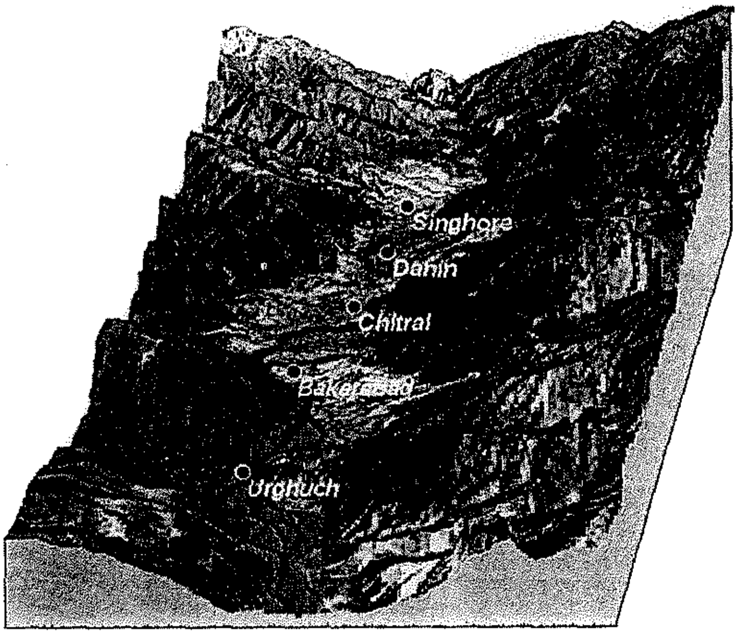
An Examination of Terraces along Chitral River Their Distribution, Surface Deposits and Genesis

A thesis presented for the degree of Ph.D in the University of Peshawar.



by

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Dedication

This study is dedicated
to my parents and my wife
in token of great debt of gratitude and love

An Examination of Terraces along Chitral River: Their Distribution, Surface Deposits and Genesis

Acknowledgements

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Mohammad Jamal Nasir

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Abstract

The study deals with the genesis of the terraces and deposits of lower Chitral Valley. Fieldwork suggests the presence of ten sequences of well-preserved terraces. The number of terraces varies from sequence to sequence, but correlation suggests eight different levels of terraces. T1 is preserved at a height of 330-350-m, T2 at 325-m, T3 at 100-115-m, T4 at 80-85-m, T5 at 60-65-m, T6 at 40-45-m, T7 at 15-m, and T8 at 05-m above Chitral river. Terraces T5, T6, T7, and T8 are preserved in almost all sequences.

On the basis of lithological characteristics, it was possible to identify six different types of deposits: older fan gravel, lacustrine material, middle fan gravel, river gravel, young fan gravel and loess. The oldest deposit is lacustrine silt at Kesu at a height of 700-m above Chitral river. The study of sections and terraces has brought to light significant events of the Pleistocene history. These events have been correlated with the work of Heserdot (1979) and Kamp (1999). Despite best efforts, the chronology of events is only tentative. There are a number of gaps in the Pleistocene geomorphology of Chitral valley, which needs to be filled by studies, using modern dating techniques.

An effort has also been made to construct a model of the Pleistocene events in lower Chitral. This is on the basis of evidence found in the study area, but in some instances dates of Kamp (1999) have also been used. While in some other cases, dating has been done on the basis of correlation with Pleistocene deposits of Karakoram-Himalayas. The model has been explained with the help of photographs and diagrams.

According to the model of late quaternary era, the Pleistocene history of the area can be divided into four glacial and three inter-glacial periods. The glacial and inter-glacial periods are named after the localities where the evidence was found. The first glacial phase (≅Mindel) dates back to >2000ka, first inter-glacial phase (≅Mindel/Riss) 200ka, Drosh cold phase (≅Riss) 190.120ka, Parwak warm phase 110-90ka (≅Riss/Wurm), Pret cold phase 90-10ka (≅Wurm), Urghuch warm phase <60ka, Sanoghur cold phase <60-10ka and Holocene <10ka.

List of Abbreviations

AEQUA	Association for the Study of the Quaternary
ASL	Above Sea level
ACR	Above Chitral River
ARB	Above River Bed
AKRSP	Agha Khan Rural Support Program
bp	Before present
Cm	Centimeter
di	Intermediate Diameter
dl	Long Diameter
ds	Short Diameter
ELA	Equilibrium Line
eds.	Editors
GR	Grid reference
Geol.	Geological
GSA	Geological Society of America
IRSL	Infrared Stimulated Luminescence
IGCP	International Geological Correlation Program
J	Journal
Km	Kilometer
Ka	Thousand Years
LGM	Last Glacial Maximum
LIA	Little Ice Age
MCT	Main Central Trust
mm	Millimeter
MSL	Mean Sea Level
myr	Million Years
NAA	Neutron Activation Analysis
NASA	National Aeronautics and Space Administration
OSL	Optically Stimulated Luminescence
Pub.	Publishers
pp	Pages
TL	Thermoluminescence
S.E.G	Spanish Association of Geomorphology
Sed.	Sedimentary
Seq.	Sequence
Vol.	Volume
USGS	United State Geological Survey
WWU	Western Washington University

Chapter No. 1
General Evironment

Chapter No. 1
General Environment

1.1. Introduction:

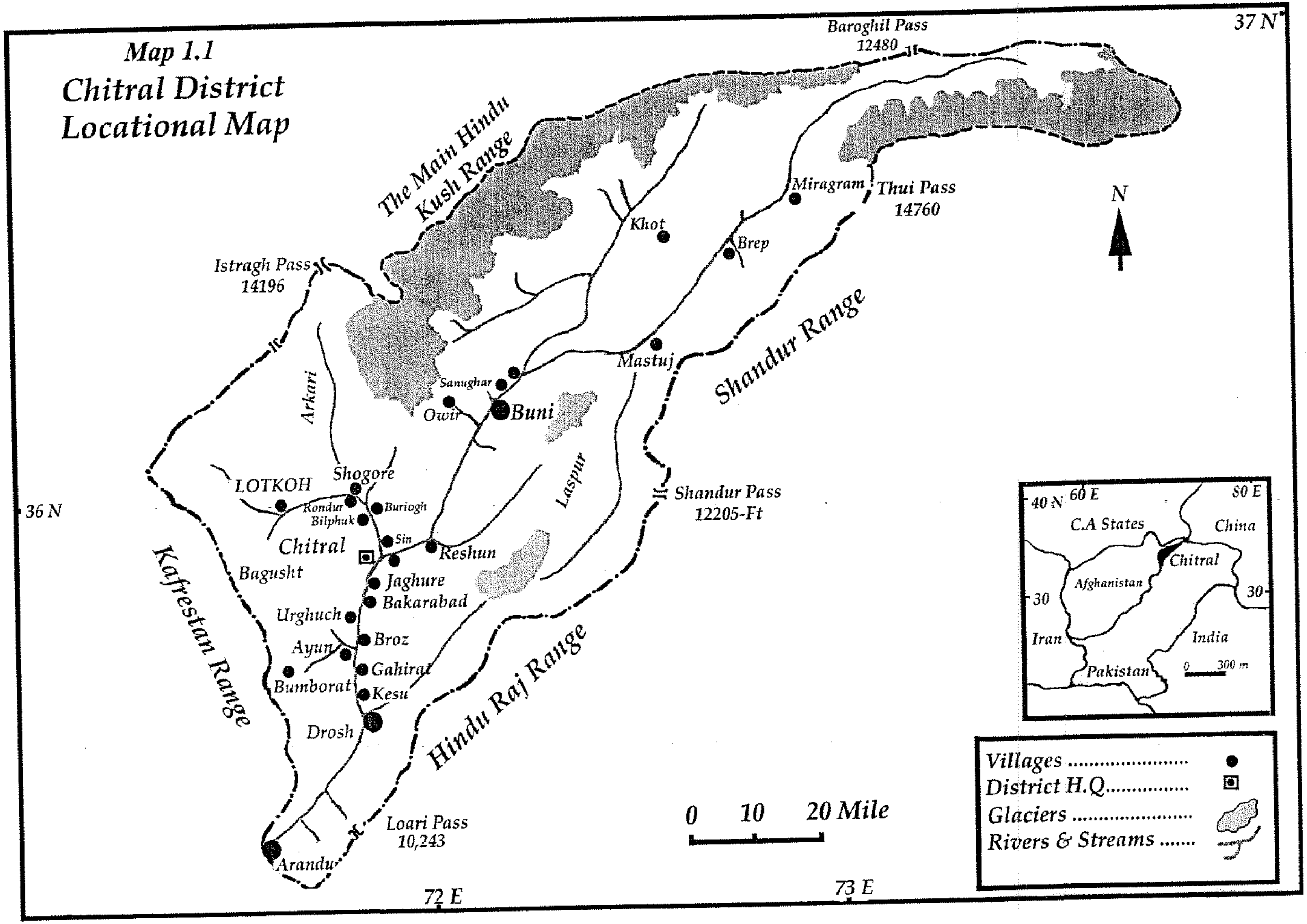
Chitral is the northern-most administrative district of Pakistan, having common border with Afghanistan on the north and west. It is bounded by the Northern Areas on the east and Dir and Swat districts towards south. Surrounded by 4,500-7,500-meters high ranges of the Hindu Kush and Karakoram, it is one of the loftiest tracts of the country. It is separated from the rest of the country by the Hindu Raj range; the only contact being through passes over 3,000-meter.

Chitral district was a princely state of Pakistan until 1969, when it was merged with Pakistan. It covers an area of 14,850 sq. km. The total population according to 1998 census is 317,198, with a density of 21 persons /sq.km.

Chitral district is extremely rugged and mountainous, with deep narrow and tortuous valleys through which runs river Chitral and its numerous tributaries. From the high glacial-bound valleys, the elevation of the country decreases as one descends into the valleys, where the land of glaciers gives way to barren hillsides of rocky cliffs and debris. The lowest elevation is at Arundu (1129m) where the Chitral river enters into Afghanistan.

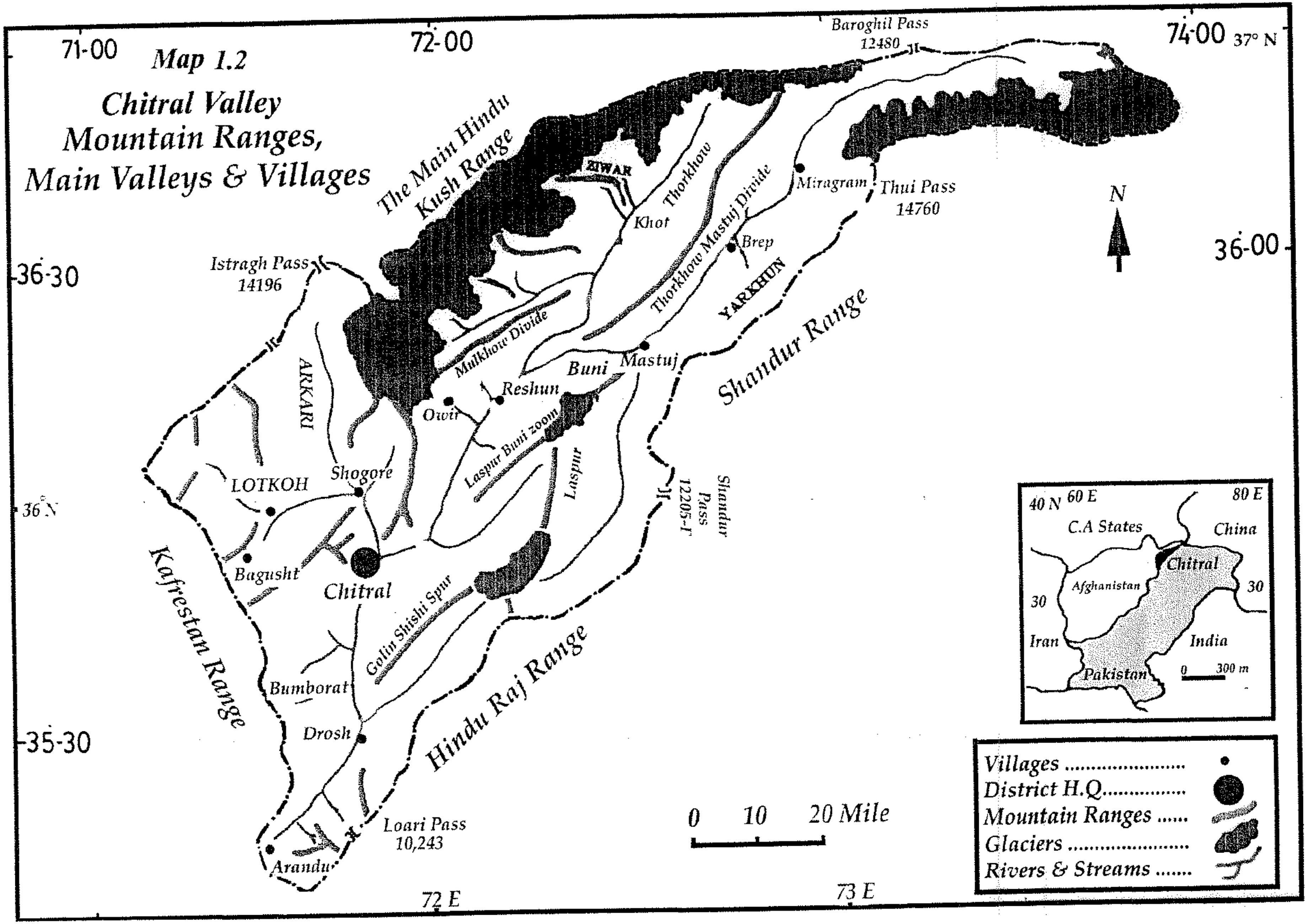
Geographical location

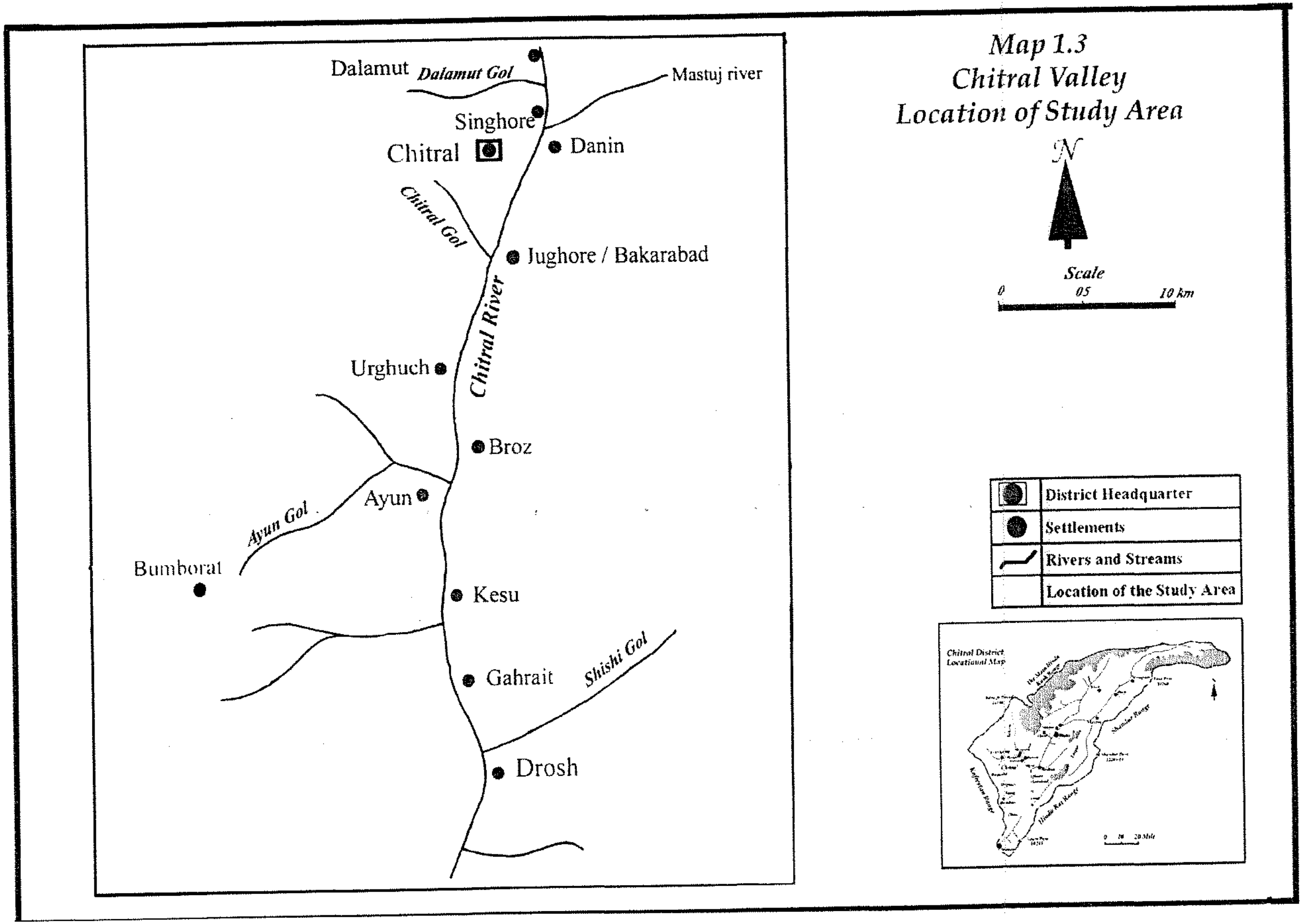
The study area is located between 35°-50' to 35°-34' North latitude and 71°-46' to 71°-34' East longitude. The study area start from Chitral town as for as Drosh, is the part of Chitral valley, which is commonly refers as lower Chitral. Chitral valley has a maximum length of 240 km; its width ranges from 2.4 to 14.4 Km. The height of the valley, above sea level, ranges from 1200-meter at Arandu to 3658-m at Baroghal ***(map 1.1 & 1.2).***


Map 1.1
Chitral District
Locational Map
The Main Hindu Kush Range
Baroghil Pass 12480
37 N
Thui Pass 14760
Miragram
Khot
Brep
N
Istragh Pass 14196
Shandur Range
Mastuj
Sanughar
Owir
Buni
Arkari
Laspur
Shogore
LOTKOH
Kondur
Buriogh
Bilphuk
36 N
Shandur Pass 12205-Ft
Chitral
Sin
Reshun
Bagusht
Jaghure
Bakarabad
Urghuch
Broz
Ayun
Gahirat
Bumborat
Kesu
Kafrestan Range
Drosh
Hindu Raj Range
Loari Pass 10,243
Arandu
0 10 20 Mile
72 E
73 E
40 N 60 E
80 E
C.A States
China
Chitral
Afghanistan
30
30
Iran
India
Pakistan
0 300 m
Villages
District H.Q
Glaciers
Rivers & Streams

Map 1.2

Chitral Valley Mountain Ranges, Main Valleys & Villages




Map 1.3
Chitral Valley
Location of Study Area
N
Scale
0
05
10 km
District Headquarter
Settlements
Rivers and Streams
Location of the Study Area
Chitral District Locational Map
Dalamut
Dalamut Gol
Mastuj river
Singhore
Chitral
Danin
Chitral Gol
Jughore / Bakarabad
Chitral River
Urghuch
Broz
Ayun
Ayun Gol
Bumborat
Kesu
Gahrait
Shishi Gol
Drosh

Study Area
Digital Elevation Model
Superimposed
by Rivers
and Major Streams

1.2. Topography

Chitral valley is generally rough, rugged and mountainous. Geographically, it may be defined as the drainage basin of the Chitral river and its affluents. It is permeated by the Hindu Kush and its many offshoots, and forms one of the loftiest tracts on the surface of the globe. In this sea of mountains, one finds more than 40 peaks over 6000-m high, which rise ridge behind ridge and finally toes themselves up into one towering mass forming the majestic Trich Mir, 8420-meter.

Physiographically, the land has a low elevation at Arundo (1200-meter) and as high as 8420-meter at Trich Mir. Other, notable highest peaks are Shogharan Dak (7300m) Koyo (7290-m), Kotal Kash (7280-m), Boni Zom (7160-m) and Soriawi (7100-m). The following lofty spurs are separated from this main range of the Hindu Kush:

I. The Mashabar and Hindu Raj range, which runs along the northeastern border of Chitral.

II. The spurs thrown off the main range of the Hindu Kush in the northwestern part of Chitral include the following:
   a. The Torikhow-Mastuj divide
   b. The spur of Molikhow and Tirikhow
   c. The Arkari-Molikhow spur
   d. The Arkari-Lutkhow divide

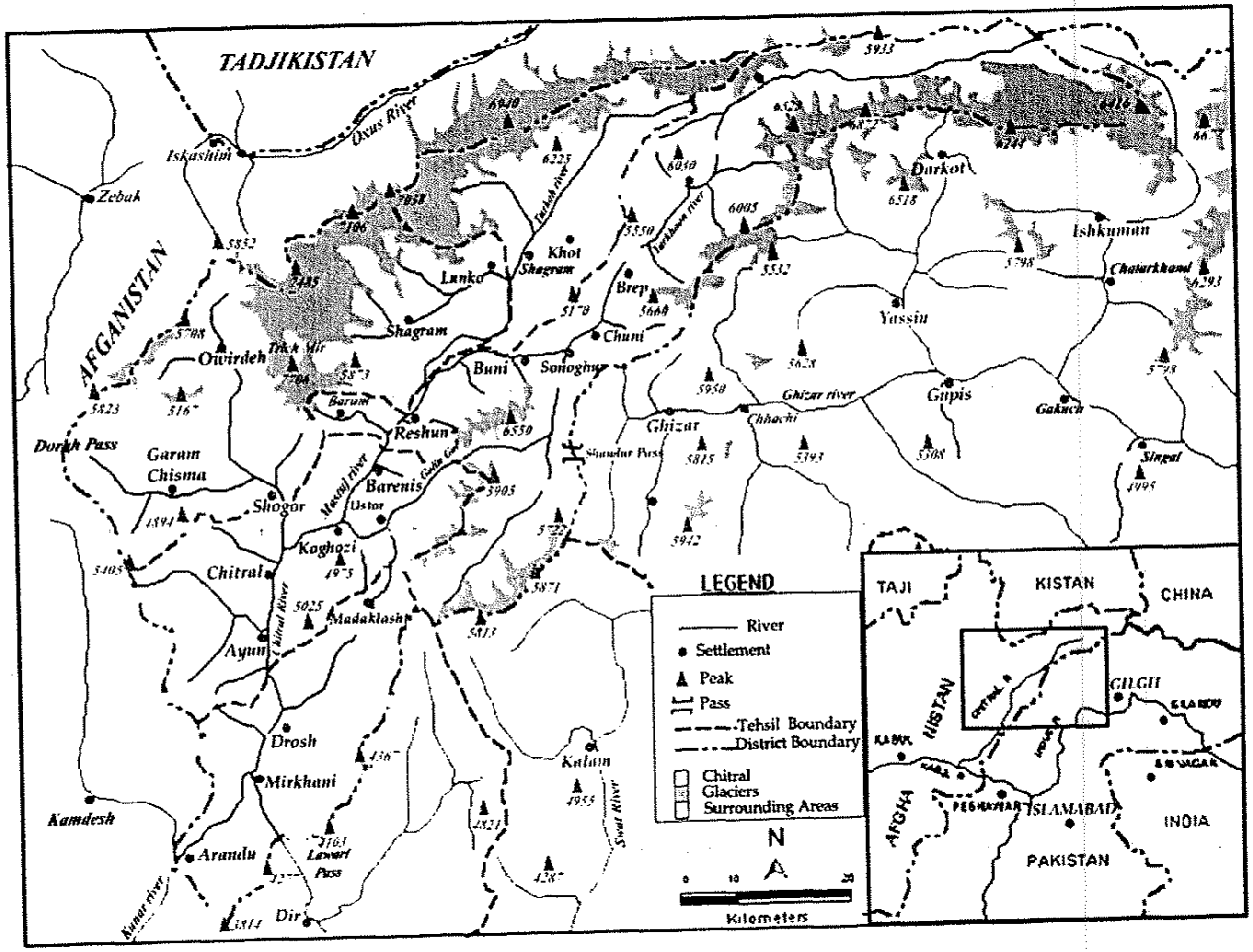
The salient features of the topography are as under.

1. The orientation of the catchment area is from southwest to northeast. High, rugged and upstanding mountains characterize tract. The valleys get narrower and narrower, while draining toward Chitral river. They are zigzag, irregular and devoid of vegetation, from west to the northeast, resulting in bare rock outcrop.

2. About 20% area is glaciated i.e. above 4300-m elevation.

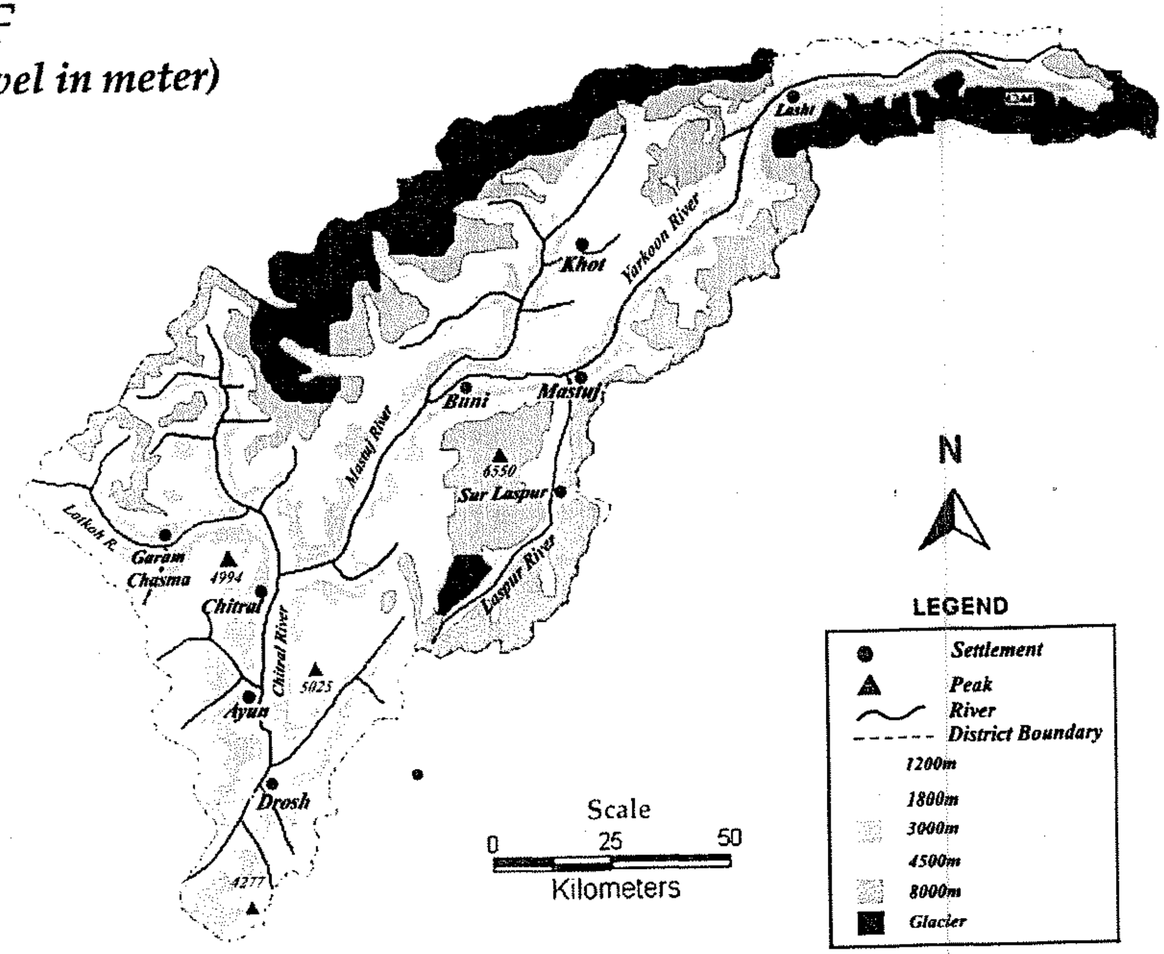
3. About 2% area is situated in the bed of valleys, where habitation is possible.

Map 1.4
Chitral District & Adjoining Areas
Distribution of Glaciers



Cartography by M. Jamal Nasir

Map 1.5
Chitral District
RELIEF
(Height above sea level in meter)



Cartography by Jamal Nasir

4. The general slope is steep to precipitous and sheer cliffs are common.

1.3. Chitral river valley:

The Chitral river takes rise in the Chaintar glacier. During its course it collects numerous hill torrents and streams. Among them Torkhow and Mulkhow rivers are important.

The main valley from its source to the border of Afghanistan is about 339 km. long. The average width is not more than three fourth of a Km. At some places, however, it widens to about 5 Km e.g. at Buni, Chitral town, Drosh and Baroghil. While at other places it narrows to a defile of less than 20 meters e.g.; Darband Koragh, Kar Bitari and many other places. The side valleys are even narrower.

The open areas comprise the fan deposits, which occur at the mouth of torrents. The origin of these alluvial fans can be attributed to temperature and humidity extremes of Chitral's climate, which cause the rock debris to burst. Avalanches, torrents and streams, which contain melt water, and floods that are caused by the summer torrential rains, have also contributed to the formation of alluvial fans. Almost all the settlements and cultivated areas are mostly confined to these alluvial fans along the river Chitral.

1.4. Climate:

The few descriptions of climate that exist are far too generalized to be of much use in a region that varies locally so much in altitude. The most useful account is that by Rafiq (1976) who describes various type of climate in Pakistan. Hamid et al (1969) also applied the various climate classification system of Koppen, together with those of Papadakis (1966) and Walter et al (1975) all place Northern Areas and Chitral into one-category, basically a dry continental climate.

However, even to the casual observer, within this region, that spans two degrees of latitude **(35°-13'-36°55N)** and three degrees of Longitude **(71°-73°E)**, there is a significant variation in temperature and precipitation imposed by topography.

The climate has the following general features:

1. The climate of Chitral is distinctly continental. It is hot in summer ranging from very hot in the lowlands, to warm in the uplands and cool in the higher elevations. The extreme maximum temperature recorded in Drosh is 45 C° for the month of July while in Chitral it is 44 C° for the same month. The mean maximum temperature for the same month for Drosh is 36 C° and the mean minimum temperature is 23-26 C°.

2. In winter most of the valleys are in the grip of cold northerly winds. The winter is less severe in the lowlands as compared to the uplands. The extreme minimum temperature recorded at Drosh and Chitral stations is -3.8 C° for the month of January and February. The mean minimum temperature for the same stations has been 0.2 C° and -1.3 C° for the months of January and February respectively.

3. Chitral district receives between 250-mm and 1000-mm rainfall annually. It increases in January; the maximum is reached in March when 135.9-mm and 135-mm rainfall is obtained in Drosh and Chitral respectively. The rainfall from December to April amounts to 448.2-mm in Drosh, or 68% of the total annual rainfall. The rainfall in the upper parts of Chitral is low; winter and spring rain is more or less the same. The winter and spring precipitation is very important because it first provides moisture to rabbi season and secondly the whole years flow of springs, streams and rivers depend on the snow-fall in these seasons.

4. The summer and autumn rains form only about 32% of the total annual rainfall. It is received from the thunderstorms, which often gives torrential rains and cause great damage due to floods. Dust storms also occur during July and August that

occasionally bring showers in the afternoons. Nearly all the moisture of the monsoon, becomes almost exhausted over the plains of India and Pakistan, before reaching these remote valleys. Thus Chitral benefits very little from the monsoons.

Table No. 1.1

Average monthly rainfall in mm for Chitral and Drosh

Month	Chitral		Drosh	
	Mean*	Heaviest Fall	Mean*	Heaviest Fall
January	32.0	37.3	87.1	95.3
February	75.7	61.7	74.7	80.8
March	153.4	39.0	135.9	72.4
April	155.7	34.8	109.7	86.4
May	47.0	35.6	61.0	50.8
Jun	6.9	6.1	21.8	38.6
July	7.9	7.4	21.3	35.1
August	9.1	8.6	23.9	115.3
September	16.3	29.7	26.4	95.3
October	18.5	24.1	34.8	64.8
November	16.3	24.4	22.4	52.8
December	49.0	33.0	39.9	77.7
Average	48.9		54.9	

Heaviest rainfall in 24 hours of rainfall
**Average upto 12 years, 1999-2002*

Table No. 1.2

Average monthly temperature in C° for Chitral and Drosh 1990-2002

Month	Chitral		Drosh	
	Maximum	Minimum	Maximum	Minimum
January	8.7	-1.3	7.1	0.2
February	10.6	0.3	10.2	1.4
March	16.1	5.1	15.1	4.9
April	21.7	8.4	21.3	9.8
May	27.3	12.8	28.1	15.3
Jun	34.8	18.7	33.8	20.3
July	36.7	20.7	36.0	23.2
August	35.7	14.7	35.1	22.7
September	31.7	13.6	32.1	18.7
October	24.7	8.2	25.6	11.9
November	17.9	3.4	17.8	6.4
December	11.5	0.1	11.1	2.4
Average	23.1		22.7	

Source: Regional Meteorological Office, Lahore.

Figure 1.1
Chitral Climograph

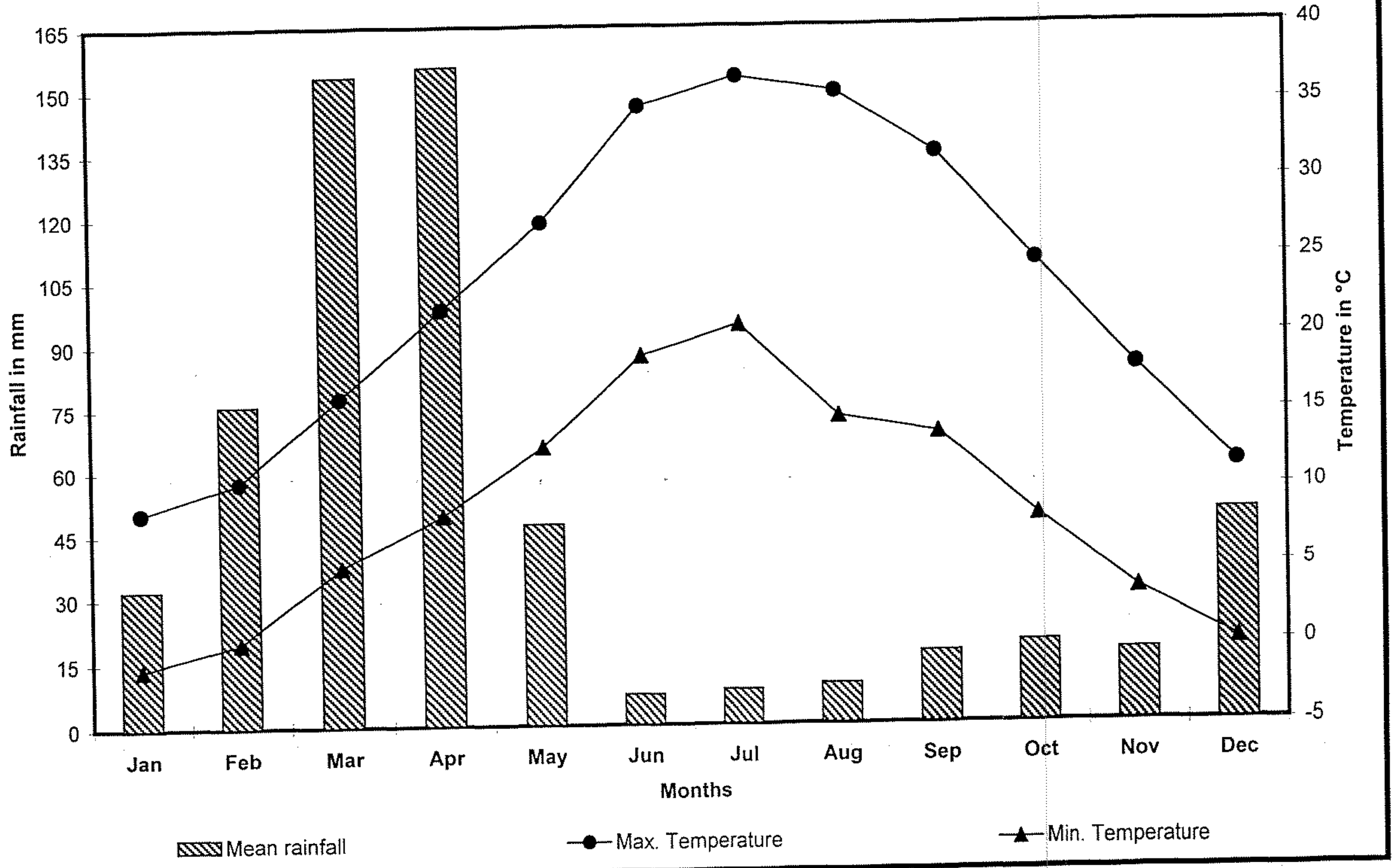
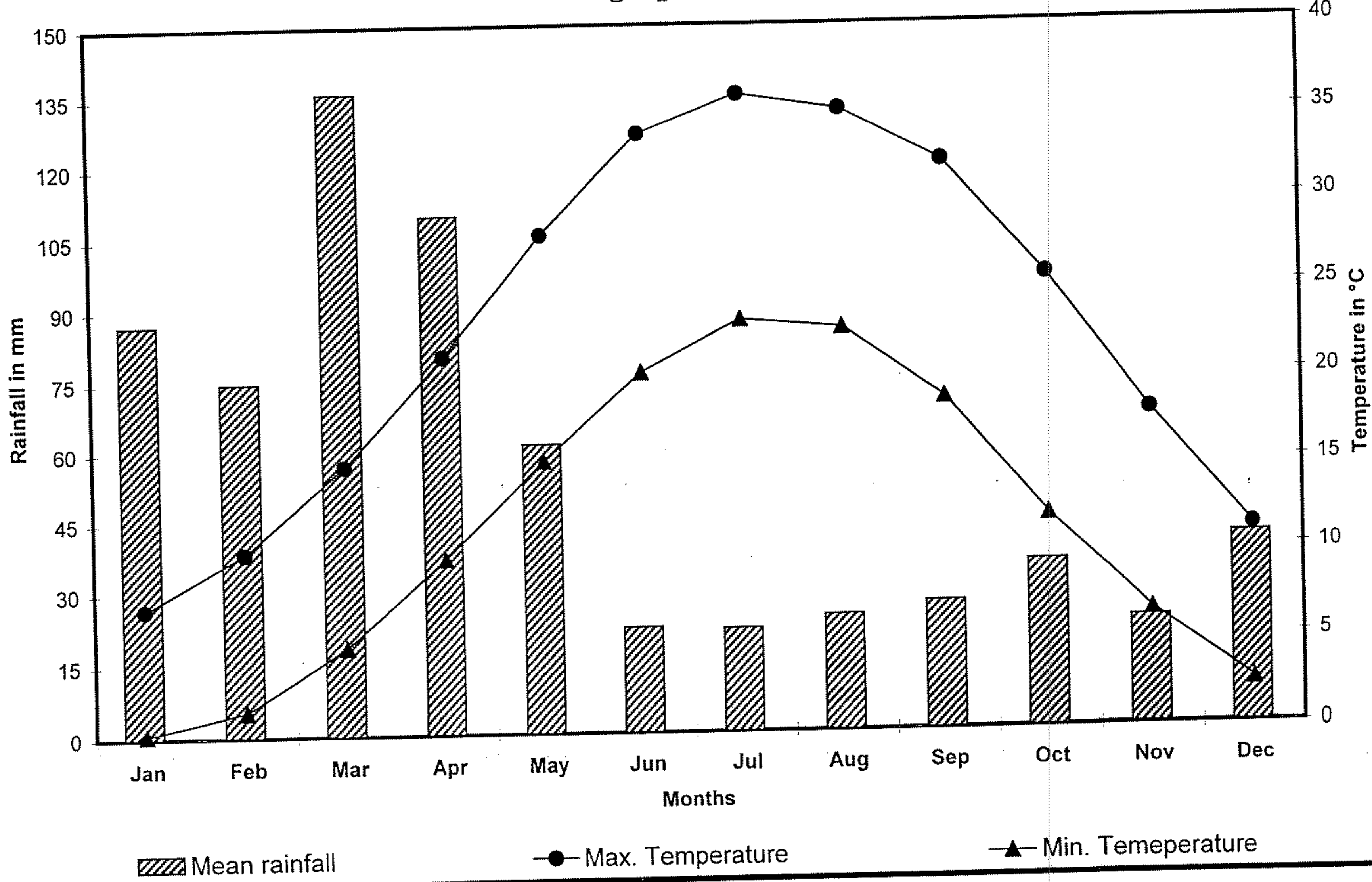
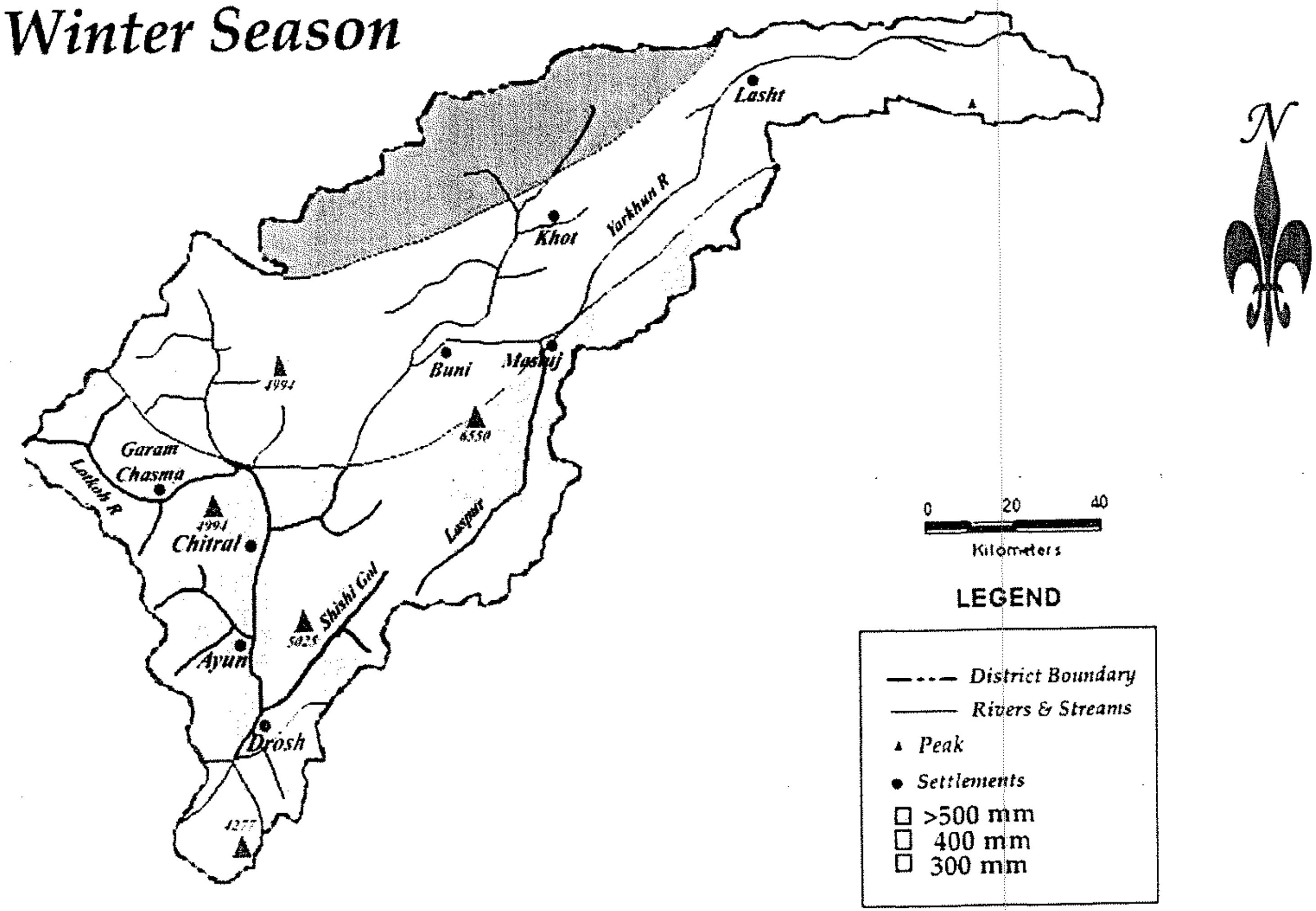


Figure 1.2
Climograph of Drosh



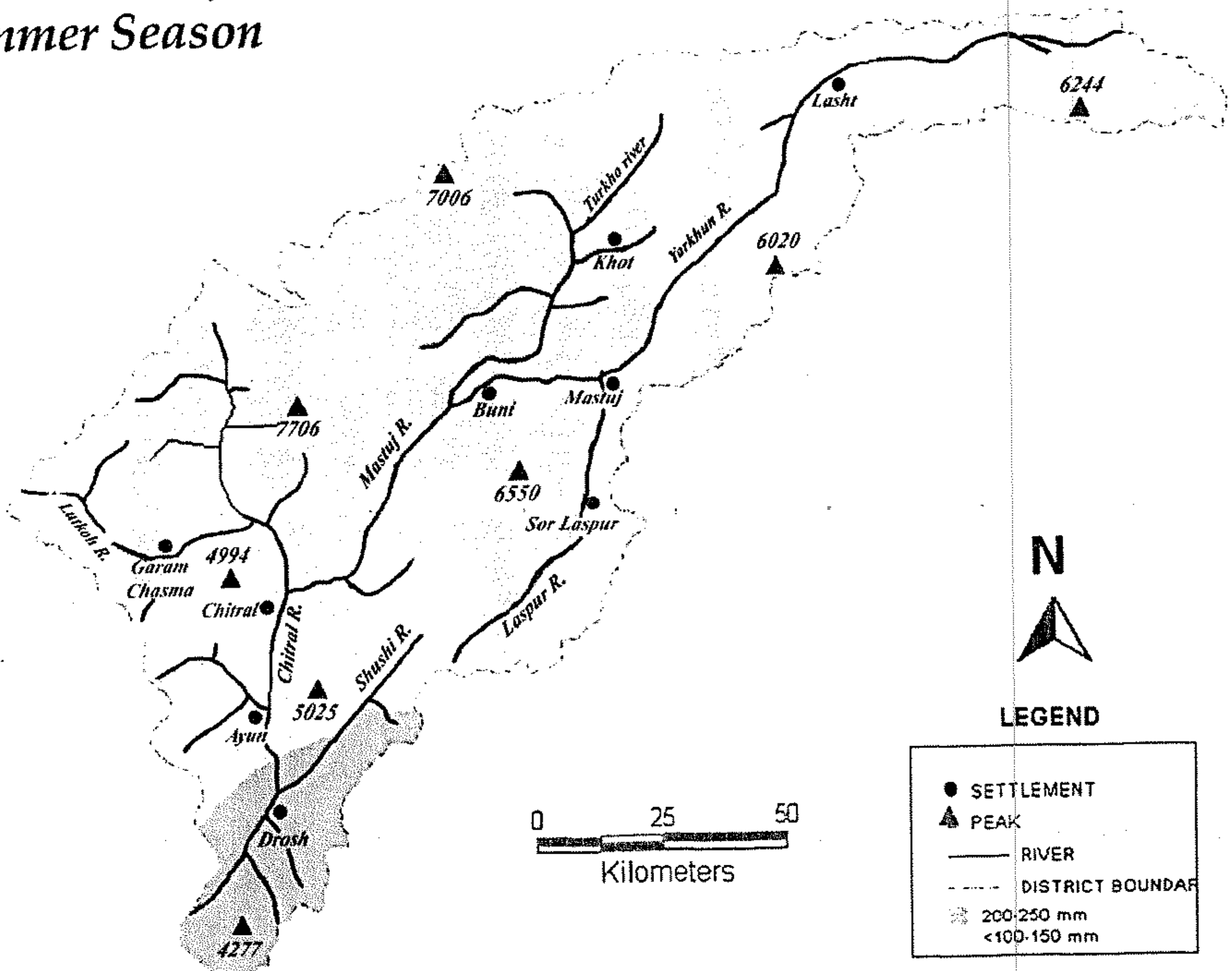
Map 1.6
Average Seasonal Rainfall (in mm)
Winter Season



Map 1.7

Average Seasonal Rainfall (in mm)

Summer Season



Cartography by Jamal Nasir

Chapter No. 2
Research Methodology

Chapter No. 2
Research Methodology

2.1. Scope of the Study

The study deals with the genesis of the terraces and their deposits. Their morphology, distribution, composition and sequence preserve a good record of Pleistocene history. Terraces not only establish the time of different stream operation, but also by their very presence invite inquiry into the rates and time spans of the different modes and why the modes of stream behavior should change. Early references available are mostly geological in nature. Terraces and deposits need intensive examination. The chronology developed on the basis of the intensive study of material and morphology of terraces will provide valuable information about the environmental changes in the valley during the Pleistocene period.

2.2. Selection of Study Area

The tectonic and climatic complexities of the Chitral river basin provide opportunities to examine responses of streams in a mountainous region.

- Broadly the Chitral valley is divided into Upper, Middle and Lower Chitral. The Climate of the valley is varies with altitude. The upper Chitral includes high mountain areas receive snow during winters and have some of the largest glaciers i.e. Chiantar glacier (40km), Darkot glacier (16km) etc. During Pleistocene these glaciers were active geomorphic agents and sculptured the area by its erosion and deposition.

- During the interglacial the climate become warm to hot resulting high melting and streams emergence. These streams emitting from glaciers carried sediments and deposit it in middle and lower Chitral (Study area). As these streams have variable supply of water therefore different type of Fluvio-glacial material is being deposited in down valley.

- During the glaciation of upper Chitral the lower Chitral have periglacial climate which favored the weathering and disintegration of the mountain slopes. As a result, a thick mental of regolith was developed over the mountain slopes.

- With a change in climate from cold and dry to humid condition the discharge of streams increases. It was easy for the swift and turbulent streams to carry away the weathered coarse debris, re-work it, and deposit it as thick gravelly alluvial fans.

- There is evidence that probably one of alluvial fans blocked the Chitral river and the valley was converted into a lake. Thick deposit of silt was laid on the pre-existing fluvial deposits of sand and gravels. Thickness of the lacustrine facies reveals a long phase of valley pounding. This lake covered a considerable part of Chitral valley as can be seen from the wide spread lacustrine deposits.

- Studies suggest that tectonic uplifting and Pleistocene glaciation are simultaneous. Rapid rate of uplifting rejuvenates the streams and helped to preserve stream terraces which are the main subject of research. These terraces preserve the geomorphic record and processes during the Pleistocene and Holocene. The magnitude of both the tectonic and climatic perturbations has produced strong impact on geomorphic processes. These complexities actually enhance the prospects of studying the Chitral river basin to better understand the landscape evolutions.

The study area lower Chitral is part of Chitral valley. Because of configuration of the valley the Pleistocene record is well preserved in the lower part of the valley as compared to upper Chitral.

2.3.1. Research Questions

Landforms do not just happen. Each shape or combination of shapes is the result of a variety of processes. Some landforms are shaped chiefly by processes operating from within the earth, other are mainly by processes and agents working on the earth crust. In dealing with landforms there are two methods of attack. One is simply to describe the landform as it appears to the eye, this is the empirical method. Another and much more meaningful method is one which not only describes the form as it is at the present time, but indicates how the form was attained. This is the scientific method. By means of the scientific method, any landform may be analyzed and comprehended not only in term of its present shape, but also in term of each phase of its evolution. Therefore the central question, which will be probed in detail during present study, is *what are the causes of the terrace formation in Chitral valley?* The secondary questions are: 1) *what are the geomorphic processes responsible for the genesis of terraces?. 2) To what extent the paleoclimate and tectonics contributed to their formation?*

2.3.2. Hypothesis

1. The genesis of landform is preserved in its form and material.
2. River terraces are produced by surges of erosion and deposition along river valleys and hence reflect periods of rejuvenation, which have affected streams.

2.3.3 Objectives

1. To identify terraces in the field and map them on a scale, 1: 63360.
2. To establish the history of stream aggradation and downcutting through study of terrace sequences.
3. Assessing climate changes during the latest Quaternary and their effect on erosional and depositional processes.
4. To examine and map surface deposits to establish their lateral and vertical relationship.
5. On the basis of the deposits, to establish a chronology of the Pleistocene events.
6. To interpret the genesis of the material and on the basis of morphological and lithological studies, to determine processes responsible for their deposition.

2.4. Techniques Used

2.4.1. Cartographic Techniques

Contours give a good idea about the topography of the area. Widely spaces contour indicate plain areas, while cliffed and steep slopes have been represented by closely spaced contours. Topographical sheet No.38 M/13 and 38 M/14 cover the Chitral area. The detail study of these toposheets reveals that wide flat areas are found at the lower height above Chitral river, and show some well marked sequences. From these toposheets contours have been traced, and the areas where there is any possibility of terrace have been marked.

2.4.2. Field Work

Fieldwork is probably the oldest and most widely used approach in geomorphology and it embraces a number of techniques. The map prepared by tracing the contours from topographic sheet was the base for fieldwork. Before going into field some terraces were recognized from the study of contours. The fieldwork was concentrated on checking laboratory work.

The entire study area from Chitral as for as Drosh was visited along with already prepared terraces map. Terraces were recognized in the field and compared with those demarcated on the contour map. Fieldwork confirmed the existence of terraces, determined from cartographic work, while a few new terraces were also identified.

Along with mapping terraces, the followings were also made in the field:

1. A detailed study was carried out of the superficial deposits, they were carefully mapped, their lithology, particle size distribution, form and roundness were examined. Sections exposed, were studied. Various beds were recognized and material sample from beds was collected for shape and roundness analysis. Also drawings of the sections were made.

2. Identification of river gravel's on terraces, and collection of samples for roundness analysis.

3. Determination of the height of Chitral riverbed at various points.

4. Absolute and relative height of terraces by altimeter was determined.

5. Correlation of terraces on the two sides of the valley was carried out.

6. Photographic record of terraces and their material was made.

2.5. Study of Surface Deposits

A variety of surface deposits, including Silt, sand, gravel, huge boulders, fan material and fine alluvium are preserved in the area. These deposits have been studied in detail, diagrams of section have been made with scale, photographs have been taken and the materials of each and every bed have been recorded with the help of a questionnaire given below. Samples have been taken from almost each bed for laboratory analysis.

A SURVEY OF SURFACE DEPOSIT

Area	____________	Locality	____________
Sheet #	____________	Grid Reference	____________
Section #	____________	Bed #	____________

Field Description

a. Composition ____________________
b. Lithology ____________________
c. Structure ____________________
d. Compactness ____________________
e. Size ____________________
f. Shape ____________________
g. Fossil ____________________
h. Color ____________________
i. Sample ____________________

Facies Identification

To establish the nature of sedimentation and processes involved, different facies were identified. This was helpful in understanding the geomorphic processes operating in time and space.

The following four facies were identified with the help of criteria established by the following workers.

a. The aeolian facies (Loess) by Smalley (1966), Vita-Finzi and Smalley (1970), Whalley et al. (1982), Pye and Sperling (1983), Brockie (1973). Palmer (1982).

b. The lacustrine facies by Picard and High (1972), Owen (1988).

c. The alluvial fan facies by Rachocki (1981), Bull (1968), Patton et al (1970), Beaty (1963) Drew (1873).

d. The fluvial facies by Leopold et al. (1964) Allen (1965).

2.5. Sampling Techniques

In the mechanical analysis of deposits, the size of sample should be representative of the material that is to be analyzed. Young (1958) has adopted an arbitrary sample of 1500-gms. For material up to coarse gravel Ragg & Bibby (1966) have taken samples varying from 18 to 44 Kg. where cobbles are included.

For material up to coarse sand, samples ranged from 100 to 250-gm have been taken (Waskom, 1958. Said (1969) used the British standard method (1961 preparation of disturbed sample for testing) and found it satisfactory. In the present study the British standard method was employed for sampling.

2.7. Laboratory analysis

The following analyses were made of the samples:

i. Size distribution analysis
ii. Color identification
iii. Shape and roundness analysis
iv. Mineralogical Composition
v. Scanning Electron Microscopy

2.7.1. Size distribution analysis

Size distribution analysis was carried out in order to determine the character of material. British scale for describing the size distribution was adopted because this has been used by a number of geomorphologists (Folk & Ward 1957, Folk 1959, Shepard and Young 1961, Sternberg & Careager 1961, Said 1969, Jordan et al. 1971 & Davies & Ethridge 1975). The coarse sediment of sand and silt was mechanically analyzed by dry sieve method; gravels and smaller boulder was manually analyzed. The size analysis was carried out to find out the source of material and to provide valuable information regarding the processes by which the sediment was laid down.

2.7.2 Shape and roundness analysis

Shape and roundness analysis have been carried out by a number of researchers. i.e. Beal & Shepard (1956). Shape and roundness of the fragments were determined according to Zing's (1935) and Caileux (1945) method respectively. Roundness may be expressed as the ratio of the average radii of the curvature of several corners or edges of the radius of curvature of the maximum inscribed sphere or to the nominal radius of the fragment (Wadell, 1935), Pettijohn, 1975).

Several methods exits for the measurement of roundness: Wadwell's (1935) method required the drawing of an image of the pebble at a standard magnification, and the measurement of the edges and corners and the maximum inscribed circles; a ratio thus obtained which is the value of roundness of the pebble. The methods of Power (1953), Pettijohn (1975) and Krumbein (1941) involve comparison of object with standard images of known roundness and the assignment of a roundness and roundness value to it. Cailleux's (1945) index of roundness is determined with the following formula;

$$2r / l \times 1000$$

Where "**r**" is the least radius of curvature in the principal plane and **l** is the length. Values ranging from 0 to 1000. Cailluex roundness index ha been widely used in some well known studies (Beal et al. 1956, Waskom 1958, Said, 1969, and Hasan, 1995) has been found to be as satisfactory as the other. Cailluex's roundness index was used in the present study in two different contexts: for material of cobble and gravel size in sections and for gravels lying on the surface of the terraces.

2.7.3 Colour identification

Colour is an important clue of the chemical composition of the sediment. Black colour indicate organic matter, Grey colour of sediment indicate quartz and feldspar etc, red, orange, brownish indicate the presence of Iron, while green, and bluish colours are the indication of copper in the sediments. In preset study "Munsell soil colour Chart, 1973" was used for colour identification.

2.7.4 Mineralogical Composition

Mineralogical compositions of the samples have been determined for the inference to be made concerning source of sediments.

2.7.5. Scanning Electron Microscopy

Microrelief and textural patterns of the fine sediments were examined with the help of scanning electron microscope. A magnification upto 1500 times, greatly enhanced the study of very fine particles of clay, silt and sand that could not be examined effectively with naked eye or petrographic microscope. The samples were analyzed in Centralized Resource Laboratory, Department of Physics, University of Peshawar. Selected images of the sample were taken with different magnification.

Chapter No. 3
Literature Review

Chapter No. 3
Literature Review

3.1. Introduction

Early references to the terraces of Chitral are very few and not of much use for geomorphology. The present study is the first attempt to examine the genesis of terraces in Chitral. A number of researchers have studied various aspects of the area. Calkins et al. (1981) worked on the Geology and mineral resources of the Chitral-Partsan area, Hindu Kush range. Haserodt (1996) worked on the geographical features and problems of Chitral. Besides he also studied the climatic conditions and historic fluctuations of glaciers in the western Karakorum.

3.2. Geology

The first geological information of Chitral is that of Grant, of the British India colonial forces. He collected some early Devonian trilobites and brachiopods from Showar Shur in the upper Yarkhun valley, 225Km north east of Chitral. Reed (1911) described these fossils. These fossils were determined to be of late Devonian age. Hayden (1915) collected several fossils from Drosh, Reshun and Shogram. These collections were described by Reed as of Devonian and Carboniferous periods (1911).

Stauffer (1875) did some geological work in 1964 in the Reshun area. His report discusses the geology of a rectangular area of 160 square mile (414 sq. Km) extending 27miles (43.4 Km) along the Mastuj river up to Buni 12 mile (19.3 Km) north east of Reshun.

The latest geological work was done by Calkins etal (1981). The report was based on field investigations covering an area of about 1400 Sq. mile (3626 sq. Km) in the Hindu-Kush mountains of Chitral State. He has divided in to the following units,

I. Devonian unit of Sarikol Shale (Devonian to Carboniferous): a broad belt of metamorphic rocks of Devonian to Jurassic age;

II. Reshun formation, a volcanic greenstone unit,

III. A limestone and Phyllis unit, a greenschist unit, and the Chitral slate, all of Cretaceous age. Elongate bodies of granite (cretaceous) underline large parts of the area.

Structurally, the Chitral area is characterized by a system of folds overturned towards east and south. According to James etal (1981) fold pattern marks the regional trend of the Hindu Kush range, from North in the southwestern part of the area to east-northeast in the eastern part. Several reverse and thrust faults separate belts of rocks of Cretaceous age from belts of older rocks.

3.3. Geology and Tectonics

Tahir Kheli (1997) worked on the " Tectono-stratigraphic framework of the Hindu Kush range in Chitral". According to him the rock formation encountered in the Chitral domain of Hindu Kush are:

- Precambrian-lower Paleozoic Chitral slates are dominantly phylitic ranging from slates to various type of schist.
- Ordovician Broghil formation is composed of medium crystalline limestone, siliceous dolomitic limestone, flaggy quartzite and inter bedded siliceous dolomitic limestone
- The upper Devonian Shogram formation is 900 meter thick and is divisible into three units: a lower massive dolomite, a middle thick-bedded dolomite and upper flaggy quartzite and bedded limestone.

- The Triassic and Jurassic undifferentiated Turikho group constitutes a thick sequence of dominantly argillaceous rocks with crystalline limestone, quartzos sandstone and conglomerate, along with acid and basic sills and dykes.
- The cretaceous Reshun formation has been divided into three litho-stratigraphic units. The lower one Krinj limestone, Awi conglomerate, and maroon marly shale's.
- The 115 million years old Trich Mir granite occurs in isolated plutons intruding Turikho group of rocks and constitute an assemblage of quartz diorite, granodiorite. Manzogranite and granite.

The four major tectonic scars in the Chitral area are

i. Reshun fault
ii. Ayun fault,
iii. Trich fault
iv. Shishi Koh fault.

3.4. Terraces

The present study is pioneer study of his nature. As mention earlier no literature on river terraces of Chitral is available, therefore literature review was either collected from the areas whose geomorphological characteristics and Pleistocene history is like Chitral or from the authors who studied river terraces and their genesis.

According to Gilbert (1914) river terraces in general is not the record of sedimentation, when in fact it records the stages of progressive corrasion. He further stated that river terraces are carved out, and not built up. They are always the wastage of flood plain, and flood plains are produced by lateral corrasion.

Russell (1898) assumed that streams would always cut downward more vigorously in the episode of drier climate. The observation and conclusion of Bryan (1940) concerning the causes of alternate alluviation and erosion in the valleys of the semi-arid southwestern region of North America support Russell assumption, that in dry region " a slight change from the dry toward the less dry in climate is adequate to convert ephemeral stream from a condition of erosion to alluviation".

Huntington (1905) stated that a change in climate from lesser to greater humidity has an important effect on the regimen of stream. Even a small change not only provide more water, but also may appreciably reduce the load of waste to be transported by encouraging increased growth of protective vegetation in the catchment areas of stream, and every change in the ratio of waste to water in a river demand a considerable adjustment of the gradient of its graded profile, resulting a great change in local base levels. Terraces making may be a result of such adjustment brought about in an episode of vertical corrasion, which will isolate portions of an earlier flood plain as terraces. Aggradation may have thickened the gravel on this flood plain in a preceding dry climate.

This concept is termed as " Huntington Principle". It implies that all episodes of increased precipitation will be characterized by degradation, at any rate in non-glaciated valleys, where dessication will cause aggradation by increasing the ratio of waste load to water in the river.

Sandford (1932) attempts to study the terraces of Thames river valley. According to him the terraces in Thames are well-marked features. In the lower area there are two conspicuous terraces at 100 and 50 feet above the present river. He referred them as Boyn hill and Taplow terraces.

Around Oxford, Sandford (1932) studied river terraces at a height of 100-feet and he referred this as Handborough terrace. At 40-50-feet above the present river is the Wolvercot terrace, which is not clearly differentiated. Associated with this terrace are the deposits of the Wolvercot channel, and the warp. (Warp is the deposit indicating a cold wet climate). It rests on the deposits of Wolvercot channel. (i.e. about 55-60 ft above present river). The next level of terraces was studied by Sandford at a height of 20-feet and is termed as Summertown Radley terrace. This is most extensive and he subdivided it into Lower and Older gravels and the upper and Lower gravels. A buried river channel is also found. Challinor (1932) has pointed out that lowering of local base level produced by some normal developmental changes in the graded profiles of trunk streams may will be of such magnitude as to cause distinct and perhaps conspicuous terracing in tributary valleys and even in some cases in the upper reaches of main valleys.

Bauling (1935) reorganized the importance of Glacio eustatism. He thought that there is evidence of worldwide lowering of sea level during the Pliocene, and Pleistocene, due to glacio-eustatic changes. He thought these lowering of sea level were the result of epeirogenic movements to be associated with Oroganic movement and a consequence of them rather than independent of oroganic movements as thought by some geologists. Eustatic lowering of sea level causes rejuvenation of a stream at its mouth. The result may be an interrupted profile with the point of intersection of the old and new base levels being marked by a nickpoint, which proceeds upstream as the new base level is extended headword.

Cotton (1940) believes that "terraces that border river valleys and mark former level of flat valley floors such as have resulted from either corrosion or valley filling. The material out of which terraces are cut have, indeed frequently been formed by valley filling and are than in some cases river laid, but terraces formation is essentially, an accompaniment of valley formation by corrosion, alternately vertical and lateral. "Cotton (1941) has suggested that river terraces may be classified as either cyclic or non-cyclic. He has classified the river terraces in a number of types including rock terraces, valley plain terraces, slip-off slope terraces, rock defined terraces, and meander scar terraces. He has also discussed in detail the role of paleoclimate and tectonics in their formation and provided criteria for the correlation of terraces.

Bryan (1941) describes in detail the causes of alternate alluviation and erosion in the valleys of semiarid region of South America. He stated that a slight change from the dry toward the less dry in climate is adequate to convert ephemeral stream from a condition of erosion to alluviation. Johnson (1944) has stressed, the problem of terrace correlation is often difficult one. Even where terraces can be established unequivocally as river terraces, there still remain two major problems: (1) If more than one terrace level exist along a valley, there is a problem of determining to which level any particular terrace tract belongs. (2) There is also the more difficult problem of correlating terraces from one valley to another.

He believes that some of the more common methods of correlation are:

I. Identification by fossils
II. Degree of dissection
III. Comparative decomposition of boulders
IV. Lithology of the terrace material.
V. Depth of weathering of terrace material.

But all these methods may not be useable because the time interval between the formations of successive terraces is usually too short for these test to be applicable. In these circumstances the only safe criteria may be the correlation of terraces, on the basis of their relative and absolute highest.

Correlation of terraces from one valley to another is even more difficult problem. In such case absolute altitudes are not likely to be the same even in adjacent valleys because of variation in stream profiles. The only positive method of correlating terraces in different valleys is to trace them until they join each other at the junction of the valleys, or join with a similar terrace in a trunk valley to which the two valleys are tributary. If the valleys are so widely separated that neither of these methods is possible, the only method may be the correlation on the basis of similarity in altitude. A similar sequence of terraces with similar vertical interval between two terraces may be strongly presumptive evidence of correlation, but it does not necessarily prove it.

Thornbury (1954) attributed the origin of terraces to the process of rejuvenation, which may result from causes, which are dynamic, eustatic or static in nature. John (1956), and Kartashov, (1972) devised a model of glacial phases aggradations during both glacial and interglacial phases, separated by two erosional episodes at the glacial-interglacial and interglacial-glacial transition.

Zeuner (1959) referred the terrace formation to the change in base level. While Donovan (1962) also attributed the formation of terraces sequence to the sea level changes. Ganseer (1964) has added a good deal to our knowledge of river terraces. He describe the Quaternary gravel terraces of the upper Sutlej valley and the terraces of Pokhara plain in lesser Himalayan Nepal. De Terra and Patterson (1939) found four main glacial stages in the Kargil basin. According to them the terraces level are usually sharp. Gansser feels that such sharp terracing is the result of some catastrophic event like bursting of moraine-dammed lake.

Research using modern methods and concepts on Quaternary geology in the Nanga Parbat and Karakoram Himalaya first begin in the 1970's and early 1980's with the opening of parts of the Karakoram Highway (Batura Glacier Investigation Group, 1979, 1980's; Miller, 1984,1985; Shroder et. al. 1989, 1990). Members of the Chinese Academy of Sciences in 1974 and 1975 were first concerned with the upper Hunza valley, and especially with the threat posed to the KKH by the Batura glacier. They recognized several stages of moraines deposition from the last Pleistocene glaciation termed the Dali Glaciation in western China (Shi 1992,Shi and Wang, 1981, Shi and Zhang 1984) to the present, with older tills present at altitude above 3500-m on the mountain sides north and south of the Batura glacier.

Porter (1970) worked in the Swat Himalaya, produced a glacial chronology that provided the first study using modern stratigraphic and sedimentologic methodology. Desio and Orombelli (1971& 1983) had noted five scattered glacial and moraines in the middle Indus and Gilgit valleys and considered that they generally decrease in age up valley following trunk valley glaciation as far down valley as Sazin, although they also recognize several younger cross-valley glacial moraines, especially around Nanga Parbat. Fyre (1973) has compiled a model of alluviation, incision and periods of surface stability from the stratigraphic relationship of alluvial gravels, till sheets and paleosols. He showed that erosion tended to occur early during a glacial pulse and deposition partly by outwash, late in the glacial pulse.

Chappell (1983) discussed the effect of sea level change. According to him a change of sea level effects the balance of erosion, transport and deposition of sediment, and there are two general patterns reflecting the effects of sea level changes. In these patterns one being manifest in the geomorphology of the land and the other being preserved in sedimentary sequence in shallow seas. According to Chappell river basins often contain features indicating different former sea levels in the form of knick points and fluvial and coastal terraces.

Faniran and Jeje (1983) divided the terraces topographically into two parts: a ***tread,*** which is the flat surface representing the level of the former floodplain, and the ***Scarp*** or the steep slope connecting the tread to any surface standing lower in the valley. According to them the tread surface is normally underlain by alluvium of variable thickness, belonging to an earlier period of valley fill events, which have been cut into during a subsequent period of fluvial erosion or down cutting.

Ahmad (1985) has provided a detail account, and dating of terraces, along with a valuable discussion on the terraces of Himalayan region in India. According to him, the valley of many rivers has relatively flat surfaces above the present lowest valley floor. He provides a diagrammatic explaination for the development of river terraces. According to him the terraces are likely to be more symmetrical in the middle parts of valley where the floors are quite extensive than in the mountains. Near the coasts too the symmetry of the terraces has been marked by the several rise and fall of sea level during the quaternary ice age. He classified terraces as paired and unpaired terraces. Besides this he also provided a good discussion on erosional terraces, structural terraces and depositional terraces. While explaining the dating of terraces he has stated that it is a different subject but as terraces are not only landforms but diagnostic of climatic changes, character of valley fills, sequences of erosion and deposition, and tectonic upheavals, chronology of terraces will be of great significance in geomorphology. Fossil deposits may be helpful in this study as also the archeological remains.

According to Watson et al. (1985) at 47 locations in Swaziland coarse, fluvial deposits, termed as Badzala gravels have been identified at heights of up to 79-meter above present river level. The pebbles and cobbles making up the deposits are invariably composed of rock types, which are highly resistant to weathering, quartzite predominates. On the basis of lithologies, the weathering features and the typologies of the associated stone tools, the gravel deposits are ascribed an early Pleistocene age.

According to Millar (1985) when a river has deposited alluvial material to a considerable depth, it may erode a portion of these deposits. The remaining sediments stand out as one or more terrace level above the present floodplain. These terraces are the remnant of former floodplains.

Anderson et al. (1985) studied the river terraces along the Rock river from Watertown, Wisconsin, to the eastern boundary of Rock Island country, Illinois. The terraces in downstream area were eroded by Mississippi river during the late Wisconsinan and Holocene. Except for the older (highest) terrace remnant upstream from Janesville, Wisconsinan (which appear to be bedrock-controlled erosional terraces). According to Anderson et al these are the result of glaciofluvial deposition.

Dawson (1985) analyzes the Severn Main terraces at Eardington, Shropshire and determines the sedimentary environment responsible for their formation. The lower unit is notable for the widespread occurrence of large sandy facies, a near absence of massive gravel, and the presence of large, locally derived, lithoclasts 1-meter in diameter. The upper unit is composed mainly of multistory, coarse, massive gravel units with limited interbeded sand facies. These are interpreted as alluvial fan deposit which prograded into the main Severn valley from the adjacent Mor Brook tributary.

Ka=1000 years). Initial degradation rates of <4-meter/Ka increased to 30-meter /Ka by 6 Ka ago during a mid Holocene climatic optimum. Since 4Ka ago degradation rates have been only 1.2-meter/Ka.

According to Bull and Knuepfer (1987) each of the eleven-degradation terrace represent pauses of a few centuries in Holocene downcutting. Thus the formation of these eleven terraces can be accounted for without postulating additional tectonic perturbations or secular climatic changes.

Owen (1988) carried out a study on " Terraces uplift and climate, Karakoram Mountains, Northern Pakistan". This is the only scientific study of the Pleistocene terraces of Northern Areas of Pakistan. According to this study the Karakoram mountains are the most dynamically active tectonic and geomorphic areas in the world. The valleys are among the deepest and hold some of the greatest thicknesses of quaternary and recent valley fill sediment comprising glacial, debris flow, fluvial and aeolian sediments. These have been eroded to form terraces. Their development is controlled by tectonic and climatic factors recording information about the last few million of uplift and climatic changes. No simple relationship exits between terrace height degree of incision and terrace deformation, and the tectonic and climatic history of the area on the other. Allocyclic processes further complicate the interpretation of terrace formation.

Shroder et al. (1990) discuss the quaternary glaciation of the Karakoram and Nanga Parbat Himalaya and recognized three main glacial stages as well as a number of later stades. The early glacitaion are Shanoz stage includes glaciated high level erosion surfaces, Bunthang till, and perhaps other tills as well. Jalipur till are tillite is both glacially and tectonically moderated and deformed; its age remains uncertain. The middle glaciation or Yunz stage includes a number of tills, perhaps had two major phases or stades, and extended the farthest down the Indus of any glaciation. The last glaciation is subdivided into several stades, the most important of which is Borit Jheel.

Hart (1986) is of the opinion that landforms are numerical evidences of climatic change. According to him some landforms are indicators that climatic change has taken place. River terraces can be used to study the extent of climatic change. According to him the oscillation of climate during the Pleistocene caused worldwide changes in the relative heights of land and sea. In general, however there is a fall of about 100-150 meter. Conversely during interglacial sea level rose, it seems that during the warmest part of interglacial sea level stood about 35 meter above present sea level. Finally he concluded that there is no single set of conditions that led to the deposition of all river terraces and it is clear that some were deposited under periglacial conditions.

Robinson (1986) with the help of diagram describes in detail the formation of terraces. According to him the process of rejuvenation lead the river carving out a new flood plain within its already existing flood plain, producing a step like effect or terrace on either side of the river. Gradually this new flood plain widened by lateral erosion of the river resulting in the cutting back of the terrace. According to Robinson (1986) if further rejuvenation occur, the process repeated and a further pair of terraces (lying at a lower level than the first pair) produced.

Bull and Knuepfer (1987) describe in detail the " Adjustments by the Charwell river", New Zealand, to uplift and climatic Changes. According to him major climatic changes and rapid local and regional tectonic movements were common in New Zealand during the late quaternary and caused a diversity of adjustments in the drainage-basin and piedmont reaches of the Charwell river, which are separated by the Hope fault. The onset of semi-arid, frigid climate during the latest Pleistocene probably greatly increased hillslope sediment yield in a periglacial environment, and the piedmont reach aggraded as much as 42m on top of a broad strath. With the return of humid climates in the Holocene, sediment yield decreased as dense forest again mantled the slopes, and the piedmont reach degradded as much as 81m. dating of eleven cut and strath terraces by radiocarbon shows that the degradation rates varied greatly during the last 14 Ka (one

Alan and Peter (1992) while discussing genesis of terraces stated that the incision of the river forms a new flood plain at a lower level, leaving the old flood plain as an abandoned remnant or terraces. Some terraces may be many thousand of years old and were formed in condition, which no longer prevails. According to them terraces are fossil features. He further stated that the fluvio-glacial meltwater of last glaciation increased the discharge and sediment load of many rivers in temperate latitude and built up the flood plains to height seldom reached by today's flood conditions.

Ahmed and Zeb (1993) studied the "Morphology and Deposits of Kund Terraces". According to their findings the terraces examined at Kund-Khairabad are erosional terraces having being formed by Kabul and Indus rivers. They suggest that these terraces have experienced considerable tectonic uplift. No absolute date is given for their formation but they believe that most probably they are pre-Pleisitocene in age.

Haleema etal (1994) studied the river terraces of Muzaffarabad. They mapped river terraces on a scale of 1: 10,000. and then explained their genesis. They identified 5 different terrace levels in the area formed by Neelum and Jehlum rivers. They attributed the origin of terraces to the process of rejuvenation, that may have been caused by tectonic uplift or a fall in the sea level, resulting change in base level of the river. They have suggested that the terraces of river Neelum and Jehlum in Muzafferabad area have been formed by Tectonic uplift.

Veldkamp (1992,1997 and Valdkamp 1993a, 1993b and 1998) focused on a quantitative reconstruction of the effects of past environmental dynamics within a fluvial system. The study area is part of the Allier basin (Limagne) in the Auvergne, Massif Central, France. The research was carried out in several stages. At first field work was carried out to determine the terrace stratigraphy and chronology in more detail. A new age estimate of the Fva (65 m above present river bed) is based on pumice clasts found in the terrace sediments. Younger terraces were dated with 14C and Th/U disequilibrium methods. Fx terrace sediments (15 and 10 m above present river bed) were mainly deposited during the Late Weichselian, while the Fwb terrace sediments (25 m above present river bed) have most probably a Late Saalian age. Due to these new age estimated a revision of the existing Allier terrace chronology is necessary. This new chronology shows a large time gap between the deposition of the Fv and Fw terrace sediments.

Edward Derbyshire (1998) worked on the Palaeoclimate reconstructions based on the Loess sequences in North China. According to him the Current opinion favours the view that loess began to accumulate in North China around 2.6 million years ago (Ma). The onset of loess deposition has been explained as a function of several triggers, including the onset of global cooling and the regional phenomenon of the uplift of the Tibetan Plateau. However, the precise relationship between loess accumulation and such factors remains contentious.

Kamp (1999) worked on the *Late Quaternary Geomorphology and Glacial History in the Eastern Hindu Kush, Chitral Northern Pakistan.* He for the first time developed a model of the Quaternary glacial history of the Eastern Hindu Kush, based on the TL, OSL dating methods (Table 3.1). The study concentrates on the analysis of geomorphological features and their paleoclimatic interpretation. It focuses on the late Quaternary; the period of last 500,000 years, but only some explanation was given for the period of 500 to 250 ka. The following are the main results of the study.

I. During the late Quaternary valleys in Chitral were filled with thick sediments. Remnant of a pre-Pleistocene valley system were involved in this process. The former drainage to the south was created during extremely powerful uplift in the north. The valley sediments date from various periods of erosion and accumulation, and testify climate change.

II. The sediments of Chitral reflect a variety of sedimentation environment: glacial, glacio-fluvial, fluvial, lacustrine, aeolian and gravitational. After accumulation the erosion process formed six type of terraces: moranic, glacio-fluvial, fluvial, lacustrine, debris and fan terraces. The most frequent type in Chitral is the fluvial fan terrace.

III. The valley sedimentation takes place in three steps, leaving an upper, a middle and a lower terrace in the main valley. Each of these terrace generation is subdivided into two different terrace levels, which reflects a short break in erosion and a short new phase of erosion. In the main paraglacial, fan with moraine and debris material built up the upper terrace. The middle terrace is composed of fluvial material, while the lower terrace is alluvial fans of the tributary valleys.

IV. An early glacial stage (≅ Mindel) is preserved only in some localities in the higher altitude. During by Drosh glacial stage, a long glacier reached as for as Drosh, at 1300-m. Under cold climatic conditions huge paraglacial fans sedimented from the slope this was Broz formation of 190 to 140 ka. It is followed by Ayun formation lasting from 140-110ka, a sedimentation of mainly fluvial deposits. From 110 to 90 ka a warm climate marked the Parwak interglacial stage. In the last ice age the Pret Glacial stage from 90 to 10 ka a huge glacier again filled the valley reaching down as for as Pret in middle Chitral at 1670-m. (Table 3.1).

Table 3.1
Late Quaternary Phases of Valley Development and Glaciation in Chitral
(Developed by Ulrich Kamp 1999)

Period	Age	Evidences	Climate
Early Glacial (Mindle)	????	Moraines on High Slopes	Cold
Drosh Glacial (Riss) High Glacial Broz Period (a,b) I/G Ayun Period (a,b)	>200Ka >190Ka 190-140Ka 140-110Ka	--------------- Lawi Moraine/Polish Surface and U shape valley Upper Terrace (a,b) Middle Terrace (a,b)	Cold Cold Cold Warm
Parwak Interglacial (Riss/Warm)	110-90ka	Lacustrine sediment	Warm
Pret Glacial (Warm) I Pret High Glacial II Sanoghar Late Glacial Urghuh Period (I+II)	90-10ka 60-30ka 30-10ka <60ka	----------------- Pret Moraine/Polish Surface and U shape Valley Sanoghar Moraine / Monur / Rhizum Moraine Lower Terrace (a,b)	Cold Cold Cold Cold/Warm
Holocene Shandur I Baram I Baram II	<10ka Neoglacial Historical Recent	------------------ Shandur Moraine Baram Moranie Recent Moraine	Warm Cold Cold Warm

Source: U.Kamp (1999)

While this study based upon the results from Haserodt, uncertainties remains as to the expanses and timing of the glacial stages and stades, as in all other studies, indeed.

Chapter No. 4
Geological Setting

Chapter No. 4
Geologic Setting

4.1. Introduction

The study area **(map 4.1)** is on the southern flanks of the Hindu Kush range, which forms the western segment of the broad mountain arc of the greater Himalayan mountain system. The map **(map 4.2)** shows the regional geologic and tectonic trends for many miles beyond the study area.

From the northeastern trend of the Hindu Kush range, the high peaks of the Himalayan mountain system swing in a great arc, first to the east through Yasin, then to the southeast through Gilgit, Kashmir, and across northern India. A system of outcrop belts of various rock types, as well as several reverse and thrust faults, help to define this arcuate pattern. The Hindu Kush merges with the Karakoram range of Gilgit and Kashmir, which in turn is indirectly connected to the Ladakh range, the Great Himalaya, and other individual ranges of Kashmir and northern India.

The rocks in study area range in age from Devonian to Cretaceous and consist mainly of regionally metamorphosed rocks of low to medium grade, and granite intrusions. A wide, north-northeast-trending belt of slate, called the Chitral slate, underlies Chitral valley, and is flanked on both sides by bands of marble and other types of metamorphic rocks. The metamorphic rocks, in turn, are flanked by granite bodies of Cretaceous age, which crop out in the western and southeastern edges of the area. Other granite bodies are found within the metamorphic rocks. (James et al 1981)

The metamorphic rocks are mainly those of the greenschist facies of regional metamorphism, increasing to the amphibolite facies as the granite bodies are approached. Rocks of low metamorphic grade include slate, marble, chlorite-quartz schist, chloritoid-sericitequartz schist, volcanic greenstone, schist, and other types. Higher-grade metamorphic rocks of the amphibolite facies and its equivalent include garnet-biotite schist, garnet-biotite-staurolite schist, amphibolite, quartz-hornblende schist, and other types. Metamorphic index minerals higher than staurolite have not been found.

Structurally, the study area is characterized by a system of folds overturned toward the east and south. An elongate synclinal belt, itself isoclinally folded internally, follows the Chitral and Mastuj rivers and is marked by the Chitral slate, which is found in the trough of the syncline. On a regional scale, the elongated fold pattern results in a system of outcrop bands of differing rock types. Several reverse and thrust faults separate belts of Cretaceous rock units from belts of older rocks. Elongated bodies of granite are found on the high ridgelines. The shape and distribution of these granite bodies indicate that they may represent anticlinal domes.

4.2. Stratigraphy

The most widespread unit mapped is a sequence of Devonian to Jurassic rocks in the western and northern parts of the mapped area. These rocks are metamorphosed and unfossiliferous over much of the mapped area and are undivided on the map except for a marble unit and an amphibolite unit.

From Partsan, a zone of essentially nonmetamorphosed rocks extends northeastward for many miles beyond the mapped area and provides information on stratigraphy and paleontology. Within this zone, a Middle to Upper Devonian unit and the black Sarikol shale is evident, Devonian and Permian fossils also were found in the undivided Devonian to Jurassic sequence.

Rock units mapped as Cretaceous include a wide synclinal belt forming much of Chitral valley and a narrower belt extending from Drosh northeastward along the Shishi river. In the Chitral valley, the Cretaceous rocks are divided into the Reshun Formation, a volcanic greenschist unit, and the Chitral slate. The Cretaceous rocks in the Drosh area is divided into the Reshun Formation, a volcanic greenstone unit, and a limestone and phyllite unit.

4.3. Devonian Rocks

4.3.1. Devonian Unit

A sequence of Devonian rocks, informally called the Devonian unit, extends from the Reshun fault near Partsan northeastward along the mountain ridges to the edge of the study area. Work done in this area by different geologists indicates that the Devonian unit forms the core of an overturned anticline called the Partsan anticline. The Devonian unit continues northeastward through the Reshun area, as mapped by Stauffer (Stauffer, 1975). Beyond Reshun, the Devonian unit extends all the way to Baroghil pass.

Devonian corals occur in a locality 1.6-km upstream from Pasti, west of the Pasti fault. Fossils from the Reshun area collected by Hayden (Reed. 1922) and Stauffer (1966) include corals and brachiopods of Devonian age. Additional Devonian collections were made by Tipper in the upper Turikho Valley near Warkup, (6.4-km) south of Rain, and in the Owir Gol (Gorge) upstream from Barum.

4.3.2. Devonian to carboniferous rocks

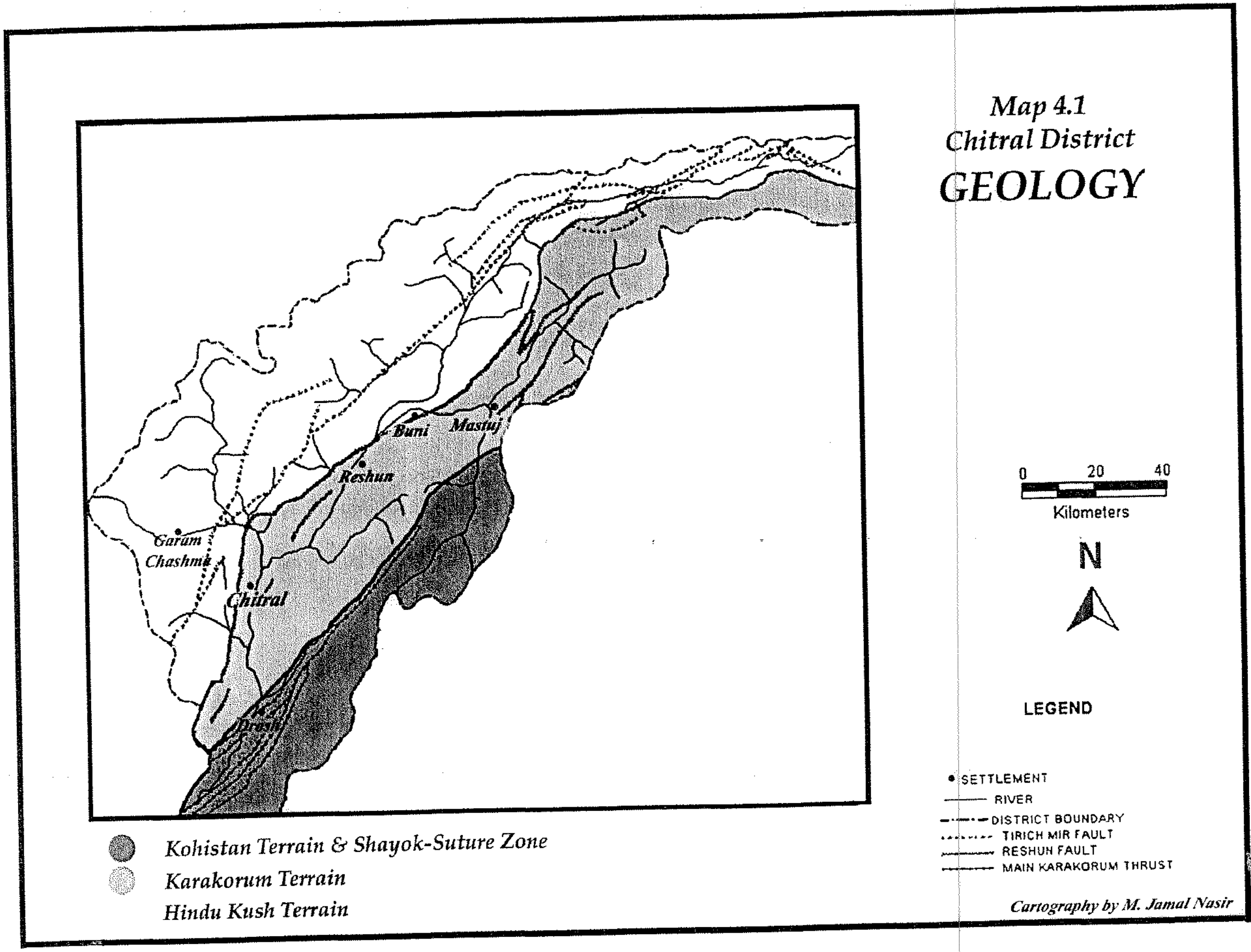
4.4.1. Sarikol shale

The Sarikol shale, named by Hayden (1915) is a thick sequence of black shale found in the Sarikol range of the eastern Pamirs of Russia. Lithologically, similar shale and quartzite forming the ridge north of Reshun (called Kosht ridge) were also thought to be Sarikol Shale by Hayden (Pascoe, 1924). During his 1923 field season, Tipper (Pascoe, 1924) traced a broad belt of shale, which he considered to be the Sarikol shale, from Kosht ridge, north of Reshun, northeastward along the upper Turikho Valley as far as Shah Jinali pass, a distance of about 98 km. Tipper, however, mapped on the basis of age (for example, Devonian period) rather than rock formations. Therefore, Tipper does not show the Sarikol shale as a separate unit. Stauffer worked out the detailed distribution of the Sarikol shale in the Reshun area.

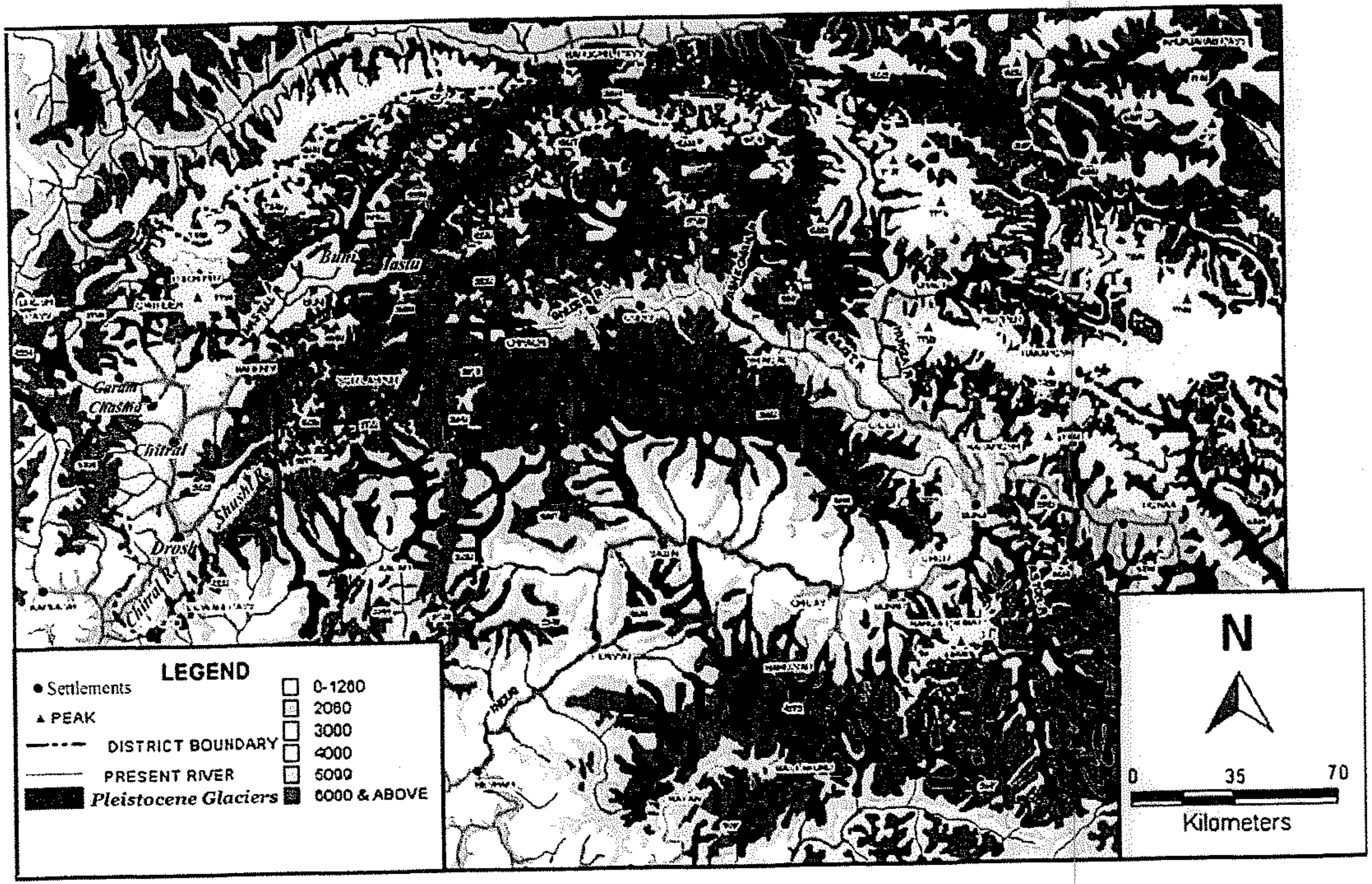
In the study area the Sarikol shale overlies the Devonian unit in two parallel outcrop belts along both limbs of the Partsan anticline. The southeastern belt is less than a quarter of a mile wide and extends for only a few Km. The northwestern belt underlies the entire Partsan basin, a width of about 4.8-km. From the Partsan basin, the belt extends northeastward through Pasti and narrows to about 305-m at the eastern edge of the study area.

The north-western outcrop belt continues into the Reshun area where, as shown by Stauffer (1966), it occupies a wide zone on the northwest side of the Mastuj river. The Sarikol shale is known from Tipper's work to extend far beyond the Reshun area, but he did not map it as a separate unit.

The Sarikol shale consists mainly of soft, thinly laminated, black shale and micaceous phyllite. Beds are 5-10 cm thick of brown-weathering dolomite and gray limestone are found in places, as are a few thin beds of brown-weathering calcareous sandstone.


Map 4.1
Chitral District
GEOLOGY
Buni
Mastuj
Reshun
Garam Chashma
Chitral
Drosh
0
20
40
Kilometers
N
LEGEND
SETTLEMENT
RIVER
DISTRICT BOUNDARY
TIRICH MIR FAULT
RESHUN FAULT
MAIN KARAKORUM THRUST
Kohistan Terrain & Shayok-Suture Zone
Karakorum Terrain
Hindu Kush Terrain
Cartography by M. Jamal Nasir

Map 4.2
The Extension of Pleistocene Glaciation in Karakorum, Hindu Kush and Himalayas



Modified from Owen 1996

Cartography by Jamal Nasir

South of Pasti, the Sarikol shale overlies rocks of Middle to Late Devonian age. On the steep slope 3.2 km north of Pasti and east of the Pasti fault, the Sarikol shale is overlain by a thick, undisturbed sequence of limestone and shale. Near Gokhten Girri pass, between Pasti and Partsan, a collection of poorly preserved brachiopods suggests a Devonian or early Carboniferous age. Hayden & Pascoe, (1924) suggested an early Carboniferous age for the Sarikol shale and Tipper (1924) suggested that it is Late Devonian. On the basis of the above information, the Sarikol shale is considered to be Late Devonian or Carboniferous in age.

4.4. Devonian to Jurassic rocks

Devonian to Jurassic rocks include a wide variety of metamorphic and sedimentary rocks they underlie the large area in the western and northern parts of the study area. Three additional outcrop belts in the eastern part of the study area (map 4.1) also are mapped as Devonian to Jurassic. Regionally, the Devonian to Jurassic rocks underlies two areas. One outcrop area is west and north of the Reshun fault and extends from Kafiristan to Shah Jinali pass, 193 km to the northeast. The other area occupies parts of a continuous belt extending from Drosh on the southwest to the Ishkuman river.

4.5 Metamorphic rocks

Because of the effects of metamorphism, the Devonian to Jurassic rocks in the Kafiristan-Hot Springs-Shoghot area is unfossiliferous, and their subdivision into specific time-stratigraphic units is not yet being carried out by geologists. These rocks consist of a wide variety of argillaceous and calcareous sedimentary and some volcanic rocks that have been metamorphosed to greenschist, calcareous schist, marble, phyllite, and other rock types. This broad group of metamorphic rocks is undivided on the map except for a belt of marble in the Hot Springs-Besti area and an amphibolite unit in the Momi area.

In the Kafiristan area, the rocks consist of green and brown phyllite, black argillite, green chlorite-quartz schist, beds of laminated tuffaceous greenstone and greenstone conglomerate, and beds of black graphitic limestone.

Two outcrop belts of metamorphic rocks in the Shishi Valley area and one in the upper part of Koghozi Gol are placed with the Devonian to Jurassic rocks. These outcrop belts consist of an inetrbedded sequence of gray and black thin-bedded marble, chlorite-quartz schist, black and brown phyllite, and calcareous phyllite.

4.6. Sedimentary Rocks

The rocks between Beshgram and Owir Gol are mapped as undivided Devonian to Jurassic rocks by Calkins et al (1981). Devonian corals found in dolomitic limestone 1.6 km west of Pasti village confirms the Devonian age for some of the rocks in this undivided unit. Tipper (Pascoe, 1924) also reported Late Devonian corals in Owir Gol 6.4 km north of Pasti. On the steep slope north of Pasti and east of the Pasti fault, the rocks, consist of an undisturbed and well-exposed sequence of various types of sedimentary rocks including limestone, dolomite, sandstone, and shale.

4.7. Cretaceous Rocks

4.7.1. Reshun Formation

The Reshun Formation was originally named the Reshun conglomerate by Hayden (1915) for the conglomerates near the village Reshun. The Reshun Formation forms three outcrop belts in the Chitral area, one on the west side of Chitral valley, a second on the east side of Chitral valley, and a third following the northeast trend of Shishi valley.

The outcrop belt on the east side of Chitral valley is in gradational contact with the overlying greenschist unit and the eastern side is faulted against granite and undivided strata of Devonian to Jurassic age. In Shishi valley, the Reshun Formation forms a gradational contact with the overlying Cretaceous volcanic greenstone unit; the eastern contact is a prominent fault zone.

The Reshun Formation consists of marble, calcareous phyllite, red phyllite, conglomeratic phyllite, and brown-weathering conglomerate.

4.7. Volcanic Greenstone

Overlying the Reshun Formation in Shishi valley is a sequence of volcanic greenstone that extends northeastward from the southern edge of the map to a point a few miles up the Shishi river, where it pinches out. These rocks in turn are overlain conformably by fossiliferous limestone and phyllite of Cretaceous age.

The volcanic greenstone consists of mafic porphyritic lava flows and some tuffs and volcanic conglomerate, all metamorphosed to low-grade greenstone. Some calcareous red phyllite is interbedded with the volcanic flows. The flows are olivine basalt containing phenocrysts of plagioclase, augite, and olivine in a fine-grained groundmass. Chalcopyrite is an accessory mineral in some flows.

4.9. Limestone and Phyllite

A belt of limestone and phyllite overlies the volcanic greenstone. North of Gurin village the volcanic greenstone pinches out and the limestone and phyllite unit is in contact with the Reshun Formation. The unit consists mainly of dark-gray, thin-bedded limestone interbedded with black phyllite and black calcareous shale. *Orbitolina* found in calcareous limestone beds on the east bank of the Chitral river 2 miles south of Drosh indicate a Cretaceous age for this unit. *Orbitolina* specimens were first found at this locality by Hayden (1915).

4.10. Green schist

A continuous belt of green schist, extending diagonally northeastward across the study area overlies by a gradational contact the middle outcrop belt of the Reshun formation and is in gradational contact with the overlying Chitral slate.

The green schist is pale-green, fine-grained, thinly laminated schist containing varying amounts of sodic plagioclase, actinolite, epidote, chlorite, and quartz. It probably represents chloritic and some what calcareous sedimentary beds and some volcanic tuffs. A few non-laminated layers containing relict feldspar phenocrysts and accessory Chalcopyrite indicate the presence of some volcanic flows. Other rock types seen occasionally in the greenstone unit include quartzose sandstone, marble, calcareous phyllite, and slate. Although different petrographically, the greenschist may be equivalent to the volcanic greenstone unit.

4.11. Chitral slate

The Chitral slate was first referred to by Hayden (1915) as the "slate series of Chitral". A short time later Tipper (Fermor, 1922) called these rocks the "Chitral Slate series."

The Chitral slate forms a northeast-trending belt 4.8-14.5 km wide following roughly the course of the Chitral and Mastuj rivers. As far north as the Lutkho river, the western margin of the slate is in gradational contact with the marble of the Reshun Formation; north of the Lutkho river, the contact is faulted. The eastern margin of the Chitral slate is gradational with the green schist unit.

The Chitral slate consists mainly of fine-grained black slate and thinly laminated phyllite. The slate is made up of alternating laminae of clay- and silt-size material and tends to break into flat slabs along cleavage planes. Layers of thick-bedded, fine to medium-grained graywacke, which contains black phyllite partings, are also present. The thinly laminated phyllite is green or black and consists of micaceous minerals arranged in paper-thin laminas. In some places, the phyllite contains thin beds of marble in which the component laminae are streaked out by internal deformation.

The age of the Chitral slate has always been considered to be Paleozoic (Tipper, Fermor, 1922; Stauffer, 1965), on the basis of a single fossil locality in Chitral Gol. Tipper (Fermor, 1922) states that it contains "a ***spirifer,*** a small *Dielasma,* and two as yet undetermined corals." Secondary evidence supporting the Paleozoic age of the Chitral Slate is the fact that the adjacent Cretaceous rocks in the Reshun area is faulted against the Chitral slate. Caltins (1981) is of the opinion that it is of cretaceous age.

4.12. Granite

According to Calkins etal (1981) five large bodies of granite are present in the area. Informal names have been applied for convenience as follows: the granite at Hot Springs, located near the Hot Springs in the northwestern corner of the map; the granite of Kafiristan in the western part of the area; the granite of Tirich Mir in the northern part of the area; the granite of Koghozi, 6.4 km east of Koghozi; and the granite in Shishi valley located along the upper eastern slopes of Shishi valley in the southeastern part of the map area.

The granite of Hot Springs is white, medium-grained, nonporphyritic, biotite-muscovite granite. It is weakly foliated parallel to the foliation of the adjacent country rock. The contact with the country rock, seen in many places, is intrusive and knife-edge sharp.

The granite of Tirich Mir forms an elongate, northeast-trending belt that pinches out in a southwestward direction. Along the Lutkho river it is only 61-m thick, well foliated, and in sharp intrusive contact with the adjacent schist. In Arkari Gol, the exact contacts were not accessible. Along this section, the granite is porphyritic, well foliated, and in a few places shows a swirly structure as brought out by the feldspar phenocrysts.

Little information is available on the granite of Kafiristan. Seen only in Rumbur Gol, it is medium grained, porphyritic, and its eastern contact with the adjacent schist is a shear zone. Its southern limit is roughly indicated by the fact that no granite is present in Bumboret valley. The northern limits of this granite body are not known.

The granite in Shishi valley is along the upper slopes of the eastern side of the valley.

4.13 Quaternary Deposits

Quaternary deposits consist of alluvial sand, gravel, and boulders in the streambeds; alluvial terraces above the streambeds; scree, talus, and landslide debris on the slopes; and upland alluvium, including boulder fields in the high basins and upper reaches of the main creeks. Larger deposits of alluvium and the terrace deposits are found along the Chitral river. In the Hot Springs area, river alluvium and terrace deposits have been combined. The only significant deposits of river alluvium are along the Chitral river, the Shishi river, and in the Hot Springs area. Narrow, discontinuous strips of alluvium exist along other major rivers and major creeks, but they are too small to show on the geologic map at the scale used.

Terraces, which stand as high as 274-427-m above the present river level, consist of poorly bedded stream deposits of clay, silt, sand, gravel, and boulders. Layers of silt and sand commonly are crossbedded. Boulders in the boulder beds consist of granite, granite gneiss, amphibolite, marble, quartzite, and slate.

Scree, talus, and landslide debris are widespread throughout the mapped area, particularly along the main rivers, where they extend upward at angles ranging from **30°** to **37°** for as much as 610-m above river level. These deposits cover the bedrock over long stretches of the streams.

Above an altitude of 3,353-m, numerous small upland basins are situated at the foot of the higher ridges and peaks. They characteristically are filled with avalanche debris and angular boulders resulting from frost heaving, snow avalanches, and other

manifestations of alpine weathering. These basins are dotted with bogs and swamps as a result of snowmelt and generally poor drainage, above 4,267 m, glacial cirques have formed. The permanent snowline is at an altitude of about 4,572-m and small permanent snowfields exist on the north- and northwest-facing slopes down to 4,267-m.

4.14 Structure

Structurally the area is subdivided into several belts by four north- and northeast-trending reverse faults (Calkins et al. (1981), which are named the Reshun, the Ayun, the Naz Bar, and the Shishi faults. These faults, which in places are thrusts, separate belts of different age groups, and provide one of the main keys to the structural interpretation of the area. Two additional faults, which are similar in habit to the main faults, are the Pasti and the Krinj faults- both in the Partsan area. On the basis of supplementary information available from outside the mapped area, the four main faults, and the outcrop belts they enclose, are extended far to the northeast (Calkins etal.1981).

4.14.1 Reshun Fault

The Reshun fault, named after the village of Reshun, separates the Devonian to Jurassic rocks on the west and northwest from the Reshun Formation and other Cretaceous rocks on the east and southeast. It is a thrust fault dipping northward at about 30°. At Partsan, the Reshun fault turns northwest for 6.4-km, then swings southwest and south where it changes to a reverse fault. It has been traced southward past Shoghot on the Lutkho river as far as Birir Gol in Kafiristan, where it disappears. At Shoghot, the fault dips **80°** W. In Awireth Gol 1 mile (1.6 km) south of Shoghot, the fault forms a horsetail structure 305-m wide and 3.2-km long, containing several individual fault slices. In this area and southward to Kafiristan, the fault dips **60°** W. to vertical.

4.14.2 Ayun Fault

The Ayun fault extends northeastward from Drosh past Koghozi and separates the Cretaceous rocks of the Chitral syncline on the west from granite and Devonian to Jurassic rocks on the east. This fault has been extended northeastward to join the Holojut fault of Matsushita and Huzita. At Darkot, the Ayun fault separates the large granite mass on the north from the Darkot Group (Devonian to Jurassic rocks) on the south (Matshushita & Huzita, 1965).

The Ayun fault was clearly verified only at one place, on the left (southeast) bank of the Chitral river 1.6-km southeast of Gahirat, where it forms a narrow shear zone dipping **45°**W. In Golen Gol, 3.- km east of Koghozi, a well-defined shear zone is not present. The only evidence for faulting is several cataclastic layers found in the granite at and near the contact with the Reshun Formation. The contact at this place appears to be more of the nature of an intrusive contact.

4.14.3. Nazbar Fault

The Nazbar fault so named by Matsushita and Huzita (1965), after Nazbar at Yasin separates the granite and Devonian to Jurassic rocks on the northwest from the narrow belt of Cretaceous rocks on the southeast. It extends from Drosh in a northeasterly direction and continues along the West Side of the Shishi river to the edge of the area. It is well exposed at Jingeret Gol, 4.8-km south of Drosh, on the west bank of the Chitral river, 1.6-km north of Drosh, at both sides of the bridge across the Shishi river; at village Tar on the Shishi river 11-km from Drosh, and in the vicinity of Kalas on the Shishi river, 23-km from Drosh.

4.14.4. Shishi Fault

The Shishi fault lies east of the Naz Bar fault and separates Cretaceous rocks on the west from Devonian to Jurassic rocks on the east. It extends northeastward from east of Drosh to the east edge of the study area. The Shishi fault is inferred to join the Naz Bar fault a few miles northeast of the study area, and to extend southwestward as far as the Pakistan-Afghan border. The fault was observed in Drosh Gol, Kaldam Gol, Punt Gol, and at the eastern edge of the study area. A shear zone that dips 75° W to vertical marks the fault. In Drosh Gol, the fault zone, which is about 24-m wide, consists of sheared serpentine 9-m and brown-weathering silica-carbonate breccia 15-m. In Punt Gol and Gawuch Gol, only narrow shear zones, 0.9-3 m wide, are evident.

4.15. Chitral Syncline

The Chitral syncline is so named for the wide belt of Cretaceous rocks between the Reshun and Ayun faults and occupying the Chitral and Mastuj valleys. The trend of this structure is slightly east of north, swinging to the northeast. The Chitral syncline is inferred to continue for many miles northeastward as defined by the outcrop belts of the Chitral slate and Reshun Formation. In the Kafiristan area, the Chitral syncline is overturned toward the east; in the Partsan area, the north limb of the syncline is overturned toward the south and is partly overridden along the north-dipping Krinj and Reshun faults by Devonian to Jurassic rocks and by the Reshun Formation.

The northeastern extension of the Chitral syncline beyond Reshun, is based mainly upon unpublished reconnaissance maps of Tipper (1926), and Calkins (1981) who shows a continuous belt of Chitral Slate from south of Chitral to Brep, 19-km northeast of Mastuj. At Brep, the slate belt splits into two narrow belts around an elongate body of granite, the northern belt continuing along the Yarkhun river to Baroghil pass. Tipper shows no faults or other structural details, and the extension of the northern faulted boundary of the Chitral syncline is mainly speculative.

4.16. Koghozi Anticline

The Koghozi anticline is the name given to the probable anticlinal structure lying between the Ayun and Naz Bar faults. An elongate body of granite, the granite of Koghozi occupies the core and is flanked on both sides by Devonian to Jurassic rocks and Cretaceous rocks.

4.17 tructure of Cretaceous Rocks at Drosh

At Drosh, and extending northeastward along the Shishi river, a narrow belt of Cretaceous rocks occupies the interval between the Naz Bar and Shishi faults. The belt is 5.6-km wide at Drosh, but narrows northeastward to less than 1.6-km. The rocks within this zone are only slightly metamorphosed, and fossil collections confirm the Cretaceous age of these rocks.

Probable extensions of the Cretaceous rocks at Drosh are found at Yasin and at Chumarkand pass, 6.4-km east of Mastuj. The rocks at these localities, were called the Yasin Group by Ivanac (1956). Tipper (1924) also mentions the presence of the "Reshun conglomerate and shales" at Chumarkand pass, where it has thickened a good deal and the conglomerate is very massive."

Chapter No. 5
Chitral River Terraces
Horizontal and Vertical Relationship

Chapter No. 5
Chitral River Terraces:
Horizontal and Vertical Relationship

5.1. Introduction

The entire study area from Singhore (Chitral town) as far as Drosh was surveyed. Terraces were recognized in the field and compared with those demarcated on the contour map. Field work confirmed the existence of at least 10 sequences of well-preserved terraces, which are as follows:

1. Dalamut Sequence
2. Singhore Sequence
3. Danin Sequence
4. Chitral Sequence
5. Jughore- Bakarabad Sequence
6. Broz Sequence
7. Ayun Sequence
8. Kesu Sequence
9. Gahrait Sequence
10. Drosh Sequence

5.2 Dalamut Sequence

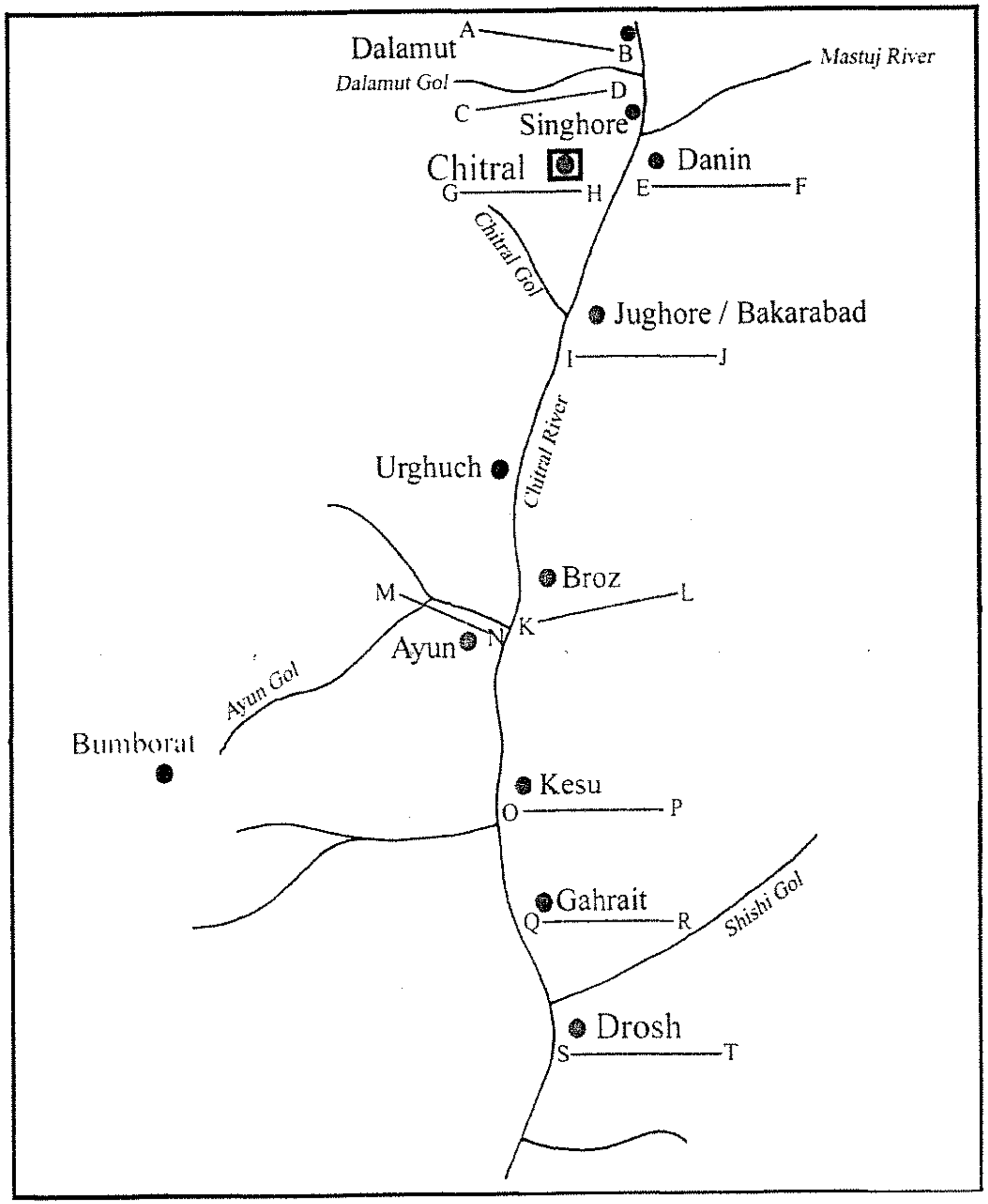
5.2.1. Location

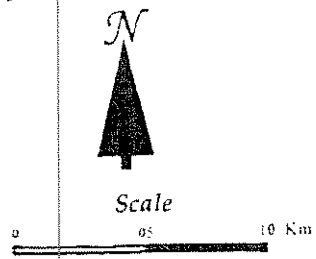
This sequence of six well-preserved river terraces is located some 3 km north of Chitral town. (GR 744206, 38 M / 13) The detail of their horizontal and vertical distribution is as follows:

5.2.1a. Dalamut Terrace (T1)

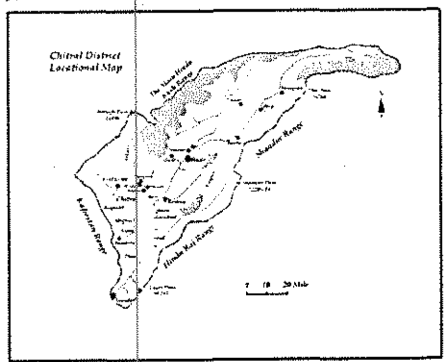
This is the highest level of river terraces in the sequence. It is preserved on the spur of the Birmoughlasht mountains. This terrace is preserved in the form of patches. Its absolute height is 1810 m ASL, while it is 355 m above the bed of river Chitral. This is an

Map 5.1
Chitral Valley
Location of Terrace Sequences

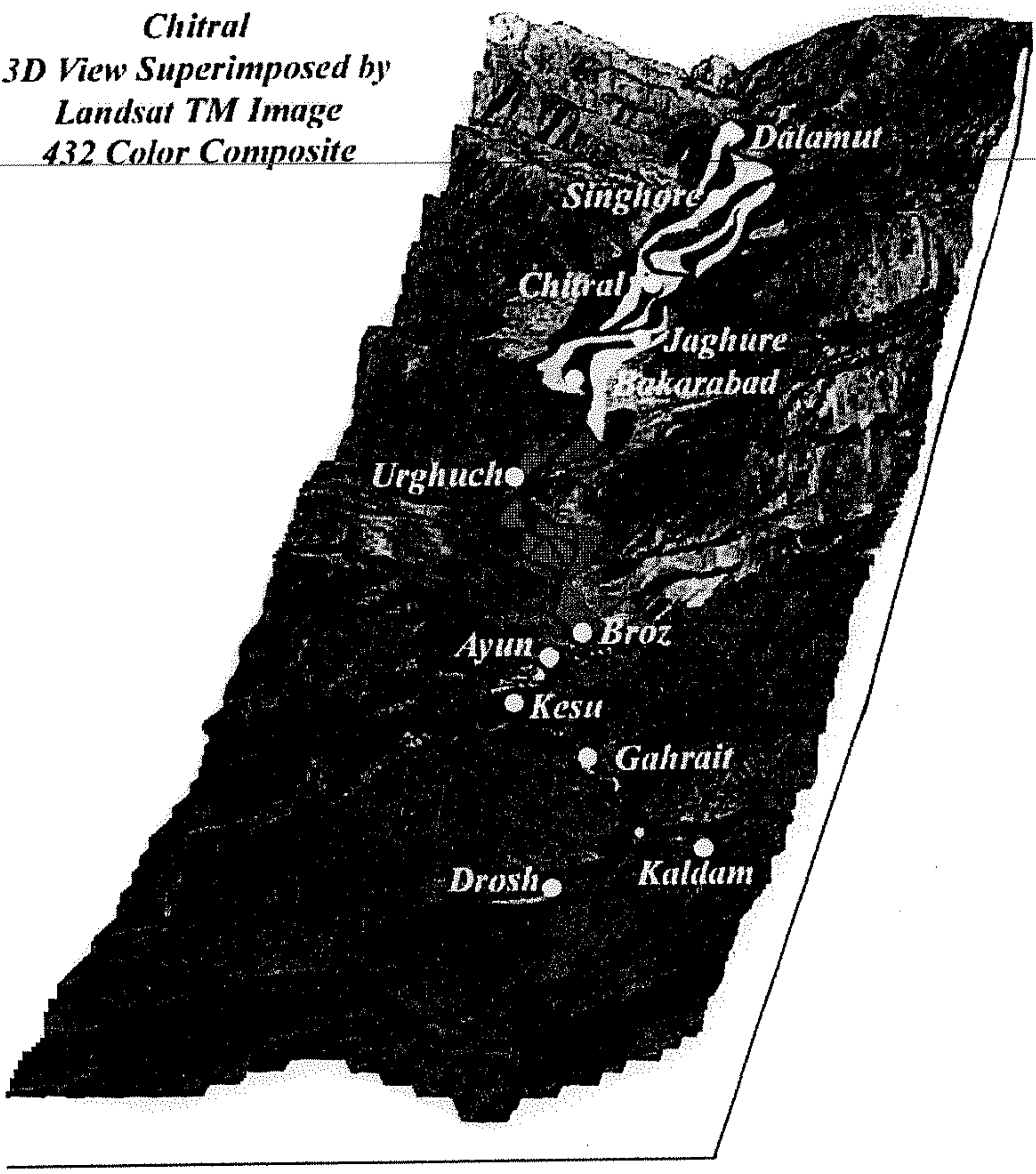




Dalmut Sequence	A-----B
Singhore Sequence	C-----D
Danin Sequence	E------F
Chitral Sequence	G-----H
Jughore Sequence	I------J
Broz Sequence	K-----L
Ayun Sequence	M-----N
Kesu Sequence	O------P
Gahrait Sequence	Q-----R
Drosh Sequence	S------T



Chitral
3D View Superimposed by
Landsat TM Image
432 Color Composite



erosional terrace cut in Chitral slate. The terrace surface slopes toward river and is covered with loessic wind-blown material.

5.2.1b. Agha Khan Hostel Terrace (T2)

This is a flat terrace covering an extensive area, at a height of 1780-m ASL. The relative height of the terrace is 325 m, above the bed of river Lutkoh (Garam-Chashma). The Agha Khan hostel as well as the Agha Khan Colony are located on it. This is a lacustrine terrace, the surface of which is covered with loessic material, heavily eroded in places.

5.2.1c. Upper Sinlasht Terrace (T3)

Sinlasht is a small village in Garam Chashma valley, located about 4-Km from Chitral town. It has an absolute height of 1720-m ASL, with a relative height of 265 m above the Garam Chashma river. Sections that are exposed show fluvial deposits. This is also covered by loessic material. Its surface is flat, sloping towards river.

5.2.1d. Orchard Terrace (T4)

Orchard terrace is a fan terrace, at a height of about 1515-m ASL, having a relative height of 60-m above the river bed. The terrace is traversed by Chitral-Garam Chashma road. **(Plate 5.1).**

5.2.1e. Middle Sinlasht Terrace (T5)

This is a broad terrace having a gentle slope, dipping toward the river. Its surface is covered by alluvium, deposited by river Lutkoh. Because of its flat surface and the presence of thick alluvium material, it is extensively cultivated. Its absolute height is 1470-m ASL, and is 15-m above the Lutkoh river.

5.2.1f. Lower Sinlasht Terrace (T6)

This terrace is preserved as a crescent-shaped narrow strip, on the left bank of Lutkoh river. This is the lowest level of terrace in the Dalamut sequence. It has an absolute height of 1460-m ASL, having a relative height of only 5-m above the Lutkoh river. It is covered by alluvium, and is extensively cultivated.

Table 5.1

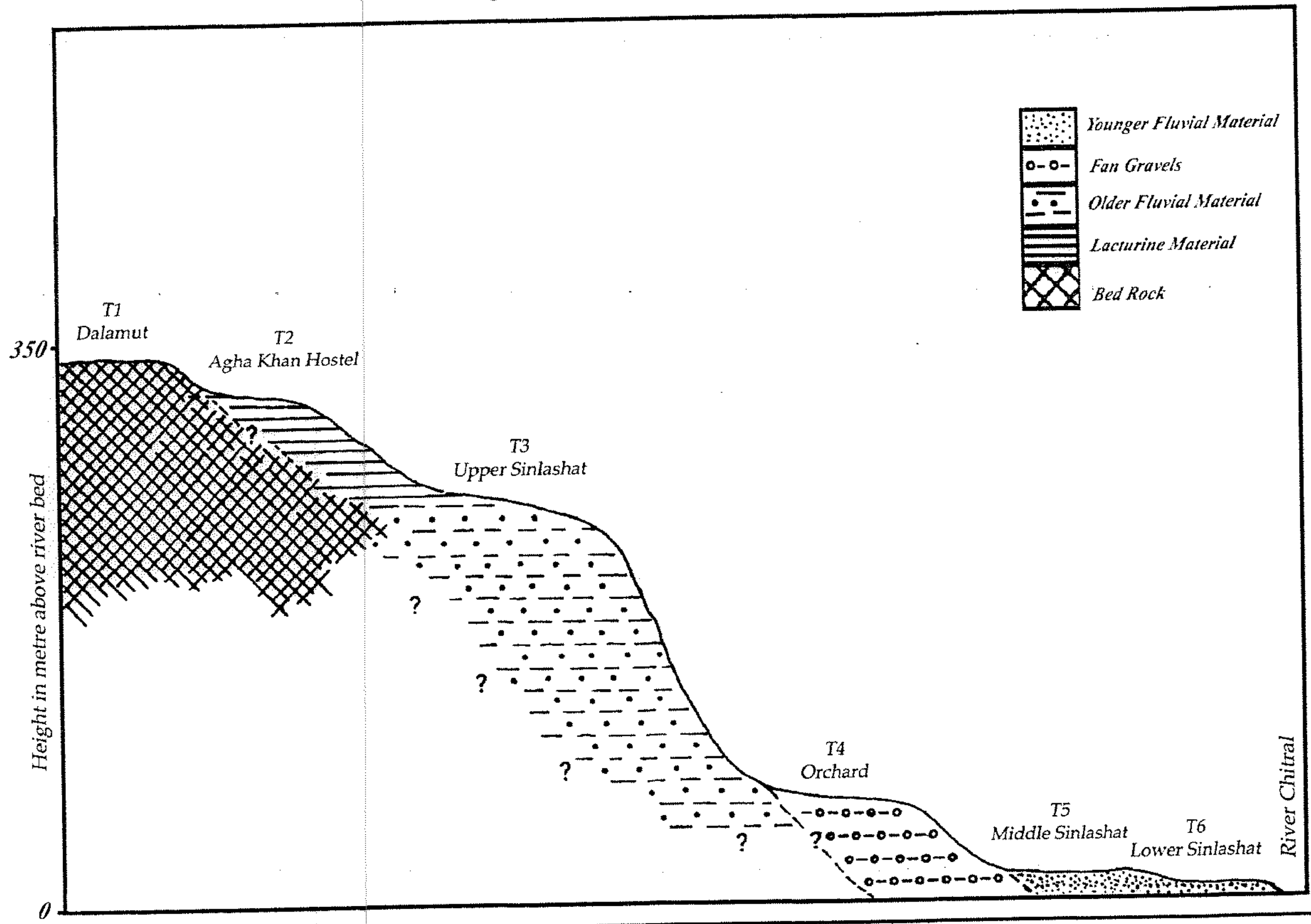
Horizontal and vertical relationship of terraces in Dalamut sequence

Terrace	Description	Height in meter		Material
		Absolute	Relative	
T1	Dalamut Terrace	1,810	355	Bed-rock
T2	Agha Khan Hostel	1,780	325	Lacustrine deposits
T3	Sinlasht Terrace	1,720	265	Fluvial deposits
T4	Orchard Terrace	1,515	60	Fan material
T5	Cultivated Terrace	1,470	15	Alluvium
T6	Sinlasht Terrace	1,460	05	Alluvium

Note:- River level at Dalamut sequence is 1455 m. Source: - Field Survey

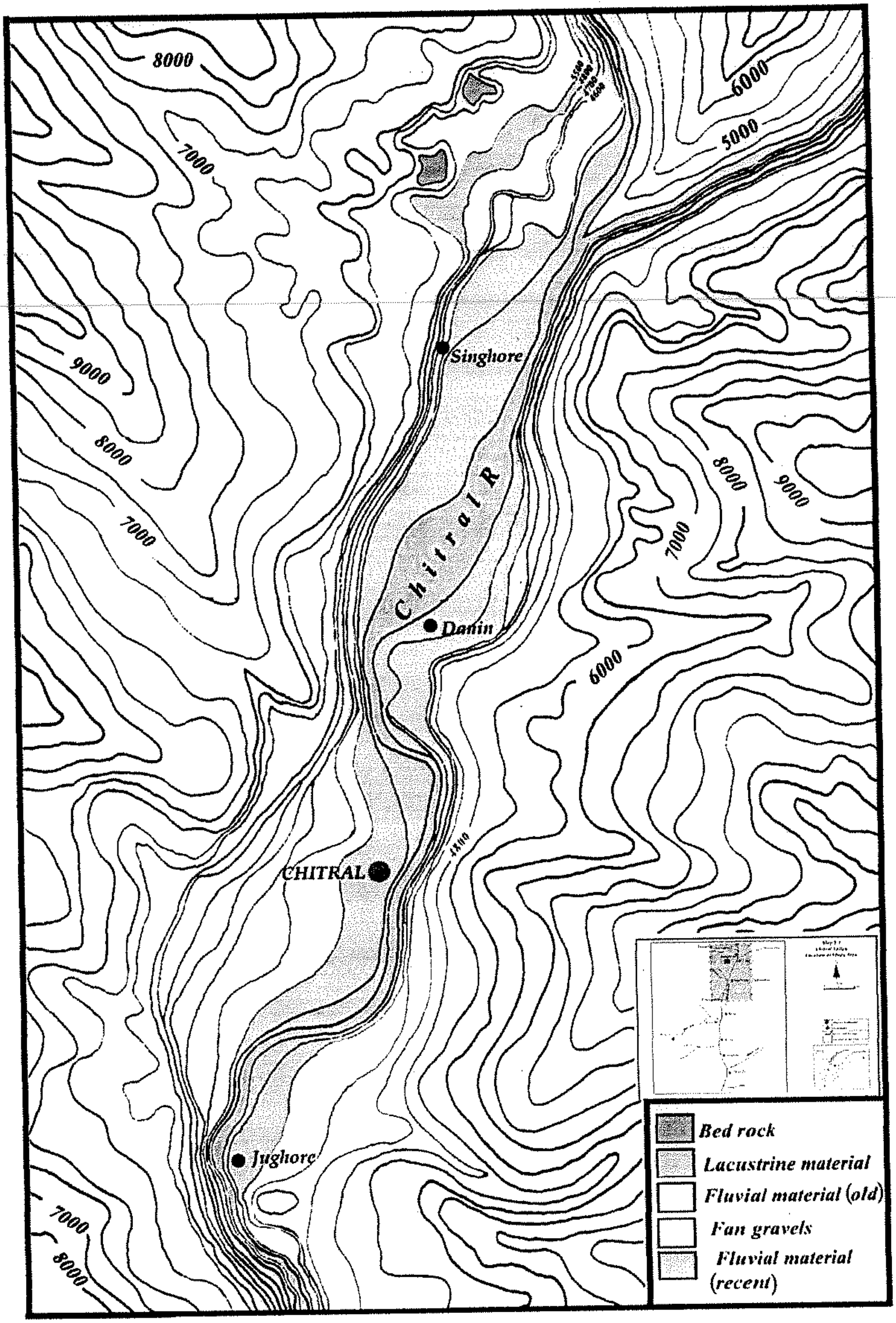
Figure 5.1

Terraces & Surface Deposits of Dalamut Sequence



Map 3.2

Distribution of Terraces in Dalamut, Singhore & Chitral Sequences



0 01 mile

Contour interval in Feet

Source: Toposheet No. 43 M/13

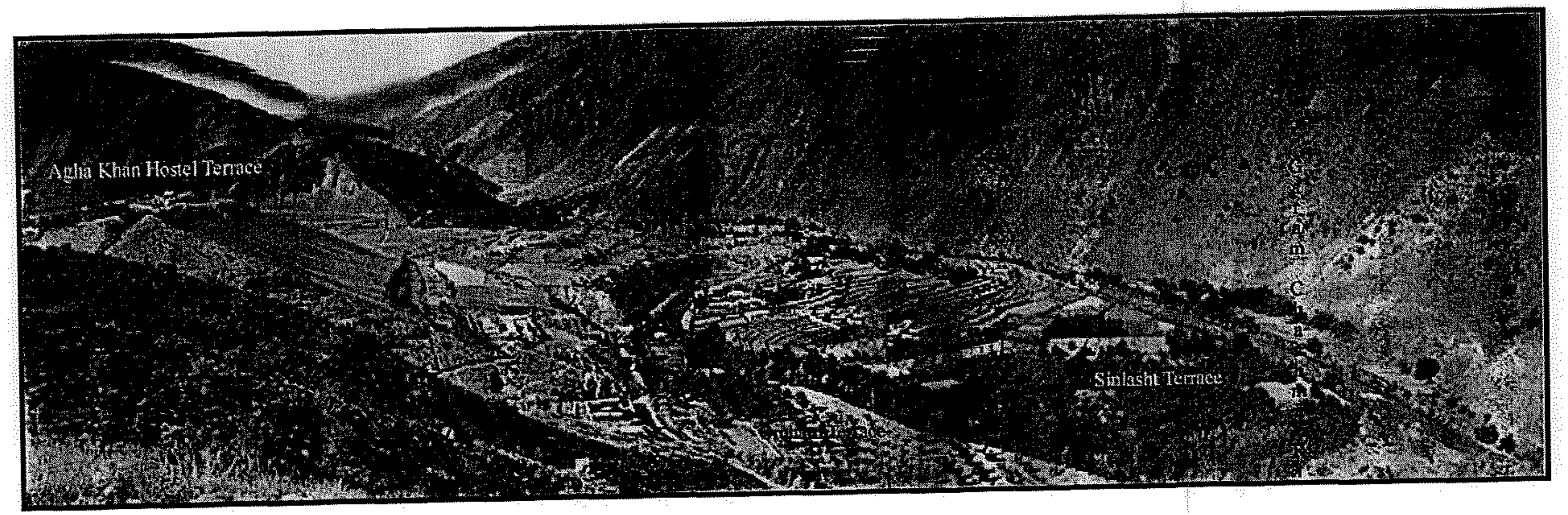


Plate: 5.1 Dalamut Sequence- Looking Toward North, From a height of 1640 meter, from upper Danin irrigation channel. The T1,T2, T3,T4, T5 and T6 are clearly Visible.

5.3 Singhore Sequence

5.3.1 Location

A sequence of well-preserved river terraces are exposed along the right bank of river Chitral, some 4-Km upstream Chitral town and one Km downstream from the Dalamut sequence. From top to bottom seven terraces have been recognized. **Plate 5.2** records the sequence of terraces. Chitral river is flowing at a height of 1450-m ASL. The horizontal and vertical relationship of the terraces in the Singhore sequence is as follows:

5.3.1a. Birmughlasht Terrace (T1)

T1 terrace of Singhore sequence is cut in the Chitral Slate and covered by loessic material. This is not an extensive terrace and preserved only in patches along the slope of Birmoughlasht mountain. The terrace surface is covered with loess deposit. Its absolute height is 1805 m ASL and a relative height of 355 m above Chitral river.

5.3.1b. Siaoch Terrace (T2)

This is an extensive and wide terrace, covering an area of approximately 1.5 sq. kms. Siaoch Public School is located on this terrace. It has an absolute height of 1780-m ASL and 330 m high above the river Chitral. Its surface is also covered by extensive deposits of loess, which in places attain a thickness of about 5-8 meters. Some clear sections are exposed along this sequence. Sections #1 and 2 show depositional sequence of this terrace. Both sections have alternate beds of silt and clay, mixed with coarse sand, which exhibits horizontal laminations. **(Plate 5.3)**

5.3.1c. Hindukush Height Terrace (T3)

This terrace derives its name from the famous Hindukush Heights hotel, located on this terrace. The absolute height of the terrace is 1720 m ASL, and relative height of 270 m above the Chitral river, which is flowing at a height of 1450 m above the sea level at the base of this sequence. Thick deposits of loess cover the surface, which is highly dissected because of gully erosion. Sections that are exposed along the terrace exhibits fluvial deposits.

5.3.1d. Ghankaroni Terrace (T4)

T4, T5 and are fan terraces. Ghankaroni Terrace (T4) is preserved at a height of about 1510-m ASL, and at a relative height of about 60-meters above the present day bed of river Chitral. This is a wide and extensive terrace, which is extensively cultivated. Ghankaroni village is located on this terrace. Its surface is covered by loessic material. Sections exposed along the terrace show fan material.

5.3.1e. Singhore Terrace (T5)

Singhore terrace is located at a height of about 50-m above river Chitral. Its absolute height is 1500-m ASL. This is preserved in the form of a crescent-shape nick, in the Singhore village . Major portion of the terrace is cultivated. The surface of the terrace is covered with wind blown loessic material.

5.3.1f. Airport Terrace (T6)

This is a wide and extensive terrace, having an approximate length of about 1200-1500-m and an average width of 700-1000-m, which in places is 1500-m. Chitral airport is located on this terrace. Besides the airport, village Balach is also sited on this terrace. Some parts of it is cultivated as well. The terrace is covered by alluvium, with well-rounded river gravels. The absolute height of the terrace is about 1465-m ASL, having a relative height of about 15-m above the present bed of river Chitral.

5.3.1g. Singhore Lower Terrace (T7)

This is a flat terrace along the banks of river Chitral, just below the airport **(Plate 5.2)**. It marks an abandoned flood plain of river Chitral. The terrace on the left bank of Chitral is cultivable, while that on the right bank is barren. Chitral-Buni road passes through this terrace. Its absolute height is 1455-m ASL, while it is just 5-m above the Chitral river. T6 and T7 of Singhore sequence are fluvial erosional terraces.

Table 5.2
Horizontal and vertical relationship of terraces in Singhore sequence

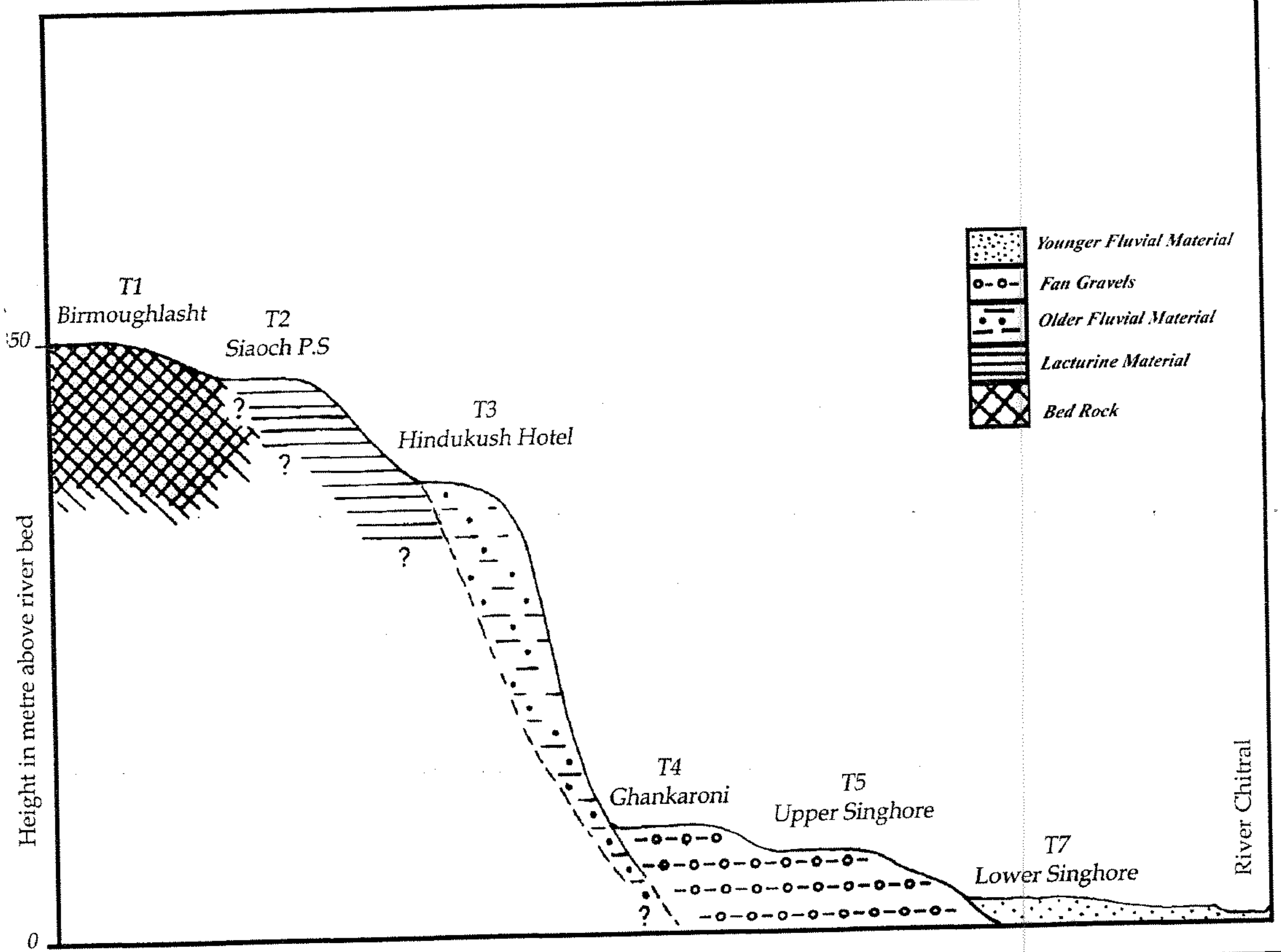
Terrace Level	Description	Height in meter		Material
		Absolute	Relative	
T1	Birmughlasht Terrace	1,805	355	Bed rock
T2	Siaoch Public School Terrace	1,775	325	Lacustrine deposit
T3	Hindukush Heights Terrace	1,720	270	Fluvial deposits
T4	Ghankaroni Terrace	1,510	60	Fan material
T5	Singhore Terrace	1,490	45	Fan material
T6	Airport Terrace	1,465	15	Alluvium
T7	Singhore Lower Terrace	1,455	05	Alluvium

Note:- River Level at Singhore sequence is 1450 m.

Source: - Field Survey

Figure 5.2

Terraces & $urface Deposits of Singhore Sequence



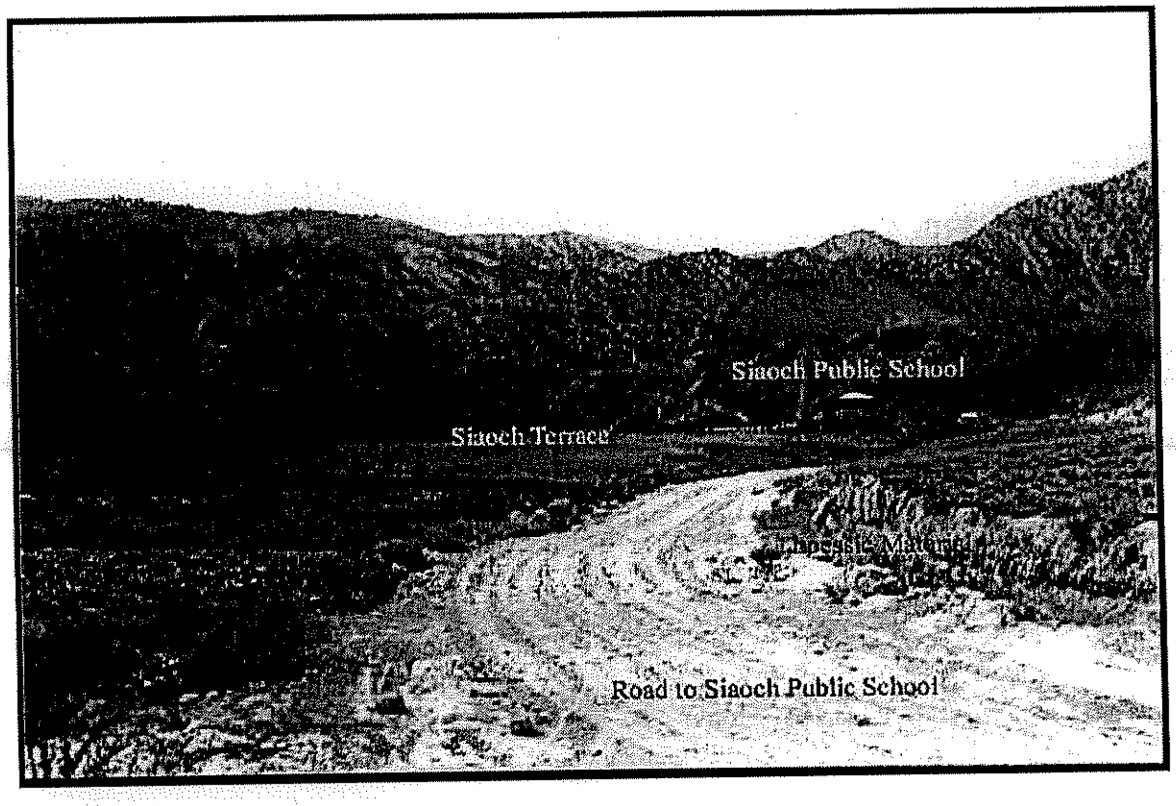


Plate 5.2. Siaoch Terrace of Singhore Sequence

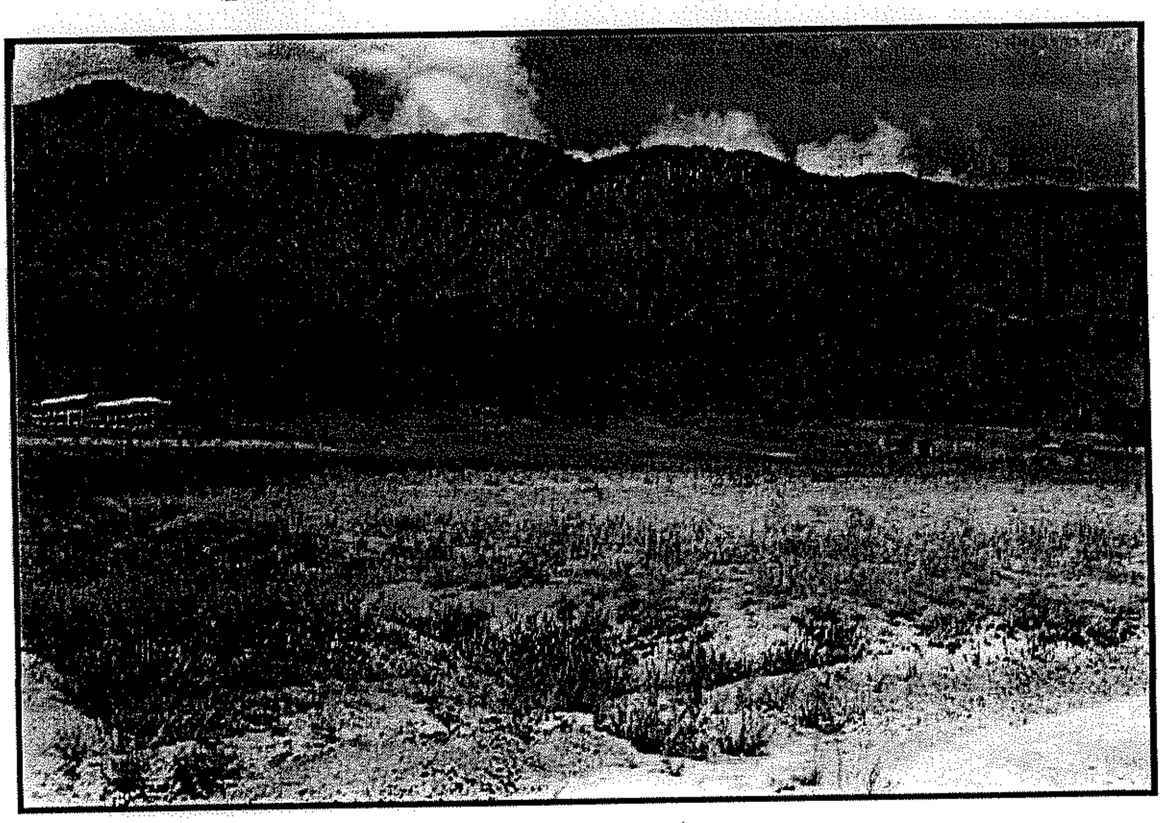


Plate 5.3. Loessic material covering the surface of Siaoch public school Terrace of Singhore sequence

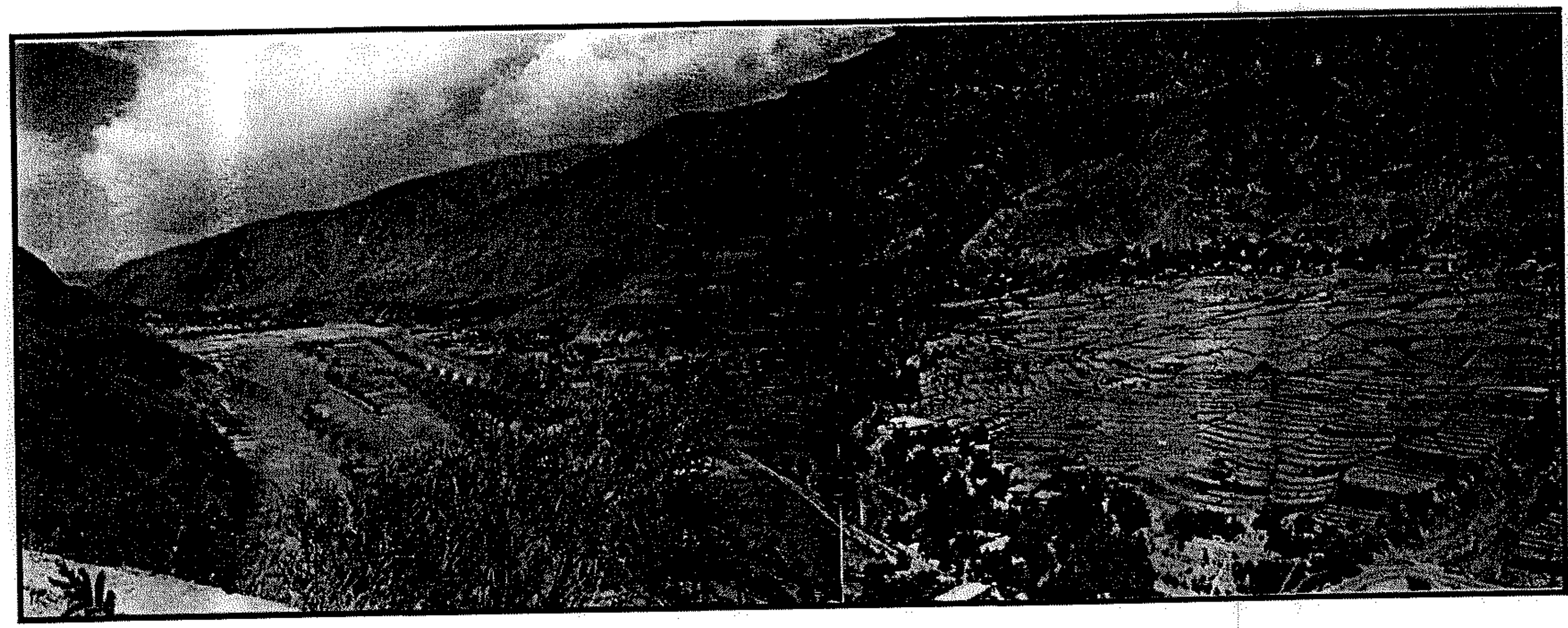


Plate 5.4. Singhore Sequence, Looking toward South from upper Danin Irrigation channel at a height of 1640-meter. All the seven terraces levels are clearly visible including Chitral Airport (T6).

5.4. Danin Sequence

5.4.1 Location

A well-preserved sequence of five different terraces has been exposed along the left bank of river Chitral, at Danin, 3 to 4Km downstream from Singhore sequence. Danin is part of Chitral town. Because it is a congested settlement, it is not easy to mark its boundaries. Cartographic analysis and detailed field study reveals three well-preserved depositional terraces in the Danin fan. The lower two terraces are the result of fluvial erosion. Details of the horizontal and vertical distribution of this sequence are as follows: **(Plate 5.5.)**

5.4.1a. Mughlanldeh Terrace (T1)

This is the highest terrace of the Danin sequence. It is the site of Mughlandeh village. This is also the main residential area of Danin, but in places it is also cultivated. It is preserved in the form of a narrow strip along the right bank of Danin gol. The absolute height of T1 at Danin sequence is 1470-m ASL, while it is 65 m high above the Chitral river.

5.4.1b. Gordaghandeh Terrace (T2)

This terrace is preserved in the form of a narrow strip of flat land, which is the main residential area of Danin. The area covered by this terrace is locally known as Gordaghandeh, a congested residential area. Looking from Birmoughlasht, it can be seen as a flat strip of land cut in the Danin fan. The absolute height of the terrace is 1455-m ASL, with a relative height of 50-m above the bed of Chitral river.

5.4.1c. CADP Rest house Terrace (T3)

T3 of the Danin sequence is preserved along the left bank of Chitral river. This is an extensive terrace, mostly covered by government buildings. This terrace is referred to as CADP Rest House terrace. The terrace has been considerably altered because of construction of buildings. Its absolute height is 1445-m, with a relative height of 40-m above Chitral river. Its surface is covered by sub-rounded to rounded gravels. The above mentioned three terraces are cut in the Danin fan by river Chitral, as confirmed by their deposits and shape.

5.4.1d. Danin Cultivated Terrace (T4)

T4 of the Danin sequence is preserved along Chitral-Buni road at Lasht. This is a crescentic-shaped narrow strip, which is cultivated. The absolute height of the terrace is 1420-m, with a relative height of only 15-m above Chitral river. The terrace surface is covered by alluvium that slopes gently towards the river.

5.4.1e. Danin Lower Terrace (T5)

This is the lowest terrace, comparable to the lowest terrace in Dalamut and Singhore sequences. Although suitable for cultivation, it is laying barren due to river floods. It is preserved in two different places: one just adjacent to airport, and another near to Al-Farooq Hotel, along the left bank of Chitral river. Presently, it is being occupied by Afghan refugees. Its absolute height of T5 is 1410-m ASL, with a relative height of only 5-m above the river level. T4 and T5 are the result of fluvial incision, in the recent flood plain of river Chitral.

Table 5.3

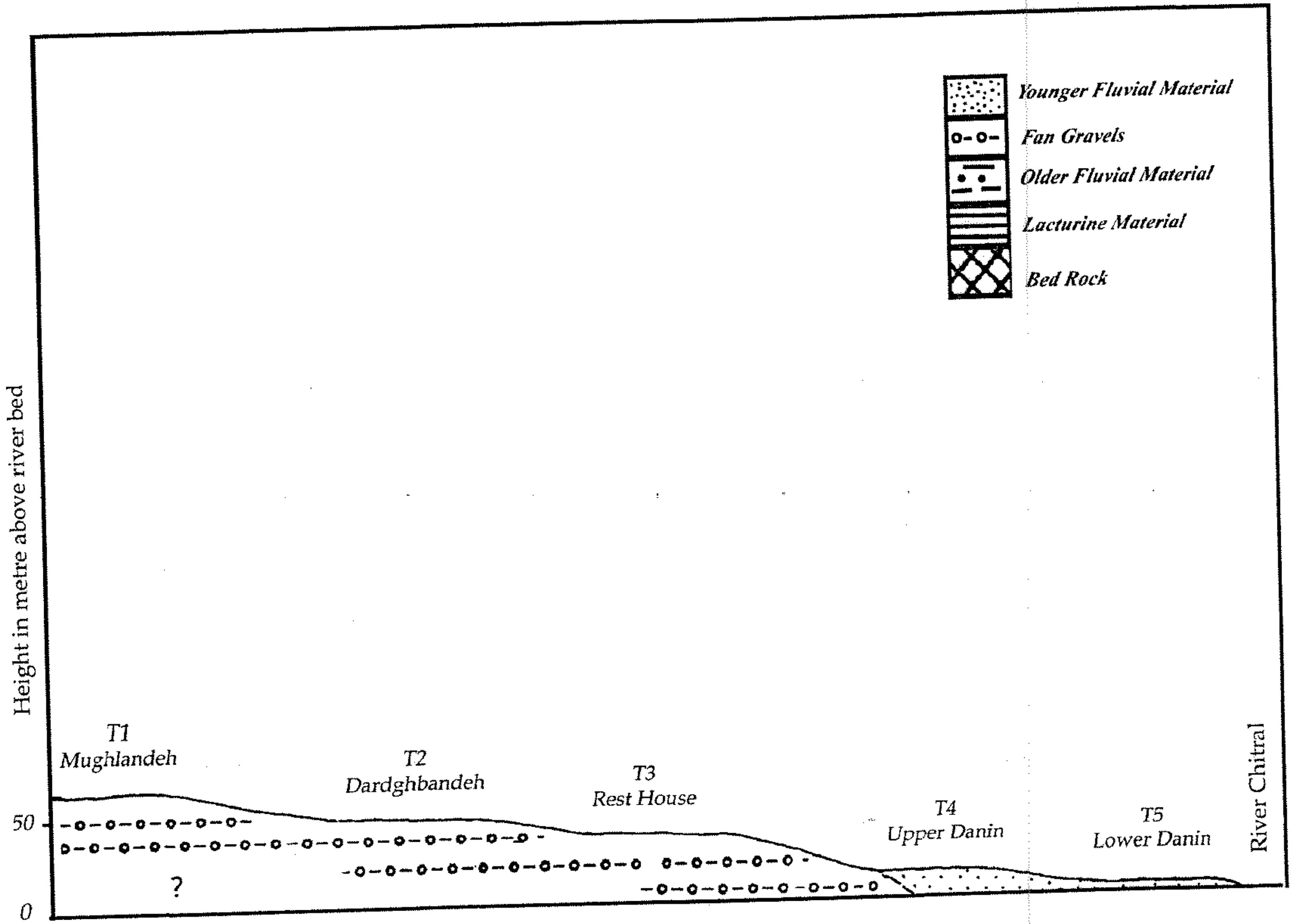
Horizontal and vertical relationship Of Terraces in Danin sequence

Terrace Level	Description	Height in meter		Material
		Absolute	Relative	
T1	Mughlandeh Terrace	1,470	65	Fan material
T2	Dardghbandeh Terrace	1,455	50	Fan material
T3	CADP Rest House Terrace	1,445	40	Fan material
T4	Danin Cultivated Terrace	1,420	15	Alluvium
T5	Danin Lower Terrace	1,410	05	Alluvium

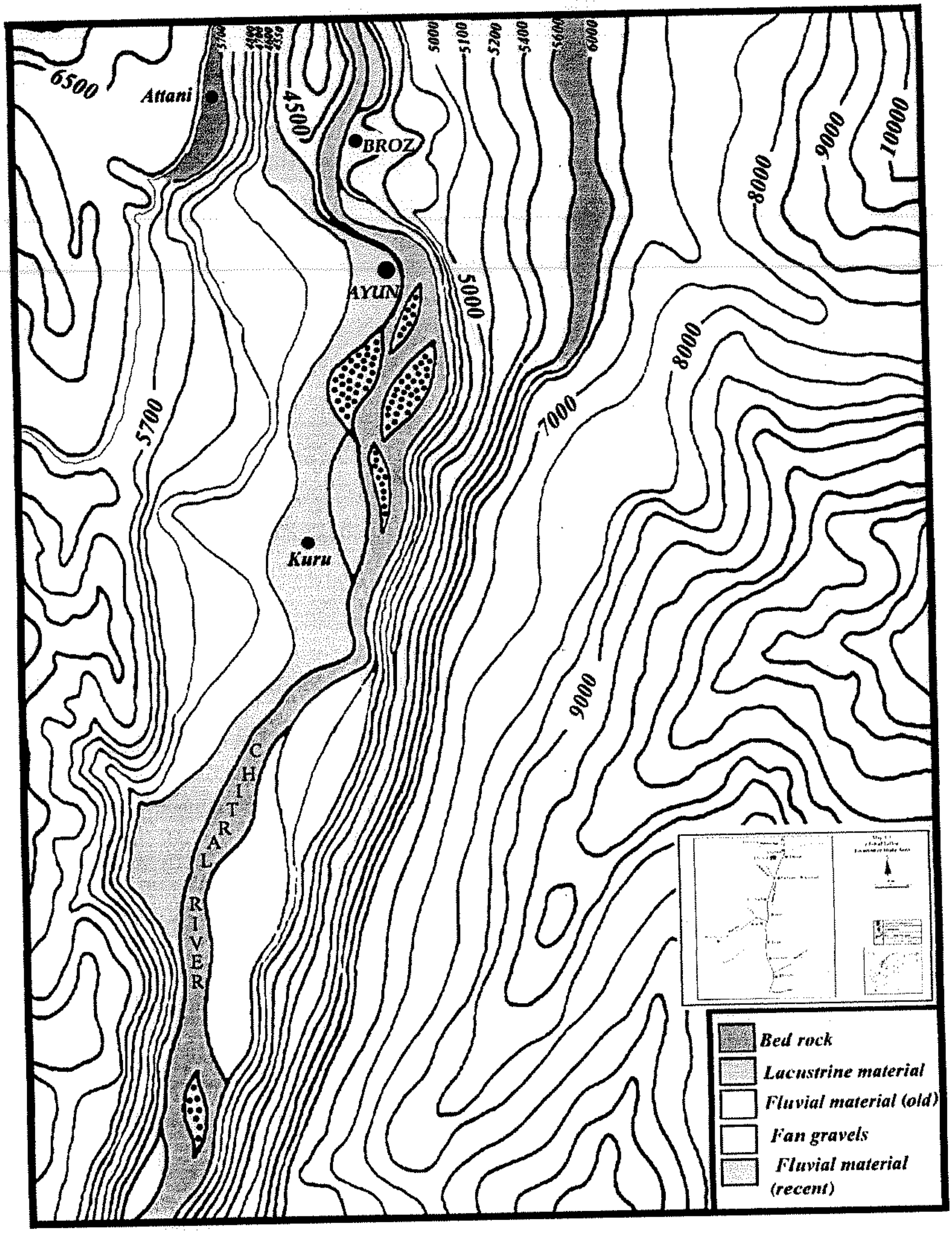
Note:- River level at Danin sequence is 1405 m. Source: - Field Survey

Figure 5.3

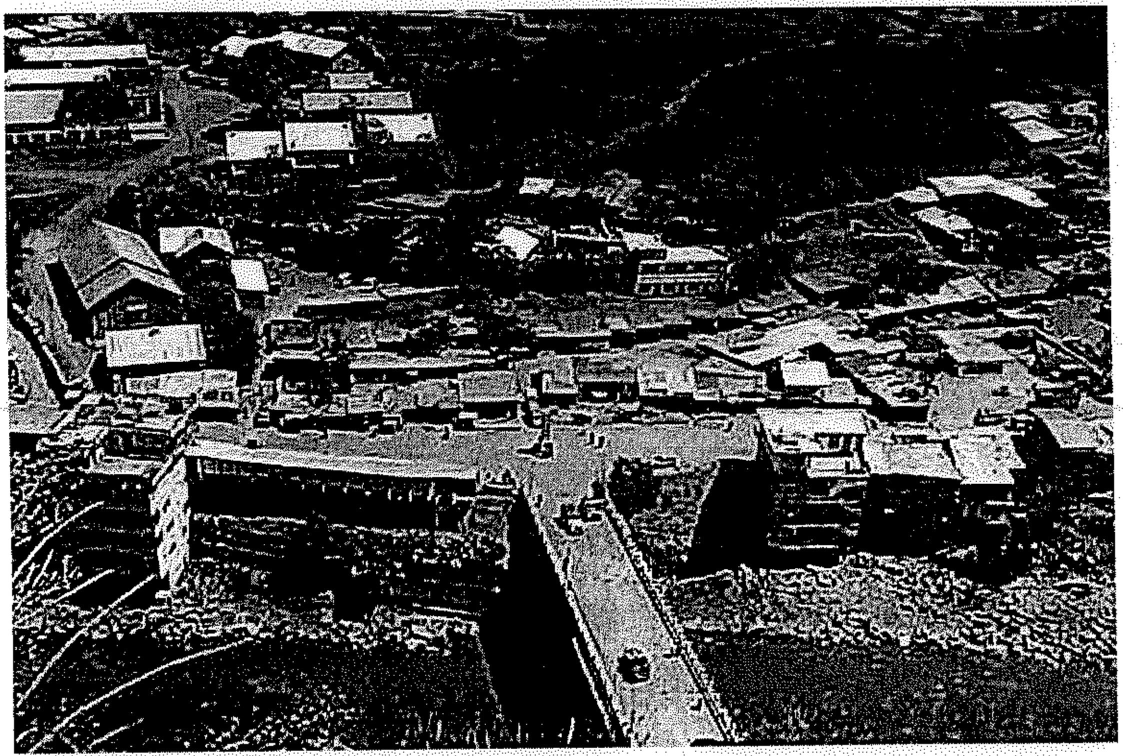
Terraces & Surface Deposits of Danin Sequence



Map 5.3
Distribution of Terraces in Broz & Ayun Sequences



0 Scale 01 mile
Contour interval in Feet
Source: Toposheet No. 43 M/14



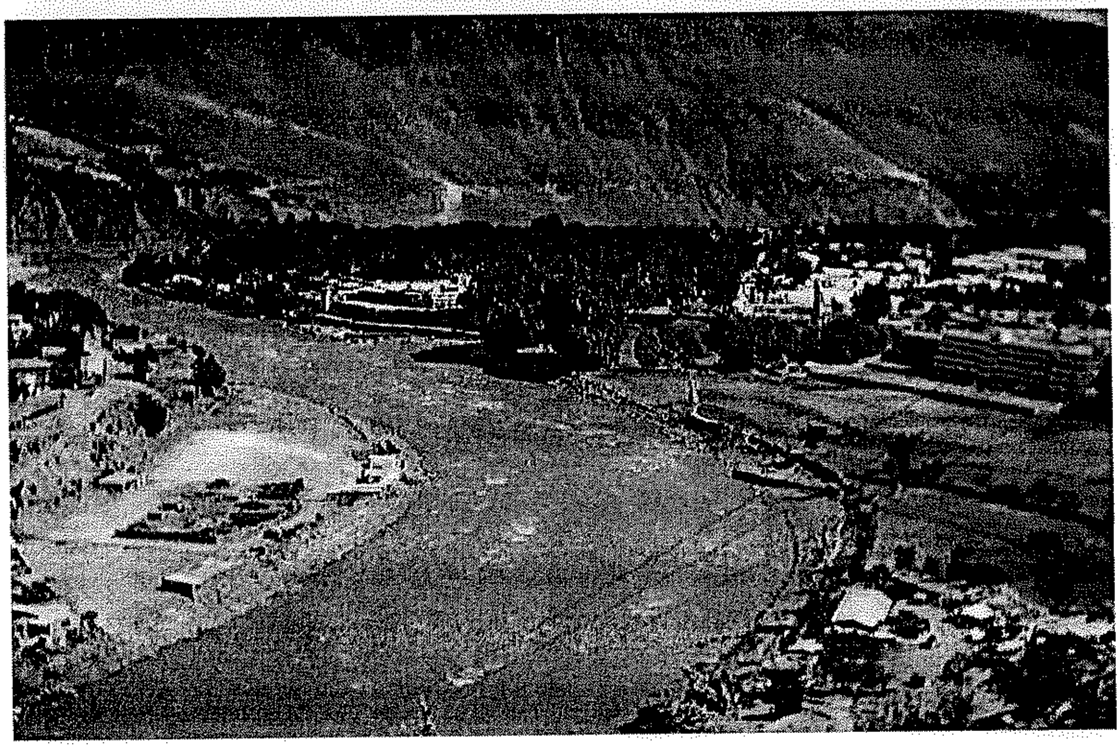


Plate 5.5. Danin sequence of terraces. The photograph (above) has been taken from the Governor House, looking towered east. Five different terraces are clearly visible. Below a closer view of Danin lower terrace.

5.5. Chitral Sequence

5.5.1 Introduction

Chitral sequence consists of eight well-preserved terraces. Chitral town is actually located on the terraces of this sequence. From top to bottom, there are eight river terraces. Most of the upper terraces are preserved as narrow strips, cut in the Chitral fan and are covered by loess deposits. The details of their distribution are as follows:

5.5.1a. T1 Kurkashandeh & T2 Patikogas

Three levels of terrace are cut in the fan material. They are in fact narrow strips that radiate from the Mulen gol. Their absolute height is 1525-m ASL respectively, with a relative height of 115, to 120-m. Field evidence suggests that they may have been cut in the fluvial deposits. Comparable terraces have not been found in any other sequence.

5.5.1b. T3 Mughlandeh Terraces &T4 Uchusht Terrace

Terraces T3, T4, T5 and T6 are depositional terraces. T3 derives its name from the village of Uchusht, which is one of the large villages located on this terrace. This is preserved in crescent-shaped strip, broad in the middle that tapers on the sides. The absolute height of the terrace is 1490-m, while the relative height is 75-m. These terraces are cut in three strips in the Chitral fan formed by Molen gol.

5.5.1c. College Terrace (Shiaqotak) (T5)

This is an extensive terrace, which is dissected by Mulen gol. The villages of Hun (Faizabad) 1470-m. Jhang Bazaar, D.C. office, and village Shiaqotak,(1470-m) and Government College are located on this terrace. The terrace is subject to flash flood almost every year. This is the main residential area of Chitral. Its absolute height is 1470-m, while its relative height is 65-m.

5.5.1d. The Muldeh Terrace (T6)

This is a wide terrace with a maximum width of approximately 500-m, but its width varies from 100 to 500-m. H.H.Palace at Noghor, village Moldeh, a portion of Shahi bazar, and polo ground (1455-m) are located on this terrace. The absolute height of this terrace is 1450 -m ASL, and relative height of about 45-m above the bed of river Chitral.

5.5.1e. Noghore Terrace (T7)

This is a wide terrace, on which are located the Fort Noghore, part of the Shahi bazar, residential and commercial buildings including AKRSP office. The absolute height is 1420-m, and a relative height of 15-m. Its surface is covered by alluvium, with some sub-rounded to rounded gravels, in places.

5.5.1f. Pamir River Side Inn Terrace (T8)

T8 is the lowest terrace in the Chitral sequence. This is a recently formed terrace, cut by Chitral river, from its abandoned flood plain in Noghore area, close to the Chitral Fort and Shahi Mosque. It is preserved in the form of a crescentic-shaped narrow strip, 5-m above the Chitral river. Pamir River-Side Inn is located on this terrace level. A portion of the terrace is also cultivated. The absolute height of the terrace is 1410-m ASL, with a relative height of only 5-m above Chitral river.

Table 5.4
Horizontal and vertical relationship of terraces in Chitral sequence

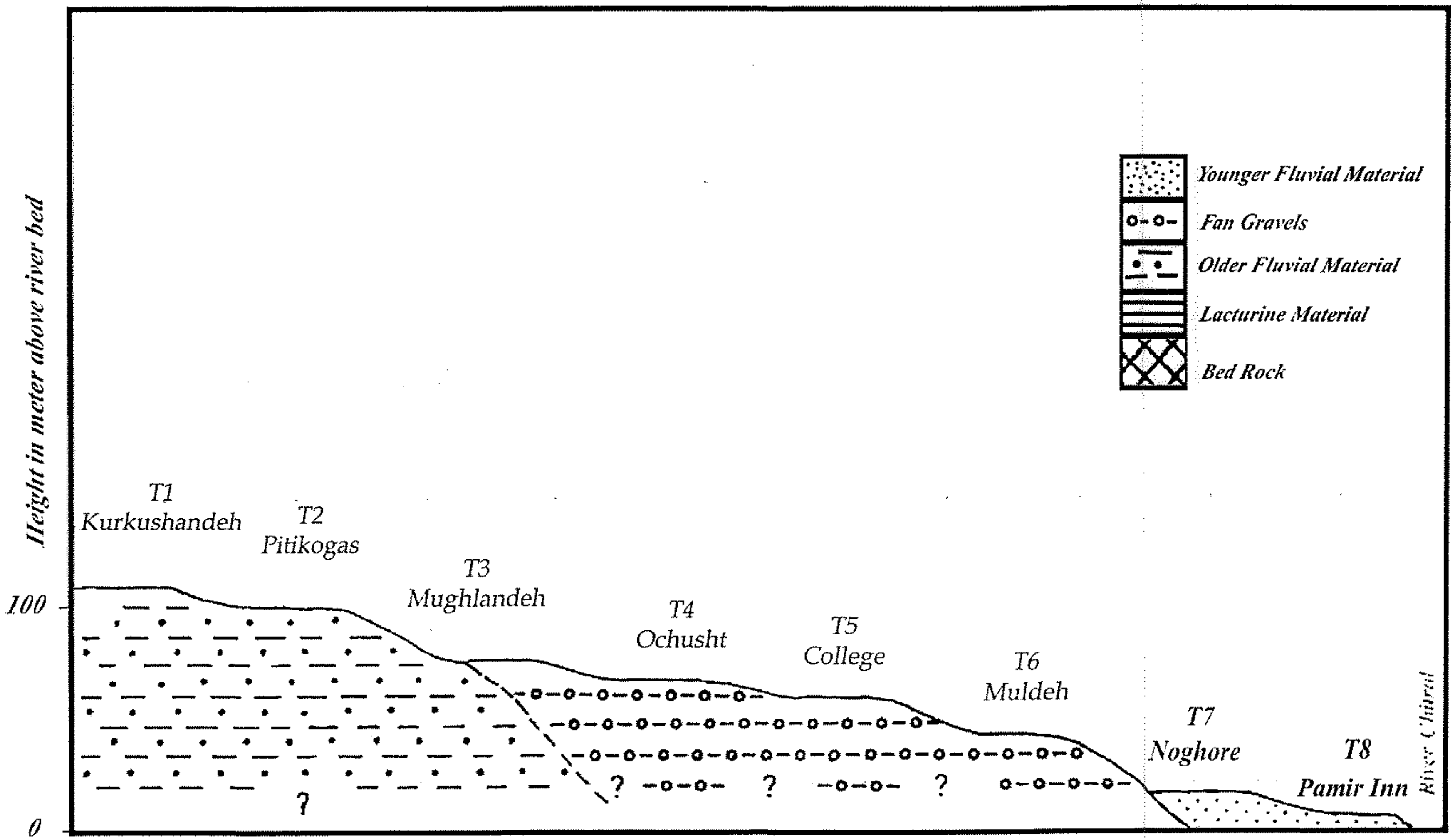
Terrace Level	Description	Height in meter		Material
		Absolute	Relative	
T1	Kurkushandeh Terrace	1,525	120	Fluvial deposits
T2	Pitikogas Terrace	1,520	115	Fluvial deposits
T3	Muglandeh Terrace	1,490	85	Fan material
T4	Ochusht Terrace	1,480	75	Fan material
T5	College Terrace	1,470	65	Fan material
T6	Muldeh Terrace	1,450	45	Fan material
T7	Noghore Terrace	1,420	15	Alluvium
T8	Pamir river side inn Terrace	1,410	05	Alluvium

Note:- River level at Chitral sequence (Back of Al-farooq hotel) is 1405-m.

Source: - Field Survey

Figure 5.4

Terraces & Surface Deposits of Chitral sequence



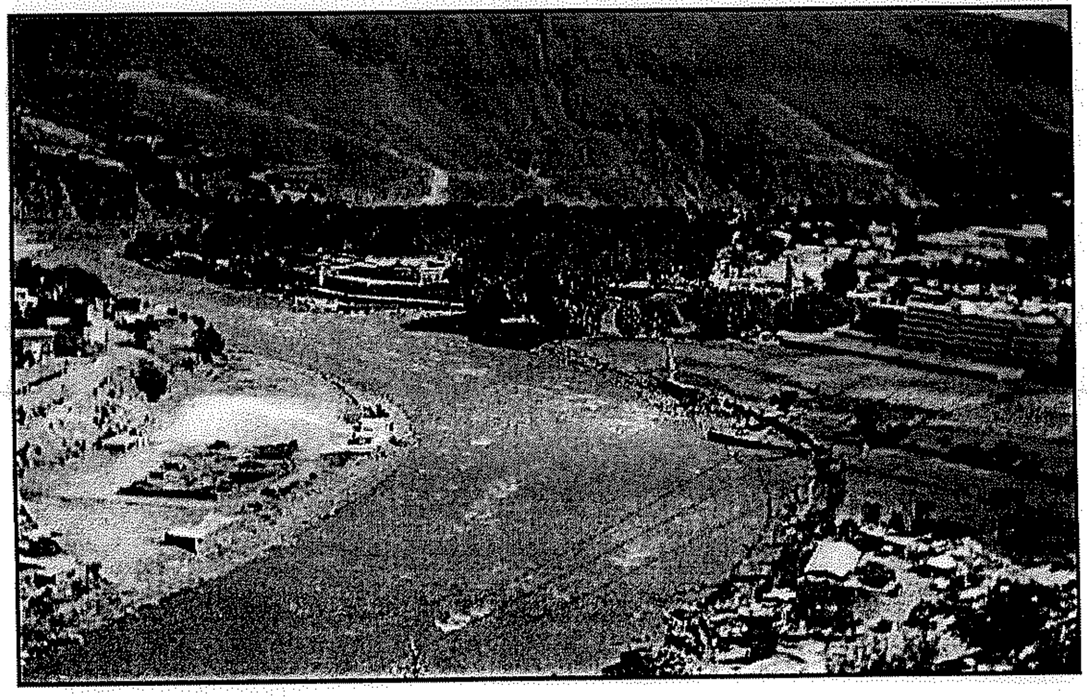


Plate 5.6. Noghore terrace (T7) of Chitral sequence. The photograph is taken from Danin looking towered west. The Chitral fort is clearly visible.

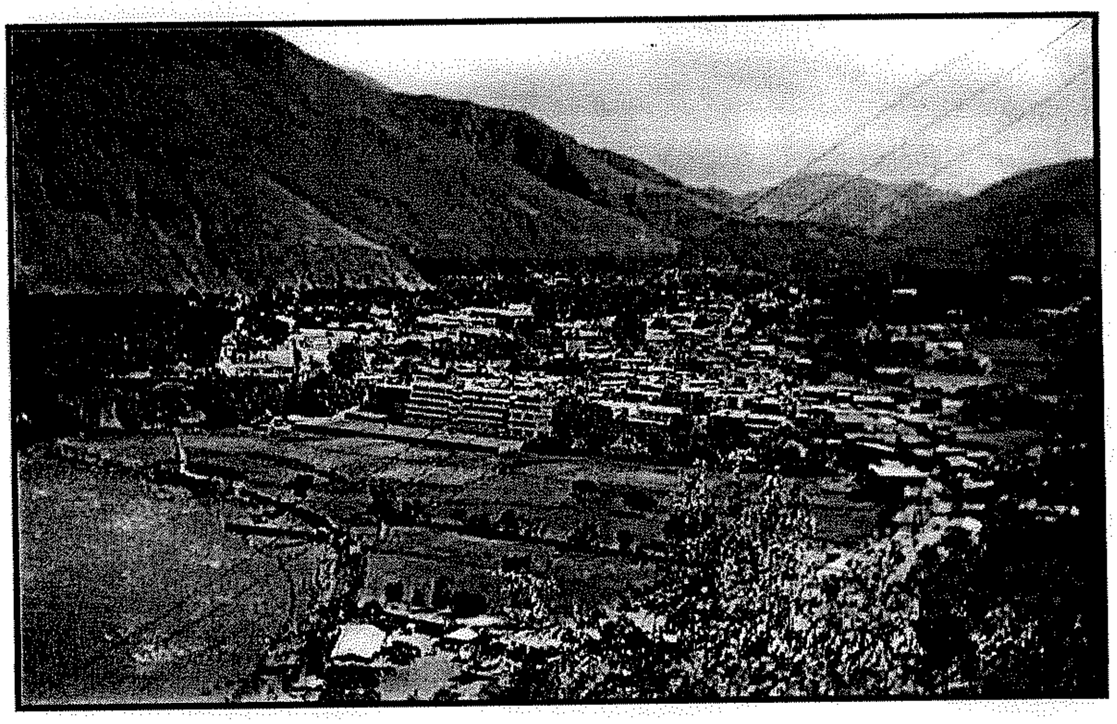


Plate 5.7. Pamir riverside inn (T8) terrace of Chitral sequence, the lowest terrace in Chitral sequence. The Pamir river side inn from which it derived its name is located on it. The major part of the terrace is cultivated.

5.6. Jughore-Bakarabad Sequence

5.6.1 Location

This sequence of well-preserved terraces is exposed in Jughore and Bakarabad villages, located some 3 Km downstream from Chitral town, along the Chitral-Drosh road. Cartographic analysis as well as field evidence suggests the existence of six terraces. The lower four terraces (T3, T4, T5 and T6) are located in Jughore, while the upper two levels T2 and T1 are preserved in Bakarabad.

5.6.1a. Bakarabad Bala Terrace (T1)

T1 and T2 of this sequence are depositional terraces with a thick cover of loessic material. It is the highest terrace of this sequence, which is a very extensive and preserved as a conical hill, which is the site of Bakarabad Bala village. It has an absolute height of 1530-m ASL, and is 130-m above Chitral river bed. Section along this terrace shows a bed of well-rounded gravels.

5.6.1b. Bakarabad Payeen Terrace (T2)

This is a wide terrace that extends from Jughore to Bakarabad. The Bakarabad petrol pump (1500-m from sea level) is located on this terrace. It has an absolute height of about 1500-m ASL, and is 100-m above the bed of river Chitral. A section exposed along this terrace shows some rounded to well-rounded gravels. The terrace is covered by a thick deposit of loess, which in places attains a thickness of more than 5-m. **(Plate 5.9)**

5.6.1c. Goldur Terrace (T3)

T3, and T4 are depositional terraces of the sequence. Goldur is not a very extensive terrace. Goldur village lies on this vary surface. Portion of Chitral-Drosh road passes through it. It has a maximum height of 1460-m ASL and is 60-m above Chitral river.

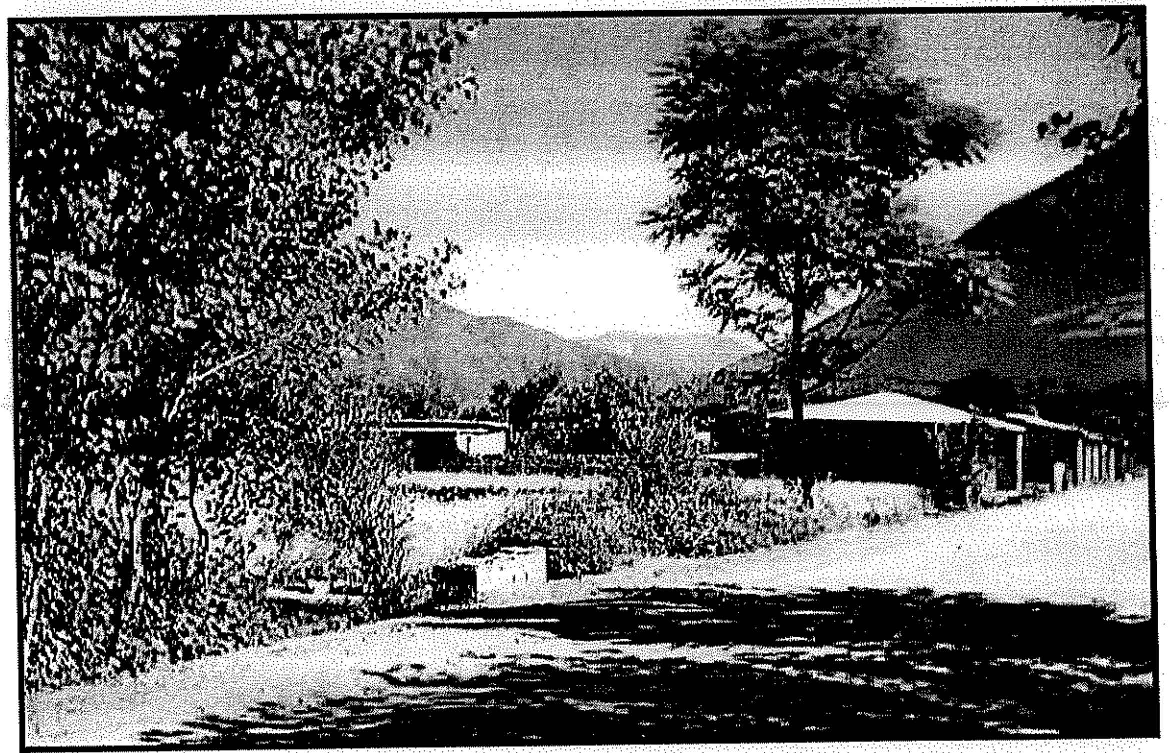


Plate. 5.8. T1 and T2 of Jughore-Bakarabad sequence. The terrace surface is covered by thick loessic material.

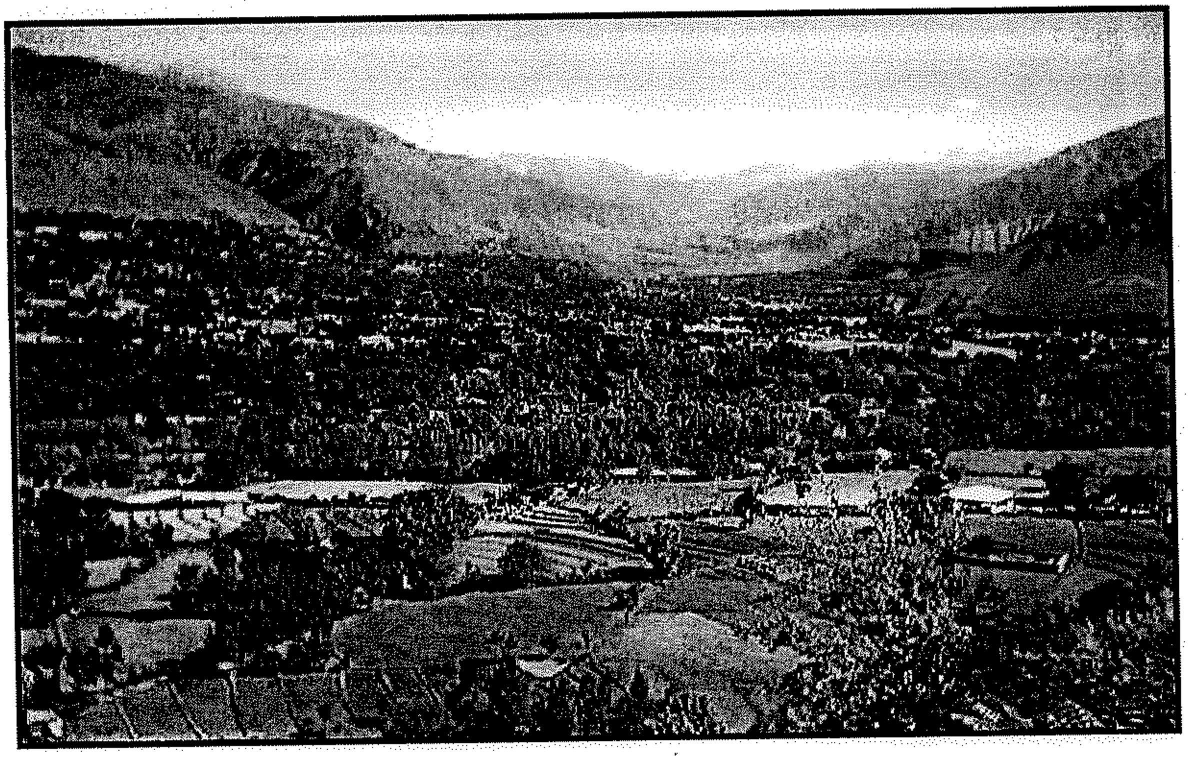


Plate 5.9. Dawashish terrace (T4) of Jughore-Bakarabad sequence. The Dawashish furniture market is located on it, but major part of the terrace is cultivated.

5.6.1d. Dawashish Terrace (T4)

This terrace extends from Dawashish Furniture Market to Bakarabad. It is, in places 1500-2000-m long, and 400-m wide. The Chitral-Drosh road passes through it. A major portion of the terrace is cultivated. The absolute height of the terrace is 1440-m ASL, having a relative height of 40-m above Chitral river. It is to be noted that T3 and T4 are cut down in fan material.

5.6.1e. Jughore Terrace (T5)

This is an extensive terrace that is very wide in the middle but tapers on the sides. It is predominantly used for the cultivation of rice. The absolute height of the terrace level is 1415-m ASL, with a relative height of 15-m above Chitral river.

5.6.1f. Shat Guvavi Terrace (T6)

This is the recent most terrace of the sequence. It has been cut by river Chitral from the old flood plain. It is predominantly used for cultivation. Its absolute height is 1405-m ASL, while it is only 5-m above Chitral river, which is flowing at 1400-m ASL. The surface of the terrace is covered by alluvium. T5 and T6 are cut down in the recent flood plain of Chitral river.

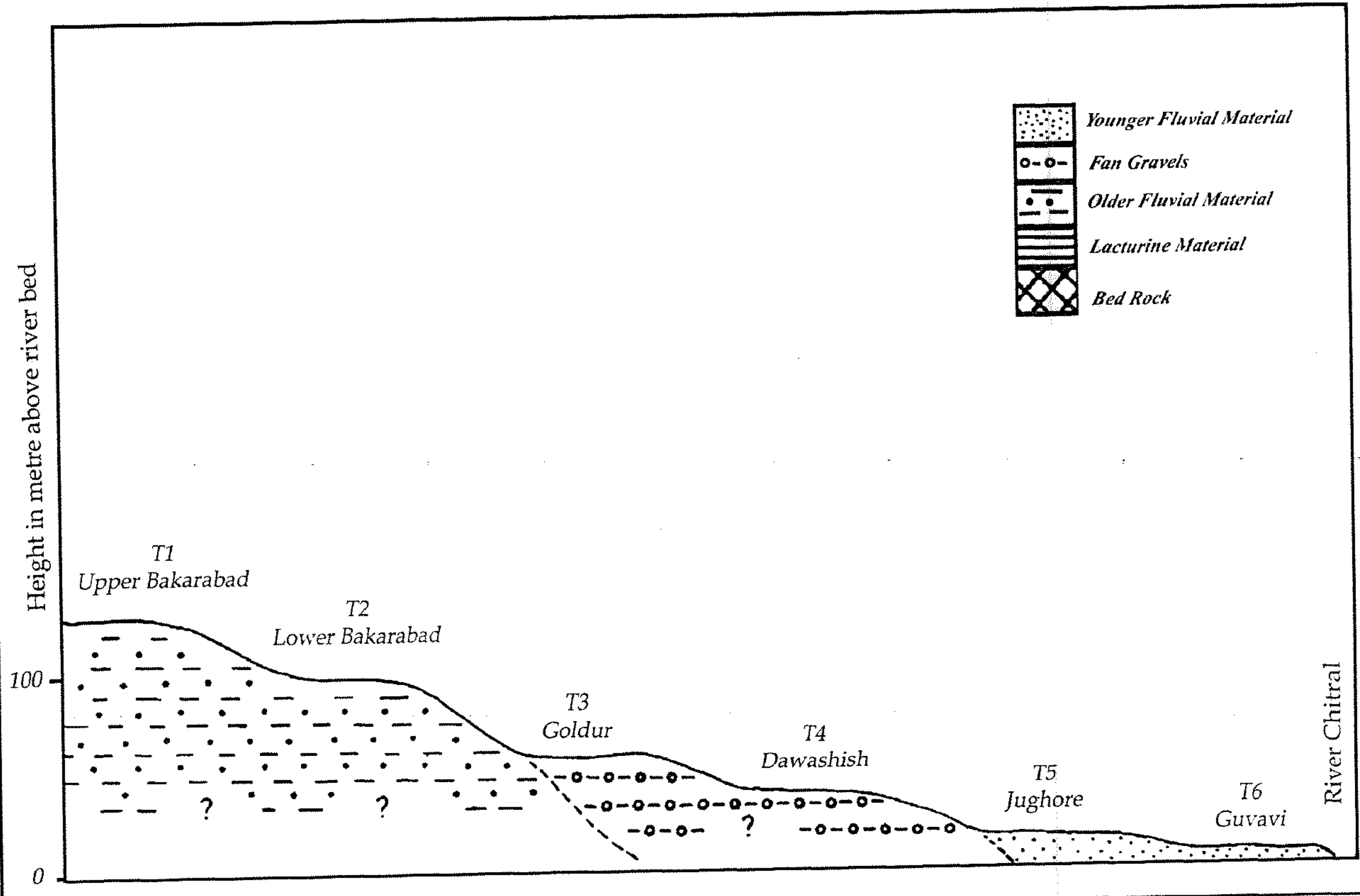
Table 5.5
Horizontal and vertical relationship of terraces in Jughore-Bakarbad sequence

Terrace Level	Description	Height in meters		Material
		Absolute	Relative	
T1	Bakarabad Bala Terrace	1,530	130	Fluvial deposits
T2	Bakarabad Payeen Terrace	1,500	100	Fluvial deposits
T3	Goldur Terrace	1,460	60	Fan material
T4	Dawashish Terrace	1,440	40	Fan material
T5	Jughore Terrace	1,415	15	Alluvium
T6	Guvavi Terrace	1,405	05	Alluvium

Note: River level at Jughore-Bakarbad sequence is 1400 m.

Source: - Field survey

Figure 5.5
Terraces & Surface Deposits of Jughore-Bakarabad Sequence



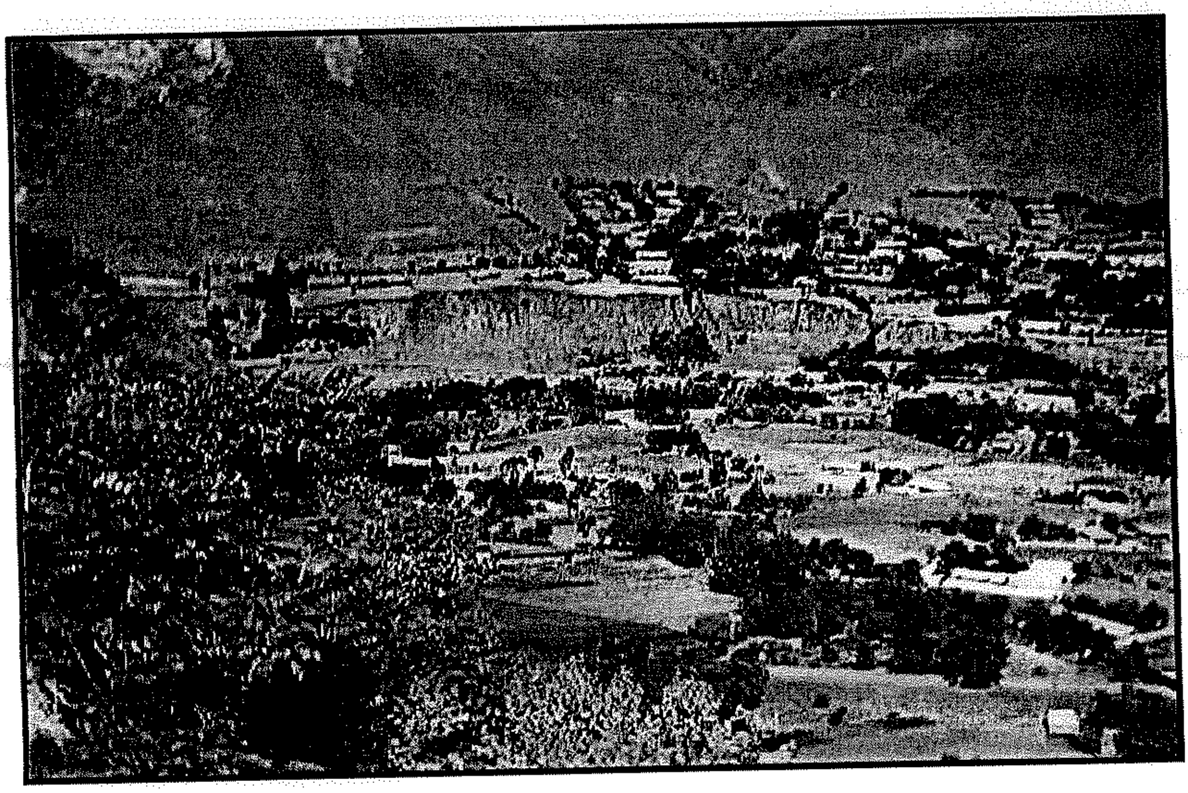


Plate 5.10. Shat Guvavi terrace (T6) of Jughore-Bakarabad sequence. This is recently formed terrace, which is only 05-meter above the Chitral river bed. The surface of the terrace is covered by alluvium and is extensively cultivated.

5.7. Broz Sequence

5.7.1. Location

This sequence of eight terraces occur some 10-Km down stream from the Chitral town, 6-7Km from the Jughore-Bakarabad sequence. Cartographic as well as field observations suggest the existence of eight different terraces. Their distribution is as follows:

5.7.1a. Daman Terrace (T1)

T1 is the highest terrace of the sequence. It is cut in Chitral slate and phyllite that is covered by loess. It is an extensive flat and barren land, clearly visible from an areoplane. Its absolute height is 1720-m ASL, with a relative height of 330-m above river Chitral.

5.7.1b. Colony Terrace (T2)

This is the second highest terrace of the Broz sequence. The surface is barren and covered by loess material with some gravels and large-size boulders. its surface is dipping toward river Chitral. Its absolute height is 1640 m, with a relative height of 250 m above river Chitral. The terrace is accessible by an unmetalled jeepable road.

5.7.1c. BHU Terrace (T3)

T3, is the depositional terrace of the sequence. A section exposes sub-rounded to rounded gravels, mixed with sandy material. This terrace derives its name from the Basic Health Unit (BHU) that is located on this terrace. A number of houses are sited on the terrace. The absolute height is 1570-m ASL with a relative height of 180- m ACR.

5.7.1d. Cultivated Broz Terrace (T4)

This is also a wide and extensive terrace with a flat surface that is extensively cultivated. It has an absolute height is 1560-m ASL and a relative height of 170-m ACR.

5.7.1e. Poultry Farm Terrace (T5)

This is the fourth highest terrace of the sequence. It is a wide and extensive terrace, which is extensively cropped. Government Nursery and Imran Poultry Farm cover a portion of this terrace. This terrace is also preserved along the Chitral-Drosh road. Part of the Broz village is located on this terrace. The absolute height of the terrace is 1530-m and relative height of 140-m ACR. Section exposed reveals fluvial nature of deposits.

5.7.1f. Kumbat Broz Terrace (T6)

This is the sixth highest terrace of the Broz sequence. It is a narrow terrace, which is also preserved in the form of a knick. The terrace which is cultivated, slopes toward river Chitral i.e. from east to west. The absolute height of this terrace is 1470-m ASL, with a relative height of about 80-meters ACR, that flows to the west of this sequence.

5.7.1f. Pong Broz Terrace (T7)

This is second lower most terrace of Broz sequence. It is preserved in the form of a knick point, which is being cultivated. Locally this area is known as Pong. The terrace slopes towards river Chitral. A section exposed along this terrace shows angular rock fragments. **(Photograph 5.0)**. The absolute height of this terrace is 1450-m, having a relative height of 60-m above river Chitral.

5.7.1g. Cheture Broz Terrace (T8)

This is the lowest level of terrace in the Broz sequence. It is not a very extensive terrace. The terrace is found on Chitral-Ayun road, close to Ayun bridge. The Government Nursery is located on this terrace. Its absolute height is 1395-m ASL and is 5-m above the Chitral river, which is flowing at a height of 1390-m ASL. This is a fluvial erosional terrace cut by the river in its recent flood plain.

Table 5.6

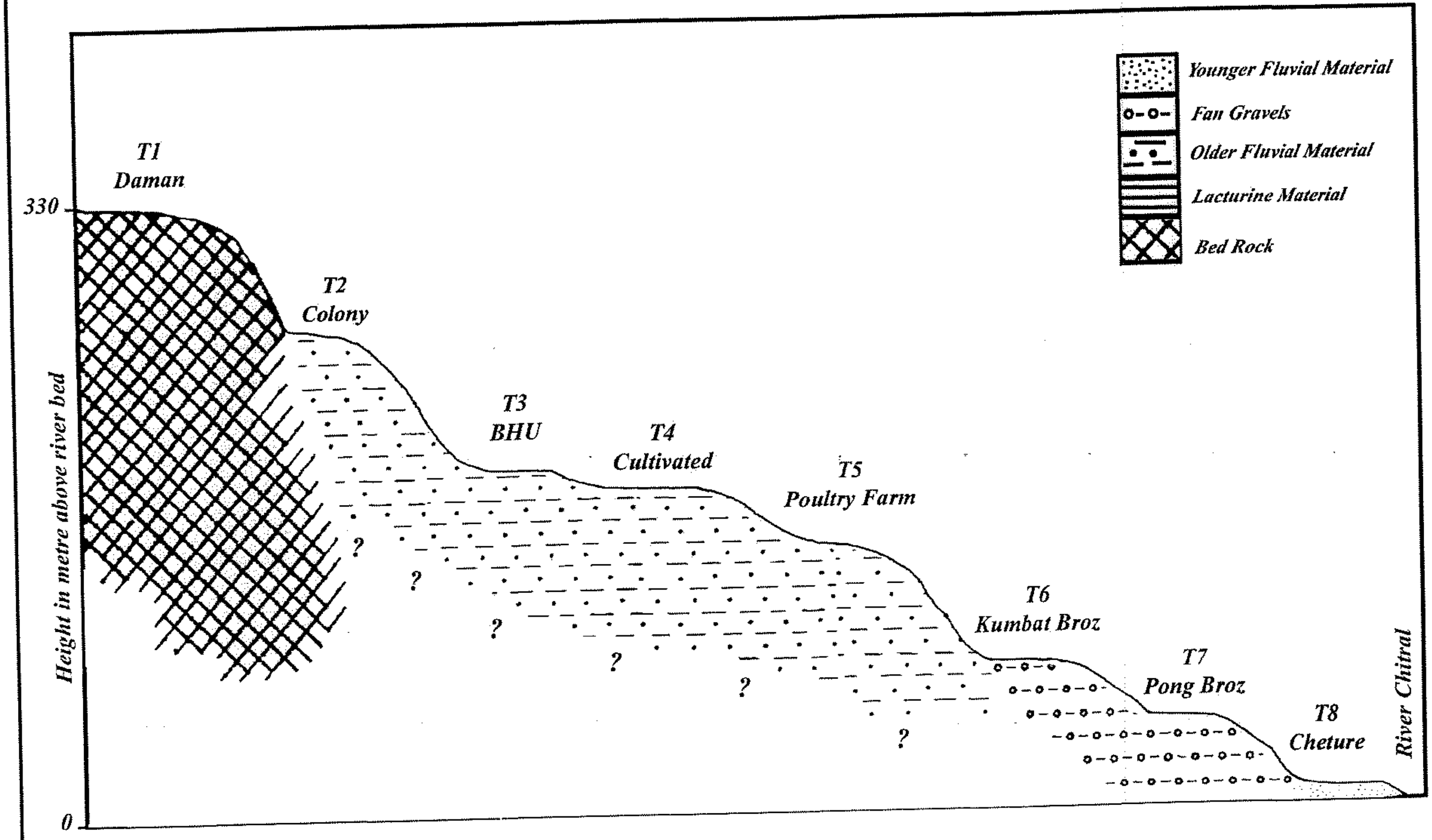
Horizontal and vertical relationship of terraces in Broz sequence

Terrace	Description	Height in meter		Material
		Absolute	Relative	
T1	DamanTerrace	1,720	330	Bed-rock
T2	Colony Terrace	1,640	250	Fluvial deposits
T3	BHU Terrace	1,570	180	Fluvial deposits
T4	Cultivated Terrace	1,560	170	Fluvial deposits
T5	Poultry Farm Terrace	1,530	140	Fluvial deposits
T6	Kumbat Broz Terrace	1,470	80	Fan material
T7	Pong Broz Terrace	1,450	60	Fan material
T8	Cheture Broz Terrace	1,395	5	Alluvium

Note:- River level at Broz sequence is 1390-m. Source: - Field survey

Figure 5.6

Terraces & surface deposits of Broz sequence



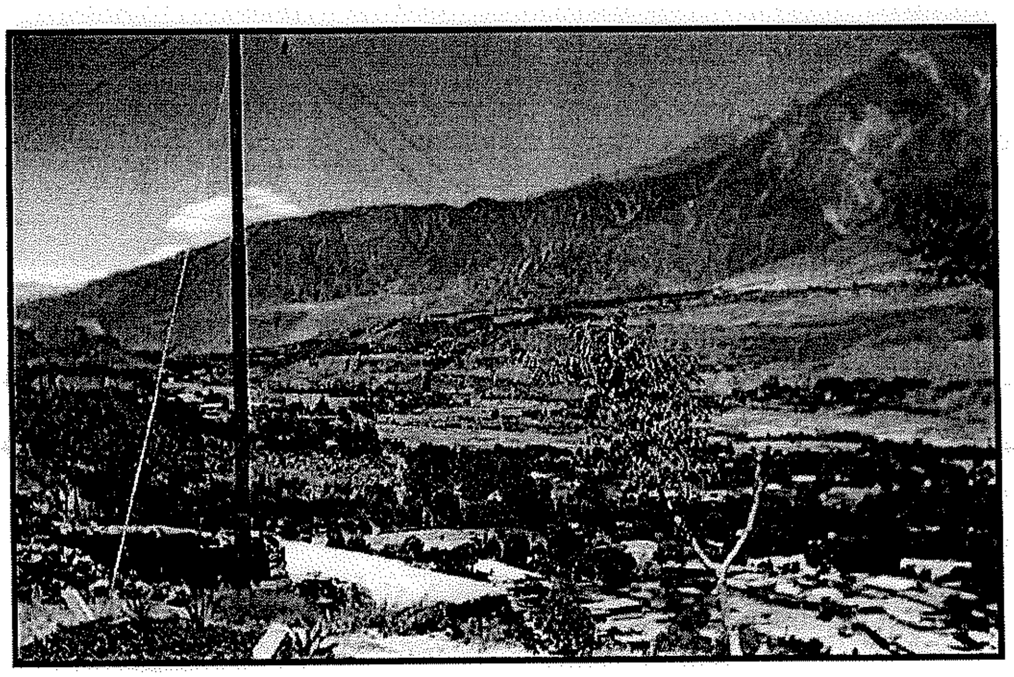


Plate 5.11. Broz Sequence, looking toward South from Shangash gol exposing the T4, and T5. On the right side of river Chitral the part of Attony terrace is exposed. The Paleo valley of Chitral river is also clearly visible on the left bank of river Chitral.

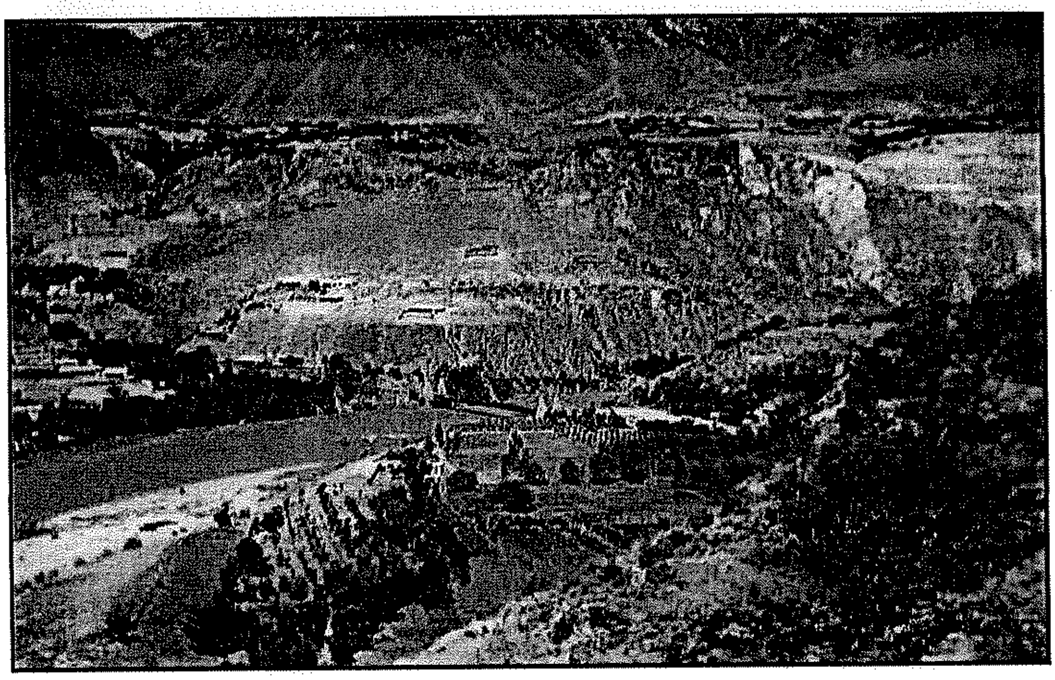


Plate 5.12. Looking from Spaghlasht toward North, a section of Broz sequence exposing T2, T6, T7, T8.

5.8. Ayun Sequence
5.8.1 Location

Ayun, one of the large size villages of Chitral, is located on a number of well-preserved terraces. It is some 25-Km down stream Chitral town, along the right bank of river Chitral, on Chitral-Kalash valley road. Here, Chitral river spreads over a wide area, with a number of braided channels. Cartographic analysis and field evidence suggest six well-marked terraces. Their distribution is as follows:

5.8.1a. Attony Terrace (T1)

This is the uppermost terrace of the Ayun sequence that is cut in Chitral slate and phyllite. It is covered by thick deposits of loess. Because of gully erosion the surface is undulating. Cultivation is carried out in patches, depending on the availability of water. Attony village is sited on this terrace. Its absolute height is 1730-m ASL and 330-m ACR.

5.8.1b. Sunhang Terrace (T2)

This terrace is cut in the fan material, the surface of which is covered by loessic material, preserved in patches. Due to the nonavailability of water it is not cultivated and remains barren. It is used as a village graveyard. It is some 1470-m high ASL and 80-m ACR.

5.8.1c. Muldeh Terrace (T3)

T3, is also a fan cut terrace of the sequence. It is preserved in the form of a narrow strip. In places its surface is flat, that is covered by loessic material, washed down from the upper slope. Because of its location, well above the river level, and the non-availability of water, it is not cultivated. The terrace is used as Eidgah. A part of the terrace is also used as village graveyard. The residential area covered by this terrace is known as Muldeh. A section exposed along Ayun gol shows some angular to sub-angular rock fragments, ranging in size from 2.5 to 25cm. The absolute height of the terrace is 1430-m, while its relative height is 40-m.

5.8.1d. Darkhanandeh Terrace (T4)

This is also a wide terrace, preserved in the form of a crescent-shaped strip, well above the river level. Darkhanandeh village is located on it, which is the main residential area of Ayun village. As the terrace lies well above the river level and is safe from the danger of flood, it is mainly used for residential purpose. Parts of it are cultivated. Its absolute height is 1405-m and relative height of 15-m ACR.

5.8.1e. Upper Kuru Terrace (T5)

This is an extensive terrace, having an approximate length of 2000-2500-m. Field evidence suggests that it may be the former flood plain of river Chitral. It is narrow along the sides but is very wide in the centre. It is generally used for cultivation. It has an absolute height of about 1395-m ASL, and some 05-m above river Chitral.

5.8.1f. Lower Kuru Terrace (T6)

It is the most recent terrace, having been formed by Chitral river by the down cutting of its own floodplain. It is only a meter above the present day bed of river Chitral. It is preserved as a triangle-shaped piece of land, which is protected from floods by an embankment. Because of its location close to river Chitral it is used for the cultivation of rice. Its absolute height is 1390-m ASL, while it is only 01-m above the Chitral river. T4, T5 and T6 are erosional terraces cut in the recent flood plain of river Chitral. A thin layer of alluvium covers its surface.

Table 5.7

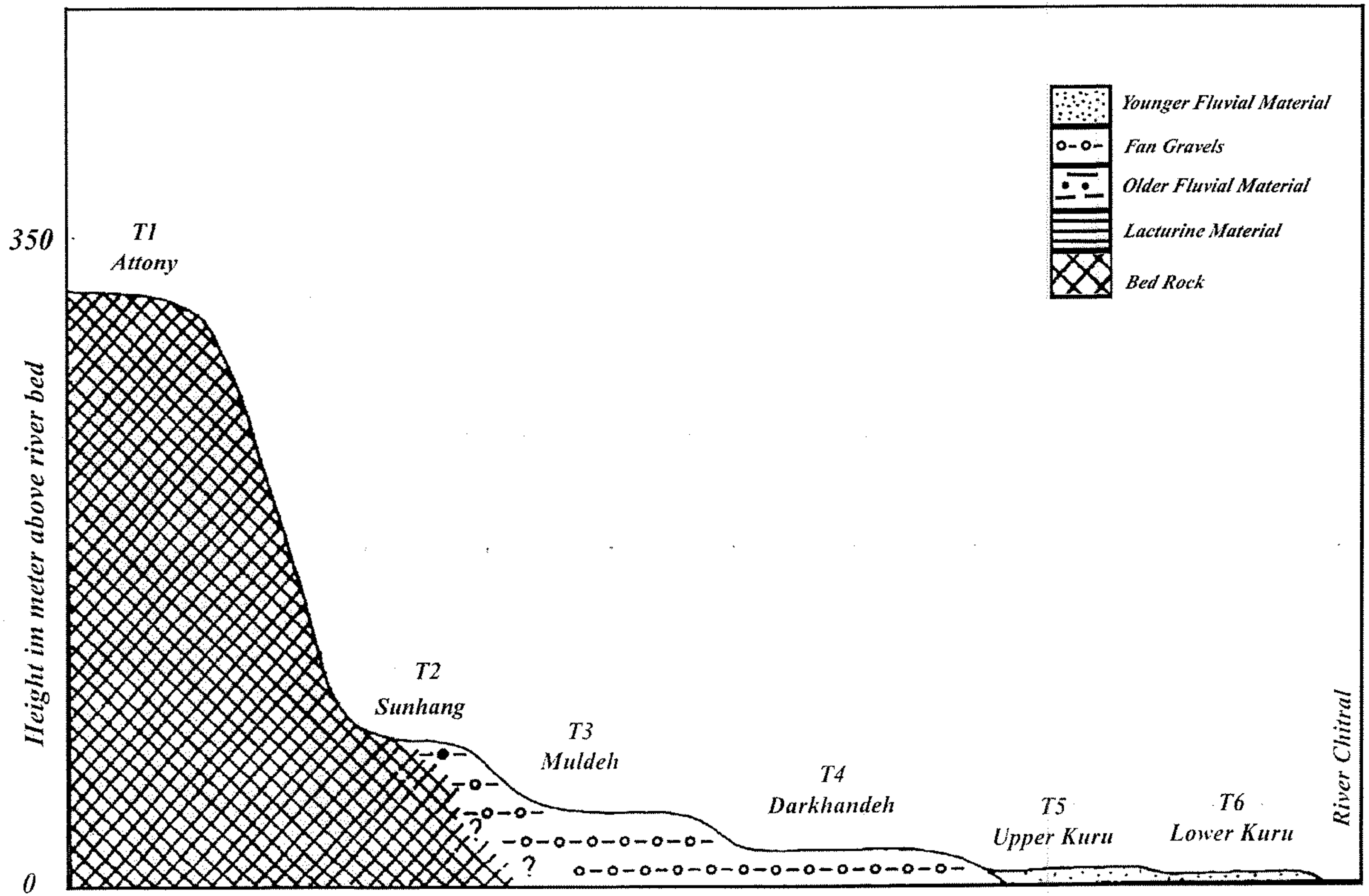
Horizontal and vertical relationship of terraces in Ayun sequence

Terrace	Description	Height in meter		Material
		Absolute	Relative	
T1	Attony Terrace	1,720	330	Bed-rock
T2	Sunhang Terrace	1,470	80	Fan material
T3	Muldeh Terrace	1,430	40	Fan material
T4	Darkhanadeh Terrace	1,405	15	Fluvial material
T5	Kuru Upper Terrace	1,395	05	Alluvium
T6	Kuru Lower Terrace	1,391	01	Alluvium

Note:- River level at Ayun sequence is 1390 m. Source: - Field survey

Figure 5.7

Terraces & Surface Deposits of Ayun Sequence



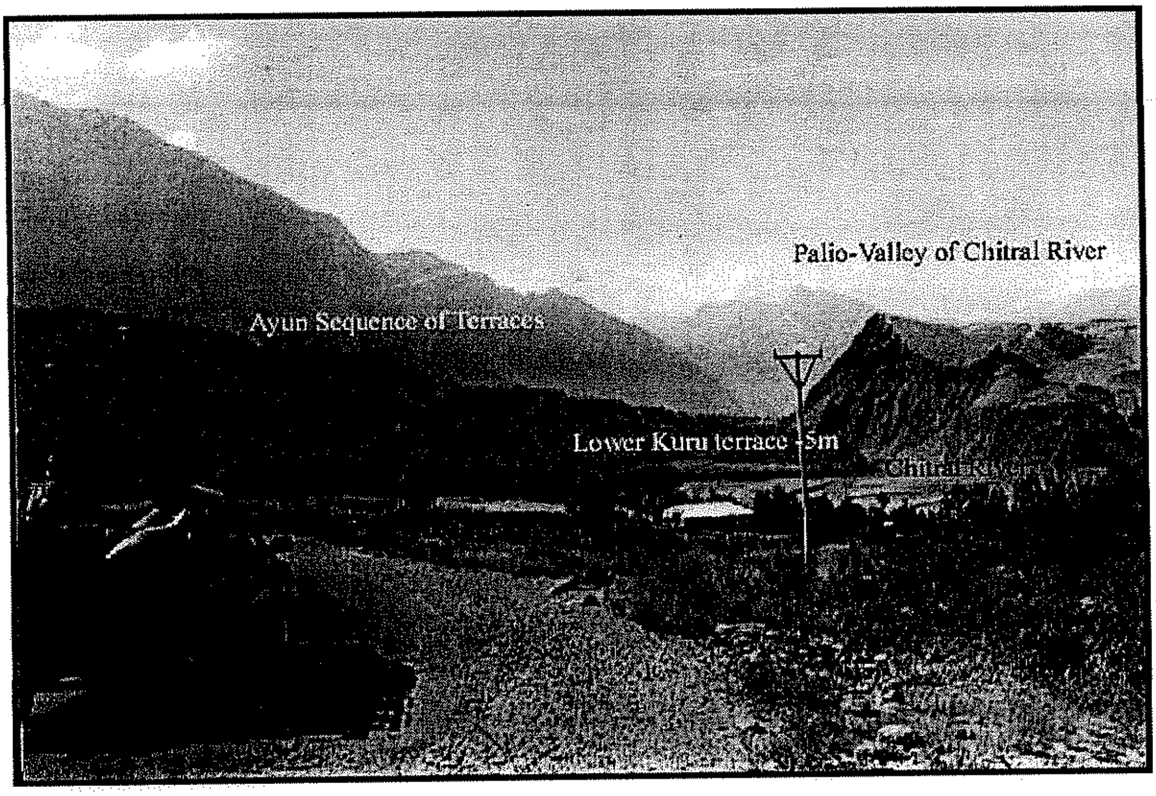


Plate 5.13. Looking from Spaghlasht toward North. A section of Broz Sequence exposing T1 and T2. The T2 (Attony Terrace) and T4 of Ayun Sequence are also visible.

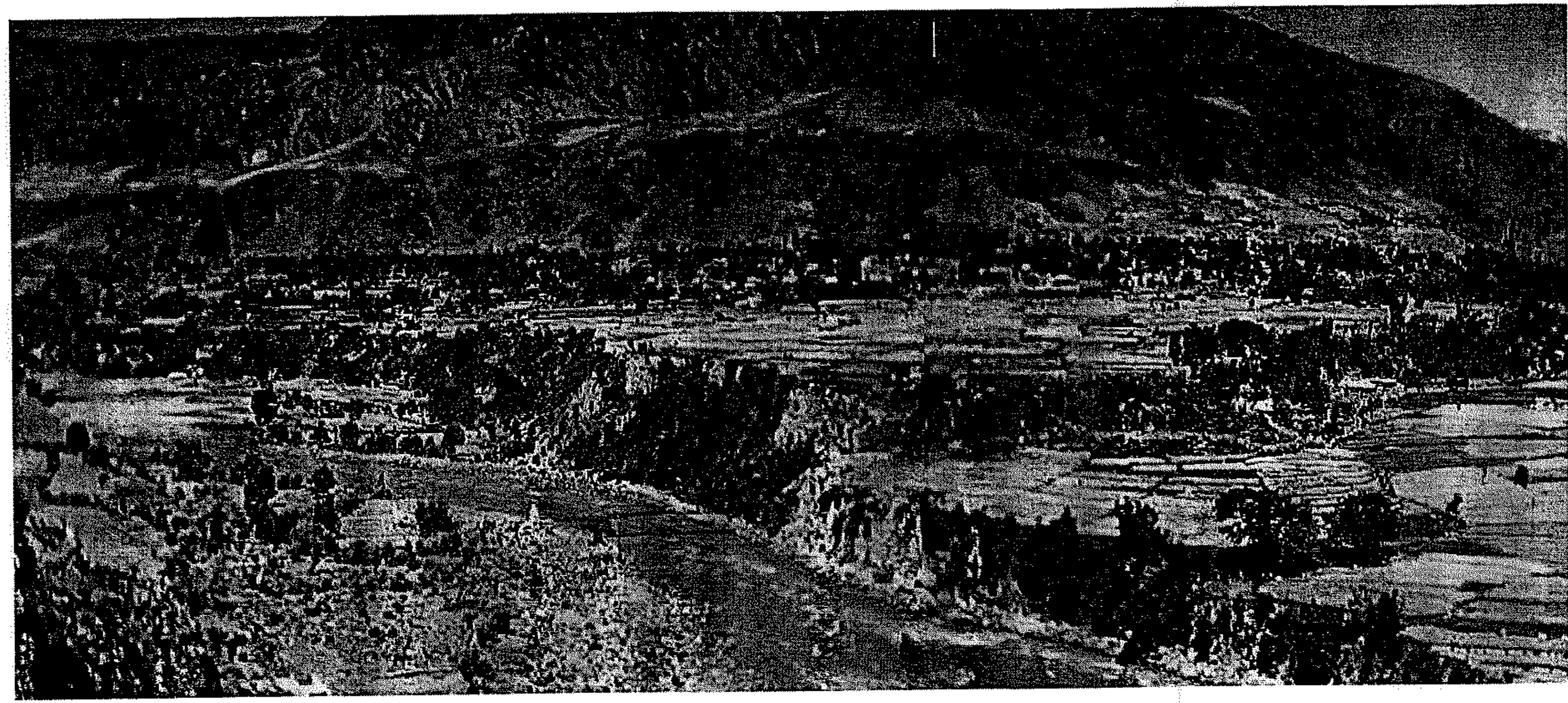


Plate 5.14 Ayun Sequence of terraces (1700-m) exposing different Terraces levels. Bangali terrace 80-m,Muldeh 40-m,Darkhanadeh 40-m and Kuru lower terrace 01-m above river Chitral.

5.9. Kesu Sequence

5.9.1 Location

Kesu is a small village, located some 30-Km down stream from Chitral town on Chitral-Drosh road. Field evidence and cartographic analysis suggests that the village is located on a number of terraces. The horizontal and vertical distribution of the terraces is as follows:

5.9.1a. Kesu Terrace (T1)

This is the highest terrace in the Kesu sequence. It is preserved as a crescent-shape strip along the foothills. Part of it is cultivated. Also it is occupied by residential units of Kesu. It is some 1320-m ASL, while its relative height is 45-m from Chitral river. The shape and material of terrace suggests that it is cut in the Kesu fan by river Chitral.

5.9.1b. Kesu Terrace (T2)

This is also an extensive terrace, which is cultivated. The Chitral-Drosh road passes through it. The absolute height of the terrace is 1300-m, while it is 15-m above the Chitral river.

5.9.1c. Kesu Terrace (T3)

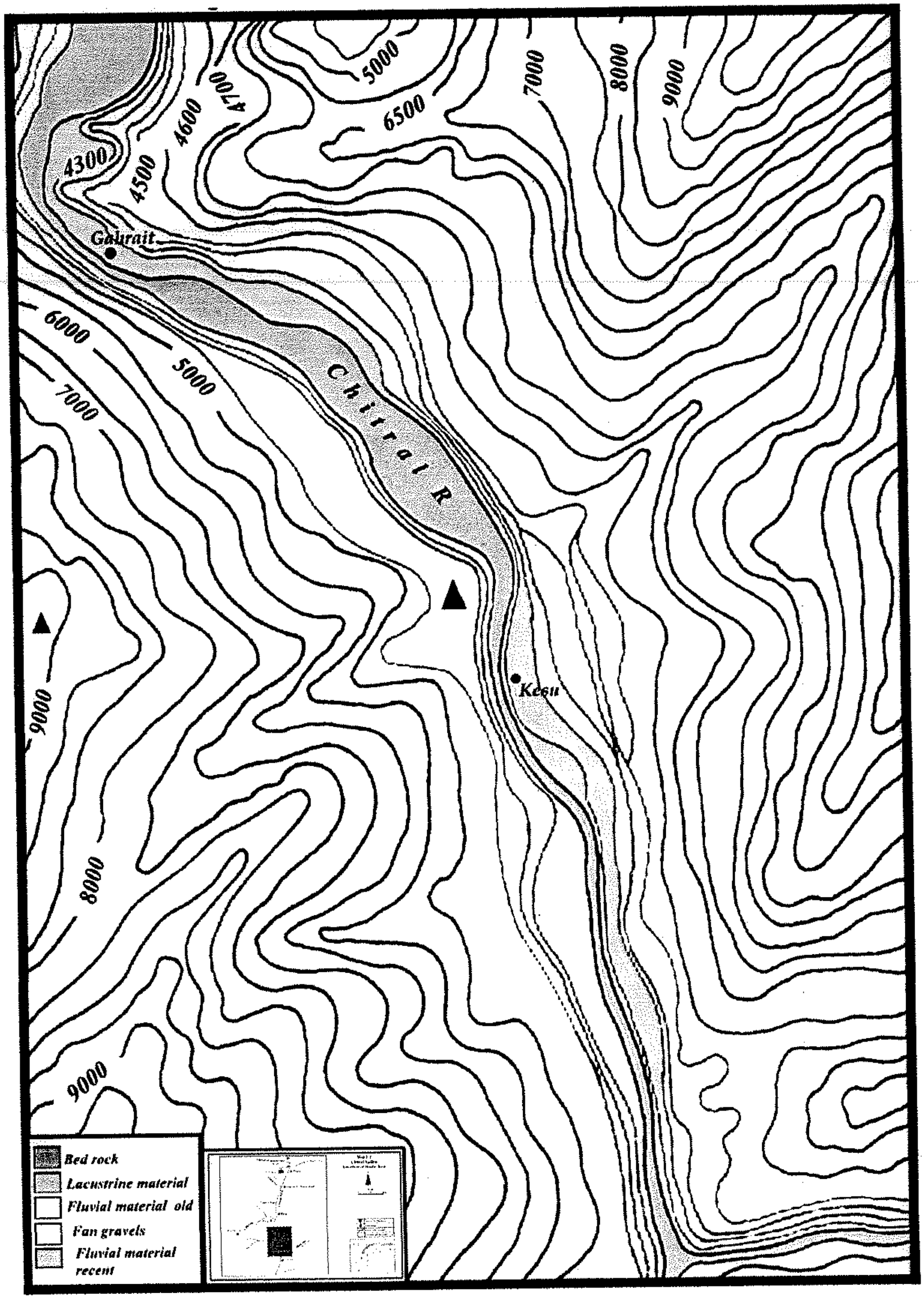
This is the lowest of terraces in Kesu sequence. It is a wide terrace, which is cultivated. It is famous for the cultivation of onions. Its absolute height is 1290-m ASL, is only 05-m ACR. T2 and T3 are fluvial erosional terraces cut in the recent flood plain of river Chitral.

Table 5.8
Horizontal and vertical relationship of terraces in Kesu sequence

Terrace	Description	Height in meter		Material
		Absolute	Relative	
T1	Kesu Terrace I	1,320	45	Fan material
T2	Kesu Terrace II	1,300	15	Alluvium
T3	Kesu Terrace III	1,290	05	Alluvium

Note:- River level at Kesu sequence is 1285-m. Source: - Field survey

Map 5.4
Distribution of Terraces in Gahrait & Kesu Sequences



0 Scale 01mile Contour interval in Feet
Source: Modified from Toposheet No. 38 M/14

Figure 5.8

Terraces & Surface Deposits of Kesu Sequence

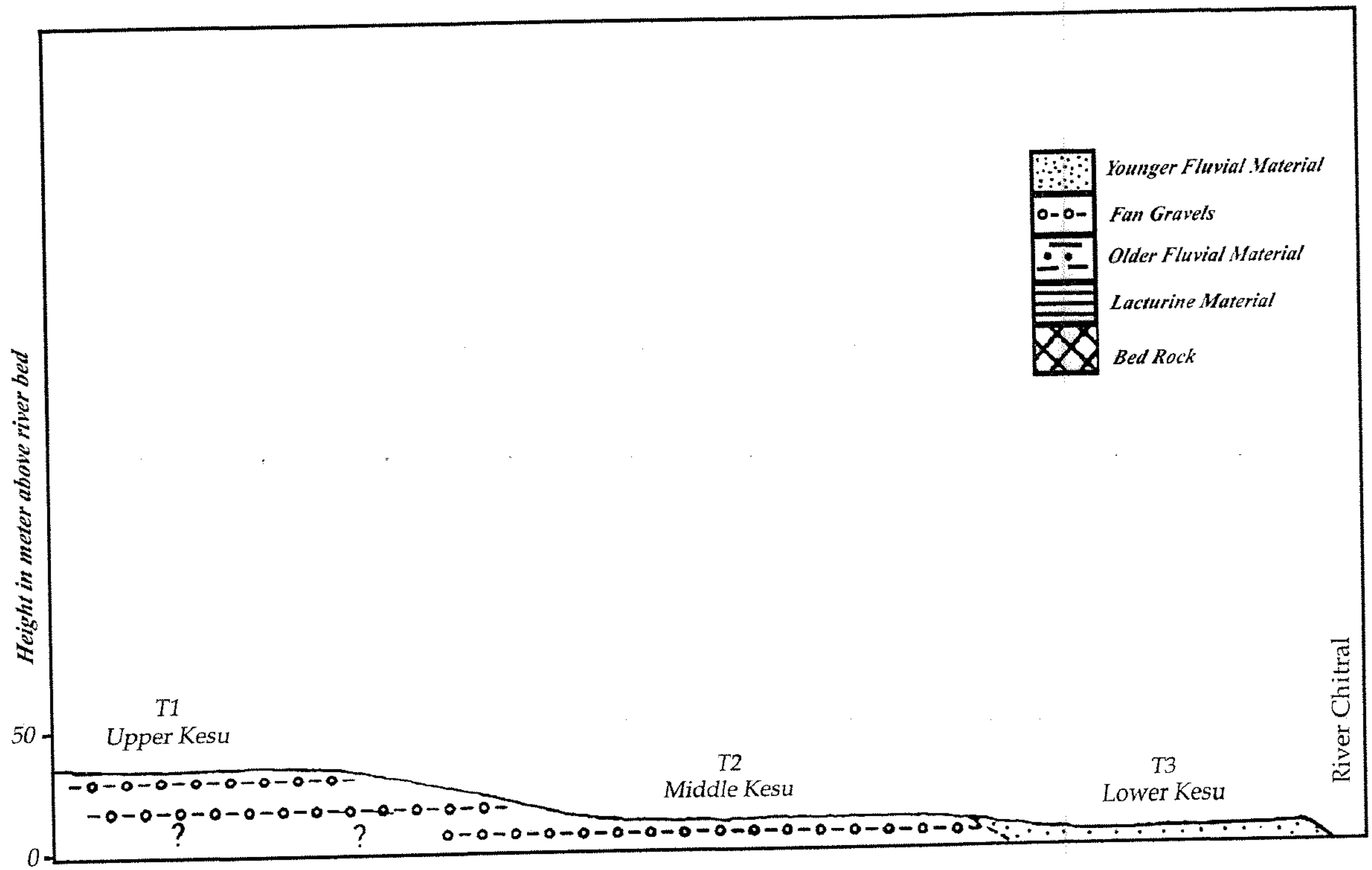


Plate 5.15. Kesu Sequence of Terraces Upper Kesu and Lower Kesu

5.10. Gahrait Sequence

5.10.1 Introduction

Gahrait is a small village, some 35-Km from the Chitral town on Chitral-Drosh road. Six terraces are preserved in sequence. The horizontal and vertical relationship of terraces in the sequence is as follows:

5.10.1a. Dronipah Terrace (T1)

This is the highest terrace of the sequence. It is a wide terrace, located at a height of 1480-m ASL, with a relative height of 170-m above Chitral river. Material exposed in section suggests fluvial nature of deposits.

5.10.1b. Banda Gahrait Terrace (T2) & Camp Terrace (T3)

The residential part of village Gahrait is being divided into two parts. The lower part is known as Banda Gahrait and the upper one is called Dronipah or Gahrait Bala. The terrace is preserved at a height of about 1410-m ASL, while it is 100-m above Chitral river. The Camp terrace is situated some 1390-m ASL, while its relative height is only 80-m ACR.

5.10.1c. Road Terrace (T4)

Chitral-Drosh road passes through this terrace. It is a narrow terrace, 60-m high, above Chitral river and preserved in a crescent-shaped strip. Its absolute height is 1370-m ASL.

5.10.1d. Chowni Terrace (T5)

This is referred to as Chowni terrace, because of location of the army installations on it, including the Fort. It is a narrow terrace with an absolute height of 1350-m ASL, while it is located some 40 m high above Chitral river, which is flowing at 1310-m ASL. Terraces T2, T3, T4 and T5 appear to be cut in the fan formed by Gahrait gol.

5.10.1e. Takht Terrace (T6)

This is the lowest terrace in the Gahrait sequence. The area located close to river is locally known as Takht. Because of its location close to Chitral river it is cultivated. It has an absolute height of about 1315-m ASL, and a relative height of only 05-m above Chitral river.

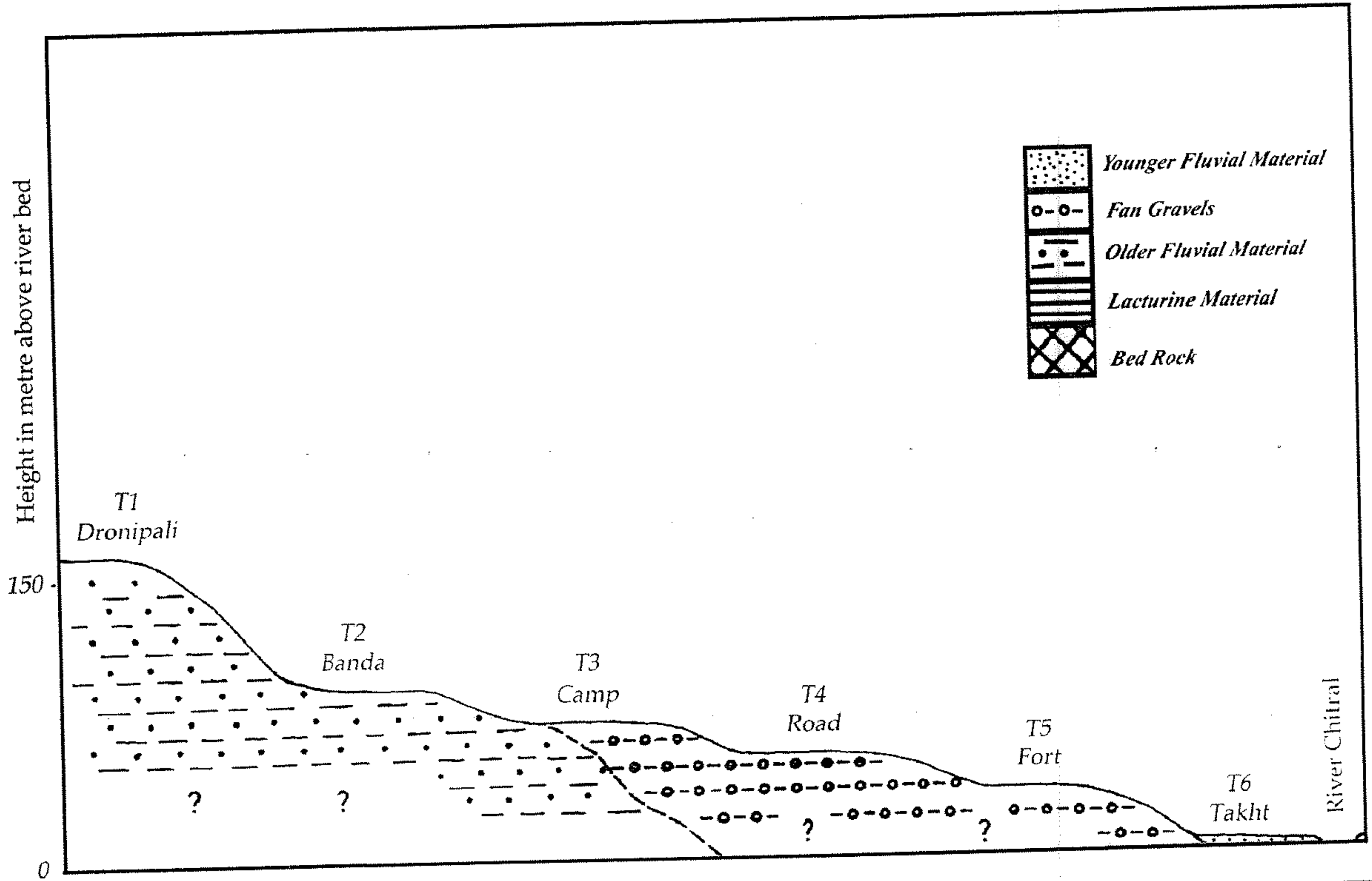
Table 5.9

Horizontal and vertical Relationship of terraces in Gahrait sequence

Terrace	Description	Height in meter		Material
		Absolute	Relative	
T1	Dronipah Terrace	1,480	170	Fluvial deposits
T2	Banda Terrace	1,410	100	Fluvial deposits
T3	Camp Terrace	1,390	80	Fan material
T4	Road Terrace	1,370	60	Fan material
T5	Chowni Terrace	1,350	40	Fan material
T6	Takht Terrace	1,315	05	Alluvium

Note:- River level at Gahrait sequence is 1310-m. Source: - Field survey

Figure 5.9
Terraces & Surface Deposits of Gahrait Sequence



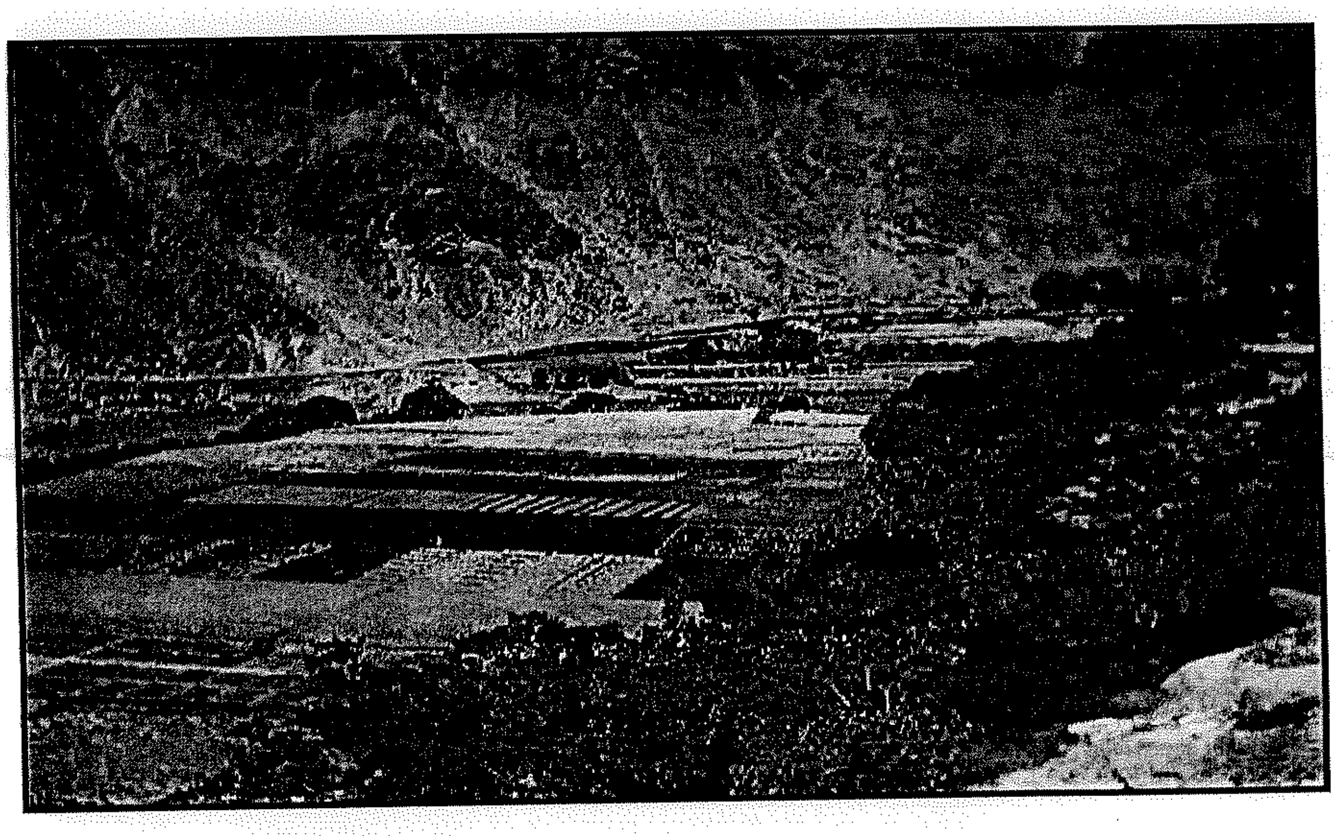


Plate 5.16. Takht Terrace of Gahrait sequence 05-m above river Chitral

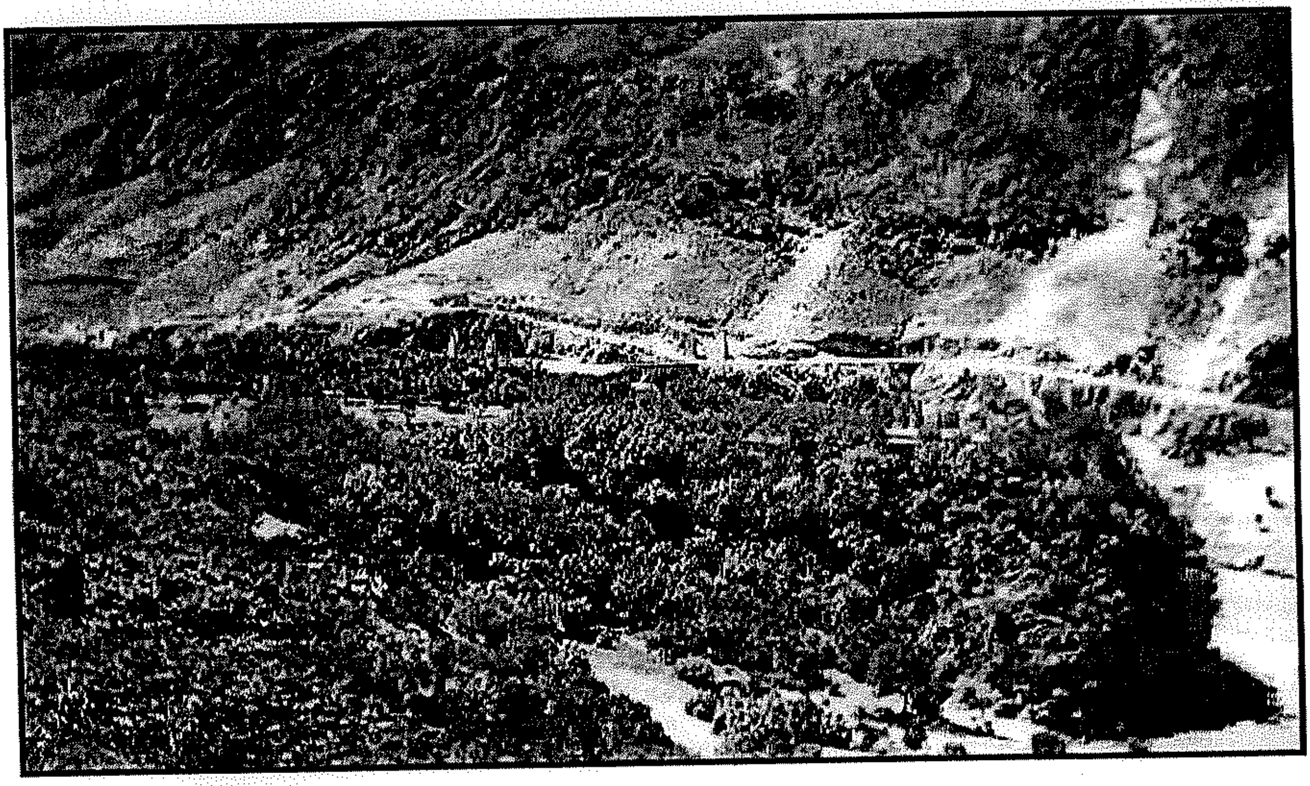


Plate 5.17. ChowniTerrace of Gahrait sequence 40-m above river Chitral

5.11. Drosh Sequence

5.11.1 Location

Drosh (35°-32' lat., 71°-46'long) is one of the large-sized villages of Chitral. Situated some 40-Km downstream from Chitral town, it is spread out, along the Chitral river. Four terraces are preserved in the Drosh sequence. The lower two terraces are broad and well preserved. Their distribution is as follows:

5.11.1a. Chitral Scout Mess Terrace (T1)

This is the highest terrace in the sequence, lying at a height of 1310-m ASL. Its relative height is 85-m. It is not very extensive. Chitral Scout Mess is situated on this terrace. It is an erosional terrace cut in the Drosh fan; its surface is covered by large-size, sub-angular to angular rock fragments.

5.11.1b. Bazaar Terrace (T2)

T2,T3 and T4 are the depositional terraces of the sequence.T2 is a narrow terrace, occupied by Drosh bazar. Chitral-Dir road also passes through this terrace. It has an absolute height of 1285-m ASL, while its height above the Chitral river is 60-m.

5.11.1c. Murad Stadium Terrace (T3)

This is the third terrace of the Drosh sequence. Located on the right bank of river Chitral at a height of 1265-m ASL, it is broad and relatively well preserved. Murad Stadium lies on this terrace. Its relative height is 45-m above Chitral river. T2 and T3 of Drosh sequence are cut in the fan material.

5.11.1d. Junali Terrace (T4)

This is the lower most terrace of the sequence, preserved along the left bank of river Chitral. It is a wide terrace and the site of the Army Halipad. It is well-preserved terrace. This fluvial erosional terrace lies only 5-m above the Chitral river, hence it is flooded during floods. Its absolute height is 1230-m ASL.

Table 5.10

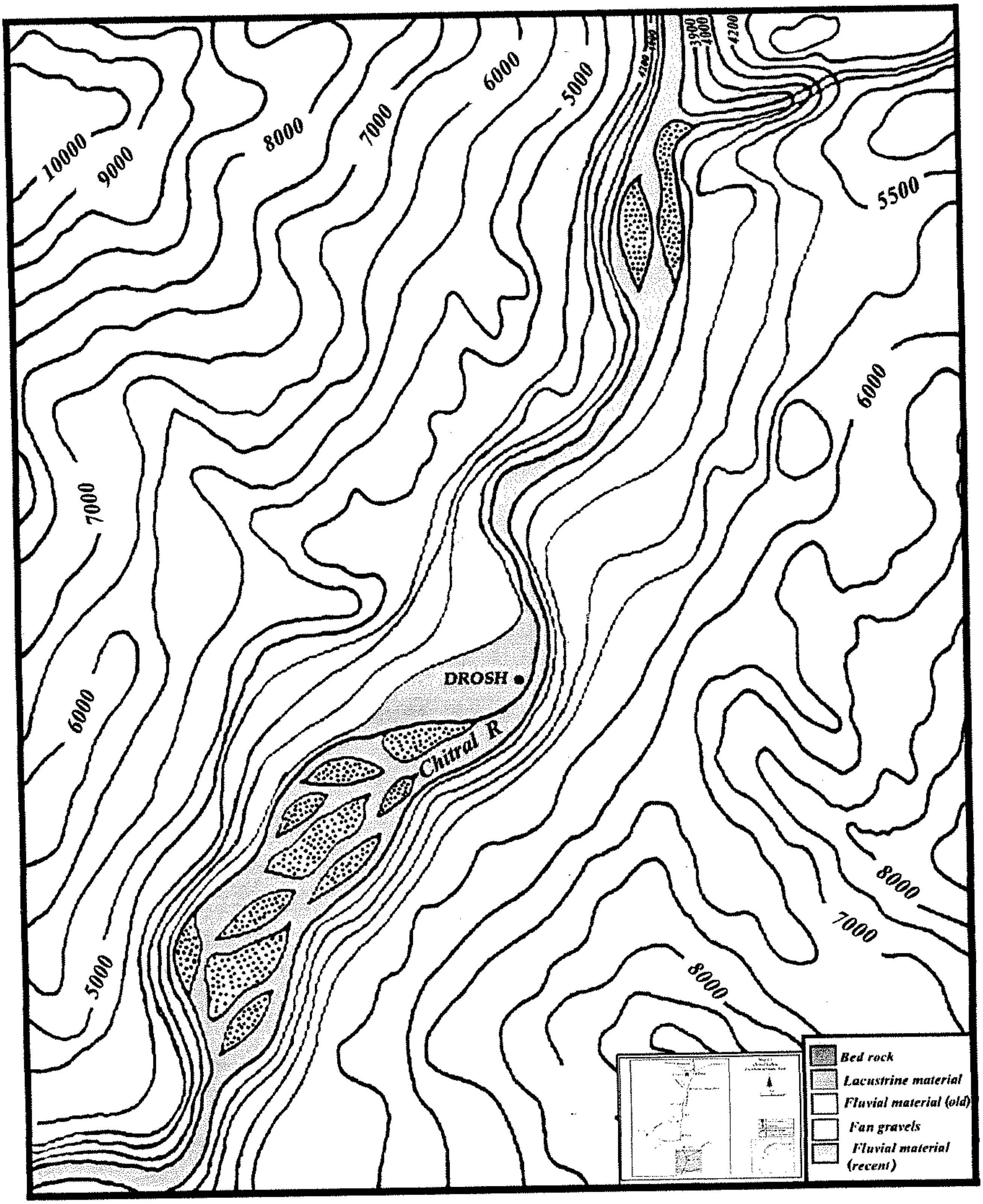
Horizontal and vertical relationship of terraces in Drosh sequence

Terrace	Description	Height in meter		Material
		Absolute	Relative	
T1	Chitral Scout Mess Terrace	1,310	85	Fan material
T2	Drosh Bazaar Terrace	1,285	60	Fan material
T3	Murad Stadium Terrace	1,265	45	Fan material
T4	Junali Terrace	1,230	05	Alluvium

Note:- River level at Drosh sequence is 1225 m.

Source: - Field survey

Map 5.5
Distribution of Terraces in Drosh Sequence



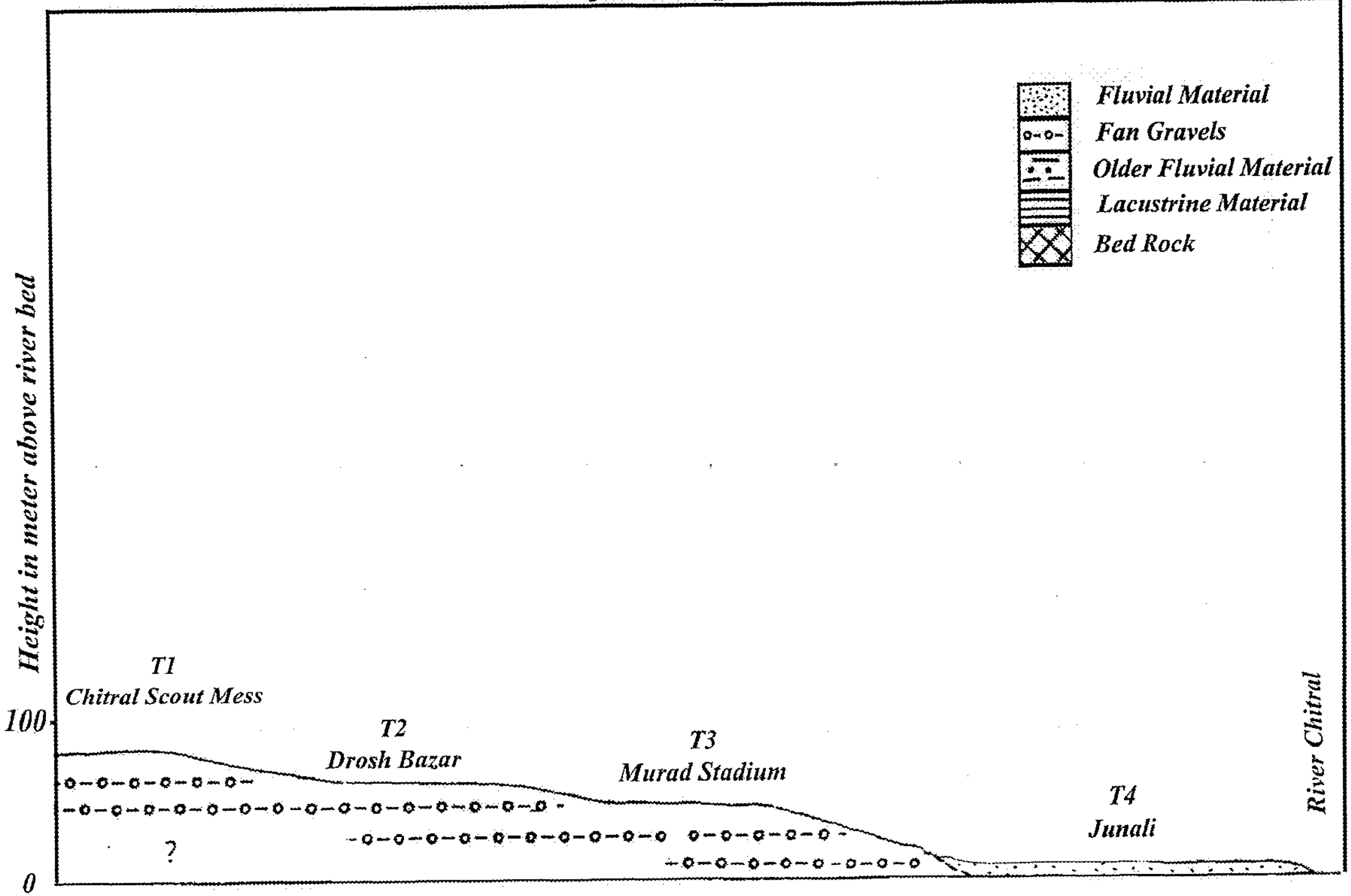
0 Scale 01 mile

Contour Heights in feet

Source: Modified from Toposheet No. 38 M/14

Figure 5.10

Terraces and Surface Deposits of Drosh Sequence



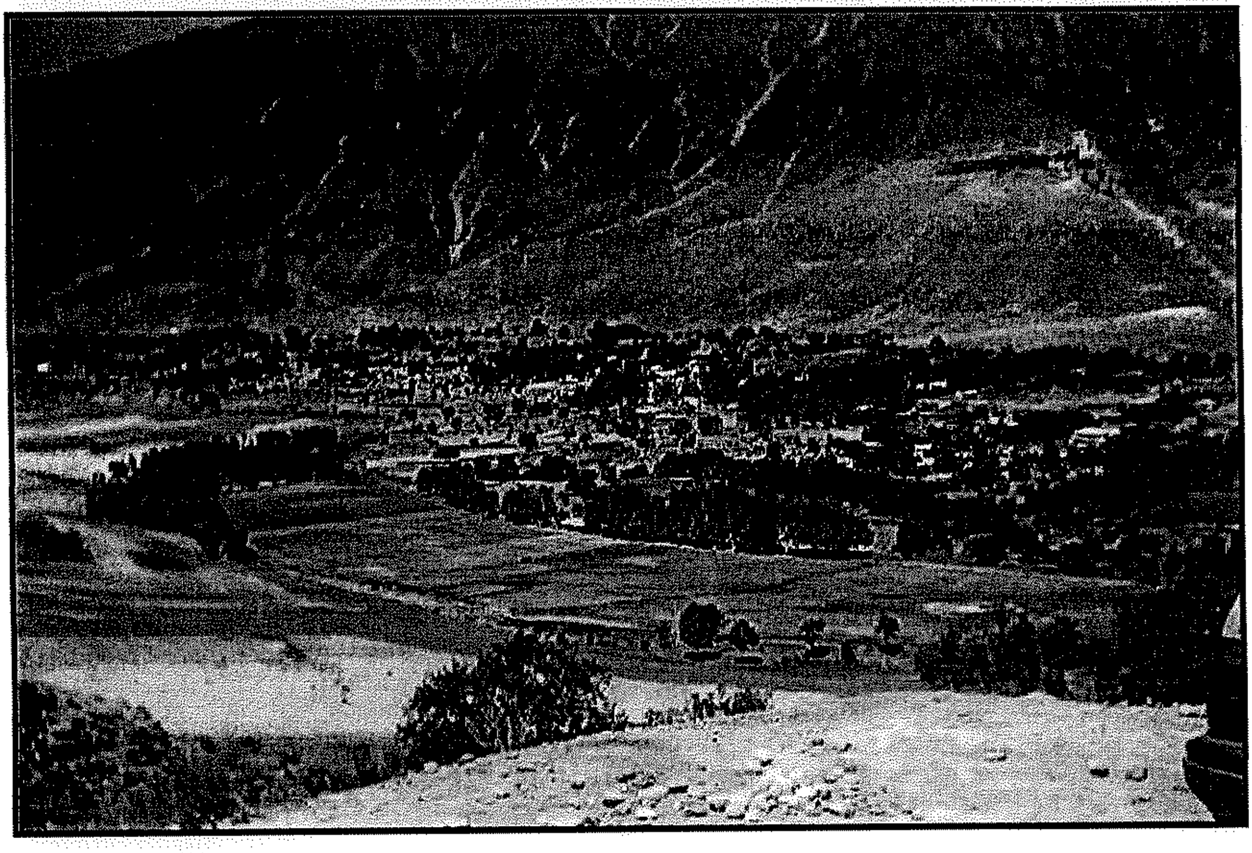


Plate 5.18. Junalit Terrace of Drosh sequence 05-m above river Chitral

Plate 5.19. Murad Stadium Terrace of Drosh sequence 45-m above river Chitral

5.12. Correlation of Terraces

5.12.1. Introduction

According to Bryan (1941) Johnson (1944), Cotton (1941) the more common methods of correlation of terraces are:

1. Identification by fossils
2. Degree of dissection
3. Comparative decomposition of boulders
4. Lithology of the terrace material.
5. Depth of weathering of terrace material.

But all these methods may not be useable because of drawbacks associated with them. Identification of fossils is one of the most scientific method for the correlation of terraces. The problem with this method is that it is not possible to find out fossils in all the terraces. The second problem is that during the course of study no fossils was recorded from the terraces as well as from sections.

The problem with degree of dissection, comparative decomposition of boulders depth of weathering is that they +are non quantitative methods. One can't quantify the degree of weathering, comparative decomposition of boulders etc. Beside the weather conditions also varies from Chitral to Drosh. This difference in weather condition also affects the weathering and disintegration process. Therefore for an area where the weather and climatic condition are so variable this may not be a useful method for terrace correlation.

In these circumstances the only safe criteria may be the correlation of terraces, on the basis of their relative and absolute highest. However the lithology, shape and roundness of the gravels were also taken in consideration. A number of geomorphologists correlated terraces on the basis of there relative height. (Sandford, 1932, Challinor, 1932, Quinn, (1957), Ahmad et al.1993, Bridgeland, et al. 1993, Haleema et al.1994, Bull et al 1987, Veldkamp 1997, Macklin, 2001)

In the present study the terraces are correlated on the basis of their relative and absolute heights from Chitral river and from sea level respectively. Additionally lithology of surface material and the material exposed in sections have been used for correlation purpose.

5.12.2. Correlation of Chitral River Terraces

Field work suggests the presence of ten sequences of well-preserved terraces in lower Chitral (from Chitral as for as Drosh). These are as follows:

1. Dalamut Sequence
2. Singhore Sequence
3. Danin Sequence
4. Chitral Sequence
5. Gughore-Bakarabad Sequence
6. Broz Sequence
7. Ayun Sequence
8. Gahariat Sequence
9. Kesu Sequence
10. Drosh Sequence

The number of terraces preserved varies from sequence to sequence. But cartographic as well as field study reveals that there are at least eight different level of terraces. The detail of their horizontal as well as vertical distribution and correlation is as follows: -

5.12.2a. T1 Birmoughlast Terrace

This terrace is preserved in four sequences only, i.e. Dalamut, Singhore, Broz and Ayun. The absolute height is 1810 and 1800-m at Dalamut and Singhore respectively, while at Broz and Ayun it records an absolute height of 1720-meter ASL. Its relative height in both the Dalamut and Singhore sequences is 355-meter above river Chitral. While at Broz and Ayun it is only 330-m high. This terrace is cut in Chitral slate covered by thick loess deposits.

Table 5.11

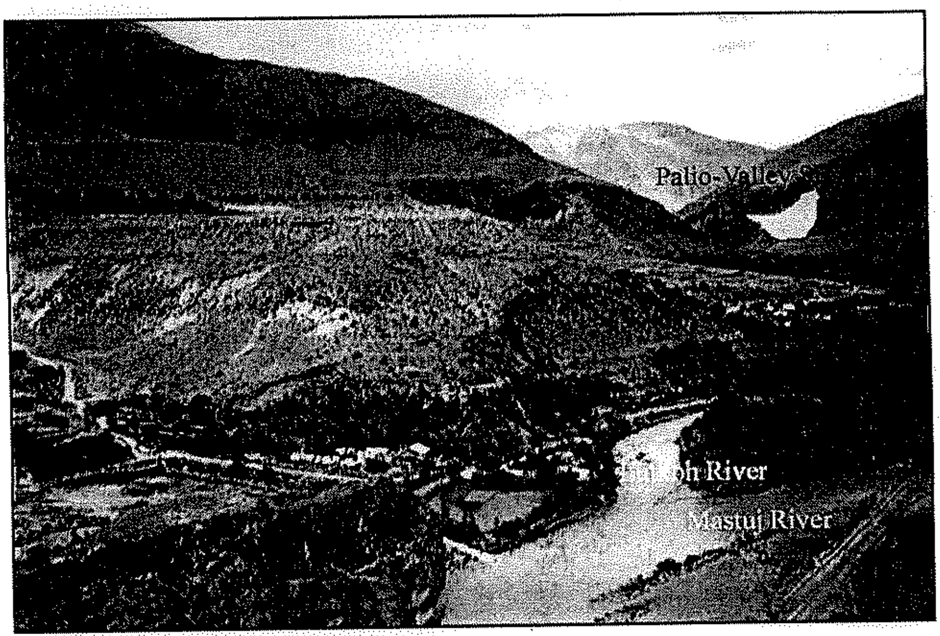
The vertical distribution of T1 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	Birmoughlasht Terrace	1,810	355
Singhore	Dalamut Terrace	1,800	355
Danin	-	-	-
Chitral	-	-	-
Jughore-Bakarabad	-	-	-
Broz	-	1720	330
Ayun	Attony	1720	330
Gahrait	-	-	-
Kesu	-	-	-
Drosh	-	-	-

Source: - Field study

PLATE

5.18



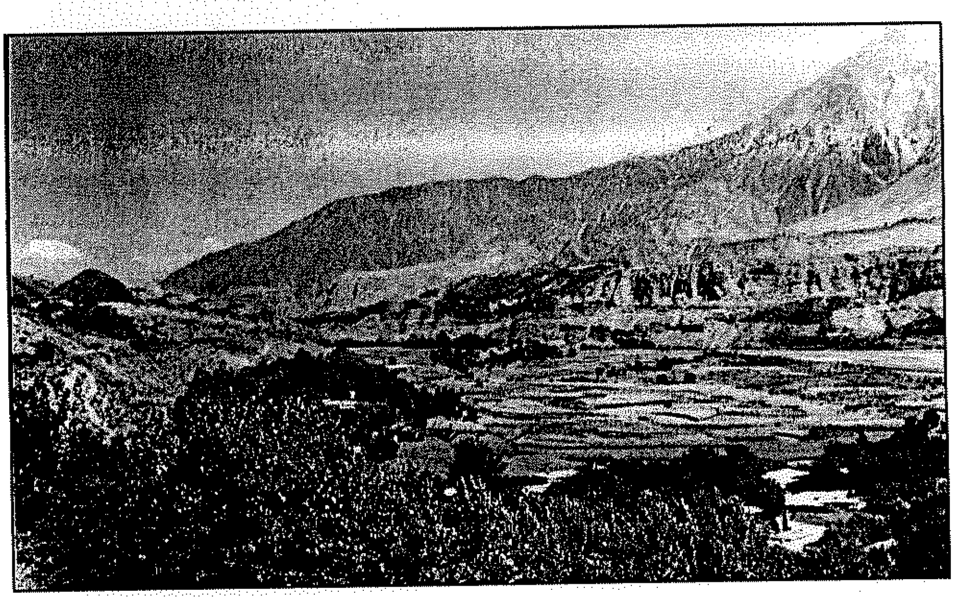


Plate 5.18. T1 at Dalamut (Above) and Broz sequence (Below). The relative height of T1 at Dalamut sequences is 355-meter above river Chitral. While at Broz and Ayun it is only 330-m high. This terrace is cut in Chitral slate covered by thick loess deposits.

5.12.2b. T2 Siaoch Terrace

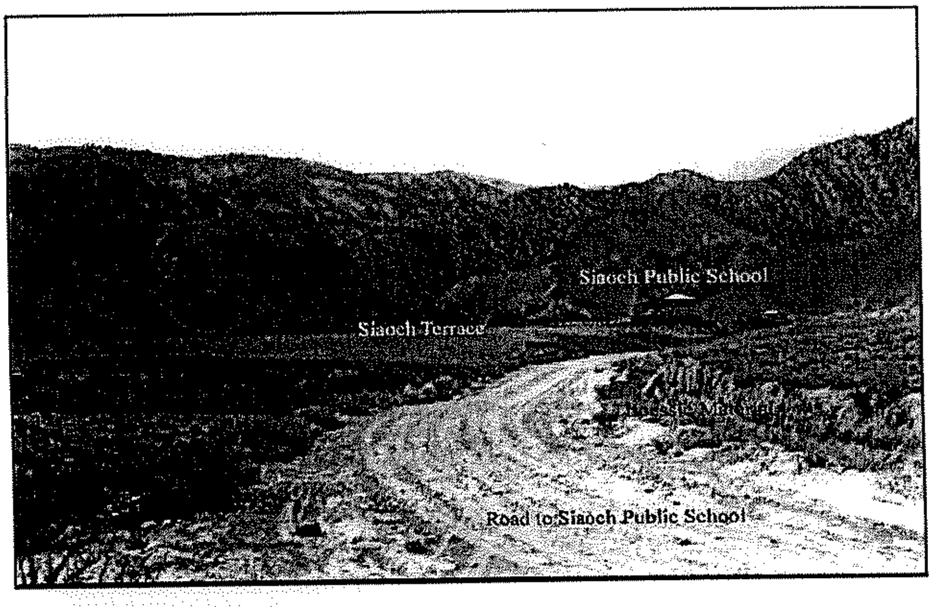
This terrace level is preserved in only two sequences, i.e. Dalamut, and Singhore. Its absolute as well as the relative height varies from sequence to sequence. The average height is 1780-m and 1775-m ASL. Its relative height is 325-m ACR. The terrace is cut in the lacustrine deposit.

In both sequences thick loess deposits cover the surface. Although this terrace is well-preserved in the two sequences, but Siaoch terrace of Singhore sequence is taken as its representative. It has a relative height of 325-m, and an absolute height of 1775-m ASL.

Table 5.12
The vertical distribution of T2 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	Agha Khan Hostel	1,780	325
Singhore	Siaoch Public School	1,775	325
Danin	-	-	-
Chitral	-	-	-
Jughore-Bakarabad	-	-	-
Broz	-	-	-
Ayun	-	-	-
Gahrait	-	-	-
Kesu	-	-	-
Drosh	-	-	-

Source: - Field study



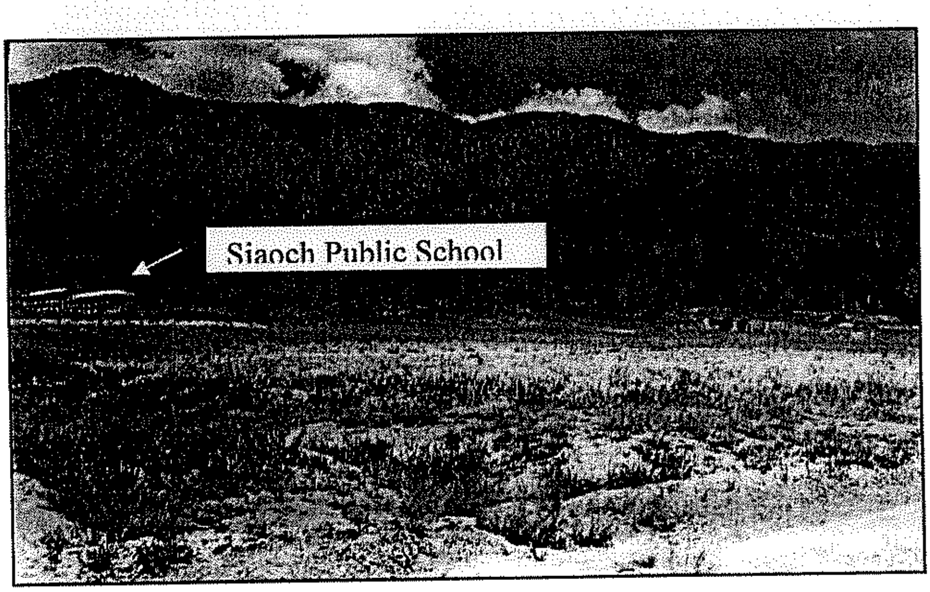


Plate 5.19. T2, Siaoch Public School Terrace, preserved in the Singhore Sequence (325 ACR) In all sequences thick loess deposits cover the terrace surface.

5.12.2c. T3 Pitikogas Terrace

This terrace is preserved in three sequences, i.e. Chitral, Jughore-Bakarabad, and Gahrait. Its relative height ranges from 100 to 115-m ACR. At Chitral it records a relative height of 115-m ACR, while at Jughore-Bakarabad and Gahrait it is 100-meters ACR. Its landuse varies from sequence to sequence, but in almost all the three sequences this terrace is predominantly used for residential purposes, while a portion is cultivated.

As far as the surface deposits are concerned, it is covered by thick deposits of loessic material, together with some large-size sub-angular to sub-rounded boulders and gravels at Gahrait and Jughore-Bakarabad sequences. The Banda Gahrait terrace of Gahrait Sequence with an absolute height of 1410-m and relative height of 100-m is taken as representative terrace for the entire study area. In all the sequences this terraces is cut in fluvial deposits i.e. Rounded gravels embedded in sandy pebbly matrix.

Table 5.13

The vertical distribution of T3 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	-	-	-
Singhore	-	-	-
Danin	-	-	-
Chitral	Pitikogas Terrace	1,520	115
Jughore-Bakarabad	Bakarabd Payeen	1,500	100
Broz	-	-	-
Ayun	-	-	-
Gahrait	Banda Gahrait Terrace	1,410	100
Kesu	-	-	-
Drosh	-	-	-

Source: - Field study

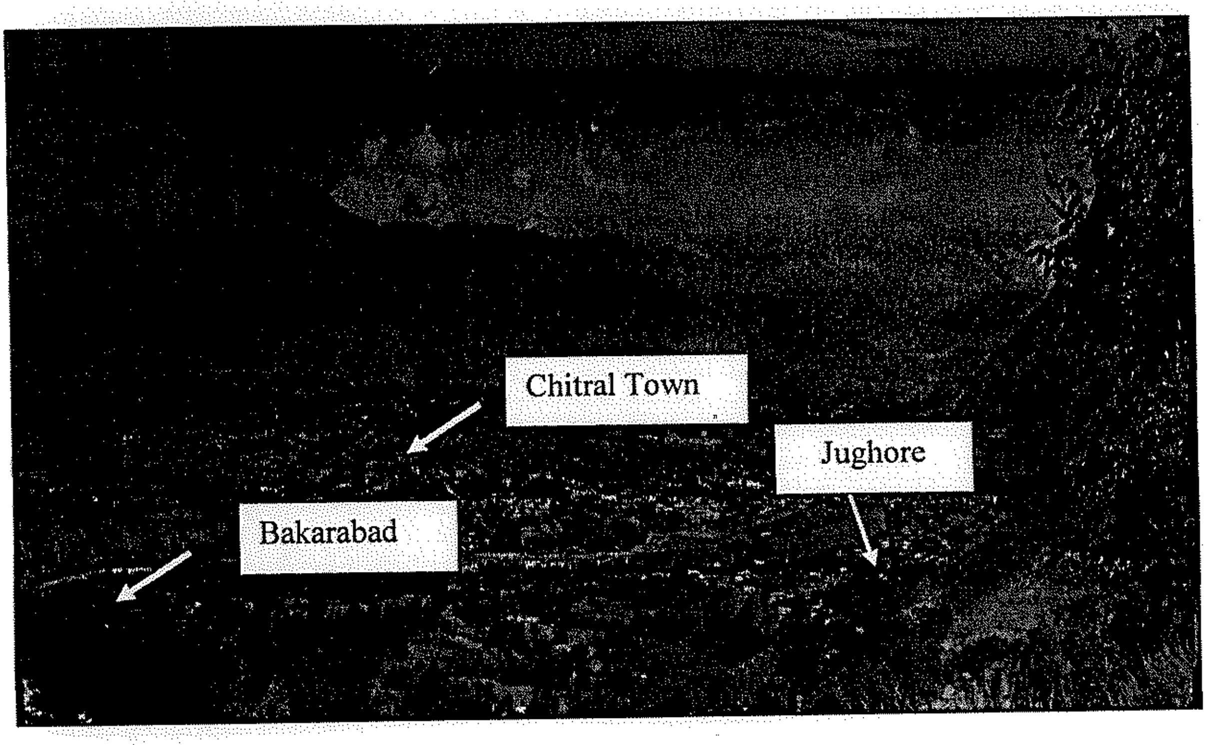


Plate 5.20. Photograph Showing different terrace level of Chitral and Jughore-Bakarabad Sequences. T3 records a relative height of 110-115-m ACR. At Chitral it is 115-m above Chitral river.

5.12.2d. T4 Sunhang Terrace

T4 is exposed in five sequences i.e. Chitral, Broz, Ayun, Ghariat and Drosh. Its absolute height varies from sequence to sequence, but its relative height is 80-m ACR in four sequences (Chitral, Broz, Ayun and Ghariat), while at Drosh it records a relative height of 85-m.

The landuse of terrace varies from sequence to sequence. At Chitral it is mostly used for cultivation but some residential units are also located on it, such as at Broz (Kumbat Terrace). At Ayun the terrace is barren and used as graveyard, while a portion is used as Eidgah. At Drosh, the Chitral Scout Mess is located on this terrace.

The surface of T4 is covered by loessic material i.e. Sunhang terrace at Ayun sequence. Sections exposed along this terrace show sub-angular to angular rock fragments embedded in pebbly muddy matrix.. Because of loess material it is used as village graveyard. The Sunhang terrace of Ayun sequence with an absolute height of 1470-m and relative height of 80-m is taken as representative terrace.

Table 5.14
The vertical distribution of T4 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	-	-	-
Singhore	-	-	-
Danin	-	-	-
Chitral	Ochusht Terrace	1,485	80
Jughore-Bakarabad	-	-	-
Broz	Kumbat Terrace	1,470	80
Ayun	Sunhang Terrace	1,470	80
Gahrait	Camp Terrace	1,390	80
Kesu	-	-	-
Drosh	Chitral Scout Terrace	1,310	85

Source: - Field study

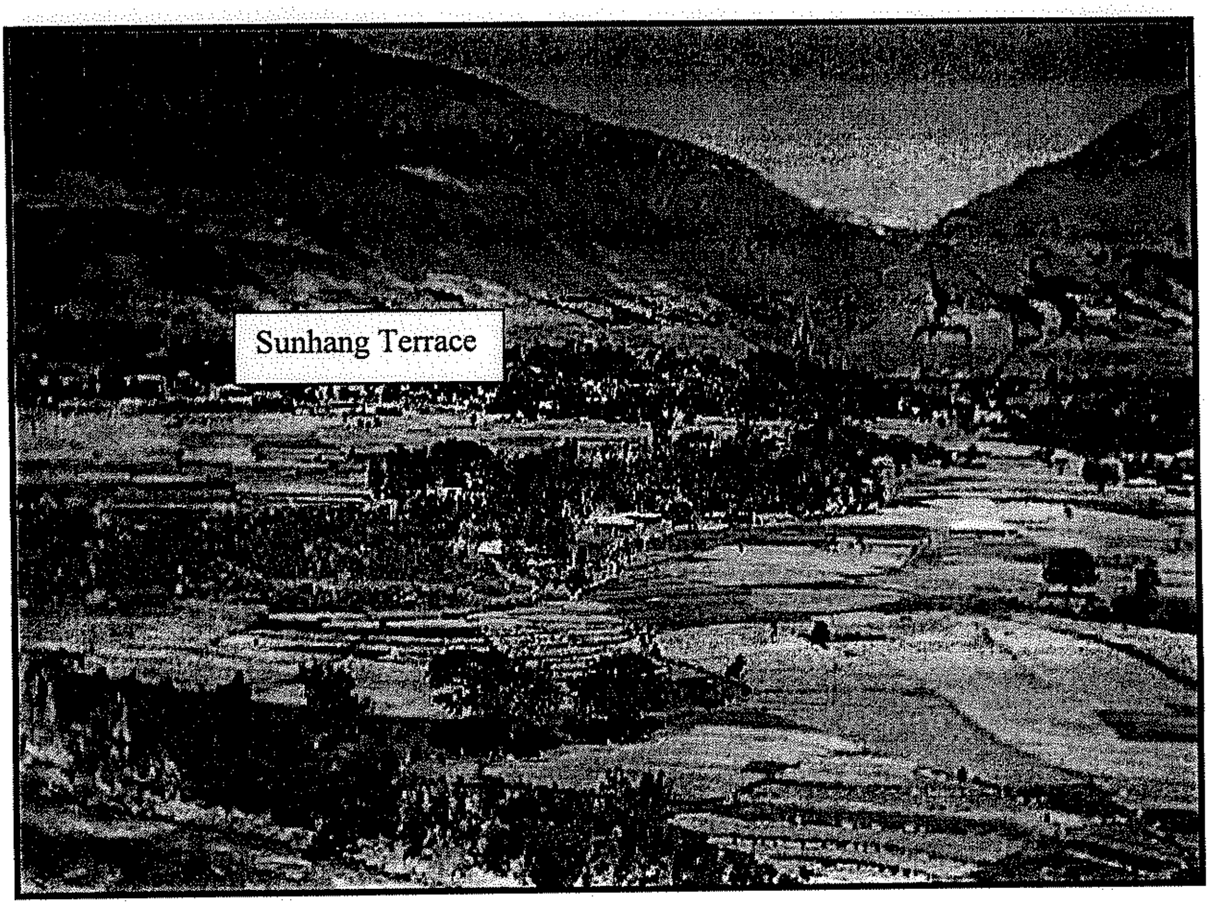


Plate 5.21. Plate showing Sunhang terrace (T4) of Ayun Sequence. T4 is exposed in five sequences i.e. Chitral, Broz, Ayun, Ghariat and Drosh. Its absolute height varies from sequence to sequence, but its relative height is 80-m ACR in four sequences (Chitral, Broz, Ayun and Ghariat), while at Drosh it records a relative height of 85-m.

5.12.2e. T5 Orchard Terrace

T5 has been identified in eight sequences i.e. Dalamut, Singhore, Danin, Chitral, Jughore, Broz, Gahrait and Drosh. Its traces are not preserved in Ayun and Kesu sequences. The absolute height of T5 varies at different sequences, while its relative height is 60-m in all sequences, except Danin and Chitral, where it is 65-m ACR. The terrace is well-preserved in almost all the above mentioned eight sequences. In some it is quite extensive i.e. Ghankharoni terrace at Singhore, Shiaqotak terrace at Chitral sequence. At Broz sequence, this terrace is preserved on a spur (Pong Broz)

The Government College, Deputy Commissioner office, and part of the Jhang bazaar are located on this terrace. The Pong Broz Terrace (Broz Sequence), Mughlandeh terrace (Danin Sequence), and Ghankhoroni terrace (Singhore Sequence) are extensively cultivated. The surface of this terrace is covered by fluvial material. Sections along the Pong Broz terrace on Chitral-Ayun road show angular rock fragments of various sizes and lithologies. Although this terrace is preserved in almost all the eight sequences, the orchard terrace of Dalamut sequence is taken as its representative.

Table 5.15
The vertical distribution of T5 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	-	1,515	60
Singhore	Orchard Terrace	1,510	60
Danin	Ghankaroni Terrace	1,470	65
Chitral	Shiqotak Terrace	1,470	65
Jughore-Bakarabad	Goldur Terrace	1,460	60
Broz	Pong Broz Terrace	1,450	60
Ayun	-	-	-
Gahrait	Road Terrace	1,370	60
Kesu	-	-	-
Drosh	Bazaar Terrace	1285	60

Source: - Field study

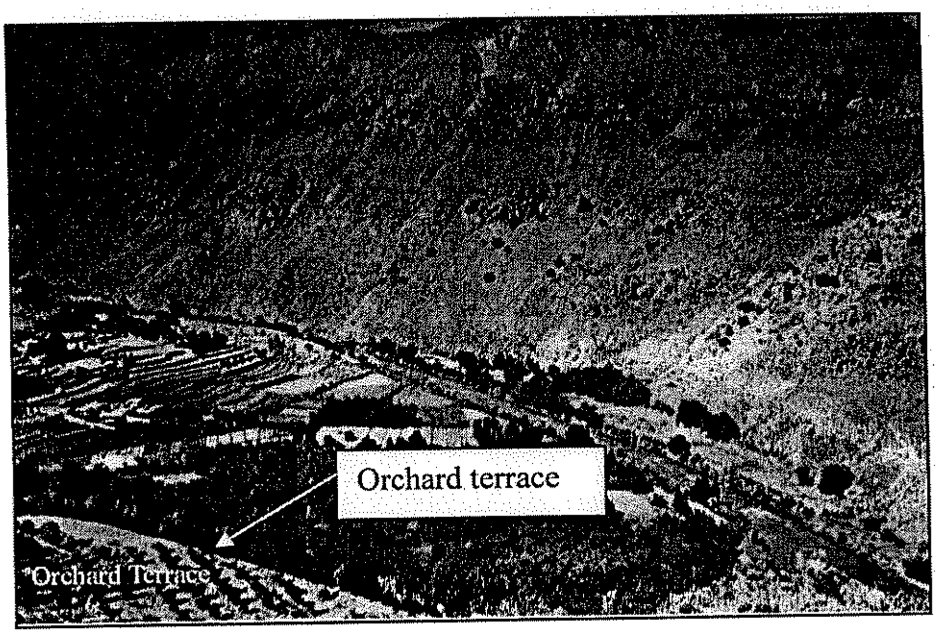


Plate 5.22. Orchard terrace of Dalamut sequence (60-m ACR). T5 has been identified in eight sequences i.e. Dalamut, Singhore, Danin, Chitral, Jughore, Broz, Gahrait and Drosh. Its traces are not preserved in Ayun and Kesu sequences. The absolute height of T5 varies at different sequences, while its relative height is 60-m in all sequences, except Danin and Chitral, where it is 65-m ACR

5.12.2f. T6 Muldeh Terrace

T6 is confirmed in eight sequences. It is missing from Dalamut and Broz sequences. Its absolute height varies in different sequences. Likewise its relative height above Chitral river varies from 40 to 45-m. In five sequences i.e. Danin, Jaghure, Ayun, Gahrait and Drosh, it records a relative height of 40-m, while in three sequences i.e. Singhore, Chitral, and Kesu it has a relative height of 45-m. Sections exposed along T6, at Ayun show thick deposits of angular rock fragments. The surface is mostly covered by loessic material. The landuse also varies in different sequences. Chitral pologround, and Drosh Murad stadium, Singhore village CADP rest house are located on this terrace. The Muldeh terrace of Chitral Sequence is considered as its representative. (Plate 6.0).

Table 5.16

The vertical distribution of T6 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	-	-	-
Singhore	Singhore Terrace	1,495	45
Danin	CADP Terrace	1,445	40
Chitral	Muldeh Terrace	1,450	45
Jughore-Bakarabad	Dawashish Terrace	1,440	40
Broz	-	-	-
Ayun	Muldeh Terrace	1,430	40
Gahrait	Chowni Terrace	1,350	40
Kesu	Kesu 3	1,320	45
Drosh	Murad Stadium	1,265	40

Source: - Field study

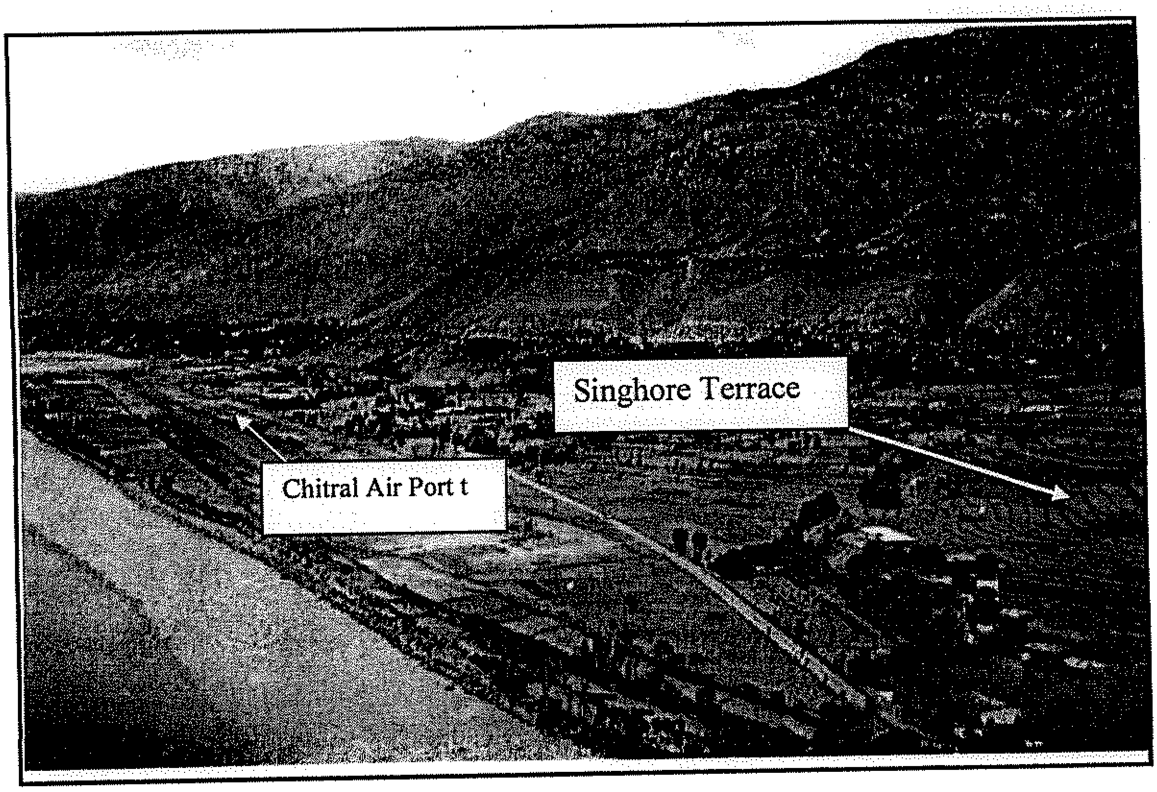


Plate 5.23. Singhore terrace of Singhore Sequence (T6), 45-m ACR. Singhore Village is located on it. it records a relative height of 40-45-m ACR. The Air Port terrace T7, of Singhore sequence is also visible.

5.12.2g. T7 Airport Terrace

T7 is preserved in seven sequences. It has not been recorded in Broz, Gahrait and Drosh sequences. Its relative height in seven sequences is 15-m ACR. This is a wide and extensive terrace covered by alluvium, deposited by river Chitral. The airport terrace in Singhore sequence is covered by sub-rounded to rounded river gravels. Its landuse varies at different sequences, but most commonly it is used for cultivation. Although it is well- preserved in all seven sequences, but the Airport Terrace in Singhore sequence having an absolute height of 1465-m ASL and a relative height of 15-m is taken as a representative of the study area.

Table 5.17

The vertical distribution of T7 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	Cultivated terrace	1470	15
Singhore	Airport Terrace	1465	15
Danin	Cultivated Terrace	1425	15
Chitral	Noghore Terrace	1420	15
Jughore-Bakarabad	Jughore Terrace	1415	15
Broz	-	-	-
Ayun	Darkhandeh Terrace	1405	15
Gahrait	-	-	-
Kesu	Kesu T2	1300	15
Drosh	-	-	-

Source: - Field study

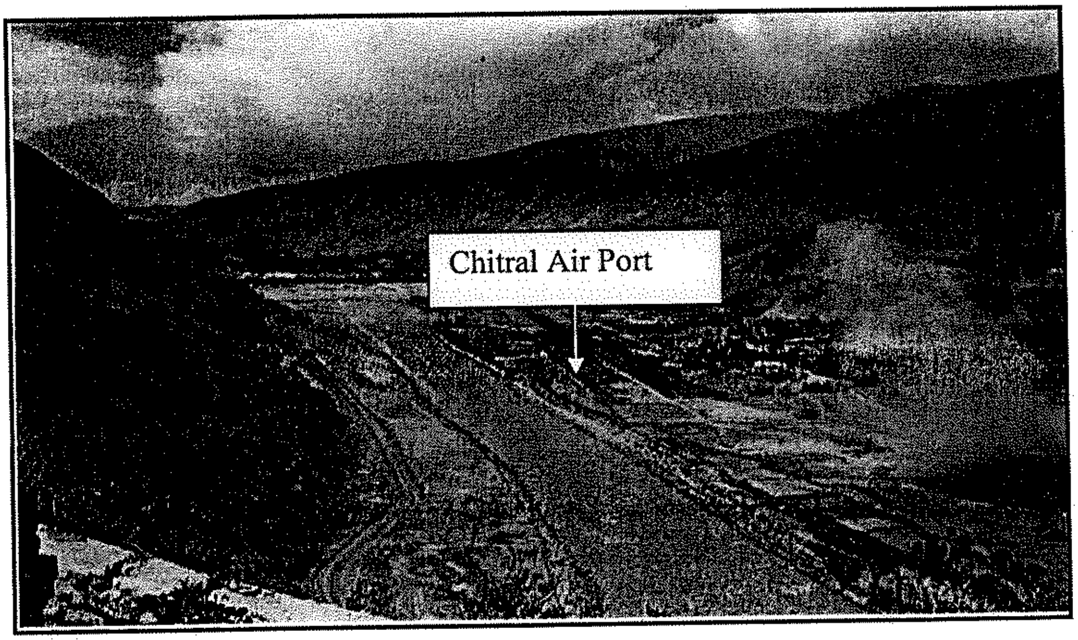


Plate 5.24. Air Port terrace of Singhore sequence (T7) 15-m ACR. This is a wide and extensive terrace covered by alluvium, deposited by river Chitral. The airport terrace in Singhore sequence is covered by sub-rounded to rounded river gravels.

5.12.2h. T8 Kuru Terrace

This is the lower most and most recent terrace, hence it is preserved in all the ten sequences. Although its absolute height varies from sequence to sequence, it has a relative height of only 05-m ACR. Its surface is covered by alluvium. Because of its location close to river level, it is flooded. It is an old abandoned flood plan. This terrace is mostly used for agriculture. This terrace is preserved in Ayun as kuru terrace and in Broz sequence as Cheture Terrace. The vertical distribution of T8 in different sequences is as follows:

Table 5.18

The vertical distribution of T8 in different sequences

Sequence	Terrace Name	Height in meter	
		Absolute	Relative
Dalamut	Sinlasht	1460	05
Singhore	Singhore	1455	05
Danin	Lower Danin	1410	05
Chitral	Pamir River Side Inn	1410	05
Jughore-Bakarabad	Guvavi	1405	05
Broz	Cheture Broz	1395	05
Ayun	Kuru	1395	05
Gahrait	Takht	1315	05
Kesu	Kesu T3	1290	05
Drosh	Junali	1230	05

Source: - Field Study

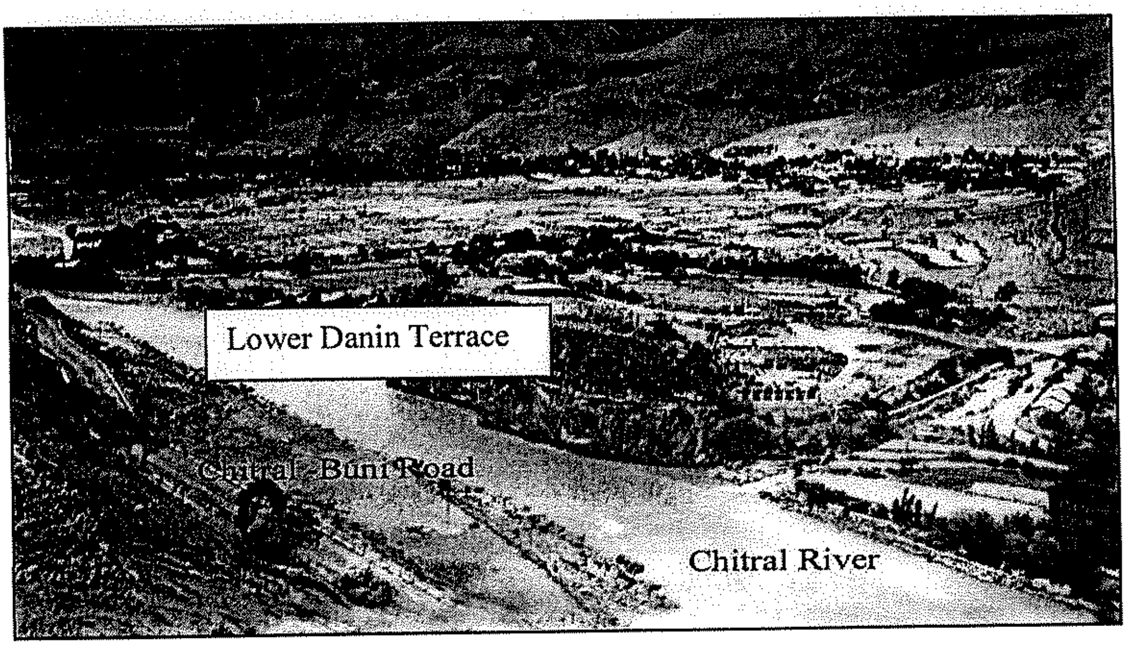


Plate 5.25. The lower most terrace of Danin sequence, Lower Danin terrace o5-m ACR. The terrace surface is covered by recent alluvium material .

Figure 5.11
Correlation of Chitral River Terraces

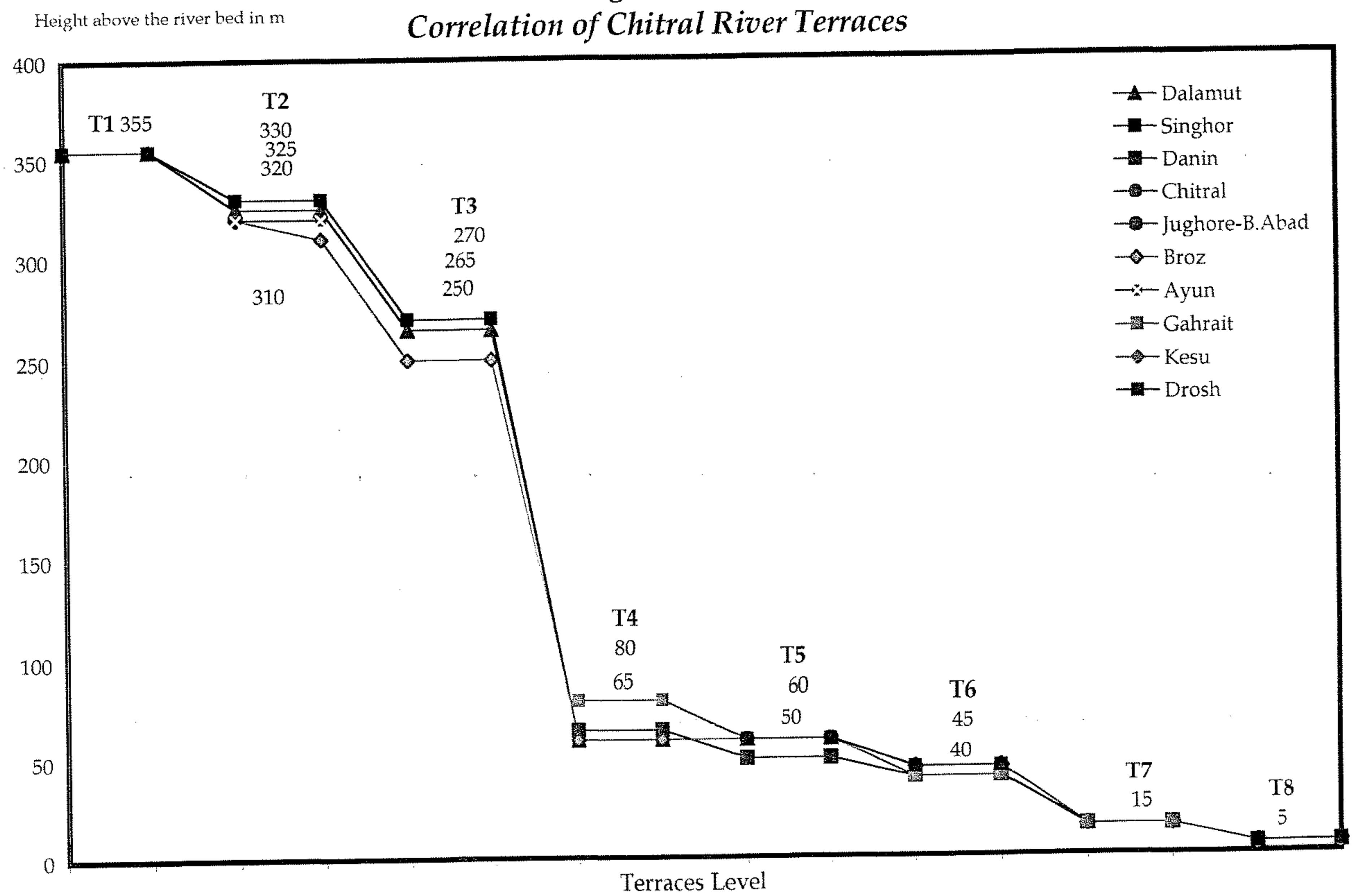


Figure 5.12 b
Correlation of Chitral River Terraces

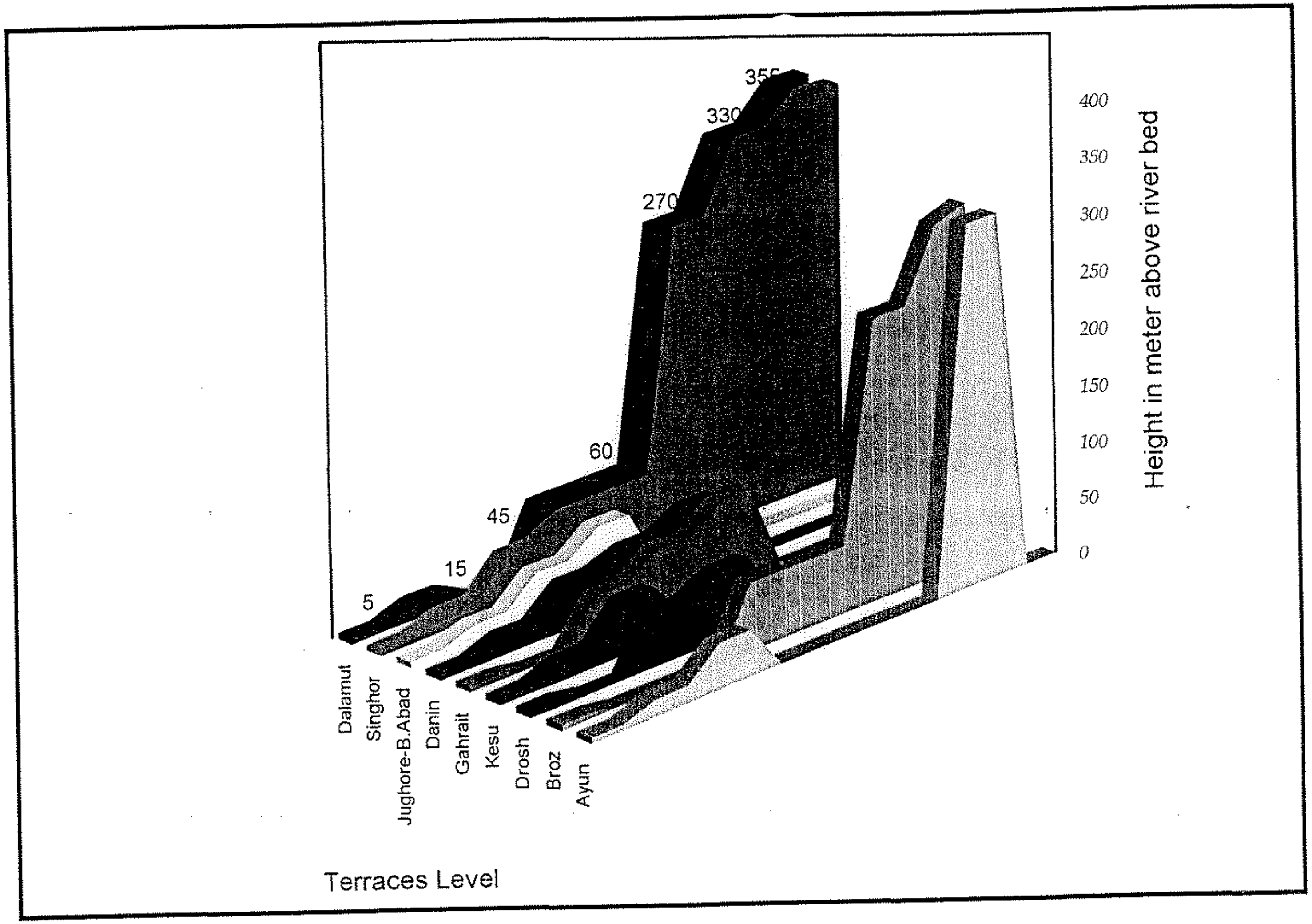
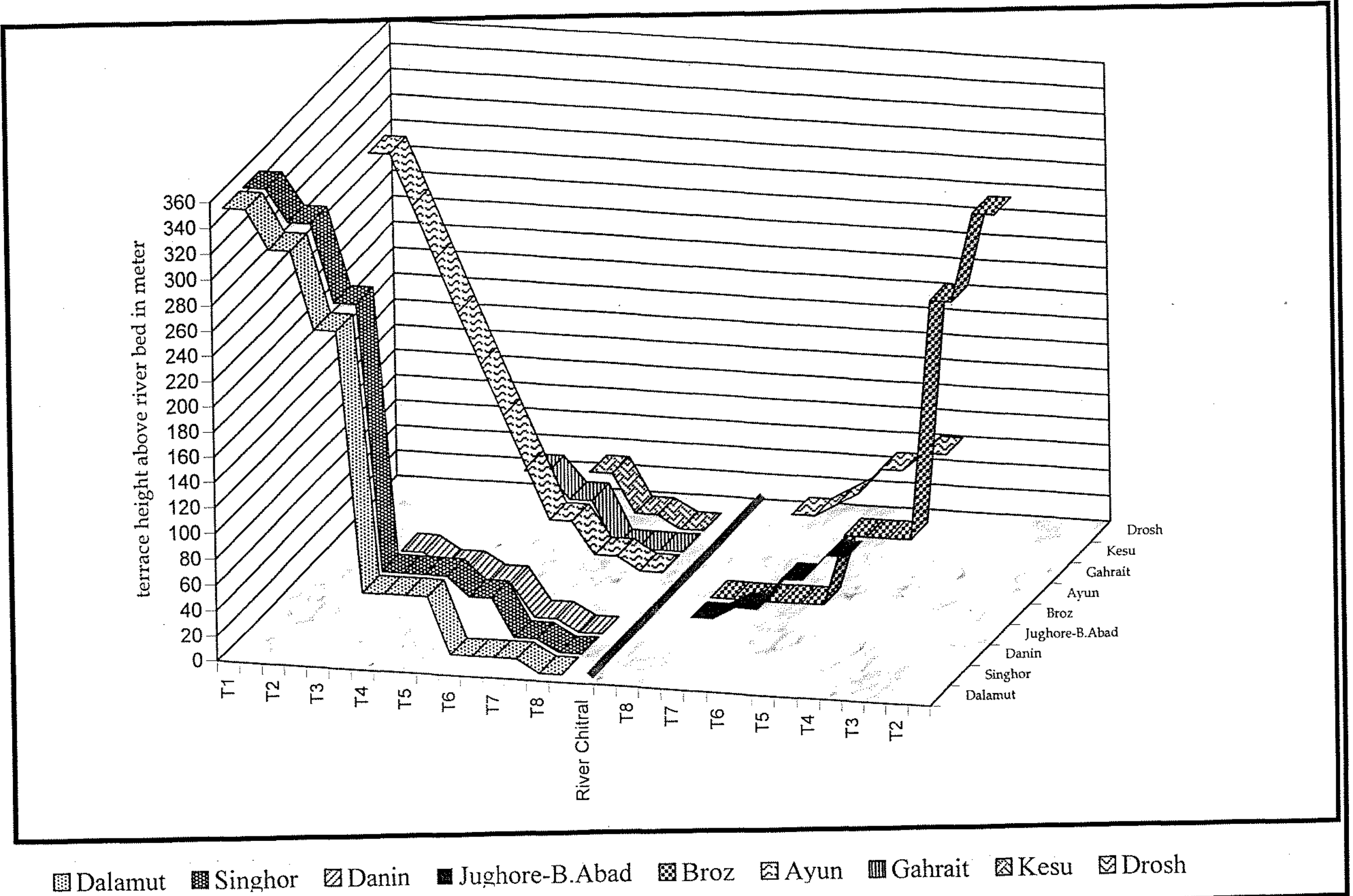


Figure 5.12 a
Correlation of Chitral River Terraces



Chapter No. 6
Study of Sections

Chapter No. 6
Study of Sections

6.1. Introduction

A Variety of surface deposits, including loess, sand, gravel, conglomerate, and boulders, are preserved in the area. These deposits have been studied in detail. A sketch of section has been made according to the scale, photographs have been taken; material of various beds has been recorded. Samples have been taken from each bed for laboratory analysis.

6.2. Section No. 1

6.2.1. Field description

This section is exposed along the western bank of Dalamut Gol, some 5-Km north east of Chitral town at a height of about 265-m ACR (GR 744206 38M/13). A number of sections are exposed along Dalamut Gol, exposing deposits of Singhore sequence. In all these sections, the sequence of deposits is more or less repeated. This section is taken as a representative for the entire Singhore sequence. It has a height of approximately 19-m from base to the top, with nine different beds. The order of deposits from base to top is as follows: **(Figure 6.2.1)**

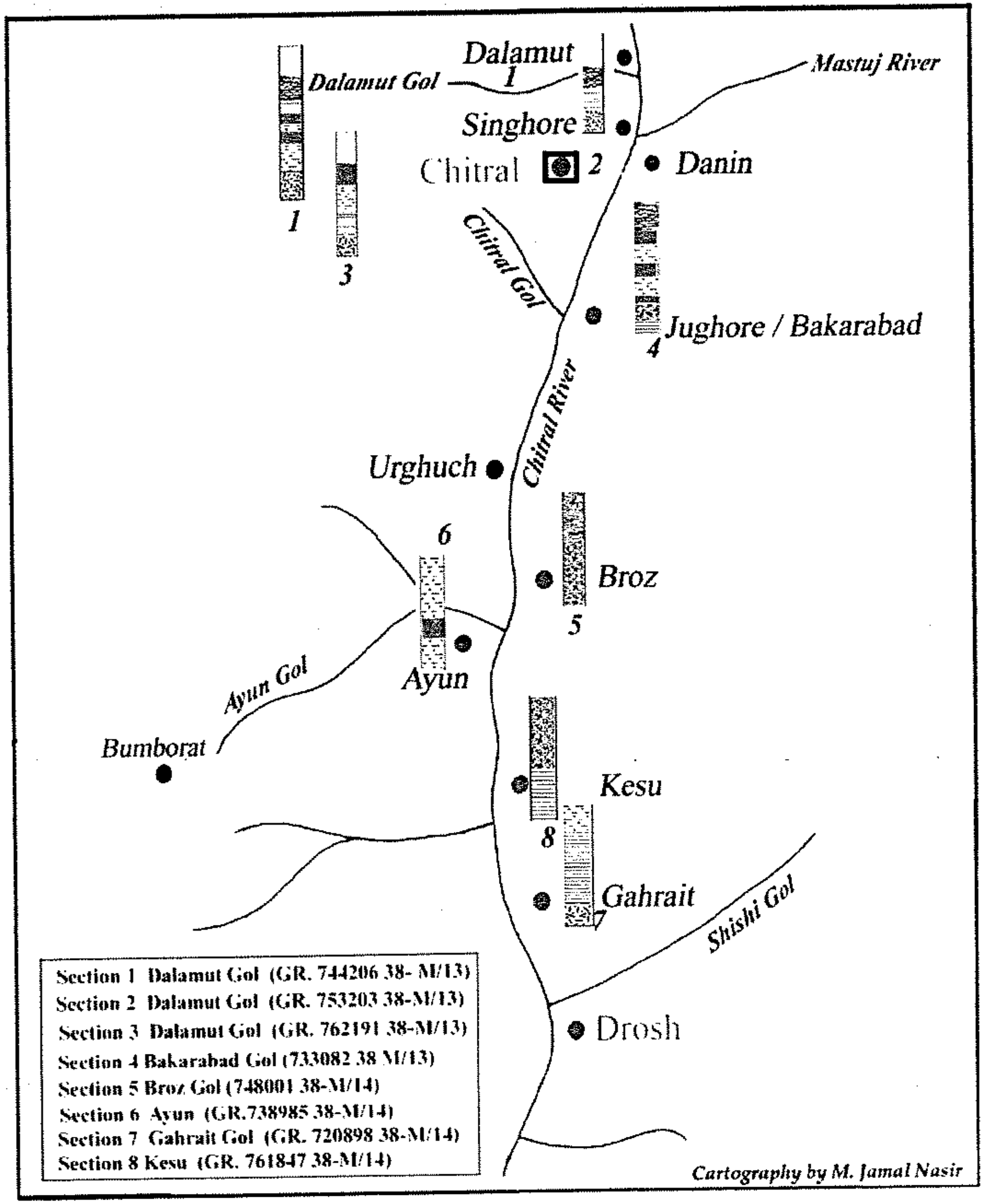
- **Bed a**

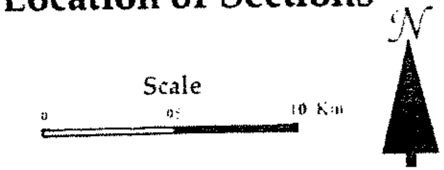
  Bed ***a*** (1.5-m thick) consists of light gray, sub-angular to sub-rounded medium size gravels of sandstone, slate and shale, seem to be of local origin. The size of material is ranging from 5 to 10 centimeters. The gravels are embedded in a loose sandy, pebbly matrix. The gravels are partly stratified and unsorted.

- **Bed b**

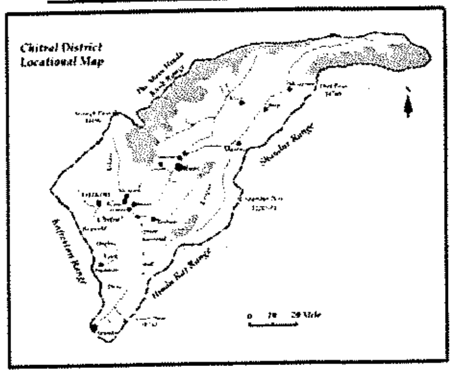
  It consists of 3-m thick bed of small-size, sub-rounded to rounded gravels, embedded in a sandy matrix. The pebble and gravels are poorly sorted and stratified. Lithologically the gravels are predominantly metamorphic i.e. granite, amphibole, quartzite etc.

Map 6.1
Chitral Valley
Location of Sections





	Description	Interpretation
	Unstratified silt	*Loess (10 ka)*
	Stratified angular to sub angular gravels	*Young Fan gravels (<60-10 ka)*
	Sub-rounded to rounded gravels, fine, medium coarse sand	*Fluvial material (90-10ka)*
	Angular to sub-angular gravels	*Middle fan gravels (110-90 ka)*
	Bedded clay/silt	*Lacustrine facies (190>120ka)*
	Angular to sun-angular gravels	*Older fan gravels (>200 ka)*



The lithology and roundness of the clasts suggest that they may be derived from the upper reaches of Chitral valley.

- **Bed c**

  It consists of hard and compact lenses of black 1.5-m thick sandy and silty material.

- **Bed d**

  This is a 3.5 thick deposit of light gray (2.5 Y 7/2) clayey siltstone. The bed shows 20 to 25 cm thick horizontal layers of pale yellow (2.5 Y 7/4) siltstone and claystone. Mass wasting frequently occurs along the bed, that has covered much of the material in the lower beds. Yellowish color fossilized roots can also be seen in places.

- **Bed e**

  The 2.5-m thick bed consists of angular to subangular rock gravels embedded in a clayey matrix, approximately. The material is unsorted and poorly stratified.

- **Bed f**

  It consists of approximately 05-m thick deposit of loessic silt of pale yellow colour (10YR 6/3). The material exhibits a lot of limestone concretion. It has been eroded severely in places horizontally.

6.2.2. Laboratory examination

6.2.2a. Texture

- **Bed c**

Sieve analysis suggest that the material is composed of 15% silt, 20% fine sand, 30% medium sand and 35% coarse sand. **(Figure 6.2.2.)**

- **Bed e**

Bed **e** is a thick deposit of alternate gray-colour, clayey siltstone, coarse sand and brownish siltstone. The material of clayey siltstone ranges from clay to coarse silt. It is composed of 20%clay, 20% very fine silt, 30% fine silt, 20% medium silt and 10% coarse silt. The material is classified as fine to medium silt. . **(Figure 6.2.2)**

6.2.2b. Roundness Analysis

Bed a

30% of the gravels are sub- angular, 40% sub-rounded, 25% rounded and only 5% well-rounded. **(Figure 6.2.3).**

Figure 6.2.3
Roundness Analysis

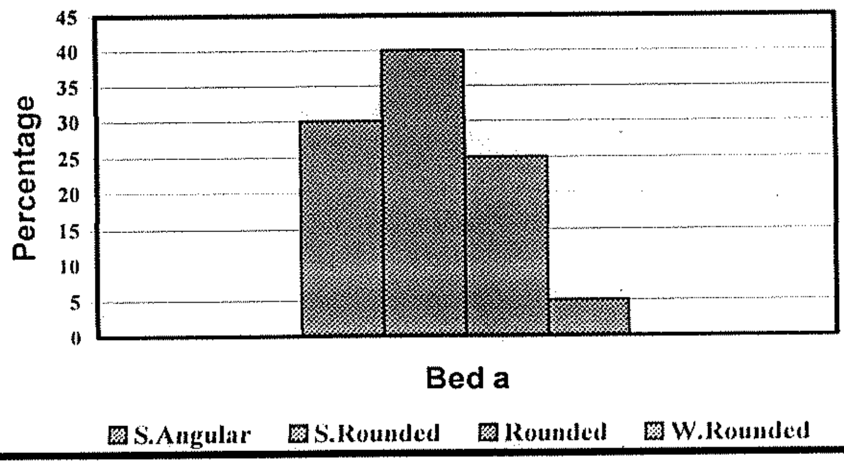
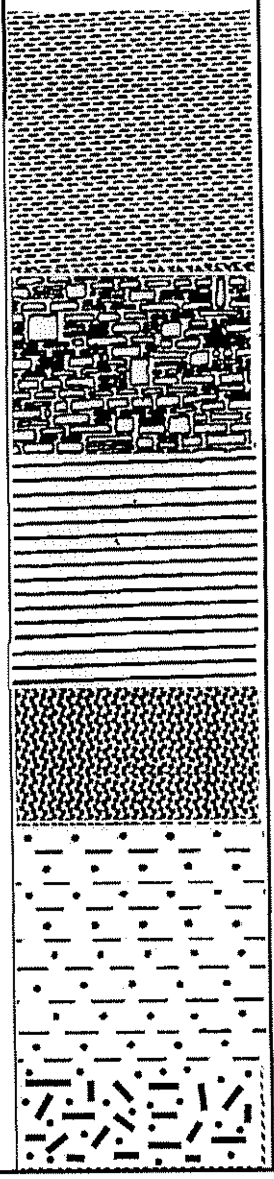


Figure 6.2.1

Statigraphic Section No. 1
Dalamut Gol (GR 744206-38M/13)

Thickness	Bed No.	Profile	Characteristics: Colour	Characteristics: Lithology & structure	Sample
05m	*g*		*Yellow 10YR6/3*	Loess with abundant organic burrow filling, (limestone concretions).	
2.5m	*e*		*Light grey 2.5Y7/2*	Angular to sub-angular rock gravels embedded in muddy matrix; unsorted and poorly stratified.	●
3.5m	*d*		*Pale yellow 2.5Y7/4*	Alternate horizontal layers of siltstone and claystone.	◍
1.5m	*c*		*Dark grey*	Loosely cemented lenses of dark grey sand and silt.	◍
03m	*b*			Small size rounded to sub-rounded gravels, embedded in a sandy matrix; poorly sorted and vaguely stratified.	●
1.5m	*a*		*Light grey*	Sub-angular to angular gravels ranging in size from 5 - 10 cm, embedded in loose sandy, pebbly matrix.	●

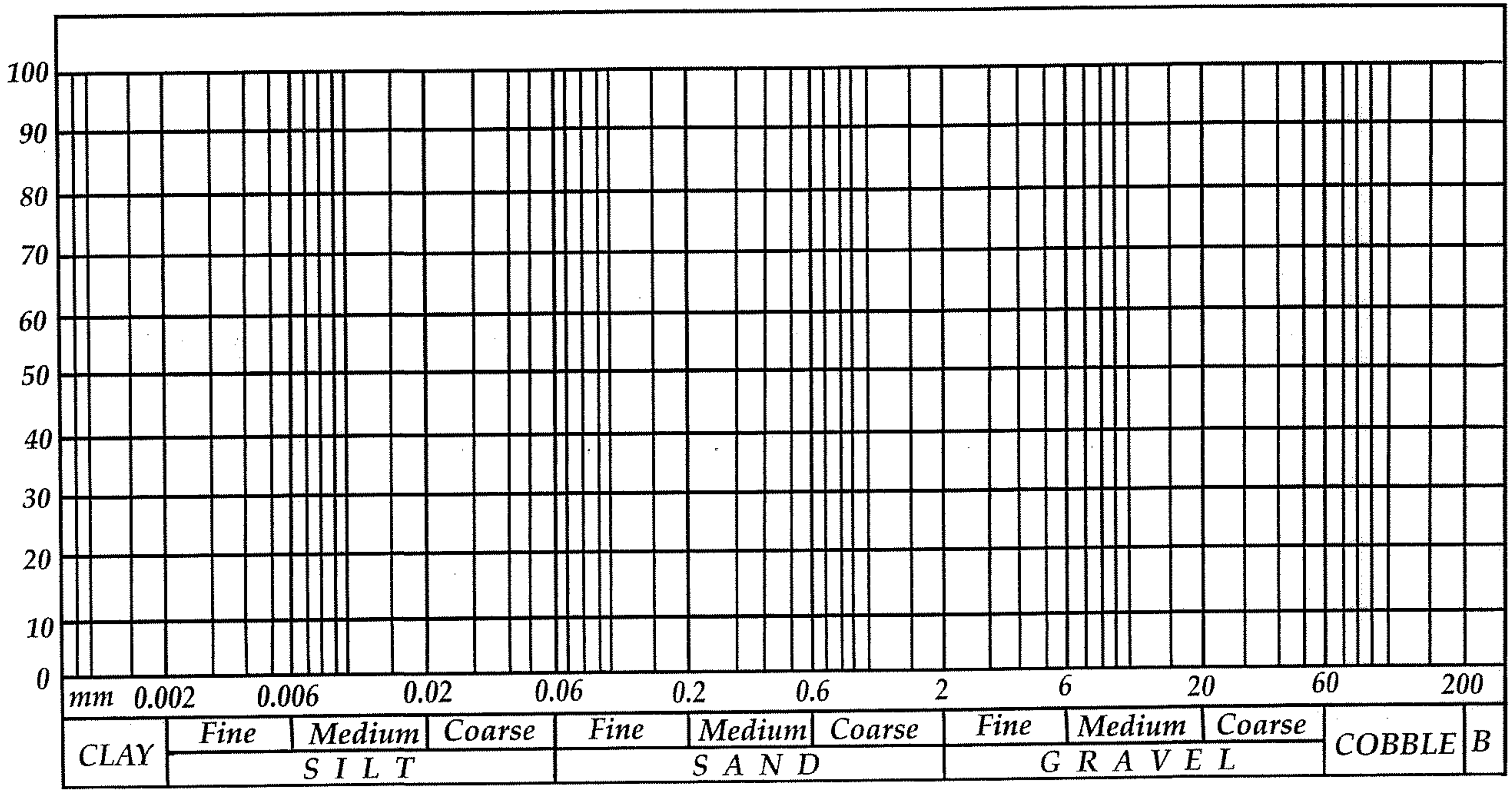
● Sample for roundness and shape analysis.

◍ Sample for size analysis.

Figure No. 6.2.2
Section No. 1
Particle Size Distribution

Location Dalamut Gol

Bed No. c & e



M. Jamal Nasir

Section No. 1

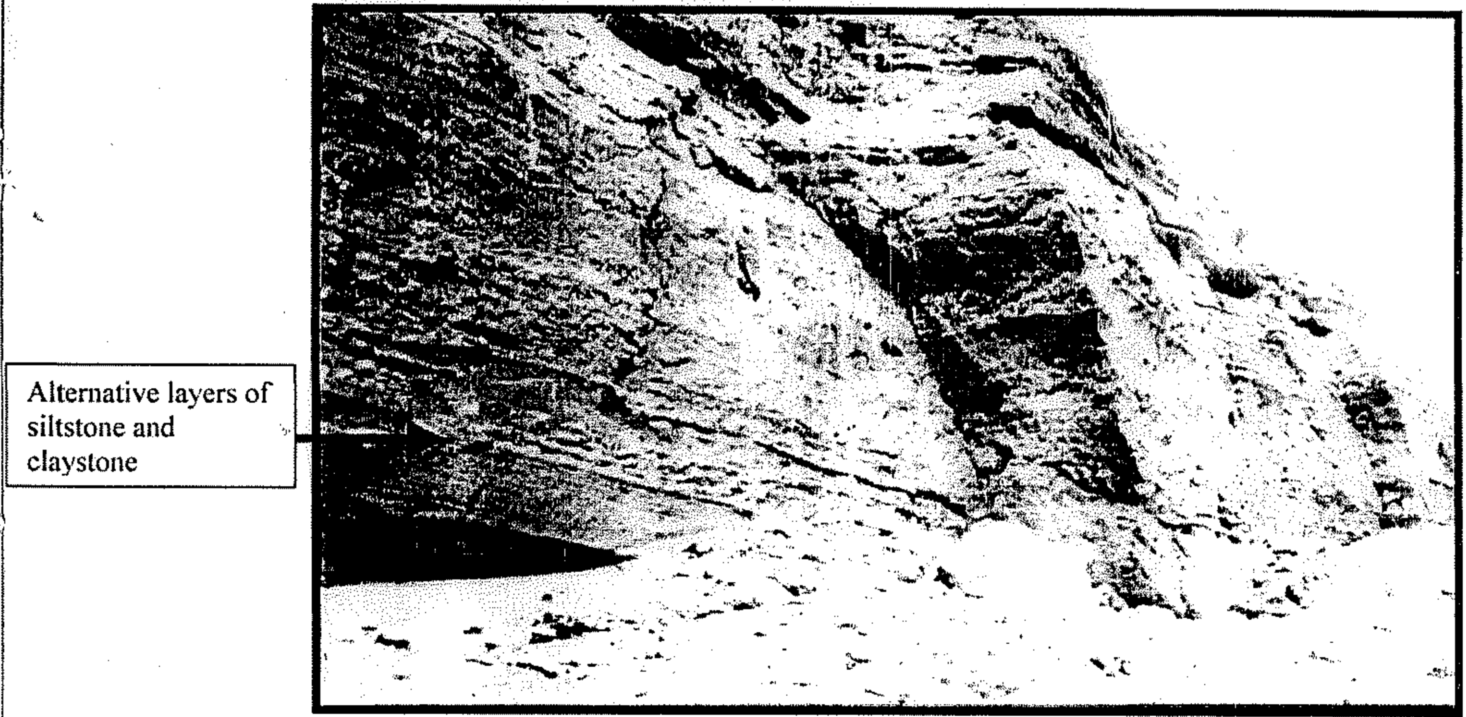


Plate 6.2.1 Photograph showing section No. 1, exposed along the western bank of Dalamut Gol. some 5-Km north east of Chitral town. Bed e of this section is composed of alternative layers of siltstone and claystone are clearly visible.

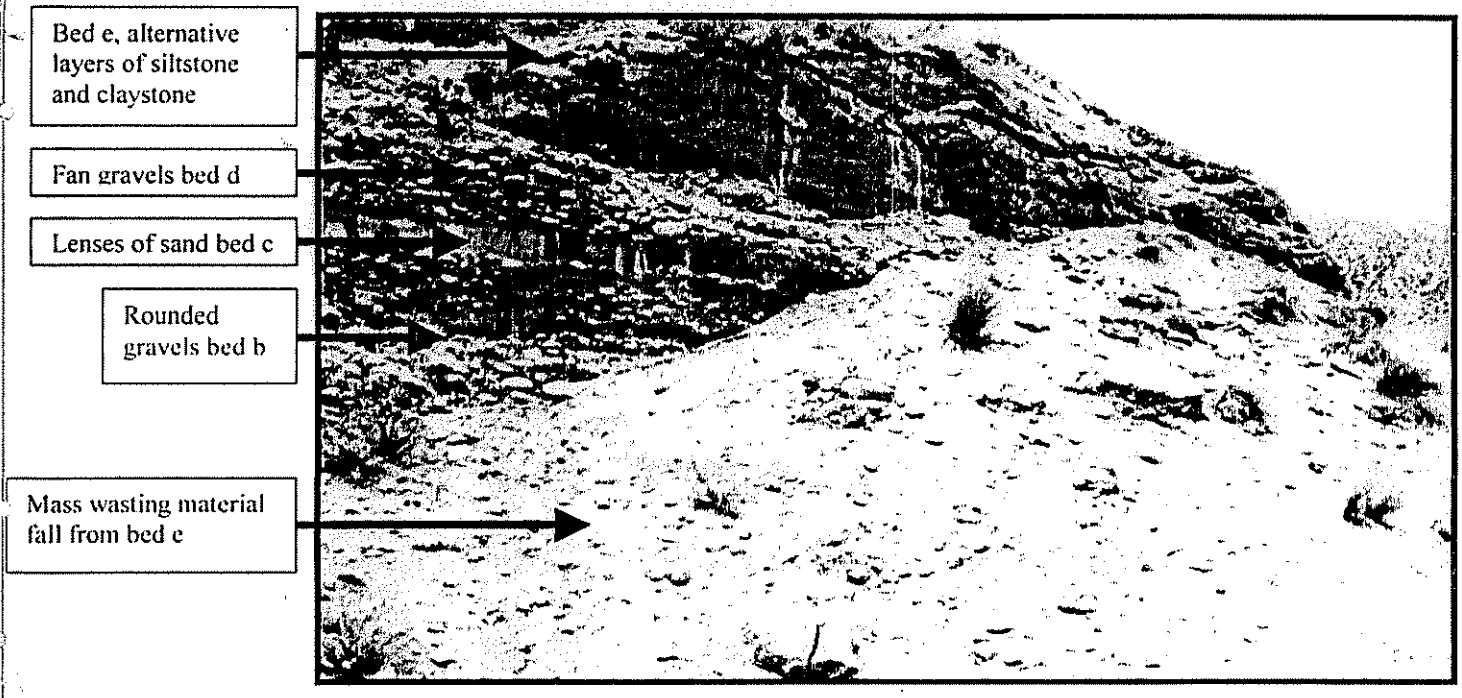


Plate 6.2.2. Section No.1 bed b,c,d, and e.Bed e is a thick layer of light gray (2.5 Y 7/2) clayey siltstone. with a maximum thickness of 3.5-m. The bed shows 20 to 25 cm thick alternative horizontal layers of siltstone and claystone pale. yellow (2.5 Y 7/4). Mass wasting frequently occurs along the bed. that has covered most of the material.

Bed b

15% of the gravels are sub- angular, 45% sub rounded, 26% rounded and only 14% well rounded. **(Figure 6.2.4)**

Bed e

The clast in bed ***f*** are mostly angular to sub-angular, 70% gravel fall in angular class, 20% sub-angular, 10% sub-rounded class. **(Figure 6.2.6)**

Figure: 6.2.4

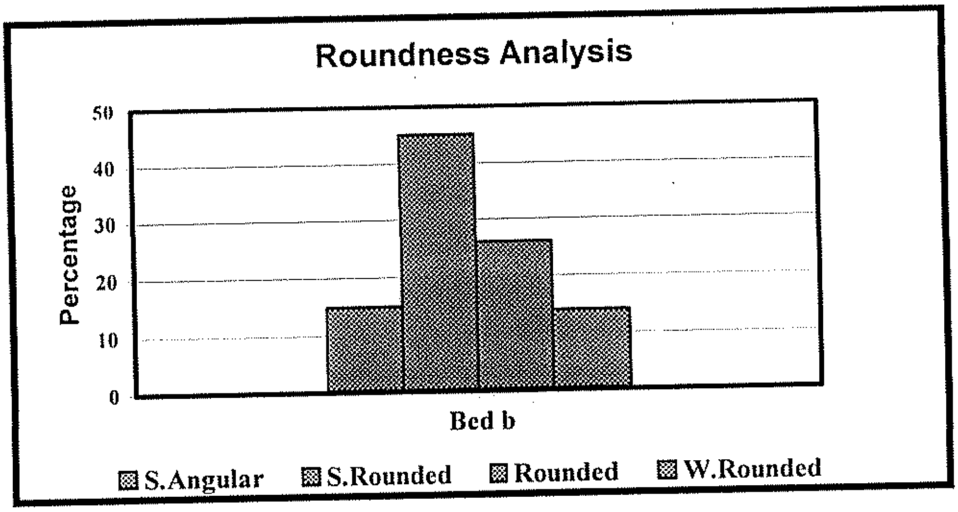
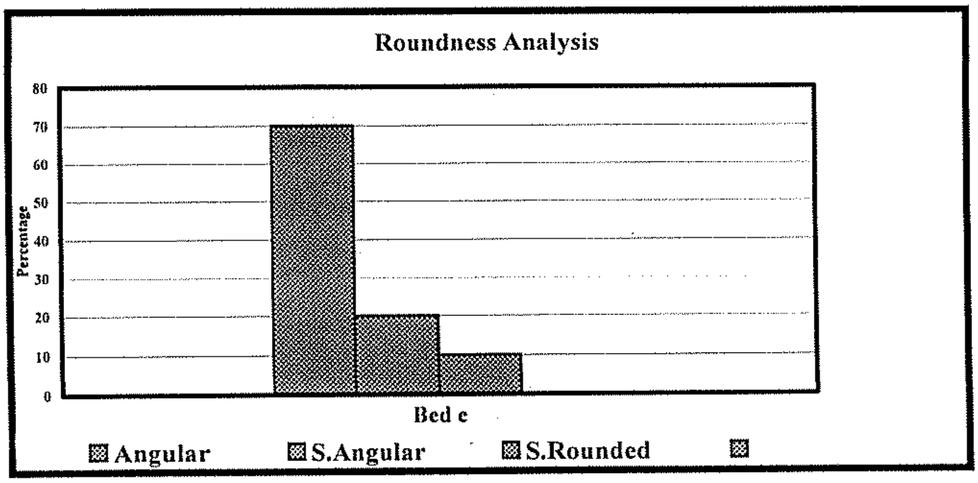


Figure: 6.2.5



6.2.2c. Mineralogical Analysis

Bed d:

A number of minerals are identified in the silt. The most important are the angular to sub angular grains of quartz and feldspars. Quartz is the important constituent making 34.15% of the sample, followed by feldspar 25.25% muscovite 10.45%, amphibole 8.52% calcite 7.20%, Chlorite 6.90%, clay 5.46%, epidote 1.05%, pegmatite 1.02%. The abundance of quartz and feldspars indicates that the material was produced by the disintegration of granite and related rocks. The sediments may have been produced by glacial erosion in the upper reaches of river Chitral i.e. Yarkhun and hot spring areas during Pleistocene period. In a later phase, the fine particles from morainic material has been picked up by eastern and western tributaries of river Chitral i.e. Yarkhun, Mastuj and Gramchashma rivers and was deposited in the lake.

Bed f is a 05 meter thick deposit of loessic silt. The sample was taken for mineralogical analysis. The mineralogical analysis suggests that deposit is dominated by quartz being 30.14%, followed by feldspars 26.60%, and clay 19.50%, muscovite 8.30%, amphibole 6.20%, Chlorite 4.75%, Pegmatite 2.51 and limonite 2.00%.The high content of quartz and feldspars indicates that the material is derived from igneous and metamorphic rocks.

6.2.2d. Scanning Electron Microscopy

The sample from ***bed f*** was analyzed with electron microscope and pictures was taken with a magnification of 1500 times. (Plate 6.2.3). The surface forms and texture of the grains are dominated by planner fracture surfaces, with angular often sharp edges and corners.

Plate 6.2.3. Scanning Micrograph of loessic grain magnified 1500 times. Most of the grains studied under Scanning Electron Microscope were founded to be angular to sub angular.

Discussion

Field and Laboratory examination suggest that the ***bed a*** was deposited by a stream on bed rock. Its massive structure with poor stratification suggests a mudflow deposit. The onset of glaciation in the upper Chitral result in severe cold climate which favored the weathering and disintegration of the rocks. As a result, a thick mental of regolith was developed over the mountain slopes. With a change in climate from cold and dry to warm and humid conditions, due to melting of snow and ice the discharge of streams increased. Melting snow also facilitated mass wasting and the weathered coarse debris, is re-worked and deposited as a thick gravelly ***bed a.***

The poor bedding of the bed a, suggest it to be fast moving, swift and turbulent stream, whose channel was changing rapidly and frequently (Reineck and Sing 1973, Khan 1990.) The presence of lenses of silt within the gravelly bed indicates change in the velocity of the stream.

This was followed by a second phase of deposition, but this time river Chitral was responsible. Most of the gravels are rounded to semi-rounded which suggests that they have been transported by river and traveled a long distance probably from its upper reaches which consist of rocks of granite, quartz, and amphibolite. This material may have been originally produced by frost shattering or due to grinding action of glaciers, (Porter 1970) in glacial environment. During inter-glacial with the change in climate from cold to humid the discharge of river increases. The sediment is than transported by river and during transportation process the gravels become rounded.

The silt and sand in ***bed c*** has probably been deposited during a cold glacial phase. The deposits of ***bed c*** suggest a change in climatic conditions. In the upper reaches the mountains are covered with thick snow and ice, due to low melting, the meager stream could only deposit fine material like silt and sand.

Bed d is a thick deposit of light gray clayey siltstone which suggests formation of a lake. The lower part shows about .5 meter semi hard light gray (2.5 Y 7/2) siltstone. The bed is weathered in its upper parts and the material covered much of the bed in the lower part. The freez/thaw activity during the cold climate resulted in the intense physical disintegration of the surrounding mountains. The surrounding mountains are mostly slate, shale, schists etc. all these rocks are especially susceptible to frost action (Leopold, et al 1964). During this period the mountain slopes were thickly covered with the weathered material and was a source of sediment for torrents.

With the increase in temperature, the regolith developed over the slope, during the cold phase, was released and was picked up by torrents coming from east and west of river Chitral. It accumulated at the foothills in the form of scree and alluvial fans. There is evidence that one of alluvial fans probably down stream Gharait blocked the Chitral river and the valley was converted into a lake in which thick deposit of silt was laid on the pre-existing fluvial deposits of sand and gravels. Thickness of the lacustrine facies reveals a long phase of valley ponding. This lake covered a considerable part of Chitral valley as can be seen from the wide spread lacustrine deposits exposed. ***Bed d*** of the section (lacustrine facies) records a thickness of about 7-m.

The mineralogical composition and scanning electron microscope analysis reveals that the dominating constituent of the sample is the angular to sub-angular grains of quartz and feldspars. They may have been originated as first cycle deposits from primary crystalline rock such as granite or metamorphic rock. The source of feldspars may be the coarse granite, metamorphic or igneous rocks such as quartz diorites as they contain abundant of feldspar. The angularity of the grains shows a single episode of fluvial transport of the first cycle sediments. (Owen 1988,Hasan 1995).

Granite is the most widespread rock in Chitral valley, it mostly covers the areas surrounding Chiantar glacier in upper Chitral and Golin gol area. The quartz, feldspar, chlorite and epidote may be derived from area between Ayun and Reshun faults. The rocks exposed here are fine grained thinly laminated Green schist containing varying amount of sodic plagioclase, octinolite, epidote, chlorite, quartz and feldspars. The muscovite may be derived from Phyllite rocks exposed in Reshun formation which is mainly laminated red Phyllite. As for as amphibole is concerned it may be transported by Lutkoh (Garamchashma river) from the area between Momi and Muzigram in Arkari gol area. Here the amphibolite unit is mainly a monotonous series of laminated dark green fine grained hornblende plagioclase schists. (Calkins et al. 1981)

The upper most bed is a 05-m thick bed of loess. The origin of loess has been attributed to the glaciated area of the Himalayas and Hindukush. The material was analyzed by Scanning Electron Microscope the surface form and texture of grains are dominated by planer fracture surface with angular and sharp edges and corners. A number of sources for the loessic material have been described by sedimentologists. Smalley (1966 & 1983) proposed that glacial grinding provide loessic material for the bulk of world loessic deposits. Boulton (1978) suggests that most of loessic particles are produced in the basal zone of the traction; of glacial environment where large forces produce fine grained wear products.

Zeuner (1949) has favored insolation, weathering and frost action to be the major causes of silt. Hasan (1995) and Khan (1990) on the other hand have suggested a warm and dry climatic condition for the deposition of loess, during the interglacial phase. Said and Majid (1977) correlated the loess deposits of Bar Daman area of southern part of Peshawar with the late cold phase of the third Himalayan glaciations.

The loessic silt in ***bed f*** seems to have been produced in the upper Chitral valley by frost weathering process during cold phase. In the first stage it may be deposited as moraines. Bulk of the fine particles may have been raised by wind and carried away in suspension and was re-deposited as loess. The mineralogical analysis and scanning electron microscopy also confirmed it.

Summary of the important events, recorded in the section:

1. The release of weathered material with torrential rains, formation of alluvial fan, with angular to sub-angular rock gravels forming ***bed a***.
2. The deposition of rounded gravels by Chitral river ***(Bed b)***.
3. The formation of floodplain by the Chitral river and the deposition of thick-bedded sand by river and its conversion into sandstone in the subsequent phase ***(Bed c).***
4. The formation of a lake in the valley and deposition of siltstone in the lake forming ***bed d.***
5. The draining of lake and exposition of siltstone.
6. A second phase of the deposition of fan material over siltstone ***(Bed e).***
7. The deposition of loess ***(Bed f).***

6.3. Section No.2

6.3.1. Field description

This section is exposed along the left bank of Dalamut gol, some 5 Km north of Chitral town at a height 260-m ACR (GR 753203 38M/13). A number of sections are cut along Dalamut gol, which expose deposits of Dalamut sequence. In almost all sections the sequence of sedimentation is more or less repeated. From base to top, four different layers of deposits have been exposed in the section. The order of deposition from base to top is as follows: **(Figure 6.3.1)**

Bed a:

The bed consists of about 4-m thick deposit of angular to sub-angular gravels. The material is embedded in pebbly matrix. The clast is predominantly medium- size gravels.

Bed b:

It is a 7m thick lacustrine facies composed of alternative beds of clayey and silty material. It comprises upto fifteen, almost horizontal sedimentation units. Each one of the units can be clearly distinguished from that of above and below. It also varies in thickness from 10 cm to 20 cm. Rootlets and burrows can be seen in each unit. The clayey material is hard, while the silty material is relatively softer. The erosion of softer beds gives it a wave like form.

Bed c:

The bed is composed of 5-m thick deposit of locally derived dark-grey sandstone and slate gravels. The clasts are predominantly coarse, angular to sub angular gravels. The material is unsorted and poorly stratified, embedded in a clayey matrix.

Bed d:

Bed ***c*** is overlying a 6-m thick deposit of pale-yellow (10YR 6/3) loess. As in Dalamut sequence, the terrace is covered by a thick deposit of loess material with abundant limestone concretions.

Figure No. 6.3.1

Stratigraphic Section No.2
Dalamut Gol (GR 753203 - 38M/13)

Thickness	*Bed No.*	*Profile*	*Characteristics*		*Sample*
			Colour	*Lithology & Structur*	
06m	*d*		Yellow 10YR6/3	Loess with abundant organic burrows filling (limestone concretions)	
05m	*c*		Dark grey	Locally derived gravels of sandstone and slate unsorted and poorly stratefied.	●
07m	*b*			Lacustrine facies, alternate beds of muddy and silty material, composed of 15 horizontal layers, varying in thickness from 10 - 20 cm. Differential erosion has resulted in a wavy surface.	
04m	*a*			Angular to sub -angular gravels of slate shale etc.	●

● Sample for roundness and shape analysis.

● Sample for size analysis.

Section No. 2

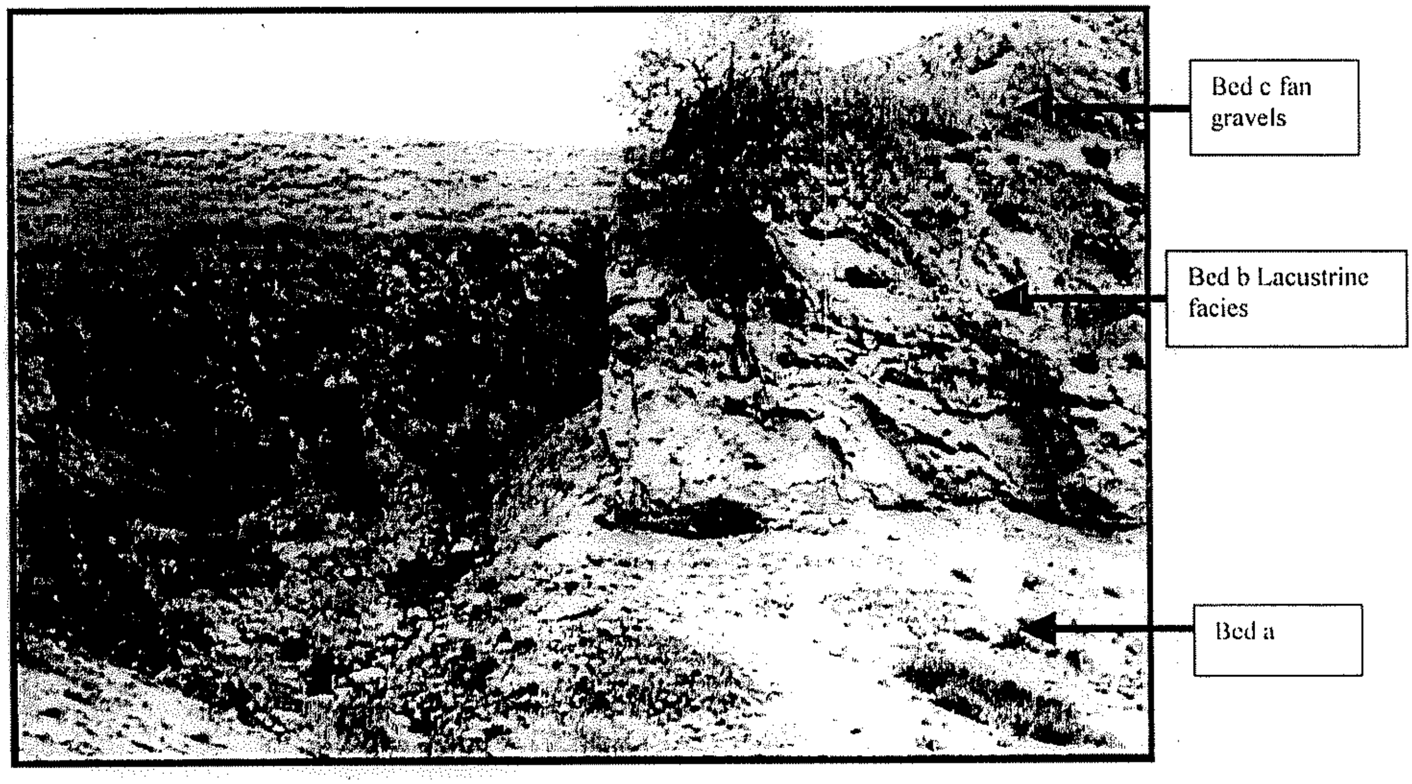


Plate 6.3.1 A view of section No. 2 exposed on the left bank of Dalamut gol. From base to top four different layers of deposits are exposed..

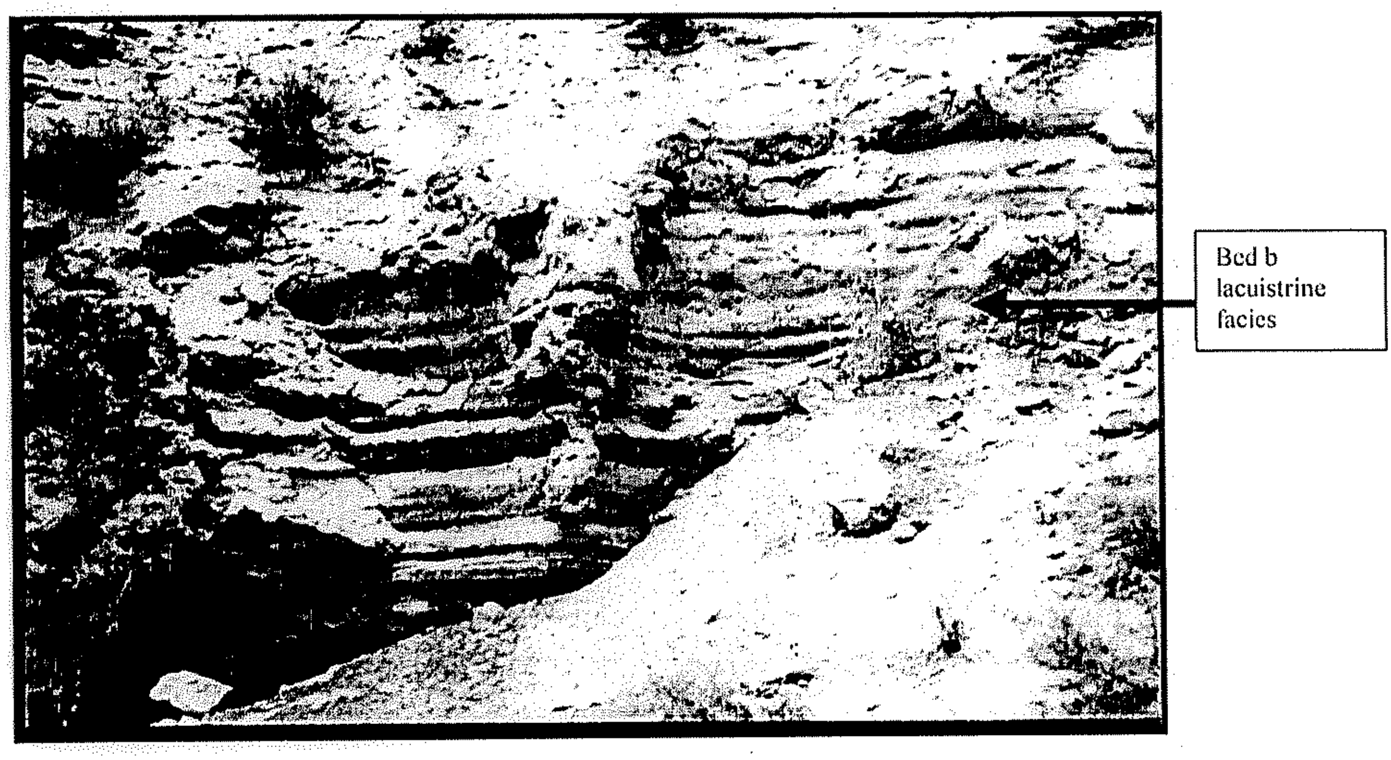


Plate 6.3.2. A closer view of section No. 2, showing bed b, 7m thick lacustrine facies composed of alternative beds of muddy and silty material. The bed comprises upto 15, almost horizontal sedimentation units. The beds vary in thickness from 10 cm to 20 cm.

6.3.2. Laboratory Examination

6.3.2a. Roundness Analysis:

Bed. a

25% of the gravels are angular, 40% sub-angular, 25% sub-rounded and 20% rounded. **(Figure 6.3.2)**

Bed. c

Bed ***c*** show that 20% of the gravels are very angular, 30% angular, 25% sub-angular, 20% sub-rounded and 05% rounded. It is conspicuous by the absence of well-rounded gravels. **(Figure 6.3.3.)**

6.3.2b. Shape Analysis

Bed a:

Shape analysis reveals that 50% of the clasts are equant, 25% oblate, 20% bladed and remaining 5% are classified as prolate. **(Figure. 6.3.4.)**

Figure: - 6.3.2

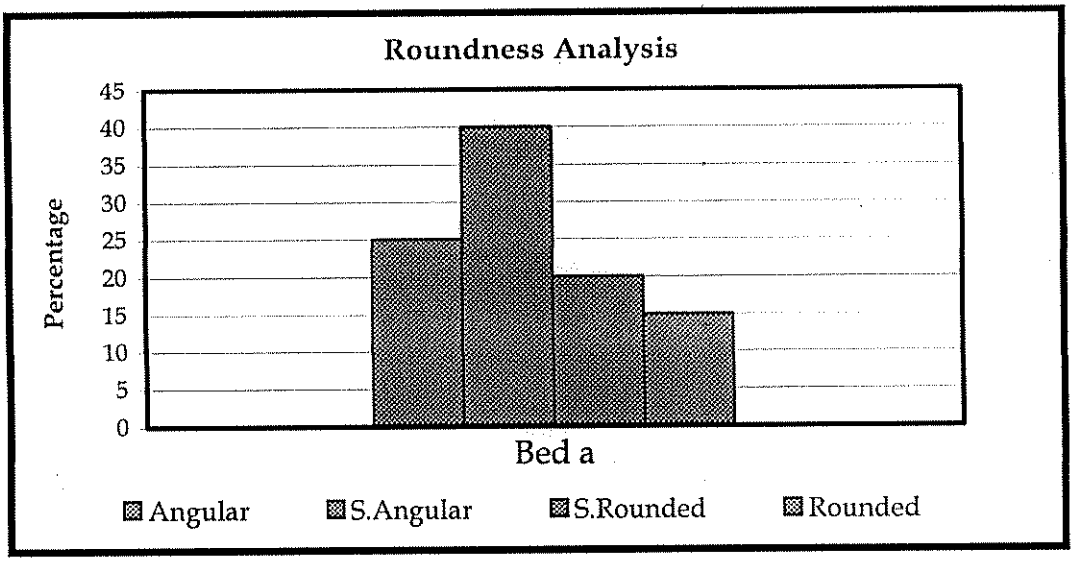


Figure: - 6.3.3.

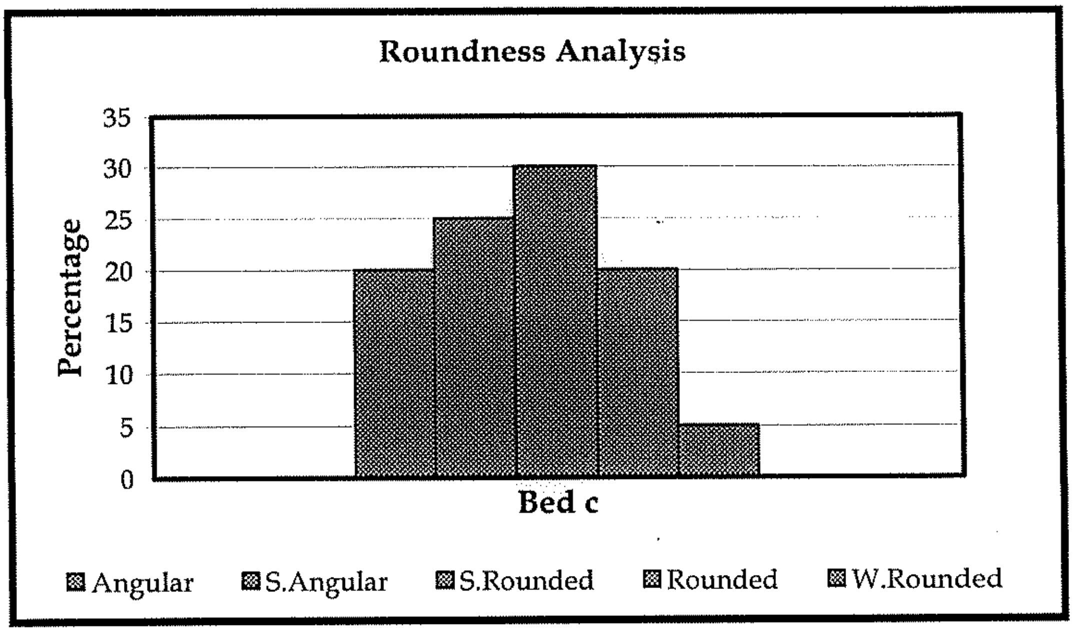
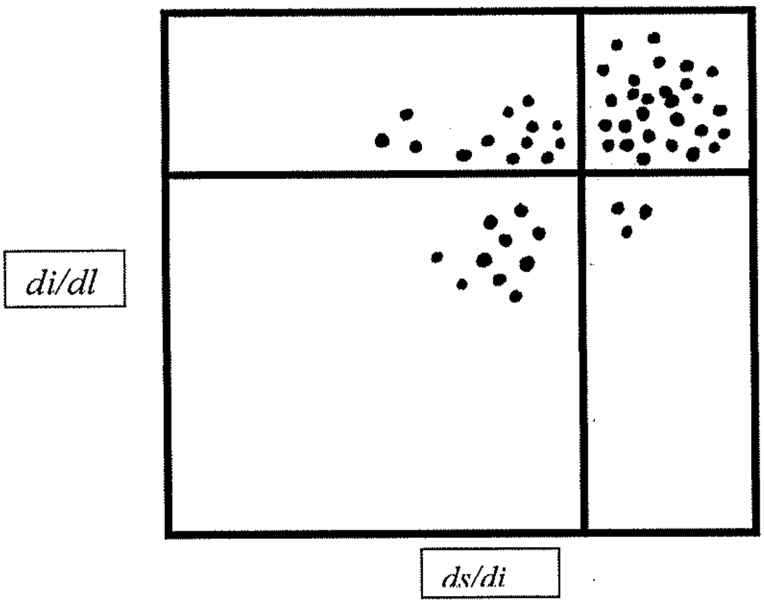


Figure 6.3.4

Shape Analysis



6.2.3c. Scanning Electron Microscopy

Bed d:

Surface texture of silt grain from bed b was analyzed under scanning electron microscope. The grain was magnified 1000 times. Surface form and texture are dominated by planner fracture surfaces, with angular and sharp edges and corners. (Plate 6.3.3). The surface features identified were scratches, dish shape concavities. This reveals that the silt may be the result of freeze-thaw stress in cold mountain environment.

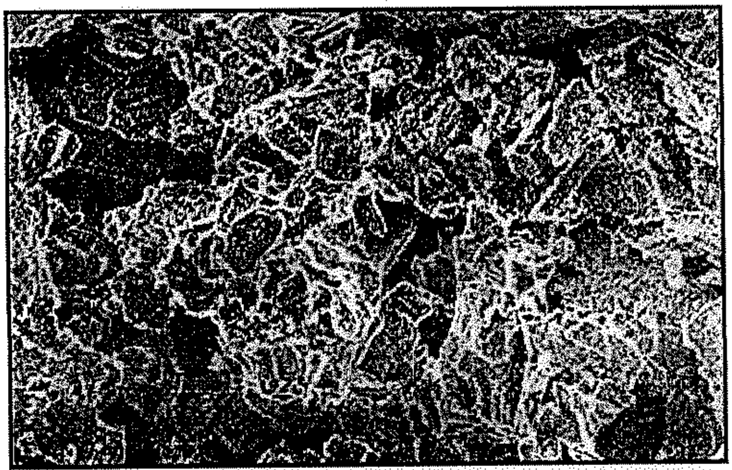


Plate 6.3.3. Micrograph of Silt from bed d showing angular and sharp edges and corners

Plate 6.3.4. Micrograph of Silt from bed b (lacustrine bed) showing sub-angular to sub rounded particles.

6.2.3d. Mineralogical Composition

Bed d

Mineralogical analysis shows that sediment is dominated by quartz feldspar and biotite. The material is composed of 29.10 % quartz, 25.38 % feldspars 15.45 % biotite, 13.32 % muscovite 5.25% calcites, 5.0% Chlorite, 3.50 % amphibole 2% clay and 1.0% epidote.

Discussion

The lower part of the section is a 4m thick deposit of angular gravels. The predominant clast is that of metamorphic rock i.e. slate, shale, etc. the lithology of the sediment suggests that the material is locally derived from the Chitral slate and shale. Field and Laboratory examination suggest that the ***bed a*** was deposited by a stream on bed rock. Its massive structure with poor stratification suggests a mudflow deposit. The onset of glaciation in the upper Chitral result in severe cold climate which favored the weathering and disintegration of the Chitral slate. As a result, a thick mental of regolith was developed over the mountain slopes. With a change in climate from cold and dry to warm and humid conditions, due to melting of snow and ice the discharge of streams increased. Melting snow also facilitated mass wasting and the weathered coarse debris, is re-worked and deposited as a thick gravelly ***bed a.***

Bed b of section 2 a 7m thick deposits of alternates beds of clayey and silty material. The horizontal bedding and compactness suggests that the material may be deposited in the lake as lacustrine facies. The thickness of the lacustrine facies reveals a long phase of valley ponding. This deposition of lacustrine facies seems to be an extension of the lake discussed in ***section 1***. The microscopic analysis reveals that material is sub-angular to sub rounded suggesting re-deposited grains of silt from moraine by slow moving stream in the lake during a cold phase.

As discussed earlier that during a cold glacial phase the physical disintegration of the surrounding mountains by freeze/thaw action produces regoliths. This material was released with the change in climate and was deposited as fan gravels. The lithology

(Slate, limestone and sandstone) and angularity suggests local origin of the sediment. The shape analysis shows that the clast is predominantly equant 50 %, which suggest that the stream was fast flowing stream. Because of high velocity of stream the material was not settled down and they remained in the state of motion till they were finally deposited.

Just like other sections of the study area this section is also overlying by a thick deposits of unstratified silty material. The material is referred as loess by Kamp and Heserdot 1999. The material is seem to be derived from moraine in the glacial phase, and was redeposited by wind in the subsequent inter glacial phase.

The scanning electron microscopy reveals that most of constituent's grain is angular to sub-angular with sharp edges and corners. The surface features identified were scratches, dish shape concavities which reveal that the silt may be the result of freeze-thaw stress in cold mountain environment.

Mineralogically it comprises detrital grains of quartz, feldspar, muscovite and amphibolites etc. derived from a granitic source and chlorite derived a metamorphic source (Owen 1988).

The formation of silt has given rise to much debate over the past 150 years particularly with regards to its part in the formation and distribution of loess (Smalley and Smalley 1983). Many workers have proposed that silt is produced in large quantities by the process of "glacial grinding" (Smalley 1966, Vita-Finzi and Smalley 1970). This view is also supported by Boulton (1978) on the basis of his work on the distribution of glacial debris and its formation within glaciers. Other believe that abrasion by aeolian action is more important (Whalley et al. 1982).

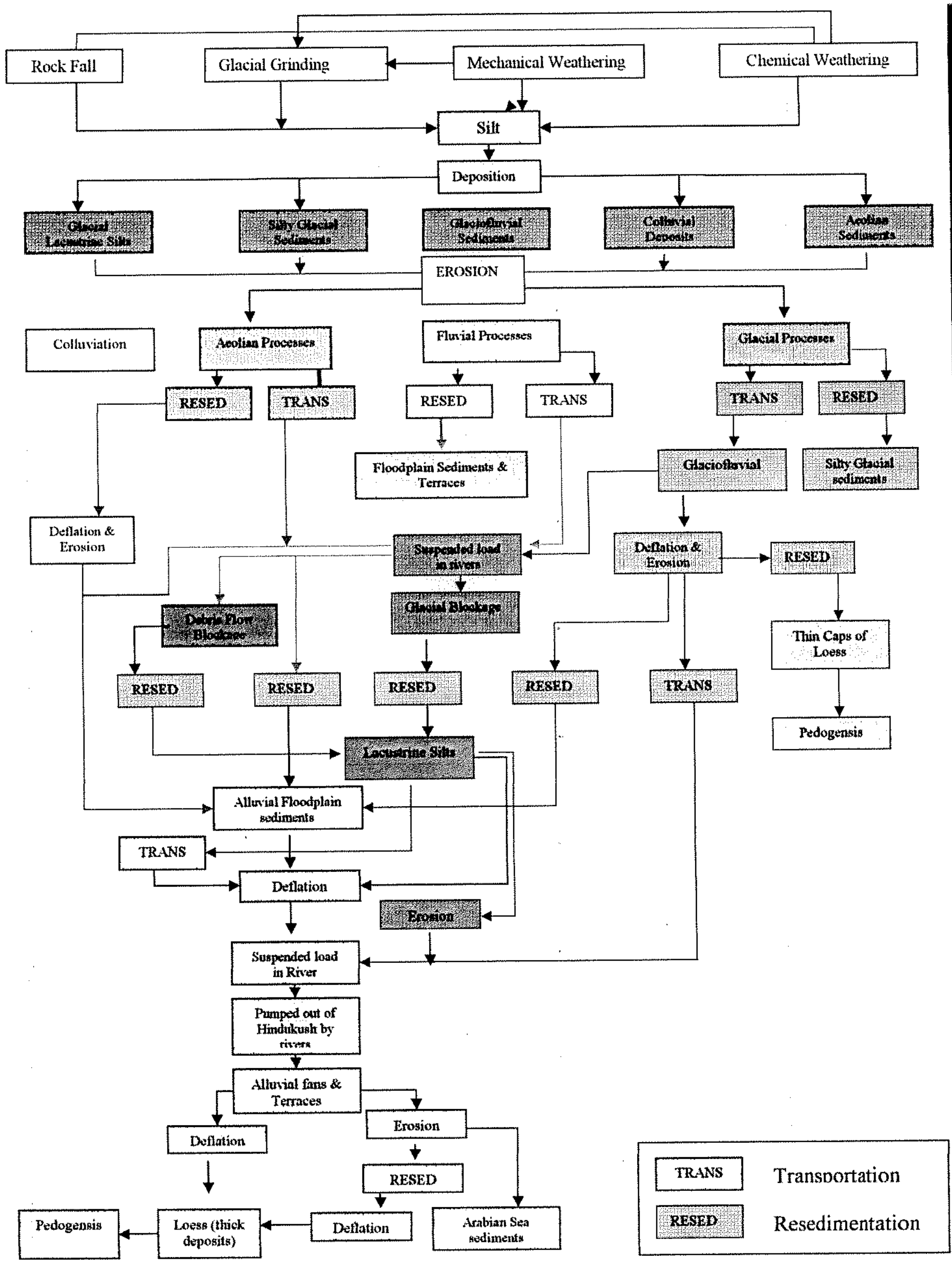
Chemical weathering of weak minerals and fragmentation of quartz by chemical dissolution may produce large quantities of silt (Nahon and Trompette 1982). The experimental work of Goudie et al. (1979) on salt (Sodium sulphate) weathering showed that sand grain breakages in quartz produce silt, Pye and Sperling (1983) supported the view that this would provide a source loess size particles. Frost shattering is important process in cold mountain areas and may be responsible for silt formation (Zeuner 1949 and Brockie 1973). Palmer (1982) stated that high energy rivers are capable of producing loess-size particles.

The formation of silt in Hindukush muntains is not simple and involves most of the processes discussed above. Glacial grinding produces large quantities of silt. Silt may also be produced by chemical weathering and freeze thaw action. Whalley (1984a) showed that these processes produce a "grus" made up of sand and silt size particles. Beside in rockfall the material is broken up into silt size grains. Abrasion occurred during aeolian transport also responsible for the formation of silt grains. The common katabatic winds carrying silts and sands down the valleys. During this transportation some of the silt may deposits within the mountains (Owen et al 1992). This process also results in the formation of large sand dunes on some of the floodplains and terraces. The rivers may also produce large quantities of silt by abrasion in a manner that describe by Palmer (1982) in New Zealand.

From the above discussion it is evident that a number of processes are available within the mountain environment capable of producing silt. These processes are summarized in the flow diagram which also shows a complex cycle of erosion and resedimentation of silt in this system.

Following its generation, silt may be deposited as sand dunes, glacio-fluvial, glacial, fluvial, colluvial or grus sediment. Alternatively it may be transported by rivers. The glaciolacustrine silts from an early generation of silt, which may then be eroded by fluvial processes and carried way by rivers, deflated by aeolian processes. Loess may be formed following aeolian deposition.

Summary of the important events, recorded in the section:



Flow Chart Showing the Cycle of Silt Transportation and Deposition in Mountain Environment. (Modified from Owen 1988)

1. The deposition of angular gravels by Dalamut gol in the depression ***(Bed a),*** a phase of fan formation.
2. Blocking of Chitral river and the formation of lake in the valley.
3. Sedimentation of siltstone in the lake forming ***bed b***.
4. A subsequent phase of erosion of fan gravels. Differential erosion of bedded siltstone resulting in a wavy surface.
5. The release of weathered material and its deposition in the foothills. A second phase of the deposition of fan material over siltstone ***(Bed c).***
6. The deposition of loess ***(Bed d).***

6.4. Section No. 3

6.4.1. Field description

This section exposed in Dalamut sequence, is located in Dalamut gol, some 5 kilometers north of Chitral town at a height of 270-m ACR (GR. 762191-38-M/13). The section is composed of three different types of deposits. The order of deposits from base to top is as follows: **(Figure 6.4.1)**

Bed a:

The lower bed in this section is occupied by 1.5-m thick deposit of angular fan gravel of slate, Shale and green schist.

Bed b:

Bed ***b*** is a 4-m thick bed of silt /sand. It is composed of alternative beds of fine, medium, coarse silt and sand. The material is stratified, with nicely preserved limination. The lowest bed exhibits cross-bedding, with small angular quartz and slate gravels. The material is poorly cemented and can be scratched with a hammer. A sample for size analysis has been collected from this bed.

Bed c:

Bed ***c*** is a 2.5-m thick layer of semi-rounded to rounded gravels, embedded in a coarse pebbly (mostly granite) matrix. The clast is predominantly granite, with large size gravels of occasional slate and sandstone. The material is poorly consolidated and unstratified.

Bed d:

It is composed of 2-m thick bed of very coarse sand. The material is stratified with beautifully preserved horizontal liminatation upto 1 cm thick. It is weakly consolidated and exhibits quartz pebbles.

Bed e:

Bed ***d*** is overlain by a 5-m thick layer of yellowish colour loess. The material is compact and can only be scratchable with hammer. It has abundant limestone concretions.

6.4.2. Laboratory examination

6.4.2a. Texture

Bed b

It is composed of 28% fine silt, 42% medium silt , 30% fine sand.

6.4.2b. Roundness Analysis:

Bed c

10% of the gravels are angular, 20% sub-angular, 46% sub-rounded and 24% rounded. Well-grounded gravel are not found. (**Figure 6.4.3)**

Figure 6.4.3

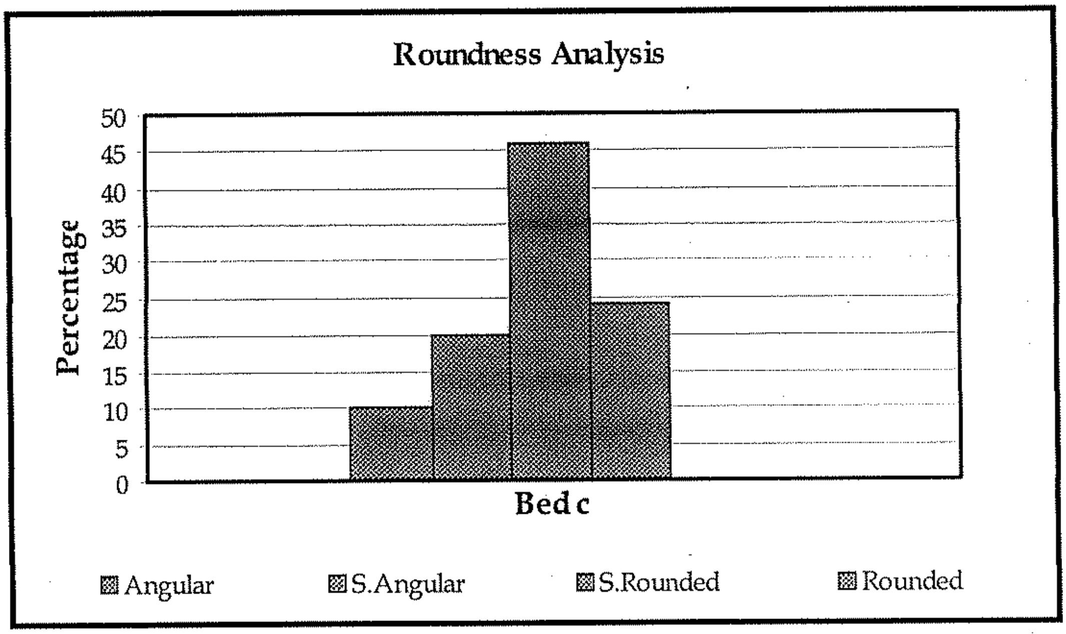


Figure 6.4.1

Stratigraphic Section No. 3
Dalamut Gol (GR. 762191-38 M/13)

Thickness	Bed No.	Profile	Characteristics		Sample
			Colour	Lithology & structure	
05m	*e*		*Yellow* *10YR 6/3*	*Loess*	
02m	*d*			Very coarse sand; the material is stratified with distinct horizontal laminations showing slight compaction.	
2.5m	*c*			Small size rounded to sub-rounded gravels, embeded in a coarse pebbly matrix. Granite fragments with occasional slate and sandstone gravels are incorporated. The material is weakly consolidated and unstratified.	◍
04m	*b*			Papery laminated alternate beds of silt and medium, coarse and very coase sand. Sandy layer contains angular quartz gravels.	◍
1.5m	*a*			Medium-size sub-angular to angular rock gravels	

● Sample for roundness and shape analysis.

◍ Sample for size analysis.

Section No. 3

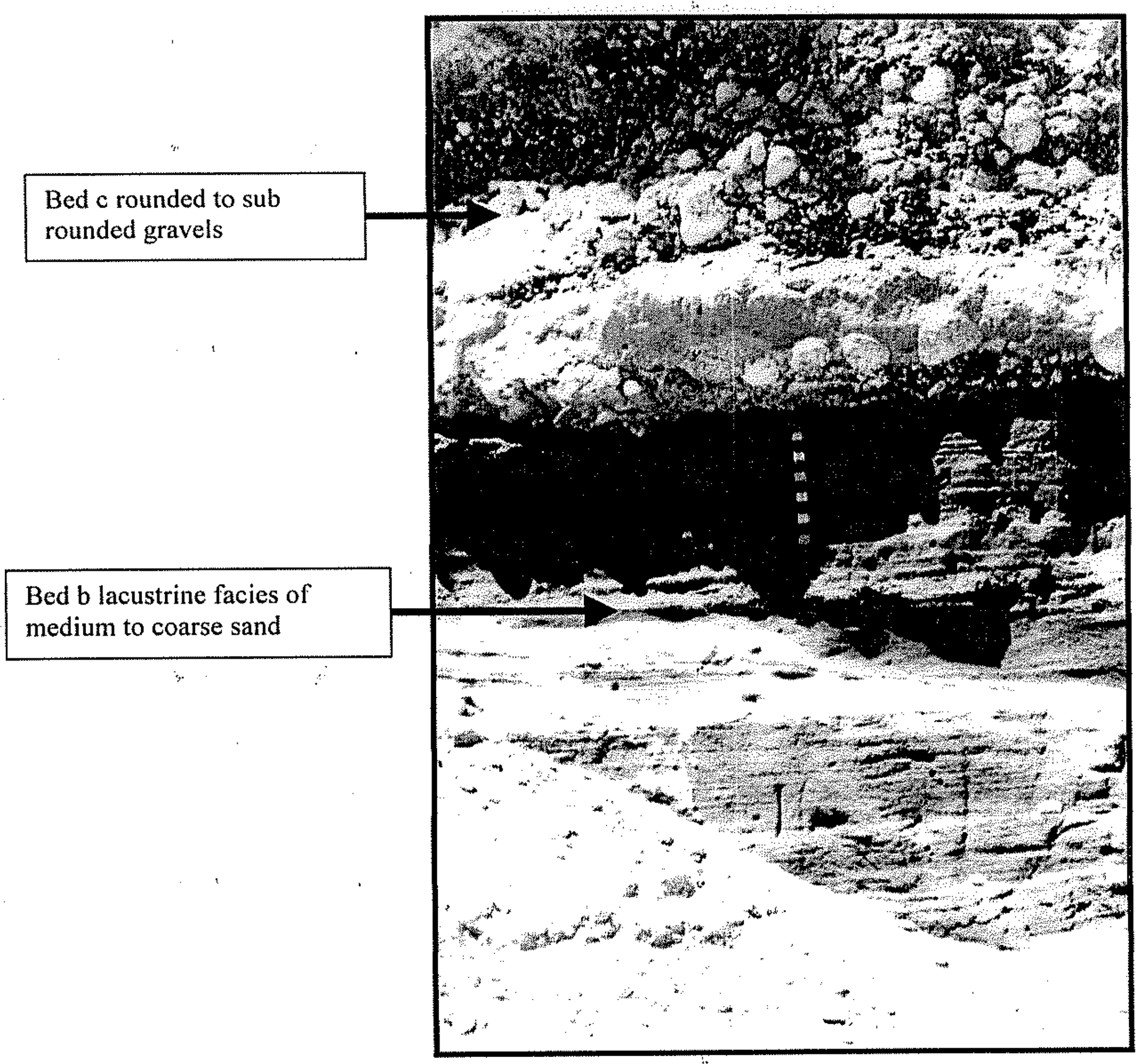
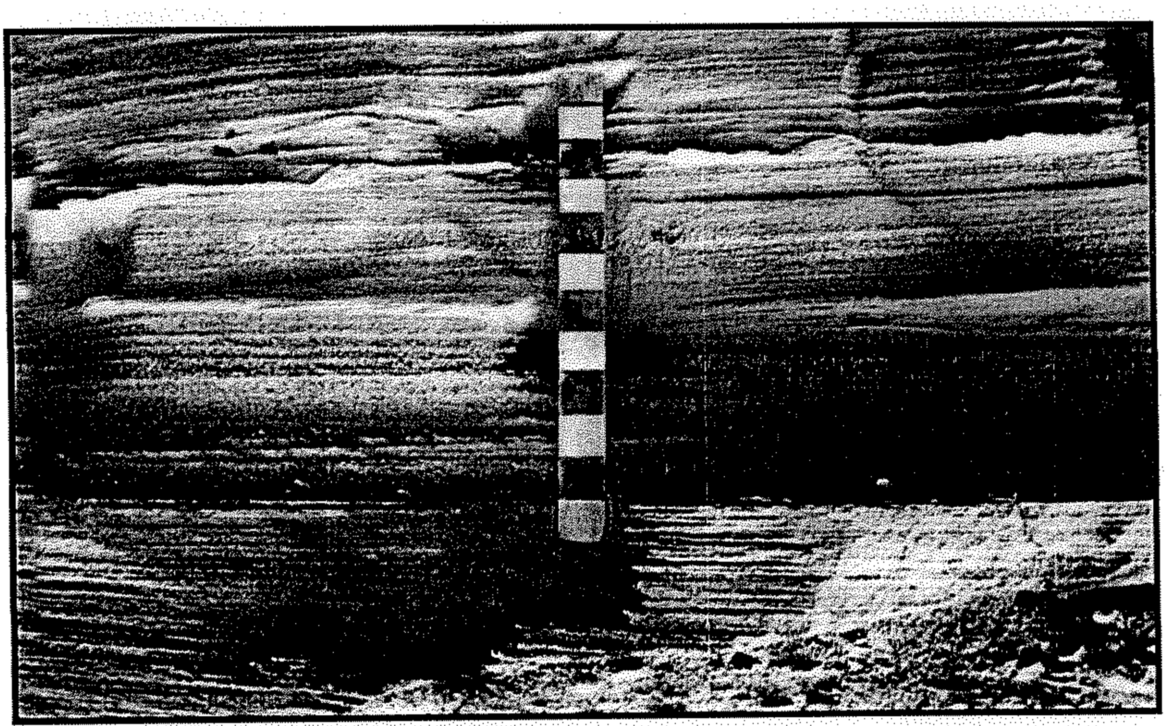


Plate 6.4.1 A view of section No. 3 exposed on the left bank of Dalamut gol. From base to top three different layers of deposits are exposed. The photograph shows bed ***b*** ***(lower)*** and bed ***c*** ***(upper)*** of the section.



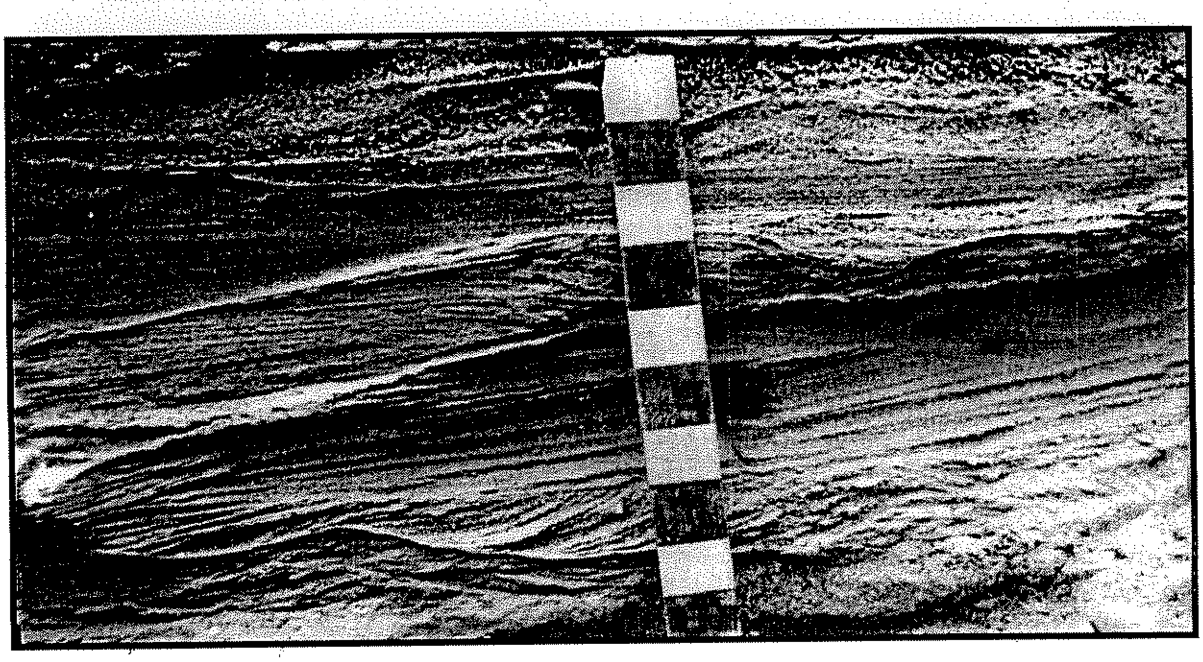
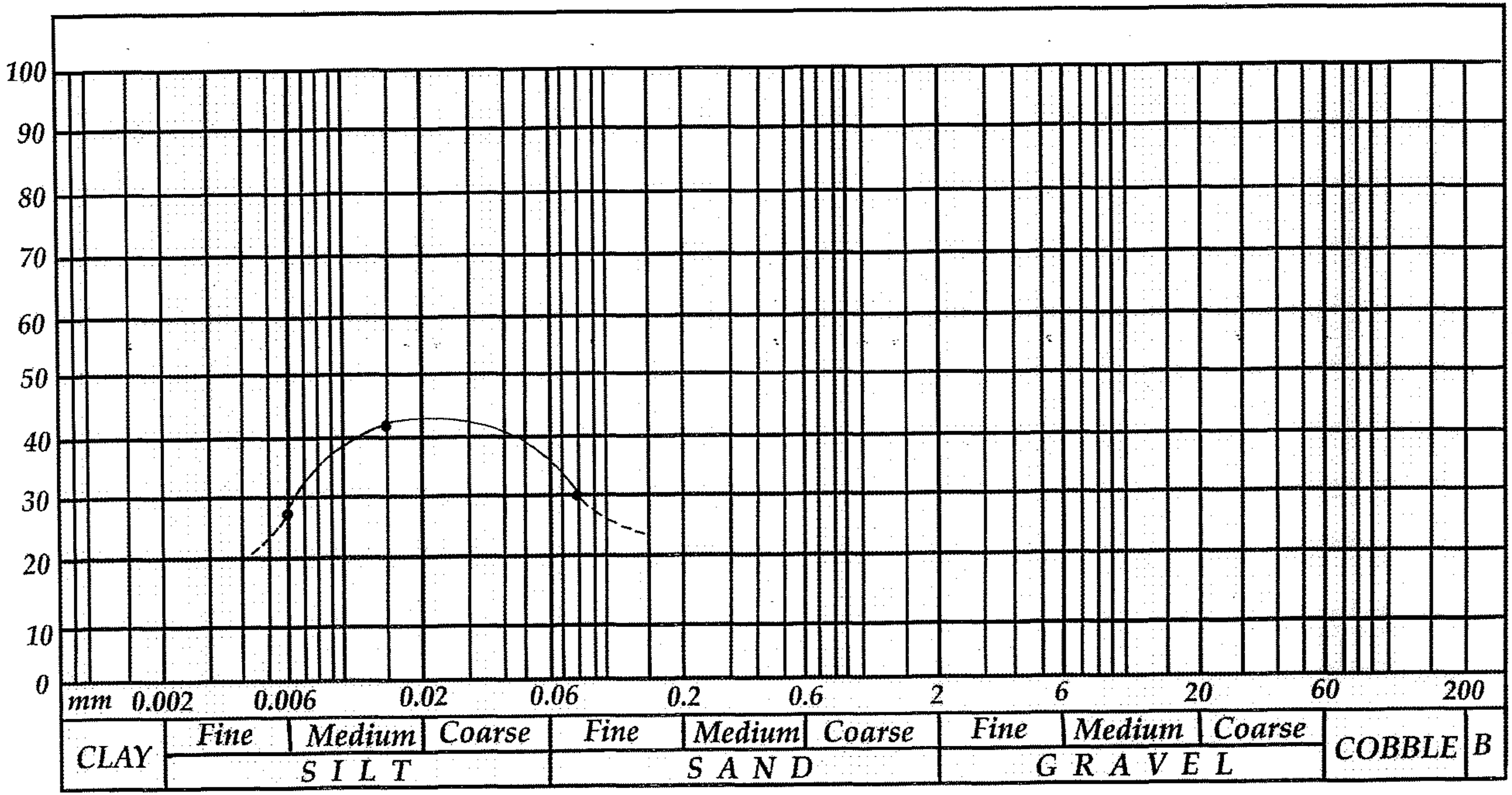


Plate 6.4.2. Section 3 , showing bed b, a 2-m thick bed of coarse sand with beautifully preserved horizontal liminations. The lower photograph shows cross bedding structure of bed d of section 3.

Figure No. 6.4.2
Section No. 3
Partical Size Distribution

Location: Dalamut Gol

Bed No. a



M. Jamal Nasir

6.4.3c. **Scanning Electron Microscopy**

Bed d

The sand grain from bed d was examined with scanning electron microscope. The grain was magnified 500 times. Most of the grains studies under microscope were angular to sub angular.

Plate 6.4.4 Scanning electron microscopic picture of sand grain from bed d.

Bed e:

The grain from loessic silt was examined with the help of scanning electron microscope. The grains were magnified 1500 times. (Plate 6.4.3). The textural features identified were scratches, cavities with sharp edges and corners.

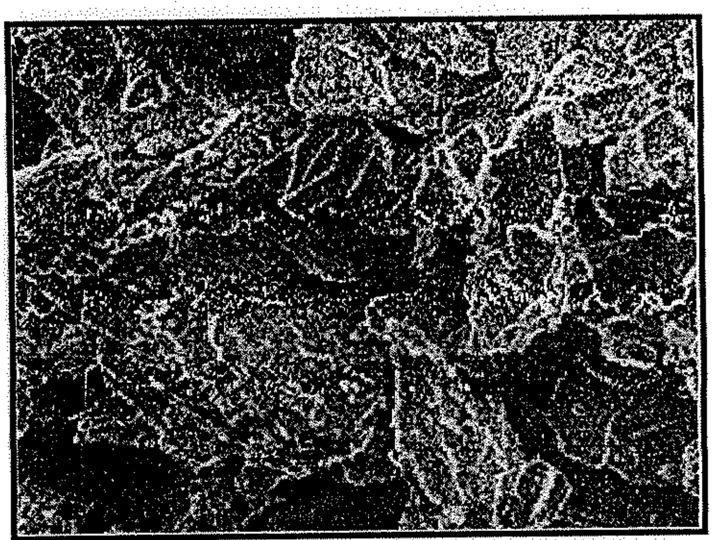


Plate 6.4.3. Micrograph of loessic silt grain from bed e

6.4.3d. Mineralogical composition

The sand in bed d is composed of quartz 29%, feldspars 22% muscovite 16%, amphibole 14% clay 10% Chlorite 6% pegmatite and the accessory minerals of limonite, haematite and epidote etc less than 3%. Mineralogical composition reveals that the sand has been mainly derived from various types of igneous, metamorphic and sedimentary rocks.

Discussion

The angular gravels deposited in ***Bed a*** of this section is lithologically very similar to the material in ***Bed a*** of ***section no.1.*** The angularity of the sediment and faint stratification suggest an alluvial fan facies.

The deposition of lenses of fine, medium and coarse sand in ***bed b*** indicates that these are "still water deposition" of a lacustrine facies of the Chitral river. The alternation of the fine to medium sand indicates fluctuating energy level of the medium. (Leopold et al 1964). The laboratory examination of the material indicate the predominance of fine to medium silt suggests that the river was slow moving which could only transport fine to medium silt and sand. While the deposition of coarse sand suggest the occasional changes in regime of river from slow to fast and turbulent conditions which may be the result of seasonal changes.

The overlaying ***bed c*** is a 2.5 meter thick layer of sub-rounded to rounded gravels. The deposition of rounded gravels of granites and occasional sandstone suggest a change in the depositional environment. It could be understandable, the onset of an interglacial phase probably increase the discharge of the river. The turbulent river Chitral transported gravels and deposited over the sand bed. The predominance of the Sub-rounded to rounded gravels (46% Sub-rounded and 24 % rounded ***figure 6.4.3***) suggest a long phase of transportation, during which the material become rounded. The deposition of ***bed d*** suggests a warm inter-glacial, when the rapid melting of the glacial ice exposed the morainic debris. The abundant supply of glacio-fluvial material resulted in an increase of the bed load of the Chitral river. The channels become widens and the channels bars were formed leading to a braiding. (Schumn 1973 and 1985)

The deposition of the coarse sand in ***bed d*** is again indicating a short change in the depositional environment. With the onset of a glacial phase the discharge of river may be decrease and it could be only transport coarse sand. The beautiful laminations indicate a low energy sate of the depositional medium. The presence of the quartz pebbles indicates the foreign origin of the sediment.

The scanning electron microscopy and mineralogy of sediment in bed d reveals that the material has been derived from the disintegration of massive plutonic granitoid rocks in the upper Hindukush valleys I.e. Laspur, Yarkhun and Garamchashma etc. However, the proximate source of the material is the morainic sediments lying in the valleys. The sediment have been transported by fluvial processes and deposited in the down valley.

The deposition of loess as bed e with its yellowish colour indicates a warm and semi-dry environment. The wind which was blowing over the morainic material picks up the clayey particles and on decrease in the energy level deposits the sediments. (Allen 1964, Kamp, 1999 & Owen et al 1992).

The summary of important events recorded in the section:

1. The deposition of angular to sub-angular gravels and a subsequent phase of fan formation (***Bed a).***
2. Blocking of Chitral river and the formation of lake in the valley.
3. Sedimentation of laminated silts / sand in the lake ***bed b.***
4. A subsequent phase of erosion of fan gravels, and erosion of fan material.
5. A second phase of deposition of small sized rounded gravels ***(Bed c).***
6. The deposition of thick bedded coarse sand by river and its compaction into sandstone with the passage of time ***(Bed d).***
7. The change of climate from cold and humid to hot and dry and the deposition of loess ***(Bed e).***

6.5. Section No. 4

6.5.1. Field description

This section is exposed on the left side of Chitral–Drosh road, at a distance of 5–6 km downstream from Chitral town at Bakarabad at a height of about 60-m ACR (GR 733082, 38M/13). This section exposes the deposit of Bakerabad-Jughure terrace sequence. A variety of deposits have been exposed in the section. **(Figure 6.5.1)**

Bed a:

Bed a is a 3 meter thick facies, composed of pale-yellow (5y 7/4), thinly bedded siltstone. It has a cm thick horizontal layers. Numerous burrows, about a centimeter in diameter, have also been examined in the material. The material is soft and easily scratchable and occasionally it is crossed by vertical crakes. The material is breaks into platy structure. The bed had been severely eroded and the detached material can be seen at the foot of the exposure.

Bed b:

Bed ***b*** is a 01-m thick deposit of angular to sub-angular material, locally derived rock gravels, ranging in size from 8 cm to 30–35 cm. Lithologically, the material is composed of sandstone, slate, shale, quartz and granite. The material is unsorted, unstratified and embedded in coarse sand and pebble matrix. The clast is easily detached from bed

Bed c:

The bed ***c*** is composed of light grey (2.5Y 7/2) coarse sand, with a maximum thickness of 0.5-m, incorporating occasional small gravels of quartz and slate. The material is compact and unstratified and hard to break even with a hammer.

Bed d:

Bed ***d*** is a 3-m thick bed, composed of small to medium size river gravels, ranging in size from 2 cm to 10 cm medium size gravels. The material is poorly sorted, unstratified and firmly embedded in dark matrix of fine grevels and very coarse sandy, pebbly matrix .The clast is predominantly metamorphic i.e. sandstone, slate, granite etc.

Bed e:

It is composed of 0.8 meter thick bed of coarse sand light grey (2.5Y 7/2) deposit. The material is hard and gives a faint impression of stratification.

Bed f:

Bed ***f*** is a 1.5-m thick bed of medium to large-size, rounded gravels of mixed lithology. Its material is unsorted and unstratified, and embedded in coarse sandy-pebbly matrix.

Bed g:

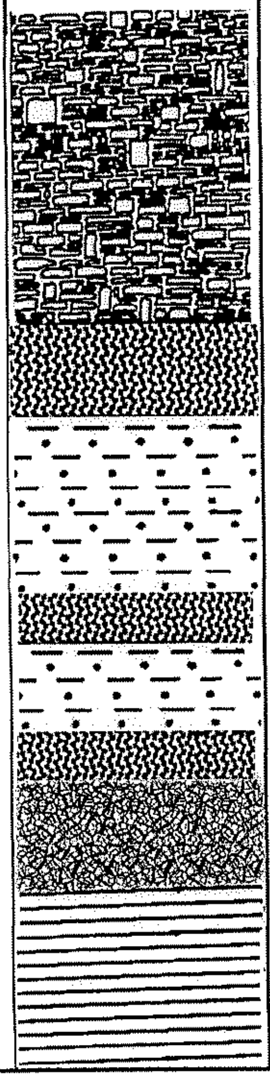
The bed is composed of medium to coarse size, light grey (2.5Y 7/2), bedded sandstone. It has a maximum thickness of about 1.5-meter. It is very hard and cannot be easily broken even with a hammer. The bed exhibits small circular root holes, about a centimeter in diameter.

Bed h

The bed consists of about 5-m thick deposit of angular to very angular, locally derived slate gravels, ranging in size of from a few cm to 30-cm. The material gives a faint impression of stratification. It is hard, and embedded in coarse pebbly-clayey matrix.

Figure No. 6.5.1

Stratigraphic Section No. 4
Bakarabad (GR. 733082 - 38 M/13)



Thickness	Bed No.	Profile	Characteristics		Sample
			Colour	Lithology & structure	
05m	h			Very angular to angular gravels , ranging from few cm to 30 cm in size. Embedded in coarse pebbly clayey matrix. The bed shows a faint stratification.	●
1.5m	g		2.5Y7/2	Medium to coarse sandstone, compact and hard contains cavities with a cm diameter.	
1.5m	f			Medium to large size rounded to sub-rounded gravels, that are embedded in coarse sandy pebbly matrix; unsorted and unstratified.	
0.8m	e		2.5Y7/2	Coarse sand; hard, gives a faint impression of stratification.	◍
01m	d			Small to medium size, rounded to sub-rounded gravels, ranging in size from 2 to 10 cm diameter. The gravels are embedded in coarse sandy to pebbly matrix. The clast is predominantly metamorphic.	●
0.5m	c		2.5Y7/2	Coarse sand with small fragments of quartz; generally compact.	
01m	b			Large size gravels, 8-35 cm in size composed of slate, shale and quartz fragments; unsorted and unstratified. The material is embedded in sand pebbly matrix.	
03m	a		Pale yellow 5Y7/4	Lacustrine facies, composed of bedded silt stone horizontal layers of about a cm thick. The material is soft and heavily eroded.	◍

● Sample for roundness and shape analysis.

◍ Sample for size analysis.

Section No. 4

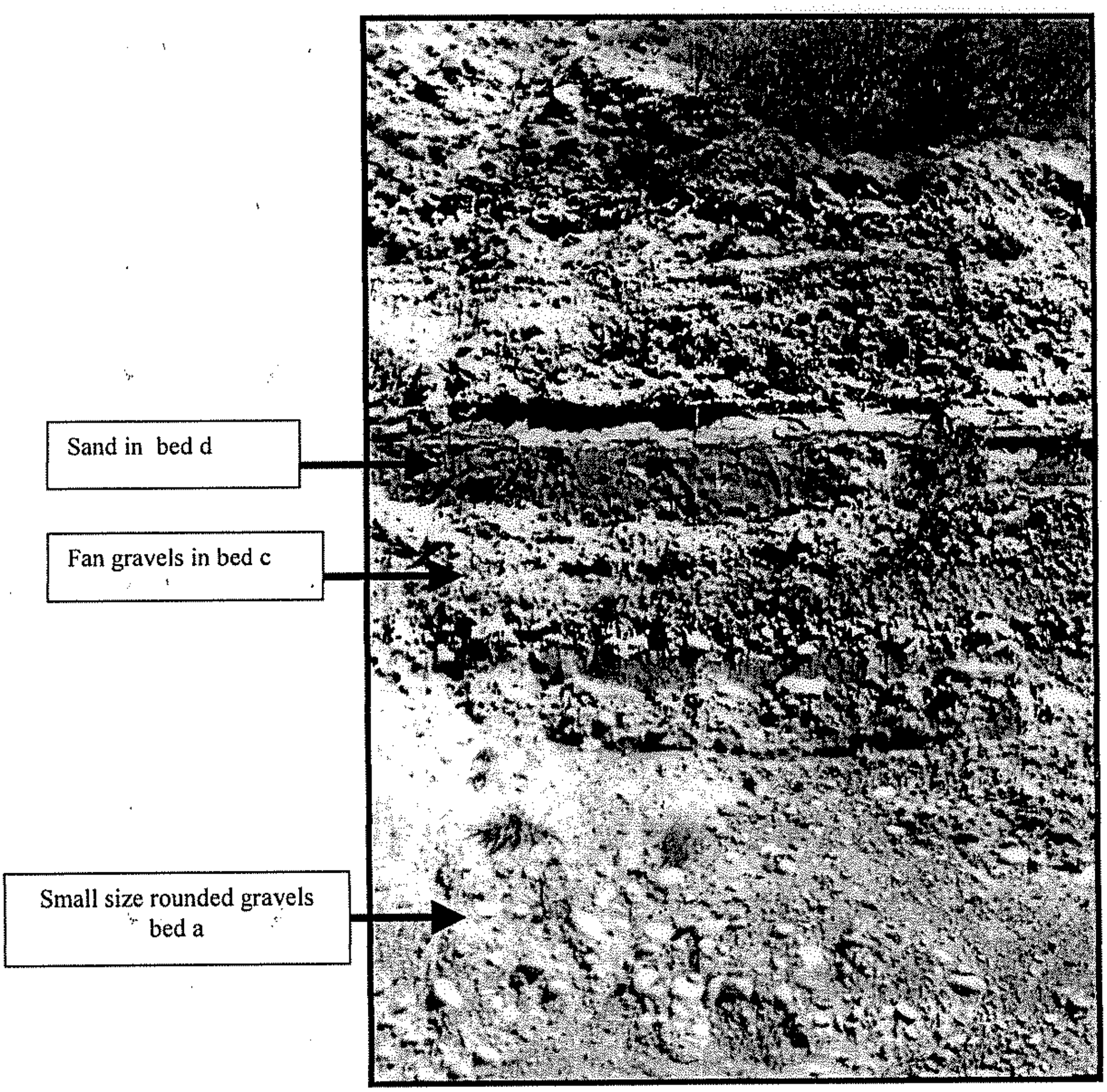


Plate 6.5.1. A general view of section No. 4.

Section No. 4

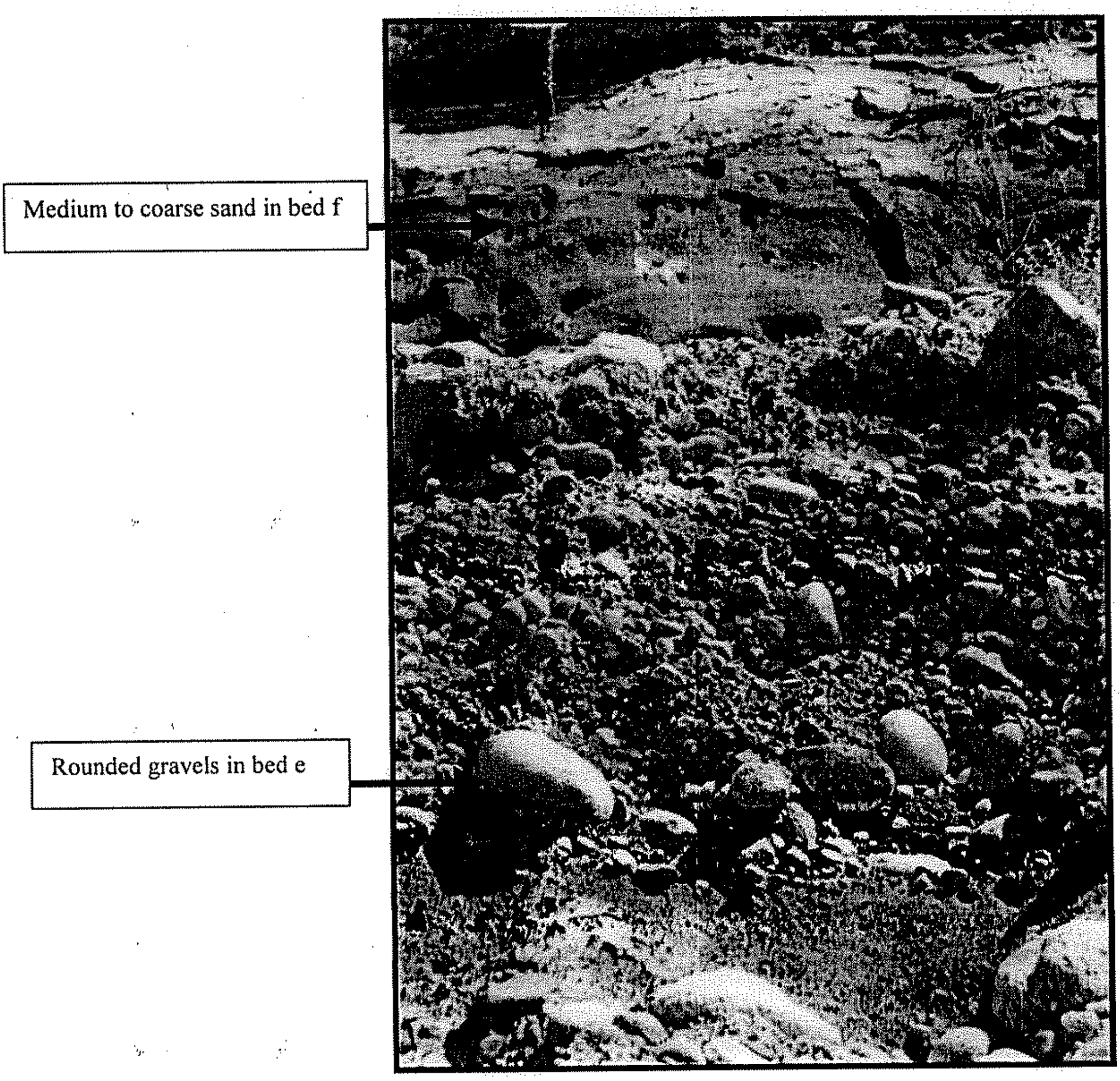


Plate 6.5.2. A closer view of beds e & f of section No. 4. The lower bed comprises medium to large size rounded to sub-rounded river gravels. The upper bed is composed of light-gray bedded siltstone.

6.5.2. Laboratory examination

6.5.2a. Roundness analysis:

Bed. b

Bed ***b*** shows that 30% of the material is angular, 35% sub-angular, 25% sub-rounded and 10% rounded. It is conspicuous by the absence of well-rounded gravels. **(Figure 6.5.2.)**

05% of the gravels are angular, 15% sub-angular, 40% sub-rounded and 40% rounded. **(Figure 6.5.3)**

Roundness analysis of bed ***f*** show that 20% of the material is angular, 15% sub-angular, 30% sub-rounded and 35% rounded. Well-rounded gravels are missing. **(Figure 6.5.4.)**

Roundness analysis of bed ***h*** show that 20% of the gravels are very angular, 30% angular, 25% sub-angular, 20% sub-rounded and 05% rounded. Well-rounded gravels are not present. **(Figure 6.5.5.)**

6.5.2b. Shape analysis

Bed h:

Shape analysis reveals that 40% of the clasts in bed ***i*** are equant, 35% oblate, 20% bladed and remaining 5% are classified as Prolate. **(Figure. 6.5.6.)**

Figure 6.5.2
Roundness Analysis

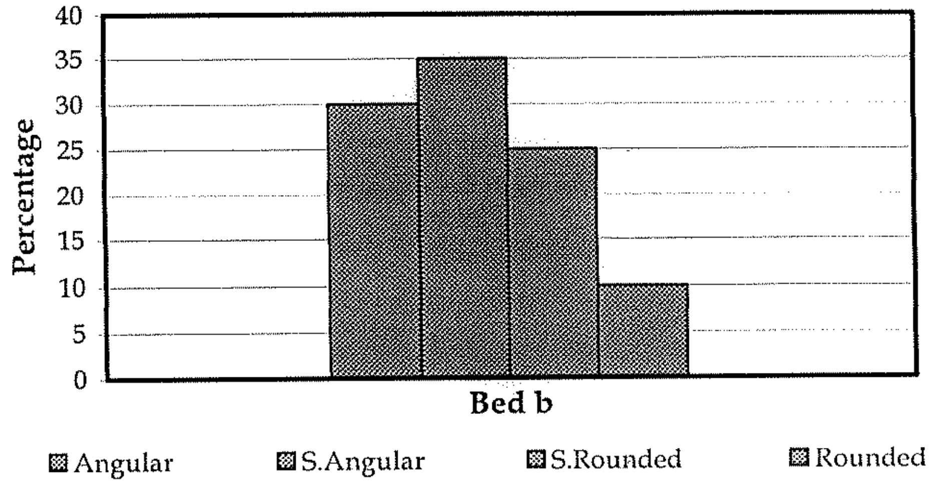
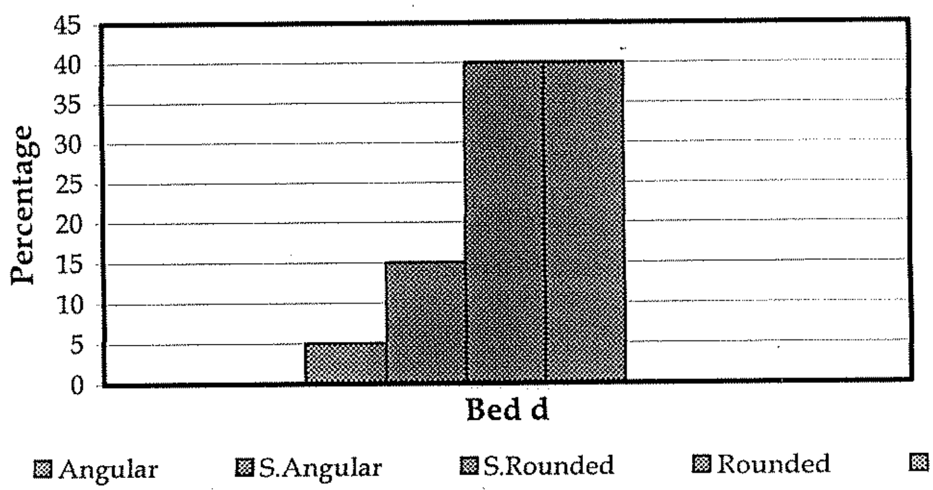


Figure 6.5.3
Roundness Analysis



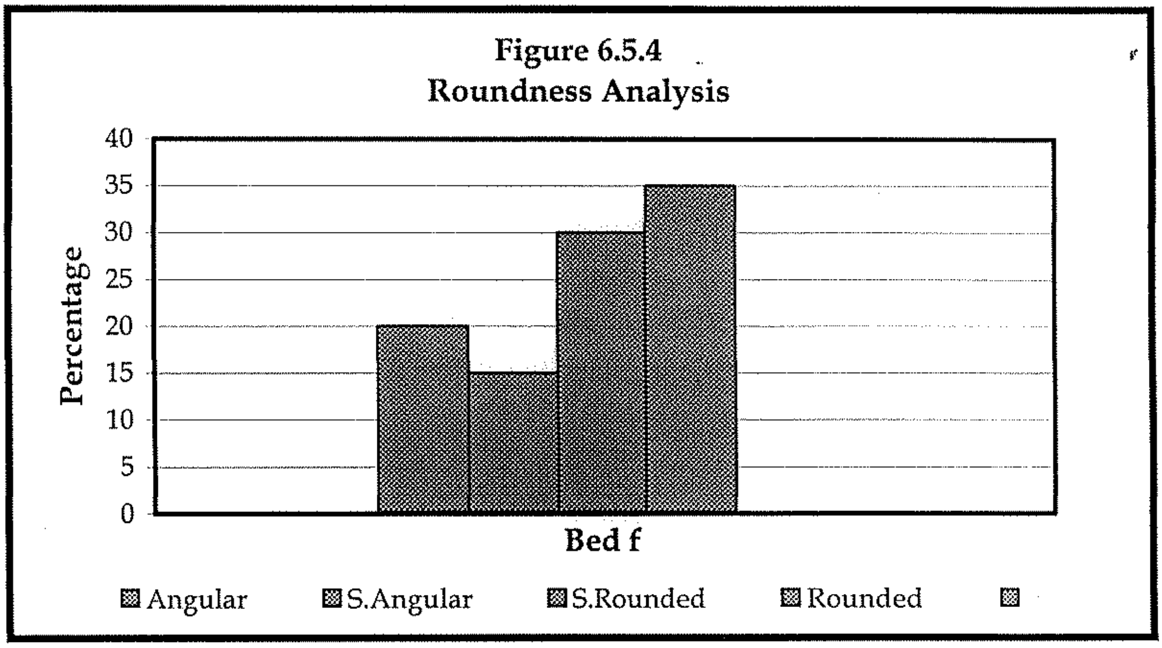


Figure 6.5.4
Roundness Analysis
40
35
30
25
20
15
10
5
0
Percentage
Bed f
Angular
S.Angular
S.Rounded
Rounded

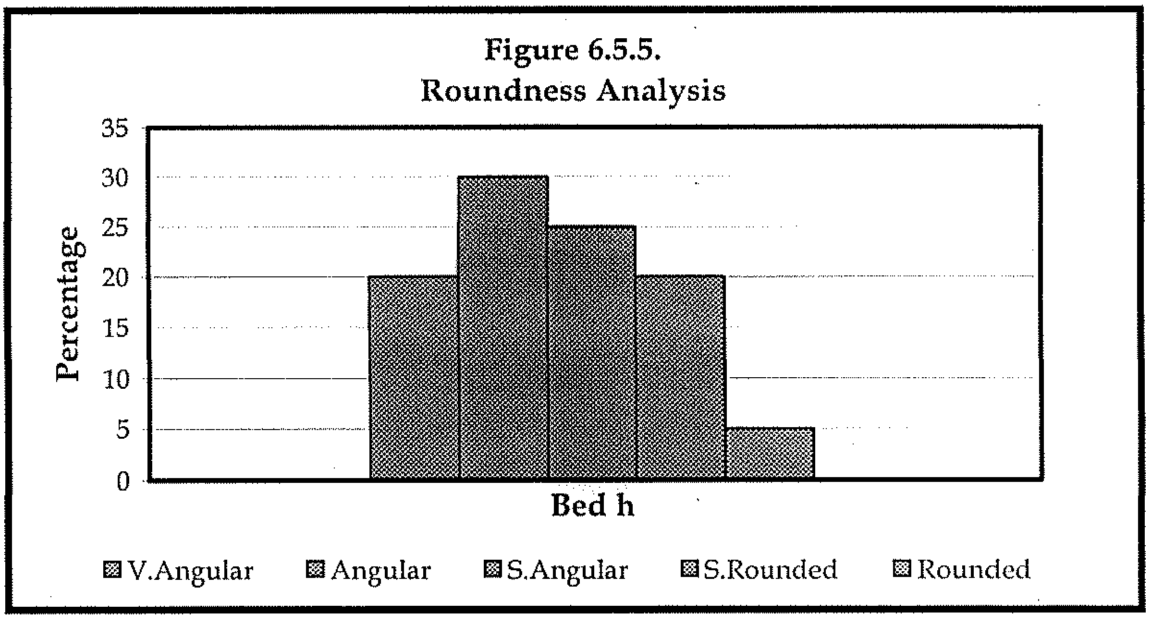


Figure 6.5.5.
Roundness Analysis
35
30
25
20
15
10
5
0
Percentage
Bed h
V.Angular
Angular
S.Angular
S.Rounded
Rounded

Discussion

Bed ***a*** is 3m thick bed of thinly bedded siltstone and claystone. Lithologically it is very similar to the lake beds exposed in section 1,2and 3. The deposition of stray lenses of small grevels of granite and gneiss with coarse micaceous sand within the bed suggests that these have been derived from the upper catchment area of river Chitral. Fine lamination, the micro ripple and the thickness of layer suggests that sometime the lake was shallow and its level was slowly fluctuating in different climatic conditions. Field examinations and the literature suggests that the material has been derived from the erosion of the moronic material produced during the Pleistocene period from the area north and west of Chitral. The angularity and sub angularity of the grain of siltstone indicates that beside fluvio-glacial sand and silt, a considerable part of the silt has been deposited directly in the lake as "wind blown loessic silt". The presence of burrows and small worm holes indicates that probably the deposition of loessic silt, the lake might have been filled and boggy and marshy conditions prevailed. The presence of only fine worm holes suggests that only small worms and their larvae could survive in such environment. (Hasan 1995, Owen 1996).

Bed ***b*** is a meter thick bed of angular to sub angular rock fragment of slate, shale, quartz etc. Due to change in environment from hot and humid to cold and dry the physical disintegration of slate, quartz and sandstone took place over the surrounding mountains due to intense frost action (Briggs, 1977), but the material was not released by the slope because it was frost jammed (King 1975).With a change of climate to worm and wet, the slope begin to release the debris, triggering the mountain torrent to deposits its material in the form of alluvial fan. Therefore the bed c and bed d have been recognized as the various facies of the alluvial fans which have been deposited by the torrent in different phases. It seems that the torrent picked up the weathered material, released by mountain slopes, reworked it and deposited. The angularity of the material (65% angular to sub-angular Figure 6.5.3) suggests that material is of local origin

The bed ***c*** with its sandy texture and massive structure, having a sharp and distinct contact with the underlying bed b, suggest that it may have been deposited as a facies of channel deposit. The occasional small gravels of quartz and granite suggest that the sediment is probably transported from the same provenance. The bed is only .5m thick which suggests a short period of depositional environment, which is probably the extension of the same depositional environment in which the bed ***a*** is deposited. This marks the end of this interglacial period.

The upper bed of this section is a 3 meter thick bed of small to medium size sub-rounded to round gravels of Sandstone, Slate and granite (40% sub-rounded and 40% rounded) The roundness of the material suggest that material is probably transported from the upper catchment area of Chitral river.

The material is seem to be originally deposited by glaciers in the upper Chitral in probably cold glacial climate. With a change of climate to warm and wet the glaciers begin to retreat. The glacier melt water together with rain water picked up the material originally deposited by glaciers, transport it. During the process of transportation the angular rock gravels were rounded down and on decrease in energy of water they were deposited.

Bed ***e*** and bed ***f*** and ***g*** are seem to be deposited in the same depositional environment. The alternation of deposits indicates the short changes in the velocity of water. At one time the melt water of glaciers increases the discharge of rivers. This could probably change the river behavior, and it behaves like a high energy stream which could transport gravels and occasional boulder, and deposit them over the torrent gravels. The predominance of sub-rounded to rounded gravels and presence of granite, amphibole, gneiss and limestone is the indicator of foreign origin of the gravels.

When the velocity of water decreased this time the river could only transport sand and deposited as bed g.

The overlaying ***bed h*** is a thick layer of very angular material. The predominance of angular material (20 % very angular, 30% angular and 25 % sub-angular) suggests a local origin of the sediment. The lithology of the sediment i.e. slate gravels also conformed this idea. The lithologic correlation of the bed suggests that they might be deposits as part of the older fan grevels deposited in last interglacial.

The section records the following events:-

1. A long phase of weathering and formation of a thick layer of regolith. The release of regolith with torrential rain and its deposition in the foothills, blocking Chitral river and forming a lake in the valley.
2. Deposition of siltstone in the lacustrine environment (***Bed a).***
3. A subsequent phase of erosion of fan gravels. Differential erosion of bedded siltstone resulting in a wavy surface.
4. Second phase of fan gravels deposition ***(Bed b)***
5. Deposition of thin bedded coarse sand ***(Bed c).***
6. The deposition of rounded gravels with interbedded sand lenses by Chitral river ***(Bed d and e).***
7. A second phase of deposition of large size river gravels ***(Bed f).***
8. Deposition of thick-bedded coarse sand, cemented into sandstone, ***(Bed g).***
9. A second phase of deposition of faintly stratified fan material over siltstone. The release of weathered material and its deposition along the foothills. ***(Bed h)***

6.6. Section No.5

6.6.1. Field description

This section is exposed along the right bank of Gumbaz gol at a height of about 6o-m ACR (GR 740990 38-M/14) near village Broz. It is in the form of a vertical cliff showing material with a maximum thickness of approximately 31-m. The following beds are exposed: (**Figure 6.6.1**)

Bed a:

Bed **a** is a 26 m thick, olive-grey (5Y 6/2) to light grey (2.5Y 7/2), material of locally derived shale and slate gravels, embedded in a clayey pebbly matrix. The clast is predominantly coarse, angular to sub-angular gravels, with considerable number of boulders and occasional rounded gravels. The material is generally unsorted, and in places exhibits horizontal layers.

Bed b:

It is 14-m thick, composed of very angular to subangular pebbles and gravels, embedded in a clayey matrix. It gives a faint impression of stratification. The deposit is too hard to be scratched with fingers.

6.6.2. Laboratory examination

6.6.2a. Roundness analysis

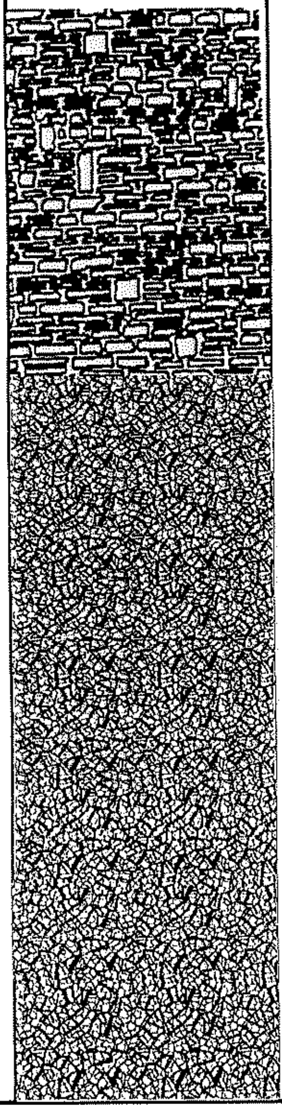
The bulk of material in ***a*** as well as in ***b*** is very-angular to angular, which suggests that the material is derived from the near by areas by Broz gol. 52% of the material is very angular, 20% angular and 18% sub-angular and only 10% sub-rounded **(Figure 6.6.2).**

6.6.2b. Shape analysis

Bed a:

The material of bed ***a*** and ***b*** were also examined for shape analysis. 68% of the material is equant, 22% oblate, and remaining 15% are bladed. **(Figure: 6.6.3)**

Figure No. 6.6.1
Stratigraphic Section No. 5
Broz Gol (GR. 748001 - 38 M/14)

Thickness	Bed No.	Profile	Characteristics		Sample
			Colour	Lithology & structure	
14m	*b*		*Light green*	The bed is composed of very angular to angular gravels embedded ina muddy matrix; poorly stratified.	●
27m	*a*		*Olive grey* 5Y6/2 & *Light grey* 2.5Y7/2	Thick bed of locally derived sandstone and slate gravels. The clasts are predominantly coarse angular to sub-angular, with occasional boulders and rounded gravels. The material is unsorted with rarely preserved localized stratification	●

● Sample for roundness and shape analysis.

● Sample for size analysis.

Section No. 5

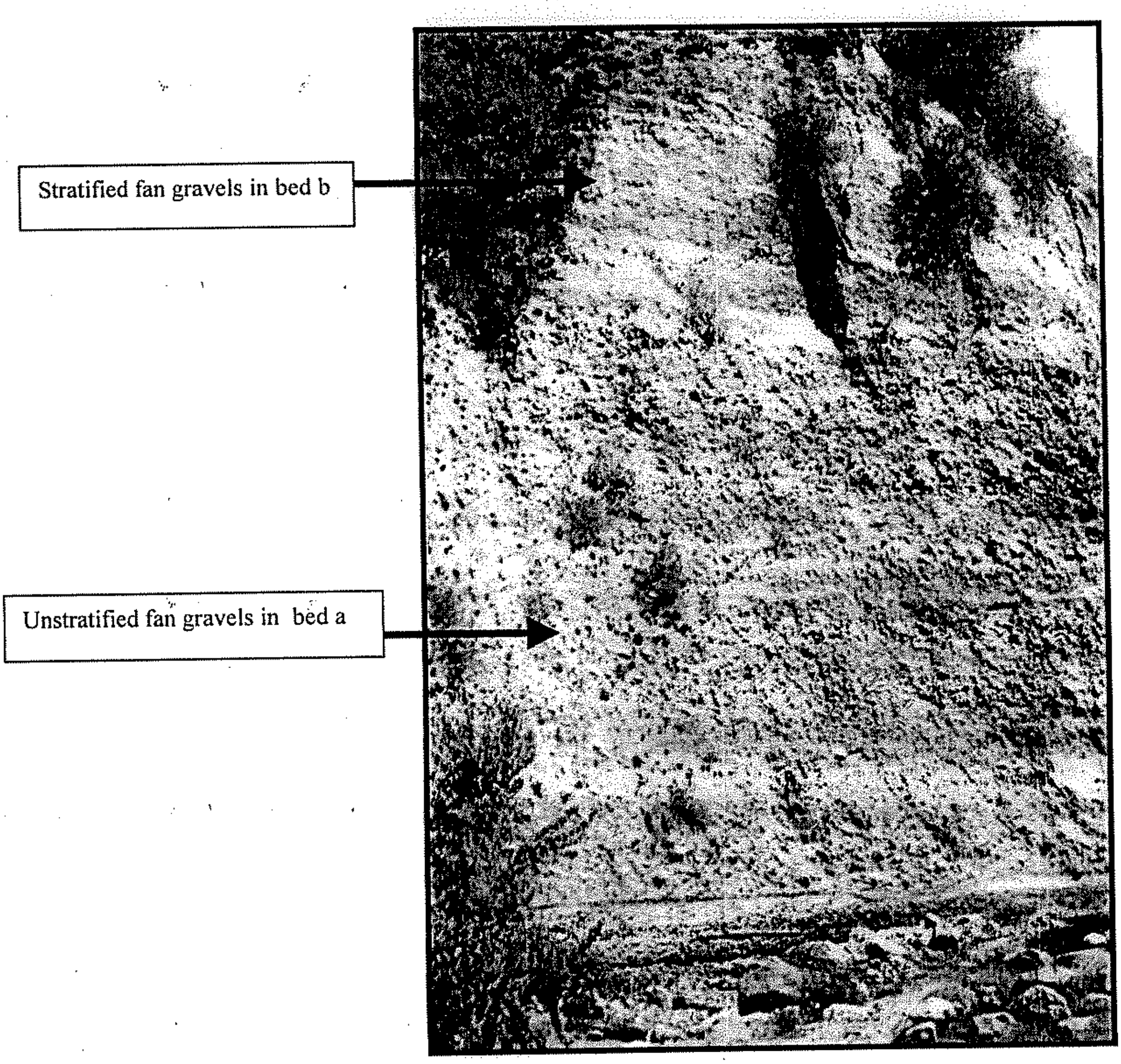


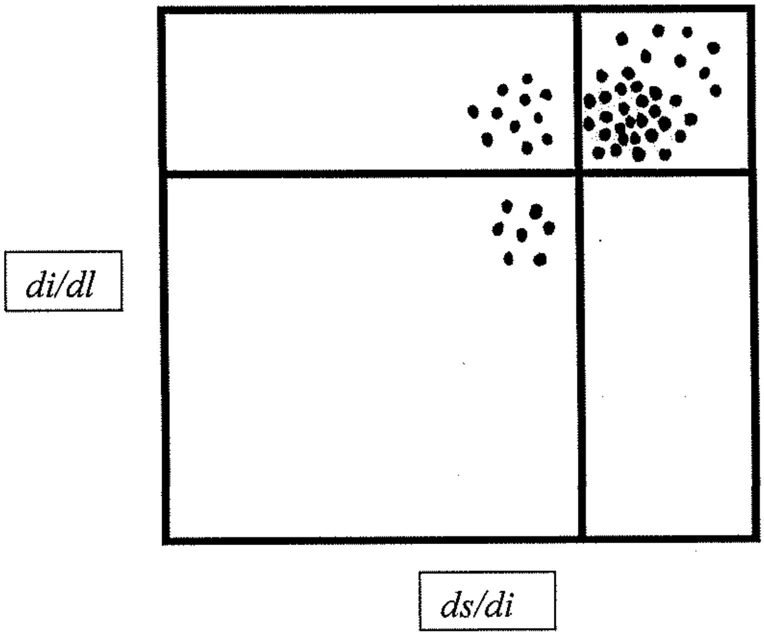
Plate 6.6.1. The section is exposed along the right bank of Gumbaz gol, near village Broz. The section is in the form of a vertical cliff with a maximum thickness of approximately 31-m., which comprises two different types of material.

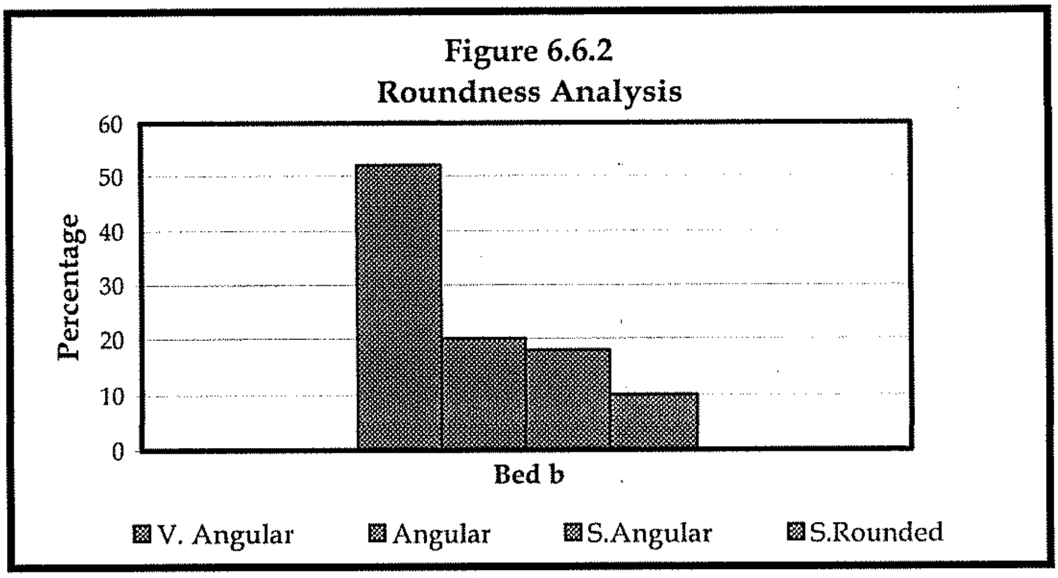
Section No. 5

Plate 6.6.2. A closer view of section No. 5. The lower bed ***a*** is a 27 m thick, olive-gray to light grey, fan gravels. The Upper bed *b* is about 14-m thick, which is composed of greenish very angular to subangular pebbles and gravels, embedded in a muddy matrix.. It gives a faint impression of stratification.

Figure 6.6.3

Shape analysis





Discussion

This section is very important because it record 40m thick deposits of alluvial facies. Thickness of the deposits indicates that during cold climate the slopes of mountains in the catchment area of Gumbaz gol are subject to intense frost action and repeated freeze and thaw, leading to mechanical disintegration of rocks. The cathchment area of Gumbaz gol is mostly composed of slate, shale, phyllite and limestone. These rocks are highly susceptible to frost weathering (Leopold et al, 1964, Ollier 1975, Gomez, 1996, Kamp 1999). Although a deep weathering zone was developed due the physical weathering but due to freezing temperature the weathered material, however was frost jammed (King 1975).

This was followed by an amelioration of climate during which the weathered material was released. Due to increase in discharge during wet condition, it was easy for the swift and turbulent gumbaz gol to carry away the weathered coarse debris, rework it and deposit it as thick gravelly bed.

The presence of cross bedding suggests the stream was fast moving, swift and turbulent, whose channel was changing rapidly and frequently (Gomez, 1996, Reineck and Sing, 1973). This is further conformed by the presence of occasional boulders.

The presence of very fine bedding and fine angular material in bed b suggests that slowly and gradually the discharge of Gumbaz gol decreases and it could only transport fine angular material. The circumstances and environment of the deposition are same as that of bed a.

The section records the following events:-

1. A long phase of weathering and formation of thick layer of regolith. The release of regolith subsequent to torrential rains and its deposition as fans ***(Bed a).***
2. A second phase of deposition of faintly stratified fan material ***(Bed b).***

6.6. Section No.6

6.6.1 Field description

This section is exposed 15km down stream from Chitral town on Chitral–Ayun road, just 2km north–west of village Ayun at a height of about 40-45-m ACR. *(GR 735994 38-M/14).* It shows depositional sequence of Muldeh terraces (T4) in the Broz sequence. Different types of material have been exposed in the section, which show the following beds: **(Figure 6.6.1)**

Bed a:

This bed, 2-meter thick, is composed of sub-rounded to rounded gravels, predominantly of greenish slate, sandstone. quartzite and amphibole embedded in a sandy-pebbly matrix. The material is unsorted, unstratified and also loosely packed.

Bed b:

The bed is composed of 2-meter thick, medium to coarse, light olive grey (5y 6/2) sand. The material is hard, and compact. There are parallel Laminae, 1 to 2 cm thick. Numerous burrows, about a centimeter to 2 cm in diameter, have also been examined in the material. Quartz gravels also occur in the bed.

Bed c:

It consists of 3 to 8.5-meter thick deposit of compact gravels. The clasts, is predominantly sub-rounded to rounded, brown sandstone, shale and amphibole gravels, embedded in pebbly sandy matrix. The deposit is too hard to be scratched with fingers, but can be easily broken with hammer.

Figure No. 6.7.1
Statigraphic Section No. 6
Ayun Gol (GR. 738985 - 38 M/14)

Thickness	Bed No.	Profile	Characteristics		Sample
			Colour	Lithology & structure	
8.5m	*c*		*Light grey* 2.5Y7/2 *light brown*	Large size boulders of about 30 - 50 cm diameter, wity occasional boulders of upto 5meter. The clasts are mostly metamorphic rock gravels. The boulders are embedded in a pebbly, gravely matrix, showing faint stratification. the material is compact and hard.	◍
02m	*b*		*Olive grey*	Medium to coarse sand, hard and compact with perallel lamination of 1-2 cm thick. The bed exhibits burrows about 1-2 cm diameter.	◍
02m	*a*		*Greenish*	Sub-rounded to rounded gravels of predominantly slat, sandstone, quartzitu and amphibole embedded in sand pebbly matrix.The material is unsorted unstratified and loosely cemented.	●

● Sample for roundness and shape analysis.

◍ Sample for size analysis.

Section No. 6

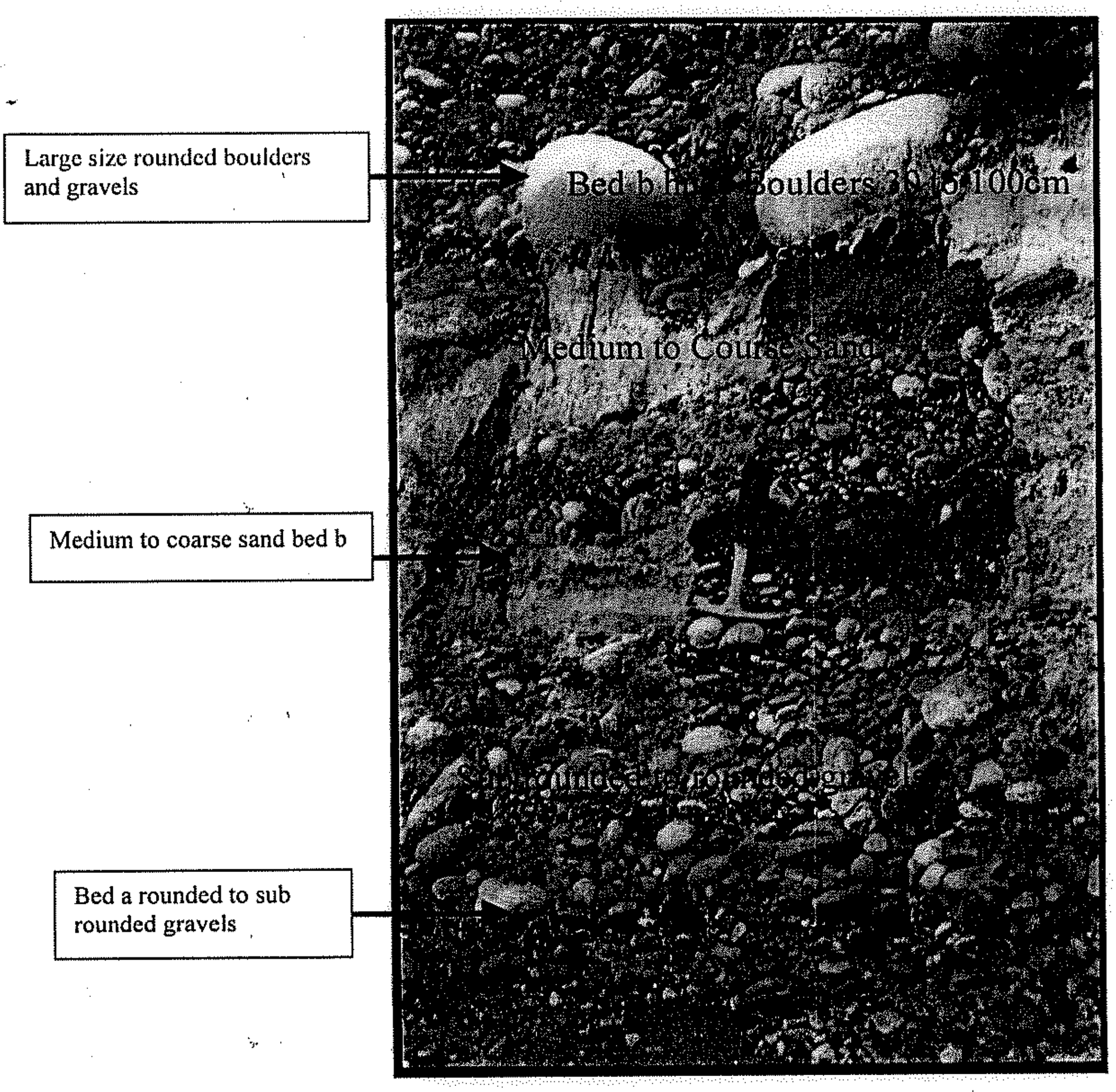


Plate 6.7.1. The photograph shows beds a, b & ***d*** of section No. 6, which is exposed 15km downstream from Chitral town on Chitral–Ayun road, just 2km north–west of village Ayun. Bed ***d*** consists of large-size boulders of about 30 cm to half a meter, with a maximum thickness of about 5 meter.

Section No. 6

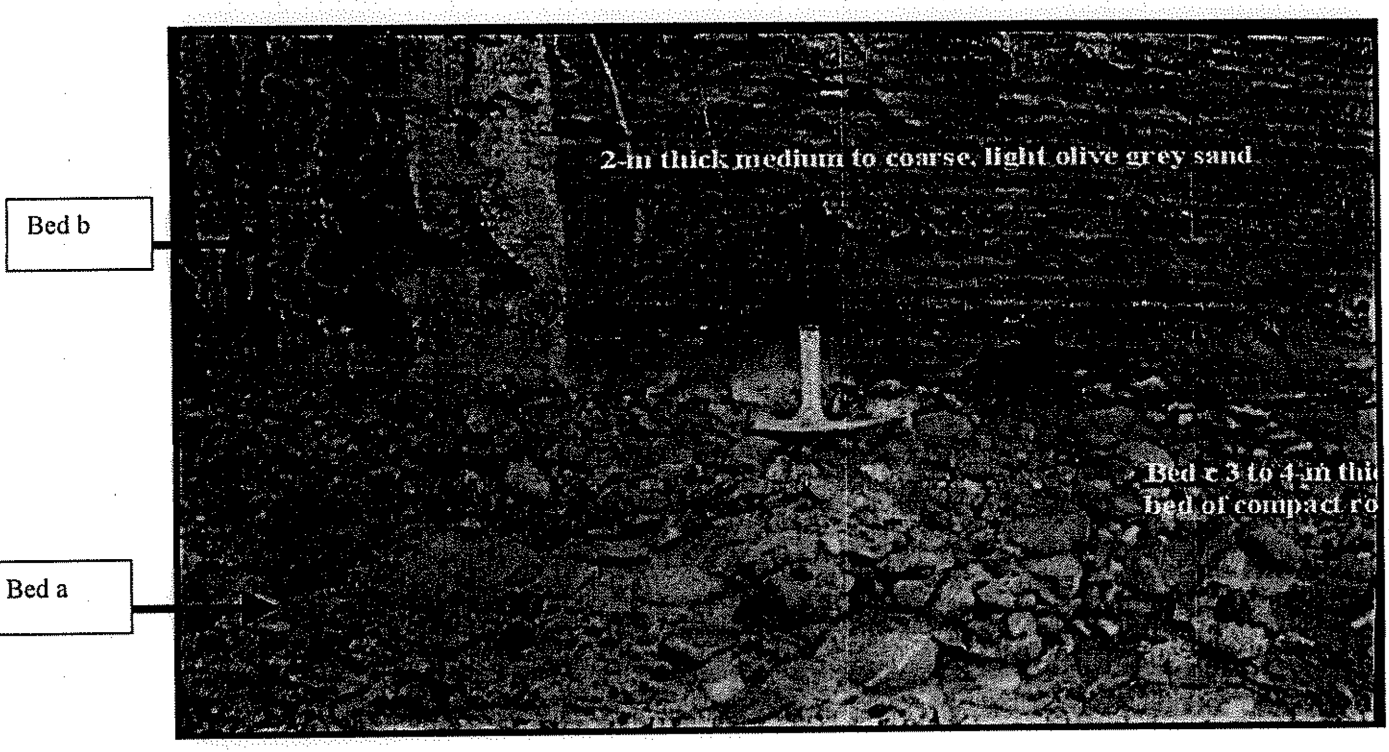


Plate 6.7.2 A closer view of section No. 6 bed a & b. Bed a consists of 3 to 4-meter thick deposit of compact gravels. The clasts, is predominantly sub-rounded to rounded, brown sandstone, shale and amphibole fragments, embedded in sandy matrix. The bed b is composed of 2-meter thick, medium to coarse, light olive grey sand.

6.6.2. Laboratory examination

6.6.2a. Texture

Bed b:

Bed ***b*** is composed of 2% silt, 10% fine sand 32% medium sand, 42% coarse sand **(Figure 6.6.2**) and 14% very coarse sand. The material ranges in size from coarse silt to very coarse sand.

6.6.2b. Roundness analysis:

Bed a:

The bulk of the material in bed ***a*** is sub-rounded to round with occasional very well-rounded gravels of foreign origin. Roundness analysis shows that 20% of the gravels are sub-angular 42% sub-rounded, 30% rounded and remaining 8% are well rounded. **(Figure 6.6.3)** Roundness analysis of bed ***c*** suggests that 8% material is angular, 14% sub-angular, 35% sub-rounded, 32% rounded and 11% well rounded. **(Figure 6.6.4)**

6.6.2c. Shape analysis

The material of beds ***a*** and ***c*** was also examined for shape analysis. Analysis reveals that 60% of the clasts in bed ***a*** are equant, 20% oblate, 15% bladed and remaining 5% are classified as prolate. (Figure: ***(Figure 6.6.5)*** According to analysis in bed ***c*** 58% of the gravels are equant, 30% oblate and remaining 12% is bladed. The composition show a marked similarity between beds *a* and *c* the sandstone gravels are mostly equant and oblate, while bladed gravels are predominantly slate.

6.6.2d. Scanning Electron Microscopy

Bed b

The sample from bed b was studied under scanning electron microscope (Plate 6.7.3). The surface forms and texture of the particles are dominated by scratches, with angular often sharp edges and corners. The scratches and sharp edges reveal that the sand may be the result of glacial action and show a single episode of fluvial transport of the first cycle sediment.

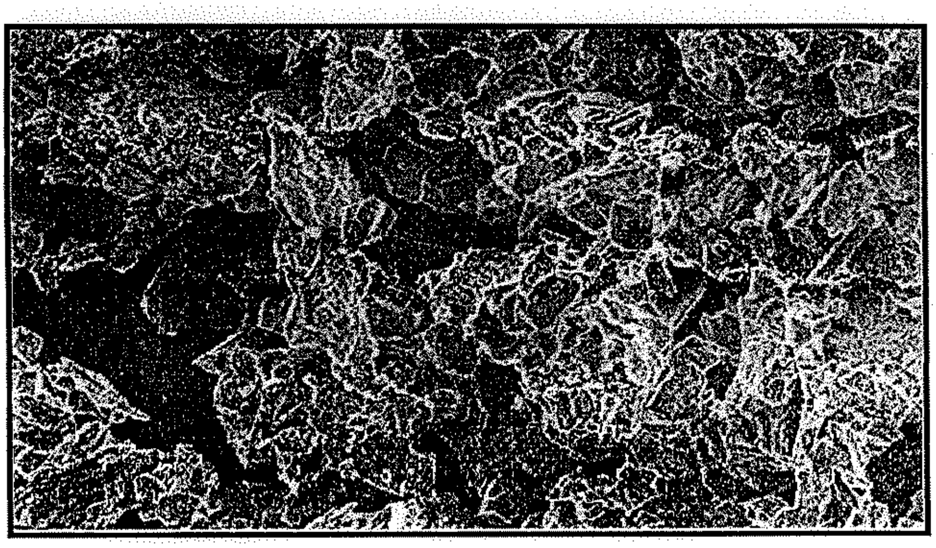


Plate 6.7.3a. Micrograph of bed b showing angular to sub-angular gains with sharp edges and corners. Magnification 1000 times.

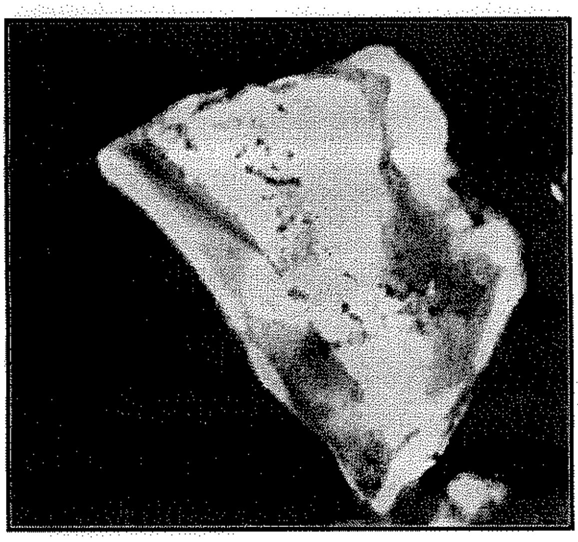


Plate 6.7.3b. Micrograph showing sub-angular sand grain Magnification 3000 times.

Discussion

The section show fluvial deposits. The gravels in ***bed a*** is probably deposited in a channel. The quartz, sandstone and amphibolites have been derived from the catchment area of Chitral river. The roundness (72% of the gravels are classified as rounded) and lithology of the gravels also conformed this. Field evidence suggest that gravels were originally deposit by glaciers in the upper catchment area as moronic material in a cold dry glacial climate. With change in climate from cold and dry to hot and humid, the discharge of rivers increases and it could start transporting gravels and boulders. During the course of transportation the gravels become rounded.

Bed b is deposited on top of gravelly bed as channel sand. The beautifully preserved 1 to 2 cm thick lamination of light olive grey sand suggests probable damming of river Chitral resulting in the lacustrine conditions. The thickness of the bed suggests that this pounding was of a short duration. The presence of quartz gravels indicates that material was derived from the area with metamorphic and igneous rocks by a swift moving low energy river.

The thick deposition of rounded gravels in ***bed c*** indicates that there is increase in the discharge of river. The swift moving low energy stream was converted into a turbulent and high energy stream, which could transport large size gravels. The presence of occasional cobbles and boulders with prominent cross bedding of sand lenses indicates a powerful, swift and braided stream having a moderate year round rainfall, which was frequently changing its channel (Thornbury, 1954, Allan 1979). The variable thickness of the 3 to 8.5 m suggests that after deposition there was a phase of erosion which reduces the thickness of the deposit from places.

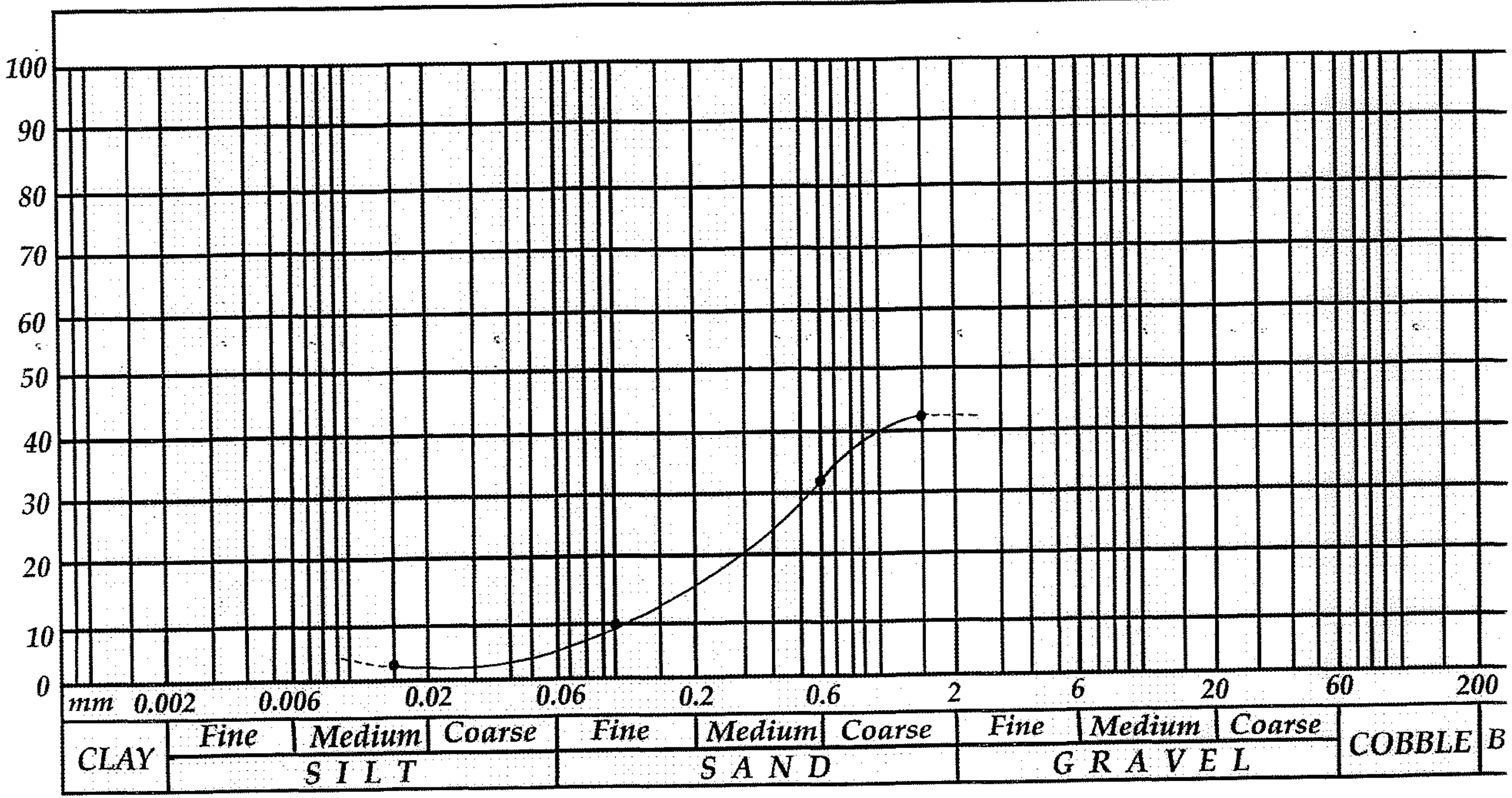
The section records the following events:-

1. The deposition of rounded gravels by Chitral river ***(Bed a).***
2. The deposition of thin-bedded coarse sand over gravels ***(Bed b).***
3. A second phase of deposition of large size river gravels. The size of the gravels indicates a high-energy state of Chitral river ***(Bed c).***

Figure No. 6.6.2
Section No. 6
Partical Size Distribution

Location: Ayun

Bed No. b



M. Jamal Nasi

Figure: - 6.6.3

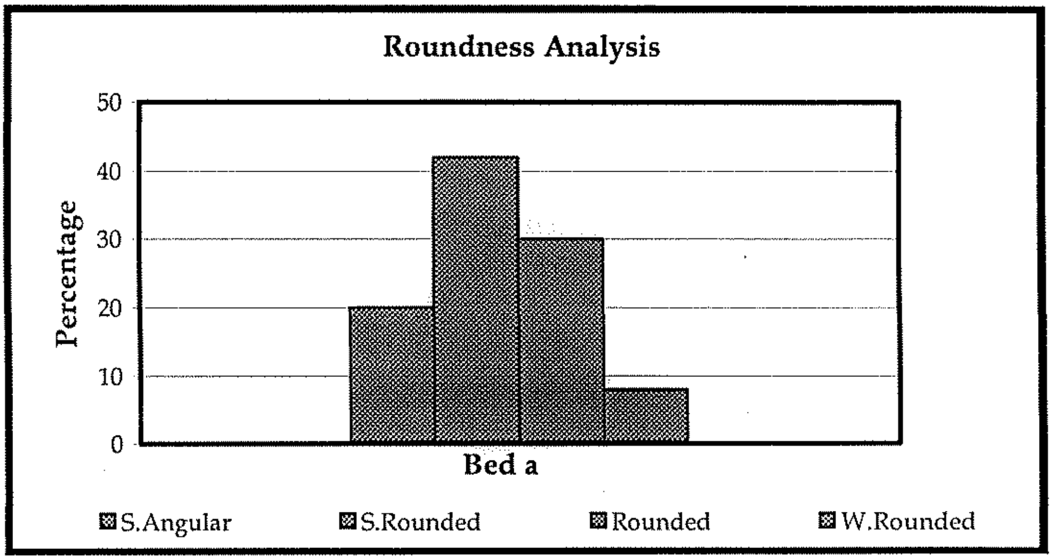


Figure: - 6.6.4

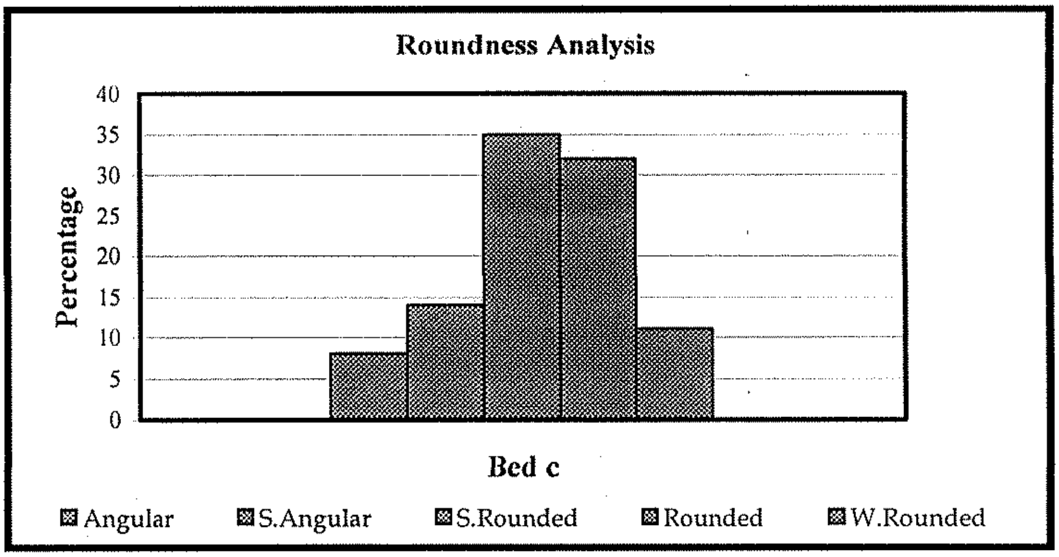


Figure 6.6.5
Shape Analysis
Bed a

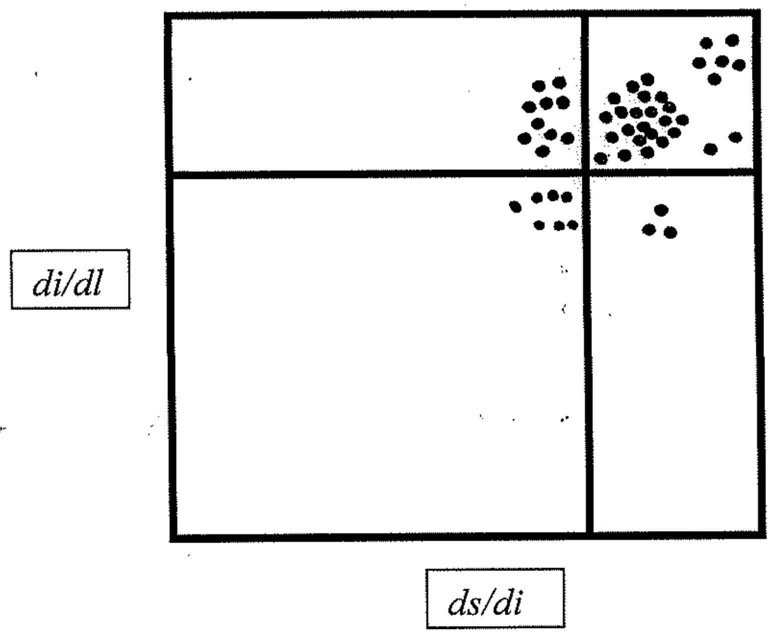
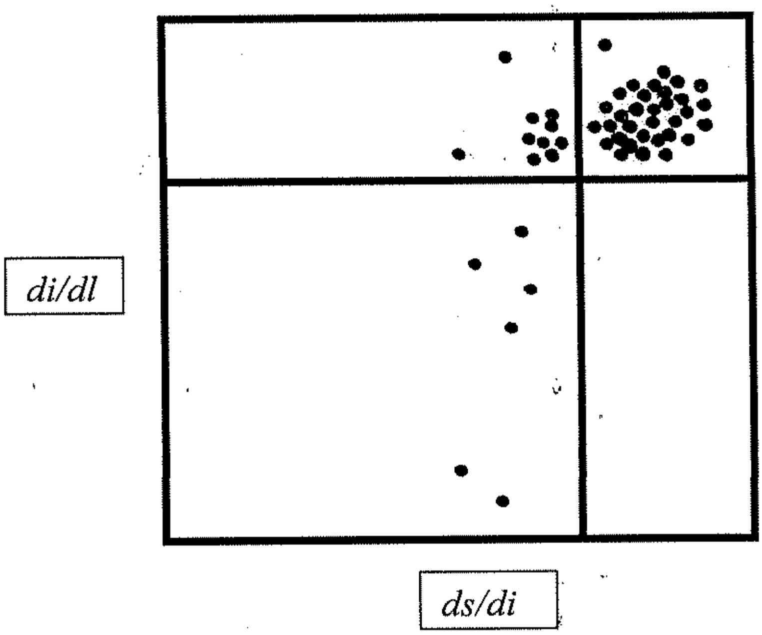


Figure 6.6.6
Shape Analysis
Bed c



6.8. Section No. 7

6.8.1. Field description

This section is exposed on the left side of Chitral-Drosh road, some 1.5 km down stream from Gahrait gol, at a height of some 35-40-m ACR . *(GR 725904 38-M/14).* It exposes depositional sequence of Gahrait terrace sequence. The following beds are exposed: **(Figure 6.8.1)**

Bed a:

Bed **a** is 1.5m thick layer of angular to sub angular rock gravels. It is unsorted and unstratified.

Bed b:

Bed ***b,*** is a 10-m thick layer of pale yellow (2.5Y 6/4) siltstone, showing horizontal layers of about 2–5 cm thick are clearly visible. The bed exhibits small cavities, 2–4 mm in diameter. The bed is hard and compact and can be scratched with a hammer.

Bed c:

Bed **c** is 3-meter thick, layer of sub-rounded to rounded gravels and boulders. The clast is embedded in coarse sandy and pebbly matrix. It is predominantly greenish slate, shale, sandstone amphobolite and granite. The material was analyzed for shape and roundness analysis.

6.8.2. Laboratory examination

6.8.2a. Texture

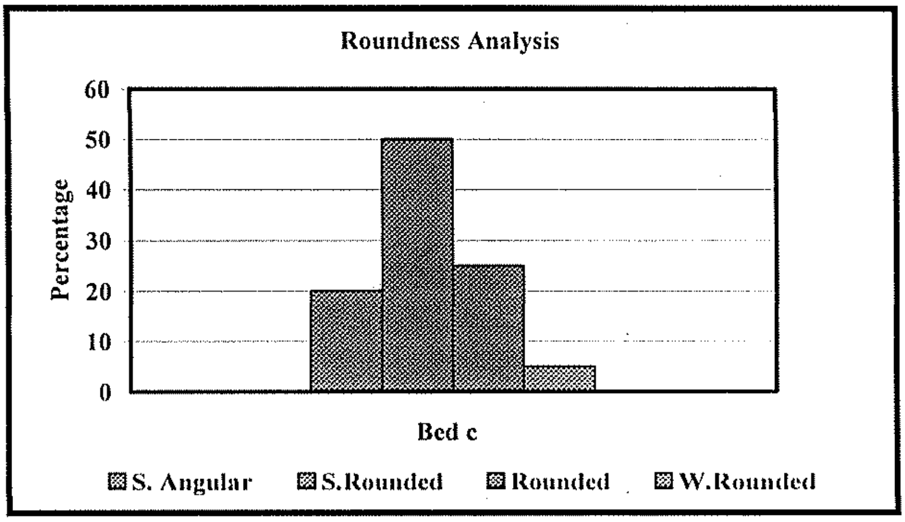
Bed a:

The material ranges in size from medium silt to very coarse sand. It is composed of 10% medium silt, 30% coarse silt, 10% very fine sand, 30% fine sand, 15% medium sand and remaining 5% coarse sand. The deposit is predominantly medium to coarse silt. **(Figure 6.8.2).**

6.8.2b. Rounded analysis

The bulk of material in bed ***b*** is sub-rounded to rounded with occasional sub-angular large size boulders. According to roundness analysis 20% of the gravels are sub-angular, 50% sub-rounded 25% rounded and only 5% well rounded.

Figure: 6.8.3



6.8.2.c Scanning Electron Microscopy

Bed b.

The surface texture of the silt grains was studied with the help of scanning electron microscope. The grains were magnified 3000 times. Most of the grains were angular to sub angular with sharp edges and corners but considerable grains were sub rounded indicating different type of transporting agencies.

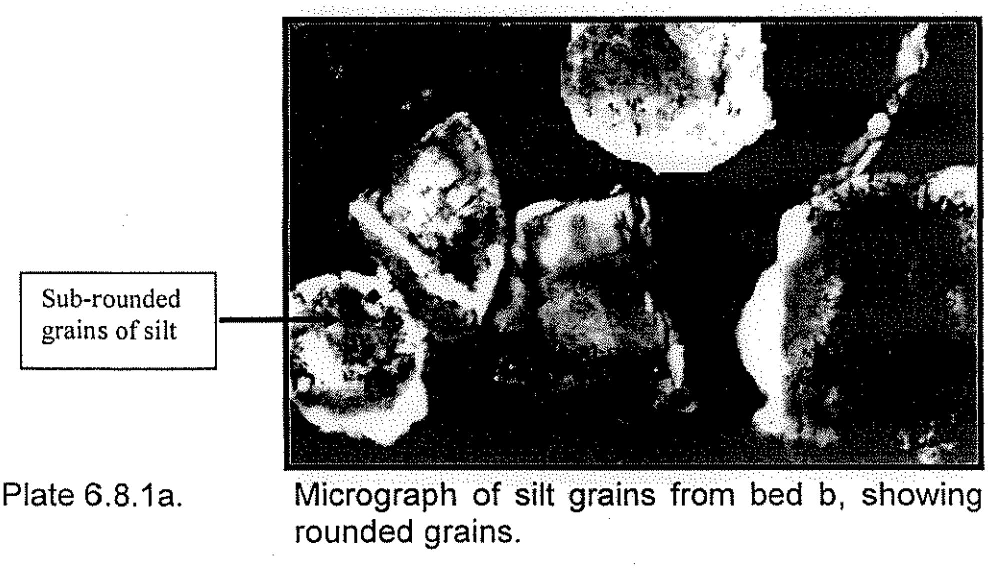
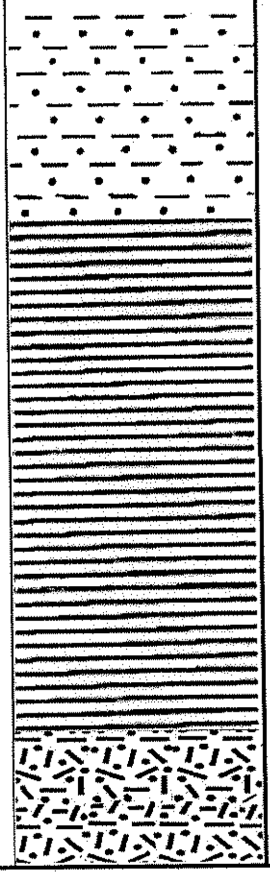


Plate 6.8.1a. Micrograph of silt grains from bed b, showing sub angular to sub-rounded grains.

Figure No. 6.8.1

Statigraphic Section No. 7
Gahrait Gol (GR. 720898 - 38 M/ 14)



Thickness	Bed No.	Profile	Characteristics		Sample
			Colour	Lithology & structure	
03m	*c*			Sub-rounded to rounded gravels of predominantly slate and sandstone, quartzite and amphibole,embedded in a sandy-pebbly matrix. The material is unsorted, unstratified and loosely cemented.	●
10m	*b*		*Pale yellow* 2.5Y7/4	Beds of siltstone, with 5-10 cm thick horizontal layers. the bed exhibits small burrows of about 2 - 4mm diameter.	◍
1.5m	*a*			Angular to sub-angular rock gravels unsorted and unstratefied.	

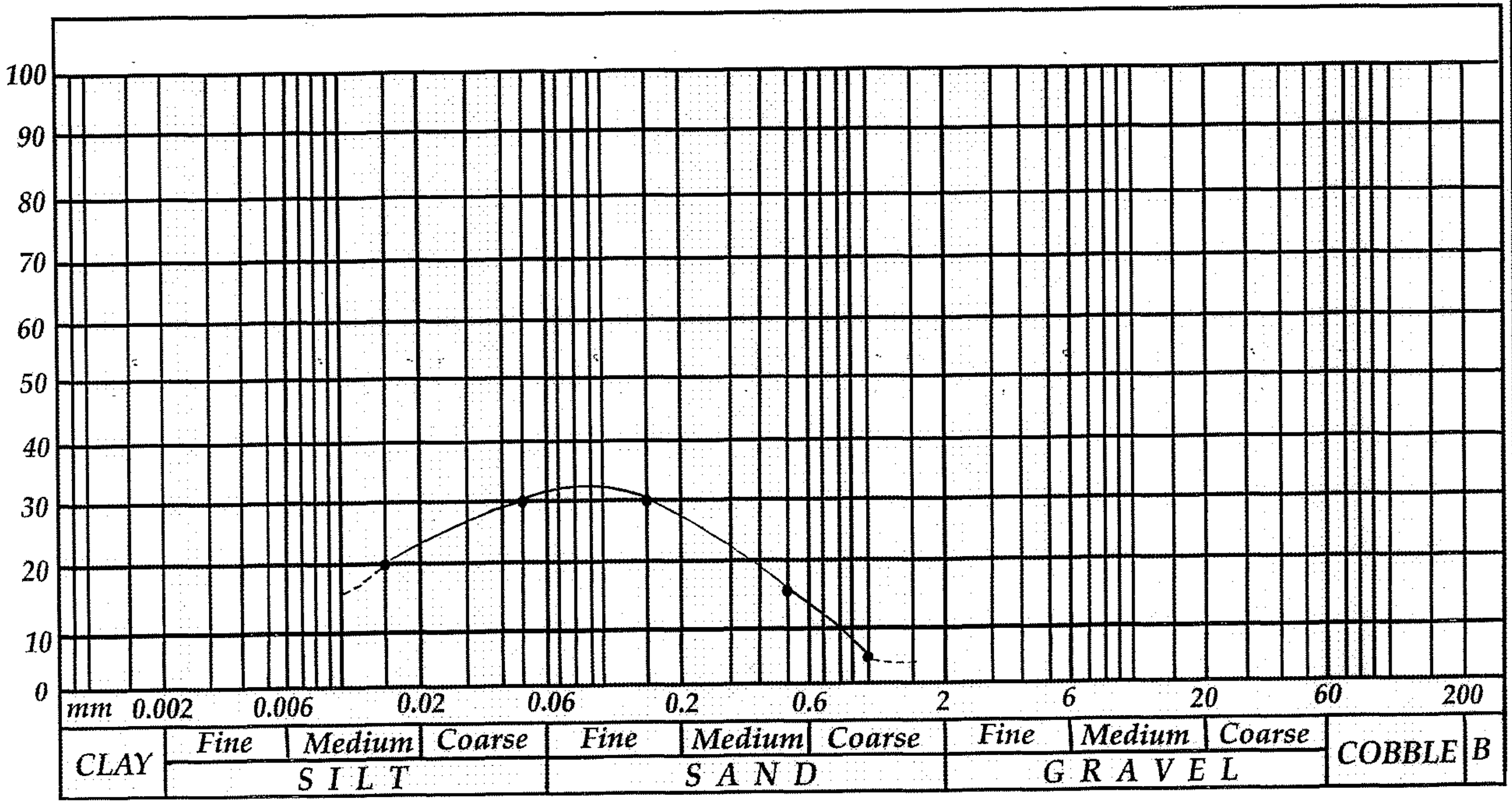
● Sample for roundness and shape analysis.

◍ Sample for size analysis.

Figure No. 6.8.2
Section No. 7
Partical Size Distribution

Location: Gahrait Gol

Bed No. a



M. Jamal Nasir

Discussion

Just like other sections of the study area, the lower part of this section is 1.5 m thick bed of sub-angular to angular rock gravels. The bed a represent facies of the older fan gravels. The environmental conditions in which the weathering and subsequent deposition of angular material is take place is discussed in detail in previous sections.

Bed b of the section is 10m thick layer of pale yellow bedded siltstone. The horizontal lamination and lithological characteristic clearly suggests a lacustrine environment of deposition. The thickness of the material indicates that deposition take place in deep water.

Field evidence suggest that during interglacial probably second interglacial the Chitral river was blocked somewhere near Drosh and it was converted into lake. On the basis of scanning electron microscopy it is suggested that fine material of the ***bed b*** was derived from the moraine material deposited by glacier during cold glacial phase, and along with fluvial deposition considerable amount of wind-blown silt may have been deposited directly into the lake. The presence of small worm-holes in the upper part of the bed and mottling suggest that during the end of this phase marshy conditions prevails converting it into a marsh in which small worms and their larvae could flourish (Hasan 1995).

The deposition of ***bed c*** probably represents the remnant of gravels bars and channel fill, which migrated laterally and disappeared under the regime of rapidly changing braiding stream within an alluvial fan system. The internal stratification of the gravel and exposure of lenses of silt and sand, indicate its deposition in different stages by high and low energy stream. During the shifting of the channel, the gravels were consolidated, while at low discharge the stream could deposit only fine material like silt and sand

The section records the following events:-

1. A long phase of weathering and formation of a thick layer of regolith. The release of regolith material with torrential rain and its deposition in the foothills, as fan gravels ***(bed a),*** the subsequent blocking of Chitral river and the formation of lake.
2. Deposition of siltstone in the lacustrine environment ***(Bed b).***
3. A subsequent phase of erosion of fan gravels.
4. The deposition of rounded-gravels and sand by Chitral river ***(Bed c).***

6.9. Section No. 8

6.9.1. Field description

This section is exposed along the Chitral–Drosh road 1.5 km south of village Kesu(GR. 761847, 38-M/14). It exposes depositional sequence of Kesu terrace, 19–20 meters high from base to the top, with different beds. The order of deposition from base to top is as follows: **(Figure: 6.9.1)**

Bed a:

Bed ***a*** is a 5.5 m thick deposit of pale yellow (2.5Y 6/4) silty material. The bed shows 5 to 10-cm thick horizontal layers. It is hard and can only be scratchable by a hammer.

Bed b:

Bed ***b*** is a 10-meter thick deposit of dark grey angular rock gravels, embedded in a clayey matrix. The clast is predominantly coarse angular to sub-angular gravels, with occasional boulders. The material is unsorted, and unstratified, and loosely packed.

6.9.2. Laboratory examination

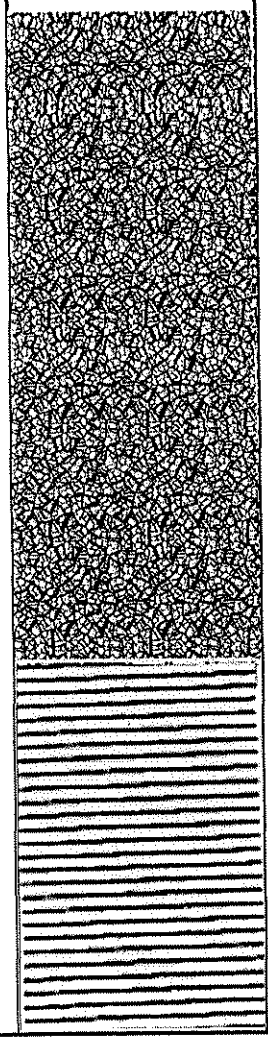
6.9.2a. Texture

Bed a:

Bed ***a*** is composed of 25% fine silt, 45% medium silt, and 30% coarse silt. It is classified as medium to coarse silt. **(Figure 6.9.2)**

Figure 6.9.1

Statigraphic Section No. 8
Kesu (GR. 761847 - 38 M/14)



Thickness	Bed No.	Profile	Characteristics		Sample
			Colour	Lithology & structure	
10m	b		Dark grey	Slate and sandstone angular gravels. The Clasts are redominantly coarse angular embedded in a muddy matrix. Sediments are poorly sorted and stratified	●
5.5m	a		pale yellow 2.5Y7/4	Thin (5 - 10 cm) clayey material showing planar lamination. the material is compact, but is scratchable with a hammer.	●

● Sample for roundness and shape analysis.

● Sample for size analysis.

Section No. 8

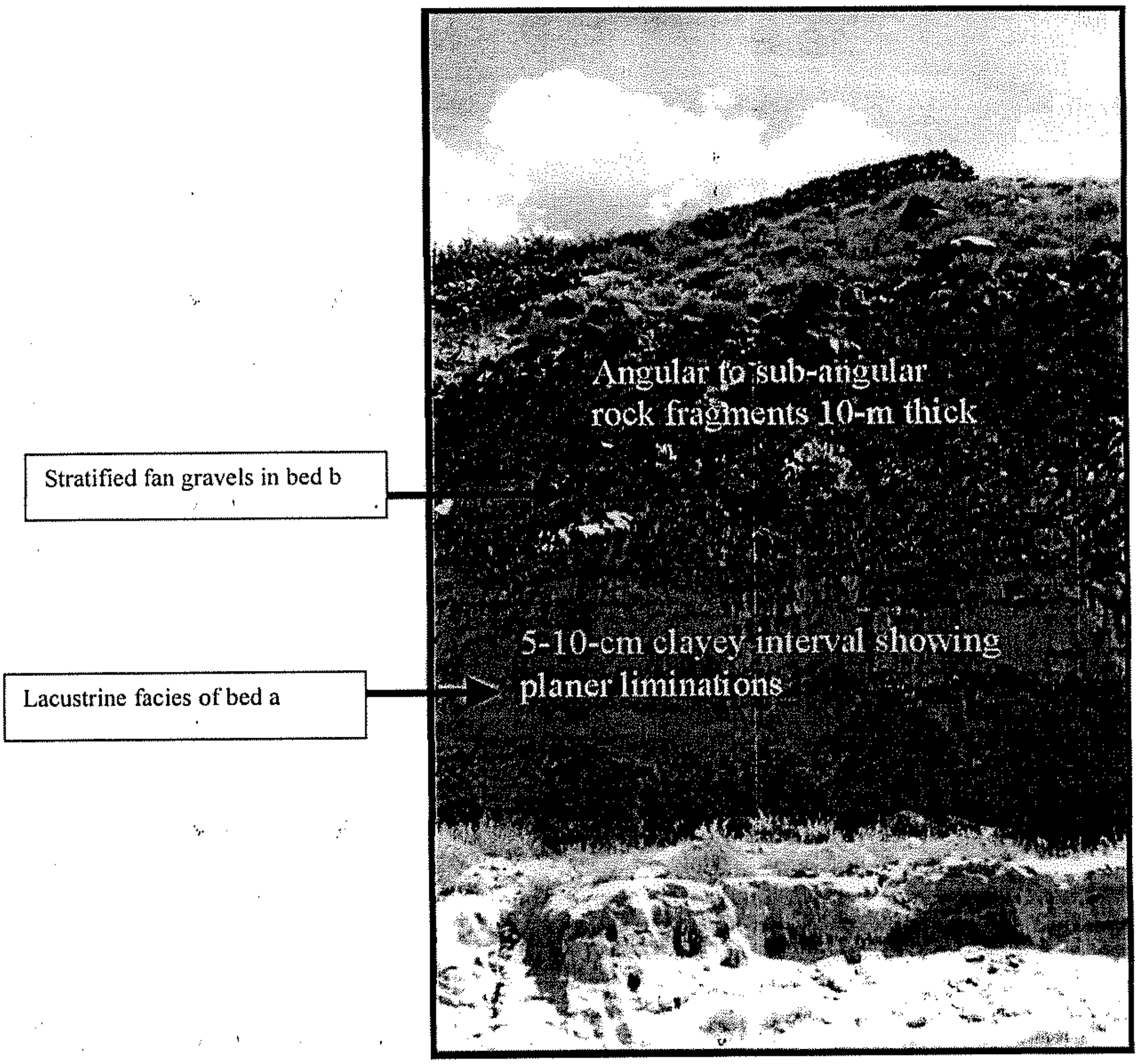
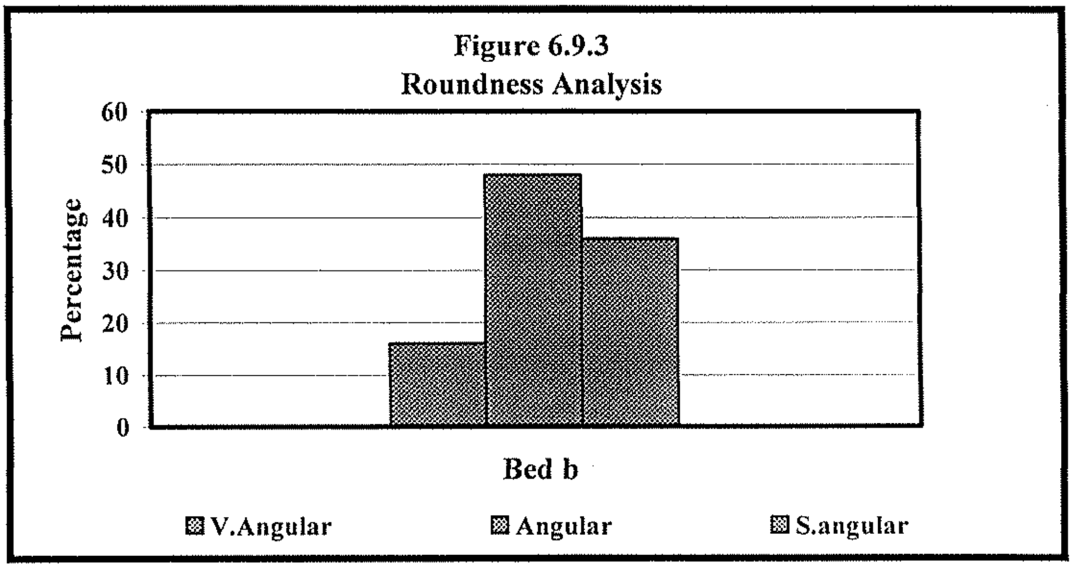


Plate 6.9.1. The Photograph shows bed ***b*** and ***c*** of the section No. 8 exposed some 1.5-km south of village Kesu. The lower bed is 4-m thick, pale yellow clayey, of 05 to 10-cm thick, horizontal layers. The upper bed is 10-m thick, deposit of angular to sub angular fan gravels. The material is unsorted and unstratified.

6.9.2b. Roundness analysis

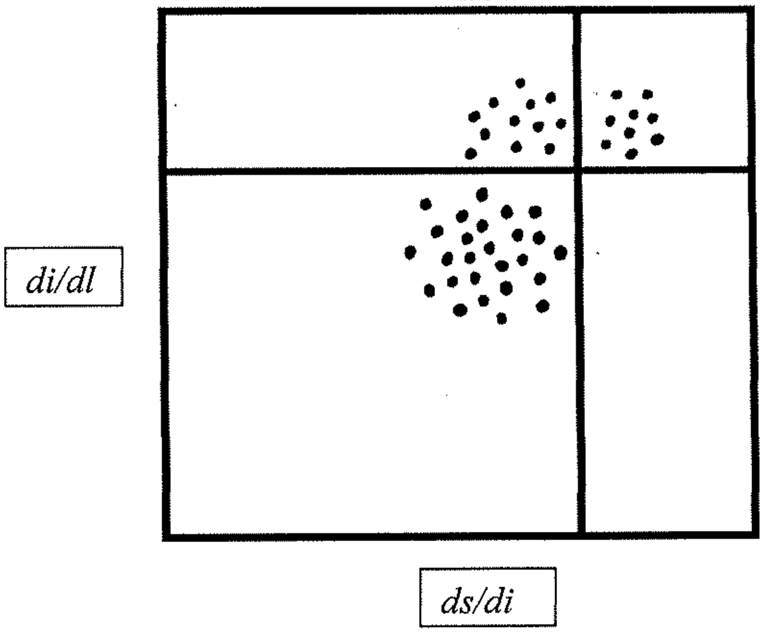
Roundness analysis suggests that the bulk of material is angular to sub-angular indicating a local origin of the material. **(Figure 6.9.3)**



6.9.2c. Shape analysis

The material was also analyzed for shape. Analysis suggests that the bulk of the material is bladed i.e. 50% and 25% oblate, the remaining 20% are equant and 5% prolate. The bladed and oblate gravels seem to be of local origin, which is also confirmed by roundness analysis. The material is predominantly slate and siltstone.

Figure 6.9.4
Shape Analysis
Bed c



Discussion

The ***bed a*** was deposited in a lake which was probably formed due to the damming of the Chitral river. It is suggested that the material was deposited in a shallow water by a swift and slow moving stream. These lake beds closely resemble with the lake beds of ***Section 4, bed g, section 6, bed b, section 7 bed b,*** suggesting similarities of the environment of deposition.

The deposition of slate, sandstone and limestone bearing graveliferous material over the lake beds, as facies of an alluvial fan indicates the mechanical weathering of slopes under freeze/thaw cycle in cold glacial climate This material is streamed up as young fan gravels. The lithology and the angularity of the material conformed the local origin of sediment.

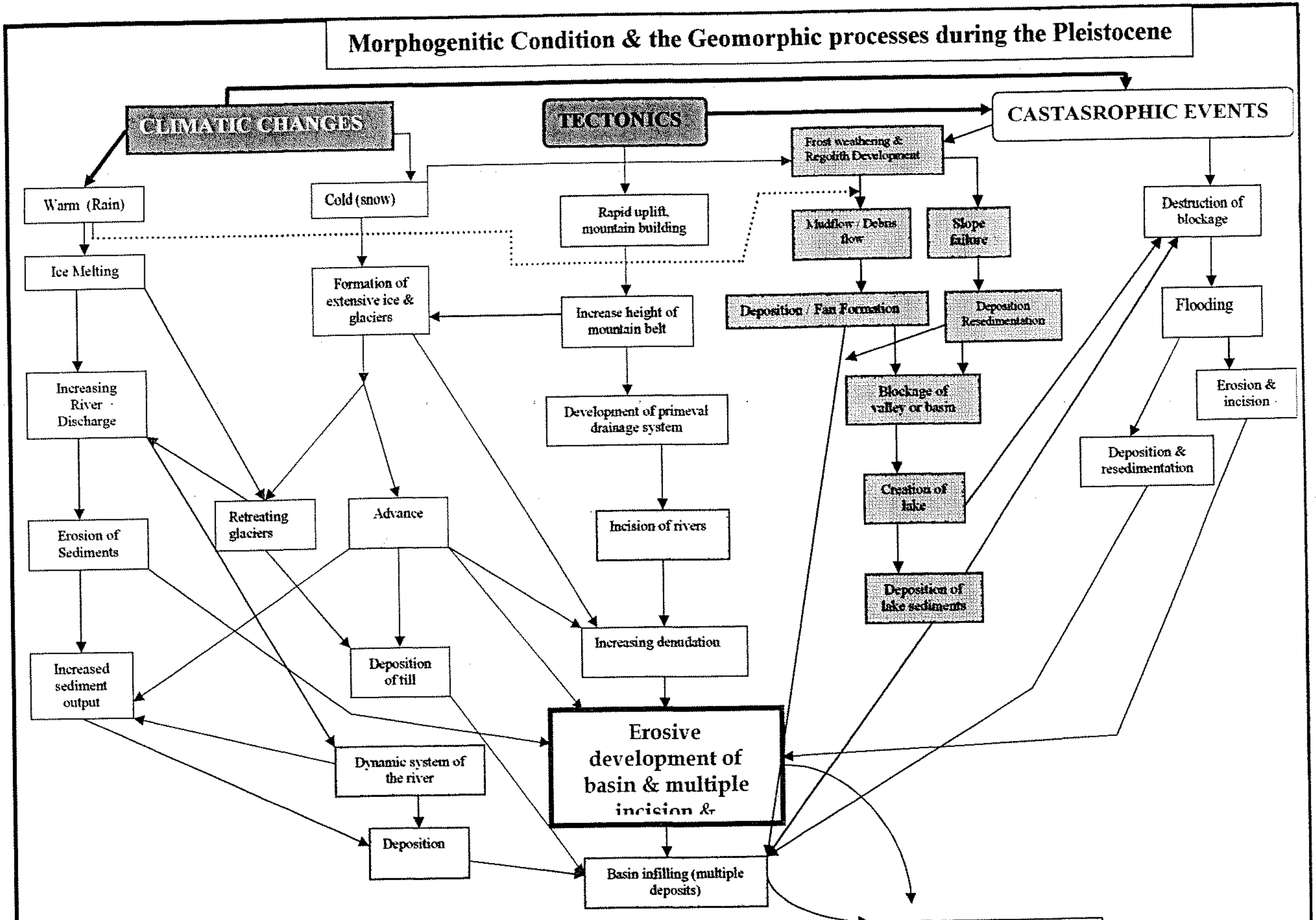
The Section records the following events:

The Section records the following events:

1. A long phase of weathering and formation of a thick layer of regolith. The release of regolith material with torrential rain and its deposition in the foothills, blocking Chitral river and forming a lake in the valley.
2. Deposition of siltstone in the lake ***(Bed a).***
3. A subsequent phase of erosion of fan gravels.
4. A second phase of deposition of poorly sorted fan material ***(Bed b).***

Conclusion

The flow chart ***(Figure 6.10 a***) shows the development of Chitral river basin and its sediment fill. The figure No. 6.10 explain the stratigraphic chronology based on the correlation of sections, while Table No. 6.1 explain the chronology of deposits based on the correlation of sections studied in different terraces sequences of study area.



Flow Diagram Showing the Development of the Chitral River basin and its Sediment Fills (Modified from Owen 1988)

Figure 6.10
Lithological correlation and interpretation of sections
Generalised Diagram

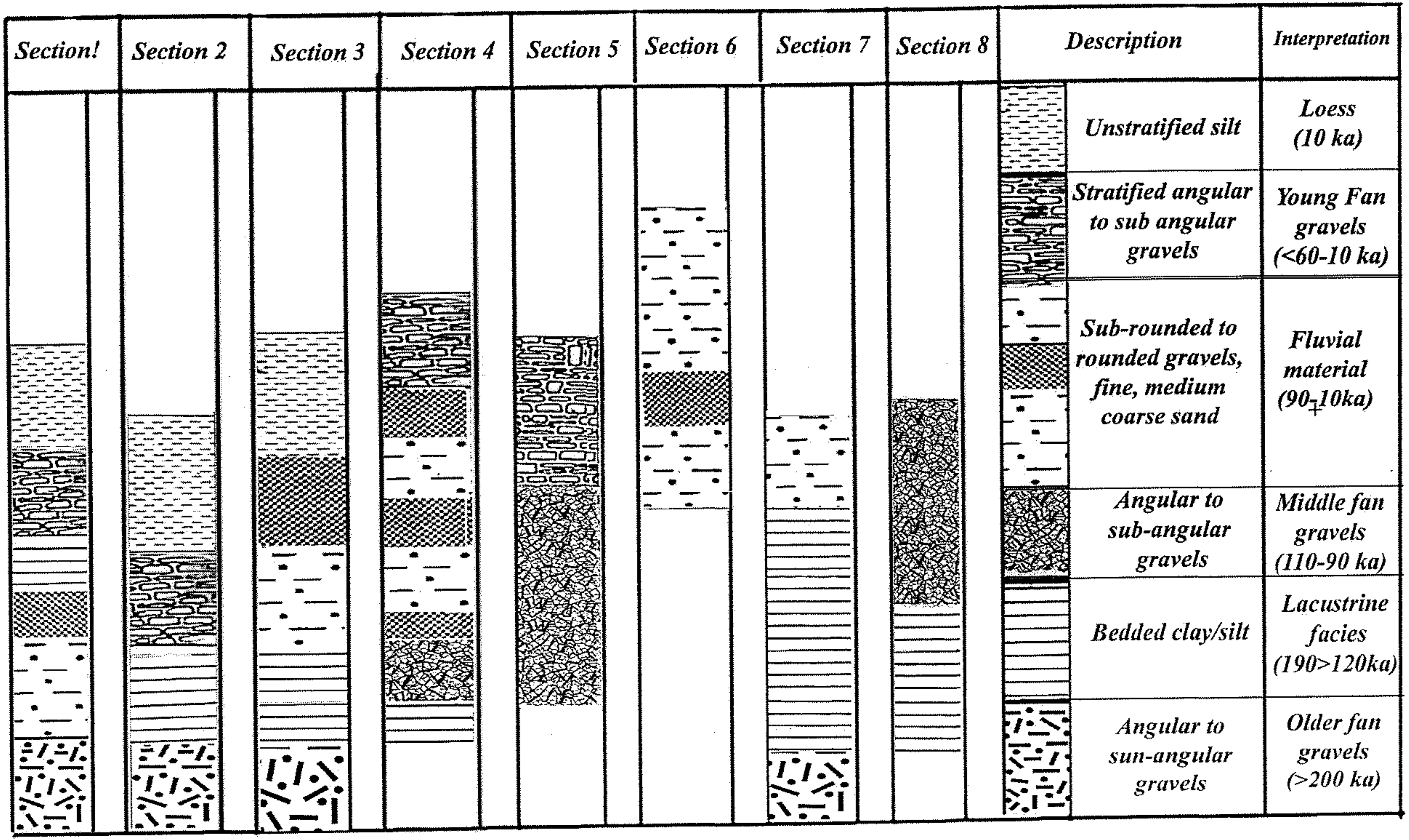


Table 6.11

Chronology of deposits based on the correlation of sections in Chitral valley

Deposits	Description	Interglacial phase	Glacial phase in Chitral	Age
Unstratified silt	Loess	Fourth glacial	Sanoghur cold phase	10ka
Stratified angular to sub-angular gravel	Young fan gravels	Third interglacial	Urghuch warm phase	<60-10ka
Sub-rounded to rounded gravels fine, medium and coarse sand.	Fluvial material	Third glacial	Pret cold phase	90-10ka
Angular to sub-angular gravels	Middle fan gravels	Second interglacial	Parwak warm phase	110-90ka
Bedded clay/silt	Lacustrine facies	Second glacial	Drosh cold phase	190>120ka
Angular to sub-angular gravels	Older fan gravels	First interglacial	First warm phase	>200ka
Bed rock	Bed rock weathering	First glacial	First cold phase	???

Source: Fieldwork

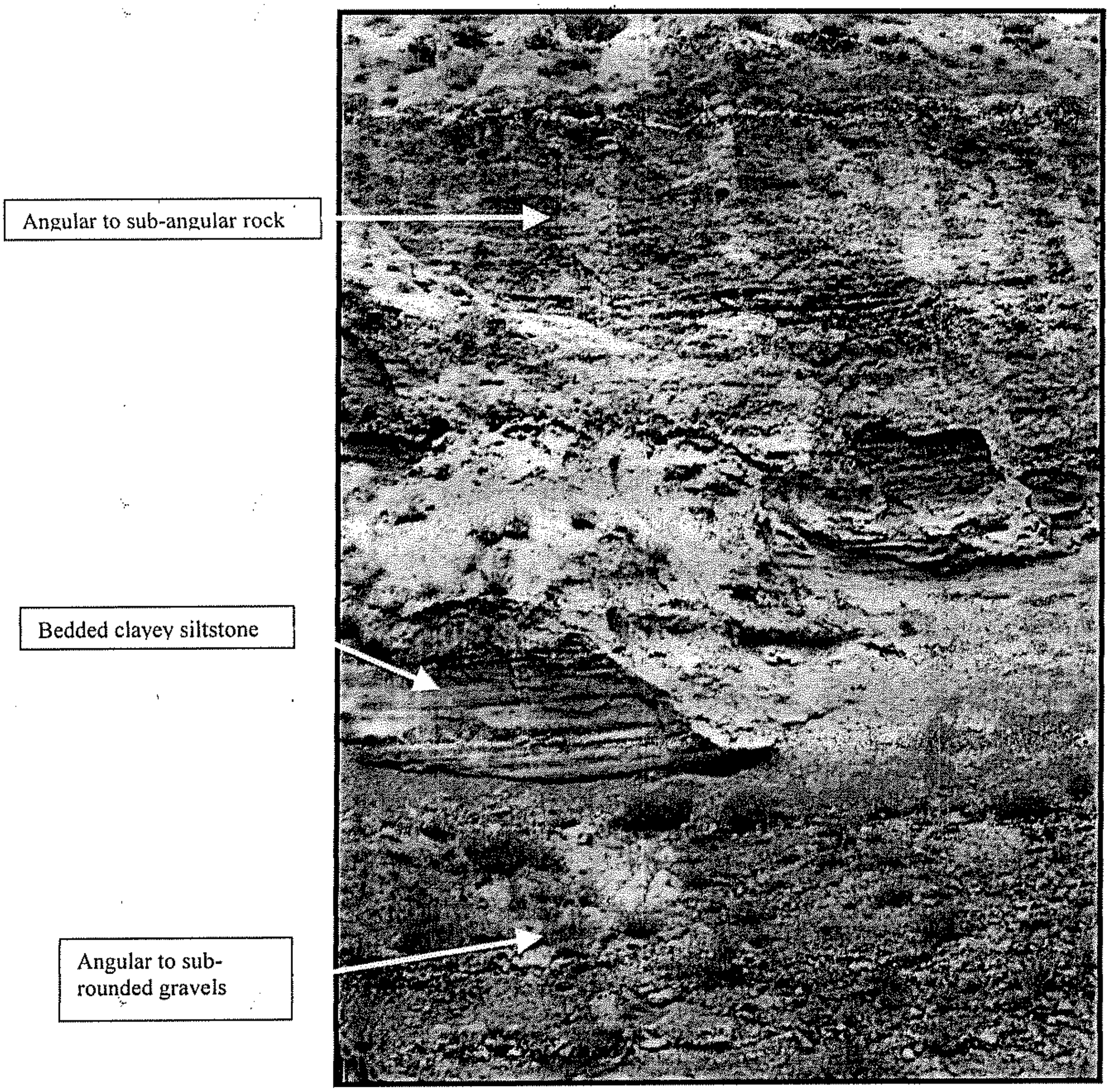


Plate 6.10.1. Plate showing the sequence of deposits in Dalamut sequence. The lowermost bed is a 1.5-m sub-angular to sub-rounded gravel ranging in size from 5-cm to 10-cm, embedded in lose sandy pebbly matrix. This is followed by 3.5-m thick bed of clayey siltstone which exhibits 20-25-cm thick alternating horizontal layers. The material is hard and is only stretchable with hammer. This is followed by angular to sub-angular rock fragments embedded in muddy matrix, poorly stratified.

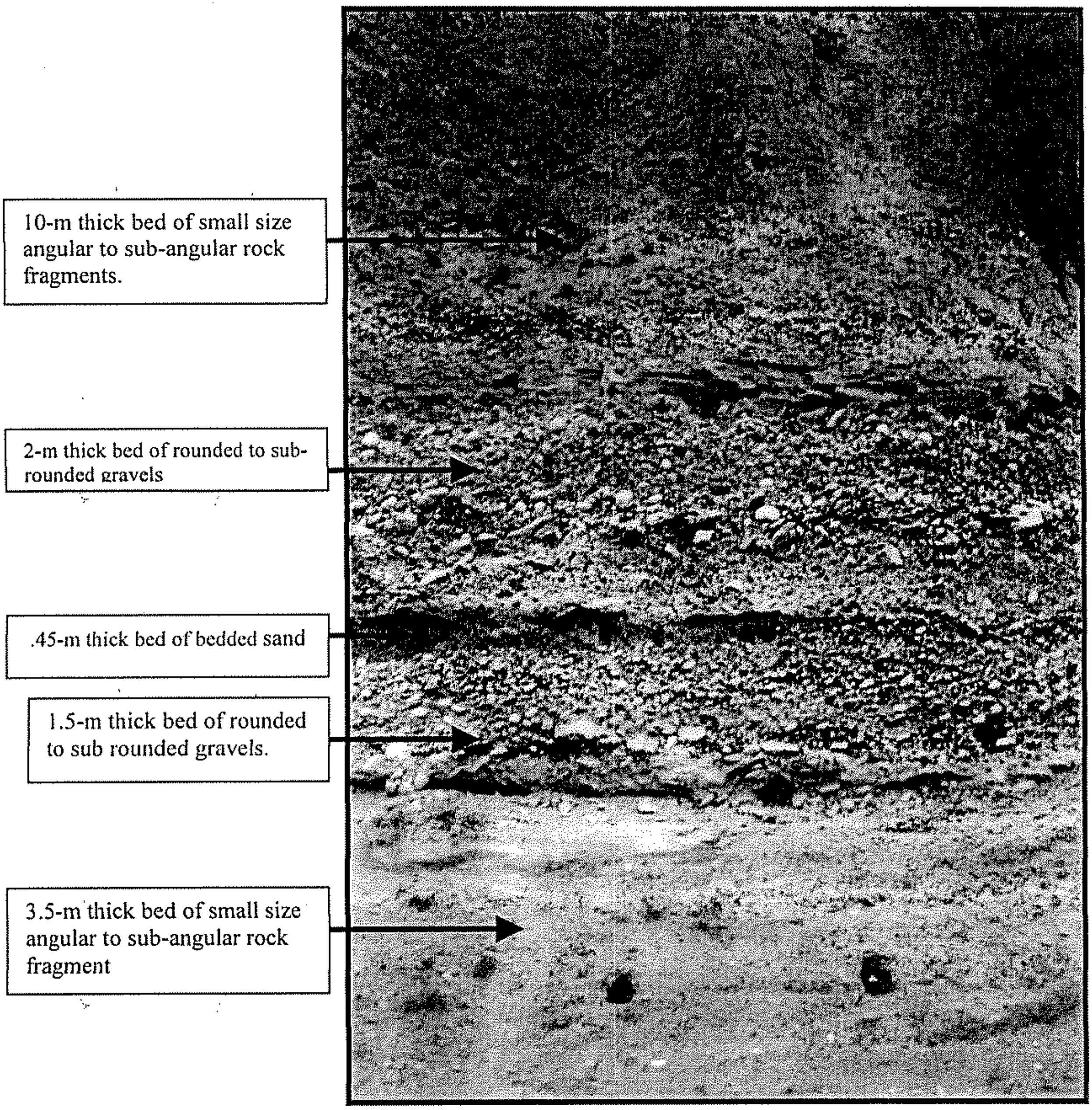


Plate 6.10.2. Photograph showing the depositional sequence of Danin sequence of terraces. The bed ***a*** of the section is composed of 3.5-m thick bed of small size angular to sub-angular rock fragment with circular holes of about 12-cm diameter. The bed b of the section is a 1.5-m thick bed of rounded to sub rounded fluvial gravels. This is followed by a , with circular holes. Bed c of the section is a 2-m thick bed of rounded to sub-rounded river gravels. This was followed by a .65-m thick bed of bedded siltstone. Bed ***e*** of the section is 10-m thick bed of small size angular to sub-angular rock fragments.

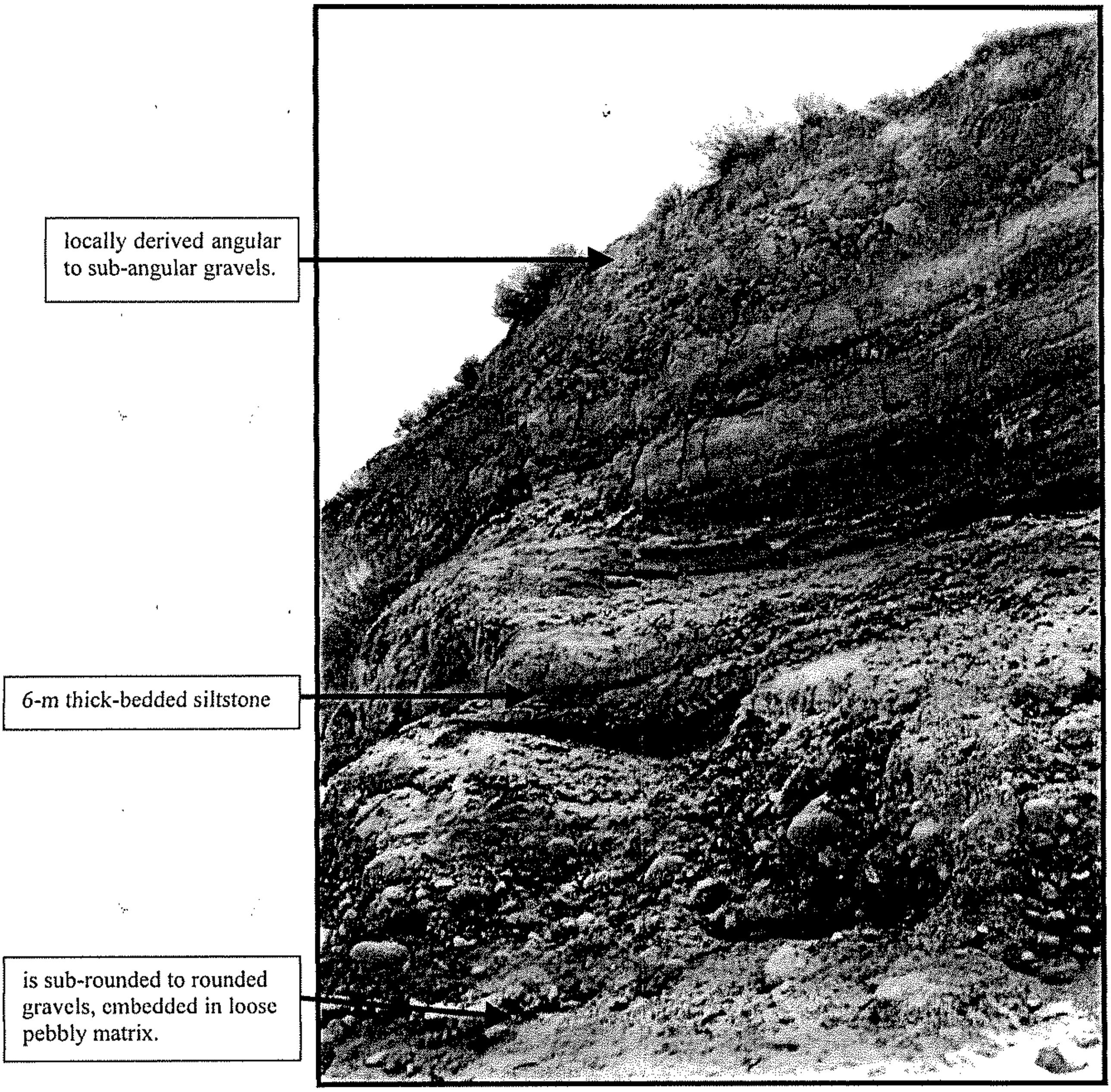


Plate 6.10.3. Plate showing the depositional sequence of Dalamut gol (GR 653203 38 M/13). Bed a of the section The bed ***b*** is . The material is medium to coarse grained lacustrine facies, alternate beds of muddy and silty material, composed of 15 horizontal layers, varying in thickness from 10cm to 20 cm. Differential erosion has resulted in a wavy surface. Bed ***c*** is

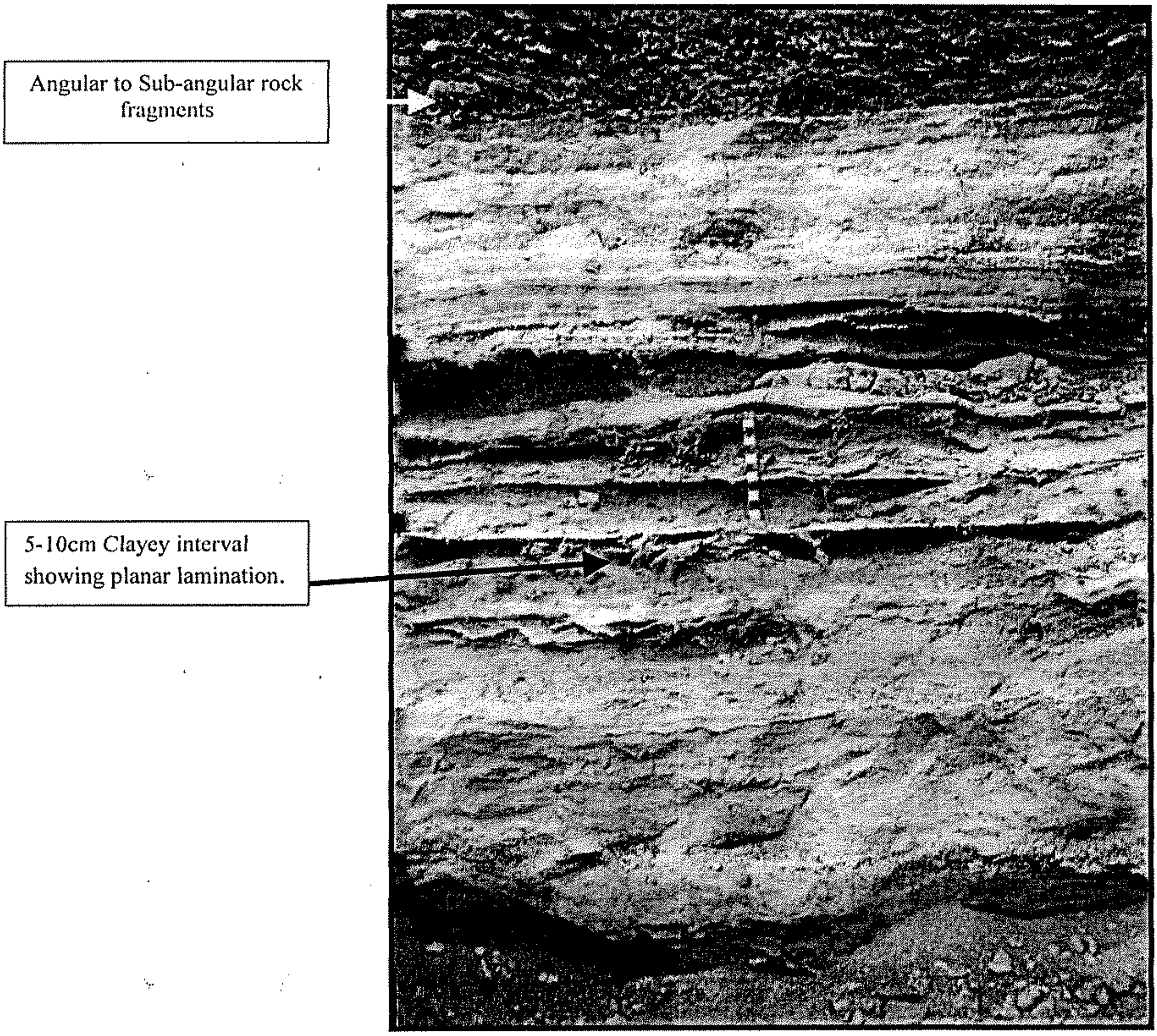


Plate 6.10.4. Photograph showing depositional sequence of section # 8, Kesu sequence of terraces. (GR 661846 38 M/14). Bed a is thin (5-10cm) clayey interval showing planar lamination. The material is compact and is scratchable with hammer. Siltstone, hard and compact & is scratchable with hammer. Angular fragments. The clasts are predominantly coarse angular embedded in a muddy matrix. Sediments are poorly sorted and lack any stratification.

Chapter No. 7
Chronology of Pleistocene Events

Chapter No. 7
Chronology of Pleistocene Events

7.1 Introduction

The study of sections and terraces has brought to light, the Pleistocene history of geomorphic events in Chitral river valley. These events have been co-related with the work carried out by Heserdot (1979) and Kamp (1999). Despite our best effort the chronology of events is only tentative. There are a number of gaps in our knowledge of Pleistocene geomorphology of this part of the world. These need to be filled by using modern dating techniques.

7.2 Chronology Based on the Study of Deposits and Terraces Formation in Pleistocene

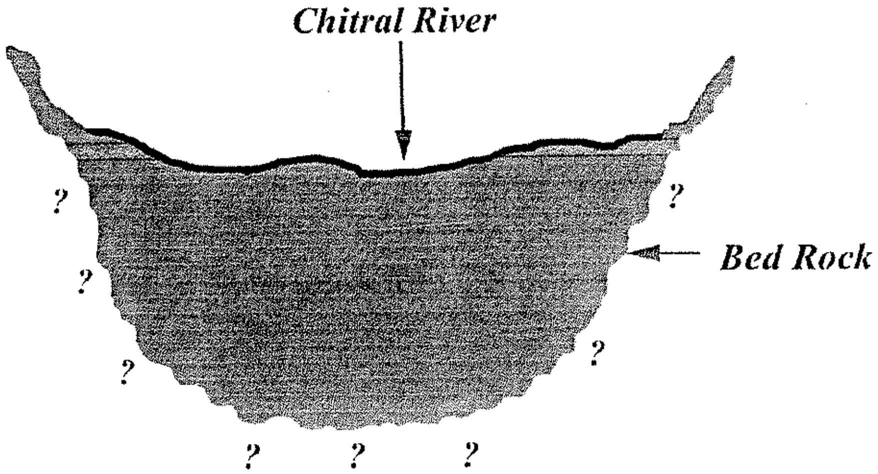
7.2.1. Pre Pleistocene / Lower Pleistocene

7.2.1a. First Cold Phase

The Himalayan-Hindu Kush uplift of the mountains during the Alpine orogony was followed by the beginning of the Pleistocene period. This was the beginning of glaciations in Hindu Kush (>200 ka). Comparable to ***Mindel Glacial*** phase of Penk and Brukner (1909) this glaciation is recorded in the form of a few isolated patches of high moraines at Kaldam and Lawi areas, 45-km down stream, Chitral Town.

The pre-Pleistocene landscape is marked by a wide valley, in which Chitral river described broad meanders. The valley floor was cut across a variety of bedrocks. With the onset of glaciation in the upper Chitral valley and also the tectonic uplift, Chitral river was rejuvenated and started erosion. This fluvial incision cut the bedrock into a terrace (T1 or the Dalamut terrace). This terrace is located at a height of 355-m ARB in Dalamut and Sighore sequences, while at Broz (Daman terrace) and Ayun (Attony terrace) it is present at a height of 330-m ARB. **(Figure 7.0a, b & 7.1a,b. Plate 7.1, 7.2,7.3 & 7.4.).** These conditions also favored the weathering and disintegration of the valley slopes. As a result, a thick mental of regolith was developed over the mountain slopes.

Figure 7.0 a
Chitral River Terraces
Model of Chronological Terrace Formation in the Lower Chitral

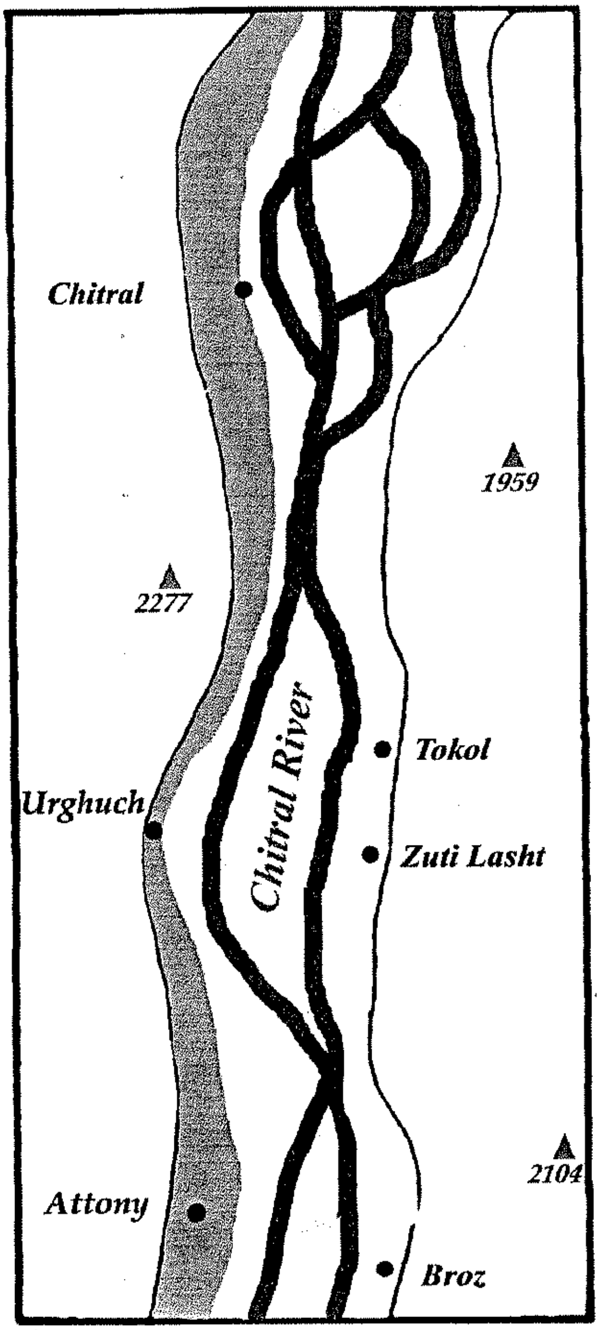


Pre-Pleistocene

The pre-Pleistocene is marked by a wide valley, in which Chitral river described broad meanders. The valley floor was cut across a variety of bedrocks. The Chitral river used to flow on top of these rocks. This is also conformed by Paleo-valleys cut in the bed rocks at a height of 300-350-m above sea level at Sin Last (Plate 8.0) and at Broz

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lower Chitral



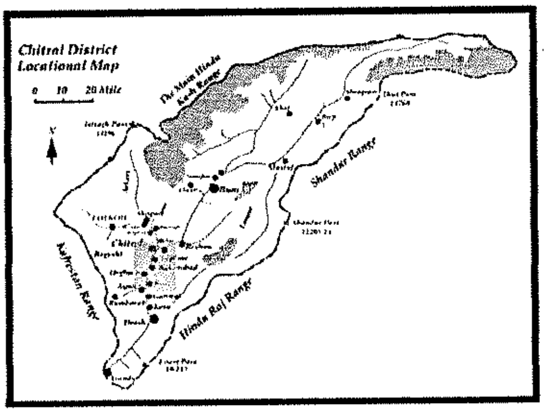


Figure 7.0 b

Pre Pleistocene

The pre-Pleistocene is marked by a wide valley, in which Chitral river described broad meanders. The valley floor was cut across a variety of bedrocks. The Chitral river used to flow on top of these rocks. This is also conformed by Paleo-valleys cut in the bed rocks at a height of 300-350-m above sea level at Sin Last (Plate 8.0) and at Broz

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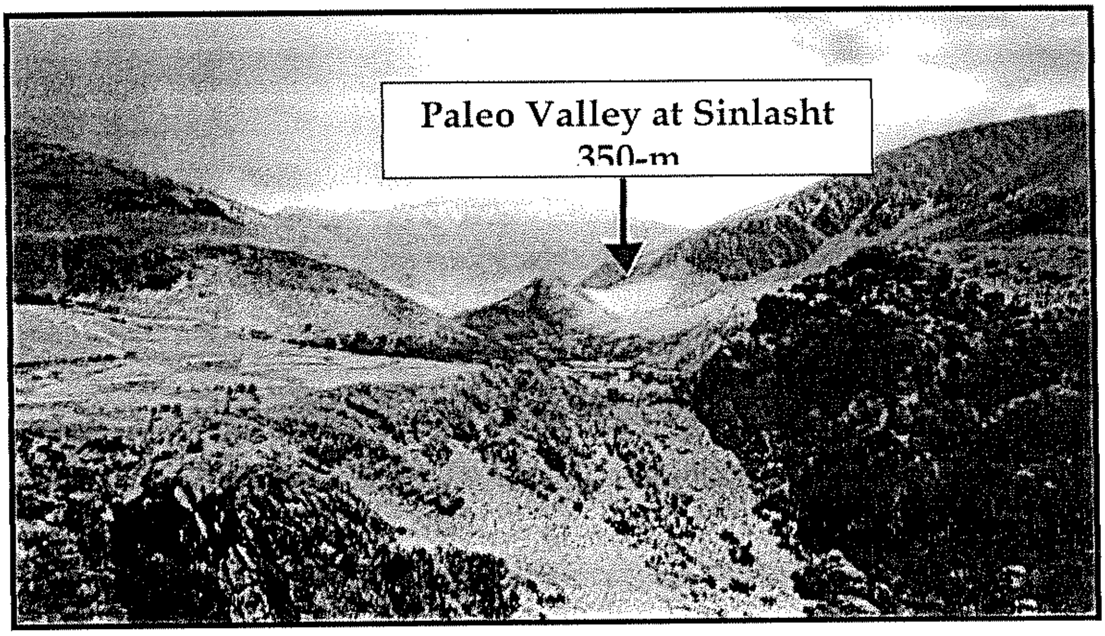
PRE-PLEISTOCENE



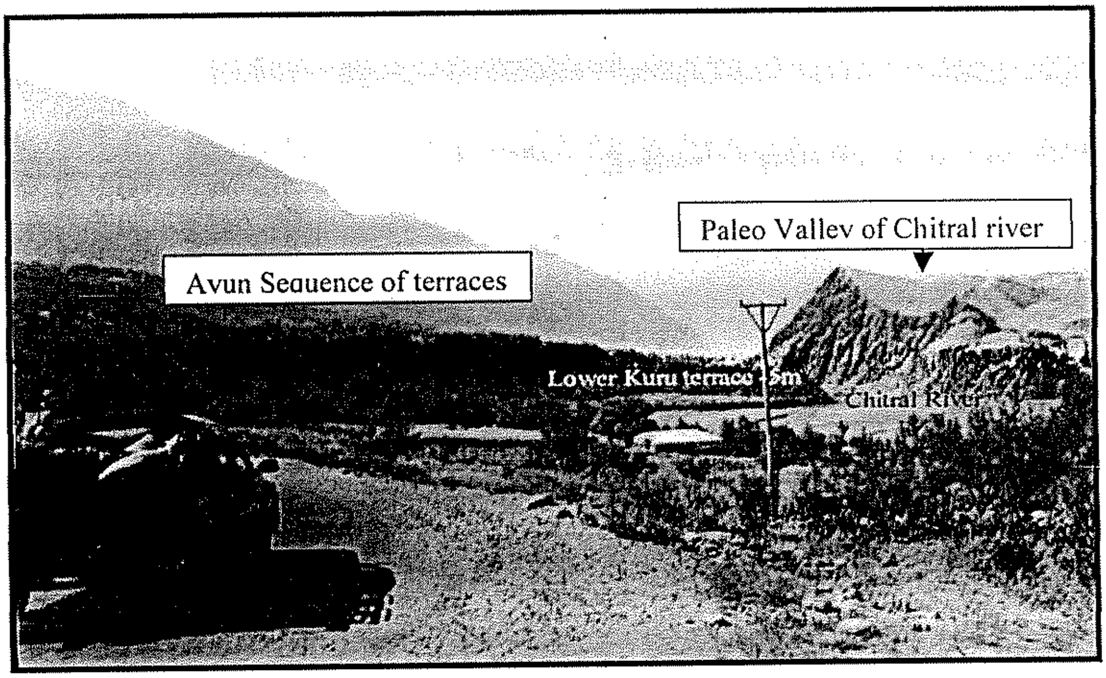
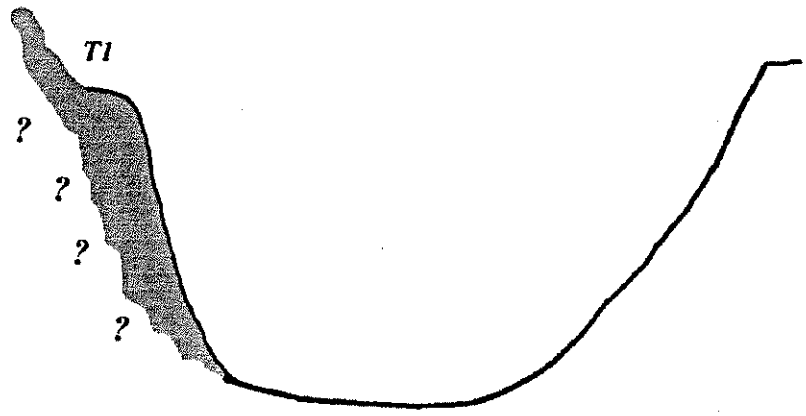


Plate 7.1& 7.2. Plate showing Paleo-valleys cut in the bed rocks at a height of 300-350-m above sea level at Sin Last. The Broz. Sequence of terraces also records a paleo valley.

Figure 7.1 a
Chitral River Tearrces
Model of Chronological Terrace Formation in the Lower Chitral

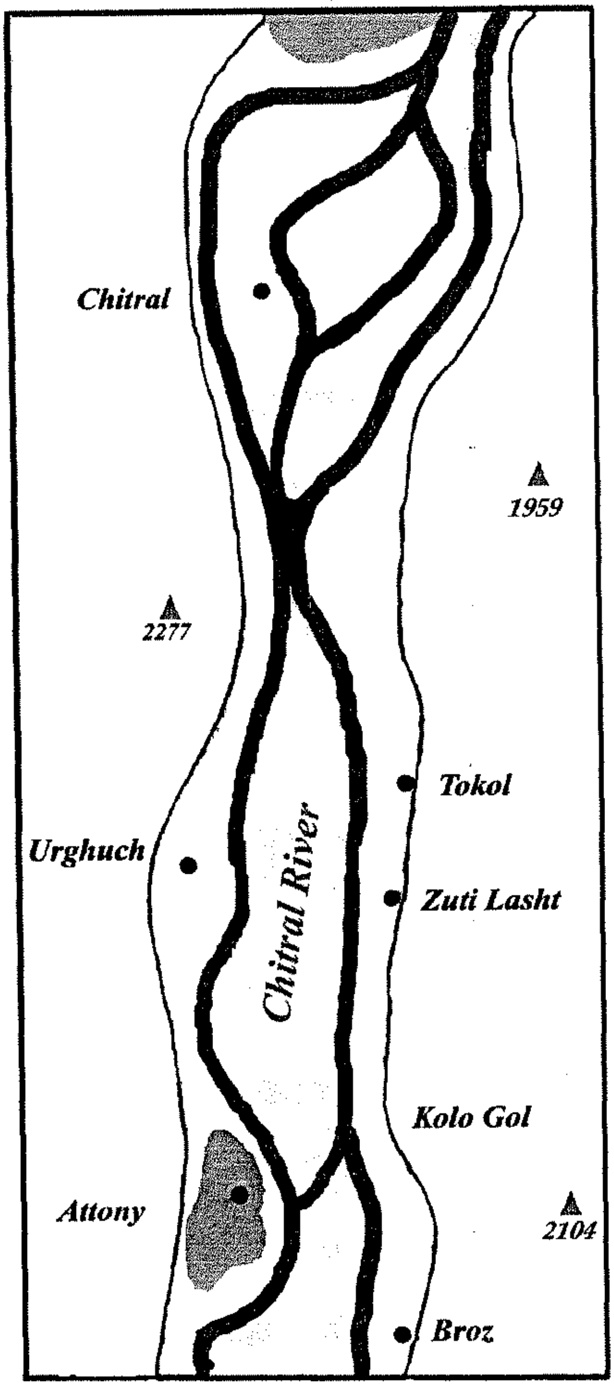


Lower Pleistocene
First Cold Phase

With the onset of glaciation in the upper Chitral valley and also the tectonic uplift, the Chitral river rejuvenated and hence it started erosion. This fluvial incision cut the bedrock into a terrace T1 or the Dalamut terrace. This terrace is located at a height of 355-m above present bed of Chitral river in Dalamut and Sighore sequences, while at Broz (Daman terrace) and Ayun (Attony terrace) record a height of 330-m from the riverbed.

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lower Chitral



T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

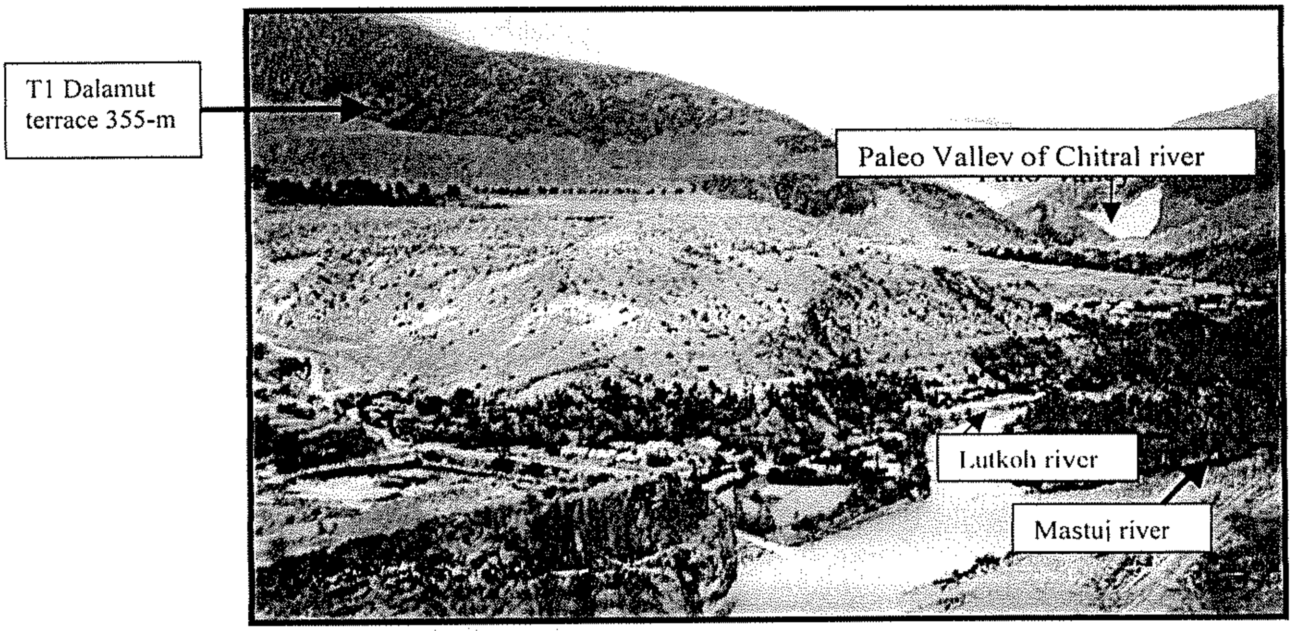
Figure 7.1 b

Lower Pleistocene First Cold Phase

The pre-Pleistocene is marked by a wide valley, in which Chitral river described broad meanders. The valley floor was cut across a variety of bedrocks. With the onset of glaciation in the upper Chitral valley and also the tectonic uplift, the Chitral river rejuvenated and hence it started erosion. This fluvial incision cut the bedrock into a terrace T1 or the Dalamut terrace. This terrace is located at a height of 355-m above present bed of Chitral river in Dalamut and Sighore sequences, while at Broz (Daman terrace) and Ayun (Attony terrace) record a height of 330-m from the riverbed.

First Cold Phase

Erosion



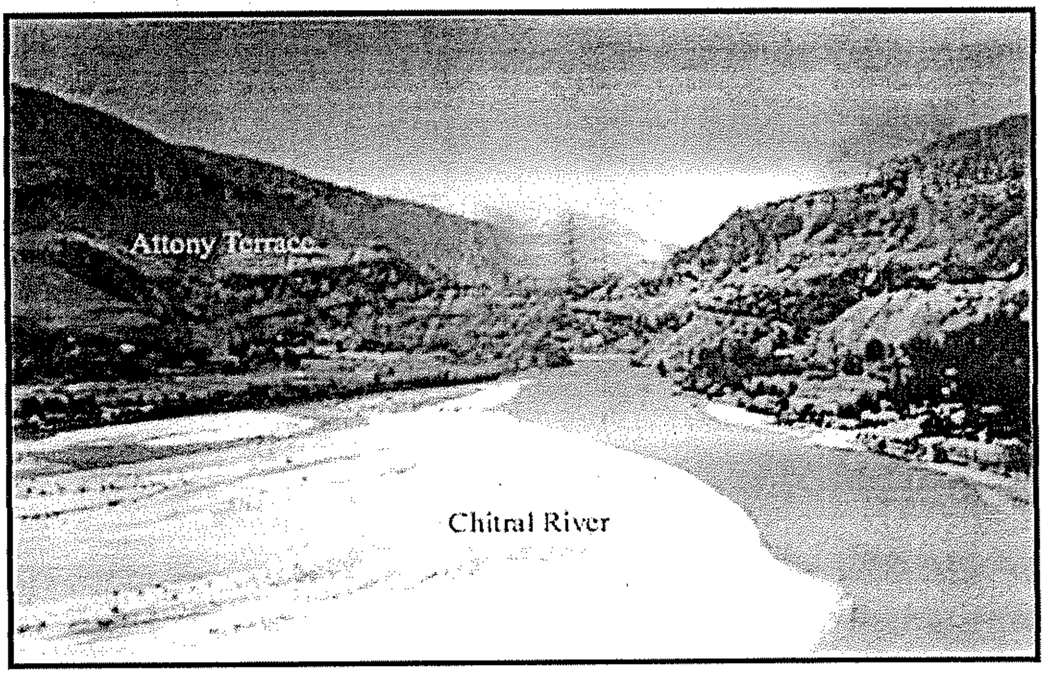


Plate 7.3 & 7.4 The photographs (above) showing Dalamut terrace of Dlamut sequence. This terrace is located at a height of 355-m above present bed of Chitral river in Dalamut and (Lower) Attony terrace of Ayun sequences.

7.2.1b. First Warm Phase

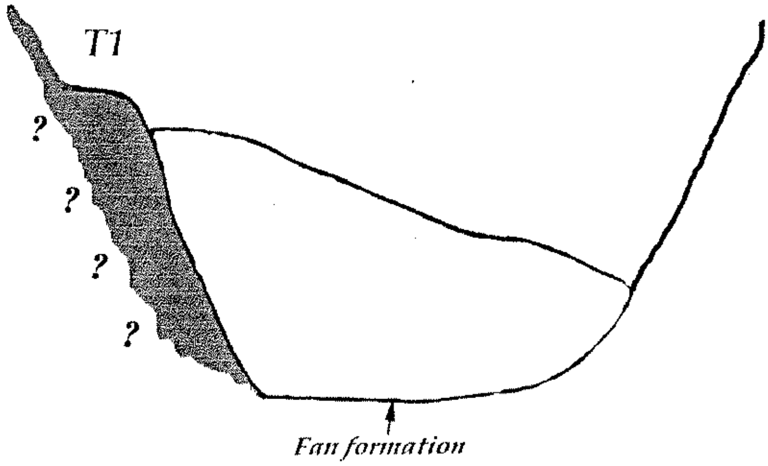
With the increase in temperature, the regolith developed over the slope, during the cold phase, was released. It accumulated at the foothills in the form of scree and alluvial fans. **(Section # 1, bed *a*).** There is evidence that one of alluvial fans blocked the Chitral river and the valley was converted into a lake. It is very difficult to say something about the exact location where Chitral river was dammed, but most probably it was somewhere near Gahrait, the present study found no evidences of lacustrine deposits down stream Gahrait,. Thick deposit of silt was laid on the pre-existing fluvial deposits of sand and gravels. Thickness of the lacustrine facies reveals a long phase of valley ponding. This lake covered a considerable part of Chitral valley as can be seen from the wide spread lacustrine deposits. In section No.1 Dalamut gol the lacustrine facies records a thickness of about 7-m. The lacustrine deposits are also exposed 5-km upstream at Kesu at a height of some 2,500-m.ASL which suggest that lacustrine beds were disturbed by folding. **(Figure 7.2a,b & Plates 7.5 & 7.6)** The lacustrine deposits have been dated back to 120-ka.

7.2.2. Middle Pleistocene

7.2.2a. Second Cold Phase

By the end of first interglacial, the climate started to deteriorate from warm dry interglacial to cold and humid. The evidence of moraine at a height of 1,300-m ASL near Drosh suggests that the whole length of Chitral river valley as for as Drosh was invaded by a glacier. Traces of moraine have not been found in other parts of the study area. This would suggest that subsequent erosion has completely removed all evidence of moraines. A number of events must have taken place, which unfortunately have left no record. What is however clear, is, that the lake formed in the interglacial period drained and bedded siltstone was exposed (Section No 3 bed ***b***, & Section No. 7 bed ***a***). Chitral river, was now flowing over the siltstone. As a result of tectonic uplift, the river incised in the siltstone forming T2 (Siaoch terrace) **(Plate 7.5)**. T2 is preserved in two sections i.e Dalamut gol and Singhore sequences, where it records a maximum height of 325-m above the present day bed of Chitral river (**Figure 7.3a & 7.3b).**

Figure 7.2 a
Chitral River Terraces
Model of Chronological Terrace Formation in the Lower Chitral



Lower Pleistocene
First Warm Phase

With the increase of temperature, precipitation start and the loose material (Regolith) developed over the slope during the Cold phase, was released with torrential rain and was accumulated at the foothills in the form of alluvial fans. One of the huge alluvial fan blocked the Chitral river and hence the Chitral valley was converted into a lake.

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lower Chitral

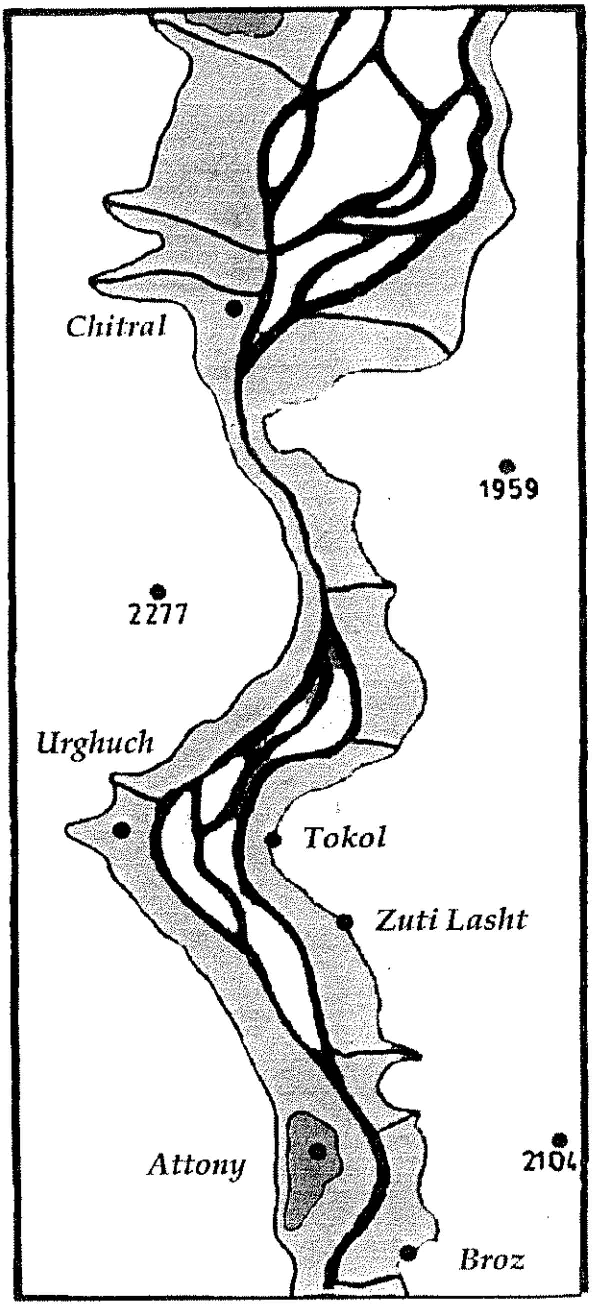


Figure 7.2 b

Lower Pleistocene First Warm Phase

With the increase of temperature, precipitation start and the loose material (Regolith) developed over the slope during the Cold phase, was released with torrential rain and was accumulated at the foothills in the form of alluvial fans. One of the huge alluvial fan blocked the Chitral river and hence the Chitral valley was converted into a lake.

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T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Drosh Cold Phase

Deposition

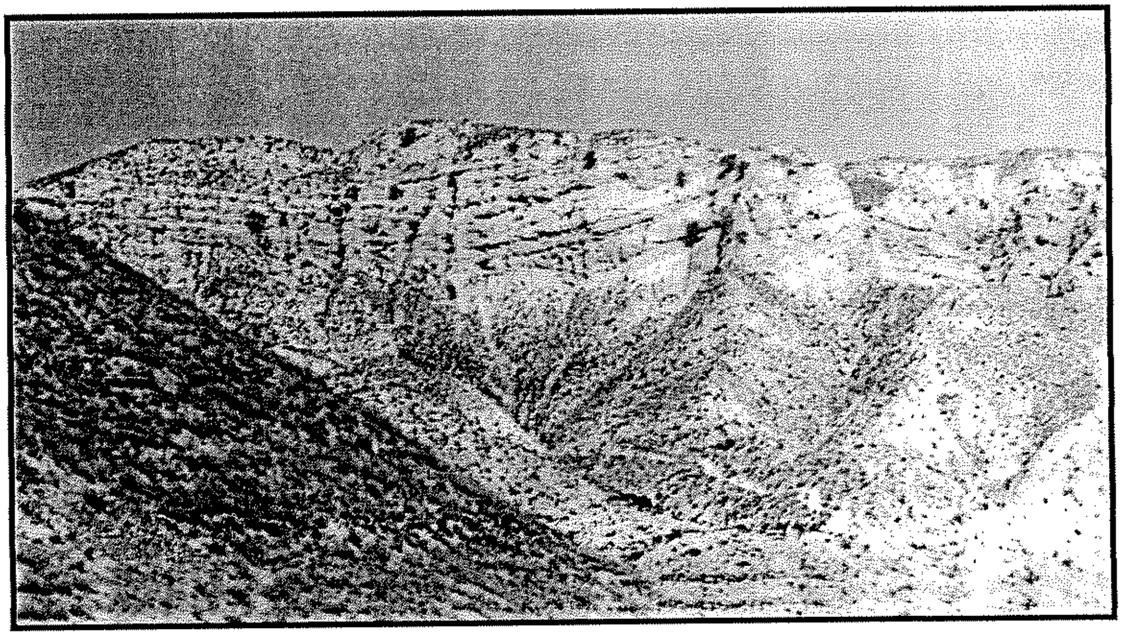
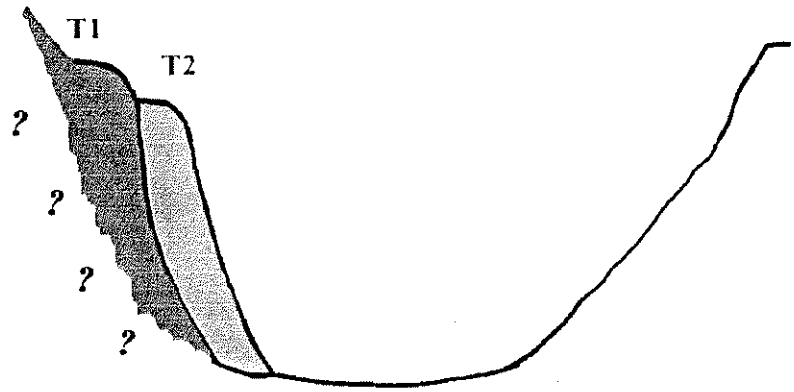


Plate 7.5. & 7.6 The photograph (above) is of Siaoch School terrace (T2 of Dalamut sequence) and (Lower) Kesu lake beds located at a height of 2000 feet from river bed. The beds seem to be disturbed.

Figure 7.3 a
Chitral River Terraces
Model od Chronological Terrace Formation in the Lower Chitral



Middle Pleistocene Second Cold Phase

The lake formed in the Warm phase was drained resulting in the complete elimination of fan material, and the exposure of siltstone. (Section # 3 bed b, Section # 7 bed a). The Chitral river used to flow over the siltstone. The accumulation of siltstone in the lake changed the local base level and hence Chitral river start incision as a result the T2 (Siaoch terrace) of the study area have been formed. The T2 is preserved in two section i.e Dlamut gol and Singhore sequence, where it record a maximum height of 325-m above the present day bed of Chitral river.

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
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T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lower Chitral

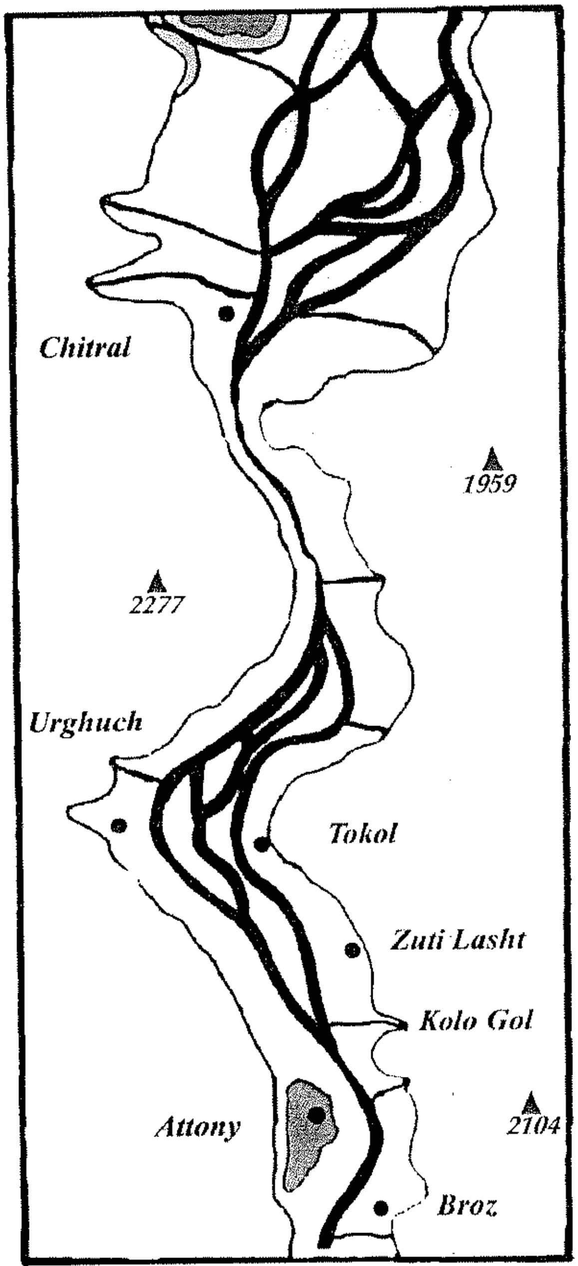

Figure 7.3.b **Middle Pleistocene**
Second Cold Phase

The lake formed in the Warm phase was drained resulting in the complete elimination of fan material, and the exposure of siltstone. (Section # 3 bed b, Section # 7 bed a). The Chitral river used to flow over the siltstone. The accumulation of siltstone in the lake changed the local base level and hence Chitral river start incision as a result the T2 (Siaoch terrace) of the study area have been formed. The T2 is preserved in two section i.e Dlamut gol and Singhore sequence, where it record a maximum height of 325-m above the present day bed of Chitral river.

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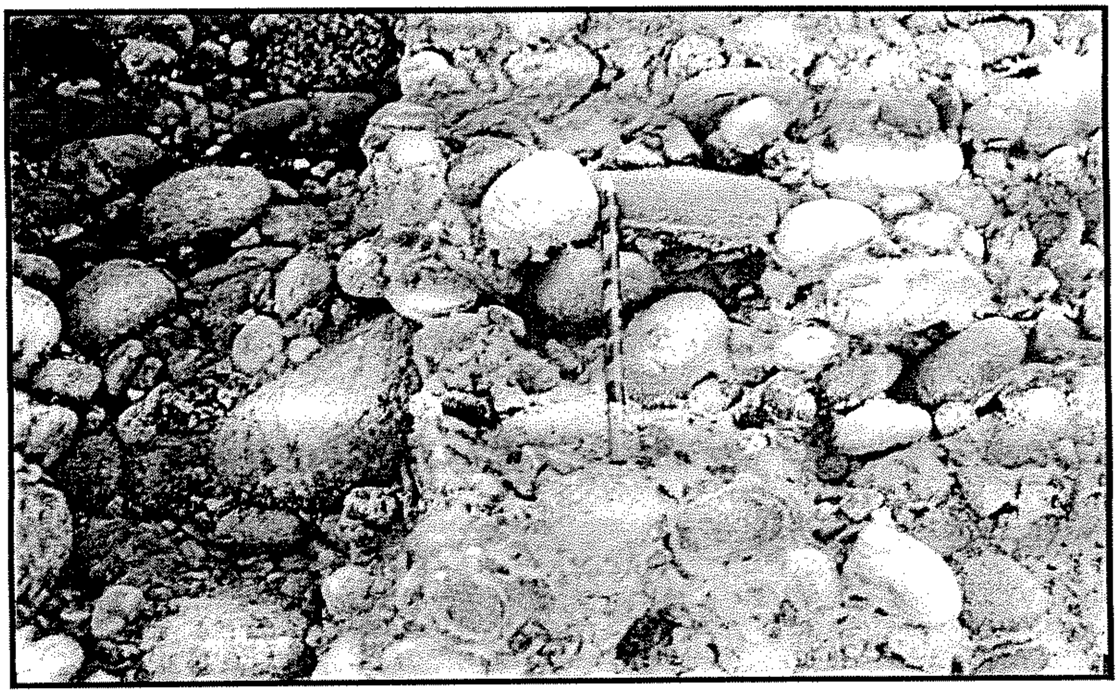
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Pret Cold Phase
Deposition



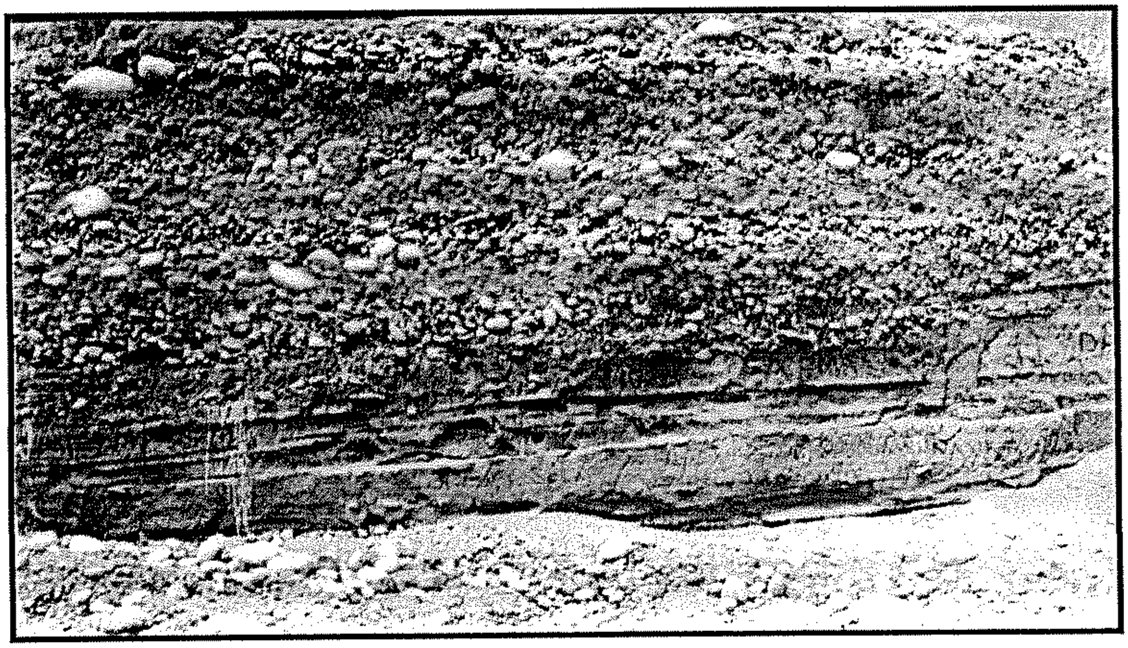


Plate 7.7. & 7.8 The photographs are showing sediment of T3 of Dalamut Sequence, (Section no.1 bed c) the rounded gravels and stratified sand is clearly visible. The T3 and T4 ware cut in the fluvial sediments.

This was followed by a pause in the uplift and a long phase of deposition, during which rounded river gravels and sand was deposited. **(Section No. 3 bed *c* and *d*, section No. 7 bed c).** On the basis of stratigraphic position and absolute dating (OSL / TL) these deposits can be correlated with the Potwar boulder conglomerate, dated back to 1.9 myr by Rendell (1970) and Mahmood-ul-Hasan (1995).

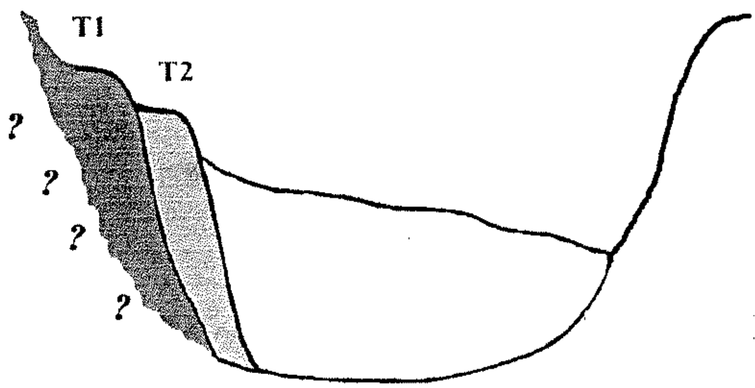
During this phase, the main glacier attained a length of about 270-km, that extended as far as Drosh 1,300-m ASL, 45Km downstream from Chitral town. By the end of this period, the climate became warmer and deglaciation started some 120Ka. As a result of the physical weathering process, a thick regolith developed on the mountain slopes.

7.2.2b. Parwak Warm Phase

The second warm phase started with the change of climate from cold humid to warm and dry, that brought drastic changes in the ecological set up of the valley. The thick regolith layer prepared over the mountain slope during the glacial phase was released with torrential rains, accompanied by mass movements. The material was deposited in the foothills as screes and alluvial fans. **(Section No. 4 bed c).** This marked the second phase of fan formation.

After the development of drainage over fans, the material suffered a long phase of erosion. This erosion may have been caused by slow tectonic uplift, which not only reduced the fans in height but in places totally eroded fan gravels. Fan material is now only exposed at Bakarabad (GR 733082 – 38 M /13). This event is dated back to 110-90 Ka (Kamp 1999), and is comparable to Riss/Wurm period of Alpine model of Glaciation **(Figure 7.4a & 7.4b).**

Figure 7.4 a
Chitral River Terraces
Model of Chronological Terrace Formation in the Lower Chitral



Second Warm Phase (Parwak Warm Phase)

The thick regolith layer prepared over the mountain slope during the Cold phase was released with the torrential rain accompanied by mass movements. The material was deposited in the foothills forming alluvial fans. (Section # 4 bed c). This was the second phase of fan formation in the study area. After the development of drainage over fan, the material suffered a long phase of erosion. This erosion may be caused by slow tectonic uplift, which not only reduced the thickness of material but also totally removed fan gravels from most of the localities.

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lower Chitral

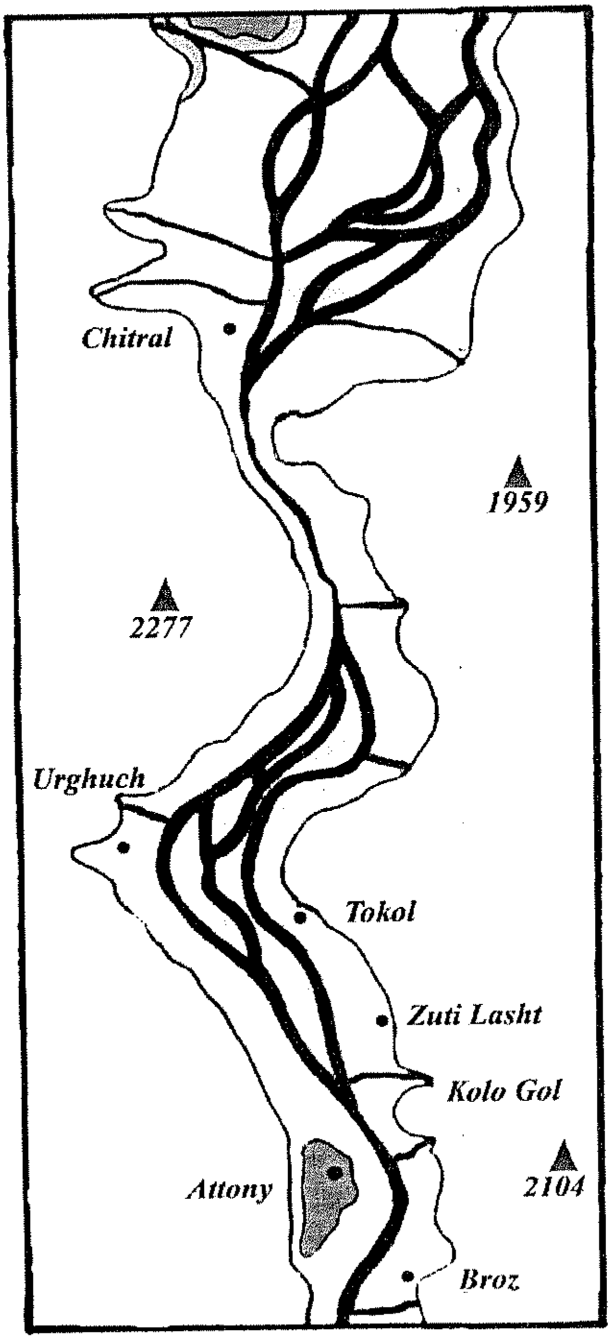


Figure 7.4 b **Second Warm Phase (Parwak Warm Phase)**

The thick regolith layer prepared over the mountain slope during the Cold phase was released with the torrential rain accompanied by mass movements. The material was deposited in the foothills forming alluvial fans. (Section # 4 bed c). This was the second phase of fan formation in the study area. After the development of drainage over fan, the material suffered a long phase of erosion. This erosion may be caused by slow tectonic uplift, which not only reduced the thickness of material but also totally removed fan gravels from most of the localities.

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T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

7.2.2c. Pret Cold Phase

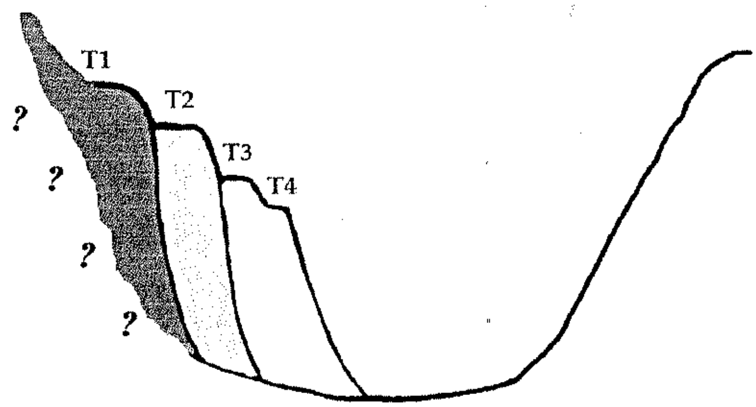
The climate deteriorated once again from warm dry to cold dry. A third phase of glaciation was set in, characterized by a cold dry climate. During this phase, a huge glacier 200-mile long filled the main valley as far as Pret a small village in middle Chitral, some 10-Km down stream Buni, 1670-m ASL.

The second phase of the deposition of fluvial sedimentation occurred during the last phase of the cold humid glacial period. **(Plate 7.7 & 7.8**) It appears as if the change of climate to warm dry interglacial had began. The clast was also readily available for onward transportation by Chitral river, because during the long glacial period, bulk of the eroded sediment had been produced by glaciers forming moraines in the valley. The availability of bulk material at the source region resulted in the sedimentation of the graveliferous deposits in the lower Chitral area. The deposits of fluvial nature are wide-spread in sections, **(Section No. 6 bed a, *b, d*, and Section No.4 bed e and f, Plate 7.9 & 7.10)**. This fluvial sedimentation was followed by an episode of slow-tectonic uplifts. Lake beds as well as the over laying gravels were uplifted and tilted. It also rejuvenated the river resulting in the formation of terraces. T3 and T4 are the result of this fluvial incision. The T3 record a relative height of 250-279-m while T4 record a relative height of 100-170-m above the present day bed of river Chitral. Kamp (1999) identified the same level of terraces at a height of 230-270-m and 140-200-m respectively. **(Figure 7.5a & 7.5b).** Along with fluvial sedimentation a thick regolith was also developed over the mountain slopes favored by cold and dry climate.

7.2.2d. Urghuch Warm Phase

The climate deteriorated once again from cold dry to warm dry interglacial, which paved the way for the third interglacial phase. This interglacial is characterized by another episode of fan formation complemented by episode of relatively rapid tectonic uplift and subsequent erosion. The weathered material developed over the mountain slopes was released with torrential rains, characteristic of the warm dry interglacial climate. The maximum thickness of the fan deposits exceeded 14-m (Section No. 5 bed ***b*** and Section No.8 bed ***b***). A number of fans developed during this phase including Singhore, Chitral,

Figure 7.5 a
Chitral River Terraces
Model of Chronological Terraces Formation in the Lower Chitral



Third Cold Phase (Pret Cold Phase)

The second phase of the deposition of fluvial sedimentation (rounded river gravels and sand etc) The sedimentation of the graveliferous deposits in the lower Chitral area. The deposits of fluvial nature are wide spread in the sections of the study area (Section # 1 bed b, c, d, Section # 3 bed c and d). This fluvial sedimentation was followed by an episode of slow tectonic uplifts, which rejuvenate the river and it, start erosion which cut the fluvial sediments in terraces. T3 and T4 are the result of this fluvial incision.

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lowe Chitral

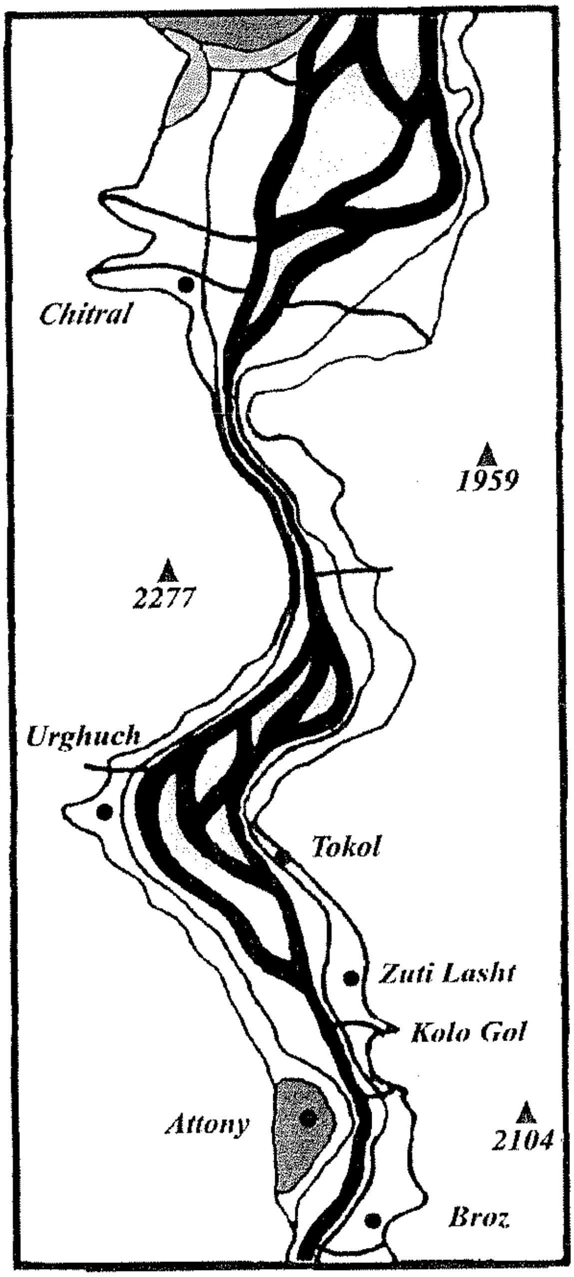


Figure 7.5 b **Third Cold Phase (Pret Cold Phase)**

The second phase of the deposition of fluvial sedimentation (rounded river gravels and sand etc) The sedimentation of the graveliferous deposits in the lower Chitral area. The deposits of fluvial nature are wide spread in the sections of the study area (Section # 1 bed b, c, d, Section # 3 bed c and d). This fluvial sedimentation was followed by an episode of slow tectonic uplifts, which rejuvenate the river and it, start erosion which cut the fluvial sediments in terraces. T3 and T4 are the result of this fluvial incision.

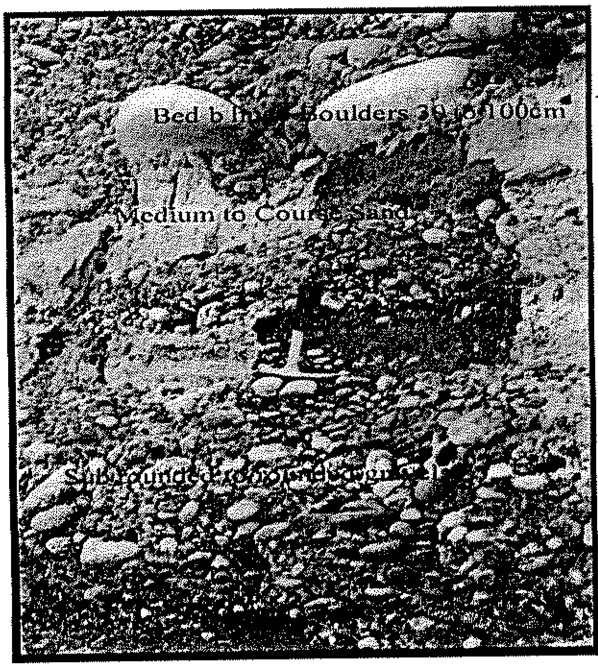
T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Pret Cold Phase

Deposition

Medium to coarse sand in bed f

Rounded gravels in bed e



Large size rounded boulders and gravels

Medium to coarse sand bed b

Bed a rounded to sub rounded gravels

Plate 7.9 & 7.10. **(Upper)***A closer view of beds e & f of section No. 4. The lower bed comprises medium to large size rounded to sub-rounded river gravels. The upper bed is composed of light-gray bedded siltstone. The(Lower) photograph shows beds a, b &* **d** *of section No. 6, which is exposed 15km downstream from Chitral town on Chitral–Ayun road, just 2km north–west of village Ayun. Bed* **d** *consists of large-size boulders of about 30 cm to half a meter, with a maximum thickness of about 5 meter.*

Broz, Ayun, Urguch and Kesu etc. **(Plates 7.11 & 7.12).** After the fan formation there was an episode of slow tectonic uplift, initiating erosion of the fan gravels. The fan deposits are cut into terraces. T5 and T6 are the result of this fluvial incision, which are well-preserved in almost all 10 sequences. This interglacial phase is dated back to <60ka. (**Figure 7.6a & b & *Figure 7.7a & b***).

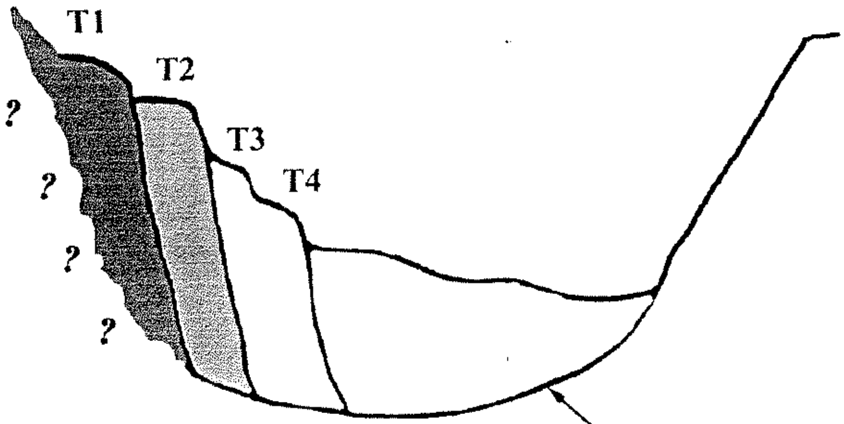
7.2.3. Upper Pleistocene

7.2.3a. Sanoghur Cold Phase

The last cold phase in the Chitral valley is characterized by the deposition of thick mantle of loess, reflecting periglacial environment. **(Section No.1 bed *g*; section No. 2 bed *d*; section No.3 bed *e*).** In places loess attain a thickness of about 10-meters. This cold phase correspond to the fourth glacial phase, dated back to < 60 Ka to >10 Ka.

The loess had a widespread distribution over the entire valley, in places, burying the pre-Pleistocene topography. A thick layer of loess covers almost all terrace surfaces in Dalamus and Singhore sequences. Thick deposits of loess have also been observed on Birmoughlasht height (7510-m ASL). A number of workers have reported loess from several parts of N.W.F.P. and Punjab i.e Allen (1994). In Mardan and Sangao area younger to older loess deposits have been mentioned by Allen and Dani (1964). These have been correlated with the loess deposits of Attock area, recording a cool and relatively dry period of steppe climate. Loess in Chitral has been dated from 15,000-to 50,000-year bp. (Kamp, 1999 & Owen et al 1992).

Figure 7.6 a
Chitral River Terraces
Model of Chronological Terrace Formation in the Lower Chitral



Third Warm Phase (Urghuch Period)

This Warm phase is characterized by third episode of fan formation in the Chitral valley complemented by episode of rapid tectonic uplift and subsequent erosion. A number of fan developed during this phase including Singhore, Chitral, Broz, Ayun, Urguch and Kesu etc. After the fan formation there was an episode of slow tectonic uplift which rejuvenate the river caused the degradation of the fan gravels and the fan deposits are cut into terraces. T5 and T6 are the result of this fluvial incision. Both these terraces are well preserved in almost all the 10 sequences.

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lower Chitral

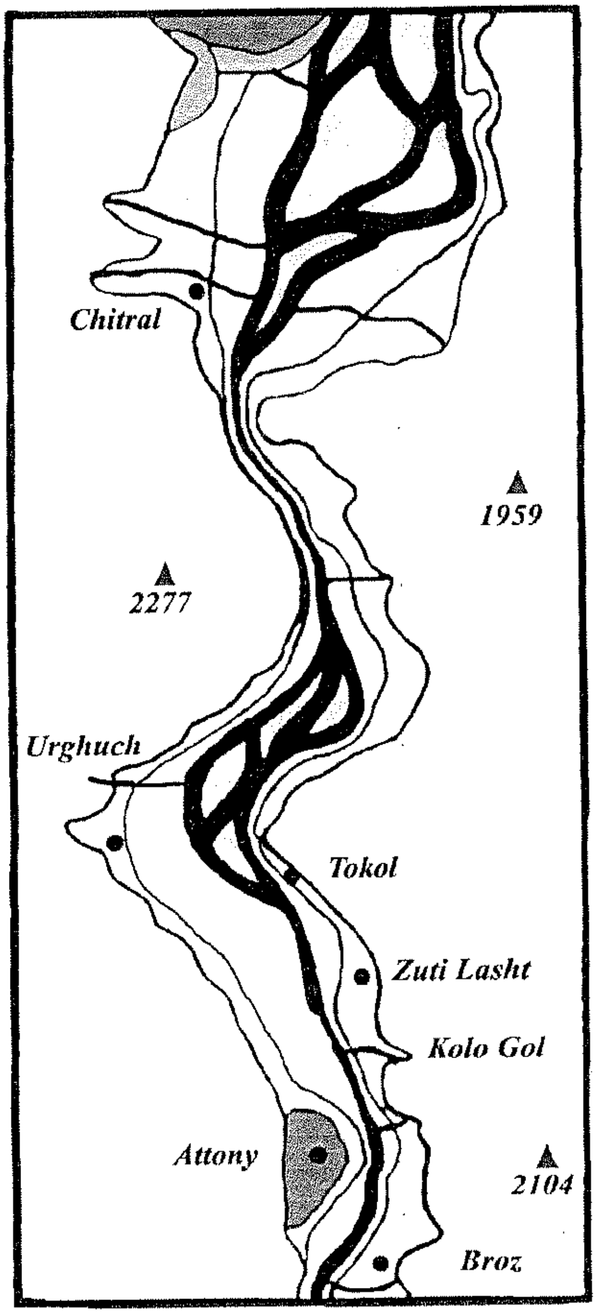


Figure 7.6 b Third Warm Phase
Urghuch Period

This Warm phase is characterized by third episode of fan formation in the Chitral valley complemented by episode of rapid tectonic uplift and subsequent erosion. A number of fan developed during this phase including Singhore, Chitral, Broz, Ayun, Urguch and Kesu etc. After the fan formation there was an episode of slow tectonic uplift which rejuvenate the river caused the degradation of the fan gravels and the fan deposits are cut into terraces. T5 and T6 are the result of this fluvial incision. Both these terraces are well preserved in almost all the 10 sequences.

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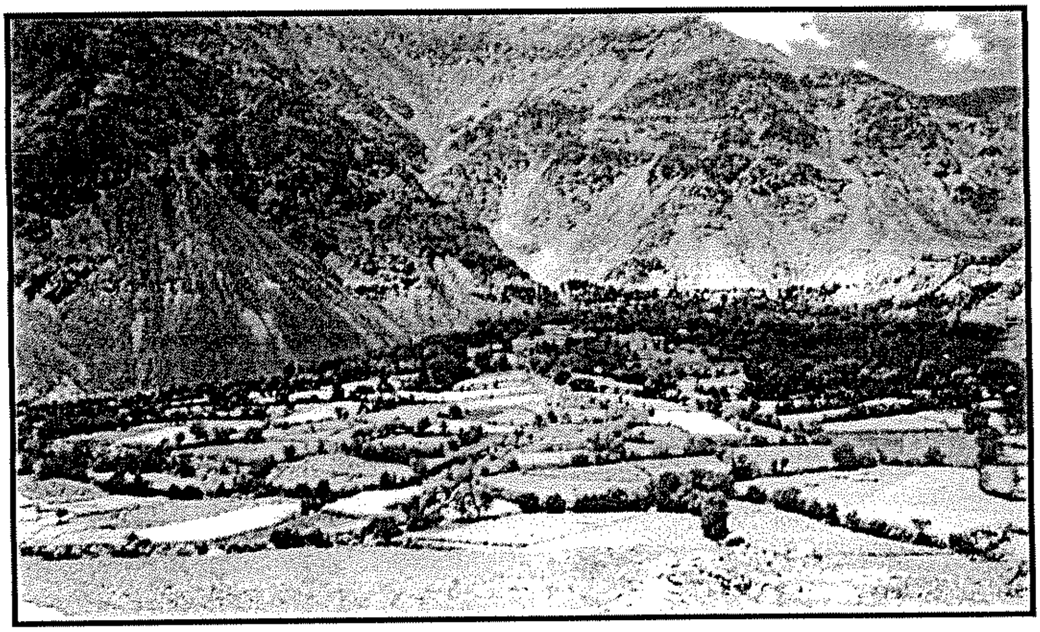
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Urghuch Period

Deposition



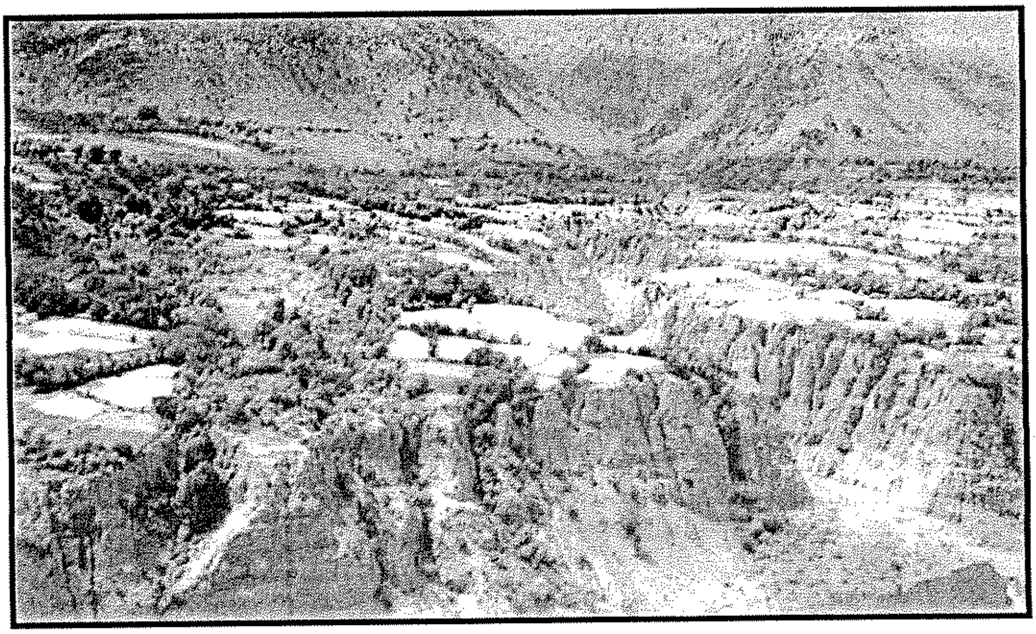


Plate 7.11 & 7.12 The photograph (above) is showing the general view of the Urghuch village and (Lower) a closer view of village in which the channel of Urghuch gol is clearly visible. The deposition is dated back to >60ka, T5 and T6 have been cut in the fan material.

Said and Majid (1977) correlated the loess deposits of Bar Daman area of southern part of Peshawar with the late cold phase of the third Himalayan glaciation. The origin of loess has been attributed to the glaciated area of the Himalayas and Hindukush. Hasan (1995) and Inam (1990) on the other hand have suggested a warm and dry climatic condition for the deposition of loess, during the interglacial phase. ***(Figure 7.7b, Plate 7.13 & 7.14).*** The present study suggests that the production of loess in cold mountainous environment is a continuous process; glaciers transported the weathered material prepared during a cold glacial phase. It was followed by the deflation of silt and clay particles from the morainic material by wind, which was redeposited as loess in lower Chitral.

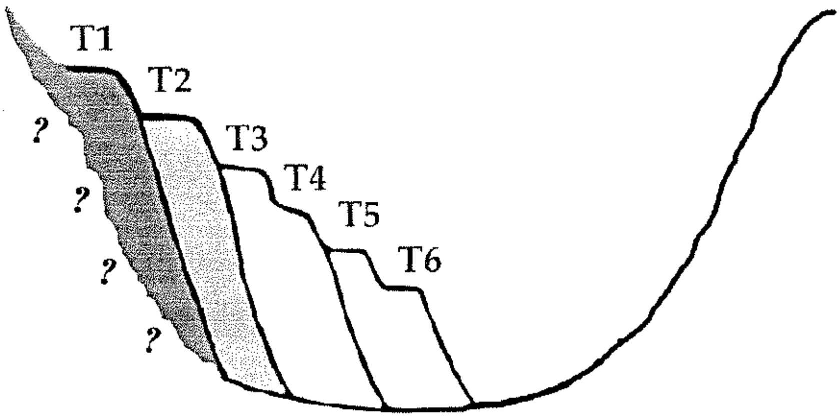
7.2.4. Post Pleistocene

7.2.4a. Holocene

The climate of Chitral valley began to improve about 15,000 year ago. The period is dominated by fluvial processes. Chitral river incised its channel; this was in response to slow tectonic uplift, and also due to the melting of glaciers that increased the discharge of the rivers. As a result, during the two phases of fluvial incision, T7 and T8 (Airport and Kuru terraces) have been formed by Chitral river in its flood plain. T7 can be observed in all sequences except Broz, Gahrait and Drosh. It records a relative height of 15-m above Chitral river bed. While T8 records a relative height of 05-m above the present day bed of Chitral river and is preserved in all the ten sequences. ***(Figure 7.8a & b, Plate 7.14 & 7.15).***

Even this geologically brief period has shown climatic variations. Several workers have been able to identify eight main Holocene phases of glacial expansion in the Himalayas, dating back to 7400-b.p., 4,500-4600-b.p., 3700-3100-b.p., 2700-2100-bp., 1700-1500-b.p., 1200-950-b.p., 700-b.p. and little ice age of 550-100-b.p. (Hasan 1995) (Rothlisberger & Geyh 1975) As for as the Chitral valley is concerned the impact of Holocene ice advances and climatic variations, on the landform development is not fully known.

Figure 7.7 a
Chitral River Terraces
Model of Chronological Terrace Formation in the Lower Chitral



Upper Pleistocene Fourth Cold Phase (Sanoghur Cold Phase)

The last Cold phase in the Chitral valley is characterized by the deposition of thick mantle of loess reflecting Cold Phase environment. (Section #1 bed g, section # 2 bed d, section # 3 bed e). In places loess attain a thickness of about 10-meter. The Sanoghur Cold Phase is dated back to between < 60 Ka to >10 Ka. by Kamp, It has been suggested that it be deposited from 15,000-t0 50,000-year bp.

T1	*Bed Rock*	*First Cold Phase ???*
T2	*Lacustrine material*	*Drosh Cold Phase (120 ka)*
T3 T4	*Fluvial material (old)*	*Pret Cold Phase (90-110 ka)*
T5 T6	*Fan Gravels*	*Urghuch Warm Phase (< 60 ka)*
T7 T8	*Fluvial material (recent)*	*Holocene (< 10 ka)*

Model of Chronological Terrace Formation in the Lower Chitral

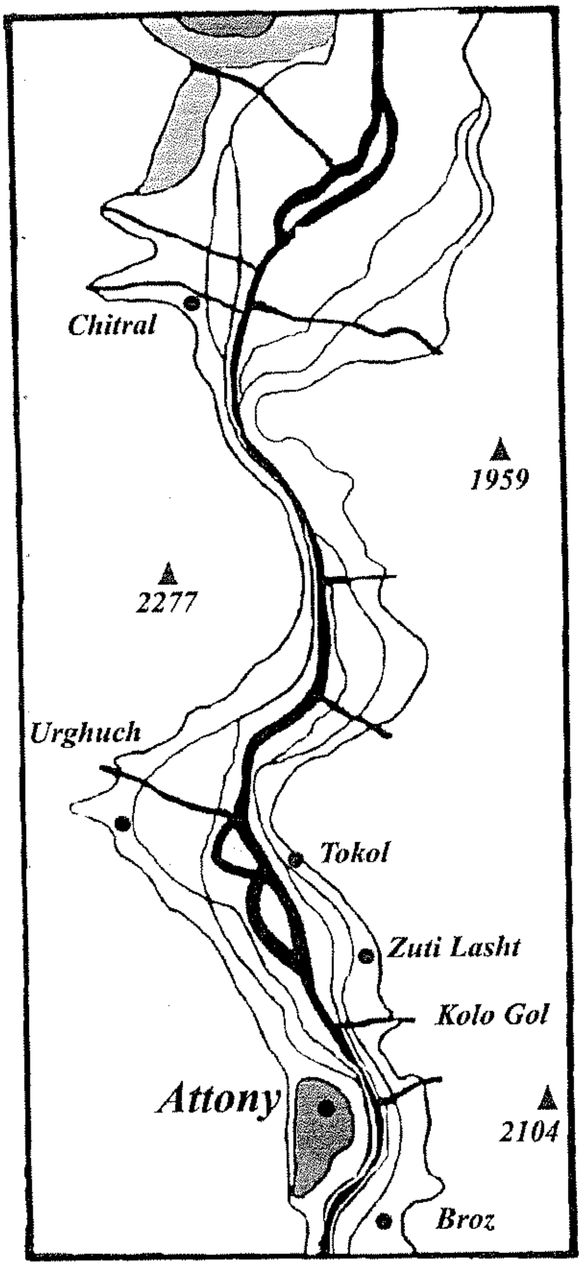
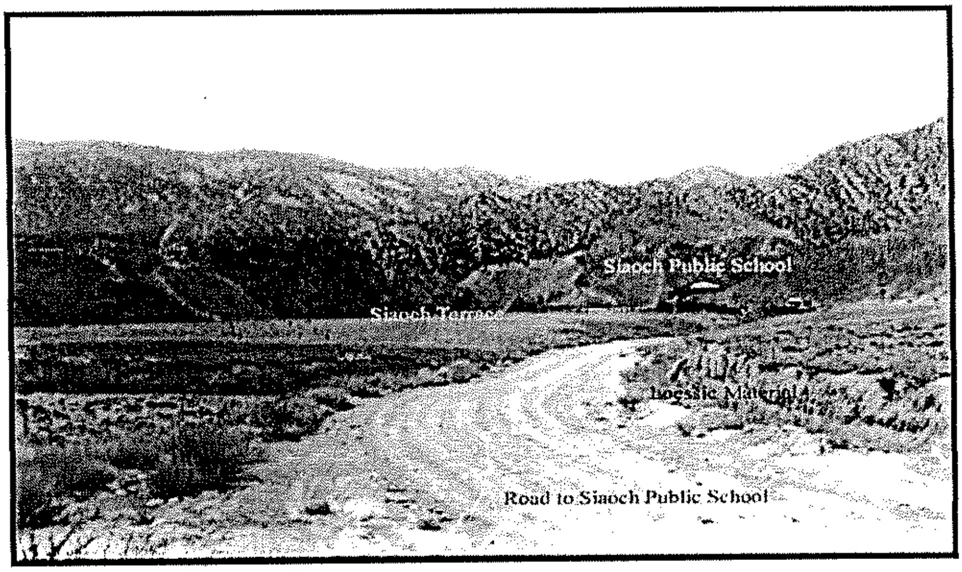


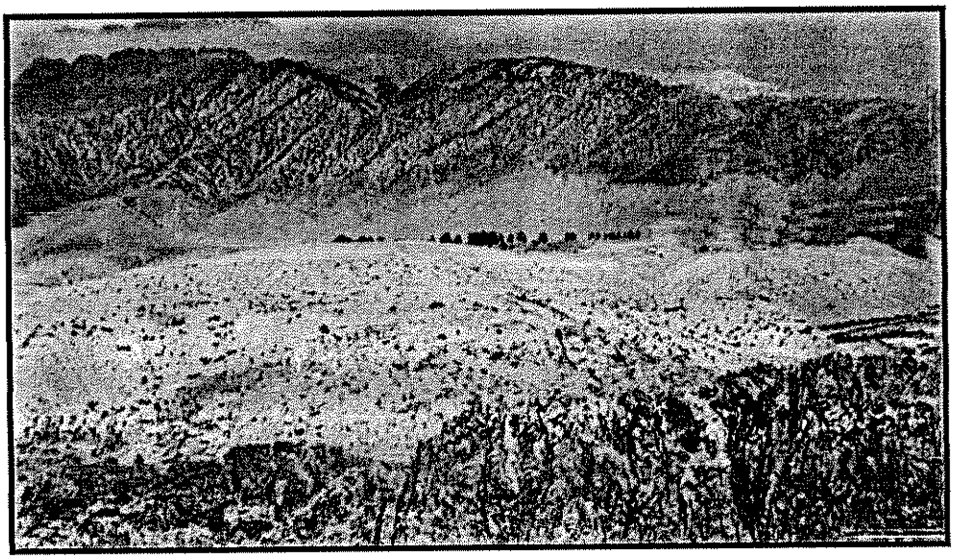
Figure 7.7 b **Third Warm Phase Urghuch Period (Erosion)**

After the fan formation there was an episode of slow tectonic uplift which rejuvenate the river caused the degradation of the fan gravels and the fan deposits are cut into terraces. T5 and T6 are the result of this fluvial incision. Both these terraces are well preserved in almost all the 10 sequences.

T1	*Bed Rock*	*First Cold Pha ???*
T2	*Lacustrine material*	*Drosh Cold Ph (120 ka)*
T3 T4	*Fluvial material (old)*	*Pret Cold Pha (90-110 ka)*
T5 T6	*Fan Gravels*	*Urghuch Wa Phase (< 60 k*
T7 T8	*Fluvial material (recent)*	*Holocene (< 10 ka)*

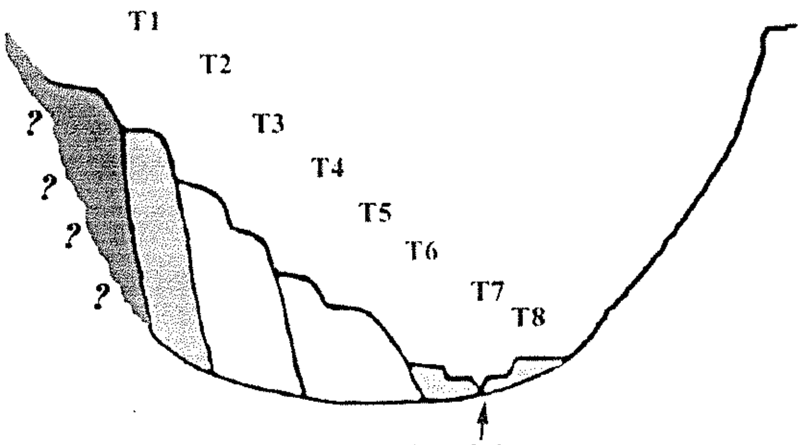
Sanoghur Cold Phase
Deposition





Plates

Figure 7.8 a
Chitral River Terraces
Model of Chronological Terrace Formation in the Lower Chitral



Post Pleistocene
Holocene

The climate of Chitral valley began to improve about 15,000 year ago. The period is characterized by fluvial incision. This incision is perhaps due to slow tectonic uplift, and because of the melting of glaciers that maximized the discharge of the rivers. As a result during two phases of fluvial incision T7 and T8 (Airport terrace and Kuru terrce) have been cut by Chitral river in its flood plain

T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Model of Chronological Terrace Formation in the Lower Chitral

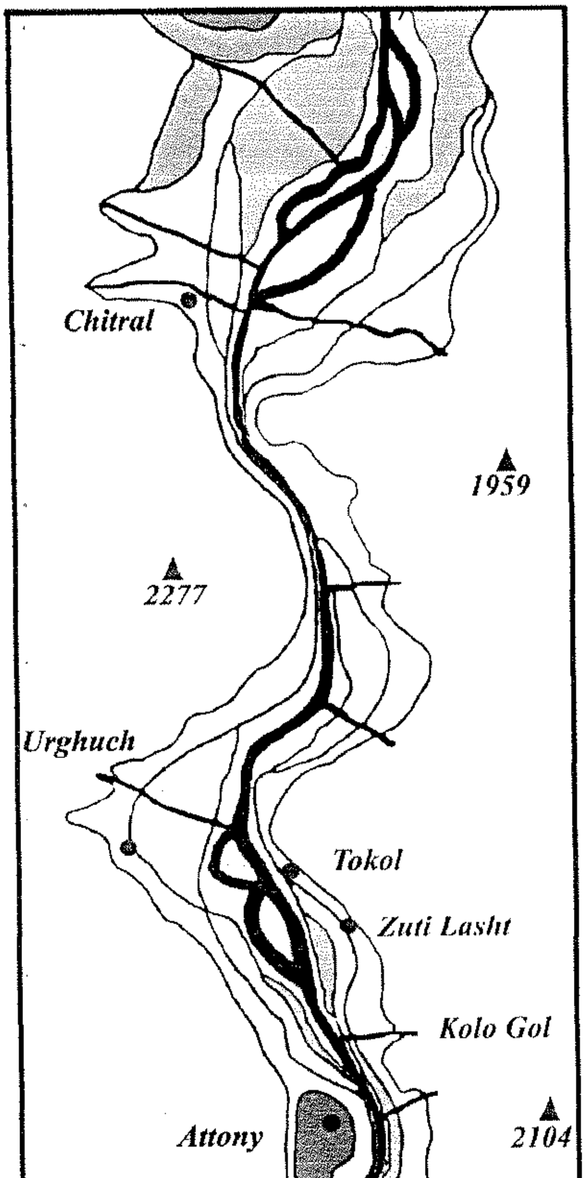


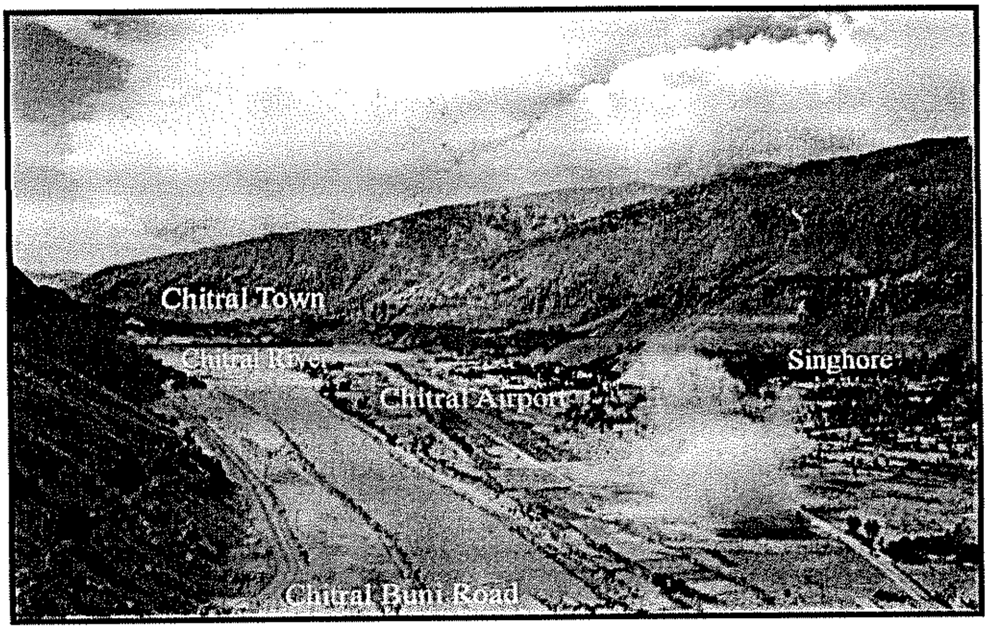
Figure 7.8 b *Post Pleistocene Holocene*

The climate of Chitral valley began to improve about 15,000 year ago. The period is characterized by fluvial incision. This incision is perhaps due to slow tectonic uplift, and because of the melting of glaciers that maximized the discharge of the rivers. As a result during two phases of fluvial incision T7 and T8 (Airport terrace and Kuru terrce) have been cut by Chitral river in its flood plain

T1	Bed Rock	First Cold Pha ???
T2	Lacustrine material	Drosh Cold Ph (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Pha (90-110 ka)
T5 T6	Fan Gravels	Urghuch Wa Phase (< 60 k
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Holocene

Erosion



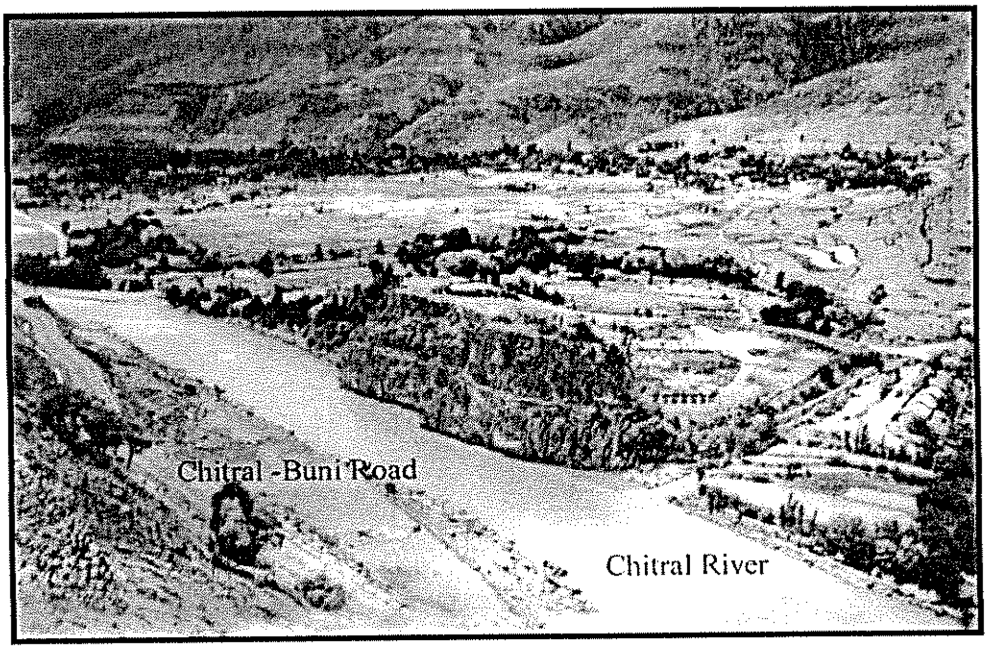
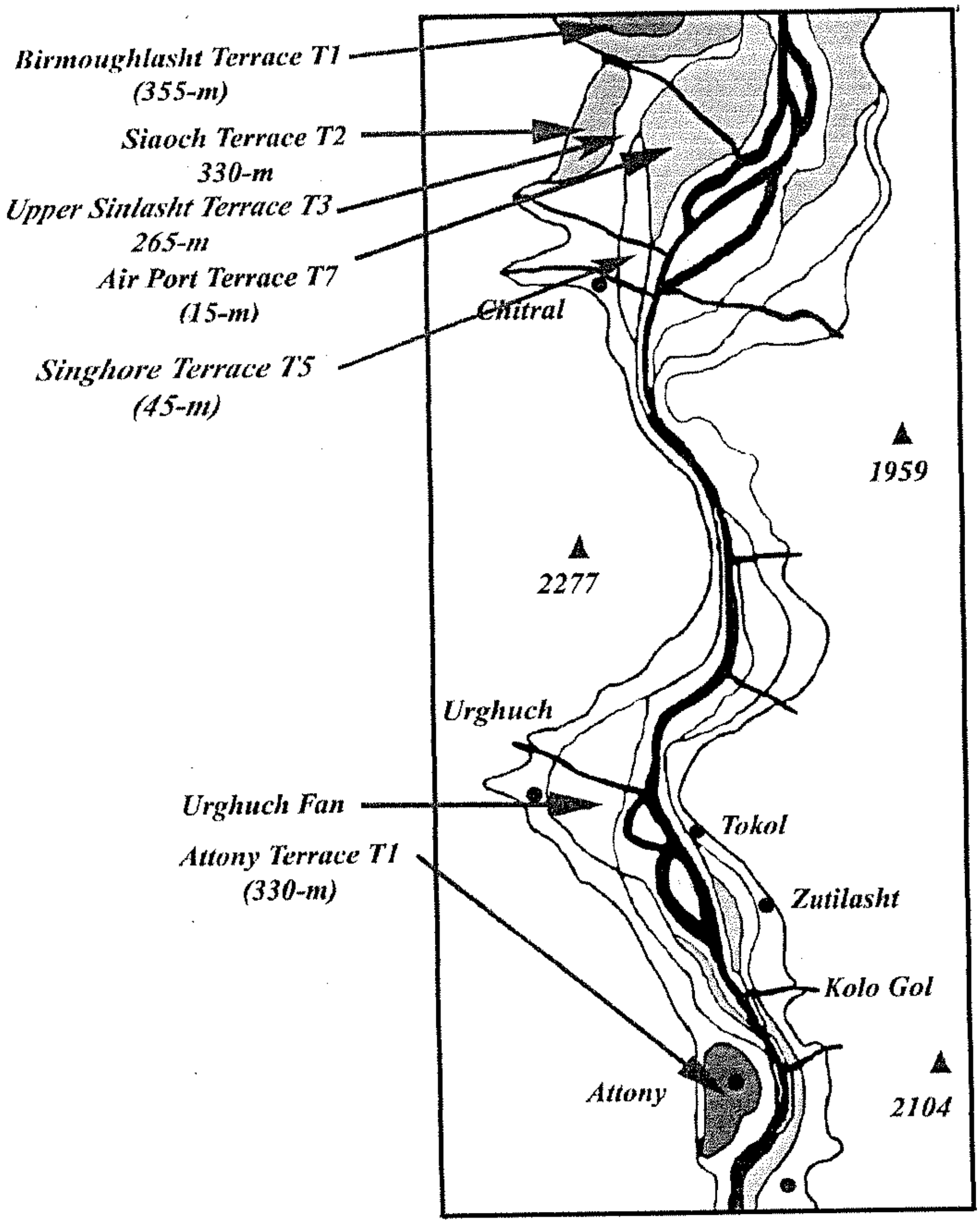


Plate 7.15. & 7.16 The photographs are showing T7 (Air Port terrace of Singhore sequence which runway of Chitral Air Port is visible) and T8 (Kuru Terrace Danin sequence on which the Chitral-Buni road is passing). T8 is only 0 m from riverbed.

Model of Chronological Terrace Formation in the Lower Chitral



T1	Bed Rock	First Cold Phase ???
T2	Lacustrine material	Drosh Cold Phase (120 ka)
T3 T4	Fluvial material (old)	Pret Cold Phase (90-110 ka)
T5 T6	Fan Gravels	Urghuch Warm Phase (< 60 ka)
T7 T8	Fluvial material (recent)	Holocene (< 10 ka)

Figure 7.9
Showing general distribution of terraces in the study area

7.3. Correlation

Correlation with other glacial chronologies is extremely difficult because the glacial record in any mountain environment is commonly incomplete (Gibbons et al., 1974) and because at least 32 glaciations have been identified in the deep sea record for the late Cenozoic (Shackleton & Opdyke, 1973). Probably many more glaciations occurred in the Himalaya-Karakoram than have been recognized at present.

Secondly the very poor age constraints on the glacial deposits and crude correlations between deposits indicate that many of the sediments which have been assigned to a single glaciation may in fact represent more than one glaciation.

The glacial history of Swat in northern Pakistan is particularly constrained by the thermoluminescence (TL) dates from loessic deposits that overlain moraines. Owen at al., (1992) showed that these loessic deposits were reworked and therefore care must be taken when interpreting these dates. They provide minimum ages, such that the last glaciation (Kalam Glacial Stage) must have occurred after at least 22Ka BP and terminated by about 6.7Ka BP. **(Table 7.3 and 7.4).**

The timing of the glaciation in Hunza valley is also partly constrained by TL dates of glacio-lacustrine and aeolian sediments (Derbyshire et al. 1974). The procedures used in dating analysis were not clear so it is difficult to evaluate the results. However the dates indicate that the older glaciation in the Hunza valley represent the last glacial maximum and occurred around 50Ka BP. With subsequent glacial event being less extensive. **(Table 7.4).**

In the Lahul Himalayas, northern India, Optically Simulated Luminescence (OSL) dating strongly suggest that an extensive valley glaciation (Batal Stage) culminated prior to 43.4 ± 10.3 Ka BP. A less extensive glacial event (Kulti Glaciation) occurred after approximately 36.9 ± 7.4 ka BP (Owen et al. 1996, 1997). **(Table 7.3).**

The comparison of results with the Eastern Hindu Kush and the surrounding mountains and other mountain ranges in high Asia, suggests a parallelism of phases and events in the early and middle glacial stages (≅Mindel/Riss). The timing of Pleistocene glaciation in the Himalayas and Tibetan Plateau region is very poorly constrained. During the last glacial cycle, glacier in the north (Kunlun, Keriya Pass) and in the south east (Khumbu) reached their maximum positions at 17-22 ka BP. approximately synchronously with the global glaciation maximum of 20-17 ka BP. In the Karakoram and northern India (Swat, Hunza, Lahul, Garhwal) the last glacial maximum appear to have been earlier, in the region of 60-40 ka BP.

Table 7.1 Chronology of Deposits and Terraces Formation for Chitral Valley

Periods	Interval	Climatic Condition	Absolute Date	Sequence of Significant Geomorphic Events
Post Pleistocene	Holocene	Temperate	<10Ka	• Development of floodplain and subsequent erosion cut the flood plain to cut into terraces and T7 and T8 of the study area have been formed.
Upper Pleistocene	Fourth Glacial	Cold Dry	Sanoghur Cold Phase <60-10Ka	• A phase of deposition this time the wind was an active geomorphic agent and the result was the extensive loess deposits of the study area.
Middle Pleistocene	Interglacial	Warm Humid	Urghuch Warm Phase <60ka	• Third phase of fan gravels and two phases of subsequent slow tectonic uplift cause the river to rejuvenate and the fan is cut in terraces. T5 and T6 are the result of this fluvial incision.
	Third Glaciation	Cold Dry	Pret Cold Phase 90-10ka (≅Wurm)	• Second phase of deposition of rounded gravels and Sand and the subsequent uplift cut these fluvial deposits to cut into terrace the T3 and T4 are the result of this fluvial incision.
	Interglacial	Warm Dry	Parwak Warm Phase 110-90ka (≅Riss/Wurm)	• Second Phase of fan formation. The evidences of this fan material are only preserved in the Bakarabad. The *Bed c* of this section is composed of 1-m thick deposits of fan material.This material is dated back to 130±10ka by Kamp.(P201)
	Second Glaciation	Cold Humid	190>120-ka Drosh Cold Phase (≅ Riss)	• The deposition of rounded gravels and sand (fine, Medium, Coarse) The material is dated back to 121± 9ka (P203) by Kamp. • Draining of Lake and the subsequent slow tectonic uplift rejuvenate the river and T2 of the study area has been cut in the lacustrine deposits. • Formation of Lake in Chitral valley and the deposition of silt.
Lower Pleistocene	Interglacial	Warm Dry	>200Ka (≅Mindel/Riss)	• Formation of alluvial fan and the subsequent blocking of Chitral river by fan. The material is exposed in the lower bed of Broz section. Also conformed by Kamp, dated back to 177± 30 ka. (P204)
	First Glaciation	Cold Humid	??? (≅Mindel)	• The development of Thick regolith on mountains. A long phase of Erosion by Chitral River and the formation of T1 (Dalamut Terrace) of the study area.

Source: Field Work

Table 7.2

Chronology and Relative Height of Terraces in different Sequences in Study Area (Lower Chitral) Compared with Kamp (1999)

Sequences Present Study	T1 355 m	T2 310-325m	T3 250-270m	T4 100-170m	T5 60-75m	T6 40-50m	T7 10-15m	T7 0-05m
	First Cold Phase ???	Drosh Cold Phase >120Ka	Pret Cold Phase 90-10Ka		Urghuch Warm Phase(< 60 Ka)		Holocene Period <10ka	
U.Kamp 1999	T4a 310-350	T4a 310-320m	T4b 230-270m	T3a 140-200m	T3b 70-110m	T2a 10-60m	T2b 10-60m	T1 0-10m
	Broz Period (190-140 Ka)		Ayun Period (140-110 Ka)		Urghuch Period (190-140 Ka)		Holocene	
Dalamuts	355	325	265	-	60	-	15	05
Singhore	355	325	270	-	60	45	15	05
Danin	-	-	-	-	65	40-50	15	05
Chitral	-	-	-	120	65-75	45	15	05
Jughore-Bakarabad	-	-	-	100-130	60	40	15	05
Broz	330	-	250	170-170	60-70	-	-	05
Ayun	330	-	-	-	7-	40	15	01-05
Kesu	-	-	-	-	-	45	15	05
Gahrait	-	-	-	100-170	60-70	40	-	05
Drosh	-	-	-	-	60-75	45	-	05

Source. Field survey 1999-2000

Table 7.3

Chronology of the quaternary of different high mountains areas in High Asia after Different Authors

Classification			Hindukush	Peshawar Vale			Garwal Himalaya	Lahul Himalaya	Lahul Himalya
Period	Glacial/I.G	Stadial	Kamp (1999)	Mahmood-ul-Hasan (1995)			Sharma & Owen (1996)'	Owen et al (1997)	Taylor & Mitchell (1997)
Holocene		Historica l	Barum II	Holocene			Bhujbas	Sonapani II	
		LIA	Barum I						
		New Glacial	Shandur I				Shivling	Sonapani I	Stage IV
			Shandur II						
Pleistocene	Late Glacial Wurm	Late glacial	Sanoghar	.Pleistocene	Uppe	Fifth Glacial	Bhagirathi	Kulti	Stage III
						Inter Glacial		Bata II	Stage II
			Pret		Middle	Fourth Glacial		Bata I	Stage I
	Interglacial Riss/Wurm		Parwak			Interglacial		Chandara	
	Middle Glacia Riss	Late	Drosh			Third Glacial			
						Interglacial			
		Early				Second Glacial			
	Interglacial Mindle/Riss		Early Glacial		Lower	Interglacial			
	Early Galcial Mindle					First Glacial			

Source: Literature Review

Table 7.4

Chronology of the Quaternary of different high mountains areas of Pakistan after Different Authors

clssification		Hindukush			Peshawar Vale	Afghani stan	Gilgit/Hunza				Swat Kohistan	
Period	Glacial/I.G	Jamal 2001		Kamp (1999)	Mahmood-ul-Hasan (1995)	Grotzbach & Rathjens (1969)	Derby Shire et al (1974)	Zhang &Shi (1970)	Shroder et al (1979)	Desio & Orombelli (1971)	Porter (1970)	Richards (1999)
Holocene		Halocene	Halocene	Barum II	Holocene	Historical	Passu II	Historical	Historical			
				Barum I			Passu I	LIA	LIA			
				Shandur I		Ramayal	Batura	Neoglacial	Neoglacial		Neoglacial	
				Shandur II								
Pleistocene	Late Glacial Wurm	Upper Pleistocene	Sanoghar Cold Phase	Sanoghar	Fifth Glacial	Salang	Gulkin II	Hunza	Darel-Shatial Moraine		Kalam I-III	Ke Gas
					Interglacial							
		Middle Pleistocene	Urghuch Warm Phase		4th Glacial		Gulkin I					Kalam I
			Pret Cold Phase	Pret	Interglacial	High Glacial	Borit Jheel		Dainyor Moraine	Dak Chowki Moraine		Gabral II
	Interglacial Riss/Wurm		Parwak Warm Phase	Parwak	3rd Glacial				Talfullung III		Gabral II	
	Middle Glacial Riss		Drosh Cold Phase	Drosh	Interglacial		Yunz	Yunz	M2 Tillite	Gunar Moraine		
					2nd glacial				Talfullung II	Dudishal Shatial Moraine	Gabral I	
									M1 Tillite			
	Interglacial Mindle/Riss	Lower Pleistocene	First Warm Phase		Interglacial				Upper Jalipur Talfullung 1			
	Early Galcial Mindle		Early Cold Phase		First Glacial		Shanoz	Shanoz	Lower jalipur tillite		Laikot	

Source: Field Work and Literature

Chapter No. 8
Summary and Conclusion

Chapter No. 8
Summary and Conclusion

Chapter 1

Chapter 1 explains the general environment of the study area. The chapter describes with the help of maps, tables and diagrams the location, topography and Climate.

Chapter 2

Chapter 2 explains the research methodology adopted for the present study. First the research questions were prepared, followed by formulation of hypothesis, objectives and methods of section studies. Finally it also describes the different test applied to the samples.

Chapter 3

Chapter 3 is literature review. Early references to the terraces of Chitral are few and far between. The present study is the first attempt to describe the distribution of terraces in Chitral, their surface deposits and genesis. A number of researchers have studied various aspects of the area. The literature was mostly collected through Internet. Lewis Andrew Owen, Prof. Haserodt and U. Kamp provided some of the important papers. Some of the literature included is published in August 2001.

Chapter 4

This Chapter discusses the geological setting of the study area. The rocks in study area range in age from Devonian to Cretaceous and consist mainly of regionally metamorphosed rocks of low to medium grade, and granite intrusions. A wide, north-northeast-trending belt of slate, called the Chitral Slate, underlies Chitral Valley, and is flanked on both sides by bands of marble and other types of metamorphic rocks. The metamorphic rocks, in turn, are flanked by granite bodies of Cretaceous age, which crop out in the western and southeastern edges of the area. Other granite bodies are found within the metamorphic rocks.

Chapter 5

This chapter explains theoretically how the terraces are formed, its classification and finally discusses the various methods for correlation of terraces. River terraces are topographic surfaces, which mark former valley floor level. In the main they are vestiges of former flood plains, although some may have little or no alluvium on them and may thus be classified as bedrock terraces in contrast with alluvial terraces, which consist of gravel, sand and alluvium.

Chapter 6

Contours gives a good idea about the topography of the area, widely spaced contours indicate the plain area while cliffs and steep slopes have been represented by closely spaced contours. Toposheet No.38/M/13 and 38/M/14 cover the entire study area at the scale of 1: 63,360.The study of the contours of these toposheets reveals that wide flat areas are present at various places on the both sides of river Chitral and show some well marked sequences. From these toposheets contours have been traced, and the areas where there was any possibility of terrace have been marked. This was the base map for fieldwork. Before going into field terraces were identified, and fieldwork was concentrated on these areas. Fieldwork confirmed the existence of at least 10 sequences of well-preserved terraces.

Chapter 7

A variety of surface deposits, including sand, gravel, conglomerate, huge boulders, erratic and fine alluvium are preserved in the area. These deposits have been studied in detail, a diagram of section has been made with scale, photographs have been taken and the material of each and every bed has been recorded with the help of a questionnaire. Samples have been taken from almost each bed for laboratory analysis.

Chapter 8

The present study construct a model of Pleistocene for lower Chitral, the evidences provided in favor of that model are also from study area i.e. Lower Chitral. In some instances the dates of Kamp (1999) were used, while in some cases the dates are calculated and assigned on the bases of synchrony of Pleistocene deposits of study area with other models presented for other parts of the Karakoram-Himalayas. The model has been explained with the help of photographs and diagrams.

According to the model of late quaternary period the glacial history of the study area can be divided into four glacial and three interglacial periods.

References

REFERENCES

1. Ahmed, S.and Aurang Zeb. (1993) "Morphology and Deposits of Kund Terraces" Unpublished M.Sc. Thesis, Department of Geography University of Peshawar.

2. Ahmad, E. (1985) Geomorphology, Kalyani Publishers, Daryaganj, New Delhi, pp: 135-145

3. Alan, C. and Peter, C. (1992) Processes and Landforms, Conceptual Framework in Geomorphology. Oliver and Boyd, United Kingdom. pp: 146.

4. Allen, J.E. (1964) Quaternary Stratigraphic Sequence in the Potwar basin and adjacent areas of N.W. Pakistan. Geol.Bull.Peshawar University Vol.1, pp.2-5.

5. Anderson, R.C. and Masters, J.M. (1985) Terraces of the Rock River Valley in Southern Wisconsin and northern Illinois, Illinois state Geological survey Division, 19, pp: 21-34.

6. Baade, J., A. lang, R. Mousbacher & G.A. Wagner (1998) Quaternary lake deposits in the Thak-Khola Graben, Mustang, Nepal. Submitted to the Proceedings of the 13th Himalaya-Karakoram-Tibet International Workshop, April 20-22, 1998, Peshawar, Pakistan.

7. Bauling, H. (1935) The Changing Sea Level. Institute of British Geographers. Phillip, London.

8. Beal, M. A., and Shepard, F.P (1956) A use of roundness to determine depositional environment. Jour. Sedimentary. Petrology, 26, pp: 49-60.

9. Beaty, C.B.(1963) Origin of alluvial fans, White Mountains, California and Nevada. Annals of the Association of American Geographers, vol. 53, pp: 516-535.

10. Beaty, C.B.(1970) Age and estimated rate of accumulation of an alluvial fan, White Mountains, California, USA. American Journal of Science, vol. 268. pp: 50-70.

11. Benn, D. and L.A. Owen, (1998) The role of Indian summer monsoon and the mid latitude westerlies in Himalayan glaciations: Review and speculative discussion. Journal of Geological Society vol. 155, pp: 353-363.

12. Bryan, K. (1940) Erosion in the valley of the south west, New Mexico. Quarterly, pp: 227-232.

13. Bloom, L. and Yonekura, N. (1980) Coastal terraces generated by sea-level change and tectonic uplift, in Models in Geomorphology ed. By Michael J. Woldenberg. Allen and Unwin inc. London. pp: 139-154.

14. Bloom, A. L., W.S. Broecker, J. M. A. Chappell, R. K. Matthews, and K. J. Mesolella (1974) Quaternary sea level fluctuations on a tectonic coast: New 230 Th/234 U dates from the Huon Peninsula, New Quinea. Quaternary Research, 4, pp. 185-205.

15. Blum, M. D., Toomey, R. S. III, and Valastro, S. Jr. (1994) Fluvial response to Late Quaternary climatic and environmental change, Edwards Plateau of Texas. Paleogeography, Paleoclimatology, and Paleoecology. vol. 108, pp: 1-21.

16. Blum, M. D. and Valastro, S. Jr. (1989) Response of the Pedernales River of Central Texas to late Holocene climatic change. Annals of the Association of American Geographers. vol. 79, pp: 435-456.

17. Boll, J, T.J. M. Thewessen, E.L. Meijer & S.B. Kroonenberg (1988) A simulation of the development of river terraces. Zeitschrift fur Geomorphologie, vol.32,1, pp: 31-45.

18. Bowler, J.M. (1970) Alluvial terraces in the Maribyrong Valley near Keilor, Victoria. Memoirs National Museum Victoria vol.30, pp: 15-58.

19. Boulton,G.S. (1978) Boulder Shapes and grain-size distribution of debris as indicator of transport paths through a glacier and till genesis. Sed. 25, pp: 773-799.

20. Bridgeland, D. et al. (1993) Correlation of Thames terrace deposits between the lower Thames, eastern Essex and the submerged offshore continuation of the Thames-Medway valley. Proceedings of the Geologists' Association vol. 104, pp: 51-58.

21. Bridgland, D.R. (2000) River terrace systems in north-west Europe: an archive of environmental change, uplift and early human occupation. Quaternary Science Reviews, vol. 19, pp: 1293-1303.

22. Brock, A.L., R.L. Orndorff, and B.J. Buck, (2000), Preliminary assessment of tectonic and climatic influences on White River terraces in the Pahranagat Valley, Lincoln County, Nevada. G.S.A. Abstracts with Programs, vol. 32, no. 7, pp: 27.

23. Brockie,W.J. (1973) Experimental frost shattering. Proceeding of 7th New Zealand Geog. Conf. New Zealand Geographical Society, Hamilton 1972, Conf. Ser. 7, pp:177-186.

24. Brookes, J.A., Scott, D.B. and McAndrews, J.H. (1985) Postglacial relative sea level change, Port au Port area, west Newfoundland, Canadian journal of Earth Sciences, 22 (7), pp: 1039-1047.

25. Bull, W.L. and Knuepfer, P.L.K, (1987) Adjustments by the Charwell River, New Zealand to uplift and climatic change. Geomorphology, 1: pp:15-32.

26. Bull, W.B. (1968) Alluvial fans. Journal of Geological Education, vol. 16.pp: 101-106

27. Bull, W.B. (1977) The alluvial fan environment. Progress in Physical Geography, vol. 1. pp: 222-270.

28. Burbank, D.W., Leland, J.F.; Reid, M., Anderson, R.S., Caffee, M. and Finkel, R. (1994) Bedrock incision and uplift rates along the Indus River, N. Pakistan. Geological Society of America Abstracts with Programs.

29. Calkins, J.A., S. Jamiluddin, Kamaluddin Bhuyan. (1981) Geology and Mineral Resources of the Chitral –Partsan Area, Hindu Kush Range, Northern Pakistan. Geological Survey Professional Paper no. 716-G. Washington.

30. Cailleux, A. (1945) Distinction des galets marines et fluviatiles. Geological Society France, Bulletin, 5 XV, pp: 375-404.

31. Chappell, J. (1983) Aspects of sea level, tectonics and isostasy since Cretaceous, in " Mega-Geomorphology" edt. for the British Geomorphological research group by R. Gardner and H. Scoging, Clarendon Press, Oxford, pp: 56-72.

32. Challinor, J. (1932) River Terraces as Normal Features of Valley Development, Geography, vol. 7, pp: 25-37.

33. Chorley, R. J., (1969), Introduction to fluvial processes: Methuen and Co. Ltd., London, P. 218

34. Cotton, C.A. (1940) Classification and Correlation of River Terraces, Journal of Geomorphology, 3, pp: 27-37.

35. Cotton, C.A. (1941) Landscape as developed by the processes of normal erosion. Cambridge University Press, London, pp: 188-220

36. Cotton, C.A. (1945) The Significance of terraces due to Climatic Oscillation" Geological Magazine, vol.82, pp: 10-16

37. Davies, D. K., and F.G. Ethridge (1975) Sandstone composition and depositional environment. Am. Assoc. Petroleum Geologists, Bulletin. Vol. 59, pp: 239-264.

38. Dawson, M. (1985) Environmental reconstruction of a late Devensian terrace sequence. Some preliminary findings. Earth Surface and Landforms, vol.10 (3), pp: 237-246.

39. Dawson, M.R., Gardiner, VOL. (1991) River terraces: the general model and a palaeoydrological and sedimentological interpretation of the terraces of the lower Severn. In Starkel, L. et al. (eds) Temperate Palaeohydrology: Fluvial Processes in the Temperate Zone During the Last 15,000 Years, Chichester: 269-305

40. Derbyshire, E. (1974) Sedimentological analysis of glacial and proglacial debris: a framework for the study of Karakoram glaciers. In: Miller, K.J. the International Karakoram project 1, Cambridge, 456-495.

41. Derbyshire, E., Li Jijun, F.A.Perrot, Xu Shuying & R.S. Waters (1984) Quaternary Glacial history of the Hunza valley, Karakoram Mountains, Pakistan. The International Karakoram project 2, Combridge, 456-495.

42. Derbyshire, E. (1996) Quaternary glacial sediments, glaciation style, climate and uplift in the Karakoram and northwest Himalaya: review and speculations. - Palaeo 120:147-157.

43. Derbyshire E. (1998) Palaeo-climate reconstruction's derived from loess sequences in North China, and uplift of the Tibetan Plateau Paper contributed to IGCP415 form a national meeting in Potsdam, Germany on 8th and 9th May 1998:

44. De Terra, H., and Patterson, H. H. (1939) Studies on the Ice age in India and associated Human Culture. The Carnage Institute of Washington, D.C. Pub. No.493.

45. Desio, A. & G. Orombelli (1971) Preliminary note on the presence of a large valley glacier in the middle Indus valley (Pakistan) during Pleistocene, Atti Della Accademia Nazionale dei Lincei 51, 377-392.

46. Dury, G.H. (1970) Rivers and river terraces. Macmillan, London: 283 pp

47. Faniran, A. & Jeje, L.K. (1983) Humid Tropical Geomorphology, A Study of the Geomorphological Processes and Landforms in Warm Humid Climate. Longman, London. pp: 118-122.

48. Fermor, L.L. (1922) General report of the Geological Survey of India for the year 1921. India Geological Survey Records, Volume 54. pp: 282-285.

49. Folk, R.L. and ward, W. G. (1957) Brazos River Bar: a study in the significance of grain size parameters. Jour. Sed. Petrology, 27, pp: 03-26.

50. Folk, R.L. (1959) Petrology of Sedimentary Rocks. Hemphill's Texas, USA.

51. Fyre, J.C. (1973) Pleistocene sucession of the Central interior United State. Quaternary Research, 3, pp: 275-283.

52. Fyre, J.C. and A.B. Leonard. (1954). Some problems of alluvial terrace mapping. American Journal of Science, vol. 252, pp:242-251.

53. Ganseer, A. (1964) Geology of the Himalayas. Wiley Interscience, London. P 289.

54. Gilbert, G.K. (1914) The transportation of debris by running water. US geological Survey

Professor Paper 86.

55. Gomez,V.A. (1996) Alluvial fans: A theoretical contribution to their most significant aspect. Quaternary and Geomorphology Vol.10, pp: 3-4.

56. Goudie,A.S., Cooke,R.U. and Doornkamp,J.C. (1979) The formation of silt from quartz dune sand by salt weathering processes in deserts. J. Arid Environ. 2, pp: 105-112.

57. Grotzbach, E. and C. Rathjens (1969) Die Heutige und die jungpleistozane vergletscherung des afghanischen Hindukusch. Zeitschrift fur Geomorphologie, N.F., Suppl. Bd.7,57-75.

58. Guccione, M.J. (1995) Indirect response of the Peace River, Florida, to episodic sea-level change, Journal of Coastal Research, vol. 11, no.3, pp: 637-650.

59. Haleema Bano, Zahida Akhtar & Sumera Malik. (1994) Some Observations on the Genesis of Terraces, Slope Form, Characteristic and the Impact of Terraces on Land Utilization. Unpublished M.Sc. Thesis, Department of Geography University of Peshawar.

60. Hancock, G. S. and Anderson, R. S. (2001) Numerical modeling of strath terrace sequence formation in response to climate oscillation. Fall American Geographer Union meeting.

61. Hancock, G. S. and Anderson, R. S., (2001) Numerical modeling of fluvial terrace formation in response to oscillating climate GSA Bulletin June (2001).

62. Haserodt, K. (1996): The geographical features and problems of Chitral Flora. Paper Presented in second Hindu Kush cultural Conference, Chitral, Northern Pakistan.

63. Hart, M.G., (1986), Geomorphology pure and applied: George Allen And Unwin, Boston MA, 227 pp:

64. Herget, J. (1998): Anthropogenic influence on the development of the Holocene terraces of the River Lippe (Germany), in: Benito, G., VOL. Baker & K. Gregory (eds.): Palaeohydrology and Environmental Changes, Chichester (Wiley), S. 167-180.

65. Horton, R.E. (1945). Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull. 56:275-370.

66. Howard, A.D. (1959) Numerical systems of terrace nomenclature a critique. J. Geol. Vol. 67, pp:239-243.

67. Huntington, E. (1905) The Glacial period in Non-glaciated Regions, Bulletin of Geological Society, America, vol. 18, pp: 3351-388.

68. Hayden, H.H., (1915): Notes on the Geology of Chitral, Gilgit and the Pamirs. India Geological Survey Records, Volume 75. No.2, pp: 55.

69. Israruddin, M.Said et al. (1975) Land-use Survey of N.W.F.PP: Part-I. Regional Development Project, Planning and Development Department. Government of N.W.F.P

70. Ivanac, J. F. Traves, D. M. and King, D. (1956) The Geology of the NW portion of the Gilgit Agency, Pakistan Geological Survey Records, Vol. 8, pp: 27

71. Johnson, D., (1944) Problems of Terrace Correlation, Bulletin of Geological Society, America, 55, pp: 793-818.

72. Jordan, C.F., Freyer, G.E., and Hemmen, E.H. (1971) Size analysis of Silt and clay by hydro-photometer. Jour. Sedimentary Petrology, 41, pp: 489-496.

73. Kamp, U. (1999) Late Quaternary Geomorphology and Glacial History in the Eastern Hindu Kush, Chitral, Northern Pakistan. (Ph.D thesis) Institute of Geography, Technical University Berlin.

74. Kartashov, J.P. (1972) Main Regularities of the geological activity of rivers in the mountain regions (in Russian) Transactions of the academy of Science (Maskow), pp: 184.

75. Khan, Inamullah (1990) The genesis of the Quaternary deposits of the vale of Peshawar, South of Kabul river. Unpublished Ph.D thesis, Department of Geography, University of Peshawar.

76. Knuepfer, P.L.K. (1988). Estimating age's of late Quaternary stream terraces from analysis of weathering and soils. Geol. Soc. Am. Bull.100:1224-1236.

77. Krumbein, W. C. (1934) Size frequency distribution of sediments. Jour. Sed. Petrology, 4, pp: 65-77.

78. Krumbein, W. C. (1940) Flood gravels of San Gabriel Canyon, California. Geological Society America, Bulletin, 51, pp: 639-676.

79. Krumbein, W. C. (1941) Measurement and geological significance of shape and roundness of sedimentary particles. Jour. Sed. Petrology, 11, pp: 64-72.

80. Kuhle, M., (1993) The Pleistocene Glaciation's of the Himalaya and Tibet and Its Impact on the Global Climate: A Relief-specific Ice Age Theory. - Journal Nepal Research Centre IX 1993:101-140.

81. Lehmkuhl, F. (1997) Late Pleistocene, Late-Glacial and Holocene glacier advances on th Tibetan Plateau. - Quaternary International Vol. 38/39, pp:77-83.

82. Leopold, L.B., Wolman, M.G. and Miller, J.P (1964), Fluvial processes i geomorphology. Freeman and Co., San Francisco, 522.

83. Macklin, M. (2001). Correlation of Middle and Late Pleistocene fluvial sequences in th Mediterranean and their relationship to climate change. Paper Presented i Workshop on "Fluvial response to rapid climatic changes & the impact of tectonic on fluvial systems (9-12 March 2001) Haarlem, the Netherlands

84. Matsushita, Susumu, and Huzita, Kazuo, eds., (1965) Geology of the Karakurum an Hindu Kush. Koto University Scientific Expedition to the Karakurum an Hindukush, 1955, Results, Vol. 7, p: 150.

85. Miller, K.J. (1984) International Karakoram Project. Vol. 1 & 2 Cambridge Universit Press, Cambridge.

86. Nahon, D and Trompette, R. (1982) Origin of siltstones: glacial grinding versu weathering. Sed., 29, pp: 25-35.

87. Nand, N. & K. Kumar, (1989) The Holy Himalaya: a geographical interpretation Garhwal. Daya Pub. House. Delhi.

88. Ollier, C.D. (1975) Weathering. Oliver and Boyd, Edinburgh, P:304

89. Owen, L.A. (1996) Quaternary lacustrine deposits in a high energy semi arid mounta environment, Karakoram mountains, northern Pakistan. Journal of Quaterna Science vol.11, pp: 461-473.

90. Owen, L.A., B.J. White, H.Rendell & E. Derbyshire (1992) Loessic silt deposits in t western Himalayas: Their sedementalogy, genesis and age. Catena vol. 19, pp: 49 509.

91. Owen, L.A., R.M. Bailey, E.J..Rhodes, W.A.Mitchell & PP:Coxon (1997) Style a timing of glaciation in the Lahul Himalaya, Northern India. A framework f reconstructing Late Quaternary Palaeoclimatic Change in the Western Himalay Journal of Quaternary Science, vol. 12, pp: 83-109.

92. Owen, L.A. (1988) Terraces, Uplift and Climate, Karakurum Mountains, Northe Pakistan. Unpublished Ph.D. Thesis Submitted to Department of Geography a Geology, University of Leicester.

93. Palmer, A. S. (1982) Stratigraphy and selected properties of loess in Wairapa, N Zealand. Unpublished Ph.D thesis Victoria University, Wallington, New Zeala (Cited in Owen 1988)

94. Pettijohn, F.J. (1975) Sedimentary Rocks, 3rd edition. Harper & Row, New York, pp: 628.

95. ---------------, Potter, P.E., and Siever, R. (1973) Sand and Sandstone. Sprinnger-Verlag New York.

96. Picard, M.D., and High, R.L. (1972) Criteria for recognizing lacustrine rocks (Eds J.K.Rigly and M.W.K. Hamblin. Society of Economic Paleontologists an Mineralogists. Special Pub. No. 16.pp:108-145.

97. Porter, S.C. (1970) Quaternary glacial record in Swat Kohistan, West Pakistan. Bulletin o the Geological Society of America vol. 81, pp: 1421-1466

98. Power, M. C. (1953) A new Roundness scale for sedimentary particles. Jour. Se Petrology, 23, pp: 117-119.

99. Pye, K. and Sperling, C. H. B. (1983) Experimental investigation of silt formation b static breakage processes: the effect of temperature, moisture and salt on quartz du sand and granite regolith. Sedim. 30, pp: 49-62.

100. Quinn, J.H. (1957) Paired river terraces and Pleistocene glaciation. J. Geol. 65. pp: 14 166.

101. Rachocki, A. H. (1981) Alluvial fans: Chichester, John Wiley and Sons Ltd. New York.

102. Rachocki, A.H. and Church, M. (1990) Alluvial fans: a Field Approach. John Wiley a Sons Ltd. New York.

103. Reed, F.R.C. (1922) Devonian Fossil from Chitral, Persia, Afghanistan, and t Himalayas: India Geological Survey Records, Vol. 41, pp: 86-114.

104. Reed, F.R.C. (1911) Devonian Fossil from Chitral, Persia, Afghanistan, and t Himalayas: India Geological Survey Records, Vol. 41, pp: 86-114.

105. ---------------- (1911) Devonian Fossil from Chitral and the Pamirs. India Geologi Survey, Vol. 6, pp: 02-167.

106. Reineck, H.E. and Sing, I.B. (1973) Depositional Sedimentary Environment. Sprin Verloy, New York. P: 439.

107. Rendell, H.M. and Thomas, K.D. (1970) Environmental changes during the Pleistoc and Holocene in the Peshawar Basin, Pakistan. Journal of Archaeological Scie vol. 7, pp: 69-79.

108. Richards, B.w., L.A. Owen & E.J. Rhodes (1999) Timing of Late Quaternary glaciati in the Himalayas of northern Pakistan. Journal of Quaternary Science.

109. Robinson, H. (1986) Morphology and Landscape. Bell and Hyman limited, London. pp 222-224.

110. Rothlisberger, F. and Geyh, M.A. (1975) Glacier variation in Himalayas and Karakoram Zeitschrift fur Gletscherkunde and Glazialgeologie, vol.21, pp: 237-249.

111. Said. M and Majid, M. (1966) The Pleistocene history of the terrestrial deposits of Ba Daman area, Peshawar valley. Jour. Science and Technology. Vol. 1,No. 1 Peshawar.

112. Said, M. (1969) The Pleistocene geomorphology of the Burbage basin. Unpublished Ph.D thesis, University of Sheffield.

113. Sandford, K. S., 1932-Some recent Contribution to the Pleistocene Succession in England Geological Magazine, No. 69.

114. Schumn, S.A. (1973) Geomorphic thresholds and complex response of drainage system Proceeding of the forth Annual Geomorphology Symposium, Binghampton, p 299-310.

115. Schumn, S.A. (1985) Pattern of alluvial rivers. Annual Review Earth Planetary Science Vol. 13, pp:5-27.

116. Sharma, M.C.& Owen, L.A. (1996) Quaternary glacial history of the Garhwal Himalay India. Quaternary Science Review vol. 15, pp: 335-365.

117. Shepard, F.P and Young, R. (1961) Distinguishing between beach and dune sands. . Jou Sed. Petrology, 31, pp: 196-224.

118. Shi, Y. (1992) Glaciers and glacial geomorphology in China. - Zeitschrift f Geomorphologie, Suppl.-Bd.vol. 86, pp: 51-63.

119. Shi, Y. and Wang Jintal (1981) The fluctuation of Climate, Glacier and Sea level sin late Pleistocene in China. In Sea Level, Ice and Climatic Change. IAHS. Publicati 131, pp 281-293.

120. Shi, Y. and Zhang Xiangsong (1984) Some studies of the Batura Glacier in t Karakoram Mountains. In: (Ed. Miller, K.) International Karakoram Proje Cambridge University Press, Cambridge. pp 51-62.

121. Shroder, J.F., M.K.Saqib, R.D. Lawrence, I. P. Madin, S.M. Higgins (1989) Quatern glacial Chronology and neotectonics in the Himalaya of Northern Pakistan. Geolo of Western Himalayas, Geological Society America Special Paper 232, pp: 275-2

122. Shroder, J.F., Lewis Owen and Edward Derbyshire (1990) Quaternary Glaciation of Karakoram and Nanga Parbat Himalaya. Geological Society America 233, 175-1

123. Small R.J. (1991) "Geomorphology and Hydrology". Longman, London, pp: 41-42.

124. Smalley,I.J. (1966) The properties of glacial loess and the formation of loess deposits. . Sed. Pet.,36,pp 669-676.

125. Smalley,I.J. and Smalley, V. (1983) The loess material and loess deposits: Formatioı distribution and consequences. In (Ed. Brookfield,M.E. and Ahlbrandt, T.S.) Eolia Sediments and Processes. Elsevier Science Publication, B.V., Amsterdam, pp. 5 68.

126. Speight, R.(1908)Terrace Development in Canterbury Rivers, Trance. N.Z Institute, 4 PP: 16-43.

127. Stauffer, K.W., (1975): Reconnaissance Geology of the Central Mastuj Valley, Chitr State, Pakistan. U.S. Geological Survey open-file report 75-pp: 551-556.

128. Steers, J.A. (1937) The unstable earth, some recent views in Geomorphology. Kalya Publishers, New Delhi. pp: 234-235.

129. Sternberg, R. W. and Careager, J. S. (1961) Comparative effectiveness of size analysis Hydrometer and pipette methods. Jour. Sed. Petrology, 31, pp: 96-100.

130. Tahirkheli, R.A.K. (1997) Tectono-Stratigraphic framework of the Hindu Kush range Chitral, Pakistan. Paper presented in 3rd Pakistan Geological congress October 2 30. Dept. of Geology, University of Peshawar.

131. Taylor, P.J. & W.A. Mitchell (1998) A preliminary Glacial Chronology for the Easte Zanskar Range, NW Indian Himalaya. Abstract for the 1998 Annual Meeting IGCP 415 and meeting of working group 2 & 7, 20. (20-8-1998) Manali, Lal Himalaya, India.

132. Thornbury, William D., (1969), Principles of Geomorphology (2nd edition): Wiley a Sons, New York 594 pp:

133. Veldkampp: A, (1992) A 3-D model of fluvial terrace development in the Allier ba (Limagne. France). Earth Surface Processes and Landforms. vol. 17, pp: 487-500.

134. Veldkamp, A., & S.B. Kroonenberg (1993a). The Late Quaternary terrace chronology the Allier. Geologie en Mijnbouw, vol. 72, pp:179-192

135. Veldkamp, A., & Kroonenberg, S.B., (1993b) Late Quaternary chronology of the Al terrace sediments (Massif Central, France). Geologie en Mijnbouw 722: 179-192

136. Veldkamp, A. (1997) Quaternary river terrace formation in the Allier Basin, France reconstruction based on sand bulk geochemistry and 3-D modelling. Unpublis Ph.D Thesis Submitted to the Faculty of Earth Sciences, Netherlands Centre

Geo-ecological research, Amsterdam, The Netherlands.

137. Veldkamp A. & J.J. van Dijke (1998) Modelling long-term erosion and sedimentatio processes in fluvial systems: a case study for the Allier/Loire system. In: (Benito G. Baker, VOL.R. and K.J. Gregory, Eds.) Palaeohydrology and environmenta change. John Wiley & Sons Ltd. pp: 53-66.

138. Vita-Finzi,C. and Smallei,I.J. (1970) Origin of quartz silt: comments on a note by Ph.H Kuenen.Journal Sed.Pet. 40, 1367-1369.

139. Wadell, H. (1935) Volume, Shape and Roundness of quartz particles. Journal of Geolog 43, 250-280.

140. Waskom, J.D. (1958) Roundness as an indicator of environment along the coast c Panhandle Florida. Jour. Sed. Petrology, 28, pp: 351-360.

141. Watson, A. and Williams, D.P: (1985) Early Pleistocene river gravels in Swaziland ar their geomorphological and structural significance, Zeitschrift fur Geomorhologi 29 (1) pp: 71-87.

142. Whalley,W.B.,Marshall,J.R.and Smith,B.J. (1982) The Origin of desert loess: son experimental observations. Nature, 300, pp:433-435.

143. Whalley,W.B. (1984) High altitude rock weathering processes. In: (Ed. Miller, K International Karakoram Project. Cambridge University Press, Cambridge, pp: 36 373.

144. Yar Mohammad Khan and Mumtaz Khan (1980) Integrated Land Resource Survey Rep of Chitral Sub-Project, District Chitral. N.W.F.P. Pre-Investment Centre, Peshawa

145. Zeuner, F.E. (1949) frost soils on Mount Kenya, and the relation of frost soils to Aeoli deposits. J. Soil Science, 1, pp: 20-30.

146. Zeuner, F.E. (1959) The Pleistocene period: its climate, Chronology and faur succession, 2nd edition, Jhon wiley, London.

147. Zhang Xiangsong & Shi Yafeng (1980) Changes of the Batura Glacier in the Quatern and recent times. Professional papers on the Batura Glacier, Karakoram Mountai Beijing, 173-190.

148. Zingg, T. (1935) Beitrage Zur Schatteranalyse. Min. Petrog. Mitt. Schweiz, 15-39.

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