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CONTENTS

THE CORRELATION OF UNIT CELL DIMENSIONS AND CHEMICAL COMPOSITION OF SOME CHROMITES FROM MUSLIMBAGH, ZHOB VALLEY, BALUCHISTAN, PAKISTAN

BY

F.A. SHAMS AND SHAFEEQ AHMAD

Department of Geology, Punjab University, Lahore.

Abstract : *Unit cell dimensions of 10 chromite specimens are presented and correlated with their chemical composition Reciprocal relations with Al_2O_3 content of chromites has been found to be most pronounced.*

INTRODUCTION

The Zhob Valley ultramafic complex in the Quetta Division, Baluchistan, covers about 2000 square miles and consists of dunites, serpentinites, harzburgites, peridotites, gabbros and related rocks. The occurrence of chromite in these rocks was discovered by Vredenburg in 1901 and the mining of the ore has been going on since then almost uninterrupted.

Description of geology of the complex and particularly the chemical investigations of the chromites have been published by Bilgrami (1963 etc.) but no X Ray data have been reported so far. The aim of this article is to present such data on a few chromite specimens and to correlate with their chemical compositions.

The samples for the present study were kindly provided by Dr. S A. Bilgrami, Ex-Pak. Chrome Mines Ltd., alongwith the chemical data, that were later published (Bilgrami, 1969). For the sake of quick information and to be of help in the study of present research, chemical data are reproduced in Table No. 1. The recasted data have been plotted in (Fig. 1) which constitutes part of the well known Steven's triangular diagram (Steven, 1944); the fundamental aluminian nature of the chromites is very well displayed.

METHOD OF INVESTIGATION

Each chromite specimen was ground to 100 mesh, cleaned with magnetic separator and purified with the help of heavy liquids. Diffractometer trace of each specimen was taken by using Co α radiation and silicon as internal standard. The chromite peaks were measured, indexed and 'a' was estimated for atleast 8 main X-Ray reflections from each specimen; mean value was computed within the range of ± 0.005 A°. These values are given at the bottom row of Table No. 1.

CHEMISTRY AND UNIT CELL DIMENSIONS

The 'a' value of each chromite was plotted against corresponding value of various oxides as given in Fig. 2. The reciprocal relationship between the Al_2O_3 content and the unit cell dimensions is shown clearly while there is no appreciable relationship with other oxide values. This conclusion supports the earlier works (Chakraborty, 1965, Clark and Ally, 1932) in the sense that increase in Al_2O_3 content lowers the cell dimension of chromite. The slope of the correlation line is fairly low and the main reason may be the somewhat small variation range in the chemical composition of the chromites investigated. Most probably, it is for the same reason that the sympathetic rela-

TABLE No. 1
Data on Chromites from Muslimbagh

No.	1	2	3	4	5	6	7	8	9	10
Balgrami's (1969) No.	15	2	24	18	14	13	11	7	27	16
Cr_2O_3	56.40	58.70	56.60	54.50	57.90	58.20	55.40	58.50	56.80	60.00
Al_2O_3	12.90	11.80	12.40	13.40	10.90	11.30	12.70	11.60	10.90	10.80
Fe_2O_3	2.97	2.97	3.34	1.60	3.84	2.97	4.95	3.07	3.22	3.07
V_2O_5	0.09	0.08	0.09	0.07	0.07	0.08	0.09	0.09	0.09	0.05
FeO	15.13	11.53	12.59	15.10	12.45	12.04	11.59	10.66	15.13	10.78
MgO	12.10	14.50	13.40	13.60	13.80	14.60	14.70	14.50	12.50	14.70
NiO	0.10	x	x	0.16	x	x	x	x	x	x
MnO	0.15	x	x	0.18	0.20	x	0.21	0.27	x	0.09
CaO	0.10	0.05	0.04	0.04	0.04	0.03	0.07	0.11	0.05	0.10
SiO_2	0.18	0.24	0.15	0.57	0.12	0.39	0.21	0.15	0.52	0.39
TiO_2	0.19	0.30	0.27	0.25	0.31	0.29	0.29	0.27	0.32	3.30
Total :	100.31	100.17	98.88	99.47	99.63	99.90	100.21	99.22	99.53	100.28

TABLE No. 1 Contd.

Partial Structural formulae on basis of 16(0) atoms.

Cr	5.744	5.952	5.776	5.728	5.952	5.968	5.600	5.940	5.984	6.080
Al	1.952	1.690	1.888	2.104	1.680	1.728	1.920	1.733	1.712	1.632
Fe^{3+}	0.288	0.286	0.323	0.160	0.374	0.289	0.476	0.294	0.323	0.296
Cell dimensions (A°)	8.288	8.278	8.288	8.292	8.310	8.299	8.296	8.293	8.278	8.296

* Total iron determined as FeO

x Not determined

tionship between cell dimensions and Cr_2O_3 content is not mark:d although it was well demonstrated by Stevens (*op. cit.* p. 26). Further work covering larger chemical range is in progress.

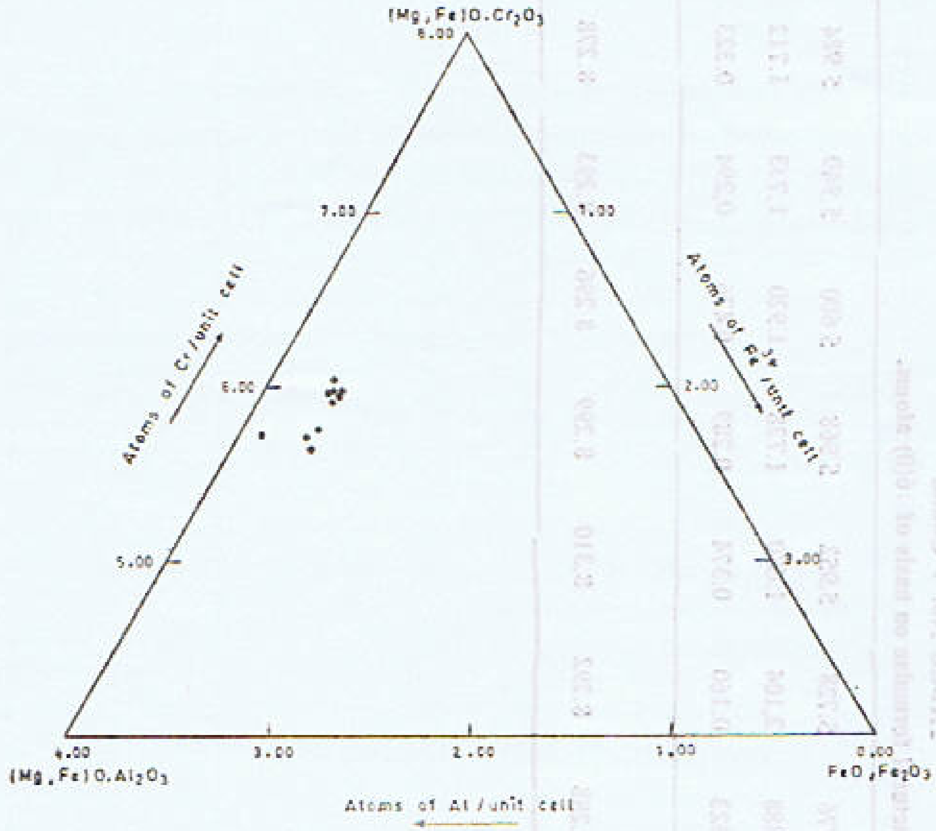

Fig. 1 TRIANGULAR DIAGRAM SHOWING COMPOSITION OF CHROMITES

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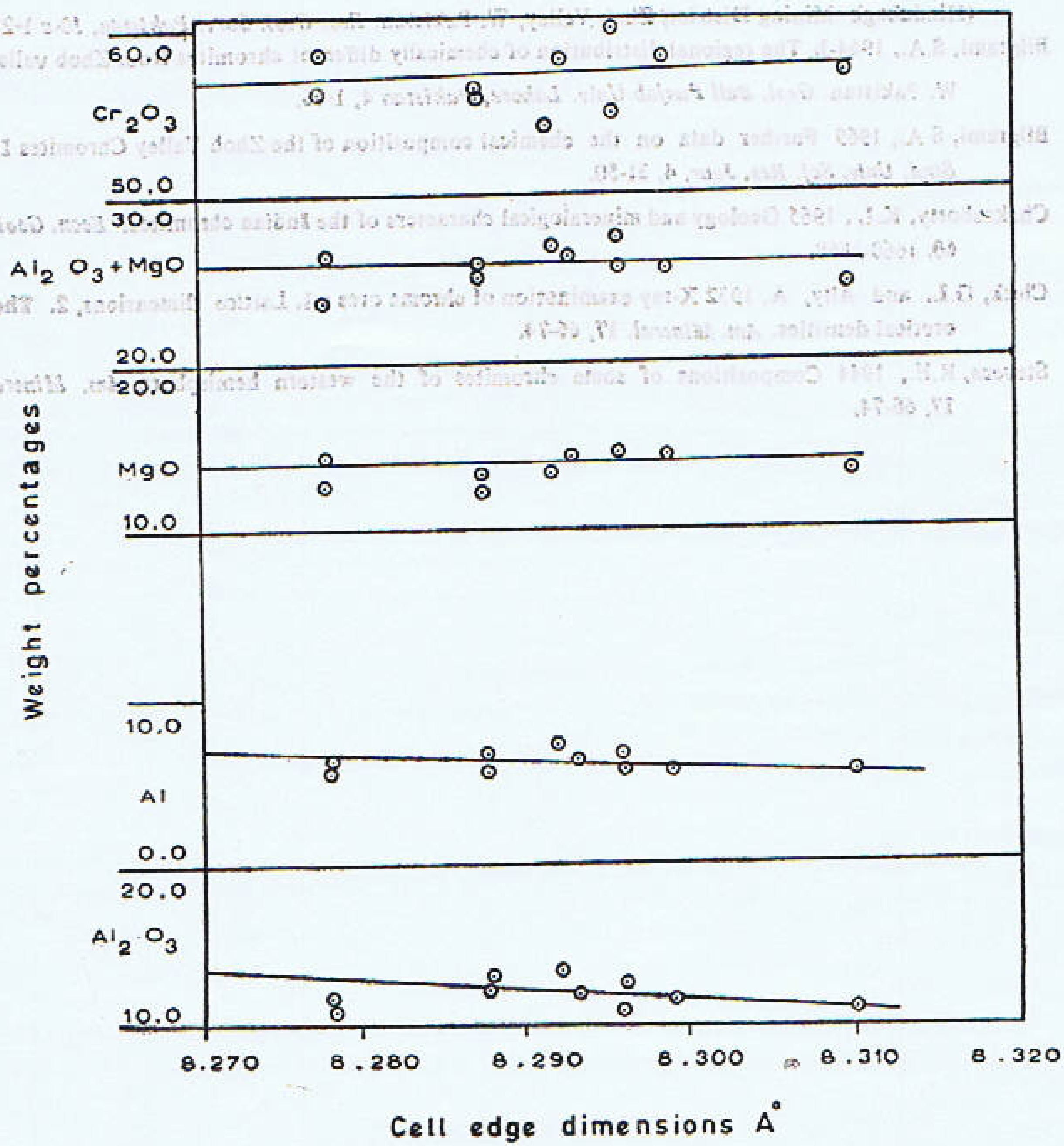

Fig. 2 Graph between cell edge dimension & weight percentages of various oxides chromites from Muslimbagh.

ESTIMATION OF SILVER BY RADIOCHEMICAL NEUTRON ACTIVATION METHOD AND STUDY OF ITS GEOCHEMICAL DISTRIBUTION IN SELECTED SULFIDE ORE SAMPLES FROM PAKISTAN

BY

FAZAL-UR-REHMAN

Geochemistry Section, Atomic Energy Minerals Centre, P. O. Box 658, Ferozepur Road, Lahore, Pakistan.

Abstract. *With the intention of studying distribution of silver metal in sulfide ore samples of different composition and different origin, a careful selection of four sulfide ore samples was made. Their silver metal content was estimated by employing radiochemical neutron activation technique. 100—200 mg of pulverised, homogenised ore samples were irradiated by thermal neutrons (at a flux of 1.5×10^{13} n/cm²/sec) for 24 hours alongwith standard rock samples and synthetic standards for silver. These irradiated samples and standards were allowed to cool for three weeks and then their silver content was separated and estimated by making radioactivity measurements of ^{110m}Ag via 657.8 keV. Finally geochemical relationship of silver with other coexisting metallogenic elements, under the then existing environments, was envisaged.*

INTRODUCTION

Neutron activation analysis has been used by a large number of research workers for the estimation of silver in materials of geological interest. Schroeder *et al.* (1966) used ^{110}Ag (half life 24 seconds) for the analysis of minerals and ores. Schindewolf and Wahlgren (1960) used a rapid radiochemical procedure for the isolation of ^{108}Ag (half life 2.3 minutes) in meteorites. However, most of the workers have preferred the use of ^{110m}Ag (half life 253 days). Morris and Killick (1960) developed a rather long method involving several precipitations to estimate silver in rocks. Smales et al. (1967) used a similar method for the estimation of silver in meteorites. During the present work, keeping in view the distance of fourteen kilometers between reactor and laboratory, ^{110m}Ag (half life 253 days) has been used, and an improved form of an earlier method, developed by Brunfelt and Steinnes (1969), has been employed. The chemical procedure mainly consists of three separate steps, as follows :

1. Disintegration of irradiated rock samples/standards by acid.
2. Precipitation of silver as AgCl.
3. Separation of precipitate.

EXPERIMENTAL WORK

(i) Sample Preparation : The sulfide ore samples were crushed and ground to a particle size −200 mesh in a vibrating disc mill. These powders were transferred to bottles of suitable size and homogenised (individually) for one hour with the help of a powder mixer (which rotates in the planes simultaneously).

(ii) Irradiation and radiochemistry : 100—200 mg of each powder ore sample was wrapped in a piece of aluminium foil (3 × 3 cm) and all of them were irradiated by thermal neutrons for

24 hours, together with three silver (salt) standards and two reference rock standards (CAAS sulfide ore—1 & Kismalm Norden) in the JEEP II reactor (Kjeller, Norway) at a flux of 1.5×10^{13}n/cm²/sec.

Silver nitrate standard solutions of three different concentrations were prepared corresponding to 10 ug, 100 ug and 1000 ug of Ag per 100ul of solution. 100 ul of each standard solution was evaporated on a piece of aluminium foil (3×3 cm). One piece of aluminium foil was also included for irradiation to serve as a blank in the radioactivity measurements.

After cooling for three weeks, the irradiated samples were decomposed with a mixture of concentrated hydrofluoric acid and concentrated nitric acid (1 : 1) in the presence of 50 mg of silver carrier. The solution was evaporated to dryness and the residue was dissolved in 1M nitric acid. The drops of concentrated HCl were added to precipitate silver as silver chloride. The AgCl precipitate, after ten minutes delay, was transferred to a blue ribbon filter paper (already weighed) and washed three times with 10 ml of washing solution (1M HNO_3) and then with water, alcohol and finally with ether. The filter paper was double-folded and placed in a watch glass and dried at 110°C for 15 minutes.

(iii) Counting procedure and chemical yield determination : The radioactivity measurements were performed by the use of ^{110m}Ag (half life 253 days) via 657.8 keV gamma line with an ORTEC 24 cm² coaxial Ge(Li) detector. A HEWLETT PACKARD digital converter (model 5451 A) interfaced to a 16 bit digital NORD—1 computer (A/S Norsk Dataelektronikk) with 4K memory was used for the pulse-height analysis. The resolution for the 1331 keV ^{60}Co gamma—line was 3.8 keV (FWHM). The integration of the peak areas was performed by a computer (Heier and Brunfelt, 1970) according to the method of Covell (1959), whereas gamma peaks of low intensity were integrated according to the method proposed by Sterlinsky (1970).

The silver chloride precipitate of each rock sample/standard was weighed alongwith filter paper and their chemical yield was found to be in the range of 50—80%.

RESULS

The experimental results obtained by radiochemical neutron activation analysis are presented in Table No. 1. In order to check the accuracy, a Nordic standard reference sample, ASK sulphide ore and Canadian reference sample, CAAS sulfide ore 1, were assayed simultaneously. Their results have been found in good consistancy with the silver values already established, ("ASK sulfide ore"—17 ppm, Johnsen and Steinnes, 1970. "CAAS sulfide ore—1" —4 ppm, Sine *et al.*, 1969) The precision of the technique had already been established by Brunfelt and Steinnes (1969). Quadruplicate analyses have been performed throughout the present work.

The available data (Table 1) have been plotted in the form of histograms (Fig. 1), when other coexisting metallogenic elements like Pb, Cu, Zn, Fe, Sb, As and Au (Table 2) have been similarly plotted in order to establish geochemical correlations between their distribution patterns and that of silver.

DISCUSSION

Silver is one of the noble metals and has a relatively simple chemistry. Its precipitation in nature is sensitively controlled by the prevailing zones of oxidation and reduction. Silver has a strong chalcophile tendency and is generally concentrated in sulfides and sulfosalts. The oxyphile character is weak, but it can form mixed basic sulfate like "argentojarosite"

TABLE No. 1

Silver content in four Pakistani Sulfide Ore Samples and Standards

Sr No.	Nature of the ore sample	Location	Values ppm	Mean Value ppm
PS—1	Galena	Ushu, Swat	841.52 132.75 829.38 831.49	833.78
PS—2	Sphalerite	Ushu, Swat	130.66 121.00 135.25 120.09	126.75
PS—3	Pyrite	Reshian, Azad Kashmir	0.85 0.80 0.89 0.78	0.83
PS—4	Boulangerite	Aviret Gol, Chitral	515.20 508.50 517.85 505.10	511.66
ASK—Sulfide Ore	Standard Reference	Bleikvassli, Norway	17.80 18.00 17.00 17.15	17.50
CAAS Sulfide Ore—1	Standard Reference	Falconbridge, Nickel Mines, Ontario, Canada.	3.75 3.95 3.80	3.92

TABLE 2 (a)

Chemical Composition (Rehman, 1975) of Sulphide ores from Pakistan

No.	Pb %	Cu %	Zn %	Fe %	Sb %	As PPm	Au* PPb
PS—1	22.02	0 46	15.82	0.44	2.22	544.5	97.1
PS—2	—	0.68	28.80	1.55	—	48.1	63.3
PS—3	—	+	—	45.89	+	497.4	15.0
PS—4	7.74	+	—	—	7.66	633.1	33,260.0

TABLE 2 (b)

Mineral Composition (Siddiqui 1970) of Sulphide ores from Pakistan

PS—1	Galena, Sphalerite, Pyrite, Chalcopyrite, Tetrahedrite, Antimonite, Quartz, Carbonate.
PS—2	Sphalerite, Pyrite, Pyrrhotite, Chalocopyrite, Calcite.
PS—3	Pyrite, Marcasite, Traces of Arsenopyrite, Quartz, Chlorite, Muscovite.
PS—4	Boulangerite Quartz. Carbonate.

— Absent.

\+ Poor counting statistics.

* Rehman, 1972.

(Mason, 1940). However, it occurs in native form in a variety of deposits and it is also a common (minor) constituent of native gold, copper, and other native metals and semi-metals (Garrels, 1954, and Latimer, 1952). Gold has always been found to contain silver. even up to 15% or more, Dorokhin *et al.*, 1969).

Regarding sulfide ore samples from Pakistan, it is quite clear from their respective minerogenetic and polymetallic association (Table 2) that galena ore and boulangerite ore samples were produced under hypogene environments whereas pyrite ore and sphalerite ore samples were produced under supergene environments (Kanehira, 1969). According to Goldschmidt (1954) the effectiveness of sulfide host minerals for silver decreases as :

Tetrahedrite — Galena — Chalcopyrite — Sphalerite — Pyrite.

In case of galena ore sample (PS—1). the distribution of silver is mainly controlled by its host minerals like galena and sphalerite which is assisted by the the minor inclusions of tetrahedrite in galena, traces of antimonite, and is further assisted by the presence of minor amounts of pyrite, gold and carbonate. Similarly silver distribution is associated with boulangerite to a small extent (Boyle, 1967) and is supplemented by the presence of traces of gold and carbonate (PS—4).

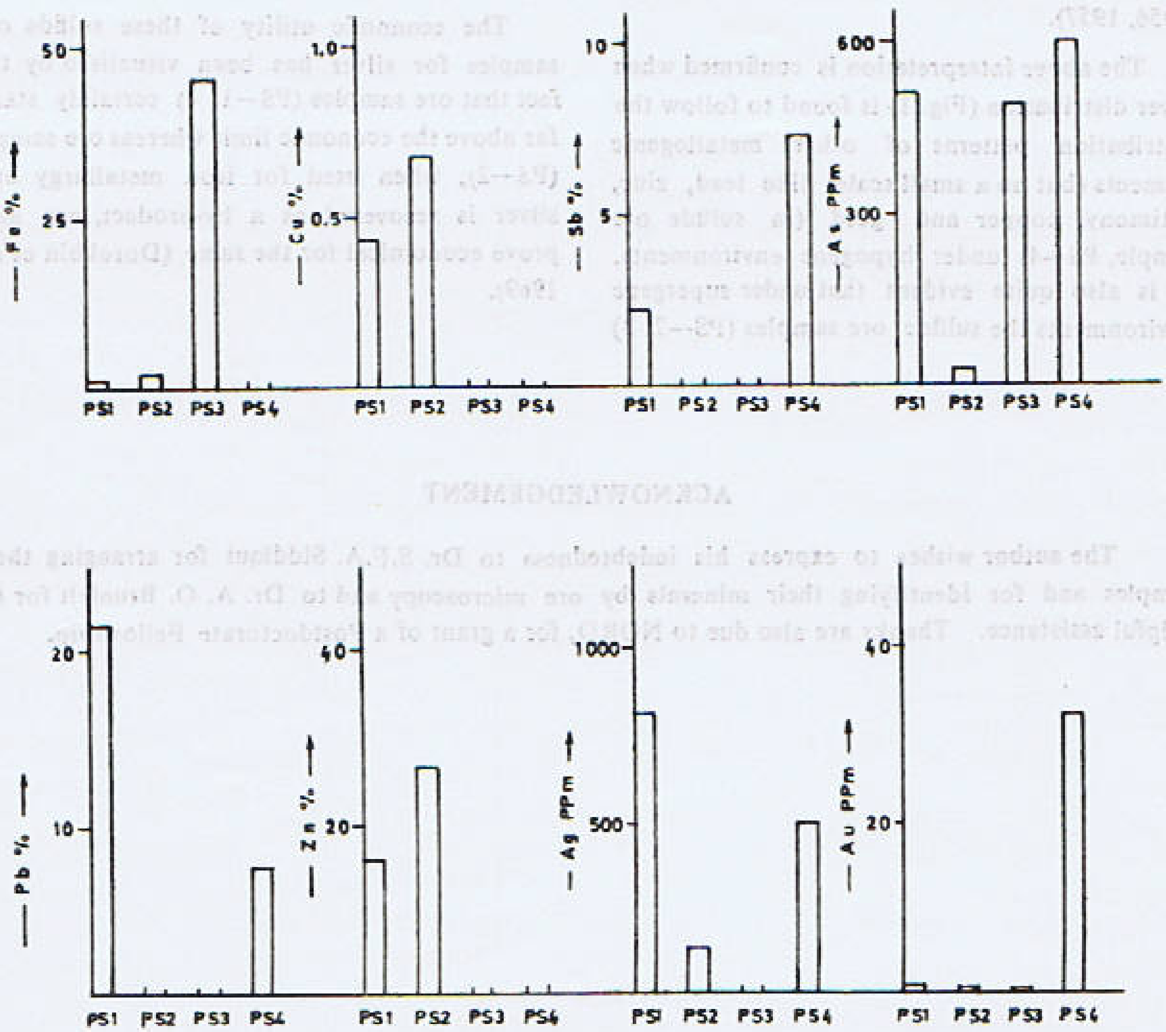

FIG.1 HISTOGRAMS SHOWING THE DISTRIBUTION PATTERNS OF Fe, Cu, Sb, As, Pb, Zn, Ag, & Au IN SULFIDE ORE SAMPLES (PS 1, 2, 3, 4)

In case of sphalerite ore and pyrite ore samples (PS—2, 3) chalcopyrite and (traces of) arsenopyrite respectively behave as host minerals and maintain control on the distribution of silver. Minor contribution may also be tendered as mechanical inclusion alongwith gold (Boyle (1956, 1957).

The above interpretation is confirmed when silver distribution (Fig. 1) is found to follow the distribution petterns of other metallogenic elements (but on a small scale) like lead, zinc, antimony, copper and gold (in sulfide ore sample, PS—4) under hypogene environments. It is also quite evident that under supergene environments the sulfide ore samples (PS—2, 3) must have followed a different rule and silver distribution does not seem to exhibit any geochemical affinity for more abundant elements (like zinc and iron), rather it seems to follow the distribution patterns of trace elements like arsenic and gold (in sulfide ore sample, (PS—3).

The economic utility of these sulfide ore samples for silver has been visualised by the fact that ore samples (PS—1. 4) certainly stand far above the economic limit whereas ore sample (PS—2), when used for iron metallurgy and silver is recovered as a by-product, can also prove economical for the same (Dorokhin et al. 1969).

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SOME ENGINEERING GEOLOGICAL PROPERTIES OF THE SEDIMENTS FROM TWO BORROW AREAS AT THE SIMLY DAM-SITE SIMLY, PAKISTAN

BY

MOHAMMAD HUSSAIN MALIK

Department of Geology, Punjab University, Lahore.

Abstract : *The Simly dam-site on the Soan river near Rawalpindi is located at co ordinates 33° 43', 45'' N and 73° 20' 25'' E. The various geological units present in the area belong to the Siwalik system. More than two million cubic yards of only silt and clay are required to be used in the construction of this dam. Two borrow areas namely Simly Plain and the Tamair valley deposits were therefore investigated for this purpose.*

Undisturbed samples from both the borrow areas were tested and an attempt is made to compare their engineering geological properties. The results are presented in the form of diagrams of the representative samples to make this paper brief.

INTRODUCTION

The Simly dam-site is situated on the Soan River about 24 miles NE of Rawalpindi. After the completion, the dam will serve the purpose of fulfilling the needs of the expanding Capital, under the Greater-Islamabad scheme.

Simly Dam would be of the 'Earth and Rock fill' type with an impervious clay core and upstream and downstream rock-fill shells.

Geology

The area is dominated by sedimentary deposits belonging to the Chingi stage of the Siwaliks. The various units seen are :

Sandstone (massive)
Sandstone (friable)
Siltstone
Clay and claystone

The area in consideration shows a huge anticlinal structure and the rocks within as a result have undergone some deformation.

Borrow Area

The excavations for spillway and the main embankment will yield some fill material (about 200,000 to 300,00 cu. yds. whereas about 2.05 milion cu yds. of only silt and clay are required, apart from the granular fill and the rock fill.

Two sources of impervious material, Simly Plain (lacustrine) and Tamair valley (alluvial), have been fully explored. A total of 200 pits were excavated for investigation purposes. Simly Plain will provide 350,000 cu, yds. and Tamair valley is estimated to yield 1.7 million cu. yds. of silt and clay. The soil at both these sources bears crops and therefore, the root zone will have to be stripped.

The granular material is available from the river bed and its estimated volume is 100,000 cu. yds. Rock fill, about 2.3 m.cu.yds., will come from the various quarries, seven in number situated near the site.

SIMLY PLAIN DEPOSITS

The Simly Plain deposits are lacustrine and cut into two parts by the river. The deposit on the left bank is about 60,000 cu.yds. and of low plasticity index. 4.1. The right bank deposit is about 300,000 cu.yds. and of plasticity index between 5 2 and 8 1. The Simly deposits consists of two zones The upper layer about 10 ft. thick comprises the recent alluvial sediments of sandy silty clay (Tescult international Ltd). Because of the large amount of silt, this zone was not recommended for the transition zone of the dam.

The lower zone is an older deposit of silty sand containing weathered coarse particle ranging from gravels to boulders.

TAMAIR VALLEY DEPOSITS

Tamair valley, about 3 miles southwest of Simly. is the other source of impervious construction material. Almost all the borrow material of this valley lies below the 2250 ft. elevation. A few outcrops of sandstone interbedded with clay-claystone are also present. The depth of bedrock is about 30 ft.

ROCK FILL MATERIAL

Approximately 1,791,000 cu. yds. of rock is required to be used in upstream rock fill, downstream rock fills and rip rap etc The area investigated contains massive sandstone which can be used for the above purpose. Seven different quarries have been investigated for this purpose most of which occur on the right bank. A major part of the rock fill will be available from these quarries, the remaining can be made available from the various excavations undertaken at the site, e.g. spillway excavations etc.

PROPERTIES OF MATERIALS

Soils and rocks were tested variedly both in situ and in the laboratory. Undisturbed samples of soil from Simly Plain and Tamair valley were tested for their engineering geological properies ; and a comparison is thus made of the properties from these two main sources of the soil. Rocks were tested in the form of cores obtained from various bore holes and on aggregate materials.

FIELD TESTS

A few tests carried out in the field are :—

1. Rebound Hammer Test
2. Moisture content
3. Field Natural Density

The results obtained from the Rebound Hamer Tests both along the bedding planes and across them, were later compared with the results from the core tests carried out in the laboratory.

Speedy Moisture Tester was extensively used at the site for instantly obtaining the moisture content for computations of dry density of the compacted fill at the upstream coffer dam.

The same tester was also used to determine the moisture content of the Simly Plain soil whenever it was overmoistured, to check if the moisture content was back to normal.

Two methods were used to determine the field natural density namely :—

1. Water Replacement method

and 2. Sand Replacement method.

Average value of the field Natural Density of Simly soil by using the water Replacement method was determined to be 136 5 lbs./ cu.ft. and the dry density of the value of 117.1 lbs./ cu.ft.

The results of this experiment show that the soil of the Simly Plain has a high dry density and a high moisture content. Therefore the danger of cracking up of soil is small.

Sand replacement method was used in Simly Plain and the Tamair valley borrow areas. The results obtained show a remarkable difference in the properties of soil from these two sources on representative samples.

Simly Plain Soil :

Bulk Density = 131.6 lbs /cu.ft.

Dry Density = 121.5 lbs/cu.ft.

Tamair Valley Soil :

Bulk Density = 99.5 lbs./cu.ft,

Dry Density = 82.64 lbs/cu.ft.

LABORATORY TESTING

A number of tests were carried out in the laboratory on the following materials :—

1. Soils
2. Rocks (cores)
3. Aggregates

Soil was sampled in undisturbed condition from Simly Plain and Tamair valley and various tests were carried out for relative study.

The various tests performed on soils are as under :—

1. Specific Gravity
2. Grain size analysis
3. Atterberg limits
4. Compaction
5. Permeability
6. Consolidation
7. Unconfined compression strength
8. Direct shear test
9. Triaxial compression Test

The results of some of these tests on two representative samples from each sits i.e. Simly Plain and Tamair valley, are given in the following figures and diagrams, (1—10) for comparison purposes.

Some Properties of Soils from Simly Plain and Tamair Valley

	Sp. Gr.	Atterberg Limits		Grain size analysis	Compaction	Permeability.	Triaxial shear	Compression	Consolidation
		Shrinkage Limit	P.I.						
Simly Plain	2 704	21.00%	18 32	Sand 26.1% Silt 44% Clay 30%	Max Dry Density 123 lbs.cu/ft. O,M C.11 6%	3.09 x10 cm/sec.	C=15 lbs/sq ft. $\phi=80$		See the diag.
Tamair Valley	2.732	16.6%	8.85	See the diag		4.10x10 cm/sec.	C=4.5 P.S.I $\phi=9.5°$	19.25 P.S I.	See the diag.

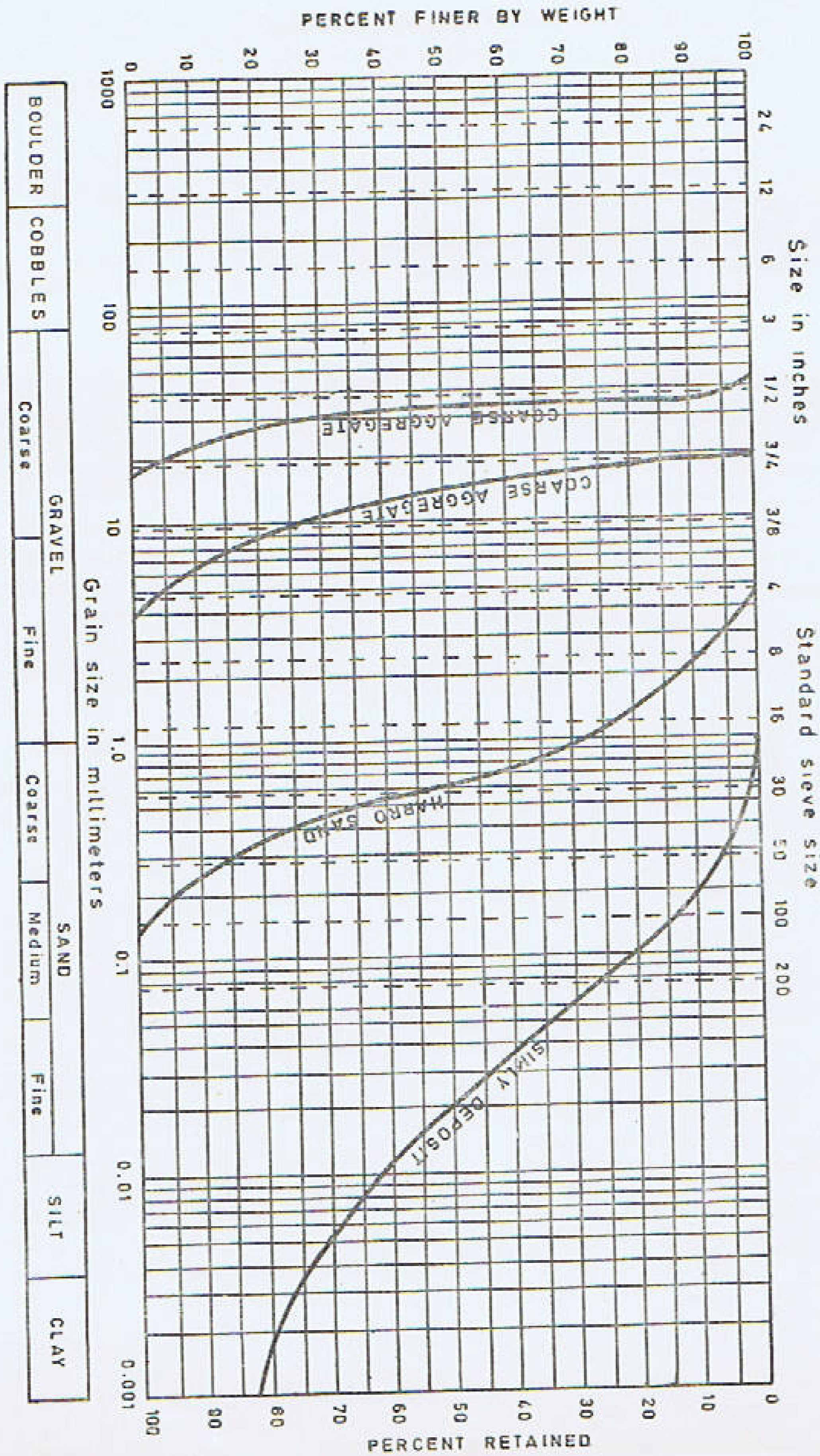


Fig. 1 GRAIN SIZE ANALYSIS OF DIFFERENT DEPOSITS.

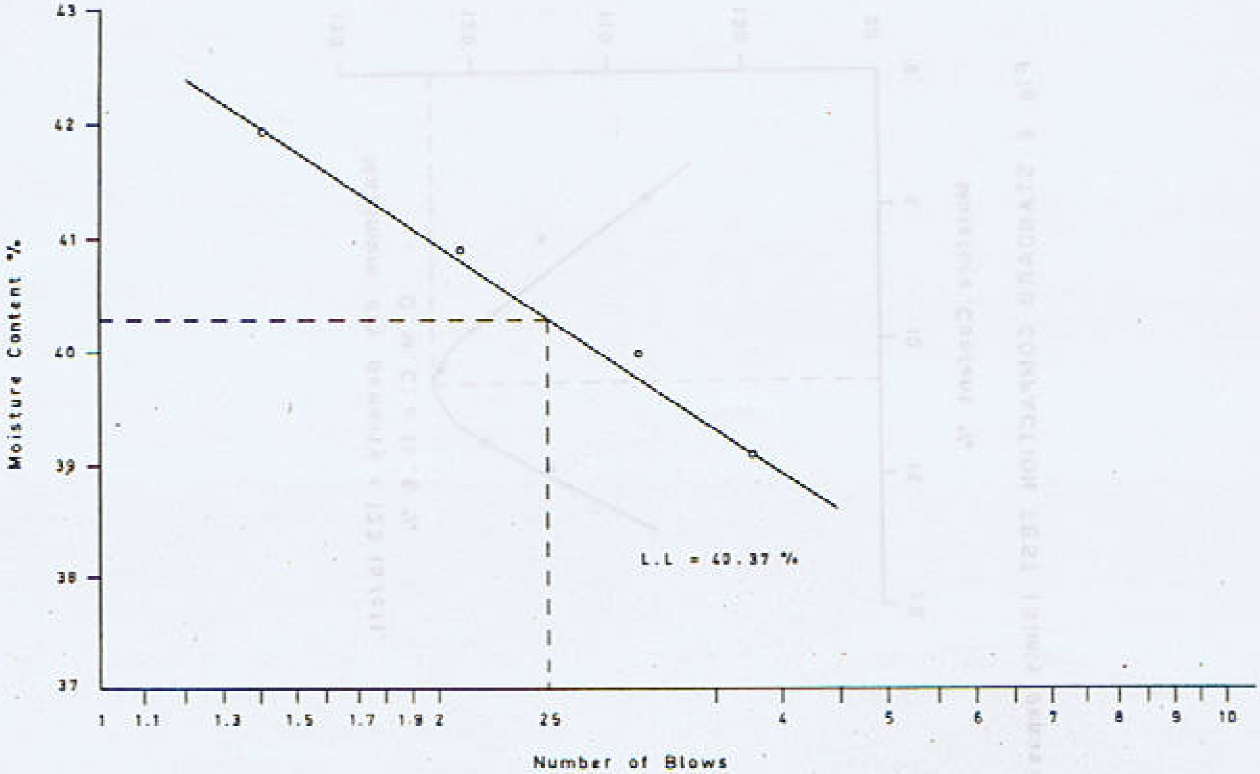


Fig. 2 SIMLY BORROW AREA

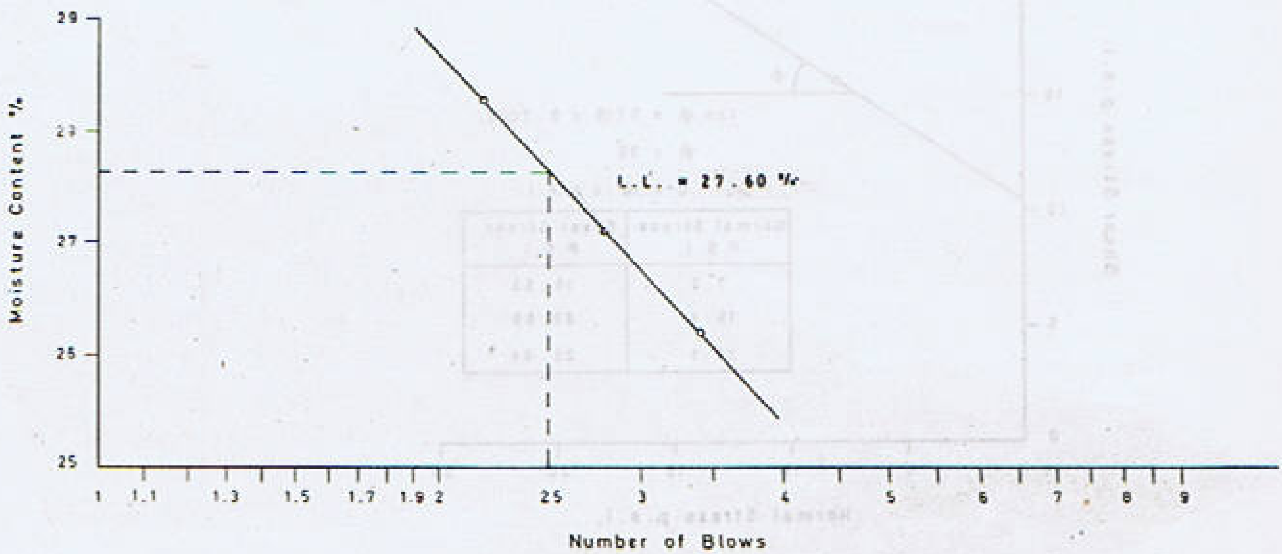


Fig. 3 TAMAIR BORROW AREA

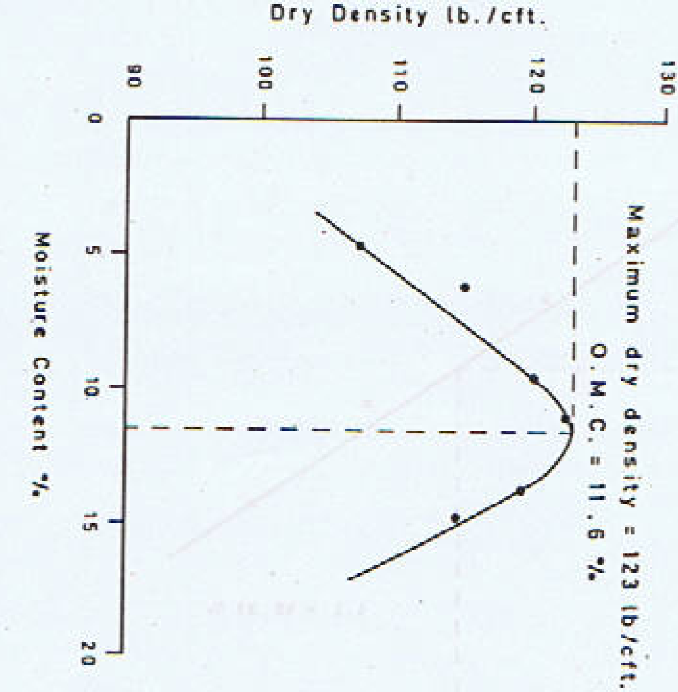
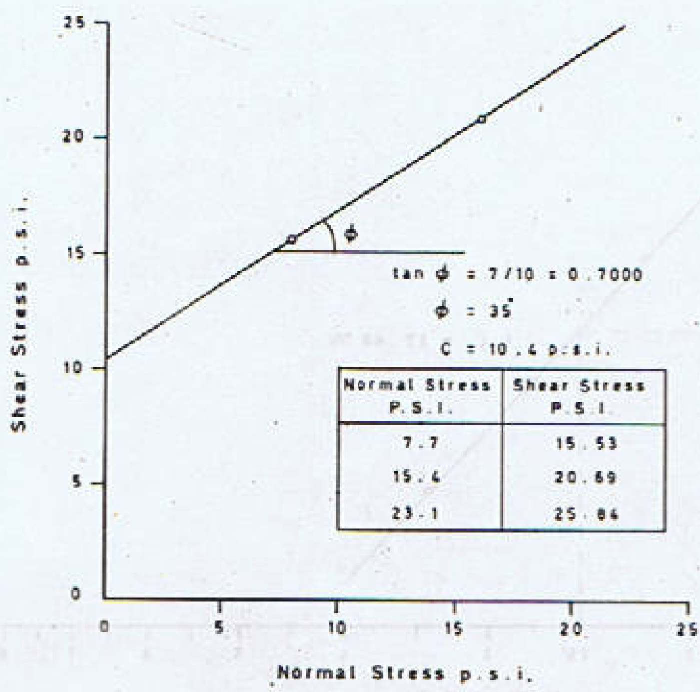


Fig. 4 STANDARD COMPACTION TEST (Simly deposits)



Normal Stress P.S.I.	Shear Stress P.S.I.
7.7	15.53
15.4	20.69
23.1	25.84

Fig. 5 DIRECT SHEAR TEST STRAIN CONTROLLED (SIMLY DEPOSIT)

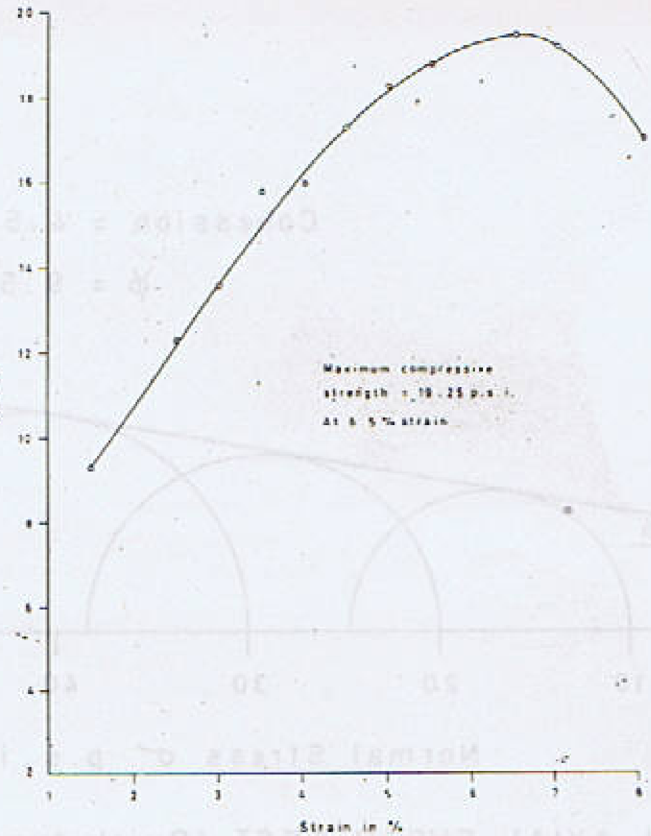


Fig. 6 UNCONFINED COMPRESSION TEST (TAMAIR DEPOSITS)

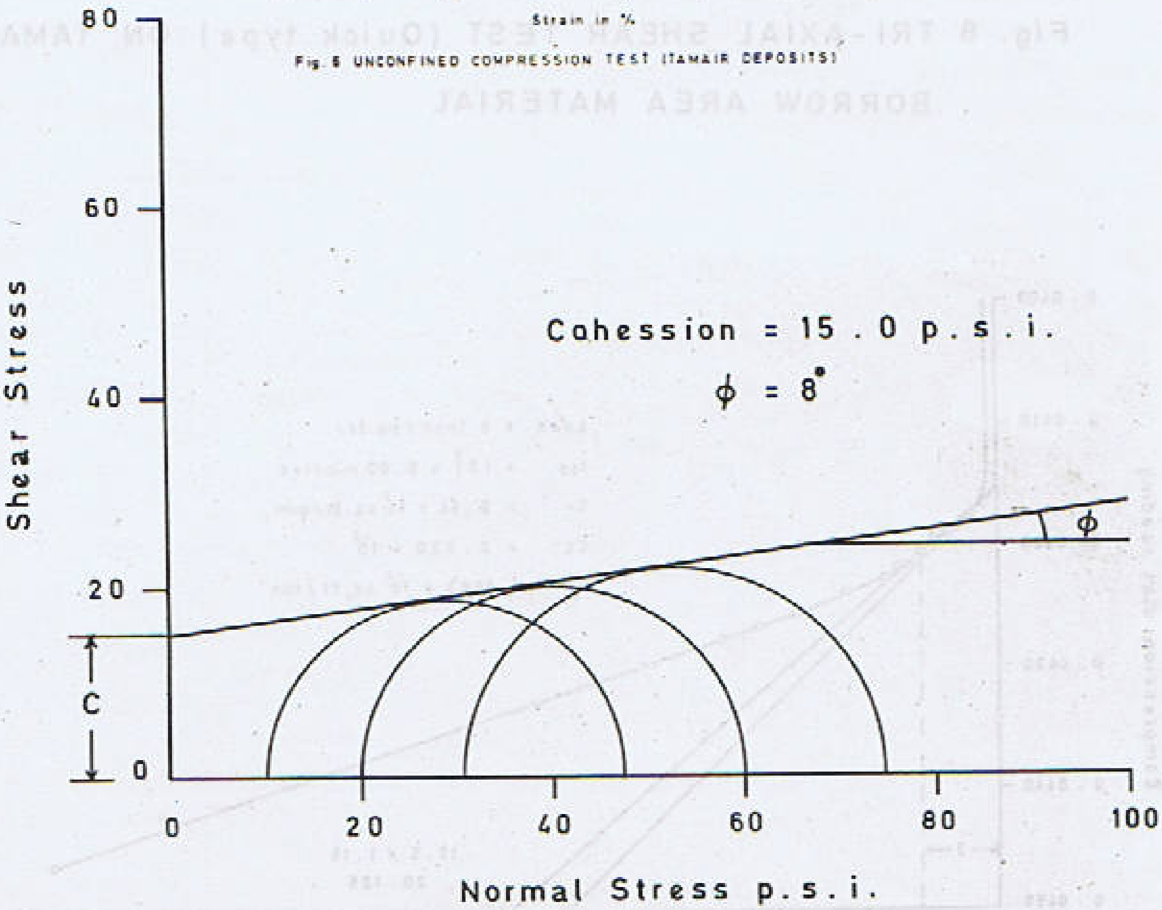


Fig. 7 TRI-AXIAL SHEAR TEST (Quick type) ON

SIMLY BORROW AREA DEPOSITS

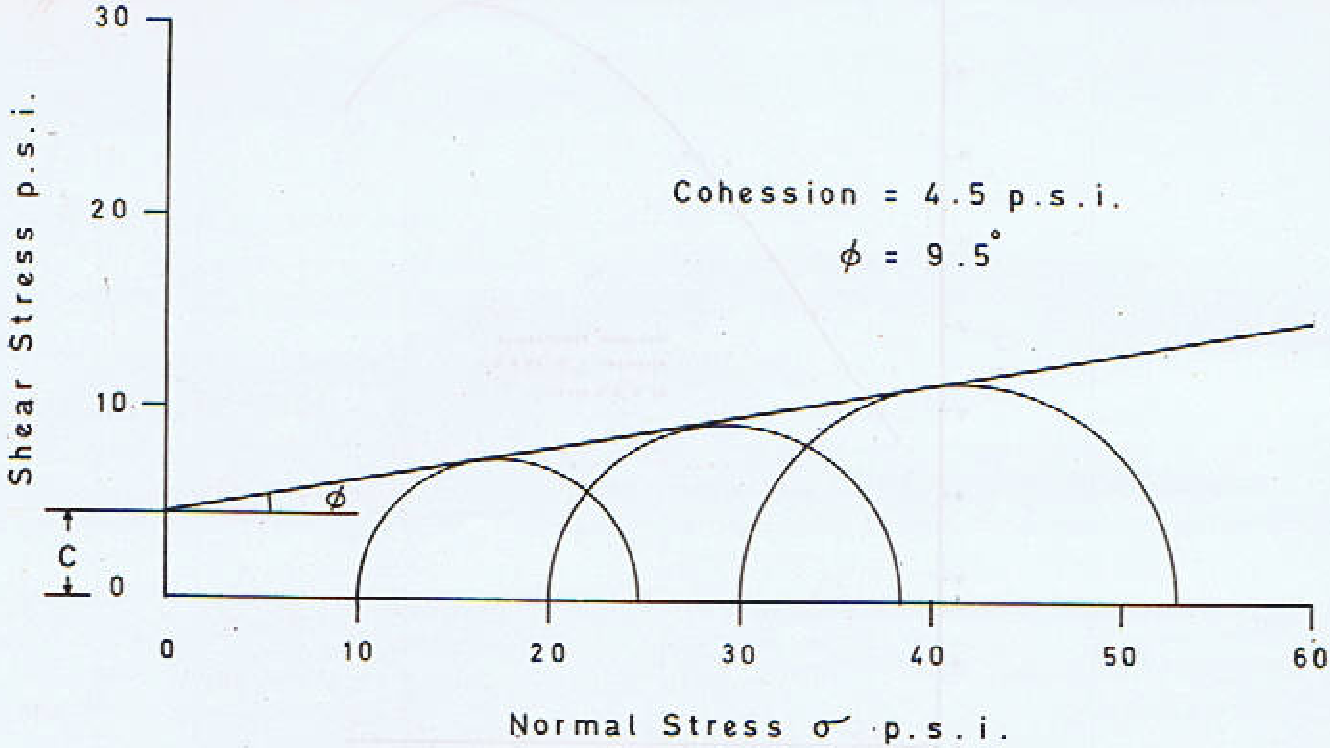


Fig. 8 TRI-AXIAL SHEAR TEST (Quick type) ON TAMAIR BORROW AREA MATERIAL

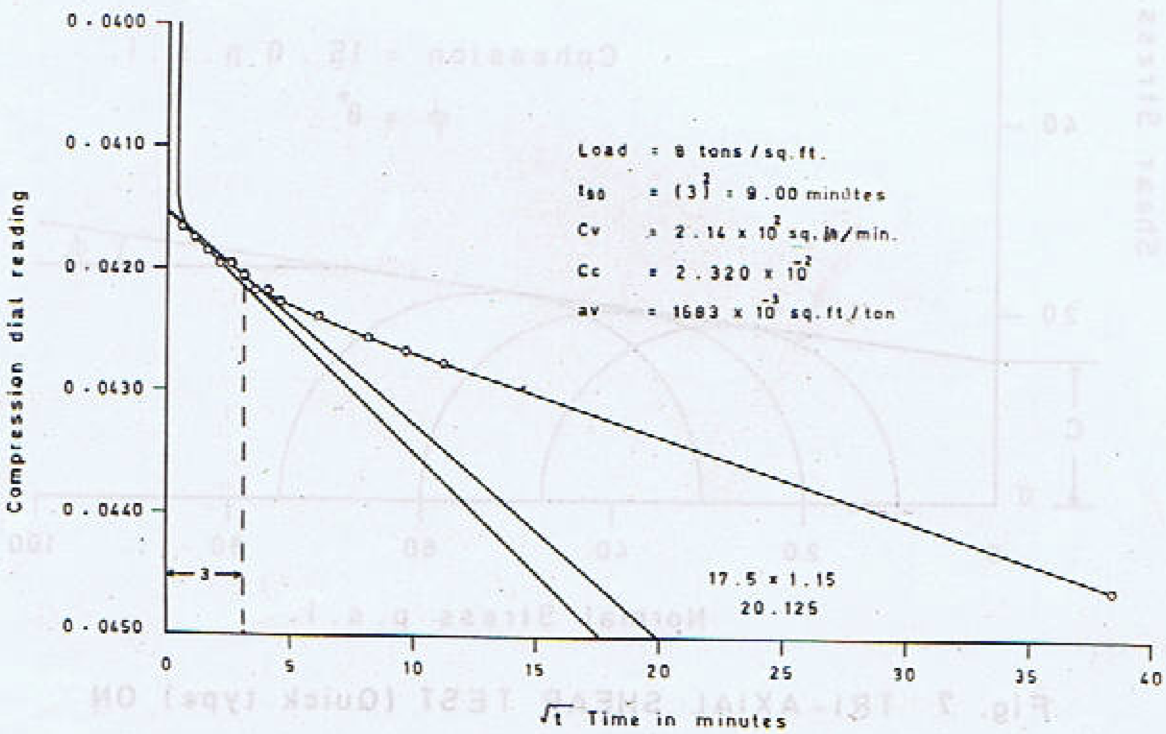


Fig. 9 CONSOLIDATION TEST SIMLY DEPOSIT

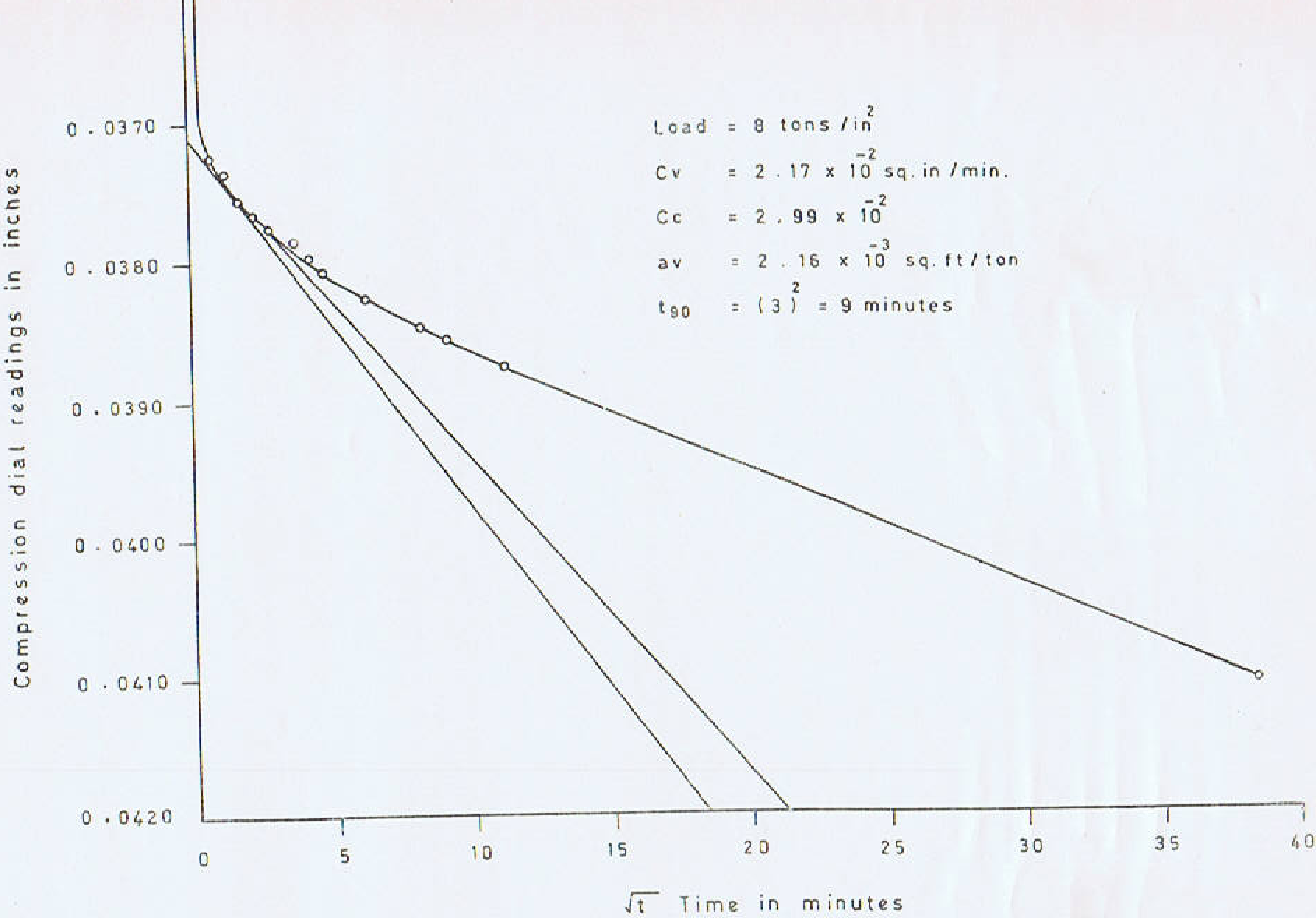


Fig. 10 CONSOLIDATION TEST TAMAIR VALLEY DEPOSITS

PETROLOGY OF THE TAGHMA AREA, SWAT DISTRICT, N.W.F.P. PAKISTAN

BY

ZULFIQAR AHMED

Department of Geology, University of the Punjab, Lahore, Pakistan.

RAHIMUDDIN KHAN & ABDUL RAUF

Abstract : *A detailed geological map of Taghma area, Swat district, N.W.F.P., Pakistan, based on petrographic rock types, is being presented. The field relations and petrography of various rock units is given. Certain genetic feature of various rock types and the china clay deposits are discussed briefly.*

INTRODUCTION

Taghma village is situated 20 km northeast of Mingora city in Swat District, N.W.F.P. The area is accessible by footpath and from an all weather jeepable road that links Mingora with Shah Dheri The area includes Taghma, Shalhand, Sada, Mohammad Beg and Narang Pora villages. The altitude of the area ranges from 1136 meters near Sada village to 2221 metres near Mohammad Beg village.

Taghma area forms a part of much larger territory of Swat district that was mapped as "Upper Swat Hornblendic Group" by Martin *et al* (1962). Jan and Kempe (1973) subdivided this group into amphibolites and epidote amphibolites; both types cover vast areas while the latter type covers all the Taghma area under discussion. Because of a large variety of igneous and metamorphic rocks grouped together in the above units, need has arisen for their further subdivision, and mapping of various petrographic units separately. Such attempts have been made already in case of areas lying to immediate West and SW of Taghma area by Moosvi *et al.* (1974). A detailed map of Taghma area is being presented herewith (Fig. 1).

GENERAL GEOLOGY

The accompanying geological map (Fig. 1) shows distribution of following separately mapable rock units of the Taghma area: amphibolite, hornblende gneiss, hornblendite, peridotite (including harzburgite) serpentinite, diorite and pegmatites.

The foliated rocks show a general NE-SW strike and dip towards northwest. By far the major part of the area is covered by hornblende rich metamorphites, such as amphibolites and hornblende gneiss. These are foliated rocks and frequently display prominent banding of alternate mafic (hornblende rich) and felsic bands. Bands show great variation in thickness from a cm to metre. Bands are quite regular and maintain uniform thickness, but at some places they are very irregular and have lensoid shapes. Bands are also disturbed by folding and faulting on a small scale. Non-banded amphibolites and hornblende gneisses are also common, and show homegeneously distributed mafic and felsic constituents. Typical augen structure is developed in hornblende gneisses at many places. In amphibolites, folding on small scale is a very common feature.

The intrusive rocks of the area are mainly dioritic, amphibolitic and peridotitic. Pegmatites of both acid and basic types are also found. Peridotitic rocks outcrop as elliptical, roughly triangular and irregular bodies of small size that are distributed sporadically, surrounded by amphibolites and hornblende gneisses, More intense alteration of peridotites has formed serpentinites at some places. The chemical weathering of feldspathic material of pegmatites and felsic bands of metamorphites has produced kaolinite which is responsible for the economically significant china clay deposits of this area.

Diorites are unfoliated, intrusive rocks with sharp contacts, having coarse grain size, and showing effects of chilling at the contacts; these occur in northern part of the area.

The regions of ultramafic rocks occupy elliptical to roughly triangular and rather irregular areas on the outcrop map (Fig. 1). They occur sporadically and are enclosed in the amphibolites and the hornblende gneisses. The rocks are mainly dunites, harzburgites and serpentinites. Visibly they lack thermal aureoles. Magnetite and a chromian spinel are present in accessory amounts. In serpentinites, magnetite forms veins and patches at some places. Some of the ultramafic bodies are dunitic in central parts and harzburgitic outwards. The completely altered ultramafites show greenish colour and appear distinct from associated unaltered rock.

Apart from pure hornblende, segregated in the darker amphibolite bands, there are massive rocks made mainly of hornblende. Those are hard, black rocks with metallic lustre, and are coarse grained. Both types are collectively called hornblendites.

Basic pegmatites with very coarse hornblende crystals are found almost everywhere. Their contacts with the enclosing hornblende bearing rocks are usually gradational. In addition, acid pegmatites with discordant relations are also present. Those are unzoned, mostly of simple-type and composed of feldspar, quartz, muscovite, green hornblende, sphene, magnetite and pink garnet. Epidote and chlorite are present as secondary products. Aplitic dykes and veins of pure quartz are present at many places, the latter may be up to 7 meters wide and up to 30 metres long.

PETROGRAPHY

Hornblende Gneiss. This is composed mainly of hornblende, epidote, plagioclase and quartz. Minor amounts of chlorite, sphene, muscovite, iron ore and garnet are present. Hornblende and epidote are commonly poikiloblastic and contain abundant inclusions of quartz. Hornblende forms long, prismatic crystals of dark, green to black colour in hand specimens. In thin sections, it is strongly pleochroic from yellowish green to dark bluish green in colour. Along fractures, it alters to chlorite, muscovite and epidote. Cummingtonite and tremolite-actinolite are rarely seen. Epidote of gneisses is a secondary mineral, derived from plagioclase and hornblende. Plagioclase varies in composition from An_{16} to An_4's Rarely, it shows alteration to epidote, sericite, kaolin and muscovite. It may also contain inclusions of hornblende and epidote. Quartz is mostly anhedral and is abundant as inclusions. It may form symplectic intergrowths with epidote. Pale red to pink coloured garnet is found as fractured grains studded with quartz inclusions. Muscovite and chlorite are rarely seen. Sphene is euhedral and pale yellow to brownish in thin sections. Magnetite and hematite are present in very minor amounts.

TABLE 1

Modal Composition of some rock samples from Taghma area, Swat.

Rock Name	GNEISSES				AMPHIBOLTES		DIORITES AND TONALITES			HORNBLENDITES	
Sp. No.	13734	13756	15426	15574	13739	15470	15538	13733	13755	13727	13749
Hornblende	35.2	22.6	30.3	38.1	57.9	41.7	74.8	21.2	40.5	85.5	92.5
Plagioclase	19.3	43.8	9.1	11.5	17.0	0.8	10.3	50.9	15.6	2.2	—
Epidote	33.0	25.5	57.5	44.0	20.0	44.2	10.9	13.0	8.1	2.0	3.9
Quartz	6.9	3.0	—	0.6	2.0	10.8	4.0	10.9	—	7.4	—
Sphene	1.3	3.0	—	5.2	1.6	2.0	—	1.3	—	0.9	3.6
Muscovite	—	—	—	—	—	—	—	—	—	—	—
Chlorite	2.4	—	—	—	—	0.1	—	—	—	—	—
Garnet	1.9	—	1.3	0.3	0.5	0.4	—	—	—	—	—
Iron Ore	—	2.1	1.8	0.3	1.0	—	—	0.5	10.0	—	—
Pyroxene	—	—	—	—	—	—	—	—	25.8	—	—
Orthoclase	—	—	—	—	—	—	—	—	—	2.0	—
Biotite	—	—	—	—	—	—	—	2.2	—	—	—

(*b*) *Amphibolites.* Hornblende enrichment makes amphibolites darker in colour, especially in the darker bands, and often concentration of pure hornblende forms hornblendite layers. Other minerals of amphibolites are epidote, quartz, plagioclase, chlorite, garnet, sphene and iron oxides. Apart from hornblende tremolite-actinolite are also present at places. Amphiboles contain abundant inclusions, making sieve-textured plates. Epidote occurs mostly near to the grains of hornblende and plagioclase, latter varying in composition from An_7 to An_{33}. Quartz forms anhedral grains and inclusions in hornblende, epidote and plagioclase. Sphene is pale yellow to brown and euhedral. Iron oxides are present as magnetite, hematite and limonite. Chlorite shows anomalous blue interference tints. Garnet is pale red to pink and mostly almandine, being abundant near contact with the gneisses. Modally, however, those amphibolites show strong variation in their contents of hornblende, epidote and other felsic minerals.

(*c*) *Diorites.* The colour index of diorites varies from below 20 to above 40 while their composition varies from gabbroic to granodioritic. They are composed of plagioclase and hornblende, with fair amount of quartz ; sometimes biotite or augite are present. Orthoclase is relatively lesser. Accessory minerals are magnetite, sphene and epidote. Plagioclase composition varies from An_{12} to An_{33} Hornblende is green and pleochroic and contains inclusions of quartz and epidote. Augite is present in more basic samples, and it sometimes shows alteration to amphibole. In more acidic samples, quartz is abundant and alkali feldspar is also present.

(*c*) *Ultramafic Rocks.* These rocks generally possess hypidiomorphic granular texture, but coarser pyroxene crystals are notable in hand specimens. Olivine is a common variety, with fractures filled by serpentine, and is highly magnesian. Pyroxene is mainly an enstatite or hypersthene and shows schiller structure commonly. Magnetite is both of primary and secondary type, latter being associated with serpentinization-veinlets. Olive green spinel is present rarely, and alters to magnetite along margins. Serpentine minerals are antigorite, chrysotile and bastite. Modal composition of three specimens of peridotites is given in Table 2.

(*d*) *Hornblendites.* Hornblende makes more than 80% of these rocks, rest being epidote, chlorite, sphene, magnetite and plagioclase. Hornblendites also contain minor amounts of kaolinized plagioclase, sphene, hematite and chlorite. Chlorite is abundant in hornblendite bands that are present in the amphibolites, described earlier.

GEOLOGY OF CHINA CLAY DEPOSITS

The china clay deposits of considerable economic value are available in the Taghma area. These have been formed through surficial chemical weathering and hydration of feldspars present in the pegmatites. In addition, the feldspathic bands of banded gneiss and amphibolites have also been similarly altered to kaolinite, but the china clay from pegmatites is of high-grade and mineable, 23 exposures of china clay have been located within a 3 km, long stretch from Chautar to Shalband At most outcrops, kaolinization of feldspars is more pronounced down to 2.5 m depth. Below this level, china clay grades to unaltered feldspathic rock. The china clay bodies also contain unaltered feldspar, quartz, epidote and mica as gangue. Chemical composition of this china clay has been reported by Moosvi *et al.* (1974), who gave an estimate of china clay reserves of Shah Dheri including Taghma area, as 2.98 million short tons of raw clay which will yield 16.5% pure clay for marketing.

CONCLUDING REMARKS

The oldest rock units are amphibolites and hornblende gneisses, both having been derived by epidote-amphibolite facies metamorphism of igneous parents of basic to intermediate compositions. Hornblende is derived from pyroxene and epidote from plagioclase. Sphene is present in both, indicating their igneous origin, and initially more Ca contents. Amphibolites contain more hornblende, and gneisses are richer in quartz, epidote and feldspar, showing that igneous parents of gneisses were comparatively more acidic. The development of garnet closer to the contacts of these rocks with igneous rocks is probably due to higher pressure, as has been suggested by Leake (1972). Both rocks have also been affected by hydrothermal alteration of feldspars and hornblende. The mobility of elements during metamorphic segregation varied from almost nil in some parts to the formation of bands of pure hornblende.

The dioritic rocks are nonfoliated and younger to amphibolites and gneisses. Their varieties are a result of magma differentiation that showed increase of silica, volatiles and alkalies and a decrease of Ca, Mg and Fe. Evidences of hybridization are not found.

The ultramafic rocks of the area are of alpine type and are supposed to have allogenic origin, as proposed by Thayer (1972). Similar bodies outcrop in the adjoining areas as well.

TABLE 2

Modal Composition of peridotites from Taghma area, Swat.

	15492	15562	15581
Olivine	20.1	36.4	38.2
Pyroxene	41.0	8.2	4.4
Sprpentine	37.0	47.0	42.0
Magnetite	1.9	7.5	15.4
Spinel	—	0.9	—

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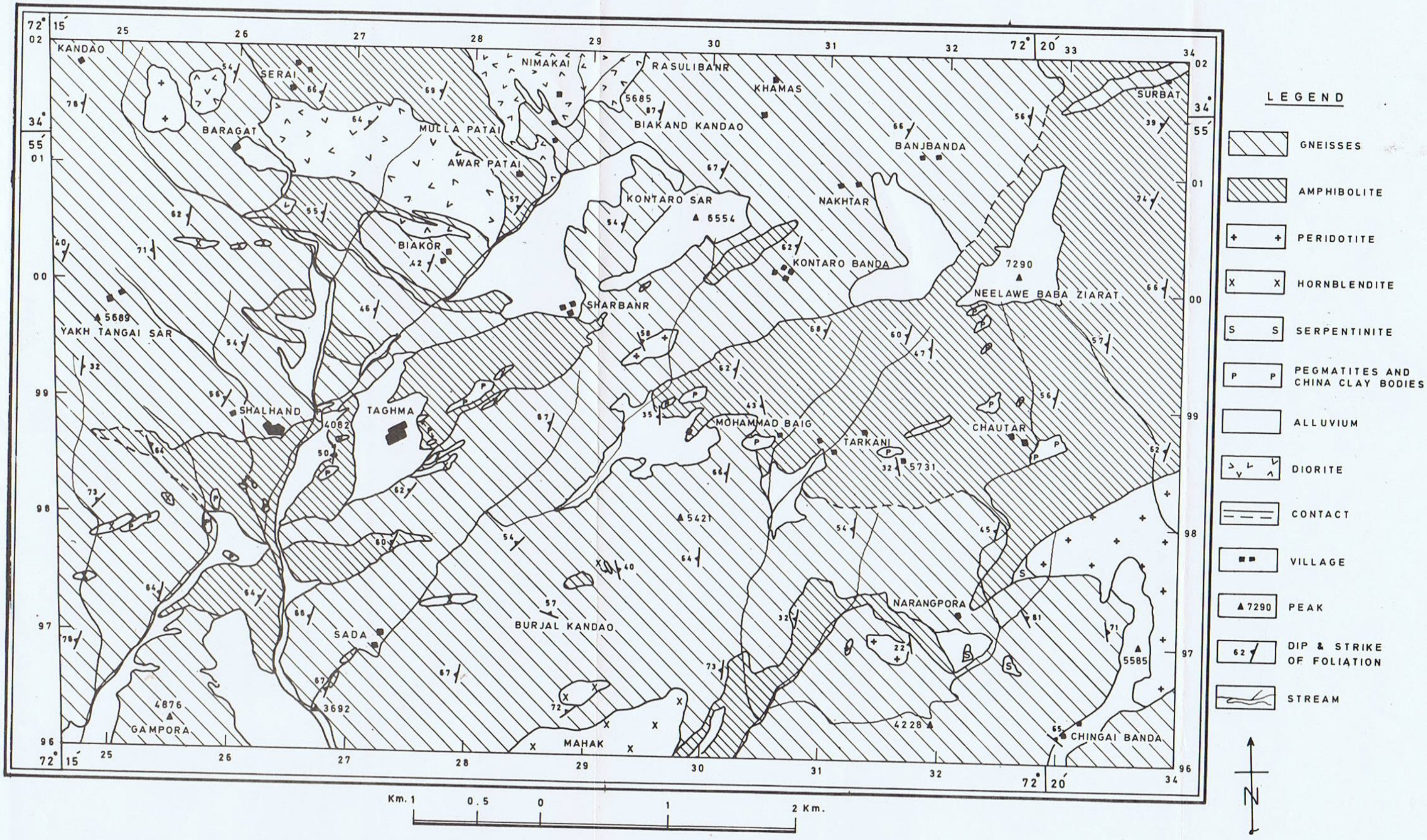

Fig. 1 GEOLOGICAL MAP OF TAGHMA AREA, SWAT DISTRICT PAKISTAN.

MODAL INVESTIGATION OF SOME GRANITIC COMPLEXES OF THE NORTHWEST HIMALAYAS, PAKISTAN

BY

AKHTAR ALI SALEEMI

Department of Geology, University of the Punjab, Lahore.

Abstract : *Modal analyses are given of 21 rocks from northwards extension of the Hazara granitic complex in the Battal-Batgram area, and 11 rocks from the Nanga Parbat granitic massif, alongwith their brief descriptions. The data were plotted in the Streckeissen's triangular diagram for quartzofeldspathic plutonic rocks and discussed. The results are compared with those from the previously investigated Hazara granitic complex and the Lower Swat granitic complex. The conclusions are generalized with reference to theories of origin of granitic complexes of the northwest Himalayas.*

INTRODUCTION

Granitic bodies are exposed throughout the length of the Himalayas, generally in sheet-like form as part of major nappes and upthrusted prisms of granitic-metamorphic lithologies. In addition, these may also occur as plutons and large dome like protrusions, such as those of the Nanga Parbat and the Hiyatulmir.

Recent work on granitic rocks of the Himalayas has shown those to be associated with regional phenomena of basement reactivation related to the socalled continent-continent collisional origin of the Himalayas. Theories of origin of the granitic complexes have, however, ranged from a purely igneous to metasomatic in nature while a simple metamorphic reorganisation of the metasediments has been postulated as well. However, some major works in this connection have suffered due either to lack of chemical data or sufficient control on sampling of material. It is only in the case of the Hazara and the Lower Swat granitic complexes that detailed chemical, mineralogical and textural studies were undertaken (Shams, 1967, 1969, 1979) that metasomatic models were established adequately.

Fortunately, most of granitic complexes of the northwest Himalayas display rather simple and almost similar mineral compositions so that it was considered useful to investigate modal characteristics of such granitic complexes that have not been yet studied in detail. The work originated from the extensive field work carried out by the author in the Battal-Batgram area as part of requirement of M.Sc. examination of the Punjab University. In view of a recent petrochemical investigation of the Nanga Parbat granite (Shams *et al.*, 1979), rocks were also included from this important complex which has been made world-famous by the classic work of Misch (1949). Due to their fundamental nature in the study of granitic rocks, attention was entirely focussed on the quartzofeldsprthic components of the rocks and were subjected to statistical analyses with the help of a Swift point counter. For the sake of understanding their modal variation all positions were plotted on the basis of recast percentages of quartzofeldspathic constituents) Steckeissen's (1967) classification triangle was used as applied to the plutonic complexes.

THE GRANITIC GNEISSES OF THE BATTLE-BATGRAM AREA, DISTRICT MANSEHRA

These rocks are the northwards extension of the socalled Susalgali granitic member of the Hazara granitic complex (Shams, 1961, 1967, 1969) and compare well in essential details except that these are related to the Pre-Cambrian Salkhala metasediments while those of the southern areas are related to the palaeozoic Tanol formation. Modal compositions of 21 samples of granitic rocks were obtained, their recast percentages of quartzofeldspathic constituents are given in Table 1 and their plotted positions in the Streckeisen's (1967) triangle are shown as (Fig. 1.) Following conclusions are significant :

(*i*) Out of 21 positions, 14 plotted in the field of potassic granite and only 7 plotted in the field of normal granite.

(*ii*) The feldspathic constituents show significant variation in relation to quartz.

(*iii*) The ultimate trend of modal variation is towards quartz monzonite.

THE GRANITIC GNEISSES OF THE NANGA PARBAT, DISTRICT DIAMIR

11 samples of granitic rocks from the Nanga Parbat were subjected to modal analyses and the data are given in Table 2 on the basis of recast quartzofeldspathic constituents, their plotted positions are shown also in (Fig. 1). Following conclusions are pertinent :—

(*i*) Out of 11 plotted positions, only 1 lied in the field of potassic granite, 3 lied in the field of alkali granite, 4 in the field of alkali syenite, 2 lied in the field of quartz syenite, and 1 in the field of normal granite.

(*ii*) There is a prominent variation relationship between quartz and alkali feldspar.

(*iii*) The ultimate trend of modal variation is towards syenite.

DISCUSSION

From the description of the two complexes given earlier, it is found that they show significantly different trends of modal variations. In the case of the Battal-Batgram granites, the variation trend is towards the monzonite composition while in the case of the Nanga Parbat complex the variation is towards syenite composition. In both the cases, however, there is a reciprocal relation of the feldspars towards the modal quartz (Fig. 1). For the sake of comparison with other granitic complexes of the northwest Himalayas, (Fig. 2) was prepared which also included outlines of plotted positions of the Sierra Nevada Batholith (Carmichael *et al*, 1974) and of the Skye granites (Tuttle and Bowen, 1958) ; both are accepted of igneous origin. The difference between the variation trends of these two com lexes is so much from those of the Himalayan granitic complexes that a straight differentiation origin can be dismissed at once : this is also supported by lack of occurrence of a basic parentage in the latter cases.

In the case of the Nanga Parbat granites, a metasomatic origin was advocated by Misch (1949) on the basis of field and petrographic data, although neither any chemical analyses were given nor statistical modal variation diagrams were utilized. According to Misch (1949), the nature of metasomatism was essentially dependent upon supply of potash through the agency of hot fluids. the evidence for this was recognized due to progressive increase in abundance and grain size of potash feldspar after kyanite grade of metamorphism has set in.

TABLE NO. 1

Micrometric analyses of some specimens of Suthangali and Susalgai granite gneisses

(recalculated to percentage)

Mineral/Sample No.	1	2	3	4	5	6	7	8
Quartz	32	48	36	30	27	53	46	40
Alk-feldspar	53	39	47	45	54	31	47	38
Plagioclase	15	13	17	25	19	16	7	22

Mineral/Sample No.	9	10	11	12	13	14	15	16
Quartz	31	36	33	43	32	30	21	24
Alk-fedspar	45	46	46	35	44	44	48	43
Plagioclase	24	18	21	22	24	26	31	33

Mineral/Sample No.	17	18	19	20	21
Quartz	34	36	28	41	27
Alk-feldspur	41	46	46	40	53
Plagioclase	25	18	26	19	20

TABLE NO. 2

Micrometric analysis of some specimens of older granites gneiss of Nanga Parbat granite complex

(recalculated to percentage)

Mineral/Sample No.	1	2	3	4	5	6	7	8
Quartz	23	14	16	22	30	15	58	10
Alk-feldspar	63	86	73	72	62	82	22	73
Plagioclase	9	0	11	6	8	3	20	17

Mineral/Sample No.	9	10	11
Quartz	30	08	12
Alk-feldspar	67	84	86
Plagioclase	3	8	2

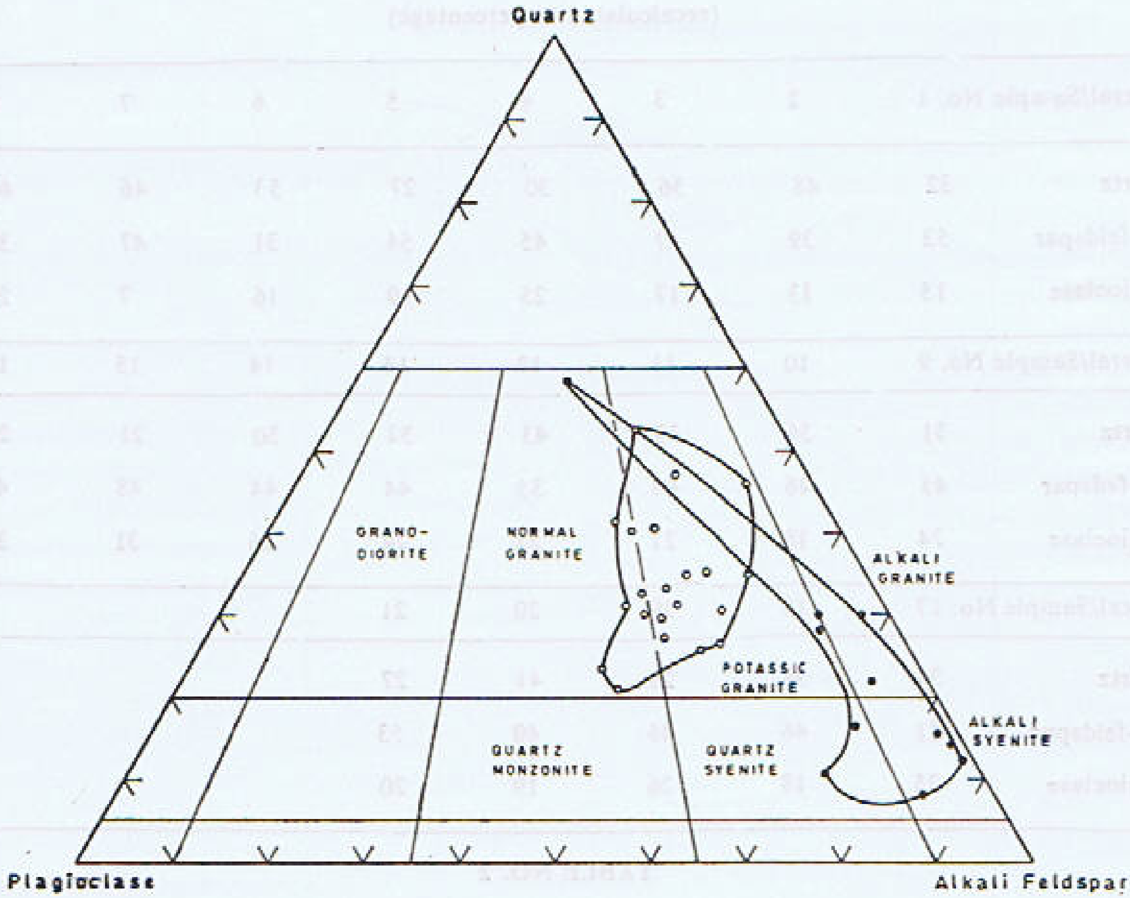

Fig. 1 Plots of modal analyses of some granitic rocks from Nanga Parbat (.) and Battal-Batgram area ($_\circ$), north of Hazara in Streckeisen's (1967) triangle.

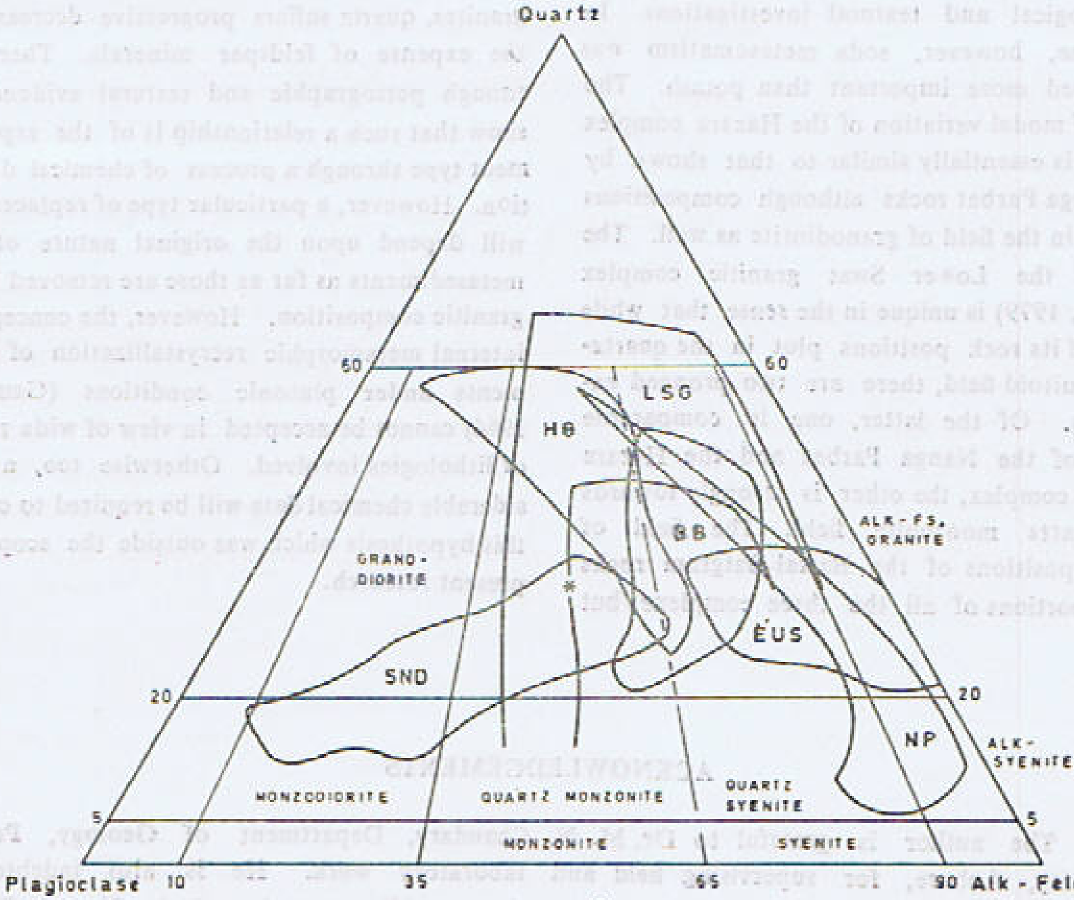

Fig. 2. Area of modal plots of granitic rocks from Nanga Parbat (NP) Battal Batgram area north of Hazara (BB) along with Hazara granitic complex (H.G; Shams 1967). Lower Swat granitic Complex (L.S.G. Shams, 1979), Sierra Nerada Batholith (SND Carmichael *et al.*, 1974), and sky granits (EUS ; Tuttle *et al.*, 1958)

A similar hypothesis was advanced by Shams (1967) in the case of the Hazara granitic complex but on the basis of extensive chemical, mineralogical and textural investigations. In this case, however, soda metasomatism was considered more important than potash. The trend of modal variation of the Hazara complex (Fig. 2) is essentially similar to that shown by the Nanga Parbat rocks although compositions plotted in the field of granodiorite as well. The case of the Lower Swat granitic complex (Shams, 1979) is unique in the sense that while many of its rock positions plot in the quartz-rich granitoid field, there are two pronged extensions. Of the latter, one is comparable to that of the Nanga Parbat and the Hazara granitic complex, the other is strongly towards the quartz monzonite field. The field of plotted positions of the Battal-Batgram rocks covers portions of all the three complexes but ultimately adopts a trend towards the quartz monzonite field. Therefore, it is justified to conclude that, in the case of the Himalayan granites, quartz suffers progressive decrease on the expense of feldspar minerals. There is enough petrographic and textural evidence to show that such a relationship is of the replacement type through a process of chemical digestion. However, a particular type of replacement will depend upon the original nature of the metasediments as far as those are removed from granitic composition. However, the concept of internal metamorphic recrystallization of sediments under plutonic conditions (Gansser, 1964) cannot be accepted in view of wide range of lithologies involved. Otherwise too, a considerable chemical data will be required to check this hypothesis which was outside the scope of present research.

ACKNOWLEDGEMENTS

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INTERPRETATION OF BOUGUER ANOMALIES OVER GILGIT VALLEY, NORTHERN AREAS, PAKISTAN

BY

MUBARIK ALI AND SHABBIR AHMED

Department of Earth Science, Quaid i-Azam University, Islamabad, Pakistan.

Abstract : *The Bouguer anomalies and up to third degree trend surface gravity analyses of the Gilgit Valley, reveal that under the alluvial cover, the metasediments of Permo-Carboniferous age extend towards East and steeply dip under the thick basic igneous complex in the southeast. These basic rocks in the northeastern segment are overlain by intrusions af granodioritic rocks of Cretaceous to Eocene age which continue up to the eastern boundary. The Permo-Carboniferous rocks in the West, contain a dyke intrusion of a granitic complex of Oligocene to Miocene age.*

INTRODUCTION

Northern areas of Pakistan include four parallel arcuating mountain ranges with northwards convexity and siwinging strike. The great Himalayas lie in the South, and towards North of it is the Kailas range, the Karakoram range and Hinduraj range (Fig. 1). The relief of the mountains varies from 5200 m to 6100 m above sea level and the highest peaks are formed of grandiorite whereas the intervening regions are composed of metasediments, The U-shaped glaciated valleys with step-like gradient contain accumulations and distributions of the lake deposits, morains stream gravel and alluvial of Quaternary age.

The Gilgit valley, which has been investigated by gravity method, lies between lat. 35° 4′ to 35° 86′ A, and long. 74° 16′ to 74° 21′ E extending from Kargah gorge in the West to the confluence of Gilgit and Hunza rivers in the East, and covers an area of about 20 Km². The valley is surrounded by highly elevated mountains of igneous and metasedimentary nature (Fig. 2).

No account of any previous geophysical work of this particular velley has been published; the purpose of the present study was to obtain information about lithological variations under the alluvial cover.

The lowest lithological unit of the area, named Darkot group (Ivanac and others 1956), is of Permo Carboniferouse age and includes slate, quartizite, limestone and gneiss. This group has been intruded and overlain by the Greenstone complex composed of epidiorite, dolerite, basalt, andesite and hornblende gneiss. The whole sequence has been intruded by granodiorite of Cretaceous to Eocene age (Bakr, 1965) According to Desio (1974), sedimentary and volcanic rock make up only 2% of the Gilgit region The Gilgit valley itself is mainly composed of hornblende granite, hornblende gneiss, hornblendite and the basic intrusives of Permo-Carboniferous age.

GRAVITY PARAMETERS AND OPERATION

In the initial phase of gravity survey the gravity parameters, like station interval of gravity observations and contour interval of Bouguer anomalies, were evaluated to suppress the noise factor which is always responsible for misleading interpretation The noise commonly is the resultant of determination error (P) and the interpolation error (P′). The error P depends upon the errors involved in the determination of elevation and coordinates of the observed points, surface density and the topographic effects; whereas the error P' is based on standard deviation in obtaining an interpolated anomaly value for any point of the Bouguer map.

The evaluated factors P and P' are 0.21 mgal and 0.16 mgal respectively from which the suitable contour internal to optimise the interpretational reliability was obtained by multiplying P with a suppressing factor 2.5.

Contour interval $= 0.21 \times 2.5 = 0.5$ mgal

Similarly for the calculation of station interval the relation $X = \left(\frac{P \times P'}{2M}\right)^2$ was utilized where M is the constant of proportionality and depends upon gravitational error factor of the area. Its average value of 0.41 for this area was calculated through special study of hundred arbitary points (Table 1).

$$\text{Station interval} = \frac{(0.21 + 0.16)^2}{2 \times 0.41} = 200 \text{ meters}$$

The actual gravity survey was operated with Master Type Worden Gravimeter Model III which has scale constant of 0.0902 mgal/scale division and linear drift rate of 0.001 to 0.002 mgal/minute. The profiles were spread along metalled and unmetalled roads and foot tracks, taking 220 gravity and elevation observations at an interval of 200 meters.

DATA PROCESSING

The processing of observed data for Bouguer anomalies and trend surface analysis up to third degree in terms of regional and residual gravity effects, was done on IBM-360 computer of the Quaid-i-Azam University, Islamabad. The Bouguer anomalies were calculated conventionally whereas the trend surface analyses involved the assumption that any observed distribution of data values comprises a regular trend and the surperimposed random effects are the residual departures, and gravity anomalies of geological interest generally project systematic departures of constant sign from the regional trend. The low degree trend surface properly defines local geological variations so that the third degree surface provides the appropriate tendency of the Bouguer, picture whereas the first and second degree surfaces give simple regional gradients of significance.

DESCRIPTION OF GRAVITY FIELDS

Bouguer Field

The Bouguer field (Fig. 3) separates strong positive gravity zone of southeastern part of the Gilgit Valley and extending up to the PIA base from the remaining negative gravity area. The positive contours which almost run E-W are directed towards northwest and gradually decrease in magnitude (from 15.0 to 1.0 mgal) at average horizontal gradient of 8 mgal/km. This zone extends towards West in the form of a belt against the negative gravity field in the North and in the South, and covers two anomalies of lower magnitudes of 1.5 and 1.0 mgal over Air base and Police office. Further, this zone in the NE (West of confluence of of rivers) is being affected by the northern negative field which changes the direction of contours towards SE and reduces the positive gravity field.

The contours of negative zone, again, extend E-W with average gradient of 10 mgal/km towards North and South on the northern and southern boundaries of positive belt and cover the western part where their magnitude increases up to −7.0 mgal in the northwestern cover.

Regional Field

The first degree trend surface (Fig. 4) clearly divides the area into positive and negative zones and the magnitude constantly increase from northwest (−7 mgal) to southeast (8 mgal) at horizontal gradient of 2.5 mgal/km. The second degree surface (Fig. 5) provides the same fluctuation of gravity but at a variable gradient which increases gradually from 1 mgal/km in northwest to 4 mgal/km. towards southeast. The third degree surface (Fig. 6) shows variation of regional gravity effects from—9 mgal in the northwest to 17 mgal in the southeast at a sharp horizontal gradient of 11 mgal/km in the northwest and SE; both gradully decrease down to 0.5 mgal/km towards central belt of the area. The contours along the northern boundary are directed to E-W but on the southern boundary are undefined, whereas in the central belt they are directed towards West hyperbolically from southeast.

TABLE 1

Data for Calculation of Constant M of Proportionality

No. of selected points on special Bouguer Profiles	Fraction of total points	Selected intervals observations (x)	$P + P'$	$M = \frac{P+P'}{2x}$
50	0.50	0.4 km	± 0.48 mgal	0.38
33	0.33	0.8 km	± 0.64 mgal	0.41
25	0.25	1.6 km	+ 0.72 mgal	0.45

Average M=0 41

Residual Field.

The residual field, that emerged in 2nd and 3rd degree analyses (Figs. 7,8), is almost similar but the picture of 3rd degree is more defined to reliable consideration because of comparable picture with Bouguer field. The positive Bouguer field of southeastern part (AA) has been intervened by the emergence of prominent negative anomaly (BB) of magnitude 3.5 mgal in the same area where the positive Bouguer contours changed their tendency due to the effect. of northern negative field. The extension of positive Bouguer field towards West (CC) is retained with the prominance of both positive anomalies. The negative field on the North and South of this extended positive belt became more pronounced and in the western part a sharp positive anomaly (DD) of 3.0 mgal evolved between Kargah and Polo Stadium.

GEOLOGICAL INTERPRETATION

The qualitative interpretation of regional gravity field in terms lithology provides information that the area is composed of denser and lighter rocks down to deeper horizons. The denser rocks which may be basic igneous ones are massively lying in the southeastern part developing positive Bouguer regional and residual (AA) gravity zone over them, whereas the negative gravity of the remaining area can be attributed to lighter rocks, most probably the Permocarboni ferous material

The disturbance in the positive Bouguer field in the east was caused by the intervention of negative field in the form of NW SE extended negative anomaly (BR), but was undefined in regional field because of strong positive masking effects smaller fluctuations in the positive contours. This anomally can be defined properly by low negative density contrast within the zone of basic igneous deposits which most propably be caused by the overlying granodioritic intrusion.

The westwards extending low positive gravity belt (CC) of Bouguer field is being defined negatively by the regional field of very small gradient directed towards West and positively by residual field (CC) of relatively smaller magnitude linked with strong positive anomalous zone. This situation can safely be explained by positive density contrast within the lighter material in the surroundings and is linked with the highdensity deposits. Lithologically it seems that the tongue of basic deposits of southeastern zone is extending towards West with attenuated thickness.

The positive residual gravity high (DD) in the negative background, not observed in the regional and Bouguer fields can be interpreted on the basis of an independent dyke intrusion of granitic complex, or hornblende granite of Permocarboniferous age.

The E-W extending negative residual field is increasing towards North and South, on the northern and southern boundaries respectively, is being confirmed by regional and Bouguer fields, and can be attributed to thick Permocarboniferous deposits associated with gneisses and gneissic granites.

CONCLUSION

Geophysically it is concluded (Fig. 9) that the Permocarboniferous metasediments are extending towards East and from PIA air base they steeply dip under the thick basic igneous deposits which massively lie in the southeastern part. A tongue of these basic deposits is continued toward West covering the area of main town, over the metasediments and is attenuated in thickness. In the northeast the basic rocks are overlain by granodioritic intrusions of Cretaceous of Eocene age in a segment, between PIA office to the confluence of Hunza and Gilgit rivers, is continued towards the eastern boundary. In the western part, the metasediments contain a dyke intrusion of complex or hornblende granite of Oligocene to Miocene age at a locality lying between Kargah and Polo Stadium. Further, the whole complex is overlain by the Quaternary alluvial of average thickness of 100 meters.

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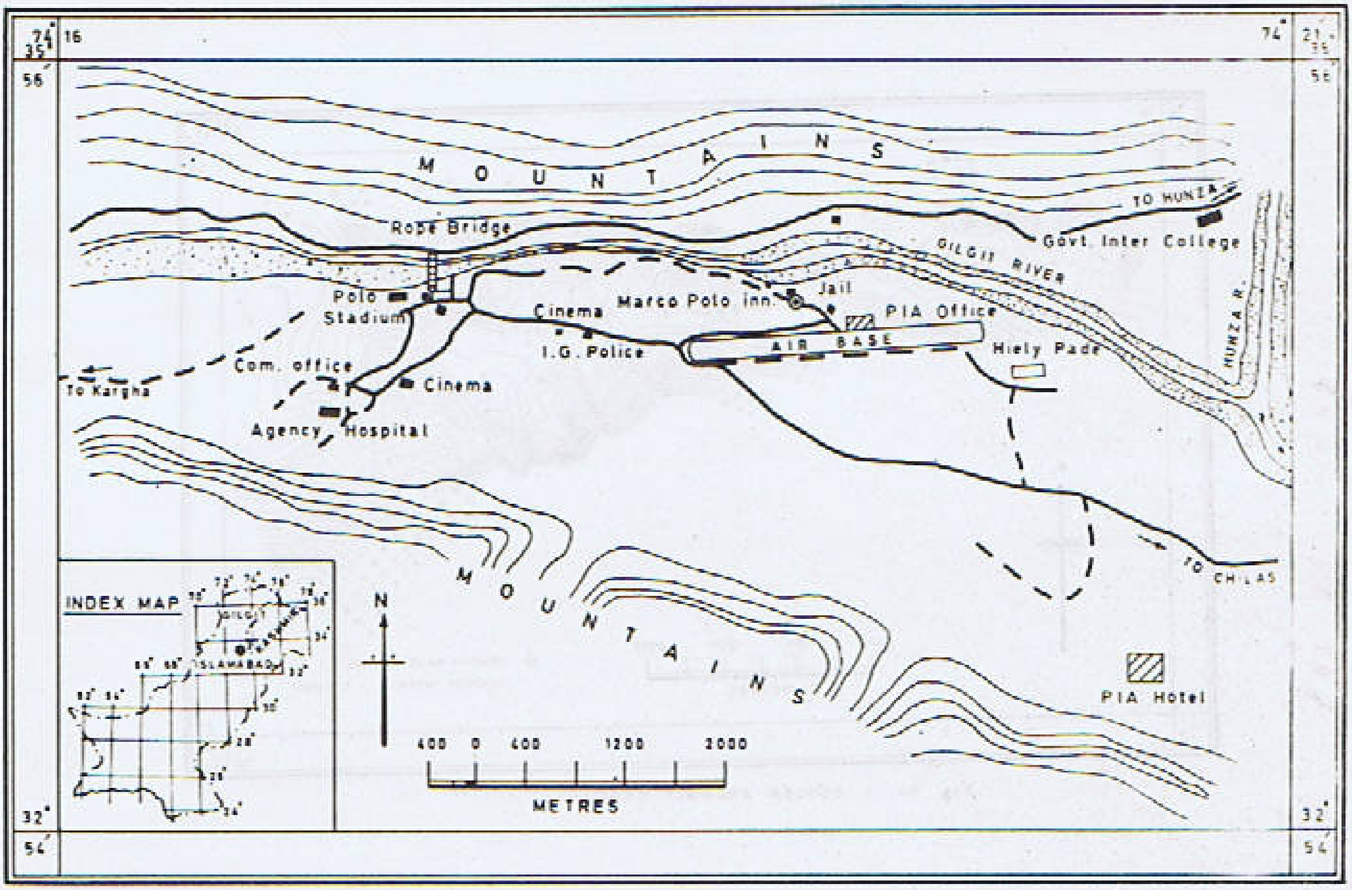

Fig No. 1 GRAVITY NETWORK

Fig No 2 TREND OF MOUNTAIN RANGES IN GILGIT

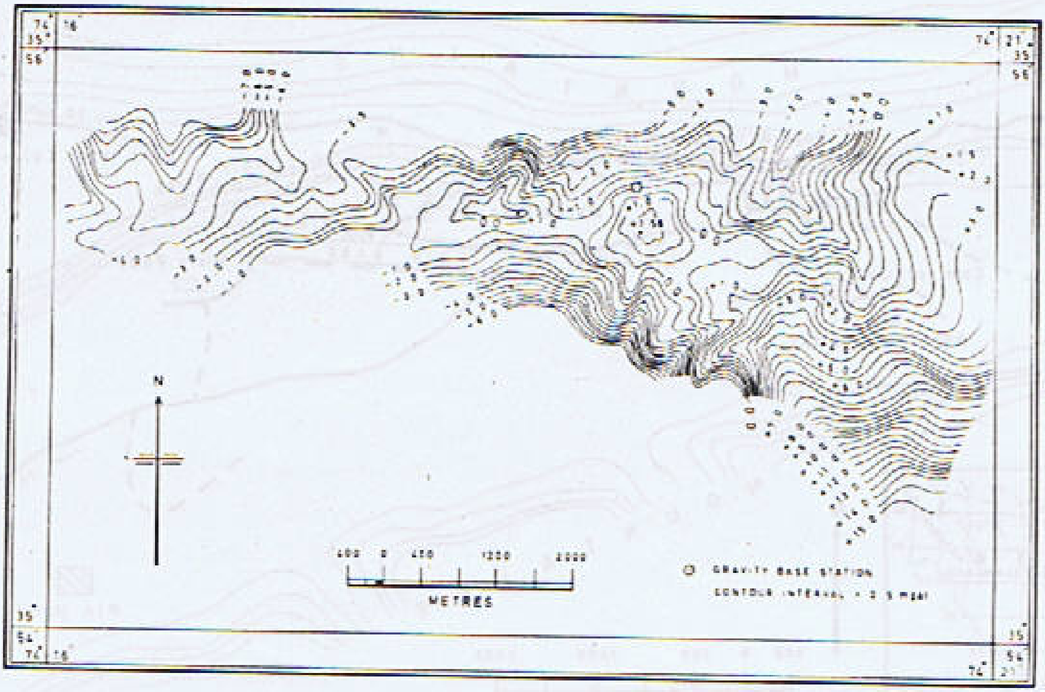

Fig No 3 BOUGER ANOMALY GRAVITY

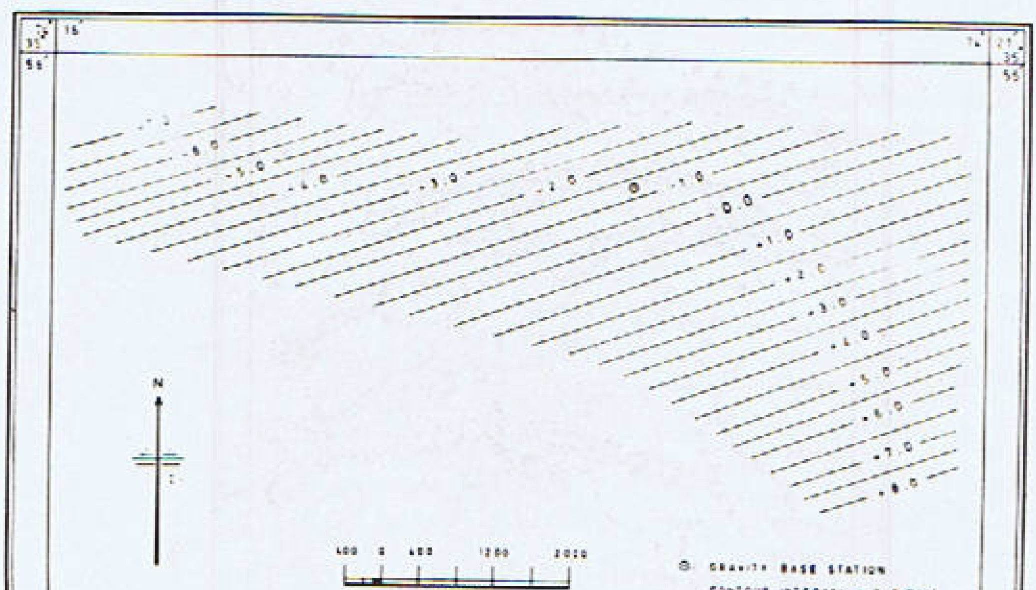

Fig No 4 REGIONAL GRAVITY MAP AT DEGREE - 1

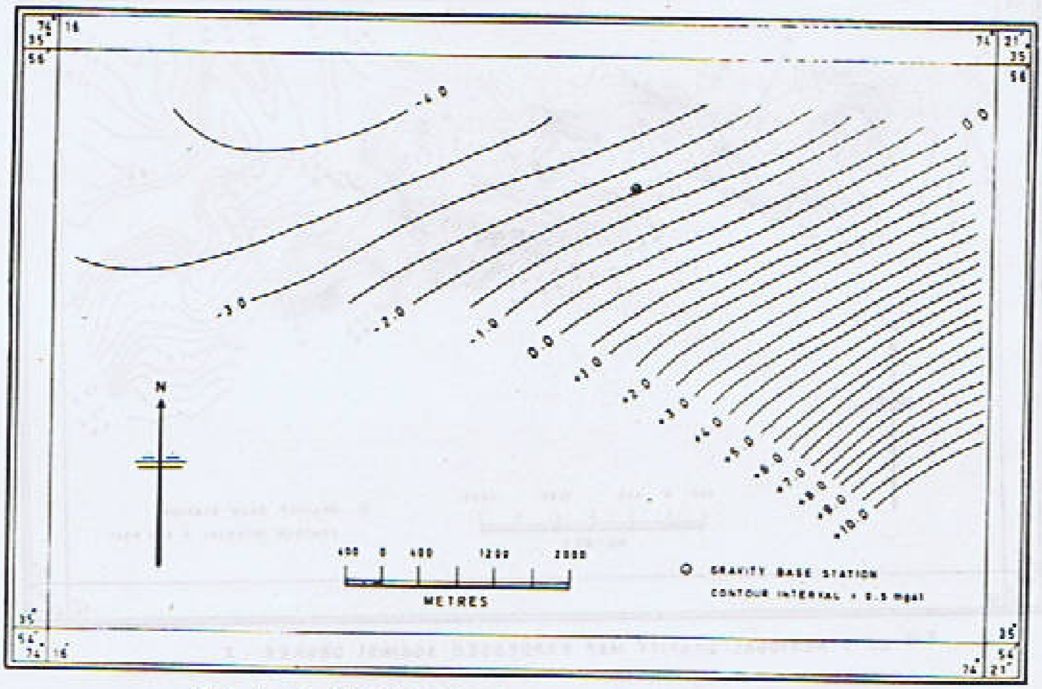

Fig No. 5 REGIONAL GRAVITY MAP AT DEGREE - 2

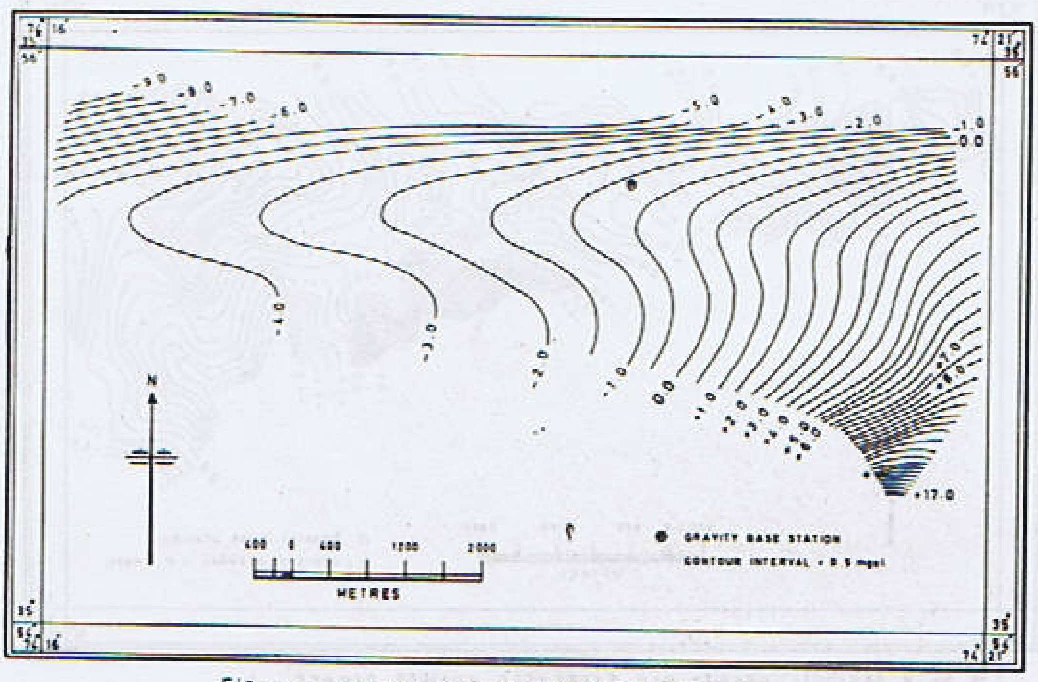

Fig No. 6 REGIONAL GRAVITY MAP AT DEGREE - 3

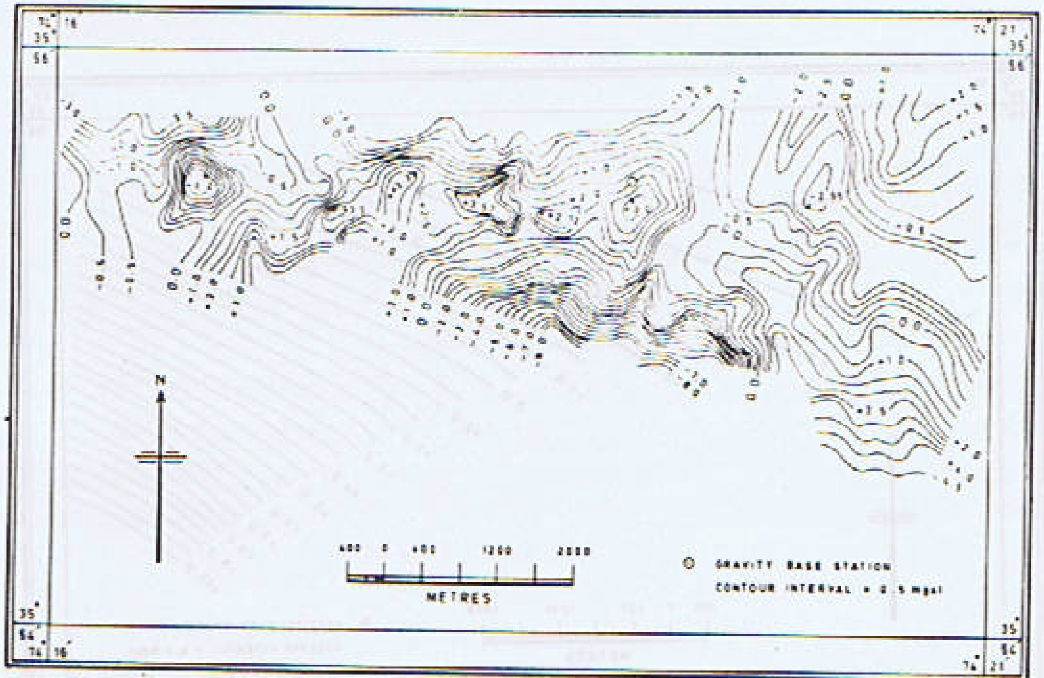

Fig No. 7 RESIDUAL GRAVITY MAP EXPRESSED AGAINST DEGREE - 2

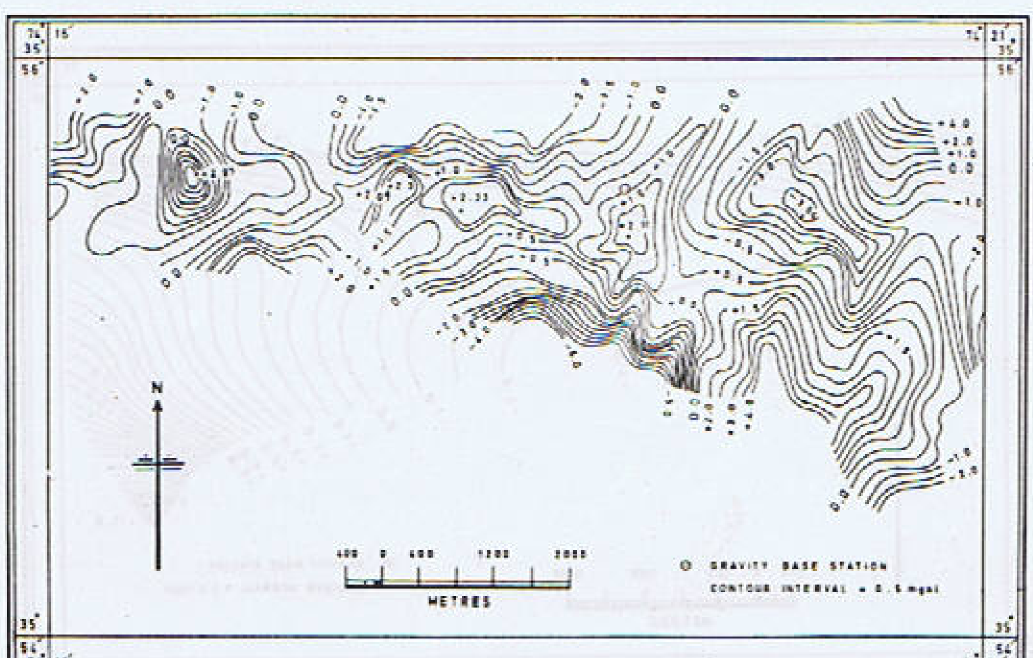

Fig No. 8 RESIDUAL GRAVITY MAP EXPRESSED AGAINST DEGREE - 3

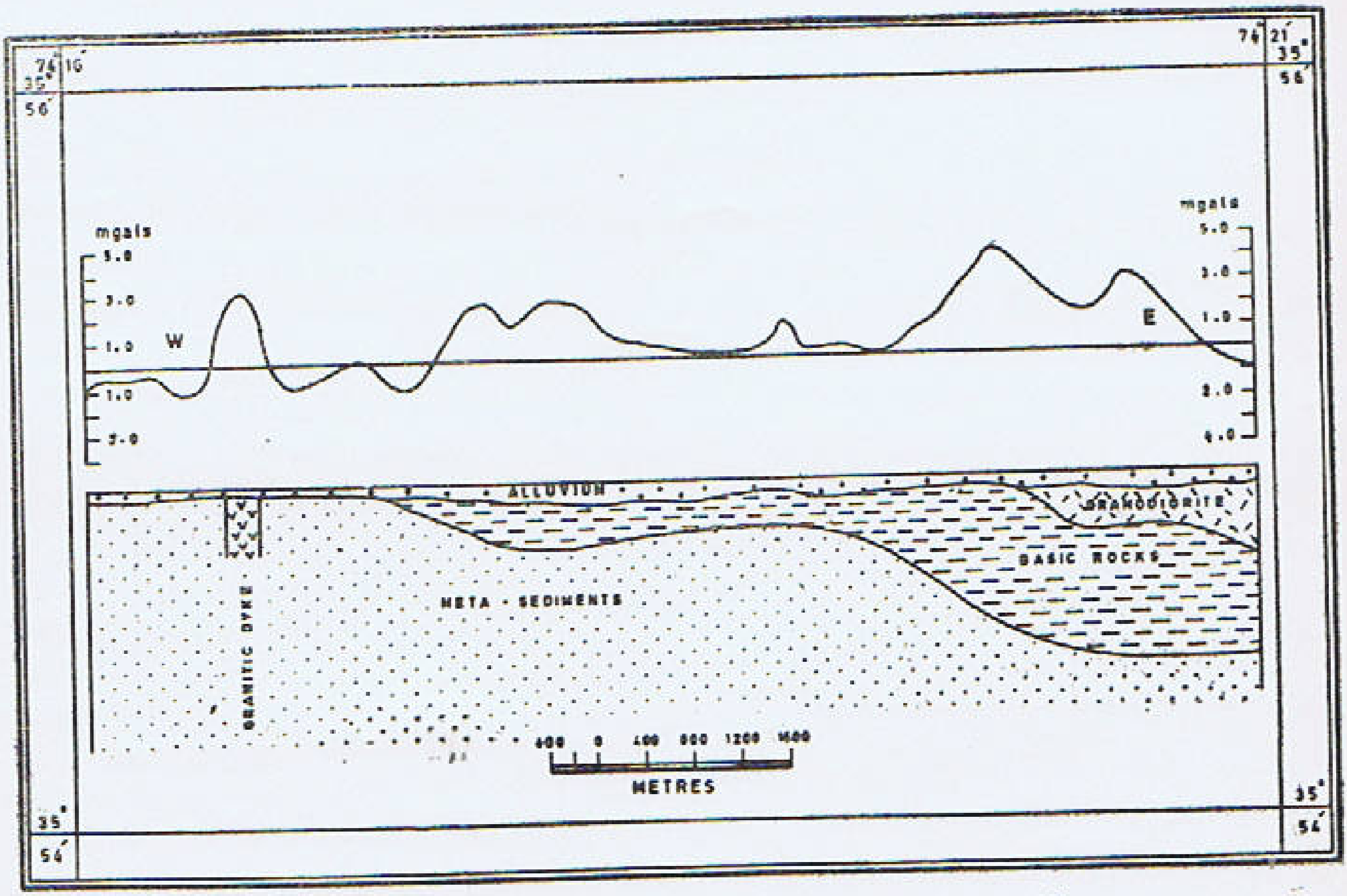

Fig. 9 INTERPRETED LITHOLOGICAL SECTION OF GILGIT VALLEY.

STUDY OF LANDSLIDE PROBLEM ALONG THE MURREE-KOHALA ROAD DISTRICT RAWALPINDI, PUNJAB. PART I : GENERAL STUDY

BY

ZAHID KARIM KHAN

Department of Geology, Punjab University, Lahore, Pakistan.

Abstract : *About 10 miles long stretch of road, from lower Topa to Phagwari village has been surveyed to study the major landslides in detail, namely the so called Kasseri. Norgali, Seher Bagla and Aliot slides, The landslides have been mapped on contour map of scale 1 . 2400 and 1 : 4800 on basis of surface geology, characteristics of the slope, types of movement and the material involved. Majority of the failures mainly occur due to lack of proper drainage facilities all along the road Engineering properties like Atterberg's limits, specific gravity. density, cohesive strength, angle of friction and grain size analysis of the soil present on unstable slopes are tested to know behaviour of the soil under different conditions. Suggestions for improving present condition of the road and to minimise possibility of its failure are proposed.*

INTRODUCTION

The road is one of the important road of the country and provides facilities of communication between Pakistan and Azad Kashmir, crossing the Jehlum river at Kohala. As far as slopes are concerned, they are very unstable all along the Murree-Kohala road, specially between Kasseri and Phagwari village (Fig. 1). Four major slides, namely Kasseri, Norgali, Seher Bagla and Aliot, were selected for present study, particularly as those are notorious to affect road throughout the year especially in rainy season. Generally, condition of the road is satisfactory and a good driver can run a light vehicle at a speed of 30-35 miles/hour, except for the landslides area, The present practice to overcome this problem is by installing structures of concrete. However, lack of systematic engineering surveys, each structures fail durin next rainy season.

The Murree formation is composed preponents such as shale, and mudstone. Survey of the area mostly covered reworked material, consisting of rock fragments with clayey and silty soil in different proportions derived from the Murree formation ; thickness of reworked material ranges between 5 to 40 feet at the central part of the unstable slopes. Surveyed area of each slide, namely, Kasseri, Norgali, Seher Bagla and Aliot are about 0.129, 0.068, 0 271 and 0 378 square miles respectively. Each slide is divided into different zones depending upon characteristics of slope, nature of movement and the material involved. Generally, strike of the rocks is N 25°E and dip is towards the W.N.W.

LOCATIONS

Location of each landslide on the Murree-Kohala road and nearby villages is given below which is followed by grid reference of its centra

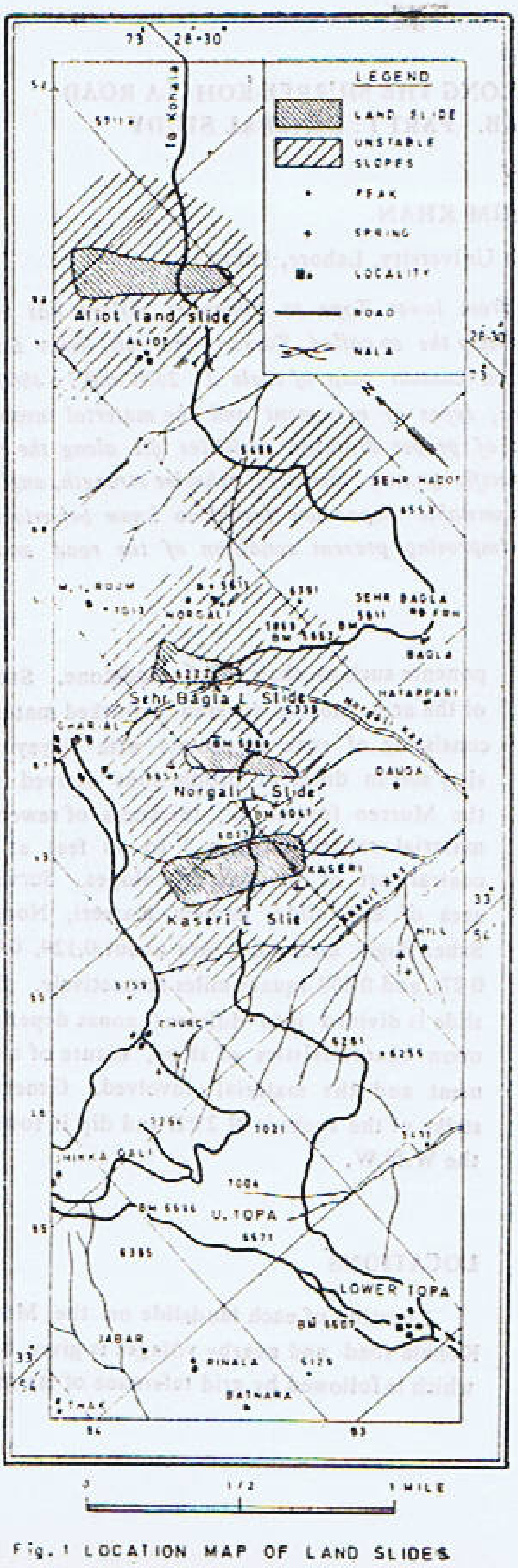

Fig. 1 LOCATION MAP OF LAND SLIDES

Name of slide	Milesone	Grid referenc>
1. Kasseri landslide	43	498858
2. Norgali landslide	43.5	503863
3. Seher Bala landslade	44	504863
4. Aliot landslide	46.5	517883

DESCRIPTION OF THE LANDSLIDES

1. Kasseri landslide : This landslide is composed of massive and hard sandstone with thin fragments of shale. The rock mass on headscarp as well as on the southern boundary of the landslide dips towards the slope. There is a compact soil cover on eastern and western side of the main creeping zone composed of rock fragments mixed with clayey and silty material good vegetation (Fig. 2). Such zones can be recognized easily due to their uniform slope, vegeation cover and absence of surface cracks on slopes such as are present also in the adjacent slumps in the slide. Bent tree trunks and open fissures of maximum 10 feet length, 3 feet width and 2 to 5 feet depth suggest unstability of the slump zone Creeping is noticeable throughout length of the landslide when compared with the adjacent soil. The landslide is more or less complex, two or three types of failures are involved but only main type is discussed and for others only referred to. Shallow and seasonal soil creep is noted in the central part of the landslide which effects surface zone of the soil down to about 5 feet and is especially active with seasonal variation in climate ; on more clayey slopes, however greater part of the creep results from volume changes caused by wetting and drying.

Continuous and permanent deep-seated deformation of the slope is in process and probably results from viscous movements, having a much lower order of magnitude than the soil and talus creep, at foot of the headscarp Road passing over the dumped material slides down within a couple of years; the older road str ps made in 1956, 1961, 1968 and 1976 are present at IV, III, II, and I locations, successively dropping in elevations, In all about 120 feet horizontal and 40 feet vertical creeping of the material had occured over the last 20 years (Fig 3). So that a continuous creep in mass is shown. Other than creeping. landslide has rock falling at the headscarp and sometime mudflows occur during heavy rainfall at the foot of the side.

2. **Norgali landslide.** Top surface of this landslide is not well marked due to eastern boundary of the slide being a headscarp of hard and massive material and western boundary of semiconsolidated mixture of rock fragment with clayey and silty soil (Fig 4). Eastern and western boundaries of the slide are stable due to presence of rock outcrops of sandstone, mudstone and shale. Dip directions of beds, such as 80' SE and 30° NW on western and eastern flanks of the slide respectively, are completely different in a very limited area and no links are found among beds at the site; this shows that there may be a fault running near western side of the landslide. To some extent, presence of rock outcrops at the central part of the slide, provides stability to its unstable zone. It is a clear cut translational failure i.e. the rock mass moves as one or break up to produce a multiple failure. The slip surface along bedding and joint planes are generally occupied by argillaceous fillings. Mostly scree is present as dumped material on southestern side of the foot of landslide. At some places, mud-flows and shallow soil-creep are observed but rock sliding is mainly involved.

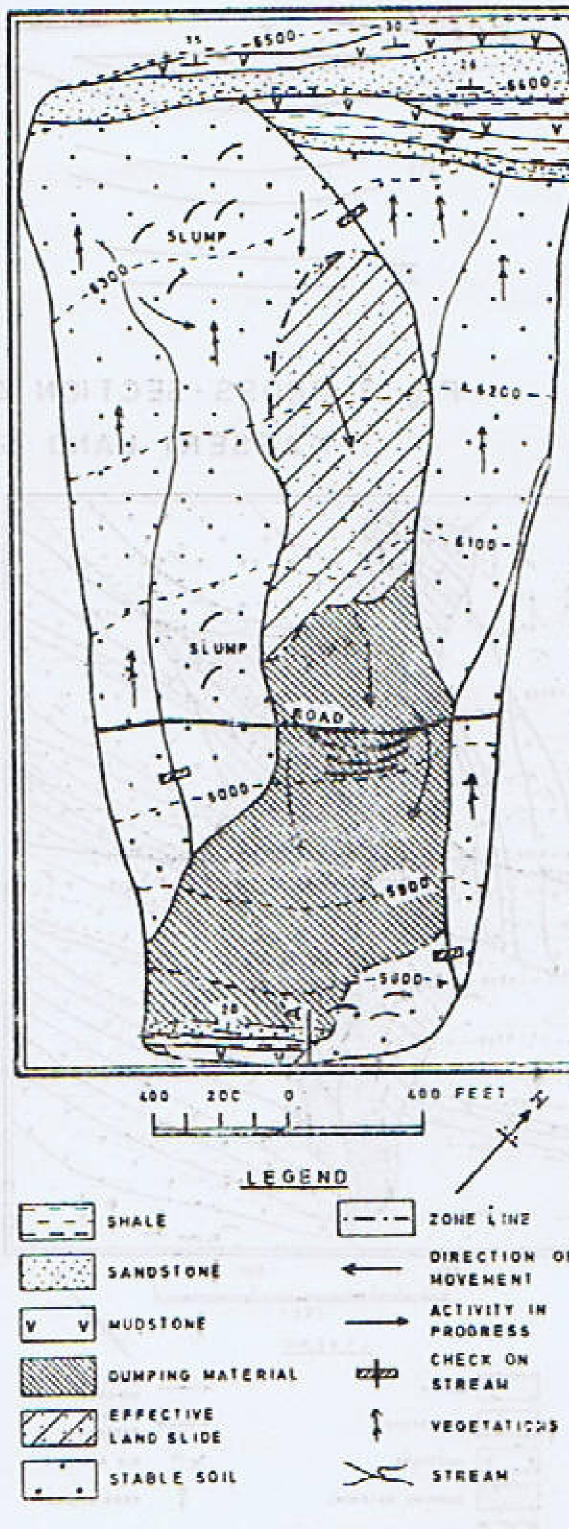

Fig. 2 KASSERI LAND SLIDE

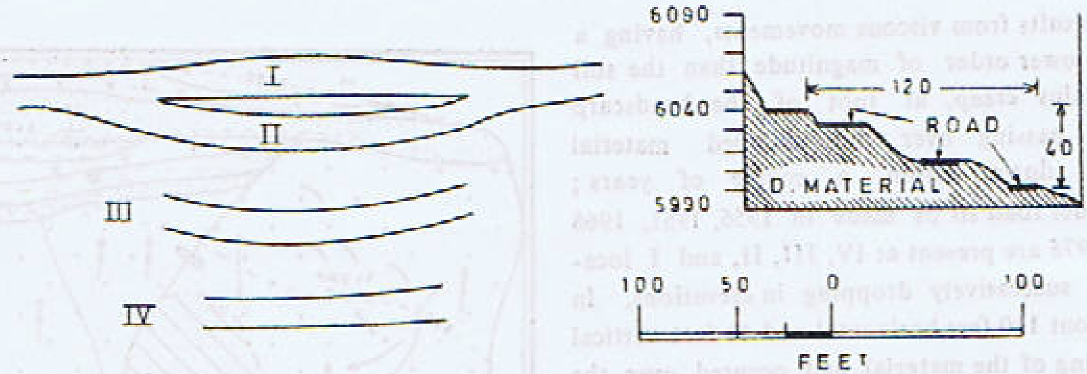

Fig. 3 CROSS-SECTION OF ROAD DISPLACEMENT IN KASSERI LAND SLIDE

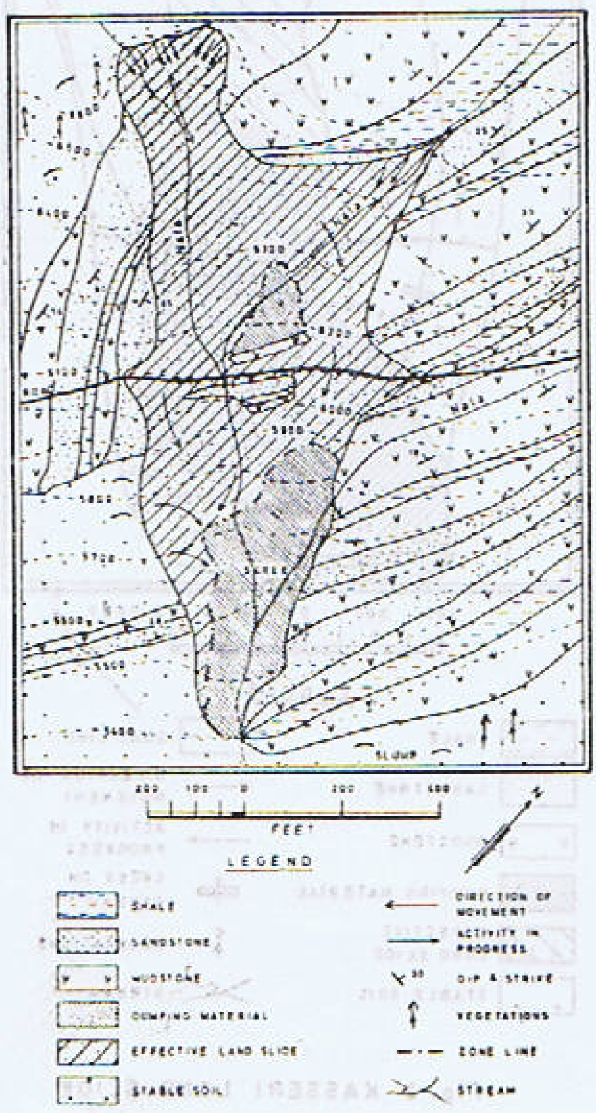

Fig 4 NORGALI LAND SLIDE

3. Seher Bagla landslide. Stable and compact soil cover, composed of rock fragments mixed with clayey and silty material derived from the Murree Formation, is present over top of the slide slope with trees and cultivated lands. There is also a big pond of water about 70 feet diameter on western side of top of the slide (Fig. 5). Eastern and western flanks of the slide are marked by hard and soft rocks such as sandstone, mudstone and shale of the Murree formation. Beds of shales are under process of erosion ultimately resulting into collapse of upper bed of sandstone or mudstone due to its undermining. Slumps have been recognized on upper portion of the slide. Main portion of the slide is characterized by uneven surface of slope with destroyed forest and big rolling rock fragments. Rock fragments mixed with soil and scree is present as dumped material on the eastern side of the slide above the road. This dumped material is characterized by tendency of the material to behave as more or less non-cohesive mass, suffering considerable distortion. Some cohesive material is also present but its proportion is fairly low particularly where debris movement occurs in this slide.

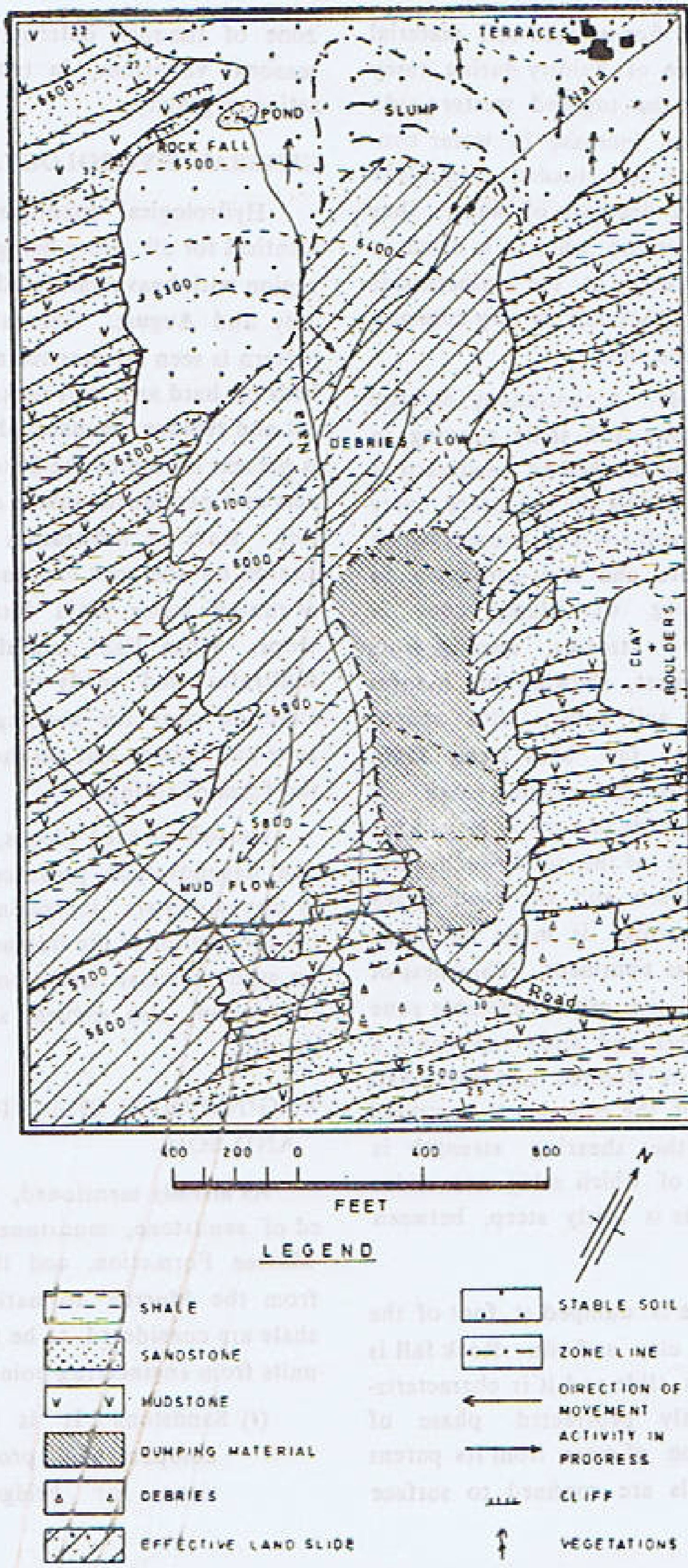

Fig. 5 SEHER BAGLA LAND SLIDE

Flowing mass of fine-grained soil material possesses high degree of fluidity during rainy season particularly at the top and western side of the slide. With an increase in water content, mudflows grade into loaded and clear stream while with a decrease of water, they grade into earth flows and when it is dried, it shows mud cracks specially at the southern side of foot of the slide. Rock fall is very common along cliffy faces of the slide.

4. Aliot landslide A continuous outcrop of sandstone, mudstone and shale running in northeast direction is marked as headscarp at 6300 feet elevation. Below the headscarp, very stable and compact soil cover is present which is used for agriculture and fruit-gardening by local population (Fig. 6). Slump zone is located between two streams, coming from northeast and northwest, showing big fissures and cracks in the soil cover, with sparce vegetation and a few bent trees. Main unstable zone is below the existing road A very big concrete structure in various steps have been built downslope of the road which fails during the rainy season and the road slides down, a temporary bridge is made by using beds of sandstone as abutment. Thickness of the broken material and soil in unstable zone ranges from 3 to 7 feet and slide represents a shear failure Where fissured and weak shale and mudstone get wet the cohesion is decreased considerably and the shearing strength is reduced as a result of which a big mass slides down. Slope of slide is fairly steep, between 25° to 35°.

Debris and scree is dumped at foot of the slide without having clay and silt. Rock fall is very common in this slide and it is characterized by a frequently protracted phase of progressive separation of mass from its parent cliff. The rock falls are confined to surface zone of the rock outcrop which is effected by seasonal variations in temperature and or the action of gravity.

GENERAL HYDROLOGY.

Hydrological conditions are more or less identical for all slides being located in a humid region with heavy rainfall during the months of July and August. Generally, Trellis drainage pattern is seen all over the area due to alternate beds of hard and soft rocks. Streams actively cut and remove the material. A big water pond is present on top of the Seher Bagla slide which acts as a permanent source of water for infiltration. Rate of infiltration is much less than run off on the rock exposures. The high speed of run-off water plays destructive role on the slope. When light rainfall occurs, more water infiltrates and tends to move towards dip direction over the bedding planes and weak zone and comes out on the ground surface in the form of springs.

On soil-covered slopes, the rate of infiltration depends upon presence of rock fragments in clayey matrix, increasing with increase in the proportion of the fragments. Heavy rainfall on such material helps in forming mudflows. Infiltration, also reduces shearing strength of the soil.

ENGINEERING BEHAVIOUR OF ROCK AND SOIL.

As already mentioned, the area is composed of sandstone, mudstone and shales of the Murree Formation, and the material derived from the Murree formation. Sandstone and shale are considered to be the most important units from engineering point of view.

(i) Sandstone : It is hard, massive and compact and provides good foundations for bridge and retaining

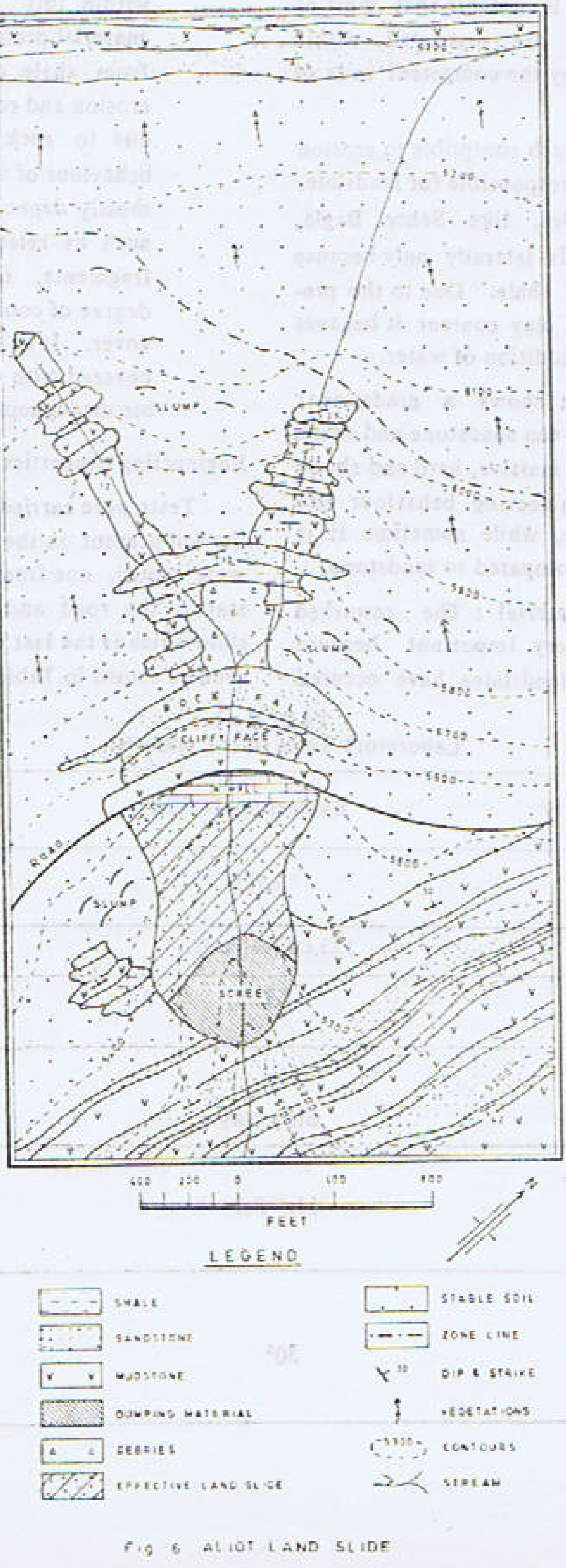

Fig 6 ALIOT LAND SLIDE

structures. It is notable that most of the landslides are restricted within certain limits by the competent beds of sandstone.

(*ii*) Shale : It is much suceptible to erosion and is mainly responsible for landslide. At some slides, like Seher Bagla, erosion extends laterally only because of presence of shale. Due to the presence of large clay content it behaves plastically on addition of water.

(*iii*) Mudstone : It shows a gradational behaviour between sandstone and shale. At places, it is massive, hard and shows competent engineering behaviour like that sandstone, while sometime it is very weak as compared to sandstone.

(*iv*) Overburden material : The reworked material is very important because most of the landslides have occured within this material Clay and silt material present on slopes was derived from shale due to weathering and erosion and rock fragments are present due to rock falls. The engineering behaviour of the intermixed soil cover mostly depends upon, its composition such as relative proportion of rock fragments, thickness of soil cover. degree of consolidation and vegetation cover. It is observed that the slopes covered with such type of soil is unstable throughout the area.

Engineering properties of soil.

Tests were carried out to find properties of the soil present on the slope. Two soil samples were tested, one from Kasseri landslide at the start of the road and second from Aliot landslide which is the last major landslide along the road as shown in Table-I.

TABLE—I
Laboratory Tests of the material.

	Engineering Property	Kasseri lands lide	Aliot landslide
	Specific Gravity	2.725	2.691
	Optimum Density	123.60 lbs/cu ft.	130 20 lbs /cu.ft.
	Optimum moisture content	11.75%	13.4%
	Grain size Analysis (Textural class)	Silty clay	Gravelly silty loam
Direct shear test	Cohesion or inherited—strength (C)	11.5 Psi	7.2 Psi
Direct shear test	Angle of internal friction. (ϕ)	30°	34°

REMEDIES

It is not possible to control landslides immediately on the basis of surface investigation A detailed exploratory investigation should be carried out to find correct subsurface conditions of the slides and it is only then that permanent remedies can be found. Some corrective measures are however suggested to minimise rate of movement of sliding masses —

(*i*) Small water tributaries rising in the landslides should be chanalized properly to the main stream.

(*ii*) Pond of water of Seher Bagla should be filled by material available at that elevation and the water should be chanalized to the main stream.

(*iii*) Forest plan should be established and plants in large numbers should be planted on the unstable slopes.

(*iv*) Small checks of very low heights, not much above the ground surface, should be made across the big nalas to minimize destructive activities of the moving water.

(*v*) Various steps such as terraces should be made on the slopes to divide it into various segments.

(*vi*) Retaining structures should be mada by placing its foundations on hard rock like sandstone.

(*vii*) Guniting should be done on the exposed surface of the shale where necessary to minimise its undermining.

(*viii*) Permanent bridge plain should be made at some placing other than metalled road, by placing the bridge foundations on hard rocks.

ACKNOWLEDGMENTS

The author is obliged to Prof. F. A. Shams, Geology Department, Punjab University, for critically revising the manuscript. The field study was done jointly by the author and four M.Sc. students of engineering geology during the months of June & July. 1978.

ON THE STEGODONT ANCESTRY OF THE ELEPHANT

BY

MUHAMMAD SARWAR

Department of Zoology, University of the Punjab, Lahore.

Abstract : *Stegodont ancestry of the family Elephantidae has been suggested, Genus Antelephas descended from Stegodon and in turn gave rise to the genus Elephas. Elephas planifrons has been regarded as ancestor of the later elephants and the mammoths.*

INTRODUCTION

Stegodont origin of the family Elephantidae has been suggested by many early workers. However, this suggestion was not supported by any good analysis. In the recent years, some workers have tried to trace the ancestry of the family from *Tetralophodon.* In this supposition they have mainly emphasized the mandibular structure, the mandibular tusks and the molars They have not taken into account the general cranial profile of the early and later forms. The cranial as well as dental analysis made by the present author has suggested a stegodont ancestry of the family Elephantidae *Antelephas* Sarwar has been regarded a transitional stage between *Stegodon* and *Elephas* Linnaeus. *Mammuthus* Burnett has been derived from the early elephants.

DISCUSSION

Elephants have been generally regarded as descendants of stegodonts by many workers such as Lull (1908), Osborn (1918), Simpson (1945). and Romer (1945) Uptil now, there have been no adequate evidence in support of this view. However, the report of *Antelephas* from Tatrot zone of the Upper Siwalik by Sarwar (in press, a) have provided sufficient morphological evidence to support the stegodont ancestry of the elephants. Ridge-plates (fig. 1) of the dental material from Tatrot zone are as high as wide and are semicircular in outline in fore and aft view. The ridge-plates are widely spaced with almost V-shaped intermediate valleys. The enamel layer is very thick. These specimens and that described by Hooijer (1955) are thus representing a transitional stage between *Stegodon* and *Elephas.* However, their general contour suggests that they are certainly on the elephantine lineage. Considering all these features, the material may be regarded as much primitive than *E. ekorensis* of Africa. According to Maglio and Ricca (1978), the ridge-plates in *E ekorensis* form U-shaped intermediate valleys between them. Enamel thickness in *E. ekorensis* is nearly 2.3 to 3.5 mm whereas it is nearly 4 to 5 mm in *Antelephas.* Ridge-plates are comparatively high in *E. ekorensis* than in *Antelephas.* These findings from the Tatrot zone clearly indicate that the view held by Maglio (1970a, 1970b, 1973) that *Primelephas* and *Stego etrabelodon* are on the ancestral line of Elephas is improbable.

Maglio's supposition regarding elephant ancestry can be refuted in the light of comparative cranial studies. The cranium at postorbital bar is comparatively the broadest in *Elephas* *ekorensis* than that of the *Tetralophodon* or *Elephas maximus*. Similarly the cranium at the frontal constriction is comparatively much broader in *Elephas ekorensis* than in the *Tatralophodon* or *Elephas maximus*. Almost the same holds true for the *Loxodonta africana* in this derivation. In contrast to this, it is seen that cranial width at the postorbital bar is almost equal in primitive stegodons (*Stegodon bombifrons*), primitive elephants *Elephas planifrons*) and *Mammuthus* but is comparatively larger than that of *Elephas maximus* or *Loxodonta*. The cranial width at the frontal constriction is smaller in early stegodonts than in *Elephas planifrons* and E. *maximus*. Looking at the occiput, there appears a gradual transition from a primitive *Stegodon* through primitive elephant to the living elephant on the one hand and from a primitive *Stegodon* through a primitive elephant to the living mammoth on the other hand. A similar transition can also be noticed from a primitive *Stegodon* to *Loxodonta*. Frontal profile of *Elephas*, *Loxodonta* and *Mammuthus* can also be derived from that of the *Stegodon*. In view of the above given cranial and dental comparisons, the present author believes that the genera *Stegotetrabelodon* and *Primelephas* were the specialized forms and have had no bearing on the ancestry of the genera *Elephas*, *Mammuthus* and *Loxodonta*. The latter genera, except the last one, probably descended from *Stegodon* through *Antelephas*. Since, the South Asia have yielded both the early as well as the later stegodons in abundance than any other part of the earth, it might have served as the centre of origin and dispersal for the early elephantids. Such a view had also been expressed by Arambourg (1942). From Asia, they migrated to eastward, northward as well as westward. Unfortumately, Tatrot zone is a least fossiliferous part of the Siwaliks and has not yielded adequate vertebrate material. This gap has just partly been filled by the *Antelephas*.

Stegodont molar plates have certain characteristic features by which these are distinguished from those of the elephants. Stegodont ridge-plates are strongly like the inverted V in fore and aft view. Intermediate valleys are thus perfectly V-shaped. The enamel layer covering the plate is very thick. Cement does not completely cover the intermediate valleys. In a transition from *Stegodon* to *Antelephas*, the upper half of the ridge-plates turned thin whereas the lower half retained its original shape. Cement completely covered the intermediate valleys but not the apices of the plates as well as their lateral sides. Enamel thickness was slightly decreased. All these changes were linked with the slight increase in the crown height. *Antelephas* exhibits such a transitional stage. With the further increase in the crown height, the lower half of right-plates also became thin, giving U-shape to the intermediate valleys. This type of molar plate is found in the later elephants.

Elephas planifrons is the most primitive of all elephants both in dental as well as in cranial morphology. Chronologically, it is the oldest elephant species and is exclusively found in South Asia. Cranial profile is very simple as compared to the later elephants and mammoths. The projection angle of the premaxillaries in *Elephas planifrons* almost shows a transition between the early stegodonts and later elephants and mammoths. Face of the skull at postorbital bar is as broad as that of the primitive stegodonts and mammoths. Occiput of the South Asiatic elephants and mammoths can be derived from that of *Elephas planifrons* and in turn it can easily be derived from that of the early stegodonts.

Apart from cranial features, *Elephas plani-*

frons also shows a transition in dental morphology. In early stegodonts, the ridge-plates are very widely spaced, low and thick enamelled with small amount of cement. The ridge-plates in *Antelephas* are intermediate between *Stegodon* and *Elephas*. The ridge-plates in *E. planifrons* are less widely spaced than those of *Antelephas* but are widely spaced as compared to those of the later elephants and mammoths. As regards the vertical height, enamel thickness and the enamel corrugacy, the ridge-plates of *Elephas planifrons* also show a transition between the two.

From *Elephas planifrons*, three evolutionary lines can be traced. Of these, the first leads to *E. corrugatus*, the second to *E. hysudricus* and *E. namadicus* and the third to *E. maximus*. The evolutionary trend in the first line as noticed by Sarwar (in press a) was the production of finely plicated enamel border with double median expansion of the ridge-plates (Fig 2). There was no increase in the number of ridge plates. The trend in the second line of evolution was towards the development of enamel corrugation and an increase in the number of ridge-plates. The enamel corrugacy was incompletely achieved in *E. hysudricus* while it was fairly developed in *E. namadicus*. Besides these, a tendency towards the development of a weak post-sinus was there in the molars of *E. namadicus* but not in those of the *E hysudricus*. Frontal profile became concave in *E. hysudricus* but ridge-like in *E. namadicus*. The evolution of *E. hysudricus* from *E. planifrons* has also been suggested by Aguirre (1969 a). Among the descendants of *E. planifrons*, *E hysudricus* is found in great abundance. The probable reason is that its molar teeth were morphologically more efficient grinders than those of the others. They were relatively high, with many compressed ridge plates. Inspite of having good grinding teeth. *E. hysudricus* was still unable to compete with members of *E. hysudrindicus*. Therefore, the species became extinct with the passage of time.

In the third line of evolution, a tendency towards the increase in the crown height of the molar and number of ridge-plates has been noticed. Molar crown became transversely wide in this line of evolution. Corrugacy gradually increased from primitive to the progressive forms reaching the maximum in *Elephas maximus*. The evolution of Asiatic elephant from *E. planifrons* has also been traced by Azzaroli (1966).

The dental characters of *Elephas hysudrindicus* noticed by Dubois (1908) and Osborn (1942) are very similar to those of *E maximus*. Infact, the molar teeth in *E. hysudrindicus* and *E. maximus* are so similar that the former species can be regarded as the early member of the latter, rather than an independant species. *E hysudrindicus*, as an immediate ancestor of *E maximus* has also been proposed by Aguirre (1969 b). In *E. maximus*, the length of the enamel layer per 100 square centimeter area of the molar surface is very large; rather the largest of all the known Siwalik elephantines. By having such a large grinding surface area, *E. maximus* has managed to survive to the present time.

Elephas irshadi (Fig. 3 A & B) was probably an offshoot from the main line. In this derivation, the mandibular depth greately increased and the ridge-plates became extremely wavy.

Maglio (1973) has tried to derive the later mammuthines from the species *Mammuthus subplanifrons*. The molar plates of the type material of this species, as figured by Osborn (1934) appears to belong to the loxodont line-

Fig. 1. Crown view of the type of *Antelephas tatrotensis* (redrawn from Sarwar, in press a) X 0 9.

age. The mandible containing last molar referred to this species by Maglio and Hendey (1970) appears to be a specialized stegodont. In the Siwalik collection stored in the Department of Zoology, University of the Punjab, Pakistan, there are some crania, mandibles and isolated teeth which appear to have been on the main line of mammuthine evolution. This material has been labelled as *Mammuthus sardhokensis* by Sarwar (in press b).

Platelephas was probably an abnormal member of the *Elephas* lineage.

Loxodont line probably got separated from the immediate ancestors of *Antelephas* somewhere in the Middle Pliocene. The early members of the genus were probably adapted for rapid migration. In Asia, they could not survive because of the presence of contemporary stegodons. Having no competition in Africa, members of the genus, flourished there rapidly and thus managed to survive to the present time.

Fig. 2. Type mandibular ramus of *Elephas corrugatus* (redrawn from Sarwar, in press a) X 0 30.

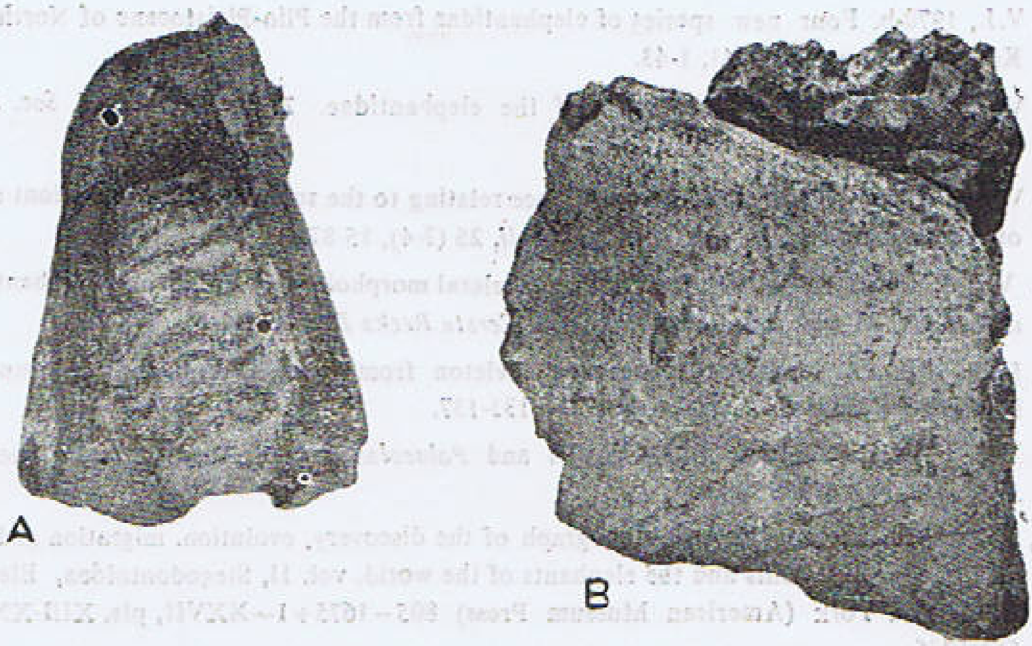

Fig. 3. Type mandibular fragment of *Elephas irshadi* A. dorsal view B. lateral view. (redrawn from Sarwar, 1974). X 0.33.

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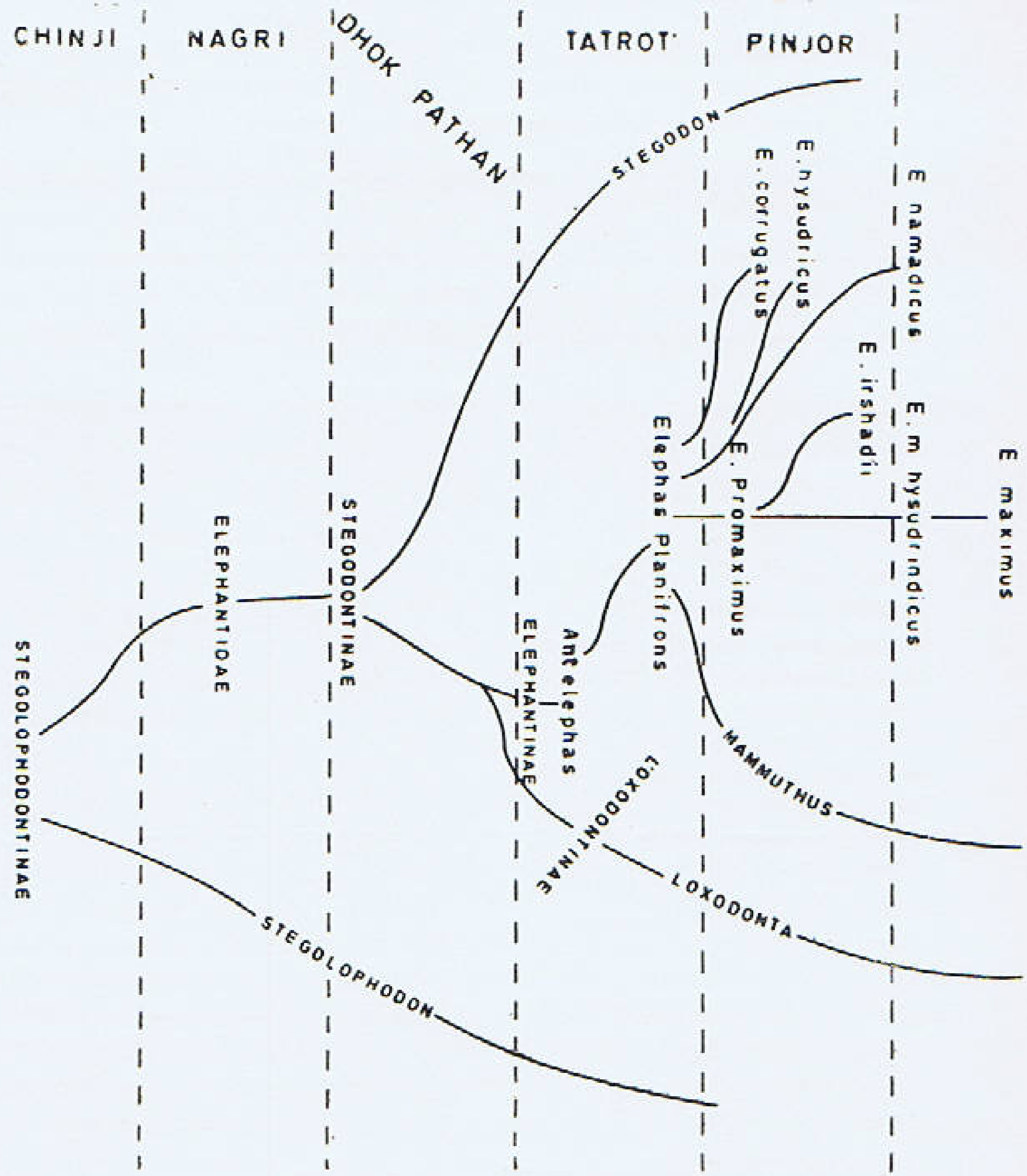

Fig 4 PROPOSED PHYLOGENY OF THE FAMILY ELEPHANTIDAE

A NOTE ON THE OBLIQUITIES OF SOME POTASH FELDSPARS FROM THE HAZARA GRANITIC COMPLEX, N.W. HIMALAYA, PAKISTAN

Abstract. *Obliquities of some potash feldspars, extracted from major members of the Hazara granitic complex, were estimated with the help of X-ray diffractometry. The results are in harmony with the conclusions drawn from extensive field and laboratory investigations as to the permeation—granitization origin of the granitic complex.*

INTRODUCTION

The Hazara granitic complex (Shams, 1961, 1967, 1969) constitutes major part of the Mansehra District and the adjoining Hazara area (Long. 72° 45', E to 73° 20' E and Lat. 34° 15'N to 34° 45' N). Being a southwards extension of the Himalayan Central Gneiss (Stolickza, 1866), it attracted attention of geologists since long (Verchere, 1866). Later, it was the focus of an illuminating controversy over origin of the granitic rocks, ranging from a metamorphic origin (Wynne, 1877, 1879) to an intrusive igneous origin (Middlemiss, 1895). No work was carried out for the next 60 years or so.

The older work, however, was based mainly on field observations only and suffered sound scientific footing. Detailed laboratory investigations and extensive revision of field studies (Shams, 1961, 1967, 1969) lead to the conclusion that the granitic rocks had originated by grantization of the pre-existing metasedimentary formations through the agency of permeating fluids of ultimate igneous origin. As a part of mineralogical research, feldspar minerals were subjected to detailed optical, chemical and related investigations due to their importance in the theories of petrogenesis. This note reports rasults of estimation of obliquities of some potash feldspar phases as function of plutonic history of the granitic complex.

RESULTS AND CONCLUSION

Alkali feldspar crystals were picked from crushed rocks, ground to 200 mesh size and cleaned of impurities with the help of an isodynamic magnetic separator and heavy liquids. Final purification was achieved by differential separation in a column of heavy liquid of suitable range; in this way, more than 98% purity was obtained The purified fraction was mixed with quartz as an internal standard and obliquities were estimated with reference to the separation of 131 and 131 peaks in the X-ray diffractograms (Goldsmith and Laves, 1954). The results are given in Table 1.

The results of obliquities, $\triangle$ as given in Table 1, are classified together as follows :—

1. Andalusite-bearing granites =0 0 0 15
2. Susalgali granitic gneiss =0 0-0 95
3. Mansehra granite =0.85 0 95
4. Sheared granitic porphyry =0.95

Mineralogical inter-relationship between various rock members of the Hazara granitic complex (Shams, 1967) showed following sequence : Metasediments ....Andalusite-bearing granites ....Susalgali granitic gneiss........ Mansehra granite.

Considering that the above sequence reflects recrystabzation history of the granitic rocks

TABLE No. 1.

The obliquities (△) of potash feldspars from some granitic rocks of the Hazara granitic complex, District Mansehra, N.W.F.P.

No.	Rock specimen	Location	Obliquity (△)
1.	Andalusite granite	North of Abl Rest House	0 0
2.	Andalusite granite	North of Karmang	0 0-0.15
3.	Susalgali granitic gneiss	Near Choran Utli	0.0-0.30
4.	Susalgali granitic gneiss	North of Jaba	0.0-0.95
5.	Mansehra granite	Near Chitta Batta	0.85
6.	Mansehra granite	Near Mansehra Rest House	0 90
7.	Mansehra granite	Near Dheri	0.95
8.	Mansehra granite	Near Basund	0 90
9.	Mansehra granite	East of Mansehra Rest House	0 90
10.	Mansehra granite	Northeast of Balhag Utli	0.95
11.	Granitic porphyry	Chitti Dheri	0.95

as a result of permeation-granitization and adjustments to plutonic-tectonic environments, the ranges of obliquities of the potash feldspars are satisfactory. Taken as an expression of ordering of the feldspar lattice, the sequence appears to be from orthoclase (△=0 0-0.15) in Andalusite-bearing granites to microcline of nearly maximum obliquity (△=0.85-0.95) in the Mansehra granites; the Susalgali granitic gneiss represent intermediate stage of the potash feldspar (△=0 0-0 95). The presence of potash feldspar of high obliquity (△=0.95) in case of the granitic porphyry is considered to be due to ordering as a result of shearing, which left no trace of orthoclase lattic although it might have been the feldspar phase to have grown originally.

F.A. SHAMS

Department of Geology, Punjab University, Lahore, Pakistan

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A NOTE ON ORE-MICROSCOPIC STUDY OF GALENA ORES FROM THELICHI VALLEY, GILGIT, PAKISTAN

Thelichi area south of Gilgit, longitude 75° 35′ 30″ to 74° 38′ 30″ and latitude 35′ 28′ 30″ to 35° 41′ lies on the southern border of the western Karakorum mountain range. Ahmad et al, (1977) have described in detail the igneous and metamorphic rocks, exposed in this area. The igneous rocks are composed of diorite with small still type instrusions of granodiorite and granite. The metamorphic rocks include slate, phyllite, marble, garnet mica schist and amphibolite. Three exposures of galena have been reported by Rizvi (1971) in Thelichi. Two exposures are in diorite and third in phyllite. Galena from Thelichi has been reported by Rizvi, (1971) to have the following chemical composition.

Pb = 58.1% to 66 2%

S = 10.4% to 13.0%

In view of nature of occurrence and mineral paragenesis as reported, it was considered urgent to identify ore minerals, particularly as Rizvi (1971) has given no details of mineralogy. Qualitative chemical analysis of two galena samples from exposures in diorite were made. Sample No. 1 from exposure No. 1, showed the presence of Zn and Ag in addition to Pb. The sample No. 2 from exposure No. 2 showed the presence of Cu and Zn in addition to Pb. It is interesting to note that Pb aud Zn are common in both the samples while sample No. 1, shows an addition of Ag and sample No. 2, shows additional presence of Cu.

In order to know the source of Ag in sample No. 1 and Cu in sample No. 2, polished sections were prepared of both the samples. Various ore-microscopic tests such as micro-hardness determination and etch tests described by Cameron (1951) and Uytenbogaardt (1973) were carried out.

Sample No. 1.

It was found that the sample 1, showed the mineral assemblage as galena, sphalerite and tennantite. Galena is generally well crystallized in simple cubic form and easily distinguished by its bright white colour and well developed triangular pits. Galena has been replaced along its cracks and borders (Fig. 1) by Fahlore group mineral (tennantite), rich in Ag contents giving it a greenish colour with light blue tone. This tennantite may be the source of Ag contents in this ore sample. Sphalerite is of light yellowish brown resinous variety and appears to be younger than galena and tennantite.

Sample No, 2.

Ore microscopic study of sample No. 2, showed the mineral assemblage, galena, sphalerite and chalocopyrite. Sphalerite shows the presence of chalcopyrite inclusions (Fig. 2). The inclusions are irregular and have tendency towards elongate grains. In most sphalerite grains, chalcopyrite inclusions are concentrated along the margin while the grains are devoid of inclusions farther away from the margin. Chalcopyrite also occurs as scattered through the ore as discrete grains.

Such unmixing of chalcopyrite from sphalerite has been reported by many workers such as Ramdohr (1924, 1969), Peterson (1942) and the experimental work carried out by Buerger (1934). Buerger observed that when sphalerite was heated in contact with chalcopyrite to temperatures of 350° to 400°C, numerous small blebs of chalcopyrite developed within the sphalerite near the contact with chalcopyrite to which he suggested the development of minute chalcopyrite blebs in sphalerite adjacent to large masses of chalcopyrite can only be accounted for by a mixing and then unmixing process having taken place. The chalcopyrite dissolved in the adjoining sphalerite to form a solid solution of the two minerals. Since chalcopyrite was more concentrated near the large mass of that mineral, more blebs have been segregated close to the mass, diminishing in number and finally disappearing further out in the sphalerite. Ramdohr (1924, 1969), observed immigration of chalcopyrite from the sphalerite grain boundaries in some low temperature ore deposits which have been heated later to sufficiently higher temperature. Also he observed that sphalerite with low iron content favours solubility of chalcopyrite at higher temperatures, which may unmix at low temperatures giving rise to chalcopyrite inclusions in sphalerite. The presence of chalcopyrite inclusions in sphalerite of sample No. 2, might have formed under the conditions mentioned by Buerger (1934).

The presence of sphalerite in both exposures suggest neutral or basic solutions, but wurtzite which would indicate acidity, has not been recognized in these ores.

Detailed work is in progress.

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SHAFEEQ AHMAD
Geology Department
Punjab University
Lahore.

Fig. 1. Galena (black) being replaced by tennantite (white) along cracks and border.

Fig. 2. Sphalerite (black) with chalcopyrite (white) inclusions

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A RECORD OF THE GENUS *MAMMUTHUS* BURNETT FROM THE PINJOR FORMATIONS OF THE PAKISTAN SIWALIKS

A right mandibular ramus (U.Z. 67/322) bearing last molar was collected by the author from the Pinjor formations exposed to the South of village Sardhok, Punjab, Pakistan. The fragment (Fig. A & B) is exclusively the horizontal ramus of the lower jaw. The general contour of the ramus is almost normal. The tooth is in the middle stage of wear. In unworn condition, it was most probably subhypsodont containing about 14½ ridge-plates and a small fore-talon. Looking from the top, the tooth appears to be a spindle shaped structure i.e. wider in the middle becoming narrower towards the anterior as well as the posterior sides. Cement is not plentiful and most probably did not cover the lateral sides of the molar plates and their apices in unworn condition. Enamel layer is nearly 4 mm in thickness. This thickness almost remains constant from top to the crown base. The number of conelets varies from 4 to 5. Conelets remain isolated till one fourth wearing of the crown. Each lateral conelet is pointed at the top and gradually increases transversely till it merges with the neighbouring conelets to form a complete enamel loop. The central conelets remain rounded throughout their depth. The vertical groove between the two innermost conelets is the maximum.

Fig. 1A. Top view of U Z. 67/322 showing the crown structure of the last molar X 0.32.
Fig. 1B. Lateral view of the same. X 0.32.

Thus the participation of the innermost conelet in the formation of complete enamel loop is very late. The ridge-plates are widely spaced and are thin anteroposteriorly. Anterior enamel border of the ridge-plates shows a weak forwardly directed sinus. This sinus appears at the middle stage of wear and disappears much before the complete wearing of the ridge-plate. Enamel border is almost simple and devoid of plications.

Low crown, thick and very simple enamel and the number of ridge-plates (Table No. 1) of the specimen under study do not allow its inclusion in the species *Elephas planifrons* or *E. hysudricus*. Comparing the specimen under study with the known relevant material of these species described by Falconer (1868) or Osborn (1942), it appears that it is a new variant in elephantid population. Low crown, widely spaced and appressed ridge-plates and simple enamel layer are the characters which warrant its inclusion in the early mammuthine population. Comparing (Table 2) with the relevant material of a primitive mammoth *Mammuthus africanavus*, it appears that the Siwalik specimen is relatively progressive. The measurements of a last lower molar of *Mammnthus africanavus* given by Arambourg (1952) confirm this progressiveness.

TABLE No. 1

Measurements (in mm) of the tooth in U.Z. 67/322

Number of ridge-plate	Length (e)	Maximum width	Height (e)	W/L index	H/W index	Lamellar frequency
14	310	95	83	31	87	4.5

e. Estimated

L. Anteroposterior length.

W. Width

TABLE 2

Comparative measurements of last molar in U.Z. 67/322 and the type tooth of *Mammuthus africanavus*.

	Type third lower molar of *Mammuthus africanavus* (taken from Hooijer, 1955)	Last lower molar in U.Z 67/322
Length	283	310
Width	95	95
Height	92	83
Height/Width index	97	87
Width/Length index	34	31

MUHAMMAD SARWAR
Department of Zoology
University of the Punjab,
New Campus, Lahore,
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