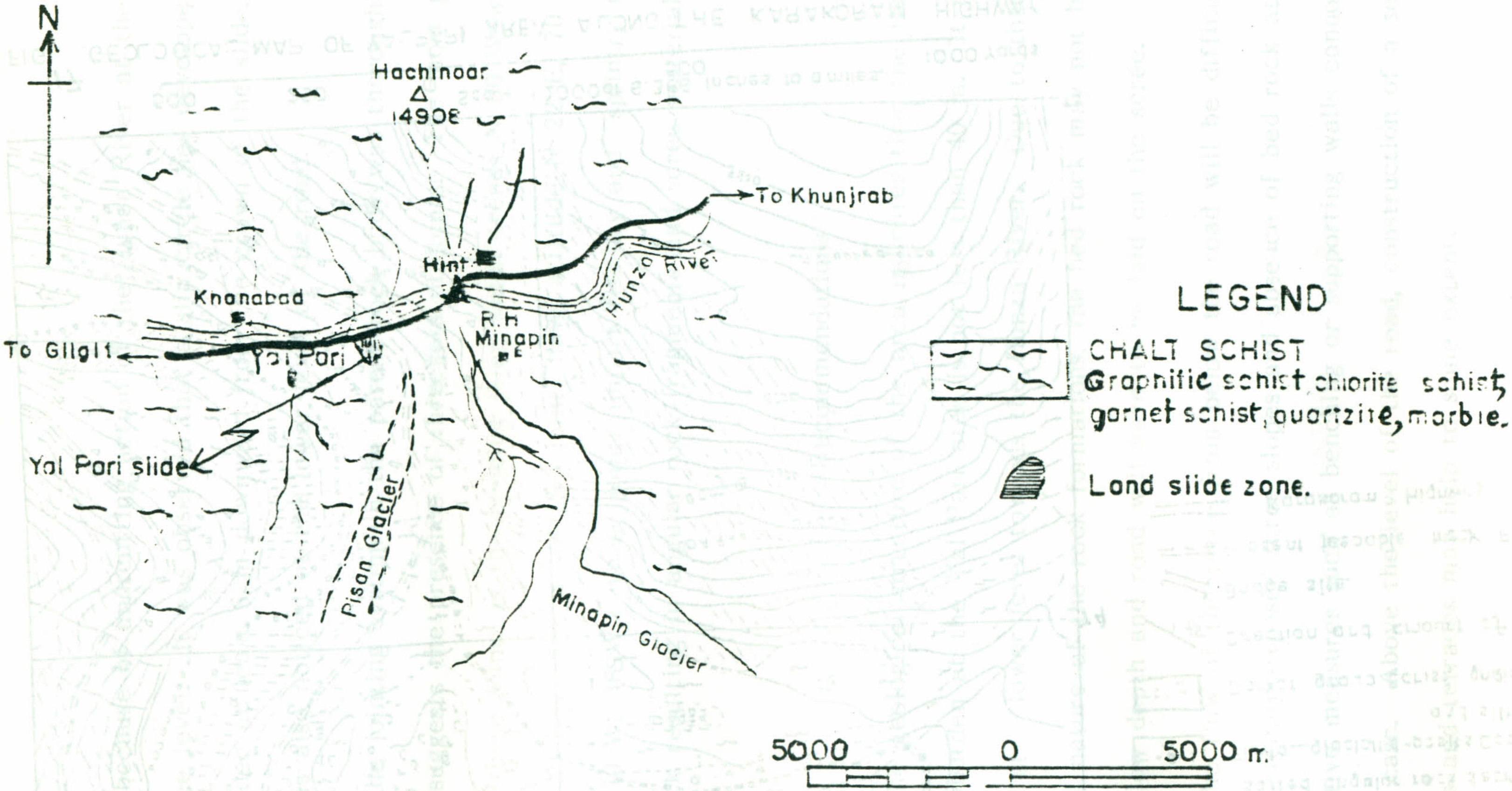


Figure 16– Generalised geological map showing location of Yal Pari Slide at Km 416 on the KKH.

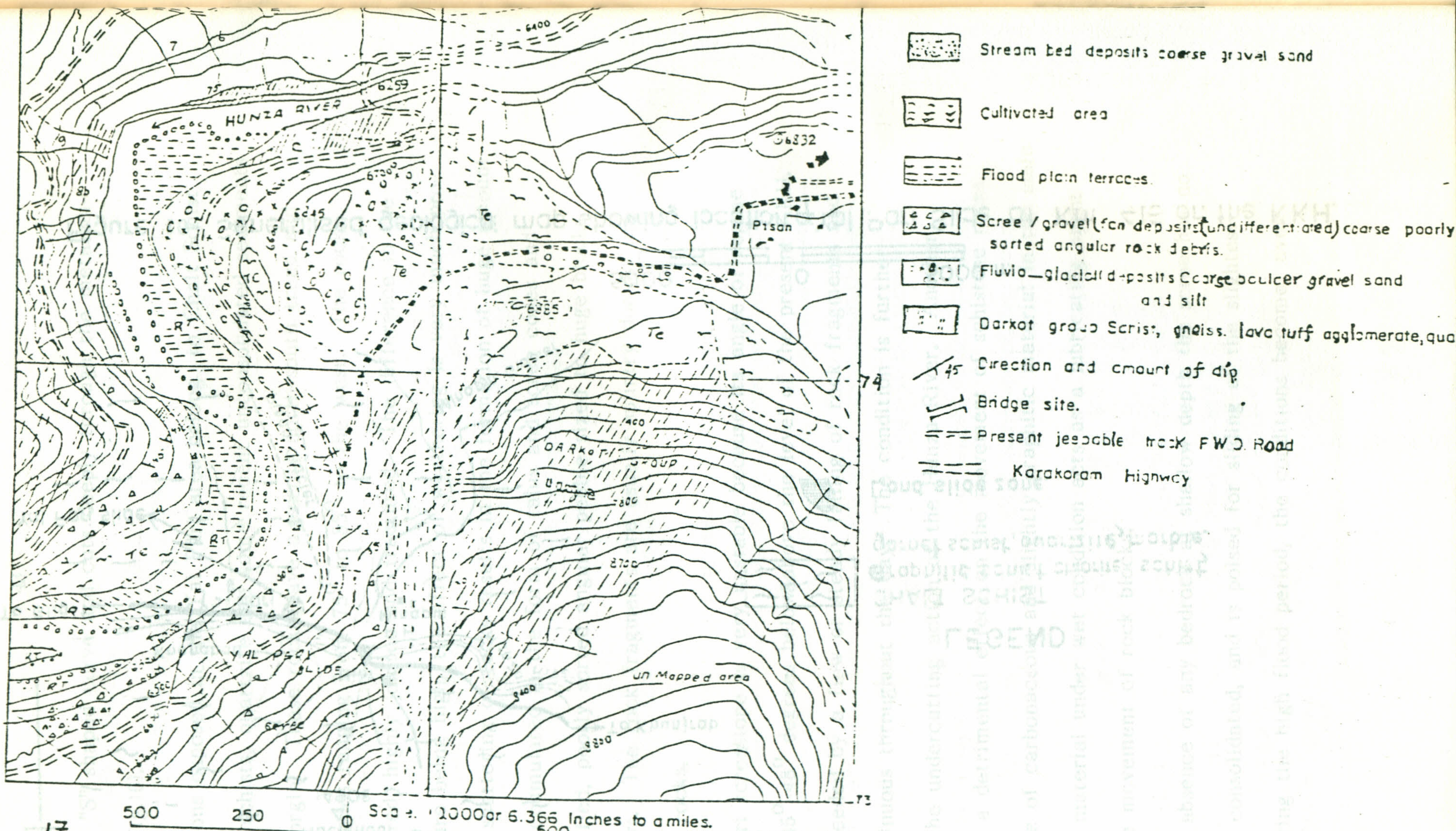
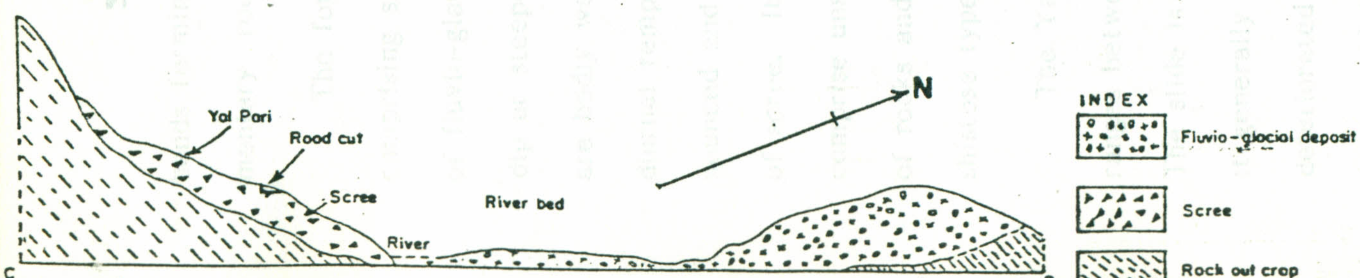


FIG. 17 .GEOLOGICAL MAP OF YALPARI AREA ALONG THE KARAKORAM HIGHWAY.



FIG_/8 GEOLOGICAL CROSS SECTION ALONG THE YAL PARI AREA.

worse because of undrcutting action of the Hunza River at the lower toe of scree level. It was observed that a slip circle has developed at the top and slided at least 6 m downward from the crown of the slide. Tensional crack is also noticed at the lower level of the road.

The jointing system in the parent rock body was thoroughly examined which suggests the presence of threesets of joints. The most prominent among these joints is the bedding joint which trends N 80 W with a steep dip of 80 NE. The other two joints have attitude N 22 E, 70 SE and N 10 W, 38SW. These joints impart fissility and splintry nature to the rock resulting in angular rock fragments and scree material.

Recommendations

The geological structure of the area indicates that the thickness of overburden at the Yal Pari area is not less than 40 m. It is much thicker at lower level towards the Hunza River. Due to the almost near vertical nature of the rock formations, the bed rock may not be encountered at shallow depth and road will have to be laid on the scree.

The flow of the scree from below the road will be difficult to control due to steeply exposed scree slopes and absence of bed rock at shallow depth. Corrective measures such as benching or supporting walls cannot be applied in this case. Above the level of the road, construction of a series of benches and terraces may help to some extent.

Furthermore it is understood that the present alignment cannot be changed as it will entail much funds. Therefore, the only possibility to keep the road open is through some of the following measures:

1. The width of the road of the slide area may be increased to atleast 15 m from the present width of 10 m. The additional 5 m may remain unmetalled road at this site. The overhanging scree should be removed and a few benches be made above the present road level. The space for such benches is available at the Yal Pari site. Scaffolding of wooden logs may also be used to check the flow of the scree material.

2. A series of spurs may be made to check the undercutting action of the River Hunza.

Shitan Pari

Shitan Pari is located on KKH at km 395 from Thakot, approximately 60 km north of Gilgit. This slide lies on Survey of Pakistan toposheet No.42 L (Scale 1:2,50,000) with Co-ordinates Lat. $36^{O}14$ 48"N and Long. $74^{O}19'$ 15" E.

Generalized geological map of the area shows that two formations are exposed at this site, Greenstone complex and Chalt Schist. The Chalt fault crosses near the affected site (Fig. 19). At Shitan Pari, Chalt schists are exposed which includes mica schist, calcareous schist, and chlorite schist. A thick outcrop of dolomitic limestone is also exposed within the Chalt schist.

Schists are of platy structure, thinly bedded and loosely jointed. At places schists are well foliated with steep vertical faces when followed upward give rise to highly fractured schist blocks. Away from the road these blocks vary from 30x15x10 cm to 100x60x10 cm. Schists are so

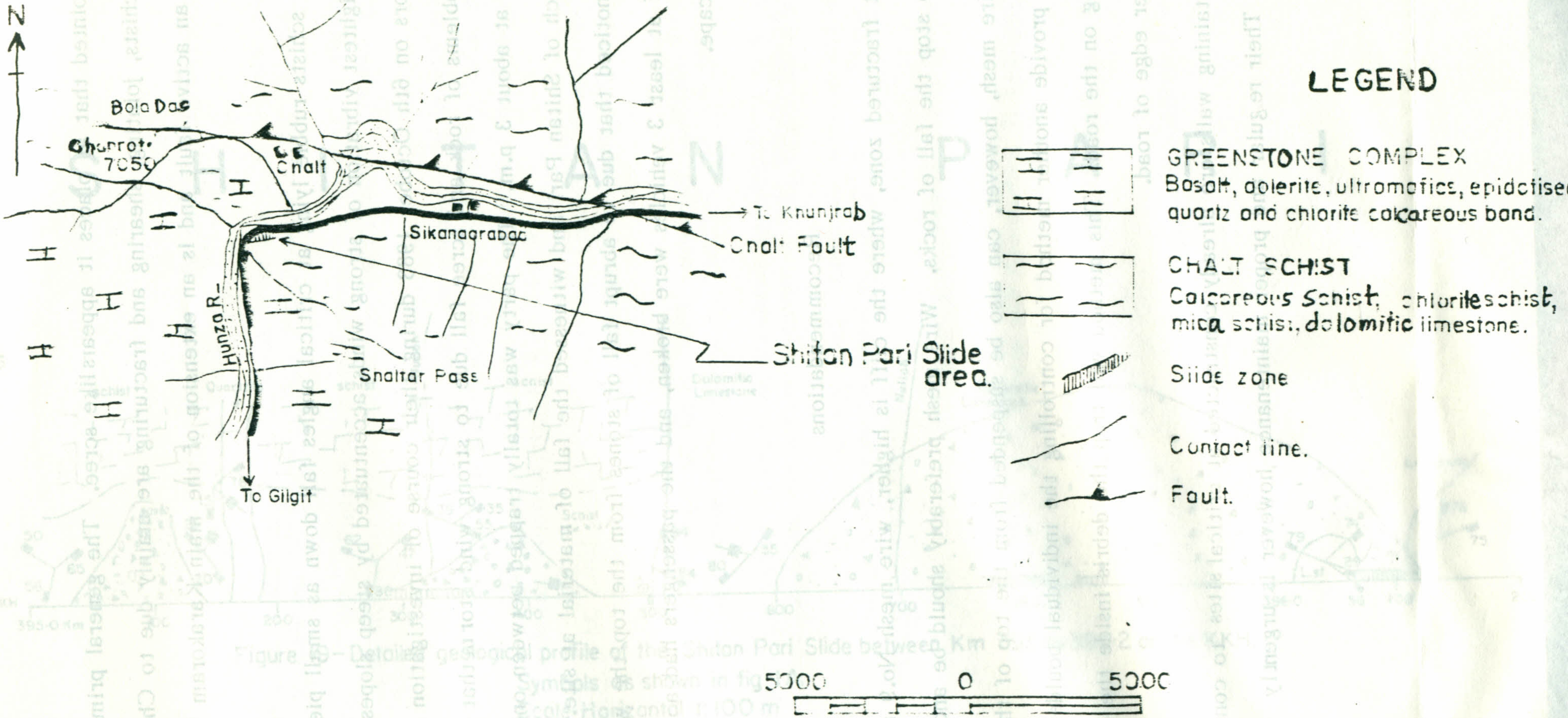


Figure 19– Generalised geological map showing location of Shitan Pari Slide area at Km 395 on the K K H.

closely jointed that at places it appears like scree. The general primary dip of the schists, jointing, shearing and fracturing are mainly due to Chalt fault which is an active fault and is an extension of the main Karakoram Thrust (Fig. 20).

The schists rubble lying at critical angles fall down as small pieces by the slightest vibration of strong winds accentuated by steep slopes. The authors on 6th October 1983 during their course of investigation encountered similr problems of rock and scree fall due to strong wind storm that hit the place at about 3 p.m. The party was totally trapped between one km long stretch of Shitan Pari and witnessed the fall of material at site. It was also noticed that due to abrupt fall of stones from the top the wind screens of at least 3 vehicles were broken, and the passengers had a narrow escape.

Recommendations

1. At fractured zone, where the cliff is higher, wire mesh No.9 may be used to stop the fall of rocks. Wire mesh preferably should be anchored.

2. Wire mesh, however, can also be suspended from the top of the face which will provide another method for controlling the individual boulders from falling on the road. This method will trap the debris inside the mesh on the inner edge of road.

3. Retaining walls are already constructed at critical sites to control the scree. Their regular and proper maintenance however is urgently required.

S H I T A N   P A R I

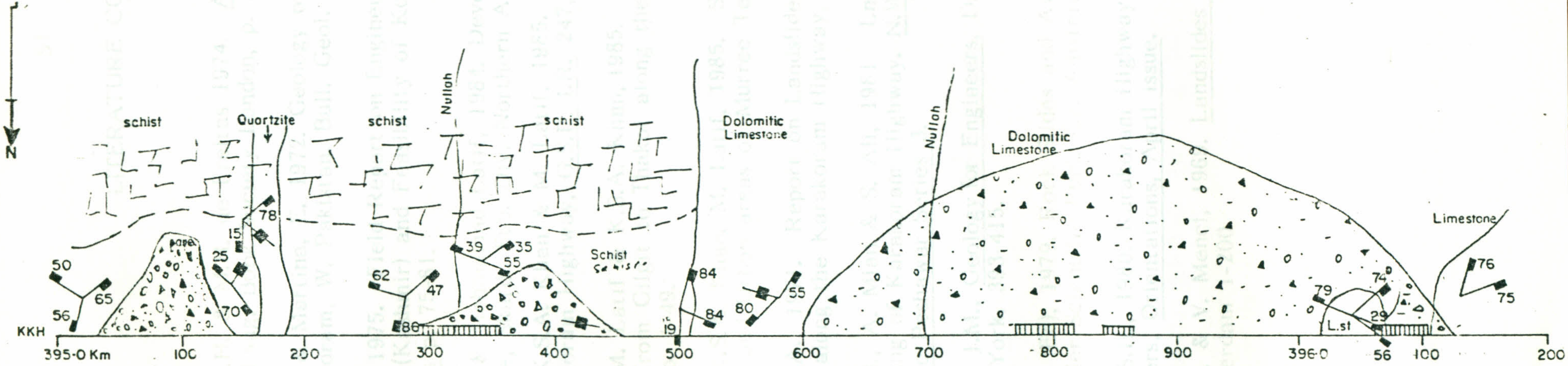


Figure 19– Detailed geological profile of the Shitan Pari Slide between Km 395 to 396·2 on the KKH.
Symbols as shown in fig 1A.
Scale Horizontal 1: 100 m
Vertical not to Scale.

LITERATURE CONSULTED

Blyth, F.G.H. & M.H. de Freitas 1974. A Geology for Engineers Eng. Lang. Book Society London, p. 371-403.

Desio, A. & Martina, E. 1972. Geology of the Upper Hunza valley, Karakoram, W. Pakistan. Bull. Geol. Soc. Ital. 91, 283-314.

Fayaz, A. 1975. Field Report on Engineering Geology of Muzaffarabad Area (Kashmir) and Feasibility of Kohala Hydel Project. P.U. M.Sc. Thesis p. 75-81.

_______, & Mohammad Latif, 1984. Development of cracks around Sermik village, Skardu Sub. Div. Northern Areas Pakistan, G.S.P. I.R. 223: 6 p.

_______, K.S.A. Khan & M. Latif, 1985. Mudflows and Avalanches along the Karakoram Highway, G.S.P. I.R. 247, 30 p.

_______, M. Latif & K.S.A. Khan, 1985. Landslides Evaluation and stablization from Gilgit to Thakot along the Karakoram Highway, G.S.P. I.R. 253. p. 1-49.

_______, K.S.A. Khan, M. Latif, 1985. Study of Landslide Problems in Rural and Urban areas of Murree Tehsil, G.S.P. I.R. 270, .43 p.

Khan, K.S.A., 1971. Report on Landslide investigations in Gilgit & Hunza Area along the Karakoram Highway, G.S.P. WREG-GR 10, 11 p.

Khan, Y.M., A. Mian & S. Ali, 1981. Land use mapping and environmental planning of Karakoram Highway. N.W.F.P. Forestry Pre-investment Centre Peshawar Series 3.

Trefethen, J.M., Geology for Engineers, D. Van Nostrand Camp. Inc. New York. 393-415.

Voight, B. (Ed), 1979. Rock Slides and Avalanches, 2; Engineering Sites Elsevier Scientific Publ. Co. Amsterdam 119-549.

Wriggins, S.H., 1980. Karakoram Highway 500 miles of men against glaciers, Orientations, April issue.

Zaruba, Q. & V. Mencl, 1969. Landslides & their Control. Elsevier Amsterdam 1-200.

APPENDIX - 3 : ROAD BLOCK LOG OF KARAKORAM HIGHWAY FROM RAKHIOT BRIDGE TO KHUNJERAB PASS DURING FEBRUARY, 1982 TO AUGUST, 1983.

February, 1982

	Date	K.M.	Volume length x width x height	Reason
89)	20-2-82	428	45' x 10' x 3'	Rock slide.
90)	"	388	40' x 10' x 2'	Scree.
91)	"	425	20' x 10' x 2'	Rock slide.
92)	"	Khyber	150 cu. m.	Heavy wind.
93)	"	446	10' x 5' x 3'	Scree slide.
94)	21.2.82	Billi	542 . 70 Cu. m.	Heavy wind.
95)	20.2.82	410	100' x 24 x 10'	Scree.
MARCH, 1982:				
96)	19-3-82	695	30' x 10' x 2'	Scree.
97)	19-3-82	428	50' x 10' x 2'	"
98)	18-3-82	410	60' x 10' x 3'	"
99)	18-3-82	556	60' x 10' x 2'	
100)	21-3-82	Shishkat 453	130' x 60' x 40'	Avalanche.
101)	23-3-82	Shishkat 474	200' x 30' x 15'	"
102)	22-3-82	Billi Deh. 552.	100' x 24' x 40'	Scree
103)	23-3-82	458.	100 x 20 x 3	Mud flow.
104)	23-3-82	Billi Deh 559.	100 x 30 x 20	Avalanche.
105)	24-3-82	574 Dih Goshkin	50 x 30 x 20	Avalanche & Mudflow.
106)	"	Billi Dih 556	30 x 20 x 10	Scree.
107)	27-3-82	463 Shishkat	600 x 40 x 60	Avalanche
108)	30-3-82	473 " Br.	500 x 40 x 40	"
109)	31-3-82	473 " Br.	700 x 50 x 80	"
110)	31-3-82	473 " Br.	1400 x 120 x 100	Glacier.

5th

APRIL, 1982:

111)	1-4-82	464	800 x 30 x 20	Avalanche
112)	1-4-82	Hasanabad 434	60 x 20 x 5	Scree.
113) 6th	6-4-82	473 Shishkat	Anormous quantity slided	Avalanche
114)	2-4-82	428 Murtazabad	40 x 30 x 6	Mudflow.
115)	7-4-82	Indra Nala 558	250 x 40 x 20	Glacier.
116)	12-4-82	Hasanabad 438	50 x 25 x 4	Rock fall.
117)	15-4-82	Deh Goshgill 590	350 x 30 x 20	Glacier.
118)	20-4-82	Deh Goshgill 590	350x 30 x 20	Glacier.
119)	24-4-82	450	20 ft. height	"
119)	27-4-82	Hasanabad 426	80 x 24 x 6	Land slide.
120)	27-4-82	Murtazabad 429	30 x 24 x 3	Mudflow
121)	"	" 434.	20 x 24 x 2	Scree.

MAY, 1982 :

122)	3-5-82	Nilt 411	70 x 24 x 2	Mudflow.
123)	"	" 412	60 x 24 x 2	"
124)	"	Hni Br. 416	50 x 24 x 4	Scree.

JUNE, 1982:

125)	15.6.82	335		Bedsoil slide
126)	19.6.82	Juglot Gah 388	50 x 40 x 15	Scree.
127)	21.6.82	436	60 x 30 x 2	Mudflow.
128)	23.6.82	Billi 558.II	70 x 30 x 20	Rock slide.

JULY, 1982:

128)	7.7.82	435	60 x 30 x 2	Mudflow

AUGUST, 1982:

129)	29.8.82	580	15 x 6 x 2 m.	Rock slide.
130)	28.8.82	552	20 x 6 x 2	Mud flow.
131)	29.8.82	556	40 x 7 x 3 m.	"

132)	28-8-82	585	10 x 25 x 1.5 m.	Rock slide.
133)	29-8-82	585	12 x 6 x 2 m.	Rock boulders.
134)	28-8-82	595	5 x 6 x 5 m.	Boulder scree slide.
135)	29-8-82	545	20 x 6 x 2	Rock slide.
136)	29-8-82	568	Glacier stones 75 x 7 x 10	
137)	8-8-82	387	300' x 100' x 3'	Heavy slides
138)	8-8-82	388	720' x 100' x 2'	"
139)	11-8-82	322	18 x 9 x 1.2m.	Heavy rain.
140)	18-8-82	288	76 x 7.5x 5.5m.	Wind stone.
141)	28-8-82	Rahimabad 380	2.4 x 5 x 6.7	Unstable Soil Conditions.

SEPTEMBER, 82:

142)	23-9-82	550	30 x 10 x 2.	Rock slide.
143)	21-9-82	562	40' x 12' x 2'	"
144)	20-9-82	521	50' x 15' x 3'	
145)	24-9-92	Jaglot Gah 338	7 x 208 x 9.9m.	

OCTOBER, 1982:

147)	27-10-82	610	50' x 20' x 4'.	Glacier.

NOVEMBER, 1982:

148)	15-11-82	Rahimabad 380	250 cu. m.	Mudflow.
149)	17-11-82	454	50' x 15' x 4'	Rock Boulders Slide.
150)	"	447.	50' x 15' x 10'	Rock slide.
151)	"	434	60' x 15' x 3'	Scree Boulder Slide.
152)	"	429	50' x 15' x 3'	"
153)	18-11-82	Shitan Pari 395.4	9 x 4.5.2.5 cu.m.	Unstable rock conditions.
153)	18-11-82	395.4	9 x 4.5x2.5 m.	Unstable rock conditions.
154)	19-11-82	352.5	61 x 7 x 7.5 m.	Due to rain fall.

DECEMBER, 82:

155)	13-12-82	Juglot Gah 374.5	.566x.425x .170 m.	Rainfall.

DECEMBER,1982:

156) 13-12-82	Shitan Pari 394.5	.850 x 425x.227 m.	Rainfall.
157) 14-12-82	Between & Jaglot 314	5.664 x.708x.680	"
158) 23-12-82	" 314	5.664x2.832x4.531 m.	Developed cracks in overhang rock.

JANUARY, 1983:

JANUARY, 1983:

1) 12-1- 83	Yal Pari 416	36 x 7 x 6 m.	Loose rock.
2) 23-1-83	454	75' x 36' x 10'	Scree Boulders slide.
3) 25-1- 83	Hini Br. 420	566.4 cu. m.	Mud flowl
4) 25-1- 83	562	30 x 7 x 8 m.	Advalanches.

FEBRUARY:

5) 6-2-83	Hasanabad Power House 434.	10 x 4 x 1 m.	Boulder Slide.
6) 12-2-83	551	220 x 12 x 2 m.	Avalanches.

MARCH,

7) 3-3-83	Shishcat Br. 473	30 x 10 x 5 m.	Glacier.
8) 9-3-83	" 473	200' x 50' x 70'	"
9) 11.3.83	" 473	300' x 70' x 30'	"
10) 12-3-83	569	350' x 25' x 38'	"
11) 11-3-83	" 552	300' x 30' x 50'	"
12) 12-3-83	545	175' x 30' x 15'	"
13) 12-3-83	547	156' x 24' x 40'	"
14) 13-3-83	563	150' x 32' x 35'	"
15) 16-3-83	Indra Nala 555 III	30 x 12 x 1.2.	Scree Boulder.
16) 20-3-83	576	60 x 12 x 7 m.	Glacier.
17) "	577	100 x 14 x 10 m.	"
18) 21-3-83	564	160' x 37' x 60'	"
19) 22-3-83	560	100 x 14 x 18 m.	"
20) 23-3-83	Billi Det 548	100 x 12 x 13 m.	"

21)	24-3-83	Billi Det 549	600 cu. meter.	Glacier.
22)	26-3-83	Near Nazar curve 425	10 x 12 x 2m.	Boulder
23)	"	458	20 x 12 x 2.m.	"
24)	27-3-83	Bangla Pari 332.5	90 cu. meter.	Heavy rain.
25)	25-3-83	Raikot Br 286.5.	50 cu. "	"

APRIL, 1983:

26)	3-4-83	Near Dih Det 563	25' x 36' x 50'	Glacier.
27)	3-4-83	457	150' x 30' x 20'	"
28)	4-4-83	483	500' x 50' x 2'	Water flow.
29)	11-4-83	560	500' x 50' x 2'	Avalanches
30)	"	563	150' x 30' x 20'	"
31)	"	577	100' x 12' x 72'	"
32)	23-4-83	439.	100 x 12 x 2m.	Mudflow.

MAY, 1983:

33)	8-5-83	451	50 x 12 x 2 m.	"
34)	11-5-83	435	100 x 9 x 35 m.	Road drain by rain.
35)	31-5-83	Hasanabad 434	30 x 12 x 2 m.	Mudflow.
36)	30-5-83	Rakhiot 285	20 x 2 x 7 m.	Rain fall.
37)	"	282.1	51 x1.5 x 7 m.	"
38)	"	282.5	25 x1.5 x 7 m.	"
39)	"	283.3	13 x 3 x 7 m.	"
40	"	284.3	10 x 2 x 7 m.	"

J U N E, 1983:

41)	9-6-83	Rakhiot 288.289	28 x1.8 x 8 m.	Mud flow.

J U L Y, 1983: N i l

AUGUST, 1983:

42)	10-8-83	Near Nagar 423	20 x 3 x 10 m.	Boulder slide.
43)	25-8-83	Near Jaglot Gah 388	90 x 4 x 16 m.	Mudflow
44)	27-8-83	304.8	30 x 8 x 1 m.	"
45)	27-8-83	304.3.5	90 x 27 x 9 m	"
46)	27-8-83	305.306	50 x 3 x 9 m	"

Data reproduced with the courtesy of Frontier Works Organization.