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Cover Photograph:
A view of boulders slide near Chilas, along the Karakoram Highway

LANDSLIDE PROBLEMS AND THEIR MITIGATION ALONG THE KARAKORAM HIGHWAY



by

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FOREWORD

Since its inception with the creation of Pakistan in August, 1947, the Geological Survey of Pakistan (GSP) has been undertaking important geotechnical, environmental and engineering geology studies for an impressive number of national development projects. And although these included several strategic projects for the country's armed forces but perhaps none has been so arduous, technically complex and of instant value as the project of 'Landslide Problems and their Mitigation Along the Karakoram Highway (KKH)

Spread over a time span of more than three decades and carried out on the request of and with the cooperation of Pak. Army Engineers and their Chinese counterparts, these studies covered a wide range of geotechnical problems relating to road alignment and its actual construction. Landslides were the main focus of study because of their intensity, severity and frequency of occurrence and damage caused by them. Landslides are thus the main theme of the present monograph.

In an exceptional case of consistency and continuity of professional endeavors and leadership, the GSP was fortunate in having the services of Kanwar Sabir Ali Khan almost through the entire period of building this engineering marvel rightly acclaimed as the eighth wonder of the world. The excellent scientific work done by him and his highly competent and dedicated team not only earned appreciation and respect for GSP from the concerned authorities and stake holders but also immensely helped in minimizing the loss of life and property during and after the construction of the KKH. These studies provided timely as well as technically and economically sound solution to a very large number of engineering problems encountered while constructing the KKH and later in its upkeep and maintenance.

The KKH passes through one of the earth's youngest and tectonically most active mountain system. It is a classical example of collisional tectonics where nature has so intricately adjusted huge crustal shortening in the emergence of high mountains. No wonder this region now has the world's highest concentration of peaks above 7,000 metres including the second highest mountain K-2 (8,611 metres). The tectonic forces which have produced this spectacular scenery are responsible for a complex interplay of the geological processes of stress building and mass movement. Active seismicity has further compounded this problem. The resultant ruptures and rock failures in the form of landslides of nearly all genetic types dominate the region's land-human relationship.

Pakistan Army, the Frontier Works Organization and the Northern Areas Administration and for which we owe them thanks and gratitude.

It is hoped that the book in hand will serve as an important work of reference and future research to all geoscientists practicing in the fields of engineering and environmental geology. It will be also equally useful to civil and geotechnical engineers interested in working in this type of unstable terrain. I compliment the authors for their hard work and relentless efforts in producing this monumental work of great academic value and practical use and application. This is surely the first published work of its kind in South Asia and the developing world.

S. Hasan Gauhar
Director General
Geological Survey of Pakistan

Islamabad,
April, 2002.

and similarly the traditional geological education is not oriented to the problem solving skills specific to civil engineering needs such as roads, tunnels and bridges etc. Therefore, effort has been made in this book to have a practical approach to the problems which can benefit both the engineers and the geologists as the subject of engineering geology is more closely related to civil engineering. It helps in identification and assessment of the problems, due to site specific geologic setting, that may arise during planning, designing and construction of engineering structures and in taking suitable remedial measures.

Slope stability analysis is the most important aspect related with any infrastructure in the mountain areas. Construction in the hilly or mountainous regions involves analysis of slopes, both failed and unfailed, so that level of risk and associated remedial measures can be taken. Slope stability analysis is a complex task and requires a theoretical understanding and experienced judgment relating to geological processes, soil and rock mechanics, and practicable remedial measures. Depending upon this judgment, each slope failure has been thoroughly studied by the authors and remedial measures suggested which include benching and terracing, provision of catchwater drains and side drains, construction of breast and retaining walls, rock-bolting, shotcreting and wire meshing etc.

This book will provide useful reference material to field engineers and geologists engaged in building roads and other structures in the mountainous terrains. It can also provide course material to students who are being trained as civil engineers and geologists.

Kanwar Sabir Ali Khan
Senior Author



MESSAGE

from

Brigadier Khaliq Ur Rehman Shad
DW & CE Army, GHQ, Rawalpindi
Former Commander 491 Engineers Group, KKH



The Geological Survey of Pakistan stood by Frontier Works Organization since construction of the Karakoram Highway which commenced in 1966. The department has played its part whenever any technical assistance was asked. Having gone through this book, I feel that it is indeed a tremendous effort made by the dedicated team of officers of Geological Survey of Pakistan. It is a well composed and comprehensive document which provides guideline to all civil engineers.

The book offers information about rock classification, soil/rock profile and its behavior under peculiar environments. Many problem areas have been identified with proposed remedial measures. The document contains sections comprising similar sets of instability problems. The type of problem, its location with size and magnitude and supported by photographs further elaborate the details and make it simple to comprehend.

Trouble shooting recommendations open new avenue of skill development by learning and adopting new techniques to undertake remedial measures. A civil engineer is well conversant with construction of breast walls, retaining walls, toe and breast wall benching with gabion, attainment of rock stability through stress reversal by resorting to rock bolting, shotcreting and fixing of wire mesh. These measures are although a costly affair when long stretches are involved but their significances cannot be over looked. This book is a useful document and my group employed in the challenging rugged terrain of the Northern Areas will be benefiting a lot from the recommendations made.

and their organizations have always been a source of consolation and satisfaction while working under extremely difficult and strenuous conditions.

This acknowledgement will remain incomplete without recording the untiring help and assistance received by the authors from their colleagues in the GSP Islamabad Office. Foremost is the encouragement and support provided by Mr. M. Saeed-uz-Zafar Khan, Director Incharge whose kind words of appreciation have always been spiriting and inspiring. Technical discussions with colleagues particularly M/S Sajid Hussain Shah, Firdous Khan, Naseer Ali Khan, Ibrarul Hasan Khan, Tahseenullah Khan, Azmatullah Khan and Muhammad Ashraf have been very useful and often provided new angles to the study of different problems. Similarly the contribution made by the GSP staff members both in the field as well as in the office to the successful completion of the work also deserve due acknowledgement. They handled the laborious job of typesetting and composing several hundred pages of text at various stages of editing and of making sketches, illustrations and data filling of dozens of proforma I & II. In this connection the authors would like to specially thank M/S Muhammad Latif, Muhammad Khurshid , Basharat Hussain, Ehtamamuddin Gohar and Jamil Murtaza.

Chapter 1

INTRODUCTION

Chapter I

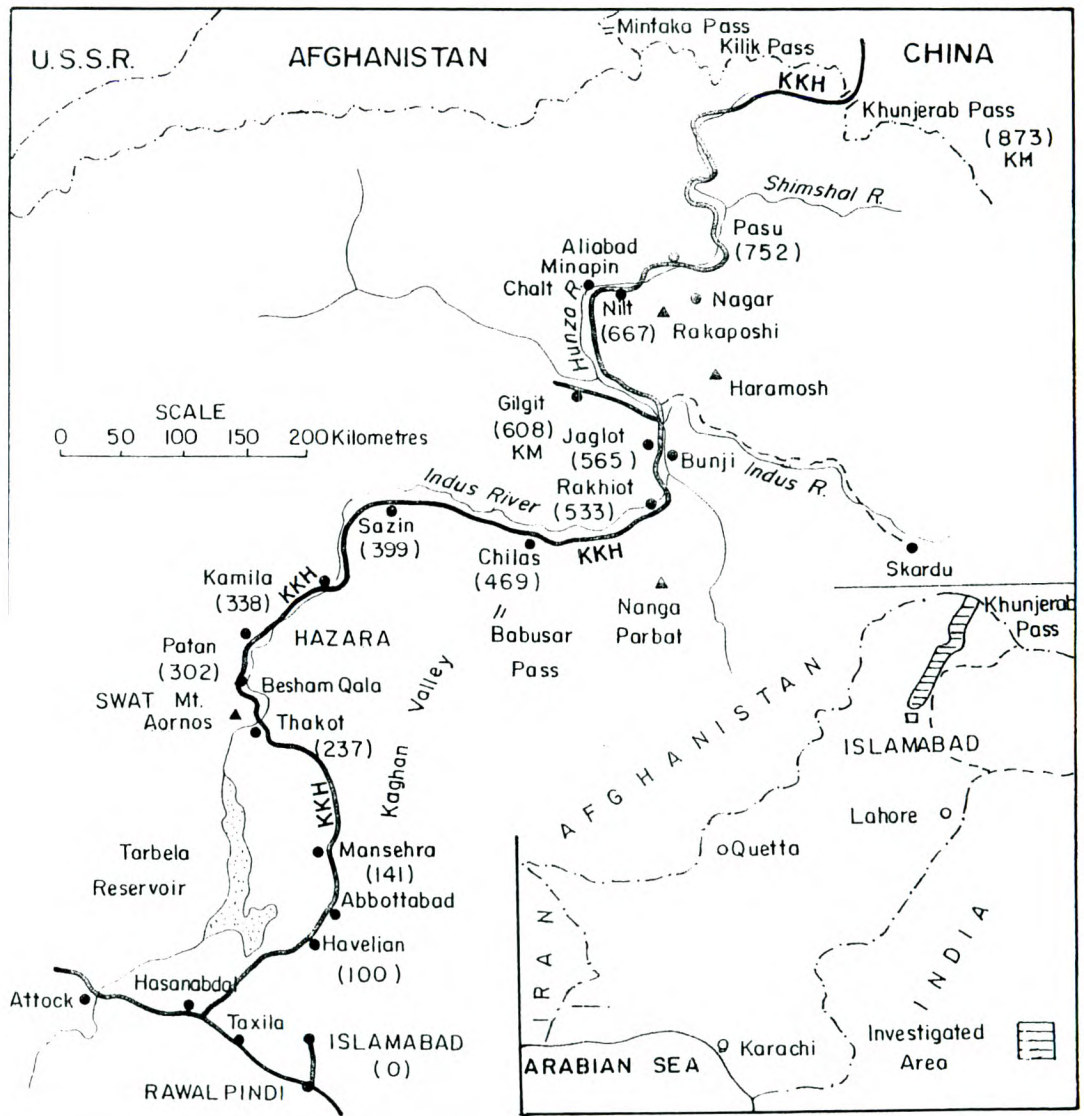
INTRODUCTION

The Karakoram Highway (KKH) is truly a marvel of civil engineering and landmark in the realm of highway construction in mountainous areas. The unique and the breath-taking terrains through which it winds its way from Pakistan to China makes it absolutely spectacular. It crosses two of the tallest mountain ranges in the world, the Himalayas and Karakoram. It starts from an altitude of about 443 m at Hasanabdal and climbs up to about 4730 m at the Khunjerab Pass (Fig 1). Along the route and not far from it there is the greatest concentration of some of the tallest peaks in the world (Kazmi & Jan 1997) One cannot appreciate the prowess of the geologists, engineers and other technical personnel, and the stupendous work involved in the completion of this super –highway, without a bird's eye view of the fascinating, yet awesome terrain through it has been constructed. The region has been sculptured by nature, through wind, glacial, fluvial and mass-movement processes. The highway is constantly under the onslaught of these immeasurable terrestrial forces. For its sheer mountain grandeur and breath – taking panorama of beauty, few places can match the superb landscape through which the KKH passes and it has been rightly called the “Eighth Wonder of the Word”.

I.I Historical Background:

The history of construction of the Karakoram Highway dates back to 1966 when this project was first conceived by the Corps of Engineers, who initiated its survey under the title “Indus Valley Road Project (IVR) which comprised the road section from Gilgit to Besham. Previously there was no direct connection between Gilgit and Rawalpindi. The only approach was through Kaghan and Babusar Pass, which was a seasonal road and remained open for only 5 to 6 months during the summer season. The rest of the year, the Gilgit valley remained cut off from other parts of the country and PIA provided the only communication link with Rawalpindi and that too largely depended upon the weather conditions. Later on, the scope of IVR project was extended upto Hunza and its survey and construction work was started simultaneously.

The strategy of construction was divided into three phases. The first phase comprised linking of main towns and villages through already existing mule



MAP OF PAKISTAN SHOWING LOCATION OF INVESTIGATED AREA

FIG: I THE ROUTE OF THE KARAKORAM HIGHWAY SHOWING DISTANCES IN KILOMETRES FROM ISLAMABAD

passed, since the last survey was carried out by Geological Survey of Pakistan (GSP). Now there is dire need of experts from GSP to restudy the same to find solution to the problems. Last study reports along the KKH would be a great help to maintain and upgrade the road in view of the trade links with Central Asian States along this route”.

The National Highway Authority (NHA) has also acknowledged (letter no. 2 (35) /90/NHA/GLT/1437, dated January, 1996) the contribution of the Geological Survey of Pakistan on this road and expressed similar views on the necessity of a renewed geotechnical survey by the GSP personnel.

1.3 Methodology:

During the survey ground identification of each trouble spot has been prominently marked on the adjacent rock face by red or white paint giving it an identification number such as GSP Slide No.22 and so on. The location and distances are given with reference to Hasanabdal – the starting point of the KKH.

The field data have been collected on a proforma, specially designed for this purpose. The field form-1 pertains to “rockmass classification detail” as designed by Prof. D.G. Price (1992) which is perhaps the one most applicable to slopes. A rockmass classification has been developed in order to relate the performance of excavation made in different rockmasses. The classification incorporates the following rockmass parametres:

1. Intact Rock Strength
2. Discontinuity Spacing
3. Conditions of Discontinuities
4. Groundwater Flow (Water Pressures)
5. Weathering
6. Susceptibility to Weathering
7. Method Of Excavation

Mass classification of Quaternary graded deposits, prepared on the basis of BS 5930 by Manurenbrecher (1992), was used for soil classification (Gravel). The main characteristics are described on the basis of the following parametres:-

rockfalls, debris slides, snow avalanches, mudflows and formation of ice crystals on the road surface. This road section is unique in the sense that it passes over the Khunjerab Pass which is said to be the HIGHEST PUBLIC HIGHWAY IN THE WORLD. The crossing is not only between the two countries i.e Pakistan and China but between two of the world's major mountain ranges, the Pamir and the Karakoram. The Khunjerab Pass itself is long and flat and 4,730 m above the sea level. This place is about 880 km from Islamabad and 400 km from Kashgar.

The second section runs between Deh and Sost and is 40 km long. It passes through some of the narrowest gorges on the KKH. It shows 9 slides numbered as GSP Slides, 10 to 18. This road section encounters two very big problem areas, hitherto, described as Kafir Pahar Slide and Dhia Slide. This zone is highly unstable and shows frequent and sudden occurrences of large scale sliding. Sost is mainly a custom and immigration check-post on the KKH at an elevation of 3,100 m.

The third section starts from Sost and ends at Shishkat Bridge. It is about 50 km long and shows 5 slide areas numbered as GSP Slides 19 to 23. In this section the KKH comes close to 4 glaciers namely Batura, Pasu, Ghulkin and Gulmit whose snouts have descended down to the road level. Among these glaciers, the Batura glacier is about 58 km long and considered among the world's largest outside the Polar region. The black Batura and white Pasu glaciers stand at a height of about 2,400 m above the sea level. The snout of Batura Glacier forced its way down the valley in 1971 and knocked down a large part of the concrete bridge. Similar incident of glacier outburst occurred in 1976 when Momhill Glacier activated a mudflow, which blocked the Hunza River at Shishkat and formed 25 km long lake and buried 130 m long RCC bridge, known as the Friendship Bridge, under the debris. The Ghulkin Glacier standing just over the KKH and has changed its course frequently. The threat of glacier pressure and mudflows is matched only by that of avalanches and earthquakes.

The fourth section starts from Shishkat Bridge and ends at Ganesh Bridge. It is 30 km long and shows 4 slides described as GSP Slides 24 to 27. This section is characterized by the occurrence of the Karakoram axial batholith and the lime-silicate marble, which serves as a host rock for ruby mineralization. Some of the

abandoned ruby mines are also seen on the KKH in this section. This section also shows some archeological scriptures on the marble rocks on the roadside.

The fifth section stretches between Ganesh Bridge and Jaglot Gah. It is about 58 km long and shows 8 prominent slide zones numbered as GSP Slides 28 to 35. This portion encompasses the main Hunza valley which is the centre of attraction for the tourists the world over. The Hunza valley shows greater relative relief than any other place on earth and that is why it can be called the "STEEPEST PLACE ON EARTH". It rises from about 1,850 m to the summit of Rakaposhi at 7,788 m, a vertical difference of 5, 938 m over 11 km.

The sixth section starts from Jaglot Gah and ends at Gilgit Bridge. This portion is 36 km long and shows 3 slide zones numbered as GSP slides 36 to 38. The road passes through sheared greenstone complex, followed by Ladakh Intrusives and shows comparatively stable slopes. The valley also widens and does not show any serious problem of sliding.

The seventh section starts from Gilgit bridge and runs upto Rakhiot bridge. It is 78 km. long and shows only 3 landslide zones numbered as GSP Slides 39 to 41. The KKH from Gilgit bridge runs along the right bank of the Gilgit River, which is joined by the Indus River at Jaglot. This place is popularly known as "TRIPPLE JUNCTION" of three great mountain ranges; the Himalayas, Karakoram and Hindukush. It also serves as a meeting point of the KKH and the Skardu road through Alam bridge on the river Indus.

The eighth section runs between Rakhiot bridge and Chilas. It is 61 km. long and shows 7 slide zones numbered as GSP Slides 42 to 48. From Rakhiot bridge the road crosses over to the left bank of the Indus River and runs under the foothills of Nanga Parbat, which is 8,126 m high and is the SECOND HIGHEST PEAK in Pakistan. It is also popularly known as the "Killer Mountain". This section is also important because of the presence of MMT, which runs right in the middle of the Indus River and is tectonically active. The Rakhiot Fault - an offshoot of the MMT is an active fault, and a source of constant subsidence and sliding. The road section also shows a series of hot springs oozing out of the ground in a linear pattern along the KKH at a place called Tatta Pani.

and poses no serious problems of landsliding. It passes through wide valleys and connects the main towns of Mansehra, Abbotabad and Hasanabdal.

The work produced in this book is of paramount significance and it is hoped that the geology (the science of earth) can help to provide understanding so that civil engineers will have a clear picture of what can be done to maintain a structure like KKH in the mountainous region. This book will provide useful reference material to field engineers involved in the construction and maintenance of roads. It can also provide useful course material for students who are being trained as civil engineers and geologists.

This introduction may be concluded with a very pertinent quotation from Boyd Dawkins (FRS) – “Geology Stands to (civil) engineering in the same relation as faith to works. The success or failure of an undertaking depends largely upon the physical conditions which fall within the province of geology, and the “works” of the engineers should be based on the “faith” of the geologist”.

Chapter 2

PHYSICAL FEATURES

Chapter 2

PHYSIOGRAPHY

2.1 Mountain Ranges

The terrain through which the KKH passes from Hasanabdal to Thakot is not so difficult. It crosses over the rolling topography of the Potwar plateau, the Pakhli plains of Mansehra and a hilly terrain between Shinkiari and Thakot. From Thakot northward, the Highway follows the valley of the Indus and Hunza Rivers up to the Khunjerab Pass and in the process it traverses three main east-west trending mountain ranges, namely the Himalayas, Koh-i-Ghizar and the Karakorams (Fig. 2). Wedged in between the high Himalayas and the Karakorams, Koh-i-Ghizar is a relatively smaller (270 kms long, 75 km. wide) and lower (4000 m to nearly 6000 m) hill range. It is straddled by the Ghizar and Indus Rivers. Owing to its lower altitude, this Range has only a few patches of permanent snow cover on its summits and contains small cirques and corrie glaciers.

The Himalayas and the Karakorams are two of the highest mountain ranges in the world. They are characterized by some of the tallest peaks in the world. There are more than 44 peaks with altitude of over 7300 m (including 5 of the world's tallest peaks, namely K2, Broad Peak, Gasherbrum I and II, Hidden Peaks and Nanga Parbat). Nearly half of the surface area of these mountains is more than 4500 m above the sea level. The upper reaches are snow-covered and dissected by numerous corrie and valley glaciers. The lower slopes are drained by deep transverse defiles and gorges with steep gradients and frequent falls.

2.2 Glaciers

The Karakorams are traversed by some of the longest glaciers in the world (Siachen 72 km, Biafo 62 km, Baltoro 60 km, Hispar 58 km, Batura 59 km, Pasu 24 km.). The Highway runs close or even on the snout of some of these glaciers like Ghulkin, Batura and Khunjerab. Several glaciers are high-activity glaciers characterized by steepest gradient in the world. For example the avalanche fed Minapin Glacier, beneath the Rakaposhi Peak (7,788 m) descends from 5300 m to 2,400 m over a distance of only 10 km. Its snout is within 2 km of the Highway.

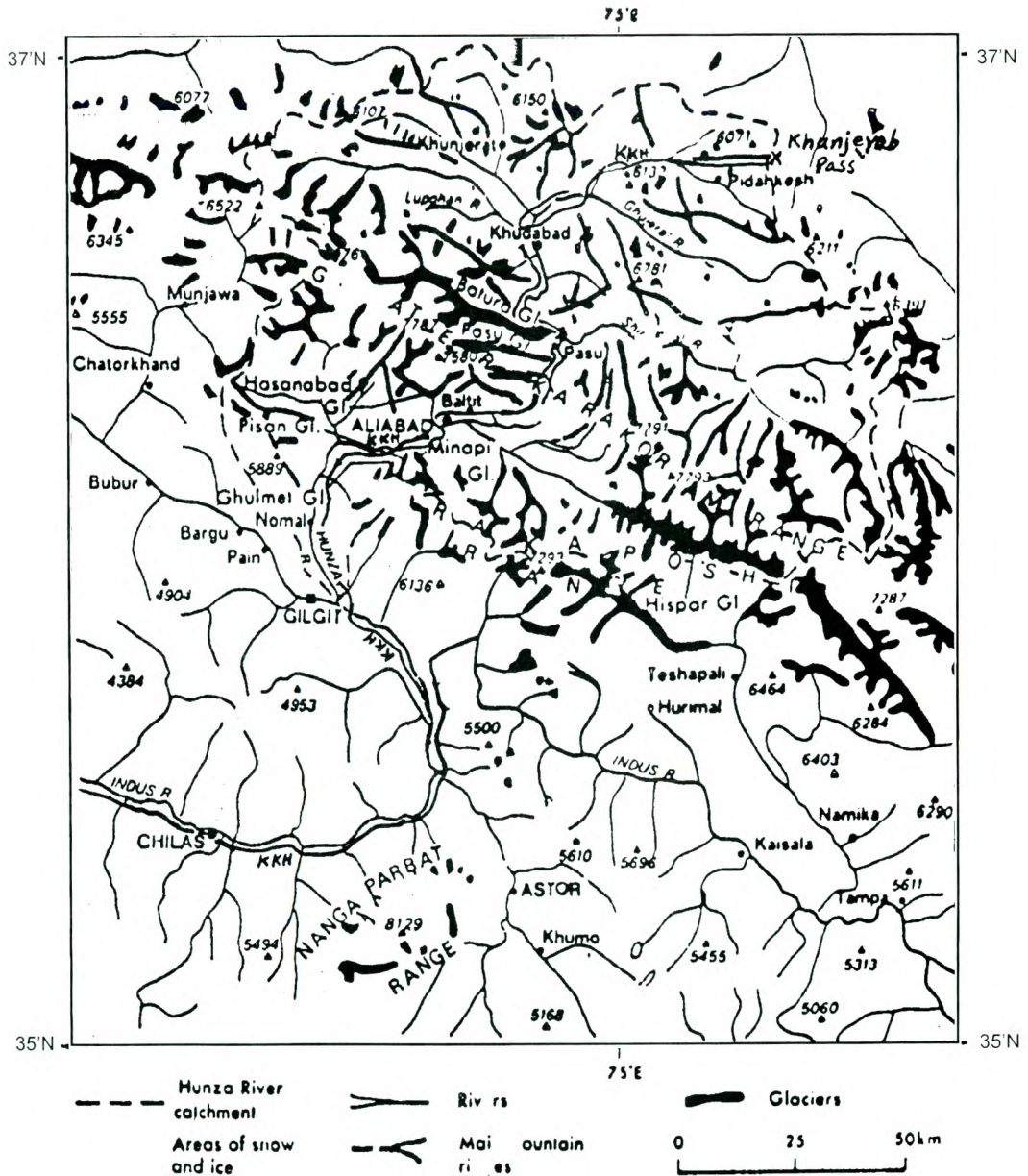


FIG - 2 PHYSIOGRAPHIC MAP SHOWING TOPOGRAPHY, DRAINAGE AND GLACIERS OF NORTHERN AREAS

- g) Glacial deposits and valley fills. These largely comprise various types of moraines, outwash fans, braided channel and other types of fluvial deposits, lacustrine sediments formed in ice-dammed lakes or those formed by massive land slides.

To this list we may add the massive, steep rocky cliffs, with a relief of hundreds of metres that stand along the valley like vertical walls of solid stone, particularly in the gorges and the narrower sections of the valley. These have also posed a great challenge in the construction of the Highway. The most difficult hazardous and to negotiate are the commonest and highly spectacular mass-movement deposits in the valley – rock falls, rock slides flows and avalanches.

2.4 Vertical Relief – Rising Mountains:

The Karakoram Highway terrain is also characterized by the highest relief in the world. In the main valleys the relief is really less than 4000 m. In the Hunza Valley, the Rakaposhi (7,788 m) exhibits a relief of about 6,000 m within a distance of only 15 km. As seen from Hini (1,600m). The greatest world (4,500 m) is the Rupal face of the Nanga Parbat, along its south-eastern flank as seen from the Astor Valley. The Rakhiot face of Nanga Parbat (8,126 m), viewed from Gunar (1000 m) on the KKH, exposes a vertical relief of about 7000 m within a short distance of 24 km. It is indeed the grandeur of these lofty peaks, coupled with this awesome relief that makes these mountains (and the KKH) so distance from others.

Another little known fact about these mountains, and the reason for their tremendous relief is that according to Zeitler et al. (1985), these mountain are still rising at a relatively fast rate of over 7 mm/year. This uplift has continued during the past 10 million years. That is how these mountains have grown to be the tallest in the world.

2.5 Physical Feature and Their Impact on the KKH

The various physical features and landform we have briefly discussed above are largely the product of weathering, and erosion and deposition through glacial, fluvial, to constitute one landmass. During this 120 million year old

Chapter 3

**GEOLOGY AND TECTONICS
OF
NORTHERN AREAS**

Chapter 3

GEOLOGY AND TECTONICS OF NORTHERN AREAS

3.1 The Main Tectonic Framework

The Karakoram Highway is well known for its grandeur by virtue of its construction in one of the highest mountainous terrains of the world. It crosses the world famous mountain ranges of the Karakoram, the Himalayas and the Hindukush. Geologically, it has the unique distinction of passing over the Eurasian Plate in its northern part, the Kohistan Island Arc in the middle and the Indo-Pakistan Plate in the southern part. The northern contact of the Kohistan-Ladakh island arc with the Eurasian Plate is commonly known as the Northern Suture or the Main Karakoram Thrust (MKT) and its southern contact with the Indo-Pakistan Plate is called the Main Mantle Thrust (MMT). Thus, on the basis of broad regional setup, the area is characterized by continent-continent and continent-arc collision zones. The MKT and MMT are the suture zones characterized by the association of ophiolitic melanges and in the case of MMT blue schist and high pressure granulites. (Fig. 3 & 3 A)

3.1.1 The rocks in the Eurasian plate are predominantly pelitic and metamorphosed and are mainly Paleozoic and sub-ordinate Mesozoic sediments into which have been emplaced (i) the Khunjerab-Wakhan –Trichmir granitoids of the Jurassic to Cretaceous age to the north and (ii) the Karakoram batholith of Cretaceous to Tertiary age to the south (Debon et al. 1987). These rocks generally follow the arcuate trend of the major megashears in the area and show an increase in the grade of metamorphism from south to north.

3.1.2 The Kohistan island arc comprises five principal units from north to south (i) the Chalt volcanic group and/or Rakaposhi volcanic complex (ii) the Jaglot group (Gilgit formation, Gashu-confluence volcanics and the Theliche formation, (iii) Chilas complex of mafic to intermediate plutonic rocks, (iv) Kamila amphibolites and (v) basic ultramafic-mafic cumulates (Jijal ultramafics). These rocks are intruded by the Kohistan batholiths of felsic, intermediate and mafic composition.

3.1.3 The Indo-Pakistan continental plate is made up of Pre-Cambrian to Cambrian basement, and Paleozoic to Mesozoic and Tertiary cover. Several episodes of plutonic and even Himalayan age have been recorded in the Indo-Pakistan continental plate margin in Northern Areas of Pakistan. The main orographic units of this tectonic plate comprise (i) Nanga Parbat-Haramosh massif, (ii) the Himalayan crystalline schuppen zone and (iii) the Himalayan fold

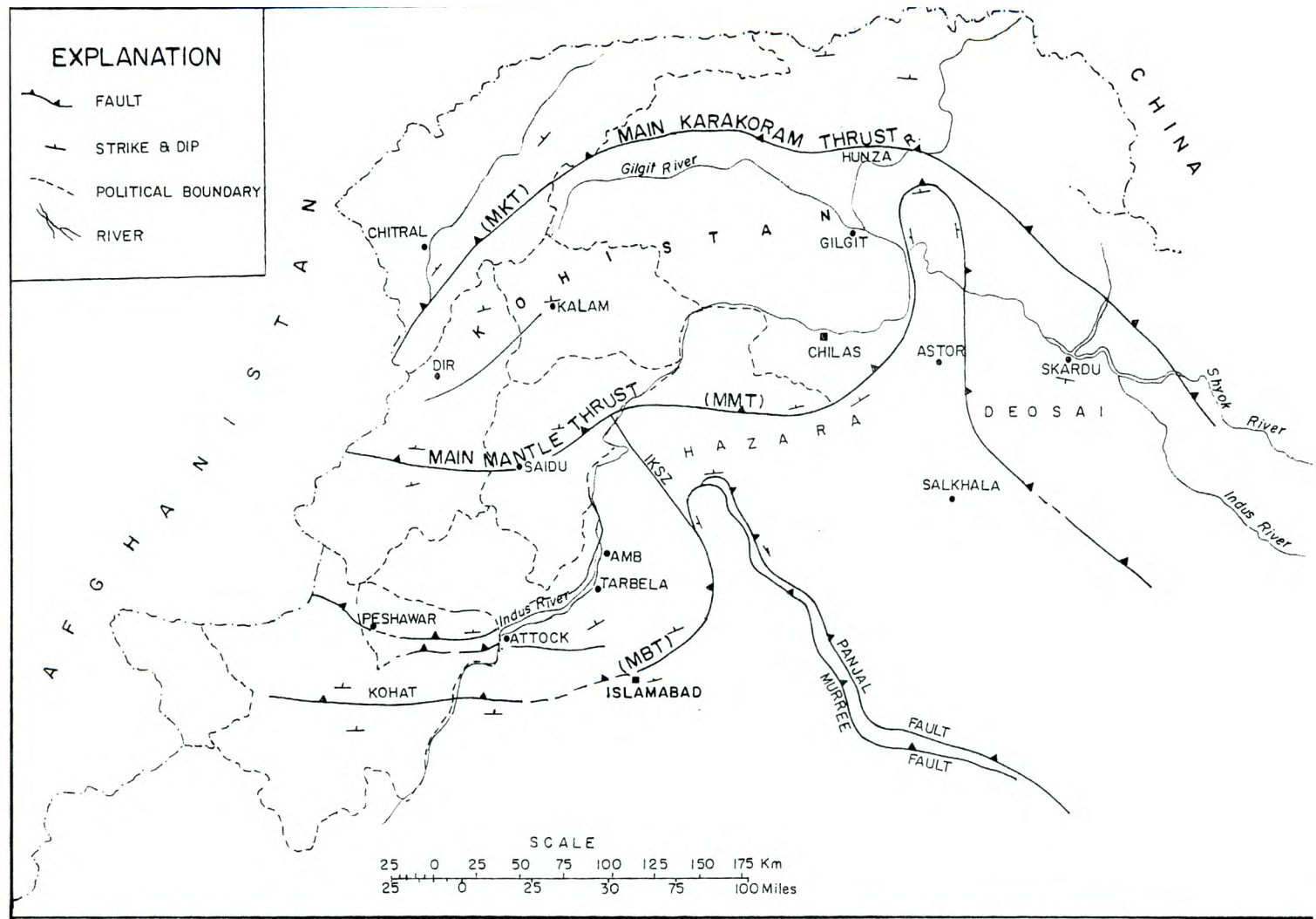


FIG: 3A MAP SHOWING MAJOR TECTONIC FEATURES OF NORTHERN PAKISTAN

(After, Tahir Kheli & Jan M.Q. 1979)

3.2 Geological Formations from Khunjerab Pass to Gilgit

The geology exposed along this section is characterised by metasedimentary and metavolcanic rocks intruded by three major Creto-Tertiary batholiths. The sequence of the formations from the youngest to the oldest is given below. (Fig. 3 B)

Formation	Brief lithology	Tentative age
Quaternary Deposits	Scree and talus cones, river deposits, terraces, fluvio-glacial deposits	Pleistocene to Holocene
Ladakh Intrusives	Diorite and granodiorite with subordinate granite; pegmatite, aplite and basic dykes	Creto-Tertiary
Karakoram Batholith	Granodiorite, massive diorite, granite, pegmatite and aplite.	Creto-Tertiary
Khunjerab Tirich Mir Granitic Belt	Granodiorite and granite.	Upper Cretaceous
Shanoz Conglomerate	White, saccharoidal pebbles and cobbles embedded in arenaceous cement.	Upper Cretaceous to Lower Tertiary
Chalt Schists	Slate, quartzite, chlorite schist, biotite schist, talc schist, quartzite turbidite (conglomerate?) ophiolitic mélange containing ultramafics, metabasalts.	Lower Cretaceous.
Greenstone Complex	Pillowed basalt, andesite, rhyolite, quartzite and tuff, marble and amphibolites with minor slate	Lower Cretaceous.
Gujhal Dolomite	Yellow, white to light grey thick bedded dolomite with minor slate	Jurassic to Cretaceous.
Misgar Slates	Dark grey to black slates and phyllites with minor quartzite and limestone	Permo-Carboniferous
Kilk Formation	Dark grey limestone, dolomitic limestone with alternating bands of arenaceous slates.	Permo-Carboniferous
Gircha Formation	Dark grey argillites, interbedded with dolomitic limestone and quartzite	Permo-Carboniferous
Pasu Slates	Dark grey, thinly bedded slates, intercalated with limestone bands	Permo-Carboniferous
Baltit Group	Gneisses, magmatitic gneiss, lime-silicate marble and garnet staurolite schist.	Pre-Cambrian to Lower Paleozoic

The slates are thinly bedded, compact, mainly arenaceous, occasionally phyllitic, associated with black limestone and few intercalations of grey and yellowish quartzite. The southern and northern contacts with the Karakoram Batholith and Gujhal dolomite, respectively, are faulted. The age of the Pasu Slates is Carboniferous(?) and Permian.

3.2.3 Gircha Formation

The name Gircha Formation, was given to the rocks which are mainly composed of dark grey argillites with interbedded light to dark grey dolomitic limestone and light grey, coarse grained quartzite. (Desio, Martina & Galimberti, 1963) The limestone is partially metamorphosed and lithologic variations like iron rich beds, claystone, calcareous-arenaceous shales, sandstone, can also be seen. Quartz veins, cutting across the sheared beds are also present. Desio (1962) reported brachiopods and foraminifera of Permo-Carboniferous age. The formation is exposed to the north of Markhun in Gircha area upto the confluence of Hunza and Kilk rivers.

3.2.4 Kilk Formation

The name Kilk Formation was proposed by Desio et al., (1963) to the rocks exposed in the area of confluence of Hunza and Kilk rivers. It consists of thick beds of dark limestone, dolomitic limestone and dolomite, separated by three levels of dark-grey arenaceous slates associated with brown sandstone and few intercalations of red arenaceous slates. This formation is strongly tectonised and the beds are subvertical with an east-west strike.

The fossils are obliterated and poorly preserved. The age assigned is Permo Carboniferous.

3.2.5 Misgar Slates

The name Misgar Slates was given by Desio et al. (1971) to a thick sequence of slates out-cropping in the area between Khunjab Pass and near the confluence of Kilk and Hunza rivers along the KKH. This formation consists of dark grey to black, very fine grained slates, phyllite with minor grey argillaceous limestone in Wad Khun area along-with light grey to white quartzite. Quartzite content increases in the area just upward from the confluence of Hunza River with Khujerab River along the KKH. The slates have varying iron content, in the form of limonite, which gives yellowish brown coloration. These slates are intensively faulted, folded and highly sheared, having the tectonic contact with the Kilk Formation. The age assigned on the basis of fossils is Permo-Carboniferous.

Chalt Schist in contact with the complex. This complex is cut by milky white massive quartz veins. Two to three joint sets and sometimes columnar jointing is also present in the rock.

The age assigned by Tahirkheli (1982), on the basis of fossils, is Lower Cretaceous.

3.2.9 Shanoz Conglomerate

Shanoz conglomerate is exposed on the right bank of Hunza River near the Karakoram Highway, about 4 km. south of Khaiber. This conglomerate consists of white saccharoidal marble pebbles and cobbles embedded in a fine grained, yellowish, arenaceous cement derived from quartz-calcareous and slightly metamorphic rock which is more abundant in the upper part where they form whole beds having undulated layering.

The age assigned to this unit by Desio (1963) is Upper Cretaceous-Lower Tertiary.

3.2.10. Khunjerab-Tirich Mir Granitic Belt

The name Khunjerab-Tirich Mir Granitic Belt was given by Jan et al. (1981) to different granitoids of Kafirstan, Tirich Mir and Khunjerab areas.

The granodiorite which is present to the west of Khunjerab Pass is medium grained biotite-hornblende granodiorite. Plagioclase is typically euhedral to subhedral and oscillatory zoned Quartz feldspar, biotite and hornblende are nearly in equal amount.

In the area between the confluence of Kilk and Hunza Rivers and Hunza and Khujerab Rivers, two large bodies, 600m and 900m wide and several small dykes of the granitoids are present. The granitoid bodies comprise fine to medium grained hornblende-biotite granite and granodiorite. The granitoids, typically, have a sharp contact with the Misgar Slate, but at places migmatized boundaries are also found.

K-Ar dating of hornblende and biotite show the ages of 107 Ma and 96.9, 4.8 Ma respectively (Ogasawara et al. 1992).

3.2.11. Karakoram Batholith

The name karakoram Batholith was used by Clark (1949) for the intrusive rocks of Hunza area which are exposed along the Karakoram Highway from Sarat to Ghulkin.

glaciers and as such enormous glacial deposits are present all over the area. The glacial morain of Karakoram Range have abundant debris which consist of large boulders and blocks of rock embedded in clayey matrix. These sediments are partly consolidated and stand at steep angles. Stability of road cuts made in these sediments is poor.

3.2.13.2. *Terraces*: The valleys of the Karakoram Range are characterised by great relief, steep-V-shaped profiles, and numerous terrace deposits.

These terraces consist of vast accumulations of loose, unsorted debris and contain many large blocks. Within the unsorted debris are layers and lenses of relatively homogeneous clays, sand, and gravels, some showing distinct cross-bedding.

Terraces are present on both sides of the valley along the entire length from Chalt to Ganesh (Hunza). Generally, there are three or more terraces found one above the other.

These sediments may create landslide problems due to lack of compaction and heterogeneous composition of the materials.

3.2.13.3. *River Deposits*: The river deposits found through out Hunza valley consist of homogeneous layers and lenses of very fine clay, often showing layers of coarser material. The deposition of the silt perhaps took place due to the occasional damming of the river. These deposits are seen at different levels and show at least more than one episode of such happenings.

3.2.13.4. *Scree and Talus Cones*: Shattering and down-slope slide of broken rocks causes the formation of these deposits which is quite common especially in those areas where metasediments are exposed. The scree consists of poorly sorted, angular to sub-angular rock debris ranging in sizes from large blocks to gravel-size fractions. These cones are 13 to 60 m thick. The extent and thickness is largely dependent upon the feeding area above the slope. The road runs at some places along such scree slopes, which are not stable.

Mansehra Granite	Porphyritic two mica granite, foliated and tourmaline-bearing in parts.	Cambrian
Tanawal Formation	Quartzites, quartzitic schists, phyllitic slates and conglomerate	Pre-Cambrian
Hazara Formation	Black slates, brown phyllites, greywacks siltstone and limestone	Pre-Cambrian
Nanga Parbat Gneisses	Granitic gneisses.	Pre-Cambrian
Besham Group	Schists, gneisses, intruded by granites and pegmatites and amphibolite dykes.	Pre-Cambrian

3.3.1. Besham Group

Treloar (1989), gave the name Besham Group to the rocks exposed in the area between Thakot and Jijal. The group consists of siliceous schists, green schists, calcareous schists, amphibolite and marble. These rocks are strongly schistose, fine to medium grained and banded.

The schists have changed into gneisses near contacts with the intrusive rocks and near the Main Mantle Thrust (MMT). These rocks have faulted contact with the Jijal Ultramafic Complex near Jijal.

The age assigned to this group is Pre-Cambrian (Treloar, P.J., 1989).

3.3.2 Nanga Parbat Gneisses

Wadia (1932) and Peter Mish (1949) have described the Nanga Parbat Gneisses in detail. Shams and Shafique, (1979) gave petrochemistry of these granitic gneisses.

Along the Karakoram Highway these gneisses are exposed in the area between Bunar Gah and Rakhiot bridge, towards the southern side of the Indus River.

These gneisses are mostly banded but at certain places augen type is prominent. These are considered to be the result of remobilization of previous granitic belts of the Indian shield with marked effects of metamorphism. The age assigned to the Nanga Parbat Gneisses by Tahirkheli, R. A. K., (1982) is Pre-Cambrian.

KKH and is composed of dolomite, quartzitic sandstone, shale and conglomerate. Marks and Ali (1961, 62) differentiated the Abbottabad Formation into the following five lithological units:-

- 1 Basal conglomerates
- 2 Lower shale and sandstone
- 3 Lower dolomite
- 4 Upper shale and sandstone
- 5 Upper dolomite

The age assigned to this formation, on the basis of fossils, is Cambrian.

3.3.7 Samana Suk Formation

The earlier name assigned to this formation was Kioto limestone by Middlemiss (1896). Fatmi (1968) designated a type section and named this formation after Samana Suk Peak in the Samana Range. This formation is comprised of grey to dark grey, thin to thick bedded oolitic limestone with subordinate marl and calcareous shale partings. The limestone of this formation is exposed as small outcrop between Khota Qabar and Abbottabad along the road.

3.3.8 Jijal Complex

Qasim Jan (1979) proposed the name of Jijal Complex for the rocks exposed from Jijal to Pattan and comprising of garnet gabbro, garnet pyroxenite and alpine type ultramafic rocks. Tectonically, this complex is delineated by the two major faults; the Main Mantle Thrust which separates it from the northern marginal mass of the Indo-Pakistan Plate and the Pattan Fault that marks its boundary with the Kamila Amphibolites.

The ultramafic part of the Jijal Complex is represented by peridotites and websterites, which are subjected to varying degree of serpentinization, being more pronounced near the marginal parts involved in shearing.

3.3.11. Gashu-Confluence Volcanics

The rock of greenstone complex have been renamed as Gashu Confluence Volcanics by Khan, T. et al. 1996. These are exposed along the KKH in the areas between Jaglot and Thelichi in the form of a thin strip. It comprises pillowed basalts, alternating with massive basalts and volcanoclastic sediments. The sequence has been metamorphosed to lower amphibolites facies. The Gashu Confluence Volcanics are equivalent of the Chalt Volcanics. Their contact with the overlying Thelichi Formation, which is of lower green schist facies is sheared suggesting the contact to be a tectonic, post-metamorphic one (Khan, M.A., et al. 1998).

3.3.12. Thelichi Formation

It was previously described as part of the Salkhala (Wadia, 1932) and as the Thelichi beds by Tahirkheli (1982). The name Thelichi Formation was given by Khan, T., et al. (1996). It comprises a sequence of slates, marble and meta-volcanic rocks. This formation is well exposed between Jaglot and Thelichi along the Karakoram Highway. The lower part of the formation contains several intercalations of felsic volcanic rocks and volcanoclastic rocks. A thick, laterally persistent unit, comprising thickly bedded marbles occurs in the middle part of the formation and serves as a useful marker horizon. The succession of slates above and below the marble unit are lithologically identical.

3.3.13. Chilas Complex

The rocks of Bahrine Granulite have been renamed as Chilas Complex by Tahirkheli (1979).

Chilas Complex is composed of feldspathic gabbro-norites and diorites associated with subordinate ultramafic rocks such as anorthosites, troctolites, olivine gabbros and mafic to ultramafic pegmatites. These rocks are cut by thin metadolerite (amphibolite) dykes and metasomatic hornblende plagioclase pegmatites.

The rocks of the Chilas Complex are exposed in the area between Bunner Gah and Lotar Gah along the KKH. The Chilas Complex has been divided into two broad rock units-(i) ultramafic and mafic rocks and (ii) the feldspathic rocks. The ultramafic and mafic rocks of the Chilas Complex are exposed in Thak Gah and Thurli area. These range from dunites to peridotites, pyroxenites, mafic-ultramafic pegmatites and hornblendites. The peridotites range from feldspathic peridotites to troctolites (cumulate). The pyroxenites occur throughout the area

some places thick gravel deposits have been deposited by the Indus River which are used for road aggregates.

Reworked loess and alluvial deposits occur in the form of terraces and flood plain material along the valley slopes and banks of the main streams in the area between Thakot and Hasanabdal. These alluvial plains are significantly developed in the low lands of Haripur, Abbottabad, Hasanabdal and Batgram areas, while they are poorly developed in the uplands between Mansehra and Shinkiari. The loess is partly consolidated and interlayered with sand and gravel. The streams have deeply incised these deposits forming nearly vertical gullies as much as 60 to 70 m deep. The alluvial deposits of Battal are composed of slightly reworked and weathered material derived from the Mansehra Granite.

Chapter 4

ENGINEERING GEOLOGY

**4 A. APPLICATION OF ROCK MASS
CLASSIFICATION IN LANDSLIDE
INVESTIGATION.**

ENGINEERING GEOLOGY

4-A ROCK MASS CLASSIFICATION

4 A. 1 INTRODUCTION

Rock mass classification is used to identify and characterize a particular rock mass. Various systems have been developed world-wide and have been used extensively. Most of these systems were developed for underground mining and have been used in underground mining with a great deal of success. Some of the systems have been extended to cover also surface stability problems, eg. slope stability and the stability of foundations. The results of these underground systems applied to surface features are not satisfactory and therefore during this field work a new approach will be followed.

4 A.1.1 CRITERIA

A rock mass classification rating developed for engineering geological purposes has to have the following characteristics:

- 1) identify the rock mass,
- 2) indicate possible problems,
- 3) preferably indicate the strength,
- 4) preferably should predict rock mass quality at locations not accessible from outcrops in the surroundings,
- 5) has to be reproducible (each time the same rock mass is classified, also by different persons, the results should be broadly the same),
- 6) the system should not be too difficult,
- 7) should not require massive amounts of tests and equipment.

4 A.1.2 PROBLEMS

A classification developed according these criteria has to deal with the following problems:

- 1) The strength of a rock mass is a sensible expression only when the future use of the rock mass is known.
- 2) The degree of weathering at different places in one outcrop does not need to be the same and the degree of weathering in different outcrops can vary widely (sometimes depending on the time the outcrop exists).
- 3) The ground-water pressures in a rock mass are not the same at every location and normally change when the rock mass is used (by example: upstream of a dam the ground-water level will increase).
- 4) The method of excavation influences the rock mass strength after excavation. The method of excavation used for the outcrop might be different from the method which is going to be used in the future.

4 A.2 Rock mass CLASSIFICATION DETAILED

The Rock mass CLASSIFICATION DETAILED is partly based upon the rock mass classification of Laubscher (see article) which is based upon the Geomechanics system. The Laubscher system is developed for underground mining circumstances but has been adjusted to surface features, and also has been adjusted to solve the special problems involved in surface classification.

4 A.2.1 System parameters

The system incorporates the following rock mass parameters:

- 1) INTACT ROCK STRENGTH
a rating for the intact-rock strength. If the strength differs in different directions then the minimum strength.
- 2) DISCONTINUITY SPACING
The spacings of maximum 3 discontinuity sets.
- 3) CONDITIONS OF DISCONTINUITIES
geometry and in-fill material of discontinuities.
- 4) GROUNDWATER FLOW (water pressures)
The groundwater flow or water pressure is incorporated to allow for adjustments on the shear strength of discontinuities.
- 5) WEATHERING
The present-day state of weathering
- 6) SUSCEPTIBILITY TO WEATHERING
The susceptibility to weathering; the time it takes to increase the state of weathering one step (steps defined in BS terms).
- 7) METHOD OF EXCAVATION
The method of excavation has a considerable influence on the quality of the rock mass.

4 A.2.2 Classification scheme

The classification has been split up in three steps:

- Step 1 The first step is the classification of the rock mass in the outcrop as found (field form).
- Step 2 Adjustment and correction of the results from step 1 to arrive at a so-called "REFERENCE Rock mass". This is the rock mass corrected for local influences of weathering and the method of excavation (calc. form).
- Step 3 Adjustment of the "REFERENCE Rock mass" to a particular application at a particular location (application form).

ENGINEERING GEOLOGY		slope stability calculation form		ROCK MASS CLASSIFICATION DETAILED														
LOGGED BY:		DATE: / / 199		TIME: : hr	slope no:													
APPLICATION		LOCATION slope	map no:															
SLOPE STABILITY		Map coordinates:	northings:															
			eastings:															
DETAILS OF SLOPE																		
Dip-direction: (degrees)		Dip: (degrees)		Height: (metres)														
(tick) hand-made : 0.99		Proposed method of excavation:																
Unknown : 1.00 excavator : 0.97		Method of excavation adjustment factor (AME):																
natural : 1.00 boring : 1.00		note: If no rock-mass classification has been made on the location of a new slope to be excavated in the future, then it must be estimated from nearby outcrops.																
----- BLASTING -----																		
smooth wall blasting : 0.97																		
conventional blasting																		
with result: good: 0.94																		
open joints: 0.80																		
dislodged blocks: 0.60																		
fractured intact rock: 0.40																		
crushed intact rock: 0.20																		
WEATHERING (AWE)																		
(tick) un-weathered: 1.00		Weathering factor (AWE):																
slightly : 0.80		(this is not the weathering of a particular observation point but the state of weathering for the location where the slope will be excavated)																
moderately : 0.60																		
highly : 0.40																		
completely : 0.20																		
INTACT ROCK STRENGTH (IRS) (from reference rock-mass cal. form) = points																		
DISCONTINUITY SPACING (ADS)																		
CORRECTED DISCONTINUITY SPACING RATING (CDS):		Correct for location weathering and method of excavation (ADS = CDS * AME * AWE):																
(from reference rock-mass calc. form)		ADS = * * = points																
ORIENTATION AND CONDITION OF DISCONTINUITIES																		
calculation AD: β = discontinuity dip σ = slope dip-direction τ = discontinuity dip-direction $\delta = \sigma - \tau$ (always the smallest angle between discontinuity and slope dip-direction) $AD = \arctan (\cos (\delta) * \tan (\beta))$					Figure 3.7 is equivalent and can be used instead of calculations.													
<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td>persistence/slope height :</td> <td>< 0.1</td> <td>0.2</td> <td>0.4</td> <td>0.6</td> <td>0.8</td> <td>> 1.00</td> </tr> <tr> <td>factor:</td> <td>0.95</td> <td>0.93</td> <td>0.91</td> <td>0.89</td> <td>0.87</td> <td>0.85</td> </tr> </table>						persistence/slope height :	< 0.1	0.2	0.4	0.6	0.8	> 1.00	factor:	0.95	0.93	0.91	0.89	0.87
persistence/slope height :	< 0.1	0.2	0.4	0.6	0.8	> 1.00												
factor:	0.95	0.93	0.91	0.89	0.87	0.85												
discontinuity:	1	2	3	4	5													
with / against						dip weight factor (DF) (use table 3.8)												
AD:																		
longest persistence/slope height:						persistence factor (PF) (use table above)												
Total weight factor (TW = DF * PF)																		
Corrected condition (CTC) (from calc. form)																		
Weighted condition (WC = TW * CTC)																		
DISCONTINUITY CONDITIONS (take lowest 3 WC ratings and divide by 3)						multiply by 40 and correct for weathering: (* 40 * AWE = ACD):												
..... * 40 * = points																		
WATER (AWA)																		
(tick) dry : 1.00		Water factor (AWA):																
moist : 0.97		(the water situation at the location where the slope is excavated)																
1.5-7.5 : 0.93																		
> 7.5 : 0.90																		
unit: m3/hr/10m2																		
SUSCEPTIBILITY TO WEATHERING (SW) (from calc. form):																		
SLOPE STABILITY FINAL RATING																		
SSR = (IRS + ADS + ACD) * AWA * SW = (..... + +) * * = points																		
preliminary index: > 80 (very good), 80-60 (good), 60-40 (fair), 40-20 (poor), < 20 (very poor)																		
Remarks:																		

10	FORMATION NAME:	Fill in the formation name as found on the map.
11	DESCRIPTION:	Describe the rock mass according the rock mass description for engineering purposes (BS 5930-1981)(Fig. 3.1.1+3.1.2).
12	LAYER STRENGTH (LS)	Fill-in the strength of intact rock material. (Use the table as a guide). This should, in general, be the minimum strength but some common sense should be used; the strength filled-in should be representative for the rock mass mapped. If the Schmidt hammer has been used or if samples have been taken then note the numbers of the Schmidt Hammer forms and/or sample numbers in the appropriate columns. The estimated strength value might be changed when laboratory test results become available. A good habit for numbering samples is to refer in the sample number to the year, group and outcrop number. For example: 91/2/4.2 (year 1991, group 2, outcrop 4, sample 2. An analogue numbering can be used for Schmidt hammer forms. For example: 90/2/4SH2 (year 1991, group 2, outcrop 4, Schmidt Hammer form 2).
13	DISCONTINUITIES (DS)	Discontinuities are all planes in a rock mass which have mechanical characteristics different from the layer strength and are not included in the layer strength. By example: If a rock mass is schistose with a layer thickness less than 10 cm, the weakness of the schistosity is already included in the layer strength and should thus not be recorded as a separate discontinuity.
	Dip direction:	Fill-in the dip direction. This is perpendicular to the strike in the direction of the dip (thus not the strike !!) (Use a three figure notation, eg. 075 and not 75 !!).
	Dip:	Fill-in the dip.
	Spacing:	Fill-in the spacing perpendicular to the discontinuity planes.
	Persistence:	Fill in the length of discontinuities along strike and along dip. If a persistence is equal or more than the outcrop dimension then fill-in '>' with the maximum persistence visible. Bedding planes will virtually always be longer than the outcrop !

- 15 WEATHERING Tick the state of weathering. Use as classification the BS standards. The state of weathering should be representative for a certain rock mass. The rock mass visible in an outcrop might have been exposed for a considerable amount of time and consequently have been weathered superficially according to the time it has been exposed. This weathering being only on the outer boundary of the rock mass, might not be representative. (see also SUSCEPTIBILITY TO WEATHERING)
- 16 SUSCEPTIBILITY TO WEATHERING Tick the susceptibility to weathering. This is indicated as the amount of time necessary to increase the weathering by one step in the BS standard definition. Different outcrops in the same rock mass but made at different times will give an indication.
- 17 WATER Indicate the amount of water percolating through the rock. Normally an estimation will do (if not use a bucket). Some remarks: 7.5 m³/hr/10 m² is a massive amount of water and comes as a small waterfall out of the rock face. Dry and moist are obvious and anything between moist and a waterfall should be in class 3.
- 18 EXISTING SLOPE ? If the classification has been done on an existing slope then fill in the details about the slope and give an estimate of the stability of the slope. The rear of the form can be used for additional details, like reason for instability, etc..

4 A.2.4 Rock mass CLASSIFICATION DETAILED calc. form

- 1 GROUP: Fill-in the group number
- 2 LOGGED BY: Initials of the person who is responsible for completing the form.
- 3 DATE: Obvious
- 4 TIME: „
- 5 outcrop number: Fill-in the number of the outcrop. To each calc. form should belong one (and one only) field form with the same number.

**4 B. SECTIONWISE DESCRIPTION OF
LANDSLIDES**

ENGINEERING GEOLOGY

4 B. Sectionwise Description of Landslides

		No. of Slides
4 B.1	Section I Khunjerab Pass to Deh GSP Slides 1 to 9	9
4 B.2	Section II Deh to Sost GSP Slides 10 to 18	9
4 B.3	Section III Sost to Shishkat Bridge GSP Slides 19 to 23	5
4 B.4	Section IV Shishkat Bridge to Ganesh Bridge GSP Slides 24 to 27	4
4 B.5	Section V Ganesh Bridge to Jaglot Gah GSP Slides 28 to 35	8
4 B.6	Section VI Jaglot Gah to Gilgit Bridge GSP Slides 36 to 38	3
4 B.7	Section VII Gilgit Bridge to Rakhiot Bridge GSP Slides 39 to 41	3
4 B.8	Section VIII Rakhiot Bridge to Chilas GSP Slide 42 to 48	7
4 B.9	Section IX Chilas to Dasu GSP Slide 49 to 60	12
4 B.10	Section X Dasu to Besham GSP Slides 61 to 68	8
4 N 11	Section XI Besham to Hasanabdal GSP Slides 69 to 71.	3

Chapter 4 B. 1

SECTION I

Khunjerab Pass to Deh

4 B.1.1 GSP SLIDE NO. 1

Location:	<i>Distance from Hasanabdal</i>	<i>790 km (Fig.4)</i>
	<i>Type of problem:</i>	<i>Scree fall/Rock fall</i>
	<i>Length</i>	<i>700m</i>
	<i>Height:</i>	<i>200m</i>

Scree fall (Kuksel Slide): Slates and phyllite rocks are exposed at a high angle of repose. These rocks are highly jointed and fractured and are under the influence of thawing and freezing effects. The process of scree formation is very much pronounced. The close jointing system in the slates, has resulted in rock fragmentation of the size of 20 mm to 100 mm. The high angle slopes activate downward movement of the scree material in bulk quantity causing traffic blockage at this place (Plate 1).

Rock fall: The slates and phyllite rocks contain bands of quartzite which are massive and 1-2 metres thick (Plate 2), where as the phyllite is thinly bedded and soft. These rocks are closely jointed and highly weathered due to the presence of horizontal and vertical shear zones within this formation. The fragmentation in these rocks occurs in the form of scree of an average size of 5cm x 5 cm x 7cm. The textural and shearing elements have reduced the rock mass strength of these rocks which ultimately results in weakening the stability of the slopes within this formation (Table 1, 2). Mass properties are unfavourable for the slope stability, due to the jointing and shearing of the phyllite rocks in this area. (Plate 3). Therefore, rock pieces keep on falling on the road side.

Recommendations

Scree fall

1. Construction of breast walls is the most economic and effective method of controlling the scree fall. These walls have already been provided but are not properly maintained. They need constant maintenance.
2. The height of breast walls be increased proportionally to counter overspilling of the scree material. The foundation must be strong enough to withstand the pressure due to the creep movement.
3. Stone pitched walls with cement mortar may be designed in this particular area.



PLATE - 1 Scree slopes at their critical angle of repose causing hazards on road due to creep movement.



PLATE - 2 Jointing pattern in the phyllite rocks causing small fragmentation of the formation.

ENGINEERING GEOLOGY						field form 1				ROCK MASS CLASSIFICATION DETAILED						
LOGGED BY: A. FAYAZ			DATE: 18 / 8 / 1996			TIME: 09 : 45 hr			outcrop no: GSP-S-1							
WEATHER CONDITIONS				LOCATION			map no:		42-P							
Sun:	cloudy/fair/bright			Map coordinates:			northings:									
Rain:	dry/drizzle/slight/heavy						eastings:									
METHOD OF EXCAVATION/DIMENSIONS/ACCESSIBILITY																
(tick)	hand-made : 0.99			Size total outcrop: (m)		l: 700		h: 200		d: 10						
unknown :	excavator : 0.97			mapped on this form: (m)		l: 15		h: 15		d: 5						
natural :	blasting : 1.00			Accessibility:		poor/fair/good ✓										
smooth wall blasting : 0.97																
conventional blasting with result: good: 0.94																
open joints: 0.80																
dislodged blocks: 0.60																
fractured intact rock: 0.40																
crushed intact rock: 0.20																
GSP-S-1, KM-790 - 100 m (K K H)																
FORMATION NAME: Misgar Slate																
DESCRIPTION (BS 5930: 1981)																
colour	grain size	structure & texture (bedding thickness)			weathering		NAME		strength							
Gray	Fine grained	Thinly bedded intensely folded and faulted			highly weathered		Phyllite		Mod Strong							
INTACT ROCK STRENGTH						sample number(s): S-1										
< 1.25 MPa :	Crumbles in hand					:	1									
1.25 - 5 MPa :	Thin slabs break easily in hand					:	2									
5 - 12.5 MPa :	Thin slabs broken by heavy hand pressure					:	3									
12.5 - 50 MPa :	Lumps broken by light hammer blows					:	4									
50 - 100 MPa :	Lumps broken by heavy hammer blows					:	5									
100 - 200 MPa :	Lumps only chip by heavy hammer blows					:	6									
> 200 MPa :	(Bull ringing sound)					:	6									
	> 200 MPa : Rocks ring on hammer blows. Sparks fly					:	7									
DISCONTINUITIES B=bedding J=joint .B1 .. 2 .. 3 .. 4 .. 5 WEATHERING (at observation point)																
Dip direction	(degrees)			45W 75E EW												
Dip	(degrees)			70SW 85W N												
Discontinuity spacing (metres)				30mm 20mm 50mm												
persistence	along strike (meters)	7		7	7			(tick) un-weathered: 1.00 slightly: 0.80 moderately: 0.60 highly: 0.40 completely: 0.20								
	along dip (meters)	7		7	7											
Roughness large scale	wavy multi-directional :1.00 wavy uni-directional :0.95 curved :0.85 slight undulating :0.80 straight :0.75	0.80		0.75	0.85			SUSCEPTIBILITY TO WEATHERING (tick) 1 year :0.05 5 year :0.25 10 year :0.50 50 year :0.90 > 50 year :1.00 sample no:								
Roughness small scale (on an area of about 0.2 x 0.2 m)	rough stepped/irregular:0.95 smooth stepped :0.90 slickensided stepped :0.85 rough undulating :0.80 smooth undulating :0.75 slickensided undulating:0.70 rough planar :0.65 smooth planar :0.60 polished :0.55	0.80		0.60	0.75											
Alteration of discontinuity walls	stronger :1.10 no change :1.00 weaker :0.80	0.80		0.80	1.00			WATER (tick) dry :1.00 moist :0.97 1.5-7.5 :0.93 > 7.5 :0.90 unit: m3/hr/10m2								
Infill material	no infill-surface staining only:1.00 cemented infill :0.97 non softening & sheared material only, e.g.free of clay, talc, etc.	coarse:0.95 medium:0.90 fine :0.85 coarse:0.75 medium:0.65 fine :0.55		0.65		0.85	0.97	EXISTING SLOPE ? dip-direction/dip /85 height: 100 (m) Stability?(tick) 1 stable 2 small problems in near future 3 large problems in near future 4 small problems 5 large problems								
karakoram	none :1.00 opening: < 0.1(m) 0.1-1 1 (m) occasional: 0.75 common: 0.50 frequently: 0.20	0.55 0.55 0.35 0.25 0.10 0.15 0.05		1.00		1.00	1.00									

Table 1. Reference rock mass classification detail of G.S.P. Slide No.1

Rock fall

1. All overhangs and loose blocks of rock lying along the slopes, be pulled down with steel bars. This practice should be carried out atleast once a year.
2. The maintenance force is presently ill equipped. They should be properly equipped with steel bars, tractors, loaders or any other suitable machinery which can be used at a height of 3-5 metres.
3. Removal of loose blocks from the rock slopes be followed by tackling the overhanging vulnerable blocks of rock with the help of controlled blasting techniques.
4. A few big blocks can be selected for rock bolting to provide further safety to the slopes (Plate 3).

4 B. 1.2 GSP SLIDE NO. 2

Location:	<i>Distance from Hasanabdal</i>	789 km (Fig.4)
	<i>Type of problem:</i>	Scree fall/Rock fall
	<i>Length</i>	1,000m
	<i>Height:</i>	200m

Scree fall/Rock fall: In this one kilometre strip, scree slides are very common. Scree keeps on falling on the road slowly and gradually by creep movement and accumulates at the base of the slope.

Two types of slopes exist in this area:-

- (i) Scree slopes
 - (ii) Rounded boulder gravel slopes
- (i) **Scree slopes:** Slates are exposed upto the skyline. These are highly weathered and sheared rocks generating a lot of scree during seasonal changes which keep on falling under the gravitational force after disintegrating from the parent rock. The height of these scree slopes ranges from 200m to 500m (Plate 5).
 - (ii) **Rounded boulder gravel slopes (RBG slopes):** These deposits are exposed upto a maximum height of 20 m above the road level (Plate 4). These RBGs are rounded to sub-rounded and vary in size from gravel, pebbles, cobbles, boulders to very fine particles which

form the cementing material (Table 3). These rounded boulders and cobbles keep on falling on the road due to the disintegration of cementing material which is less in this area.

Recommendations:

(i) Scree Slopes:

1. Construction of **uncemented** breast walls are recommended with a wide base to uphold the **creeping** material from the top.
2. At places **breast walls** are already constructed which require proper maintenance.

(ii) RBG Slopes:

1. Construction of **breast walls** will cost heavily due to the length of the slide. The gap **available** between the road shoulders and the base of the slope can be very effectively **utilized** in this zone. Therefore, it is recommended that where the **slopes join** the road, a gallery type structure may be constructed, by using the **material** and loose rock blocks available at the site. This structure will **uphold** the falling scree and will act as a barrier between the slopes and the road.

4 B.1.3 GSP SLIDE NO. 3

Location:	<i>Distance from Hasanabdal</i>	<i>785 km (Fig.4)</i>
	<i>Type of problem:</i>	<i>Scree fall/Rock fall</i>
	<i>Length</i>	<i>100 m</i>
	<i>Height:</i>	<i>300 m</i>

Rock fall: Slates and phyllites are exposed in the catchment area of this slide (Plate 6). These rocks are highly weathered, closely jointed, sheared and badly fractured. The site reflects implications of unfavourable geological processes. Which result in complete **shattering** of the rocks into fragments and various block sizes ranging from **gravel** to boulders (Table 4). Tectonic effects are also prevalent in the form of minor folds and faults in the area. The rocks keep on falling on the road.

Recommendations

1. The slide can be **controlled** by adopting the following methods:-

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)	
LOGGED BY: A.FAYAZ		DATE: 03 / 9 / 1998		TIME: 11 : 30 hr	
outcrop no: GSP - S - 3		map no: 42 - P			
WEATHER CONDITIONS		LOCATION			
Sun:	cloudy/fair/bright ✓	Map coordinates:		northings:	
Rain:	dry/drizzle/slight/heavy			eastings:	
GSP KM- 785 (K.K.H)		DIMENSIONS/ACCESSIBILITY			
		Size total outcrop: (m) l: 1000m h: 200m d: <			
		mapped on this form: (m) l: 100m h: 100m d: <			
		Accessibility: poor/fair/good ✓			
MAP UNIT NAME: Misgar Slate					
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour) clayey soil and scree of Phyllite material No vegetation cover, grey to black, Weathered surface brownish grey.					
ESTIMATION OF GRAINSIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES					
FIELD		LABORATORY			
boulders > 200 mm (from scanline)	(A) 10 %			$f = \frac{100 - (A+B)}{100} =$	
cobbles > 60 mm (from scanline)	(B) 50 %				
gravel > 2 mm	- %	(C) %	C' = f x C =		
sand > 0.06 mm	%	(D) %	D' = f x D =		
finer < 0.06 mm	40 %	(E) %	E' = f x E =		
Total: A + B + C' + D' + E' =		% (should be 100 %)			
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil					
ORGANIC CONTENT (tick) none/little/substantial					
VISUAL IDENTIFICATION (tick)					
for coarse and very coarse soils (tick)		for fine soils 40%			
well graded/uniform/gap graded		dilateny: none/very slow/slow/quick			
		toughness: none/slight/medium/high			
PARTICLE NATURE					
for coarse and very coarse soils					
particle shape: (tick) angular/sub-angular/sub-rounded/r unded/n.a. flat/elongated/spherical/n.a.					
texture: (tick) rough/smooth/polished/n.a.					
compactness of coarse soils (tick) loose/dense/slightly cemented/n.a.					
strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.					
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy					
SLOPE ANGLE (approximately): 135° degrees					
Remarks:					

Table 4. Reference soil classification (Gravel) of G.S.P. Slide No.3.



PLATE - 6 A view of GSP slide No. 3. Showing abandoned road in the centre of the slide.



PLATE - 7 Scree slopes; a source of constant trouble

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)	
LOGGED BY: A. FAYAZ		DATE: 19 / 8 / 1996	TIME: 12 : 15 hr	outcrop no: GSP-S 4	
WEATHER CONDITIONS		LOCATION	map no:	42-P	
Sun:	cloudy/fair/bright	Map coordinates:	northings:		
Rain:	dry/drizzle/slight/heavy		eastings:		
GSP-S 4 KM-784 (KKH)		DIMENSIONS/ACCESSIBILITY			
		Size total outcrop: (m)	l: 300	h: 200	d: 20 m
		mapped on this form: (m)	l: 100	h: 200	d: 10 m
		Accessibility:	poor/fair/good ✓		
MAP UNIT NAME: River bed deposits					
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour) Brownish grey gravels, 5-6 layers, Not homogenous, No vegetation cover.					
ESTIMATION OF GRAINSIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES					
FIELD		LABORATORY			
boulders > 200 mm (from scanline)	(A) %			$f = \frac{100 - (A+B)}{100} =$	
cobbles > 60 mm (from scanline)	(B) %				
gravel > 2 mm	70 %	(C) %		C' = f x C =	
sand > 0.06 mm	20 %	(D) %		D' = f x D =	
finer < 0.06 mm	10 %	(E) %		E' = f x E =	
Total: A + B + C' + D' + E' =		% (should be 100 %)			
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil					
ORGANIC CONTENT (tick) none/little/substantial					
VISUAL IDENTIFICATION (tick)					
for coarse and very coarse soils (tick)			for fine soils		
well graded/uniform/gap graded			dilatency: none/very slow/slow/quick		
			toughness: none/slight/medium/high		
PARTICLE NATURE Scree					
for coarse and very coarse soils					
particle shape: (tick) angular/sub-angular/sub-rounded/rounded/n.a. flat/elongated/spherical/n.a.					
texture: (tick) rough/smooth/polished/n.a.					
compactness of coarse soils (tick) loose/dense/slightly cemented/n.a.			strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.		
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy					
SLOPE ANGLE (approximately): 35° degrees					
Remarks: up to 100 m height, Scree Slopes are exposed, further upward rocks are exposed, these rocks are highly jointed and fractured and is a source of Scree.					

Table 5. Reference soil classification (Gravel) of G.S.P. Slide No.4.



PLATE - 10 A view of Deh mudflow / avalanche site at the confluence of Khunjerab River with the source nullah at right corner.



PLATE - 11 Deh avalanche looking down stream showing the damaged portion of the KKH on the right bank.

PLATE - 12 Rast Kharchani avalanche site showing the source area up to the ridge top.





PLATE - 13 GSP slide No. 7 showing the scree material piled up on both sides of the road.



PLATE - 14 Another view of slide No. 7 showing the catchment area of the snow avalanche.

ENGINEERING GEOLOGY				field form 1		ROCK MASS CLASSIFICATION DETAILED			
LOGGED BY: A. FAYAZ		DATE: 19 / 8 / 1996		TIME: 15 : 00 hr		outcrop no: GSP-5-8			
WEATHER CONDITIONS			LOCATION		map no:		42-P		
Sun:	cloudy/fair/bright		Map coordinates:		northings:				
Rain:	dry/drizzle/slight/heavy				eastings:				
METHOD OF EXCAVATION/DIMENSIONS/ACCESSIBILITY									
(tick) hand-made : 0.99			Size total outcrop: (m)		l: 1000		h: 400		d: <
unknown : 1.00 excavator : 0.97			mapped on this form: (m)		l: 100		h: 50		d: <
natural : 1.00 boring : 1.00			Accessibility:		poor/fair/good ☒				
BLASTING									
smooth wall blasting : 0.97									
conventional blasting with result:									
good: 0.94			GSP- S. 8, KM - 758 (K K H)						
open joints: 0.80									
dislodged blocks: 0.60									
fractured intact rock: 0.40									
crushed intact rock: 0.20									
FORMATION NAME: Misgar Slate									
DESCRIPTION (BS 5930: 1981)									
colour	grain size	structure & texture (bedding thickness)		weathering		NAME		strength	
Grey	Fine grained	Highly Jointed, folded and faulted		Highly weathered		SLATE		Med. Strong.	
INTACT ROCK STRENGTH					sample number(s):				
< 1.25 MPa : Crumbles in hand					:1				
1.25 - 5 MPa : Thin slabs break easily in hand					:2				
5 - 12.5 MPa : Thin slabs broken by heavy hand pressure					:3				
12.5 - 50 MPa : Lumps broken by light hammer blows					:4				
50 - 100 MPa : Lumps broken by heavy hammer blows					:5				
100 - 200 MPa : Lumps only chip by heavy hammer blows					:6				
> 200 MPa : Rocks ring on hammer blows. Sparks fly					:7				
					S-8				
					schmidt hammer results:				
DISCONTINUITIES B=bedding J=joint .. 1 .. 2 .. 3 .. 4 .. 5 WEATHERING (at observation point)									
Dip direction		(degrees)		NS	N30W	N60W			
Dip		(degrees)		W	40SW	80NE			
Discontinuity spacing		(metres)		50mm	1m	5m			
persistence	along strike	(meters)		<	<	<			
	along dip	(meters)		<	<	<			
Roughness large scale	wavy multi-directional	:1.00		0.95	0.80	0.85			
	wavy uni-directional	:0.95							
	curved	:0.85							
	slight undulating	:0.80							
	straight	:0.75							
Roughness small scale (on an area of about 0.2 x 0.2 m)	rough stepped/irregular	:0.95		0.95	0.80	0.80			
	smooth stepped	:0.90							
	slickensided stepped	:0.85							
	rough undulating	:0.80							
	smooth undulating	:0.75							
	slickensided undulating	:0.70							
	rough planar	:0.65							
	smooth planar	:0.60							
polished	:0.55								
Alteration of discontinuity walls	stronger	:1.10		0.80	0.80	0.80			
	no change	:1.00							
Infill material	no infill-surface staining only	:1.00							
	cemented infill	:0.97							
	non softening & sheared material only, e.g. free of clay, talc, etc.	coarse:0.95 medium:0.90 fine:0.85							
	soft sheared material e.g. clay, talc, etc.	coarse:0.75 medium:0.65 fine:0.55		0.55	0.42	0.55			
	gouge < irregularities	:0.42							
karst	gouge > irregularities	:0.17							
	flowing material	:0.05							
	none	:1.00		1.00	1.00	1.00			
	opening: < 0.1(m)	0.1-1		1.00	1.00	1.00			
occasional:	0.75		0.55	0.35					
common:	0.50		0.25	0.10					
frequently:	0.20		0.15	0.05					
WATER									
(tick) dry : 1.00									
moist : 0.97									
1.5-7.5 : 0.95									
> 7.5 : 0.90									
unit: m3/hr/10m2									
EXISTING SLOPE ?									
dip-direction/dip									
EW / 45									
height: (m)									
Stability ?(tick)									
1 stable									
2 small problems in near future									
3 large problems in near future									
4 small problems									
5 large problems									

Table 6. Reference rock mass calculation detail of G.S.P. Slide No.8



PLATE - 16 A view of mudflow at site No. 9 showing mouth of the source nullah and its catchment area. Remnants of mudflow are visible in the lower half.



PLATE-17 Another view of the nullah course at site No. 9 showing gentle gradient of the fan deposits.

Chapter 4 B 2

SECTION II

Deh to Sost

4-B 2.1 GSP SLIDE NO. 10

Location:	<i>Distance from Hasanabdal</i>	<i>754 km (Fig.4)</i>
	<i>Type of problem:</i>	<i>Avalanche</i>
	<i>Length</i>	<i>60 m</i>
	<i>Height:</i>	<i>50 m</i>

Capt. Ijaz Shaheed Avalanche: On 17th March, 1996, Capt. Ijaz, Subedar Nadir, Dozer Operator Muhammad Amin and Sepor Sultan of FWO were hit by this avalanche and died on the spot. Naib Subedar Amir Hayat and Lance Naik Shaukat were injured. This site has been named after Capt. Ijaz Shaheed in memory of his services.

Slates are exposed in the catchment area of this avalanche. These slates are highly sheared, fractured and break into different size fragments (Plate 18, 19). The debris comprises 50% coarse material scree alongwith 50% fines (Table 8).

At this site the topographical configuration is very rough and uneven along the slopes of the main nullah. It is almost vertical for the first 30 metres from the road level followed by 150 metres rock slopes at an angle of 70°. Further up many tributaries join the main canyon to impart necessary momentum to the avalanche (Plate 20).

As mentioned earlier, the rocks exposed in the catchment area are slates which are in highly weathered condition forming thick detritus which keeps on creeping down-slopes during the snowfall and melting seasons. It is due to this reason that the months of March and April are dangerous for triggering of avalanches in these areas.

Recommendations

1. Topography of the slope especially, at the road level, supports the idea of bridging this avalanche by a snow shed (Plate 20).
2. Rock exposed at the road level are comparatively sound. The intrusion of diorite dykes have provided strong anchoring places for the concrete structures and sufficient space is available for the foundation of the shed for by-passing the sliding snow at this site. The slope angle of the slide also favours the construction of a snow shed at this point. This type of structure



PLATE - 18 GSP slide No. 10 showing anchoring rocks at the avalanche site for a concert structure.



PLATE - 19 Remnants of snow avalanche showing the Khunjerab River passing underneath the avalanche material making a snow bridge.

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)	
LOGGED BY: A. FAYAZ	DATE: 22 / 8 / 1996	TIME: 7 : 30 hr	outcrop no: GSP- S-10		
WEATHER CONDITIONS		LOCATION	map no:	42 - L	
Sun: cloudy/fair/bright		Map coordinates:	northings:		
Rain: dry/drizzle/slight/heavy			eastings:		
GSP- S-10 KM - 754 (KKH)		DIMENSIONS/ACCESSIBILITY			
		Size total outcrop: (m)	l: 100	h: 50	d: 10
		mapped on this form: (m)	l: 10	h: 10	d: 2
		Accessibility:	poor/fair/good ✓		
MAP UNIT NAME: Misgar Slate					
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour) Scree, fines, grey, No Vegetation cover.					
ESTIMATION OF GRAINSIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES					
FIELD		LABORATORY			
boulders > 200 mm (from scanline)	(A) 5 %			$f = \frac{100 - (A+B)}{100} =$	
cobbles > 60 mm (from scanline)	(B) 65 %				
gravel > 2 mm	20 %	(C)	%	C' = f x C =	
sand > 0.06 mm	10 %	(D)	%	D' = f x D =	
fines < 0.06 mm	%	(E)	%	E' = f x E =	
Total: A + B + C' + D' + E' =		% (should be 100 %)			
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil					
ORGANIC CONTENT (tick): none/little/substantial					
VISUAL IDENTIFICATION (tick)					
for coarse and very coarse soils (tick)			for fine soils		
well graded/uniform/gap graded ✓			dilatency: none/very slow/slow/quick		
			toughness: none/slight/medium/high		
PARTICLE NATURE					
for coarse and very coarse soils					
particle shape: (tick) angular/sub-angular/sub-rounded/r unded/n.a. flat/elongated/spherical/n.a.					
texture: (tick) rough/smooth/polished/n.a.					
compactness of coarse soils (tick) loose/dense/slightly cemented/n.a.			strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.		
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy					
SLOPE ANGLE (approximately): 60° degrees					
Remarks: Material comes along through snow avalanche and making slopes in most of the area.					

Table 8. Reference soil classification (Gravel) of G.S.P. Slide No.10.



PLATE - 21 Debris slide are very common along the Karakoram Highway (KKH). Deeply weathered slate rocks and colluvium resulting from the disintegration of rocks in situ are lying at their critical angle of repose. Notice the angular fragments.

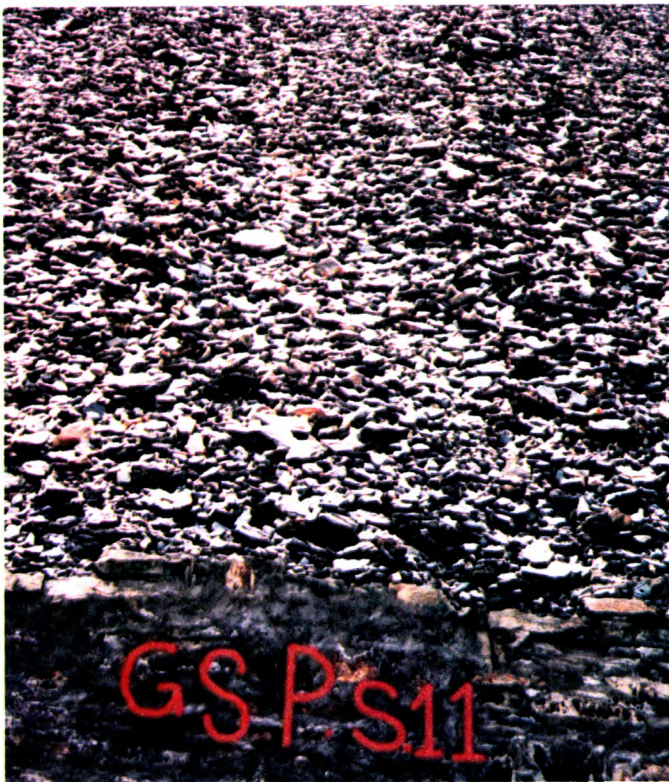


PLATE - 22 A close view of a debris fan at site No. 11, This material was brought down from the highly fractured slates on side slopes.



PLATE - 23 Mudflow slide No. 12 showing the damaged water drain to change of nullah course because of mudflow.



PLATE - 24 Another view of the damaged water drain due to change of nullah course of mudflows slide No. 12.



PLATE - 25 Damaged toe wall at the river bed level at the site of GSP slide No. 13.



PLATE - 26 Overflow of scree from the breast wall.



PLATE - 27 A view of the Kafir Pahar slide zone.

IV. **Localised phenomenon.** Generally, the rocks are exposed at very steep angles forming vertical cliff faces. Differential weathering and erosion removes low strength jointed blocks leaving hanging ledges of comparatively stronger blocks. These blocks fall down with the slightest vibration created by vehicular movement. The rock slides are also triggered due to the stress release at newly excavated cut-slopes. Therefore, all rock-slidings are localized phenomenon, affecting approximately 450 metres stretch of the affected road (Plate 28).

B. **Scree fall:** The other major problem 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 (Figs. 7 and 8). 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 small angular rock fragments and finally changes into clayey soil. The scree resulting from disintegration of the rock is loose to partly compact and forms 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 flows 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 on heating 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 rock fall in the Kafir Pahar area.
1. **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 blocks to get a comparatively more stable rock at the face. Obviously care must be taken to avoid damaging the slope where it is being trimmed by further blasting.

Fractured rock masses can be held together by rock bolts.
Sliding rock masses along a joint plane can be stabilized by
the installation of rock anchors

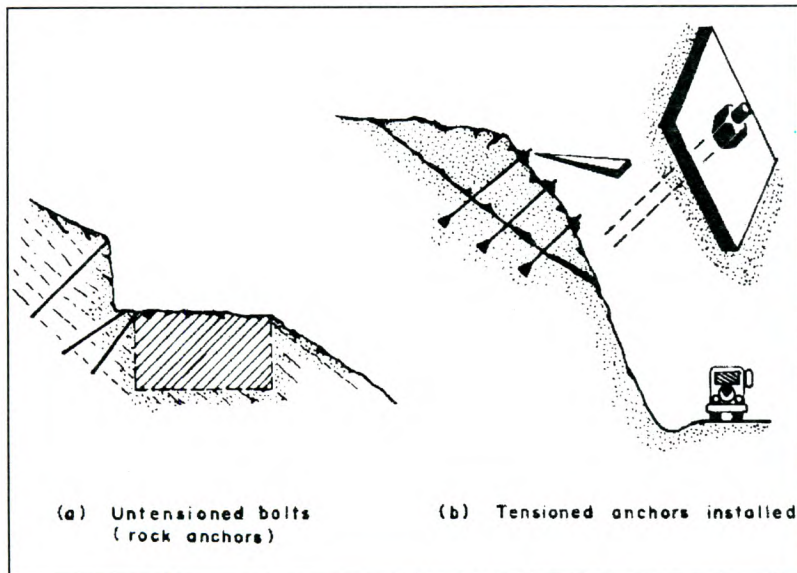


PLATE - 28 A Rock bolting and anchoring of fractured rocks.
(Courtesy - ICIMOD)

ENGINEERING GEOLOGY		field form 1		ROCK MASS CLASSIFICATION DETAILED	
LOGGED BY: A. FAYAZ		DATE: 22 / 8 / 1996		TIME: 09 : 30 hr	
outcrop no: GSP. S-15					
WEATHER CONDITIONS		LOCATION		map no: 42-L	
Sun: cloudy/fair/bright		Map coordinates:		northings:	
Rain: dry/drizzle/slight/heavy				eastings:	
METHOD OF EXCAVATION/DIMENSIONS/ACCESSIBILITY					
(tick) hand-made : 0.99		Size total outcrop: (m)		l: 500 h: 100 d: 10 m	
unknown : 1.00 excavator : 0.97		mapped on this form: (m)		l: 50 h: 10 d: 2	
natural : 1.00 boring : 1.00		Accessibility:		poor/fair/good ☒	
BLASTING					
smooth wall blasting : 0.97					
conventional blasting					
with result:		GSP - S-15 KM - 736			
good: 0.94		(KKH)			
open joints: 0.80					
dislodged blocks: 0.60					
fractured intact rock: 0.40					
crushed intact rock: 0.20					
FORMATION NAME: Misgar Slate					
DESCRIPTION (BS 5930: 1981)					
colour	grain size	structure & texture (bedding thickness)	weathering	NAME	strength
Grey	Fine grained	thickly bedded and intensely folded and faulted	Mod	Slate with minor quartzite	Strong
INTACT ROCK STRENGTH			sample number(s):		
< 1.25 MPa : Crumbles in hand :1 $1.25 - 5$ MPa : Thin slabs break easily in hand :2 $5 - 12.5$ MPa : Thin slabs broken by heavy hand pressure :3 $12.5 - 50$ MPa : Lumps broken by light hammer blows :4 $50 - 100$ MPa : Lumps broken by heavy hammer blows :5 $100 - 200$ MPa : Lumps only chip by heavy hammer blows (bull ringing sound) :6 > 200 MPa : Rocks ring on hammer blows. Sparks fly :7			GSP - S-15		
			schmidt hammer results:		
DISCONTINUITIES B=bedding J=joint .. 1 .. 2 .. 3 .. 4 .. 5			WEATHERING (at observation point)		
Dip direction (degrees) NS 70W 30W			(tick) un-weathered: 1.00		
Dip (degrees) E 80SW 85SW			slightly : 0.80		
Discontinuity spacing (metres) 50mm 1m 80mm			moderately : 0.50		
persistence			highly : 0.40		
along strike (meters) 7 7 7			completely : 0.20		
along dip (meters) 7 7 7					
Roughness			SUSCEPTIBILITY TO WEATHERING		
large scale wavy multi-directional : 1.00			(tick)		
wavy uni-directional : 0.95			1 year : 0.05		
curved : 0.85			5 year : 0.25		
slight undulating : 0.80			10 year : 0.50		
straight : 0.75			50 year : 0.90		
Roughness			> 50 year : 1.00		
small scale rough stepped/irregular: 0.95			sample no:		
smooth stepped : 0.90					
slickensided stepped : 0.85			WATER		
rough undulating : 0.80			(tick)		
smooth undulating : 0.75			dry : 1.00		
slickensided undulating: 0.70			moist : 0.97		
rough planar : 0.65			1.5-7.5 : 0.93		
smooth planar : 0.60			> 7.5 : 0.90		
polished : 0.55			unit: m ³ /hr/10m ²		
Alteration of discontinuity walls			EXISTING SLOPE ?		
stronger : 1.10			dip-direction/dip		
no change : 1.00			/		
weaker : 0.80			height: 100 (m)		
Infill			Stability ? (tick)		
no infill-surface staining only: 1.00			1 stable		
cemented infill : 0.97			2 small problems in near future		
non softening & sheared material only, e.g. free of clay, talc, etc. coarse: 0.95 medium: 0.90 fine : 0.85			3 large problems in near future		
soft sheared material e.g. clay, talc, etc. coarse: 0.75 medium: 0.65 fine : 0.55			4 small problems		
gouge < irregularities : 0.42			5 large problems		
gouge > irregularities : 0.17					
flowing material : 0.05					
karst					
none : 1.00					
opening: < 0.1 (m) 0.1-1 > 1 (m)					
occasional: 0.75 0.55 0.35					
common: 0.50 0.25 0.10					
frequently: 0.20 0.15 0.05					

Table 12 Reference rock mass classification detail of GSP Slide No. 15



PLATE - 30 Showing snow avalanche and the slope along the left bank of the Khunjerab River.



PLATE - 29 Showing remnants of snow avalanche on the rock face across the river coming from the opposite side.

ENGINEERING GEOLOGY		reference rock-mass calculation		ROCK MASS CLASSIFICATION DETAILED		
LOGGED BY: <u>A. FAYAZ</u>	DATE: <u>26 / 10 / 1998</u>	TIME: <u>11 : 40hr</u>	outcrop no: <u>GSP. S. 16</u>			
METHOD OF EXCAVATION (ME)						
Method of excavation adjustment factor (from field form 1) (ME):			<u>0.40</u>			
WEATHERING (WE) (at observation point)						
Weathering adjustment factor (from field form 1) (WE):			<u>0.80</u>			
INTACT ROCK STRENGTH (IRS)						
IRS (MPa)	141-136	135-126	125-111	110-96	95-81	80-66
rating	15	13	12	10	9	7
INTACT ROCK STRENGTH (IRS) = <u>50</u> MPa = <u>4</u> points						
DISCONTINUITIES		1	2	3	4	5
Dip direction (degrees)	<u>N/S</u>	<u>75E</u>	<u>EW</u>			
Dip (degrees)	<u>70E</u>	<u>45SE</u>	<u>85S</u>			
DISCONTINUITY SPACING (DS) (metres)		<u>.50</u>	<u>.40</u>	<u>.50</u>		
for the determination of the rating use the three (3) discontinuities with minimum spacing						
rating (DS): (use fig. 3.6)		<u>40 * (.65 * .56 * .21) = 3.05 points</u>				
Corrected (CDS): DS / (ME * WE) =		<u>3.05 / (.40 * .80) = 9.53 points</u>				
persistence	along strike (m)					
	along dip (m)					
CONDITION OF DISCONTINUITIES						
Roughness large scale (Rl)	<u>0.85</u>	<u>0.80</u>	<u>0.85</u>			
Roughness small scale (Rs)	<u>0.75</u>	<u>0.65</u>	<u>0.60</u>			
Alteration of discont. walls (Aw)	<u>0.80</u>	<u>0.80</u>	<u>1.0</u>			
Infill material (Im)	<u>0.65</u>	<u>1.0</u>	<u>0.55</u>			
Karst (Ka)	<u>1.0</u>	<u>1.0</u>	<u>1.0</u>			
Total (Rl * Rs * Aw * Im * Ka =) (TC)	<u>.331</u>	<u>.416</u>	<u>.280</u>			
Corrected (CTC = TC / WE) (CTC)	<u>.427</u>	<u>.52</u>	<u>.35</u>			
Discontinuity condition average (take lowest 3 CTC ratings and divide by 3):		<u>.432</u>		multiply by 40: (CD):		<u>17.29</u>
SUSCEPTIBILITY TO WEATHERING (SW)						
Adjustment factor for susceptibility to weathering (from field form 1) (SW):			<u>0.50</u>			
REFERENCE ROCK - MASS FINAL RATING (RFR)						
RFR = (IRS + CDS + CD) * SW = <u>(4 + 9.53 + 17.29) * .50 = 15.41</u>						
preliminary index: >80 (very good), 80-60 (good), 60-40 (fair), 40-20 (poor), <20 (very poor)						
Remarks: <u>V. POOR</u>						

Table 15 Reference rock mass calculation of G.S.P. Slide No.16

In the lower part of the slide a gully has been formed which facilitates the material to roll down to the road. This gully is also visible from the road level (Plate 31). (The Dhia slide zone, the KKH and the Khunjab River are well manifested in Plate 32).

Generally, the slide becomes active during the hot season. The melt-water from the higher slopes aggravates the situation and stones start falling down. These stones are of various sizes and they crumble into many small pieces due to attrition. On observing the nullah configuration from the top and at the road level, it is noted that a ledge of rock is exposed in the lower part of the slide which obstructs direct fall of boulders on the road from the top. It gives ample time to the workers to take shelter away from the slide zone. For this purpose a watchman constantly vigiles the slide and warns the people against the falling stones by whistling.

Below the gully and above the road level, a complete berm has already been constructed, which helps in retaining small pieces of rocks at this level. This berm is approachable by the dozer and requires clearing once a week.

Undercutting action of Khunjab River is also creating instability at this site. River takes a sharp turn at this point and its flow directly hits the base of the retaining walls and keeps on damaging it round the year. Lately a lot of protective work was done by reconstructing the retaining walls, toe walls and the gabion walls. These walls were damaged in the next flood season and cracks are visible in the remaining parts of the walls. It is likely that these walls may start collapsing in the next season. This slide is very dangerous and causing a lot of problem in the maintenance of the road.

Recommendations:

FWO engineers have placed a full time dozer at this site to cope with the problem. This step was necessary to keep the road open for traffic round the clock. These dauntless people of FWO have been performing this duty for the last 20 years and it may continue for a still longer period if some rational protective measures are not taken. Huge amounts of money have already been spent on this particular site but the situation has not improved. Now this problem needs to be tackled tacitly as the Karakoram Highway is being widened and improved.

After careful examination of the catchment area of the Dhia Slide and topographic configuration from the top of the slide to the base at the road level it was observed that a huge quantum of debris material is lying at the nullah top which may continue to fall down for an indefinite period of time. A dependable

solution may lie in the avoidance of this nullah and relocating the road with some drastic measures. Different alternatives were considered at the site and are discussed here to select the best proposal for further safety of the KKH (Sketch diagramme).

Proposal No. 1: To live with the problem as it is and keep on clearing the road on regular basis with the help of a dozer.

Proposal No. 2: Bridging on the road at an upper level where the shortest span between two rock exposures is available. The road will pass underneath and the debris will be allowed to pass over the bridge with natural slopes available around (Sketch 6).

Proposal No. 3: Bridging on the road at a lower level slightly above the berm already present above the road. Traffic will pass underneath the bridge allowing the debris material to pass over the slanting roof according to the natural slopes. (Sketch 6).

Proposal No 4: A tunnel be constructed in the affected area in the hard rocks, exposed on the road side. It will save the traffic from the falling stones which will roll over the tunnel structure into the river directly.

Proposal No. 1 is being followed presently. A permanent hut has been constructed at the site with required men and machinery. Stones keep on falling from above and are removed effectively to clear the road on a regular basis. This practice is being carried out for the last 20 years and will probably continue indefinitely.

Proposal Nos. 2, 3, and 4 are aimed at providing a permanent solution by constructing some permanent structure to protect the men and machinery at the site. Sufficient technical data and historical background of this slide zone has been collected to have an idea of the nature and gravity of this problem. Further study of different proposal is recommended to solve the problem on permanent basis.

4-B 2.8 GSP SLIDE NO. 17

Location:	<i>Distance from Hasanabdal</i>	<i>732 km (Fig.5)</i>
	<i>Type of problem:</i>	<i>Rock fall</i>
	<i>Length</i>	<i>700 m</i>
	<i>Height:</i>	<i>200 m</i>

Rock fall: At this slide zone contact between slates and dolomitic limestone is present. Generally the rocks are hard, massive and thickly bedded, Joints are very



PLATE - 33 showing the source at the saddle on the top with slate rocks on the flanks. The stone pitched water fall (centre) and KKH (bottom) are also visible.

ENGINEERING GEOLOGY		reference rock-mass calculation		ROCK MASS CLASSIFICATION DETAILED							
LOGGED BY: A. FAYAZ		DATE: 26 / 03 / 1997		TIME: 11 : 00 hr							
outcrop no: GSP. S-17											
METHOD OF EXCAVATION (ME)											
Method of excavation adjustment factor (from field form 1) (ME): 0.80											
WEATHERING (WE) (at observation point)											
Weathering adjustment factor (from field form 1) (WE):											
INTACT ROCK STRENGTH (IRS)											
IRS (MPa)	141-136	135-126	125-111	110-96	95-81	80-66	65-51	50-36	35-21	20-6	5-0
rating	15	13	12	10	9	7	6	4	3	1	0
INTACT ROCK STRENGTH (IRS) = 75 MPa = 7 points											
DISCONTINUITIES		1	2	3	4	5	note: dip-direction and dip will be used when type of use of the rock-mass is known.				
Dip direction (degrees)		10W	45W								
Dip (degrees)		85SE	70SE								
DISCONTINUITY SPACING(DS)(metres)		2	1				rating (DS): (use fig.3.6) $40 \times (.95 + .85 + \dots) =$ 32 points				
for the determination of the rating use the three (3) discontinuities with minimum spacing							Corrected (CDS): DS/(ME*WE) = 32 $.8 \times .8 =$ 51 points				
persistence	along strike (m)	>	>								
	along dip (m)	>	>								
CONDITION OF DISCONTINUITIES											
Roughness large scale (Rl)		0.85	0.85								
Roughness small scale (Rs)		0.80	0.70								
Alteration of discont. walls (Aw)		1.0	0.80								
Infill material (Im)		0.45	0.65								
Karst (Ka)		1.0	1.0								
Total (Rl*Rs*Aw*Im*Ka =) (TC)		0.31	0.31								
Corrected (CTC = TC / WE) (CTC)		0.39	.39								
Discontinuity condition average (take lowest 3 CTC ratings and divide by 3):		0.39		multiply by 40: (CD):		16					
SUSCEPTIBILITY TO WEATHERING (SW)											
Adjustment factor for susceptibility to weathering (from field form 1) (SW): 0.50											
REFERENCE ROCK - MASS FINAL RATING (RFR)											
$RFR = (IRS + CDS + CD) * SW = (.75 + .51 + .16) * .50 = .37$											
preliminary index: >80 (very good), 80-60 (good), 60-40 (fair), 40-20 (poor), <20 (very poor)											
Remarks: POOR											

Table 17 Reference rock mass classification of GSP Slide No. 17

Chapter 4 B 3

SECTION III

Sost to Shishkat Bridge

4-B 3.1 GSP SLIDE NO. 19

Location:	<i>Distance from Hasanabdal</i>	<i>701 km (Fig.10)</i>
	<i>Type of problem:</i>	<i>Debris flow</i>
	<i>Length</i>	<i>50 m</i>
	<i>Height:</i>	<i>50 m</i>

Debris flow: The slide occurs at the contact between slates and dolomitic limestone in the catchment area of the slide mass. The slates underlie the dolomitic limestone and are highly fractured and sheared and disintegrated into small fragments of scree and talus material which spread out in the form of small fans.

This talus material is deposited in sufficient quantity above the nullah catchment area in the slide zone. As the rocks occur vertically in the catchment area of the nullah, water comes down with a lot of speed during the melting period and due to this momentum a huge amount of the debris is brought down.

Recommendations:

1. As the run off water is mainly responsible for the flow of debris it is imperative that the nullah water be channelised.
2. Catch water drains may be constructed starting from the basement of the rock outcrops in the upper part of the nullah.
3. Diversion of water towards the right bank of the nullah may also be considered.

4-B 3.2 GSP SLIDE NO. 20

Location:	<i>Distance from Hasanabdal</i>	<i>698 km (Fig.10)</i>
	<i>Type of problem:</i>	<i>Scree slide</i>
	<i>Length</i>	<i>150 m</i>
	<i>Height:</i>	<i>120 m</i>

Scree slide: Slates are exposed in the high ridges of the catchment area of this slide. The slates break up into scree and fall down along the slopes, thus forming scree slopes in the shape of fan deposits. These slopes are exposed at their critical angle of repose. With the increase of supply of scree from the high ridges, the debris material flow down under the gravitational pull at its critical angle. The exposed material is composed of 50% of fine soil with equal amount of pebbles and cobbles.



PLATE - 34 A glacial stream from Ghulkin glacier overflowing the road surface in 1996.

Chapter 4 B. 4

SECTION IV

Shishkat Bridge to Ganesh Bridge

4-B 4.1 GSP SLIDE NO. 24

Location:	<i>Distance from Hasanabdal</i>	<i>656 km (Fig. 11)</i>
	<i>Type of problem:</i>	<i>Rock fall</i>
	<i>Length</i>	<i>200 m</i>
	<i>Height:</i>	<i>150 m</i>

Rock fall (Mohammadi Pahar Slide): Granodiorite rocks are exposed at this site. These rocks belong to the axial batholith of Karakoram Range i.e. the heart of the Karakoram central part. These are hard, massive, widely jointed and most of the joints are iron stained. Pegmatite veins are also present in granodiorite rocks and most of them run parallel to the road. About 15 such pegmatite veins were noted, which vary in thickness from 10 cm to 60 cm. The master joint trends parallel to the road, forming vertical cliff wall. The jointing system results into boulder size blocks (Tables 21 and 22). Most of the slope surfaces at this place have been smoothened due to the fall of big blocks of rock along the master joint, thus reducing the possibility of further rock fall problems (Plate 38). However, at a few places, facing the Hunza River a few blocks are day lighting towards the road. These blocks are vulnerable to slide down.

Recommendations:

1. Scaling down of loose blocks lying along the road as well as on the slopes be carried out.
2. The remaining overhanging blocks of rocks may be removed by using controlled blasting techniques to get a comparatively smooth surface.

4-B 4.2 GSP SLIDE NO. 25

Location:	<i>Distance from Hasanabdal</i>	<i>652 km (Fig. 11)</i>
	<i>Type of problem:</i>	<i>Rock fall</i>
	<i>Length</i>	<i>320 m</i>
	<i>Height:</i>	<i>500 m</i>

Rock fall (Sarat Slide): Granodiorite rocks are exposed in the catchment area of this slide. These rocks are highly weathered, intensively jointed and fractured. The source rocks exposed are about 10m high at most of the places in the main supply area, and about 20 metres high at other two places (Plate 39). Blocks of rock keep on falling along the slopes due to fracturing and weathering effects. After dislodging from the parent rocks, these blocks start sliding along the slopes and break up into small pieces due to attrition by striking against the other

ENGINEERING GEOLOGY			field form 1		ROCK MASS CLASSIFICATION DETAILED			
LOGGED BY: A. FAYAZ		DATE: 28 / 6 / 1996		TIME: 13 : 15 hr	outcrop no: GSP. S-24			
WEATHER CONDITIONS		LOCATION		map no: 42- L/15				
Sun:	cloudy/fair/bright ✓	Map coordinates:		northings:				
Rain:	dry/drizzle/slight/heavy			eastings:				
METHOD OF EXCAVATION/DIMENSIONS/ACCESSIBILITY								
(tick) hand-made : 0.99		Size total outcrop: (m)		l: 200	h: 50	d: 10		
unknown : 1.00	excavator : 0.97	mapped on this form: (m)		l: 70	h: 50	d: 5		
natural : 1.00	boring : 1.00	Accessibility:		poor/fair/good				
BLASTING								
smooth wall blasting : 0.97								
conventional blasting								
with result:								
good: 0.94								
open joints: 0.80								
dislodged blocks: 0.60								
fractured intact rock: 0.40								
crushed intact rock: 0.20								
GSP. S-24 KM-656 (K K H)								
FORMATION NAME: Karakoram Batholith								
DESCRIPTION (BS 5930: 1981)								
colour	grain size	structure & texture (bedding thickness)		weathering	NAME		strength	
Light Gray	Coarse Grained	Massive, Medium, grained & jointed		Slightly Weathered	Granodiorite		Hard	
INTACT ROCK STRENGTH				sample number(s):				
< 1.25 MPa : Crumbles in hand				:1				
1.25 - 5 MPa : Thin slabs break easily in hand				:2				
5 - 12.5 MPa : Thin slabs broken by heavy hand pressure				:3				
12.5 - 50 MPa : Lumps broken by light hammer blows				:4 schmidt hammer results:				
50 - 100 MPa : Lumps broken by heavy hammer blows				:5				
100 - 200 MPa : Lumps only chip by heavy hammer blows (Dull ringing sound)				:6				
> 200 MPa : Rocks ring on hammer blows. Sparks fly				:7				
DISCONTINUITIES B=bedding J=joint .. 1 .. 2 .. 3 .. 4 .. 5 WEATHERING (at observation point)								
Dip direction (degrees)		NS		60 E		NS		(tick) un-weathered: 1.00 slightly : 0.80 moderately : 0.50 highly : 0.20 completely : 0.20
Dip (degrees)		+		86W		20E		
Discontinuity spacing (metres)		2		1		4		
persistence	along strike (meters)	>		>		>		SUSCEPTIBILITY TO WEATHERING
	along dip (meters)	>		>		>		
Roughness large scale	wavy multi-directional	:1.00		0.80	0.85	0.95		(tick) 1 year : 0.05 5 year : 0.25 10 year : 0.50 50 year : 0.90 > 50 year : 1.00
	wavy uni-directional	:0.95						
	curved	:0.85						
	slight undulating	:0.80						
	straight	:0.75						
Roughness small scale (on an area of about 0.2 x 0.2 m)	rough stepped/irregular	:0.95		0.65	0.70	0.95		sample no:
	smooth stepped	:0.90						
	slickensided stepped	:0.85						
	rough undulating	:0.80						
	smooth undulating	:0.75						
	slickensided undulating	:0.70						
	rough planar	:0.65						
smooth planar	:0.60							
polished	:0.55							
Alteration of discontinuity walls	stronger	:1.10		0.80	0.80	0.80		WATER
	no change	:1.00						
	weaker	:0.80						
Infill material	no infill-surface staining only	:1.00		1.00	0.65	0.97		(tick) dry : 1.00 moist : 0.97 1.5-7.5 : 0.93 > 7.5 : 0.90 unit: m3/hr/10m2
	cemented infill	:0.97						
	non softening & sheared material only, e.g. free of clay, talc, etc.	coarse: 0.95 medium: 0.90 fine: 0.85						
	soft sheared material, e.g. clay, talc, etc.	coarse: 0.75 medium: 0.65 fine: 0.55						
	gouge < irregularities	:0.42						
gouge > irregularities	:0.17							
flowing material	:0.05							
karst	none	:1.00		1.00	1.00	1.00		1 stable 2 small problems in near future 3 large problems in near future 4 small problems 5 large problems
	opening: < 0.1 (m)	:0.1						
	occasional: 0.1-1 (m)	:0.35						
	common: 0.1-1 (m)	:0.10						
	frequently: 0.1-1 (m)	:0.05						

Table 21. Reference rock mass classification detail of G.S.P. Slide No.24



PLATE-38 Muhammadi slide showing massive granodiorite rock with a network of pegmatite veins.

boulders lying along the way. Some of these blocks reach the road surface and cause damage (Plate 40).

The downward movement of these boulders is diverted into two directions from the middle of the slope and rock pieces from above may fall to either side depending upon its momentum.

Recommendations:

1. The main supply area in this slide zone is very limited, therefore, this slide may be controlled by checking the supply line of rock material from the source which is located in the form of a ridge about 500 metres high from the road level. Scale down the loose material from the slopes with steel bars.
2. After getting comparatively better slopes, controlled blasting techniques may be applied for the remaining vulnerable blocks to achieve more stable slopes.
3. A strong breast wall may be erected to hold rest of the falling material from the slopes.

4-B 4.3 GSP SLIDE NO. 26

Location:	<i>Distance from Hasanabdal</i>	<i>647 km (Fig.11)</i>
	<i>Type of problem:</i>	<i>Scree slide</i>
	<i>Length</i>	<i>300 m</i>
	<i>Height:</i>	<i>10 m</i>

Scree slide (Lal Bajri Slide): Gneissose rocks are exposed in the catchment area of this slide but the problem lies within the glaciated deposits which are overlying these rocks on both sides of the Hunza River. Most of these morainic deposits are already eroded by the river during the construction of the road. Only a few small patches of about 20 cubic metres exists on the left side of the slide at a height of 50m above the present road level. These two patches are the main source of slide material at the Lal bajri Slide. These glaciated deposits are somewhat cemented but keep on supplying the bajri type material due to the seasonal variation of temperature and moisture. Slope angle in the slide area is about 40 degrees. Along these slopes, bushes and shrubs have grown up, thus providing partial stability to the slopes (Plate 41).

Recommendations:

1. To check the repeated occurrence of this slide the supply of debris material may be channelised. It has been observed that the bajri which is not much

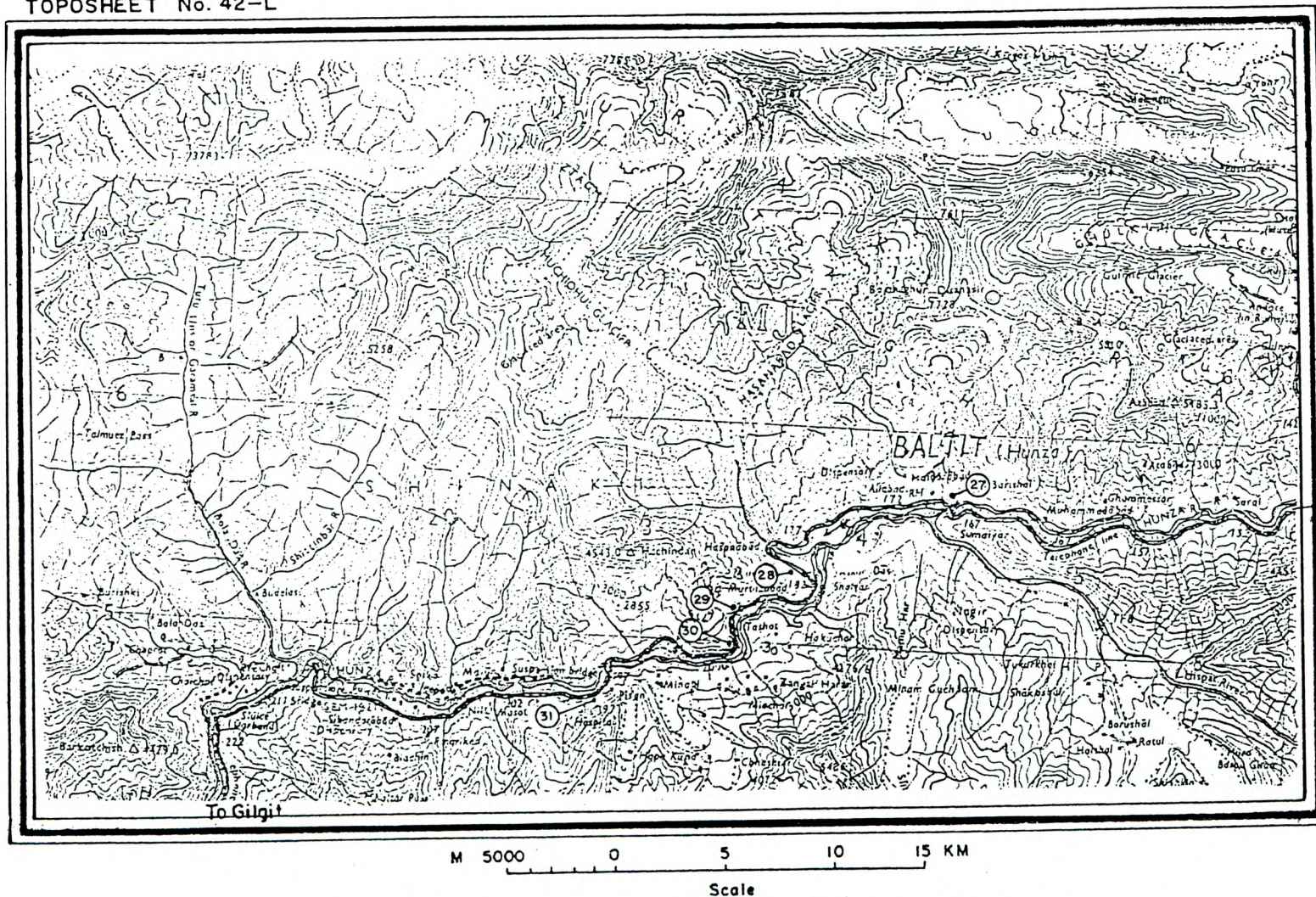


Fig. 12 - Location Map of GSP Slide 27 To GSP Slide 31, Along the Karakoram Highway.

can be removed by the help of dozers. Once the supply line is cut off the remaining soil and bajri will attain its angle of repose and the problem of constant clearance of the road will be solved. The height of the existing breast walls should be increased by 50 cm to retain more material along the slope.

2. Some vegetation on these slopes will also help stabilising the loose bajri.

4-B 4.4 GSP SLIDE NO. 27

Location:	<i>Distance from Hasanabdal</i>	<i>636 km (Fig.12)</i>
	<i>Type of problem:</i>	<i>Rock and scree fall</i>
	<i>Length</i>	<i>300 m</i>
	<i>Height:</i>	<i>50 m</i>

Rock and scree fall (Ganesh Bridge Slide): The slide material at this site is derived from fluvio-glacial deposits, which are loosely cemented (Table 23). These heterogeneous deposits range from fine clayey silt to big erratic boulders. These deposits are about 10m thick, which are composed of two layers of upward coarsening sequence of 5m thickness each (Plate 42).

These are interbedded with 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 steep slope angle (Plate 42). These deposits decrease in grain size fining upward and are repeated 2-3 time 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 creeping down like a sand run, leaving big boulders unsupported and vulnerable to sliding subsequently. Removal of fines by coater and Strong wind action has accelerated the loosening of the matrix, thus facilitating the debris to slide down (Plate 43).

Recommendations:

1. Benching may be done at 3m vertical interval with 2m width inside the terrace.
2. Plantation can be done on the margin of these benches.
3. A good example of this treatment may be seen at and around Aliabad (Hunza), where local people have cultivated fields on such types of terraced benches (Plate 44).
4. Another alternative is to fix a wire mesh along the slopes from the top to check the boulders and debris from falling directly on the road.



PLATE - 44 Benching and plantation along the hill slopes in Hunza area.

Chapter 4 B. 5

SECTION V

Ganesh Bridge to Jaglot Gah

4-B 5.1 GSP SLIDE NO. 28

Location:	<i>Distance from Hasanabdal</i>	<i>623 km (Fig.12)</i>
	<i>Type of problem:</i>	<i>Scree and boulder fall</i>
	<i>Length</i>	<i>2000 m</i>
	<i>Height:</i>	<i>200 m</i>

Scree & boulder fall (Hasanabad Slide): Fluvio-glacial deposits of Hasanabad glaciers are exposed at this site. Material in these deposits comprises 30% of fines and rest of the 70% occurs in the form of boulders and gravels (Table 24). Generally, the slope angle formed by these fluvio-glacial deposits ranges between 70-80 degree. Some gullies are formed by water and exposed at regular intervals of about 10-20 metres in the slopes. During the rainy season these gullies provide an easy passage to the scree and boulders. Comparatively finer materials are exposed along these gullies. The slope material is cemented and shows graded bedding (Plate 45). These deposits gradually coarsen upward. Two sequence of these graded materials are exposed along the slopes.

Boulders embedded along the slopes are erratic and may suddenly fall by removal of the matrix around them. Thus two types of problems exist:-

1. Fall of boulders.
2. Fall of scree along the gullies.

Recommendations:

1. Multiple benching is proposed along these slopes at regular intervals along the gullies.
2. A line of popular trees may be planted behind the existing retaining walls and at other suitable places to uphold the loose material. This method is successfully being utilized for stabilization of slopes and cultivation in Aliabad and Hunza area (Plate 46).

4-B 5.2 GSP SLIDE NO. 29

Location:	<i>Distance from Hasanabdal</i>	<i>618 km (Fig.12)</i>
	<i>Type of problem:</i>	<i>Mudflow</i>
	<i>Length</i>	<i>22 m</i>
	<i>Height:</i>	<i>1000 m</i>

Mudflow (Murtazaabad): This mudflow follows the course of nullah, which has a seasonal flow. The rocks exposed in the catchment area of this nullah

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)		
LOGGED BY: A. FAYAZ		DATE: 31 / 8 / 1996		TIME: 9 : 45 hr		
outcrop no: GSP. S-28		map no: 42-L				
WEATHER CONDITIONS		LOCATION				
Sun:	cloudy/fair/bright ✓	Map coordinates:		northings:		
Rain:	dry/drizzle/slight/heavy			eastings:		
GSP. S-28 KM- 623 (KKH)		DIMENSIONS/ACCESSIBILITY				
		Size total outcrop: (m)		l: 2000	h: 200	d: 30
		mapped on this form: (m)		l: 150	h: 50	d: 10
		Accessibility:		poor/fair/good ✓		
MAP UNIT NAME: Fluvio-glacial deposits						
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour) Coarsening upward material in two sets, with erratic boulders, A few bushes can be seen. Not homogenous.						
ESTIMATION OF GRAIN SIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES						
FIELD		LABORATORY				
boulders > 200 mm (from scanline)	(A) 40 %			$f = \frac{100 - (A+B)}{100} =$		
cobbles > 60 mm (from scanline)	(B) 30 %					
gravel > 2 mm	10 %	(C)	%	C' = f x C =		
sand > 0.06 mm	20 %	(D)	%	D' = f x D =		
finer < 0.06 mm	10 %	(E)	%	E' = f x E =		
Total: A + B + C' + D' + E' =		% (should be 100 %)				
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil ✓						
ORGANIC CONTENT (tick) none/little/substantial						
VISUAL IDENTIFICATION (tick)						
for coarse and very coarse soils (tick)			for fine soils			
well graded/uniform/gap graded ✓			dilatency: none/very slow/slow/quick			
			toughness: none/slight/medium/high			
PARTICLE NATURE						
for coarse and very coarse soils						
particle shape: (tick) angular/sub-angular/sub-rounded/r. unded/n.a. flat/elongated/spherical/n.a.						
texture: (tick) rough/smooth/polished/n.a. ✓						
compactness of coarse soil: (tick) loose/dense/slightly cemented/n.a.			strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.			
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy						
SLOPE ANGLE (approximately): 70-80 degrees						
Remarks:						

Table-24 Reference soil classification (Gravel) of GSP Slide No.28.

consist of gneisses. The problem starts from where the rocks come into contact with glacial deposits. The configuration of the nullah course at this site plays an important role in the creation of this problem. It is like a stepped and vertical fall which is followed by a flat area. The topographic configuration combined with the action of water generates this mudflow in the nullah, especially after the rains (Plate 47).

Recommendations:

As discussed this mudflow occurs due to the seepage of rain water into the fluvio-glacial material which on saturation starts flowing down in the form of a mudflow. Therefore, steps may be taken to check the ingress of excessive water in the loose material. To control this ingress of water the nullah configuration may be effectively exploited. The vertical falls in the nullah course should be used to check the water from seeping into the material. At these places 4-5 vertical stone pitched falls are recommended to be constructed along the course of this nullah and mudflow.

However, the flat areas in-between the two water falls may also be lined so that water may seep into it. The materials in these flat areas are permeable and lining will reduce the seepage. These flat areas require proper attention as the water seeps down quickly and saturates the material which later on starts moving like a mudflow. The channelization of this nullah will minimize the mudflow problem to a great extent.

4-B 5.3 GSP SLIDE NO. 30

Location:	<i>Distance from Hasanabdal</i>	<i>616 km (Fig.12)</i>
	<i>Type of problem:</i>	<i>Rock fall</i>
	<i>Length</i>	<i>900 m</i>
	<i>Height:</i>	<i>70-100 m</i>

Rock fall (Nasirabad): This slide zone extends for about one km area in the form of a pari. Schists and gneissose rocks are exposed along this pari. These rocks are highly jointed fractured and tectonically disturbed. Joints are wide open and filled with secondary material. Rock pieces ranging from the size of gravel to boulders are lying precariously along the slopes of this pari. The whole area has become unstable due to intense shearing and fracturing (Tables 25 and 26). The road runs almost parallel to the strike of the rocks which dip away from the road. Slope angle is between 60-70 degree (Plate 48).

A portion of the slide at km 616 has stabilized as all the unstable blocks along the master joints have fallen down. In the remaining area of this slide zone

ENGINEERING GEOLOGY		reference rock-mass calculation		ROCK MASS CLASSIFICATION DETAILED							
LOGGED BY: A. FAYAZ	DATE: 22 / 7 / 1997	TIME: 11 : 30 hr	outcrop no: GSP. S-30								
METHOD OF EXCAVATION (ME)											
Method of excavation adjustment factor (from field form 1) (ME): 0.20											
WEATHERING (WE) (at observation point)											
Weathering adjustment factor (from field form 1) (WE): 0.40											
INTACT ROCK STRENGTH (IRS)											
IRS (MPa)	141-136	135-126	125-111	110-96	95-81	80-66	65-51	50-36	35-21	20-6	5-0
rating	15	13	12	10	9	7	6	4	3	1	0
INTACT ROCK STRENGTH (IRS) = 40 MPa = 4 points											
DISCONTINUITIES		1	2	3	4	5	note: dip-direction and dip will be used when type of use of the rock-mass is known.				
Dip direction (degrees)		85 E	35 W	40 E							
Dip (degrees)		40 SE	80 NE	45 SE							
DISCONTINUITY SPACING (DS) (metres)		40	30	70			rating (DS): (use fig.3.6) 40*(.65 + .58 + .72) = 11 points				
for the determination of the rating use the three (3) discontinuities with minimum spacing							Corrected (CDS): DS/(ME*WE) = 11 = 137 20 * 40 points				
persistence	along strike (m)	>	>	>							
	along dip (m)	>	>	>							
CONDITION OF DISCONTINUITIES											
Roughness large scale (Rl)		0.75	0.80	0.85							
Roughness small scale (Rs)		0.55	0.78	0.70							
Alteration of discont. walls (Aw)		0.80	0.80	0.80							
Infill material (Im)		0.55	0.55	0.65							
Karst (Ka)		1.00	1.00	1.00							
Total (Rl*Rs*Aw*Im*Ka =) (TC)		.18	.26	.31							
Corrected (CTC = TC / WE) (CTC)		.90	0.66	0.78							
Discontinuity condition average (take lowest 3 CTC ratings and divide by 3):				0.78		multiply by 40: (CD):		31			
SUSCEPTIBILITY TO WEATHERING (SW)											
Adjustment factor for susceptibility to weathering (from field form 1) (SW): 0.25											
REFERENCE ROCK - MASS FINAL RATING (RFR)											
RFR = (IRS + CDS + CD) * SW = (4 + 137 + 31) * 0.25 = 43											
preliminary index: >80 (very good), 80-60 (good), 60-40 (fair), 40-20 (poor), <20 (very poor)											
Remarks:											
<u>FAIR</u>											

Table-26 Reference rock mass calculation of GSP Slide No.30.

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 worse because of undercutting action of the Hunza River at the toe of the scree slope (Plate 49). It was observed that a slip circle had developed at the top and slid at least 6 m down-ward from the crown of the slide. Tensional cracks are also noticed at the lower level of the road.

The jointing system in the parent rock body was thoroughly examined. Three sets of joints are observed and the most prominent joints is the bedding joint which trends N 80° W with a steep dip of 80° NE. The other two joints have imparted fissility and splintery nature to the rocks resulting in angular fragments and scree material. (Fig. 13)

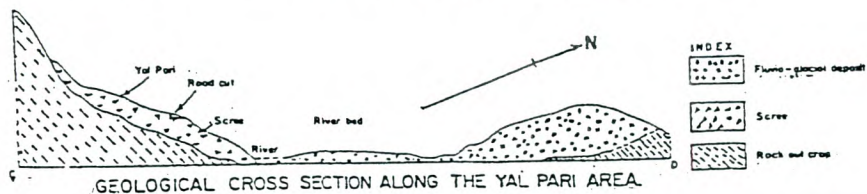
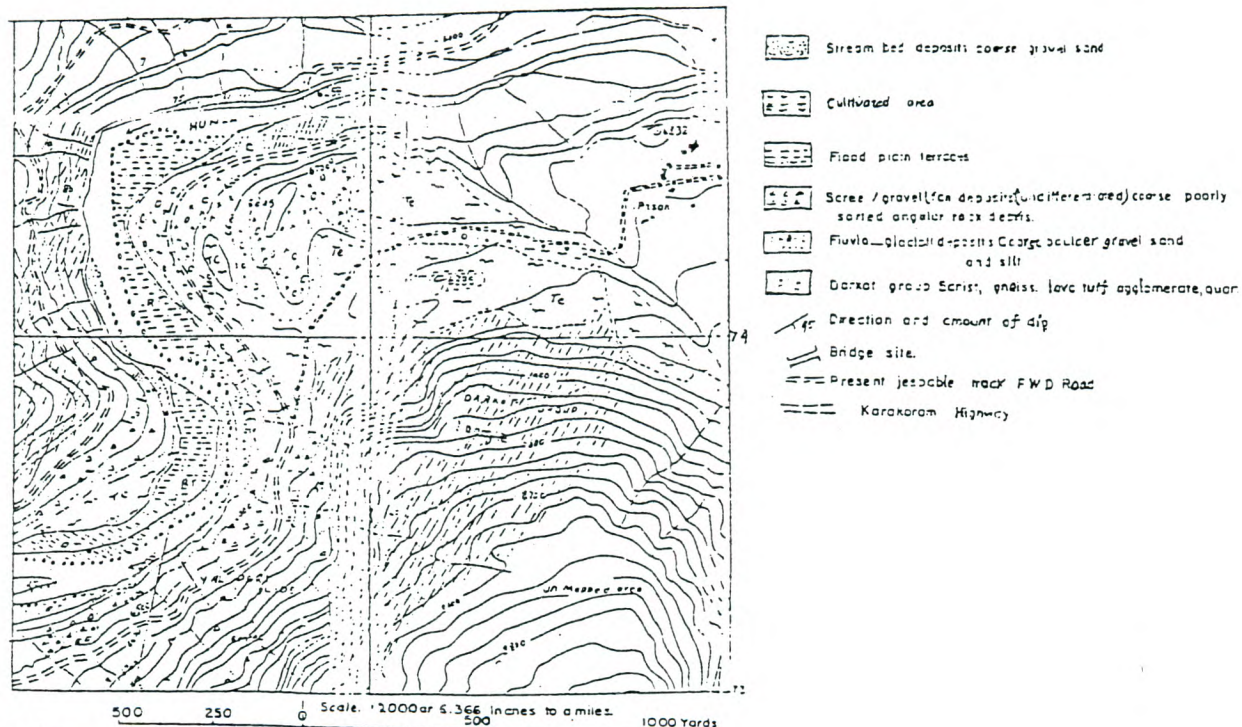
Recommendations:

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 be encountered at a shallow depth and a part of the road will have to be laid on the fill and scree material.

The flow of the scree down the road level will be difficult to control due to steeply formed scree slopes and incompetency of the bed rocks at this place. 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.

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

1. The width of the road at the slide area may be increased to atleast 15m from the present 10 m. The additional 5m may remain unmetalled at this site. The overhanging scree should be removed and 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 scree material.
2. A series of spurs at the bed level upstream of the present site may be made
3. to check the undercutting action of the Hunza River.



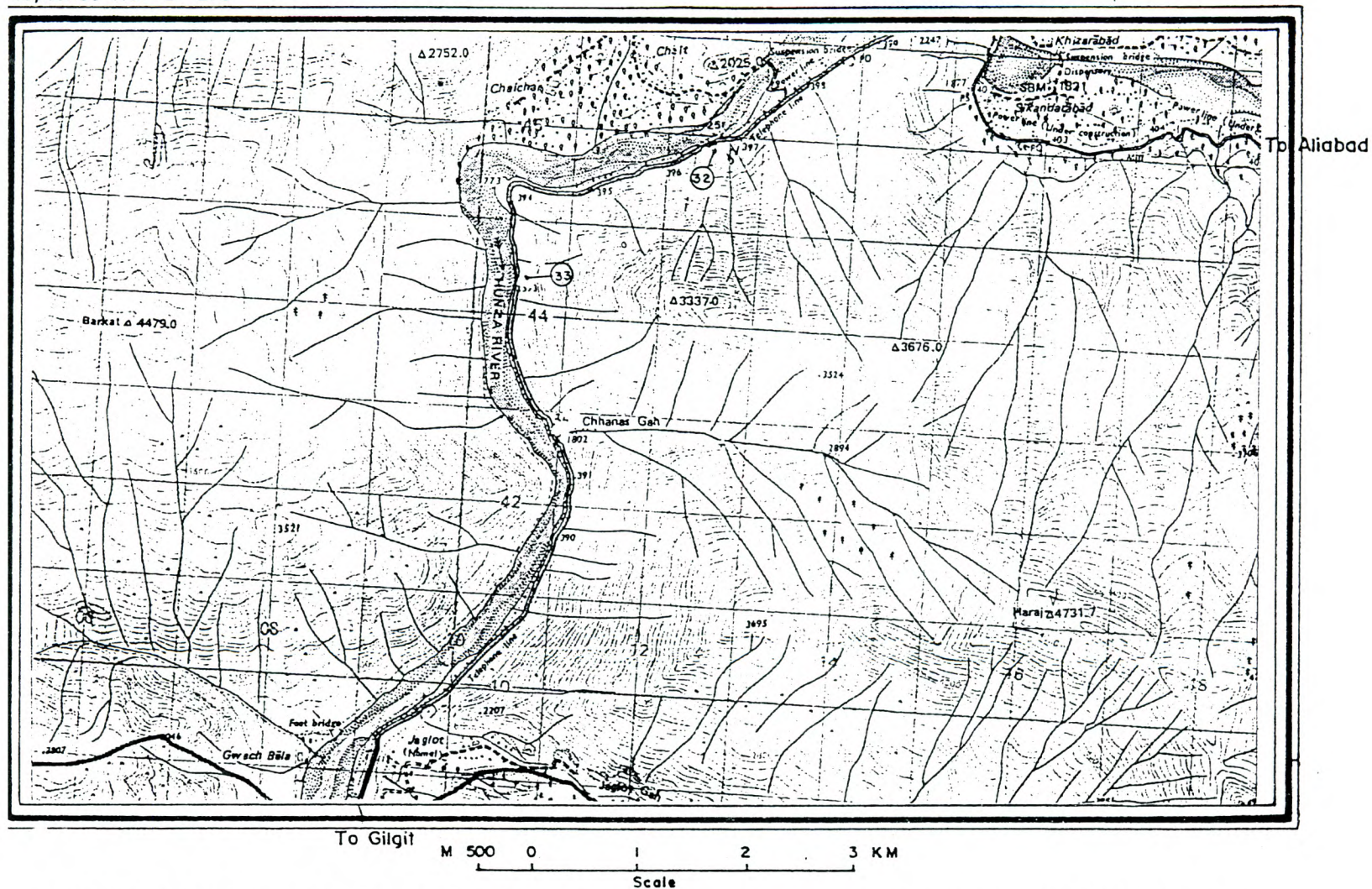


FIG.14- LOCATION MAP OF GSP SLIDE 32 TO GSP SLIDE 33, ALONG THE KARAKORAM HIGHWAY

ENGINEERING GEOLOGY				field form 1		ROCK MASS CLASSIFICATION DETAILED				
LOGGED BY: A. FAYAZ		DATE: 2 / 9 / 1996		TIME: 9 : 40 hr		outcrop no: GSP. S-32				
WEATHER CONDITIONS			LOCATION		map no:		42-L/8			
Sun:	cloudy/fair/bright ✓		Map coordinates:		northings:					
Rain:	dry/drizzle/slight/heavy				eastings:					
METHOD OF EXCAVATION/DIMENSIONS/ACCESSIBILITY										
(tick) hand-made : 0.99			Size total outcrop: (m)		l: 1200		h: 50		d: 10	
unknown : 1.00 excavator : 0.97			mapped on this form: (m)		l: 50		h: 20		d: 5	
natural : 1.00 boring : 1.00			Accessibility:		poor/fair/good					
smooth wall blasting : 0.97			GSP. S-32 KM-587 (KKH)							
conventional blasting										
with result:										
good: 0.94										
open joints: 0.80										
dislodged blocks: 0.60										
fractured intact rock: 0.40										
crushed intact rock: 0.20										
FORMATION NAME: Chalt Schist										
DESCRIPTION (BS 5930: 1981)										
colour	grain size	structure & texture (bedding thickness)		weathering		NAME		strength		
Light Grey	Fine	Highly jointed and fractured		Mod Weathered		Slates		Hard		
INTACT ROCK STRENGTH					sample number(s):					
< 1.25 MPa : Crumbles in hand :1 1.25 - 5 MPa : Thin slabs break easily in hand :2 5 - 12.5 MPa : Thin slabs broken by heavy hand pressure :3 12.5 - 50 MPa : Lumps broken by light hammer blows :4 50 - 100 MPa : Lumps broken by heavy hammer blows :5 100 - 200 MPa : Lumps only chip by heavy hammer blows (Dull ringing sound) :6 > 200 MPa : Rocks ring on hammer blows. Sparks fly :7					GSP. S-32 Schmidt hammer results:					
DISCONTINUITIES		B=bedding	J=joint	.. 1	.. 2	.. 3	.. 4	.. 5	WEATHERING (at observation point)	
Dip direction		(degrees)		60W	20 E	35 E			(tick)	
Dip		(degrees)		70NE	45 NW	50NW			un-weathered:1.00	
Discontinuity spacing		(metres)		10	40	30			slightly :0.80	
persistence	along strike	(meters)		7	7	7			moderately :0.50	
	along dip	(meters)		7	7	7			highly :0.40	
Roughness large scale	wavy multi-directional	:1.00		0.80	0.85	0.95			SUSCEPTIBILITY TO WEATHERING	
	wavy uni-directional	:0.75								
	curved	:0.85								
	slight undulating	:0.80								
	straight	:0.75								
Roughness small scale (on an area of about 0.2 x 0.2 m)	rough stepped/irregular	:0.95		0.60	0.80	0.65			(tick)	
	smooth stepped	:0.90								
	slickensided stepped	:0.85								
	rough undulating	:0.80								
	smooth undulating	:0.75								
	slickensided undulating	:0.70								
	rough planar	:0.65								
	smooth planar	:0.55								
Alteration of discontinuity walls	stronger	:1.10		0.80	0.80	0.80			sample no:	
	no change	:1.00								
Infill	no infill-surface staining only	:1.00		0.55	0.85	0.90			S-32	
	cemented infill	:0.97								
	non softening & sheared material only, e.g. free of clay, talc, etc.	coarse:	0.95							
		medium:	0.90							
		fine:	0.85							
material	soft sheared material e.g. clay, talc, etc.	coarse:	0.75	0.55	0.85	0.90			WATER	
		medium:	0.65							
		fine:	0.55							
	gouge < irregularities	:0.42								
	gouge > irregularities	:0.17								
karst	flowing material	:0.05		1.00	1.00	1.00			(tick) dry :1.00 moist :0.97 1.5-7.5 :0.93 > 7.5 :0.90 unit: m3/hr/10m2	
	none	:1.00								
	opening: < 0.1 (m)	0.1-1	> 1 (m)							
	occasional:	0.75	0.55							0.35
	common:	0.50	0.25							0.10
	frequently:	0.20	0.15	0.05					EXISTING SLOPE ? dip-direction/dip 60E / 70 height: 50 (m) Stability ?(tick) 1 stable 2 small problems in near future 3 large problems in near future 4 small problems 5 large problems	

Table-27 Reference rock mass classification detail of GSP Slide No.32.

2. Retaining walls are already constructed at critical location along the slide zone to control the scree. Their regular and proper maintenance, however, is urgently required.

4-B 5.6 GSP SLIDE NO. 33

Location:	<i>Distance from Hasanabdal</i>	<i>584 km (Fig. 14)</i>
	<i>Type of problem:</i>	<i>Mudflow</i>
	<i>Length</i>	<i>300 m</i>
	<i>Height:</i>	<i>85 m</i>

Mudflow: This mudflow follows the nullah channel. Catchment area of this nullah seems to be very large but it has no perennial flow. The water therefore, comes through this nullah, after the melting of snow or during rainy season only.

Material is composed of 50% of broken rock pieces gathered along the course of the nullah and the remaining 50% comprises fine silty material. This material has no cohesion and looks very permeable. Coarse rock material occurs on the top while the finer material lies underneath (Table 29).

The debris material is also differentiated into two types – one with big boulders and blocks of rock and the other having smaller rock fragments and scree material. This material is separated from a ledge of rock exposed at the mouth of a gully along the path of this nullah. It appears that at the time of mudflow outburst the heavier material, because of its bigger load, moved first followed by the finer material on the other side of the ledge. When water mixes with this type of material it starts moving like a mudflow.

Recommendations:

1. A vertical fall exists along the path of the nullah at a height of about 80 metres from the road level; proper channelization of water may be carried out at this point.
2. This channelisation may be supported by stone pitched lining of the nullah to stop the ingress of water and smoothly drain it into the river.

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)	
LOGGED BY: A. FAYAZ		DATE: 2 / 9 / 1996		TIME: 10 : 30 hr	
outcrop no: GSP. S-33					
WEATHER CONDITIONS		LOCATION		map no: 42 L-8	
Sun: cloudy/fair/bright ✓		Map coordinates:		northings:	
Rain: dry/drizzle/slight/heavy				eastings:	
GSP. S-33 KM-584 (KKH)		DIMENSIONS/ACCESSIBILITY			
		Size total outcrop: (m)		l: 300	h: 85 d: 50
		mapped on this form: (m)		l: 30	h: 10 d: 5
		Accessibility:		poor/fair/good ✓	
MAP UNIT NAME: Fluvio-Glacial deposits					
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour) Boulders, gravels, pebbles and fines, Coarsening upward layering, Not homogenous, Scanty vegetation cover of no importance					
ESTIMATION OF GRAINSIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES					
		FIELD		LABORATORY	
boulders > 200 mm (from scanline)	(A)	20 %		$f = \frac{100 - (A+B)}{100} = \frac{100-5}{100}$ $f = \frac{50}{100} = .05$	
cobbles > 60 mm (from scanline)	(B)	30 %			
gravel > 2 mm		10 %	(C)	10 %	$C' = f \times C = .05 \times 10 = 5$
sand > 0.06 mm		40 %	(D)	40 %	$D' = f \times D = 40 \times .05 = 20$
finer < 0.06 mm		%	(E)	%	$E' = f \times E =$
Total: A + B + C' + D' + E' =					% (should be 100 %)
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil					
ORGANIC CONTENT (tick) none/little/substantial					
VISUAL IDENTIFICATION (tick)					
for coarse and very coarse soils (tick)			for fine soils		
well graded/uniform/gap graded ✓			dilatency: none/very slow/slow/quick		
			toughness: none/slight/medium/high		
PARTICLE NATURE					
for coarse and very coarse soils					
particle shape: (tick) ✓ angular/sub-angular/sub-rounded/r. undd/n.a. flat/elongated/spherical/n.a.					
texture: (tick) ✓ rough/smooth/polished/n.a.					
compactness of coarse soils (tick) loose/dense/slightly cemented/n.a.			strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.		
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy					
SLOPE ANGLE (approximately): 45° degrees					
Remarks: Mudflow material is composed mainly cobbles and fines. Fine material is cohesionless and Soluble, which starts flowing like a mudflow with the introduction of water.					

Table-29 Reference soil classification (Gravel) of GSP Slide No.33

A Part of Toposheet No. 42-L/8

To Aliabad

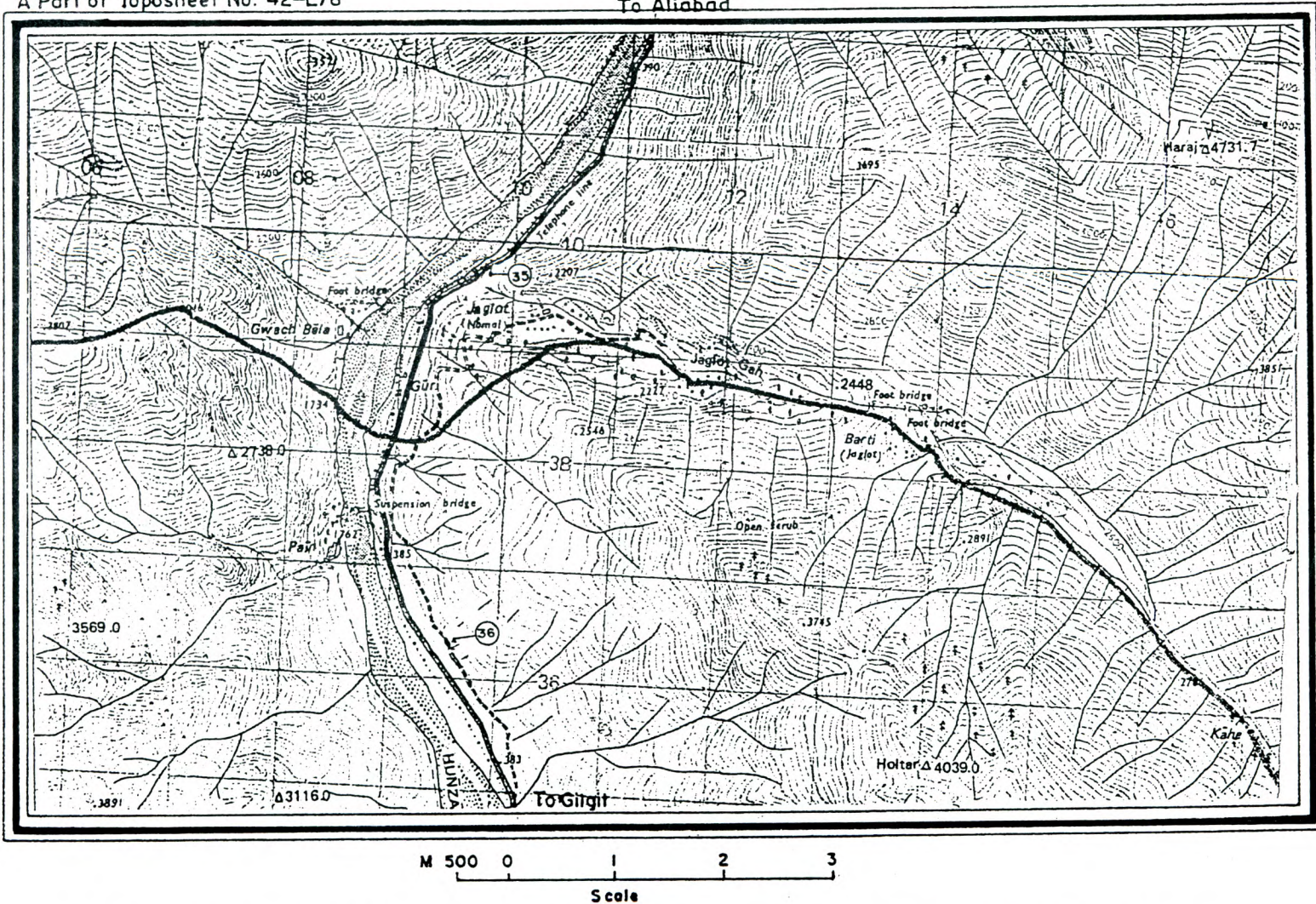


FIG.17- LOCATION MAP OF GSP SLIDE 35 TO GSP SLIDE 36, ALONG THE KARAKORAM HIGHWAY

cemented and compact in dry conditions. During wet conditions it is highly incompetent and starts flowing like mud on saturation with water.

A traverse was made upto the Juglot village at the top of the ridge, along the old road. It was noted that the village terrace is located between two high ridges and forms a narrow valley which extends eastward upto the foothills of Rakaposhi group of glaciers. The village terrace is underlain by big erratic boulders of mostly basic igneous rocks and material of glacial origin. These boulders are embedded in fine wind blown sand on the surface but underneath there is the same glacial fill material.

The geomorphology of the area indicates that the fill material is derived from the snout of some older glacier. The remnants of this glacier are also found on the opposite bank of the Hunza River. The river had segmented and removed most of the material from glacier snout area. However, the coarser material, comprising big boulders, is still lying scattered all over the Juglot village terrace. It is likely that the seasonal rains may have removed the finer material from these boulders which has either been washed away or transported to the lower level below (Plate 50).

During 1996 field season, the surface drainage of the village terrace was also examined to find out the source of water of the springs located at the road level. At the site of the Juglot Gah Mudflow, the following springs were noted:-

<i>Location</i>	<i>No of springs</i>
1. Along the road side	4
2. Below the road level	2
3. Above the road > 50m	2
(i) Stepped channel }	}----- regular flow
(ii) Up in the nullah }	
4. Along Juglot Gah	2
Total springs:	10

These springs, especially located above the road level, were causing major problems. A stepped channel has already been constructed to catch water of the main spring, but the flow of this spring is tremendous and has started damaging the water channel.

To find out the source of water of these springs, a traverse was made around the Juglot Gah catchment area. It was observed that about 8-10 Kanal land was

As a result of engineering geological investigations regarding the causes of the slide in this area, the following factors have also played their role in the development of this mudflow:

1. Removal of toe support:

The Jaglot Nullah is constantly eroding and undercutting the terrace deposits (Pari) causing large scale removal of the sediments and making the overlying material more vulnerable. However, undercutting action of the Hunza River has been controlled to some extent by making spurs and toe walls at the bed level. The removal of toe support by Jaglot Gah has been one of the main causes in the flow of sediments.

2. Increase in pore water pressure:-

The pore water pressure on debris material in the slide zone is due to

- (a) freezing of water in the soil.
- (b) seepage of water in the tills.
- (c) swelling of clayey contents on hydration.

Due to the seepage of water in the sediment of the Pari area pore water pressure is created, which results in dislocation of soil particles. The presence of water in the glacial till material acts as a lubricants for the embedded, erratic boulders which glide down when the wall pressure increases.

3. Creation of new slopes;

New unstable slopes are created by the movement of mudflow. These slopes add to the instability of the area.

4. Removal of lateral support ;

The new road cuts result in removal of lateral support to the sediments above the road, which make them vulnerable to slide.

5. Transitory earth stresses:-

Transitory earth stresses created by vibration from blasting and movement of machinery and traffic results in activation of slide movement and rolling down of hanging boulders.

Chapter 4 B. 6

SECTION VI

Jaglot Gah to Gilgit Bridge

4-B 6.1 GSP SLIDE NO. 36

Location:	<i>Distance from Hasanabdal</i>	<i>570 km (Fig. 17)</i>
	<i>Type of problem:</i>	<i>Debris fall</i>
	<i>Length</i>	<i>700 m</i>
	<i>Height:</i>	<i>25 m</i>

Debris fall (Rahimabad): Material exposed along the slopes of this slide comprises river bed deposits, containing pebbles and gravels with a few erratic boulders. The cementing material is less than 15% still, at places, vertical slopes are stable. Slope angle is 70 to 86 degrees (Table 30).

A few water channels have developed forming small gullies in these vertical slopes. These gullies act as outlets for the cobbles and gravels upto the road. The river bed deposits are overlain by morainic material which facilitate the debris to fall down through the gullies on the road.

Recommendations:

1. After scaling along the slopes, wire mesh be suspended at critical points to restrict the fall of loose material along the side of the road.
2. A water channel is also proposed parallel to the road alignment to safely drain out the main water flow.
3. As the gravels directly fall on the road, it requires regular clearance of the fallen material.

4-B 6.2 GSP SLIDE NO. 37

Location:	<i>Distance from Hasanabdal</i>	<i>563 km (Fig. 18)</i>
	<i>Type of problem:</i>	<i>Rock and Boulder fall</i>
	<i>Length</i>	<i>300 m</i>
	<i>Height:</i>	<i>40 m</i>

Rock and Boulder Fall (Jutal): This slide occurs along the banks of the nullah, leading its way into the Hunza River crossing the KKH at this point.

Material brought by the nullah, through flash floods is exposed along both the banks. Slope angle is 60-80 degrees. Overhangs of the parent rock and vulnerable boulders are lying along the slopes, which may fall at any time. These

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SECTION VII

Gilgit Bridge to Rakhiot Bridge

4-B 7.1 GSP-SLIDE NO. 39

Location:	<i>Distance from Hasanabdal</i>	<i>520 km (Fig. 19)</i>
	<i>Type of problem:</i>	<i>Mudflow</i>
	<i>Length:</i>	<i>120 m</i>
	<i>Height:</i>	<i>70 m</i>

Mudflow (Chamongarh FC Check Post): Remnants of an old mudflow are seen at this point. The catchment area of this slide seems to be very large as it has brought a huge quantity of debris material through its course.

Rocks are exposed vertically along the slopes at an angle of 70° – 80° . Mud brought through the nullah is lying at the same angle as that of the slope. The material of this mudflow comprises fine sediments mixed with gravel.

A fault zone crossing this point is clearly visible. This fault zone exists between the granitic and gneissic rocks forming thick gouge material. During heavy rains (which are scanty in this area) this gouge material moves downward along with the run off water causing this mudflow. Presently it seems to be inactive as some vegetation have grown on the existing mudflow material.

Recommendation:

1. Channelization of this nullah, with stone pitched fall at the road level, is recommended to safely pass the rain water through this nullah across the road.
2. Retaining and breast walls are already constructed, however, breast walls to uphold the slope material above the road may be extended towards the FC check post.
3. A traverse upto the catchment area of this mudflow is proposed to see if any change in the geometry of the nullah course is possible to avoid this mudflow.

4-B 7.2 GSP-SLIDE NO. 40

Location:	<i>Distance from Hasanabdal</i>	<i>491 km (Fig. 20)</i>
	<i>Type of problem:</i>	<i>Rockfall</i>
	<i>Length:</i>	<i>1,000 m</i>
	<i>Height:</i>	<i>70 to 100 m</i>

Rockfall Shagachalgah: Metasedimentary rocks are exposed along this long pari extending to about a kilometre in length. These rock outcrops are fractured,



Fig. - 20 Location map of GSP slide 40, along the Karakoram Highway

Fig. - 21 Location map of GSP slide 41, along the Karakoram Highway

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SECTION VIII

Rakhiot Bridge to Chilas

4-B 8.1 GSP SLIDE NO. 42

Location:	<i>Distance from Hasanabdal</i>	<i>468 km (Fig. 22)</i>
	<i>Type of problem:</i>	<i>Sliding and ground Subsidence</i>
	<i>Length:</i>	<i>1000 m</i>
	<i>Height:</i>	<i>500 m</i>

Slide (Tatta Pani): Tatta Pani is an old slide which is highly active and posing constant problems even after a lapse of 30 years, when it was first studied in 1970 by GSP during the initial alignment of the road (Kanwar 1971). A series of attempts have been made to stabilize this slide, but uptill now, no permanent solution could be found.

During the current investigations a breast wall was being constructed by the FWO engineers (Plate 51). These stepped walls will be connected to the existing retaining walls and then road will be widened by filling the gaps between these retaining structures near the memorial of Tatta Pani martyrs (Plate 52).

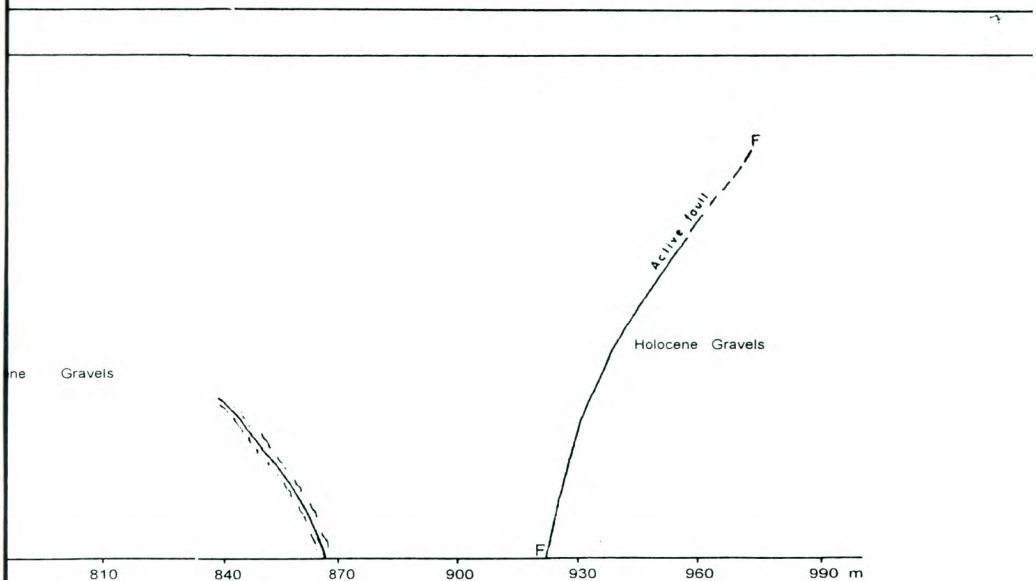
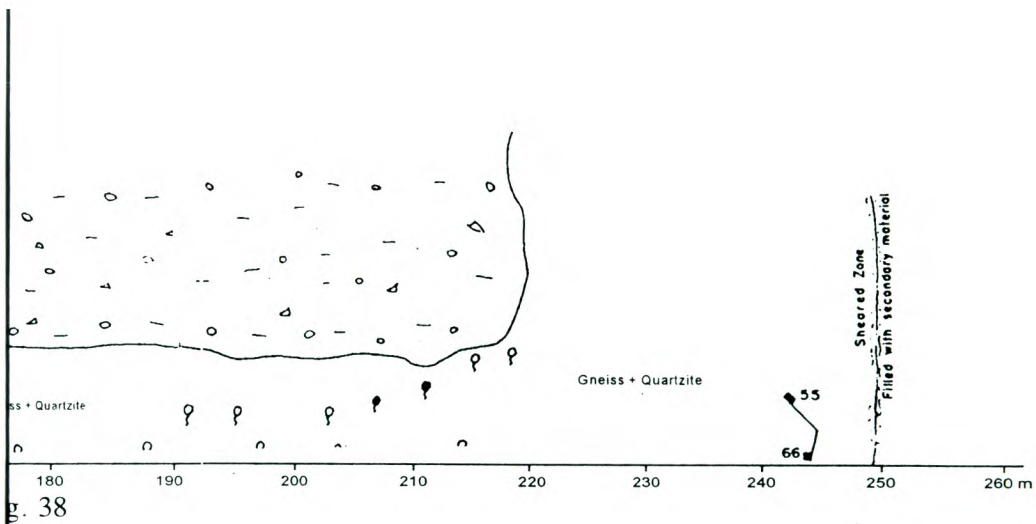
The slopes above the existing level show overhanging, loose, erratic boulders, which require immediate removal before they damage the structure of the under construction walls.

Ground subsidence problem is still active and the movement is noticed even by the local travelers (Plate 53).

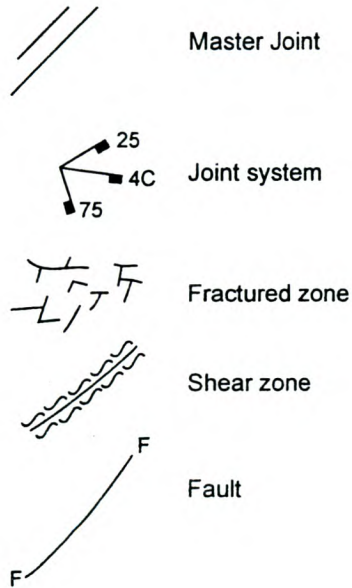
Because of the presence of an active fault (The Tatta Pani Fault) coupled with the undercutting action of the river (Plate 54) the area has become highly unstable and causes constant problem in the maintenance of the road and safety of the people. (Figures 8-9-10).

Recommendations:

1. From 1983, when the last study was made along the KKH by the GSP, uptill now, a lot of money and efforts have been put in by the FWO engineers, but the problem is aggravating day by day.
2. The maintenance cost of this slide is prohibitively expensive therefore, it is high time that the realignment and shifting of this road section to the other side of the river be considered seriously.



INDEX



I N D E X

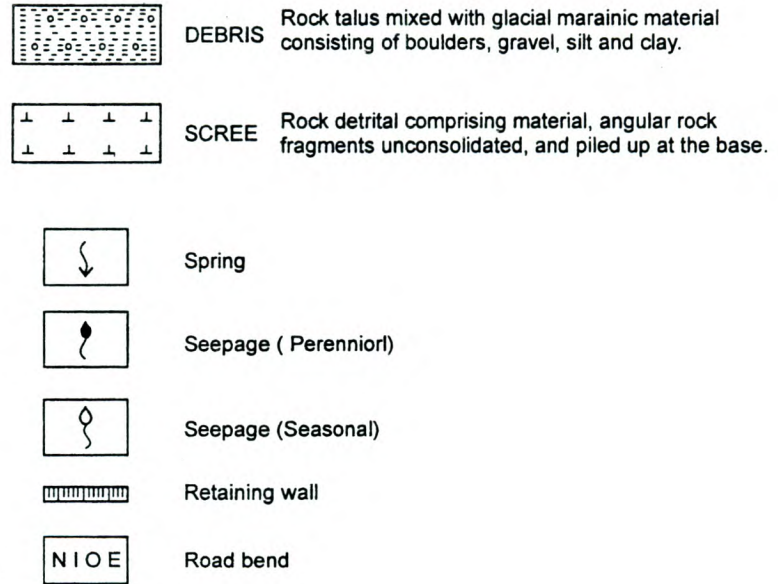


Figure - 25 : Symbols of geological details as used in various geological profiles.



PLATE - 53 Road sinking problem in the zone of subsidence of the Tatta Pani area due to the presence of an active fault.



PLATE - 54
Undercutting action
of the Indus River at
the toe of the Tatta
Pani Slide.

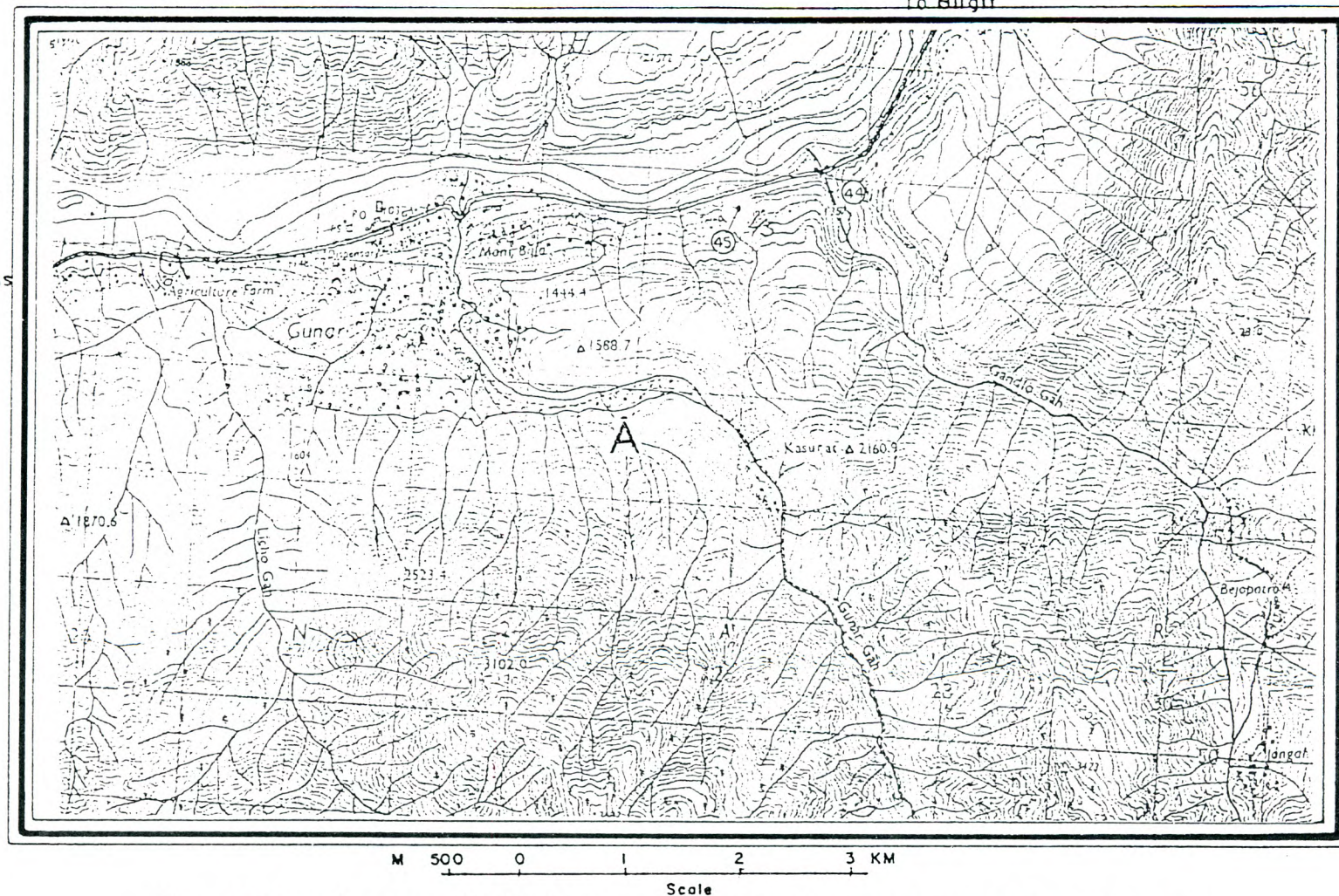


Fig. - 27 Location map of GSP slide 44, to GSP slide 45, along the Karakoram Highway

3. The seepage of rain water can not be effectively checked in this area because of the gravely material exposed all over the area.
4. Effective surface drainage may be provided alongside the road to safely drain out the rain water.

4-B 8.4 GSP SLIDE NO. 45

Location:	<i>Distance from Hasanabdal</i>	<i>446 km (Fig. 27)</i>
	<i>Type of problem:</i>	<i>Debris slide</i>
	<i>Length:</i>	<i>2300 m</i>
	<i>Height:</i>	<i>200 m</i>

Debris slide (Gunner Farm): The gneissic rocks are encountered in the vicinity of the slide area. The material involved in sliding mostly consists of reworked alluvial deposits comprising silt, sand, gravel and boulders. The finer material is predominantly clay. These alluvial deposits are partly stratified and compacted (Plate 58).

The village terrace is cultivated and is irrigated by small fresh water channels connected to the main nullah, upstream. Surplus water from these channels flows over the terrace and falls down on the road below the terrace. Rain water also attains the same flow direction and after passing over the road, finds its way into the river. This process of overflow removes the finer sediments as well as the binding cement from the coarse material and makes them loose and vulnerable to sliding. This phenomenon also has its negative impact below the road level.

Recommendations:

1. Gunner Farm slide may be effectively controlled by channelizing the surface drainage. Surplus water be diverted to proper culverts to check its ingress into the subsoil near the road.

Although surface drainage itself is seldom sufficient for stabilization of the slopes, it can contribute substantially to the drying and thus, also control the landslide.

2. The run off area, on the alluvial terrace immediately above the road is very large. Therefore, some additional work may be required for the control and channelization of water.



PLATE - 57 Vertically cliff face along the KKH at Gandlo as result of under-cutting action of the River. Bif boulders hanging precariously.



PLATE - 58 Reworked fluvioglacial deposits which are partly stratified and compacted at Gunar Farm.

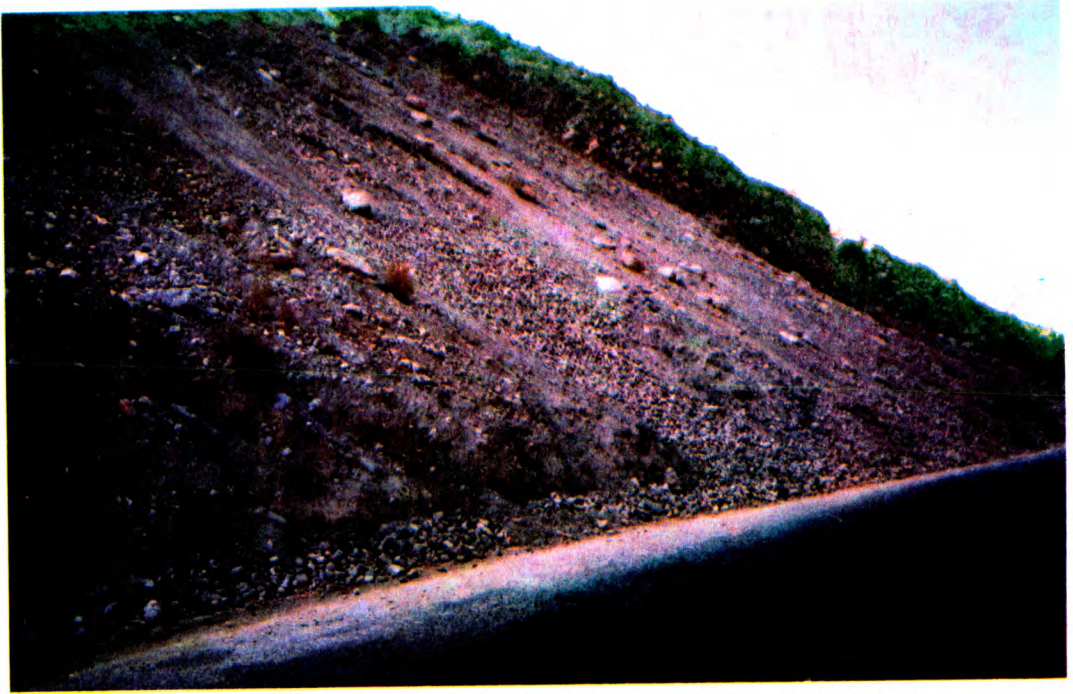


Plate - 59 River bed and morainic deposits, a source of debris flow near Lichi Gah.



Plate - 60 Another view of the debris slope of Lichi Gah showing a big boulder crept down after a few days of first photo (Plate-59)

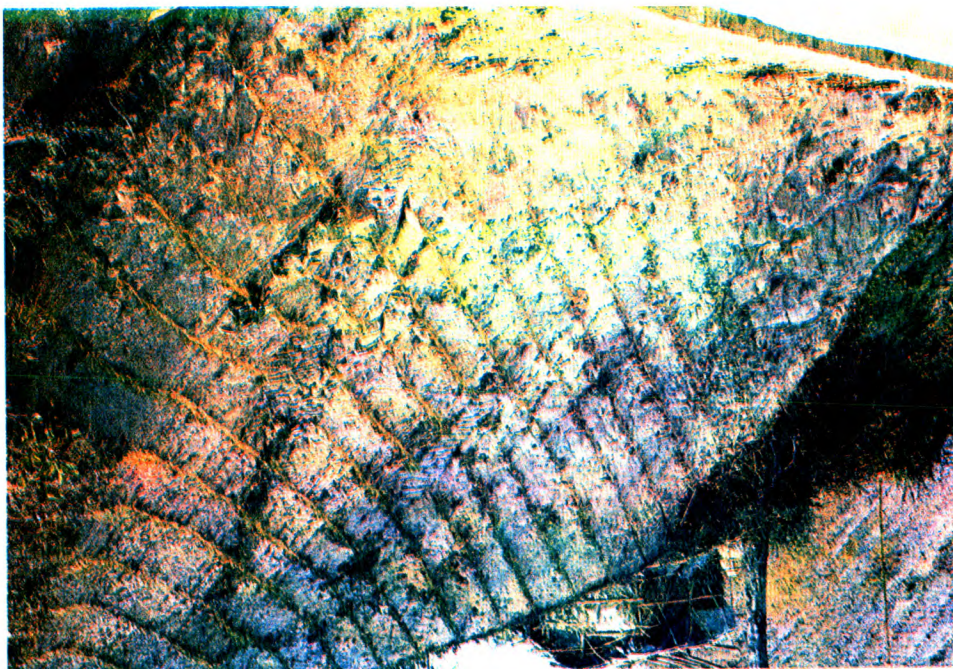


Plate - 62 Diagonal grass lines planted on steep slopes.
(Courtesy ICIMOD)



Plate - 63 Terracing of slope below road and grass painting.
(Courtesy ICIMOD)

Fig. - 29 Location map of GSP slide 48, along the Karakoram Highway



Plate - 65 A symbolic representation of a series of check dams or dykes constructed to reduce the impact of a rapid mudflow. (Courtesy ICIMOD)



Plate - 66 A cascade for gully control.
(Courtesy ICIMOD)

Chapter 4 B. 9

SECTION IX

Chilas to Dasu

4-B 9.1 GSP SLIDE NO. 49

Location:	<i>Distance from Hasanabdal</i>	<i>407 km (Fig. 30)</i>
	<i>Type of problem:</i>	<i>Rock and boulder fall</i>
	<i>Length:</i>	<i>50 m</i>
	<i>Height:</i>	<i>600 m</i>

Rock and boulder fall (Gichi): This slide originates in a nullah, from where the rocks and boulders come down alongwith the water. This nullah does not have perennial flow. Rocks exposed in the catchment area of this nullah are gabbros/norites. Slope angle above the road level is about 40-45 degrees. Rock debris lying along the slopes coarsens upward. It contains about 30% fines while the rest of them are boulders, pebbles and cobbles (Plate 67).

Due to less cementing material, stones keep on falling with the ingress of water. It appears that in the higher reaches of the catchment area of the slide, some morainic deposits occupy the hill tops which come down mixed with rock talus (Plate 68). The major portion of the debris material comprises big boulders.

Recommendations:

1. A breast wall is already constructed to hold the falling debris, which is filled to its capacity. A stepped retaining wall be erected at the road level and where space permits its height be increased to a reasonable limit, so that it can withstand maximum load of the slided material.
2. The hanging block of rocks be thrown down with the help of steel bars.

4-B 9.2 GSP SLIDE NO. 50

Location:	<i>Distance from Hasanabdal</i>	<i>362 km (Fig. 31)</i>
	<i>Type of problem:</i>	<i>Debris avalanche</i>
	<i>Length:</i>	<i>100 m</i>
	<i>Height:</i>	<i>900 m</i>

Debris avalanche (Harbon-1): The Harbon Debris Avalanche (Harbon-1) has formed a vertical scar clearly visible from a distance which may be the result of

ENGINEERING GEOLOGY		reference rock-mass calculation		ROCK MASS CLASSIFICATION DETAILED		
LOGGED BY: A. FAYAZ	DATE: 25 / 7 / 1997	TIME: 11 : 30 hr	outcrop no: GSP. S- 52			
METHOD OF EXCAVATION (ME)						
Method of excavation adjustment factor (from field form 1) (ME):			0.80			
WEATHERING (WE) (at observation point)						
Weathering adjustment factor (from field form 1) (WE):			0.80			
INTACT ROCK STRENGTH (IRS)						
IRS (MPa)	141-136	135-126	125-111	110-96	95-81	80-66
Rating	15	13	12	10	9	7
INTACT ROCK STRENGTH (IRS) =			40 MPa =			4 points
DISCONTINUITIES		1	2	3	4	5
Dip direction (degrees)	40W	45E	60W			
Dip (degrees)	75NE	85NE	45NE			
DISCONTINUITY SPACING(DS)(metres)		3m	1m	5m		
for the determination of the rating use the three (3) discontinuities with minimum spacing						
						note: dip-direction and dip will be used when type of use of the rock-mass is known.
						rating (DS): (use fig.3.6) $40 \times (0.74 \times 0.80 \times 0.93) =$ 22 points
						Corrected (CDS): DS/(ME*WE) = $\frac{22}{0.80 \times 0.80} =$ 34 points
persistence	along strike (m)	>	>	>		
	along dip (m)	>	>	>		
CONDITION OF DISCONTINUITIES						
Roughness large scale (Rl)	0.95	0.80	0.80			
Roughness small scale (Rs)	0.80	0.65	0.65			
Alteration of discont. walls (Aw)	1.00	0.80	0.80			
Infill material (Im)	0.55	0.42	0.65			
Karst (Ka)	1.00	1.00	1.00			
Total (Rl*Rs*Aw*Im*Ka =) (TC)	0.418	0.174	0.27			
Corrected (CTC = TC / WE) (CTC)	0.52	0.22	0.34			
Discontinuity condition average (take lowest 3 CTC ratings and divide by 3):		0.36		multiply by 40: (CD):		14.4
SUSCEPTIBILITY TO WEATHERING (SW)						
Adjustment factor for susceptibility to weathering (from field form 1) (SW):			1.00			
REFERENCE ROCK - MASS FINAL RATING (RFR)						
$RFR = (IRS + CDS + CD) \times SW = (40 + 34 + 14.4) \times 1.00 =$ 52						
preliminary index: >80 (very good), 80-60 (good), 60-40 (fair), 40-20 (poor), <20 (very poor)						
Remarks:						
FAIR						

Table - 34 Reference rock mass calculation of GSP Slide No. 52

4-B 9.12 GSP SLIDE NO. 60

Location:	<i>Distance from Hasanabdal</i>	<i>291 km (Fig. 34)</i>
	<i>Type of problem:</i>	<i>Rock fall</i>
	<i>Length:</i>	<i>20 m</i>
	<i>Height:</i>	<i>30 m</i>

Rock fall (Dassu): Amphibolite rocks are exposed in this area, which are highly jointed and sheared. Joints are daylighting and dipping towards the road. Catchment area of this rock fall is very limited. Due to intense jointing rock breaks up into blocks of varying sizes and keep on falling on the road. A few boulders are also seen lying along side the road.

Recommendations:

1. As the catchment area of this rock falls is not very big, the scaling and controlled blasting technique will help to re-slope the rock upto a comparatively safe angle along the exposed master joint.
2. There are also traces of mudflow along the nullah. However, this does not seem to be problematic. Occasionally, water brings mud during heavy rains, but below the causeway, no traces of damage are seen to warrant detailed investigations.
3. Check dams in the catchment area of this nullah may help a great deal to control this mudflow. (Plate 65)

Chapter 4 B. 10

SECTION X

Dasu to Besham

4-B 10.1 GSP SLIDE NO. 61

Location:	<i>Distance from Hasanabdal</i>	<i>278 km (Fig. 35)</i>
	<i>Type of problem:</i>	<i>Mudflow/Rock fall</i>
	<i>Length:</i>	<i>1,500 m</i>
	<i>Height:</i>	<i>100 m</i>

Mudflow (Keru): The catchment area of this mudflow is limited. However, the topographic elements and climatic factors generate occasional mudflows.

Rock fall: About two km portion of the road was damaged due to heavy blasting, which has not been stabilized uptill now. Loose blocks of rock and boulders keep on falling during rains and the road is damaged all along this portion of the road.

Recommendations:

1. As the rainfall in this area is very common, therefore proper channelization of the nullah flow, will help in controlling this mudflow (Plate 65).
2. In this section of the road rock bolting at a few places may be done.

4-B 10.2 GSP SLIDE NO. 62

Location:	<i>Distance from Hasanabdal</i>	<i>264 km (Fig. 35)</i>
	<i>Type of problem:</i>	<i>Mudflow</i>
	<i>Length:</i>	<i>30 m</i>
	<i>Height:</i>	<i>150 m</i>

Mudflow (Kiyal): The catchment area of this nullah is not very large. However, heavy rains bring down a lot of muck in the form of mudflows through this nullah. The material exposed along the catchment of this nullah comprises terrace deposits which on saturation with the rain water bring huge boulders and other coarse material on the road.

Recommendations:

1. Proper drainage of the nullah is required, especially in the last 50 metres above the road level. A channel with stone pitched base is recommended in this portion.

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)		
LOGGED BY: LATIF		DATE: 5 / 12 / 1998		TIME: 14 : 00 hr		
outcrop no: GSP. S- 66						
WEATHER CONDITIONS		LOCATION GSP. S-66		map no: 43- E/6		
Sun: cloudy/fair/bright ✓		Map coordinates:		northings:		
Rain: dry/driizzle/slight/heavy				eastings:		
GSP- S-66 KM- (KKH)		DIMENSIONS/ACCESSIBILITY				
		Size total outcrop: (m)		l: 1000m	h: 100	d: 20m
		mapped on this form: (m)		l: 30	h: 30	d: 10
		Accessibility:		poor/fair/good ✓		
MAP UNIT NAME: JITAL-COMPLEX						
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour)						
Pyroxenite rock boulders, homogenous; grass and small bushes are grown on the slope						
ESTIMATION OF GRAINSIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES						
		FIELD		LABORATORY		
boulders > 200 mm (from scanline)	(A)	30 %		$f = \frac{100 - (A+B)}{100}$		
cobbles > 60 mm (from scanline)	(B)	45 %				
gravel > 2 mm		15 %	(C)	%	C' = f x C =	
sand > 0.06 mm		5 %	(D)	%	D' = f x D =	
finer < 0.06 mm		5 %	(E)	%	E' = f x E =	
Total: A + B + C' + D' + E' =				% (should be 100 %)		
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil						
ORGANIC CONTENT (tick): none/little/substantial						
VISUAL IDENTIFICATION (tick)						
for coarse and very coarse soils (tick)			for fine soils			
well graded/uniform/gap graded			dilatency: none/very slow/slow/quick			
			toughness: none/slight/medium/high			
PARTICLE NATURE						
for coarse and very coarse soils						
particle shape: (tick) angular/sub-angular/sub-rounded/r. undred/n.a. flat/elongated/spherical/n.a.						
texture: (tick) rough/smooth/polished/n.a.						
compactness of coarse soils (tick) loose/dense/slightly cemented/n.a.				strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.		
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy						
SLOPE ANGLE (approxim tely): 38 degrees						
Remarks:						

Table - 35 Reference soil classification (Gravel) of GSP Slide No. 66

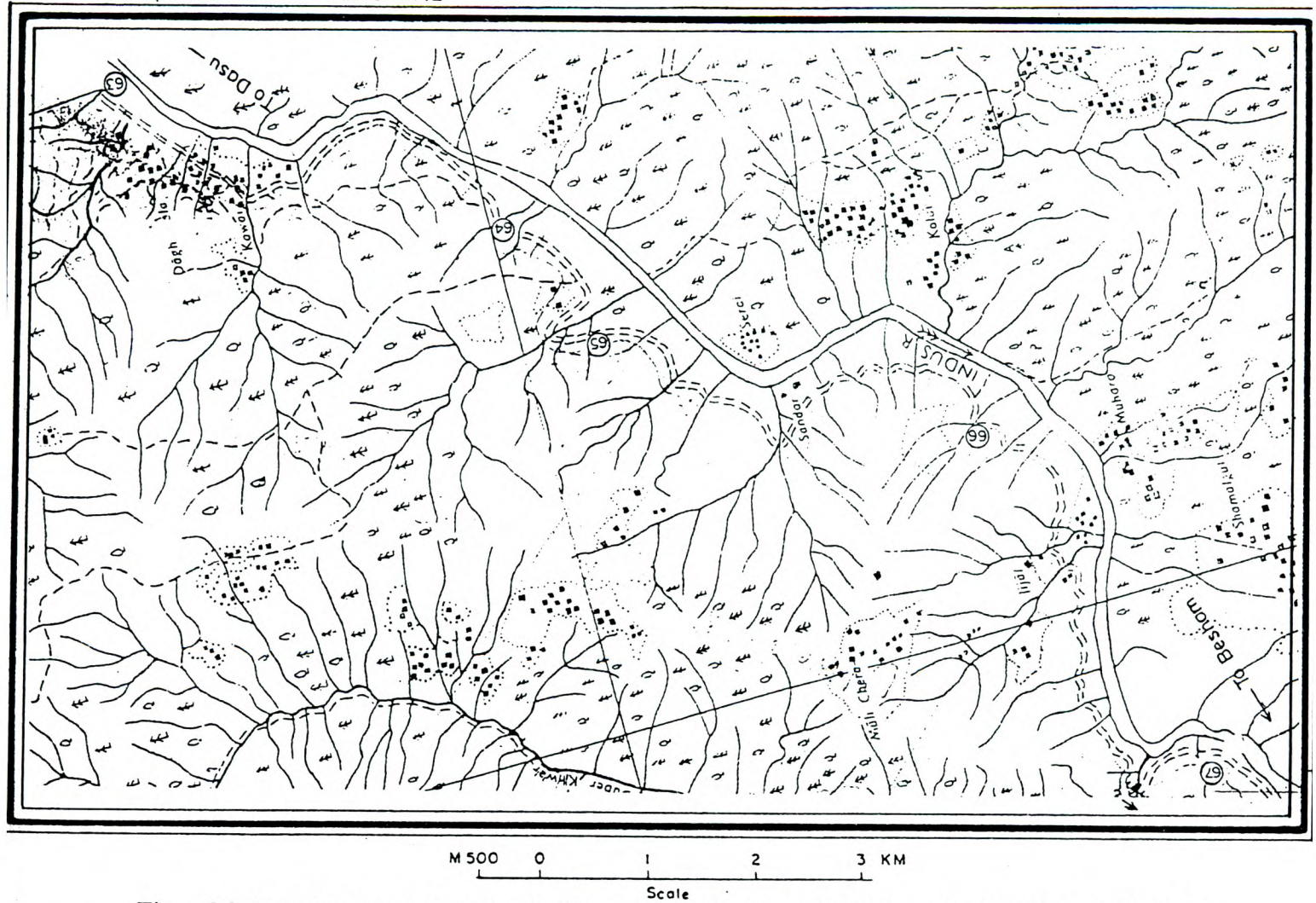


Fig. - 36 Location map of GSP slide No. 63, 64, 65, 66, and 67 along the Karakoram Highway

also exposed. The Main Mantle Thrust (MMT) crosses the Karakoram Highway at this point. In a one km long strip, at least 4 to 5 slides occur at different intervals. As the material and the rock types in this strip are the same, all these slides are discussed collectively.

This section of the road is the re-entrant of a fault zone, with the presence of a thick gouge material. Slickensiding is also visible on the rocks. The surface rocks at many places all along this zone have broken into small fragments and fine gougy material (Plate 69).

As the area falls in the heavy rain fall zone, the process of rock weathering is very active. Serpentinization is very common which makes these rocks slippery on wetting and accelerates the process of rock decay forming clayey soil (Plate 70). The natural rock slopes being also steep, the downward movement of loose debris is activated. (Table 35)

The fault plane, passing through the nullah re-entrant, is causing upward enlargement of the slide scarp. A gully is formed for the flow of water, along which most of the material falls in the shape of debris.

From the road level upto the top of the ridge, the whole material is vulnerable to slide due to:

- i. Ingress of water into the subsoil.
- ii. Strong wind action.
- iii. Vehicular movement
- iv. Temperature effects diurnally and annually.
- v. Fault breccia effect

Recommendation:

1. An abandoned water channel is seen at a height of 50 m from the road level. This is the right place for laying wire mesh network after proper scaling of the slope. This particular area is of the size of 120 m x 200 m x 100 m which is not large. The following measures be taken to control the slides:
 - a. Scaling of slopes.

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)	
LOGGED BY: LATIF	DATE: 7 / 12 / 1998	TIME: 11 : 15 hr	outcrop no: GSP. S- 67		
WEATHER CONDITIONS		LOCATION	map no:		
Sun: cloudy/fair/bright		Map coordinates:	northings:		
Rain: dry/drizzle/slight/heavy			eastings:		
GSP. S- 67		DIMENSIONS/ACCESSIBILITY			
KM-234(KKH)		Size total outcrop: (m)	l: 30	h: 40	d: 10
		mapped on this form: (m)	l: 20	h: 40	d: 10
		Accessibility:	poor/fair/good		
MAP UNIT NAME: FLUVIAL DEPOSITS					
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour) granodiorite and quartz boulders. No layering, homogeneous, partly covered by bushes & grass					
ESTIMATION OF GRAINSIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES					
		FIELD	LABORATORY		
boulders > 200 mm (from scanline)	(A)	35 %			$f = \frac{100 - (A+B)}{100} =$
cobbles > 60 mm (from scanline)	(B)	30 %			
gravel > 2 mm		25 %	(C)	%	$C' = f \times C =$
sand > 0.06 mm		5 %	(D)	%	$D' = f \times D =$
finer < 0.06 mm		5 %	(E)	%	$E' = f \times E =$
Total: A + B + C' + D' + E' =		% (should be 100 %)			
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil					
ORGANIC CONTENT (tick): none/little/substantial					
VISUAL IDENTIFICATION (tick)					
for coarse and very coarse soils (tick)			for fine soils		
well graded/uniform/gap graded			dilatency: none/very slow/slow/quick		
			toughness: none/slight/medium/high		
PARTICLE NATURE					
for coarse and very coarse soils					
particle shape: (tick) angular/sub-angular/s. b-rounded/n.a. flat/elongated/spherical/n.a.					
texture: (tick) rough/smooth/polished/n.a.					
compactness of coarse soils (tick) loose/dense/slightly cemented/n.a.			strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.		
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy					
SLOPE ANGLE (approximately): 38 degrees					
Remarks: Along the KKH, About 2 km portion is covered with loose material. During torrential rains, material comes downward.					

Table - 36 Reference soil classification (Gravel) of GSP Slide No. 67

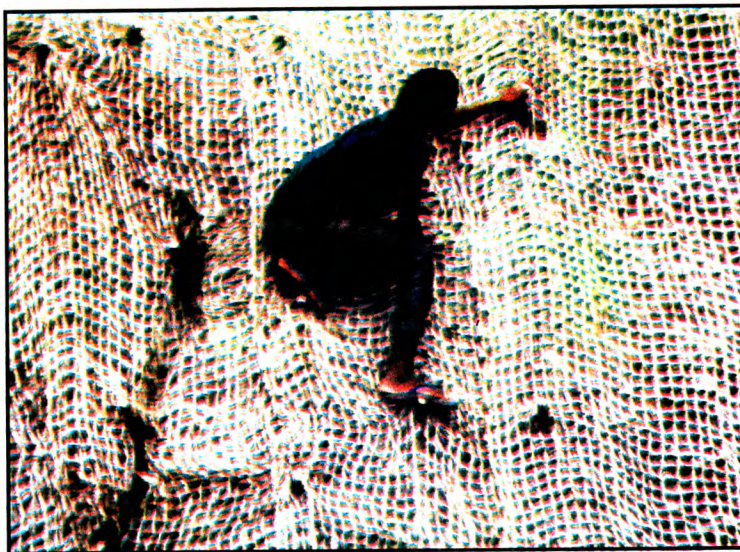


Plate - 71 A wire mesh netting technique, cutting are fixed with stake and covered by jute manually. (Courtesy ICIMOD)



Plate - 72 Another view of the meshing work, Completed on a road slope along the Dharan-Dhankuta Road, Nepal. (Courtesy ICIMOD)

ENGINEERING GEOLOGY		field form 1		SOIL CLASSIFICATION (GRAVEL)	
LOGGED BY: LATIF	DATE: 7 / 12 / 1998	TIME: 14 : 00 hr	outcrop no: GSP- S-68		
WEATHER CONDITIONS		LOCATION	map no:	Lahori Nala	
Sun: cloudy/fair/bright		Map coordinates:	northings:		
Rain: dry/drizzle/slight/heavy			eastings:		
GSP- S- 68 KM-222(KKH)		DIMENSIONS/ACCESSIBILITY			
		Size total outcrop: (m)	l: 80	h: 25	d: 30
		mapped on this form: (m)	l: 60	h: 25	d: 30
		Accessibility:	poor/fair/good		
MAP UNIT NAME: TERRACE DEPOSITS					
DESCRIPTION: (main constituents, layering, homogeneity, vegetation cover, colour)					
<i>Heterogenous, Bushes and grass, Brown to dark brown,</i>					
ESTIMATION OF GRAINSIZE DISTRIBUTION/SIEVING GRAVEL, SAND & FINES					
		FIELD		LABORATORY	
boulders > 200 mm (from scanline)	(A)	20 %		$f = \frac{100 - (A+B)}{100} =$	
cobbles > 60 mm (from scanline)	(B)	10 %			
gravel > 2 mm		10 %	(C)	%	C' = f x C =
sand > 0.06 mm		35 %	(D)	%	D' = f x D =
finer < 0.06 mm		25 %	(E)	%	E' = f x E =
Total: A + B + C' + D' + E' =			% (should be 100 %)		
(tick): more than 35 % < 0.06 mm: fine soil / less than 35 % < 0.06 mm coarse soil					
ORGANIC CONTENT (tick): none/little/substantial					
VISUAL IDENTIFICATION (tick)					
for coarse and very coarse soils (tick)			for fine soils		
well graded/uniform/gap graded			dilatancy: none/very slow/slow/quick		
			toughness: none/slight/medium/high		
PARTICLE NATURE					
for coarse and very coarse soils					
particle shape: (tick) angular/sub-angular/s.b-rounded/r. rounded/n.a. flat/elongated/spherical/n.a.					
texture: (tick) rough/smooth/polished/n.a.					
compactness of coarse soils (tick) loose/dense/slightly cemented/n.a.			strength of fine soils very soft/soft/firm/stiff/very stiff/n.a.		
CARBONATE CONTENT: reaction with HCl: (tick) none/slow/fair/fast/frothy					
SLOPE ANGLE (approximately):					30° degrees
Remarks: <i>It looks stable now a days may be ^{due to} proper channelization of irrigation water.</i>					

Table - 37 Reference soil classification (Gravel) of GSP Slide No. 68

Chapter 4 B. 11

SECTION XI

Besham to Hasarabdal

4-B 11.1 GSP SLIDE NO. 69

Location:	<i>Distance from Hasanabdal</i>	<i>187 km (Fig. 37)</i>
	<i>Type of problem</i>	<i>Debris slide</i>
	<i>Length:</i>	<i>500 m</i>
	<i>Height:</i>	<i>110 m</i>

Debris slide (Lasa): The rocks exposed in this slide comprise mica schists. General foliation and jointing trend is towards the road side, which is daylighting.

A distinct slip circle is formed at the crown of the slide, which has moved downward by 5-10 metres (Plate 75). From the sides the movement is visible upto one metre. In the middle of this slip circle, broken rock fragments have piled up and are vulnerable to slide downward (Table 38). Catchment area of this slide is not very large and is visible from the road level.

The slide zone extends down to the nullah bed. Undercutting action of this nullah has accelerated the downward creep of the debris material. It may not be the main cause of the slide, but it is possible that slide originally started due to this reason and with the passage of time the slide zone extended upward. During the rainy season it is highly activated and causes blockage of traffic.

Recommendations:

1. At the height of about 10 m from the road level, a bench is being created to uphold the debris material and to provide a platform for the material coming from the top. This platform be maintained and a stone pitched retaining wall be constructed on it to uphold the falling material. Road width at this place is sufficient to provide passage for the smooth flow of traffic.
2. There is no permanent spring in the active slide zone with the exception of a small spring about 100 m towards Thakot on the main road. However, small seepages develop in the slide zone during the monsoon period and create slush conditions. As the catchment area of this slide is not large, therefore, proper channelization of spring water be done to safeguard the road from the debris material falling on it.
3. Side drains along the road are also recommended to safely drain the water into the nullah.
4. Scaling of the loose boulders, vulnerable to sliding also need removal, for the future safety of the road. Biotechnical stabilization is also recommended

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APPENDICES

SOME COMMONLY USED GEOLOGICAL TERMS

Appendix-1

Acidic

Term applied to igneous rocks containing more than 65 per cent silica (SiO_2).

Calcareous

Term applied to sedimentary rocks containing calcium carbonate.

Calcite

The mineral calcium carbonate, CaCO_3 .

Chert

Very fine-grained, siliceous rock containing crypto crystalline quartz, chalcedony, opal, or a combination thereof. Porous varieties are usually light coloured and have splintery fractures. Dense varieties are hard, have conchoidal fracture, greasy luster, and occur in many colours including white, yellow, brownish stained, or green. The coloured varieties are sometimes called 'Jasper' and dense, gray variety called 'flint'. All varieties will scratchy glass and cannot be scratched by a knife blade. Some of its constituents may be reactive with cement alkalis, it should also be considered suspect as concrete aggregate for exposed concrete in cold climates.

Clay

Very fine particles consisting of hydro silicates of aluminum or magnesium or both. In concrete aggregates, the term frequently refers to these materials occurring as coatings fine than the No.200 (75mm) sieve which may be removed by washing. Clay may also occur well dispersed in rocks between laminations so as to weaken the structure or cause the particle to be susceptible in freeze-thaw attack.

Claystone

An indurated clay, having the texture and composition of shale but lacking its fine lamination fissility, a massive mudstone in which clay predominates over silt, a non-fissile clay shale.

Conglomerate

- (1). Rock consisting of rounded pebbles cemented together with finer material.
- (2). A coarse-grained, clastic sedimentary rock, composed of rounded to sub angular fragments larger than 2mm in diameter (granules, pebbles, cobbles, and

Adverse Hydrological Conditions

Groundwater table rises up temporarily in the monsoon. It washes out the cementing material from soil and rock masses.

Perched water table builds very fast in the monsoon on impervious surface, e.g. clay seams, clay layers, bedrocks, etc.

Water pressures in tension cracks not only pushes the slope forward but it also generates pore-water pressure along joints or bedding planes. As the slide starts, the opening of the rough joints increases due to dilatation. Thus, the plane of sliding acts as a natural channel for the flow of water.

Seepage from choked catch drains may raise pore-water pressure along the slip surface. Inadequate size and choking of roadside drains may also lead to the same problem.

Pressure of aquifers, such as sand layers or sandstone layers (in between impervious beds) can cause very high pore-water pressure on overlying layers in slopes in sedimentary deposits.

Saturation destroys capillary tension in soils and reduces its cohesion **because** of the increase in moisture content. Earthquake may liquefy loose, fine solid and seams in the rock mass.

Anthropogenic Factors

a. Deforestation

Intensive deforestation has taken place in most part of the Himalayas, Karakoram.

b. Improper Land Use

This includes:-

- agricultural practices on steep slopes.
- irrigation on steep and vulnerable slopes
- overgrazing and
- quarrying for construction material without considering the conditions of the terrains.

c. Construction Activities

Improper or total lack of terrain capability evaluation before placement of infrastructure on hills, roads and canals, located in areas with high slope instability, results in frequent hazards. And unlined canal across a potential or

Earthquake induced landslide were caused by 33.5 percent of the total shocks in China, excluding earthquakes in marine areas, in Xizang and Taiwan (Feng and Gue 1985). Apart from the earthquakes themselves (i.e. seismic accelerations, duration of shock, focal depth, and angle and direction of the approach of seismic waves), the environmental factors, such as geology and landform, play an important part in the formation of landslides induced by earthquakes. This is why some smaller earthquakes induced far more landslides than other large earthquakes. Geological structures and the lithological character of rocks influence the landslides. Landslides are commonly seen on the slopes and spurs of mountains cut by faults. On slopes consisting of loosened limestone and igneous rocks, falls occur readily, but on slopes consisting of claystone, shale and phyllite, falls are few of in number.

Erosion Process

Blocking of natural drainage system and narrow culverts by logs, boulders, and gully bank slides.

High flow velocities in steep gullies move very large boulders that destroy roads, culverts, and the ecosystem.

Large-scale slide of banks along steep gullies or nullah can even block the river after very long spells of continuous rains and form a landslide-dam.

Uncontrolled flow of rainwater on slope surface washes out solid and boulders. Wind erosion leads to the formation of heaps of loose soil or slope material (thin chips of rocks) on the road.

Falls

Falls are abrupt movements of slope materials that become detached from steep slopes or cliffs. Movements occur by free fall or a series of leaps and bounds down the steep slope. The relatively free character and lack of a slide plane differentiates the rock fall and rockslide. Depending upon the type of slope materials involved, it may be a rockfall, soilfall, earthfall, boulder fall and so on.

GLACIAL LAKE OUTBURST FLOODS

Glacial lake outburst floods (GLOF) are debris torrents from a sudden and catastrophic release of water from a lake of glacial origin. The lakes are usually impounded by glacial ice or moraine. GLOF are generated either by the overlapping of lake water by ice or moraine, or by seepage and piping under these dams, resulting in their ultimate collapse. GLOF are common in glaciated mountain ranges, including the Himalayan and Karakoram. There are numerous

Landslide Trigger

- i. Cloud burst (200-1,000mm per day)
- ii. Uncontrolled flow of water on slope surface from over flooded steep gullies.
- iii. Toe cutting may activate failure by over toppling of rock blocks or slides in colluvium.
- iv. Earthquake vibrations.
- v. Blasting vibrations.
- vi. Flash flood due to glacier lake outburst/failure of landslide dam/cloudburst, etc.

Mass Wasting

Mass wasting is a general term for a variety by which large masses of earth materials move under gravity, either slowly or quickly, from one place to another. The term landslide is commonly used to denote downward and outward movements of slope-forming materials along surface separation by falling, sliding, and flowing at a faster rate. Although landslides are primarily associated with mountainous regions they can also occur in areas of low relief, especially in surface excavation for highways, buildings and open-pit mines. The geological history and human activities often cause unstable conditions that lead to slope failure.

Mechanics of Landslides

Once the landslide has taken place, it is easier to know its mechanics. It may be recalled that the mode of sliding may be idealized for simple and common landslides as given below:-

Rock Slope

- i. Planar sliding.
- ii. Wedge sliding along two joint planes.
- iii. Circular wedge sliding.
- iv. Dip sliding/sliding of regolith (Crozier 1986).

Soil/Talus Slope

- v. Talus or debris slide along bedrock/clay seam (just like dip sliding) in case of dip slopes in talus.
- vi. Circular wedge sliding in homogenous soil mass or colluvium.

Gullies

- vii. Circular/plane wedge sliding along banks.

- g. Seismic activity. The Himalayan Range lies in a high seismicity belt. Several active faults have been mapped. Landslides due to seismic loading are very common.

Progressive Failure of Landslides

Theoretically, cut slopes should fail in the first instance monsoon wherever conditions for sliding exist. However, in reality, slopes may fail progressively in several years. If corrective measures are not taken in time, failure may progress slowly upwards to several hundred metres. Eventually it may reach the top of the mountain. Another interesting observation is that some rock slopes fail violently, releasing a vast amount of stored strain energy in the form of rock blocks moving with a fast speed. However, such failures are rare. Violent failure is possible along pre-existing, non-circular surfaces of weakness only because movement is locked in until brittle failure of the hard rock occurs.

Intensive field research is needed in order to know more about landslides in the Himalayas. Natural landslides may be more difficult to understand and control. These are defined as landslides caused by natural causes. Man-made landslides are defined as those occurring due to man-made causes (as discussed above).

Rainfall-induced Landslides

Rainfall is another important landslide trigger. There is a direct correlation between the amount of rainfall and the incidence of landslides, as indicated below:-

- a. If cumulative precipitation of the area amounts to about 50mm to 100mm between the dry and daily precipitation is more than 50mm, somewhat small-scale and shallow debris landslides will occur.
- b. When the cumulative precipitation amounts to about 150mm, and daily precipitation is about 100mm, the number of landslides has a tendency to increase with precipitation.
- c. When cumulative precipitation exceeds 250mm over two days and has an average intensity of more than 8mm per hour in one day, the number of large and vast landslides increases sharply.

Slides

The term slides refers to the mass movements with a distinct surface or zone of weakness separating the slide material from the more stable underlying materials. The two major types of slides are rotational and transitional.

LANDSLIDE DATA
Between Khunjerab Pass and Gilgit
AUGUST, 1996 to JULY, 2000

Appendix - III

F.W.O Loc (KM) S. No	Date & Time	Size of Slides LxWxH (Ft)	Type of Slide
AUGUST, 1996			
213. KM-630	11/1400	200x300x1	Boulder fall
214. KM-618.5	19/0500	30x30x4	Mud Flow
215. KM-618.7	19/0500	30x30x4	Mud Flow
OCTOBER, 1996			
216. KM-620	03/0700	50x20x10	Mud Flow
217. KM-619	03/0900	40x25x8	Mud Flow
218. KM-624	23/1600	100x3x49	Boulder fall
NOVEMBER, 1996			
219. KM-751	04/1520	50x15x25	Glacier
220. KM-609	04/2300	250x15x15	Boulder fall
DECEMBER, 1996			
221. KM-791	03/0900	15x15x8	Rock Slide
222. KM-745	04/1630	180x25x20	Rock Slide
223. KM-772	30/1130	54x15x15	Boulder fall
JANUARY, 1997			
1. KM-745	18/1250	25x18x3	Rock slide
2. KM-773	21/1215	25x12x10	Rock slide
3. KM-740	26/1145	110x22x15	Rock slide
4. KM-614	08/0800	200x30x30	Boulder fall
5. KM-656	09/1230	200x22x20	Boulder fall
MARCH, 1997			
6. KM-746	15/1130	95x22x10	Rock slide
7. KM-625	20/0700	30x25x6	Boulder fall
8. KM-803	19/1730	20x4x8	Snow avalanche
9. KM-625	21/0700	15x20x4	Boulder fall
10. KM-625	31/0900	100x30x8	Boulder fall with Scree
APRIL, 1997			
11. KM-627	15/0600	30x30x4	Mud Flow
12. KM-615	16/1100	100x50x30	Scree with Boulder fall
13. KM-601	25/1500	30x30x3	Mud Flow
14. KM-602	24/2000	100x22x1	-do-
15. KM-601	25/1100	40x30x3	-do-
MAY, 1997			
16. KM-618	04/0100	30x30x4	Mud Flow
17. KM-602	04/1200	40x30x4	-do-
18. KM-619	04/0800	50x30x6	-do-
19. KM-745	04/1300	100x19x6	Rock Slide
JUNE, 1997			
20. KM-752	21/1800	95x22x10	Mud Flow
21. KM-618	30/0630	50x30x6	-do-
JULY, 1997			
22. KM-618	01/0800	50x30x5	Mud Flow
23. KM-743	15/1200	95x25x6	Boulder fall
24. KM-768	16/1500	62x25x6	-do-
25. KM-768	18/1050	200x25x4	Mud Flow
26. KM-759	18/1730	150x75x3	-do-
27. KM-581	20/2100	450x22x8	-do-
28. KM-751	21/0730	25x30x8	-do-
29. KM-781	21/1800	120x15x3	Mud Flow
30. KM-570	22/0800	25x22x22	-do-

F.W.O Loc (KM) S. No.	Date & Time	Size of Slides LxWxH (Ft)	Type of Slide
31. KM-571	22/0800	510x22x6	-do-
32. KM-572	22/0800	90x21x200	-do-
33. KM-573	22/0800	310x22x3	-do-
34. KM-577	22/0800	180x22x6	-do-
35. KM-637	23/0830	30x30x3	-do-
36. KM-640	23/0800	60x40x6	Mud Flow
37. KM-578	27/0800	450x28x11	Boulder fall
AUGUST, 1997			
42. KM-618	02/0730	600x300x3	Mud Flow
43. KM-733	02/0800	200x200x10	Rock Slide
44. KM-602	02/1700	30x30x4	Boulder fall
45. KM-577	11/0815	30x31x25	Road Washed
46. KM-577	12/1130	75x30x24	Mud Flow
47. KM-577	12/0630	30x30x25	-do-
48. KM-633	13/0600	50x30x8	Boulder fall
49. KM-577	15/0630	31x125x10	-do-
50. KM-577	15/0930	-do-	-do-
51. KM-577	15/1130	-do-	-do-
52. KM-577	16/1320	-do-	Mud Flow
53. KM-735	22/0700	28x16x3	Road cut
54. KM-577	22/0730	30x20x5	Rock Slide
55. KM-632	24/0900	153x93x25	Boulder fall
SEPTEMBER, 1997			
56. KM-726	12/0830	35x7x4	Rock Slide
57. KM-637	27/1730	25x6x2.5	Boulder fall
58. KM-625	28/1200	20x2x12	Mud Flow
59. KM-658	30/1400	100x4x2.5	Rock Slide
OCTOBER, 1997			
60. KM-745	01/1100	60x30x5	Rock Slide
61. KM-649	03/1200	50x30x3	Boulder fall
62. KM-692	30/0800	50x10x9	Boulder fall
FEBRUARY, 1998			
63. KM-725	07/0800	60x13x10	Boulder fall
64. KM-583	17/1400	450x135x90	Glacier
65. KM-663	17/1500	411x30x30	Avalanche
66. KM-583	18/0400	500x40x50	-do-
67. KM-653	18/1400	25x12x5	Boulder fall
68. KM-693	18/1300	50x13x5	-do-
69. KM-663	21/1100	600x60x40	Avalanche
MARCH, 1998			
70. KM-618	10/1300	25x7x2	Boulder fall
71. KM-618	14/1300	25x6x2	-do-
APRIL, 1998			
72. KM-649	21/1500	30x20x1	-do-
73. KM-618	25/0900	30x20x8	Mud Flow
74. KM-730	25/1500	25x14x5	-do-
75. KM-564	25/1500	30x20x3	-do-
76. KM-581	25/1700	100x35x12	Rock Slide
77. KM-574	26/0700	150x50x3	Mud Flow
78. KM-735	25/1700	150x20x8	-do-
79. KM-618	25/0900	50x20x8	Mud Flow
80. KM-618	25/0900	50x20x10	-do-
81. KM-617	25/0900	60x20x15	-do-

F.W.O Loc (KM) S. No.	Date & Time	Size of Slides LxWxH (Ft)	Type of Slide	F.W.O Loc (KM) S. No.	Date & Time	Size of Slides LxWxH (Ft)	Type of Slide
179. KM-615	23/0600	200x30x10	Boulder fall	230. KM-745	22/1400	180x30x24	Boulder fall
180. KM-582	29/1100	95x25x12	Boulder fall	231. KM-757	24/1200	380x31x25	Mud Flow
MARCH, 1999				232. KM-762	26/1200	480x30x60	Avalanche
181. KM-651	02/0800	500x21x50, 750x25x45	Boulder fall	233. KM-763	26/1200	65x10x5	-do-
182. KM-733	09/6000	30x15x10	River Scoring Action	234. KM-786	29/1200	360x300x55	-do-
183. KM-745	12/0700	60x30x20	Boulder fall	235. KM-726	30/1500	61x25x25	Mud Flow
184. KM-733	13/1030	65x10x25	Mud Flow	236. KM-727	30/1400	180x25x25	-do-
185. KM-754	14/1300	40x5x15	Avalanche	237. KM-651	06/0900	105x30x9	Boulder fall
186. KM-753	14/1400	150x5x10	Avalanche	238. KM-663	06/1500	108x46x25	Mud Flow
187. KM-757	15/0900	40x10x30	Mud Flow	239. KM-797	13/1700	195x31x46	Glacier
188. KM-775	14/1300	60x15x30	Boulder fall	240. KM-604	18/1500	130x25x20	Boulder fall
189. KM-743	21/1300	20x22x7	Mud Flow	241. KM-610	21/0700	130x25x15	-do-
190. KM-729	21/1600	30x8x1	-do-	242. KM-718	22/1015	45x30x5	Mud Flow
191. KM-733	21/1345	60x67x18	-do-	243. KM-759	25/1400	60x10x8	-do-
192. KM-743	23/1100	60x25x6	-do-	244. KM-759	27/1000	50x6x8	-do-
193. KM-729	21/1030	84x25x6	-do-	245. KM-751	08/1800	30x25x8	-do-
194. KM-651	24/1330	91x72x16	Boulder fall	246. KM-750	17/1930	25x20x6	-do-
195. KM-797	21/2215	200x8x10	Avalanche	247. KM-751	17/1945	25x20x8	-do-
196. KM-741	26/1500	30x30x6	Mud Flow	248. KM-730	30/0900	40x25x20	River scoring
197. KM-733	26/1000	75x30x6	-do-	1999 - 2000			
198. KM-818	28/1245	25x24x9	-do-	1. KM-733	19/0730 Jul,99	30x20x10	Debris Slide
199. KM-651	28/2130	25x24x5	-do-	2. KM-709	19/0800 -do-	50x22x7	Mud Flow
APRIL, 1999				3. KM-517	21/0730 -do-	61x19x7	-do-
200. KM-739	02/0700	25x22x4	Boulders fall	4. KM-733	22/0900 -do-	30x20x15	Debris Slide
201. KM-759	02/1945	80x22x4	Avalanche	5. KM-733	30/0500 -do-	100x20x20	-do-
202. KM-733	04/0900	25x22x4	Mud Flow	6. KM-709	02/0800 Aug,	750x25x6	Mud Flow
203. KM-618	04/1200	25x24x5	-do-	7. KM-711	02/0830 -do-	425x24x6	-do-
204. KM-742	04/1700	150x21x9	Boulder fall	8. KM-619	04/0700 -do-	35x21x30	Boulder fall
205. KM-741	04/1500	40x22x7	Mud Flow	9. KM-577	06/0630 -do-	107x22x13	Mud Flow
206. KM-741	05/1100	60x21x6	-do-	10. KM-568	11/0500 -do-	182x31x12	-do-
207. KM-651	05/1800	60x25x10	Boulder fall	11. KM-569	11/0500 -do-	50x7x3	Mud Flow
208. KM-648	06/1215	30x35x10	Mud Flow	12. KM-520	12/0400 -do-	150x66x10	Mud Flow/ Boulder fall
209. KM-618	08/0700	30x2x5	Mud Flow/ Boulder fall	13. KM-577	12/0500 -do-	35x8x5	Mud Flow
210. KM-608	08/0830	150x21x25	Boulder fall	14. KM-582	12/0530 -do-	100x6x9	-do-
211. KM-775	08/1500	80x7x9	Avalanche	15. KM-618	15/0800 -do-	120x12x20	Boulder fall
212. KM-665	12/1500	400x30x21	-do-	16. KM-606	15/1700 -do-	50x15x10	-do-
213. KM-651	11/1100	50x21x4	Mud Flow/ Boulder fall	17. KM-733	06/1910 Sep,99	40x20x20	Gutter hole in Road
214. KM-581	12/0900	150x50x30	-do-	18. KM-733	03/0900 Oct,99	60x21x21	Boulder fall
215. KM-751	12/1600	40x210x30	Avalanche	19. KM-745	24/0900 -do-	69x21x3	-do-
216. KM-733	12/1400	90x21x6	Mud Flow	20. KM-766	04/1600 Nov,99	20x8x3	-do-
217. KM-735	12/1500	75x30x15	Boulder fall	21. KM-725	06/1200 Dec,99	30x24x6	-do-
218. KM-665	12/1830	450x21x100	Avalanche	22. KM-615	16/1500 -do-	50x24x6	Debris Slide
219. KM-748	13/0600	100x22x12	Boulder fall	23. KM-587	31/1700 -do-	80x10x2	Mud Flow/ Boulder fall
220. KM-582	13/0600	100x24x30	Mud Flow	JANUARY, 2000			
221. KM-747	13/0600	100x22x12	Boulder fall	24. KM-746	04/1700	80x22x8	Boulder fall
222. KM-756	13/0900	80x7x7	Avalanche	25. KM-608	17/1530	50x10x7	Mud Flow
223. KM-751	14/1200	300x21x30	-do-	26. KM-608	23/1800	45x10x25	-do-
224. KM-735	15/0900	90x21x22	Mud Flow	FEBRUARY, 2000			
225. KM-745	15/1400	300x22x16	Boulder fall	27. KM-665	1/1600	200x27x20	Avalanche
226. KM-737	18/1000	35x20x10	Mud Flow	28. KM-775	15/1600	60x6x24	Boulder fall
227. KM-739	18/1600	150x21x21	Mud Flow	29. KM-664	20/1100	675x71x60	Avalanche
228. KM-750	21/1600	34x13x8	Glacier	30. KM-783	27/1615	20x8x5	Mud Flow
229. KM-733	22/1600	30x10x5	Boulder fall	APRIL, 2000			
				31. KM-665	02/1800	57x27x15 M	Avalanche

LANDSLIDE DATA
Between Gilgit and Hasanabdal
JULY, 1996 to JULY, 2000

Appendix-IV

FWO S. No.	Loc (KM)	Date & Time of Occurrence	Size of Slide LxWxF (Ft)	FWO S. No.	Loc (KM)	Date & Time of Occurrence	Size of Slide LxWxF (Ft)
1.	KM-291	04-7-96/1500	30x20x7	51.	KM-327	21-3-98/0900	40x20x14
2.	KM-234	04-7-96/1815	23x20x5	52.	KM-323	21-3-98/2130	75x12x14
3.	KM-243	04-7-96/1830	22x20x4	53.	KM-280	22-2-98/2200	50x11x8
4.	KM-246	04-7-96/1850	23x20x5	54.	KM-335	22-2-98/2200	50x12x12
5.	KM-230	14-7-96/1915	10x8x6	55.	KM-349	22-2-98/2200	60x10x10
6.	KM-241	14-7-96/2130	20x22x6	56.	KM-280	22-2-98/2200	225x12x30
7.	KM-242	14-7-96/2210	20x24x5	57.	KM-335	22-2-98/2256	50x12x12
8.	KM-241	14-7-96/2210	75x24x8	58.	KM-335	22-2-98/2256	90x25x30
9.	KM-242	14-7-96/2215	40x22x8	59.	KM-280	15-2-98/0500	500x30x24
10.	KM-242.40	14-7-96/2145	20x20x7	60.	KM-290	15-2-98/0900	300x15x6
11.	KM-243.50	14-7-96/2230	42x24x8	61.	KM-291	15-2-98/0900	15x10x6
12.	KM-243.70	14-7-96/2235	90x24x10	62.	KM-315	18-2-98/1700	100x25x24
13.	KM-315	16-7-96/1100	20x15x10	63.	KM-335	18-2-98/1600	200x25x24
14.	KM-317	16-7-96/0845	250x40x30	64.	KM-349	19-2-98/2100	100x20x24
15.	KM-334.50	03-8-96/0330	50x24x5	65.	KM-180	20-2-98/1400	400x24x150
16.	KM-236	03-8-96/0430	40x2x24	66.	KM-237	20-2-98/1900	100x24x10
17.	KM-236.50	03-8-96/0515	150x24x10	67.	KM-280	23-2-98/1400	15x11x10
18.	KM-238	02-8-96/2345	24x3x18	68.	KM-335	23-2-98/1400	15x12x12
19.	KM-239	02-8-96/2315	36x3x24	69.	KM-349	23-2-98/1400	15x10x10
20.	KM-239	02-8-96/2315	75x2x24	70.	KM-280	23-2-98/1700	40x11x10
21.	KM-211	02-10-96/1315	47x15x6	71.	KM-349	24-2-98/1500	70x20x12
22.	KM-448.50	03-10-96/0615	50x20x15	72.	KM-184	24-2-98/1500	500x24x3
23.	KM-448.50	03-10-96/1630	630x30x30	73.	KM-180	04-3-98/0830	500x30x50
24.	KM-449	17-10-96/0530	150x30x15	74.	KM-183	03-3-98/1800	500x25x10
25.	KM-260	20-10-96/0600	50x20x15	75.	KM-188	04-3-98/0915	200x30x20
26.	KM-466	31-10-96/0300	240x24x30	76.	KM-189	04-3-98/0930	200x25x5
27.	KM-427	25-11-96/1630	50x20x3	77.	KM-180	04-3-98/0830	500x30x50
28.	KM-474	25-2-97/0400	04x10x25	78.	KM-183	03-3-98/1800	500x25x10
29.	KM-278	25-2-97/1000	50x8x5	79.	KM-188	03-3-98/0915	200x30x20
30.	KM-242	16-3-97/1030	70x20x10	80.	KM-189	04-3-98/0930	100x25x5
31.	KM-326	19-3-97/0915	54x15x10	81.	KM-222	04-3-98/0950	90x20x15
32.	KM-245	20-3-97/1630	54x15x10	82.	KM-335	04-3-98/1430	200x20x20
33.	KM-326	19-3-97/1630	40x25x10	83.	KM-374	04-3-98/1030	70x25x20
34.	KM-302	19-3-97/1650	50x20x08	84.	KM-317	06-3-98/1745	150x24x20
35.	KM-466	7-4-97/0445	125x30x06	85.	KM-317	06-3-98/1030	150x24x20
36.	KM-240	14-4-97/1630	30x5x2	86.	KM-323	07-3-98/1800	220x24x60
37.	KM-315	14-4-97/0530	110x225x9	87.	KM-222	08-3-98/1500	100x24x20
38.	KM-184	28-6-97/0315	100x40x50	88.	KM-293	08-3-98/1600	100x24x20
39.	KM-310	28-6-97/0740	50x10x8	89.	KM-359	25-4-98/0800	90x21x18
40.	KM-466	27-8-97/2230	80x24x10	90.	KM-191	25-4-98/0945	89x26x23
41.	KM-216	9-9-97/0745	100x15x20	91.	KM-451	25-4-98/1230	70x10x24
42.	KM-280	16-2-98/0100	500x30x24	92.	KM-280	25-4-98/0430	50x5x15
43.	KM-280	18-2-98/1100	75x18x30	93.	KM-359	25-4-98/0730	100x2x10
44.	KM-315	18-2-98/1700	100x25x24	94.	KM-191	254-98/0630	150x24x6
45.	KM-335	18-2-98/1600	200x25x24	95.	KM-451	25-4-98/1230	70x10x24
46.	KM-349	19-2-98/2100	100x20x24	96.	KM-313	25-4-98/2030	100x20x24
47.	KM-280	20-2-98/1600	30x11x6	97.	KM-465	26-4-98/0730	35x22x6
48.	KM-280	20-2-98/1930	30x24x20	98.	KM-326	26-4-98/0001	200x20x24
49.	KM-180	20-2-98/1930	400x12x10	99.	KM-465	26-4-98/0730	70x22x6
50.	KM-323	21-2-98/0900	75x12x14	100.	KM-326	26-4-98/0001	200x20x24

FWO S. No.	Loc (KM)	Date & Time of Occurrence	Size of Slide LxWxF (Ft)	FWO S. No.	Loc (KM)	Date & Time of Occurrence	Size of Slide LxWxF (Ft)
207.	KM-324	17-3-99/0900	100x24x10	259.	KM-239	31-5-2000/1400	24x4x30
208.	KM296	20-3-99/0730	600x24x100	260.	KM-239	31-5-2000/1400	24x8x35
209.	KM-324	21-3-99/1800	100x24x15	261.	KM-240	31-5-2000/1400	24x10x50
210.	KM-296	24-3-99/1200	100x24x10	262.	KM-240	31-5-2000/1400	24x7x40
211.	KM-296	25-3-99/0800	160x24x35	263.	KM-471	11-6-2000/0600	40x20x10
212.	KM-305	11-4-99/0730	500x25x34				
213.	KM-315	12-4-99/0530	65x24x10				
214.	KM-303	13-4-99/1245	20x24x4				
215.	KM-305	13-4-99/1245	500x24x25				
216.	KM-310	13-4-99/1245	30x24x5				
217.	KM-315	13-4-99/1245	24x12x7				
218.	KM-324	13-4-99/1245	40x24x10				
219.	KM-300	13-4-99/1245	24x23x3				
220.	KM-341	13-4-99/1245	130x30x50				
221.	KM-349	13-4-99/1245	120x25x24				
222.	KM-365	13-4-99/1245	150x24x14				
223.	KM-350	13-4-99/1245	56x24x4				
224.	KM-465	13-4-99/1245	15x24x5				
225.	KM-295	25-4-99/1230	240x40x24				
226.	KM-295	27-4-99/0730	40x24x20				
227.	KM-270	2-7-99/2030	600x24x7				
228.	KM-271	2-7-99/2030	140x24x10				
229.	KM-273	2-7-99/2030	250x24x10				
230.	KM-274	2-7-99/0600	900x24x12				
231.	KM-222	11-7-99/1730	24x10x10				
232.	KM-222	19-7-99/1830	100x10x24				
233.	KM-191	9-8-99/2005	20x20x2				
234.	KM-466	9-8-99/2100	150x24x25				
235.	KM-417	11-8-99/0300	10x24x3				
236.	KM-418	11-8-99/0300	15x24x25				
237.	KM-420	11-8-99/0300	25x24x25				
238.	KM-424	11-8-99/0300	30x14x4				
239.	KM-425	11-8-99/0300	60x24x8				
240.	KM-429	11-8-99/0400	10x24x3				
241.	KM-427	11-8-99/0500	110x24x6				
242.	KM-425	26-8-99/1400	200x4x4				
243.	KM-240	1-9-99/1600	130x25x6				
244.	KM-241	1-9-99/1600	120x30x8				
245.	KM-242	1-9-99/1600	75x15x6				
246.	KM-243	1-9-99/1600	135x30x5				
247.	KM-244	1-9-99/1600	150x24x6				
248.	KM-485	2-9-99/2015	150x24x4				
249.	KM-486	2-9-99/2015	50x12x6				
250.	KM-339	6-11-99/2300	22x7x6				
			30x6x5				
			40x5x5				
251.	KM-260	15-1-2000/0600	100x25x10				
252.	KM-260	2-2-2000/0600	60x15x24				
253.	KM-306	10-2-2000/0530	30x5x24				
254.	RM-307	12-2-2000/1015	33x5x24				
255.	KM-328	1-4-2000/1700	250x15x24				
256.	KM-306	3-4-2000/1615	80x10x24				
257.	KM-238	31-5-2000/1400	300x24x12				
258.	KM-239	31-5-2000/1400	24x6x60				

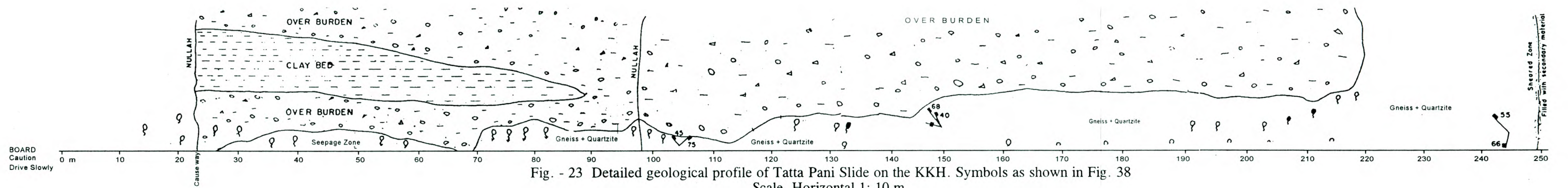


Fig. - 23 Detailed geological profile of Tatta Pani Slide on the KKH. Symbols as shown in Fig. 38
Scale. Horizontal 1: 10 m.
Vertical. Not to scale.

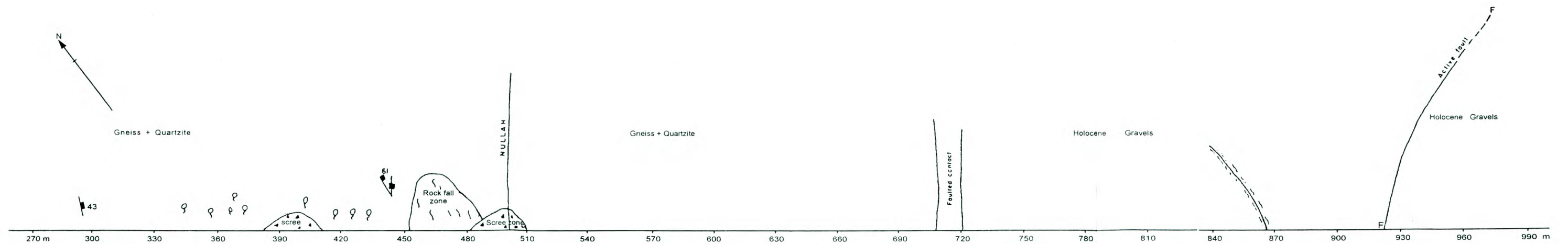


Fig. - 24 Detailed geological profile of Tatta Pani Slide on the KKH. Symbols as shown in Fig. 38
Scale. Horizontal 1: 30 m.
Vertical. Not to scale.