PLEISTOCENE SEDIMENTS AND CHRONOLOGY OF MIDDLE INDUS AND LOWER GILGIT VALLEYS BETWEEN SHATIAL AND DAINYOR

by

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A thesis

presented to the National Centre of Excellence in Geology, University of Peshawar in partial fulfillment of the requirement for degree

of

MASTER OF PHILOSOPHY

IN GEOLOGY

Session 1983-84

C O N T E N T S

ABSTRACT

Thick valley-fill deposits preserved in deep valleys in Indus, Gilgit and Hunza river areas and a variety of age dates allow new defination of Quaternary events in Karakoram Himalaya. Three glacial stages of Pleistocene are recognized with several advances in Holocene. The early stage is indurated lower Jalipur tillites and hetrogenous upper Jalipur valley-fill sedimentary rock younger than 1 to 2 myr. and folded, overturned or overridden by movement of Raikot fault associated with rapid overall uplift rates of Nanga Parbat - Haramosh massif. Middle stage is two tills intercalated with in variable sediments, including thick lacustrine units dipping upto 43° along fault. Indus-Shatial tills record the farest advance down Indus of Pleistocene glacier at this time. Late stage consists of three or more seperate advances that retain moraine topography; the Dianyor moraine near Gilgit was produced by a major longitudinal glacier from Hunza. Downstream at Jaglot, Nanga Parbat, Shatial and elsewhere, transverse glaciers blocked Indus to produce lake deposits now dipping upto 6° along the fault. Catastrophic breakout floods emplaced some Punjab erratics and sediments that was reworked into locsses in the Himalayan fore land.

ACKNOWLEDGEMENT

In the name of Allah, the most merciful and benificial. All praises be to Him with whose grace I have reached this stage.

I would like to express my profound gratitude and indebetness to Professor Dr. John Ford Shroder Jr. University of Nebraska at Omaha U.S.A. for suggesting this topic and overall supervision of the thesis. He had been kind enough to teach me geomorphology and most of his ideas are incorporated in this thesis. I am also thankful to him for is guidance in field and laboratory work.

I owe deep acknowledge and thanks to Professor Arif Ali Khan Ghauri, National Centre of Excellence in Geology for his valuable discussion and reading the final draft of the thesis, and also for providing transport during the field work.

Professor Muzaffar Ali Rizvi, Chairman, Department of Mining Engineering University of Engineering and Technology is particularly thanked for his kindness and encouragement.

I am also thankful to my friends, Mehtab Ahmed Lodhi, Habib-ullah Khan and Shahina Tariq for helping me in various ways, without which I would have not been able to complete this work.

Mr. Sabir Hussain of the National Centre of Excellence in Geology is thanked for typing the manuscript.

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CHAPTER-1

INTRODUCTION

The area of this project comprises the lower Hunza Valley, Gilgit and middle Indus Valleys up to Sazin Village, but also includes the tributary valleys from Kohistan and Nanga Parbat that join the main river and have a rich stratigraphic record of Quaternary history, tectonism and geomorphic processes now preserved in deep valley . This section is approximatly 200 km long with a nearly three per thousand average inclination. The height at Gilgit point is 1440 meters above sea level while height at Shatial is 800 m, so the relief difference between the two points is 640 m.

SCOPE OF INVESTIGATION

The main objectives of this investigation are as follows:

1. To locate and map all the tills, moraines and the lacustrine sediments, and to draw cross-sections of the main valley at suitable places.

2. To measure thickness of various glacial till deposits and to correlate them within the area.

3. To establish a chronology of Pleistocene glaciation i.e., the sequence of ancient glaciation in order to understand the glacial history in early, middle and late Pleistocene times.

4. To understand the age and nature of active tectonism in the area.

FIELD PROCEDURE (METHODOLOGY)

The project was initiated after a reconnaissance journey to Gilgit and Hunza in January 1984. The main feasibility field work was don

June and July 1984. The final data collection, field measurements and correlation work were carried out during the fall of two consective years i.e. 1984-85.

Many sections were visited in and around Hunza, Gilgit and upper and middle Indus drainage basins. The work was organised as a detailed study of early to late Pleistocene longitudinal tillites, tills and moraines in the main Gilgit and Indus valleys and the study of late Pleistocene sediments and transverse moraines from side valleys. Side valleys reconnaissance included Naltar, Astor, Gor, Ame Ges, Gini, Thalpan, Ghichi and Skardu valleys. The sections chosen for detailed work in the Gilgit and Indus valleys were selected mostly on the basis of their location away from side valleys where complications could have developed by the movements of transverse glaciers.

During the detailed mapping of the area from Gilgit to Sazin all important sections and areas, the sites of older and younger lake beds formed by the temporary damming of the valleys were marked at their proper locations.

Data collection techniques primarely involved measuring and describing sections and stratigraphy of the outcrops of early and middle Pleistocene age. Buried tills were correlated on the basis of relative lateral position, type of clasts and weathering and lithologic contacts. Younger material was studied mainly by reconnaissance of surface weathering phenomens, especially formation of desert varnish, exfoliation spalls, granular disintegration and size of weathering pits and hollows.

To established the chronology of the study area, compiling of lake sediments from various valley fill units was done and their TL (thermoluminescence) dating was done (at University of Nebraska at Omaha by Shroder). This new technique enables measurement of the length of time, same minerals have been exposed first to sunlight and then buried in sediments away from the surface.

PHYSIOGRAPHY

The Karakoram-Himalayan region, commonly refered to as the northern areas of Pakistan, extends between 34° 40' N and 37°N latitude and 72° 31' E and 78°E longitude. For the purpose of administration it is divided into three districts, i.e. Gilgit, Diamir and Baltistan. The region covers an area of 43388.8 km^2 and is exceedingly roughed, including parts of the world's greatest mountain systems, i.e. the Himalayas, the Karakoram and the Hindukush.

The Karakoram-Himalayan region has great variation in relief. The maximum is (8,272 meters) from the mouth of Indus gorge to the summit of K2 (8,611 meters) a straight line distance of some (416 kms). The mountain systems of the area possess some of the highest peaks of the world e.g. K2 (8,611 meters), Nanga Parbat (8,125 meters),Rakaposhi (7,790 meters) and Haramosh (7,397 meters). Within 100 km radius of Gilgit there are about two dozen lofty peaks, ranging from 5,454 meters to 7,878 meters. The area consists largely of very steep slopes.

Interupting the mountain systems are numerous valleys ranging from 4.8 km to 128 km in length, which are divided into three catagories according to their size and form. The main valleys are 16 km to 64 km and the short valleys are 4.8 km to 16 km long. An important observation regarding the drainage in the area is that almost all large and small streams drain into river Indus (Symposium on Resources and development in the Karakoram Himalayas, 1983, Geography Department, University of Peshawar).

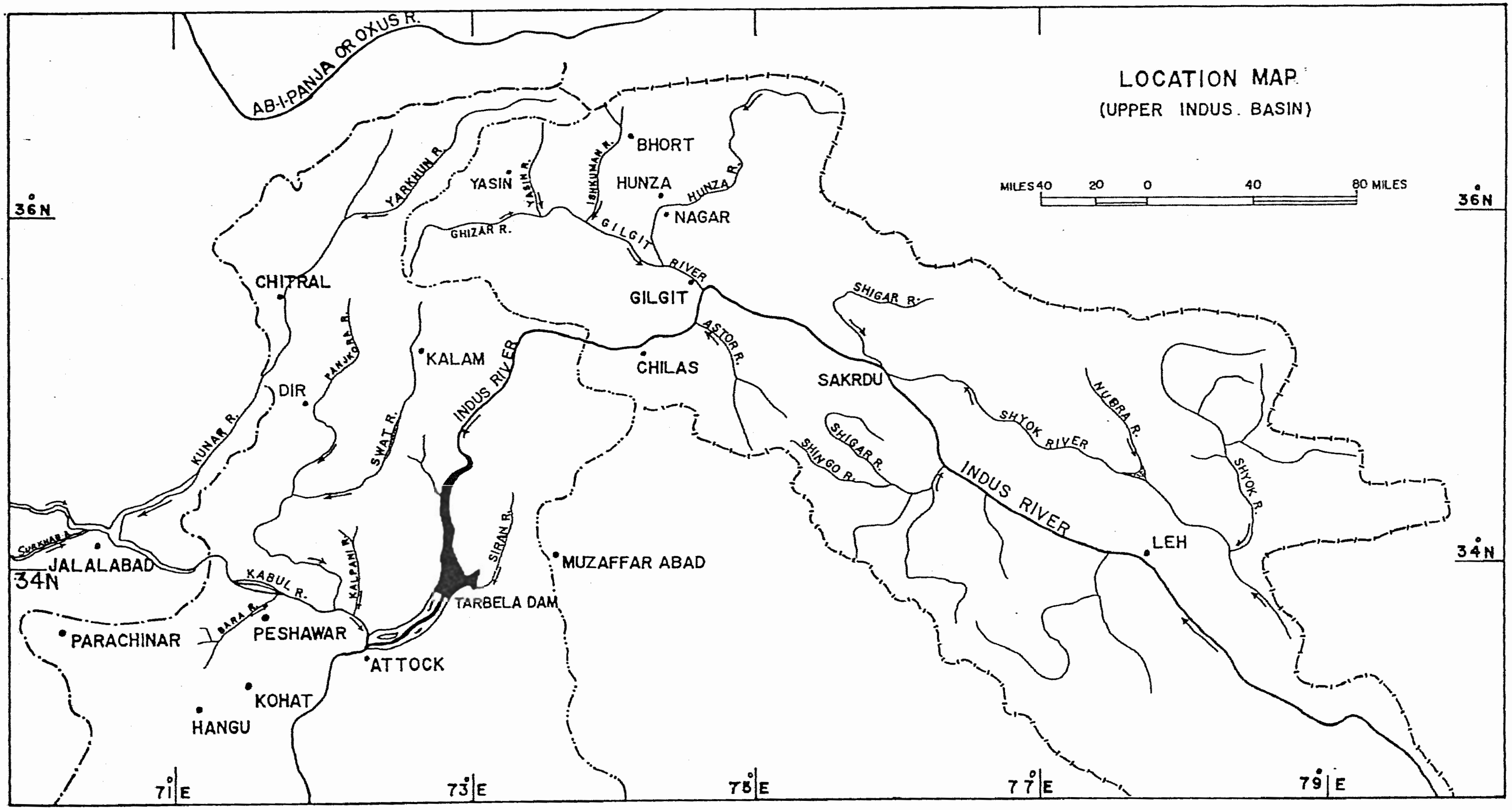


Fig.1 LOCATION MAP OF THE AREA

The main Indus river rises in the snow covered Kailas range of the Himalayas, flows about 600 km through Ladakh into Baltistan where it spreads over a large area and forms small scattered pools. Here the Shyok river joins it from the east and in the broad Skardu basin the Braldu-Shigar river system enters from its sources in the glaciers of K2 massif and the main Karakoram-Himalaya to the north. From Baltistan the upper Indus continues to flow northwest for a further 100 km into a deep canyon and past Haramosh peak (7,397) into Diamir district. At Sassi Village the river bends sharply south along an active fault element of the Nanga Parbat-Haramosh syntaxis and later flows out into the broad open valley of middle Indus to join the equally broad valley of Hunza - Gilgit tributaries. These tributaries constitute main drainage of the Rakaposhi massif and western Karakoram, which was the chief source of glaciers down the Indus during Pleistocene time. The Indus river than flows south about 25 km in the broad steep sided valley to receive Astor and other tributaries from Nanga Parbat massif on the southeast (Fig.1). The river then turns due east of the massif along the active fault element of the syntaxis and later maintains its wide valley. It also receives other tributaries including Thalpan, Dudishal, Gini, Khanbari etc. from both north and south up to Sazin. Here the river receives the Darel and Tangir rivers from north out of Kohistan massif and narrows again before swinging south to flow 170 km in a deep gorge with numerous tributary canyons to Tarbela Dam at the mountain front.

From a geographical point of view, the valley may be divided into two parts: The upper part between Gilgit and Astor river confluence

(50 km) having a north-south direction and a relatively broad bottem occupied by large lacustro-glacial terraces, covered with huge alluvial fans. The second or the lower part (392 km), where the river remain confined in a deep rocky gorge, is very winding and can be divided into following four sections.

1. From Astor up to Bandi-Sazin (153 km), having an east-west trend.

2. From Bandi-Sazin up to Komila Bridge (32 km), having again a north-south direction.

3. From Komila Bridge up to about 7 km down stream from Besham Qila, having north-east to south-west direction.

4. The last section from Besham Qila up to the foot of the mountain at Tarbela (132 km) takes again the general north-south direction, but has a sinuous course before reaching the plain. This irregular route provides the evidence of a very complex tectono-morphologic history of the region traversed by Indus. The same idea is advanced by Desio and Orombelli (1971).

CLIMATE AND VEGETATION

The Karakoram Himalayan region is characterized by an extremly rugged topography with high mountains and deep gorges. Due to diverse topography, the climate of this region is highly variable depending upon the elevation, slope, orientation of ranges, valley width, changes in its course and other physical conditions. Generally winters are very cold and summers mild to very hot. The temperature ranges between -2.2°C to 35°C. Situated in the heart of high mountains the region receives less than 254 mm average annual rainfall. The precipitation approaches 508 mm in Astor valley, 254 mm to 381 mm in Darel and Tangir Valleys and 127 mm to 254 mm in the northeast (National Symposium on Resources and Development in the Karakoram, Himalayas, 1983, Geography Department, University of Peshawar).

REGIONAL GEOLOGY AND TECTONIC HISTORY

The northern segment of Pakistan hosts three of the best known mountain chains of the world, the Himalaya, Karakoram and Hindukush. Among these, the lesser Himalayas received much attention by the earlier workers because of an easy access. The Middle and Upper ranges remained more remote until the late 1960s when the opening of Karakoram Highway linked them with the modern world.

The geological and tectonic features developed in the northern part of Pakistan are the product of collision of Indian plate with the Eurasian plate 55 m.y. ago. This collission occurred due to the northwards subduction of the floor of Tethys ocean under the Eurasian plate sandwiched between the two mighty continents; Eurasia and Indo-Pakistan.

The northern and southern limits of Kohistan Island arc are marked by two branches of Indus suture zone which marks the collision line of India and Eurasia in Pakistan (Desio, 1964). The northern one, the Hini-Chalt-Yasin-Drosh line is called northern megashear (Matture et al., 1979) or Main Karakoram Thrust (Tahirkheli et al., 1979) which separates the Kohistan rocks from the Asian mass. The southern line which has been traced along Babu Sar - Jijal - Shangla - Mingora and Khar fault is named as southern megashear (Matture et al., 1979) and Main Mantle Thrust (Tahirkheli, 1979).

The tectonic setting of the Kohistan and the adjoining areas have been variously interpretted by Tahirkheli (1979, Powell (1979), and Klootwijik (1979). A recent tectonic model of northern Pakistan, however, has been modified from the earlier workers and is based on the recently determined radioactive ages. (Jan and Asif, 1981). It includes the following events:

1. EARLY TO MIDDLE CRETACEOUS

Northward facing subduction of Neo-Tethyan crust to produce volcanic and plutonic rocks (Drosh, Chalt, Shyok, Kohistan amphibolites) resulting in the formation of Kohistan Ladakh Island arcs.

2. LATE CRETACEOUS

Intrusion of Chilas, Jijal, Kargil basic complex and development of blueschist, also some early granites of Kohistan and Ladakh.

3. PALEOCENE TO VERY EARLY EOCENE

Collision of the island arc with India (Powell, 1979), obduction of ophiolites and blueschists, simultaneous north and south facing subduction of the oceanic crust intervening between Gondwanic microcontinent and the island arc to produce the earlier phases of regional metamorphism in the Karakoram and Kohistan-Ladakh granitic belts.

4. EOCENE TO EARLY MIOCENE

Eruption of Eocene Kalam volcanites and younger intrusions in two granitic belts (Jan et al., 1981).

5. POST EARLY MIOCENE

Crustal thickening and production of the youngest plutonic rocks in the Karakoram belt (Jan et al., 1981).

STRUCTURE

The main features of the geological structures are generally east-west trending faults of different ages, generally deformational episodes indicated by varied trends of folding and associated foliation (Ishtiaq et al., 1981). The structures of the area are the direct out come of the interaction between the three major tectonic elements of the region that were sutured together in the mid Cenozoic i.e., the Asian plate on the north, the Indian plate on the south and the mafic-rich Kohistan island arc cought and crumpled between the two mighty plates (Coward et al., 1984). The Hunza river near Chalt passess through the northern megashear or Main Karakoram Thrust which is trending N 85^{o}W near Chalt (Amjad and Saqib, unpublished thesis, 1981) and is considered the northern suture zone between Kohistan island arc and the Eurasian plate in this region. The upper Indus flows parallel to this zone and just south of it in the Ladakh pluton, part of the Kohistan arc. The Nanga Parbat - Haramosh syntaxis is a major warped part of the Main Mantle Thrust (MMT) or suture zone between the Indian plate and the Kohistan arc (Shroder, unpublished data, 1986). The lower part of the upper Indus appears to have been deflected to the north and entrenched by active tectonism in this zone in late Cenozoic. Late Pleistocene sediments at Sassi have been faulted by this activity (I. Madian, unpublished thesis, 1986). The upper middle Indus seems to have been deflected past Nanga Parbat massif in a long arc to the west along the active MMT fault zone at the mountain base (Ganser, 1980; Lawrance and Ghauri, 1983; Lawrance and Yeats, 1984). Thus in this tectonically active area early Quaternary sedimentary rocks, especially the Jalipur units, are preserved.

GEOMORPHOLOGY

The geomorphology and the Quaternary history of the Indus valley, including its tributaries in western Himalayas, are the result of complex interaction between exceptionally active cenozoic tectonism including some of the world's most recent uplift, i.e. 1 cm/year (Zeitler *et al.*,1982) which is coupled with equally high denudation rates (1.8 mm/year; Ferguson 1984) that are produced by the processes of weathering, rivers, glaciers, frost wind and mass-movement (Shroder unpublished data, 1986). This geomorphic variability is also controlled by great vertical climatic zonation that has varied through climatic change in Late Cenozoic. Another important contributing factor is the steepness of the terrain and its maximum relief with a continuous gradient of about 540 m/km in 11 km from the Hunza valley bottom at 1,850m to the summit of Rakaposhi (7,790 m) and the relief of over 7,000 m in 21 km from Indus valley bottom to the summit of Nanga Parbat isolated out in front of the main Karakoram Himalaya. The interaction between these controlling factors produces dynamic geomorphic processes that have sculpted a multi-faceted landscape. Erosional processes are dominant but the sediments are preserved either high on valley side walls or in deep valley bottoms along the faults and plate suture zones which allow the formulation of essential chronologies to establish geomorphic history.

Intensive study of bed rock and structure by several investigators in the last two decades has contributed significantly to new understanding of Quaternary chronology and geomorphology of the area.

PREVIOUS WORK

In the past, Karakoram and Hindukush could not receive much attention due to the problem of access and lack of facilities available. There were no regular roads and the area was unsafe. The mountain sides are rugged and treacherous, but some pioneering geologists and mountaineering expeditions ventured into this area and contributed a great deal towards introducing the region to the outside world.

A brief account of the work produced, since the turn of this century, on the stratigraphy, geography and the history of sedimentation in this part of the world, is listed below:

Oestreich (1906) first studied the Quaternary geology of Karakoram velleys, concentrating on the areas from Kashmir to Skardu and Shigar. He could not produce any chronology but still his early work provides many useful informations.

De Filippi's expedition (1913-1914) and Dainelli (1922, 1934) made the first studies of glaciation in the north western Himalaya and laid the foundation for later glacial-geological research in Karakoram Himalaya and nearby areas including the Kashmir basin. They concentrated more on the upper Indus basin and its tributaries particularly around Shyok-Saltaro area, Skardu basin and Shigar-Braldu approaches to K2 mountain. Dainelli (1922) mapped and speculated about glacial effects for down the Indus, past Nanga Parbat and up its tributaries into Hunza. However, the main problem with his work was the correlation of his basic four fold sequence of Pleistocene glaciation. (Table 1) which is presumed to be parallel to that reported from the Alps by Penck and Bruckner (1909) (Porter, 1970). However extensive landforms and several sections described by him can be interpreted usefully in the light of modern understandings. Dainelli's map also provides locations of the wide variety of terraces, moraines, tills, lake clays, alluvium and eolian deposits that occur in the Karakoram (Table 1).

Norin (1925) visited some of Dainelli's sites in Kashmir, Skardu, Shigar and Shyok and produced a different chronology of two fold glaciation that was based upon Swedish varve chronology.

Grinlinton (1928) noticed a high level erosion surface possibly a site of disected plateau in the Himalaya directly east of Kashmir basin (from which sprang out the present higher peaks). A high level glaciation was thought to develop on this surface prior to later valley incision. His low level epoch of glaciation included four glacial advances.

A more detailed study of this area by De Terra and Peterson (1939) provided additional details. Although they traversed from upper Indus terrain in Kashmir in northern Pakistan to some parts across the border now in India. They retained the basic four fold subdivision established by Dainelli but recognized the greater antiquity of some deposits and pushed the sequence further back into Pleistocene (Table 3).

The many terraces of the Indus and its tributaries, the associated surfaces of erosion and deposition in Tibetan Plateau in the north in Himalaya up to Potwar Pleateau and the Punjab plain in the south, led the earlier workers to describe a Cenozoic tectonism and geomorphic evolution of the region.

Misch (1936) first described the Jalipur sequence of folded and faulted group of sandstone of diamictites which were investigated in detail by Olsen (1982) Misch described this sequence as gray, micaceous, well stratified sandstone that were conglomerates at places. He concluded that the unit is late Teritary to Early Pleistocene in age. Olson (1982) concluded on the basis of fission-track dates provided by Zeitler et al. (1982) that the maximum age of the Jalipur sandstone is about 2 million years and is much younger than thought before.

Paffin and others (1956) firstly identified high level erosion surface called" Pre-Pleistocene relief" above 4000 m in Hunza, Karakoram. Another level at 3000 m below the first one and deep gorges incised 1000 m. This upper surface was named "PATANDAS" by Chinese researchers (Batura Glacier investigation Group, 1979). The surface is smooth with scattered erratics, which probably represent a valley floor with a higher bench at 5200 m above it. The age of the Patanda surface is constrained by a bed rock (Rb/Sr date of 8.6 m.y.). Derbyshire et al. (1984) suggested that the surface is at least of early Pleistocene and can be correlated broadly with the Potwar Plateau, while the higher relief in Hunza would therefore be of Pleiocene age.

Wiche (1959) discussed glacial effects around Haramosh and in the Kohistan ranges between Chilas and Gilgit. He divided the Dianyor section in Gilgit valley into oldest and younger units (Table 4). He also maped moraines in Darel and Tangir valleys which are important in understanding the ice dams blocking the Indus near those sites in late Pleistocene.

Schneider (1959) discussed and described stratigraphy, morphology and weathering of various sediments in Hunza area recognizing a three fold sequence with upper and lower terrace remnants plus a moraine sequence which is close to modern glaciers (Table 4).

Porter's (1970) work, in Swat Kohistan was the first modern study applying relative age dating, morphology, stratigraphy of moraines and terraces, weathering properties of surface clasts and degree of soil development. Porter recognized three drift sheets Liakot (oldest), Gabral, and Kalam units, each one less extensive then the preceeding one.

Desio and Orambelli (1971) firstly described occuratly the presence of multiple moraines in middle Indus valley and erosional features of glaciers (both longitudinal and smaller transverse) above the Jalipur (Table 4). They recognized the Dudishal and Shatial moraines as the oldest and belived in furthest extent of longitudinal ice down the Indus valley. They also mentioned moraines at Gunar but were not certain about their being longitudinal or cross valley glacier. They described Dak Chouki moraine and called it as a typical and well preserved moraine amphitheatre, with the convexity towards west, that rises on the surface of a great valley bottom terrace consisting of fluviolocustrine or lacustro-glacial deposits. It is attributed to the last stage of the Pleistocene.

Kazmi (1977 unpublished data) tried to relate his work to the four fold chronology of De terra and Paterson (1959) and gave local names to the old non-geographic ordinal number system.

Said and Majid (1977) mapped Pleistocene sediments in Peshawar valley and related them to the four fold chronology.

A detailed study of glacial drift in the Hunza valley and around Batura glacier was under taken by Chinese scientists in response to the potential hazzards to the K.K.H. by the advances and variable water discharge from the Batura Glacier (Batura Glacier

Investigation group, 1976,79; Zang and Shi, 1980; Shi and Zang, 1984; Zang 1984). They recognized three Pleistocene glacial stages in Hunza valley and named these as Shanoz (oldest), Yunz and Hunza, followed by minor fluctuations in Holocene (Table 4).

Shanoz glaciation is named for isolated weathered erratics, 1000 m above and on both sides of Batura Glacier. Yunz glaciation is a group of weathered glacial sediments in a difluent col about 500 m above and runing southeast from the lower end of Batura to Passu glacier, while Hunza glaciation is the name given to weathered tills above and below Batura Glacier in Hunza valley.

Most recently Cronin (1982) described an early till at Buntag that Dainelli (1922) had assigned to his second glaciation and a later till at Satpura (Third glaciation) Cronin indicated that Bunthag till was deposited earlier to Brunches chron (0.73 m.y.).

Derbyshire et al. (1984) provided evidence for strongest tectonism in both north and south that started in early Pleistocene and disrupted wide spread areas of broad valleys and lake basins,

During the International Karakoram Project (Miller 1984), a number of British, Chinese and Pakistani scientests made studies including some useful ones on the glacial history of Hunza valley (Derbyshire et al., 1984). The prior Chinese work was directly incorporated into new chronology on the basis of thermoluminescence dating with the Yunz judged older, the late Pleistocene glaciation was further divided into three parts named Borit Jheel Ghulkin I and Ghulkin II.

1. Photograph showing Punjab erratics near Harro river. The rock is Nanga Parbat gneiss.

Rendell (1984) realized that the old work should be re-examined in the light of modern researches. She worked out a new modified relative chronology of Siwalik and Plesitocene deposits in the middle Soan valley of Potwar Plateau where early man sites exist (Table 4).

More recently Rendell (1985) has been successfull in obtaining thermoluminescence (TL) dates for two main phases of deposition of Potwar loess (Shroder written communication,1986).

The presence of large exotic blocks of crystalline rock in the vicinity of Indus valley outlet from the mountains east and south of Attock, were of great interest for investigators since 19th century. Vicary (1851) and Verchere (1866) first described them and Wynne (1877) and Theoblad (1887,1880) issued a series of papers on the subject.

The erratics under discussion are distributed along what is either an ancient Indus channel or a valley margin flood berm which corresponds roughly to the Harro River. They occur in alluvial deposits and some are isolated in loessic or lake sediments (Shroder, oral communication, 1986).

The common idea about the presence of these erratics is that they resulted from catostrophic floods down the Indus (De Terra and Paterson, 1939; Burbank, 1982) but there is no evidence to confirm that the temporary blockage of Indus river was due to glacier or simply landslip, and there are uncertanties about timings of their transport. A poosibility of ice bergs coming down with the flood and depositing these erratics at the present location has not yet been worked out (Discussion with Shroder and others).

Up to now the most recent and well organized contribution towards setting up the glacial stratigraphy of the northern areas of Pakistan is made by Shroder (1985). He has constructed a three fold chronology of the area with Jalipur glaciation being the oldest; overlain by valley fill during interglacial period. The middle Pleistocene glaciation is lower middle and upper middle followed by an interglacial period. The late stage Pleistocene glaciation is subdivided in four late stades of glaciation.

PRESENT WORK

The present work is mostly based upon Shroder's (1985) work which includes revisitation of the sites describe by others like Olsen (1982), Desio and Oramballi (1970), and Shroder (1985). The author has also discovered some new sites, determined the probably termination point for each glacial stage and sub stage and confirmed and revised the preliminary work by Shroder (1985).

CHAPTER-2

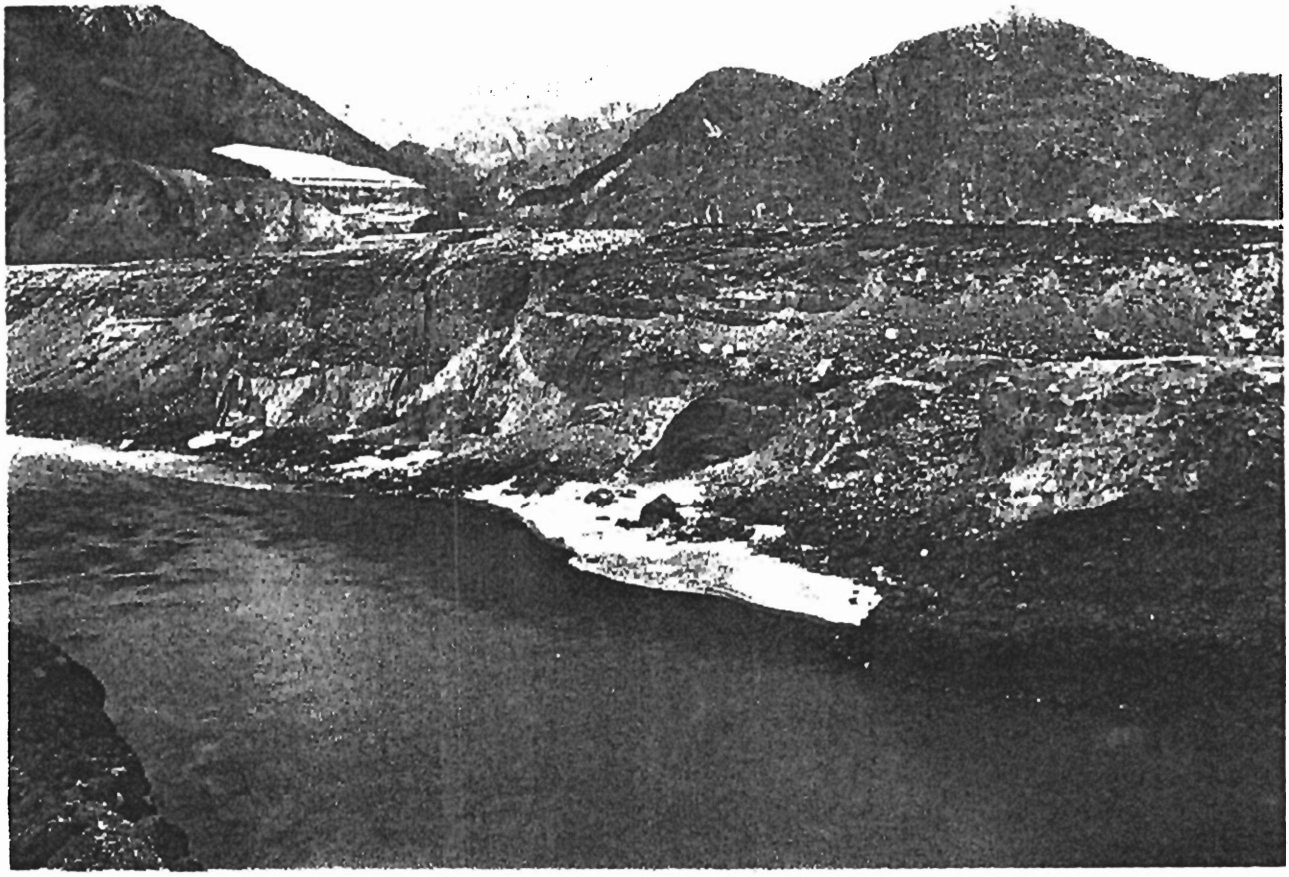
RESULTS

In establishing the Quarternary chronology of glacial and fluvial sediments in northern Pakistan, Shroder's work (1985) has been the main source of imprecation. However, the sequence was latter rearranged with the support of additional data and study of some new sections. The final chronology includes an earliest Pleistocene sequence which is sufficiently hard and indurated to constitute compact rock. This sequence is followed by a group of stacked tills of probably middle Pleistocene age which are blanketed by series of moraines of late Pleistocene and Holocene time. This sequence can be roughly correlated with the ordinal scale of four fold glaciation by Dainelli (1922) and De Terra and Paterson (1939).

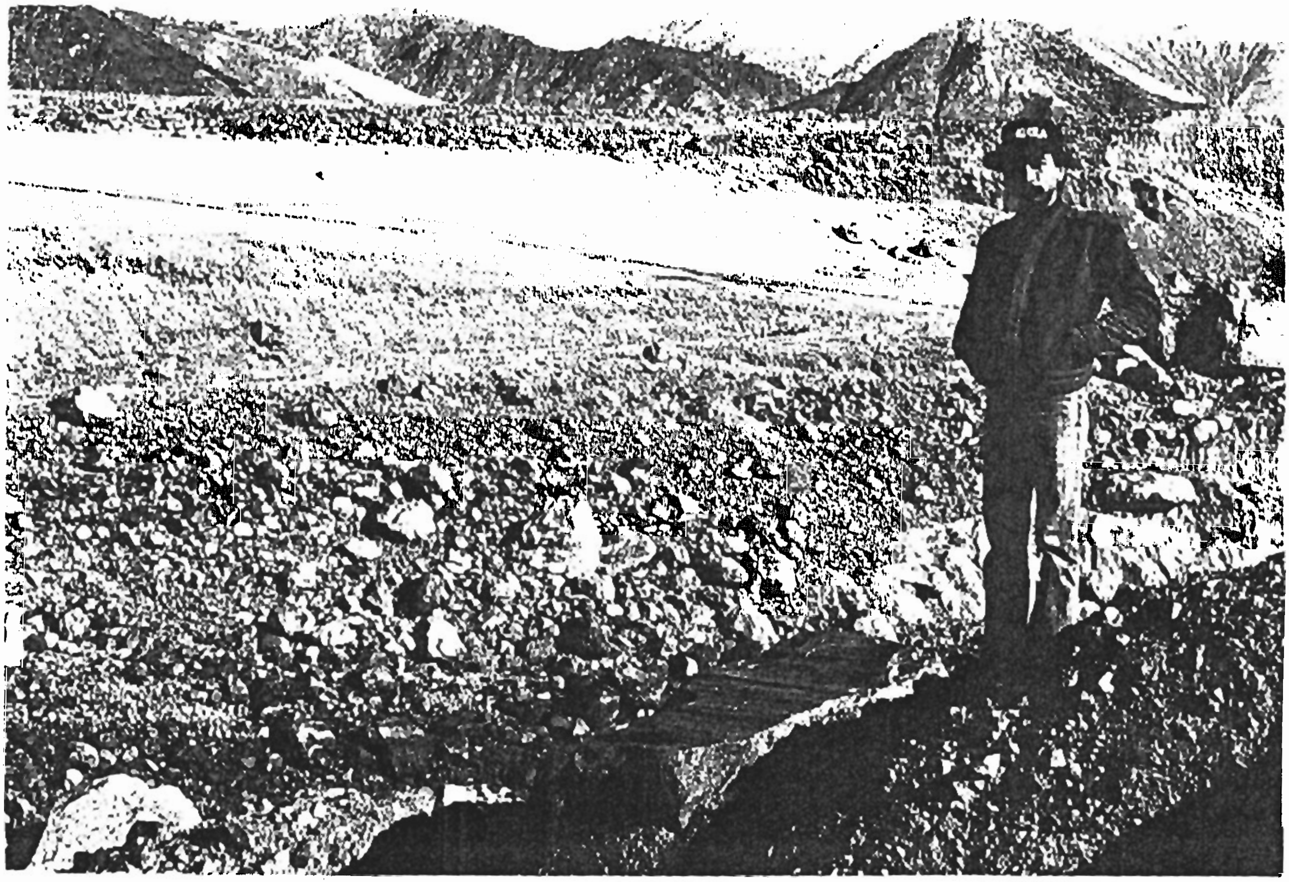
Following is a summary of the events drawn from the fluvial observations and measurements.

EARLY GLACIATION (LOWER JALIPUR TILL)

The Jalipur sequence was first described by Misch (1936) as a folded and faulted group of sandstones and diamictites. Since then not much attention was paid to this very important deposit. Later in 1952, Olsen carried out a basic, but significant work on these young deposits. The known outcrops of this unusual sequence are extended in a series of more than ten discontineous exposures along the main Indus river from the lower Gilgit valley over 100 km down the Indus valley to an elevation of about 500 m near Chilas. Almost all the



2. Photograph showing Jalipur in Indus river at KeGes bridge.



3. Photograph of a grooved and striated boulder near KeGes bridge.

Jalipur units are well indurated basal diamictite affected by subsequent tectonism.

The early to middle Pleistocene of the middle Indus valley is represented by the unusual Jalipur sequence. The most prominant and the westermost exposure of the Jalipur basal diamictite occurs at KeGes. Olsen (1982) described it as "at least 35 m of massive, unsorted, oligomictic matrix-supported conglomerate". The oligomictic nature of the diamictite and deformed soft sediments led Olsen to describe this unit as sedimentary in nature and not a glacial origin for the unit. However,the sedimentological characteristics of the diamicton that are indicative of ice contact deposition include:

(1) Small (less than 1 m) pods and lenses of fine grained sands and silts which are the characteristics of subglacial and englacial melt water deposition within lodgement and ablation tills. (Appendices A).

(2) Few linearly striated clasts (Appendix A).

(3) The great linear extent of the Jalipur sequence down valey.

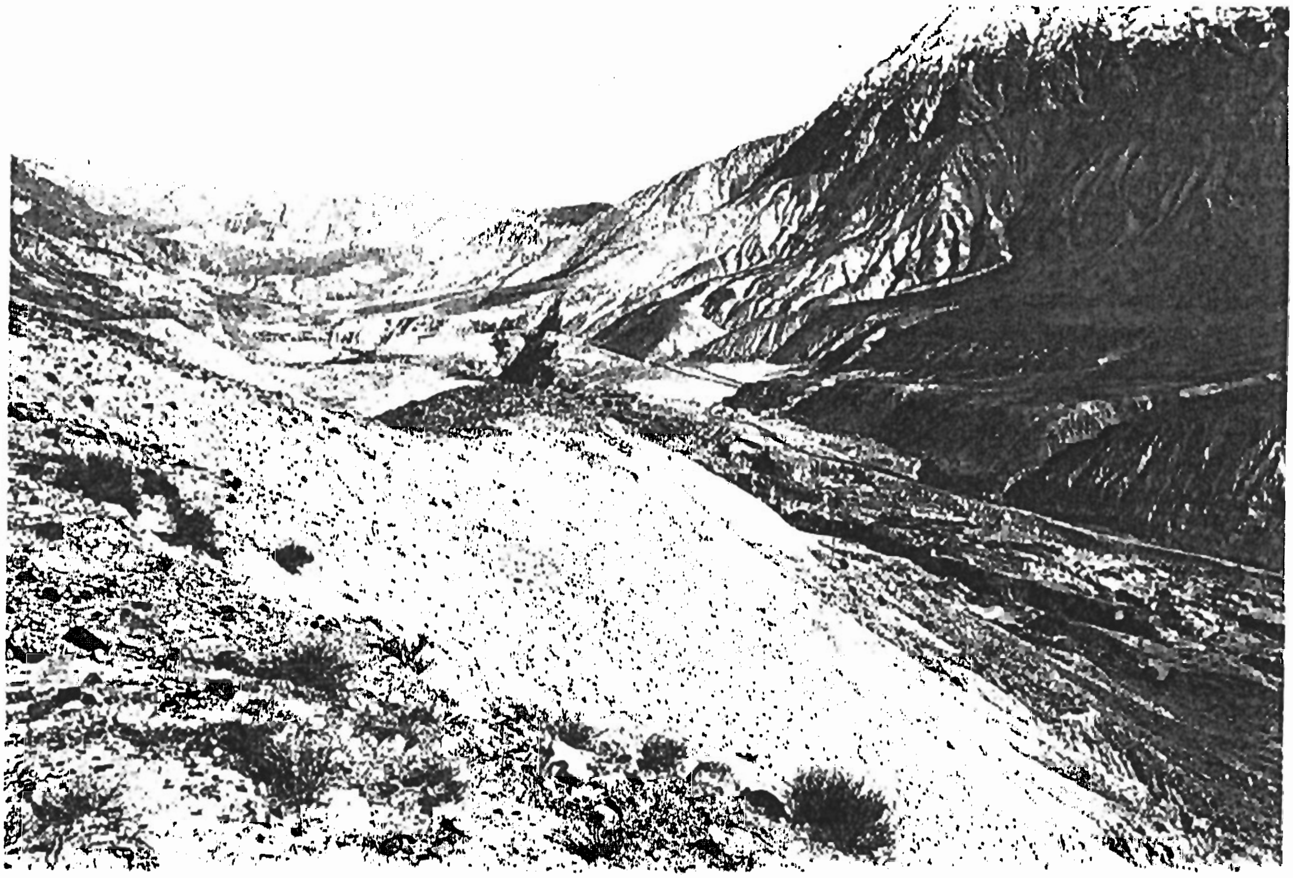
(4) The great thickness (up to 75 m) of similar matrix-supported diamictite.

(5) The presence of other clast lithologies in different localities.

(6) The presence of complexly contorted lacustrine siltstone with internal dropstones (Appendix C) at patro and at other places.

The unit does not have the alternating matrix-supported and grain supported stratification that is characteristic of the local mud-rock flow type of mass movement, which being the only other process that produces deposits somewhat similar in appearance. Furthermore the mudflows cannot produce lenses of fine clastics enclosed in a matrix-supported diamictite as found in the case of Jalipur. Finally the soft sediments deformation and dropstones are clear indicators of the units' being glacial in origin. The example is the glacier from Sai Nala between Jaglot and Bunji that dammed Indus river thus deforming the lake-beds (lacustrine clays). The above mentioned evidences suggests the basal Jalipur diamictite as tillite and is clear evidence for first glacial deposition in the western Himalayas.

The contact of lower Jalipur tillite with the underlying bedrock has been observed clearly at only one accessable place at Patro where slickensides trending 560^{o} to 80^{o}E were observed. These grooves were first mistaken with glacial striations but close observation revealed that they are tectonic slickensides on the lower sides of the limbs of a tightly overturned syncline produced by both lower and upper Jalipur (Lawrance and Shroder oral communications, 1985). At other places in deep gorge of Indus the contact of tillite with underlying bedrock showed the Jalipur sequence preserved in basins in the form of roches moutonnees. This therefore is another evidence for ice contact deposition. The author could not find



4. Photograph of overturned syncline of Jalipur as viewed from Patro moraine.

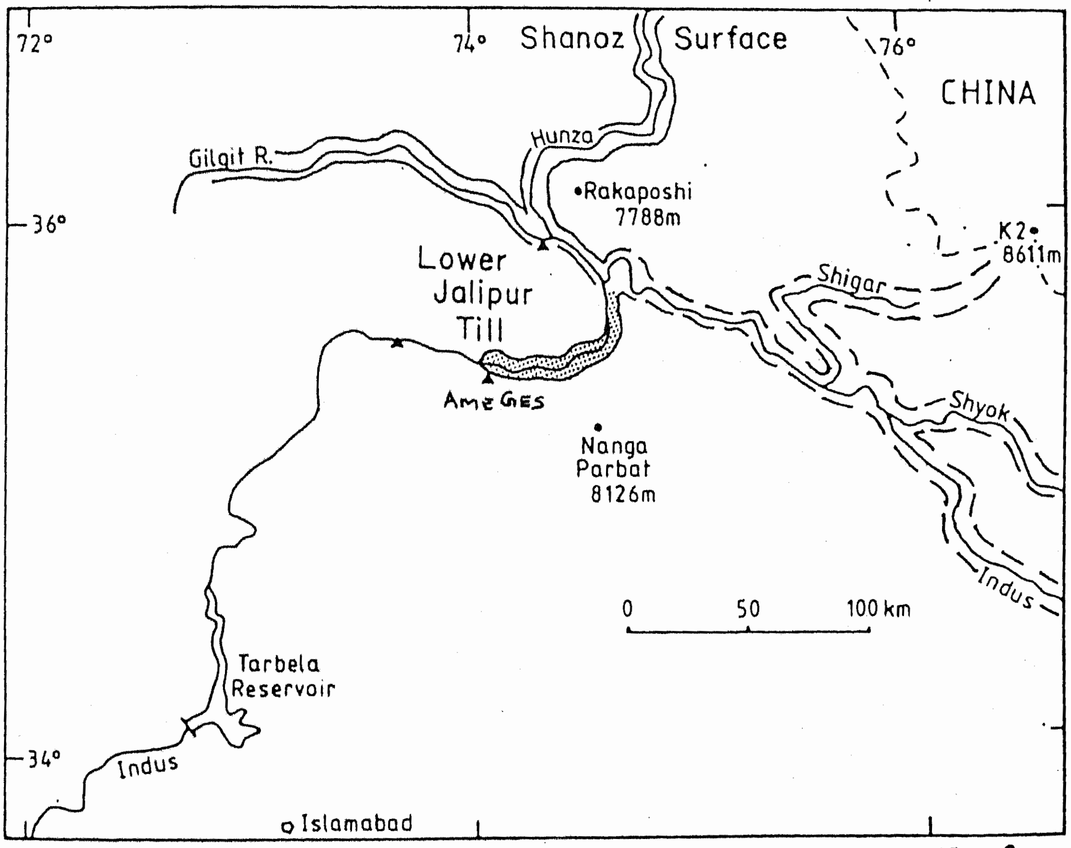
5. Another view of overturned Jalipur syncline, contorted lake beds with dropstones are present.

out any other locality where the diamictite overlies any other clastics above bedrock. Instead the diamictite rests upon the bedrock at all localities of observations providing an evidence for direct deposition of till.

During the Jalipur glaciation, many side valleys apparently contained ice that produced probably correlative planation surfaces in Hunza, in Shigar and elsewhere, thousands of meters above the present valley floor. The depositional record of which survived aside from a few erractics on high level (3000-4000 m) terraces.

According to Shroder (1985), the original surface was probably a rolling upland of hills and broad valleys that served as snow-catchment areas interspread with broad valleys that become axes of ice transport at the onset of early Pleistocene glaciation. Subsequent tectonism then has lifted parts of this surface above original levels and warped, overturned and faulted the Jalipur down into Indus trough to protect it from subsequent erosion.

The main Indus valley is quite wide from Chilas upstream while downstream from few km west of Chilas to Sazin, it is considerably less wide and is almost V-shape further west of Sazin. The possible explanation for this feature is that multiple glacial periods and surges occured upto Chilas but beyond, only a single ice mass of early middle glacial stage passed down stream from Chilas to Sazin. High level terrace remnants of an earlier broad



Early Glaciation

FIG 2.

6. Photograph showing Kame and outwash associated with Early middle till (M1) at Dudishal.

7. Photograph showing lake beds upstream from darel ice dam.

valley have been observed on both sides of main Indus valley, climbing up the valley walls further downstream from Sazin to Shatial. These high level terraces are the remnants of pre-Jalipur valley that has been raised in a westerly section due to subsequent tectonism, most probably due to the thrust faults.

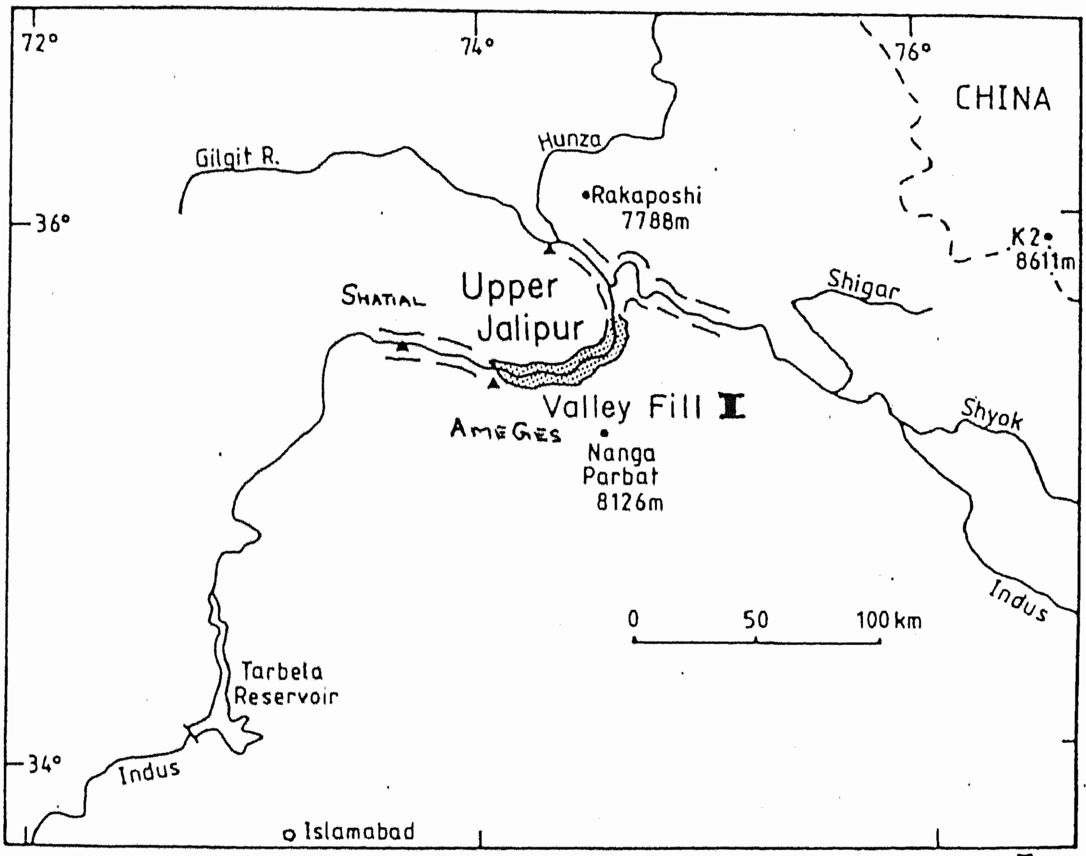
The Jalipur tillite is well indurated with no morainal topography being preserved on this old deposit. It is characterized by strongly weathered clasts which are difficult to remove from the binding matrix because of the disintigration of both clast and matrix.

PROBABLE END MORAINE

As described earlier, the most distinctive of all the Jalipur outcrops, KeGes bridge section is the most distinctive (75 m in thickness, Olsen, 1982). This being the westernmost exposure except another inaccessable part of it which is present 4 km downstream on the north east bank of Indus. No further exposures or outcrops have been observed, so the possible end moraine of first Pleistocene glaciation is at KeGes bridge area. However, it is also possible that this longitudinal glacier came down all the way upto Sazin but did not extend any further. (Fig.2)

EARLY-MIDDLE INTERGLACIATION (VALLEY FILL I)

The erroded top of Jalipur tellite is overlain by thick fluvial, alluvial clastics (Fig.3). These according to Olsen (1982) are similar to sediments being deposited in the Indus and surrounding valleys today. The thick and bedded clastic units that



Early—Middle Interglaciation

Fig 3.

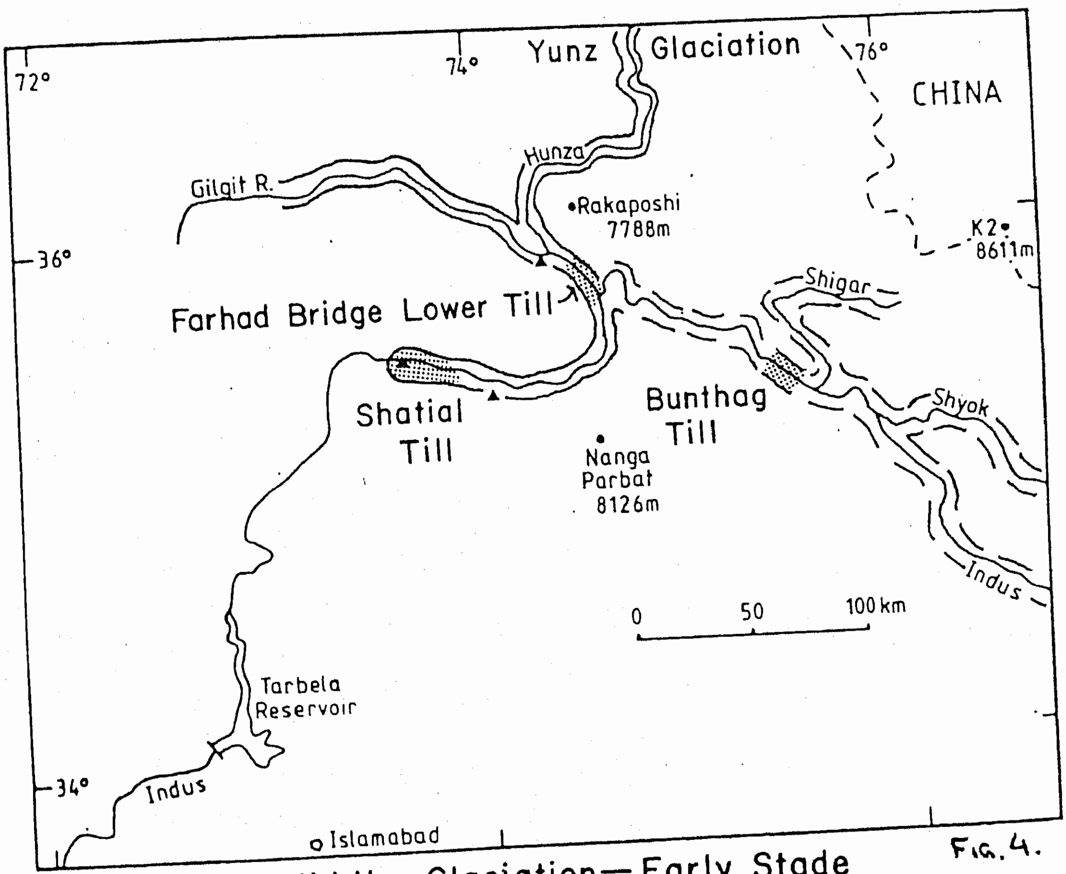
overlie the Jalipur sequence record on interglacial interval named as "VALLEY FILL I" (Appendix 1A,1B,1C). This interglacial period was long enough for the valley to fill with multi-process alluvial fan deposits from side valleys (as at Jalipur itself) and the more planer alluvial and lacustrine terrace deposits of the main valley. The fisson track dates obtained from sandstones present in this valley fill I, indicates the maximum age of the material to be 2 million years (Zeitler et al., 1982; Olsen, 1982; Shroder, 1985).

It has been observed that both tillite and overlying valley fill units are extensively deformed in the vacinity of Nanga Parbat near Raikot bridge. At Drang and Gor the gneissic bedrock has been thrusted at a high angle to the north over the tillite. While at other places e.g. Patro the valley fill I has been tilted up at steep angles or is even overturned in a tight syncline.

MIDDLE GLACIATION

The middle glaciation is represented throughout the middle Indus and lower Gilgit valleys by two stacked tills seperated by valley fill section. Which are preserved all along and on both sides of the main Indus valley at different attitudes above the river bottom. Among other, sediments are the glacio-fluvial, interglacial, fluvial and lacustrine sections that most likely developed due to:

1. The damming of main Indus by transverse valley glaciers.
2. Landslips.



Middle Glaciation—Early Stade

FIG. 4.

On the basis of revisitation of sites described by Shroder (1985) and the discovery of some new sites the two stacked tills were found separated by valley fill section (valley fill II) these two stacked tills allowed to divide the middle stage glaciation into:

1. Early stade middle glaciation
2. Late stade middle glaciation

Although the timing and duration of the interval is not clear.

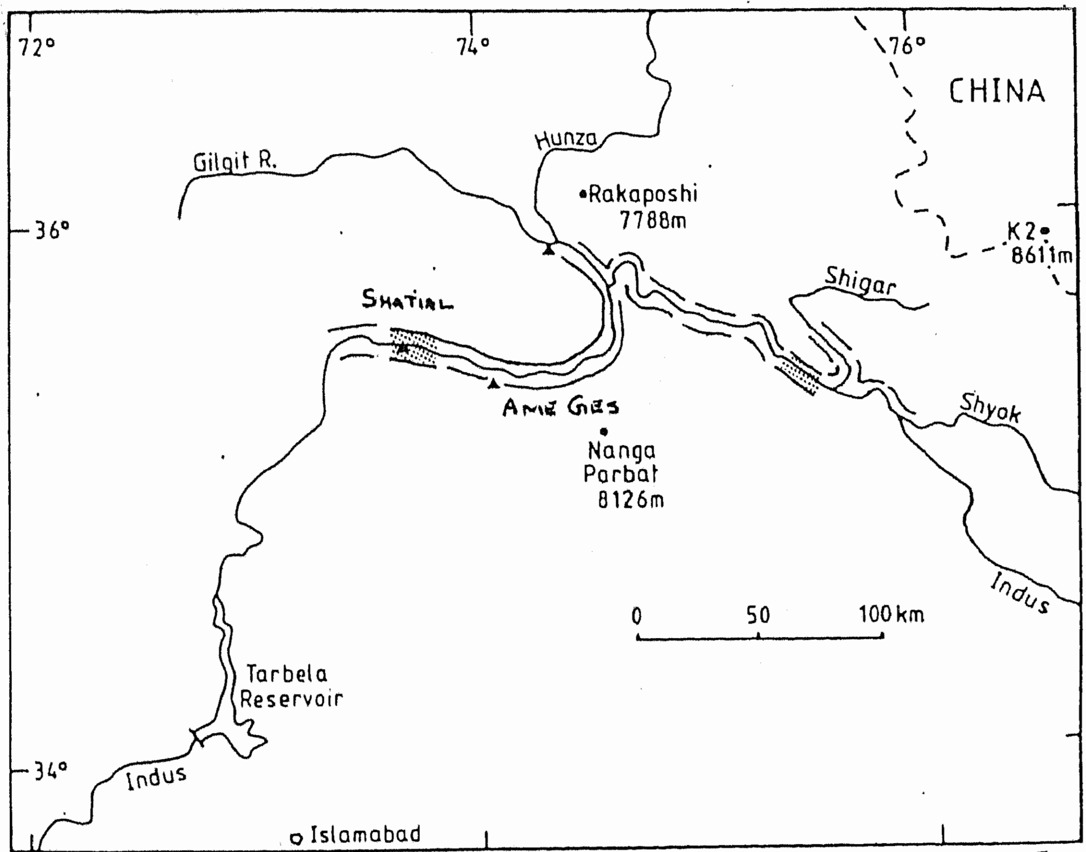
EARLY STADE MIDDLE GLACIATION

Starting from Sazin-Shatial area, which is the farest extent of Indus valley glaciation, numerous exposures of older till can be seen, with all the evidences of its being glacial, such as grooved and striated bedrock, buried roche moutonnee and other features of longitudinal valley glacial origin. This 150 m thick till which is situated between Daral and Tàngir valleys above the north end of Shàtial bridge is well indurated and not much weathered in its basal portion, where it is plastered against the valley wall and protected. It is cemented mostly by $CaCO_3$, probably derived by weathering of plagioclase rich norite which is characteristics of local bedrock. Both eastern and western ends of this till are overlain by a 100 m thick bedded clast, the middle part of which is scoured into series of maga-ripples having a wavelength of 27m to 30m (Fig.4) formed as a result of the catastrophic or breakout flood caused by temporary ice dam. These dams were produced from the accumulation of Daral -

Shatial cross valley moraine (L1). The evidence of which is present in the form of cross-valley moraines from Daral valley (details on the following pages). The glacial deposits in this area can be traced upstream in a series of disconnected exposures.

About 10 km upstream from Shatial at Dudishal between the KKH and the Indus River, occurs a section of till that Desio and Oromballi (1971) recognized as one of the older glaciation in the Indus valley (Photo 6). Close to the Indus river are exposures of bedrock knobs overlain by clast supported and matrix free angular colluvial blocks lodged in intervening hollows. This presumed colluvium passed upwords through a series of shear planes into relatively fresh matrix-supported lodgement till the upper part of which is cavernously weathered, with common angular disintigration. Many tills in this section between shatial and Chilas contain predominantly angular clasts of local norite bedrock. It was observed that the clast was more rounded than other tills upstream.

Directly across and down the Indus river, a place called Cheig i.e. (Cavernously weathered site) the same till is present high along the north side of the valley and is overlain by an estimated 50-100 meters of bedded coarse clastics of valley fill II. (Fig.5). This resembles lateral moraine (in aerial photographs) as it dips outword from the valley axis and into the valley wall slopes to form a ridge but on actual field examination, it is an eroded fluvial remnant.



Middle Glaciation—Valley Fill II FIG 5.

On the south side of the valley, 1-2 km upstream from Cheig, in KKH roadcuts occur roche moutonnee forms, overlain directly by lodgement till. Striations on stoss slope trending between 200° and 220° SW. At one striated bedrock outcrop which is overlain by till that is itself overlain by massive contorted bedrock, appears to be till or rockfall from south wall. Clastic dikes, a few cm to .5 m wide have been injected from below with plastic till, rounded mud balls, and erratics (Appendix D). Shroder (1985) beleives that the slope failure occured soon after deglaciation while the till was still wet.

No evidence of Jalipur ice part Chilas can be traced, therefore in every likelihood Jalipur ice did not reach much part Chilas, with the result that the valley could have been partly chocked with local frost-scattered rock prior to the arival of M1 ice. It has also been observed that this glacier does not appear to have eroded the valley much deeper, but clearly cut it wide. Had the case been otherwise, the angular clast and open matrix would be destroyed.(Shroder Oral communication, 1985).

Many other tills and overlying valley fill terrace clastics occur upstream from Shatial sites (Appendix D) are not accessable. However these sites visited by auther. On the study and correlation were found to be Early Middle till (M1).

Several tills in Gilgit valley,upstream from Chilas are quite clearly exposed and show intresting features. Among there are the Bunner Das terrace, Drang Jabardar Peak section, Farhad bridge section and Dainyor section etc are improtant and are described below:

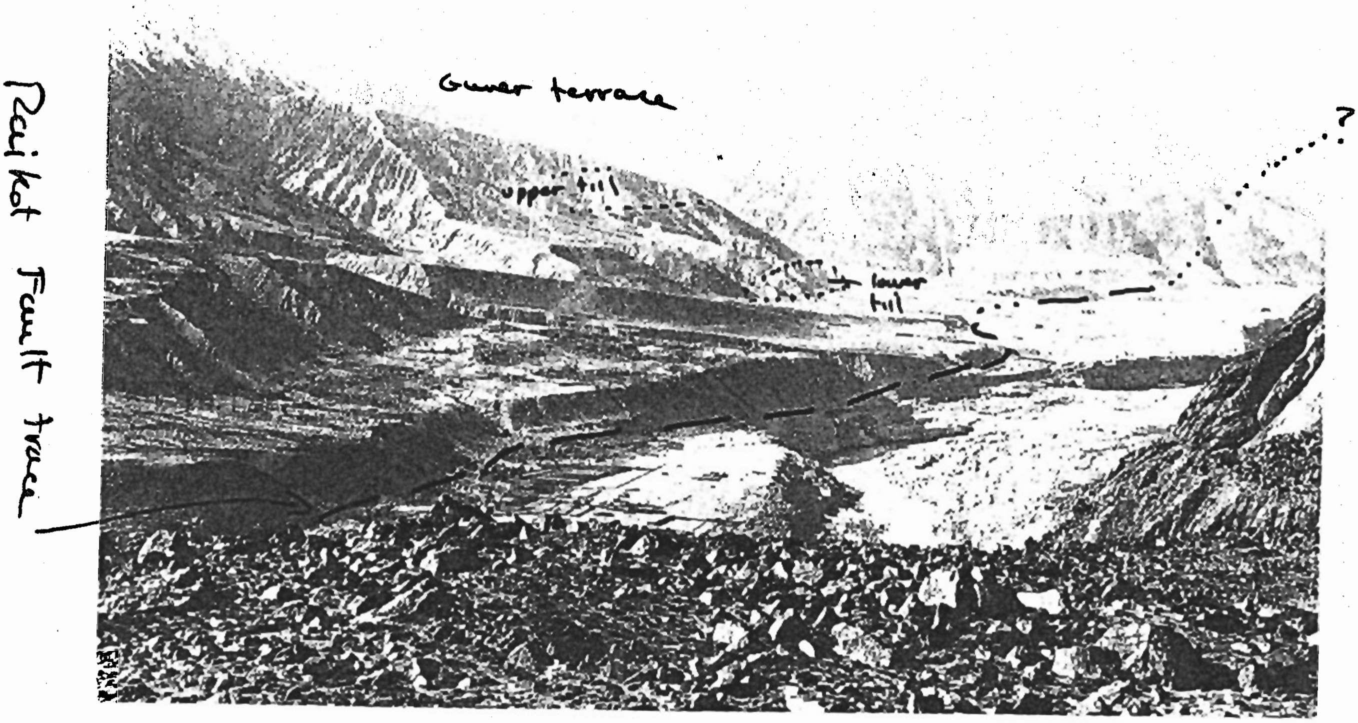
BUNER DAS TERRACE SECTION

Southwards of AmeGes village, above Buner Das village, 25 km midway between Chilas and Nanga Parbat, has about 30 m of a lower (M1) till with clasts both from Hunza and Nanga Parbat, and is overlain by about 60 $\pm$ m of lake beds that dip up to 43°E; all these indicates the Nanga Parbat Haramosh uplifting which is sufficnt to effect glaciation by this time. The upper 145$\pm$ m of (M2) till is lithologically similar which is overlain by a 240 $\pm$ m of fluvial clastics of valley fill III. Directly across the valley to the north occur thick kame terraces that dip in part outward from the Indus thalweg and contain lake clays with dropstones as internal disconfirmities or angular unconfirmities (Appendix B).

PATRO GAH, GUNER FORM SECTION

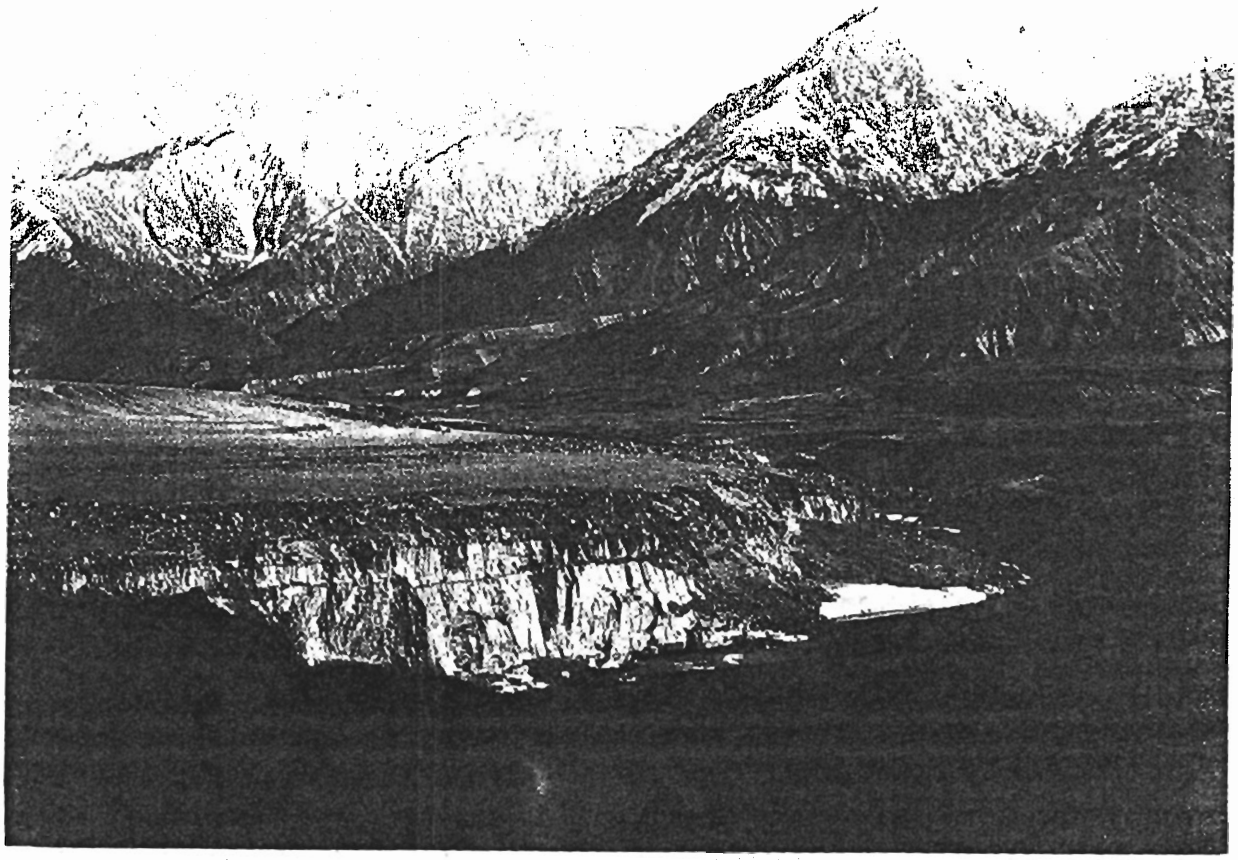
Another complete section 30 km upstream from Chilas is exposed in this area. Jalipur is present down at the bottom of Indus Gorge. This section has an overturned syncline (Coward, 1982). Across Indus river on northern side, younger lake beds are exposed probably due to late stage glaciation coming out of side valleys.

Plastered as against the bedrocks, two strongly erroded and disintigrated tills are located these two tills differ from one another in clast size, colour, hardness and degree of compaction. Thus having no morainal topography. These probably are the Early and late middle Pleistocene glacier tills. The one at higher

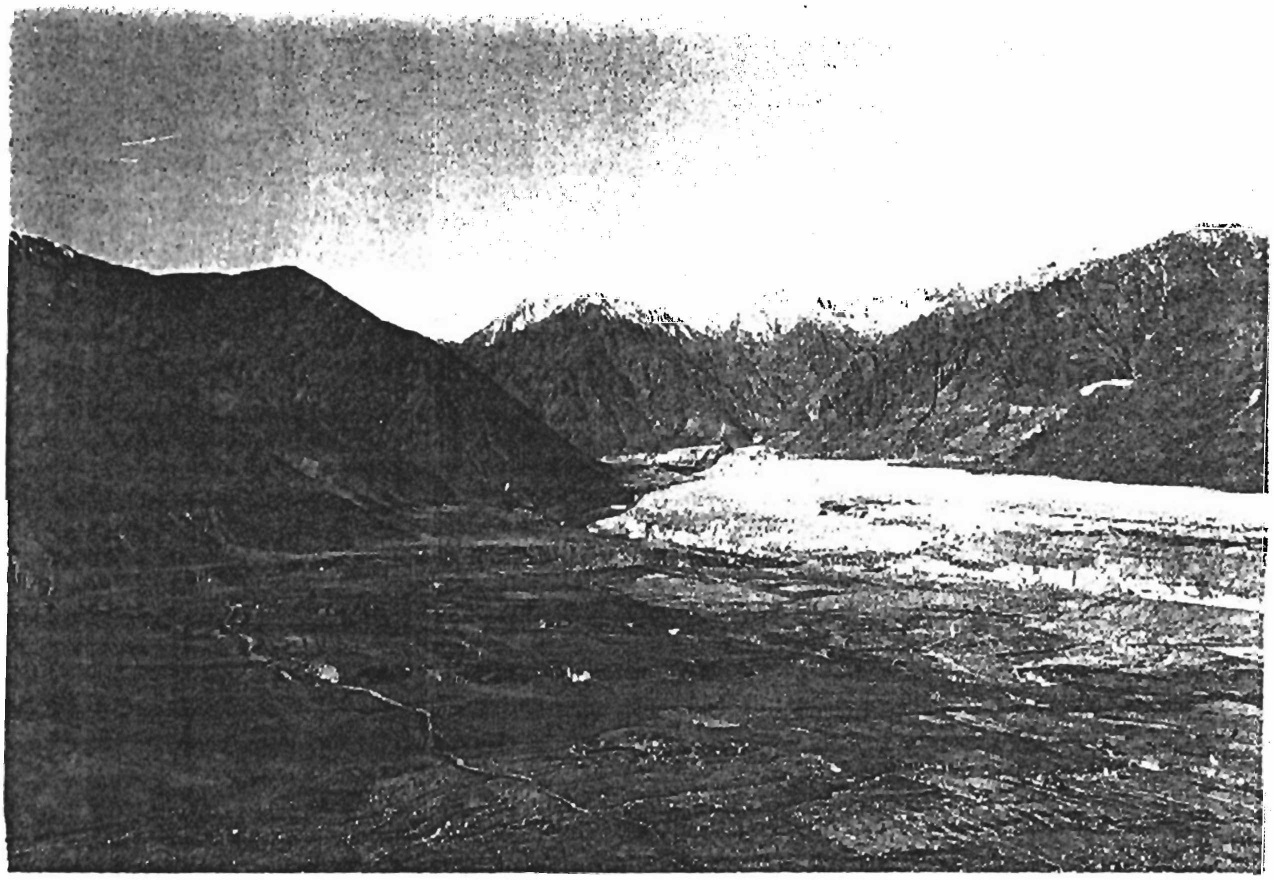


8. Photograph showing the lower and upper till of early and late middle glaciation at Guner Terrace. The young Raikot Fault trace is also marked.

9. Photograph showing a closer view of lower till at Guner Terrace (Buner Das Terrace). Nanga Parbat Augen gneiss can be seen.



10. Photograph showing another view of Guner (Buner Das) Terrace while looking southeastwards.



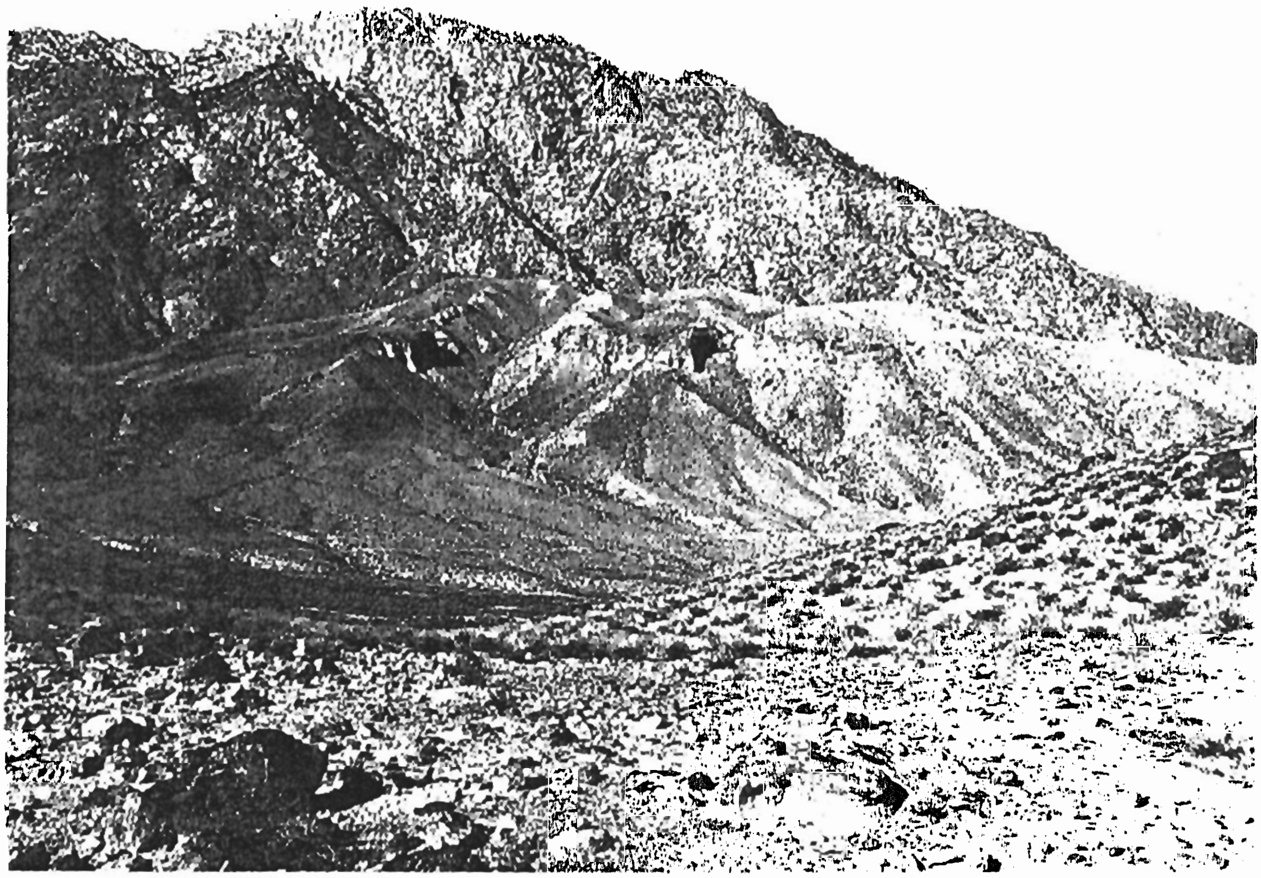
11. Photograph showing view down stream towards Buner bridge from Guner (Buner Das) Terrace. Jalipur can be seen in River Canyon.

elevation is M1 or Early Middle Pleistocene glacier till, while the lower one which is resting on the upper one is M2 of late middle Pleistocene time.

The late glaciation has also been found multy stade as many evidences which are discussed later in this chapter. On the southern portion of this area the glacio-fluvial material (valley fill II) that seperates the two middle stage glaciations provides a clear evidence for their being M1 and M2. A cross section of the area may be consulted for a better understanding of the area.

DRANG JABAR DAR PEAK SECTION

The section is exposed across the active fault (Lawrance and Ghauri, 1983; Lawrance and Shroder, 1984) at the base of Nanga Parbat (Fig.). Along the fault the noritic bedrock is thrusted over highly sheared Jalipur tillite near Drang bridge on Indus gorge. The till resting above on upthrown bedrock is correlated on the basis of lithology and position with the longitudinal main valley glacier i.e. Early Middle Pleistocene glaciation (M1) overlain by about 20 m of glaciofluvial clastics. This glaciofluvial material is then covered by over 130 m of monolithologic gneiss with relatively little matrix. It initially looks as if it is emplaced by a massive rock slide from adjacent Jabardar peak but is infect a late stade till of middle Pleistocene glaciation (M2) from Nanga Parbat as the same material was present 20 km downstream at Buner Das terrace section. Up above this M2 is present



12. Photograph showing a probably middle till and valley fill on north side of valley above Patro moraine.

a 125 m thick fluvial deposit with lacustrine silts and lenticular bodies. This is named as VALLEY FILL III which is further covered by late glacial moraines described later in this chapter. (Appendex E).

Two km downstream from Astor valley confluence are extensive tafoni weathered tills that are plastered along the aperently ice erroded rock terraces on the mountain front, representing the Early middle Pleistocene tills. The rock cut terrace that slopes into Astor valley more steeply than the present very steep gorge indicate an old U-shaped valley bottom (500 m above the present valley bottom, apperantly due to active faulting). This old valley bottom records tributary ice that came down from Nanga Parbat to the early middle trunk valley glacier at early middle Pleistocene time.

FARHAD BRIDGE SECTION (APPENDIX F)

On the northern side of lower Gilgit valley near its confluence with the Indus,shows the transition from Jalipur to tills of middle glaciation. The Jalipur is located in the inner gorge of the Gilgit river, while on the valley side just above the old road from Gilgit is a tofoni weathered till resting on bedrock equals the Early middle glaciation. This till is overlain by a 120 $\pm$ m thick medium to coarse bedded fluvial clastics (valley fill II). Above this is 125 $\pm$ m of probable late middle (M2) till with Hunza lithologies, and on top is an upper unit of bedded clastics over 65 m thick of valley fill III.

PROBABLE END MORAINE

The Early middle glaciation (M1) was the largest among the others as it came down all the way from Hunza upto Sazin - Shatial area. The patches of this glaciation still preserved as tills at different localities (mentioned above) all along Indus valley. Thus the probable end moraine for this early middle glaciation is Sazin Shatial area as evident from the presence of (M2) till. No single till has been observed further downstream from Sazin. It is also important to note that the valley becomes narrower beyond Sazin. This probably is due to subsequent aplifting.

VALLEY FILL II

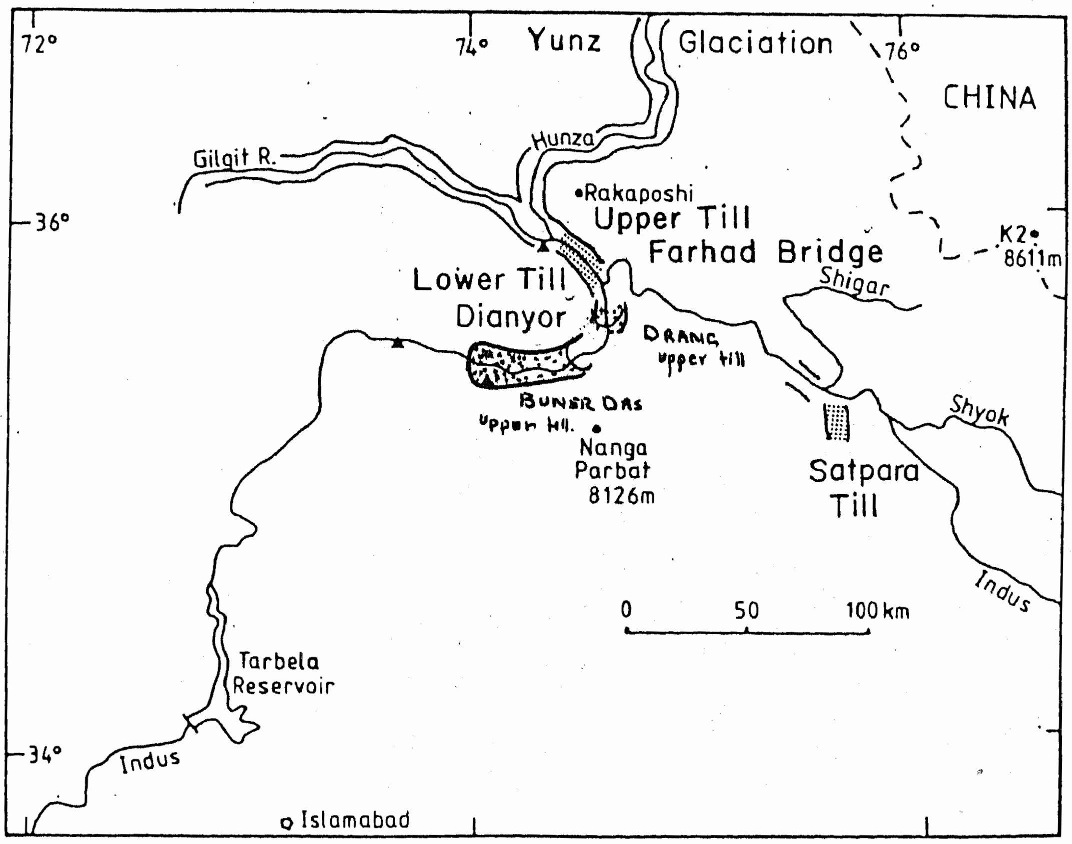
Overlying the early middle glaciation is the valley fill II that is the result of the interglacial period between the two middle stades glacial periods. It occupies this position on almost every section visited.

LATE MIDDLE GLACIATION AND VALLEY FILL III

The late stade middle glaciation is the name given to tills found at different localities in different sections measured.

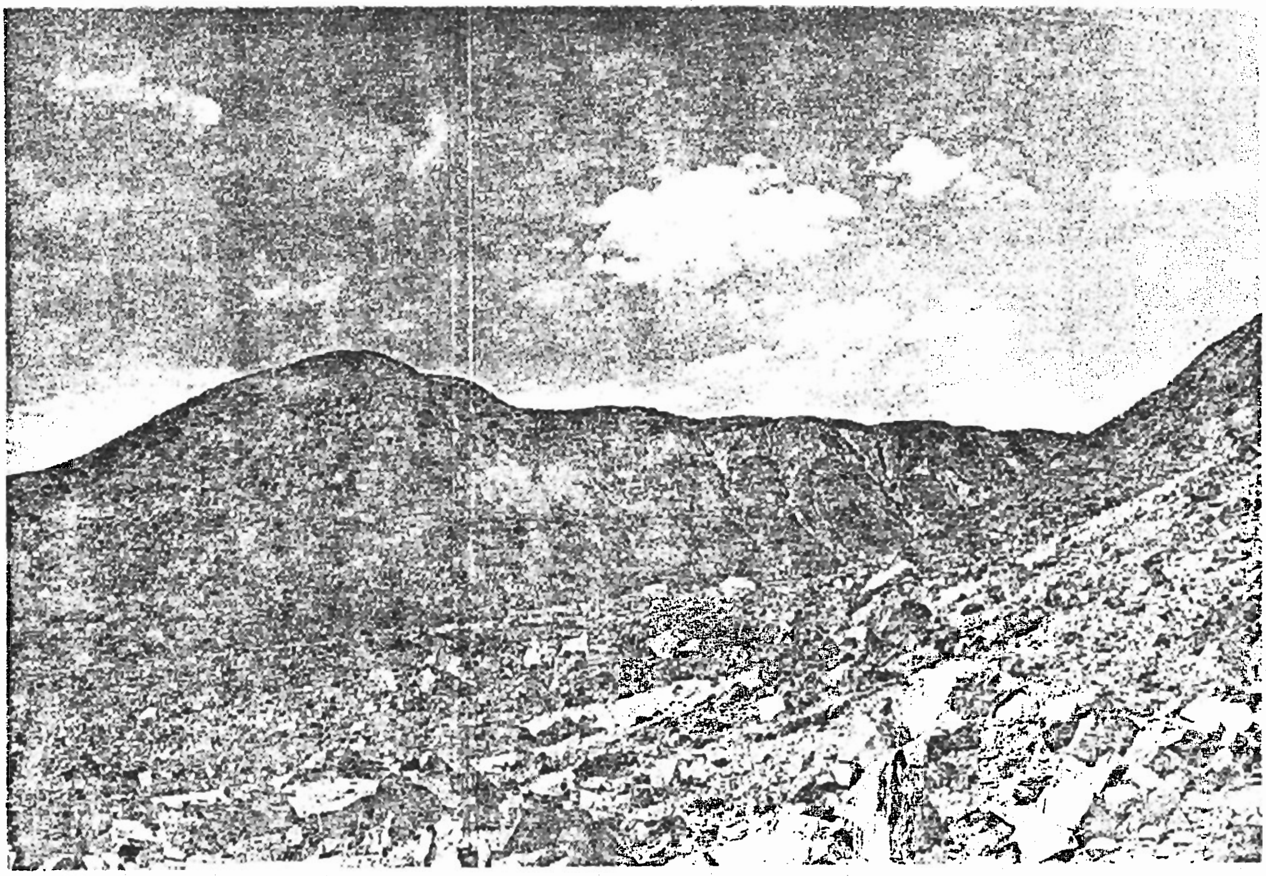
At Buner Dar section, resting above the valley fill II, are the monolithologic gneiss with relatively little matrix. This gneiss resembles much to a rockslide but later investigation indicated that it is late middle glacial till that came out of Nanga Parbat.

At Guner Patro Section, few km upstream from previous section, on the northern side of Indus river in Shingan nala and



Middle Glaciation — Late Stade

Fig. 6



13. Photograph showing upper and lower tills of middle stage glaciation at Farhad Bridge.

Cross Section of Indus at Patrogah & Gunar Gah Areas

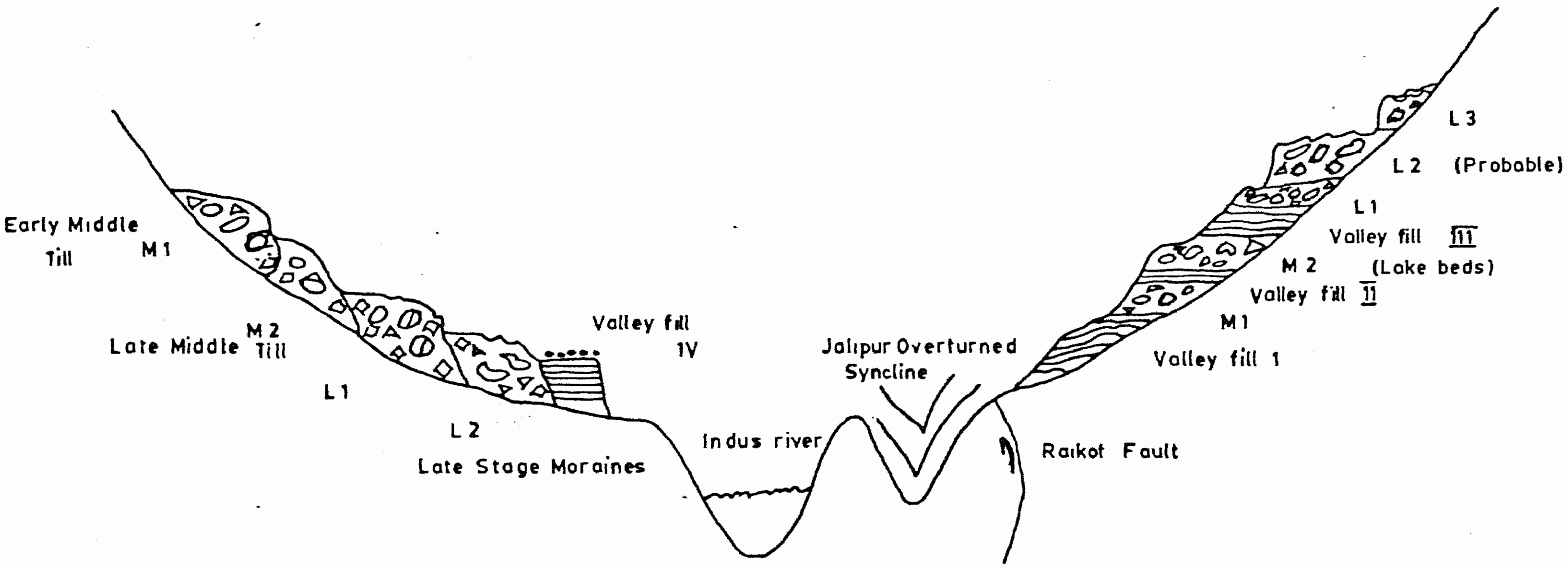


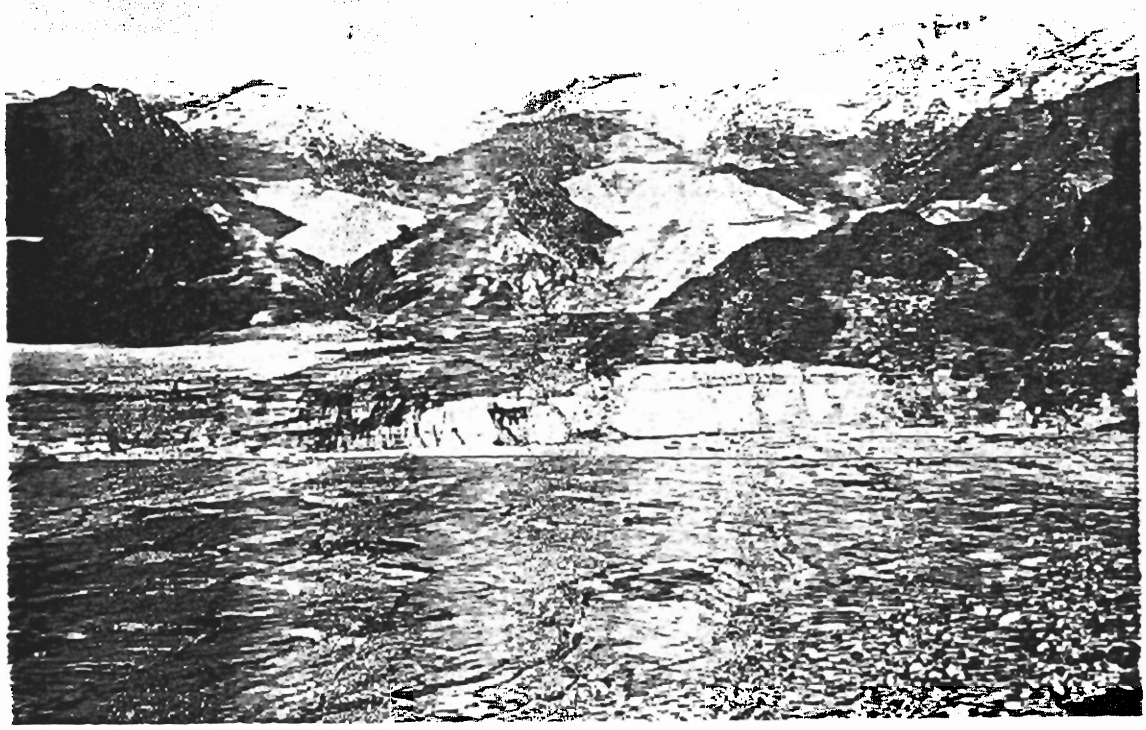
Fig. 7

adjacent areas. Two tills are present. These are highly weathered and disintigrated and lie one above the other the lower one is greyish and more distingueshed. It is probably related to Early Middle glaciation (M1). The second till which is more fresh looking, semi consolidated with lithologies from Nanga Parbat. This belongs to late middle glaciation (See cross section No. 1, Fig.7)

In another complete section i.e., Drang Jabardar Peak section, lies the same monolithologic gneissic material that was initially taken as a massive rockslide from the adjacent Jabardar peak but this till is preserved at intervals at places on the southern side of Indus river.

The Astor valley comming and from north eastern side of Nanga Parbat had major ice streams through it in the past that generated numerous glacial features in the early and late middle Pleistocene time. At Mangdoian, where the U-shape of Astor valley terminates in a pronounced knick point at an-elevation well below the terraces of old valley bottom. This more recent valley and associated tills probably represents the late middle glaciation. Further up the Astor river more M2 tills and even late stage moraines are present.

Farhad bridge section is a complete and important section in the lower Gilgit valley near its confluence with the Indus River. This section consists of about 125 $\pm$ m in thick semi consolidated, fairly fresh with boulders partially weathered and lithologies from Hunza valley (M2), overlain by other series of alluvial beds that



14. Photograph of Kame Terraces above [illegible] village.

[illegible]. Another view of Kame Terraces above [illegible] Village.

are greater than 65 $\pm$ m thick and continue to the top of the terrace (valley fill III) (Appendix F).

Dianyor Section which is a thick terrace sequence ($>$ 600 m) situated 10 km due east of Gilgit on the south flank of Rakaposhi, represents the Quaternary sequence of the area. It consists of:

1. A basal till with prominant, soled, faceted, polished and striated boulders (upto 3 $\pm$ m in diameter) of crystalline rock from the Hunza valley.

2. 30 $\pm$ m thick conformable bedded sand and gravel derived from the same location as the till and interpreted as glaciofluvial.

3. 25 $\pm$ m of slightly disconfirmable or angularly unconfirmable lacustrine silt indicating an age greater than 100,000 TL year B.P.;

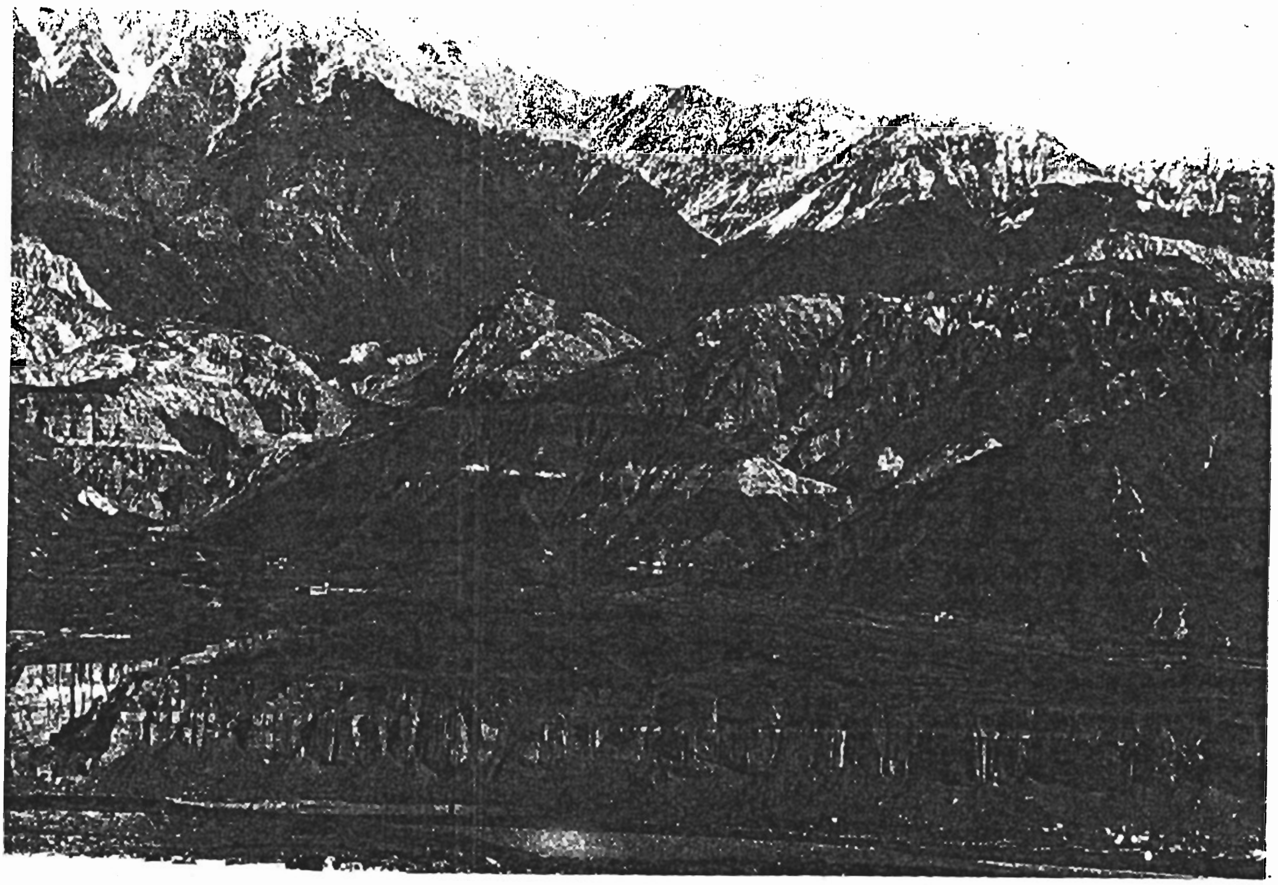
4. 100 $\pm$ m of angularly unconfirmable or strongly disconfirmable thick fluvial sand and gravel.

5. 120 $\pm$ m thick sand and gravel strongly disconfirmable to the previous.

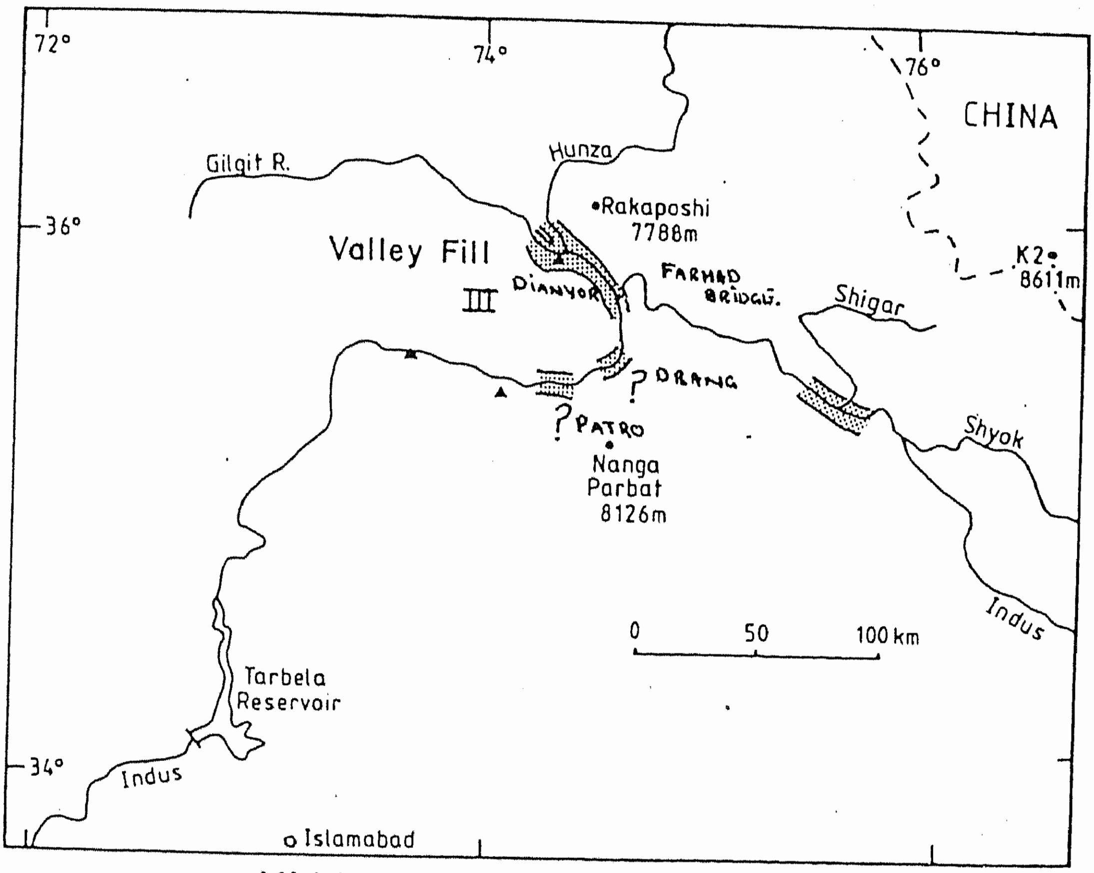
6. 240 $\pm$ m of disconfirmable upper till with subdued moranal topography, extensive cover of loess and blown sand and strong desert varnish in places where boulders have not undergone granular disintigration (post-maximal varnish development).

The basal till at Dianyour appears to be equivalent to the upper (M2) till at Farhad bridge. The reason to make this assumption

16. Photograph showing view of Dianyor Section about 10 km due east of Gilgit on the south flank of Rakaposhi.



17. Another view of Dianyor section with Gilgit river is fore ground.



Middle—Late Interglaciation Fig.8

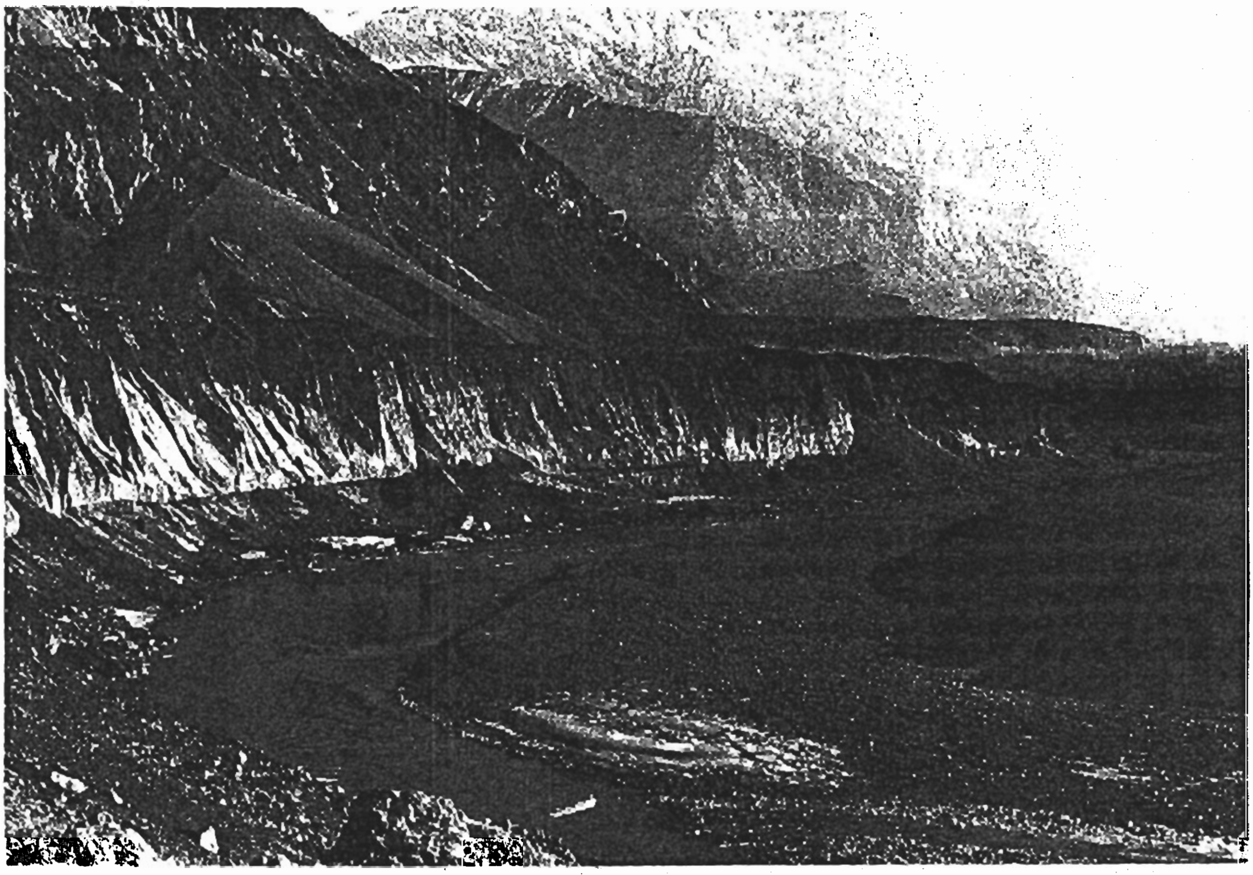
is that the prominant lacustrine unit at Dianyor does not occur between the two tills at Farhad Bridge section, but it occurs, with in thick fluvial valley fill III terraces at many other scattered sites along the lower Hunza and Gilgit valleys. The dam that produced the lacustrine sediments was ice or landslip further down at Nanga Parbat. The lower Dainyor till is therefore correlated with the late middle stade glaciation (M2) and the overlying fluvial and alluvial unit as a third valley fill stage of interglacial age immediatly prior to the last glaciation of late Pleistocene.

END MORAINE

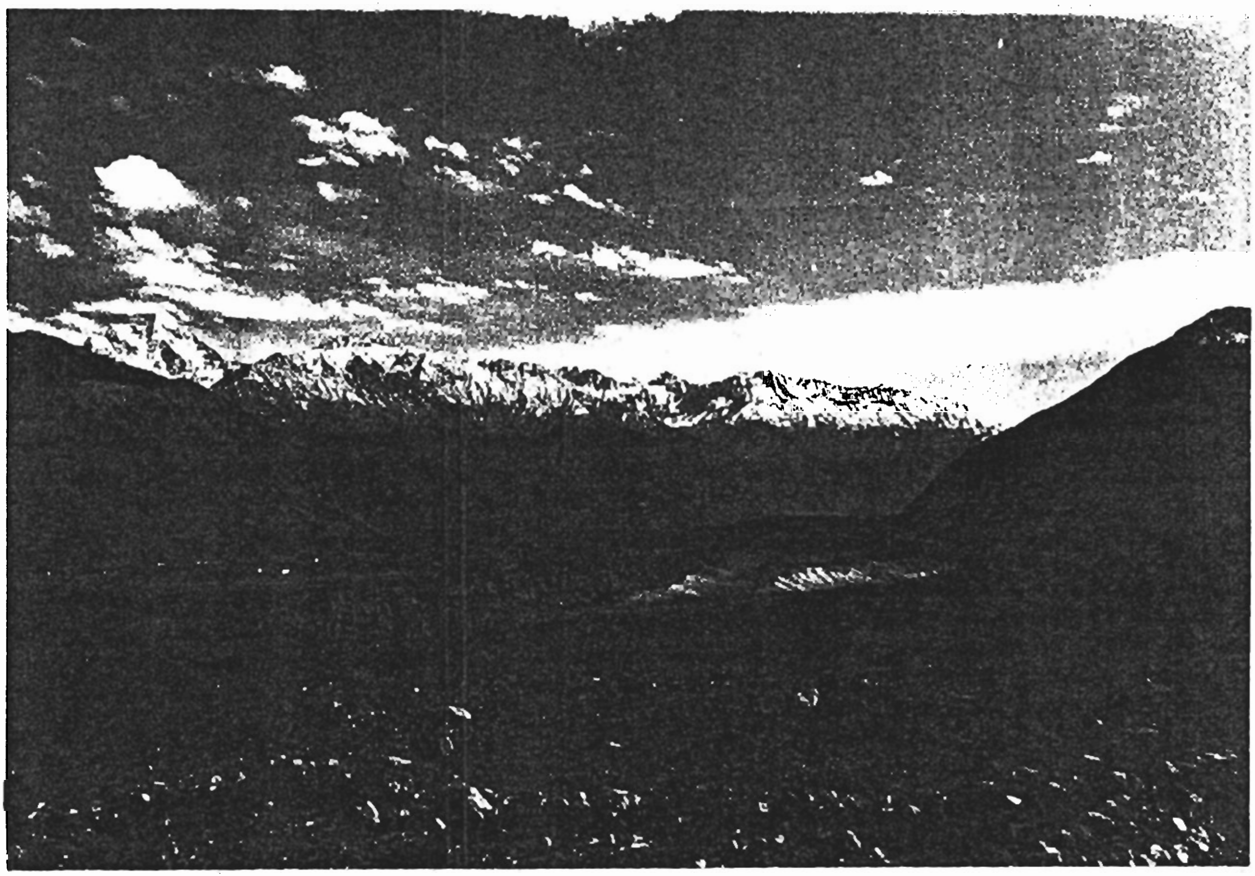
The probably site for this late stade middle glaciation is at AmeGes/KeGes area. Here it is more likely to be present, and from there downstream not a single till of late middle glaciation has been observed or found, with the same lithology as occur in sections upstream.

LATE PLEISTOCENE GLACIATION AND VALLEY FILL IV

The late Pleistocene is represented by multiple tills, and Transverse glaciers or cross-valley or "expanded foot" moraines and valley fills, plus few longitudinal moraines. They preserve morainal topography with enclosed kettle like lacustrine deposits. Most of these moraines still retain their original landform characteristics. Among these only the prominant deposits at lower elevations (4000 m) were included in this study.



18. Photograph showing base of Dianyor (Dak Chauki) moraine in Gilgit river.



19. Photograph of Dianyor (Dak Chauki) moraine.

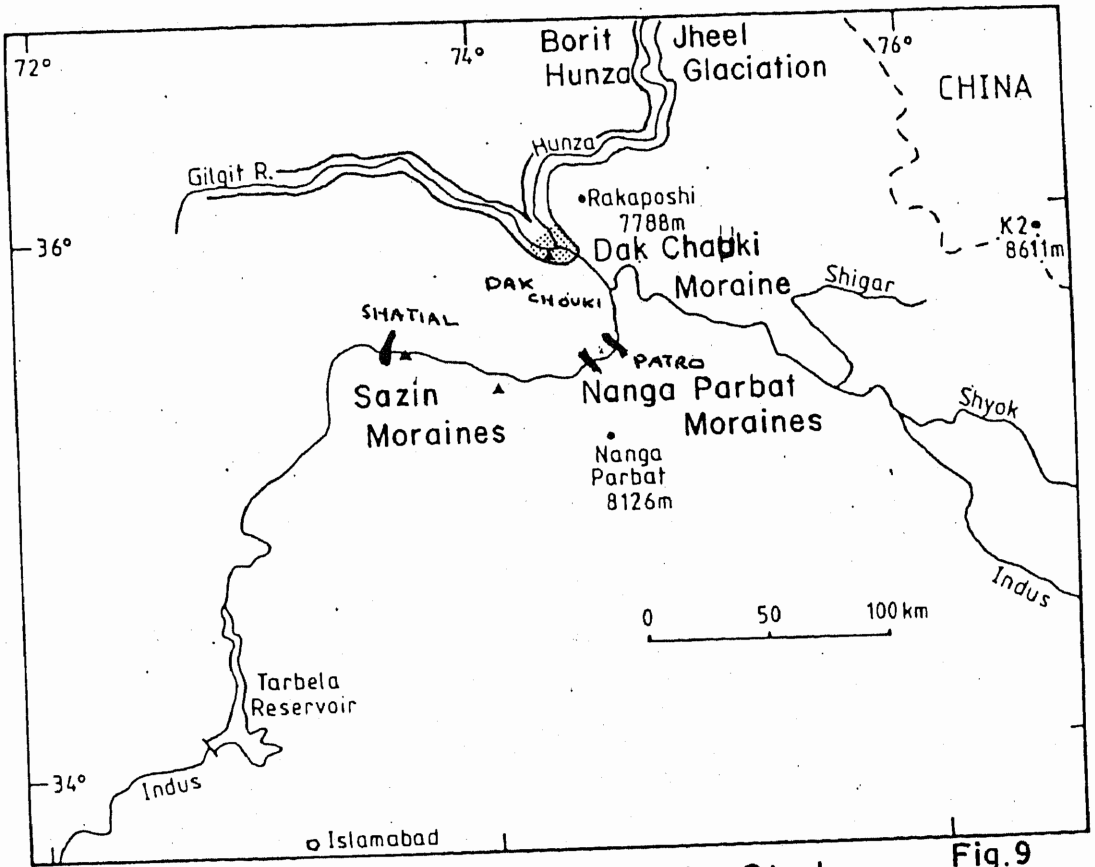


Fig. 9

Late Glaciation — Early Stade

The late Pleistocene glaciation has also been found multi-stade. On the basis of many evidences, it is divided into 4 stade namely L0, L1, L2 and L3. The L0 represents the oldest and L3 is the youngest events of late Pleistocene time.

The oldest of the late stage glaciation are a few extensively eroded moraine remnants from transverse glaciers that occurs at the mouth of Bagrot and across Patro at Nanga Parbat, Probably L0 ?.

The most prominant late stage moraine is a massive longitudinal glacier that decends from Hunza into Gilgit valley at Dainyor (Dak Chauki - Borat Jheel). This moraine extends all the way across Gilgit valley (with a maximum relief of 750 m indicating an ice thickness of at least that much in this area (Shroder 1985). This moraine was firstly named as Dak Chauki Moraine by Desio and Orombelli (1971). The deposit has got a pronounced hummocky topography with enclosed kettle lakes, some of which are cut through by Gilgit river (Photo19). The Dak Chauki moraine, 10 km directly southeast of Gilgit, is one of the largest and important till of the area as it records the major ice advance from the Hunza and upper Gilgit valleys in late Pleistocene. Derbyshire (1984) thought that Borat Jheel advance from Hunza terminated near Astor,but the absence of an end moraine there indicates that the Dak Chauki is probably the terminous point.

There are many other glacial advances in late Pleistocene time down the Gilgit and Indus valleys. These"expanded foot" or cross-valley glaciers left prominant moraines behind.

Starting from Shatial - Sazin area in the middle Indus valley, the ice barrier (L1 ?, L2) flowed out of adjacent Daral valley in the Kohistan block and descended southwords across the main valley to block it and produced prominant lake sediments (as a result of damming of River) on both sides of Indus river over 50 km upstream to Chilas. The TL dates on these sediments is 38,000 ± 2600 TL y BP (Shroder 1985). The massive end moraine that was produced by the ice is situated on the southern bank of Indus above Shatial. It is clearly observed on aerial photos and setellite imageries. Two big massive lobes lying on top of one-another, were cut and emplaced into the east-west trending cliffs on the south beach 5 km down the main Indus valley. These were originated from the ice of the transverse valley to the north. Probably as the ice extended into the river, it deflected southwards forming a loop around the ice, thus cutting the valley wall into a bowl shaped valley as happened in Gor valley, north of Nanga Parbat. (discussed in the following pages). The Darel-Shatial moraine still retain its surface morphology i.e., concave towards Darel valley. The upper moraine has a cover of over 1 m of loess and the lower one about .5 m. The two loess deposits have few erratics resting on their surfaces. The ice front was about 750 m thick above the Indus valley bottom and was later cut through the Indus Shatial till of early middle glaciation (M1), present on the north bank of Indus above Shatial bridge. When the ice mass broke and the pent-up lake was released, the top of the Indus-Shatial till and the valley fill II was scoured extensively by flood waters. This is evident, from the presence of magma-ripples (with a wavelength of 24.3 m to 27 m and amplitude .6 m to .9 m) on top of Indus-Shatial till. Which is characteristic of catastrophic breakout flood associated with temporary ice dams. Such catastrophic floods were exceptionally common during late Pleistocene time in the Indus drainage. (Mason,1935; Burbank,1983)

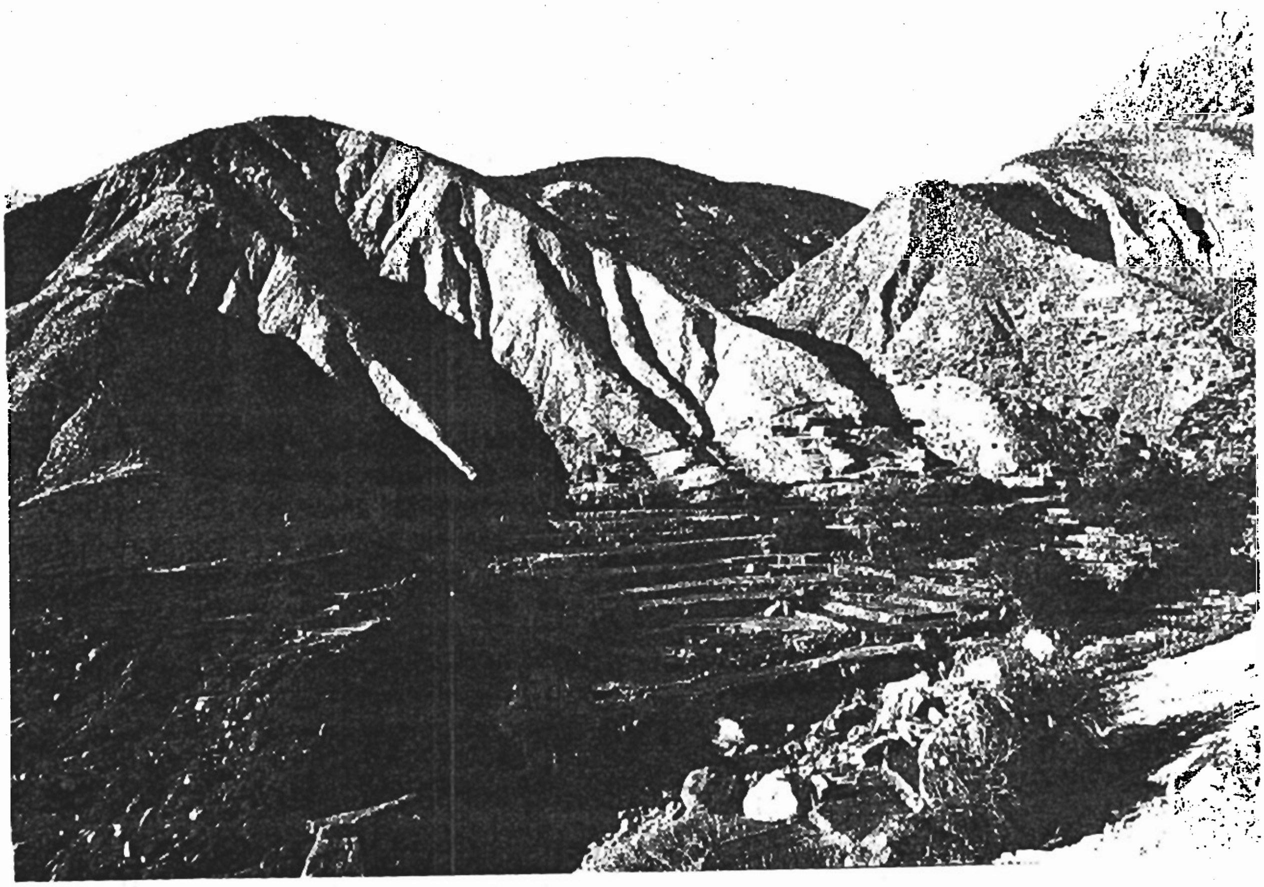
The presence of Punjab erratics many hundreds of kms away from the source can be most logically attributed to these floods.

At Shatial occurs one of the most obvious dams and lacustrine sequence of the middle Indus (Photo 7). The lake sediments are present on both sides of the river over 50 km upstream of Chilas.

Ten km from Chilas,upriver at Gini another "expanded foot" probably L1 descended from southern side valley (Gini Gah) which overlain the lower middle stade Glaciation (M1). These have typiical morainal topography. Desert varnish is dominant and disintigration of boulders were not so common. These morraines were probably produced by Salat Peak (4577 m). Evidences of more than one glacial surges have been found as occurrence of lake sediments upstream behind the probable dam.

Glaciers also descended from Diamir and Patro cirques on Nanga Parbat and were diffluent in to Guner valley to produce two parallel ice streams (L0 ?, L1, L2 ?). Lichi Gah terrace between Guner and Buner is a valley fill sequence probably formed between the two moraines. It has prominant lacustrine deposits as well, Terrace deposits on the north side of Indus river at KeGes and AmeGes may be Kame Terraces associated with these ice masses, although the terraces may be older.

20. Photograph of Patro moraine as viewed upstream from Buner Das Terrace.



21. Another view of Patro moraine above Shingan Nala.

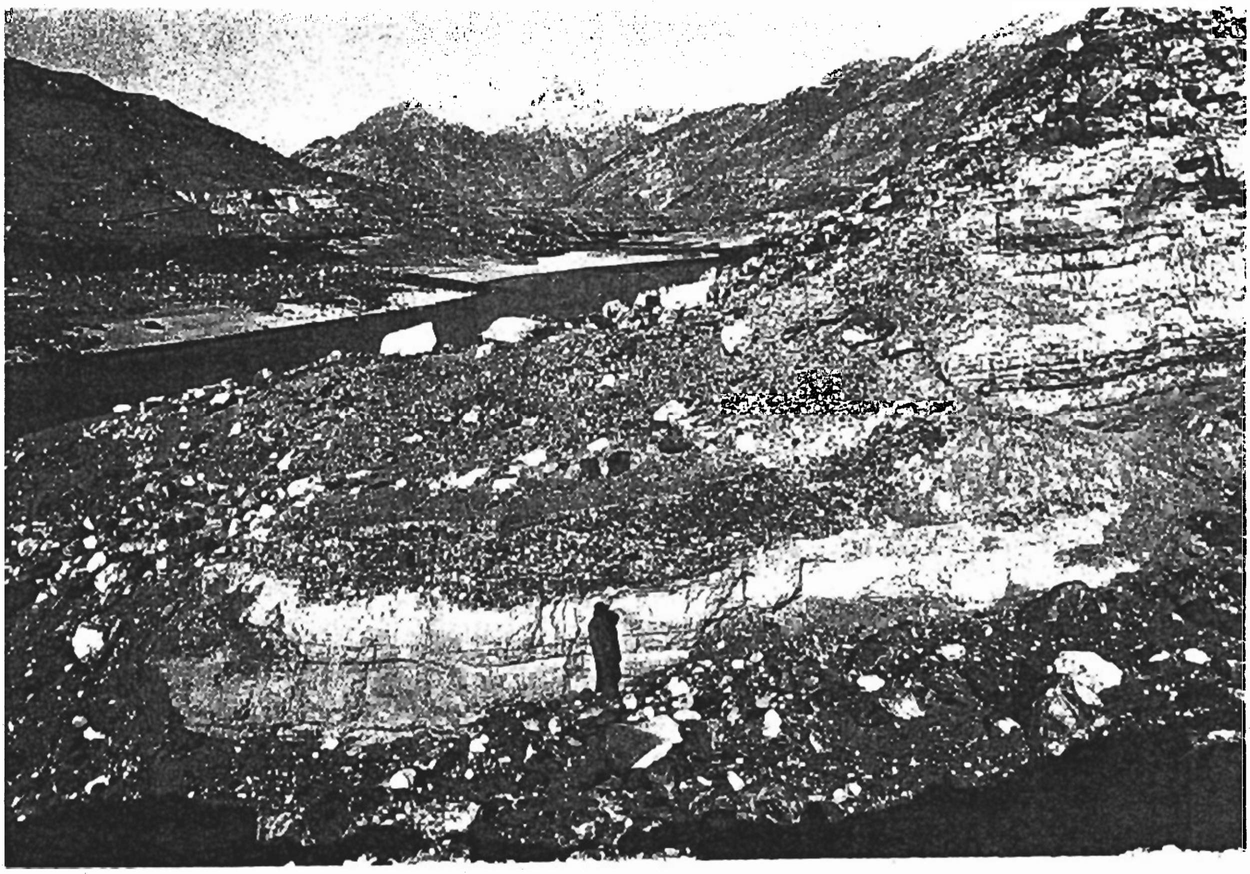
At Patro these two massive moraines, certainly of late Pleistocene time, descended from Nanga Parbat. The L1 till still preserving morainal feature is resting upon M2, and is being overlain by another till from northern side of Indus (cross section 1). The late Pleistocene glaciation has also been traced on south bank of Indus, where three successive stades of late Pleistocene (L1, L2 and L3) are lying above each other. These moraines still preserve their morainal features. The desert varnish is maximum on younger one, while it is post-maximal on the older one. Besides the disintigration of granitic boulders is also found.

There is evidences of confluence glaciation also in Raikot area (see map). Where the glacier from Buldar and Riakot valleys off Nanga Parbat descended at Gor.

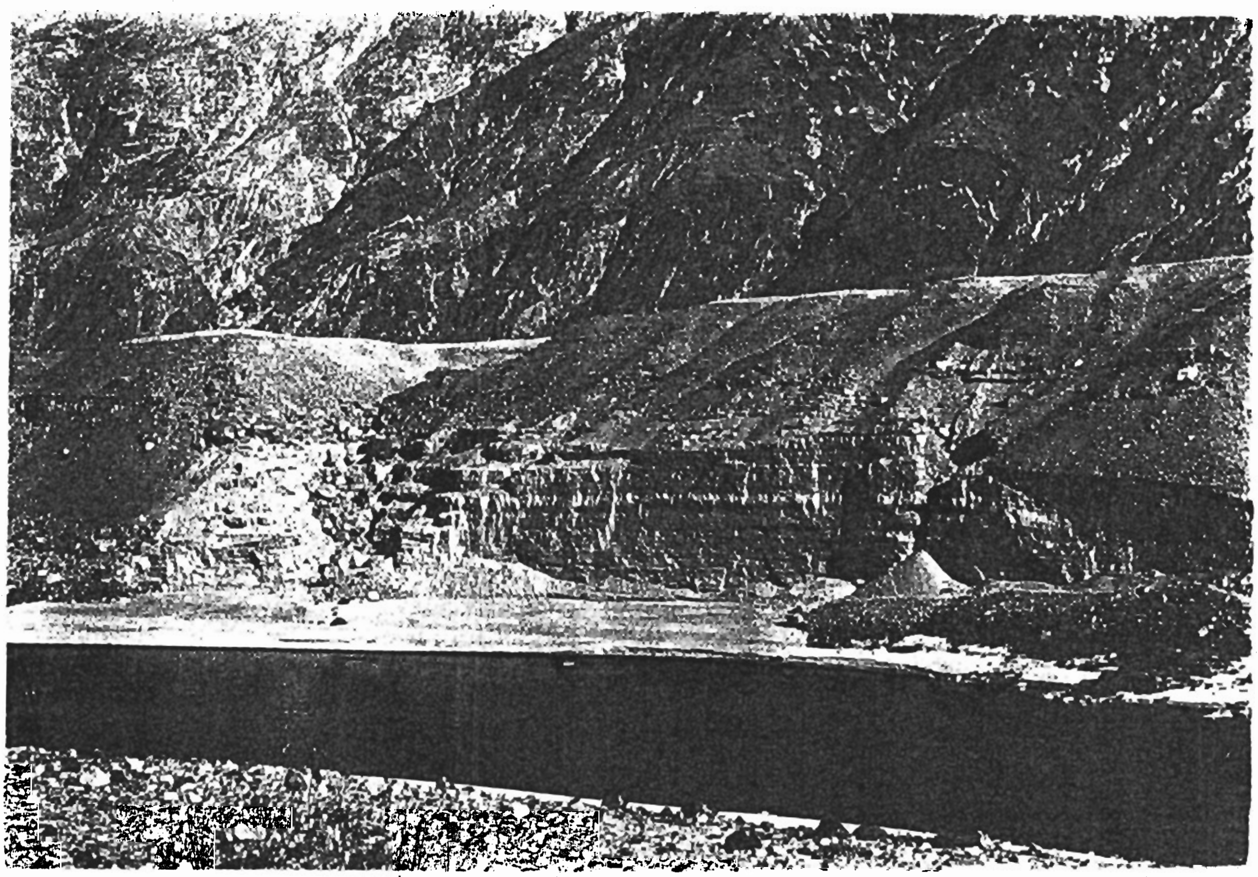
At Gor, the largest of ice dams that filled the Indus gorge with 1 - 1.5 km of ice that scattered massive moraines (L0,L1,L2) to an altitude of about 3000 m at Gor on the north side of Indus. The Gor valley is a large, (more than 7 km across) south facing bowl shaped basin with eroded moraines and other sediments resting on the bedrock shelf of 800-1000 m above the top of the other moraines in the valley below. This probably is the L0.

At Bunji three moraines that came from side valleys, both from north and south are present. These are.

1. The lower or earlier (L1)
2. The middle yellowish till (L2)
3. The youngest (L3)



22. Photograph showing dipping lake beds at Bunji.



23. Photograph of lake beds behind Jaglot (Sai) moraine at Bunji.

Bunji Bridge CrossSection

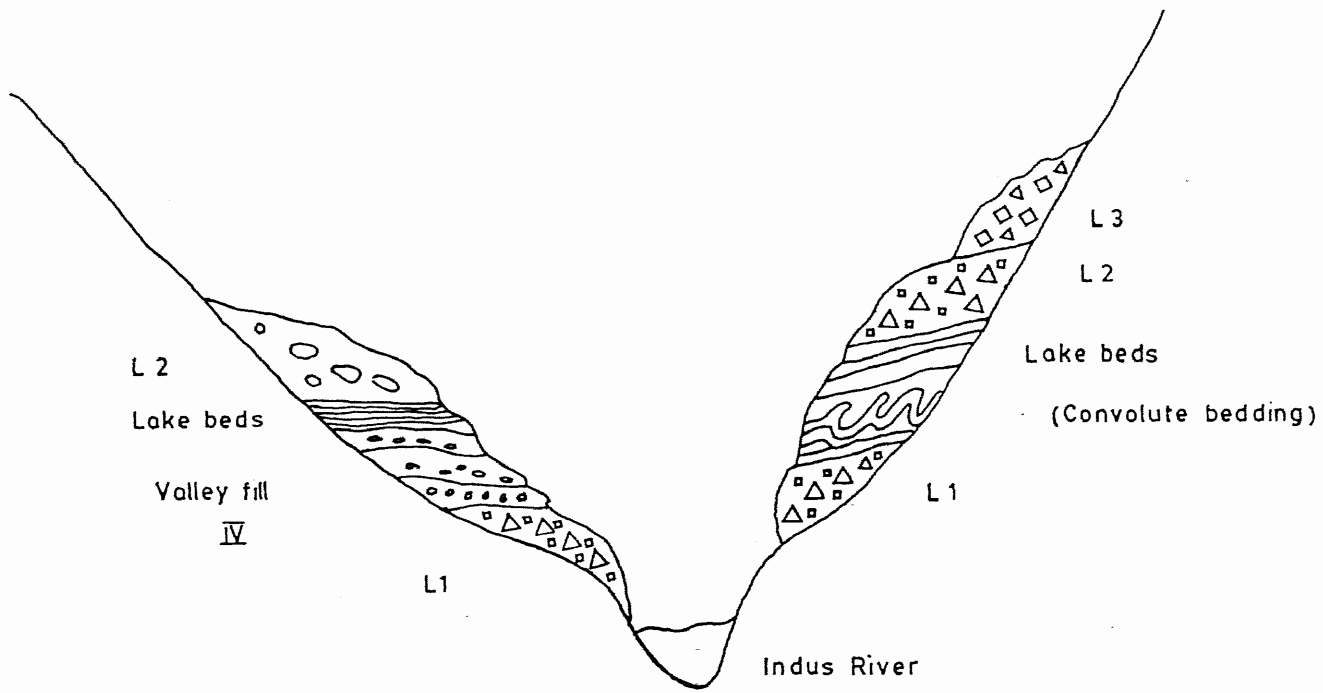
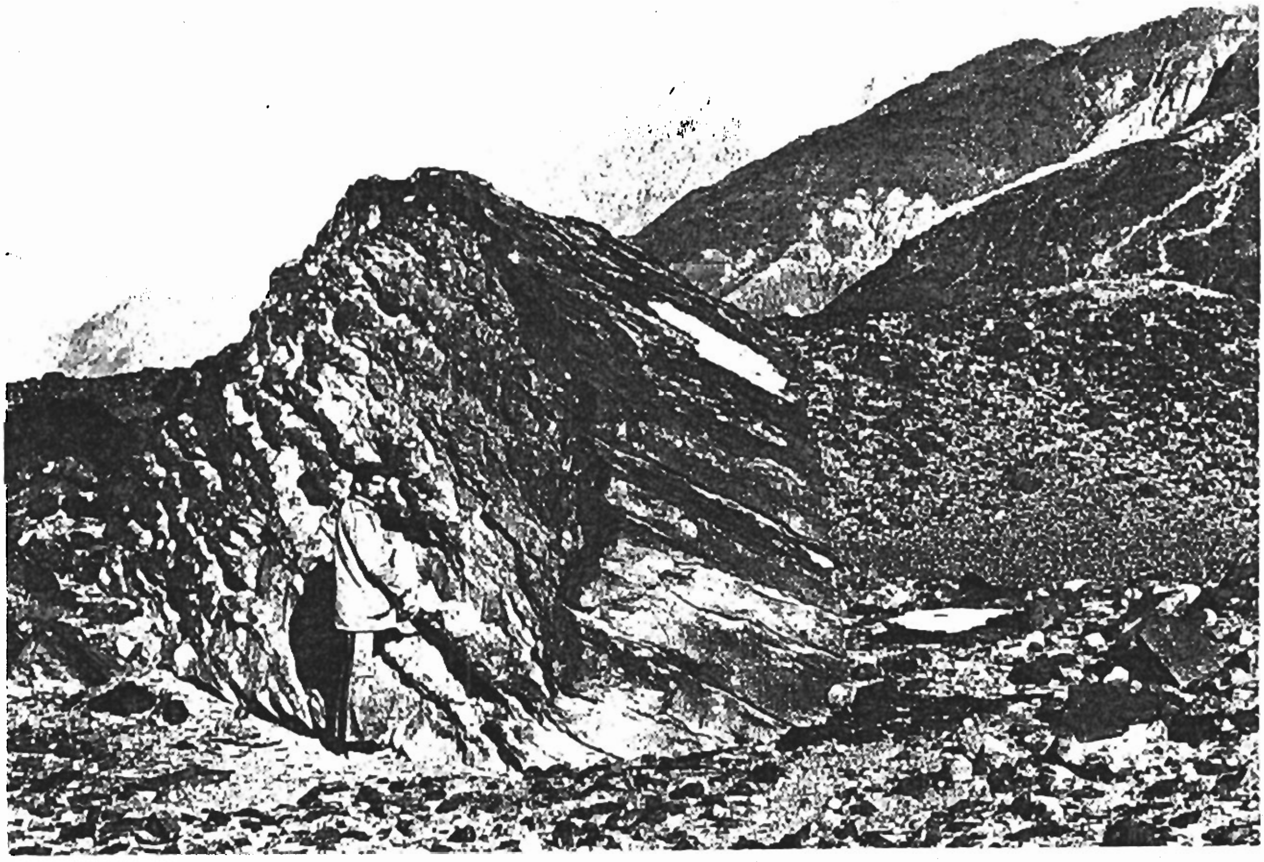


Fig. 10

The lower or earlier (L1) is at the river base that blocked the Indus producing lacustrine sediments. The second yellowish till (L2) from Sai Nala occurs on both sides that produced thick late sediments, deformed into contorted bedding by later ice pressure. The older of these lake beds dips 6°W as a result of continued uplift of MPHM. This side valley serge again dammed the river and produced a second set of lake beds behind. The younger (L3) glacier that came down both from Sai Nala in the North west as well as from Bunji Nala in south east (cross section 2.) is evident by younger and moraines with quite fresh appearence. (photo22).

About 15 km up the lower part of the upper Indus from its confluence with the Gilgit River, occurs the Shuta moraine on the inaccessable south side of the River. It could be moraine from Skardu valley but is most likely a late glacial moraine from the Haramosh massif.

Three prominant end moraines are found about 10 km downstream from Dainyor terrace (Dak Chauki moraine) at the mouth of Batkor Gah. These moraines constrict the Gilgit channel and overlap each other on a large alluvial fan directly across KKH. The glacier that produced these moraines is most likely responsible for the dam across the Indus that produced lacustrine deposits overlying the main valley alluviam of Gilgit and Hunza river, behind the Dak-Chauki end moraine. The dating for these lake deposits occurring on Gilgit - Naltar road at the confluence of Hunza and Gilgit - Rivers is 31,400 ± 2000 TL yr. BP (Shroder 1985) Table 6).



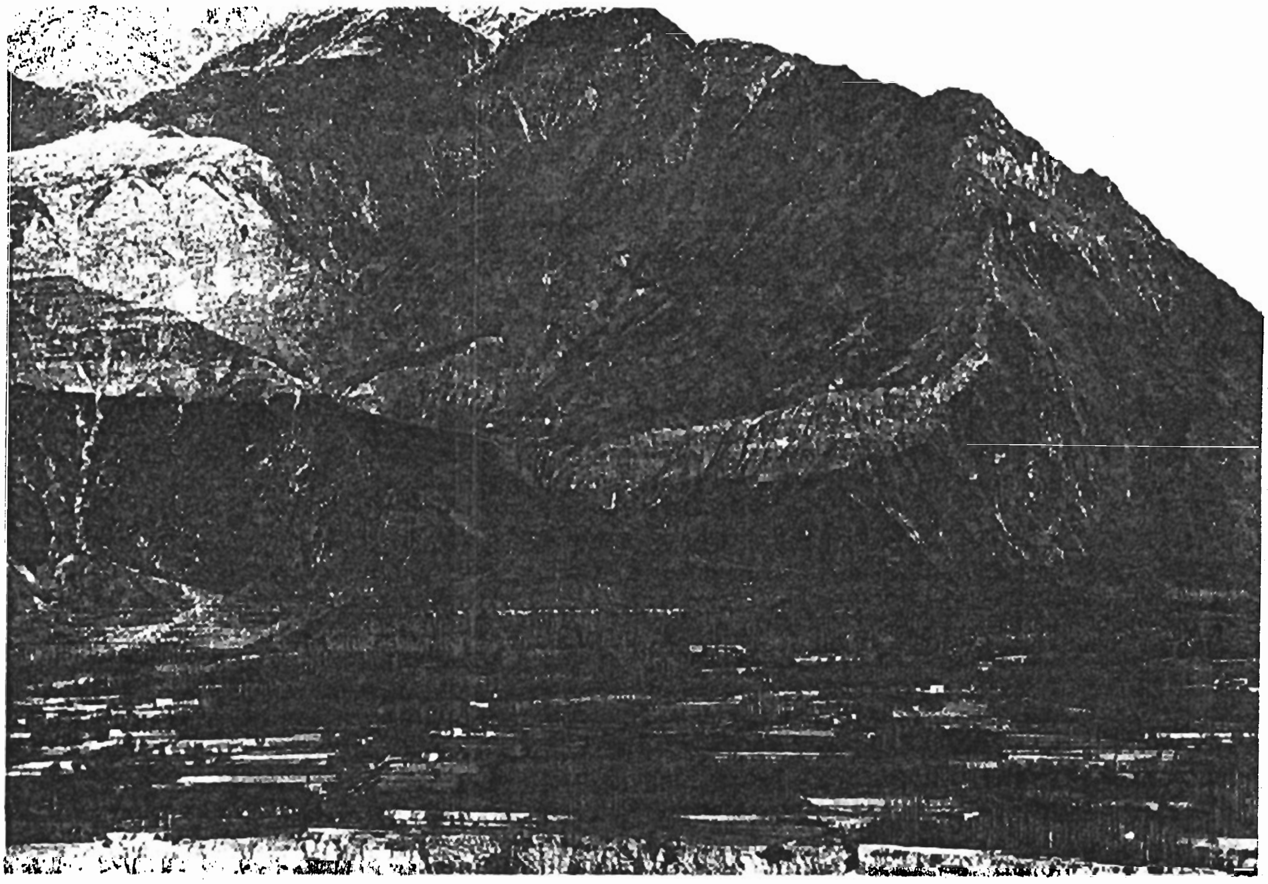
24. Photograph showing granite erratic boulder at Dianyor moraine.

An intresting feature indicating recent tectonism in the area is the tilting of lacustrine sediments at Buner das, Bunji, and at Dainyor section. The lake beds are dipping about 4° SE. As mentioned earlier. The Cenozoic tectonism and active faulting is reported from the area (Lawrance and Ghauri, 1984). The tilting of lake beds may be related to the same event of deformation.

At the mouth of Bagrot Gah approximatly 2 to 3 km downstream from a fresh looking end moraine of late Pleistocene (L1), glacier descended from Bagrot Gah (Nala) to rest upon alluvial fan. It contains boulders of about 2 m in diameter with very prominant desert varnish. The granitic boulders in this moraine were mostly disintigrated in much the same fashon as observed in Patro moraine. Most of the clast is from Rakaposhi. The moraine is most probably equivalent to (L1).

Along with these tills and moraines there are some other end moraines in tributary valleys, most of them are inaccessable.

These moraines at places (Darel-Shatial) are overlain by about 40 m of bedded gravels. These gravels would constitute part of a valley fill IV of late Pleistocene and perhaps Holocene age, but such later deposits were not analyzed in datail for this thesis.



25. Photograph showing late stage glacial moraine at Bagrot gah.

CHAPTER-3

LANDSLIDES

As mentioned earlier the area under discussion in geomorphologically and structurally a very complex area. It has a high relief difference, rugged topography and unstable surfaces. Many large landslips have occured in the middle and upper Indus valleys. Some of these are along the active fault that runs part Nanga Parbat to Haramosh.

In the 19th century, there are records of two major landslips that temporary blocked Indus and Hunza river gorges producing large lakes. On brekage of these dams devastating floods swept the valley causing clossel losses to life and properity.

During 1841 earthquake from a rock spur of Nanga Parbat fell at Licher Gah and pushed over unconsolidated sediments damming the Indus to a depth of 150-300 m. The lake backed up nearly to Gilgit and stayed for many months. Finally the dam gave way and a catastrophic flood of huge wall of water rushed downstream destrying all that came in its way. A whole batallion of Sikhs army camped at Attock 350 km downstream was completely washed out. (Belcher, 1859, Mason 1929).

The site of this landslip was relocated during the course of present work and mapped. The vertical drop of rockslides was about 1900 m and the horizontal distance of transport was about 4 km. The landslide material most probably rested over the cemented diamictite i.e. Jalipur and the younger sandy till. After the failure of dam, the flood water produced scour marks and four mega ripple with a wavelength of about 110 m and amplitude of 2.5 - 6 m. (Shroder, unpublished data).

Another major landslide occured in 1858 at Pungurh near Sarat in the Hunza river gorge which also caused major flooding down river after the dam breakage. (Goudie et al., 1984). No records of losses by the flood are however available. Even today many types of landslips that repeatedly cut the Karakoram highway and cause much loss of money through constant engineering maintenance.

The young topography and related unstable slopes are a constent cause of landsliding in the area. These may have many more events of landslips, damming of gorges, lake developments and floods in the past, the indications of which are completely washed away. This phenomenon, however, explains the transportation of extreemly large load downstream for great distances which otherwise was not possible by the streams only. The occurrence of Punjab erratics must therefore be related to one or several episodes of such catastrophic floods.

CHAPTER-4

CONCLUDING STATEMENT

On the basis of analysis, mapping and measurement of topographic elements, landforms, sediments and other related features in Hunza, Gilgit and middle and upper Indus valleys. Three major episodes of Pleistocene glaciation have been identified. These episodes are described below.

1. LOWER GLACIATION (EARLY JALIPUR STAGE)

This stage is recorded on the basis of well indurated tillites and overlying sedimentary rocks of the first valley fill phase. These deposits are effected by all phases of subsequent tectonism. These tellites and valley fills are younger, one to two million years and are folded, overturned and overriden by basement faulting at several places. Jalipur tillites are correlated with oldest high level glaciated surface of Shenoz glaciation of Hunza and old valley level of first glacial expansion in Skardu-Shigar areas (Table 4).

2. MIDDLE STAGE GLACIATION

The middle glacial stage followed subsequently by interglacial period is represented by two stacked tills and two interbedded valley fill sediment units. Thus middle Pleistocene glacial period is divided into two periods with an interglacial period in between. These are named as:

1. Early middle Glaciation (M1)
2. Late middle Glaciation (M2)

The early M1 glacier was the longest trunk glacier in the Indus system and may have surges from side valleys or even in main valley to carry it so far.

The late middle glacial period is represented by multiple tills and moraines, mostly from side valleys. Most of the material of this period still retains its original landform characteristics.

3. LATE PLEISTOCENE GLACIATION

Four stades of late Pleistocene has been recognized in the the increasing order of their age from L0 to L1, L2 and L3.

The Holocene period is represented by a variety of sediments and landforms specially moraines of Neoglacial, little ice age historical time.

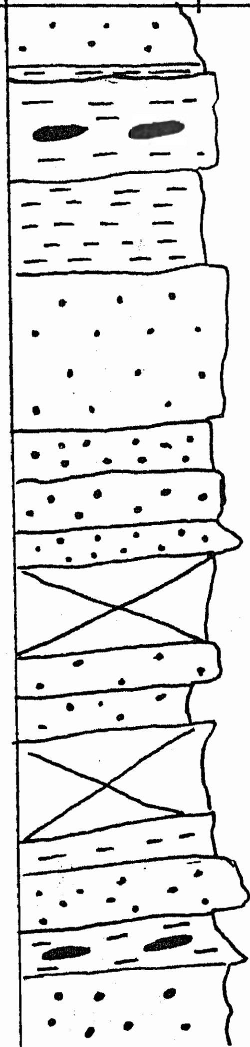
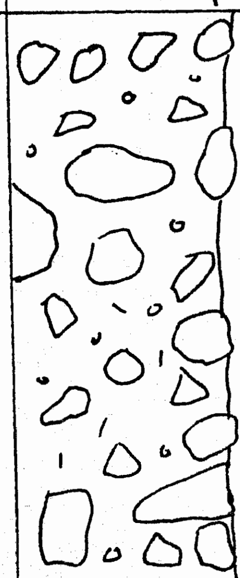
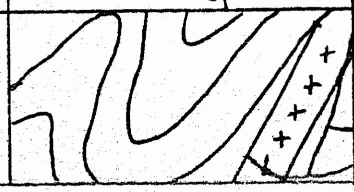
The chronology so far established is taken from previous work-done on four-stage glacial history which can be clearly observed in early till, the two middle tills and the major late moraine.

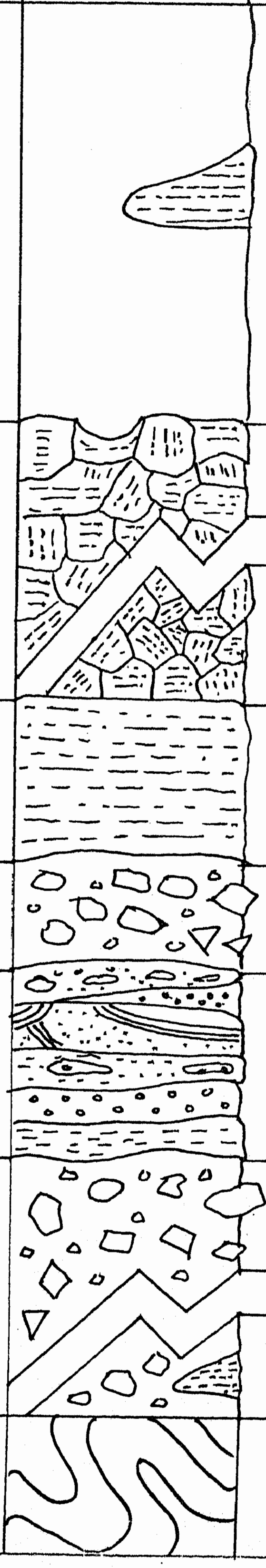
The basic chronology described and discussed here can be taken as a base for further detailed work in adjacent valleys like Skardu, Shigar, Diamir and other adjacent valleys up to high level erosion surfaces. It is also important to know in what way glacier comming from K2 and from Hunza were connected with each other. Further work in upper Gilgit river valley and in Kohistan massif will also be important.

LIST OF APPENDICES

Appendix 1

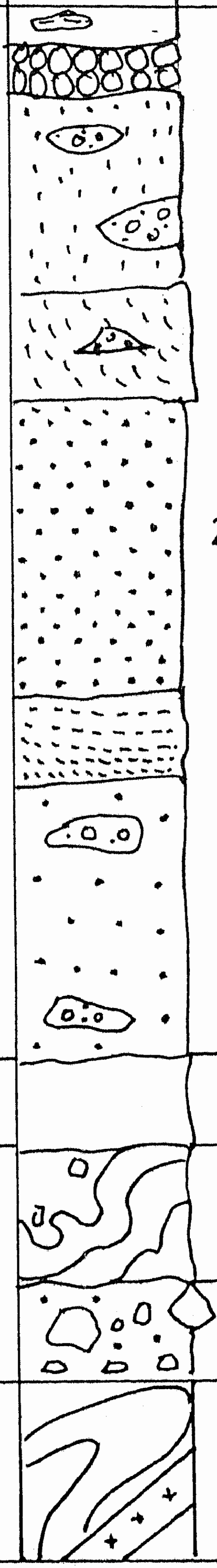
KEGES SECTION 1A

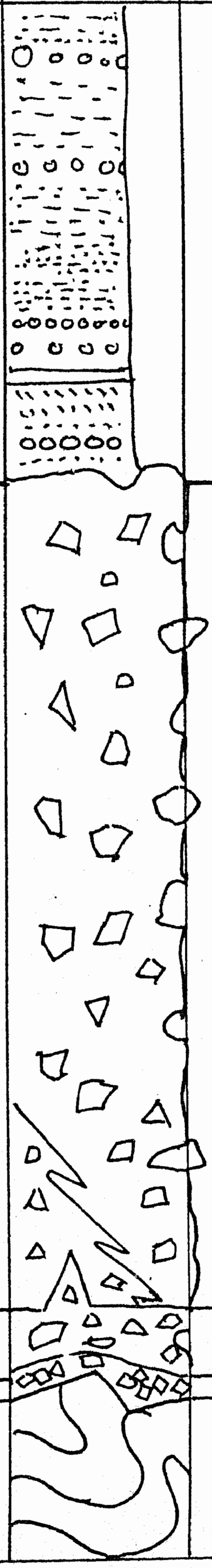
STAGE	SUB STAGE	UNIT NO.	SECTION	METERS	ROCK STRATIGRAPHIC UNIT	
EARLY TO MIDDLE INTER-GLACIATION		2		60 m	UPPER JALIPUR VALLEY FILL I	
EARLY GLACIATION		1		35+	LOWER JALIPUR TILLITE	
					BEDROCK	

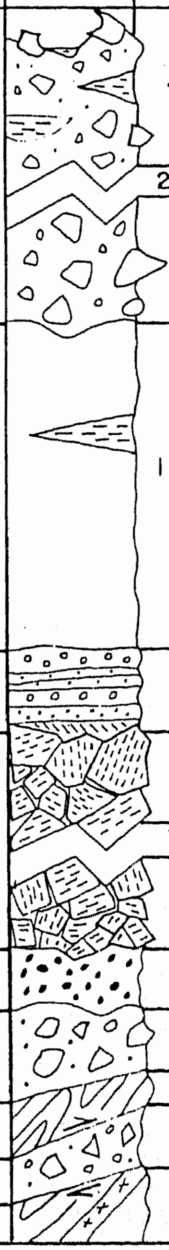


STAGE	SUB STAGE	UNIT NO.	SECTION	METERS	ROCK STRATIGRAPHIC UNIT	CHARACTER
MIDDLE TO LATE INTER-GLACIATION		6		245 +	VALLEY FILL III	
MIDDLE GLACIATION	LATE STADE	5		20 100 25	M 2	 Columnar section not shown
		4		60 +	VALLEY FILL II	
	EARLY STADE	3		30 +	M I	
EARLY TO MIDDLE INTER-GLACIATION		2		140 +	UPPER JALIPUR VALLEY FILL I	
EARLY GLACIATION		1		27.5 20 27.5	LOWER JALIPUR	 Columnar section not shown
					BEDROCK	

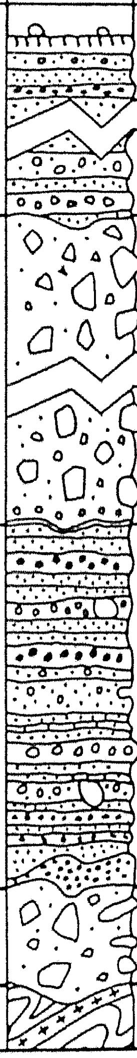
PATRO SECTION

STAGE	SUB STAGE	UNIT NO.	SECTION	METERS	ROCK STRATIGRAPHIC UNIT	
EARLY TO MIDDLE INTER-GLACIATION		3		220+	UPPER JALIPUR VALLEY FILL I	
		2		?		
EARLY GLACIATION		1		30± 10±	LOWER JALIPUR	
					BEDROCK	

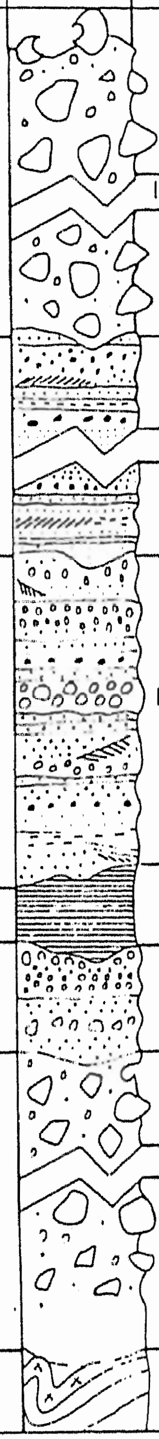
STAGE	SUB STAGE	UNIT NO.	SECTION	METERS	ROCK STRATGRAPHIC UNIT
	INTER STADE	4		75+	VALLEY FILL II
MIDDLE GLACIATION	EARLY STADE	3		200+	M 1
		2		10±	
		1			
					BEDROCK

Stage	Substage	Unit No.	Section	Meters	Rock-Stratigraphic Unit	Character
Late Glaciation		7		40	Nanga Parbat Moraines	
				200		Columnar section not shown
				40+		
Middle to Late Inter-Glaciation		6		100+	Valley Fill III	
		5		25		
Middle Glaciation	Late Stade	4		30	M 2	
				70		Columnar section not shown
				30		
		3		20	Valley Fill II	
	Early Stade	2		20	M1 Till	
					Sheared Bedrock	
Early Glaciation				15 ±	Lower Jalipur Till	
		1			Sheared Bedrock	

1F

Stage	Substage	Unit No.	Section	Meters	Rock-Stratigraphic Unit	Character
Middle to Late Inter-Glaciation		4		20	Valley Fill III	
				20		Columnar section not shown
				25±		
Middle Glaciation	Late Stade	3		40	Upper Till M2	
				40		Columnar section not shown
				45±		
	Inter-Stade	2		120±	Valley Fill II	
	Early Stade	1		30	Lower Till M1	
					Bedrock	

1G

Stage	Substage	Unit No.	Section	Meters	Rock-Stratigraphic Unit	Character
Late Glaciation				40+ 160 40+	Dak Chauki Moraine	Columnar section not shown
Middle to Late Inter-Glaciation				30 60 100 25± 30+	Valley Fill III	Columnar section not shown
Middle Glaciation				30 80 30±	Lower Till M 2	Columnar section not shown
					Bedrock	

1H

STAGE	SUB STAGE	UNIT NO.	SECTION	METERS	ROCK STRATIGRAPHIC UNIT
Middle Glaciation		4		60.5m	VALLEY FILL II
	Early Stade	3		21 m	M1
Early to Middle Inter-glaciation		2		30m	UPPER JALIPUR VALLEY FILL I
Early Glaciation		1		15m	Lower Jalipur
					BED ROCK

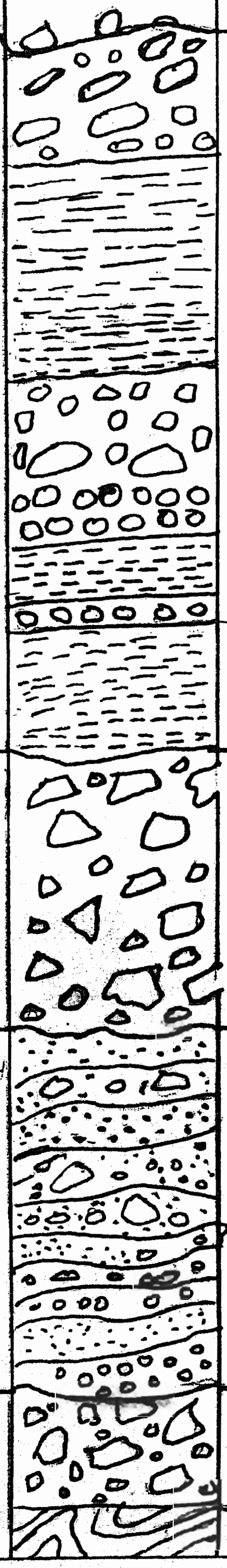


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Table 1.- Dainelli's analysis (1922) of Himalayan glaciations (after de Terra and Paterson, 1939).

4th Glaciation -	(post-Wurm 1 of Alps): Weakest of advances; Snowline in Kashmir, 3,800 m; Thick outwash at Skardu but no glaciation in main Indus Valley; Deosai Plateau not glaciated; 20 % of total mountainous Indus Basin glaciated (10 % today).
3rd Interglacial-	Erosion of older lake sediments; all major valleys free of ice.
3rd Glaciation -	(Wurm of Alps): Kashmir snowline, 3,500 m; Skardu lake dammed by tributary glacier; No glaciers in Kashmir of Indus Valleys; Lakes in Baltistan, Indus Valley near Leh, and elsewhere; Deosai thinly glaciated; 30 % glacial cover on mountainsof Indus Basin.
2nd Interglacial-	Erosion in mountains.
2nd Glaciation -	(Riss of Alps): Kashmir snowline, 3,000 m; Glacier snouts into Kashmir lakes. Main Indus glacier extends to northwest Punjab plains where erratics are carried by icebergs in periglacial lakes; Strong glaciation all over Karakoram Himalaya; 50 % of area glaciated.
1rst Interglacial-	Damming of Kashmir Basin and early karewa lake beds; Great erosion following uplift; entrenchment of all rivers, especially Indus at Skardu.
1rst Glaciation -	(Mindel of Alps): Intensive glaciation in main Himalaya; Ice cover on Deosai.

Table 2.- Translations of figures 5, 27, and 54 of Dainelli (1922) that show the variety of Quarternary surfaces and deposits occurring in Karakoram Himalaya. The order of features is arranged approximately in a relative chronology in order of superposition. (After Shroder, 1986).

<u>Terrace Orography in the (Upper) Indus Basin</u>

- Terrace more or less preserved with original surface.
- Terrace successively lowered.
- Rock isolated on valley bottom with superficial lower terrace deposits.
- Zone of emergent relief of the terrace.
- Approximate limit of the bottom of the old valley level.

<u>Shigar Valley</u>

- Orographic limit of the valley.
- Recent alluvial cones.
- Recent sand.
- Post-glacial terraces.
- Alluvial fans of the 4th glacial expansion.
- Moraine of the 4th glacial expansion.
- Moraine of the 3rd glacial expansion.
- Lacustrine clays of the 3rd glacial expansion.
- Moraine of the 2nd glacial expansion.
- Trace of suspended threshold (high-level valley of the 2nd glaciation).
- Smoothed ground lowered and rounded by the 2nd glaciation.
- Terrace level representing old valley level of the lrst glacial expansion.

The Basin of Skardu

- Recent alluvial fans.
- Recent sand and alluvium
- Alluvial fans of the 4th glacial expansion.
- Moraine of the 4th glacial expansion.
- Sand (dunes) of the 4th glacial expansion.
- Alluvium of the 4th glacial expansion.
- Moraine of the 3rd glacial expansion.
- Lake clay of the 3rd glacial expansion.
- Moraine of the 2nd glacial expansion.

Table 3.- Deposits and events in upper Indus area (from de Terra and Paterson, 1939).

Fourth Glaciation	Terminal moraines 4 Glaciers in tibutary valley only Terrace 4, loose gravel
Third interglacial stage	Erosion and uplift Terrace 3 Degradation
Third	Terminal moraines 3, local glaciation of Indus Valley
Glaciation	Terrace 2, younger valley fill, boulder gravel; lake silt locally 450 feet.
Second interglacial Stage	Terrace 1 Degradation Erosion
Second	Ancient valley fill Boulder gravel
Glaciation	Great Indus Glacier
First interglacial stage	Erosion
First glaciation	Dissected trough valleys

Table 4.- Correlation chart of Quaternary Period in north Pakistan.
(After Shroder, 1985).

Series	Glacial Non-Glacial: Stage	Stade	Landforms & Deposits / Middle Indus-Gilgit-Hunza Valleys: This Paper	Derbyshire & others, 1984	Zhang & Shi 1980	Schneider 1959	Wiche 1959	Desio & Orombelli, 1971	Olson 1982	Upper Indus: Cronin 1982	Swat Kohistan: Porter 1970	Tentative Dates: Years
HOLOCENE			Historical	Pasu II	Historical	Older Moraines of recent glaciers				Individual Moraines		10^2
			Little Ice Age	Pasu I (4) (5)	Little Ice Age							10^3
			Neoglacial	Batura	Neoglacial						Neoglacial	10^4
PLEISTOCENE	Late Glaciation		L3 (1) (2) Darel-Shatial Moraine L2 L1 Dianyor Moraine	Ghulkin II — Ghulkin I (6) (7) (8) Borit Jheel (?Hunza)	Hunza Glaciation	? Earth pyramid Series ? Diluvial Moraine ridges ?	Younger Valley Fill	Dak Chauki Moraine	-Remote Sensing Digital Analysis- Stratigraphically undifferentiated diverse clastics		Kalam Glaciation Late Stade; Kalam Glaciation Intermediate Stade; Kalam Glaciation Early Stade	10^5
	M—L Inter G.		L0 (3) Valley Fill III	(9)		Alluvium	Oldest Valley Fill			—?— Strong Erosion; Alluviation		
	Middle Glaciation	Late Stade	M2 Tills	Yunz	Yunz	Blockschutt diamicton		Gunar Moraines		Satpara Till	Gabral Glaciation Late Stade	
			Valley Fill II			Alluvium ?				—?— Valley Fill		
		Early Stade	M1 Tills	Glaciation	Glaciation	Highly Indurated terrace remnants		Dudishal, Shatial Moraines		(12) Bunthog Till	Gabral Glaciation Early Stade	
	E—M Inter G.		Upper Jalipur Valley Fill I	Shanoz Glaciation	Shanoz Glaciation	High-level terrace remnants			(11) Jalipur Sequence		Laikot Glaciation	10^6
	Early G.		Lower Jalipur Till	(10)						(13)		

G. = Glaciation

Table 5.- Report of thermoluminescence dating analysis for three samples of lake sediments collected in middle Indus, Gilgit, and Hunza River valleys. (After Shroder, 1985).

1. Alpha-1943	3-Gilgit Hunza confluence	sediment U = 6.14 ppm, $K_{2}0$ = 2.87%	31,400 ± 2,000* Th = 10.59 ppm;
2. Alpha-1944	2A-Sazin	sediment U = 4.87 ppm; K_2O = 2.08%	38,100 ± 2,600** Th = 14.07 ppm;
3. Alpha-1945	1A-Gilgit	sediment U = 3.57 ppm; K_2O = 3.24 %	greater-than 100,000*** Th = 11.53 ppm;

* Weighted mean of dates from Regen, Residual and R-Beta techniques. Date based on initial water content. If estimated 75 % of saturation is taken the age calculates to 45,900.

** Residual and R-Beta techniques exhibit saturation. Age based on Regen technique - no trap saturation and no sensitivity change on laboratory bleach. Date based on initial water content. If estimated 75 % of saturation is taken, the age calculates to 56,000.

*** All techniques exhibited trap saturation probably caused by rather high uranium and thorium producing a dose rate about twice normal. A minimum age was calculated on the basis of first curvature of the Regen plot. The above samples were submitted to Alpha Analytic, Inc. for thermoluminescence dating on the individual sediment basis. Samples were extracted in dim light and treated with a series of acids and peroxides to remove carbonated and humic acids that might create spurious signals. The cleansed sediment was further disseminated with dilute sodium oxalate solutions the 4-11 micron particle size fraction was separated for multiple glow analyses by the fine-grain technique, using 3 methods of dating: Regen, Residual, and R-Beta (Wintle and Proszynska, 1983). In general reproducibility was good in each case and each sample produced stable plateau/temperature regions. Mineral sensitivity and apparent equivalent dose (ED) were determinated by alpha and beta irradiations using calibrated AM-241 and Sr-90 plack sources. U, Th were determined by thick-sources alpha counting, and k by atomic absorption. Cosmic dose was taken as 0.014 rads/yr. Water content was taken as initial value that results from high aridity at all sites. In more humid temperate climates a water content of 75 % would be estimated. The dates above are thus probably not far off minimum calculations considering initial deposition as saturated lake sediments impounded behind temporary ice or landslip dams, with probable rapid dam failure subsequently, followed by valley dissection and drainage of the ground water to present aridity.

Table 6.- Dates constraining Quaternary chronology of middle and upper Indus Gilgit, and Hunza drainage basins. (After Shroder, 1985).

DATE NUMBER HEREIN	DATE	DATING METHOD	MATERIAL AND LOCATION	REFERENCE
1.	31,400±2,000 yr B.P.	Thermoluminescence	Lacustrine sediments Gilgit-Hunza River confluence	Alpha-1943 Alpha Analytic
2.	38,100±2,600 yr B.P.	Thermoluminescence	Lacustrine sediments Sazin, Middle Indus River Valley	Alpha-1944 Alpha Analytic
3.	>100,000 yr B.P.	Thermoluminescence	Lacustrine sediments Dianyor Terrace Gilgit River Valley	Alpha-1945 Alpha Analytic
4.	325±60 yr B.P.	Carbon - 14	Wood Fragments Minapin Glacier moraine, Hunza	Derbyshire, *et al*, 1984
5.	830±80 yr B.P.	Carbon - 14	*Juniperus* sp. Minapin Glacier moraine, Hunza	Derbyshire, *et al*, 1984
6.	47,000±2,350 yr B.P.	Thermoluminescence	Lacustrine silts Pisan Glacier, Hunza	Derbyshire, *et al*, 1984
7.	50,000±2,500 yr B.P.	Thermoluminescence	Lacustrine silts Batura Glacier, Hunza	Derbyshire, *et al*, 1984
8.	65,000±3,300 yr B.P.	Thermoluminescence	Lacustrine silts Pasu Glacier Hunza	Derbyshire, *et al*, 1984
9.	139,000±12,500 yr B.P.	Thermoluminescence	Lacustrine silts Ghulkun Glacier, Hunza	Derbyshire, *et al*, 1984
10.	<<8.6 myr B.P.	Rubidium-Strontium	Granodiorite Patundus erosion surface, Hunza	Derbyshire, *et al*, 1984
11.	<<2 myr B.P.	Fisson track	Detrital zircon Jalipur Sandstone Middle Indus Valley	Olson, 1982
12.	>0.72 - 0.98 myr B.P.	Paleomagnetic time scale	Mudstone, Bunthag Terrace, Skardu	Cronin, 1982
13.	<<8.2 myr B.P.	Fisson track	Apatite in nearby bedrock, Skardu	Cronin, 1982

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