GEOLOGY AND MINERALISATION AT LAKHNIWALI–PEELIWALI HILL

MADAN-KUDHAN SECTION
KHETRI COPPER BELT, RAJASTHAN (INDIA)

DISSERTATION
IN PART FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF
M. Sc. Tech. DEGREE IN APPLIED GEOLOGY

SUBMITTED BY

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- CERTIFICATE -

Certified that the dissertation entitled "Geology and Mineralization at Lakhniwali-Pooliwali Hill, Madan Kudhan Section, Khotri Copper Belt, Rajasthan" being submitted by Sri Dinesh Chandra Sharma in partial fulfilment for the award of degree of M.Sc. Tech. in Applied Geology of the University of Roorkee, Roorkee, is a record of student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

(K.K.Singh)

Dated May 3,1967

5/5/67

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PREFACE

From early times until eighteenth century copper was produced in small quantities. Since then it has become an indispensable metal in modern civilization. For a country like India Copper Deposits of Rajasthan are boon to the nation and appears as silver lining in the dark sky. Besides its recent discovery, these deposits have been centres of mining activity since historical times.

This dissertation embodies the results of investigation carried out by the present worker during June - November 1966 on the geology and mineralization of copper deposits at Lakhniwali-Peeliwali hill of Madan- Kudhan section, which lies in the Khetri Copper Project, at a distance of 10 Km. north northeast from Khetri town; in the Junjhunu district of Rajasthan. This topic of current interest and importance was suggested to the author by the Department of Geology and Geophysics, University of Roorkee, Roorkee.

To make the thesis self illustrative at large, all the important diagrams, maps and sections have been placed

-/ p.t.o

towards the end. But the presentation of the observations and conclusions is subjected to the limitations set by time and Laboratory facilities. It is hoped that further investigation of similar nature in other parts of the belt will substantiate these observations and unravel many unsolved problems.

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Mention must be made of Sri P.C.Punj, Section

Cutter, and Sri Raja Ram, Photographer, without whose help it would have been very difficult to bring the dissertation in the present form. Last but not the least my thanks are due to the Typist for typing the dissertation within a very short time.

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A B S T R A C T

Lakhniwali - Peeliwali hill of Madan Kudhan section of Khetri Copper Belt of Rajasthan have been studied with especial emphasis on structures and mineralisation.

The ridge comprises of the rock formations belonging to Ajabgarh series of Delhi system. These rocks have been intruded by magnetite - amphibolites and permeated by mineralizing solutions. The recent unit comprise of Gossan bands, occurring in enechelon pattern, alluvium and wind blown sands. Various rock types show the effect of regional metamorphism having typical mineral assemblages of amphibolite facies. The retrogressive metamorphism is indicated by sericitization and chloritization. Fe-Mg metasomatism has developed typical anthophyllite -cummingtonite assemblage.

Based upon the study of the regional structures and structural analysis of the area, it has been concluded that the rocks have been deformed by the stresses acting from about N 130 and N 310 directions, producing anticline with regional axis trending N 40° and plunging towards north. These stresses have produced various sets of tension and shear joints, faults and smaller folds during different stages of deformation.

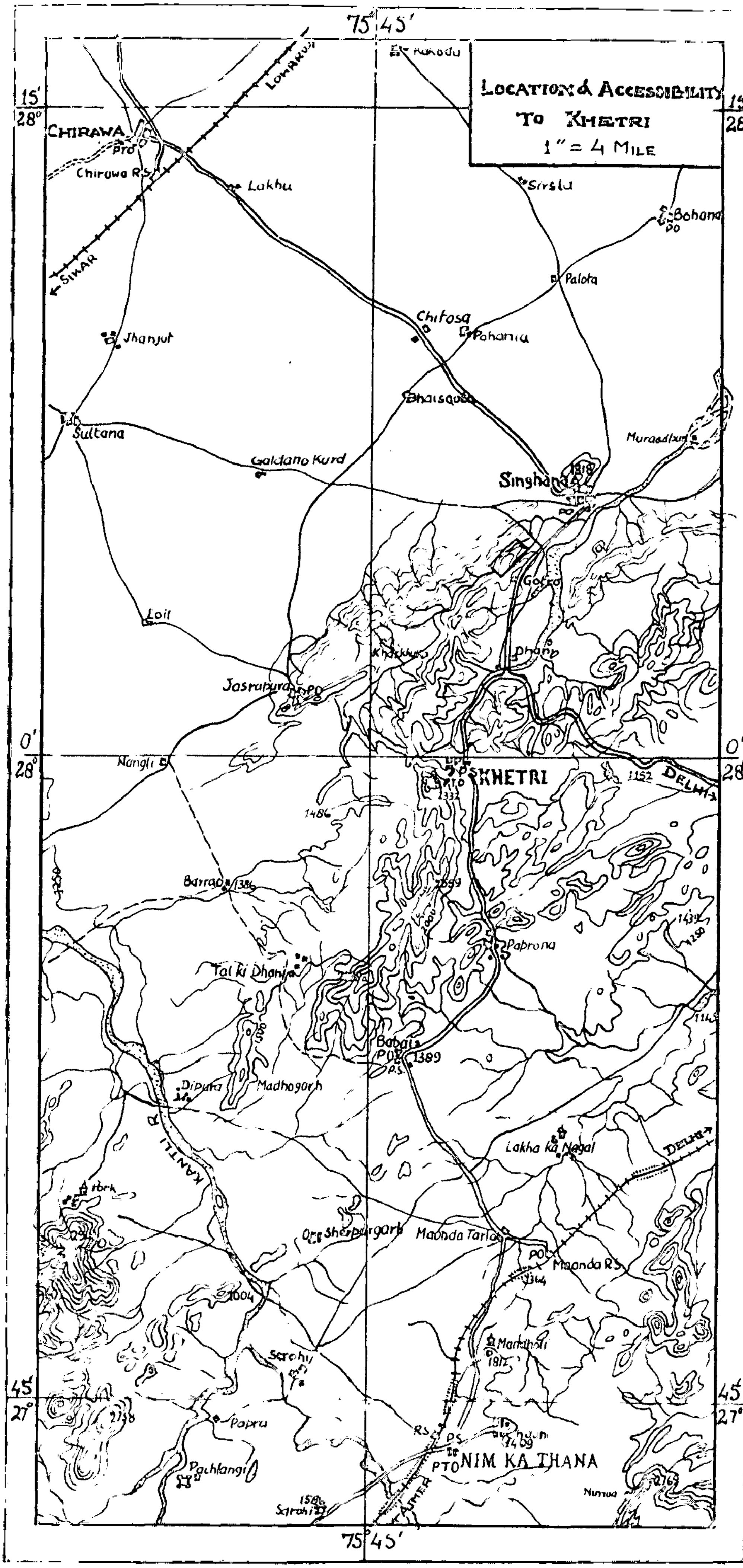
The presence of only few metal ions like Fe, Cu, Wo, Ti in thispart, as compared to many metallic ions present in the southern part of the belt, have indicated that the mineralisation took place probably at an early stage of sulphide activity in this part at about 450°C. The granite present all along the belt might have acted as the source to give rise the hydrothermal solutions.

Various structural features have predominated over the lithological features in the ore localization. The faults have served as important channelways for the movement of mineralising solutions, and at places have been mineralised. Bedding joints have been most important locii for mineralization, apart from the schistosity, giving various vein patterns.

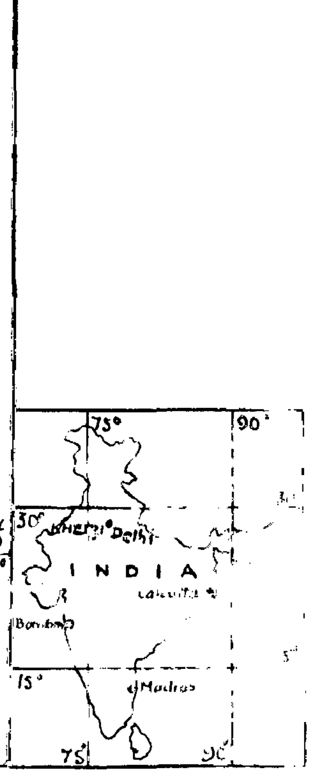
The Ore reserve calculations of this belt have indicated huge reserves, amounting to about 60 million tons for this section. So far no attempt has been made to estimate the ore reserves at Lakhniwali - Peeliwali hill due to lack of presence of sufficient data.

CONTENTS

CHAPTER I



LOCATION & ACCESSIBILITY TO KHETRI
1" = 4 MILE
75° 45'
15' 28°
0' 28°
45' 27°
CHIRAWA
Chirawa R.S.
LOHARU
SIWAR
Lakhu
Sirslu
Bohana
Palota
Chitosa
Pahania
Jhanjut
Bhaisgosa
Sultana
Galdana Kurd
Singhana
Muraadbus
Gotro
Loil
Dhanp
Jasrapura
Nangli
KHETRI
DELHI
1152
1486
Barrad
1386
Paprona
Tal ki Dhani
Babai
1389
Dipura
Madhogarh
Lakha ka Nagal
KANTLI R
Sherpurgarh
Maonda Tarla
Maonda R.S.
1004
Markhol
1812
Papra
Pachlangi
2758
NIM KA THANA
Nimua
AJMER



75°
90°
30°
Khetri
Delhi
INDIA
Calcutta
Bombay
15°
Madras

CHAPTER I

INTRODUCTION

1.1. Location:-

The area under investigation occupies the northern most part of Madan Kudhan Section of the Khetri Copper Belt, Rajasthan. The belt runs for about 80 K.Ms from Singhana in the north to Raghunathgarh in the south. The area lies within Khetri Copper Project which is about 10 K.Ms. NNE of Khetri town and 3 K.Ms SSW of Singhana village in topo sheet No.44P between lattitudes N28°4'45" - N28°30'35" and longitudes 75°48'45" - 75°47'40". The Lakhniwali-Pooliwali block which have been mapped and studied in detail extends for about 1 Kilometer along and 500 meters across the strike.

Khetri Copper Project is connected to Delhi and Jaipur by all weather metal road. It is also connected to Nim-ka-Thana and Chirawa railway stations of Western Railway (MAP 1) by tar roads.

1.2. Climate and Drainage:-

The climate of the region is characteristic of semi-desertic type. The 'Great Thar Desert' lies in the west of Khetri Copper belt. Though the climate is not but it is not unbearable. The temperature variation is great varying from 5°C in January to 50°C during June. The average rainfall varies between 25-40 Cm. The rain during June-September is brought by SW monsoon from Arabian Sea, while in the January-February by NE cyclonic winds.

The area is not traversed by any important river except a seasonal Kharkhar River, which flows towards NE on NW flank of Peeliwali-Lakhniwali block with great speed during rainy seasons, and has eroded phyllites and schist to make its way. Some small streamlets (nalahs) join the Kharkhar across the valley.

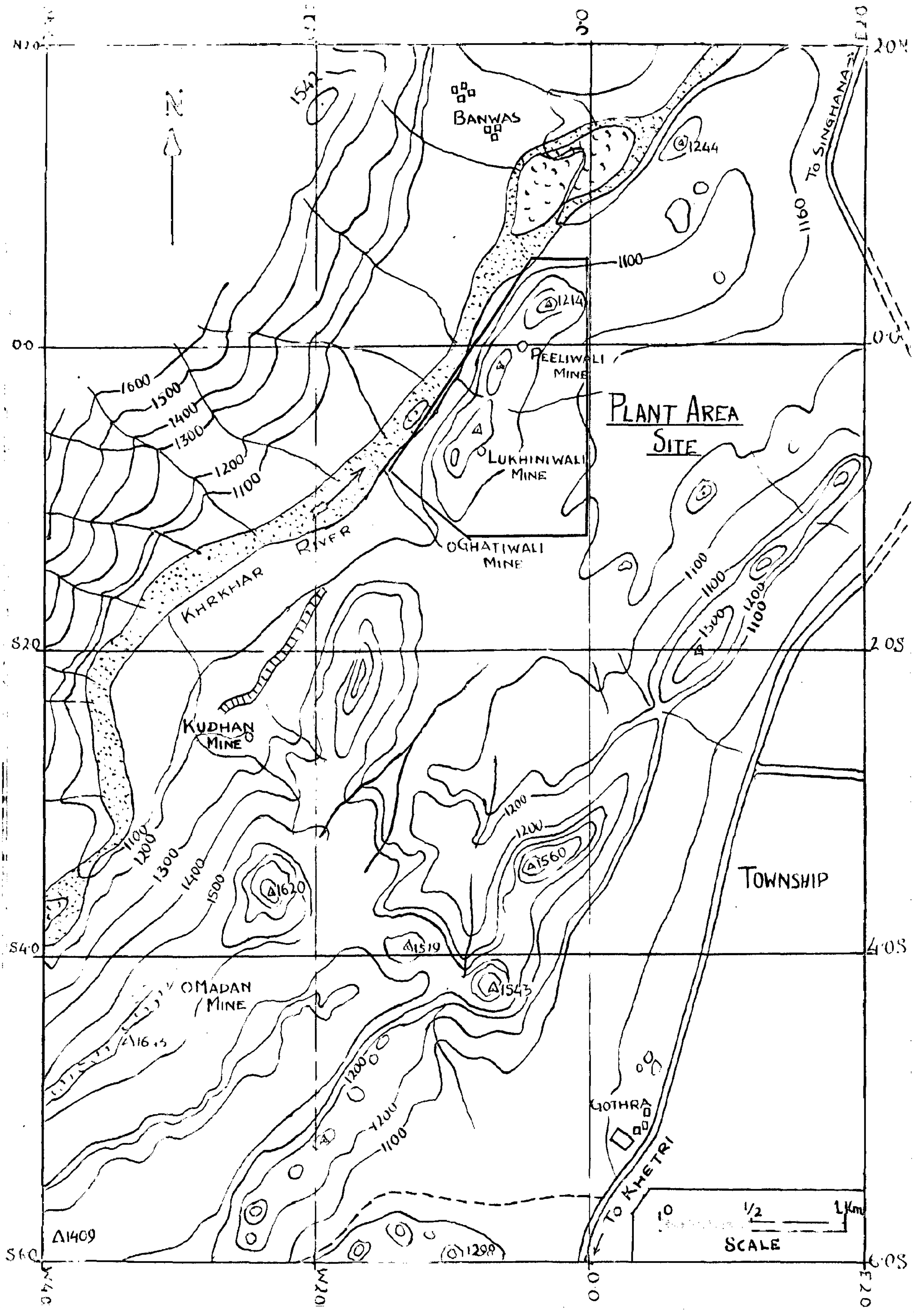
1.3. Weathering :-

The chief agents of weathering in the region are temperature, wind and rains. Rains have caused both mechanical as well as chemical weathering, while wind caused only abrasion and at the same time removal of the weathered product from the hill tops. The weathered soil is brought to the lowgrounds and depressions where it is deposited and compacted by subsequent rains. Sand particles have been transported even to many kilometers depending upon their fineness. These have produced typical sand dune pattern. The variation in the temperatures aided by moisture and wind have resulted in oscillatory action of weathering.

1.4. Soil and Vegitation :- (After Weathering)

The low lying area is covered with alluvium and wind blown sediments. The soil is light brown to fawn colour and seems to be quite productive and fertile. This has been inferred from the fact that fields are green whereever water is available for cultivation.

Vegetation is very sparse in the area except along rivers and also on hill-ranges. The low lands generally have scanty scrubby growths in addition to almost ubiquitous



Map-2 -- Showing Topography & Drainage Pattern at Madan-Kudhan Sectio
The Red Marked Area Have Been Mapped & Studied

"euphorbia royallina" and "cactus" bushes and sparse grass, which require very little water for their growth and existence. (Photograph No.1).

1.5. Topography and Geomorphology :-

The topography of an area is result of differences in the resistance of the rock to erosion. Hence the geomorphological characters of the area are based upon the lithology and structures of the rock types.

The area forms a part of the Aravalli ranges of Rajasthan. The topography is very much undulating characterised by plains and sharp apexed ridges. (Photograph No.2). The ridge trends N35°E with steeper western slope at about 41° and gentle eastern slope at about 23°. There is a marked variation in average slope angle on either of the limb. Accordingly, the erosional agents in this area have worked from SE direction towards NW. The topography of the ridge has also been structurally controlled by joints parallel to the strike of the formations: The other set of joints and faults have also helped the erosional agents to carve out the present topography. Topographic features are shown in map. No.2.

The natural agents of weathering in association with structure and lithology of the region have produced the present day geomorphological features: The quartzites are resistant to weathering while schists and phyllites are easily weathered consequently the quartzites form the ridges while phyllite and schist formed the low-lands and valleys, as shown in figure 2.

The other important geomorphological feature is sand dunes. They are formed due to alluviam and wind blown sands brought by wind action from distant areas. These dunes range in their trend from N-S to NNE-SSW and occur throughout the lowlands. These dunes are considered to have been shaped chiefly by SW blowing winds from April to September.

1.6. Inhibitants and Industry :-

The area around Khetri and Singhana is populated by Rajasthanis who speak blended Rajasthani and Punjabi language. They also speak Hindi which can be easily followed. The general standard of living is low and people are quite poor, earning their living by agriculture only. The second means of earning is the erraction of Khetri Copper Project which is employing about 2,500 persons at present from the nearby villages.

1.7. PREVIOUS GEOLOGICAL WORK -

Hackett(1877) was first to mention about abandoned copper workings of Khetri Copper belt in northern part and also about large heap of slag left behind after extensive mining and smelting of copper at Singhana.

Hackett (1881) mapped the area and included Alwar quartzites in lower Delhis,which he earlier included in Aravalli system. Hockett (1880) also mentioned about nature of occurrence of copper at Kolihan.

Heron (1923) mapped the area structurally and lithologically around Khetri and mentioned about host rocks; schists, slates, and impure limestone of Alwar series, for minemalization at different localities.

Dunn (1943) pointed out briefly the potentialities of the belt. Deb (1948) described the petrographic features of some of mineralised rocks and identified important ore minerals after microscopic studies.

West (1949) reported about themining activities of Jaipur Mining Corporation during 1944-46, which was closed because they could not reach rich loads after spending sufficient time and money.

Chandra and Ramienger (1955) assigned the length of copper belt only to be 18 miles extending from Singhana in north to Babai in south. Structural controls for mineralisation of ores were also discussed to some extent.

Venkatesh and Das Gupta (1958) reported that the mineralisation is restricted along shear zones in schists and phyllites, and said that contact between autho-phyllite - cummingtonite bearing rock with garnetiferous schist rock is more highly mineralised.

Roy (1959) discussed about the old workings of Singhana, Banwas, Madan, Gothra, and Kharkar, based upon unpublished reports of Grookshank (1948) who predicted rich ores at depths, based upon studies and mining of secondary ore by ancient miners.

Verma and Patni (1962) dealt with the general aspects of mineralisation in the Madan and Kolihan section.

Das Gupta (1960-67) and Roychaudhary and Das Gupta (1965) have carried out detailed petrological and minerographical studies in this belt on regional scale.

Rao and Rao (1965)and Mukherjee (1966,67a,b) have worked on the presence of trace elements in different parts of the belt.

1.3. Scope of Present Work:-

For the country like India, which is deficient in base metals, the copper ore deposits of Khetri are a boon, to the Rajasthan State in particular and to India in general. These deposits were intermittently mined in past few centuaries by ancient miners. The present day importance of copper is felt by everyone. At the initiation of Dr. K.K.Singh, the investigation of these deposits at Lakhniwali - Peeliwali hill was undertaken in June, 1966.

(A) Field Investigation :-

A total period of thirty two days spread over in two field seasons (June and November, 1966) was devoted for the field investigations. The following works were carried out in the field :-

(1) Detailed Geologic mapping of the Lakhniwali - Peeliwali hill on 1:1000 scale, (topographical map by the curtesy of M/s N.M.D.C).

(2) Detailed structural mapping on 1:1000 scale.

(3) Geologic mapping of underground working of Lakhniwali Adit in north drive and First NE X-cut on 1 Cm. = 1 meter scale.

(4) Preparation of diagrammatic plans, sections and sketches of various important geologic features.

(5) Collection of systematic and representative samples of all rock units and ore minerals (more than 125 samples were collected).

(B) Laboratory Investigation :-

The following laboratory investigations were carried out in the laboratory of the Department of Geology and Geophysics, University of Roorkee, Roorkee :-

(1) Consultation of various references on the related subjects and survey of upto-date literature on the present Belt.

(2) Petrographic studies:-

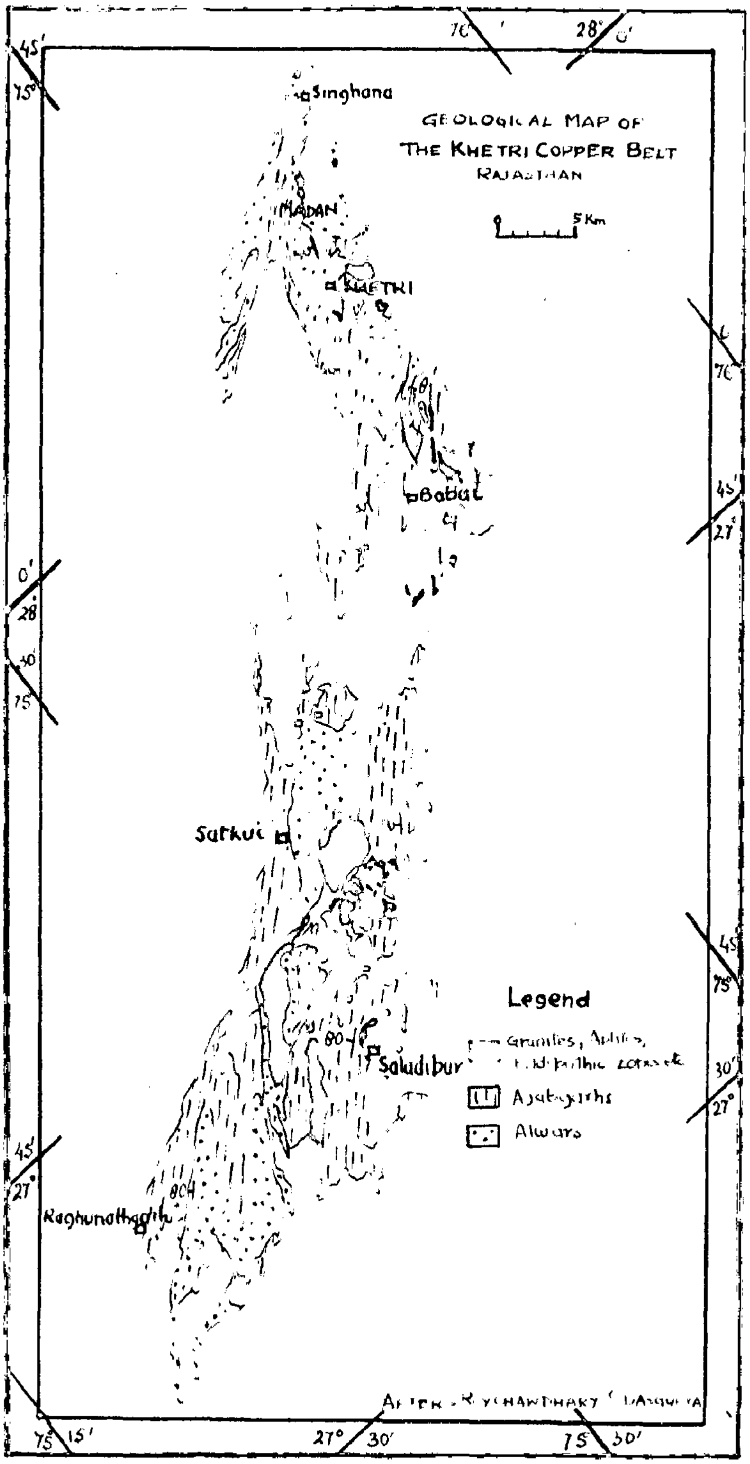
(a) study of megascopic characters of the samples.
(b) study of rock sections under petrological microscope.

(3) Ore Microscopic studies:

(a) study of various ores and their associates under reflected light in the ore.
(b) study of association of gangue and ore minerals in their polished sections.
(c) determination of poragenesis of ores.

(4) Analysis (mega-fabric) of the various structural elements with the help of synoptic II poles of various S-planes in the lower hemisphere of schmidt's equal area net.

CHAPTER II


Geological Map of
The Khetri Copper Belt
Rajasthan
5 Km
Singhana
Madan
Khetri
Babai
Satkui
Saladipur
Raghunathgarh
Legend
Granites, Aplites, Feldspathic zones etc.
Ajabgarhs
Alwars
76°
28°
75°
27°
45'
30'
15'
0'

Map-3

CHAPTER II

GEOLOGY OF THE AREA

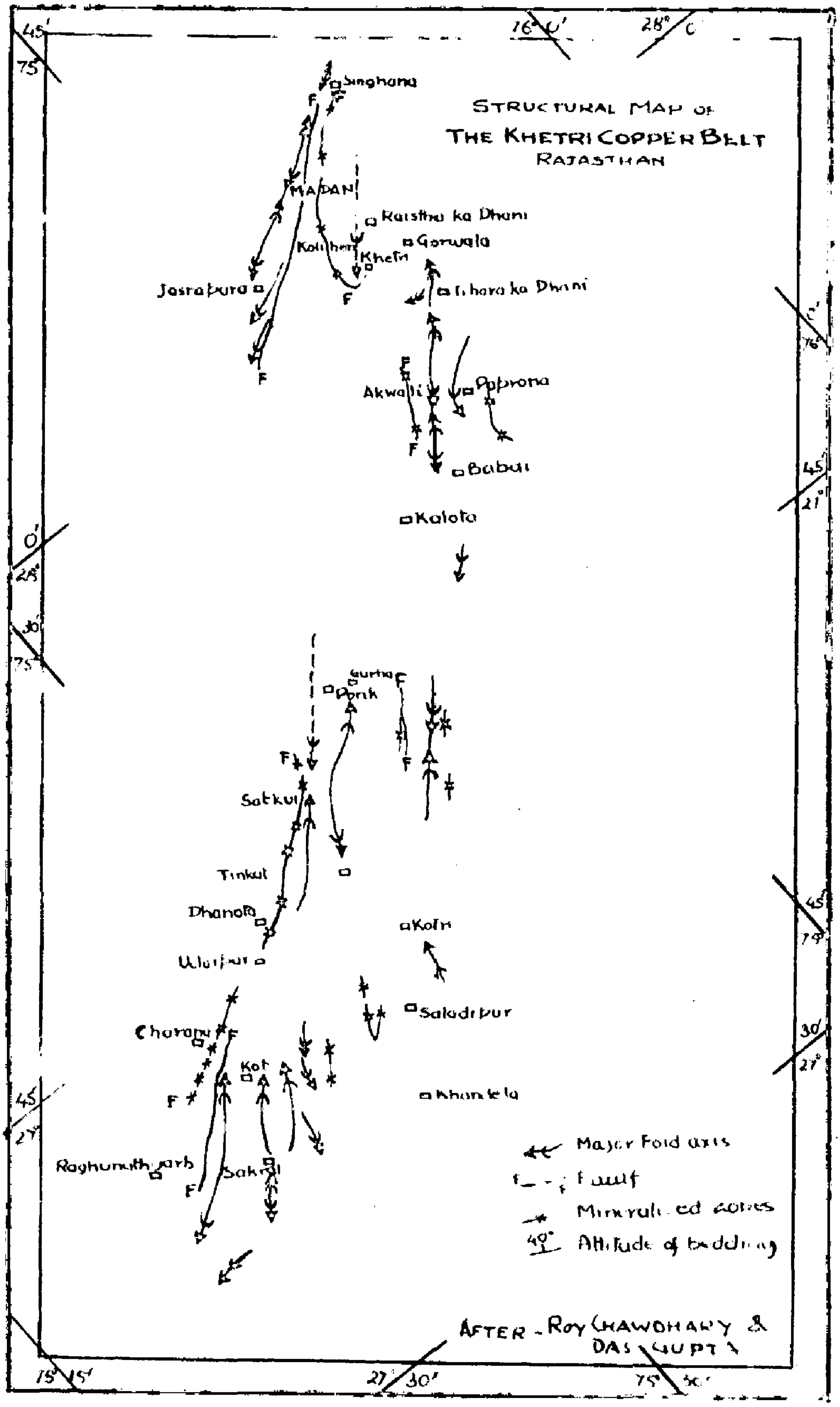
2.1. Regional Geology and Structures :-

The Khetri Copper Belt is made up of rocks belonging to Alwar and Ajabgarh series of Delhi system of pre-cambrian age. The older Alwar series chiefly consisting of arenaceous sediments is represented by rocks varying in composition from orthoquartzite to arkose, interbedded with phyllites, schists, marble and amphibole quartzite at places. The younger Ajabgarh series is represented by various types of schists and phyllites, which have been derived from metamorphism of argillaceous sediments. Schists at many places are interlayered with thick white massive quartzites, locally marble and other calc-rocks.

The quartzite of both Alwar and Ajabgarh series show current bedding, ripple marks and graded bedding, which have been of great help to determine stratigraphical sequence. The contact between two series is gradational and at many places is associated with the development of anthophyllite-cummingtonite bearing rock developed due to metasomatism. The rocks of Alwar and Ajabgarh series were later intruded by granites, pegmatites, basic rocks and ankerite (Map. 3).

The generalised geological section of the belt, as given by Das Gupta and Roychaudhary (1965), is as follows:

INTRUSIVES	Ankerite
	Younger basic rock
	Granite, pegmatite, quartz etc.
	Older basic rock


STRUCTURAL MAP OF
THE KHETRI COPPER BELT
RAJASTHAN
Singhana
MADAN
Jasrapura
Khetri
Gorwala
Babai
Kalota
Satkui
Tinkal
Dhanota
Kot
Saladipur
Khandela
Major Fold axis
Fault
Altitude of bedding
AFTER - ROY CHAWDHARY & DAS GUPTA

MAP-4

DELHI SYSTEM	AJABGARH SERIES	Quartzites, phyllite, Schists etc. Marble, calc-gneiss etc. Various types of schists and phyllite.
	ALWAR SERIES	Amphibole quartzite, amphibole gneiss, marble etc. Arkosic quartzite, quartzite with intercalated phyllite and schist. Phyllite and Schist

Regional strike of the formations varies from NNE-SSW to NE-SW direction. The belt is characterised by large scale doubly plunging folds, which have been faulted in normal and reverse type with increasing intensity of deformation. The reverse faults are important from the point of view of mineralisation, which acted as channel ways for mineralising solutions. The major fold axis plunges either NE or SW, the axes of two folds may be at right angles to each other, where superposed folding is pronounced. The plunge of folds is moderate (25°), but some of the later folds have steeper plunges. The cores of anticlines are occupied by Alwars (Map 4).

The faults are though numerous but are dip-slip type with insignificant lateral movement at the contact of lithologic units. They run sub-parallel to the strike of the formation and can be traced to several kilometers. The faults of limited extent are arranged in enechelon pattern. Sub-parallel shear zones developed along major faults are more important, than the fault themselves, for mineralisations. Large scale transverse faults are few and limited in their extent and are not important from mineralisation point view (Map. 4).

The rocks have been subjected to highest grade of regional metamorphism as shown by pelitic assemblages containing minerals like garnet, Kyanite, stanrolite and sillimanite and rocks like calc-gneisses and amphibolites. The metamorphism has been accompanied by deformation, feldspathization, and igneous activity. The presence of andalusite near the contact of older basic rock indicates thermal effect. The progressive metamorphism has been followed by retrogressive metamorphism as indicated by serocitization of andalusite or chloritization of garnets. All these were followed by ferromagnesian metasomatism which produced anthophyllite, cummingtonite, chlorite-biotite. Out of all these rock types, garnetiferous rocks have been most important from mineralisation point of view.

2.2. Geology of Lakhniwali-Peeliwali Hill :-

The rock types exposed at Lakhniwali-Peeliwali hill belongs to Ajabgarh series of the Delhi System (of Heron). The geological succession as observed from SE to NW is as follows:-

Recent -	Alluvium and wind blown sand Gossan band
Intrusive & Mineralising veins	Calcite veins Quartzveins and sulphide quartzveins Magnetite-amphibolite
Ajabgarh series	Amphibole bearing garnetiferous chlorite quartzite/schist. Garnetiferous chlorite quartzite/schist. Chlorite quartzite/schist. Feldspathic tremolite quartzite. Paragneiss. Feldspattic quartzite

South east of plant valley feldspathic quartzite comes in contact with magnetite quartzite further south granitic exposures are met with.

Feldspathic quartzite occupies maximum areal extent and covers entire plant valley. It is greyish white to brownish white with little iron content. It is altered at the surface while fresh at few meters of depths and dips at about 65^{o} due N 315^{o}.

Overlying feldspathic quartzite is Paragneiss which is exposed along the south eastern stope of Lakhniwali hill. This is varying in thickness with an average thickness of about 10 meters. It is not exposed all along the strike length and is covered by scree material and soil cover, but the contact between this and overlying rocks have been observed at southern and northern end dipping at about 68^{o} - 80^{o} due N 310^{o}.

Feldspathic tremolite quartzites overlie paragneiss and is about 80-90 meters in thickness dipping at about 65^{o}-75^{o} towards N300 to N325^{o}. It is traversed by various magnetite amphibolite-quartz veins which occur as more resistant band of 1-3 meters of thickness. Magnetite-amphibolite - quartz veins protrude on the surface with higher relief due to their higher hardness and have altered to limonite producing typical box work pattern.

Chlorite quartzite/schist overlie feldspathic tremolite quartzite. The schist and quartzite are so closely intercalated that it is difficult to mark the individual bands. Quartzites are resistant to weathering and occ-ur near the hill top. It varies in thickness from 20-30 meters, dipping confirmably with overlying and underlying formations.

Garnetiferous chlorite quartzite/schist which is overlying the chlorite quartzite rock is persistant throughout the entire length of hill, and is characterised the presence of garnet bands. (Plate 13). Individual garnet bands vary from few millimeters to as much as 3 Cms. It is varying in outcrop width and is much wider and thicker at Lakhniwali hill as compared to Peeliwali hill. The thickness varies from 50 meters to 100 meters, dipping towards N305°-330° at about 65-85°.

Amphibole bearing garnetiferous rocks does not occur as distinct band but shows very irregular nature. It occurs in small pockets (plate 14) as well as in bands. The contacts are very much gradational. The amphibole needless vary in thickness from few inches to 4 inches in size radiating from a common centre (plate 15)and colourless to dark grey in colour.

On the north western flank of Lakhniwali - Peeliwali hill, Kharkhar river has made its way through the phyllite rocks. This rock unit is also not exposed.

All these formations have been traversed by later intrusives like Magnetite-amphibolite veins, quartz veins, sulphide lenses and calcite veins (Figure 13).

The recent units associated with garnetiferous chlorite quartzite/schist amphibole bearing garnetiferous chlorite quartzite/schist and chlorite quartzite/schist is represented by Gossan bands which extend in an enechelon fashion along the strike (fig. 5). The ores have been backed away from these zones and are characterised by presence of reddish and greenish secondary iron and copper minerals like linorite, goethite, malachite etc.

A generalised section of the section showing all the rock formations present is shown in (Fig. 2). Two sections of across the Lakhniwali Peeliwali will show the variation in the thickness of individual rock units (section along X-Y and X'-Y').

2.3. STRUCTURES AT LAKHNIWALI-PEELIWALI HILL

The structural feature of an area are the image of the forces which have disturbed the rock formations. The complexities in the structural element increases with the increase of intensity, epochs of disturbances and mountain building activities. The Lakhniwali-Peeliwali hill which is the northmost part of the north-easterly plunging antochine forms the western limb of the fold (map. No.4). Different structural elements in this hill have been studied on the surface and underground and their control on mineralization has been partly worked out.

I - Planer Structures -

(i) Bedding (S_1 planes) :-

Bedding has been observed in various rock types. In the feldspathic quartzites the graded bedding of quartz-grains, together with the colour bands have been utilised for deciphering bedding. Though this feature is not exposed at many places but on the southern end, graded bedding in feldspathic quartzite (fig. 3) have been observed. From this the dip of the formation comes to be 65° due $N310^{\circ}$ on the bedding.

In the garnetiferous chlorite quartzite rock, the garnet bands have been taken as index of bedding (plate 13), which are the product of regional metamorphism of peletic sediments intercalated with psammetic bands. The dip of the garnet bands, and hence of the formations, varies between 65° to 85° towards $N300^{\circ}$ to $N330^{\circ}$. The general dip of the formation is about 70° due $N310^{\circ}$ (fig. 6).

(ii) Foliations (S_2 planes) :-

The schistose rocks exhibit foliation along which the rocks easily break down. The foliation is parallel to bedding in this region, dipping about 70° in $N310^{\circ}$ to $N320^{\circ}$ direction. Foliation varies greatly in their direction from $N280^{\circ}$ to $N345^{\circ}$ depending upon the flexuring of the beds (fig. 18).

The poles of 200 bedding and foliation planes were plotted together and contoured. Two maxima were obtained with plunge 70° in direction $N310^{\circ}$ and $N330^{\circ}$ (fig. 6).

(iii) Joints (S_3-planes) :-

Several set of joints are present at Lakhniwali-Peeliwali hill, which have partly controlled the present day topography of the ridge. Few joints are smaller about 2 to 3 meters in strike length, while others extend for a long distances along and across the strike of the formations.

Seven main set of joints are observed and a schematic block diagram of these joints is shown in (Fig. 7). The poles of joint plances were plotted in the lower hemisphere of schmidt net for structural analysis in (fig. 8, 9) to show their structural relationship with the fold-axes (of desitter 1963 pp. -103). The seven set of joints are as follows :-

(i) Dip joint (first order tension joint) striking N125°-N305° parallel to stress direction. The dip of these joint vary from 30° to as high as 90°. This has probably also produced.

(ii) Strike joint (second order tension joint) striking N35°-N215° and are parallel to bedding and regional axes of fold. The dip of these joints varies from 60° to 90°.

(iii) Bedding joint are parallel to primary banding dipping 70° due N310°.

(iv) and (v) Oblique joint are diagonal to the dip and strike joints and they correspond to the first and second order shear joints.

(vi) and (vii) The other two probable set of joints are product of release in tension when deformation ceased. Normal shear joints trend parallel to Axis of fold with dip between 45° and 20°. The joint with the dip still lesser than 20° have been termed as thrust shear joints and are present in the area.

All these joints show the variation in amount and direction of dip. Most of the joints are straight but some curved joints of smaller scale(?) are also observed.

(iv) Faults :-

The Lakhniwali-Peeliwali hill is characterised by the presence of numerous dip slip and strike faults. The transverse faults vary in their throw greatly from a meter to as high as 25 meters. The transverse faults have served as the conduits for the movement of mineralizing solutions and at the same time have acted as important locci for mineralization (fig. 15).

(A) Dip Slip Faults :-

The transverse faults are dipping steeply southward (section 1 and 2). These faults have probably produced the saddles between the hilltops (fig. 1). Along the Lakhniwali-Peeliwali ridge, and four saddles corresponds roughly to four faults.

(i) The northermost fault has developed fault braccia in between chlorite quartzite schist and Feldspathic quartzite (fig. 5-B). This bracciated material have been later on cemented by magnetite quartz solutions (plate 29). This fault probably has maximum throw as compared to other faults because feldspathic quartzite is abutting against the chlorite quartzite/schist.

(ii) The second fault passes from Peeliwali old working. This fault is associated with 5 meter wide gossan band across the strike which was mineralised by sulphides as indicated by the presence of limonite gocthite and malachite along it, and the offsetting of chlorite quartzite/ schist on the two sides (map -1).

(iii) The third fault which is trending E-W is an inferred fault. It could not be confirmed because of lack of sufficient outcrops on the two sides of this probable fault. However, the offsetting of the chlorite quartzite/ schist on the two sides and their probable extension has lead to the inference of this fault. Much detailed underground mapping in north drive may confirm its occurrence.

(iv) The faults of smaller scale are present in the magnetite-amphibolite intrusives (?). The bands of magnetite - amphibolite, which are about 1 to 3 meters in thickness have been very clearly displaced by dip slip faults with the throw varying from 1 meter to as much as 5 meters.

(B) Oblique Fault :-

The fourth major fault passing from the saddle at Lakhniwali-Peeliwali hill trends N60°-N240° dipping at about 75° due south. This is oblique in nature and is 1st order shear fault, having vertical throw of about 8 to 10 meters, as determined from section 2. The Lakhniwali old working turns towards north at about 15 meters from the surface confirming the throw.

(c) Strike Faults :- (Second order tension faults)

The area is characterised by the presence of strike faults along the formation boundaries. A probable strike fault at Lakhniwali-Peeliwali hill exists west of Lakhniwali hill which forms a steep stope for about 30 meters, within garnetiferous chlorite quartzite/schist. These faults have developed during the stage of folding of rock formations.

The enclosure of Anthophyllite-cummingtonite bearing rock in between the garnetiferous chlorite quartzite/ schist on two sides near and south of Lakhniwali Adit can be explained due to strike faults; otherwise the enclosure may be considered only a lens of amphibole bearing rocks produced due to Fe-Mg metasomatism.

(II) Linear Structures -

(i) Folds :-

The hill itself is the western limb of the northeasterly plunging fold with beds dipping at about 70° due N310°. Minor scale folds are few. A plunging anticline and syncline with a plunge of 26° due N335° is present in the paragneiss towards the southern end of the area (plate 5). A broad flexure has developed on the western flank of the Lakhniwali hill about 150 meters along the strike with a plunge varying from 80° towards N300°. (Fig.8)

(ii) Puckerings :-

The puckering in the micaceous bands is present in the paragneiss (plate 12)with the plunge of pucker at about 70° due N300°. The folding in the paragneiss has caused the breaking of competent quartzo-feldspathic bands (plate 5)into blocks.

2.4. STRUCTURAL ANALYSIS :

(A) Introduction :-

Failure by rupture in the rocks of outer shell of the earth is expressed by the joints, faults foliations and cleavages. The study of the stresses which have produced these features is of great important in the hydrothermal ore deposits for the localization of ores.

An attempt has been made to visuvalise the relationship between the fracture pattern and regional stress direction. There is no doubt about the facts that the joints are developed due to same stress conditions as the faults acting at the time of folding.

(B) Relationship between stress and fractures :-

From the study of the various joint patterns at Lekhniwali-Peeliwali hill and considering the axis of axial plane foliations (S2) and the major anticline to be trending about N35°-N215°, following conclusions have been derived :-

(i) Major subhorizontal stress acted from about N125° and N305° directions (perpendicular to S_2).

(ii) In the initial stage of simple stress conditions Dip joints (First order tension joints) and oblique joints trending N70°-N250° and N150°-N330° (First order shear joints) were developed.

(iii) When folding took place giving rise to anticline, bedding joints and strike joints (second order tension joints) trending N35°-N215° and oblique joints (second order shear joints) trending N20°-N200° and N355°-N175° were developed.

(iv) Finally the release in the stresses produced joint trending N35°-N215° with dip lesser than 45° and can be called normal shear joint and those with still lesser angle (below 20°) are the thrust shear joints.

All the stress conditions are shown in Fig10.

(C) Conclusion :-

Keeping in the mind the Mohr (1962) - Anderson (1951) theory of rupture, author has tried to correlate various joints patterns and faults to regional stress direction causing the deformation in the rocks. What is given here is not final conclusion. The area which have been taken into consideration is very small for structural analysis, and to further substentiate these a systematic and detailed regional study of the various structural feature is wanted.

CHAPTER III

CHAPTER III

3.1. FELDSPATHIC QUARTZITE

Megascopic Characters :-

The Feldspathic quartzites is light greyish white in colour and is fine grained. On the exposed surface it has changed to light brown due to leaching of iron contents.

Textural features :-

It shows granoblastic texture. The inter spaces between the quartz and feldspars have altered recrystallised.

Mineral assemblage :-

Quartz, Felspar, sericite, magnetite and limonite have been recognised, the sericite is the alteration product of felspar which is albitic in composition.

3.2. PARAGNEISS

Megarcopic character :-

Paragneiss is characterised by the parallel bands of chlorite - biotite and quartz-feldspars (~~plate~~ fig 19). The bands vary in thickness from few m.m. to few C.ms. The feldspars are altered to Kaoline and sericite.

Textural feature :-

Paragneiss show the gneissose texture in the microscope. The lights and dark bands are arranged parallel. Andahisite contains few inclusions of quartz giving sieve structure (plate 18).

Mineral assemblage :-

Quartz, Biotite, Muscovite chlorite, andalusite and Magnetite are present. The felspars alter to sericite and Kaolinized even on the surface. The name has been given because it is result of regional metamorphism of alternating quartzo-feldspathic and peletic sediments.

3.3. FELDSPATHIC TREMOLITE QUARTZITE

Megascopic characters :-

Feldspathic tremolite quartzite is exposed on the eastern flank of the Lakhniwali Peeliwali hill. It is characterised by the occurrence of needles of tremolite and actinolite of varying size from few m.m. to 2 Cm. embedded in the quartzo-feldspathic groundmass. This formation is highly weathered on the surface and gives reddish brown colour due to alteration of iron content into limonite (~~plate~~) showing typical boxwork pattern.

Textural features :-

The rock shows porphyroblastic texture. Quartz and felspar occur in the groundmass in which needles and prisms of tremolite and actinolite are embedded as porphyroblast (plate 19). The amphibole needles are crowded with the inclusion of quartz and felspar and also give poikiloblastic texture (plate 25) and inclusions are generally arranged parallel to the elongation direction of crystals.

Mineral assemblage :-

The feldspathic tremolite quartzite contains quartz, tremolite, actinolite, albite, sillimanite magnetite, chlorite, biotite, limonite and sericite. Tremolite and adinolite alters to chlorite and biotite, while, albite to sericite and magnetite to limonite (~~fig.~~).

3.4. CHLORITE QUARTZITE/SCHIST

Megascopic characters :-

Chlorite quartzite/schist is characterised by the greenish colour. The chlorite flakes are generally randomly oriented and do not appear to be schist, but at places schistosity is developed. The contact between this formation and overlying garnetiferous rock is not very sharp but is marked by the appearance of garnet from east to west.

Textural features :-

The chlorite quartzite rocks are granoblastic and chlorite flakes do not exhibit preferred orientation. The individual flakes vary in their size from very small size to few m.m. in the fine grained compacted rock.

Mineral assemblage :-

The mineral assemblage in this rock is simple and quartz, chlorite, muscovite, biotite, albite and sillimanite (?) is present. Chlorite is present ubiquitously in all other overlying rocks of Lakhniwali-Peeliwali hill.

Two types of chlorites have been recognised - Chlinocblore and Pennine. Chlinocblore is characterised tabular or pseudohexgonal crystals, and sometimes bent. The extinction varies about 0°-7° and shows polysynthetic twinning (~~Fig.~~). Pennine is characterised by parallel extinction and green to brownish green pleochroism. It gives anomalous blue colour.

3.5. GARNETIFEROUS CHLORITE QUARTZITE/SCHIST

Megascopic characters :-

The garnetiferous chlorite quartzite/schist is characterised by the presence of garnet crystals arranged in bands. The individual crystal varies in size from few m.m to about an inch and is dark reddish brown in colour.

Textural features :-

Garnets are arranged in bands alternating with the quartz -chlorite bands. Individual garnet occurs as porphyroblast and have the inclusions of quartz showing sieve structure (plate 23). These quartz inclusions are probably the remnant of the earlier sediments and produce blastosammatic texture.

Mineral assemblage :-

Following mineral assemblage is recognised in the section :

(i) quartz-chlorite-biotite garnet

(ii) quartz-chlorite-muscovite -garnet

(iii) quartz-biotite-garnet-andahisite

(iv) quartz-chlorite-biotite-garnet-sillimanite

The garnet is of almandine variety and is pinkish brown. The sillimanite is characterised by prismatic colourless needles 2nd order polarisation colour and parallel extinction. It is distinguished from the andalüsite by its higher interference colour andalusite shows greyish birefringence., while sillimanite shows second order colours.

Garnet, sillimanite and andalusite alters to chlorite, biotite, sericite and exhibit retrogressive metamorphism.

3.6. <u>ANTHOPHYLLITE CUMMINGTONITE BEARING ROCK</u>

(i) <u>Megascopic characters</u> :-

In hand specimen the anthophyllite cummingtonite bearing rocks usually have an appearance of an amphibole with aggregate of radiating prism (plate 14) which help in easy identification of these rock types in the field. The coarser crystals measure from 1 Cm. to 10 Cm. in length and 0.5 m.m to 2 m.m across the length. The rock is usually dark grey to dark greenish coloured and is rich in quartz, chlorite, biotite and garnet. At places these rocks have concentration of considerably big sheaf - like or fan -shaped crystals of anthophyllite and cummingtonite (plate 15). In some cases these rocks also show an unusual hornfelsic characters which with the sheaf of anthophyllite and cummingtonite. This feature is visible even in the handspecimen and helps to distinguish these rocks from other rocks (plate 14, 15).

(ii) <u>Textural features</u> :-

The rocks do not show any banding or schistosity, which might have been lost during metasomatic replacement of rocks. Quartz chlorite portion within anthophyllite bearing rock show faint schistosity (fig. 25). In biotite-chlorite rock the flakes are arranged at random further foliation is not developed uniformly in different parts of the same section (plate 24). The anthophyllite cummingtonite rock pass gradually and imperceptibly along the strike into schist and quartzites. In some cases rock also shows hornfelsic structure with sheafs of anthophyllite and cummingtonite (plate 23). This feature is visible even in hand specimen and helps to distinguish the rock from other amphibolites.

(iv) <u>Mineral assemblages</u> :-

Beside the anthophyllite and cummingtonite the rock contains one or more of the following minerals : Chlorite, garnet, staurolite, talc, andalusite, tourmaline, cordierite, hornblende, quartz, carbonate albite, biotite, magnetite, pyrite, pyrrhotite chalcopyrite and limonite.

Although anthophyllite and cummingtonite are intimately associated (plate 24) commonly one of the two is prominent in single specimen. From the microscopic examination of the rock they can be classified as following assemblages :-

(a) Assemblage derived from pelitic rocks comprising biotite, andalusite, staurolite, garnet, muscovite, sericite, magnetite etc.

(b) Assemblage derived from the quartzite rock consisting of sericite muscovite, biotite, K-felspar, albite and magnetite.

(c) Assemblages derived from semi-pelitic rocks with higher amount of quartz in peletic rock consists of anthophyllite chlorite, cordisite, talc etc.

(d) from Amphitrite quartzite composed of actinolite, albite and magnetite, consists of cummingtonite hornblende, biotite, chlorite.

The common minerals quartz magnetite, plagiocla tourmatine and carbonates are always associated.

3.7. MINERALOGY

Anthophyllite :-

It occurs as coarse prisms, blades, idioblastic crystals, or in sheafs replacing earlier minerals. It is commonly colourless to pale grey green and brown. It shows following pleochroic scheme

Z = colourless, Y = light and X = tan;
Z < Y < X.

Anthophyllite contains numerous inclusions of quartz of various shapes some of these are arranged parallel to elongation direction of host rock. Such quartz are also seen at the contact of two coarse prism of anthophyllite (Plate 25). With the arching of the anthophyllite prisms, the quartz grain also show corresponding arching and both minerals exibit strain shadow. Magnetite grannular are randomly distributed. Inclusions of biotite, chlorite and plagioclase are minor (plate 24).

Anthophyllite grains contain small pleochroic hallows (?) around tiny zircon grains. Fractures are sub-normal to cleavage plane (110). These fracture do not extend with matrix. Fractures in some cases were left open and were apparently filled with later veinlets of quartz. Locally flaky minerals, like biotite, muscovite and chlorite, have developed along the cracks. (Plate 25)

Cummingtonite :-

It occurs similarly as the anthophyllite. It occurs as sheafs, fan shaped bundles, or blades with elongation parallel to C axis. Locally the bundles of needles of this mineral are arranged in bow-tie fashion (Plate 24).

The cummingtonite is generally colourless. The extinction varies within 15°-25°. Twinning on (001) and (100) are common. The cummingtonite shows sieve structure and almost all minerals including quartz occur as inclusions.

Chlorite :-

It is present almost in all the assemblages. Two varieties have been recognised :

(i) Pale green peninite showing ultra blue interference colour,

(ii) and distinctly pleochroic.

The second type is most commonly developed and has following pleochroic scheme X = yellowish green, or colourless Y=greenish yellow or bluish green and Z=green $X < Y < Z$.

Chlorite flakes commonly contain pleochroic hallows around zircon inclusions. The mineral occurs as (i) aggregates of flakes, pseudomorphously replacing earlier biotite or Amphiboles (plate 21). Coarse grains without any evidence of replacement (plate 23)and irregular shaped flakes and patches enclosing earlier minerals like quartz, andalusite, Amphiboles etc. The third type is sometimes associated with Anthophyllite-cummingtonite bearing rock without replacing that. Chlorite derived from biotite have fine inclusion of magnetite. Chlorite flakes occur normal to fractures and the outlines of anthophyllite, cummingtonite, biotite etc. and also along the flakes.

Biotite :-

It forms main mass of the country rocks, but does not occur as major constituent in anthophyllite cummingtonite rock. The mineral is present in the cleavage and cracks of the amphiboles or in association with cleavage and cracks. Inclusion of zircon surrounded by pleochroic hallows are quite common. It also occurs in intergrannular space between quartz grains (~~plate-~~).

Characteristic pleochroism of the biotite crystallised during Fe-Mg metasomatism is from colourless or pale yellow to yellow to reddish brown.

Hornblende :-

This assemblage occurs only in assemblage rich in cummingtonite. The mineral shows following pleochroic scheme X= yellowsish brown, Y=yellowish green and Z green $Z > Y > X$.

Cordierite :-

The mineral occurs as xenoblastic or porphyroblastic grains showing sieve structure because of inclusion of rounded quartz (plate 26). Cordierite is usually associated with anthophyllite but in some cases with cummingtonite. It is colourless with higher refractive index than quartz. Some of the grains of this mineral are altered to micaceous peninite along cracks and border. (Plate 26)

Tourmaline :-

This is usually minor but locally occurs in conspicuous amount (~~Fig.~~). In few grains zoning is observed with gfeenish blue core and bluish outer- rim to reddish violet core to violet outer- rim.

Garnet :-

It is pale pink with high relief, probably almandine, Grains with crystalloblastic outlines are noted. The grains contain the inclusion of fine and coarse quartz (plate 23) and alters along cracks into chlorite or biotite (plate 21).

Andalusite :-

It occurs as porphyroblastic grains set in a groundmass predominantly of quartz, biotite and amphiboles. It is pleochroic from colourless to pink. Two sets of cleavages (1D) are also developed. The mineral sometimes contain numerous inclusions of quartz and magnetite showing spongy texture. The andalusite also alters to peninite and sericite. It also contains few inclusions of carbonaceon matter. (18 - Plate)

Staurotite :-

Crystals are pale golden yellow to colourless and are common in amphibole assemblages. The mineral also shows the deeper pleochroism at few places. They show penetration and contact twins (Plate 20). Inclusions of quartz are common.

No foliation or bedding can be recognised in the garnetiferous quartzite. But locally both the groundmass quartz and quartz inclusions, within the garnet porphyroblasts have the same orientation as indicated by interference colours.

3.8. Meatasomatic Changes :-

Altered wall rocks surrounding the mineralised zones present a remarkable example of ironmagnesia metasomatism. Anthephyllite rocks have better developed by the replacement of arkosic quartzite than the schistose rock, where both type of rocks have been fully replaced the end product is a rock chiefly consisting of Fe-Mg amphiboles.

From the paragenesis of the mineral assemblages it is seen that the chemical changes were also involved in the process of metasomatism. There was a continuous addition and removal of constituents. The most important of the materials added are Mg, Fe (iron-magnesian amphiboles, chlorite) H_2O, F & B (albite); and Si (quartz). Most of the K (biolite) some Si (quartz) and Ca (oligoclase)have been withdrawn from the host rock. It might have been derived from the original andalusite (anthophyllite formed) at the contact of andalusite (plate 18), and muscovite which were extensively effected by the metasomatism.

Biolite, ubiquitous in the country rock schist, is however, insignificant in the zone of anthophyllite-cummingtonite bearing rocks. This suggests that K - was removed during metasomatism. Also biotite rich rocks with unoriented flakes of biolite are conspicuous in the areas adjacent to zone of metasomatism (~~plate~~)suggesting a possibility that they are formed by the K-removed from this zone. Sericite is absent in the zone of Mg-Fe metasomatism, though occurring in the andalusite bearing rocks outside the main zone (Pl. 18,19). Its late formation also indicates that inspite of the availability of the necessary constituents for its formation, it does not crystallise, presumably because the physico-chemical conditions were not suitable.

Introduced Na has been deposited as albite which is almost present in all assemblages. This indicates that during metasomatism Na, unlike K, can form distinct felspar provided there is sufficient (~~plate~~).

Pre-existing silica has been removed from the rock, but some silica has been added along with the newly formed mineral especially along with sulphides (plate 25). It is,however, difficult to distinguish the introduced quartz from released silica because both the types have recryslatlized and shown same mode of occurrence.

3.9. Age of Metasomatism :-

Iron-magnesia metasomatism is directly connected with the mineralization and appears to have partly preceeded the main phase of sulphide deposition, which also occupied shear and fault zones, transecting many earlier stfuctures. The mineralization probably took place during the later stage of folding, but minor movement of ions continued throughout the period sulphide phase. Granite was emplaced towards the closing stage of fold movements but is only slightly mineralised as indicated by veins along fracture zones within granite. Presumably the mineralisation started immediately after the emplacement of granite, but the Fe-Mg metasomatism on granite and intrusive basic rock is not seen in the field (Das Gupta 1965). Anthophyllite-cummingtonite - bearing rocks as a rule contain only minor amount of sulphides especially in the zones of mineralization. The sulphides did not form from simultaneously with the anthophyllite cummingtonite but are cryslatlized later from residual fluids.

3.10. Metamorphism :-

The rocks of Ajabgarh series have been subjected to regional metamorphism of varying grades. The different facies can be distinguished by the presence of various mineral assemblages. The peletic rocks are characterised by the presence of following important minerals assemblages :

(i) Muscovite - biotite - chlorite,
(ii) Tremolite - biotite - chlorite,
(iii) Andalusite - muscovite- biotite,
(iv) Muscovite - biotite - garnet,
(v) Muscovite - biotite - staurolite-garnet,
(vi) Muscovite - staurolite-biotite-garnet-staurolite,
(vii) Sillimanite -andalusite- biotite -garnet.

The quartzite rocks have been metamorphosed and cemented and compacted quartz and albite are present ubiquitously. The calcium and Magnesian content of the sediments probably gave rise to actmolite and tremolite minerals.

The highest grade of metamorphism impressed on the area, outside the metasomatic zone is of sillimanite - almandine sufacies (Turner 1949) of amphibolite facies of regional metamorphism. The metamorphism has been followed by feldspathization and igneous activity. The presence of andalusite indicates that the thermal effect has also played some role. The progressive regional metamorphism has been followed by retrogressive metamorphism as indicated by sericitization of andalusite (plate 18) and chloritization of garnets along the fractures (plate 21).

CHAPTER IV

CHAPTER IV

MINEROGRAPHY AND PARAGENESIS

4.1. INTRODUCTION :

The ore minerals from the different parts of the Khetri Copper Belt have been described by Hackot (1887), Mallot (1891), Dunn (1943), Crookshank (1948), Deb (1948), Verma and Patni (1962), Das Gupta (1963), Roy Choudhory and Das Gupta (1965), Rao and Rao (1965), Mukherjee (1966,67a,67b).

With the advances in the techniques in ore microscopy the number of minerals and trace elements discovered are increasing with time. Pyrrhotite, chalcopyrite, pyrite and magnetite are most widely spread minerals. The other minerals reported in minor amount are cubanite, vallerite, ilmenite, sphalerite, tetrahedrite, arsenopyrite, galena, rammelsbergite l mackinawite, rutile, cuprite, tenorite and goethite. The chief gangue minerals reported are quartz, chlorite, and garnet, with minor amount of amphiboles, apatite andalusite, scapolite, zircon, cordierite, and sideroplesite. Semi-quantilotive analysis of the ore minerals under Infrared spectroscope by Mukherjee (1967) indicates presence of Pb, Zn, Sn, Ag, Co, Ni, Mo, In, Ga,Ti, Mn, V, Cr. Bi and Ba as trace elements.

4.2. Nature of Occurrence of Ores :-

Although the sulphide ores are found to occur in minor amounts in the adjoining formations, but broadly garnetiferous chlorite quartzite/schist and amphibole bearing garnetiferous chlorite quartzite/schist have acted as important host for the mineralization. The mineralization is much controlled by structural planes such as shear planes, joints, fractures and foliations, rather than lithology. These planes have served as the channelways for mineralizing solutions and at the same time the localizers of sulphide ores. (Fig 15)

Mode of Occurrence :-

The sulphide ores occur in various forms as vein filling, lenses, braccia filling impregnations and disseminations.

(a) Vein filling varying in thickness from few millimeters to as thick as 5 Cm. is present along the joints, fractures and foliations. The vein filling along joints produce various features like parallel veins, rectangular veins and horsetail feature (Fig. 17). The joints in which filling has taken place vary in their strike length and openings. The bedding joints are most important from mineralisation point of view varying in their openings from 1 Cm. to 5 Cm. The other less important joints are oblique (Fig. 18). The sulphide veins continue for few meters ending gradually or they may end abruptly.

(b) Along the pre-mineralization faults typical braccia filling occurs (Fig. 11). The interspaces are filled by quartz, calcite and sulphides enclosing chloritic braccia (plate 16, 28).

(c) The mineralization has also localised as lensoid bodies varying in their size from 30 Cm. to as big as 10 meters. The lenses pinch and swell with irregular and transitional contacts exhibiting hydrothermal replacement predominating over vein filling (fig. 16).

(d) Fine impregnations and disseminations of sulphides is present ubiquilously. These disseminations vary in size from few millimeters to a centimeter (Fig. 18).

Ore Minerals :-

Of all the sulphides pyrite is most abundant as compared to other minerals. It occurs as grannular aggregate varying in size from five grains to few millimeters. It is most commonly localized along the joints (Map. 7).

Pyrrhotite occurs with pyrite along the joints but is also associated with it in the lenses with chalcopyrite and magnetite (fig. 12).

Chalcopyrite occurs with pyrite, pyrrhotite and magnetite as irregular concentration (fig. 12)along joint fractures and foliations replacing the country rock and producing various features like parallel veins, rectangular veins horsetail and lenses.

Magnetite occurs as inclusions within sulphides as fine grained grannular aggregates in the lenses and along larger joints (fig. 19) - the magnetite grains.

These sulphides and oxides of hydrothermal origin have been attacked by descending meteoric water giving rise to malachite, limonite, goethite ect. as secondary leached product. They occur along larger joints and faults through which water can descend.

4.3. Ore Minerals at Lakhniwali Peeliwali Hill :-

The minerographic study of the ores in Lakhniwali -

Peeliwali hill of Madan Kudhan section have been studied in detail with 20 polish sections (blocks) and 7 thin polished section (slides). The study has lead to the conclusions that the minerals are simple and few in number. The primary sulphides which have been identified are pyrite, pyrrhotite and chalcopyrite. The other sulphides reported from various parts of the belt have not been observed by the present worker. Amongst hydrothermal oxides magnetite titaniferous magnetite and wolframite have been found Calcite and quartz are present as hydrothermal gangue. Covellite malachite, and limonite are the secondary minerals.

4.4. Description of Minerals :-

The ore minerals which have been observed are discussed in detail individually. The paragenesis is later described in this Chapter, is determined from textural relationship of these minerals.

(i) Pyrite - Pyrite shows various forms from massive to grannular and also radiating needles having brass-yellow colour and greenish black to brownish block streak.

In the polished sections the pyrite is characterised by its yellowish white colour, pitted appearance and higher hardness. In sheared and bracciated country rock they occur as braccia filling. The grains of pyrite are moulded by the chalcopyrite (~~fig.~~). It contains the inclusions of magnetite and rarely of pyrrhotite and chalcopyrite. When occurring in chalcopyrite its boundaries are replaced by the later. The significance of these inclusions is discussed later in this Chapter. Pyrite when associated impurities or replaced shows variation in colour (4 / 598) few grains also show low anisohopism which may be either due to strain effect or due to low symmetry in the crystal structure.

(ii) Pyrrhotite - Pyrrhotite is second most important sulphide mineral present in the Lakhniwali-Peeliwali block. This can be distinguished from other sulphides by its characteristic bronze-yellow or Copper-red colour and greyish black streak. They generally occur as either the disseminated grains with other sulphides or as irregular pockets.

Under reflected light pyrrhotite shows varying forms such as massive grennular aggregates, elongated prism veins or isolated grains (plate 27,31). It is characterised by its pinkish white colour and strong anisohopism from greyish blue to dark brown colour. It occurs within chalcopyrite mass as inclusions or as interstitial filling (plate 27). It also shows prismatic cleavage and simple twinning (~~plate~~) which may be due to strain effect. Few inclusions of magnetite octahedrons chalcopyrite and pyrite grains have been observed (plate 31). Pyrrhotite boundaries are also moulded by chalcopyrite.

Two types of pyrrhotites, pyrrhotite I and pyrrhotite II have been distinguished from the fact that the distinct veins of pyrrhotite II cut across already formed pyrrhotite I (~~plate~~). The pyrrhotite II shows less straining effect and much clear anisotropism as compared to pyrrhotite I.

(iii) Chalcpyrite - It has typical brass-yellow colour but often tarnished giving beautiful colour combination like deep red, pink, violet and blue. It has dark greenish black streak and is softer than other two sulphides.

Chalcopyrite in polished sections shows golden yellow colour, and is isotropie, at few places where grains have broken due to the deformational stresses show variation in colours as well as in anisotropism (plate 31). It is associated with pyrite, pyrrhotite, magnetite and wolframite. It shows inclusions of pyrite, pyrrhotite and magnetite giving rise to vein texture (plate 31). Chalcopyrite occurs in various forms as fine shreds, impregnations (plate 32) vein-filling and irregular masses (plate 27), showing various textures. At few places chalcopyrite occurs as inclusion in magnetite, pyrite and pyrrhotite.

(iv) <u>Magnetite</u> - It is most abundant amongst oxide minerals and is well distributed in the ores. It occurs as fine grained grannular aggregates along with other sulphides, gives dark black dark streak and is strongly magnetic.

Magnetite is found to occur almost in all the polished sections studied. The colour of the magnetite is slightly bluish and darker grey than the usual colour of the magnetite. It varies in form from anhedral irregular grains to octatredral grains (plate 30) with faint cleavages. The quartz is most common inclusion, but sometimes sulphides are also present as inclusions. The pyrrhotite and chalcopyrite have replaced the magnetite partly - giving irregular replaced boundaries (plate 31).

Two types of magnetite have been distinguished associated with the sulphide ores. Magnetite I is slightly pinkish in colour, irregular fine grained and faintly anisotropic (~~plate~~). This is thought to be titaniferous magnetite. The other variety the magnetite II is slightly dark bluish grey, with subhedral to enhedral grains and is isotropic. Some grains have shattered and exhibit strain effect (~~plate~~).

(v) Wolframite - It has been recognised in the polish section (4/584) by characteristic elongated prismatic crystals, greyish with brownish tint colour, and anisotropism from greyish to brownish colour. It occurs within the magnetite II groundmass (plate 30) and its boundaries have been slightly replaced by the magnetite. This mineral have been reported for the first time from this belt.

(vi) Quartz - It is most common gangue mineral associated with the Ores. Three types of quartz, have been recognised. Quartz I is that present in the country rock and is more strained and is replaced by hydrothermal minerals. Quartz II is the one which came along with the ore minerals at an early stage and was later on broken replaced by later incomming mineralizing solutions. This is transparent in colour and occurs as irregular inclusions within the ores (plate 27, 32). Quartz III is the one which formed along with and after the ore minerals. This quartz is less broken and replaced occurs within ores and also replaces them (plate 31).

(vii) Calcite - Calcite is recognised both in the hand specimens as well as in the polished sections. It forms independent units giving rise to typical calcite veins in the country rock (~~plate~~ fig. 13) or as impregnated with other ores.

Calcite in sections shows alteration and uneven extinction which is due to the deformation and strains. It occurs as interstitial filling in quartz matrix as well as in ore matrix (~~plate~~ 27).

SECONDARY MINERALS

(viii) Malachite - It is only secondary copper mineral which can be distinguished megaseopically, and is usually associated with quartz forming extrenuous thin layer, on quartz, of green colour.

(ix) Limonite - Limonite is associated with the gossan band present at the top of the hills. It shows typical colours varying from yellow through brown to maroon with the rate of decrease in alteration of primary minerals. Limonite shows typical box-work pattern (~~plate~~).

4.5. Textures and Structures in the Ores :-

The textural features, which depend upon the mineralizing solutions, stage of mineralization and host rocks vary greatly. In general the sulphides show replacement texture predominent over vein filling texture (plate - 26 to 33).

Individual ore minerals show various types of textures. Pyrite, pyrrhotite and magnetite show grannular texture (plate 30, 32), while chalcopyrite shows vein filling and replacement texture and also occurs as irregular masses (plate 31, 32). The inclusions of pyrite, pyrrhotite and magnetite within chalcopyrite shows island texture (~~plate~~). Chalcopyrite also shows fine shreds and impregnation within the country rock (~~plate~~). Covellite has replaced the chalcopyrite along cracks showing secondary replacement texture (~~plate~~). Typical interstitial filling texture is shown by chalcopyrite, pyrrhotite and calcite (plates 27). The interspaces were later on expanded and the host rock especially quartz was broken as the mineralization advanced. Breccia filling texture is shown by pyrite (plate 28). All these filling textures are associated with replacements of varying degree.

4.6. Paragenetic Sequence :-

From the textural studies of the ore minerals in sections following four different stages of the mineralization of have been recognised :-

(i) Oxide phase - gave rise to quartz, wolframite and magnetite.

(ii) Sulphide phase - gave rise to pyrite, pyrrhotite and chalcopyrite.

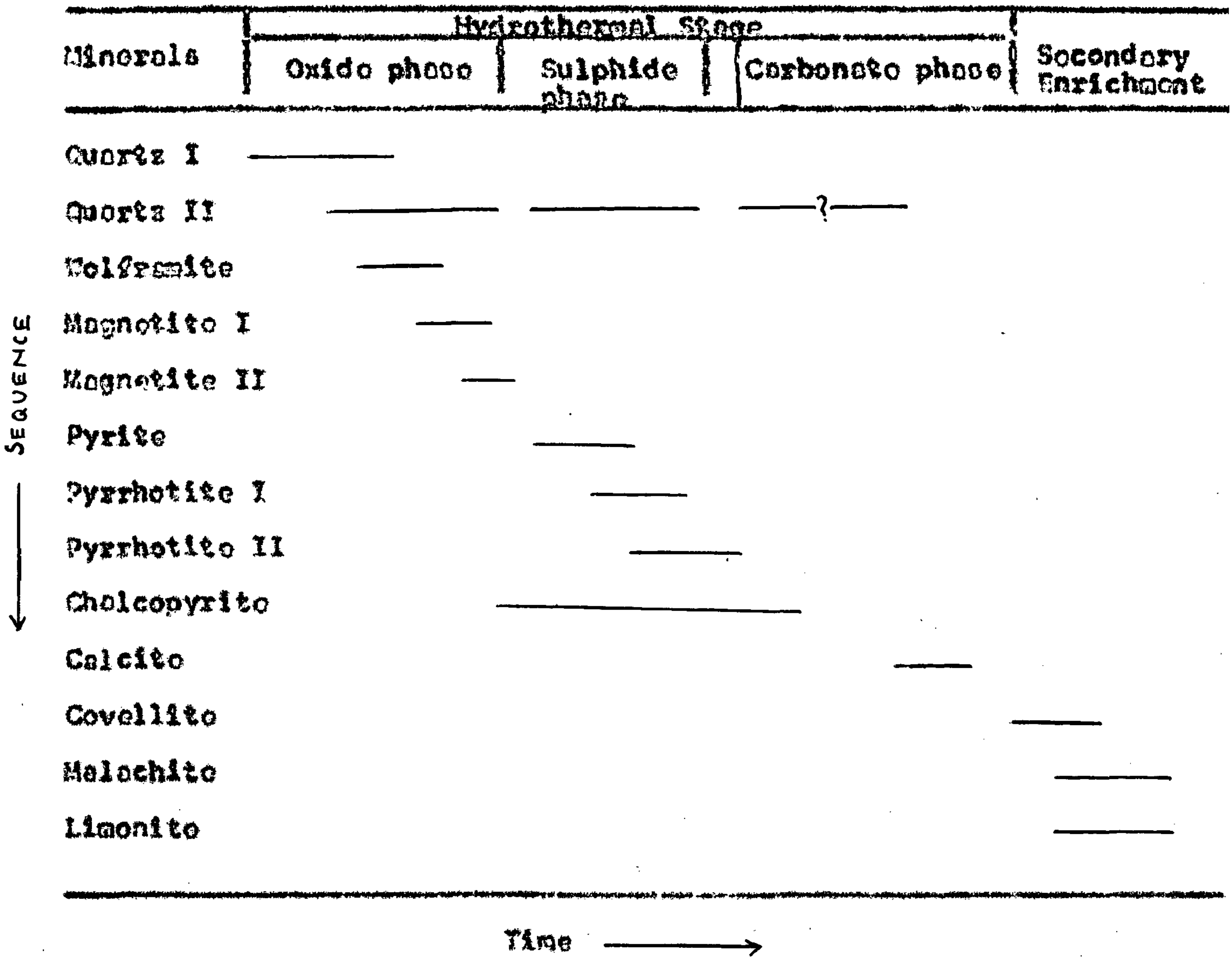
(iii) Carbonate phase - Calcite is formed in the last phase of hydrothermal activity.

(iv) Secondary enrichment - limonite, malachite, and covellite have been formed due to weathering and leaching of already deposited ore mineral.

The inclusion of quartz grains in all the ores show that it was first to form and continued till the end. Wolframite occurs as embedded within magnetite groundmass with slight alteration along the prismatic boundaries indicate that it formed earlier which was followed by magnetite I and magnetite II. Since magnetite occurs inclusions in sulphides with outer corroded boundaries at places, it was formed earlier than sulphide. The occurrence of pyrite octahedrous within chalcopyrite and pyrrhotite shows that it crystallized earlier than the two sulphides, but since it contains the inclusions of magnetite (~~plate~~) it is inferred then it formed later than the magnetite. Then pyrrhotite I and pyrrhotite II crystallized just one after the other. Pyrrhotite is followed by the chalcopyrite which contains inclusions of pyrrhotite, pyrite and magnetite. Calcite is the last phase of hydrothermal mineralisation which occurs as pore filling within the country rock as well as around and within chalcopyrite (plate 27). Sometimes the later minerals also occur as inclusions within the early formed minerals, creating difficulties to determine paragenetic sequence. But since these inclusions are rare and few in number, it is believed that they are present due to orientation and cutting of the sections. General paragenetic sequence of Lindgren is kept in mind to determine this sequence.

The action of weathering and leaching have given rise to supergene minerals, like malachite, limonite, and covellite, after the emplacement of oxides and sulphide minerals.

Paragenetic Sequence



4.7. Conclusions :-

In the southern part of the Madan-Kudhan section few minerals of Ni, Co, As, Pb, and Zn have been recognised, but these minerals are not present in the northern part. This has lead to conclude that the mineralisation in the southern part took place in many phases one after the other continuing for a long time, introducing many new minerals and replacing already existing ones.

The percentage of metal in the sulphide

mineral seems to be inversely proportional to their relative age. Late sulphides contain more metalions than the earlier one (Mac Diarmid after Bandy). Since the Lakhniwali-Peeliwali hill is rich in few minerals which are hard pyrite, magnetite, pyrrhotite, it is speculated that the mineralisation took place earlier than in the southern part of the belt. The source of mineralising fluids is still not definit, but the granites exposed on the south east of the magnetite quartzite hill near Gotro village and further south might have acted as the source rocks.

CHAPTER V

CHAPTER V

EXPLOITATION OF ORE DEPOSITS

5.1. Ancient Mining Operations :-

As regards ancient mining operation in the belt, verbal information reveals that copper was mined from Khetri during period of Chandra Gupta Maurya (about 300 B.C). As far as written evidences are concerned, " Ain-e-Akbari" shows that copper was mined from this area during Moghul period (1400-1600 A.D). The biggest proof of this activity is the accumulation of about 1 m.ton of copper slag near Singhana. Intense mining and smelting activities took place between 1759 - 1872 A.D. The restive political conditions towards the end of the 18th century must have caused a set back to the industry. Some of the ancient mining prospects, all along the strike length warranting tremendous ancient mining activities are :

1. Madan-Kudhan
2. Kolihan
3. Babai
4. Akwali
5. Satkui
6. Dhanota

Some of the ancient mining prospects of Madan-Kudhan section of Khetri Copper Project are as follows :

A. Pooliwali	}	North block
B. Lakhniwali	}	
C. Ghatiwali	}	Central block
D. Madan	}	
E. Kudhan	}	
F. Damdumwali	}	South block.
G. Mohamadwali	}	

These workings extend pretty well along the strike and dip of formations and have been developed within the ore bodies. The development have been very irregular owing to the fact that mining was limited only to richer portions. The method adopted for mining was varient of present day sub-level stoping e.g. cut and fill method of mining. These workings are characterised by various inclined shafts of which some are flooded while others have been cleaned by present day miners. (Plate 9)

Beside the old workings are of immense importance because they give a clue about shape, size and nature of occurrence. The intermittent mining activity along the strike gives the frequency and distribution, and suggests break in minealization in between lenses. It would not be an exaggeration to say that about 4.5 m.ton of ore have been mined in old days.

The old workings are directly connected with some of the new adits driven by G.S.I., I.B.M or N.M.D.C. Short description of few old workings of Madan Kudhan section is given below:

(i) Peeliwali old stope

It is the northermost slope of the section in garnetiferous rock, about 12 meters deep and 18-20 meters in circular diameter, which is filled with dump, debris, and caved rock fragments. There are several narrow vertical and inclined shafts in the north and NE of this slope, probably meeting the same stope and indicating its extension in NNE direction. At present this slope is not accessible. (Pl.7)

(ii) Lakhniwali Old Stope

This is the second biggest old stope of Mádan - Kudhan section and lies between latitudes 4010-4150, situated on eastern slope of the hill which is accessible by an open cut pit and shaft about 9 meters deep. It is connected to numerous small old stope all along strike direction (NNE). The bulk of mineralisation is concentrated in central part of stope and lies well within the faulted block between Ghatiwali fault in south and Peeliwali fault in north. Lakhniwali main cross cut intersects a narrow inclined shaft at 353 meter level (Plate 8).

(iii) Ghatiwali old stope

This stope is located south of transverse fault near hair pin bend between parallels 3760 and 3880. It has been cleaned and is accessible by a narrow inclined about 2 m. diameter and 12-13 m, in depth. There are two big stopes, and lowest portion towards south is water-logged. This is about 22-25 m. high, and crystals of gypsum, malachite and native copper are developed on the roof as stallectite. The extent of working indicates that ore body is plunging towards SW and leans out towards north. This stope has been intersected by north drive of Ghatiwali 368 in. level development. The ore body in this stope appear to be a single lens, located on the footwall side of Ghatiwali main lens.

(iv) Madan Old Stope

This is the biggest stope in the area located between parallels 2860 and 2650 at 500 m. R.L. The entrance is through an open cast pit about 60x25x10m. The actual entrance to the underground stope is through a vertical shaft approxi.

12 m. high. Some of the stopes are as high as 21 m . to 28 m. and are water-logged. The direction of elongation of working is towards 35^{o} due SW, which is also probable direction of plunge. This has been intersected by new Aidit No.IV at 393 in. R.L.

(v) Kudhan old stope

This stope is developed through open pit, of about 5 m . x 7 m . with a depth of 21 m ., along major fault zone (I.B.M). This working is located west of garnetiferous chlorite quartz schist on the contact of Phyllite and dolomite marble. There are numerous small shafts and pits around it of appreciable depth mostly in SW and north direction probably joined with main stope. At present this slope filled with debris and is not approachable.

5.2. Present Exploration and Development -

The scientific approach for exploitation of copper ore in this region began in 1944, when Jaipur Minning Corporation Ltd. took up an ambitious programme, after getting lease for 20 years from Mewar Darbar. They prepared surface Geological Map from Singhana in the north to Khetri in the south on the scale of 6" = 1 mile; and lay out for exploratory drilling and mining operations based upon the maps.

They drilled four holes with a total of 520 meters length. Three out of four cut across the mineralised zone. Fox stated that first bore hole encountered an old working and was abandoned second met 12' wide lode containing 6 % cu, and third struck a 4' wide lode with 12 % cu. Based upon these data, underground mining commenced at 357 m. level opening Lakhniwali Adit for 29 m.,at 368 m level opening Ghatiwali Adit for 53 m. and Adit No.IV and V. Unfortunately none of these openings reached the mineralized zone, and on the advice of their American Consultant Mr. Altshulor further operations were suspended, though they retained the lease upto 1955.

Geological Survey of India started intensive mapping of entire belt when the lease was released by Jaipur Mining Corporation Ltd. They mapped the area litho-logically and structurally. Few bore holes were drilled to make sure of the structures and extension of the ore bodies, different gossan zones were aligned and exploratory pits were opened.

Indian Bureau of Mines launched a detailed study in March,1957, which has been very well described in the"Report on Madan Kudhan Khetri Investigation, Part I". I.B.M. Launched an exploratory programme in three different phases.

1. Geological Mapping.
2. Diamond Core drilling
   (a) 48 bore holes with total length of 14,063 m.
   (b) 14 bore-holes from underground workings opened, with total length of 842 in.

Thus, a total of 14,905 m. of drilling was completed with an average core recovery of 86 %. Most of the holes were inclined at an angle from 30°-70°, three were vertical, and two were used to prove structure. Out of these

35 holes reached to an average depth of 417 m.
7 holes reached to an average depth of 518 m.
4 holes reached to an average depth of 870 m.

Exploratory mining operations commenced in 1959, February, and a total of 3,309 in. of exploratory mining was completed by November,1964, which were then handed over to N.M.D.C. for further development. The bulk of this mining was done at 350 in. level from parallels 2920 to 3550!

Geological survey of India and Indian Bureau of Mines (1954) carried out the reconnaissance survey. Sen Gupta and M.N.S. Rao (1956) mapped several magnetic and self potential anomalies and found that S.P.anomaly was always associated with the magnetic anomaly.

Paul (1962) carried out geophysical investigations at Singhana, and Paprona and found several self potential resistivity and magnetic anomalies.

Officers of National Geophysical Research Institute (1964) carried out combination of several geophysical techniques for exploration to overcome the difficulties arising due to graphite, graphitic phyllite and ferragenous quartzite which often interfere in interpretation.

At present, the area is under the control of Hindustan Copper Ltd. formerly under National Mineral Development Corporation, for further development and mining operations. Till June 1966 at 350 in. level there were two main drives with a length of 605.5 in. in hanging wall. These drives are connected in the north by an inclined shaft No.III at R.L.374 in. with an inclination of 30^{o} in the south, and by inclined shafts No.I and II at R.L.400.04 in the north. The total underground development at this level consists of 2607.2 in. The drives and crosscuts are irregular and at several places have been developed upon the ore-body alongstrike, and ore zones seems to cut across strike. Ore zones have not been fully exposed due to limited number of X-cuts.

At Adit No.IV at 384 m. level, a total of 749 m. of underground development has been completed. Further in the south of this Adit a total of 225.2 m. crosscuts along foot-wall drive and 175 m. drive has been devloped.

At Lakhniwali Peeliwali Adit the existing opening of 23 m. have been extended ahead to touch Lakhniwali Old working. From this place drives have been opened in the north to a distance of 180m with cross cuts 150 m. and in the south to the surface with total length of 160m along & 40m x-cut Due to the lean mineralisation in this zone further development have been suspended. The plan of this working is shown in Map. No.7. This hill was mapped underground to study the nature and intensity of mineralisation. About 100 meters of underground mapping was done in the north drive, and First eastern cross cut (Map. No.7).

In other parts of belt of this region, Exploratory mining and development is progressing with a fast speed especially at Adit No.IV and inclined shaft No.III. Apart from these Adits and drives, two main vertical shafts are also under construction. In the north is service shaft reached to a depth of 250' and in the south is production shaft which has reached to a depth of 400'. The work is being done around the clock to enhance the progress.

5.3. <u>ORE RESERVES CALCULATION</u>

(i) Method of Estimation :-

Plotting of the various intersections in the drill holes and X-cuts have been used in the estimation of ore reserves. The number of drill holes that cut the formations below the 1000' elevation are fewer in number, hence the blocks at 1000' level and below it are of larger size, in comparison to those at higher level than this where a drill hole at higher elevation and one at lower elevation are few hundred feet apart along strike, these are often considered to represent a block. Where the distance between the hole is great, theoretical width and grades are interpretted between actual figures from widely separated holes.

The number of intersections at various levels varies greatly, with only four holes cutting the ore at depth more than 400' below Sea level. For this reason, the estimate was divided into three separate depth intervals

(1) From 100' below the surface to 1000' elevation
(2) From 1000' to 500' elevation
(3) From 500' above sea level to 850' below sea level.

The ore was divided into three classes, as Proven, Probable and Possible. Where intersections are within 300'-400' vertically apart and at the same level, or between short distance above or below the intersections it is called Proven. where holes are further apart, or ore in the block is not at the same level, it is classed as Probable. Where there is no information above and below an intersection, or where vertical interval in many hundred feet apart, ore is called Possible.

(ii) <u>Ore Reserves</u>

Total number of intersections used for the calculation of Ore reserves amount to be 72. For all calculations tonnage factor used is 11 cubic feet, due to heavier minerals like garnet and amphibole gangue. Total proven probable and possible ore computed per intersection at various depths are as follows:

(i) Above 1,000' elevation 360,000 tons
(ii) 1,000' to 500' elevation 1,240,000 tons
(iii) 500' above and 850' below S.L. 2,550,000 tons
(with 5% S, 0.02 02/ton Au, and 0.502/ton Ag)

Following table summarises ore reserves at Madan Kudhan section, Khetri Copper Belt, Raj.

Description	Ore Reserves (in 000's) tons			Total (in 000's)	% Cu	Tons per vertical ft.
	Proven	Probable	Possible			
100' below surface to 1000' elevation	8513	8155	-	16668	0.92	56400
1000' to 500' elevation.	10299	5783	6198	22280	0.98	44500
500' above S.L.to 850' below S.L	580	4478	15355	20413	1.03	15100
Total 100' below surface to 850' below sea level	19392	18416	21553	59361	Average 0.98	Average 27600

In brief the total ore reserves amount to be 59,361,000 tons with average ore grade of 0.98% Cu with 27,600 tons per vertical feet of depth.

If further development shows that ore per vertical foot between 500' above and 850' below sea level equals to that between 100' from surface to 1000' elevation, more than 50,000,000 tons will be added. If ore per vertical foot between 1,000' to 500' elevation equals to that from surface to 1000' elevation, 5,900,000 tons of ore will be added.

5.5 Ore Reserves at Lakhniwali Hill :-

Due to lack of time and sufficient number of channel samples and bore-hole data, it could not be possible to estimate the ore reserves of this block. To the best of informations, the deposits at Lakhniwali Peeliwali hill are Low grade (about 0.5 % Cu-content) and are pyrite rich.

This has lead to the intermittent development of the Lakhniwali adit. At present further development has been suspended since rich zone had not been encountered inspite of about 500 meters of excavation.

CHAPTER VI

CHAPTER VI

SUMMARY AND CONCLUSIONS

Lakhniwali-Peeliwali hill (Long.75°47'43"-45°47'47" and Latt.28°04'30") which have been studied forms the northernmost part of the Madan Kudhan section of Khetri Copper Project, which is situated at a distance of about 10 Kms. NNE of Khetri town.

The area have been mapped on the scale of 1 Cm. to 10 meters. The underground mapping at Lakhniwali- Mine in the north drive and NE-Xi-Cut was done on the scale of 1 Cm. to 1 meter covering about 100 meters of distance to study the control of structural feature in the localization of ores.

The rock types which are exposed at Lakhniwali - Peeliwali hill belongs to Ajabgarh series of Delhi system. Garnetiferous chlorite quartzite/schist and amphibole bearing garnetiferous chlorite quartzite/schist are the main rocks exposed at the tip towards the western slope of hill. The other rock units are feldspathic quartzite, Feldspathic tremolite quartzite, Feldspathic tremolite and chlorite quartzite/ schist on the eastern slope of the hill. Further west phyllites have been covered by the alluviam of Kharkar river.

The original sedimentary rocks have been subjected to regional metamorphism. The peletic sediments have given rise to the mineral assemblages belonging to the amphibolite facies like chlorite, biotite, magnetite, garnet, sillimanite etc. The psammetic rocks were recrystallised giving rise to quartzite and the interstitial peletic material has given rise to interstitial biotite, Chlroite etc. The rythemic banding of arkosic and peletic sediments gave rise to para-gneiss. The regional metamorphism has been followed by the thermal metamorphism giving rise to andalusite which is regarded as the product of thermal metamorphism. These rocks have been subjected by Fe-Mg metasomatism in the later periods giving rise to very interesting anthophyllite - cummingtonite mineral assemblage. These minerals have replaced the country rocks and show more affinity towards quartzites than schists. All these rocks have been subjected to the retrogressive metamorphism causing sericitization and chloritization of various rock types.

The area forms a part of the doubly plugging fold running from Singhana in the north to Jasrapur in the south, plunging at about 30°. The study of regional structures and structural analysis of the present area have revealed that the stresses acted from N130°-N310° causing various types of deformation in the rocks. The beds dip at about 70° due N310°. The foliation planes are also parallel to the bedding. The analysis of the joints show that seven sets of joints are present. They appear as (i) Dip joint (ii) bedding joint (iii) strike joint, (iv) oblique joints I and (v) oblique joints II. These joints were developed during the progressive stages of deformation of rocks from horizontal condition to the stage of folding. During the release of these forces when folding ceased two more sets (vi) and (vii) of joints are developed dipping at low angles and are parallel to bedding. 350 readings of joints were plotted on the schmidt's net, but inspite of all these joints present in the field sharp maxima were not obtained. This is probable due to the preferential selection of joint observations, more frequent and regularly occurring joints were not collected properly, while others with little variation in the directions were taken comparatively more in numbers giving rise to random distribution to joints patterns. For this reason further detailed studies are warranted in the southern parts of this belt.

After the deformations in the rocks, probably in the later stages of folding, granits were emplaced all along this belt. These granits are the most probable source for the mineralising solutions, though no detailed correlation has been made so far.

The ore minerals which have been observed in this region are few, such as pyrite, pyrrhotite I & II, chalcopyrite, magnetite I & II wolframite, ilmenite. Of all these pyrite is predominating and chalcopyrite is poorly developed. Wolframite have been reported for the first time, though chemical analysis of the samples have not been carried out, but the optical characters have confirmed its presence. Magnetite is ubiquitous and is darker bluish grey instead of its usual grey colour under reflected light. This is attributed to some impurities or association of other metallic ions which could not be worked out.

The paragemetic sequence has been determined from the textural studies, both in band-specimens as well as under reflected lights, keeping in mind the Lindgren's paragenetic sequence for hydrothermal ores. The mineralisation probably took place at about 450°C giving rise to wolframite magnetite pyrite, pyrrhotite, chalcopyrite in the orderly sequence. Quartz continued to form during different stages of mineralisation and calcite was formed at the last stage as it crosses all these minerals as in form of veins. These minerals have been subjected to action of weathering by and meteoric water and leading of ores has given rise to covellite limonite, goethite, malachite etc.

The mineralisation in this part of the belt probably took place earlier than in the southern parts. This has been concluded on the theory that the early solutions contains less metal ions. Since the deposits at Lakhniwali - Peeliwali hill contains metallic ions of Cu, Fe, Wo, Ti, etc. only as compared to Cu, Fe, Pb, Zn, Ni, Co, Cr, Bi, etc. present in the southern parts, it is speculated that mineralisation in southern parts took place in many phases giving rise to many new minerals and replacing already deposited ores. This view further gives support that mineralisation in northern part took place during early stage and in single phase.

The ore estimation at Lakhniwali-Peeliwali hill has not been attempted so far due to lack of sufficient channel samples and bore-hole data. The Lakhniwali Peeliwali block is rich in pyrite and copper contents are lower than 0.5 %. This has lead to the intermittent development of this mine by various firms during different times. The ore reserves for entire Mad an-Kudhan section have been estimated to be about 59.3 million tons with an average copper content of 0.98 % from surface to the depth of 850' below the Sea Level.

" A map is record of geological facts in their correct relations - facts, be it noted, not theories. There must always be a sharp distinction between observation and inference. You can see a contact exposed on the surface, you cannot see it underground so perfectly" said McKinstry.

The author does not claim to have done anything original but he has satisfaction of gaining some practical experience of independent work - as geologist. A student of geological sciences is expected to aquire the needed skill somehow after graduation so as to hunt for ore minerals. Though the ores at Lakhniwali Peeliwali hill are economically poor, but a day will come when even these deposits will gain their importance as the near surface resources are decreasing continuously with the over increasing demand for Copper.

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APPENDICS

APPENDIX (i)

LOCATION OF OLD WORKINGS OF COPPER

Singhana	28°06'45", 75°50'30"
Banwas	28°05'00", 75°48'30"
Peeliwali	28°04'30", 75°47'45"
Lakhniwali	28°04'30", 75°47'46"
Madan	28°04'15", 75°48'30"
Kudhan	28°04'15", 75°48'25"
Masjidwali	28°04'00", 75°48'00"
Gotro	28°04'00", 75°48'30"
Damdumwali	28°04'15", 75°47'45"
Kharkhar	28°02'30", 75°45'00"
Kolihan	28°01'00", 75°44'00"
Khetri	28°00'00", 75°47'00"
Akwali	27°56'00", 75°46'00"
Babai	27°53'20", 75°45'30"
Satkui	27°49'00", 75°32'00"
Saladipura	27°41'00", 75°31'00"
Dhanota	27°44'45", 75°30'00"
Raghunathgarh	27°39'00", 75°21'00"

APPENDIX (ii)

READINGS OF BEDDING AND FOLIATION

Locations	Amount	Direction	Formation
3900-4000	76	300	Garnetiferous chlorite
	78	305	quartzite schist
	80	301	"
	72	310	Amphibole bearing chlorite quartzite/ schist.
	78	303	"
	78	304	"
	76	302	"
	77	309	"
	70	305	"
	72	320	"
	81	310	Gossan
	80	305	Garnetiferous chlorite quartzite/schist
	75	311	"
	67	306	"
	68	312	"
	80	302	"
	60	300	"
	80	305	"
	65	305	"
	85	310	Chlorite quartzite
	78	319	Feldspattice Trem. quartzite
	60	314	"
	65	325	"
	62	310	Ferruginous quartzite
	63	307	Felds.Trem.quartzite
	70	300	"
	71	308	"
	57	330	Ferruginous quartzite
	60	308	"
	68	304	"
	58	309	"

Location	Amount	Direction	Formation
	90°	307 - 127	Chlorite quartzite
4000-4100	66	297	Garnetiferous chlorite quartzite / schist
	78	300	"
	66	300	"
	68	295	"
	69	304	"
	67	302	"
	69	300	Amphibole bearing G.C.Q./Sch.
	72	305	"
	80	306	"
	78	297	"
	78	299	"
	80	320	"
	75	295	"
	72	303	"
	69	298	"
	70	307	"
	72	320	"
	70	322	"
	72	315	Garnetiferous chlorite quartzite/ schist.
	72	309	"
	78	305	"
	70	305	"
	72	300	"
	68	320	"
	68	309	"
	70	313	"
	74	315	"
	65	312	"
	80	308	"
	62	315	Chlorite quartzite

Locations	Amount	Direction	Formation
	60	302	Chlorite quartzite
	71	317	"
	65	304	Felds.Trem.quartzite
	62	303	"
	71	308	"
	61	302	Ferr.Quartzite.
	55	317	Feldspa.quartzite
	61	318	"
	72	295	Gar. Chl.Qtz./Sch.
	68	300	"
	68	318	"
	65	311	Amphibole bearing G.Ch.Q/Sch.
	80	304	"
	76	292	"
	71	310	"
	90°	305-125	"
	82	302	Gar.Chl.Qtzite/Schis
	80	295	
	86	291	
	70	312	
	81	300	
	78	307	
	57	305	
	69	302	do
	70	300	
	80	301	
	87	296	
	65	300	
	70	298	
	72	300	
	55	303	
	70	302	
	75	303	
	67	306	
	61	307	
	73	280	Chlorite quartzite
	65	305	"

Locations	Amount	Direction	Formation
	75	308	Chlorite quartzite
	74	306	"
	71	305	"
	68	300	"
	72	298	"
	66	321	"
	75	306	Gossan
	71	309	"
	82	310	Feld.Trem.Qtzite
	75	313	"
	65	307	"
	63	303	"
	63	300	"
	65	306	Ferr.Qtzite
4200-4300	64°	325	Garn.Chl.Qtzite
	63	323	"
	70	306	"
	80	298	"
	67	305	"
	72	313	"
	68	311	"
	72	302	"
	63	321	"
	72	328	Amph.bearing G.Chl.Qtz.
	68	324	"
	68	312	Garn.Chl.Qtz/Sch.
	60	309	"
	53	314	"
	72	309	"
	68	300	"
	80	302	"
	72	293	"
	78	267	"
	71	287	"
	62	316	"
	70	310	"

Locations	Amount	Direction	Formation
	78	317	Gar.Chl.Qtz/Sch.
	73	309	"
	72	300	"
	56	296	"
	68	309	Chlor.Quartzite
	65	302	"
	67	300	"
	73	292	"
	80	306	"
	75	291	"
	62	301	"
	65	303	Feld.Trem.Qtz.
	70	324	"
4300-4400	75	322	Gar.Chol.Qtz/Schist
	62	319	"
	70	308	"
	60	317	"
	50	306	"
	60	304	"
	62	311	"
	58	345	Amph.G.Ch.Q/Sch.
	81	312	"
	76	319	Chlorite qur.
	60	327	"
	72	335	"
	62	318	"
	66	317	"
	67	309	"
	68	305	Gossan"
	54	312	Chlorite Quartzite
	72	328	"
	75	330	"
	62	306	Amph.G.Ch.Q/Sch.
	74	318	"
	81	300	"
	65	315	"

Locations	Amount	Direction	Formation
	66	308	G.Ch.Q/Sch.
	72	315	"
	72	319	"
	68	316	"
	77	300	"
	70	304	"
	73	335	"
	85	331	"
	82	325	"
	62	315	"
	60	312	Chlorite Qtz.
	68	321	"
	76	305	"
	74	308	"
	72	297	"
	70	305	"
	73	312	"
	63	311	"
	68	308	Feld.Amph.Qtz.
	54	396	"
	52	323	"
	72	345	Chlorite Qtz.
	72	343	"
	70	338	"
	52	305	Ferr.Qtz.
	50	327	Feld.Qtz.
	54	355	"
	56	353	"

APPENDIX (iii)

READINGS OF JOINTS

Location	Amount	Direction	Rock Type
(3900-4000)	72	N 290	Gar.Chl.quartzite schist.
	70	N. 53	"
	64	N 54	"
	44	85	"
	67	170	"
	36	120	"
	65	300	Amphibole Bearing chlorite quartzite/schist.
	63	223	
	65	88	
	45	105	
	85	180	
	78	63	
	34	67	
	49	185	
	68	44	
	38	108	
	49	175	
	63	157	
	52	71	
	85	56	
	52	352	
	56	173	Garnetiferous chlorite quartzite schist
	49	174	"
	60	84	"
	56	156	"
	30	72	Chlorite quartzite rocks
	79	58	"
	65	87	"
	82	75	Felds.Trem.quartzite and Mag.quartzite

Location	Amount	Direction	Rock Type
	65	30	Felds.Trem.quartzite and Magn.Qtz.
	66	28	"
	63	68	"
	65	128	"
	54	135	"
	90	230-60	"
	54	358	"
	70	41	"
	75	305	"
	66	21	"
	70	47	"
	73	300	"
	59	353	"
	80	210	"
	63	90	"
	70	92	"
	55	193	"
	40	315	"
	59	242	"
	43	184	"
	45	302	"
	38	113	"
	80	305	"
(4000-4100)	85	210	Garn.chlorite quartzite/Schist
	70	12	"
	65	315	"
	79	42	"
	38	117	"
	80	181	"
	85	53	"
	58	351	"
	72	62	"
	57	59	Amphibole Bearing Garn.chlorite quartzit schist
	75	306	"

Location	Amount	Direction	Rock Type
	80	307	Amphibole bearing Garn.chlorite qtz. schist.
	42	305	"
	82	297	"
	48	63	"
	50	202	"
	60	41	"
	76	72	"
	30	120	"
	55	197	"
	45	27	"
	85	172	"
	62	202	"
	81	349	"
	30	160	"
	62	208	"
	48	112	"
	55	61	"
	41	76	Garn.chlorite qtz/ schist
	36	78	"
	38	45	"
	72	311	"
	78	313	"
	80	180	"
	70	85	"
	21	317	"
	45	N.	"
	62	73	"
	52	187	"
	56	90	"
	71	144	"
	72	176	"
	38	73	"
	21	312	Chlorite quartzite/ Schist
	46	136	"
	50	87	"

Location	Amount	Direction	Rock Type
	24	72	Chlorite qutz/Schist
	65	71	"
	62	186	"
	68	182	Felds.Trem.Quartzite
	47	90	"
	69	131	"
	34	285	"
	65	75	"
	62	192	"
	34	293	"
	69	128	"
	52	294	"
	85	27	"
	41	320	Felds. quartzite
	75	102	"
	56	53	"
	50	322	"
	67	100	"
(4100-4200)	75	208	Garn.chlorite qtz/Schist
	50	178	"
	80	42	"
	28	120	"
	59	75	"
	78	342	"
	81	345	"
	75	205	Amplubole bearing Garn.Chl.Q/Sch.
	60	93	"
	47	21	"
	66	213	"
	38	124	"
	80	212	"
	62	152	"
	48	57	"
	58	42	Garn.chlorite qrtz/Sch.

Location	Amount	Direction	Rock Type
	88	182	Garn.chlorite quartzite/Schist
	60	41	"
	54	90	"
	50	186	"
	31	73	"
	48	180	"
	38	120	"
	42	28	"
	52	48	"
	49	137	"
	57	53	"
	33	172	"
	59	48	"
	40	178	"
	12	306	"
	75	47	"
	90	12-192	"
	57	38	"
	62	301	"
	70	316	"
	80	252	"
	43	351	"
	81	120	"
	67	180	"
	62	181	Chlorite qutz/Schist
	90	40-230	
	80	300	"
	52	82	"
	86	202	"
	78	307	"
	64	6	"
	17	318	"
	90	90-270	"
	21	142	Felds.Tran.quartzite with Magn.quartzite
	27	145	"
	80	4	"

Location	Amount	Direction	Rock Type
	90	30-210	Felds.Trem.quartzite with Magn.quartzite.
	47	332	"
	85	32	"
	65	296	"
	52	76	"
	37	197	"
	43	73	"
	42	210	"
	71	291	"
	78	112	"
(4200-4300)	70	335	Amplubole bearing Garn.chlorite quartzite/schist
	76	297	"
	63	184	Gan.chlorite quartzite/schist
	45	48	"
	67	303	"
	63	181	"
	52	51	"
	90	10-190	"
	35	90	"
	82	300	"
	43	181	"
	60	73	"
	67	285	"
	90	7-187	"
	58	48	"
	31	113	"
	62	283	"
	20	110	"
	58	324	"
	42	69	"
	28	357	"
	70	307	"
	70	310	"
	42	123	"

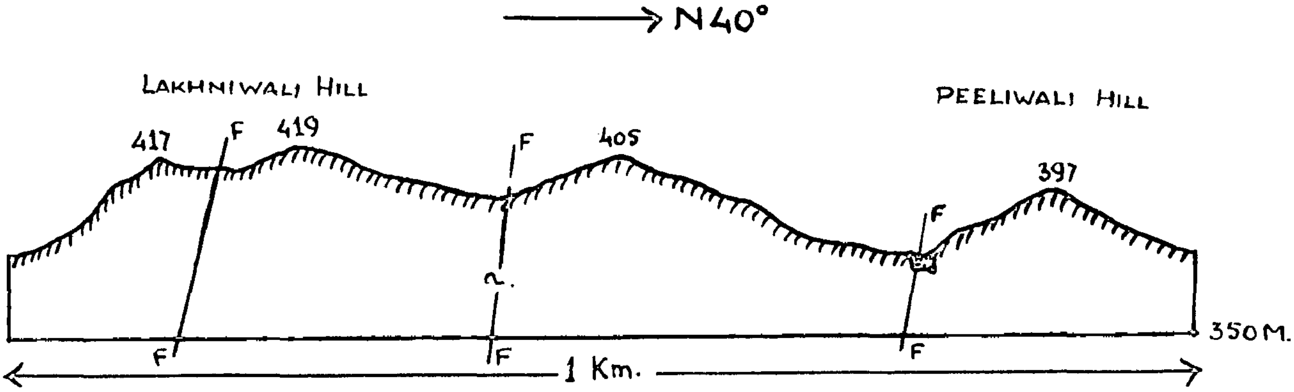
Location	Amount	Direction	Rock Type
	45	81	Gan.chlorite quart-zite/schist
	90	18-198	
	70	21	"
	44	111	"
	56	180	"
	42	120	"
	57	176	"
	54	175	"
	48	81	"
	37	185	"
	48	93	"
	57	303	"
	58	57	"
	62	31	"
	47	191	"
	71	72	"
	80	287	"
	50	353	Chlorite quartzite/schist
	52	68	"
	78	307	"
	67	301	"
	45	117	"
	80	182	"
	41	356	"
	67	58	"
	23	125	"
	82	65	Felds.Tre.quartzite
	30	131	"
	90	35-215	"
	35	133	"
	40	116	"
	65	330	"
	46	206	"
	48	91	"
	61	72	"

Location	Amount	Direction	Rock Type
(4300-4400)	53	192	Garn.chlorite quart-zite/schist
	80	54	"
	45	282	"
	63	18	Felds.Trem.quartzite
	30	138	"
	90	49-229	"
	48	323	Amplubole bearing garn.chlorite quart-zite.
	70	15	"
	46	327	"
	20	150	"
	62	73	"
	45	317	Garn.chlorite quart-zite/schist
	59	168	"
	46	N	"
	80	96	"
	48	312	"
	48	296	"
	52	79	"
	52	313	"
	20	308	"
	38	321	Chlorite quartzite/schist
	55	127	"
	48	293	"
	45	352	"
	62	258	"
	65	51	"
	38	132	"
	70	180	"
(4400-4500)	58	304	Amplubole bearing Garn.chlorite qurtz/schist
	69	262	"
	70	49	"

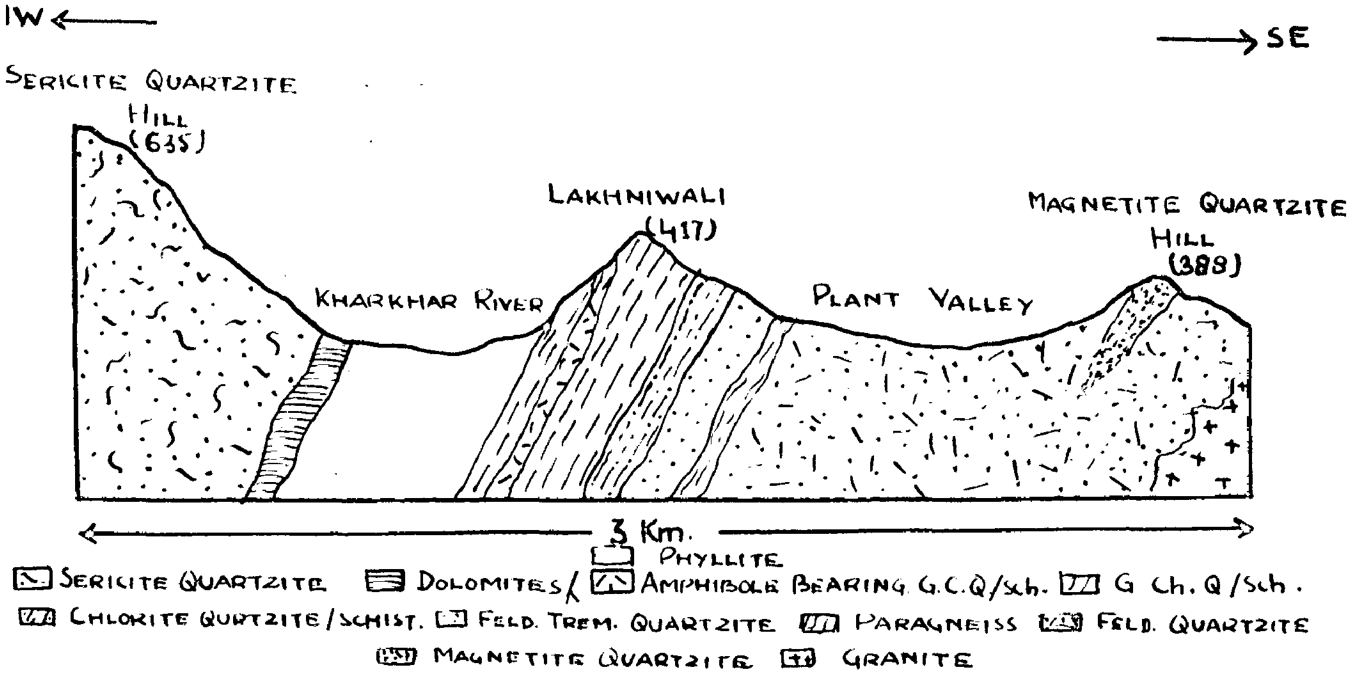
Location	Amount	Direction	Rock Type
	68	54	Amplubole bearing Garn.chlorite quartzite/ Schist.
	70	186	"
	78	48	"
	32	270	"
	35	158	"
	60	352	"
	38	N	"
	53	303	Gan.chlorite quartzite/ Schist.
	47	273	"
	43	152	"
	65	238	"
	8	316	"
	40	356	"
	82	336	"
	59	62	"
	58	255	"
	65	32	"
	55	327	"
	45	152	"
	32	76	"
	63	236	"
	62	342	"
	64	114	Chlorite quartzite/Schist
	70	180	"
	74	300	"
	90	32-212	"
	30	326	"
	80	307	"
	70	71	"
	90	56-236	"
	70	234	"
	60	305	"
	85	56	"
	30	11	"
	58	55	"
	40	N	"
	70	312	"

Loaation	Amount	Direction	Rock Type
	67	341	Chlorite quartzite/ Schist
	74	339	"
	90	41-231	Felds.Trem.quartzite
	65	308	"
	90	28-208	"
	48	346	"
	38	351	"
	48	326	Amplubole bearing chloritic quartzite
	67	86	"
	43	125	"
	55	196	"
	38	128	"
	42	137	"
(4500-4600)	41	325	Felds.quartzite
	44	328	"
	54	28	"
	52	125	"
	53	353	"
	52	182	"
	60	180	"
	49	356	Chlorite quartzite
	56	342	"
	87	195	"

FIGURES



... showing the control of ...



ig.2 ... eological sec... ... showing the ... of formations and control of rock ... to produce the ...

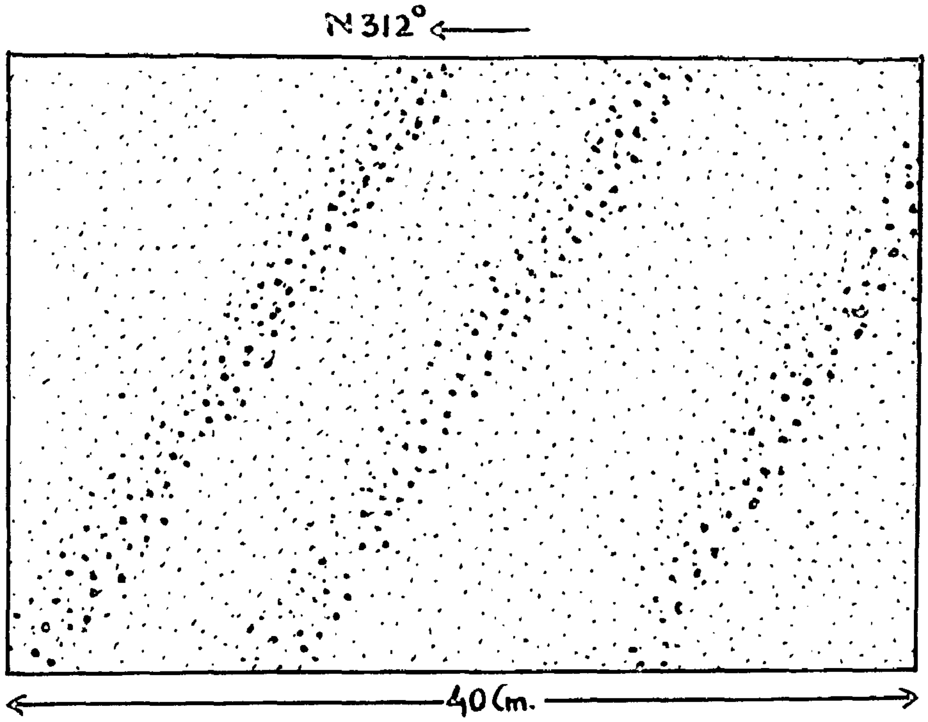
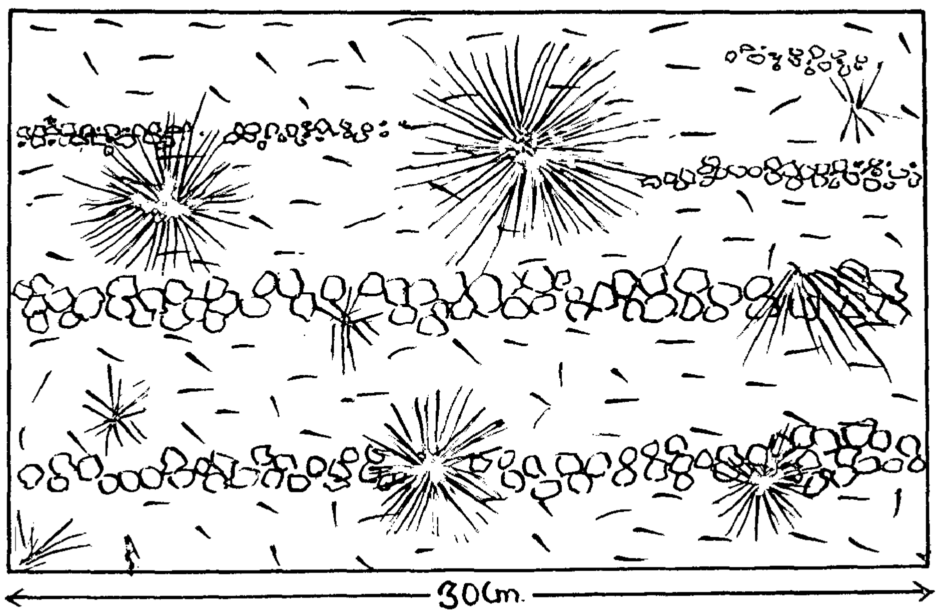


Fig.[illegible]. - [illegible] bedding [illegible] quartz [illegible] in feldspathic quartzite, Locality [illegible] of [illegible]



[illegible]

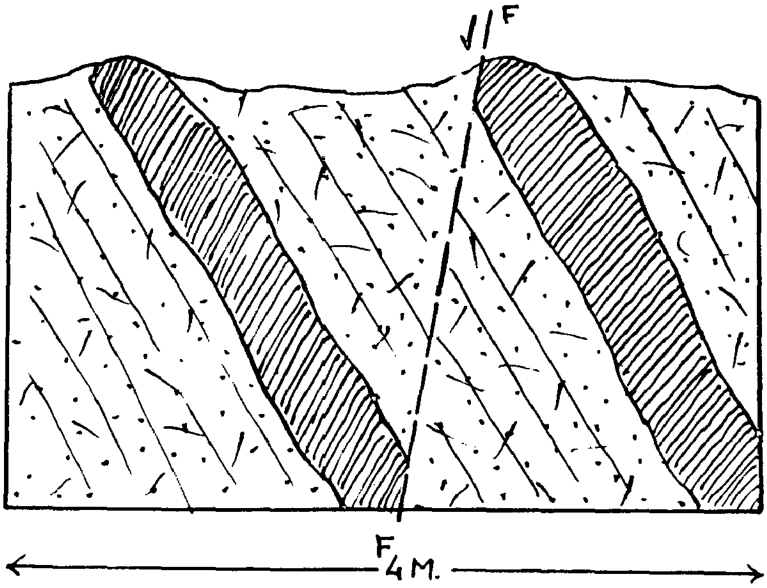


Fig. 5-A - Displacement of Magnetite amphibolite, band (lined closely) along one of the numerous small scale faults associated with them. These intrusives are emplaced within Feldspathic tremolite quartzite, south east of Lakhniwali hill.

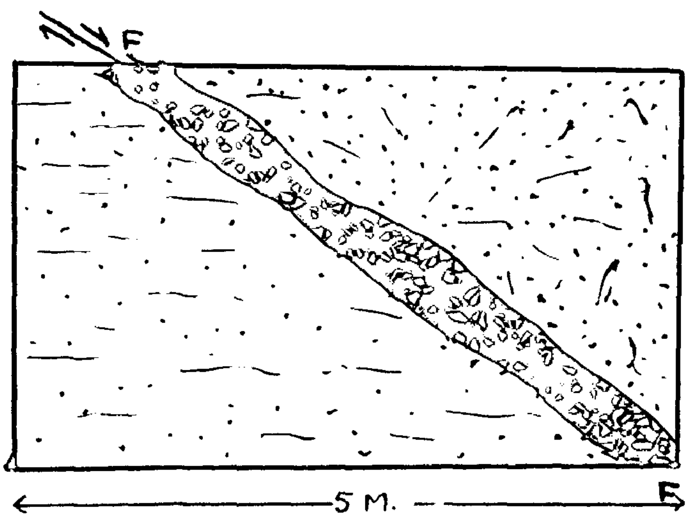


Fig. 5-B - Bracciation of quartzites along the fault zone north of Peeliwali hill causing abutment of Feldspathic quartzite (dotted with irregularities) in the north against Chlorite quartzite/schist on south. The fault is recemented by magnetite quartz solution.

)0 POLES OF S_1 & S_2 AT LAKHNIWALI-PEELIWALI HILL

1-10% 10-20% 20-25% 25-35% >35%

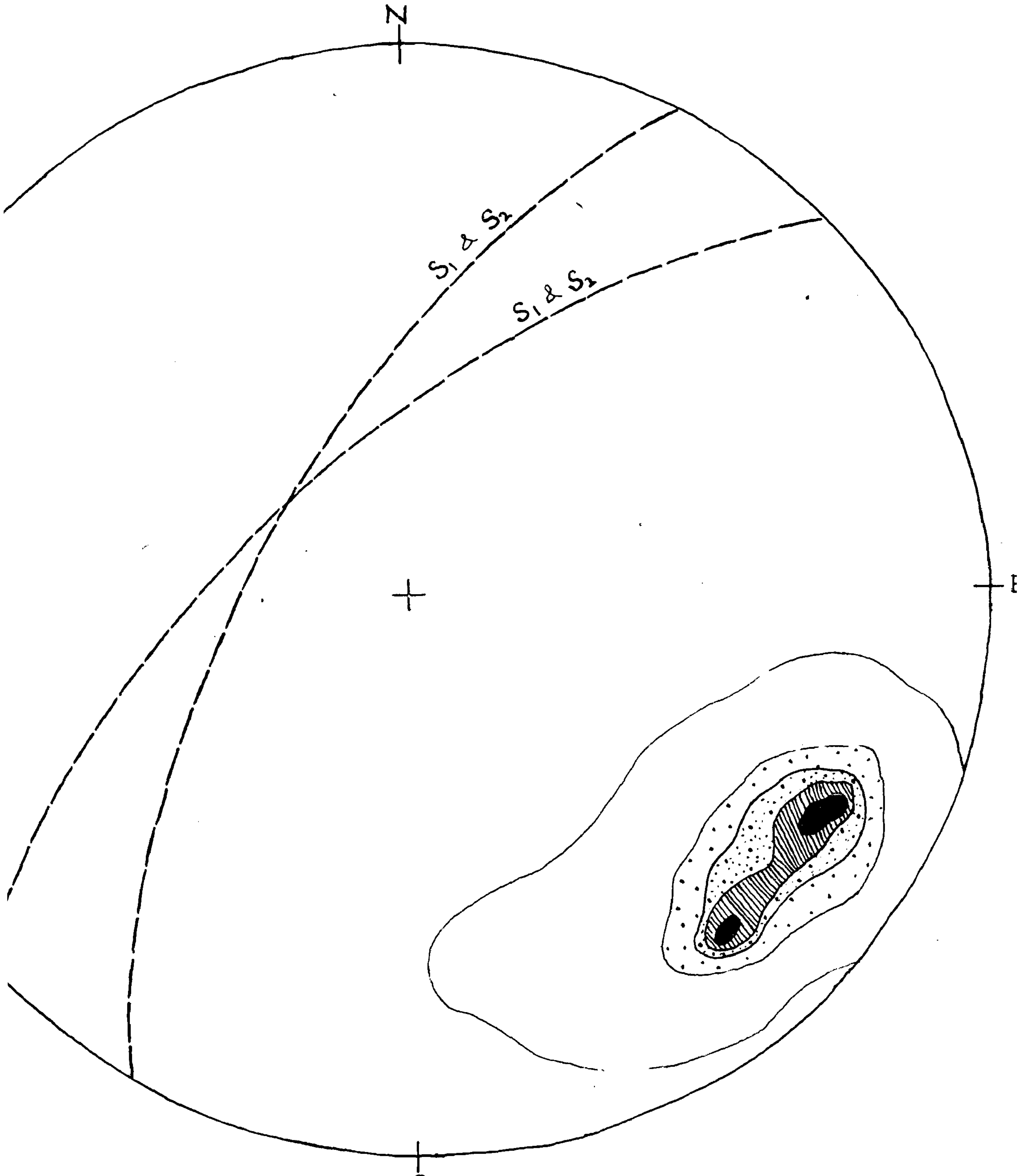


FIG. 6

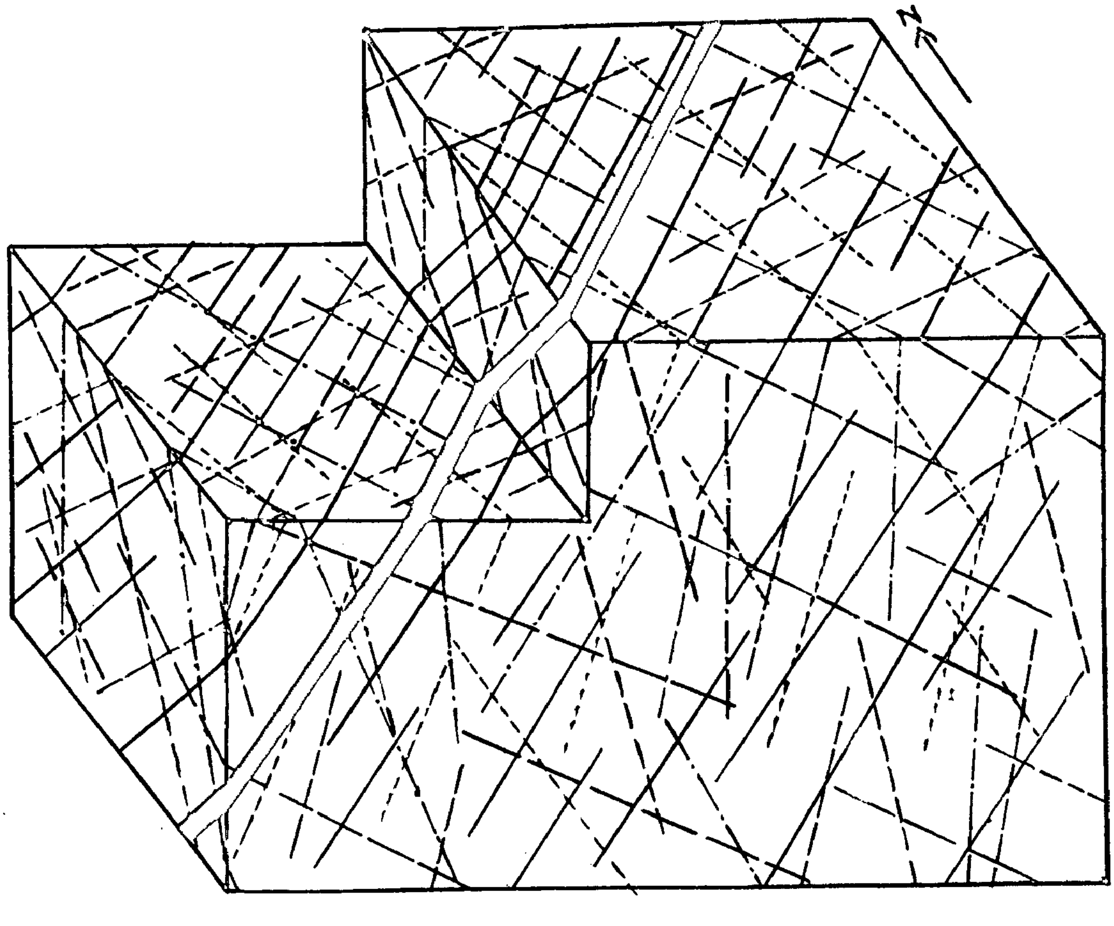
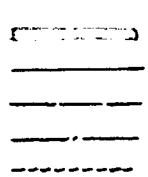


Fig.7. [illegible]



POINT DIAGRAM OF 350 POLES OF JOINTS
AT LAKHNIWALI-PEELIWALI HILL

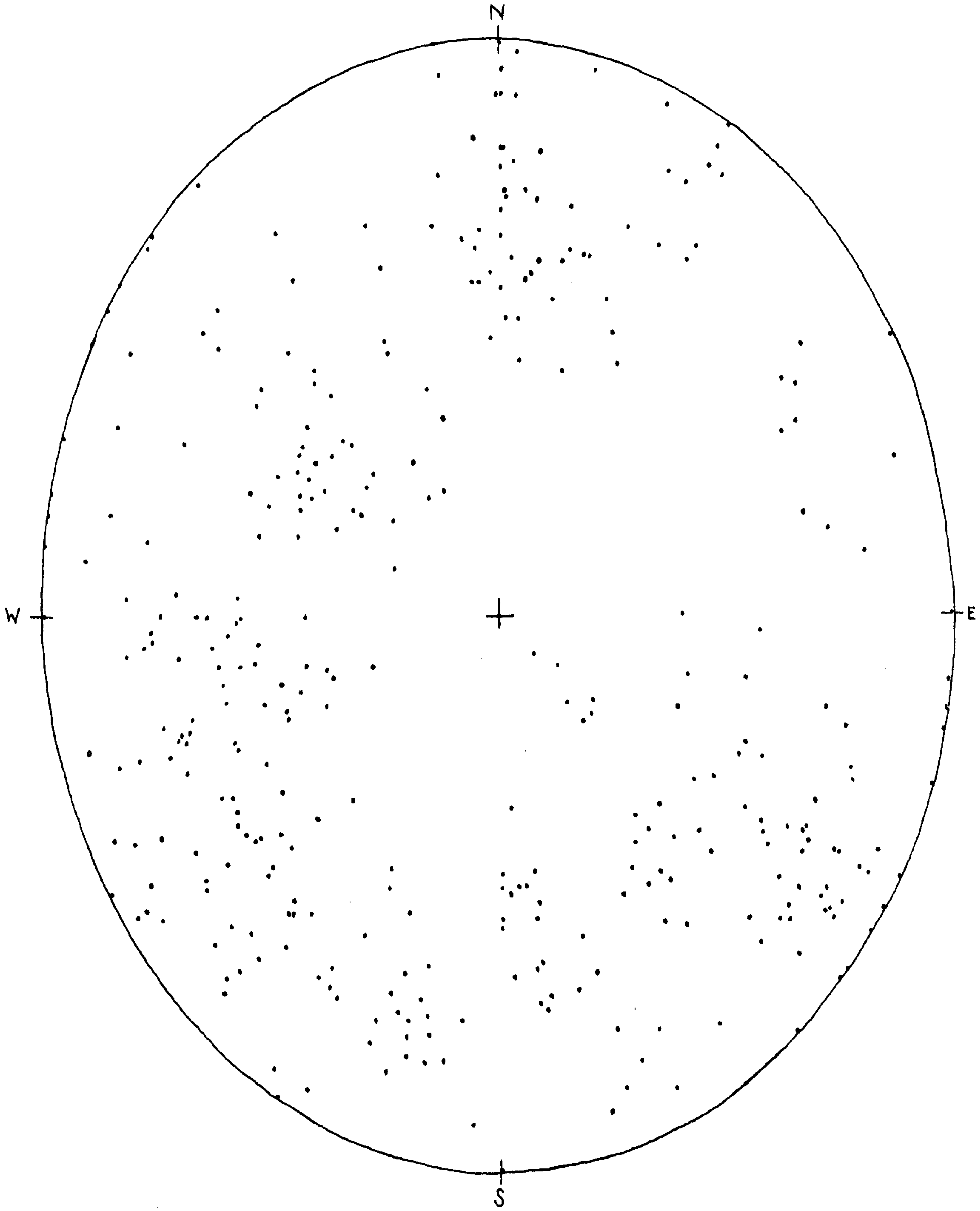


FIG. - 8

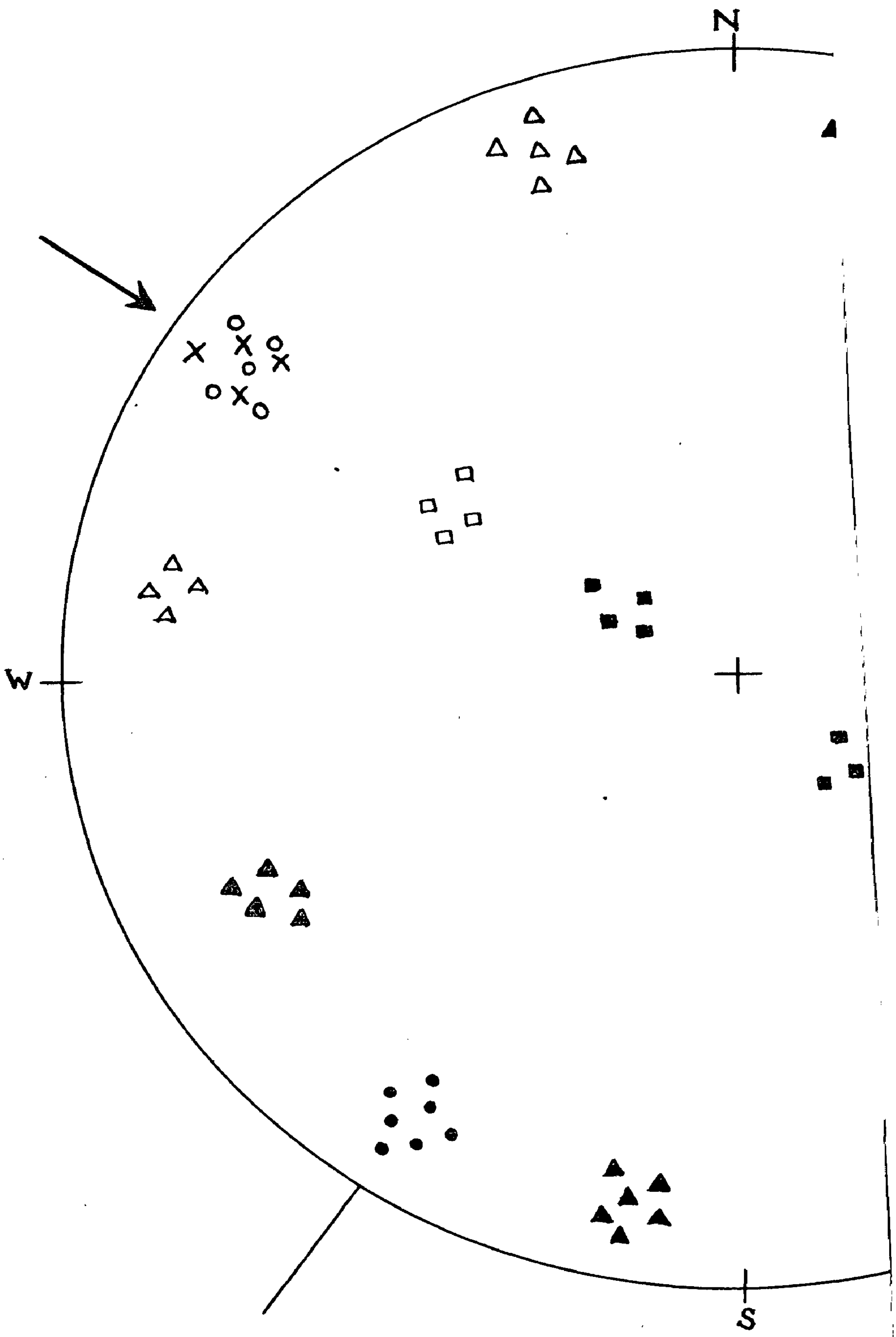


FIG.- 9

IDEALISED DIAGRAM OF POLE OF JOINTS AT LAKHNIWALI
BEETWEEN FOLD AXIS & JOINTS :- ● DIP JOINTS (F
JOINT (SECOND ORDER TENSION JOINTS), ▲ OBLIQUE JOINT
JOINT (SECOND ORDER SHEAR JOINTS), X STRIKE JOINT
□ STRIKE JOINT WITH DIP <45° (NORMAL SHEAR JOIN
(THRUST SHEAR J

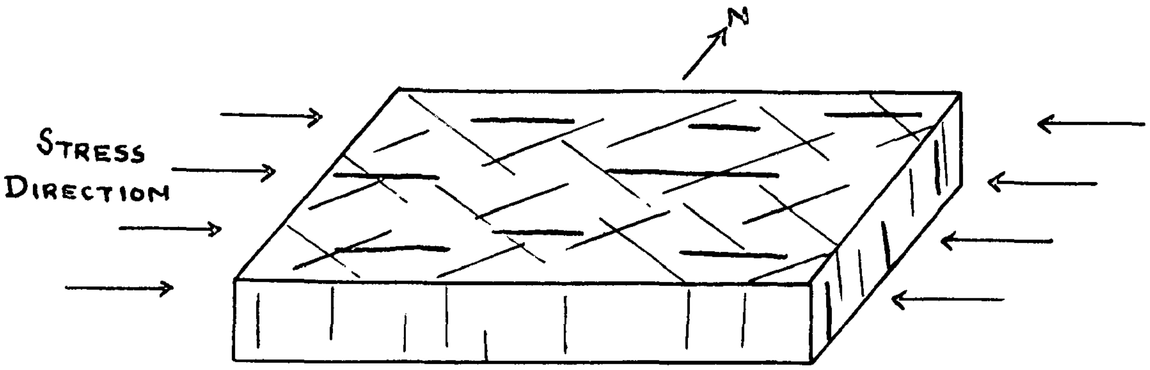


Fig. 10-A - Schematic diagram showing the development of First Order Tension joints (thick lines) and shear joints (fine lines) due to the stresses from the two sides when the beds are horizontal.

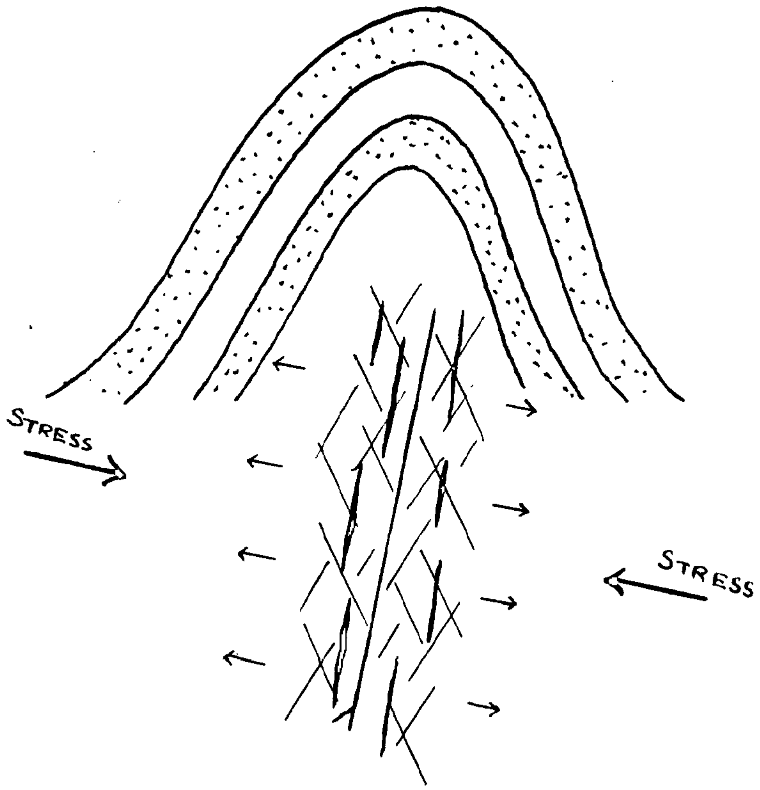


Fig. 10 -B - Schematic diagram showing the development of Second Order Tension joints (thick lines) and shear joints (thin lines) during the stage of folding of the rock in an anticline.

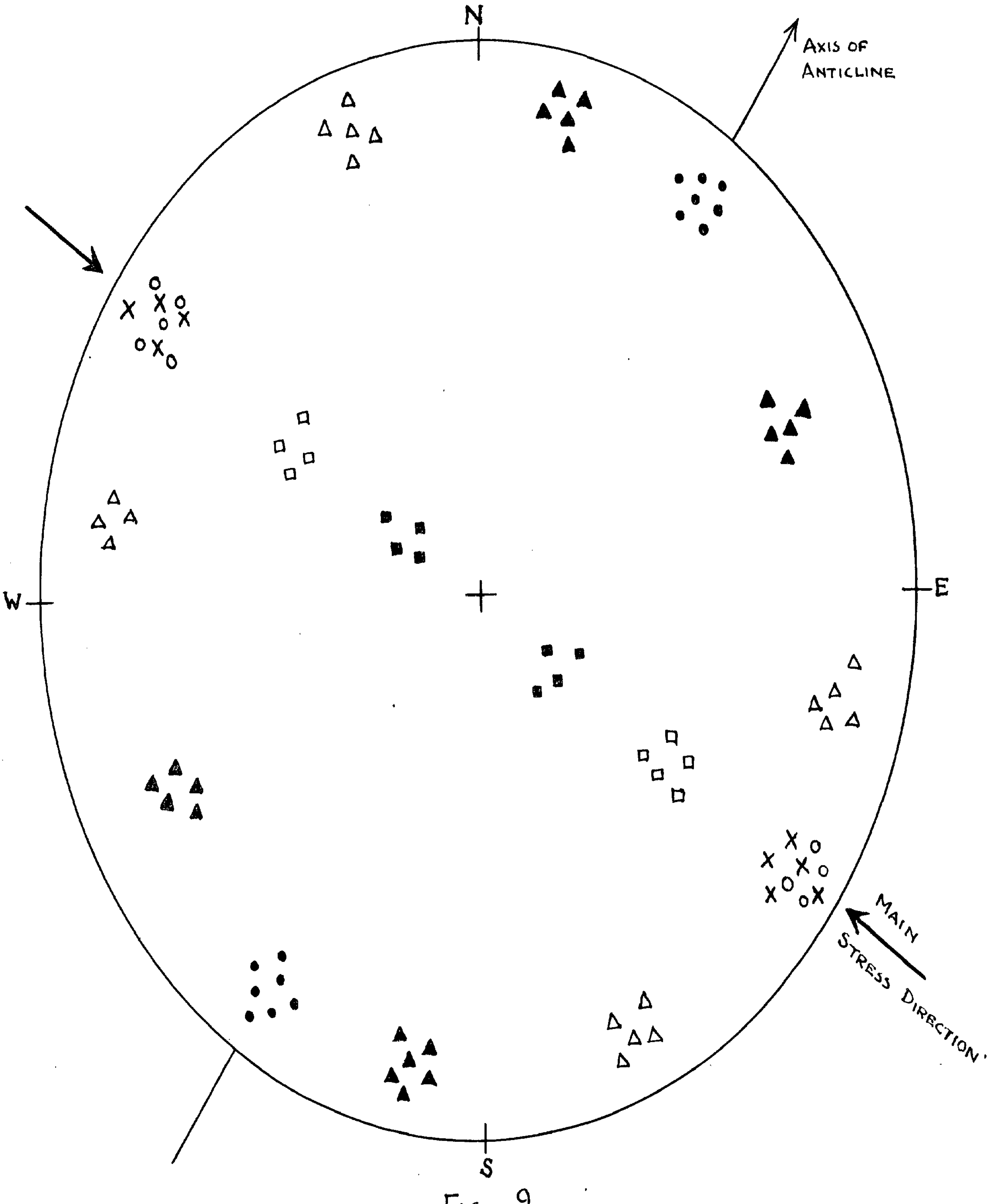
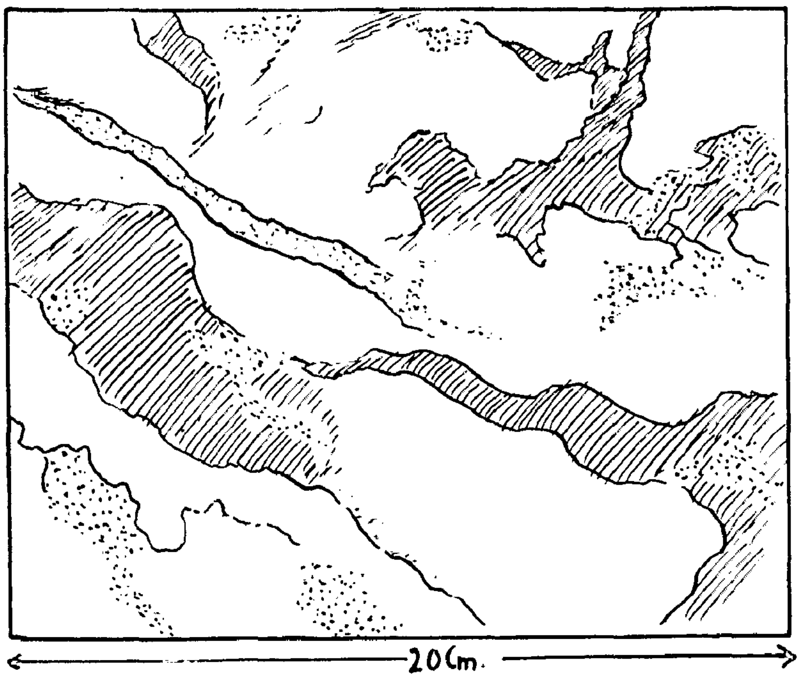


Fig.- 9

Idealised diagram of Pole of Joints at Lakhniwali-Peeliwali Hill showing Relationship beetween Fold Axis & Joints :- ● Dip Joints (First Order Tension Joints), o Strike Joint (Second Order Tension Joints), ▲ Oblique Joints (First order Shear Joints), △ Oblique Joint (Second Order Shear Joints), X Strike Joint (Frictional Shear Joints) □ Strike Joint with Dip <45° (Normal Shear Joints), ■ Strike Joint with Dip <20° (Thrust Shear Joints)


20Cm

[illegible]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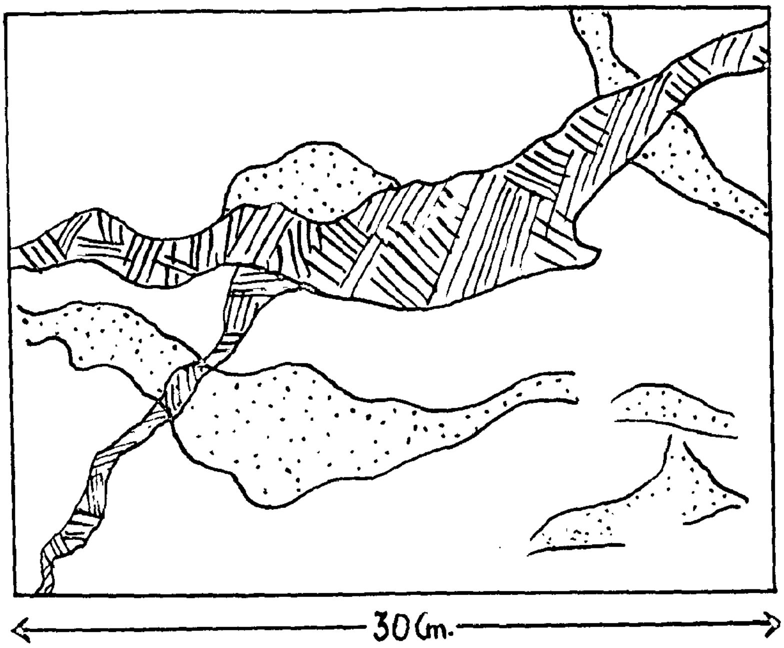
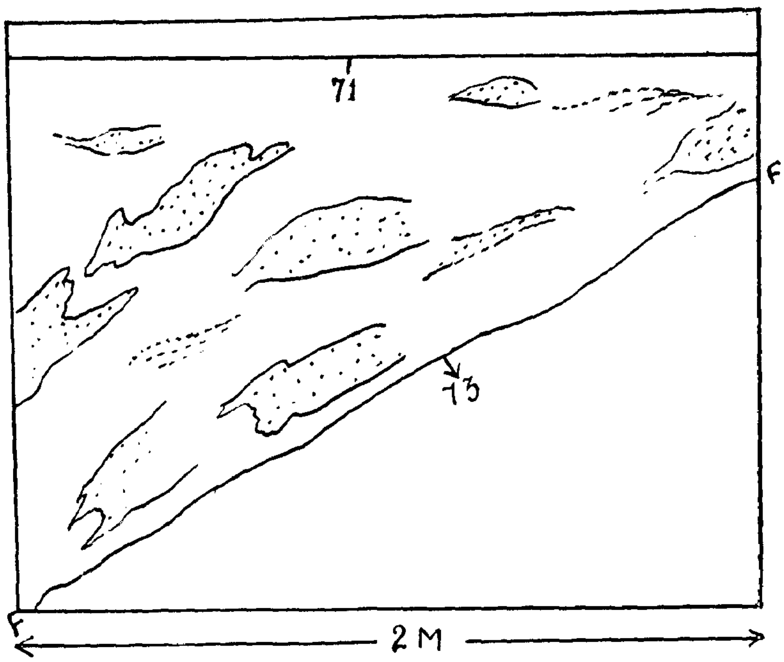


Fig.[illegible]. - [illegible] vein [illegible] cutting across [illegible] vein [illegible] and amphibole [illegible] bearing quartzite [illegible] (plain) showing the later origin of [illegible].



[illegible]. - [illegible] faults [illegible] bedding.

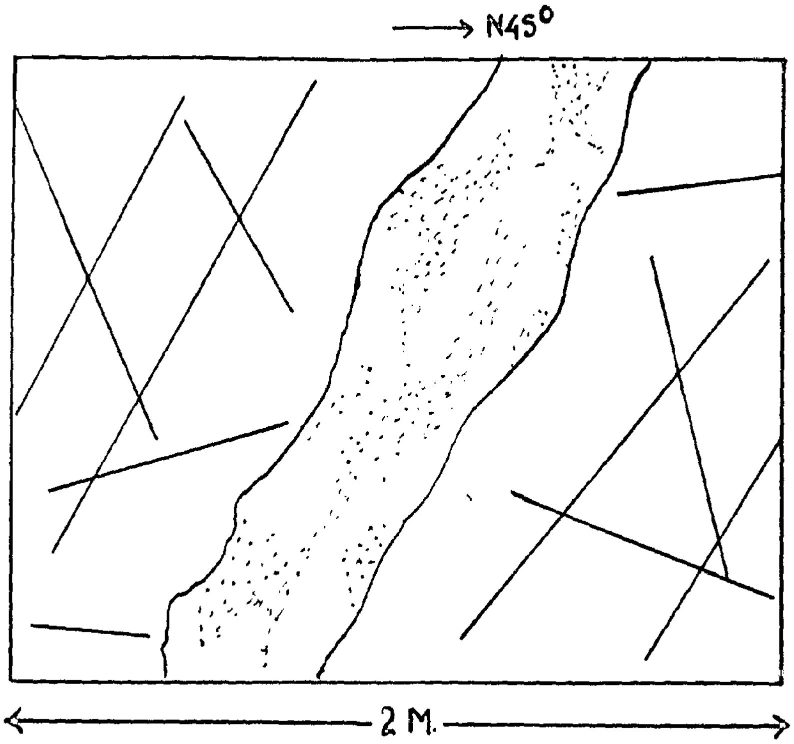


Fig.15 - A mineralised fault and joints at Lakhniwali N-Drive.

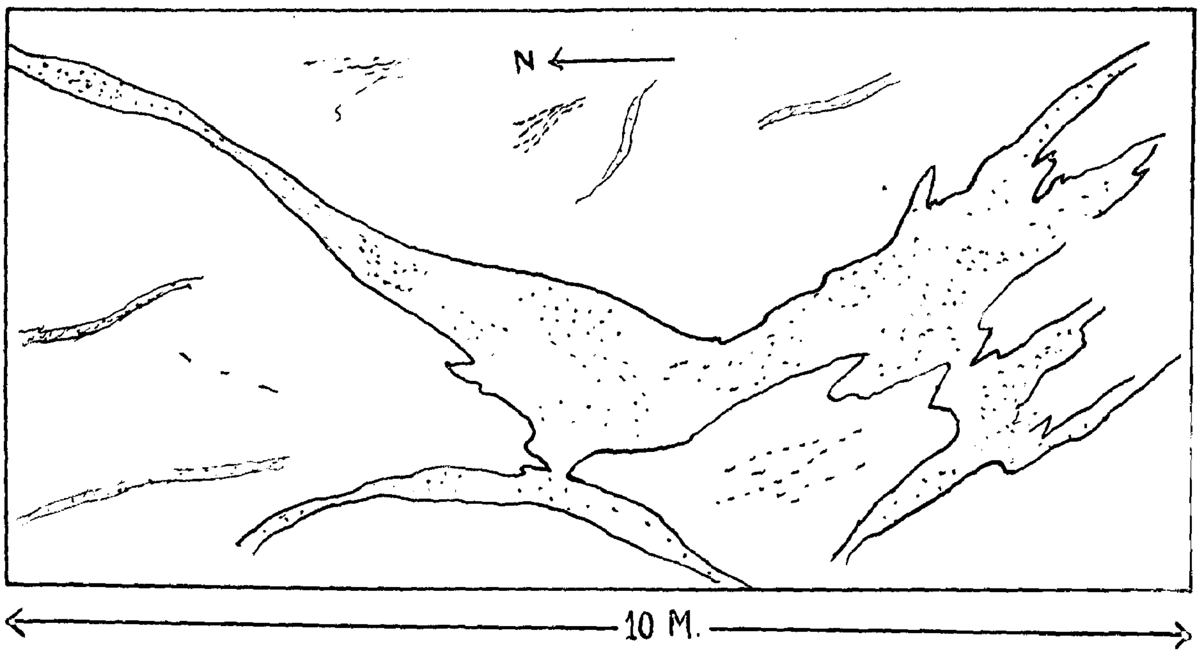


Fig.16 - Emplacement of Ore in the form of irregular lenses having gradational contacts with the country rock at Lakhniwali N-Drive.

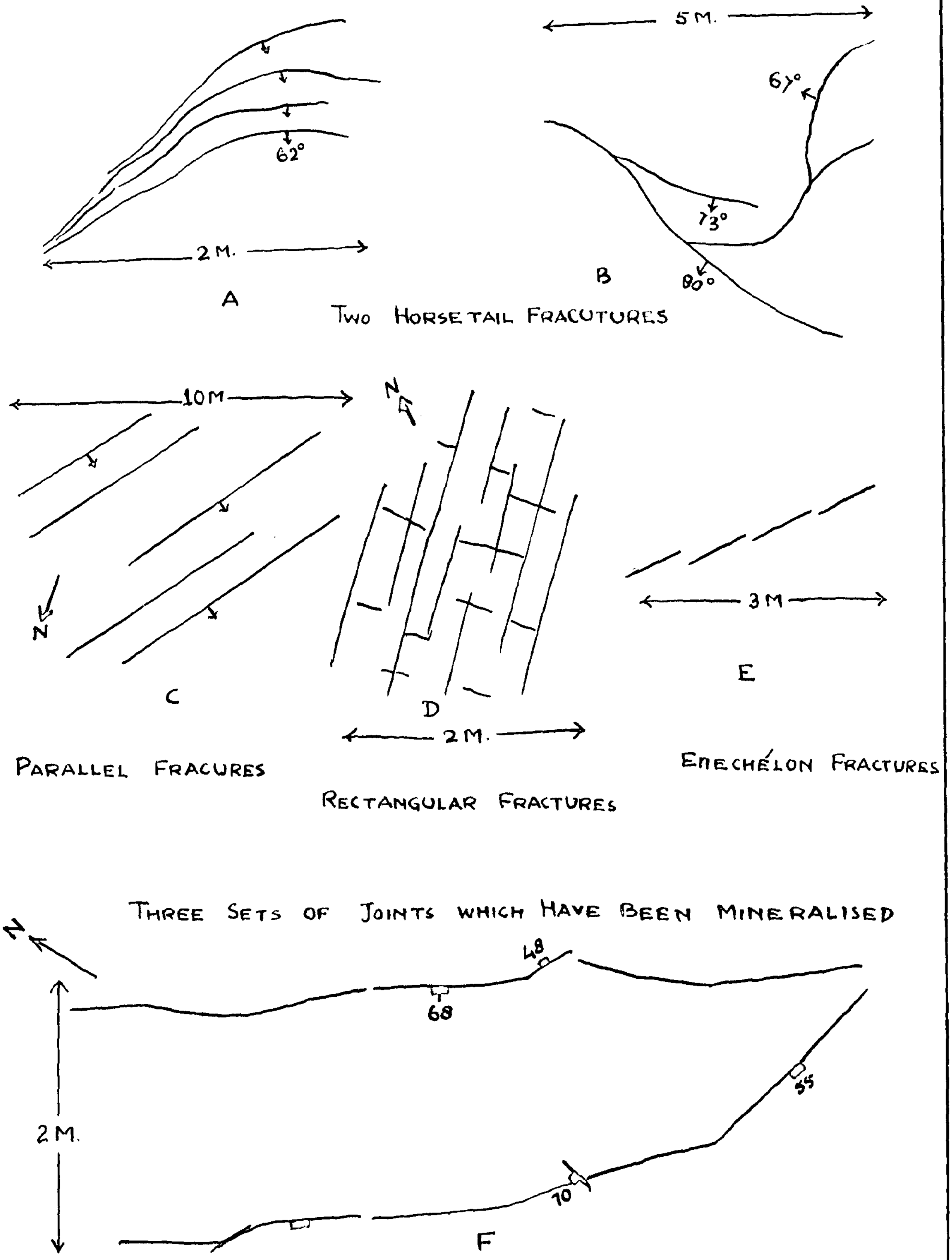


Fig- 17 Various Types of Vein Patterns at Lakhniwali-Peeliwali Mine.

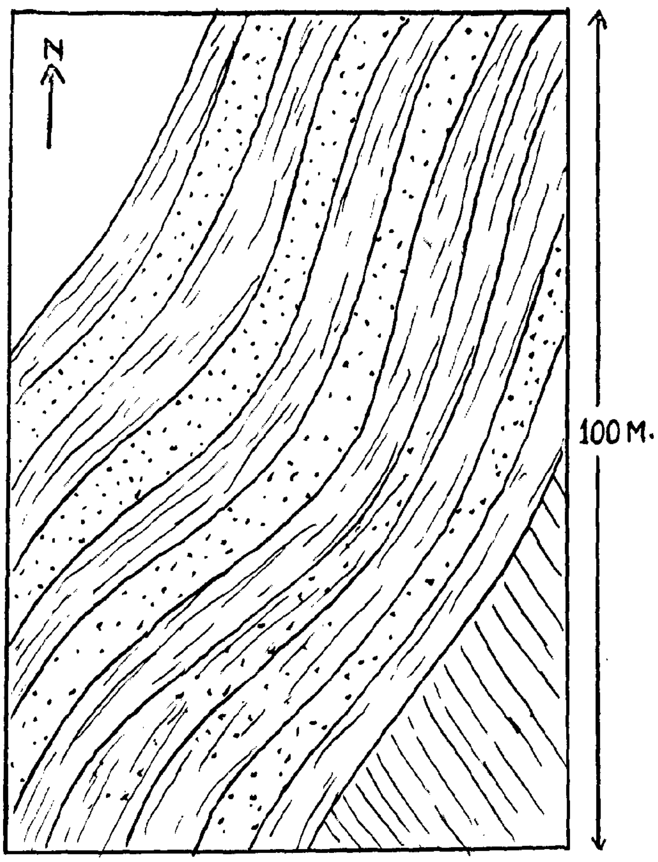


Fig.18 - A Broad Flexure on the western slopes of Lakhniwali hill top in the garnetiferous chlorite quartzite/schist rock.

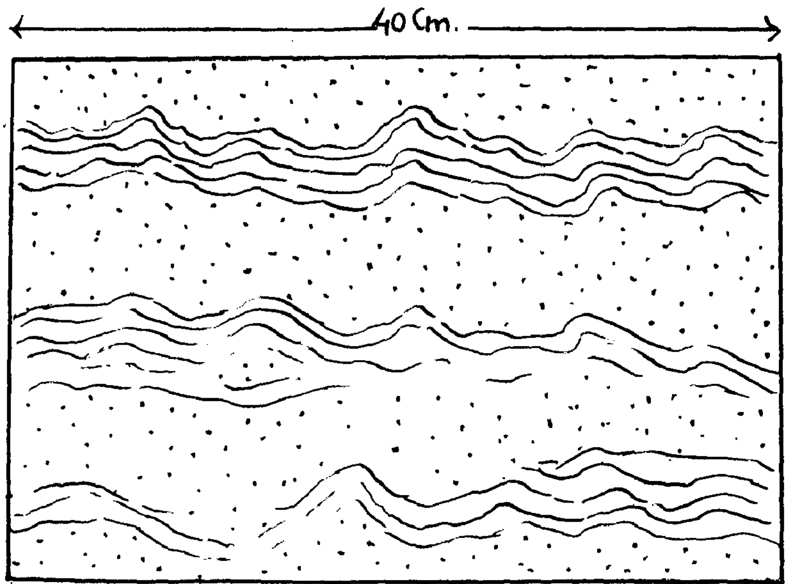


Fig. 19 - Puckering in the micaceous bands (lined) interlayed with quartzo-feldspathic bands (dotted) in the Paragneiss north of Peeliwali hill.

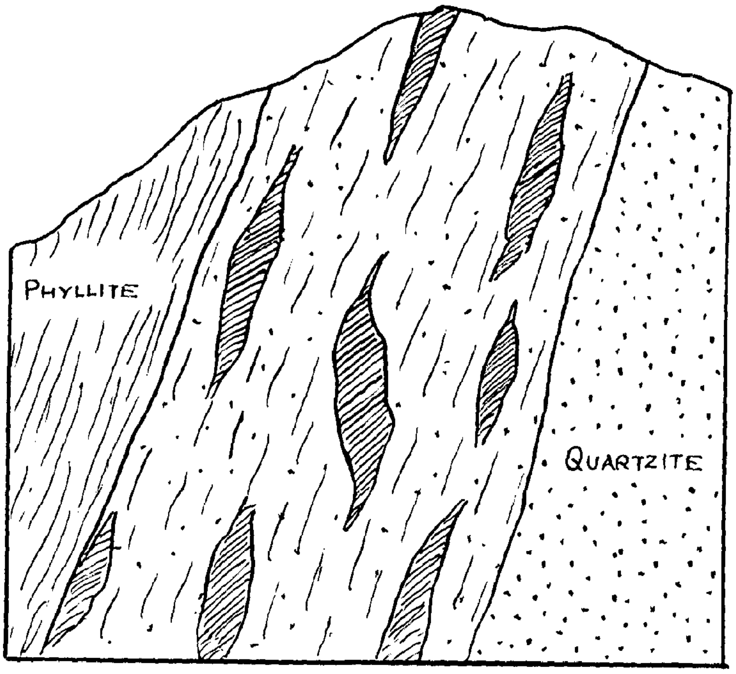


Fig. 20 - A generalised diagram showing irregular nature of mineralised lenses emplaced in the garnetiferous chlorite quartzite/schist in Khetri Copper Belt.

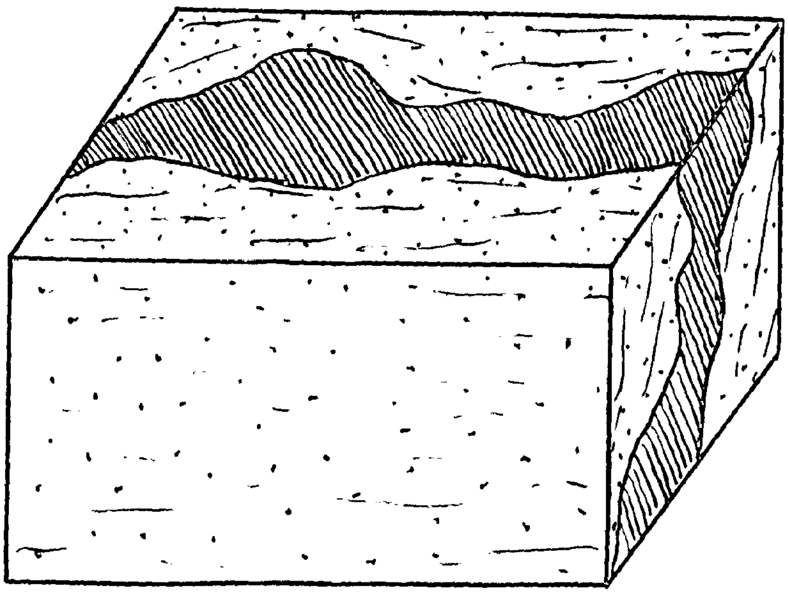


Fig. 21 - Pinching and swelling of a mineralised lens along the schistosity planes. These irregularities are present in both, vertical as well as horizontal planes.

PHOTOGRAPHS

FIELD PHOTOGRAPHS

PLATE 1 - A general view of the eastern slope of Lakhniwali hill dipping about 27°. Note the protruding magnetite - amphibolite quartz bands on the left and Singhana Camera facing hill behind electric pole. N 35°.

PLATE 2 - Control of joints pattern to give rise to sharp apexed ridges. Note the four set of joints.

Bedding joint dipping N310°, oblique Joints A dipping 32° due N50°, B - 60° due N250°, C-80° due N165° and a horizontal joint.

Camera facing N40°.
Locality - south of Peeliwali hill top.

Plate 12

Specimen No.4/508
Locality - north of Peeliwali hill.

Bands of dark (biotite and chlorite) and light (quartz, feldspar) colour minerals in paragneiss.

Plate 13

Specimen No. 4/

Locality - Western slope of Peeliwali hill.

Banded garnetiferous chlorite quartzite. Note the vertical bands of garnet (darker) interbedded with quartzite (lighter).

Plate 14

Specimen No.4/566

Locality - south west of Lakhniwali hill.

Typical radiating crystals of anthophyllite - cummingtonite in the garnetiferous quartzite rock, in the outcrops.

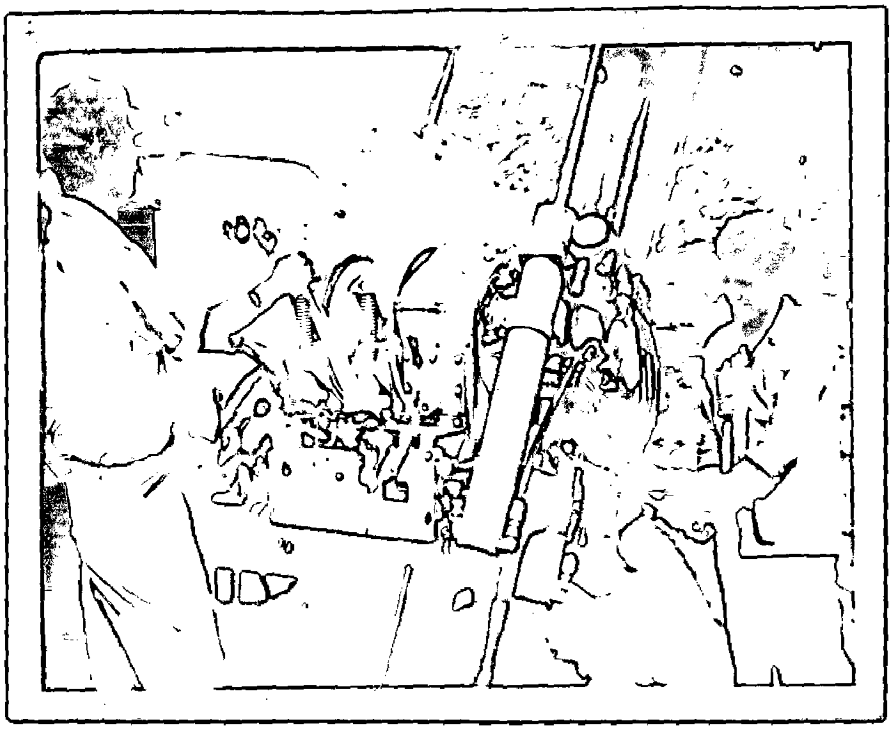


PLATE 11 - Inclined borehole drilling at 60° in progress on the Kharkhar river to cross the mineralised zone further east. Camera facing west.

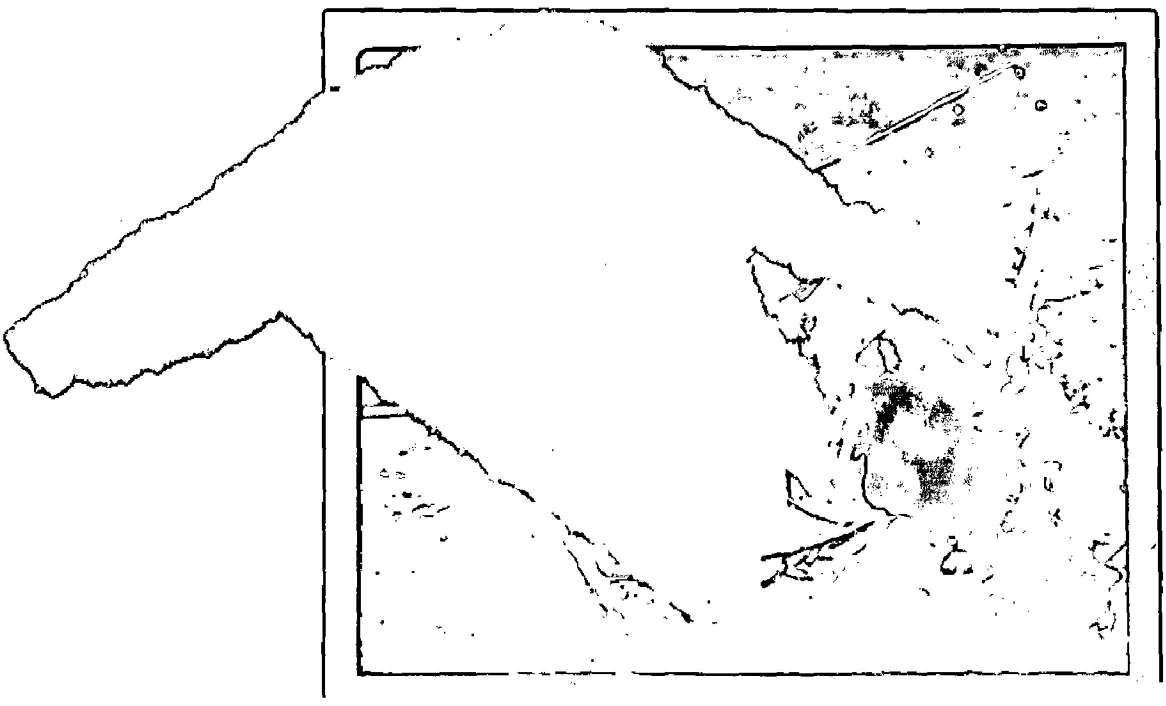


PLATE 7 - Peeliwali old working showing different smaller shafts and passages used for mining operations. Camera facing north.

PLATE 8 - Lakhniwali old working, with the vertical dip of schist foliation, camera facing south.

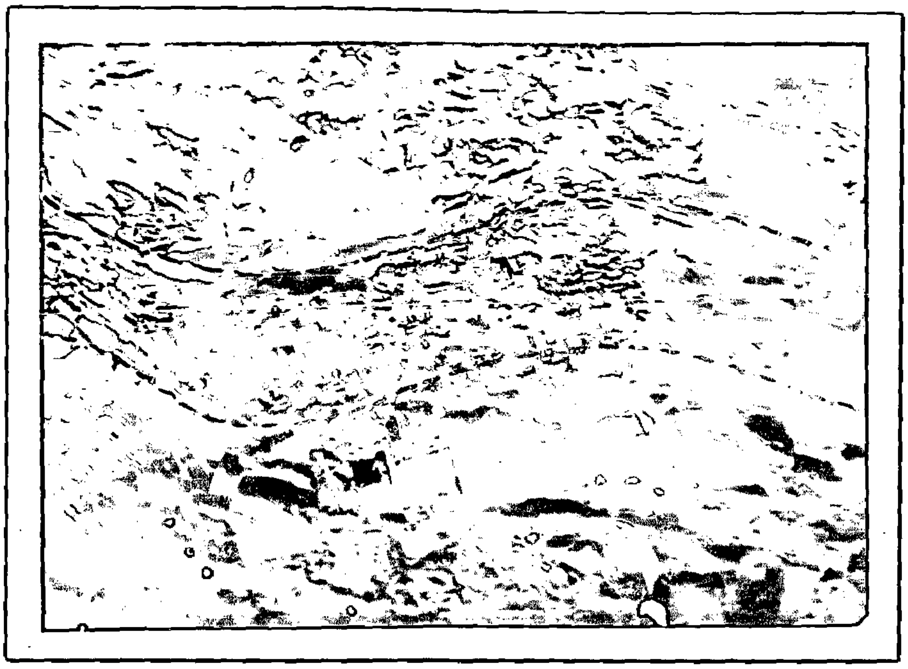
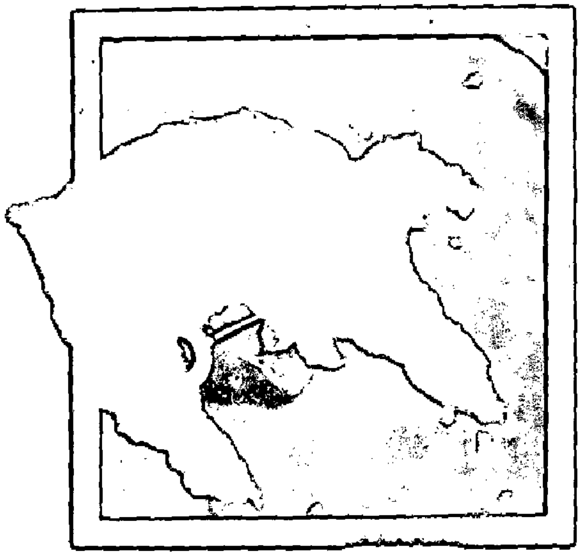


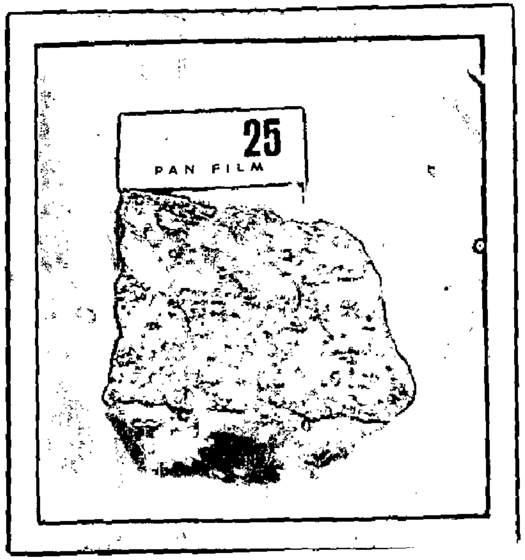
PLATE 5 - Folding in Paragneiss causing the breaking of interveining quartz - Feldspathic bands into blocks. Camera facing N310°, locality southern end of Lukhniwali hill.

PLATE 6 - Brecciation along a fault zone. Note the shearing of rocks on the two sides of fault. Camera facing N 120°, Locality western flank of Peeliwali hill top.

PLATE 3 - River Kharkhar on the western slope of the Lakhniwali -Peeliwali hill showing typical shrubby vegitation. In the background is sericite quartzite hill. Camera facing N270°.

PLATE 4 - Three sets of joints in garnetiferous chlorite quar[illegible]th of Lakhniwali hill. Bedd[illegible]due N315°. Dip jo[illegible]rike joint - 36° [illegible] N210°.

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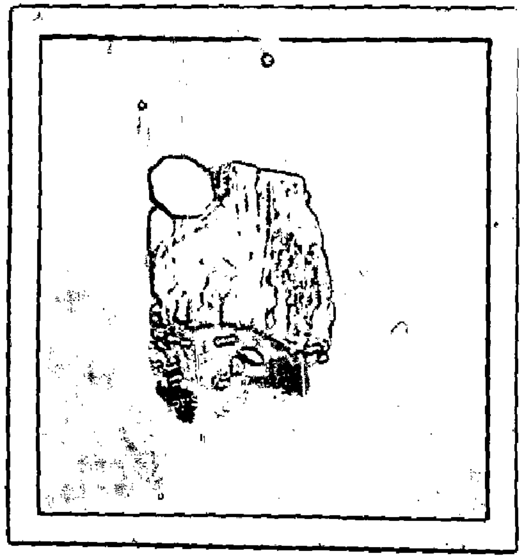


PLATE 18 - Specimen No.4/508

Locality - SSE end Lakhniwali hill.

A large prism of andalusite in Paragneiss, showing inclusion of quartz grains (rounded white) giving rise to sieve structure. Biotite (irregular) prismatic flakes are randomly oriented with varying shades due to pleochroism. The black (rounded) grains are zircon and larger octahedrons are of magnetite. In the background is quartz (clear) and feldspar (altered). 120x.

PLATE 19 - Specimen No.4/545

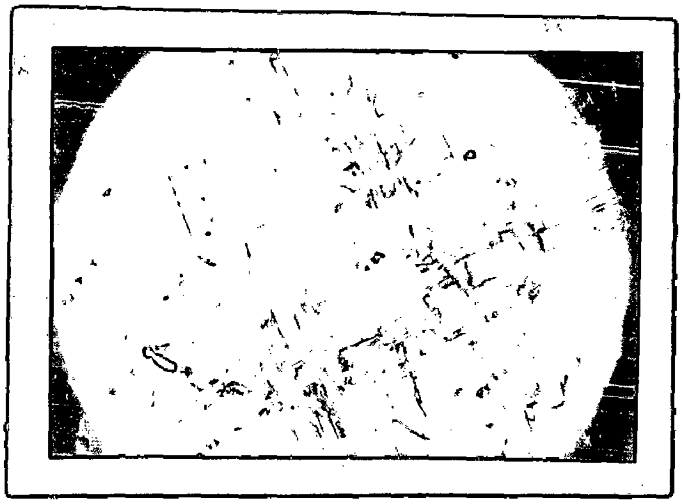
Locality - from eastern flank of Peeliwali hill.

Feldspathic Tremotite quartzite. Griss-Goss prismatic needles (dark grey) of tremotite, showing fracture across the cleavages. In the ground mass of quartz (clear) and altered feldspar (pitted). 120x.

PLATE 20 - Specimen No.4/547

Locality - Magnetite amphibolite intrusive band on eastern slope of Lakhniwali hill.

Hornblende (greyish)prismatic and basal section showing two directional cleavage and hypidiomorphic texture. The small magnetite (black) grains are disseminated. In the centre is a crystal of sphene (elongated gran) and quartz (clear) is in minor amount. 120x.



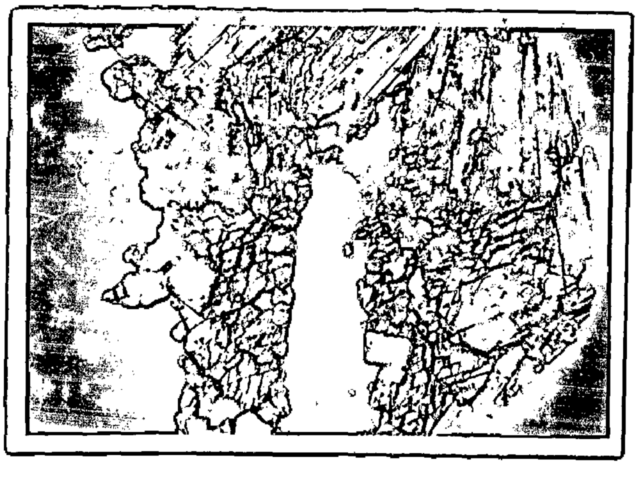


PLATE 21 - Specimen 6A/5

The Garnetiferous chlorite quartzite schist. Porphyroblast of Garnet (pitted) has quartz inclusions giving rise to sieve structure and is replaced by chlorite flakes (greyish) along fractures. The chlorites on the left show extreme development with subordinate quartz (grey) including some magnetite (black) and limonite (black irregular) on left 120x.

PLATE 22 - Specimen No.4/518

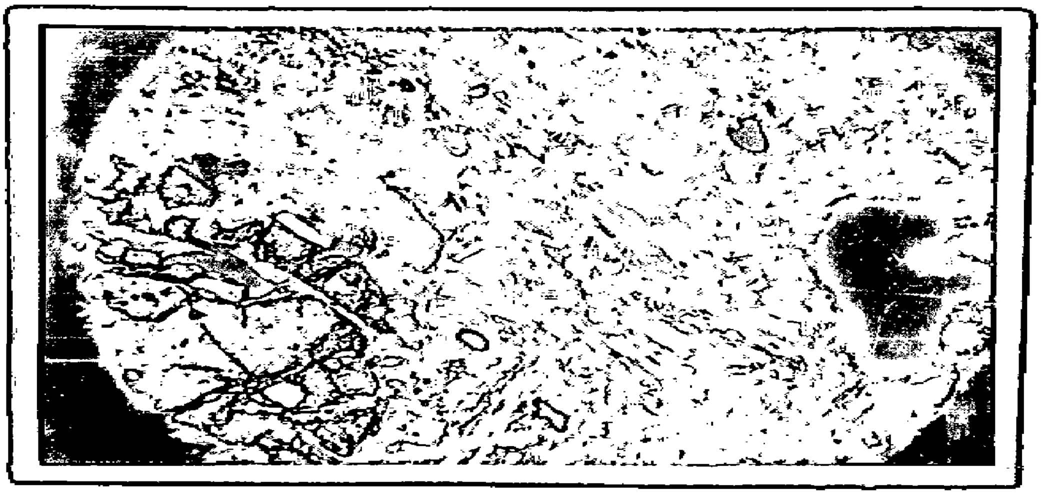
Locality - From the top of Peeliwali Hill.

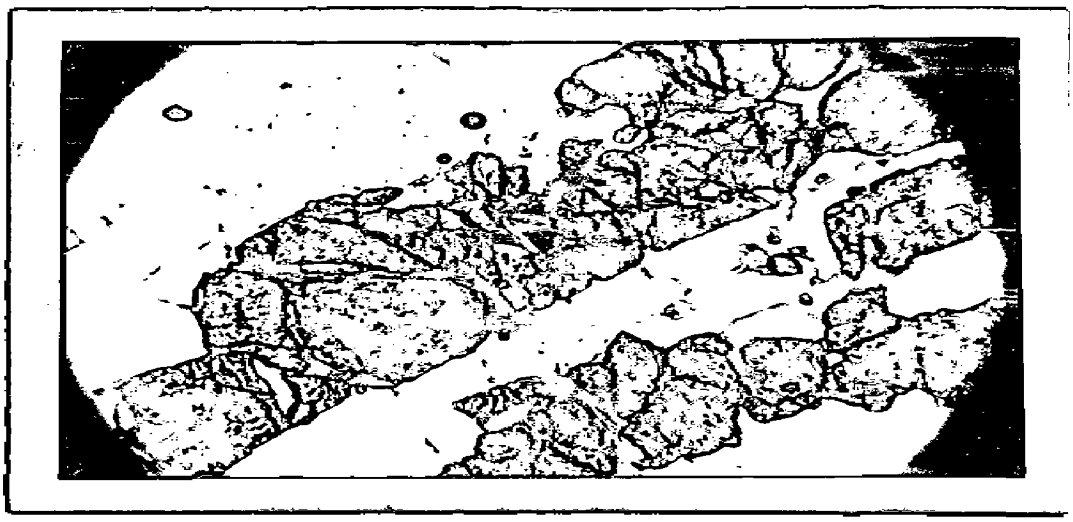
Banded garnetiferous chlorite quartzite. Garnet (pitted) occurring as porphyroblast and are replaced by chlorite (greyish) along the fractures. The black small grains are of magnetite and quartz in the groundmass 120x.

PLATE 23 - Specimen No.4/556.

Locality - north of Lakhniwali hill.

Garnetiferous (pitted dark drey) chlorite (light grey flakes) quartzite (base) schist. Quartz occurring as inclusion (both elongated as well as rounded) within the porphyroblast garnet showing sieve structure. Black octahedron of magnetite are disseminated in garnet as well as in chlorite. 120x.





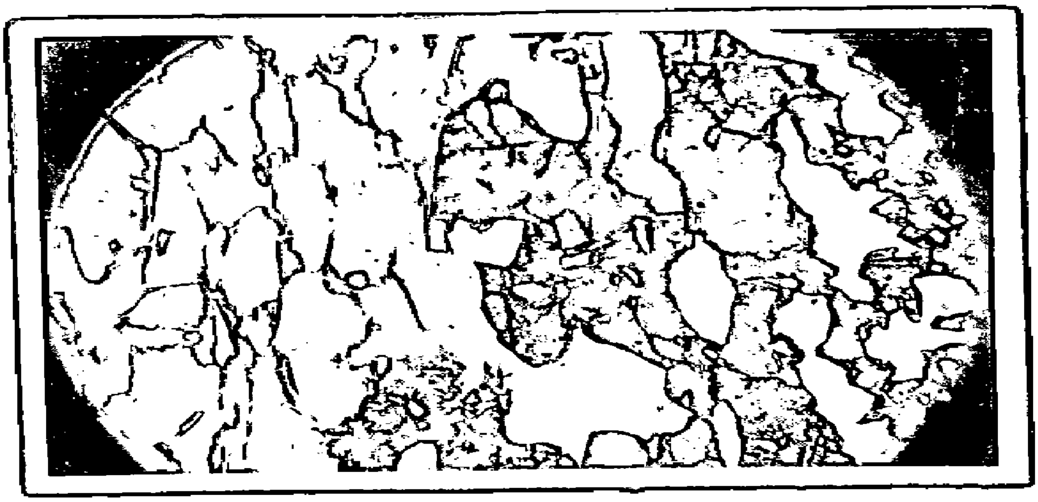


PLATE 24 - Specimen No.4/588

Locality - Lakhniwali NE-X_1 cut.

Inclusion of quartz (white) in the porphyroblast of anthophyllite (grey) exhibiting sieve structure. Magnetite (black) octahedrons also occur as of later origin replacing the two 120x.

PLATE 25 - Specimen No.4/584.

Locality - Lakhniwali NE-X_4-cut

Chlorite quartzite rocks, having cordirite (C) which have been been replaced by biotite along the fractures. Later sulphides (black) have replaced quartz (Q) and cordirite -120x.

PLATE 26 - Specimen No.4/529

Locality - south west of Peeliwali Old working.

Anthophyllite -cummingtonite (dark-grey) prims in the groundmass of quartzite, showing porphyroblastic texture. Amphiboles are partly replaced along the cleavages and fractures. Magnetite (black)occurs as dessimination 120x.


C
Q

PLATE 27 - Specimen No.4/615

Locality - From Lakhniwali mine dump

Interstitial filling texture by Chalcopyrite, (Ch), pyrrhotite P, and Calcite (C). These interstitial spaces have expanded as the mineralising solutions came. Note the replacement of quartz (dark grey) grains by chalcopyrite producing irregular boundaries.

PLATE 28 - Specimen No.4/608

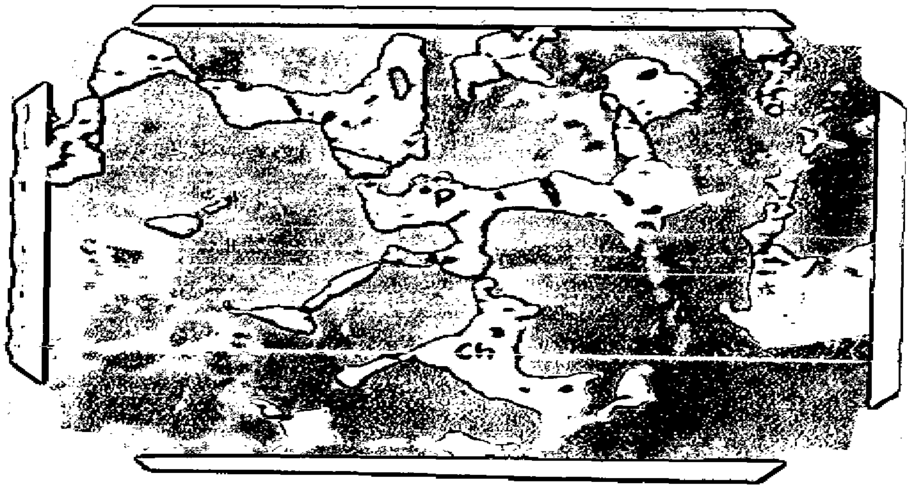
Locality -Lakhniwali Mine drump.

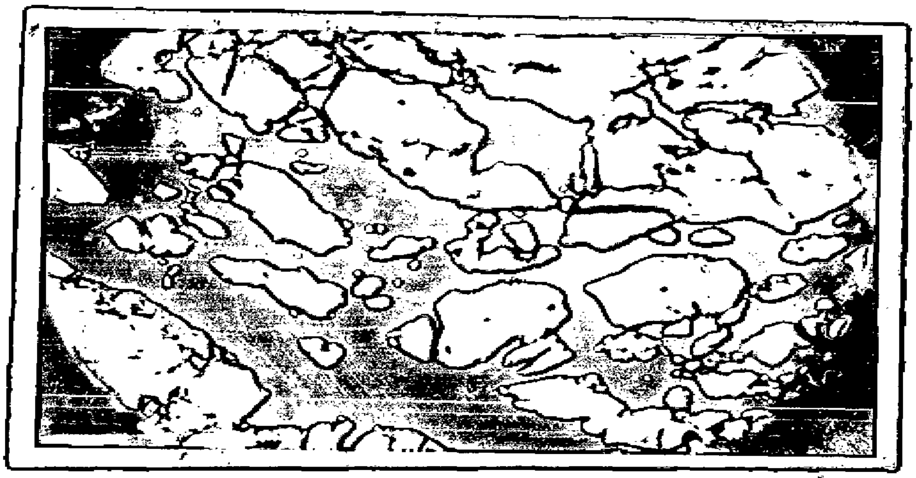
Braccia filling and replacement texture by pyrite (black) replacing quartz (white) and chlorite flakes (grey.)

PLATE 29 - Specimen No.4/512

Locality - From fault zone north of Peeliwali.

Bracciation of quartzite (dark grey) along the fault. Bracciated material is later on filled by the magnetite (greyish) giving rise to braccia filling texture.


P
Ch



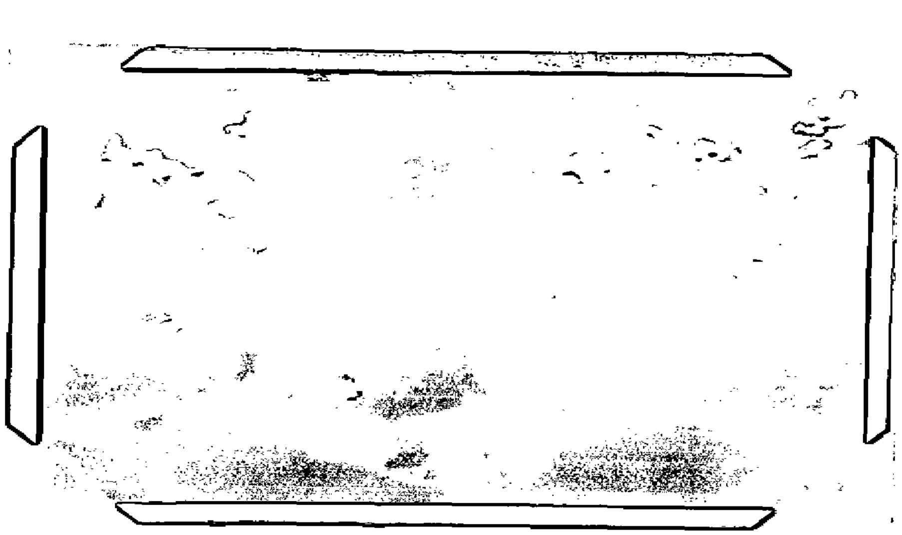


PLATE 30 - Specimen No.4/584

Locality - From NE-X_1-cut at Lakhniwali mine.

Prismatic crystal of Wolframite (W) enclosed within the magnetite (grey). Chalcopyrite (white) is replacing magnetite. While magnetite has modified the boundaries of wolframite.

PLATE 31 - Specimen No.4/614

Locality - From Lakhniwali Mine dump.

Replacement of quartz (black) by the chalcopyrite exhibiting replacement texture. The magnetite and pyrrhotite (pitted) on the top left corner occur as grains which have also been replaced by chalcopyrite (white). Note the colour variation in the chalcopyrite due to strain effect.

PLATE 32 - Specimen No.4/597.

Locality - From Lakhniwali NE-X_1 - cut

Braccia filling and replacement of quartz and mica (black) by pyrrhotite (grey) having cleavages and chalcopyrite (white) at right bottom.

PLATE 33 - Specimen No.4/598

Locality - From NE-X_1 CW, Lakhniwali Mine.

Two types of pyrite, though the boundaries are not very sharp, but the one is darker in colour and shows colour variation when rotated. This change in colour is attributed to impurities. Magnetite (M) occurs as replaced grain

GEOLOGICAL SECTION ALONG X-Y

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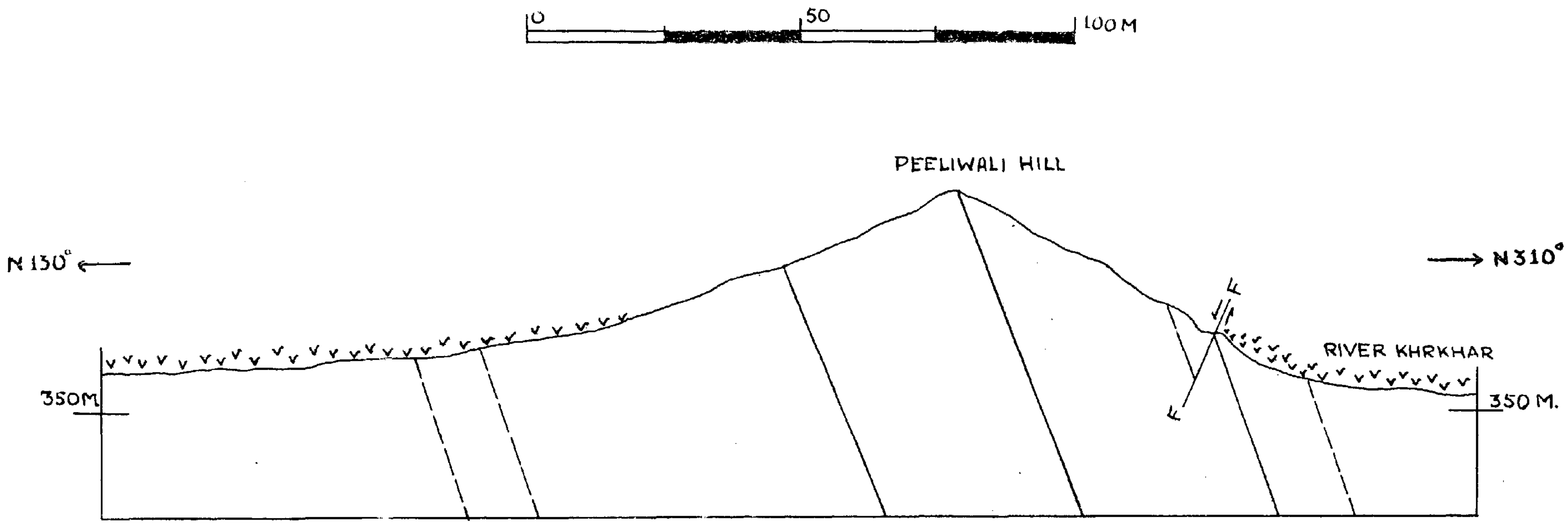

LEGEND - SAME AS GEOLOGICAL MAP

GEOLOGICAL SECTION ALONG X'-Y'

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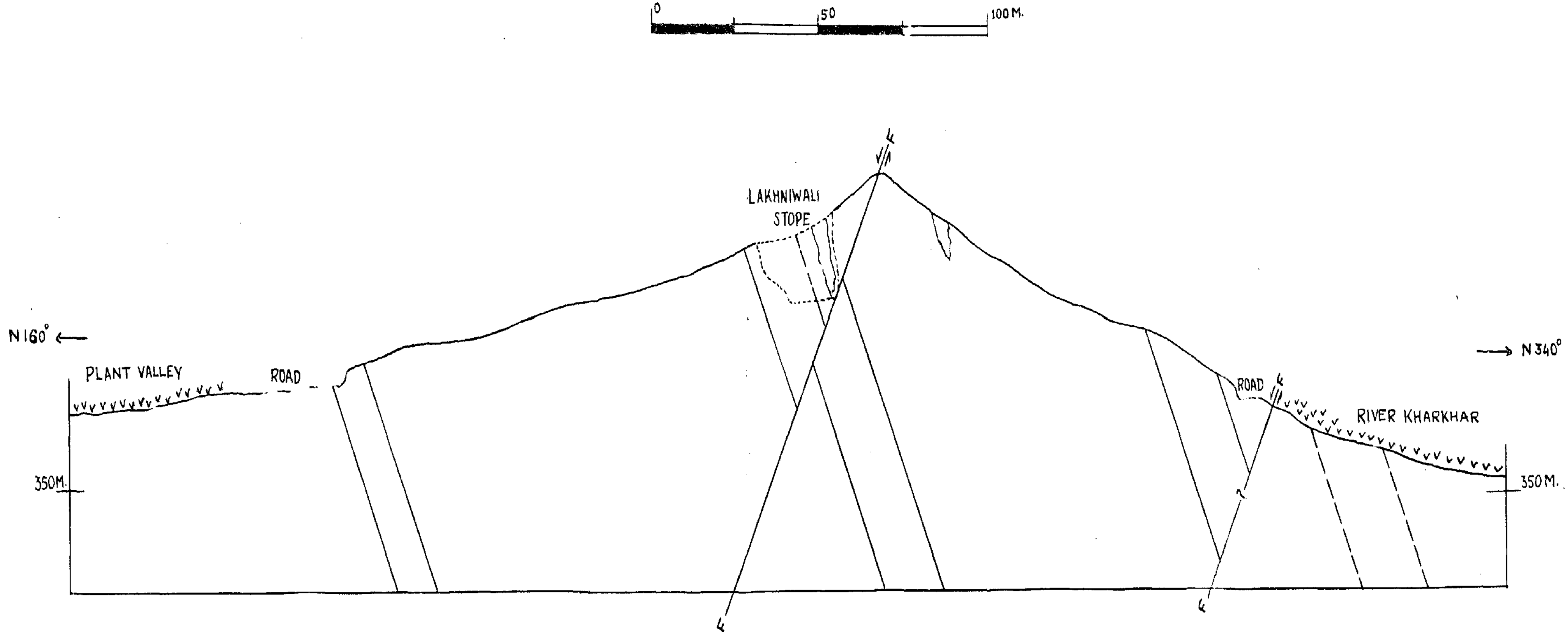

LEGEND - SAME AS GEOLOGICAL MAP