PETROLOGICAL AND STRUCTURAL STUDIES OF GULABGARH AREA, UDHAMPUR DISTT; JAMMU AND KASHMIR STATE

THESIS SUBMITTED TO THE UNIVERSITY OF JAMMU
FOR THE AWARD OF DEGREE OF
DOCTOR OF PHILOSOPHY
IN GEOLOGY
IN THE FACULTY OF SCIENCE

BY
AUTAR KRISHEN KOUL

Under the supervision of
Dr. T. R. Sharma
Prof. & Dean, Faculty of Science
Department of Geology
University of Jammu

Post Graduate Department of Geology
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JAMMU-180 001
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PETROLOGY

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C E R T I F I C A T E

Certified that

(i) the thesis embodies the work of Shri Autar Krishen Koul and is worthy of consideration for the award of Ph.D Degree

(ii) the candidate has worked under my supervision for the period required under rules

(iii) the candidate has put in the required attendance in this department during that period and

(iv) the conduct of the candidate remained satisfactory during the period of his research work.

(Dr.T.R.SHARMA) 29.6.1985
Supervisor

29.6.85

HEAD
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JAMMU - 180001

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29.6.85

(AUTAR KRISHEN KOUL)

CHAPTER - I

INTRODUCTION

From the start of Geological investigation in Kashmir Himalaya in preindependence period, the south-west of Pirpanjal Range has become centre of investigation by different workers not only because of its structural complexity which has bearing on the evolution of the entire Kashmir Himalaya but also because of its stratigraphic diversity.

The detailed geological mapping of this part of southern Pirpanjal Range was not done upto 1937. However, later worker's like Das, Hazra, Kohli and Nanda and several other members of Geological Survey Of India mapped the area. To the east of study area, the detailed investigation was done only upto Ramban and to the west, the detailed study was done upto Budil. Between Ramban and Budil the area of Gul-Gulabgarh has not been investigated in such detail manner as the eastern and western parts of Pir Panjal and, therefore, attracted the attention of the author. Hence, the present research investigation which was started in the month of July, 1978, received full concentration from the author till todate.

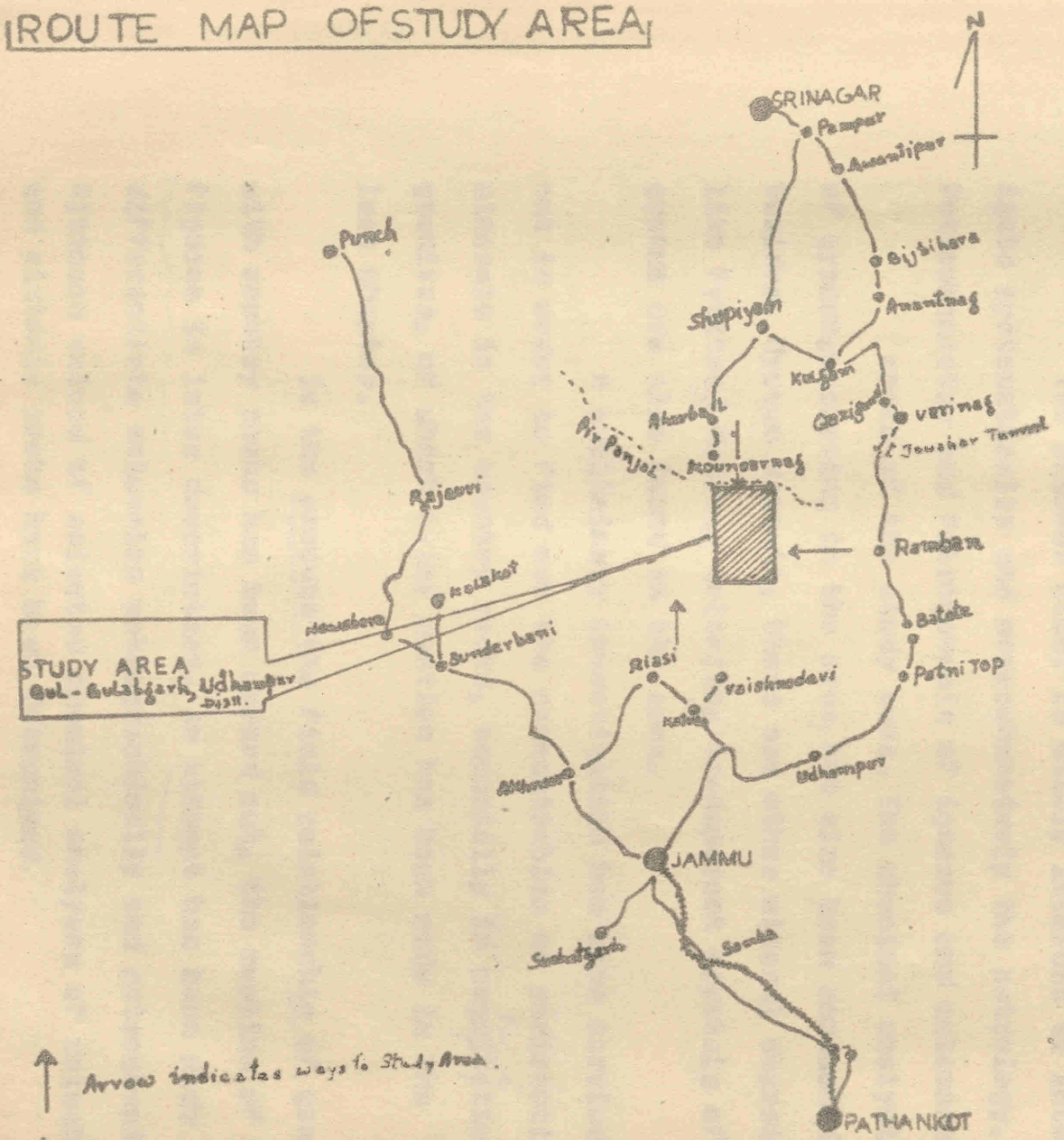
Wadia described briefly the geolgy of the area in " Geology of India". It was much later that Sharma et al. (1978) investigated the area and briefly described its geology. The purpose of the present investigation is to prepare a detailed geological map and to make a comprehensive study of stratigraphy, structure and petrology of various rock types exposed in the area, with special emphasis on granitoids and volcanic rocks. This thesis embodies the results of these investigations.

The area forms a part of Mohr Tehsil, Udhampur Distt. Jammu and Kashmir State(Location map Pl-1 Fig. No. 1). It falls between parallels of Lat. 33° 16'; 33° 27' N and Long. 74°51' : 75° E and forms part of Survey Of India toposheet no. 43 K/15. The area has been mapped on 1:63360 scale.

The terrain is quite rough and extremely rugged, traversed by numerous streams. The prominent streams are Barneal nalla and Gulabgarh nalla which on cutting across regional strike of the rock formations flow south - westerly and south-easterly - direction, respectively. These torrential nallas confluence at a place near Gulabgarh village, where from it assumed the name of Gulabgarh nalla. It cuts across the regional strike of country rocks. The direction of this stream is south - westernly which finally merges with river Ans, which flows from west of the area along the Murree Thrust, at a place near Sahr village. The river Ans takes abrupt turn at Sahr and apparently flows in the southernly direction across the strike of Murree formations

Fig. No. 1

ROUTE MAP OF STUDY AREA



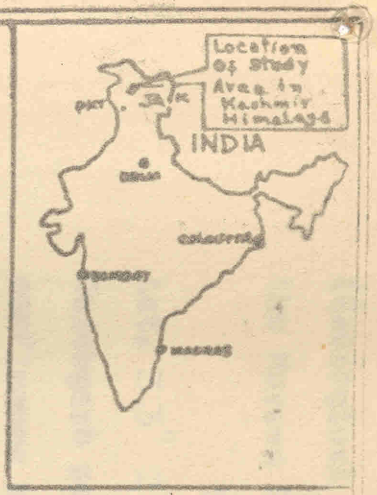


PLATE-I

(Geological Map Fig. No. 2). Village Mohr is situated on the Murree Formations.

The Gulabgarh village (Long. 74° 55′ 15″ E & Lat. 33° 25′ 45″ N) is a valley at the foot hills of Gulabgarh pass of Pir Panjal Range and is situated at the confluence of Gulabgarh and Sarneal nallas.

The present study is mainly intended to investigate systematically and comprehensively the petrology, Petrochemistry and Petrogenesis of igneous and metamorphic rocks of the study area. The chemical analysis of gypsum, occurring in the area, has also been conducted. Besides, Gypsum deposit, there are other mineral deposits like Pyrites & Ochres. Selenite, transparent crystals of gypsum are also found in the area.

A preliminary investigation has been carried out in order to find out the concentration of radioactive minerals in the country rocks, espacially in pegmatitic granites, of which brief mention has been made in the last chapter.

In the process the field relationship of granites with country rocks has been worked out, the mention of which figures in later description. An attempt has been made to differentiate volcanics petrographically and petrochemically. Rittmann values of selected chemical analyses of volcanic and plutonic rocks have been determined.

The accessibility to the area is quite difficult.

No motorable road exists within the area. Bridle paths are few. Footpaths are the common means of approach. Higher reaches always remain under snow cover throughout the year. Frequent torrential rains, punctuated by cloud bursts at times, during the monsoon months, prove great hazards for the field geologists. The ideal period of field work is May - June, and October - November months.

Method of study

To describe the geology of the area, the work has been undertaken on the following lines.

a. The area has been geologically mapped on 1:63360 Scale and the lithostratigraphic succession has been built up. (Fig. No. 2) In all an area of about 423 Sq. km. has been studied.

b. Attitudes of the formations, structural details of faults, thrusts and joints- patterns of the granitoids have been recorded on the structural geological map (Fig. No. 3 Pl-2)

c. Representative rock specimens of the area have been collected and large number of thin sections have been prepared.

d. Analytical work of rock samples has been done both by rapid and conventional methods. The quantitative analysis of major elements and trace elements was done by rapid and conventional methods. The quantitative analysis of major elements and trace elements was done by rapid method, using A. A.S. in Geochemical laboratory of Geology Department, Delhi University. These results were later on substantiated by repeated analytical work of same samples using A.A.S. in N.D.R.I. Karnal. And the determination

of other trace elements was also carried out in N.D.R.I., KARNAL. Some classical analytical work in respect of rock samples was followed in the Regional Research laboratory of C.S.I.R., JAMMU.

The values of such elements in their oxides form and as cations in respect of trace elements, are presented in tabular form. The various chemical and their genetic aspect, on the basis of chemical analyses of rock samples, have been drawn.

e. Microscopic study of different rock types has been made.

f. Detailed mineralogical examination of important rock types has been conducted. Modal analysis of thin sections particularly granites has been conducted by swift Automatic point counter, and Six-Spindle Integrating Stage.

g. Before this the staining of uncovered thin section was conducted after the method given by Bailey et al (1960) in order to distinguish between K-feldspar and plagioclase under microscope using Swift Automatic Point Counter and Six - Spindle Integrating Stage.

h. Field photographs and Photomicrographs have been taken to elucidate field relationship of structural, textural and genetic aspects of rock types.

i. Fossils both in-situ and rolled have been reported from the area for the first time, which needs further investigation before any conclusion regarding their stratigraphic position is established.

J. The calculation of Rittmann norms synonmous to

C.I.P.W. in respect of selected samples of volcanic and plutonic rocks, has been done. However, more emphasis has been laid on the study of petrography, petrochemistry and petrogenesis of igneous rocks.

k. Radioactivity at places has been recorded around the granitoids of pegmatitic variety near Khour, Lar, Doolmarg villages, located in the study area. Besides, a few other minerals of economic and academic importance have been noted in the present work.

It is hoped that the present work will provide useful data on the various geological aspects of the study area to the future workers.

CHAPTER - II

PREVIOUS WORK

The area of study received comparatively little attention by the earlier workers. Whatever published literature is available, it pertains essentially to the area which fall in strikewise continuation. A brief account of the previous work is, therefore, presented in the following pages. The start of geological investigations in Kashmir Himalaya dates way back to nineteenth century, viz., many workers like Godwin Austin (1861, 1864, 1866), Stoliczka (1866) who gave short account of geomorphology and stratigraphy of Kashmir, including parts of PirPanjal Range. Stoliczka especially worked in Western Tibet, Ladakh and Eastern Kashmir.

Lydekker (1876, 1878, 1879, 1880, 1882, 1883) was infact the first worker whose observations are of some importance in Pir Panjal Range and Western Kashmir. He presented data on lithology of the vast area of Kashmir, Ladakh and Jammu, also Chamba and Pangi valleys of Himachal Pradesh and Kaghan area of Hazara, now in Pakistan. He broadly divided Kashmir stratigphy in five broad systems viz. (i) Metamorphic system (ii) Panjal system (iii) Zanskar system (iv) Tertiary system, and (v) Alluvial system. The core of Pir Panjal, he regarded as metamorphics of Archaean to lower Palaeozoic and it was supposed to be flanked to the south and south - west

as also to the north-east by the Panjal System of slates of Cambro-silurian age. Panjal System of Lydekker comprised argillaceous phyllites, slates (Dogra slates) and Traps. Zanskar System was regarded to be comprising rocks of Carboniferous - Mesozoic age. It contained the fossiliferous Kulings (Triassic, Jurassic) and Chikim series(Cretaceous).

The Panjal System according to Lydekker was followed in the south by the Tertiary System, the two units being separated by a thin strip of Kuling and Supra Kuling of Carboniferous-Trias age. The Tertiary system comprised Sirmur series, Siwalik series, the former contained the Indus Tertiaries, Subathus and the Murrees. The Alluvial System consisted of Karewa series of Pleistocene and Alluvial of Recent age.

During the same period, other geologists of Geological Survey Of India e.g. Wynne, Middlemiss, Medlicott started work in Jammu and Punjab hills. The collective efforts of these workers produced a broad picture of geological setting of the entire Western Himalaya and subsequently it was substantiated by latter workers.

Middlemiss divided Lydekker's Panjal System into system of the Palaeozoic on the basis of fossil evidences. He also divided the Panjal volcanics into the Agglomeratic slates and Panjal Traps. He worked mostly on the geology of eastern and south- Eastern Kashmir(1910,1911,1919)

Middlemiss(1910) recorded the existence of Gonduana plants from the Agglomeratic slates of Apharwat in the Western Pir Panjal which became a guiding factor for the subsequent

workers on the Gonduana stratigraphy of India. PL-4

Sion (1928) mapped the eastern part of Kashmir in continuation to the work of Middlemiss and described marine fauna of Agglomeratic Slates which gave the lower limit to the Panjal vâlcanics.

Wadia(1928) gave an excellent account of the geology of Pooneh area and the syntaxial bend in north-western parts of Kashmir valley.

He briefly described the geology of Gulabgarh pass and its southern lower reaches. Wadia divided Lydekkers Panjal System into the major groups viz. the Dogra Slates and the Agglomeratic Slate and the associated Panjal traps. It was Wadia who introduced the term Dogra Slates in the geological literature which he meant a group of slightly metamorphosed Slates, Phyllites, Schists interbedded with contemporaneous Lava flows which are distinct from the Panjal Lavas. In addition another group of dominantly arenaceous rocks(a part of Lydekker's Panjal System) was demarcated and considered to be of Gonduana age, which were designated as Gonduana bed. Wadia later on divided the Kashmir tectonically into three divisions (i) Foreland (comprising Murrees and Bis Sivalike(ii) Autochthonous belt comprising rocks in age from Carboniferous to Eocene and (iii) Kashmir Nappe,. The contact between the foreland and a autochthonous belt was marked by a high angled thrust, called Murree Thrust and the Kashmir Nappe was thought to have come to rest on the

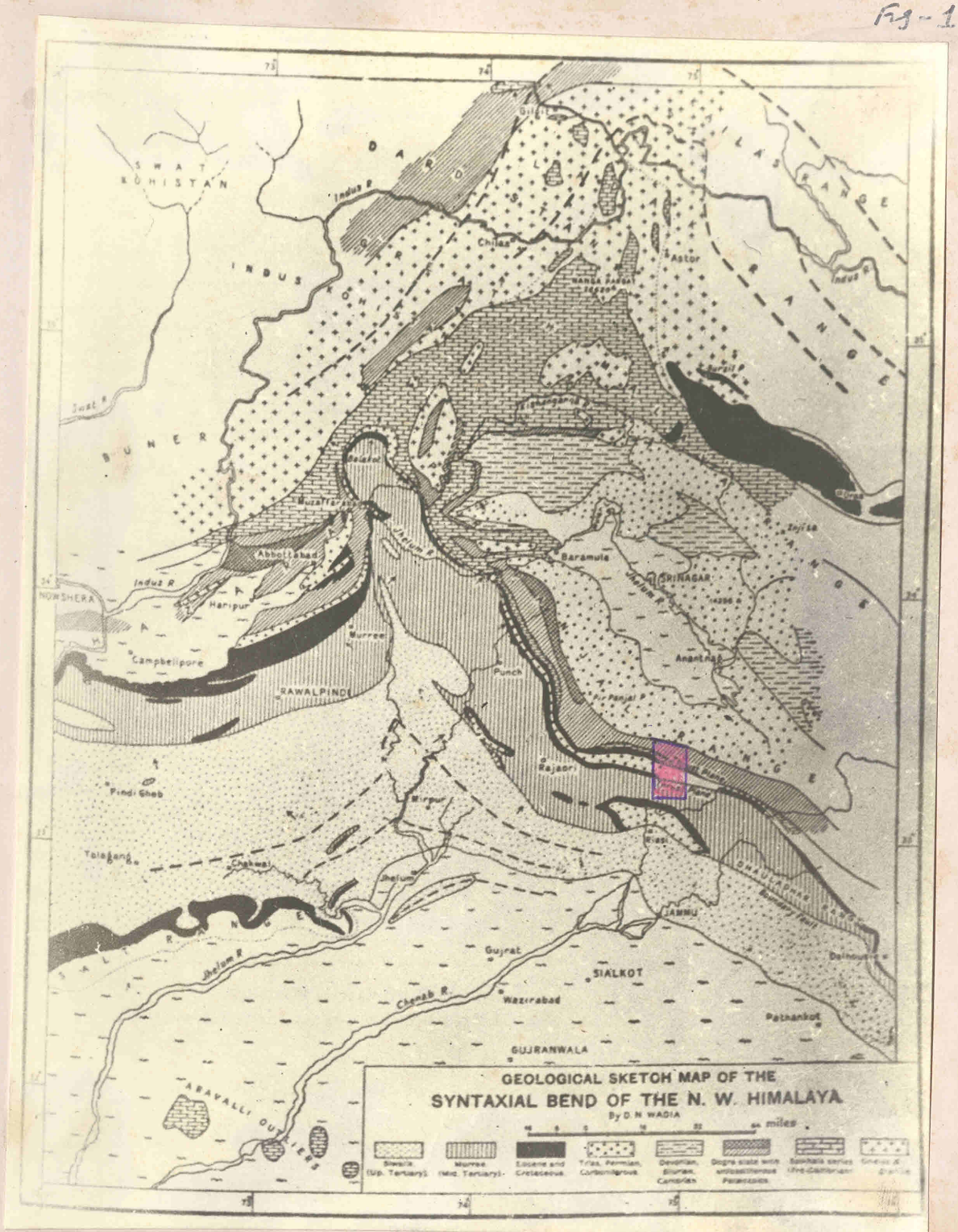
autochthonous belt along a low angled thrust plane, called the Panjal Thrust.

Wadia(1931,1934,37,38) amended his earlier views on stratigraphy of western Kashmir. He divided the metamorphics into Salkhala series as older and Dogra Slates as younger in age. He made the parts of Dogra Slates of Poonch equivalent to the Salkhala Series(Wadia,1934)(Fig. Pl-4 ~~No.1~~) The mapping of Poonch was extended to the east of Budil, wherein the continuation of the major structures and rock units were demarcated (Heron,1937). While demarcating these structures in the area he recorded Cambrian formations with" Scanty fossils to the south of Pir Panjal in a belt which runs from Budil to Banihal along Dogra Slates. These findings were later on confirmed by Goe,(West,1949). The stratigtaphic break from Silurian to Carboniferous in north -western Kashmir and the presence of continuous sequence in eastern Kashmir prompted Wadia,(1938) to propound existence of a mid Palaeozoic land bridge in Western Kashmir. Besides, he believed his Gonduana beds as equivalents of Tanaual Series of Hazara and regarded it to be of (?) Devonian-Carboniferous age. During this time, West and Auden worked on similar unfossiliferous formations of Simla and Garhwal areas. The Correlation between formations of Pir Panjal and Hazara with Simla Hills was made p-ossible by Wadia and West after having seen each other areas of attraction.

Wadia (1934) also found Cambrian and Ordovician formation rich in fossils in north-west Kashmir and, therefore, grouped the same as Lower Palaeozoic sequence.

PLATE-3

Fig-1



AREA OF STUDY
(AFTER D.N. WADIA)

De Terra(1935) proposed a scheme of Tectonic Zones to the north-east of Wadia's Kashmir Nappe, where the age of some granites was also suggested by him in his report.

Srikantia and Bargava(1974) drew a relationship between Salkhalas of Kashmir and Jutogh of H.P. They have given a stratigraphic and tectonic relationships of Salkhala series and the Dogra Slate. According to these workers, the Dogra Slates, on the subthrust side of the Salkhalas, is equivalent to the Simla Group and the Dogra Slate which overlies the Salkhala is equivalent to the Haimanta and both are not the same. They have also seen that Jutogh have the highest grade of metamorphism, it is absent in the Salkhala and they are also believers of Nappeism. According to their findings, Panjal Thrust does exist but forms the basepant of Salkhala-s while-as Panjal Thrust lies over Dogra Slates as Wadia (1931) puts in. They also say that the Batoi-Digdol Section on the National Highway is of a tectonic sequence and bears a remarkable similarity with the Dalhousie Section.

Wakhloo and Shah(1968) observed in Su-ran valley that Salkhala and Dogra Formations are overlain by Baflaiz volcanics and Tanawal formations, which are folded into several overturned Synclines and anticlines. The Salkhala and Dogra Formations are thrust over the Panjal Trap and Eocene of auto-Chthonous belt along the Panjal Thrust. The Baflaiz volcanics being spilitic-Keratophyritic in Character, are different from main Panjal volcanics and are of lower

Palaeozoic age. Subsequently they (Uakhlee and Shah, 1970) divided the rocks of the south-western flank of the Pir Panjal Range into four tectonic zones instead of three of Wadia by adding another thrust, called Chandimar Thrust within Kashmir Nappe of Wadia. The foreland belt and autochthonous zone of Wadia have been redesignated as Murree zone and Schuppen zone, whileas the Nappe zone has been divided into crystalline zone and the axial zone.

Sharma and Gupta(1971) who worked in the Thana-Mandi area, have shown the area being covered by Dogra Slates with spilites-Keratophyre intrusives and effusives which have been thrust along the Panjal Thrust over the rocks of the autochthonous zone, which comprise Panjal Trap with outliers of Eocene.

Krishna Rao et al.(1974) mapped the Mandi-Thana Mandi belt between Murree Thrust and the Panjal Thrust. According to them the Eocene rocks of Wadia are not true Eocene but slightly older than the Agglomeratic Slates and Succession exposed between Murree Thrust and the Panjal Thrust is normal and rightside up.

According to Karunakaran and Ranga Rao(1976) the nomenclature Gamir and Saila Formations used by them for the first time are a part of Agglomeratic Group after the work of Rao et al.(1975). What must have tempted these authors appears a sound argument for the inclusion of Saila in the Agglomeratic Slate as the former is devoid of any Eocene fossils which are otherwise found in Rajpur. The only

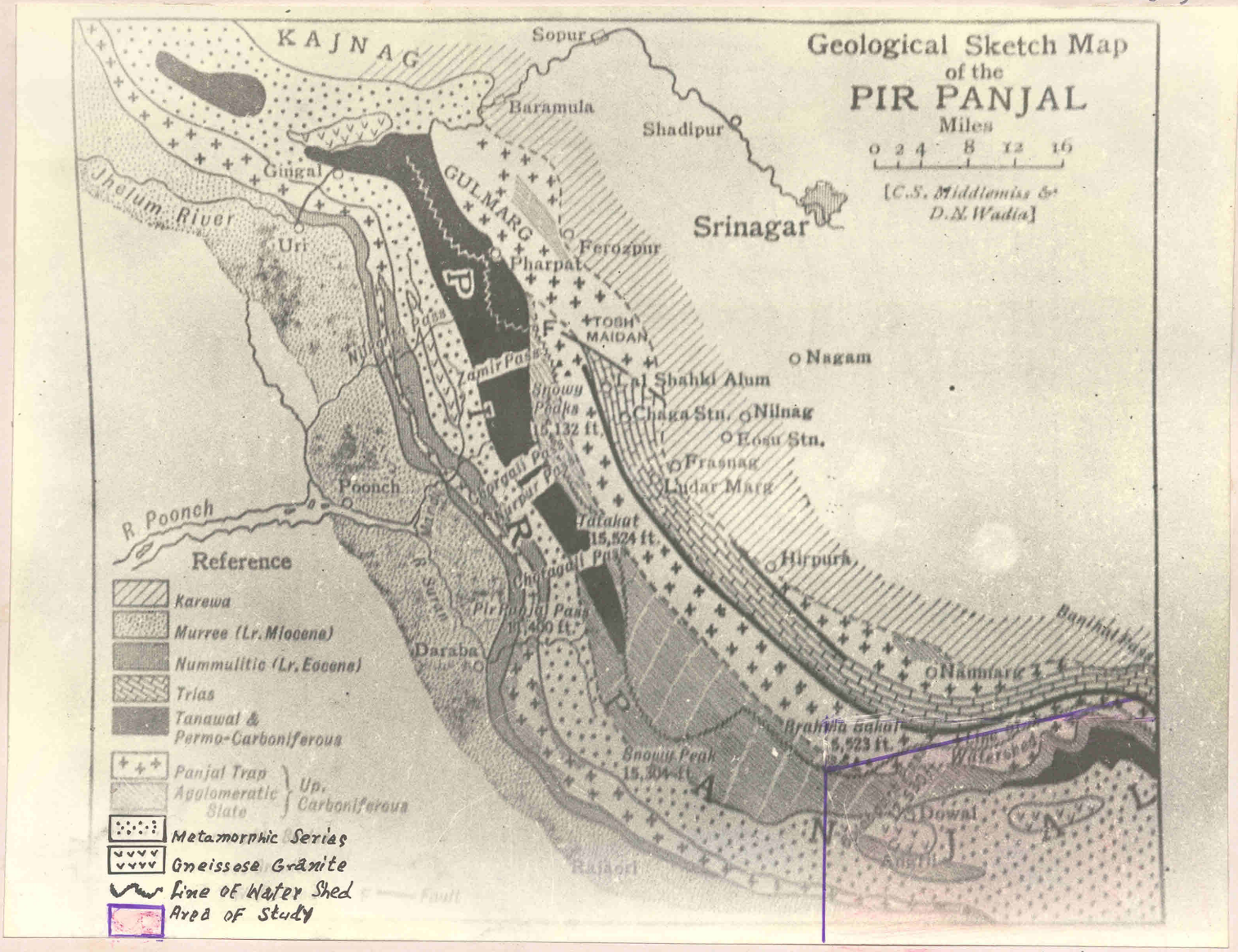
difficulty right now is that these terminologies are not so deeply entrenched like other terms used in the thesis is because this kind of lithofacies is yet to be confirmed elsewhere in the Kashmir Basin. However, the author has ventured to propose that these two sub-lithofacies, in absence of fossils, be grouped under a major Group in which the Gamir and Baila Formations have slightly a position like Infra-Agglomeratic Slate.

Sharma et al.(1978) observed in ThanaMandi that the area is covered by the rocks ranging in age from Devonian to Triassic with outliers of Nummulitic limestone of Eocene age. According to them the Dogra Slates with penecontemporaneous Lava flows of Precambrian age of Wadia have been grouped under Agglomeratic Slates and Panjal Trap of Carboniferous age. Similarly, the Eocene rocks of Wadia(Slate-quartzite/conglomeratic-Lime-Stone association) all along the Murree Thrust are not true Eocenes but are different from fossiliferous Murree Formations. Thus their position has been put stratigraphically just below Agglomeratic Slate. They further stated that the north of Murree Thrust, the entire sequence is conformable and gradational and Wadia's Panjal Thrust does not exist as several lithounits which existed in the Wadia's autochthonous Zone in ThanaMandi area also appeared, when traced along strikewise in the Wadia's Kashmir Nappe (Fig. No. PL-4 2)

Bhat and Sadhu (1965) mapped an area between Dodaj and Samhot villages in Poonch district and according to them the area is covered by Formations like

PLATE-4

Fig-2



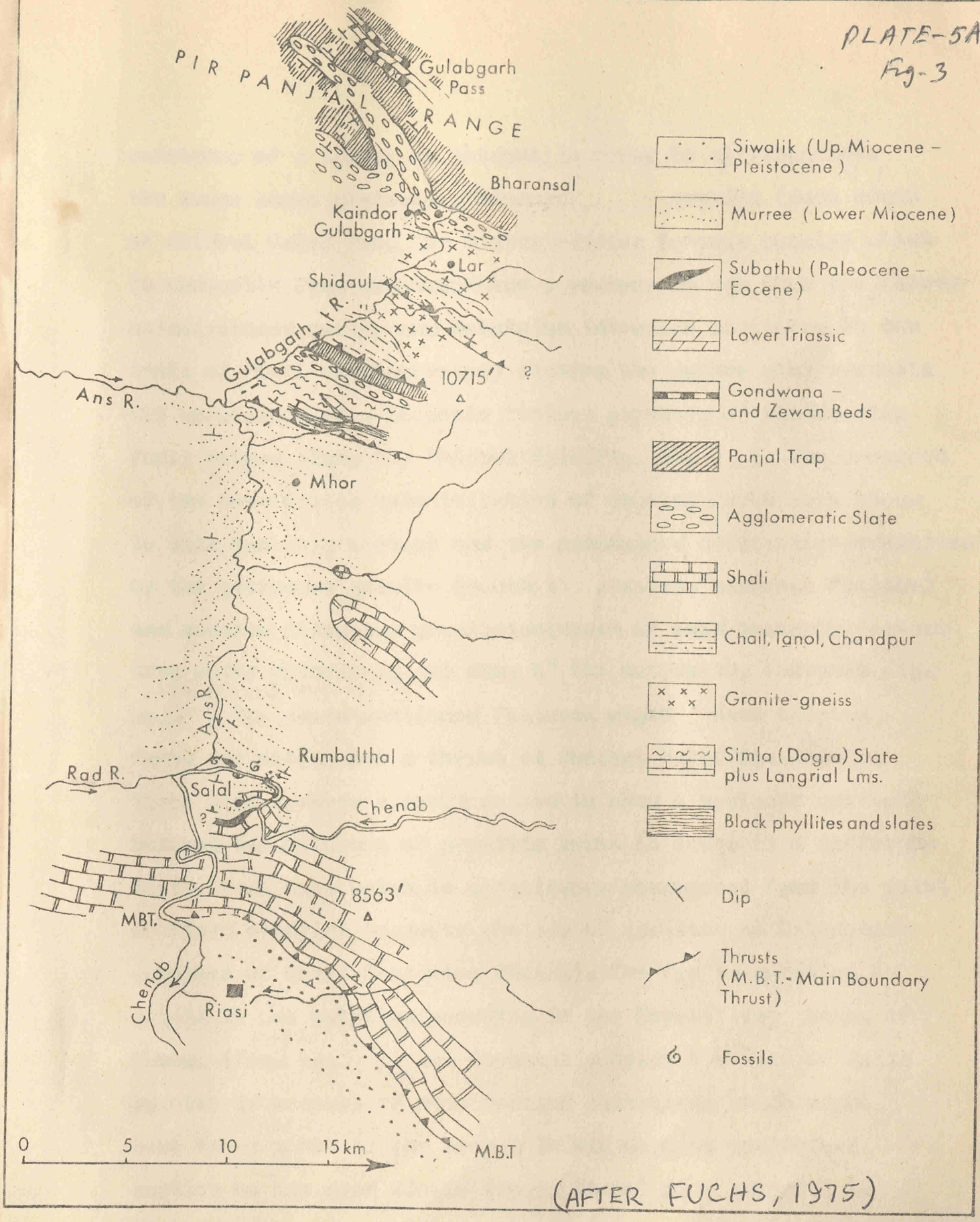
(AFTER MIDDLEMISS et al.,)

Baffliaz Schists, Agglomeratic Slates, Panjal trap and Eocene Lime^Stones.

Dhall and Sadhu (1964) mapped the area between Surankot and Poonch. According to them, the area is covered by Dogra Slates, Agglomeratic Slates, Panjal Trap, Gangamopteris beds, Zewan bed, Triassic beds, Ranikot and Laki Stages of Eocene and the Murree Formation. These are traversed by two important thrusts, i.e. Panjal Thrust and Murree Thrust. Along the Panjal Thrust, the Dogra Slates have been thrust over the Laki stage of the Eocene and along the Murree Thrust, the Nummulitics have been thrust over the Murree Formation.

Fuchs (1975) made a traverse along the Gulabgarh nala section and along Ans River in southern position of study area(Pl. – 5 , Fig. No. 3) . In his report(1975) he recognised five zones from south to north: (1) Siwaliks, (2) the Murree Zone, (3) the Parautochthonous Zone, (4) the Chail Nappe (5) the Crystalline Nappe. He recognised two tectonic units in the region of Kashmir Nappe of Wadia in addition to normal par-autochthonous Zone in south of Panjal Thrust. The Chail Nappe comprising essentially the epimetamorphic Chails intruded by granite gneiss, are the southern continuation of the Chail Nappe which is exposed in Kishtwar Window. The crystalline Nappe according to him shown in his map is essentially a succession of Chail-Tanol, Agglomeratic Slate, Panjal Trap, Gondwana Beds, Zewan Formation and Lower Triassic Lime-stone. Here the Chail-Tanols are intruded by more massive metagranites and in between these two Nappes, he points to the

PLATE-5A
Fig-3



(AFTER FUCHS, 1975)

Fig. 2. Scetch map along the Riasi — Gulabgarh section.

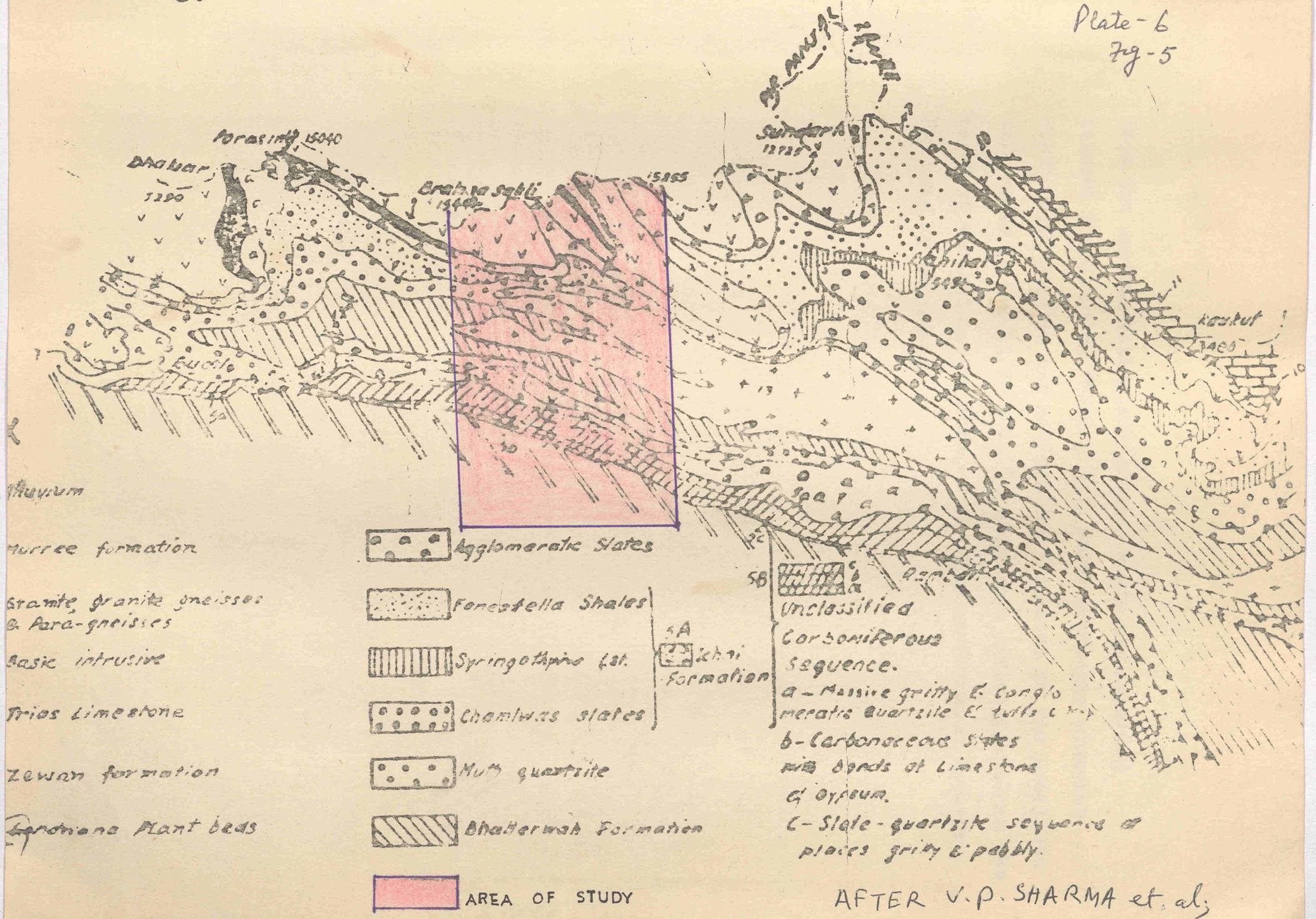
existance of a thrust at Shidoul in order to differentiate the lower augen gneisse, gneissose granite (just south of Shidoul Nala) from the higher massive igneous complex which is undoubtly less metamorphosed , younger in age than the former metamorphosed rocks, and maintains intrusive contacts. On the basis of field and laboratory studies the author also supports the occurrence of a tectonic feature probably of strike-slip fault nature along the Shidoul Nala(Fig. No. 4 in the folder). The presence of the conspicuous mylonitisation of country rocks very close to this tectonic contact and the pronounced deformation, exhibited by the gneissose granite (south to proposed tectonic feature) and massive intrusive granitoids(north of said tectonic feature seen under microscope are some of the noteworthy features Fig. No.5 Structural map - Pl-5) The above mentioned features might have tempted Fuchs (op cit)to put a thrust at Shidoul Nala(Fig. ~~No.3~~ Pl-5A). There also appears a sound reason to show a tectonic contact between two outcrops of granitic rocks in order to differentiate their ages which is conspicuous phenomenon from the point of field study. He suggests the age of granites to Caledonian granites of Chail Formation (Mandi). The age in question he points to the granites occuring in the Crystalline Nappe of Fuchs. (Fig. No. 3 Pl-5A). But he equally holds the view of Wadia (op.cit) in respect of post-Permian intrusions which might have taken place in the area . In his working geological section he has used Simla (Dogra Slate) plus Langrial Lms including black phyllites and slate instead of Damir and Baila formations used by the author of this thesis.

Sharma et al.(1979) worked on stratigraphy and structure of Ramban - Banihal-Gulabgarh-Budil sector of Pir Panjal Range, Jammu and Kashmir State(Fig. No. 5 PL-6). They have covered an area of 2000 sq km. They have reported the presence of carboniferous fossils within the Dogra Slates of Ramban, the lateral gradation of the Dogra Slates of Ramban, into the Agglomeratic Slates of Ramban, into the Agglomeratic Slates of Loni-Jraunsal-Chemsar Gali area; the lateral gradation of the Syringothyris LimeStone of Banihal into calcareous Slates, pebbly Slates and conglomerates towards south-east as well as north-west, the discovery of Fenestella fossils within the Salkhalas and Dogra Slate of Bagodas-Dodanali area, the discovery of very thick plant bed horizon within the Agglomeratic Slates of Dhakiar(4660 m) Parasing(4584 m) area, the discovery of marine fossils within the Agglomeratic Slates of Kogara-Mal area which they have incorporated in such a way that they have been able to resolve rock formations into various lithostratigraphic units ranging in age from Cambro-Silurian to Carboniferous. According to them the rock formations strike in general NW-SE direction and dip to the north east direction. The area is folded into a regional anticlinorium which is complementary to the Kashmir synclinorium in the north east and Bhaderwah-Chamba synclinorium in the south-west. According to them there exists only one thrust plane, of course high angle reverse fault, called Murree Thrust, separating Tertiary from pre-Tertiary. To the north-east of the Murree Thrust, all the rock formations show conformable and gradational contacts with one another. As such,as they put in , there is no existence of Panjal Thrust. Further, they are of the opinion

GEOLOGICAL MAP RAMBAN-BANIHAL-GULABGARH-BUDIL

SECTOR OF THE PIR PANJAL RANGE J&K STATE

Plate-6
Fig-5



AFTER V.P. SHARMA et. al;

that the various lithostratigraplic units are repeated several times due to folding into north westerly plunging overturned synclies and anticlines. The cores of the synclines are formed by Panjal Trap or PermoTriassic sequence, whileas the cores of anticlines are made up of Silurian-Devonian sequence, intruded by granites.

CHAPTER - III

PHYSICAL FEATURES

The Physical features of the area are testified by the present developed valleys and hill ranges, their trends and drainage patterns. The physical features are the result of Physico-chemical impacts on Country rocks which give shape to the present landform features of the area. The Kashmir Himalaya runs NW-SE separating the regions of Jammu and Kashmir. To the south of Great Himalaya, the mountain range of great importance, viz; Pir Panjal Range separates Jammu region from Kashmir valley. The area of study falls south of Pir Panjal Range. It forms a part of the Lesser Himalaya. The whole country is one of great inhospitable and rugged terrains. The altitudes of the area of study vary between (1370 m)-(4706m). The h-ighest peak in the Pir Panjal Range of study area is Brahma Sakli(4706 m) and Didam Gali also known by Gulabgarh pass(3610 m). The Pir Panjal Range is a westernly continuation of the Dhauldhar Range and behaves like an arc with its convexity towards south-west. This range runs for a distance of about 400 km. The name Pir Panjal is usually applied to this range separating Chenab Basin from Jhelum Basin. The extensions of Pir Panjal to the north of Jhelum are the Kazinag and Shamasabari Ranges which finally merge with the north-Kashmir Range. It is prominent watershed between Jammu region and Kashmir valley showing what Wadia calls the orthoclinal



SOURCE : D H A Spate, INDIA AND PAKISTAN - 1967

Fig. 1·1

PHYSIOGRAPHIC MAP OF THE NORTH WESTERIN HIMALAYAN COMPLEX SHOWING TREND OF PRINCIPAL MOUNTAIN RANGES.

(AFTER SPATE, 1967)

structure, i.e. gentle slope towards north and a steep escarpment to the south. The range is of considerable importance geographically and meteorologically as it brings a climatic barrier between Kashmir valley and Jammu region. To the south of Pir Panjal, huge escarpments and vertical cliffs produce typical topography of the area, but there is different feature observed in the northern side of the watershed where gentle sloped valleys are sites of thick vegetation.(Pl 10 Fig.No.b)

The southern faces are normally barren and rugged with scanty soil cover and poor vegetation. But as we move further south, the forests constitute a conspicuous feature. They are unevenly distributed. Torrential streams, water falls and land slides are noteworthy features of the area of study. There are subsidiary ranges to the south of Pir Panjal which alternate with deep valleys. These subsidiary ranges are aligned in such a manner that streams flow through deep valleys along regional strike. The ranges in the far south of Pir Panjal are longtudinally streched along regional strike, the torrential Gulabgarh nala cuts gorge in south-westernly direction across the regional strike of subsidiary range near Gulabgarh village.

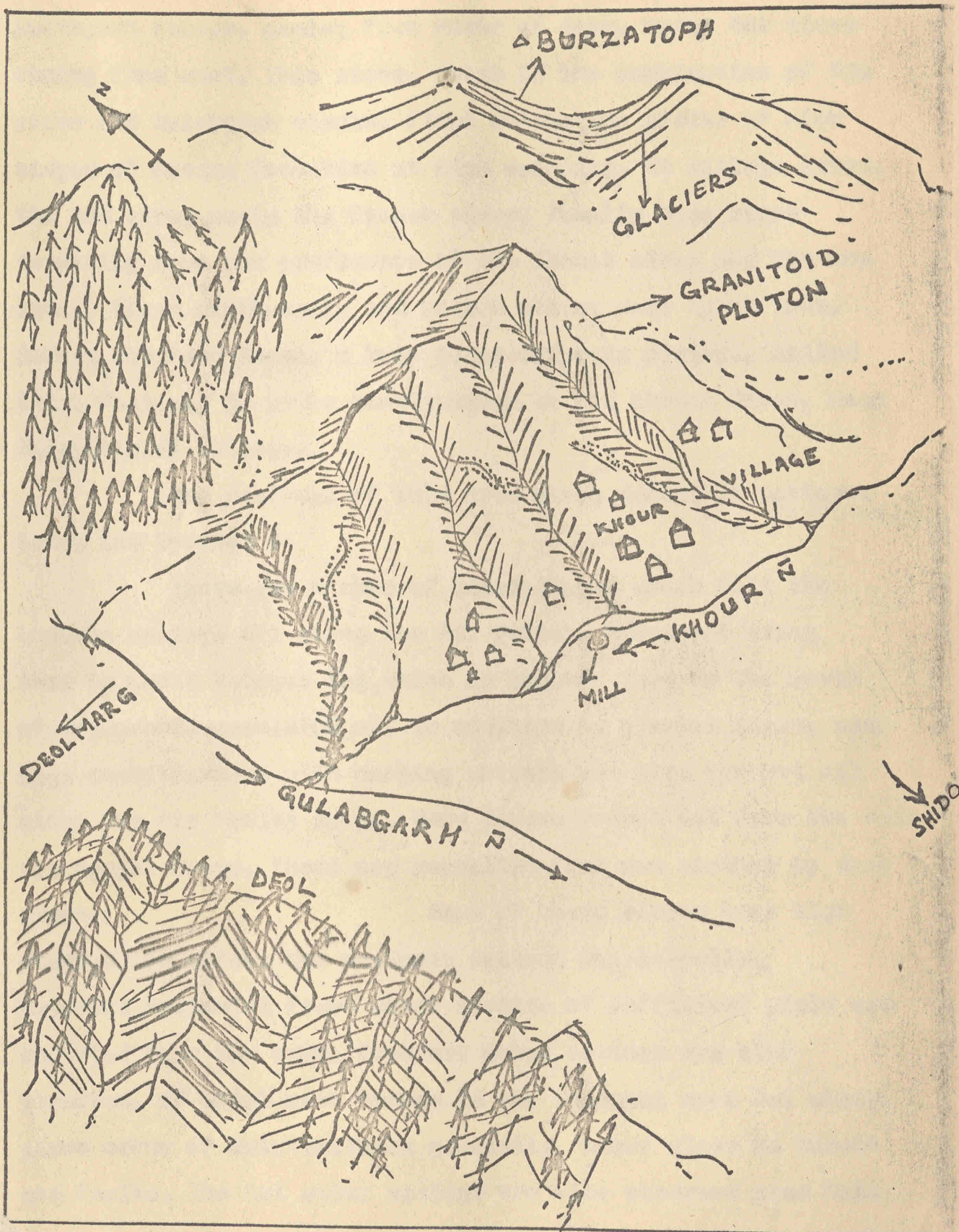
To the north of Didam Gali, a mountain pass in the Pir Panjal Range, there is a vast meadow surrounded by thick pine trees,a place called Nakuas. Near this pass in the south, there are U-shaped valleys covered by thick valley-glaciers (Pl - 12 Fig. No. c&d)and are having vertical scarps all along the range. This is a characteristic feature of the lesser Himalaya. These peaks are barren , and are covered at

places by scree, talus and morain deposits.

Main rivers and streams in and outside the area of research work figure in Geological Map(Plate I Fig-1).

Chenab and Ans rivers are the main water courses, whileas among streams, Gulabgarh and Barneal nallas need special mention. The Chenab river flows outside the limits of study area, but quite close to the eastern sector. Initially it flows between the great ranges on the eastern side and then cuts across the Pir Panjal near Kishtwar, then flows almost parallel to Pir Panjal for a considerable distance of over 120 km. It then turns abruptly to the south and finally flows into the Jammu hills. The Chenab river, coming from Eastern side, moves along National Highway in the northernly direction upto Ramban, beyound which it takes turn to west. Thereafter it flows parallel to strike and finally meets the Ans river coming from west, at Arnas village.

The Gulabgarh stream, main tributary originating from Thinmarg glacier, joins enroute with other small tributaries flowing along deep valleys in the Pir Panjal Range. This nallah assumes a torrential form after other subsequent tributaries join it coming from the valleys, between subsidiary ranges. This nalla meets another nala, called Baraneal nala coming from N-E, near a village called Gulabgarh. The confluence of these two nalas results in a stream called Gulabgarh stream, which is seen cutting across the strike of country rocks and moves south westwardly. At Sahr village, where the



ROUGH SKETCH OF GRANITOID PLUTON

Gulabgarh stream, coming from north of Sahr, meets Ans river coming from west. This river, which is the combination of Ans river and Gulabgarh stream, flows across the strike of high ridges of Murree formation at high velocity. At village Arnas, the Ans river meets the Chenab river. Finally huge river resulting from the confluence of the Chenab river and the Ans river, flows southwardly and enters plains near Reasi town. Before reaching Reasi, a huge hydro-electric project, called Salal Project, is under construction on the Chenab River, near Salal(Bidda) village.

The drainage of this area shows dendritic pattern. (Pl-7, fig:1)

Lakes and Springs :-

There are number of glacial lakes which fill the hanging valleys all along the Pir Panjal. Prominent among them is Chota Kaunsar Nag, which is located just to the north of Shrameakei peak(4706 m). In addition to glacial lakes, some huge amphitheaters with hanging valleys are also present all along the Pir Panjal Range. Many ridges branch out from the main Pir Panjal Range. These are separated from one another by deep gorges. Some of these ridges bear high peaks which affect the drainage pattern considerably. Numerous perennial fresh water springs of sufficient yield are reported from the area. Some hot water springs are also observed, of which most famous is the Tatapani near Gul which gives odour of Sulphur. These generally occur close to thrust and faults. The hot water springs are also observed near Mala

PHYSIOGRAPHIC MAP SHOWING DRAINAGE PATTERN

Fig. No. PLATE-7

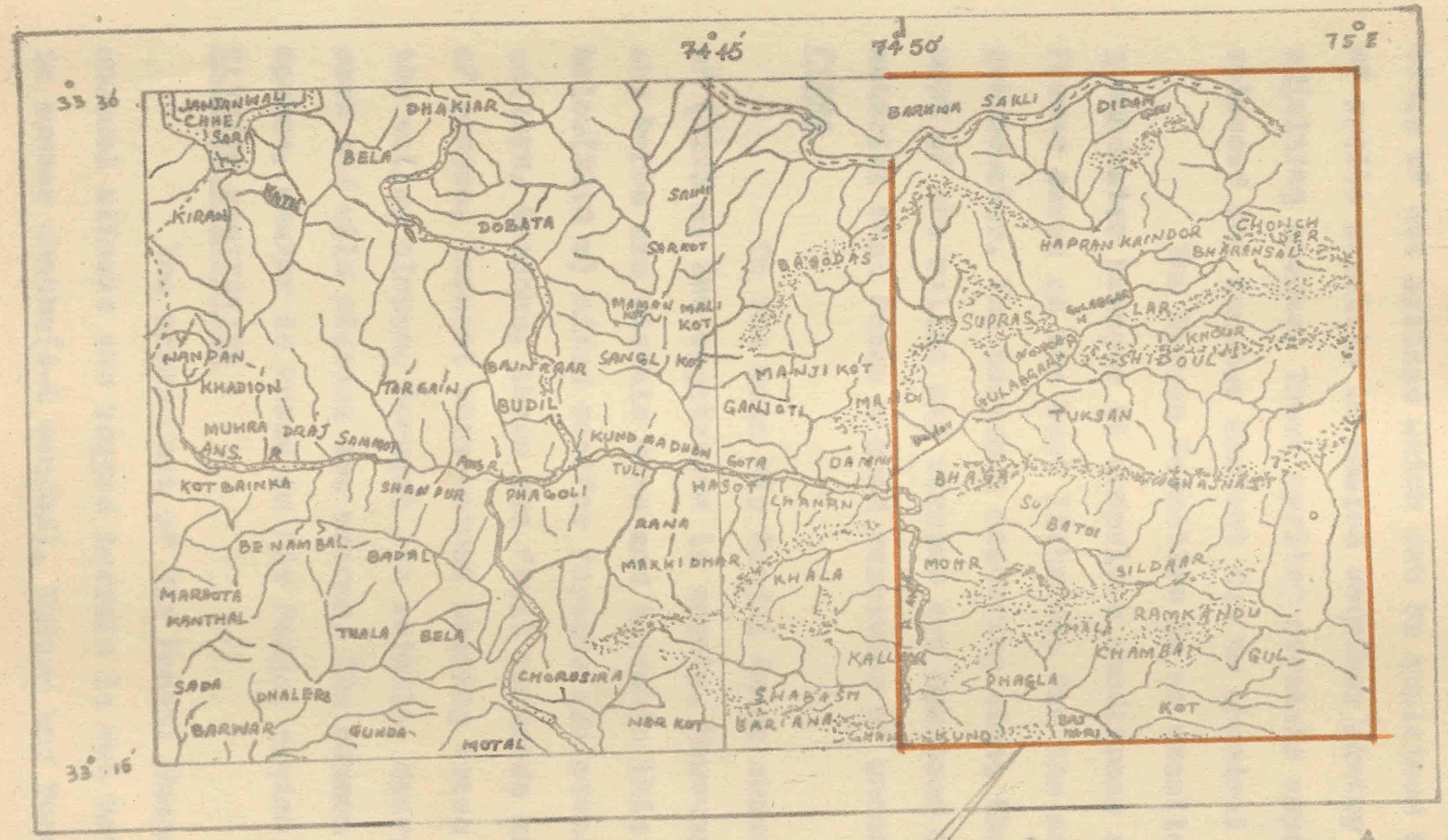


Fig-1

and Sildhar which are located along the Murree Thrust.

Encrustations of sulphur can be seen along the sides of hot springs which can be explained by the presence of pyrite crystals in shales and other country rocks in the adjoining tracks. These pyrite crystals appear to have released the supphur content due to chemical weathering.

The Murree formation is an excellent reservoir of groundwater because it comprises sandstones and shales, the former serve as the best lithology for the occurrence of groundwater. The terraces occurring along the valleys of most of the nallas and streams are composed of coarse gravel material that forms a good reservior of underground water.

FLORA

On the main Pir Panjal Range above the altitude of (2210 m) the vegetation is scanty. However, small shrubs and herbs are visible here and there in this range. But below(2210 m) mixed conifer forests are present in the shaded valleys. Besides, there are fruit orchards on the lower slopes of ranges. Amongst them walnut bearing trees are numerous on the valley slopes. Amongst the animals, deers, reptiles, snow cock and wild pigeons are common. The common partridge, caxcpabea, chukar is known in Pir Panjal region in summer.

CLIMATE HABITATION

The upper part of Pir Panjal Range with its unusual climate and rugged terrain is not habitable. However, in summer months(4-5 months), Gujars and Backawals, nomadic

tribes carry their belongings and cattle across the Pir Panjal in an effort to settle on other side of waterdivide. They live there and carry their flocks to great heights for grazing and keeping their fodder grown by itself in summer months for winter days when high reaches remain under heavy snow for all these winter months. They live for the summer months in high reaches in small huts called Dhoks and are made for the purpose. These Dhoks are made even at elevation over (3505 m). These Dhoks are deserted towards the end of september when the occupants move with their families and cattle to lower altitudes. The area is thinly populated with very few shops seen here and there. The well known villages are Batôt ,Mohr, Angrala, Saddar located at lower altitudes and Adbee,Noach, Khour, Ler, Kaindora, Gulabgarh etc.are located at higher altitudes. The agriculture is less developed due to unfavourable topography and non-availability of soil. Paddy and Maize are the usual agricultural crops.

The area is divided,on the basis of climate or heights of terrain into three zones, viz.

1. Non-vegetation zone:ie(From Pir Panjal in the north to subsidiary hills upto Khour in the south).
2. Vegetation Zone: ie (From Shidoul village to Murree Thrust)
3. Outer hot Zone: ie (From Mohr village upto Arnas).

MEANS OF COMMUNICATION

The only motorable road is upto Gul from east and upto Arnas from south (Fig. No. PL-1). These two places are

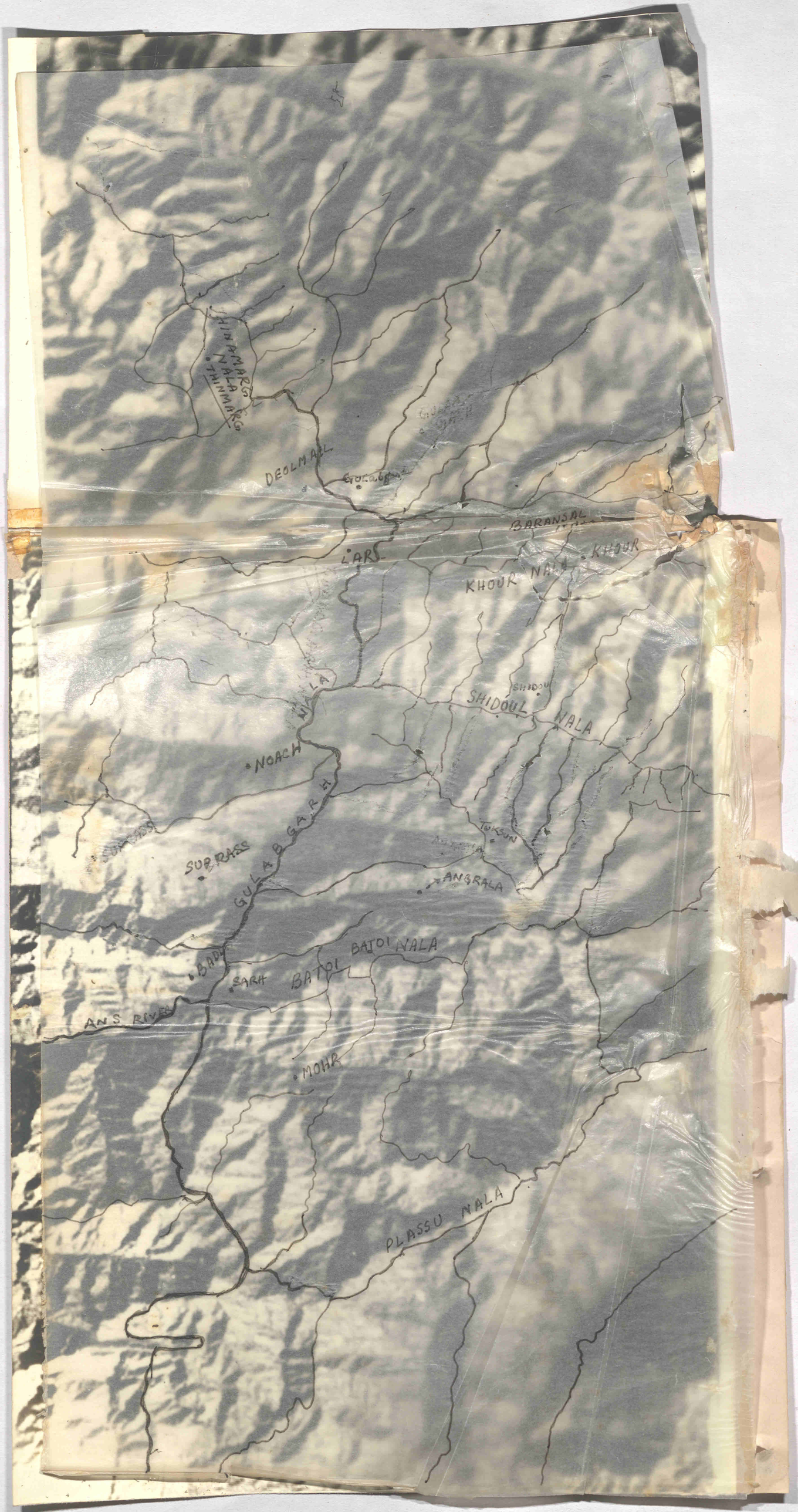
starting points of the area of study. The area can also be approached through Hakuas village of Kashmir valley situated north of the Pir Panjal Range. To reach interior parts of the area one has to move mostly on foot. A pony track is available only upto Mohr Tehsil. Bridges are scarce. The nallas are bridged over by loosely held planks of wood or tree trunks which get washed off quite often during monsoon season.

In higher Pir Panjal, the terrain is extremely rugged and rough and only few margs (pastures) are present, among them, Thimmarg and Doolmarg are worthy of mention.

To work on higher reaches in the area becomes a matter of difficult task for a geologist. Rock outcrops better exposed along cliffs and scarps, cannot be easily approached. Outcrops along the valleys and gentle hill slopes are usually covered by soil cover and vegetation. Good exposures are available in the nalla or gorge, but the study in such environment is a dangerous task.

The best period for field work in this area is May-June and October-November months. Winter months and Monsoon present inhospitable conditions for field work.




HINAMARG NALA
THINMARG
DEOLMAIL
BARANSAL
LARS
KHOUR
KHOUR NALA
SHIDOUL
SHIDOUL NALA
NOACH
GULABGARH
SUPRASS
TOKSUN
ANGRALA
BADI
SARH
BAIOI
BAIOI NALA
ANS RIVER
MOHR
PLASSU NALA

Satellite imaginary taken by INSAT-1B gives three dimensional view of the Gul-Gulabgarh Area. An attempt has been made to draw important drainages and important places of study are (By courtesy from

Dr. Ravinder Kumar,
Centre of Advance Studies
in Geology, Punjab University
Chandigarh.)

CHAPTER - IV

GEOLOGICAL SETTING AND STRTIGRAPHY

GEOLOGICAL SETTING

The North-West and South-East region of Kashmir Himalaya shows development of rock formations ranging in age from precambrian to Recent. Most of the formations occuring in Kashmir valley are fossil bearing while as most of the formations of study area are devoid of fossils. In this chapter an attempt has been made to build up the stratigraphic sequence based on lithology and fossils, Then their corelations with equivalent formations found above and below the Fossiliferous beds reported elsewhere. Were made Some trace fossils have been found in shaly quartzitic formations occurring within flaggy quartzites of Agglomeratic Group.

Wadia(1928, 1931) divided Jammu and Kashmir regions excluding Ladakh into three structural divisions(i) The foreland, (ii) The autochthonous Zone, and (iii) The Kashmir Nappe. Wadia's antochthonous zone is a belt of tightly folded rocks, held between Murree Thrust in the south and Panjal Thrust in the north. According to him the rocks of this belt were mainly Panjal volcanics and Eocene and he traced this zone upto Jhelum Syntaxis and beyound it also. This zone is the widest in the western region, whileas it narrows down eastward.

The thinning of the belt goes to the extent that on the Jammu-Srinagar Highway; near Pira, the two thrusts come closer to one another that only very few mateas of highly mylonitised Panjal volcanics and Eocenes are exposed. This zone then widens near Basohli.

Nappe zone of Wadia contains a fossiliferous succession in Kashmir valley but areas to the south west of Pir Panjal comprise unfossiliferous metamorphics, viz., (Salkhala series, Tanawals, Panjal volcanics and Zewan bed apart from a few patches of Triassic limestone.

The Stratigraphic position of metamorphics is almost clear as is evident from the field relationship. Wadia (1928) mapped these metamorphics as unit of Dogra Slates and brought even present delimited the massive intrusive granitoids as part of metamorphics. (Fig. Pl-4 No. 2) Later on he changed his view and in 1934 he mentioned that these metamorphics belong to the older Salkhala Series. Gansser (1964) in his map has shown all these outer metamorphies of the western Pir Panjal as a part of Salkhala Series.

Shah et al (1980) proposed the following stratigraphic succession of Parautochthonous zone and Southern Kashmir Synclinorium of Jammu and Kashmir region (Fig. Pl-8 No. 1) as follows:-

Stratigraphic "Succession Of Parautochthonous Belt."

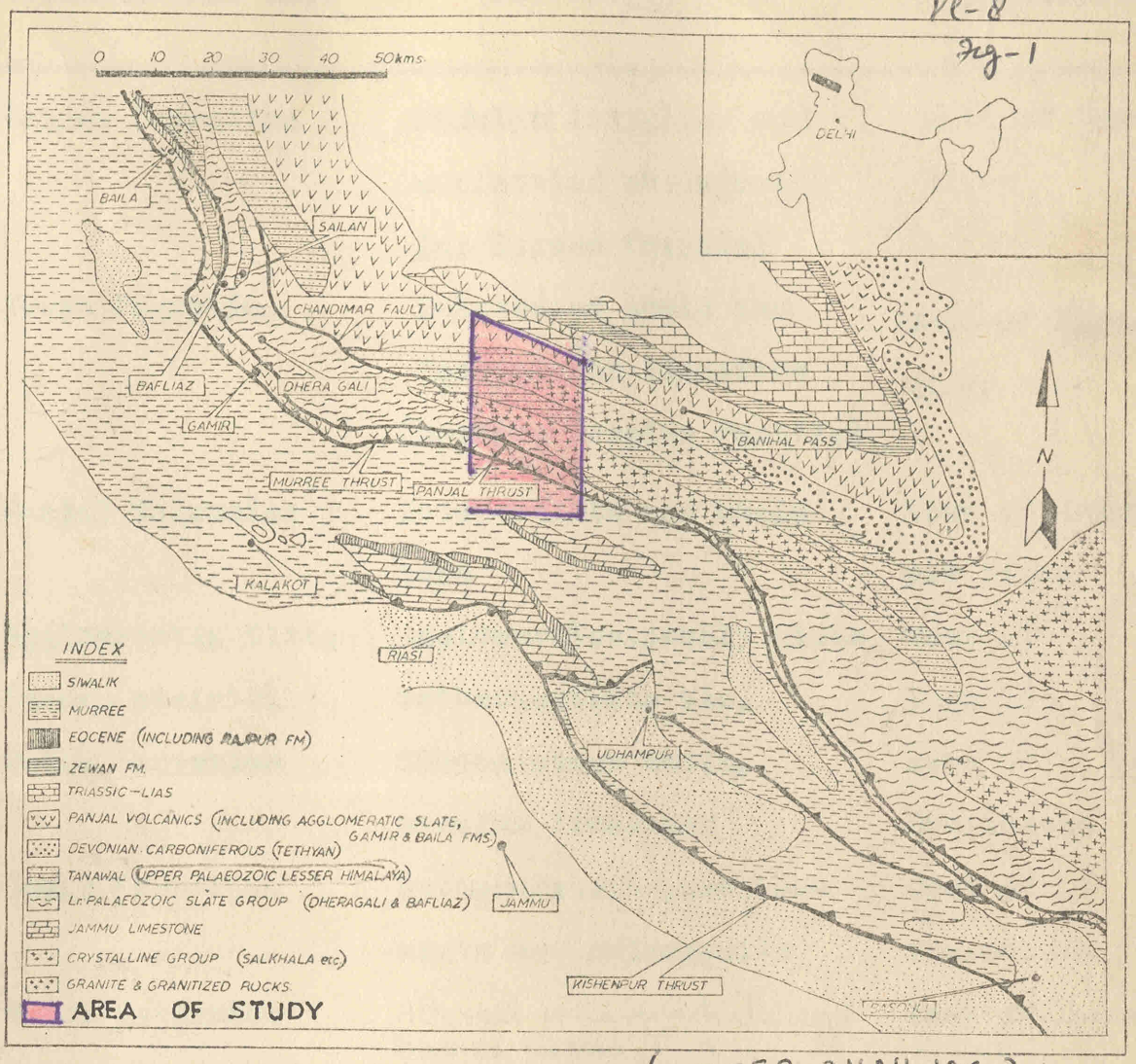


Fig. 1. Geological sketch map of the Kashmir Himalaya showing various tectonic and stratigraphic units.

TECTONIC SETTING OF LESSER HIMALAYA OF JAMMU

The outer and Lesser Himalaya can be divided into the following tectonic units from south to north : (Fig. 1).

South	Outer Siwalik Belt
	— — — · — — — · — — — Jammu Fault — — — · — — — · — — —
	Murree Belt, with Jammu Limestone capped by Eocene (Subathu facies) in basement high regions and Siwalik rocks in the synclinal areas
	— — — · — — — · — — — Murree Thrust — — — · — — — · — — —
	"Parautochthonous" zone containing Shali Formation, Mandi Trap, Aggolomeratic Slate, Panjal Trap and Eocene (Hazara facies) showing a younging of succession westwards
	— — — · — — — · — — — Panjal Thrust — — — · — — — · — — —
North	Kashmir Synclinorium, with the southern limb bearing rocks of the mixed Tethyan and "Lesser Himalayan" affinities

Stratigraphic Unit	Lithology	Distribution
Rajpur Formation	Nodular limestone and variegated shale(bearing Eocene fossils)	West of Suran River
Zewan Formation	Calcareous shale and ferruginous limestone (bearing Permian fossils)	West of Suran River
Panjal Volcanics	Intermediate and basic Lava	West of Ratanpir Ridge
Agglomeratic Slate (sensu stricto)	Agglomerates,pebbly slate orthoquartzite etc.	West of Baechli
Baila Formation	Carbonaceous shale, nodular limestone	West of Dharamsala
Gamir Formation	Orthoquartzite,conglomerate and calcarenite	West of Dharamsala
Mandi Volcanics	Altered intermediate and basic Lavas	East of Chenab River.
Shali Formation	Limestone and Shale	East of Dharamsala.

Stratigraphy of The Southern Kashmir Synclinorial Basin

Stratigraphic unit	Lithology	Lateral passage or equivalence in the north.
Panjal Volcanics	Basic and intermediate lavas	
Agglomeratic Slate	Agglomerate,greywacke, orthoquartzite,pebbly slate	

Tanwal Group	Conglomerate, Orthoquartzite, psammite schist and phyllite	Fenestella Shale Syringothyris Lst Muth Quartzite
Baffiaz Formation	Spilitic lava, agglomerate, tuff, sandy phyllite	Dogra Slate (Cambro-Silurian)
Dhera Gali Formation	Quartz-schist, sericite schist and phyllite	

Some of these formations are associated with intrusions of basic Sills and dykes, granites of pegmatitic, aplitic, and gneissose varieties.

The Stratigraphic successions and tectonic classification of part of the Kashmir Himalaya was given by Wadia (1931) and Srinkantia (1973) and the comparison between the ~~three~~ two is shown in the following table:-

Wadia (1931)	Srinkantia (1973)
Cambrian Sediments	
Dogra Slate	Haimenta
____ Tectonic to normal ____	
Salkhala	Salkhala
_____normal/Tectonic —	—Panjal Thrust—
Dogra Slate	Simla Group
_____Panjal Thrust___	—Thrust ——
Autochthonous folded belt of Panjal volcanics with Sporadic Carboniferous-Permian with Eocene outliers	Main Shala structural belt with Mandi , Darla volcanics and the Sunder Nagar Formation with sporadic outliers of carboniferous to Permian

Murree Thrust

Murrees

Thrust

Siwaliks

Murree Thrust

Palaeogene

Thrust

Siwaliks

The stratigraphic Successions proposed recently by Fuchs(1975), Sharma et al(1979) ase as follows:-

Fuchs(1975)	Sharma(1979)
Siwalik (Up Miocene-Pleistocene)	Alluvivm
Murree(Lower Miocene)	Murree Formation
Subathu(Paleocene-Eocene)	Granite, granite gneisses and Para-gneisses
Lower Triassic	Basic intrusive
Gondwana-and Zewan Beds	Trios Limestone
Panjal Trap	Zewan Formation
Agglomeratic Slate	Gonduana plant beds
Shali	Agglomeratic Slates
Chail, Tanol, Chandpur	Fenestella Shales
Granite-gneiss	Syringothyris Lst Ichni Formation
Simla(Dogra) Slate	Chamlwas Slates
Plus Langrial Lms.	Muth quartzite
Black phyllites and slates	Bhaderwah Formation

The area of present study contains complete autochthonous zone which is bounded by the Murree Thrust and Panjal Thrust and a part of Nappe zone which lies immediately north

of Panjal Thrust. The formations exposed starting from oldest to the younger rocks are as follows: Salkhala Group, Tanwal Formation, Bafliaz volcanics (Cambro Silurian?) Gamir and Baila Formation Agglomeratic Slate (of Infra Agglomeratic Slate), (granitic intrusions and dykes of amphibolites and metadiabase) Panjal Trap, Gangamopteris thin bed followed by zewan bed near the watershed and thick Murree Formation in the south.

The autochthonous zone of the area is a narrow belt of tightly folded rocks of Gamir and Baila Formations, Agglomeratic Slate which are collectively regarded as Agglomeratic Group on the basis of thickness of belt and wide distribution in the Pir Panjal Range. The Panjal volcanics in this zone is truncated by the Panjal Thrust in the north near Helakhetaji. After that comes a belt of low grade phyllites, Carbonceous & Slates and Phyllites, Sponge-type carbonaceous phyllites containing Selenite crystals which are distributed unevenly, talcose schist around Angrala and Bari-Baikh. Around Baddar a contemporaneous thin patch of Bafliaz volcanics is found in assoceation with purple phyllites, Chlorite schists, injection gneisses north of Baddar village. This is followed in the north by Schists, gneisses granites, a sub unit of Salkhala group around Tuksun, Suprass, Ados and Noach villages. In the further north follows a thin patch of Tanawal, Agglomeratic Slate and and Panjal Trap along the crest of Pir Panjal. Near Khour and Shidoul villages intrusive granitoid pegmatitic variety of acid granites are located together with comparatively thin

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aplitic variety of leucogranites of younger age near north of Lar village. These granites of [redacted] origin are having sharp contacts with meta-Sedimentaries of Tanawal formation in the north and north-east of Khour village, and in the north to Shidul nala, there is yet another contact rock of chloritic, talcose schists and sericitic or silvery phyllites which show evidence of thermal contact metamorphism of Tanawal Formation due to Granitic intrusion. However, this phenomenon is conspicuous locally along strike direction of Tanawal Formation. From these field observations it can be inferred that these intrusives are of post-Tanawal age- which are metamorphics of Infra Agglomeratic Slate. Evidences of igneous activity in the so called older metamorphics of Salkhala Group exposed near Tuksun, Saprase, Adbes and Noach, is supported by observing the quartz veins peircing through the foliation of phyllites and Slates (PL 9 Fig. No. 2,4). Also thick quartzo-feldspathic veins occuring in intervals with country rocks near Adbes ridge, yield full evidence of igneous activity, to have taken place later than older granitic intrusions because these rocks are without perthites and look a fresh aplitic vein of quartz and feldspar and such later intrusions can be taken a case of Post-kinematic group of granites. The local occurrence of so-called migmatites north-east of Tuksun village can also be attributed to the injection of quartzo-feldspathic material through pre-existing rocks of phyllites and schists which gave rise to apparent migmatites and augen gneisses respectively

The Agglomeratic Slates are folded. The Panjal Trap occurs in the cores of synclines all along waterdivide. Around Didamgali pass, there is a thin patch of Gangamopteris bed along the flanks of syncline where its core is made of Zewan beds of Permian Age. In the aforesaid framework of regional geological setting it has been seen that the area of study shows stratigraphic succession ranging from the Precambrian formations to the Murree Formations(Fig. No. |).

In the Kashmir valley there is a nice development of fossiliferous palaeozoics but a similar set up is not develeped in this part of Pir Panjal region on the south of Watershed. There is a facies variation and the bulk of the formations comprise volcanics and metasediments. It is held by various workers that the metamorphics of south Pirpanjal are different from the other parts of Kashmir valley, possibly because of the relative abundance of pelitic material(ie a source material) which may be more in north of Pir Panjal.

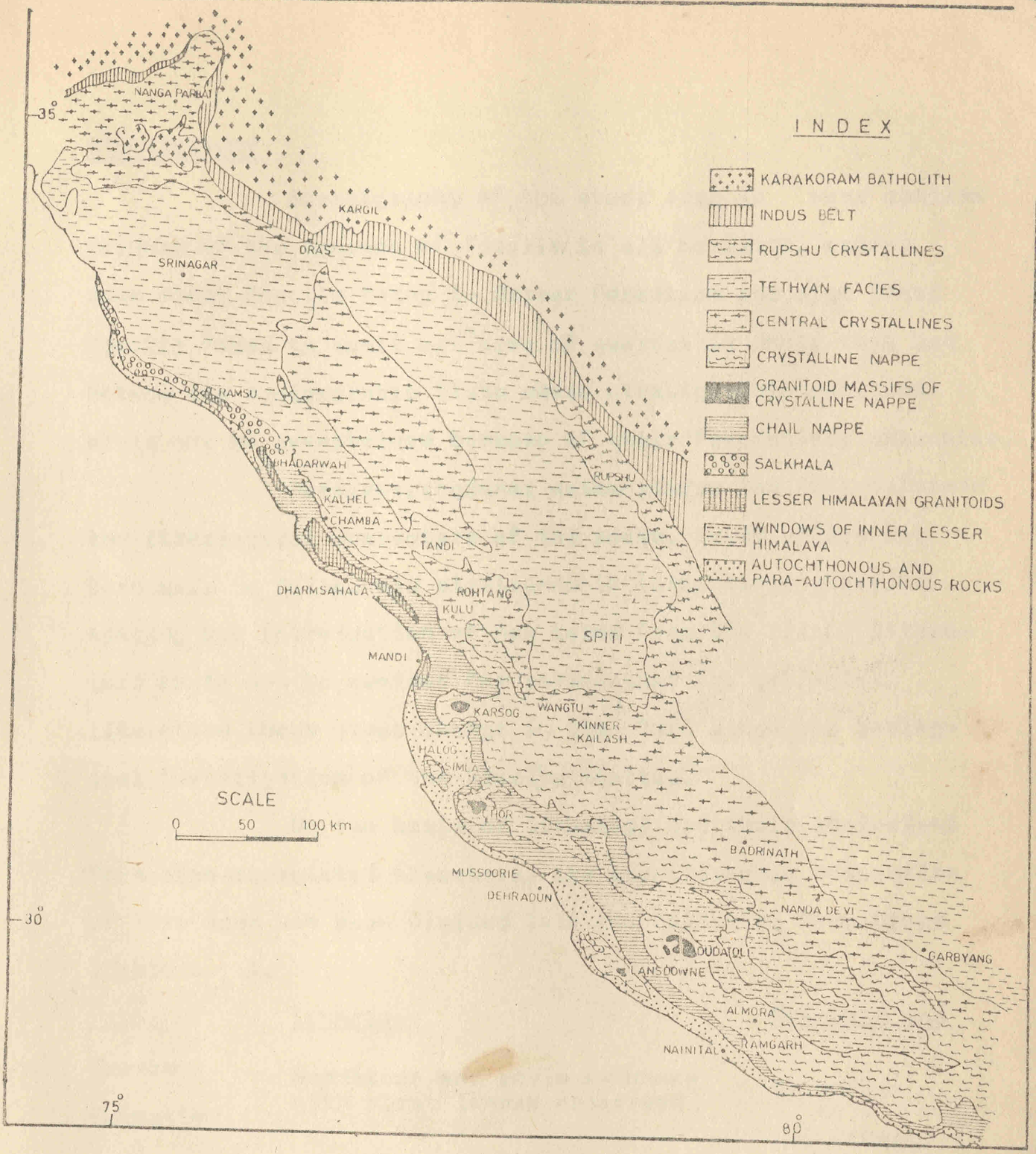


Fig. 1 Distribution of granitoids in the Kumaon and North-Western Himalayas.

Afk whom?

STRATIGRAPHY

Stratigraphy of the study area is very complex because of the absence of fossils in all horizons, except some plant fossils found in Murree Formation and also trace fossils found in small outcrop of quartzitic shale thin bed before the Agglomeratic Slate whose stratigraphic position could not be ascertained because of their fragmentary character.

Moreover, regional metamorphism has also deformed the lithological characters of the rocks. Every effort has been made to follow old stratigraphic terminology wherever needed, but introduction of new terms from the recent literature could not be avoided for reasons that the geological literature shows great change in its form since the geological investigation of the Himalya started.

On the basis of lithology and their equivalent formation-correlated elsewhere, the stratigraphic succession of this area has been divided into the following formations (Table — 1).

Units	Lithology	Possible age
Murree Formation	Sandstone and shale sequence with plant leaves preserved	Oligocene to Lr. Miocene
Zewan Bed	Ferrugenious Lst. with thin intercalations of shale	Up. Permian
Gondwana-Bed	Buff coloured clay, slaty quartzits with plant fossils Lr. Gondwana horizon.	Upper Permian
Panjal Trap	Massive grey, green, and purple amygdaloidal basalts	Permo-Carboniferous.

Agglomeratic Group	2. Agglomeratic Slate	quartzitic slate, graywack like slates	Upper Paleozoic.
	1. Baila Fm.	Shale, Slaty, Laminated Lst. Lenticular and nodular Lst.	
	(Gypsum Bed)		
	Gamir Fm.	Cream coloured, grey ortho-quartzite, Lst. Slaty Shale variegated shales with uneven pockets of coaly material	
Bafliaz Volcanics		Chloritic schist, grey and purple phyllites associated with spilites	Lower plaezoic possibly ordovician.
Tanawal Formation		grey coloured sericite phyllites dark colour slates, silvery phyllites, Psamite schist, Talcose phyllite schist light green orthoquartzite, pebbly phyllite and conglomeratic schists.	(? Lower Cambrian)
Salkhala Group	2. Gneisses and schists Gneissose Granites		
	1. Slate phyllites and loose carbonaceous shale with uneven selenite crystals, graphitic phyllite and schists.		Precambrian.

SALKHALA GROUP

Wadia(1931,1934) named the oldest rock formations of the Kashmir Nappe as "Salkhala Series" which derive its name after a little village situated on the left bank of the Kishenganga river near Keran in the Karnah Tehsil of Mazaffarbad distt.(now in Pakistan occupation). It is here that Wadia found such rocks to be typically developed. Gupta et al(1979) after

studing the supracrustal rocks of Drabsala, Doda Distt. regarded these rocks as Salkhala Formation, which, according to them, were deposited in the early geosynclinal stages of Himalayan orogenic cycles.

Sharma et al (1975) prepared a map on Bhadrawha area which indicates a number of granite bodies both in the rocks of Salkhala Formation and Bhadarwah Formation. The term Salkhala was widely used by many workers and is deeply entrenched in geological literature of Kashmir Himalaya But in late sixties this term was discouraged by various authors on the plea that there is no exact type area seen anywhere in the Kashmir Himalayas, which might testify the lithology as envisaged by Wadia in 1931. The characteristic features of this series according to him, are " Wavy crystalline schists, Phyllites, Carbonaceous Slates, generally altered to graphitic phyllites and schists, as a rule pyritous, associated with carbonaceous, or grey or white limestone often dolomitic and calcareous slates".....", Igneous intrusion are a notable consituent of this series. The schist is also included in this series. Severe plication and contortion are the most conspicuous characters of these rocks. The shape of the Salkhala outcrop is closely related to and reflects the tectonic trend of the region. Because there is hardly any difference in lithology between Dogra Slate and Salkhala Series, therefore, it has been a considerable problem for the author to resolve whether the schists, slate rocks of the

area could be included in Salkhala Group or Dogra Slate. Perhaps the absence of marble and graphite, are the only criteria which justify the inclusion of these rocks in Salkhala Group.

The problem of the lithostratigraphic classification of Himalayan crystalline rocks is a highly debatable question mainly because of the polymetamorphism that they have suffered at different times ranging from Precambrian to Tertiary. The crystalline rocks constituting the core of the Himalaya referred popularly to Central crystalline axis, and comprises rock of varying ages. Even fossiliferous Jurassic are known to be involved in this metamorphic complex (Tandi LimeStone, Powell and Conaghan 1973 which includes intrusive granites and granodiorites. It seems that the Tertiary metamorphism has obliterated the individual rock unit boundries as is borne out by a uniform natural regional metamorphism.

The crystalline rocks of the area under study also constitute a branch of the so-called Central crystalline axis and as such it is difficult to determine its exact Stratigraphic position. However , on the basis of unmetamorphosed or weakly metamorphosed rocks overlying this crystalline complex and known to be Tanawals of lower most Palaeozoic age (op.cit) it is possible to conclude that they are probably Precambrian . The intrusive granites within the complex could be younger, but in the absence of any geochronological data, it is not possible

to infer that. Accordingly in the present work the entire crystalline complex to the south of area is included as a part of Salkhala Group. This includes the gneisses and gneissose granites which have an intrusive relationship with the Schistose rocks.

Distrubution

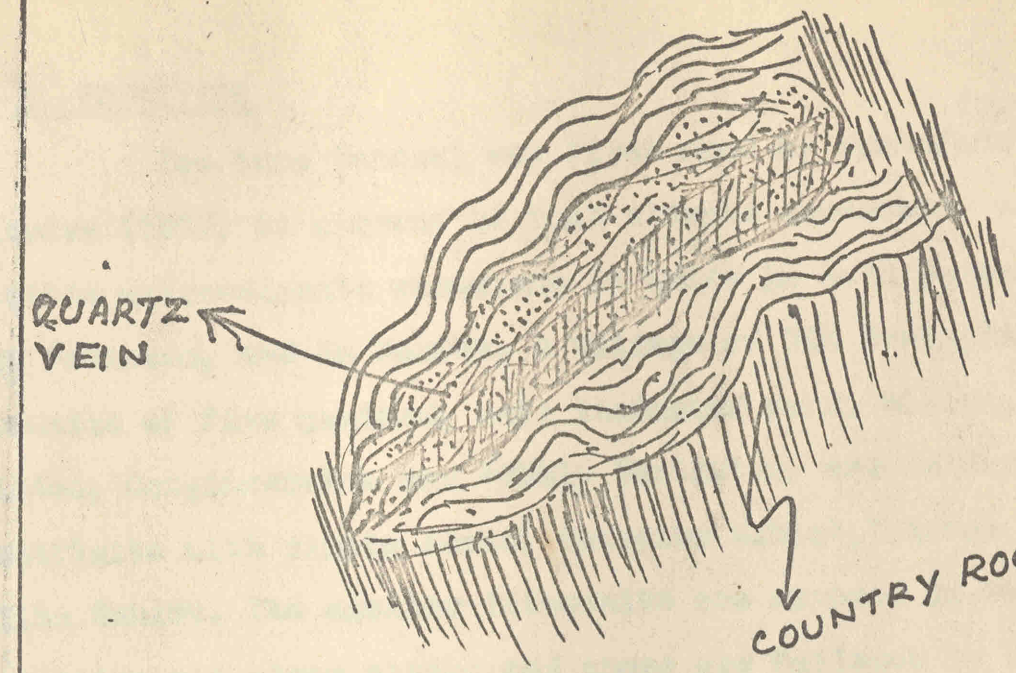
The extension of Salkhala Group in the area of study is from village Benjar in the east to a place near north of Baddar village in the west longitudinally and laterally from Helkhetaji in the south to Beribeikh in the north which include some prominent villages like Angrala, Tuksum, Noach etc.

Lithology

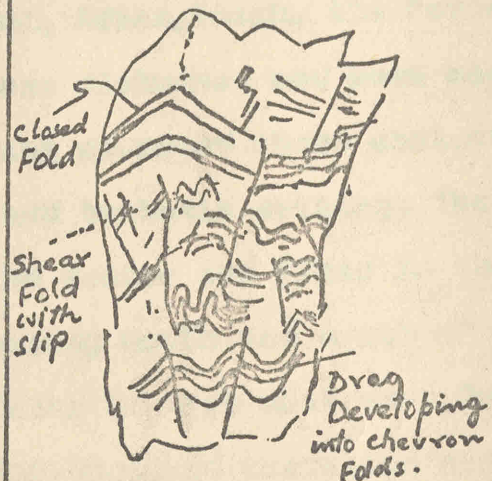
The Salkhala Group has been divided into the units. The northern limit is covered by gneissose rocks and gneissose granites including augen gneisses and injection gneisses while as the sourthern belt of Salkhala Group is schist, phyllites, dark slate and loose spongy phyllite found north of Helkhetaji along Tuksun-Angrala nala (Pl. 14 Fig. e). The Salkhalas on the whole are highly folded and compressed. Also thick quartz veins are seen piercing through the chloritic and sericitic phyllites and schists of the country rocks along foliation (Pl. 15, Fig. e). Severe plications, contortions and the uniform degree of regional metamorphism are the chief characterstics of these rocks in the Study area.

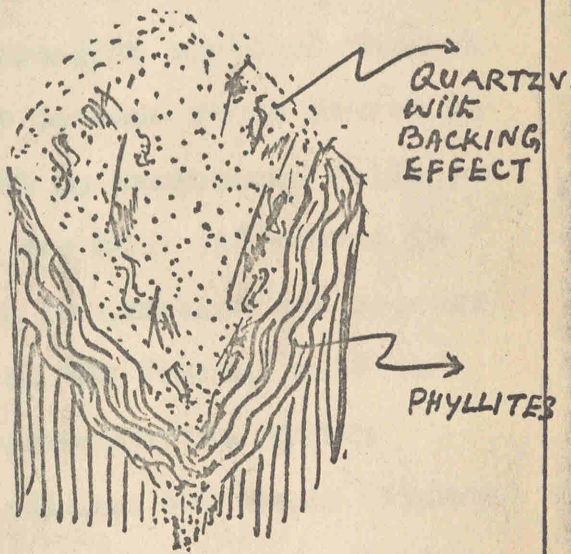
Plate-9

Fig. 2



QUARTZ VEIN WEDGING ALONG FOLIATION OF PHYLLITIC ROCKS IN GNEISSOSE BELT OF SALKHALA GROUP.





QUARTZ VEIN WEDGING THROUGH COUNTRY ROCKS (chlorite - sericite Phyllite)

TANAWAL FORMATION

The term Tanaual was first used by Wynne (1879) and Middlemiss (1896) to a group of much altered arenaceous and quartzitic metasediments occurring in bands in both Hazara, now in Pakistan, and in Karnah, a village of J&K State, India and consist of fine grained, well laminated sandy slates, Phyllites, Conglomerates and Pebbly Phyllites, and feldspathic quartzite with ripple marks, Psammite Schist, Talcose Phyllite Schist. The similar lithounits are exposed in Shidoul Nala section all along strike and these are followed by alkali granites-granodiorite suites while ascending the Shidoul subrange across strike direction. These granitoid-like rocks intrude the Tanaual Formation and while comparing with lower gneissose granite and Augen gneisses occuring south of Shidoul Tuksun, Adbes, Noach, the former higher igneous rocks appear to be less disturbed and more massive with no pronounced foliation showing preserved sharp contacts. This may mean difference in age and tectonic setting. The granites in question are coarser in the centre and finer in the margins. The Tanaual outcrop occurring north and south of granite-granodiorite pluton coalesce towards west near Gulabgarh village and these thicken in the westward direction along strike direction and close to Lar village, thin intercalation of pebbly phyllite, chlorite schists and phyllites a unit of Tanaual formation, are enclosed at places in the granite. Shearing was locally found along the intrusive contacts of granite-granodiorite which has intruded Talauale.

About 1.5 Km north of Lar village and near Bhransal Nala, dark to light grey coloured Sericite phyllites, schists and white and green quertzite, psammitic and conglomeratic schists outcrops are found north west of Gulabgarh village along nala section. The boulders and pebbles of conglomerate bed show much elongation(1:3), the spindle shaped boulders may attain length of 25 cm or even more and these components are mainly quartzites, grey dolomite slate, etc. The matrix of this conglomeratic bed happens to be schistose-phyllite of arenaceous material and the matrix of arkosic schists has been seen near west of Bharnasal. (Pl- , fig)

Fuchs(1967) finds close resemblance between the coarse clastic chail facies of Nepal and the assemblages of Tanawals of study area. From Barnsal over Gulabgrah village, the Tanawals follow the axis of NW - SE striking anticline.

STRATIGRAPHIC POSITION

The age of the Tanawal series is still a debatable question and it was in 1975 that their stratigraphic position was believed to have been ascertained on the basis of fossil findings in Hazara, Pakistan. However, the views still differ widely and many workers stress the need of viewing the over all regional setting of Tanawal series before any concrete conclusion is drawn. The author briefly presents the views of various workers who have studied them in various sections of Kashmir Himalaya. Wadia(1931) indicated their age to be much older than Gondwanas on the basis of high grade dynamic metamorphism seen in some members of this group, i.e. thinly foliated quartz and

mica schists. He does not include in Tanawals the outcrops older than Devonian or younger than lower Gondwana but this view is not in hormony with the probable age of Tanawals in the study area which appears to be older than devonian. He has related, basal conglomerate of Tanawals seen at Talhatta to be Tanakki and Blaini boulder beds of glacial origin which is considered by him to suggest the basal part of Gondwana age but this again does not seem plausible as the boulders in conglomerate do not show any sign of striations which could suggest glacial origin. "The Tanawal is not a stratigraphic formation but a group constituting a facies equivalent of the Middle and upper palaeozoic fossilferous succession of the Kashmir succession and can be seen passing lateraly into them" (Shah, 1978; Sharma, 1976).

In the western region(Poonch-Gulmarg section) the unfossiliferous units of Tanawal Group was divided into the following three formations (Shah 1980).

		AGGLOMERATIC SLATE	LOWER PERMIAN
Tanawal Group 1800 m	Suinar Fm.	3.Alternating quartzite and conglomerate beds	
		2.Feldspathic grit and arkose	
		1.Crossbedded calcareous orthoquarzite	
	Buniyar Fm.	Psammite schist and grey phyllite	
	Sailan Fm.	2.Cherty slate with bands of quartzite	
		1.Pebbly Slate,Phyllite etc.	

Baffiaz Formation (Possibly Lower Palaeozoic

The overlying and underlying beds of the Tanawal succession are fossiliferous and according to him their stratigraphic postion is more or less established. But in the area of study the Tanawal is underlain by (gneissose granite unit of Salkhala Group whose age is regarded to be Precambrian, and there is no such bed existing anywhere in Himalaya region to have age gap from precambrian to lower Permian i.e the Tanawal formation is taken care of by whole of palaeozoic era which seems to be ambiguous phenomena. Similarly, situation can hold time all along regional strike.

The contact at Sailan in the Suran valley between Bafliaz formation and lower Tanawal is normal and towards the top, the upper Tanawals(i.e. Suoran Formation) have vertical and lateral passage into the Agglomeratic Slate(Wakhloo and Shah, 1967). Here in the area under study, almost similar succession is observed except with only the difference that is the base of Tanawal formation in the stucy area is Salkhala Group and the contact between the two lithounits is of suspected tectonic one and Tanawal are overlain by Agglomeratic Slate which forms the limbs of anticlinorium. As reported earlier, the Agglomeratic Slate is known to be fossiliferous in the Apharwat section and represents lower Permian age and from this it is apparent that Tanawals will have(?) ordovician to lower Permian Stratigraphic Range.

Fuchs(1975) is not in favour of separating Tanols (i.e. Tanawals) from overlying Aggcomeratic Slate because as

Middlemiss too quoted from the same area (1909) and also Fuchs affirms that this is not the only instance of a gradation from Tanol into Agglomeratic Slate (Gulmarg Section; Wadia 1934, Middlemiss 1911) and (Chambapangi section by Fuchs and Gupta, 1971).

Recently Tanawals of the type area in Pakistan are underlain by late Precambrian Hazara formation and overlain by Abbotabad formation. The latter have yielded Hyolithids and other concid forms of Lr. Cambrian age. The age of Tanawal is, therefore, suggested to be cambrian age, and is intruded similarly by Manishra Granite, an equivalant to Dalhausi granite (Ibrahim Shah, 1977) and this age has prompted the author to regard granites associated with Tanawals to be as found elsewhere in the adjoing areas around Dalhousie in the east of study area along strikewise which gave the radiometric age as 450±25 my (Bhanot et al., 1974) which comes around Ordovician- silurian period and fits well in the stratigraphic column if Tanawals are taken to be older than silurian through which granitoids of Khour-Shidoul- and Lar Villages of study are found intruding. But gap between late cambrian to Middle Carboniferous can be justified. The break is attributed to universally recognised

Hercynian break found along whole of the Himalayan belt. This break is almost reported by G.S.I. various authors e.g. Srikantia(1976) with respect to Zanskar area where this break is recorded, Hyden(1966) reported Similar break from Spiti, Valdiya (1971) reported from Kumaon Himalaya . Similar Hercynian break is reported from Nepal (Stocklin, 1980) and lately Bassi et al. (1983-84) also reported this break while studying new -Phanerozoic basin in Kanour, north-eastern portion of Himachal Pradesh. With these breaks recorded from various sections of Himalaya may justify for a similar break to exist in the study area as well.

Srikantia and Bhargava in their paper "Chail Series of H.P." (May, 1985) have recommended for the deletion of term of Chail from the geological literature as it has lost its validity as a stratigraphic terms which was hitherto continued by Fuchs(1981), Valdiya(1978)(1981);Virdi(1981). The term was initially used by Pilgrim and West(1928) while making critical study of now called Himachal Himalaya. According to Bhargava et al.(op cit) Chails occur in two tectonic horizons - the lower Chail allochthon as a thrust sheet over the Shali and the upper Chail allochthon as an infra Jutogh thrust sheet. They concluded that lower Chail allochthon which is a sedimentary unit belongs to Simla group and also regional nappe tectonically overlying the Shali-Simla Groups and is designated as the Salkhala thrust sheet; while as the Upper Chail allochthon is found to be a used part of the Jaunsar Group.

therefore Chail-Tanol as Fuchs has used in his investigation of area of study (op. cit.) is vald only if the name "Chail" is dropped from this association and only Tanol the term used by Fuchs kept which seems to be plausible from the findings of present author who has adhered to the use of Tanawals in its perspective manner.

BAFLIAZ VOLCANIC FORMATION

Wadia(1928) found some basic lavas in Poonch area which were certainly different from the Panjal Traps and considered them as contemporaneous with the Dogra Slates.

Wakhaloo and Shah(1968) named the lavas as Bafliaz volcanics on account of their exposure near Bafliaz village in the Suran Valley of Poonch district. The term has been retained in the present work for similar rocks found near village Baddar(Long. 74^{0} 51' Lat. 33^{0} 22') Moreover, the traps occurring near Baddar exhibit close petrological and chemical affinity and lie in strike continuity with the Bafliaz volcanics of Suran Valley, West of the present area. These characters amply support the use of this nomenclature. These exposures are found to be penecontemporaneous with Salkhala Group of rocks.

Lithology: These volcanis are found to comprise spilites which are penecontemporaneously interbedded with chloritic schists and phyllites and purple clay. The spilites are massive, amygdaloidal , porphyritic, fine grained, very much Schistose in character due to subsequent tectonic movements. The rock units of this formation are light green to dark green, and purple

in colour.

Stratigraphic Position : The stratigraphic position of this formation is also very difficuat to ascertain due to absence of fossils. Wadia(1928) considered these basic lavas as contemporaneous to the Dogra Slate. As already mentioned, the age of Dogra Slates of north western Kashmir is from late precambrian to lower cambrian(Wadia 1934), therefore, the age of Bafliaz Volcanis in the area can fit well with the metamorphs of the area. These extended from right bank of Gulabgarh Nala upto west of Baddar in the strike direction.

Shah(1971) has assigned a lower palaeozoic age to this volcanic formation. The presence of Trilobite fragments found in slates of Bafliaz Volcanies formation at Alal village near Thanamandi Rajouri Distt. as reported by Sharma and Gupta (1973), Shah et al(1980) support this view.

AGGLOMERATIC GROUP (ii) Agglomeratic Slate

(i) Gamir and Baila Un-differentiated Fm.

Gamir and Baila Formation : This formation lies in the South of the belt sandwitched between Murree and Panjal Thrusts. It starts in the west from Uri in the Jhelum valley extending eastward through Poonch, crossing Srinagar - Jammu highway in the east near Pira and further east it extends upto Bhasoli. Besides this there exist, Agglomeratic Slate belt above which lies Panjal Traps of the same type found along the crest of Pir Panjal in the north of Panjal Thrust-or in Kashmir Basin. However, this unit is widest in the west and narrows down in the middle in the area under investigation byt then it further

widens as we move towards far east.

Though Gamir and B-aila are two different units but here these are considerd as one undifferenteated unit because of its varried lithology and complicated structures(Rao et al. 1976) Karunakaran and Ranga Rao,1976. According to them Panjal Trap, Gamir and Baila formations, Agglomeratic Slate and Panjal Trap constitute a conformable sequence of carboniferous to permocarboniferous age, exposed between the Murree and Panjal thrusts all along the base of the Pair Panjal and Dhaulndhar ranges. Gamir formation is exposed as a thin strip to the north of Muree Thrust and consists of massive white quartzite, purple shale, grey shale with calcite partings, calcareous quartzite with bands of cherty shale and bands of quartzites with ripple marks(Pl.13 Fig.d) near Batoi village, gritty quartzite with bands of conglomerate alternations of gray, marroon and green slaty shales, and marly, grey and purple coloured limestone, etc.

Baila formation overlying Gamir formation consists of alternate bands of geey, dark grey shale and lenticular nodular limestone. At places, near Sildhar, interbedded layers of limestone and shale are seen to have thin lenticular quartzite bands, varigated shales and carbonaceous shales with occasinal coal bands found in pockets. However, these coaly pockets are found unevenly but all along the Murree Thrust between Sahr in the west and Sildher in the east.

[redacted]) The nomenclature of these unfossileferous formation proposed by G.N.G.C. Workers, has been retained in this work.

Stratigraphic Postion : Different views regarding their stratigraphic position, expressed so for, can be broadly groupedin three schools of thought (Shah, 1980), (A) These formations are considered Eocene in age and their infra-Agglomeratic Slate position is due to overturned fold, because they are reported to be exposed in the inverted limb of an anticline while as the normal limb formation of an anticline constitute the Rajpura formation(Wadia, 1928) what must made him to take them as Eocene(without fossils), on the basis of lithology in deep enviorments such as carbonaceous shale including the coal seams and nodular limestone in the Baila formation/Wadia continued to say that it (Baila) represented a reverse limb and is correlable to Rajpura formations, But two points go against these views. First, the Rajpura formation is rich in fossils while-as the belt under question is without any fossil control. Also as pointed out by Rao et al,(1975), the thick quartzites of Gamir are not occuring in Eocene of the subathus, and the point was not kept in mind by Wadia in his observation regarding the age of such unfossiliferous rocks. Later workers like Shastri(1964), Sadhu (1972) etc. also considered the quartzite of the Gamir formation as part of the Eocene, But they have ignored the fact that the Rajpura formation is fossiliferous with Eocene fossils

and the former belt of Gamir is without fossil record.

(B) Wakhloo and Shah (1970) and Shah(1971) proposed that the Gamir formation is a part of the Agglomeratic Slate and the Baila formation represents Eocene. This was perhaps due to the Gamir being lithologically similar to Agglomeratic Slate in various parts of Kashmir and also contains bands of breccia. The rocks of the Baila have a close similarity to the Eocene succession of the Subathu facies is not Hazara facies. In addition the contact between the Baila and the overlying Agglomeratic Slate is invariably of a tectonic nature as the entire sequence was right side up indicated by the nature of schistosity and the occasional cross bedding which indicate only a few local inversions(Shah 1980). It follows that the Agglomeratic Slate has been thrust over the Eocene Baila which rests unconformably on the Gamir formation(Agglomeratic Slate). But the main objections to it are absence of Eocene fossils in the Baila and also the absence of the intervening panjal volcanics and Zewan formation between the Gamir and Baila.

(C) Karnukuran and Ranga Rao(1976) proposed the Gamir and Baila formation to be a part of the Agglomeratic Group the inclusion of the Baila in the Agglomeratic Slate was prompted by the absence of Eocene fossils in it, while they are in abundance in the Rajpur formation. But the kind of lithofacies constituting the Baila is not known in any Agglomeratic Slate Succession in the Kashmir Basin (Shah, 1980).

From these discussions regarding the stratigraphic position of the Baila formation the idea that the sequence represents the inverted limb of the Eocene succession is not

true. It is obvious that the rocks which underlie the Gamir formation should be older than the Agglomeratic Slate. Karunakarn and Ranga Rao (1976) state that the Gamir is underlain by the Mandi volcanics which is exposed to the east of Chenab and this in turn is underlain by the Shali formation which is exposed to the east of Dharmsala. This shows that when traced in strike direction from Himachal Pradesh to Kashmir though apparently paraautochthonous zone has a uniform lithology it reveals varying rock succession dating from probably precambrian through permian and Eocene with major stratigraphic breaks in between (Shah, 1980).

Gamir and Baila formation extends vertically from Batio village to Serni, across the regional strike in the east whileas in the west it extends vertically from Sahr to Baga and laterally the belt extends from Sildhar in the east to Baga village in the west Permo-Carboniferous fossils from the graphitic shales and limestones of this unit are reported from the area 20 Km. north of Udhampur (Sharma, 1973). An outcrop of gypsum quite suitable for the manufacture of fertlizers and plaster of paris is found in Baila formation near Batoi village. The gypsum has intercalation of lt. stone streaks and shaly material if closely seen.

Agglomeratic Slate : The term Agglomeratic Slate was introduced by Middlemiss(1910) in the Kashmir valley. The typical Agglomeratic Slate as described by him comprises mainly of a dark grey rock, dotted at random with larger patches of white and grey tuffs with foreign angular pieces and some times rounded pieces or

pebbles, interbedded at places with grit and conglomerates and in his words the Agglomeratic Slate of Kashmir is an accumulation of clastic sedimentary material formed around ruptured portions of the earth's crust which eventually became foci for the extrusion of basic lava flows. The term Agglomeratic Slate should be used in its true word, connating the formation to contain volcanic pource and glassy matrix which Wadia in his observation while describing some sections made it clear that Agglomerates are graywackes at places merging into slates. Here in some of thin section of this formation, graywacke texture has been noticed (Photo(f) PL-19) But as the name implies, it should be volcanic in origin and Agglomeratic Slate in some horizon in Kashmir is reported to be fossiliferous; therefore, marine origin is inferred There are two schools of thought about its origin, one thought is advocating to marine origin as expressed by Bion(1928) and Reed (1932), and the other school of thought favours volcanic origin as expressed by Wadia(1928).

From these two observations the author feels inclined to keep this important formation to have resulted as due to volcanic activity through pre-existing sea.

Since this thick horizon has no formational name because of its diversity in lithology, i.e. the slates contain orthobreccias, quartzites, conglomerats and also some intervening slates. As such this important horizon in Kashmir Himalaya may be regarded as Agglomeratic Group instead of giving its

formational name. Agglomeratic group is used in the present study simply to take care of other rocks which are here and there associated with Agglomeratic Slate found in the area around Arital, Kaindora , etc. in strikewise direction with thickness about 400 m vertically.

A sample from the upper part i.e. true agglomerate, is reported to have yielded(Permo-carboniferous) spores and plant remains (Fuchs, 1975), but despite best efforts the present author has not met with any plant remains from the said horizon.

Litholorgy : The Agglomeratic slate occur near Gulabgarh below Panjal Trap, north of Panjal Thrust. It comprises dark grey and white quartzites, grey and brown, fine to medium grained sandstones and quartzitic sandstone. Cross bedding , oscillatory ripple marks and clay gall breccias are not uncommon. In some cases, angular or rounded pebbles and boulders are found embedded in grey slate, siltstone, sandstone or graywake matrix. These angular or rounded fragments mainly consist of green white quartzite, caarbonate rock, slate, volcanic fragments, etc.

Distribution : The Agglomeratic Slates have wide distribution in the area. Towards the eastern side, beyond Bharnsal village where Agglomeratic Slate rests over Tanwals conformably and in the western side strikewise, a thick zone of Agglomeratic Slate extends even beyond N - W of Daoulmarg. These slates have different postions at different places. Near Arital, the slates are overlain by Panjal Traps, while as near N-E of thiamarg the slates are underlain by Panjal Trap, because of the structural

control of the Pir Panjal crest. The anticlinoium is composed of Panjal volcanics where-as the Panejal Traps occupy the core of synclines and Agglomeratic Slates occupy core, of anticlines in the area.

Stratigraphic position : To find the stratigraphic position of A gglomeratic slate in the area, it is not so easy to delineat the lower limit of its age because of the absence of marker horizons of fossiliferous strata i.e. syringothyris limestone and fenestella shale found in the southeastern parts of Kashmir valley and partly due to the absence of fossils in the Agglomeratic Slates of the study area. And also due to the absence of fossils in underlying Tanawal formation it has become rather a complicated issue to fix up the lower age limit of Agglomeratic Slate. However, the upper carboniferous age can be fixed because at some places, the Agglomeratic Slate are overlain by Panjal Traps and gangamopteris beds and Zewan beds of Permian age in Didamgali section of Pir Panjal Range.

Middlemiss(1910) established the stratigraphic position of this formation on the basis of its faunal content. But at the same time, he was under this notion that this formation occupies different portions in different sections. According to him its age is ranging from Moscovian to the top of Uralian or bottom lower part of (M.Carboniferous) Artinskien which are based on some difinite faunal and floral evidence within the formation at various places like Nagmarg, Kolahai and Apharwat. And also at DidamGali (Gulabgarh pass) discovery of plant bed

and Zewan beds forming the core of syncline(Middlemiss,1909) shows the age of the plant bed to be lower Gondwana (Lower Permian) found within the Agglomeratic Slate of the area under study.

However, in the area, there seems to occur a relationship in position between Agglomeratic Slate and Panjal Trap. At some places the Agglomeratic Slates occupy infratrappean position and at places the same formation occupies supeatrappean position. This may be due to structural aspect existing in the area, which is given by anticlinorium and also supported by Sharma et al.(1976). The same relationship is exposed near Pir Topa and Sangliam of western Pir Panjal Shah,(1971). Though this is not surprising because agglomerates are known to be interbedded with Panjal Trap in Bandipur-Nagmarg area (Wadia 1934) and in Toshmaidan area of Apharwat Region of Pir Panjal Middlemiss,(1911) where conglomerates and grits are overlying Panjal Traps. Hence on the basis of the lithological resemolence with that of Kashmir valley and overlying Panjal Trap followed by discovery of Gondwana plant bed in the core of syncline Middlemiss (1909) in the area of Gulabgarh it can be concluded that its range exists from lower part of Middle carboniferous to upper carboniferous.

Panjal Traps : The Panjal Trap are porphyritic as well as massive in hand specimens. The Panjal Trap of both the horizons exhibit the same textural feature with colour waring from green, purple, grey and dark green. The only difference which is evident in the field between the two traps of the same age is in their schistose character. The traps which occupy the core of synclines along the crest of Pir Panjal appear to have developed schistose stucture while-as the shistosity is missing within the traps in the perautochthonous zone which look fresh, hard in appearance. On the whole, the traps in the area are much epidotised. When seen under microscope, both the traps have amygdales filled with quartz, chlorite, Zeolites and in few sections the cavities seen to be filled with calcite.

Under microscope, the traps are porphyritic in texture and minerals found in them are plagioclase feldspars (An 35-55) epidotes, and uralitized pyroxenes, but olivine is conspicuously absent in them, chlorite is plentiful.

The traps in the area under study occupy the core of synclines along the crest of PirPanjal ranges while-as immediately south of Panjal Thrust, the traps are found all along the strike of the region.

Stratigraphic position : Here the traps are overlying the true Agglomeratic Slate whose stratigraphic position is amply clear as upper carboniferous and at Didam Gali (Height 3810 m) the

traps are overlain by younger formations of Permian age called gangamopteris bed and Zewan bed.

From this, it is proved that the Panjal Traps of the area range from upper carboniferous to Permian age.

GONDWANA BED

This is a thin bed forming the limbs of syncline near Didamgali on the Pir Panjal Range and was reported first by Middlemiss (1908). It is shown on the geological Map(No.) Detailed description of this outcrop has not been attempted since it falls outside the limits of study area towards north. However, traverses have been taken and outcrops have been plotted while crossing over the Pir Panjal Range from the Kashmir valley to the south to approach the study area.

MURREE FORMATION

This formation has a type area in Pakistan and named after the hill station Murree in Pakistan and was also called "Red Rocks" by Lydekker. The Murree Formation, a thick lithological assemblages of shale and sandstone has wide aerial distribution not only in this area but also other areas of the Himalaya on regional scale. The Murree Formation is divided into two parts, by the earlier workers and these are known as lower Murree and upper Murree.

The lower Murree exposures are seen while coming to the field from the direction of Riasi and its outer limit starts from north of Kanthan bridge over the river Chenab. These on first look appear to be Sandstones-Shales alternation

containg few beds of bluish yellow weathered limestones, which show some remains of unidentified nature. These beds are similar to lower Murree as described by Wadia (1928). The lower Murree appears to be highly plicated and faulted poorly preserved current bedding and graded bedding is noticed in few outcrops Red colour of rocks is suggestive of its continental nature and continued sequence of sandstones, siltstones and clay stones points towards the occurrence of oscillatory movements in the depositional site. These exposures extend upto a small village Matlose which is situated hardly 5 K.m. from Arnas. Then much north of Matlose witness the exposures of upper Murrees which actually fall on the study area. For about 25 K.m. only these murrees are exposed along the trail which follows up the Ans River. The lower Murree formation is partly extending upto Murree Thrust along the area called Mohr and Mala and Sahr villages in the west of study area.

An interesting feature observed in the field is the presence of a thin boulder bed running strikewise near a place about 2 K.M. south of village Matlose such boulder bed has been reported for the first time and contains huge sized boulders interspersed with pebbles and cobbles of limestone, quartzite etc. within the sandy matrix. And perhaps this thin boulderbed shall be a passage bed between lower Murree and upper Murree and the latter portion of Murree actually forms a part of interest. The characteristic feature of this upper Murree is noticed by the presence of dip slopes and a series of

strike ridges and valleys which is evident from the geological map attached. They are much folded and dip N.N.E at varying angles indicated in the geological map. These folds are normally isoclinal. Symetrically and asymetrially (Fig. 13 PL. f) synclines and anticlines are beautifully displayed in Ans river section especially near village Mailose.

Lithology : These Murrees are essentially composed of alternating sandstone and shale with interclations of clay rocks in between the sandstone which is greenish grey to purplish red in colour and has micaceous tinge with glauconitic character. These rocks look to be somewhat hard and quartzitic in nature. The shale is generally reddish brown, purple and greenish grey in colour. The shale and sandstone are traversed by veins of calcareous cementing material which is evinced by the infrequent local occurrences of patches of carbonate weathering in holes. They are the product of syngenetic disruption of carbonate laminae in the sandstone. The red and purple micaceous shales are seen crumbled due to weathering. Rarely cross bedding with conspicuous ripplemarks have been noticed in few outcrops of sandstones.

This formation is distinguished from lower Murree by thick bedding, very fine to occasionally medium grained and grey silty and clay matter are less frequent in upper Murrees. Intraformational conglomerates are present in this formation. Predominance of coarse clastics in the upper Murree is suggestive of high energy conditions. And presence

of tree trunks found elsewhere in the formation by various workers and plant impression of Sabal majors leaves on shaly material is again suggestive of deposition in lagoons and swamps. The lower and upper contacts of this formation are transitional (V.V.K.Rao et. al. 1976).There are occurences of rock slides at places along the traverse which is perhaps due to the fact that underlying loose material, i.e. shale and clay, upon weathering gives way to overburden of heavier and denser material like sandstones. However, the shaly and clay materials contain plantiful of montmorillonit-e mineral which has property of swelling on exposure to rains thus rendering least resistance to overburden and making the affected spots much slippery which consequently become the areas of weak zones. To such slide , a term gravity-slide is proposed.

Distribution : The Murree Formation forms the thickest horizon of all the beds in the study area and covers about half of the study area. Dipwise, it extends from Matlose in the south to a place about 3 K.M. north of Mohr and strikewise it extends from Gul in the east to Sarh in the west or to a junction of Gulabgarh nala and Ane River coming from the west. Southern limit of Murree formation follows exactly the important high angled reverse fault called " Murree Thrust" of Wadia (1928) as shown in geological map. The prominant places which are the outer limits of Murree formation are Mutgala, Sildhar in the east and a place south of Satoi, Sahr village in the west and

all are found along the E-W trending Murree Thrust. These formations dip roughly 40° to 60° N.N.E. and lower and upper Murrees in juxta-position dip beneath an undifferentiated unfossiliferous Gamir and Saila Formation and the contact between the two units is of tectonic one. The striking feature of the study area is that the northern limit of Murree formations follows exactly the drainage courses of Satmi nala in the east and Ane river in the west.

Stratigraphic position : It may be mentioned that plant impressions like Sabal major(Pl.4 Fig.c) found in study area and tree trunks found elsewhere in the formation are not useful in assigning any age to the formation. Since it overlies the lower Murree and underlies lower Siwalik, therefore, its position is taken to be infra-Siwaliks. On the basis of this unmistakable evidence, its age may be considered to be of lower Miocene age. The contact between Siwaliks and Murrees is of tectonic one where Murree Formation rest conformably over Siwaliks far south of the study area and hence not indicated in the geological Map . Excellent conformable sequence of Murree Formation and Siwalik Formation is exposed in the Kalakote coal field (Bhandari et al. 1967). It is, therefore, sufficient to infer that the lower age limit of Murrees to be Oligocene and extending upwards to Middle Miocene.

It may not be out of place to record the trace fossils from a bed of quartzitic shales occuring in Sildhar-Malkhetaji

section near north of serni village before true Agglomeratic Slate is encounterd in a dip wise traverse. This lithology has yielded tribolite fossils possibly Rusophycus sp. (Pl.14 Fig.b)

The other fragmentary fossil shows inclination with Monomorphichus (Pl.14 Fig.a), but since the markings are radially arranged and originate from a broken oval part, could be also a part of pygidium . The age of such sequence whose stratigraphic position could not be ascertained because of inhospitable conditions prevailed and also due to its poor preservation. These fossils make it a difficult thing for the author to come out with catagorical evidence at this stage in such highly deformed region. According to Dr. S.K.Shah, Prof. of Geology, University of Jammu, the probable age for such fossil is cambro-silurian or it may go to even (Ordovician ?). This discovery of such fossils in the study area is significant one, in the sense that it was found for the first time and may became a guiding factor for future investigation.

Similarly, rolled fossils of Brachiopods shells, possibly of Productus sp. in host siliceous limestone were found around Baddar which is the western limit of my field. The field beyond Baddar along western direction, does not fall in the work of this thesis and, therefore, the source for such fossils could not be ascertained. Surprisingly enough, these fossiferous boulders are used in large number as building material by local population.

CHAPTER - V

Structure And Tectonics

In this chapter, an attempt is made to present the results of observations on the structures and tectonics of the area. The structures are classified into macro structures and (2) Micro structure. The macro structures are those that have been observed in the field and are further sub-divided into Major structure and Minor structure. Major structure are on regional scale and comprise folds, joints, thrusts and faults etc. Minor structures are found within the formations on minor scale e.g. cleavages, lineations, etc.

Micro structures are those features that are observed under microscope and have been interpreted from the size of the mineral grains and their mutual relationship. This microscopic examination of rock sections has thrown light on their textural and structural features which otherwise could not be seen in the field with unaided eyes.

On the basis of tectonic units Wadia(1961) has proposed the following structural zones in the lesser Himalaya on the north western part of India.

Foreland zone — 1. Sivalik belt characterised by Jura type open

simple folds and reverse strike faults.
2. Sirmur belt.

Authochthonous fold zone. — 3.Carboniferous Eocene belt includes carboniferous Triassic cores within the recumbent folds of Eocene.

Nappe Zone. — 4.Dogra Slates,5.Crystalline belt of metamorphose rocks intruded by granites.6.Late palaezoic sequence of Tanawals,Agglomeratic Slate,Traps. 7.Tibetan belt includes marine sediments from cambrian to Eocene.

Valdiya (1964) proposed a fivefold classifications for the structural zones of the entire Himalaya (1) the autochthonous Siwalik Zone, comprising Jura type simple open folds,affected by steep reverse faulting(ii) the para-autochthonous Lesser Himalaya Zone made up of early Tertiary formations within severely compressed folds, broken by steep faults,(iii) the Krol Nappe System consisting mostly of unfossiliferous sediments and he included the thrust bound folded belt of Kashmir and the Nawakot nappes of Nepal (iv) the Kashmir nappe, which includes the Kashmir,Jutogh, Garhwal,Kathmandu and Khumba nappes, is a belt made up of Pre-Cambrian crystalline and is characterised by huge recumbent folds, and (v) the Tethys Himalaya,comprising cambrian-Eocene fossiliferous sediments showing imbrications and clean thrust sheets with attendant folding.

Fuchs(1975)divided the Riasi-Gulabgarh section into the following structural units from (S to N):-

1.The Siwaliks:Folded Miocene to pleistocene molasse deposits.

2.The Murree Zone — Along steep angle thrusts and in anticlines shalis(Permo-Carboniferous ?) are exposed, overlain by paleocene-L.Miocene strata. This zone is much folded.

3. The parautochthonous zone	It is thrust on the Murree zone. The sequence of this seems to represent a normal Proterozoic-Permo-Carboniferous succession; probably it also comprises palaeocene-Eocene beds, but no recumbent folds as reported early by Wadia (1928).
4. The Chail Nappe	The epimetamorphic Chails intruded by granite gneiss are the southern continuation of the Chail Nappe which is exposed in the Kishtwar Window.
5. The Crystalline Nappe	This comprised the succession of Chail-Tanol, Agglomeratic Slate, Panjal Trap, Gondwanas, Zewan Formation, Lower Triassic But he is not in a position to separate Chail Nappe from crystalline nappes however, at Shidoul, he assumed a thrust separating southern granite gneiss (Chail Nappe) from the Chails-Tanols which are intruded by more massive metagranites (Crystalline Nappe).

On the basis of structure lithological characteristics of the study area, the following units have been recognised from south to north (Fig. 5).

1. Murree Zone	Early Tertiary rocks are thrown into isoclinal folds.
2. The Para-autochthonous Zone	The sequence seems to be normal of lower palaeozoic to permocarboniferous rocks which are thrust onto the Murree zone along the Murree Thrust. This zone is confined between Murree Thrust in the south and Panjal Thrust in the north.
3. Crystalline zone	It is a thick belt of meta-sediments comprising gneisses and schists non-foliated intrusive granitoids to the north of Panjal Thrust and is bounded to the north by Pir Panjal Zone.
4. Pir Panjal Zone	It is the belt consisting of Agglomeratic Slates, Panjal Traps, Gonduana bed and Zewan Formation in open folds.

Classification of structures is proposed as follows:-

Structure

Macrostructures	Microstructures
Major Structures(Folds,Faults, Thrusts)	Minor Structures(Lineation, foliation,puckering etc.

Major Structures include(1) Thrusts (2) Folds. (3) Faults

1. Thrust. Two thrusts are well established,and a third is of tectonic nature inferred one. The former two thrusts are the Murree Thrust and the Panjal Thrust. The Murree Thrust being high angled reverse fault and is a tectonic contact between the Murree Formation and overiding unfossiliferous Gamir and Baila Formations. This thrust exactly follows the Ane. River in the west and small stream called Batoi nala and Sildhar nala in the east (Fig. 1 (Pl-5)).

The Murree Thrust has a WNW-ESE trend and shows a dip ranging from 35°- 55° to the north-east. This thrust name is considered to be continuation of Main Boundary Thrust. The development of calcilutite is pronounced along the road section near Sahr village. The second major tectonic feature of the area is the Panjal Thrust and it is referred to as a "Low angled decollement" along which the Kashmir Nappe moved (Wadia 1934). In the present area of study,Panjal Thrust is a tectonic contact between Panjal Trap of para-autochthonous zone of Permo-Carboniferous age in the south and Salkhala Group occasionally overlain by Safliaz Volcanics in the north. This thrust has gentle trend and shows an inclination of about 35° NE. The two prominent thrust sheets,very close to

each other on the east of the study area exhibit intense degree of shearing. This thrust is noticed near Nalakhataji (3420 m) and re-emerge near just south of villages Selmat-kota (south-west of Saddar village). Besides these two major thrusts there is a suspected tectonic break possibly of strike-slip fault nature between the Tanawal Formation and Salkhala Group, which runs parallel to Shidoul nala in the east and extends beyond Gulabgarh nala traceable near south of Sarmadhar (structural map.). This appears to be a persistant tectonic feature in western Pir Panjal also and seems to be correlatable to Chandimar fault of Poonch belt (Shah, 1980). (Fig. 1 Pl-8 &). It is an established fact that a basic difference between the tectonic setting of Kashmir and the tectonic setting of the rest of Himalaya lies in the absence of Central Crystalline Axis which separates the Lesser Himalayan facies from the Tethyan facies and the Tethyan facies of rocks is not so sharp as in the rest of Himalaya (Shah, 1978). To the south of CCA comes another regional tectonic thrust called the Main Central Thrust (MCT). But there is no equivalent of main central thrust in Kashmir Himalaya. However , the Panjal Thrust is treated as its nearest equivalent because it demarcates the Tethyan belt of Kashmir from the rocks of Lesser Himalaya and outer Tertiary zone. But it is neither a zone of maximum deformation or metamorphism (concept of main central thrust of Bordet 1970, Brunel 1975, Lefort 1975) nor are the

high grade matamorphics resting on gently metamorphosed rocks (Vaikrita thrust of Valdiya 1979),(Shah 1980). According to Wadia, Panjal Thrust is a decollement type along which the Kashmir Nappe moved. All the beds within the area right side up and all thrusts follow the strike of well bedded formations and appear to represent Bedding Thrusts.

Folds These are more prominent in the southern portion of study area and are found mostly within the Murrees and some found are in Agglomeratic Slates.(Pl.16 Fig. f). The folding is comparatively simple in the Murree Zone and northwardly, the similar folds are seen compressive and isoclinal in nature. The Murree are thrown into anticlines and synclines along the Ans River Section.

Plassu nala and Narlu nalla flow along the axes of anticlines of Murree Zone (Geol. Map 1).Folding is not intense as reported by earlier workers but the folding is much compressed and prominent in the east as seen in the field. Both symmetrical, asymmetrical anticlines and synclines are beautifully displayed along the right bank of River Ans, especially near the villages of Matlose and Arnas(Pl.13 Fig.e&f). The fold axes of synclines and anticlines follow exactly the regional strike. The formations comprising para-autochthonous zone and Panjal Zone of this area show isoclinacal folding with slightly high angle axial planes.

Minor Structures The imprints of the various tectonic elements that took place during the long history of the area and which can be studied directly in the field are documented as minor structures. These are smaller in magnitudes. Minor structures may be classified as planar and linear structures. The area of study comprises all the three types of rocks, igneous, sedimentary and metamorphics and they exhibit excellant structural features.

1. Planar Structures These structures consti[tute] bedding schistosity, Fracture cleavage(c) slip or shear cleavage(S), joints, etc.

a) Bedding schistosity These features are more prevalent in less metamorphosed belt of Salkhala Group and Tanawal Formation of the study area. In the metamorphics of the area, the bedding schistosity or foliation is regarded to be the result of isoclinal folding and mimetic crystallisation (Parallel to the original bedding) and also due to regional metamorphism. Immediately north of Murree Thrust near Batoi and Sahr villages the carbonate bands intercalated with quartzitic bands indicate the bedding in the meta-sedimentary rocks.

b) Fracture cleavages The fracture cleavage(Billings, 1964, Hills 1965, Mead 1940) converging towards the cores of the minor folds, sometimes shows parallalism with the axial planes, especially in the Kaindora Agglomeratic Slates and Shidoul nala section of sericite phyllites and black slates near Gulabgarh village. There are some prominent fracture cleavages. It is felt that these fracture cleavages have been produced

by earth movements directed from NE-SW.

c) Slips or shear cleavage It very much resembles the fracture cleavage but then it is characterised by minor slips of mineral bands. In a way it amounts to axial foliation (Pl. 9 Fig. 2).The shear cleavage is well developed in the phyllites and schists of the Tanawal belt of the area i.e.north of Tukeun in the east and north of Adbes in the west (Pl. 9 Fig. 3).

d) Joints These are related to rock flowage and also some of them reflect a response to residual stresses that persisted even after the cessation of rock flowage, eg. quartzite of Agglomeratic Slate found near of Deolmarg. Slates of area show typical one set of joint, such as near Arital N10°E-S10° W, 32° N Dip; so have phyllites of other places in the area.Schists and quartzite of area show typical two sets of joints and granites or gneissose granites show typical three sets of joints (Structual map No. Pl-2, fig.3).

(2)Linear Structures include slicken sides,Boudinage structures, Mineral lineation, minor fold axes,puckers etc. Slickenside are well developed especially along the major thrusts and along minor dislocations within the Granite pluton and also near a contact between talcose schists and gneisses in Deolmarg (Pl. Fig.) and this area of minor dislocation shows much crushing and Pseudo - Columnar (Pl-15, Fig 1)

b) Boudinage Structures The competent quartzitic bands in between the incompetent chlorite-sericite rich bands of phyllites, schists of Tanawal Formation of the study area are the sites for such structures (Pl.16 Fig.2). Near Tukeun nala show boudinage structure

along foliation in gneisses (direction of boudins is E-W and steep dip northwards.) The size of Augen of feldspar in gneisses is about 3" x1" thick and at places boudinages are as big as 4' x 1' in and around Tuksun (Pl. 16 Fig. a). Here it is normally observed that quartz grains (Pl-15 fig b) have been stretched parallel and perpendicular to the fold axes of the phyllitic rocks of the area:-

(c) Mineral linestion This is well marked in schists of the Tanaual Formation where it is formed due to streaky development of chlorite, mica and talc in the schists of Tanaual Formation.

(d) Minor foldaxes Small crinkles or crenulation are of secondary origin. The calcareous shales, limestone interbedded with quartzites of Agglomeratic Slates near Kaindora have produced disharmonic folds. This is due to the fact that different rock units of different strength suffer disimilar strain under similar geological conditions. Phyllites at places are mostly folded into open angular kink folds along the foliation as seen from phyllites and schists from Tanaual formation (Pl. 14 Fig. d). Commonly these features are found with different orientation near the thrust zones, e.g. cheveron folds found in the shaly slates with calcite partings near north west of Sahr village. Powell and Conaghan (1973) and modern theory for the formation of these thrusts is the collision of destructive plate tectonics giving rise to the birth of

Himalayas. It is also observed that Himalayas is still rising. As is evident that northward movement of India after collision shall release pressure at right angles to the direction of movement of plate as a whole(rock machanics) and these pressures will result in the formations of weak planes which later on become thrusts.

Minor folds of different orientions along the limbs of major folds are also met within the rocks of Murree formation. It is also observed in quartzite,or limestone rocks which are introduced with incompetent material like shales,slate and phyllites in which smaller and more complex folds of secondary origin have resulted.

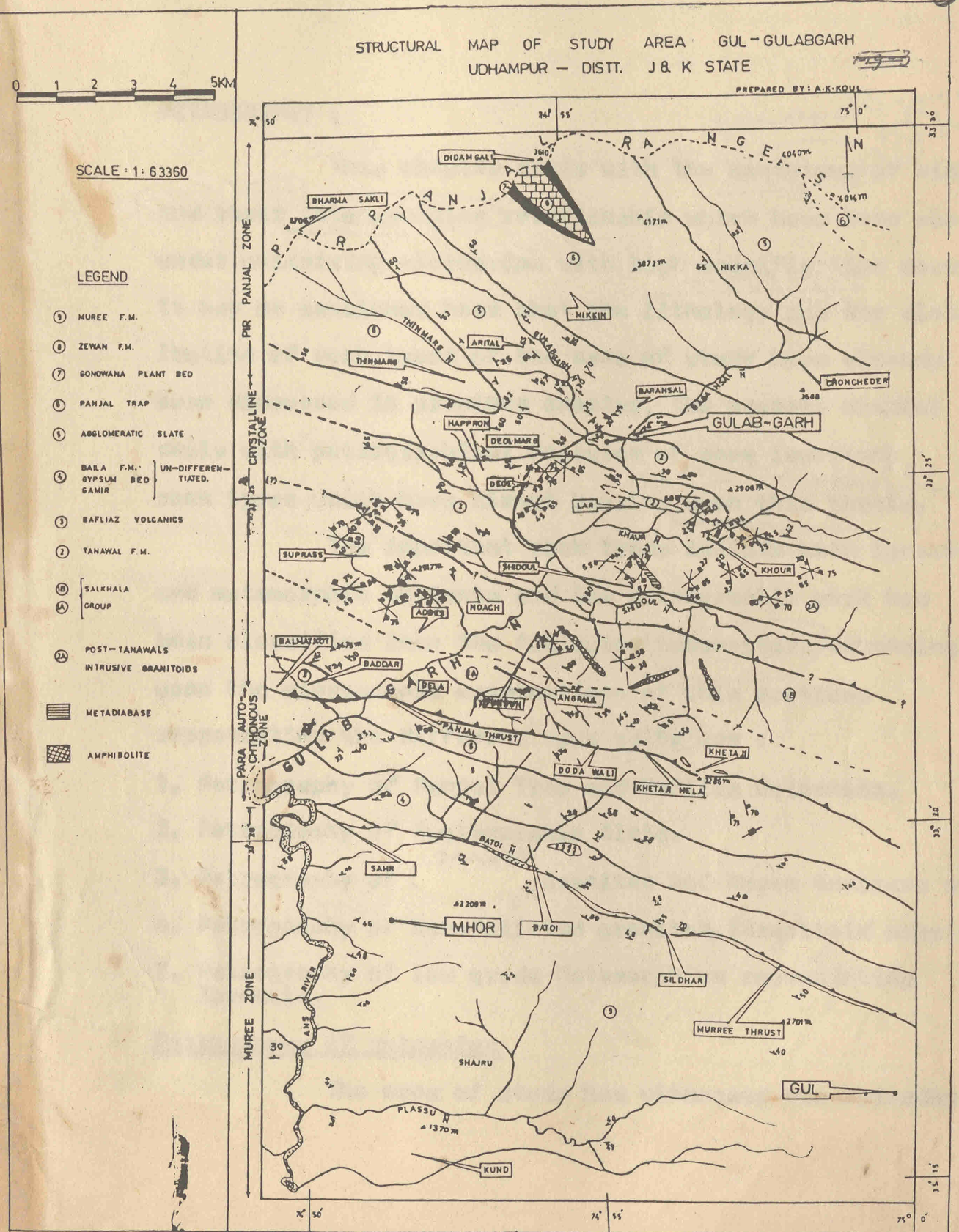
(e) Puckers Minute fold axes or puckers less than 10 cm. in wave length are usually found within the schists and phyllites of Tanawal Formation (Pl.14 Fig. d). These puckers are again due to intruded nature of competent rock, like quartzite along the foliation of incompetent rocks but orientations of these puckers are seen to be different.

(f) Microscopic structures nedd not be described separately here as these features are given under sub-para Tanawal section of petrographic chapter. This has been affected in order to avoid much of repetition.

PLATE-5

STRUCTURAL MAP OF STUDY AREA GUL – GULABGARH UDHAMPUR – DISTT. J & K STATE

PREPARED BY : A.K.KOUL



CHAPTER - VI

P E T R O G R A P H Y

PETROGRAPHY :

This chapter deals with the behaviour of minerals and their intergranular relationship which have been observed under polarizing microscope with high magnification power. It may be mentioned here that the lithology and the distribution of rock types of the area of study have aleady been discussed in previous chapter. The present chapter deals with petrographical features of some important rock types which have direct bearing upon this thesis.

The important rock types include both igneous and metamorphic variants and the petrographic work has been classified into the following subchapters depending upon the microscopic examinations of thin sections representing the different rock suits are :

1. Petrography of Panjal Trap and Bafliaz volcanics.
2. Petrography of Agglomeratic Slate.
3. Petrography of [redacted] granites and Augen Gneisses etc.
4. Petrography of Non-foliated granites.(Granitoid complex).
5. Petrography of low grade Metamorphics representing Tanawals.

<u>Petrography of volcanics</u>

The area of study has witnessed two episodes

of volcancity because two stratigraphically distinct volcanic suites are recognised in the area. The mention of which is made under stratigraphic chapter. Therefore the separate study of petrography of thin sections of these samples is undertaken to, light their genentic aspect.

The traps of older age found within the low grade crystallines of Safliaz formation, comprising chloritic schists and phyllites are dark green, green and purple in colour and are found to be high sheared. This Safliaz association is overriding Permo-carboniferous sequence of para-autochthonous belt the contact between the two lithounits is of tectonic one called Panjal Thrust, which truncates the Safliaz volcanics in the north. Though these rocks are apparently massive and leached, yet these contain fine cavities which can be seen under microscope. These traps have conspicuous epidote and silica veins cutting across the formation at places. Its sp. gravity is found to be 2.85.

Whileas Panjal Traps of younger age are found in two horizon :- one horizon, overlying typical Agglomeratic Slates, was found within the para-autochthonous belt of study area with small thin outcrop of the same exposed immediately along Murree Thrust in the Batoi Nala near Jamlan bridge. The other horizon, alternating with Agglomeratic Slates and occupy the core of syncline along the crest of Pir Panjal. This thick bed of Panjal Trap appears to develop feeble schistosity and similar traps in the para-autochthonous belt

look to be non-schistose and fresh.

Megascopically, the Panjal Traps are of light green, dark green, grey and purple in colour where as the latter coloured trap is absent along the crest; they are massive and compact; amygdaloidal varieties are not uncommon as well. Though more amygdaloidal varieties are found in the northern belt along the crest of Pir Panjal intermingled with big and large voids yet these are filled with secondary quartz, chlorite and calcite in some specimens, while as the amygdales of Panjal Trap found elsewhere in the para-autochthonous belt are small in size and are filled with secondary quartz, epidote and chlorite (Pl. 18 Fig. b) with little calcite and also blades of clinozoisite in sphere luritic form (Pl. 18 fig. a). In higher elevations the traps have large and big amygdales than those found in the lower elevations. However, it is difficult to demarcate the separate boundaries of the flows.

Since the area has undergone severe tectonic disturbance as evidenced by numerous thrusts, the identity of separate lava flows has become undifferentiable which otherwise might have been present before major tectonic events took place. One interesting feature of Panjal Traps of the study area is that they possess magascopic cross cutting veins of quartz as shown in (Pl. 13 Fig. c) and perhaps these fissures and crakes are postconsolidated phenomena and were subsequently filled by secondary quartz.

The amygdales are generally oval, circular shaped varying in size and other vesicles are met within some Panjal Trap of study area. The specific gravity of Panjal Trap varies from about 2.70 to 2.90.

The petrology of Panjal Trap with its petrography has been detailed by various authors in the past, among those were Middlemiss (1910), Wadia (1928, 1931) Mathur and Wakhalbo (1933) Ganju and Rajnath (1930), Wakhloo (1946, 1961) Wakhloo/Shah (1970), Sharma and Gupta (1973) Ismail Bhat (1978), etc.

Under the microscope, the Bafliaz volcanics exhibit typical prophyritic texture (Pl. 19 Fig. a) and intergrandlar texture. The predominant feldspar in the section is albite-oligoclase range plagioclase and other subordinate minerals found in the section are epidote, chlorite, little quartz and calcite and iron ores dispersed in glassy matrix. The anorthite content of fldspar varies from An_5 - An_{15}. Albite mostly occurs in the form of tiny laths (Pl. 19 Fig. a) but bigger laths are also noticed in few coarser samples.

The angle of extinction of these albite crystals is found to be 10^0, $2V_z$ ranges from 78 - 80^0. Some phenocrysts of feldspar show corroded margins, formed due to magmatic corrosion. Sericite development is found in few laths of albite mineral.

Epidote in the same section occure as granular to colmunar aggregates (Pl. 18 Fig. e) and its characteristic

colour is pistachee green and is feebly pleochoic with high relief. It shows high interference colour of 2nd order to 3rd order. Some crystals of epidote are zoned. Few crystals of clinozoisite without any appreciable pleochrism are found in the section. It occurs in groundmas, amygdales and veins.

Chlorite is of light green to dark green colour, occurs in fibrous aggregates scattered in the ground mass. This mineral shows parallel extinction. It is also found in amygdalas. (Pl. 19 Fig. a). The amygdales of spilite are as shown in (Pl. 19 Fig. a). Iron oxides occur in clusters of medium grains or minute grains size in the amygdales.

Quartz occur as medium grain and also a variety of found in the amygdeales and also quartz occurs in the form of interlocking grains surrounded by epidote. It also appears in small vein which cut through the big clusters of epidote showing higher orders of interference colour (Pl. 19 Fig. a).

The Panjal Traps, examined under microscope generally show well developed porphyritic texture with phenocryst of plagioclase feldspars. Actinolite-association in few sections augite, tremolite whereby actenolite changes to calcite by reaction. Very few sections showed glomeroporphyritic texture, where by plagioclase feldspars are clustered in radial manner. there are other textures found in them, the common among them is sub-ophitic to ophitic, where pheno

crystals of pyroxene enclose partially or completely plagio clase laths. other textures met with are intersertal, intergranular, pilotaxitic and hyalopilitic. The Panjal trap owe its green colour or dark colour due to alteration of augite and other anorthetic rich plagioclase feldspars. The size and shapes of amygdales vary from specimen to specimen which are filled with chalcedony, fuchsite and penninite, a variety of chlorite in order from walls of cavities towards centers of each cavity (Pl. 19 Fig. b) There is suspected, sill showing doleritic texture, concordant to the trap. Along the margins of invading trap, the minerals like spherulites of clinozo - site (Pl. 18 Fig. d) and in addition, big phenocrystlas of Augite and epidote interposed in Iron dust have also been spotted in such hybrid rocks.

Megascopically, the Panjal Traps are massive and compact and vesicular in character which look fresh and are light grey, green purple and dark green in colour. In purple and green trap varieties, the amygdales are bigger than other varieties (Fig. b Pl. 18). The cavities in case of purple variety are almost circular, filled with sutured quartz veins of chalcedony or epidote, though mostly secondary in nature, cut accross the thin sections of various Panjal Trap (Pl. 18 Fig. d). In the same section epidote is either overiding quartz aggregates or itself is being cut by the later mineral formed as secondary product. Even the cavities are partially filled with calcite grains and epidote grains. Few calcite grains are

also found in the ground mass. Very few sections of trap of para-autochthonous belt show conspicuous presence of epidotes. Throughout field very little relic ground mass is seen.

The lavas of ten show wide spread alteration of the nature of epidotisation, chloritisation and silicification (Pl. 18 Fig. 2). Devitrification is also the most common feature in these. At Arital near the contact, the lavas are interbedded with the Agglomeratic Slates, where the contact metamorphism is induced causing a chilling effect (Pl. 18 Fig. a) structure found in some sections of trap is tectoblastic [illegible] checked with the Atlas by Augistethis (Pl. 18 Fig. c & f) where tectoblasts of feldspar wedging through the pyroxene crystal, thus the area of wedging becomes an altered product of pyroxene. Flow texture is not conspicuous in traps of study area. These rocks seem to have suffered much alteration and tectonic events on large scale. The following chief minerals are found in selected section of Panjal Trap.

Plagioclase: This mineral is found to have been altered in almost all the sections examined, due to low grade metamorphism. Groundmass on high magnification shows the presence of microlites of high temperature albite, which are partly Chloritized and dust inclusions are rendering them slightly blurred. The margins of plagioclase phenocrysts have been found saussuritized. An contant of such

Not possible

plagioclases, ranges from An 25-55 Ab. The relief of such mineral is high owing to clouding when seen under polarized light. Plagioclases of Adesine-Labradorite [illegible] variety gave 2V = 70°-73° and $2V_x$ of albite variety equal to 55°. Plagioclases have often been altered to epidote due to metamorphic transformation of calcic plagioclase to epidote with the liberation of sodic-plagioclase according to the reaction given in the chapter of Petrogenesis.

Augite : Augite is showing high relief with irregular cracks filled with unidentified altered mineral. The pyroxene is non-pleochroic under ordinary light. The mineral shows higher order interference colours of yellow, pink, blue. This mineral does not show any schiller structure; birefringence range from 0.020-0.027 and R.I. is from 1.670-1.734. The extinction angle of mineral from section to section varies from 35°-45° and $2V_x$ = 54°-58°. Zoning of augite is not so conspicuous. There are inclusions of magnetite and epidote grains present in the augite mineral. Cross twinned pyroxene crystals also found in trap; fine microlites of pyroxene are embedded in a ground mass of glass mixed with opaques.

Epidote: This is the 3rd most abundant mineral present in the trap rocks of study area. In some sections this forms subordinate to earlier described minerals and in other sections this miner al is found in large number as granular matrix. These occur in granular form and also

in prisms. In few sections it is found in columnar aggregates Epidote has interference colour of second to upper third order, birefringence is weak almost equal to .0005, R.I. is moderate ranging from 1.715-1.742 and 2V = 68°-85°.

Actinolite - Tremolite: It is colourless, non-pleochroic and has low R.I. measured between 1.631 - 1.665. It occurs as prismatic crystals with faint cleavages. It shows parallel extinction, 2V of this maneral is found more or less equal to 80°. The interference colours are of middle second order. Another variety of epidote which occurs as big grains showing mid night blue and yellow interference colours associated with iron rich epidote, ziosite and clinozoisite varieties.

Chlorite : This mineral fills up the gas cavities and forms important consituent of groundmass. This mineral is light green in colour and shows slight pleochroism penninite variety of chlorite, occupying the core of amygdale, shows berlin blue interference colours in fibrous form. Birefringence is less moderate between 0.002-0.007 and its Z ^ C= 2°. Penninite variety shows birefringence and R.I. equal to 0.001 to 0.003 and 1.572 - 1.581 respectively. Other minerals of secondary origin filling the cavities being high temperature quartz (chalcedony and non-pleochroic deep greenish feathery mass of chromemica called fuchsite.

The modal determination of volcanic rocks was not taken up for certain factual reasons. First, the primary minerals are altered and occur as few phenocryste and very fine aggregate mass of the same assemblage occur in groundmass which remain beyond recognition of a petrographer. Also glass in such rocks which is in more or less devitrified state the early stages of alteration are not easily detected under the microscope. It is certain that volcanic rocks are not generally holocrystalline or if they are, then their grain size is too small to expect modal determination with more accuracy. Besides both instruements such as integrating stage and point counter, normally used in the modal analysis are subjected to considerable errors, even if great care is taken. Therefore, the author of thesis has made use of Rittmann method of calculating norms direct from chemical analysis which serves the petrographical purposes such as the correct denomination and systematic position of volcanic rocks, which otherwise could not be determined by modal analysis. C.I.P.W. norms found in wt. % has its own significance in so far as petrochemical problems are concerned whileas Rittmann method of norm, which are complementary with each other, gives the saturated norms in vol.% which show close approximation with the modal analysis of the same specimen. There are instances such as in undersaturated volcanics the

results of norm calculations on C.I.P.W.System often show "great" anomalies, therefore can possibly give wrong results in the determination of rock types. This fact was admitted by Chayes & Yoder (1971).

Therefore in the present context, the author remained inclined to depend much on Rittmann method. Above all, the use of the Rittmann norm calculation method bracketed with Streckeisen's classification system of volcanic and plutonic rocks has a particular advantage which many authors never thought of todate, is that only a few rock names are used because older petrographical literature is overburdened with more than a thousand meaningless local rock names (Rittmann, 1973).

It needs mention here that there are certains, sillimanite which do not exist in the mode, but figure in Rittmann's norm system, But then it is not abnormal phenomenon because some reasons have been ascribed to this discrepancy, which seem to be more plausible in the mind of the author. One reason being that their presence in the calculation may be caused either by secondary alteration or by the presence of modal biotite or muscovite or thirdly by the digestion Rittmann (op. cit.), of argillaceous material in the melt from which final crystallisation took place. Therefore, the Rittmann's calculation of norm in respect of all trap specimens and few plutonic rocks of study area is presented briefly in the following manner.

TABLE - 2 Rittmann Norms of the Traps of the Culebgarh Area.

Sample Nos	B-1	Sp-8	B-3	Sp-5	B-2	Sp-4	Sp-13	Sp-12	Lg-63
$\bar{\epsilon}$	6.24	6.59	39.48	6.82	6.57	4.30	4.40	6.18	18.18
σ	1.35	1.49	2.28	3.97	2.35	1.88	0.22	0.84	3.40
ox^o	0.32	0.30	0.42	0.24	0.32	0.34	0.66	0.20	0.25
C.I.	46.06	48.10	41.43	33.50	40.00	37.72	31.71	43.71	26.42
Saturated Norms									
Ap	27	34	20	8	24	29	16	21	3
Il	46	42	8	64	50	62	62	54	18
Mt_o	33	33	48	34	31	40	20	31	71
Or	65	150	125	50	125	170	150	24	90
Ab	445	345	435	390	390	435	215	305	705
An	400	425	413	685	505	355	473	570	485
Sil	-	-	-	-	-	-	-	-	-
Wo	10	192	208	126	158	172	190	184	182
Hy	564	644	522	530	550	436	32	530	236
Q	-4	-32	-40	-115	-57	+71	+378	+ 23	-31

Continued from Table .....

Sample Nos.	B-1	Sp-8	B-3	Sp-5	B-2	Sp-4	Sp-13	Sp-12	LG-63
Volume of Minerals									
Labradorite	-	-	-	66.00	-	-	43.34	53.60	-
Sanidine	-	5.47	6.16	-	3.86	8.05	-	-	-
Andesine	53.20	46.43	52.41	-	56.79	48.17	-	-	72.13
Sub-calcic Augite	-	40.86	34.23	-	28.83	-	-	-	-
Augite	26.35 (pigeonite)	-	-	15 (Clino-Pyx)	-	32.27	27.81	38.80	22.13
Olivine	-	2.28	3.42	-	5.90	-	-	-	0.15
Nepheline	-	-	-	13	-	-	-	-	1.45
Hypersthene	14.87	-	-	0.50	-	-	-	-	-
Magnetite	1.52	1.52	2.28	2.00	1.42	1.80	0.90	1.45	3.24
Ilmenite	1.73	1.47	0.31	3.00	1.83	2.00	0.10	2.22	0.70
Apatite	1.57	1.97	1.10	0.50	1.37	1.65	0.90	1.22	0.20
Quartz	0.76	-	-	-	-	5.15	24.95	2.69	-

Petography of Agglomeratic Slate : Colour of Agglomeratic Slate is gray to dark in hand specimen and two distinct rocks of the stratigraphic horizon are noticed, one black coloured imbricated cleavage- bearing slates having a phyllitic character preserved and other grey coloured formation with slaty cleavages preserved. The specific gravity of Agglomeratic Slate varies from 2.55 to 2.85.

Under microscope the Agglomeratic Slates are composed of angular to sub-rounded grains of quartz and feldspars, which are embedded in volcanic glassy material of iron dust arranged along foliation. The rock shows fragmented inequigranular texture in which plagioclases enhedral crystals show deformed twinning (Pl. 19 Fig. e) a "case of slight mylonitization" Whereas some thin sections of Agglomeratic Slate show grayuacke texture (Pl. 19 Fig. f), in which only angular fragments of quartz are arranged in impure matrix wrapped by iron dust. Most of these quartz grains show undulatory extinction. The feldspars are also present in the matrix, Shown in the (Pl. 19 Fig. f). Here the grains are elongated and aligned in definite directions.

Micas are also present in varying proportions. Some of which as alteration product of feldspar but then these are in excess of biotite; the quartz, feldspar and mica often associated with chlorites. Other minor minerals present include haematite, ilmenite, little magnetite etc.

Petrography of Gneisses granites , Augen Gneisses etc.

The rocks of the Salkhala Group, when viewed from south to north of the study area, comprise different types of phyllites-schists-augen gneiss-gneissose granites. The phyllites are green, grey, silvery rocks. The S-planes are partly wavy and crumpled (Pl. 15 Fig. b). Some intrusive meta-dia-basic bodies cutting through the augen gneisses are observed.

Gneisses are rich in muscovite and chlorite, also present are some biotite and Xenoblastic grains of feldspar and quartz. These gneisses appear of para-gneissic character. These are followed northward by typical augen gneisses and gneissose granites. These gneissose granites are penetrated by dikes of pegmatite, aplite (leucocratic) and quartz veins which are spotted between Noach and Adbee. The northern part of gneissic outrop is coarse grained and porphyroblastic augen structure is, very conspicuous (Pl. 16 Fig. a).

The southern part of this gneissic outcrop is fine to medium grained and mineral assemblage is chlorite-muscovite-biotite and the rock grades from schist to gneiss from south to north-ward direction suggesting progressive increase in the grade of metamorphism. The augen gneisses in the north are intruded by amphibolite Boudin structure along foliation in these gneisses are common with E-W foliation strike, steep dip northwards. These boudins are 2-3 cm. thick and

at places boudins are as big as 0.10 mx1.15m.m. as around Tuksun (Pl. 15 Fig. b and e).

Biotite gneiss and porphyritic gneissose granite are white to grey coloured, dmedium to coarse grained showing prominent gneissosity and lineation which are defined by mica rich layers with alternating bands of quartzof elds-pathic composition(Pl. 16 Fig. d). The blastoporphyritic gneissose granite including augen gneiss show distinct granitoid texture under microscope (Pl.22 Fig. b) thus appear to indicate igneous parentage.

Under the microscope these rocks show idioblastic granular texture, (Pl. 22 Fig. d) and gneissose structure. Evidence of deformation shown by undulosity and mortar texture in quartzgrains (Pl.35 Fig. d) and deformed twin lamellae in feldspars, microfaults in feldspare twins as shown Pl- 26; fig. f. and bending of cleavages in muscovite and biotite crystals are some noteworthy features.(Pl.21 Fig. c and f). Strained shadows occur in quartz grains, also in feldspars to some extent. Böhem lamellae and strained shadow effects are conspicous in quartz grains. Feldspar grains show irregular cracks being subsequently filled with late aggregates of quartz and sericite meterial (Pl.35 Fig. c x a) The rocks are mainly composed of K- and Na- feldspars perthite, quartz, biotite, chlorite, with varying proportions of muscovite in addition to accessories like sphene, epidote, clinozoisite, little tourmaline,

zircon, apatite and iron oxide.

Quartz : It shows wide variation in size and shape in chlorite-biotite muscovite gneiss, it occurs as elongated grains. In granite gneisses it occurs as anhedral crystals and show blastoporphyritic tendency. The quartz grains have serrated and sutured boundaries with the feldspars and platy minerals. This mineral occurs at late stage of generation. One is older occuring as big subhedral grains and other is younger occurring as recrystallised mass along the interstices but surprisingly the interstitial quartz also show undulosity (Pl. 21 Fig. b). Quartz is seen to have been r replaced by perthites which seems a case of feldspathization (Pl. 26 Fig. a). It occurs as inclusions in porphyroblasts of potash feldspars a feature of granitisation. In few sections of granite gneisses it shows corrosive relationship with biotite, plagioclases and microcline microperthite (Pl. 36 Fig. b). In schist, it occurs as large cryslals of first generation surrounded by fine recrystalised younger quartz aggregates. Relief in quartz is very low with many inclusions of perthites.

There are trains of undidentified inclusion perhaps iron dust in quartz for (Pl. 28 Fig. a) incipient feldspathisation is also noticed in few sections. Silicification is also prominent feature whereby perthite is

replaced by large irregular anhedral quartz grains along the margins with the release of sericite. (Pl. 23 Fig. b).

Feldspars : These represent the major consituent of such rocks and are of potash feldspar and plagioclase feldspars. Whereas the former is mostly untiwnned orthoclase a little of uhich is perthitic and microcline if any, occure only as porphyroblasts of microcline- microperthite. These microperthitic and untiwnned feldspare occur as subhedral metacryste i.e. in augen gneiss quartz and por-phyroblasts in gneissose granite uhileas in muscovite-biotite gneisses or schists it occure in small amount as irregular grains. These are large colourless and show fine dust along the cleavages under ordinary light due to clouding (Pl. 26 Fig. b). Twinning is not common in perthites though few sections show relic carlsbad twinning (Pl. 36 Fig. a). They usually exhibit non-uniform undulatory extinctions.

The plagioclase occurs as two generations one older as meta-cryst with faint and broad twin lamellae preserved and other set of water clear crystals occuring as interstitial or replacing the older plagioclase, are of younger age (Pl. 24 Fig. e). Minor Myrmekitic texture is observed in few sections (Pl. 26 Fig. e) near the junction of microcline and the altered plagioclase. The inclusion of fresh albite in potash feldspar and same times aggregate mass of opaques, biotite and epidotes are found as inclusions in the former. There occure parallel grouth

of perthite with muscovite (Pl. 22 Fig. C). The blasts of feldspar are enveloped by laths of chlorite-biotite association.

Potash feldspar (orthoclase perthite variety) is found in lesser proposition in gneissose-granites, but is more common in gneissose variety. Fresh orthoclase with carlsbad twinning is rare. Few fine strings of sodic material are present in untwinned orthoclase with preserved cleavages (Pl. 24 Fig. d). These are due to exsolution phenomena. A few microveins of Soda material are found cutting accross the blast of orthoclase. The other potash feldspars subordinate to untwinned orthoclase is microcline microperthite enveloped by bent laths of platy minerals, like laths of muscovite, and biotite. Chlorite Since these feldspars are altered therefore exact 2V and other numerical property could not be found out.

Plagioclase crystals are represented by albite with (An_5-An_{12}) and few variety contain (An_{15}-An_{25}). Twinning is after albite, combined albite carlsbad law. The twin lamellae are broad and uniformly spaced. They show intense atteration on decalcification (Pl. 23 Fig. e). As a result of which numerous flakes of muscovite, epidote clino zoisite are observed arranged irregularly and also along cleavages of metacrysts. Both big and small grains of plagioclase have sutured margins and contain inclusions of quartz micas, opaques; and opaques contain euhedral crystals of apatite showing thereby the

derivative of igneous body. Early formed plagioclase, (kaolinized cleaved) and found as inclusions in microcline microperthite which is replacing early formed plagioclase (Pl. 24 Fig. c). Plagioclase grains in contact with perthite and quartz show corrosion effect which is observed in granite gneisses like augen type. Some plagioclase crystals look very fresh and commonly occur as interstitial and even old plagioclase are seen to be replaced by fresh plagioclase. According to Marmo this is the case of albitization (Pl. 21 Fig. e).

Biotite : This mineral is light brown to straw yellow in colour. Very few crystals show deep brown colour with distinct cleavages and is arranged in irregular streams. Brown biotite relics are held pokilitically in fresh chlorite (Pl. 22 Fg. a). Most commonly the biotite occurs in parallel association with fresh chlorites which show an evidence of reverse metamorphism. Biotite is generally found highly pleochroic from shades of light brown rather strain yellow to dark brown and shows straight extinction. Most of the crystals which wrap round the porpyroblast of feldspars show bending in cleavages (Pl. 21 Fig. e and f). Micro-faults are not ruled out (Pl. 23 Fig. b). It contains mostly inclusions of quartz, iron ores, sphene grains and epidote mineral. Few leucoxene are also present . In some sections alteration to muscovite is evident because muscovite crystals with high relief and distinct cleavages are preserved. Blades of muscovite impregnating biotite crystals are noticed in these rocks in question. (Pl-23, fig, b)

Muscovite : It is subordinate to biotite and also occur as accessory in some thin sections. It is colourless and some times is interpenetrating the biotite flakes. Some crystals show bird eye structure and also show fan structure. Most of the crystals show high relief and with distinct cleavage of relic biotite. (preserved) These occur along foliation.

Two types of Muscovite have been which recognised i.e. Muscovite which are older one and occurr, as streaky flaks in the ground mass and also as inclusions with corroded margins in feldspars and sometimes it occurs as sericite in nature. Younger generation of Muscovite is recrystallised or altered from biotite which is due to retrograde metamorphism. At places it is kinked (Pl. 22 Fig. e). Pl 21 Fig. c

Chlorite : Light green coloured aggregate mass showing slight pleochroism. Few crystals with dark green colour occur as fibrous form and are foliated along prominent foliation. This variety is having high relief with preserved cleavages. Foliated fibrous mass of chlorite shows high pleochroism and pleochroic scheme is as X=light green, Y= green, Z=dark green. It is present mainly as alteration product of biotite and occuring in close association with it. Sphene, epidote, opaques, clinozoisite apatite and little zircon occur mainly as accessory minerals in these rocks. Out of these, opaques, sphene and epidote are compartively in appreciable amount. The opaques show parallel growth with biotite giving appearance

of birds eye structure (Pl.21 Fig. c). These opaques even centre around beautiful grains of apatite mineral with euhedral margins (Pl.21 Fig. d), and these features point to have been crystallised from magma. This feature is met with only in gneissose granite. Other features seen in these sections are zoning in epidotes(Pl.35 Fig. b).

Petrography of Non-foliated granitoids.

The term Granitoids is applied here in this thesis to rocks ranging from granite-granodiorite-tonolite-ademallite-syenite which have been found to represent the acid suite developed in the area. This is also realized on the basis of chemical classifications. These rocks occurr as intrusive body into the Tanawal formation i.e. country rocks. The rocks are fine-medium to coarse grained, buff to grey in colour which show sharp contact with the country rocks e.g. Tanawal formation. The grain size varies from place to place, while as the coarseness is more near Khaur and a part of Shidoul, fine grained character is conspicuous near margins which show chilling effect. Along the contacts, the effect of intrusive on country rocks is not pronounced except the development of porphyroblast of feldspars in the country rocks due to granitization (soda metasomatism) Cataclastic effect is conspicuous whereby Sericitic material fills the cracks of prophyroblast of feldspars (Pl.20 Fig. b). The colour index of these rocks is leucocratic type as compared to other types. Petrographically some granitic rocks

occuring around Khour nala section and north east of it possess relatively higher proportion of mafic minerals as compared to granites of Lar area where they are fine grained and light coloured with less of mafics. Other rocks which appear low in mafic content are found near it. There are small outcrops of veins of apilitic and pegmatitic varieties of leucogranite which appear to be much younger than the surrounding granite-granodiorite suite.

The rocks display considerable similarity in mineralogical assemblages except that there is a quantitative variation of these mineralogical assemblages from rock to rock whose names have been assigned on the basis of chemical data (op. cit.) and modal data. Therefore, the microscopic examination of all essential minerals alongwith accessories is taken together and presented in the following manner.

Under microscope, these rocks show well developed hypidiomorphic granular texture(Pl. 36 Fig. d) and the crystals of various minerals show partly straight (Pl. 28 Fig. b) margins along crystal faces and some crystals show sutured margins along other sides. The former is suggestive of crystallisation direct from melt(magma) while as the latter feature is directed to later change due to granitization. In some sections there is sieve structure (Pl. 34 Fig. e).

Granophyric texture seen in rocks of quartz syenite found between south east of Khour and Shidoul(Chandhal). Porphyritic texture is locally observed in some rocks. Very

few sections show myrmekitic texture along margins of perthites.

Under microscope, the following minerals are chiefly present in almost all types of rocks but with only one difference is that the amount of these minerals vary from one type to another (Model analysis chart). The minerals in order of preference are perthites, (orthoclases) with microcline perthite, plagioclase perthites, quartz plagioclase, biotite, hornblende, muscovite epidote; and zircon, magnetite, apatite, Ilmenite and sphene occur as accessory minerals.

Poor english

Perthites: The detailed study of these perthites is separately dealt with which follows and here only mention is made. Orthoclase perthite contains inclusions of quartz and shreds of sericite (relic) and there are microcline microperthites showing relic carlebad twinning and also inclusion of oligoclase both large, small, rounded are embayed within K-feldspar. The plagioclase perthites contain at the margins a rounded microcline which lookes to be of younger generation. Some microcline microperthites have remnants of platy plagioclase a which show replacement from plagioclase to younger microcline perthite (Pl. 24 Fig. c).

What do you mean?

Pl. 23 Fig e

These perthites show sharp contact against other crystals, in some cases sutured contacts with quartz or other mafic minerals are noticed (Pl. 29 Fig. b). Fresh microcline with high triclinicity occurs interstitially. And from sections seen, it is microcline feldspar of course perthitic which appear to be of late stage of formation. The perthites show fractures

along which leached material from adjacent mafic mineral permeates. Perthites also contain biotite flakes arranged in particular direction giving impress of slight foliation. Irregular shaped rounded or amaeboid inclusions of quartz with optical continuity are distributed in perthites showing feldspathisation. (Pl. 31 Fig. c). Pl. 36 Fig. b

Plagioclase : This mineral appears to be of two generations one is older grains which occur as inclusions, perthitic and other younger plagioclase which occur as interstitial or along the contact of plagioclase perthite and microcline microperthite (Pl. 32 Fig. b-b). Even older plagioclase are being replaced by fresh albite, a case of albitization. Older grains of plagioclase with faint broad lamellae contain plentiful of epidotes and calcite grains (Pl. 22 Fig. f). Mostly these plagioclase feldspar (An 15-23%) grains are deformed in some sections. But then the fresh plagioclase of younger generation have An content range from (8-10) ie. albite-oligoclase range. Plagioclase are devoid of conspicuous zoning, though the central portions are much clouded and sericitized, give as Pseudozoning. The plagioclase has found to have the following twin laws, one is pure albite twin, few are combined albite and pericline type (chess-board type)(Pl. 28 Fig. e) and mostly the plagioclase with combined albite and carlsbad twinning is present which are partially sericitized (Pl. 25 Fig. c). Fresh albite, including untwinned albite form mantle of the inset of microcline perthite(Pl. 32 Fig. b).

Meaning not clear

Highly sausseuritized, the older plagioclase crystals are covered with dense aggregets of large sized epidote/zoisite, calcite in few sections. The cores of plagioclase being more altered than margins (Pl.34 Fig.e). The crystals of plagioclase show sutured and sharp contacts with crystals of quartz locally. $2V_x = 77^0$, low relief.

Quartz : Quartz forms allotriomorphic granular aggregates along with grains of feldspars. Quartz grains are either big or small granular and inequidimensional. In most thin sections quartz shows corrosion effect, Quartz forms sub-parallel to elongate grains with lobate, convexoconcave in shape. Some crystals of quartz show magmatic corrosion (Pl. 28 Fig. b). Quartz in these rocks occurs both primary in the sense that they have been crystallised direct from molten magma and are being replaced by perthite, a case of K-metasomatism (feldspathisation) (Pl. 28, 29 Fig. b), and it is also secondary occurring as interstitial and even in few sections local silicification results in with the release of sericite in the replacing quartz, but such crystls of quartz are large with irregular boundries and are lighly undulosed showing strained shadow effect (Pl. 36 Fig. b). It forms minute bands studded in streaky micaceous large crystals within the feldspars. The primery quartz shows interpenetrating sutured margins and the similar grains show straight margins on the other side with the perthites. However, all the quartz crystals show undulose ex-tinction (Pl. 28 Fig. b) except locally recrystallised mass of quartz grains which are much later in phase because these only do not show undulosity. At some places, hardly very few, a feebly myrmekitic intergrouth

of quartz in plagioclase in contact with microcline microperthite is noticed.

Biotite : It occurs as large flakes or small shreds associated with muscovite or with hornblende in few sections of rocks around Lar. Biotite in few sections contains shreds of hornblende (Pl.36 Fig. e). Some are without cleavage but brown in colour containing cluster of epidotes but such flakes are found normaly in plagioclase or plagioclase perthites (Pl.25 Fig. d). These flakes show corroded outline. Most of the flakes are bleached along cleavages ragged and show sign of alteration. Parallel grouth of muscovite and magnetite are much common features met with large flakes of biotite one also found along cleavages. Prismatic and pyramid sections show pleochroism. But one feature is observed under microscope that there occurs clusters of biotite with anhedral crystals of sphene and magnetite containing inclusions of apatite (Pl. 36 Fig. d). All plyminerals occur as inclusions in perthites in most of the sections. Biotites are found of two generations, one older, which are brown, brownish green coloured with thick cleavages and variety of green coloured biotite flakes with feebly. Pleochroic character, showing sagenitic structure (Pl.36 Fig. d) with needles of rutite present in biotite crystals.(Pl.36 Fig. d) Some show birds eye structure which are without cleavages. Yellowish brown biotite show pleochroic halos. And the other younger variety is pale yellow coloured with distint cleavages found in just

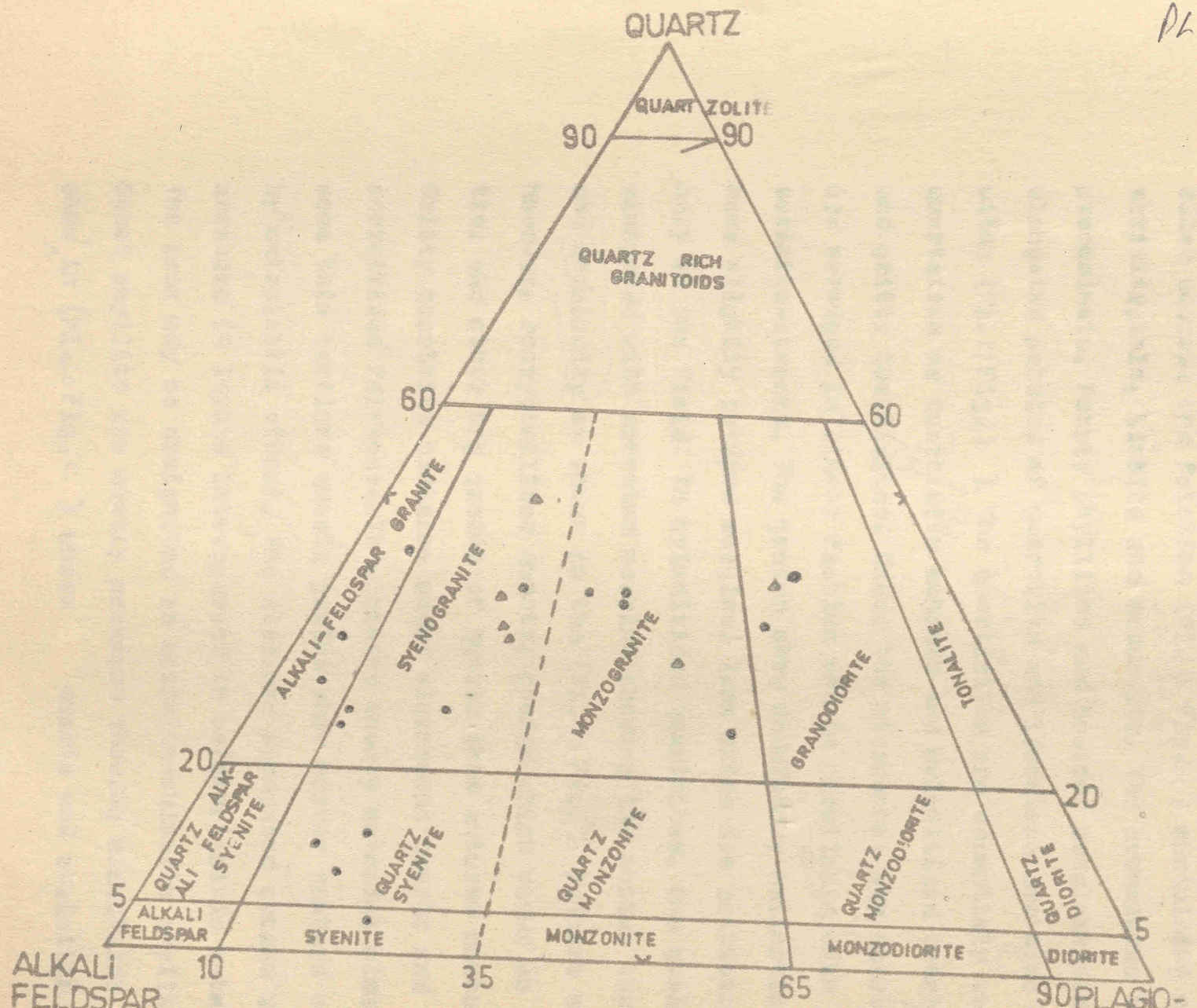
a position with older biotite crystals. Leaching of iron ore is so much that it masks the rounded biotite is shown in (Pl. 35 Fig. e) which is evident by noticing a particle of biotite in enclosed rounded opaque sections and pyramid sections show pleochroism. The pleochroic scheme is x=yellow, y=brown, z=dark brown. Relief is high and basal sections show no pleochroism $2V_x$=22. There are sections fresh granitic rocks which contain no biotite except small flakes and shred of muscovite.

Epidote : Granodioritic variety of rocks normally contain much of epidote which occure in veins cutting across the perthites as shown (Pl. 35 Fig. e). Some varieties of quartz syenite and even adamellite also contain epidote though in less quantity. These occur as anhedral grain showing conspicuous zoning and also granular mass as inclusions in perthite with biotites and iron ore (Pl. 34 Fig. e). But Lar granite or leucogranite contains no epidotes. The recrystallised quartz has inclusions of epidote.

Hornblende ; It is found in two sections crushed with broken two cleavages associated with biotite flakes, a conspicuous feature. These altered crystals are brown coloured and are contained in biotite flakes showing grouth with the host hornblende; pleochroism is feeble and other optical properties could not be found because of its fragmentary character.

The accessory minerals observed in thin sections of these rocks include euhedral crystals of apatite enclosed either in magnetite or in biotite, enhedral crystals of sphene (Pl. 36 Fig. e) Ilmenite with leucoxen and haematite together with magnetite.

PLATE-80



CLASSIFICATION OF SELECTED SAMPLES OF BOTH FOLIATED & NON-FOLIATED GRANITOIDS OF STUDY AREA (AFTER STRECKEISEN-1976).

Petrography of low grade Metamorphics representing Tanawals.

Tanawals represent complex lithology. Important lithounits include psammitic schists with pebbles of varying sizes accross the folation (Pl. 15 Fig. d) or Pl. 20, fig. b) containing chlorite, sericite, talc, biotite and muscovite. The arenaceous types predominate. Pebbly phyllites and boulder conglomerate, bearing elongated pebbles of quartzite and limestone are also met with (Pl. 17 Fig. b). The quartizites are essentialy sericitic quartzites or quartizite schists and mylonitized quartizites and gritty quartizites. Under the microscope the quartz grains are arranged in linear fashion and in parallelism with sericite-streaks. The grains show undulatory extinction and have slighily sutured margins. Iron oxide are scattered randomly in the field. In mylonitised quartzites, the grains are elongated with serrated margins showing the mortar texture and undulosity as shown in the (Pl. 26 Fig. b). There are however, recrystallised quartz, grains which occur as interstitial and other big grains of quartz show sutured contacts. Gritty quartzite contains under microscope quartz and sericitized feldspars. It contains cherty material also. In some thin sections quartz grains show mortar texture produced by cataclastic effect. The strained elongated grains are arranged in layers interspersed in calc-sericitic material. The rock may be designated as sericite-chlorite phyllite. Other phyllits are mostly puckered showing microfolds as shown in (Pl. 20 Fig. C) where quartz and sericitic

material are aligned along limbs of microfolds. However, primary folds of S_1 giving rise to the axial plane cleavages S_2 in which patches of fine grained talc are present together with tourmaline and magnetite as accessories. This is named as talc-chlorite sericite-biotite-phyllite. Among schists found in the belt, the chlorite-sericite schist is the commonest type. It contains some tourmaline crystals besides the presence of chlorite, sericite and quartz. In some sections of talc schists and chlorite-sericite-quartz schists, lot of opaques (magnetite and hamitite) are present, in addition to some zircon as accessory mineral, hametite, graphitic schists in which grains of cline zoisite are present with inclusions of graphitic material. These clinozioisite and chlorite flakes are at inclined to the main foliation; these are typical medium grained schists in which medium grains of quartz are embedded in chlorite-sericite material along typical foliation (Pl. 20 Fig. e).

The thin sections of rocks collected from the area close to northwest of Happron village show undulose quartz grains and chloritoid crystals. Chloritoid crystals are pleochroic, weak birefringence, relief high and are length fast. Zircon grains are present which are euhedral, showing high relief. The chloritoid mineral appears to have formed due to stress conditions of parental pelitic rock of chlorite-sericite-quartz composition which has changed to low grade

schist under dynamic metamorphism. At places chloritoid crystals show polysynthetic twinning. This rock is named as quartz chloritoid-sericite schists. Thin sections of rocks from the area close to the nearby Shidoul village show catalastic effects showing a morter texture, where by the quartz grains are annealed. Also porphyroblast of plagioclase show sericitization. Twin lamalle are deformed of plagioclase crystals (Pl. 20 Fig. e). All these factors indicate that these rocks lie close to the zone of tectonic disturbance which is indicated by a suspected tectonic plane.

Murree Formation : The thesis deals primarly with the petrology of igneous and metamorphic rocks. However, a brief petrographic account of litho-units belonging to Murree Formation is presented below.

The sandstone in Murree Formation shows gray, greenish grey, and purple colours. It is fine to medium grained and poorly sorted. These sandstones are hard, compact and quartzitic in nature. Some specks of muscovite and biotite are present in hand specmen. In some specimens of sandstone, calcite veins are found traversing through them. At places, these sandstones show thin laminations. The cementing material in majority of rock specimens is calcareous in character.

Under microscope, the sandstone consists of quartz, feldspars, mica, calcite and iron-ores form the cementing material. Quartz is the predominent constituent of this rock and the size of such grains varies from 0.07 mm to 0.01 mm and are angular to subrounded in shape. These crystals of quartz

From where you have forched upking ward)

are equigranular and are poorly sorted. Quartz crystals do not show any specticular undulosity, suggesting a polygenetic origin of quartz grains. The plagioclase are mostly sodic in character with rare occurence of calcic variety and show tiunning according to albite-law. Few feldspar laths are wholly kaolinised. Muscovite, biotite and chlorite occur as minor constituents. Calcite occurs in the form of veins cutting across the quartz veins. The fresh recrystalised calcite grains show well developed rhombohedral cleavages.

Besides these the grains of ilmenite magnetite, epidote, tourmaline occur as heavies in these sandstones

Microscopic And Petrogenetic Characters Of Intrusive Granitoid Rocks of post Tanaval Age.

The Characters are summarised as under :-

1. The feature of perthitic K-feldspar enclosing partially or tend to embay or even poikilitically enclose the plagioclase crystals anhedral to subhedral in shape mostly sericitized in the cores giving rise to the picture of zoning. And it may be emphasized that not only the plagioclase, even micas, epidote and quartz are included within the perthitic K-feldspars. It is clear to assume that K-feldspar is the last mineral to form, may it be orthoclase or microcline microperthite (Pl. 34 Fig. No. a).

2. Individual minerals are usually subhedral with sharp boundries, while the Phenocrysts are commonly euhedral and therefore such minerals should be earlier formed ones (Pl. 36 Fig. b, c & d) PL. 29 Fig a

3. Included minerals or crystals show sharp boundaries with the host and are not completely absorbed and are in Physico-Chemical harmony with the host showing thereby earlier crystalisation from the melt (Pl. 29 Fig. c+d).

4. A uniform pattern in the overall texture is common even if texture is porphyritic or micropoikilitic which shows the crystallisation from melt, has taken place under similar conditions of Physico-Chemical enviornment.

5. The crystals of perthites or quartz show partly straight, sharp margins and partly ruptured margins with eachother, thereby showing neomagmatic origin from the melt, former feature and replacement origin for the latter feature (Pl. 28 Fig. b). for the

6. The Plagioclase perthite and orthoclase perthite contact is invariably marked by narrow clear rims of albite-oligoclase whose convexity is towards perthitic K-feldspar showing albite as secondary due to metasomatism leading to replacement of orthoclase perthite (Pl. 30 Fig. e). Pl. 36 Fig. b

7. The chief and dense interposition of clinozoisite, epidote and calcite, in calcic rich plagioclase of older generation bears a clear indication of decalcification possibly related to pressures to which melt must have been subjected at the time of its emplacement (Pl. 34 Fig. e). Pl. 32 Fig a)

8. The perthitic (film, string vein or patch type) fabric of K-feldspar and plagioclase is yet another feature akin to deformational stresses which induced exsolution of sodium from the K-feldspar and the testimony of this, the association of highly undulant quartz is very significant in respect of stress conditions helping exsolution phenomenon, not only exsolution, even replacement of earlier K-feldspar or plagioclase by Sodic lamellae introduced from outside source such as metasedimentaries of arenaceous composition through which granite pluton has emplaced or from later

intrusion of leucogranites found locally in the area (Pl.31 Fig.e).

9. The topo concentration of magnetite in perthites (Pl.32 Fig.f) in mafic minerals (Pl.29 Fig.e) such as biotite shows the low temperature crystallization from the last stage of melt. Otherwise big euhedral opaques are first to crystallise from the melt.

10. The tendency of albite inclusions within plagioclase or K-feldspar perthite oriented parallel to crystallographic or structural directions shows influence of the host feldspar on the inclusions during crystallization in fluid environment which can permit the rotation of already formed crystals (Shermerhorn, 1956). This feature is suggestive of neomagmatic origin of the granitic rock including the leucocratic types of younger phase in which this is a common thing (Pl.23 Fig.d).

11. The K-feldspars show inversion with each other i.e. the Microcline microperthite is containing relic of orthoclase perthite showing replacement action and vice versa is also possible where we find even island of microcline of high triclinicity (Pl.30 Fig.b). Even plagioclase is being replaced by microcline perthite of inferior triclinicity showing thereby what in most sections microcline is the last mineral out of all other minerals to be formed at low temperature (Pl.30 Fig.a).

12. In a broad way the incidence of twinning especially in combination twinning is very much higher in

sections which are characterised by undulant and elongate quartz grains showing sutured and interlocking margins. This shows that rocks have suffered much stress episodes after emplacement that the twinning in feldspars is not only conspicuous on different laws but there are even deformatinal effects Shtao show that twinning and undulosity dependent on mechanical stress.

13. Absence of zoning in plagioclases comparatively rich in An content is expected in rocks where plagioclase shows distinct and deformed twinning as there exists an inverse relationship between zoning and twinning of feldspars (Emmons, 1943).

14. The streaky or schlieren muscovite found within perthites shows simultaneous crystallization from the melt. Even included crystals of biotite and magnetite showing magmatic corrosion because of their crenulated margins and this indicated that early formed minerals were resorbed by later events (Pl. 29 Fig. a,f) due to anatexis.

15. Euhedral crystals of apatite within magnetite or corroded grains or skeletal grains of magetite and likewise the biotite flakes contain magnetite within it (Pl. 29 Fig. b,a). In some sections biolite is completely masked by magnetite due to aggregation of leached iron oxide (Pl. 36 Fig. f). Even biotite streaks are found in association with hornblende which is heavily fractured which shows alteration from hornblende to biotite due to

slight reverse metamorphism that the affected the granitoid pluton (Pl.36 Fig. e). From these observations, it may be concluded that in such rocks apatite was first to crystallize followed by magnetite, hornblende and then lastly biotite; muscovite replaces biotite under hydro-thermal conditions and among the series of feldspars, microcline seems to be the last low-temperature forming mineral.

16. Perthites contain elongate, lobate quartz within the perthites and fractured irregular undulant quartz crystals contain trails of inclusions along fractured regions showing the incipient feldspathisation whereby the quartz is replaced by feldspars (K-feldspars and now in present state by perthitic K-feldspars, which is partly undulant and clouded (Pl. Fig.).

17. The elongate undulant quartz triangular in outline, fill the contacts of perthites i.e. they are of secondary nature (younger age) filling interstices. Also a big anhedral quartz contains small rounded grain of perthite riddled with sericite as inclusions. This processes is due to silicification which is prevalent after crystallisation had ceased and resulted due to later deformations (Pl. 26 Fig. d).

18. There are two generations of plagioclase-feldspars (Pl-34 Fig a). The older ones with faint and broad twin lamelae are replaced by fresh albites having thin albite and polysynthetic twinning conspicuous with the introduction of sodium ions and release of Ca^{++} ions. Such a process is low temperature albitization. And even quartz grains contain development of very fine twin lamellae (Pl.26 Fig. c, d).

19. As pointed in the foregoing para, the minerals present in thin sections are euhedral in outline showing straight margins with the adjacent crystals of different minerals and other crystals exhibit sutured contacts. These features point to at least two stages of development e.g. the neomagmatic crystallisation of the prime minerals and the post-magmatic re-crystallisation characterized by partial or complete replacement of earlier minerals by younger minerals stable at low pressure and temperature conditions.

20. Graphic intergrowths between quartz and (exsolution) perthites particularly along the margins of crystals (Pl.25 Fig.a) show simultaneous crystalization at low temperature from melt at a time of deformation. This seems to be probable assumption for experimental and petrographic reasons. The deformation causes a shift in equillibrium not only in pressure-temperature parameters but also between crystals and containing melt. The deformation thus promotes the release of pressure which causes "abrupt" lowering of temperature. This results in unmixing of K-feldspar and quartz components in such melt. Which upon further falling of temperature, causes simultaneous crystallisation from the melt. An evidence of neomagmatic origin is testified. Again the author of the sis ascribes the magma to neomagma which for all practical purposes is the same magma derived from basaltic parent magma but the difference is only in respect of quantity which is more in case of anatectic magma. used by the author.

21. The few sections show only one type of feldspars i.e. perthites are present together with little quartz; very few fresh albitic lamellae occuring along intersites (Pl.31 Fig.b). These features point to one-feldspar granites. Mostly other sections show perthites and plagioclase feldpars together with quartz (Pl.32Fig.a) This feature points to two-feldpars granite.

22. The biotite displays a characteristic sagenitic microstructure, (Pl. Fig.). It contains incomplete crystallographically oriented aciculer needles of rutile in 110 and 010 planes. This is perhaps as a result of Sub-solidus exsolution of rutile from titanium bearing biotite as a result of physical conditions. Or it might have developed at the same time as hornblende being replaced by biotite (Collerson et al; 1 979); in Barker, Fin the latter view is plausible and hence has influenced the author to accept the later reasoning. Perhaps this can be possible explanation for inadequate presence of hornblende in rocks under reference. The association of crushed hornblende with green coloured biotite in very few sections is noteworthy (Pl.36Fig.e).

23. The presence of undulant quartz, presence of gliding twinning in plagioclase crystals and clouding of feldspars are in some a way connected with later events of deformation, to which the emplaced graniteids have been subjected.

Clouding : The thin sections of igneous rocks of study area have revealed the phenomenon of clouding which is associated not only with feldspars, which include potash feldspar and plagioclase, but even fractured crystal of quartz also display the phenomenon of clouding. The phenomenon is due to the presence of numerous micro dark particles such as dust-like specks, short rods or thin, hair-like growths and needles, in rocks under question. This common feature has, therefore, attracted the attention of author.

Various opinions have been expressed by different workers about their possible origin and these opinions are highlighted hereunder.

Macgregor (1931) linked clouding of plagioclase with thermal metamorphism. According to him, the later heating results in exsolution of iron dust which was present in the plagioclase in solid solution. He also believed in the solubility of iron in plagioclase towards sodic end members of series. And he found iron oxide as twice in oligoclase-anorthite than in albite or potash feldspars. He concluded that clouding of plagioclase marks low grade after recrystallisation of these pre-exististing feldspars with higher temperatures. With this hypothesis, petrologists have taken it as an evidence for such rocks, with clouded plagioclases, to have been subjected to thermal metamorphism. The above observation does not seem to take care of clouding in potash feldspars or quartz which are seen in respect of granites of

study area, therefore his hypothesis appears unsatisfactory in respect of rocks of study area.

Grout (1933) confirmed the occurence of clouded plagioclase in hornfels xenoliths in gabbros of Minnisota and concluded from his close examination of such rocks that cloudiness is not due to attack on old feldspars as envisaged by Macoregor (op. cit.) because the feldspars found in such rocks are newly formed from clay minerals.

Joplin (1935) did not agree with Macgregor's opinion that clouding is an exsolution phenomenon. Anderson (1928) found clouding in Potash feldspars as well as plagioclase feldspars.

Reynolds (1946) remarked that desilicated and basified rocks are commonly characterised by clouded lime soda feldspars. As is normally seen in the study area that plagioclases commonly show (Pl. 25 Fig. b PL 34 Fig a) clouded core and clear margins, as according to Williamson (1936) it is not necessary that these areas shall have compositional change. Shand (1945) also found that the clear margins of plagioclase crystal may not have the same composition as the dusty cores of the same crystal of plagioclase. However, on the basis of experimental work on iron bearing Potash feldspars conducted by Faust (1936) and Rosenqvist (1951) it is generally believed that Fe^{+3} may substitute to a limited extent for Al^{+3} in the feldspar lattice and this

iron would exsolve on cooling resulting in the formation of haematite or magnetite grains or particles.

Kuno (1936), from this observations on clouded zones of plagioclse phenocryste of Hakone volcano, concluded this clouding might be due to mixing of two differnt magmas. In such volcanic rocks the type of clouding plagioclase is produced by the incorporation of foreign particles through rapid grouth of the plagioflase.

Poldervaart et al.(1954) etudied plagioclase of many igneous complexes of the world, eg, Bushveld, stillwater, Sudbury, Baltimore plutons etc. and concluded from his observation that plagioclase may show slight clouding even in rocks which did not show any evidence of thermal metamorphism. Feldspars bearing coronites and meteorites contain clouded plagioclase and even charnockites. Basic dykes and Basement rocks of southern mysore all contain clouded plagioclase. Clouding is found not only in plagioclase but has also been observed in apatite, spinel, olivine, pyroxene, potash feldspar, quartz biotite, hornblende, garnet and even in calcite. The particles producing clouding vary in size, some time within the host and it is noted that the particles consist of other minerals, such as biotite, spinel, rutile and hornblende as well as opaque ones.

Poldervaart et al.(op. cit) thought of two contrasting views with regard to the origin of the particles producing clouding in plagioclase. According

to them one view relates to incorporation of particles in the crystal of feldspar at the time of its formation and the second theory holds that material, responsible for the formation of clouding, was introduced into the crystal after its formations and they concluded that both the theories supplement one another and are probably correct.

According to Poldervaart et al. (op. cit.) clouding occurs in unmixed plagioclases of intermediate composition and intense cloding is not reported from the end members of the plagioclase series and favourable conditions, which may give rise to the phenomenon of clouding are (1) the existence of sufficiently high temperature for long duration. (2) the presence of an aqueous fluid. (3) the presence of iron bearing minerals in the parent rock ~~from which feldspar bearing rock~~ from which feldspar bearing rock recrystallised. These conditions are normally met in thermal metamorphism but yet, however, clouding is conspicuous in rocks of study area which have not subjected to the thermal metamorphism. Also it is a worth noting that an excess of water in the preexisting rock would help recrystallisation of plagioclase more easily rather than helping to produce clouding in plagioclase and therefore in such cases, thermal metamorphism does not produce clouded plagioclase as easily thought by Macgregor (op. cit). According to Poldervaart et al. more intense clouding cannot be formed due to exsolution alone

but may be produced by diffusion of external material into the crystal after its formation along minute surfaces of physical discontinuity throughout the crystal which act as weak passages for such diffusion. It is also found that the rate of diffusion along such passage is considerbly higher than experimentally determined rates of diffusion through crystal lattice . In number of thin sections of the study area,presence of clouding has been observed in both perthitic plagioclase or perthitic potash feldspar, quartz and biotite laths, Iron ores form inclusions (Pl. 29 Fig. b). The clouding in such minerals seems to have been caused due to diffusion of Iron dust after the formation of host minerals.

Myrmekite : It consists of cauliflower like grouth of acid plagioclase in close interpenetration with worm-like quartz found along the contact between potash feldspar and plagioclase without sericitization and are directed away from the margins of plagioc-lase as shown in the (Pl. 26 Fig. 4). This peculiar quartz - feldspar intergrouth was described by Michel-levy (1893) and later by Sederholm (1913). Secke (1908) has determined that the amount of quartz in the intergrouth increases as the host plagioclase becomes more basic and it appears that it supports the hypothesis that the quartz is released as a result of the replacement of potash feldspar by reaction plagioclase very rich in An-content.

Sederholm (op. cit.) considers that the Juxtaposition of these two feldspars is important for the formation of myrmekite and stresses on such reaction as synantetic.

It needs mention here that in sections perpendicular to the quartz rods, the quartz crystals may appear as drop-perthitic feldspar. This feature has been noticed in few sections of rocks of non-foliated granoids granitoids of study area (Pl. 32 Fig. a). The coarseness of the intergrouth looks to be fine and restricted to the marginal parts of the perthites which according to Marmo (op. cit.) be called myrmekite in broader sense , and is found mostly in pegmatite.

A careful study of the natural occurrences of myrmekite was given by (Orescher - Kaden, 1948) who thought that myrmekite was developed with the formation of younger microcline called pre-microcline myrmekite. By pre-microcline myrmekite he meant the replacement of myrmekite by potash feldspar. In addition, he also described post-microcline myrmekite, which according to him, would be formed by the solution effect originating from the resolution of the prexisting microcline.

The classical theory of its origin goes to Becke (1908), according to whom myrmekite is produced with a replacement of potash feldspar by plagioclase which is evident from the fact that potash feldspar is more rich in quartz than it is in plagioclase and this excess of SiO_2 is formed while replacing potash feldspar. This theory was later accepted by various petrologists, including Sederholm.

From this theory, it is drawn that myrmekite can never occur at the contact between quartz and feldspar and likewise no myrmekite is developed at the contact between sodic rich plagioclase and replaced potash feldspar because albite and potash feldspar have same SiO_2 content. From this it is inferred that myrmekite is younger than the surrounding potash feldspar and even myrmekite formation is later than the crystallization of muscovite (Mehnert 1968).

Exner(1961) from Alpine rocks thinks that some myrmekitic grouth is found in cataclastic zones. From these expressions, it is inadequate to explain the formation of myrmekite in total by active replacement of plagioclase by potash feldspar. Through this reaction known ,one does not lead to the formation of myrmekitic texture by quartz metasomatism because it does not lead to formation of myrmekite(Mehnert 1968).

The suggestion of Drescher-Kaden(1948) attracted attraction of petrologists who work with truly granitized rocks. Potash metasomatism fitted well with the formation of synkinematic granites. However , his view is later on modified and recast as proposed by Edelman(1949) who said that microcline is secondary in the gneissose graintes(synkinematic) with which microcline always occure. This view fits well while observing scanty development of myrmekite in few sections of metamorphic belt of Salkhala Group (Pl. 24 Ph. c) where it seems to be a quantitative relation between the myrmekite and microcline because in one section there is poor development of quartz blebs in partially twinned and altered plagioclase in contact with microcline porphyroblast.

Edelman tried to connect the formation of myrmekite with the microcline porphyroblasts mantled in the plagioclase rims the constituents of the decomposed plagioclase migrate outwards zoneuise in the microcline porphyroblasts. Similar view was accepted by Seitsaari (1951) and found that

in the process of myrmekitization, an excess of silica is there but it is difficult to know the exact mode of formation, whether it is due to an introduction of silica or due to decomposition of silicates and the removal of cations or perhaps due to primary quartz, but he stressed the importance of temperature of formation of the myrmekite which cannot be very low because myrmekite is usually sparse and weak in the rocks containing muscovite and epidote and the similar situation is afforded in rocks of study area which contain muscovite and epidote i.e. low grade facie assemblages. According to him it is abundant in rocks into which large amount of patassium introduced through normal graintization. Similar view can be taken which is accountable for the sparse or poor myrmekitic texture in intrusive granite rocks of study area, which are found to contain epidote and muscovite, the former being in handsome quantity.

Entirely different view, expressed by spencer (1945) who considers the exsolution and rearrangement of albite and of assumed calcic feldspar, formerly held in solid solution in the potash feldspar would produce plagioclase containing myrmekites, the calcic feldspar being decomposed into anorthite and quartz.

Experiments on the solubility and crystallisation of orthoclase and quartz from hydrothermal solution conducted by Schloemer (1962) yielded some interesting results i.e. one such result relates to the intergrouth of potash

feldspar and quartz at temperature of 400°c and with a pressure of 1000 atm. Structures similar to those of graphic growth (granite) and of myrmekite were obtained either directly through co-crystallization of the potash feldspar and quartz or due to infiltration of quartz into the marginal rims of the broken pieces of orthoclase. An interesting solution to this problem was suggested by Carman and Tuttle (1963), their observation gave rise to existence of "myrmekite molecule" which is a solid solution series between $NaAlSi_3O_8$ and $CaAl_2Si_6O_{16}$. At high temperature more than 16 wt% are dissolved in one or two feldspars. At lower temperature, the solid solution dissolves and three phases form i.e. two feldspars and quartz. Thus, their experiments support the view expressed by Spencer(op. cit) that quartz and plagioclase of myrmekite are derived by exsolution from alkali feldspar in a response to a lowering of temperature. (Hubbard, 1966).

From these observations it may be concluded that myrmekite is especially characteristic feature of granitized rocks but even there the myrmekite is not always similar nor does a similar interpretation seems to work for all of the (Marmo, 1971) who advocates for replacement viz-a-viz potassium metasomatism. He concludes that an exsolution either during or slightly after the growth is most probable by way of examining rapakivi granite. From these discussions it is apparent that there are other factors too in addition

to Potash-metasomatism which cause the formation of myrmekite. Otherwise, myrmekites would be much more common than they actually are in rocks which have suffered potash metasomatism, granitization and feldspathization. These are very common features in synkinematic rocks, locally myrmekite are active in any granites especially those rich in youngest generation of feldsper i.e.

It may be said that, myrmekite is occasional in granitized rocks, and yet there are myrmekites, the most convincing explanation of whose origin is metasomatic(Marmo, 1971). Myrmekite, on the other hand, is actually rare in most granites in which perthites are common and there are instances in such rocks rich in quartz which probably has been crystallised more or less simultaneously with the bulk feldspars where myrmekite is not always present (Marmo, 1971). It may be mentioned that the myrmekite is strongly developed in Oke-Patara Granodiorite and less so in the Ikerre Granite in the charnockites of south west Nigeria(Hubbard, 1966). In the Ikerre granite, myrmekite is restricted to the interfaces between perthitic alkali feldspars and the adjasent feldspar which may be plagioclase or another grain of potash feldspars. Here Hubbard indicated the existence of close genetic relationship between myrmekite and associated perthite. The same phenomenon is active in granites rich in perthites of study area where the myrmekite is rare corresponding to high degree of perthitic feldspars which give rise to inverse relationship

between these two petrogenetic features in question. However, it can be inferred that during albitization of older plagioclase rich in An content whereby older plagioclase is replaced by fresh sodic plagioclases and an excess of sodic material which is liberated during the above process form the perthitic lamellae along the weak planes of or structural planes of pre-existing orthoclase or plagioclase. The released cations will result in the formation of epidote, sphene and calcite giving rise to the phenomenon of decalcification which is being observed in the thin section of intrusive granitoids of study area. From such observation it may be mentioned that more the perthites, the less rare is the occurrence of Myrmekite. It needs mention here that foregoing interpretations may be valid for different cases. And keeping in view various explanations mentioned above, and on the basis of study of rock sections of study area, the present author is inclined to support exsolution theory of Mahnert (op. cit.).

This conclusion has been drawn on few evidences:

1. Perthites in granites and gneissose granites in particular of Gulabgarh area partly as a result of exsolution which has a direct bearing on the process of exsolution through which crystallising melt must have passed.

2. The plagioclases, in which these very few slender quartz blebs occur, are basic and An content in plagioclases of older generation with combine twinning is found to be 10%-25% and fresh plagioclase (An_0-10%) laths rich in Ab component with incomplete twin lamellae are also found which are of younger generation. The contention of Mehnert is extended here that exsolution has produced more quartz from basic plagioclase. But the preponderance of perthites hampers the development of myrmekites as discussed earlier which might be possible cause of its scarcity in rocks of study area rich in perthites.

Marmo (op. cit.) stresses on various other factors responsible for the formation of myrmekite such as granitization, feldspathization, etc. and thus supports metasomatic origin in the development of myrmekite.

Where as Mehnert (1968) expresses exsolution phenomenon which looked to him as the most plausible explanation for such growth. According to him, the amount of quartz blebs produced in any process is proportional to An content of the surrounding plagioclase or replaced plagioclase i.e. the more basic the plagioclase, the more quartz is produced . According to him, this is in agreement with the exsolution theory provided the surrounding plagioclase is not pure albite(100% Ab). But as several authors reported the occurrence of albite in myrmekites which contradicts his belief of exsolution origin, Upon this it is still doubtful,

whether the "albite" in such rocks is pure albite(100% Ab) or plagioclase rich in albite which means the latter plagioclase may contain some amount of An content. He states that the contention of those authors is an open question and one has to confirm the so-called "albite" in myrmekite bearing rocks whether it is really 100% Ab or albite rich in plagioclase. He also concluded that the quartz stems are very slender in rocks where plagioclases are albite rich for example (albite-oligoclase)range (An=15 % - 23%) in rocks of study area as well) which is again in favour of the exsolution since the surplus SiO_2 as wormicules of potash feldspar against albite rich plagioclase is "very small."

Perthites: The conspicuous microscopic feature of intrusive granites of the study area is the presence of perthitic feldspars, (Ph. b Pl. 32), in addition to plagioclases of varying An content. Even in metamorphic terrain, where the gneissose granites and augen gneisses are exposed, they also show some amount of perthitic feldspars, (Pl.25 Fig. c). The rocks of the study area have experienced deformation, shearing, fracturing, thrusting, faulting and folding due to tectonic activity and the intensity of activity is so much that even talcose schists exhibit a vertical jointing resembling columnar jointing of basalts (Pl.15 Fig.f). The version Chayes is recalled here that the formation of perthites is closely related to shearing stress acting upon*

* the rock

involved. This means that microperthite is usually rare in granites or lacking where quartz shows no proof of deformation as indicated by its absence of undulosity. The quartz is very much undulant, which otherwise in the granites and gneissose grainte of the study area, granites show typical mortar texture . Therefore, perthites are common . The observation of Chayes(op. cit.) gets expected features in such rocks confirmed in the area under study . From this, it can be said that shear seems to promote the unmixing of already metastable alkali feldspar, which otherwise might remain optically homogeneous, without stress conditions. Shearing also promotes coalescence of the already unmixed albite units. Thus it can be summarised that coarseness and form of perthites are not only the functions of temperature but they also depend upon long complex history of the rock suffering stress conditions from time to time(Mehnert, 1968). This feature has attracted attention of author because almost all sections of granites or granitelike rocks are dominantly rich in perthites(modal 40 - 67 vol %).

This study of perthites including experimental part , was revived by various workers, like Machatschki (1928), Barth (1930), Taylor et al.(1934), Chao et al.(1939), Bragg (1937), Alling (1938) and Drescher-Kaden (1948). In late fifties the origin of perthites and their comprehensive study has received considerable attention by Tuttle (1952), Chayes (1952), Laves (1952), Gates (1953)

Mackenzie and Smith (1955), Smith and Mackenzie (1959), Michot (1961), Laves and Saldatos (1963), Venkataraman (1962), and Senkataraman et al. (1964) Mehnert (1968) and Marmo (1971).

Before discussing the origin of perthites, it would be appropriate to present here first the types of perthites observed in the rocks of study area and thus propose a classification of perthites of study area. Depending on the relative coarseness of their intergrouth, macro, micro or crytoperthite can be distinguished. There is another word mesoperthite, which is a synonymous to macro. Also depending upon the shape of intergrowing masses and their angular relationship, the following forms have been noticed in sections of Intrusive granites and gneissose graintes:-

(a) Vein perthite, the most common types shows relatively broad lamellae but varying in size, orientation and outline. These veins cross the whole crystal boundary and meet the boundaries of perthites which are mantled by sodic plagioclase (Pl. 27 Ph. 7).

(b) String perthite, these perthites are at angle with each other and confined to boundaries of crystals (Pl. 28 Ph. d).

(c) Interpentrating perthites where the perthitic lamellae of varying size and outline show criss-cross arrangements (Pl. 31 Ph. d).

(d) Patch perthite. This is still more irregular than the vein type but often associated with it (pl.33 Fig.a).

(e) Braid perthite in which the albite sheets are arranged parallel to the prisms (PL-31, fig e).

(f) Plate perthite whereby the plagioclases showing discontinous twinning as remnants in microcline microperthite (Here replacements of microcline appears to take place along narrou twin lamellae (Pl.27 Fig. f.).

(g) Film perthite. These soda rich feldspar blebs occur as thin films pertpendicular to (010) and at an angle of 73° to 001 and are larger than the string type (Pl.30 Fig.d.).

(h) Vein perthite, these are vary common in pegmatites and relarively large in size, rather irregular vein shaped. Generally they are roughly parallet to the (100) face. Some of the terms was used first by Anderson after having viewed many pegmatite sections containg only perthites (senso stricto).

(i) Composite perthites (PL.30 Fig.f.)

Meanuhile, perthites of non-foliated granitoids and gneissose granites including augen gneisses of metamorphic belt of study area have been classified into two major subclasses depending upon the type of rocks in which the notewarthy forms of perthites are present. These rocks seem to be of different ages and noted with different geological setting in the

field. Though both granitic rocks are intrusive in nature yet, the thick band of mylonitised augen gneisses and gneissose granites group of igneous parentage suffered polymetamorphism on regional scale, whileas, the granitoid intrusion found around Khor, Lar and Shidoul villages has suffered different environments connected with varying low temperature and low pressure(mild metamorphism). Hence they are nonfoliated in sensu stricto. From these observations, perthites are split up into metamorphic perthites where quantity rather volume of perthites is less than the volume of perthites found elsewhere in the north of study area of which a different terminology of magmatic perthite is proposed.

Alling (1932) gave a classification as shown in the following lines. It is based upon a thermal scale ranging from high (magmatic) temperatures to low temperatures. In the process he used closed and open systems in which the perthites have formed in chemical reactions going on while crystallising directly from the melt in magmatic perthite or system arrived at situations where different reactions must have occured while recrystallising during metasomatism or metamorphism. However, in the figure, (op. cit.) he has retained Andersen's terms in column but with minor change where he discourges the use of vein perthite which otherwise is likely, according to him, to get confused with low temperature vein conditions as used by him in column 3. Marmo uses

terms like perthitic orthoclase and perthitic plagioclase showing chess board structure (Pl. 28 Fig. e) and the same terminology is retained in the present discussion. In a few perthitic orthoclase crystals herringbone structure is noticed (Pl. 27 Fig. a).

There are different opinions about the mode of formation of perthites. These are discussed briefly here :

Gates (op. cit.) suggested three processes for the formation of perthite (i) unmixing of originally K - Na feldspars into K-or Na - rich portions, respectively (ii) Simultaneous crystallization or growth of K- and Na-feldspar, (iii) partial replacement of an earlier homogeneous feldspar by reaction with foreign substances e.g. hydrothermal solution.

Unmixing : The formation of some perthitic textures by unmixing from homogeneous potashsoda feldspar was first proposed by Vogt (9105, 1906, 1908), Gates (1953) considers Unmixing as process for the origin of fine, regular perthitic intergrouths. Alling (1932) attributes exsolution to various reasons, one reason being due to polymorphism and the other reason being due to inclined solubility curves in thermal diagrams. By polymorphism it is meant that an inversion point is reached whereby there is a decrease in solubility of one solid solution for another such a condition was

authenticated by Warren and Harker. The latter condition is dependent upon phase rule diagrams and if potash feldspar is monomorphic, then some perthites are due to separation because of decrease of solubility with falling of temperature and that is the meaning of term exsolution.

Bowen and Tuttle (1950) have experimentally examined that synthetic potash feldspars form a continuous series of solid solutions at high temperature and with falling of temper-ature this homogeneous feldspar will unmix into a submicroscopic intergrowth of two feldspars. Laboratory experiments indicate that potash feldspar can hold up about 52% soda feldspar in solid solution at high temperature but apparently does not retain more than 18% at ordinary temperatures (Kozu and Endo,1921 ; Dittler and Khole,1925; Spencer, 1930,1937, 1938). This clearly showed that remaining 2% of soda feldspar crystallised as perthitic growth in potash feldspar. It is also stressed that the time and the temperat-ure required depend upon the coarseness and amount of soda feldspar present in the perthite. Spencer(1945) uses X-Ray data to oppose Andersons contraction-crack theory and this data explains about the preferred orientation of the film and vein perthite as one to unmixing.

The above discussion on perthites appears to point out that there is a general trend of accepting unmixing as an origin for fine, film and string perthite.

Mehnert holds that very fine shaped perthites with balanced contact of Na and K can be considered as geological thermometers for ma-gmatic temperature. From this observation it is felt that the system must have reached or passed near that the temperature of the maximum of solvus 660-715°c for exsolution to effect under actual water pressure and An content. Thus the coarse but regular vein perthites, showing uniform distances of lamellae are regarded by many petrologists to be amongst low temperature formations. According to Laves and Soldatos (1963), the perthites produced by unmixing from Na-K-mixed crystals of the monoclinic sanidine under comparatively high temperature, then the ions seem to him to be still in high mobility and, therefore, produce broad domains of exsolution with the addition of further sodic ions along the already existing blebs of the broad, thick perthites.

Simultaneous Crystallisation: This process of simultaneous crystallisation has been used for those perthites which contain fairly high percentage of soda feldspar. Vogt(1905, 1906, 1908) from the chemical composition of cryptoperthites concluded that they represent eutectic mixture and hence were formed by simultaneous crystallisation, as represented in his Fig. & type V). Alling does not believe in the existence of eutectic perthite. The polymorphism of

orthoclase and albite if taken to support these perthites then the existence of eutectoid perthites is probable and not universally true.

Mehmert thinks in a mixture of albite and potash feldspar, with different parameters, different phenomena are observed. For example, crystallisation of this material in the presence of albite component in solid solution held in potash feldspars at the same temperature of crystallisation. Likewise, if the crystallization is very rapid and the temperature raised, only single feldspars would probably be formed which can't be perthitic but then if the crystallisation is more prolonged there would be sufficent time for exsolution during the process, the excess of albite as separate unit is being crystallised simultaneously with orthoclase forming a fine perthite intergrouth. And there is third situation where temperature of crystallization is lower, the ability of potash feldspar to take albite into solid solution. Therefore, if the crystallisation of both feldspars is simultaneous, they show growth together in the form of coarse perthite. Warren (1915) attributes perthites, containing more than 28% plagioclase to simultaneous crystallisation. Anderson (1928) believes that simultaneous rhythmical crystallisation of solutions, saturated in plagioclase, result in the formation of antiperthites.

Spencer (1938) believes the crystallographic continuity of the vein perthite and microcline as a support to this origin i.e. simultaneous crystallisation. Finally, Barth considers this origin for interlocking and guttate perthites.

Replacement : This type of origin received little attention in the early studies of perthites but now it is gaining importance from time to time, as there is development of certain perthitic textures, which owe their origin to replacement. Smyth (1893) and Wenglein (1903) thought that the perthitic albite lamellae were introduced from without into the previously formed microcline. After that no serious effort was made in respect of this 3rd origin till 1928 when Anderson gave detailed classification of pegmatite perthites. He states that a process involving both recrystallisation produced by circulating solutions along cracks of minerals and a replacement of microcline partially by albite, by same circulating solutions, has played an important part in the formation of all ordinary perthites of the pegmatitic granites.

Alling (1938) considers the processes of unmixing and replacement as overlapping whereby, unmixing being a high temperature phenomenon, whilese the replacement is a low temperature phenomenon.

Goldich and Kinser (1939) considered firmly the origination of braid perthites to be partly due to exsolution and partly due to replacement.

Mehnert (1968) considers broad, irregularly formed perthites, in which one component predominates the other, indicate a relatively low temperature phenomenan. This is evident in albitization metasomatic features. The formation of patch perthite and the chess-board albite with numerous transition and degrees of replacement are due to metasomatic processes.

Another process of similar nature ie., late albitization from outside by way of hydrothermal solutions results in the formation of cleavelandite randomly oriented in the early formed K-feldspar.

Orescher-Kaden (1948) Rosenqvist (1950, 1952), Robertson (1959) explained the formation of coarsely and irregularly shaped type of vein perthite having been formed due to replacement alone.

From these discussions, it is apparent that various perthitic textures are produced as a result of unmixing, replacement or simultaneous crystallization or from a combination of these processes and the factors which control each process are contraction cracks, internal compression, atomic structure, solution effect and lastly tectonism of an area. These discussions reveals that the perthites of study area depending upon the factors as well as the perthitic textures observed in thin section, the origin of unmixing, replacement or combination of both

unmixing with falling temperature replacement due to metasomatism satisfy their existence in all intrusive granitoids rocks of study area including metamorphic & rocks of Salkhala group. The detailed study of perthites has been done on the basis of petrographic work using polarizing microscope. Here the author is influenced by the observation made by Chayes(op. cit.) that shear stress conditions favour the unmixing of already metastable alkali feldspar which is further confirmed by the presence of highly undulant quartz and similar features in sight of these intrusive rocks under study.

CHAPTER - VII

PETROCHEMISTRY

This chapter deals with the study of petrochemistry of Igneous rocks which include granitoids of Post-Tanaual age and volcanites of the study area. The petrochemistry of metamorphic belt of Salkhala Group has been described briefly. An attempt has been made that chemical data of both younger non-foliated granitoids and older foliated granitoids of Salkhala Group has been restricted to common variation diagrams , and their results are drawn jointly to avoid repetition.

Forty-two representative samples (Table 9 & 11) have been analysed for petrochemical interpretations and the major oxides including trace elements of corresponding samples have been presented. The same data have been plotted on binary and ternary variation diagrams. Repetition of some of the diagrams, capable of giving clear picture, could not be avoided. For convenience sake, the author has grouped these diagrams into the following categories:

(1) Binary variation diagrams.
(2) Ternary variation diagrams.

The various variation digrams drawn on the basis of percentages of each oxide have direct bearing on the

chemistry of rocks involved and their chemical behaviour noticed with each parameter.

HARKER VARIATION DIAGRAM

Coming to the classical variation diagram of Harker (1909) wherein weight percentages of the major oxides of each analysed rock sample are plotted against the weight percentage of SiO_2. The principle assumption on which it was constructed concludes that silica percentage is an index of the stage of magmatic evolution attained.

Likewise, the weight percentage of each major oxides taken along ordinate against corresponding weight percentage in of each SiO_2 taken along abscissa for the granitoids of study area are plotted (Pl.48 Fig.17). This diagram reveals that with increasing SiO_2 there is uniform decline in MgO, CaO, FeO, Fe_2O_3 and Al_2O_3 but there is erratic behavior in respect of K_2O and Na_2O, the account of which may be attributed to the variable enrichment of Na^+ and K^+ due to later processes of metasomatism.

Later workers like Wager and Deer (1939) and Walker and Poldervaart (1949) raised some doubts with the classical variation diagram of Harker. Even Bhayes (1949b) pointed out the disadvantage of such diagrams in the discrimination between different possible processes involved in variation between rocks of a plutons.

Nevertheless, the Harker's variation diagram continues to be a guiding diagram and is still being used

by petrologists.

LARSEN VARIATION DIAGRAM.

Larsen (1938) observed that Harker's diagrams work well with calc-alkalic rocks but donot properly fit in rocks of alkalic series or rocks with silica deficient. In order to overcome this discrepancy, Larsen suggested an improvement over Harken's diagram. In his diagram, he proposed the plotting of weight percentage of each major oxide against the sum of $\frac{1}{3} SiO_2 + K_2O-(FeO+MgO+CaO)$ taken along abscissa which is called Larsen Index. From the diagram given on plates 52, 53, it is apparent that Na_2O, K_2O and total alkalies register increase with increasing L.I. There is corresponding decrease in the case of MgO, CaO, FeO, Fe_2O_3 in respect of both foliated gneissose granites of Salkhala group and non-foliated intrusive granitoids of Post-Tanaual age. Some plots of Al_2O_3 show little erratic nature But then even, scattering of points in Al_2O_3 field, make one feel that there seems a general upward tendency with rising values of Larsen Indices.

THORONTON AND TUTTLE VARIATION DIAGRAM.

Thoronton and Tuttle (1960) made use of new parameter based on the normative quartz, orthoclase, albite, leucite, Nepheline + Kalsilite called Differentiation Index which is equal to the sum of above mentioned normative minerals. In the present context, only three normative minerals appear

in the calculated C.I.P.W norms of chemically analysed samples given in the table 13 . Therefore, here D.I. is taken to be the sum of normative quartz + orthoclase + albite. The D.I. is a measure of the basicity of igneous rocks of the study area. The main theme behind this method is that the fractional crystallisation of all complex silicate melts finally reache the Bowen's System of SiO_2 - $NaAlSiO_4$ - $KAlSiO_4$ (1937) and is well known by the name "petrogeny's Residual System". This was also supported by Yoder (1957) vide his system of K-fedspar-Anorthite-water and by Schairer (1954,1957) vide his ternary system of cordierite-leucite-silica and cordierite-albite-silica. The earliest minerals to fractionate in a differentiating magma (and at the moment from the anatectic magma), are high temperature, followed by relatively low temperature minerals, which are present in the residual melt. These latter minerals represent the salic constituents of the C.I.P.W norm except the anorthite molecule, which is the basic constituent of igneous rocks together with Zircon, corundum apatite, etc. (PL- 51 & 55.

Diagrams Show the plots of weight percentages of various major oxides against the corresponding D.I values of each sample taken along abscissa for granitoids of Study area. In this diagram the Na_2O, K_2O and total alkali-s show upward trend with increasing values of D.I. and Fe_2O_3 FeO, MgO, CaO, show typical downward trend with increasing

D.I.values which is similarly shown by Al_2O_3 rock sample. The similar feature is registered by the low grade metamorphics given on table 11 MgO appears to have very slight increase with each value of D.I.

KUNO VARIATION DIAGRAM.

Kuno (1968) proposed a new parameter "Solidification Index" which he defined as $\frac{MgO \times 100}{MgO+FeO+Fe_2O_3+Na_2O+K_2O}$ and is denoted by S.I.

Kuno (op. cit.) assumed that "the S.I. value for each sample of Intrusive granite decreases proportionately with the amount of the residual liquid". The S.I. is a better index than SiO_2 weight percentage , because SiO_2 value does not change steadily throughout the fractionation. The S.I. values for the granitoids of the area are given in table 12 .

From (Pl. 50 Fig. —)it is clear that K_2O, Na_2O and total alkalies show an increase with the decreasing value of solidification index. Whileas, CaO, MgO, FeO and Fe_2O_3, Al_2O_3 show downward trend with decreasing values of solidification. As usual the plots of Fe_2O_3 show some scattering of points, but there appears a slight decrease with increasing S.I. which seems to be abnormal due to weathering of specimens which might have escaped detection before processing for analysis.

POLDERVAART AND PARKER VARIATION DIAGRAM.

Crystallisation index is a modified form of differentiation index and it was used by Poldervaart and

Parker (1964) which accounts for the progression of partial magma or igneous rocks from the "Primitive System" Anorthite - Diopside - Forsterite. According to them, it is felsic and mafic constituents which play important role in the crystallisation of magma.

According to Poldervaart and Parker (op.cit) the chief components of a fractionating magma are the mafic and felsic members of the reaction series here called C.I. = (An +Di' + Fo' + Sp') in which An= normative anorthite Di' = Di = magmanesium diopside ($CaMgSi_2O_6$) and is determined as 2.157003 En Di (En of normative diopside) F'o = normative forsterite plus normative enstative converted to forsterite and is equivalent to Fo+0.700837 En Hy (En of normative Hypersthene)

Sp' = is used in ultramafic rocks

The C.I. does have a preference over SiO_2 or S.I. because it is based on theoritical petrological principles. The C.I. values of analysed samples are given in the Table 12 and the plots are given in (Pl.54 Fig.-). C.I.Point towards the more acidic members of non-foliated intrusive granitoids. From the (Pl.54 Fig.-) it is apparent that the value of C.I. decreases as there is a progressive rise in Sio_2,Na_2O,K_2O whileas C.I. increases with the gradual rise in respect of CaO,MgO,FeO. However, the plots in Fe_2O_3 field are some what erratic, thereby don't show any appreciable trend. These features are normally met with in acid varieties of plutonites with few exceptions in the

sense that saturated rocks in question show random plotting

All these foregoining diagrams point to magmatic descent of these foliated & non-foliated granitoids.

NIGGLI VARIATION DIAGRAM.

Niggli (1954) suggested a method by which al, fm, c, alk and Si, known as Niggli values, can be calculated from the chemical analysis. These values are plotted on a binary variation diagrame taking Si and mg along the abecissa and other Niggli values along the ordinate as shown in the (Pl. 49 Fig. -). It may be inferred from the graph that alk values show upward trend; whileas c and fm values show a downward trend with rising values of Si. One particular disturbing point riese about the behaviour of al values with varying proportion of silica, is in that all points are disposed behavior may be attributed to non avaliability of direct and reliable method for the determination of Al^{+++}. Trends exhibited by values other than al are similar to those observed in well established magmatic granites.

The similar picture is revealed by foliated type of gneissose granites as shown in (Pl. 70 Fig. -). These features are commonly associated with neo-magmatic differentiation

Another Binary variation diagram is between mg and c of Niggli values. From the graph one can infer that most of the plots of non-foliated intrusive granitoids fall in the corner, where for any value of mg there is corresponding proportion of c. The values of c, mg are seen to be on

decreasing trend (PL-71, Fig-e). But for few plots of foliated gneissose-granite rocks, the value of mg increases with the increasing value of suggesting there by that some gneissose rocks rich in mafics which seems to indicate regional metamorphism of peltic or arenaceous sediments (Paragneisses).

IRVINE AND BARAGAR DIAGRAMS 1971.

Irvine and Baragar (1971) used the following parameters:

From the graph (Pl.63 Fig.a) it is found that almost all the points of both foliated and non-foliated varieties fall either in Calc-Alkaline field or along the immediate vicinity of the common line of the two fields viz., Tholeiitic field and Calc-Alkaline field. From this diagram, it may be inferred that the anatectic magma has Calc-alkaline affinity and the presence of points within the discrimination line point to the fact that some amount of contamination of the magma might have taken place before actually crystal-fractionation took place.

The diagram shows Normative Colour Index plotted against normative plagioclase. The points of analysed samples both in respect of foliated and non-foliated rocks under study, fall either in granodiorite field or in granite field. No plots are noticed in grabbro or diorite fields which tally with the other ternary or binary diagrams exhibiting the various rock types. (PL-63; Fig-b)

MIYASHIRO DIAGRAMS.

Miyashiro (1974) has proposed diagrams where he has plotted $\frac{FeO^t}{MgO}$ against SiO_2 and FeO^t as shown in the (Pl.61 Fig.-).

According to Miyashiro (op.cit.), the advanced fractional crystallisation is measured by the index $\frac{FeO^t}{MgO}$ ($Feo^t = FeO + Fe_2O_3$)

Plottings of rock analyses on these diagram afford the nature of the magma, to which lineage it is brought to the present stage.

In (Pl.61 Fig.-) three fields demarcated are as (A) calcalkaline ,(B) Calc-alkaline + tholeiitic (C) Tholeiitic. The plot of the rocks falls in fields A and C, pointing predominently to a tholeiitic trend.

COLEMAN AND PETERMAN VARIATION DIAGRAM.

In this diagram, the values of analysed samples of gneissose rocks of Salkhala Group have been plotted. From the figure it is apparent that these gneisses show general increase in K_2O with SiO_2. The fields are given by coleman and Peterman (1975). The grey gneisses overlap partially continental trondhjemites and most of the points fall in continental granophyre showing thereby continental conditions prevelent during their emplacement before effects of metamorphism actually occured. Here it is also evident that gneisses exhibit an almost linear inclined trend of potash increasing for Silica values. The plots of these rocks

under investigations show fields in same approximation with the uivak grey gneisses of labrador marked by hollow circles in the diagram, (pl-62; fig-a).

The following ternary variation diagrams have been discussed to substantiated the evidences in each case of rock formations with more emphasis laid on the intrusive granitoids of study area.

(1) An-Ab-Or Ternary diagram. It was proposed by Mcgregor (1975) for Amitsoq gneisses. It shows relationship between normative albite, normative anorthite and normative orthoclase the values of which are given in the Table 7 .

Here the values of normative albite, anorthite and orthoclase calculated from analysis of study area, are plotted in diagram (Pl.65a Fig.-) very few plots fall in granodiorite under field of Amitsoq Gray Gneisses. Other plots fall in granite and adamellite fields. The field of tonalite is without any plot. However, the classification boundaries are from O'Connor (1965).

(2) Q-Ab-Or. Ternary diagram. The normative quartz, albite, orthoclase calculated from the chemical analyses of metamorphic rocks of study area are given in the Table 7

And these values, after plotting in the said diagram fall in and very close to a field of granodiorite suite and some plots fall in Amitsoq augen gneisses as shown in the figure. The majority of samples occupy a relatively confined area

away from Or-apex and show a distinct disposition along Q-ab direction. There seems no clear distinction between calc-alkaline trend and trondhjemitic trend. Though one or two plots fall in Amitsoq grey gneisses. From these observations, the gneisses of study area are correlatable with Amitsoq gneisses of ancient complex. (PL-64)

In (Pl.56 Fig.a) which is variation diagram between SiO_2-alkalies -mafic oxides, the points of oxides of intrusive granites cluster near SiO_2 and the behaviour of alkalis with respect to silica is constant. In a similar ternary diagram, between FeO-CaO and Mgo the trend of the plots follow the (FeO+CaO) side of a tringle which means the concentration of MgO is very negligible against other oxides forming the varieties of a diagram. Ternary diagram between quartz-albite and orthoclase, Winkler (1974) draws a countour line dashed on the basis of experimental anatexis. And according to him the composition of the melt formed by anatexis falls with in this field, and some of the plots of analysed samples of non-foliated intrusives fall in this counter and other points fall outside this contour as shown in the (Pl.58 Fig.+). The former feature shows that crystallisation from the melt whileas to account for the irratic behaviour of other points, point that the pre-existing rocks must have been granitised due to soda and K-metamorphism of which later on were capable of attaining the shape of present granite granodiorite suite.

AFM TERNARY PROJECTION DIAGRAM.

It shows the disposition of values of gneisses of Salkhala Group In the diagram the plots are restricted to alk- total iron boundary. Some plots occupy the granite field and follow Tingmuli Trend. (PL-62 ; fig-b)

TERNARY DIAGRAM OF TUTTLE AND BOWEN (1958)

This diagram is drawn between normative quartz, albite, and orthoclase of analysed samples. The basic principle on which this has been constructed relies on those rocks which contain 80 percent or more of the normative constituents i.e. albite + orthoclase + albite. The boundary abc indicates the composition of true granites in which there are some plots of analysed samples of non-foliated intrusive granitoids of study area. From the (Pl. 57 Fig.-) it is clear that those values falling outside the inner contour diagram show such rocks to be something other than true granites as normally used in the thesis as granite looking rocks.

AFM TERNARY PROJECTION DIAGRAM.

It is constructed on the basis of weight percentages of major oxides of analysed samples of both rock types in question. From the (Pl. 66 Fig. b) the suite defines a linear trend which is similar to that exhibited by calc-alkaline igneous suites, and close to Amitsoq Grey Gneisses and Amitsoq augen gneisses of Archaean age.

Normative An-Ab-Or or Ternary Diagram : From this Diagram (PL-66, fig.a.), it is apparent that the plots of these granitoids occupy mostly

granite field of O'Connor (1965) and few plots fall in coleman's continental granophyres which is in connor's field of adamellite. The dashed curved line represents a barrier of 1Kb pressure which means these granites of study area are evolved under low pressure conditions except two samples of gneissose granites are evolved under low pressure conditions.

$CaO-Na_2O-K_2O$ Ternary diagram suggested by Glikson (1979), (in Barker, F. 1979) is a chemical classification similar to that of O'Connor's classification (Op.cit.) except with one difference that unlike latter's diagram, Glikson uses $CaO-Na_2O-K_2O$ weight percentages as parameters. From the (PL.65 Fig. b) it is clear that the plots of these rocks occupy almost the same fields as given in O'Connor chemical classification. The fields are granite granidiorite - adamellite and little Trondhjemite etc.

AFM TERNARY DIAGRAM

It is based on weight percentages of Major oxides recalculated to hundred percent given in Table 15. It is proposed by Barker and Arth (1976). The plots of these granitoids are restricted to alkalic corner with little affinity for total iron of rock samples of study area. The main feature is apparent from the (Pl. 65 Fig. a) that the rocks of study area show a typical calc-alkaline trend.

THERMAL TERNARY VARIATION DIAGRAM

This diagram is based on experimental work of Kleeman (1965). Here the normative anorthite, albite and orthoclase of both foliated and non foliated granitoids of

study area after recalculation to hundred percent are compared in respect to the thermal trough in the ternary diagram of Ab-An-Or. Some plots of these rocks fall in the thermal trough which indicate that these granitoid rocks, have formed due to crystallisation from anatectic melt at a temperature range between 650°c and 690°c. The composition of granites whose value fall in the thermal trough is seen to correspond with composition in the low temperature trough is seen to correspond with composition in the low temperature trough of the system Q-An-Ab-Or system (PL-59, Fig-a).

Qz-Ab-Or TERNARY DIAGRAM :

It is proposed by Von platten (1965) and is based on pressure at depths which can cause anatexis. The principle behind this experiment to see the effect of anorthite content in alkali feldspars of many granite rocks causing anatexis of pre-existing rocks. He believed that the minimum temperature to effect anatexis may be more than 720°c corresponding to 4Kb and he used water pressure between 4Kb-7Kb in the fundamental system Quartz-albite-Orthoclase-H_2O. From his experimental data, he suggested a diagram as shown in (pl.59 Fig. b.) with dashed isobars known as cotectic-bars.

From the figure, the plots of analysed samples of both foliated and non-foliated granitoid outcrops of study area, fall in this trough, showing thereby, that such granitic rocks appear to have been formed from anatectic melt, and to account for other plots outside the cotectic bars, it is presumed that these rocks were formed due to

metasomatism of rocks formed by the crystallization of anatectic magma.

PETROCHEMISTRY OF VOLCANICS:

In all nine selected samples of Panjal Trap and one sample from Bafliaz volcanics of the study area have been analysed and the values of their major oxides determined. Then the undermentioned variation diagrams, binary and ternary, have been constructed using respective parameters befitting each individual diagram as shown in the following pages.

HARKER'S VARIATION DIAGRAM:

Different oxides have been plotted in this diagram against SiO_2 (Pl.37 Fig. a). K_2O shows sympathetic relation with SiO_2 and the upward trend is sharp. There is a gradual increase of Na_2O with the increase of SiO_2. MgO, CaO, FeO, Fe_2O_3, TiO_2 curves show downward trend, Al_2O_3 shows downward trend.

S.I.V/S ALL OXIDES

In this diagram (Pl.37 Fig. b), FeO, MgO, CaO, show gradual increase with S.I. whilese SiO_2, Na_2O after some limit of S.I., K_2O, Al_2O_3 show a downward trend with increasing value of S.I.

SiO_2 V/S $Na_2O + K_2O$

This is a diagram between weight percentages of $Na_2O + K_2O$ taken along ordinate and weight percentages of SiO_2 taken along abscissa and provides three fields of

magma character. Upon close examination, the plots of analysed samples of volcanic rocks of study area, fall mostly in Tholeiite and calc alkali rock series. And a spilite sample from Baddar marked by(x) falls in alkali rock series .

FELSIC INDEX V/S MAFIC INDES:

Simpson (1954) showed that magmatic differentiation can be studied by plotting the mafic index as $\frac{100\ (FeO+Fe_2O_3)}{MgO+Fe_2O_3+FeO}$ against the felsic index as $100 \times (K_2O + Na_2O)/(CaO+Na_2O+K_2O)$ in (Pl.38 Fig.-) based on Green and Poldervaart weight percentages are used (on a dry basis) instead of oxide weight percentages. The trends of Deccan traps(Sukeshwala and Poldervaart , 1958) is also included in the diagram. After having plotted the values of analysed samples of Panjal Trap of study area, it is clear from the figure that the traps of study area follow the Deccan Trap teend of differentiation and these occupy the field of early stage to middle stage basalts.

K_2O V/S Na_2O DIAGRAM :

In this diagram, there are three fields, viz., (1) Spilite, (2) High alumina basalt (3) Alkali basalt. After plotting the respective values of alkalies of analysed samples of volcanic rocks of study area, the plots fall in the high alumina basalt for Panjal Traps and the value for spilite sample falls correctly in spilite field, (PL-39, Fig a).

D.I. V/S $Na_2O + K_2O$ DIAGRAM:

This diagram has been shown in (Pl.39 Fig. b) Here (Na_2O+K_2O) is taken along ordinate and D.I. taken along abscissa. From this diagram, it is apparent that differentiation of volcanic rocks of study area has not proceeded beyond Hawaiite Stage. This clearly shows that the differentiation did not go beyond the andesite stage.

MgO V/S Al_2O_3/SiO_2 DIAGRAM :

In this diagram, MgO V/S Al_2O_3/SiO_2 (Murata, 1961) for the volcanic rock suite of the study area, the plots fall amidst the two trend lines and most of the points cluster in the field B and C which show typical character of andesites (Hawaiite), (PL-46, Fig. a).

Al_2O_3 V/S TiO_2 VARIATION DIAGRAM :

Tanaka et al. (1970-71) gave a method of plotting Al_2O_3 versus TiO_2. The values of chemical analyses of volcanic rocks of study area have been drawn in the figure. This diagram provides three field, A is the field of Cenozoic basalt of Japan (circum-oceanic), B is the field of Hawaiian tholeiites and ocean ridge basalt (oceanic Island), and C is the field of late Palaeozoic green rocks of central Japan (geosynclinal). And all the plots of rocks of study area fall in field B", i.e. rocks appear to have extruded in a marine condition. (PL-46, Fig. b).

Al_2O_3 V/S $\frac{An \times 100}{Ab + An}$ DIAGRAM

This is a plot between weight percentage of Al_2O_3 and normative plagioclase composition, which is calculated as $\frac{An \times 100}{Ab + An}$. The respective values of volcanic rocks of study area are plotted in this bionary diagram which clearly point to tholeiitic field including the spilite sample of Baddar village of Gulabgarh area, (PL-41, fig a).

Normative colour Index V/S Normative Plagioclase Composition.

In this diagram, which provides different fields as shown in (Pl. 41 Fig. b), the normative colour Index is taken, along ordinate and normative plagioclase composition is taken along abscissa of binary variation diagram. Accordingly the values of normative C.I. and normative plagioclase volcanic rock samples of study area are plotted in the said diagram. Under close examination of the picture, the plots fall in Basalt and andesite fields of the diagram.

GOTTNI - RITTMANN DIAGRAM, (PL-44, fig-a).

Gottni (1968,70) and Rittmann (1967,70) have proposed a diagram between the log of σ taken along abscissa and log τ taken along ordinate. The values of σ and τ of volcanic rocks of study area are given in the Table 2 after computing the chemical data of analysed samples of Panjal Trap and spilite from the study area according to method given by Rittmann (1967,70). It is clear from the diagram that the plots fall in the A and B fields. The

spilite sample falls in field C. In the diagram field A represents non-orogenic arcs, B field represents lavas situated in orogenic field Island arcs, and C represents alkaline derivatives of both. This shows Traps of the study area belong to both orogenic and non-orogenic belts. Variation diagram between Q and T where

$$T = \frac{\text{Saturated norm of Anorthite}}{\text{Saturated norm of ilmenite}} = \frac{An}{Il}$$

and ΔQ is un used quartz after distribution is over according to the method given by Rittmann (op. cit.). In this diagram ΔQ is taken along abscissa and $T = \frac{An}{Il}$ taken along ordinate. This diagram is discriminative type which distinguishes tholeiites and alkali basalts from the so called high alumina basalts or hawaiites from true andesites. From the figure the fields fall in hawaiite rock types which is more related to andesites if not true andesites, (PL-45, fig-a).

As we know that rocks belonging to a magmatic differentiation series, the oxidation degree, increases with the more salic differentiates. Also, the oxygen fugacity is generally greater in the magmas of orogenic belts than in non-orogenic belts. It is found that the degree of oxidation is always lower in the present magma than in the solidified rocks which have crystallised from the magma. The rocks which have crystallised from the course of crystallisation from the magma, the water capable of causing quick oxidation will get enriched in

the rest of melt. Therefore, it is clear that the present oxidation value cannot be true degree of oxidation which might have been in the parebt magma before crystallisation of these volcanic rocks of study area. So this idea influenced Rittmann to propose a relationship between degree of oxidation and the corresponding alkali content in Na^+, K^+. And according to Rittmann such statistical correlation does exist in volcanic rocks of the world. In the present context, the weight percent of total cations of alkali-s from the chemical analyses of rocks of study area is taken along abscissa and degree of oxidation given in the table calculated according to method of Rittmann, ist taken along ordinate. In the figure, the plots fall in and around (T) which represents Tholeiitic basalts, (PL - 45, fig b.).

TiO_2-K_2O-P_2O_5 VARIATION DIAGRAM:

It was proposed by Pearce et al. (1971). This is a sort of discriminative type which distinguished Oceanic from non-Oceanic tholdiites. The weight percentages taken from the chemical analysed samples of volcanic rocks of study area, were recalculated to hundred percent before plotting in the ternary diagram. Such a plot for the rocks of the area of study reveals that most of the points cluster in the oceanic region, very few plots fall in non-oceanic or very close to the discriminent boundary and do not extend far away from that. However, altered basalts, which point to oceanic region are unlikely to have a non-oceanic origin,

Pearce et al. (op.cit.).(PL-40)

ACF DIAGRAM :

This was suggested by Miyashiro (1965) for the volcanic rocks of Japan. Here this diagram is used for the volcanic rocks of study area which provides two distinct fields. One is basalt andesite and other field is Shale-Greywacke field. The parameters used in the diagram are A= Al_2O_3 - Na_2O - K_2O, C= CaO - $\frac{10}{3}$ P_2O_5 - Co_2, F=MgO+FeO-Fe_2O_3-TiO_2. These parameters are recalculated to hundred percent before plotting them, from the diagram it is clear that the plots occupy basalt -andesite which characterises the volcanic rocks of study area, (PL-42, fig-a).

The calcic nature , of the volcanic rocks of the study area, is revealed by normative orthoclase-albite-anorthite, Ternary Diagram (Pl.42 Fig. b.)

In Na_2O - K_2O-CaO ternary diagram after re-calculating to hundred percent the chemical values of analysed samples, the points cluster very close to the CaO corner, Showing their high calcic nature, (PL-43, fig-a).

Total Iron-alkalies (Na_2O+K_2O) -CaO ternary diagram. Here the plots fall very close to the boundary of total iron and CaO. Which point to the fact that the traps of the study area, are iron and calcium rich and poor in alkalies whileas the spilite sample is slightly away from the join of total iron and CaO, (PL-43, fig. b).

TRACE ELEMENT STUDIES OF GRANITOIDS AND VOLCANITES

Petrochemistry of major elements of granitoids and volcanites of study area has been dealt with in the preceding pages. Here an attempt has been made to understand the role played by trace elements in the granitoids and the volcanic rocks of the area. These elements are found in extremely small proportions.

Generally, the trace elements do not form steep chemical gradients because these elements are present in less concentration in the silicates of each mineral. Therefore, these can reveal in a better way the sequence of changes which are brought about during the evolution of igneous rocks. Paul Gast (in Allegre and Hart, 1978) has stated that the trace element study is a powerful weapon in experimental petrological approach to solve major problems.

PROCEDURE OF TRACE ELEMENT STUDY

Powdered rock samples were given tri-acid treatment i.e. HF- $HClO_3$- H_2SO_4 before bringing them in solution forms. Under desired concentration of each trace element, necessary dilution was affected to bring that sample under detectable range of wave length of each element using Atomic Absorption Spectrophotometer (Double Beam Model-1902 of Australian Origin).

TRACE ELEMENT STUDY OF GRANITOIDS

In all eight elements have been estimated depending upon the availability of facility at the Centre and recorded in

ppm concentration given in the Table-19&20, for against each sample and these are: Zn, Cu, Ni, Co, Cr, Pb, Sr and Li. For understanding the distribution of various trace elements in both foliated and non-foliated rock samples from the study area, the plots of all trace elements against SiO_2 have been made and their relationship drawn in the ~~Fig.~~ Plate 72-73, 74-75. is summed up in the following lines;

COPPER From the graph of each trace element it can be inferred that there is general increase in the trend of Zn, Pb, Li with corresponding increase in SiO_2, whileas there seems to be general decline in Cu, Ni, Cr, Sr and Co with corresponding increase in SiO_2 values in case of foliated gneissose granites. This suggests that Zn, Pb, Li occur in more acidic igneous rocks and Cu, Ni, Cr, Sr occur in more basic igneous rocks.

In case of non-foliated granites, there is general increase in the trend of Pb, Li with respect to SiO_2, whileas there is gradual decline in respect of Cu, Ni, Cr, Sr with increasing values of SiO_2. In case of Zn in the rocks in question, the plots show slight decline which is nothing but an abnormality suspected in its values, (See plts. 72, 73, 74, 75).

~~Fig.~~ Plate 77 & 76 shows a variation diagram in which various trace element values are plotted along ordinate against D.I along abscissa. The figures represent both foliated granitoids of Saikhala Group (Fig. 76 Pl. 77) and non-foliated granitoids of Post -Tanaval age. In case of foliated granitoids, there is

general increase trend of Zn,Pb,Li and slight increase in Co; whileas there is decline in case of Ni,Cr,Cu. Amongst these, the plots of Sr show erratic distribution and the trend is uniform.

COPPER (Cu)

This element occurs in nature as monovalent and divalent such as cuprous and cupric i.e. Cu^{2+}, and Cu^{3+} each having ionic radius 0.96 Å. respectively and 0.70 to 0.72 Å.

This element has a higher affinity for sulphides than for silicates. Sandell and Goldich (1943) have found that the amount of Cu present in American igneous rocks is inversely proportional to that of silica and proportional to that of Sulphure (Wedepohl, 1972). Wager and Mitchell (1951) concluded that Cuprous and Cupric occur as free ions during the early stages of crystallization from magma, and later on they may be incorporated in silicate minerals. In silicate forms the Cu may be camouflaged by Na^{+} (0.98 Å)and Fe^{2+} (0.74 Å) and here Cu does not enter into the silicate structure.

Copper in granites may be associated with all silicate minerals, but biotite is considered to be one of the important Cu host minerals and it occurs in intergrowth. Wedepohl (1972) computed the averages of concentrations of 660 biotite samples from granites and found 86 ppm Cu as an average in the mineral.

Mexham (1965) in (Wedephol,1972) showed a higher tendency

of Cu concentration in biotite than in the coexisting hornblende.

Biotite is the chief ferromagnesian mineral in the granitoids of the study area mostly in granodiorites and syenites. The average concentration of Cu in granites and granodiorites is 20.5 ppm whileas in quartz-syenites /syenites the average concentration of Cu is 63.3 ppm. This average of Cu concentration agrees with that given by Serykh (1963) in (Wedepohl,1972) who has also reported an average of 20.3 ppm Cu for 75 analysed granites and granidiorites from Khazhakhistan in U.S.S.R.

CHROMIUM (Cr)

This element is generally concentrated more in ferromagnesian minerals, whileas it shows a considerable decrease in the later phases of the differentiation series, its ionic radius being 0.65 $\mathring{A}$. One peculiarity is noticed about its diadochic behaviour with Fe^{3+} in silicates, however, a higher concentration of Cr is noticed in these granitic rocks of the study area. Rankama and Sahama (1950) have reported Cr content between 2 to 6.8 ppm in granites. The presence of magnetite and biotite in the granitoids make it suitable sites for the concentration of Cr. Goldschmidt (1954) in (Wedepohl, 1972) has demonstrated that the earlier formed rocks are rich in Cr than the later formed rocks and investigations of Neckolds and Mitchell(1948), Wager and Mitchell (1951) and Bilgrami (1961) in (Wedepohl,1972) have confirmed the observation of Goldschmidt (op.cit.)

The results of Wager and Mitchell (op.cit.) show that

Cr^{3+} is camouflaged by Fe^{3+} during crystallization of a silicate melt. Cr shows high degree of concentration relating to Fe^{3+} in minerals containing iron and as such is removed first rapidly from the magma. Cr is also found in high concentration in pyroxenes. The camouflage business is due to two obvious reasons, first Cr has smaller electronegativity (1.6) than Fe^{3+} (1.8) and secondly both elements have same ionic radii i.e. Cr^{3+} (0.64 Å) and Fe^{3+} (0.65 Å). It is also shown by Howie (1955) in (Wedepohl, 1972) that Cr is preferentially found in magnetites than in the ilmenites. In the present study the higher concentration of Cr in granitoids of younger granites is accounted for due to higher percentage of magnetites and biotite. Small amounts of Cr also occur in plagioclases and K-feldspars, possibly as Cr-O in the tetrahedral positions (Ringwood, 1955) in (Wedepohl, 1972). However, the relative concentration in gneissose granites of metamorphic belt seems to be less clear. In the case of granitic rocks of study area, especially in case of non-foliated variety; clustering behaviour of Cr plots with the increase of SiO_2 and D.I. according to Nockolds and Allen (1953) is not in favour of true magmatic origin.

COBALT (Co)

It resembles Ni in physical and chemical properties. Its ionic radius is 0.82 Å and e = 1.7. Co is considered to be diadochic with Fe^{+2} (0.83 Å). Therefore, it follows Fe^{+2} very closely. Co is less abundant in nature than the element Fe^{2+}.

Newhouse (1936) in (Wedepohl, 1972) and Ramdohr (1940) in (Wedepohl, op.cit.) have shown that igneous rocks contain small quantities of common sulphide minerals for example pyrite which becomes favourable nucleii for Co- Ni. If no sulphide minerals are present in the rocks, that will affect the overall concentration of the rocks under study. Goldschmidt (1954) in (Wedepohl, op.cit) found the rough relative ratio between Ni and Co in igneous rocks as 100 : 40. This is due to the fact that this element is only one third in abundance in original melt as compared to Ni. Earlier the ratio between Ni and Co as suggested by Clarke and Washington (1924) in (Wedephol, 1972) is 2 : 1 and Vogt (1931) gave ratio as 10 : 1. Sandell and Goldich (1943) have shown that the physico-chemical relationship between Co and Magnesium is more apparent than between Co and Fe^{2+}.

Nockolds and Mitchell (1948) have pointed out that Co enters crystal lattice with the same ease as does Fe^{2+} because both elements have same ionic radius, therefore, apparantly Co can be camouflaged in the compounds rich in Ferrous.

In the present study an average Co in case of non-foliated granites is 32 ppm, which is slightly higher than the values found in other granitic rocks of world. In case of foliated granitic rocks of metamorphic belt , the average concentration of cobalt is found to be 42 ppm.

In the present study,Co does not show systematic variation with Ferrous iron as compared to Mg. From this observation,

one can suggest that Co may proxy for Mg. Nockolds and Allen (1956) found that Co:Mg ratio is constant throughout a rock series whileas Co:Fe ratio varies from fraction to fraction, i.e., the ratio is higher in early formed minerals but decreases with advancing fractionation. From these observations Mason(1966) believes that the radius of Co^{2+} may be identical with that of Mg^{2+}.

Average concentration of Co in granites ranges from 2 to 8ppm (Rankama and Sahama1950). Therefore, apparent increase in its concentration in the rocks of study area is possibly due to later alteration of minerals as a result of granitizations

NICKEL (Ni)

The behaviour of Ni in granitic rocks is similar to that of Co . Ni shows greater affinity for Mg and ferrous iron, because of its similar ionic radii with Mg and similar charge with the latter. The ionic radius of Ni is 0.78 Å . From this observation it may be said that Ni-Mg diadochy is very often cited as a classical example of camouflage principle. Nockolds and Mitchell (1941) and Ringwood (1955) in (Wedepohl, 1972) did not agree with this principle. Ringwood (op.cit) thinks that Ni cannot proxy extensively for Mg but instead suggests that Ni enters crystal lattice at the expanse of Ferrous iron. Ni has a tendency to become enriched in the early differentistes rich in magnesian and ferromagnesian

minerals (Ramakma and Sahama, 1950).

In granites, Ni is almost quantitatively adjusted in biotite structure. Since the biotite mineral is high in granitoids of study area, so the average concentration of Ni is found to be 140 ± 15 ppm, and the average concentration of Ni in foliated granites of study area appears to be less in amount.

Ni is also incorporated in the silicate structure of chlorite and higher values of Ni in rocks in question is primarily due to ion exchange process with the country rocks rich in Ni at the time of emplacement. And above all a good quantity of chlorite bearing gneisses and gneissose granites are favourable centres for the accumulation of Ni as fresh chlorites are seen to have developed at the cost of biotite due to reverse metamorphism.

ZINC (Zn)

Zinc shows closer relation with ferrous iron (0.83 Å) than Mg^{2+} (0.78 Å). It is found as lithophile as well as chalcophile association in the upper lithosphere. The ionic radii of zinc is known to be 0.83 Å. According to Goldschmidt (1958) in Wedepohl, 1972), the Zn ion enters the lattices of magnesian silicates with the help of ferrous ions which dilate the Zn ions before they could make entry into magnesian silicates. Therefore, Zn in igneous rocks follows ferrous oxides.

As we know the Zn is present in various minerals and is controlled by the presence of Zn in the melt and secondly the degree of ability of a particular crystal structure to incorporate this element. According to Sandell and Goldich (in Wedephol, 1972), the amount of Zn in igneous rocks is roughly equal to the sum of Mg and Fe^{2+}.

Wedepohl (1953) in (Wedepohl, 1972) and Mason (1969) think that biotite mineral is the most important Zn carrier in granitic rocks. It is also found that the granitic rocks rich in ferromagnesian minerals are richer in Zn than the lighter granitic rocks.

In the analysed samples, the average concentration of Zn found in foliated gneissose granites and non-foliated intrusive granites is as 102 ppm and 130 ppm respectively; whileas Zn element in quartz syenites is abnormally high (about 275 ppm) in both the rock types.

STRONTIUM (Sr)

It is a fact that no independent Sr mineral is known to occur in nature which could be formed during the main stage of crystallization. The ionic radius of Sr is 1.12 Å. Sr in igneous rocks is controlled chiefly by major elements Ca (ionic radius 0.99 Å) and Potassium (ionic radius 1.33 Å). Mason (1958) in Wedepohl, 1972). The ionic size of Sr indicates that it can proxy for either Ca or K. According to "Goldschmidt's admittance theory", which implies that Sr is admitted into

the smaller Ca -lattice, but it is entrapped in the K- lattice which has a large radius (1.33 Å). Sr^{2+} is camouflaged by plagioclase feldspars rich in Ca and also by K in K-bearing feldspars such as microcline or orthoclase; only biotite mineral being an exception, where the proportion of Sr is outside the detection limit. The Av. Sr concentration in granites as found by Turekian (1956) is about 282 ppm and according to Noll (1934) in Wedepohl (1934) the Sr concentration is about 90 ppm in granitic rocks. The average Sr in rocks of study area both in foliated and non-foliated granitoids is about 90 ppm. and about 80 ppm respectively. The relation between the Ca^{2+} and Sr^{2+} is given in the diagram which shows a linear trend suggestive of the fact that the concentration of Sr^{2+} is proportional to Ca^{2+}.

LEAD (Pb)

Due to oxygen fugacity in the earth's crust, divalent Pb is more common in nature. Pb is both a chalcophile and lithophile element. Chalcophile variety occurs as galena and lithophile variety is occurring in silicate minerals. The ionic radius of Pb^{2+} is known to be between 1.18 - 1.32 Å.

The rule of Goldschmidt states that Pb^{2+} should be relatively concentrated in early formed K-bearing minerals and it doesnot enter into K-feldspar lattice with the same pace as K does. Pb ions hence become more concentrated in the residual

melt as envisaged by Ramakama and Sahama (1950), Nockolds and Mitchell (1948).

Wedepohl (1968) in Wedepohl (1972) believes that because of the size Pb^{2+}, this element will be incorporated in silicates with structural positions of large monovalent and divalent metals. It also replaces K^{+} in such minerals containing K^{+} ions (Wedepohl, Op.cit.)

Pegmatites are special accumulators of Pb and Rb. Mica usually contains less Pb than the K-feldspar. Igneous rocks rich in K-feldspar may contain 5- 100 ppm. Biotites of igneous rocks contain an average of 37 ppm whileas plagioclases contain an average of 19.5 ppm Pb (Wedepohl, 1974). In Mg. The Pb concentration in both outcrops of study area in question is about 83 ppm and 63 ppm respectively.

LITHIUM (Li)

This element occrs in the crust of earth as 20 ppm (Mason, 1966). According to Mason (op.cit), it is ionic size and not chemical properties which is decisive in crystallization as Li -ion is very much smaller than any other alkali ions such as Na^{+} (0.97 Å), K^{+} (1.33 Å). The ionic radius of Li is known to be 0.68 Å , e = 1.7. On the basis of chemical properties Li would follow the other alkali elements in magmatic crystallization. Therefore, as is seen that the ionic sizes of Li and Mg are identical and also because Li ions has a lower charge than Mg and Ferrous iron, so it should be

admitted into the magnesian and iron bearing minerals such as amphiboles, micas, magnetites, ilmenites and pyroxenes. According to Mason (op.cit.), Li is found in considerable amount in the liquid until a very late stage of differentiation. It is also found that Li v/s Mg shows a steady increase in the rocks of study area. The average Li content in both foliated and non-foliated granitoids of study area is found to be 85 ppm and 55 ppm respectively.

TRACE ELEMENTS OF PANJAL TRAPS:

Studies relating to behavior of trace elements during crystallisation are of great importance in delineating the various processes involved in the formation of different types of rocks. In the present study, the behavior of the following determined trace elements in volcanic rocks especially in Panjal Trap has been dealt with briefly. The trace elements found in the selected trap specimens are Sr, Cr, Ni, Co, Cu, Pb, Zn, Li and are given in the table .

Few diagrams have been drawn with these elements to trace out logical genesis of these volcanic rocks.

According to manner of occurrence, the trace elements found in the volcanites of this area can be divided into the following groups.

(i) Trace elements which are concentrated in the basic rocks and show a gradual decrease with increasing acidity e.g. Ni, Cr, Pb, Cu, Co.

(ii) Trace elements which are more enriched in the acidic varieties and decline with the decreasing acidity e.g. Sr, Zn, Li, etc.

From these observations, it is apparent that like the major elements, trace elements also follow certain variation trends, which may not be so sharp, yet possess some diagonestic pattern directly connected with the nature

of the magmatic liquid and its stage fractionation

SRONTIUM (Sr)

As for the traps of Gulabgarh are concerned Sr values range from 80 to 110 ppm . In graph Sr is showing an increasing trend which is quite normal. Condie et al.(1969) have given concentration of Sr in tholeiites (353 ppm), submarine tholeiites as (125 ppm) an alkali basalts as (761 ppm) Also Sr shows over all an increasing trend towards later differentiates . Various workers have given different reasons for this Sr-depletion charcter of various types of tholeiites of the world. Condie et al. (op.cit) are such workers who point an expensive plagioclase crystallisation from a Ca-Al rich primary tholeiite suite. Other features of the trace element have already been given in the discussion which figure in the trace element of granitoids. Other similar features in respect of other trace elements have been disscussed under trace elements of granitoids and hence have not been repeated in this discussion in question .

NICKEL (Ni)

Reverse phenomenon is observed in these rocks that is Ni in thebasic rocks is usually very high which goes on diminishing in the later differentiates . The average concentration of Ni in the volcanic rocks of Gulabgarh is 143 ppm . Chiefly Ni is concentrated in the magnetites and pyroxenes which are the main carriers of this element in traps of study area, and from figure Ni shows a considerable fall towards less basic members of the rock suite .

COBALT (Co)

McDoughall and Lovering (1963) show that co enters the same minerals as the Nickal, but in lesser amount. The Co also selected Fe^{2+} sites for the concentration in the trap rocks of study area. From (Pl.47 Fig. a) there is a sharp decline of Co with respect to SiO_2 and average concentration of this element is found to be 66 ppm in trap rocks of study area. The other characteretic of this element already discussed in respect of trace elements of granitoids. This elements in trap also proxyed by Mg^{2+} found in the same rock suites.

CHROMIUM (Cr)

Cr is concentracted more in the basic rocks than in acid valeties. The ferric iron is understood to have close affinity towards Cr and in analytic work it might be proxyed by Fe^{+} present in the samples. From the (PL47-A) figure there is a apparent decline u.r.t. increasing value of SiO_2 suggesting thereby that its concentration is expected in rocks of higher acidic values. $\frac{Cr}{Fe^{+3}}$ ratios for Gulabgarh traps show that Cr gets depleted as compared to Ge^{3+} in the later differentiates of study area. Other characteretics of this element are same as envisaged under granitoids of the study area. The average concentration of Cr in traps of Gulabgarh is

147 ppm which appears to be on the higher sides.

COPPER (Cu.)

The geochemistry of Cu is controlled by its highly chalcophyl nature, so much so that its association in the lattice of silicate minerals being formed during magmatic evolution as independent mineral is very uncertain, Wager and Mitchell (1951) found that the amount of Cu which enters olivine, pyroxene, plagioclases and iron ores is less than in the residual magma and its concentration goes on increasing to this extent that a stage comes where sulphide phase in the middle stage (Prinz 1967). The other characteretic features already figure in the granatoids of the study area and that is why this has not been touched. In the Panjal Traps of Gulabgarh, Cu content ranges from 30-90ppm.

LEAD (Pb)

Under normal conditions Pb accumulates in mafic magmas as a result of partial melting of ultramafic mantle rocks. Orinarily Pb bears close affinity with K to which it is chemically related. The other characterstic features of this element is already discussed in the rocks of intrusives granites of study area.

Pb in case of traps of Gulabgarh ranges between 40 to 120 ppm. From the (Pl. 47 Fig. a) it is revealed that Pb shows a decrease from the basic to the

acidic, members.

ZINC (Zn)

Zn has a large tendency to subsitute for ferrous iron. Diorites and andesites considered to be intermadiate in Zn concentration between granites and basalt. Zn concentration in the volcanite of Gulabgarh is more in the less basic members, which is revealed by the (Pl. 47A, Fig.). The geochemistry of Zn is controlled by iron concentration in the rocks in question which is prevelent in the trap rocks. The erratic behavior of Zn in the traps of Gulabgarh may be due to these rocks being less evolved in nature. Other characterstic features of this element figure in the discussion of this trace element studied under granitoids of the study area.

LITHIUM (Li)

The lithium is a rare earth element and its presence in igneous rocks vary from more basic to more acidic. The concentration of Li is expected more in acidic rocks. The chemistry of this element allows it to replace Mg^{2+} and Fe^{2+} in minerals because of its small size. The geochemistry of Li, therefore differes markedly from that of other alkali metals in the sense that it is contained in the femic silicate minerals.

The regular change in Li content and the increase in $\frac{Li}{Mg}$ ratio occurring with differentiation has

been well established Taylor et.al. (1966) working on andesites of different localities found the concentration of Li in the range of 11 to 25 ppm. From the figure (PL47A) Li v/s SiO_2 it reveals rapid increase in the later differentiates. The average concentration of Li in the volcanites of Gulabgarh is 23 ppm. which fully agrees with the values of andesites found by Taylor (op. cit.)

TABLE- 4 Chemical Analysis of Volcanites of Gulabgarh Area.

Sample Nos:	SiO_2	K_2O	Na_2O	MgO	CaO	FeO	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	MnO	Total
B-1 51.03	51.03	0.60	2.75	5.96	10.31	7.98	4.12	13.35	1.70	0.70	0.15	100.55
SP-5	45.12	0.48	2.42	6.04	11.50	9.77	3.44	17.44	2.55	0.23	0.05	100.12
SP-13A	58.20	0.48	2.94	2.98	9.00	3.31	7.00	12.35	1.55	0.42	0.14	99.97
B-3	49.64	1.20	2.69	6.23	10.19	6.47	5.89	14.14	2.92	0.51	0.17	100.23
B-2	48.58	1.20	2.42	4.15	10.91	4.02	7.30	15.56	2.00	0.62	0.11	99.17
SP-8	50.00	1.08	2.15	7.02	11.01	5.35	4.31	13.35	1.70	0.92	0.16	99.07
SP-4	52.28	1.42	2.69	4.84	8.82	8.33	5.28	12.08	2.18	0.81	0.20	100.02
SP-13	55 .84	0.48	1.34	2.98	12.99	3.31	7.25	11.95	1.55	0.32	0.16	100.30
G-63	52.00	0.86	4.36	5.67	9.33	7.10	4.13	13.00	0.02	0.12	0.10	99.73

* Analyst: A.K.KOUL

TABLE-5 Different petrochemical values Recalculated to hundred percent for the volcanites of Gulgulabgarh.

Sample Nos.	B-1	Sp-5	SP-13A	B-3	B-2	SP-8	SP-4	SP-13	G-63
Or	6	6	8	14	13	16	16	7	6
Ab	47	39	32	43	36	35	40	30	47
An	47	55	60	43	51	49	44	63	47
A	38	48	22	42	50	36	44	22	31
C	31	16	35	38	43	32	12	35	35
F	31	36	43	20	7	32	44	43	34
Na_2O	20	17	11	19	19	15	29	11	30
K_2O	4	3	4	9	9	7	18	4	5
CaO	76	80	85	72	72	78	53	85	65
F	56	59	70	59	58	52	58	58	68
A	16	14	11	14	19	15	16	13	11
M	28	27	19	27	22	33	36	29	29

TABLE 6 PETROCHEMICAL DATA FOR THE ROCKS OF GUL-GULABGARH

Sample No.	S.I.	D.I.	Mafic Index	Felsic Index	Al_2O_3/SiO_2	Normative plagioclase composition	Normative colour Index.
B-1	31	31	66	15	0.26	49.46	27
SP-5	25	23	69	12	0.40	65.00	23
SP -13A	15	37	74	9	0.21	65.00	23
B-3	30	31	64	17	0.28	51.00	23
B-2	17	30	67	16	0.32	58.00	20
SP-8	23	32	60	13	0.26	58.00	15
SP-4	35	44	57	32	0.22	41.76	23
SP-13	34	36	70	10	0.21	69.00	18
G-63	27	42	67	23	0.25	43.36	1

Different values recalculated to hundred percent

Sample Nos.	B-1	Sp-5	Sp-5A	Sp-13A	B-3	B-2	Sp-8	Sp-4	Sp-13	G-63
Total Iron	32	48	48	42	45	44	46	51	41	52
$Na_2O + K_2O$	50	10	10	19	14	14	12	16	19	24
CaO	18	42	42	39	41	42	42	33	40	24
K_2O	20	15	15	13	29	31	34	31	14	30
TiO_2	57	78	78	70	59	52	53	54	74	66
P_2O_5	23	7	7	17	12	17	13	15	12	4

Table-7

Normative Qz-Or-Ab and Or-Ab-An, recalculated to hundred percent in respect of Intrusive (non foliated) granitoids.

Sample No.	G-1	G-10	G-11	G-17	G-23	G-24	G-25	G-27	Ler granite	G-29	G-30	G-31	G-33
Qz	40	48	50	33	18	61	58	36	50	26	6	20	28
Or	35	44	24	31	44	25	34	22	23	51	51	74	25
Ab	25	8	26	36	38	14	8	42	27	23	43	6	47

Sample No.	G-34	G-35	G-38	G-39
Qz	13	13	18	10
Or	46	30	40	46
Ab	41	57	42	44

Or	55	79	35	42	54	60	76	28	42	67	54	90	29
Ab	40	15	37	48	45	34	19	53	50	30	45	7	54
An	5	26	28	10	1	6	5	19	8	3	1	3	17

Sample No.	G-34	G-35	G-38	G-39
Or	48	30	48	49
Ab	42	55	49	48
An	10	15	3	3

Normative Qz-Or-Ab and Or-Ab-An recalculated to hundred percent in respect of gneisses and gneissose granites.

Sample No.	G-2	G-4	G-5	G-8	G-13	G-14	G-15	G-18	T-Gneiss G-40	G-41	G-42	G-44	G-46
Qz	30	51	53	40	63	38	41	25	37	43	35	35	32	42
Or	46	31	33	6	9	18	34	21	38	7	15	24	40	33
Ab	24	18	14	54	28	44	25	38	25	50	50	41	28	25

Or	65	57	66	9	67	25	65	23	44	12	20	51	55	56
Ab	33	33	27	85	21	62	41	58	32	84	60	31	34	43
An	2	10	7	6	12	13	4	19	29	4	20	18	11	1

Table- 8 Niggli values for the rocks of Gulabgarh area (Granites)

Sample Nos.	G-1	G-10	G-11	G-17	G-23	G-24	G-25	G-29	G-30	G-31
al	46	32	30	42	46	33	43	44	35	46
fm	13	45	38	14	14	48	29	20	19	23
c	4	4	16	10	3	5	5	5	9	2
alk	37	19	16	34	37	14	23	32	32	29
Si	455	424	286	355	294	296	431	292	237	242
qz	207	208	122	+119	46	140	239	64	11	26
k	0.57	0.81	0.48	0.11	0.53	0.63	0.80	0.67	0.56	0.92
mg	0.19	0.19	0.44	0.10	0.11	0.08	0.18	0.15	0.15	0.20

Niggli values for the granitoidsof Gulabgarh Area.

Sample Nos.	G-34	G-35	G-38	G-39	Lar Granite
al	44	46	37	38	52
fm	14	8	22	19	8
c	9	14	5	7	9
alk	33	32	36	36	31
si	258	354	290	262	477
qz	26	126	46	18	253
k	0.51	0.59	0.48	0.49	0.44
mg	0.12	0.35	0.11	0.16	0.36

Table-9 **Chemical Analyses of Granites - Granodiorites-Syenites of Gulabgarh Area.**

Major oxides	G-1	G-10	G-11	G-17	G-23	G-24	G-25	Lar granite.
SiO_2	75.32	73.18	68.60	73.30	66.56	74.80	74.16	76.16
TiO_2	0.20	0.55	1.27	0.21	0.83	0.83	0.83	0.29
Al_2O_3	12.86	14.05	15.16	14.60	17.52	14.26	12.48	13.97
Fe_2O_3	1.54	2.11	1.49	2.58	2.25	2.31	3.16	0.36
FeO	0.57	1.15	2.80	0.79	1.29	1.00	2.01	0.72
MnO	0.07	0.03	0.07	0.03	0.10	0.03	0.09	0.02
MgO	0.26	0.40	1.32	0.19	0.23	0.66	0.59	0.33
CaO	0.83	0.84	3.85	1.95	0.55	1.11	0.83	1.39
Na_2O	2.69	0.80	4.12	4.81	4.04	1.34	0.80	2.87
K_2O	5.54	6.50	2.89	3.77	6.98	3.44	4.98	3.37
H_2O	0.16	0.18	0.10	0.26	0.18	0.10	0.10	0.28
P_2O_5	0.28	0.23	0.67	0.07	0.25	0.77	0.35	0.62

Major oxides	G-29	G-30	G-31	G-32	G-33	G-34	G-33	G-27	G-42	G-35
SiO_2	65.12	62.60	61.24	64.30	66.41	63.56	67.72	68.30	67.40	61.54
TiO_2	1.70	0.95	0.83	0.95	1.16	0.41	0.12	0.45	1.05	1.57
Al_2O_3	16.69	15.46	20.00	15.85	14.53	18.36	16.48	15.75	13.18	17.12
Fe_2O_3	3.11	3.76	4.43	3.16	3.67	2.94	1.62	1.80	3.54	3.54
FeO	1.58	2.44	1.29	1.58	1.87	0.72	1.82	2.05	1.95	2.29
MnO	0.13	0.20	0.18	0.12	0.23	0.41	0.05	0.08	0.05	0.15
MgO	0.43	0.53	0.81	0.53	0.36	0.29	1.30	1.25	0.42	0.86
CaO	0.83	2.23	0.56	1.67	1.11	2.51	2.80	2.85	1.73	5.35
Na_2O	2.42	4.31	0.53	4.53	4.31	4.04	4.36	4.30	2.15	5.12
K_2O	7.46	6.36	8.35	6.74	6.14	6.50	3.28	3.14	5.05	3.85
H_2O	0.26	0.26	0.16	0.36	0.36	0.16	-	-	0.07	-
P_2O_5	0.40	0.62	0.18	0.25	0.25	0.73	0.25	0.20	0.64	0.57

Analyst. A. K. KOUL.

Table- 10 Niggli values for the [illegible]

Sample Nos.	T-Gneiss G-2	G-4	G-5	G-8	G-13	G-14	G-15	G-40	G-42	G44	G46
al	50	34	52	47	42	48	42	96	44	32	46	45
fm	18	26	23	23	34	15	16	15	27	8	19	26
c	4	7	5	6	7	10	5	7	19	14	3	20
alk	26	20	23	25	29	8	33	33	24	22	32	33
si	336	270	406	493	336	441	493	410	416	280	354	416
qz	132	90	214	293	140	309	171	178	220	92	126	184
k	0.35	0.68	0.69	0.69	0.09	0.33	0.27	0.57	0.22	0.61	0.59	0.55
mg	0.25	0.43	0.32	0.17	0.13	0.11	0.17	0.17	0.16	0.33	0.35	0.25

Table 12 C.I.P.W. Norms of schist and gneissose granite of Salkhala Group.

Sample No.	G-2	G-4	G-5	G-8	G-13	G-14	G-15	G-18	G-41	T-gneiss	G-40	G-42	G-44	G-46
Q	25.80	43.38	45.54	34.74	48.78	33.48	36.54	19.14	28.32	25.56	37.56	26.34	26.76	37.62
Or	41.14	25.58	28.36	5.00	22.24	15.57	31.13	15.01	13.34	27.24	5.56	30.02	34.47	30.02
Ab	20.44	15.20	11.53	46.64	6.81	38.78	22.53	38.25	38.25	18.34	43.49	18.34	22.53	22.53
An	1.39	4.73	2.50	2.22	3.89	7.51	1.66	12.51	13.07	15.57	2.22	11.12	11.13	1.11
C	5.10	6.83	5.81	3.37	7.24	-	3.16	2.04	2.15	-	5.81	-	0.61	3.27
Di	-	-	-	-	-	-	-	-	-	4.54	-	3.72	-	-
Hy	1.60	1.20	1.20	1.00	5.72	0.80	0.80	5.61	4.78	5.51	0.70	-	1.26	2.42
Mt	1.62	1.16	1.39	2.55	3.25	1.39	2.08	2.55	1.83	2.09	2.09	0.32	1.16	2.09
Ha	1.44	1.76	2.24	2.24	-	1.28	0.48	-	-	-	1.28	3.52	-	-
Il	0.76	0.61	0.76	0.76	0.76	0.30	0.76	0.76	0.46	1.82	0.76	1.98	0.76	1.22
Ap	0.63	0.34	0.67	1.34	0.67	0.34	1.00	0.34	0.34	1.01	1.34	1.68	0.67	0.67

Sample No.	G-2	G-4	G-5	G-8	G-13	G-14	G-15	G-18	G-41	G-40	G-42	G-44	G-46	T-gneiss
Normatice Plagioclase Composition	22	20	15	50	11	47	25	51	51	46	29	31	24	34
Normative Colour Index	5.42	4.73	5.59	6.55	8.63	3.77	4.12	8.92	7.12	4.83	9.22	3.18	6.05	13.96

Table - 13

12

ble No. 15 S.I.D.I.L.I and C.I Values for the Instrutive granitoids (non- foliated)

ample No.	G-1	G-10	G-11	G-17	G-23	G-24	G-25	Lar granite	G-27	G-29	G-30	G-31	G-33	G-34
.I. S.I	2.45	3.65	10.46	2.31	1.56	7.54	5.11	4.31	9.97	2.87	3.85	5.26	11.42	2.00
.I. D.I	98	87	70	90	91	84	85	92	85	86	86	82	84	84
.I. L.I	28.94	28.50	17.79	25.27	27.10	25.60	26.26	26.32	21.42	26.33	22.03	26.10	19.83	25.00
.I. C.I	2.09	3.20	18.60	6.74	1.53	2.58	2.72	4.17	14.68	2.44	3.62	3.34	15.31	10.35

ample No.	G-35	G-38	G-39
.I. (S.I)	5.49	2.22	3.19
.I. D.I	70.	89	88
.I. L.I	19.83	24.88	26.00
.I. C.I	16.98	2.87	4.65

.I.. D.I. & L.I Values of gneisses and gneissose granites of Salkhola Group, of Study Area.

ample No.	G-2	G-4	G-5	G-8	G-13	G-14	G-15	G-18	G-40	G-41	G-42	G-44	G-46	I-gneiss
.I. S.I	4.68	5.24	4.35	3.87	3.91	3.17	2.94	10.04	3.01	10.05	3.20	3.66	5.39	17.02
.I. D.I	87	84	85	86	78	88	90	72	87	80	75	88	90	71
.I. C.I	27.05	26.45	22.45	22.02	22.40	24.71	27.60	18.63	23.15	19.61	23.42	22.73	27.31	17.03

Table-13 C.I.P.W. Norms of Intrusive Granitoid suite of Gulabgarh.

Sample No.	G-1	G-10	G-11	G-17	G-23	G-24	G-25	G-27	G-29	G-30
Q	37.08	42.00	35.04	29.94	15.66	51.96	48.78	30.84	21.90	5.34
Or	32.80	38.36	17.24	28.36	41.14	20.57	29.47	18.90	43.92	43.92
Ab	22.53	6.81	17.82	31.96	34.06	11.53	6.81	35.63	20.44	36.68
An	2.50	2.50	13.90	6.39	1.11	1.39	1.67	12.51	1.67	0.83
C	1.50	4.69	1.63	0.61	2.96	7.75	5.10	0.71	4.03	1.30
Hy	0.70	1.00	6.96	0.50	0.60	1.70	1.50	4.55	1.10	-
Mt	0.16	1.39	5.10	0.93	1.86	0.93	4.18	2.55	0.46	1.62
He	0.80	1.12	-	1.92	0.96	1.76	0.32	-	2.88	2.72
Il	0-46	1.52	2.43	0.61	1.52	1.52	1.52	0.91	3.04	1.98
Ap.	0.67	0.67	1.68	1.34	0.67	1.68	1.01	0.67	1.01	1.34

C.I.P.W. Norms of Intrusive Granitoid suite of Gulabgarh.

Sample No.	G-31	G-34	G-33	G-35	G-38	G-39	Lar granite
Q	16.38	11.28	21.54	10.08	15.96	8.88	44.34
Or	61.16	38.36	20.02	22.80	36.14	40.03	20.02
Ab	4.71	34.06	36.68	43.49	36.68	38.78	24.10
An	1.94	8.34	12.23	12.23	2.22	2.50	3.61
C	7.14	1.63	5.71	-	-	-	4.28
D.I.	-	1.36	-	2.66	1.00	2.74	-
Hy	2.00	0.70	4.88	-	-	-	1.33
Mt	1.85	1.16	2.32	2.78	2.55	2.32	0.46
Hem	3.20	2.08	-	1.60	1.90	1.60	-
Il	1.52	0.76	0.76	3.04	2.28	1.82	0.61
Ap	0.33	1.68	0.67	1.34	0.67	1.34	1.34

Sample No.	G-I	G-10	G-11	G-17	G-23	G-24	G-25	G-27	G-29	G-30
Normative Plagioclase Composition.	26	10	32	38	35	14	9	49	22	38

	G-31	G-34	G-33	G-35	G-38	G-39	Lar Granite
	7	42	49	55	39	42	28

Sample No.	G-1	G-10	G-11	G-17	G-23	G-24	G-25	G-27	G-29	G-30
Normative Colourk Index	3.12	5.03	14.49	3.96	4.94	5.91	7.32	8.01	7.48	10.52

	G-31	G-34	G-33	G-35	G-38	G-39	Bat Granite
	8.57	6.06	7.96	7.08	7.73	8.48	2.40

TABLE- 14 Modal Analysis values for Intrusive granitoids recalculated to hundred percent for the Streiksen's Diagram in respect of the samples collected for the ~~third~~ time from the field.

Sample Nos	LG-1	LG-2	LG-3	LG-4	LG-5	LG-6	LG-7	LG-8	LG-9	LG-10	LG-11	LG-12
Foliated granitoids												
Quartz	26.61	40.22	39.53	11.82	13.42	9.03	3.50	28.30	25.49	46.50	36.64	42.40
Plagioclase	47.22	24.86	28.36	12.65	15.91	14.29	15.65	5.53	6.52	3.70	42.45	41.55
Alk- Feldspar	26.15	34.90	32.11	76.53	70.67	76.68	75.85	66.17	68.00	49.79	20.91	16.05

Sample Nos.	LG-13	LG-14	LG-15	LG-16	LG-17	LG-18
Quartz	26.50	39.38	51.33	51.69	35.04	30.20
Plagioclase	15.32	27.41	13.82	16.37	1.42	5.23
Alk Feldspar	58.18	33.21	34.84	42.49	63.58	64.57

The ~~above~~ selected values for ~~Nos~~ foliated gneisses and gneissose granites. (Modal Analysis) samples collected for the third time from the field.

Sample Nos.	LG-19	LG-20	LG-21	LG-22	LG-23	LG-24
Quartz	35.39	50.97	33.83	38.92	40.73	41.13
Plagioclase	17.91	12.85	24.15	13.76	14.94	41.16
Alk-Fledspar	46.70	36.18	30.12	47.32	44.33	17.74

Table-15

CaO-K_2O-Na_2O recalculated to hundred percent in respect of intrusive (non-foliated) granitoids.

Sample No.	CaO	K_2O	Na_2O
G-1	10.58	66.54	22.88
G-10	10.30	80.70	9.00
G-11	35.45	26.61	37.94
G-17	10.50	35.80	45.70
G-23	4.75	60.32	34.93
G-24	19.17	59.41	21.42
G-25	12.55	75.35	12.10
G-27	27.70	30.50	41.80
G-29	7.70	69.10	23.20
G-30	15.04	55.92	29.04
G-31	4.89	90.47	4.64
G-33	26.80	31.50	41.70
G-34	19.20	49.80	31.00
G-35	27.19	31.25	41.55
G-38	9.60	53.11	37.29
G-39	12.85	51.88	35.25

CaO-K_2O-Na_2O recalculated to hundred percent in respect of gneisses and gneissose granites.

Sample No.	CaO	K_2O	Na_2O
G-2	10.50	56.60	32.90
G-4	16.80	63.80	29.40
G-5	11.94	68.77	19.88
G-8	18.60	45.42	35.97
G-13	42.20	27.37	30.43
G-14	18.75	29.70	51.45
G-15	9.60	53.11	37.29
G-18	27.84	25.77	46.39
G-40	15.43	13.35	81.22
G-41	4.89	90.47	4.64
G-42	36.78	44.33	18.89
G-44	23.13	52.65	9.00
G-46	6.73	60.84	32.43
T-Gneisses	42.41	39.84	18.75

FeO(total)-Na_2O+K_2O-MgO recalculated to hundred percent in respect of non-foliated granitoids.

	FeO(total)	Na_2O+K_2O	MgO
G-1	19	79	2
G-10	29	70	11
G-11	33	56	11
G-17	26	72	2
G-23	23	76	1
G-25	43	52	5
G-27	30	60	10
G-29	30	67	3
G-30	34	63	3
Lar granite	14	82	4
G-31	12	81	7
G-33	327	582	611
G-34	24	74	2
G-35	36	58	6
G-38	32	65	3
G-39	27	70	3
G-24	36	56	8

FeO(total)-Na_2O+K_2O-MgO recalculated to hundred percent in respect of gneisses and gneissose granites.

	FeO(total)	Na_2O+K_2O	MgO
G-2	25	72	3
G-4	32	44	4
G-5	35	40	5
G-8	46	50	4
G-13	54	42	4
G-14	29	68	3
G-15	24	69	7
G-18	33	57	10
G-40	25	72	3
G-41	27	63	10
G-42	40	56	4
G-44	24	70	6
G-45	24	70	6

* $FeO^t = FeO + 0.9\ Fe_2O_3$

TABLE- 16 Rittmann norms for the selected samples of Intrusive granitoids of Gulabgarh Area.

Sample Nos.	G-23	G-1	G-38	G-25	G-30	G-35
t	16.24	30.80	8.85	14.07	11.74	10.30
	5.50	2.10	4.65	7.99	5.99	4.00
ox^o	0.60	0.68	0.61	0.58	0.56	0.41
C.I.	11.20	6.45	10.03	12.80	12.20	24.06
Saturated Norms						
Ap	10.00	11.00	11.00	13.00	24.00	22.00
Il	20.00	2.00	30.00	20.00	24.00	26.00
Mt_o	14.00	8.00	26.00	41.00	32.00	34.00
Or	740	590	650	530	675	600
Ab	650	435	665	130	795	420
An	20	40	57	35	72	60
Sil	87	67	-	149	-	-
Wo	-	-	4	-	22	20
Hy	58	50	87	66	106	108
Q	+ 208	+ 581	+ 247	+ 741	+ 17	+ 215

Continued from Table .....

Volume %	G-23	G-1	G-38	G-25	G-30	G-35
Quartz	14.3	35.92	16.88	46.1	2.97	2.90
Orthoclase	75.5	52.19	62.30	30.3	68.60	57.44
Plagioclase	-	5.44	11.19 (oligoclase)	2.5 (Oligoclase)	16.25 Oligo	15.60 (Oligoclase)
Biotite	8.7	-	5.00	-	3.48	4.00
Muscovite	-	2.96	-	8.3	-	4.30
Cordierite	-	-	-	9.6	-	9.20
Garnet	-	2.52	-	-	-	-
Magnetite	1.1	0.31	1.10	1.7	1.33	1.65
Ilmenite	-	0.09	0.85	0.8	0.37	0.65
Apatite	0.4	0.57	0.58	0.7	1.24	1.00
Hornblende	-	-	1.10	-	5.00	2.50
Sphene	-	-	0.27	-	0.78	0.76
Rock type	Alkali feldspar	Alk-Granite	Quartz-Syenite	Alk-Plagioclase	Syenite	Syenite.

Table-#7 Trace elements in ppm of volcanites of Pul-Gulabgarh Area, Udhampur District, Jammu

Sample Nos.	Sr	Rb	V	Ba	Zr	Cr	Ni	Co	Cu	Pb	Zn	Ga	Li
Sp-5	90	25	125	225	140	172	206	70	88	40	150	20	16
B-2	100	26	200	165	150	118	172	86	60	120	118	27	22
B-3	110	29	167	160	160	204	116	82	70	100	130	25	22
Sp-8	80	80	150	165	180	148	150	64	84	100	178	30	25
B-1	85	63	160	200	175	146	174	60	50	80	132	20	27
Sp-4	90	70	150	300	200	107	104	50	48	80	178	39	27
Sp-13	110	85	60	350	315	86	94	22	30	40	300	40	28
Av. of eight samples													

TABLE- 18 Different ratios for Traps of the Gulabgarh Area, Distt: Udhampur, Jammu

Sample Nos	K/Rb	$\frac{Ga \times 10^3}{Al+Fe}$	$\frac{Ga \times 10^3}{Al}$	$\frac{Sr \times 10^3}{Ca}$	$\frac{Ni \times 10^3}{Mg}$	$Co/Mg \times 10^3$	Cr/Fe^{*3}	V/Fe^{*3}	Li/Mg	Ba/K
Sp-5	156	0.183	0.234	11.03	5.64	1.917	0.0072	0.0052	0.0004	0.057
SP-5A	144	0.182	0.227	12.06	3.38	2.702	0.0075	0.0054	0.0005	0.020
B-2	377	0.203	0.332	12.91	6.90	3.453	0.0023	0.0039	0.0008	0.016
B-3	338	0.217	0.314	14.47	3.11	2.198	0.0049	0.0040	0.0016	0.016
SP-8	110	0.377	0.432	10.24	3.56	0.522	0.0049	0.0049	0.0006	0.018
B-1	78	0.205	0.268	4.10	4.87	2.016	0.0050	0.0055	0.0008	0.040
SP-4	166	0.353	0.621	14.37	3.58	2.413	0.0028	0.0040	0.0009	0.025
SP-13	46	0.353	0.644	11.93	5.28	3.595	0.0017	0.0011	0.0020	0.089
Average	178	0.253	0.359	11.38	4.29	2.352	0.0045	0.0043	0.0010	0.035

TABLE 19 - Trace elements (in ppm) of Foliated Gneissose granites and Gneisses of Salkhala Group of the Area of Study

Trace Element	G-2	G-4	G-5	G-8	G-9	G-13	G-14	G-15	G-18	T-Gneiss	G/40	G/41	42	44	46
Cu	22	20	24	18	24	24	24	24	28	24	10	26	32	32	18
Cr	208	68	100	96	54	120	100	70	68	236	52	60	148	36	44
Co	44	52	30	38	22	30	40	46	30	40	34	35	30	46	32
Ni	232	112	108	154	88	128	124	100	110	204	82	120	230	88	116
Zn	156	186	384	384	114	172	104	166	160	102	50	170	88	74	90
Sr	90	60	70	100	70	80	70	60	90	80	60	100	80	80	80
Pb	100	100	160	40	Tr	40	80	100	105	60	Tr	110	80	20	20
Li	110	74	88	116	6	44	50	134	70	86	48	60	158	154	122
S.I.	87	84	85	86	79	88	90	73	71	80	80	75	88	87	90

* Analyst: A.K.KOUL

TABLE- 20 Trace elements (in ppm) of Non-foliated intrusive granitoids of the area of Study

Trace element	G-1	G-10	G-11	G-17	G-23	G-24	G-25	G-27	G-29	G-30	G-31	G-33	G-34	35	G-38	G-39
Cu	36	14	22	39	28	18	24	35	18	30	66	32	14	10	78	46
Cr	100	38	134	148	62	222	250	125	108	250	234	120	22	tr	222	94
Co	28	30	48	22	48	34	32	25	58	44	38	26	42	48	34	40
Ni	110	78	82	150	92	222	280	78	206	246	804	75	82	52	96	128
Zn	160	162	80	168	110	104	116	150	106	160	202	135	106	166	274	290
Sr	80	80	100	60	100	40	80	36	80	60	60	45	90	100	50	50
Pb	80	60	80	60	20	100	80	70	60	40	60	60	100	60	40	40
Li	86	110	78	40	22	24	82	64	68	44	56	56	tr	tr	22	36
D.I.	93	87	70	90	91	84	85	85	86	86	82	78	84	76	89	88

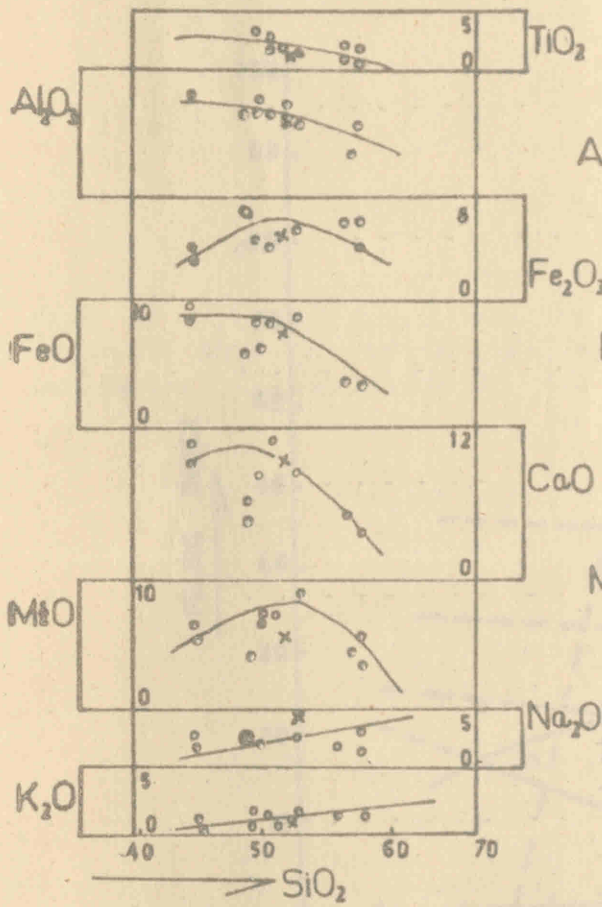
Table - II Chemical Analysis of Gneisses, Schists and Gneissose granites of Salkhala Gr.

Major Oxides	SAMPLE NUMBERS											
	G-2	G-4	G-5	G-8	G-13	G-14	G-15	G-18	G-40	G-41	G-42	G-44
SiO_2	68.02	73.12	73.60	71.60	72.30	73.90	73.40	67.75	72.40	68.90	67.40	70.08
TiO_2	0.41	0.29	0.41	0.41	0.37	0.41	0.41	0.42	0.41	0.25	1.05	0.41
Al_2O_3	17.11	16.00	14.21	14.21	14.05	13.19	13.84	16.80	16.08	13.15	13.18	15.42
Fe_2O_3	2.62	2.55	3.21	4.05	2.18	2.29	1.90	1.70	1.74	1.20	3.54	0.85
FeO	0.86	0.65	0.79	1.15	3.88	0.57	1.01	2.50	0.57	1.85	1.95	0.86
MnO	0.21	0.14	0.28	0.13	0.09	0.10	0.12	0.06	0.41	0.05	0.05	0.04
MgO	0.63	0.49	0.46	0.39	0.43	0.33	0.33	1.25	0.26	1.10	0.42	0.39
CaO	1.11	1.11	0.83	1.11	1.11	1.67	0.83	2.70	1.11	2.80	1.73	2.07
Na_2O	2.40	1.34	1.34	4.54	0.80	4.58	2.69	4.50	5.12	4.50	2.15	~~2.07~~ 2.69
K_2O	6.98	4.33	4.78	0.80	3.72	2.65	5.30	2.50	0.96	2.30	5.05	~~2.69~~ 5.85
P_2O_5	0.64	0.14	0.27	0.13	0.28	0.14	0.38	0.08	0.62	0.15	0.64	0.23

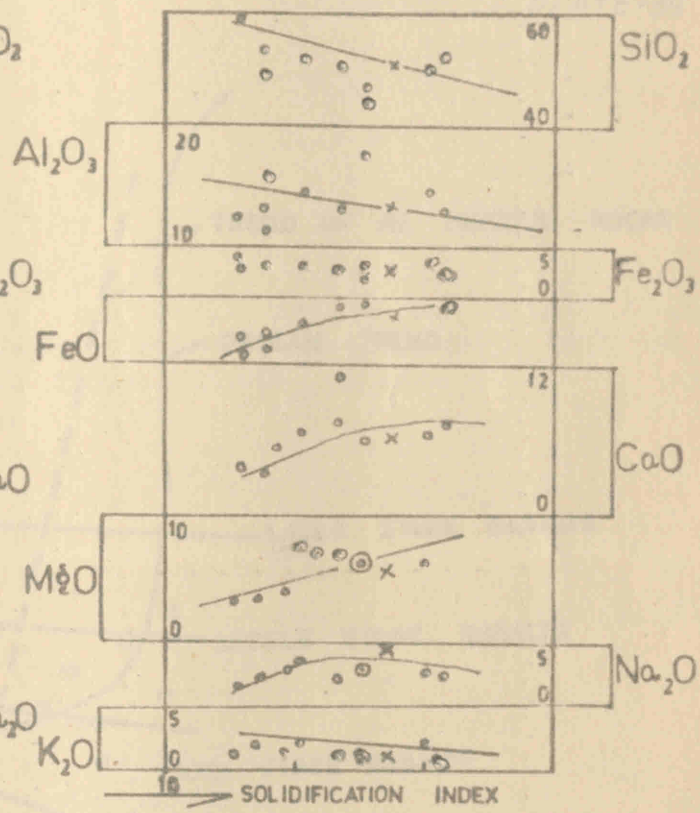
Sample Nos	G-46	T- Gneiss
SiO_2	74.36	67.92
TiO_2	0.63	0.95
Al_2O_3	13.59	14.27
Fe_2O_3	1.43	1.39
FeO	1.37	3.15
MnO	0.05	0.05
MgO	0.60	1.89
CaO	0.56	4.57
Na_2O	2.69	2.15
K_2O	5.05	4.00
P_2O_5	0.35	0.05

Analyst: A.K.Koul

PLATE-37

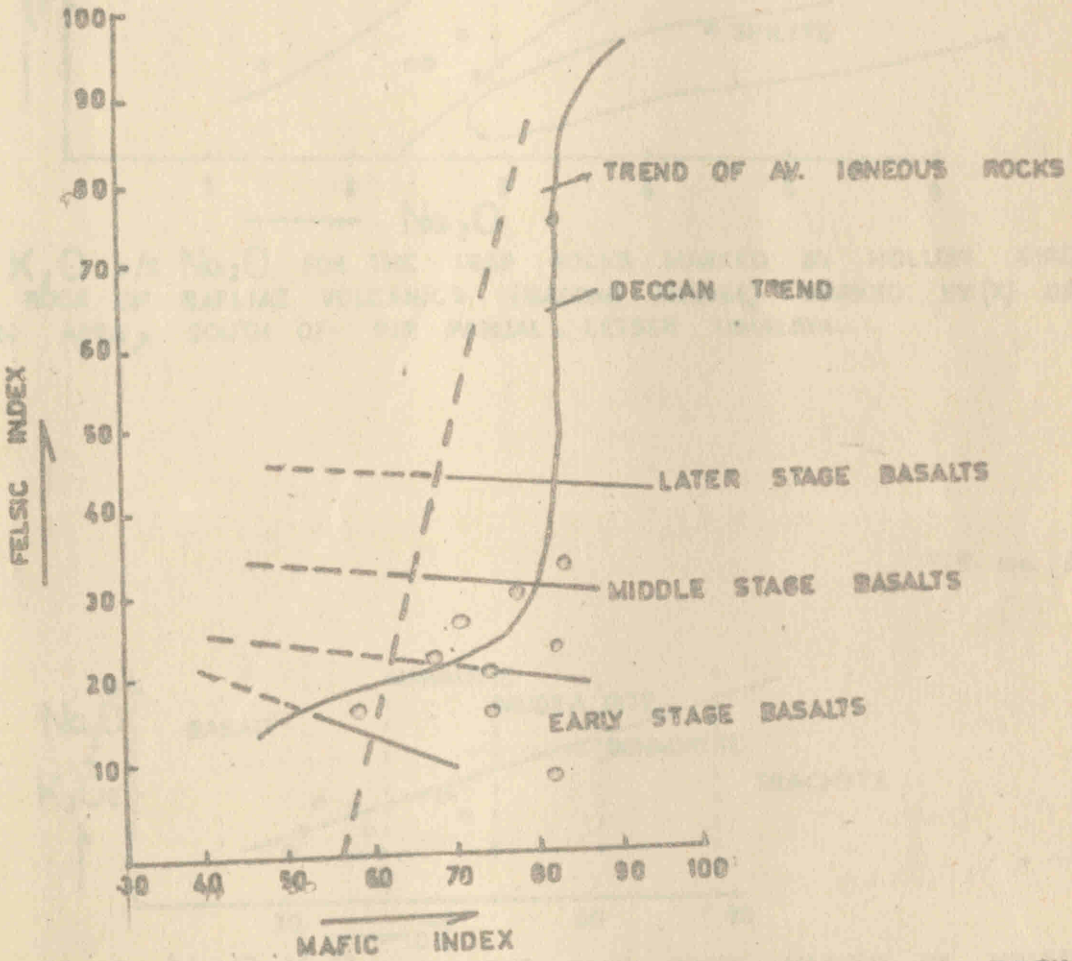


(a) HARKER VARIATION DIAGRAM FOR THE PANJAL TRAP MARKED BY HOLLOW CIRCLES & SPILITE FROM BAFLIAZ VOLCANICS MARKED BY CROSS (×) OF GULABGARH AREA, SOUTH OF PIR-PANJAL, LESSER HIMALAYA.



(b) SI V/S ALL OXIDES FOR THE TRAP ROCKS OF GULABGARH AREA SOUTH PIR PANJAL. UDHAMPUR DISTT. LESSER HIMALAYA, HOLLOW CIRCLE (○) ARE PLOTS OF PANJAL TRAP & CROSS (×) IS A SAMPLE OF SPILITE FROM BADDAR VILLAGE OF STUDY AREA.

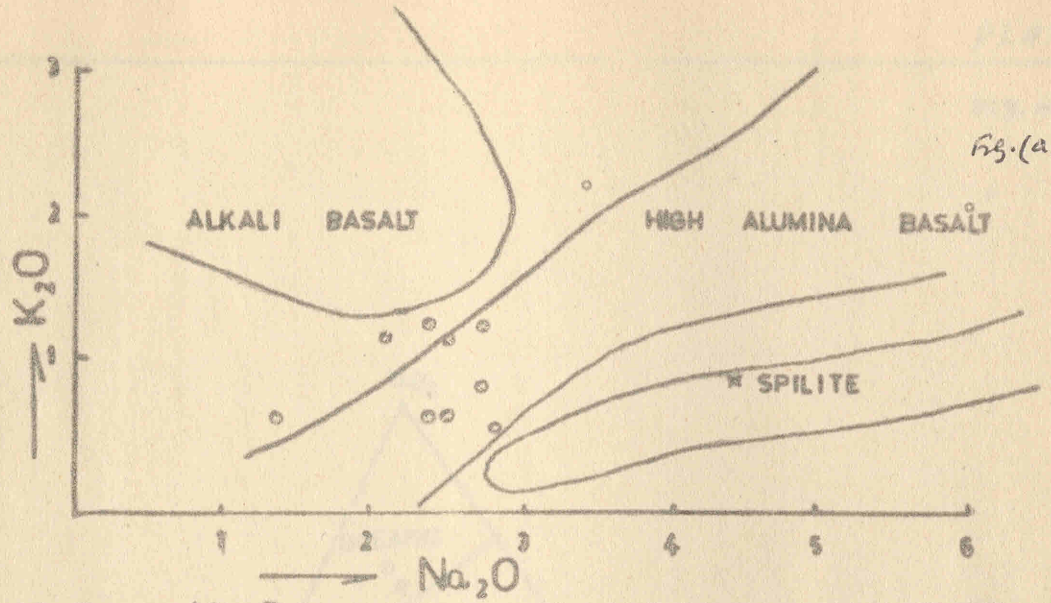
PLATE-38



VARIATION DIAGRAM BETWEEN MAFIX INDEX AND FELSIC INDEX OF PANJAL TRAP OF GULABGARH AREA. THE TREND OF THESE PLOTS IS VERY CLOSE TO DECCAN TREND.

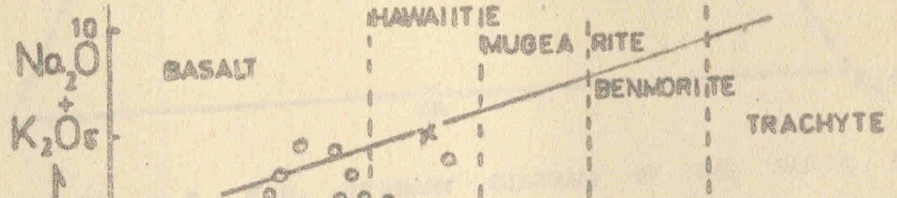
PLATE-39

Fig.(a)



PLOT OF K_2O V/S Na_2O FOR THE TRAP ROCKS MARKED BY HOLLOW CIRCLES (o) SPLITE ROCK OF BAFLIAZ VOLCANICS (BADDAR VILLAGE) MARKED BY (X) OF GULABGARH AREA, SOUTH OF PIR PANJAL. LESSER HIMALAYA.

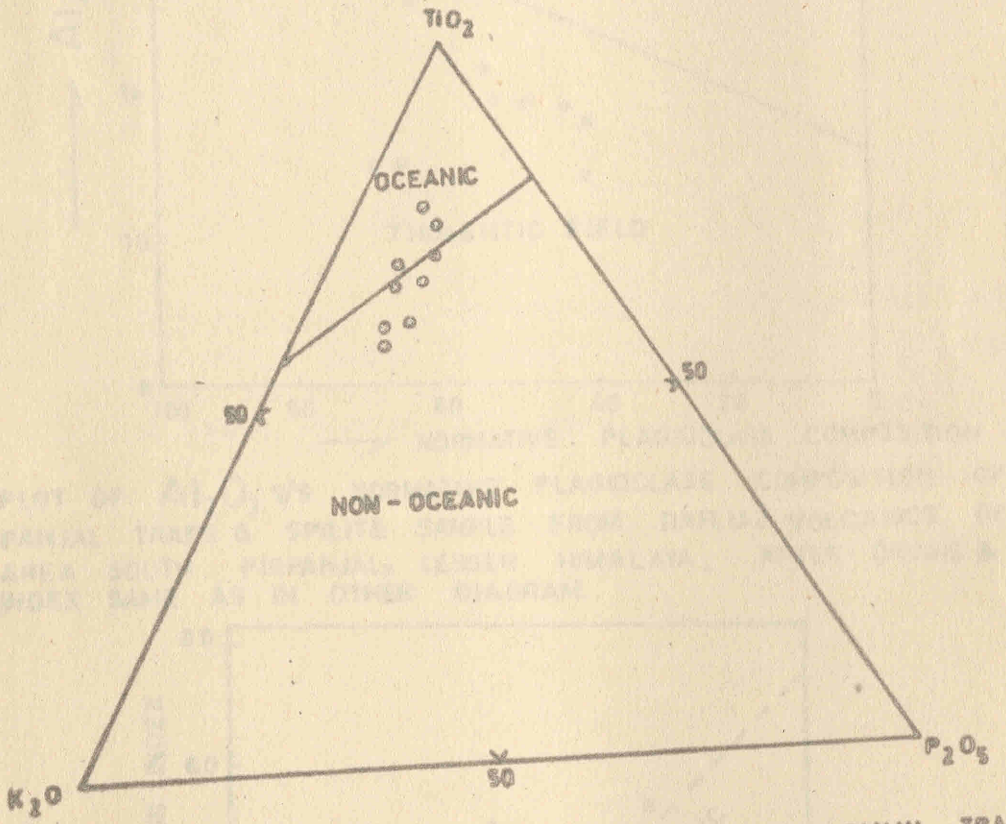
Fig. No. (b)



PLOT OF D.I V/S Na_2O+K_2O FOR THE TRAP ROCKS MARKED BY HOLLOW CIRCLES (o) SPILITE ROCK OF BAFLIAZ VOLCANICS BADDAR VILLAGE MARKED BY (X) SOUTH OF PIR PANJAL OF GULABGARH AREA, LESSER HIMALAYA.

PLATE-40

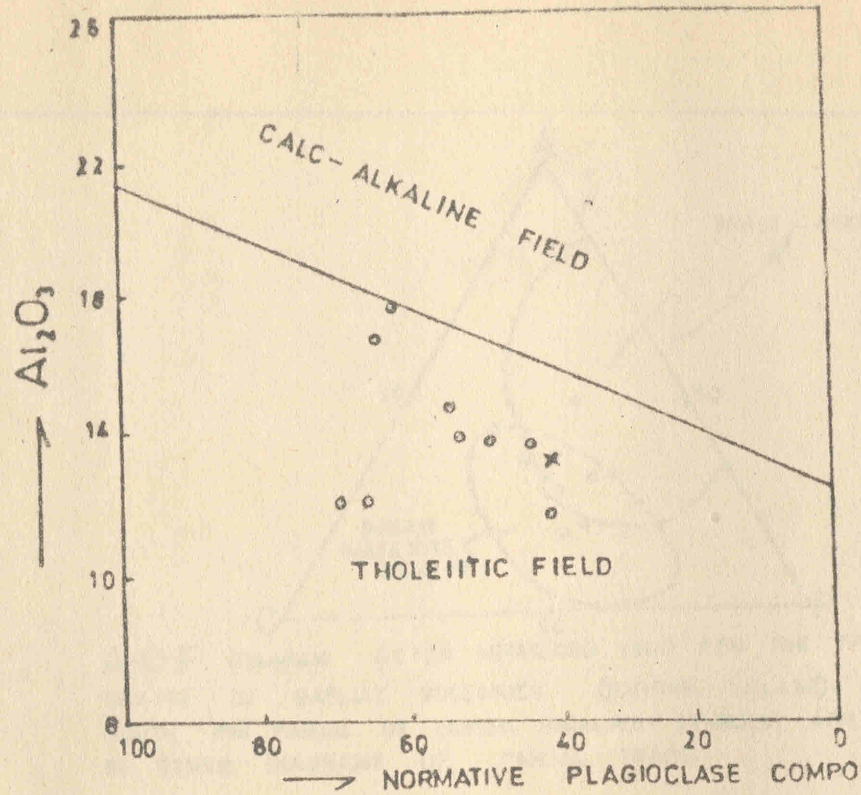
Fig. no. (a)



$TiO_2 - K_2O - P_2O_5$ TERNARY DIAGRAM OF THE PANJAL TRAPS OF GUL-GULABGARH AREA, THE STUDY AREA, AFTER PEARCE. et al (1971).

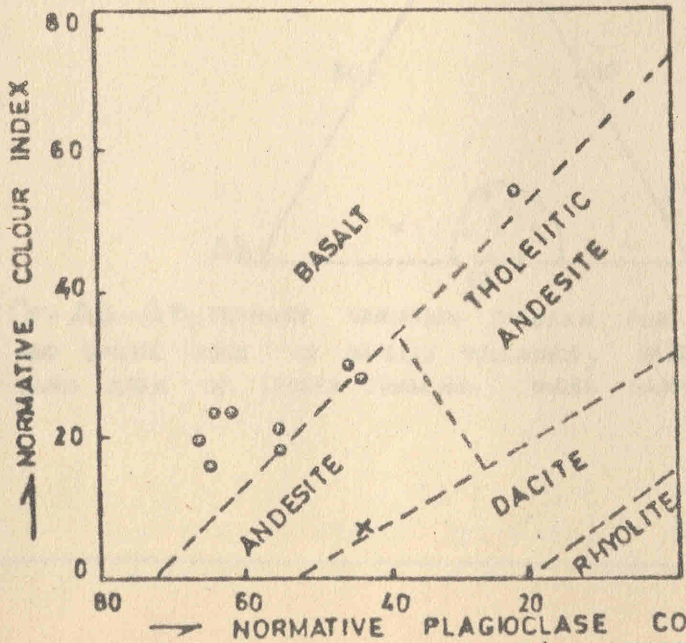
PLATE-41

Fig. no (a)



PLOT OF Al_2O_3 V/S NORMATIVE PLAGIOCLASE COMPOSITION OF PANJAL TRAPS & SPILITE SAMPLE FROM BAFLIAZ VOLCANICS OF GULABGARH AREA SOUTH PIRPANJAL, LESSER HIMALAYA. AFTER (IRVINE & BARAGAR 1971) INDEX SAME AS IN OTHER DIAGRAM.

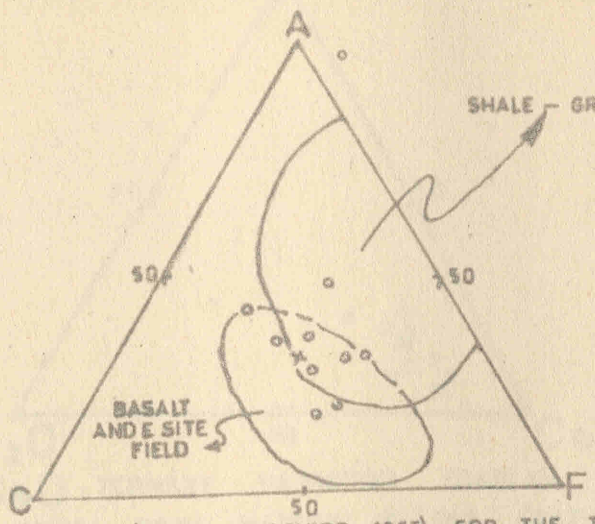
Fig. no. (b)



PLOT OF NORMATIVE COLOUR INDEX V/S NORMATIVE PLAGIOCLASE COMPOSITION FOR TRAP ROCKS SOUTH PIRPANJAL & SPILITE OF BAFLIAZ VOLCANICS BADDAR VILLAGE OF GULABGARH AREA, STUDY AREA, LESSER HIMALAYA.

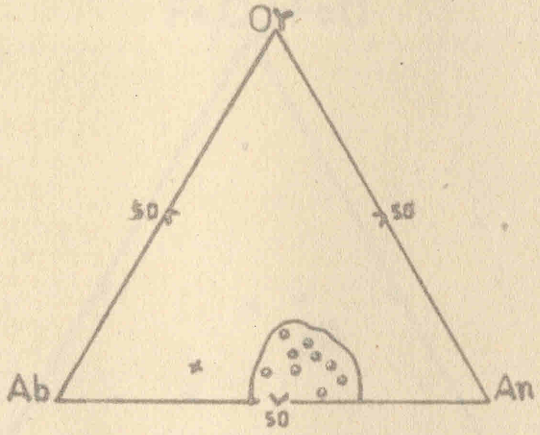
PLATE - 42

Fig. No. (a)



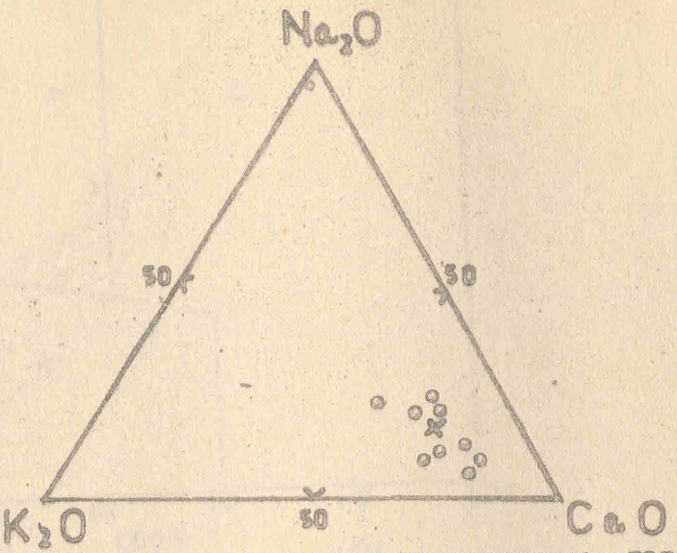
A-C-F DIAGRAM (AFTER MIYASHIRO 1955) FOR THE TRAP ROCK AND SPILITE OF BAFLIAZ VOLCANICS (BADDAR VILLAGE), GULABGARH AREA, SOUTH PIR PANJAL OF LESSER HIMALAYA. SYMBOLS ARE SAME AS INDICATED IN OTHER DIAGRAMS OF PANJAL TRAPS.

Fig. No. (b)



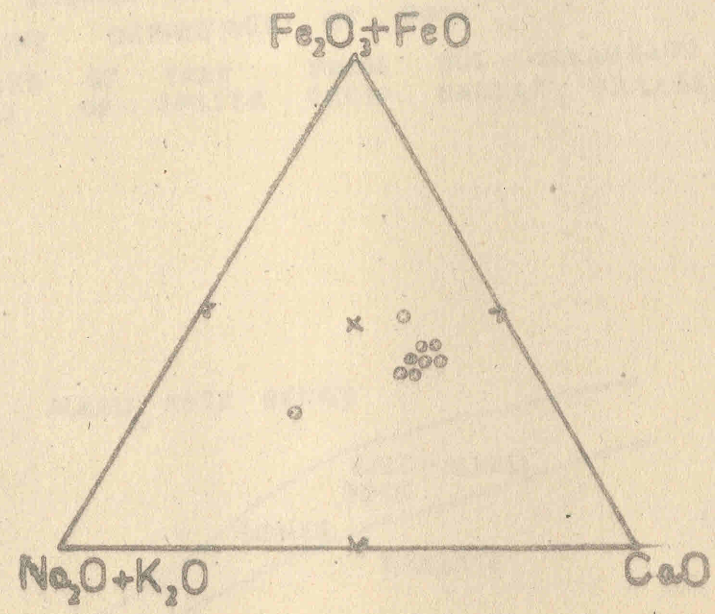
Or-Ab-An TERNARY VARIATION DIAGRAM FOR THE PANJAL TRAP ROCKS AND SPILITE ROCK OF BAFLIAZ VOLCANICS, BADDAR VILLAGE OF GULAB-GARH AREA OF LESSER HIMALAYA. INDEX SAME AS IN OTHER FIGURES.

PLATE-43



Na_2O-K_2O-CaO TERNARY VARIATION DIAGRAM FOR THE PANJAL TRAP ROCK & SPILITE ROCK FROM BADDAR VILLAGE (BAFLIAZ VOLCANICS) SOUTH PIR PANJAL, GULABGARH AREA, LESSER HIMALAYA. INDEX SAME AS IN OTHER DIAGRAMS.

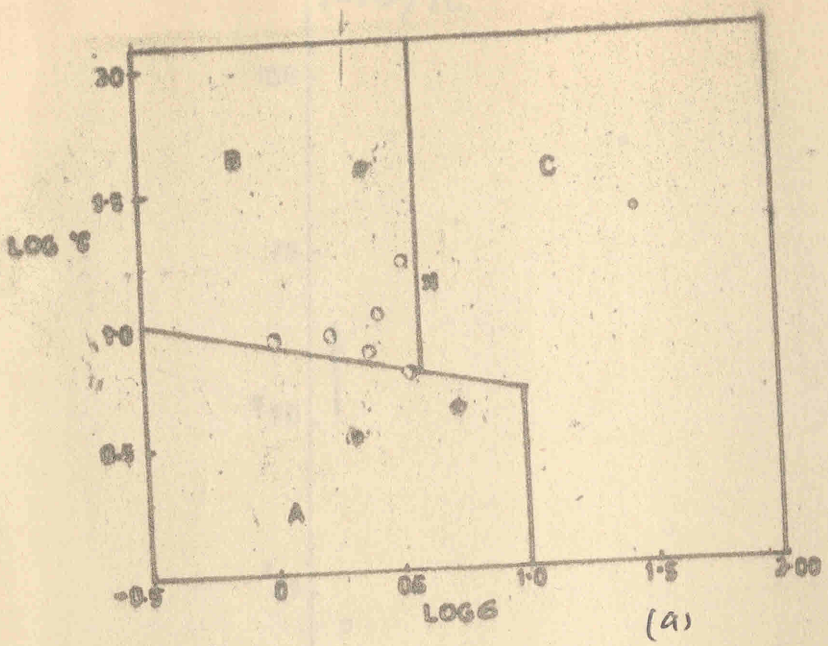
Fig. No. (a)



$(Fe_2O+FeO)-(Na_2O+K_2O)-CaO$ TERNARY VARIATION DIAGRAM FOR THE PANJAL TRAPS AND SPILITE ROCKS OF BAFLIAZ VOLCANICS (BADDAR VILLAGE) OF GULABGARH AREA, LESSER HIMALAYA. INDEX SAME AS IN OTHER FIGURES.

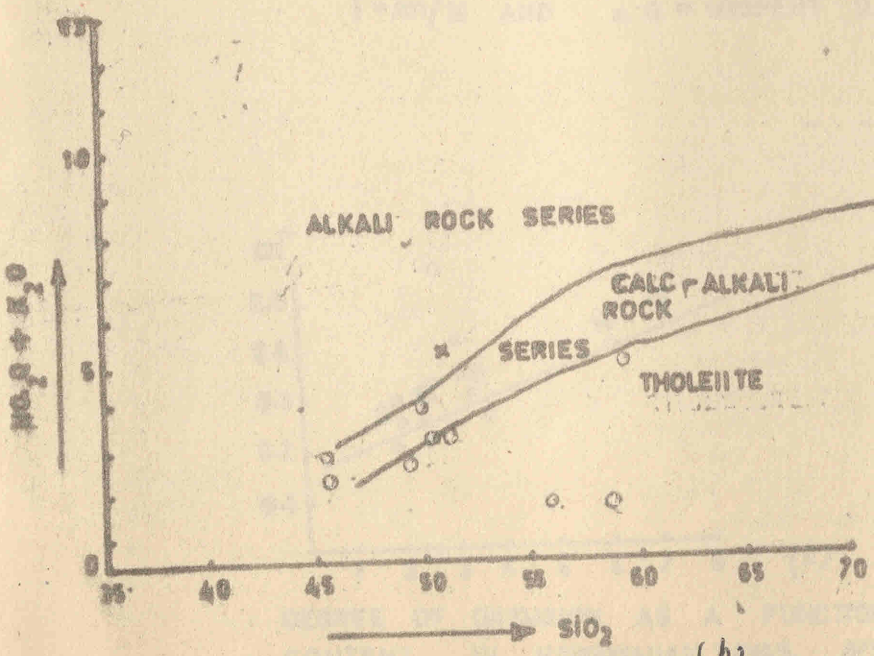
Fig (b)

PLATE-44



(a)

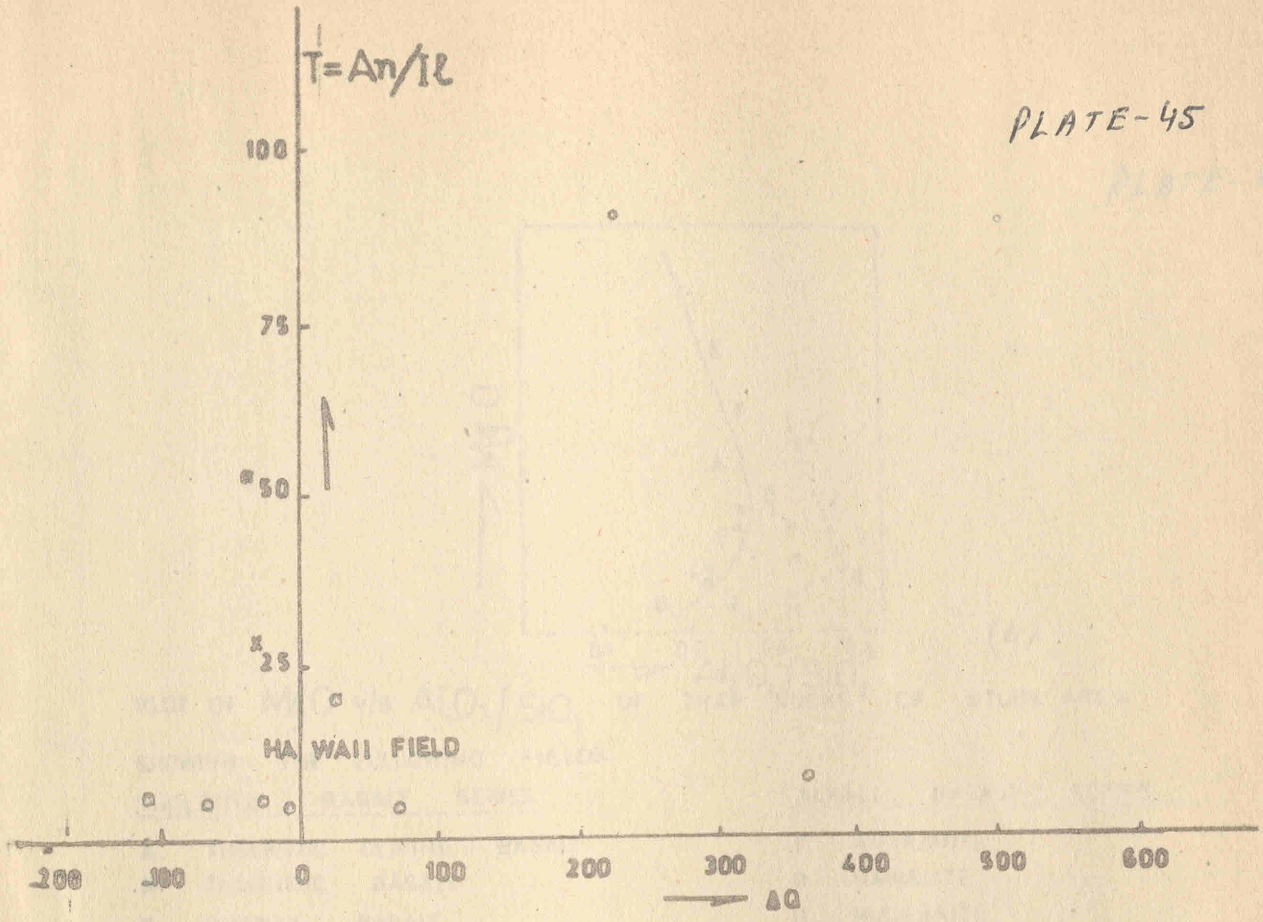
DIAGRAM OF LAVAS OF ACTIVE VOLCANOES OF THE WORLD PLOTTED IN THE GOTTINI – RITTMANN DIAGRAM.
A – LAVAS SITUATED IN NON – OROGENIC BELTS & ISLAND ARCS
B – LAVAS SITUATED IN OROGENIC BELTS
C – ALKALINE DERIVATIVES OF BOTH
o – SAMPLES OF TRAP FROM GUL – GULABGARH AREA
X – SAMPLE OF SPILITE FROM BADDAR VILLAGE, STUDY AREA.



(b)

VARIATION DIAGRAM FOR BASALTS OF GUL-GULABGHARH AREA X-SAMPLE FROM BAFLIAZ VOLCANICS & o- SAMPLE

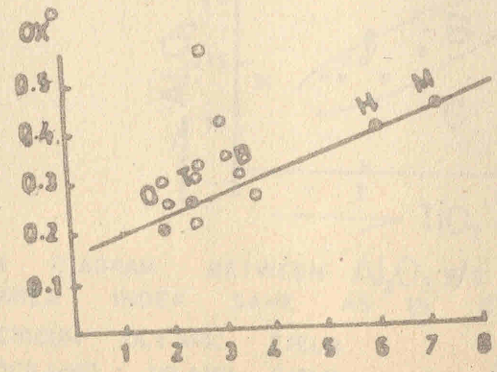
PLATE-45



(a)

DIAGRAM SHOWING AFTER RITTMANN T V/S ΔQ FOR THE VOLCANICS OF GUL-GULABGARH (AFTER RITTMANN 1973 P.34)
T=An/Il AND Δ Q = UNSPENT QUARTZ

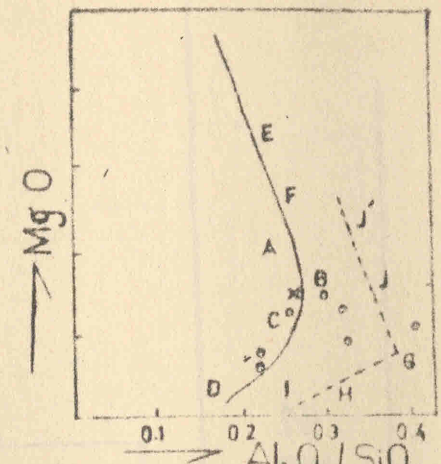
Fig. No.



(b)

DEGREE OF OXIDATION AS A FUNCTION OF ALKALI CONTENT IN HAWAWAIIAN LAVAS. AVERAGES:
O= OCEANITES B = ALKALI — BASALTS, H = HAWAIITES
M=MUGEARITES. T = THOLEIITIC BASALTS.

PLATE-46



(a)

PLOT OF MgO v/s Al_2O_3/SiO_2 OF TRAP ROCKS OF STUDY AREA SHOWING THE FOLLOWING FIELDS.

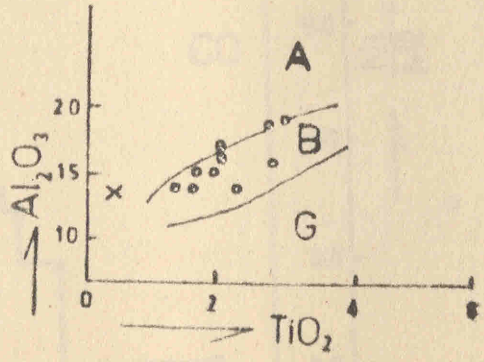
THOLEIITIC BASALT SERIES

A. THOLEIITIC OLIVINE - BASALT
B. THOLEIITIC BASALT
C. QUARTZ BASALT
D. GRANOPHYRE
E. PICRITE

ALKALI BASALT SERIES

F. ANKRAMITE
G. HAWAIITE
H. MUGEARITE
I. TRACHYTE

Fig. No. (b)

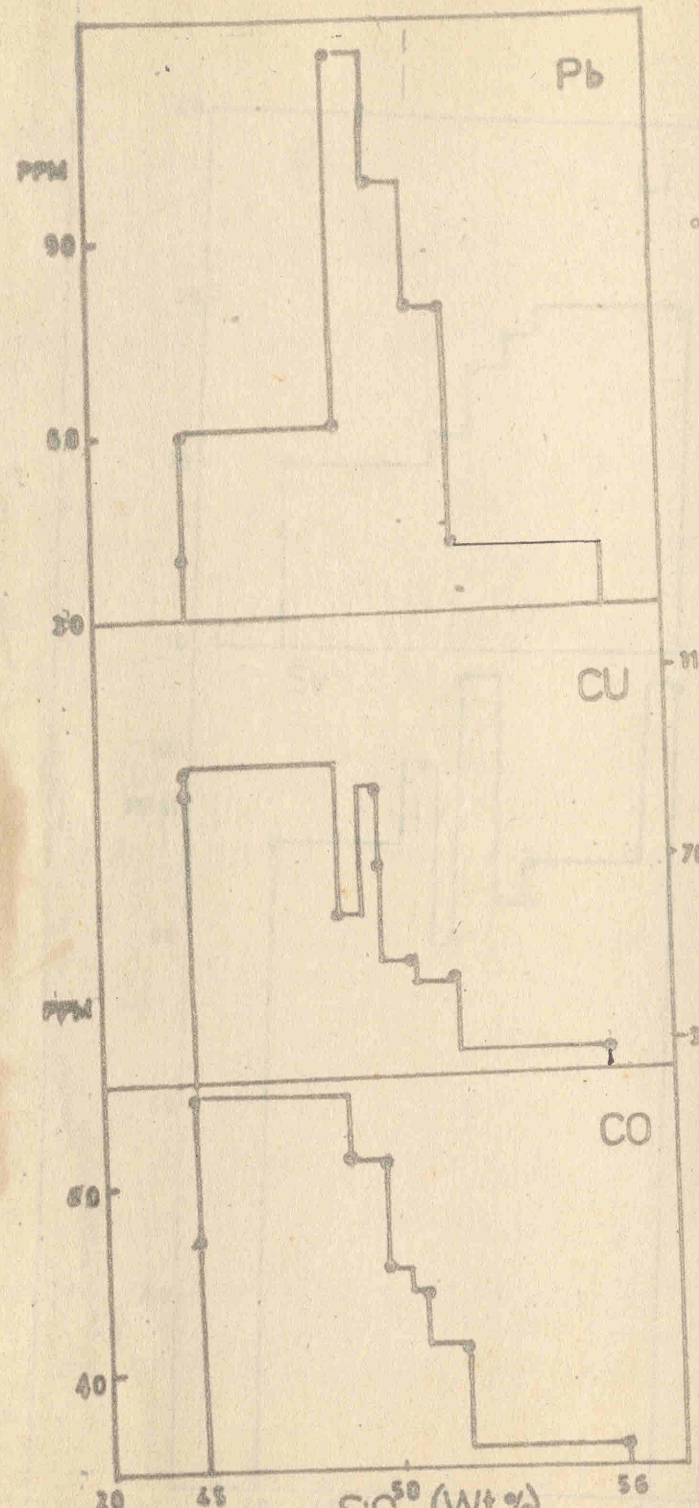


VARIATION DIAGRAM BETWEEN Al_2O_3 v/s TiO_2 OF TRAP ROCKS OF STUDY AREA INDEX SAME AS IN OTHER DIAGRAMS.

A. CIRCUM OCEANIC FIELD.
B. OCEANIC ISLAND FIELD.
G. GEOSYNCLINE FIELD.

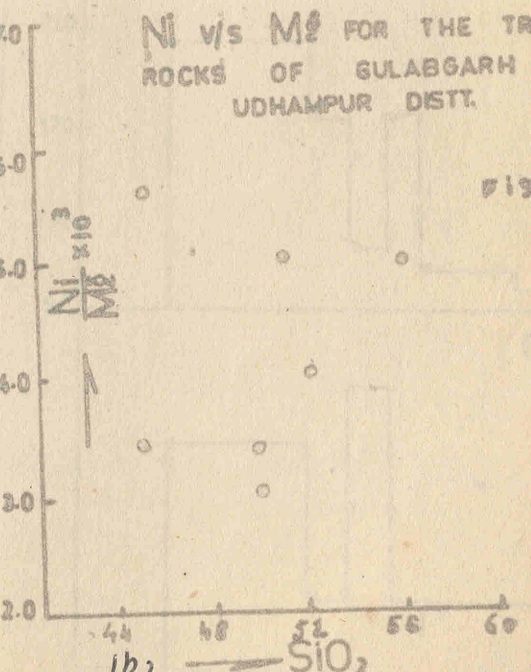
(b)

Fig. No.



(a) — SiO_2 (Wt%)

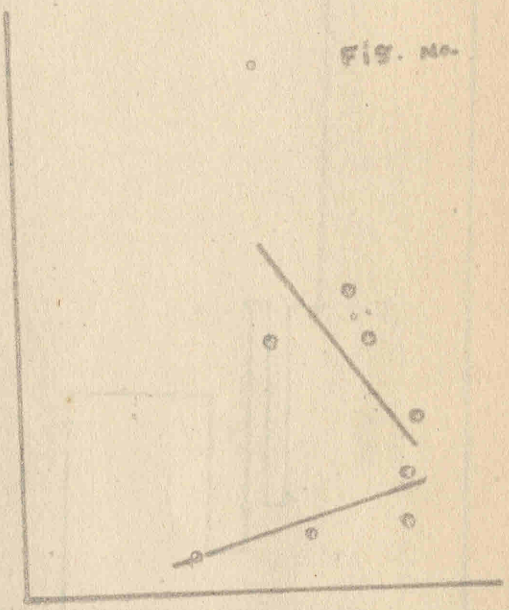
DISTRIBUTION OF Co, Cu, Pb, WITH RESPECT TO SiO_2 OF THE PANJAL TRAP OF GULABGARH, UDHAMPUR DISTT.



(b) — SiO_2

$\frac{Ni}{Mg} \times 10^3$ v/s SiO_2 FOR THE PANJAL AREA, TRAPS OF GULABGARH & UDHAMPUR DISTT.

Fig. No.

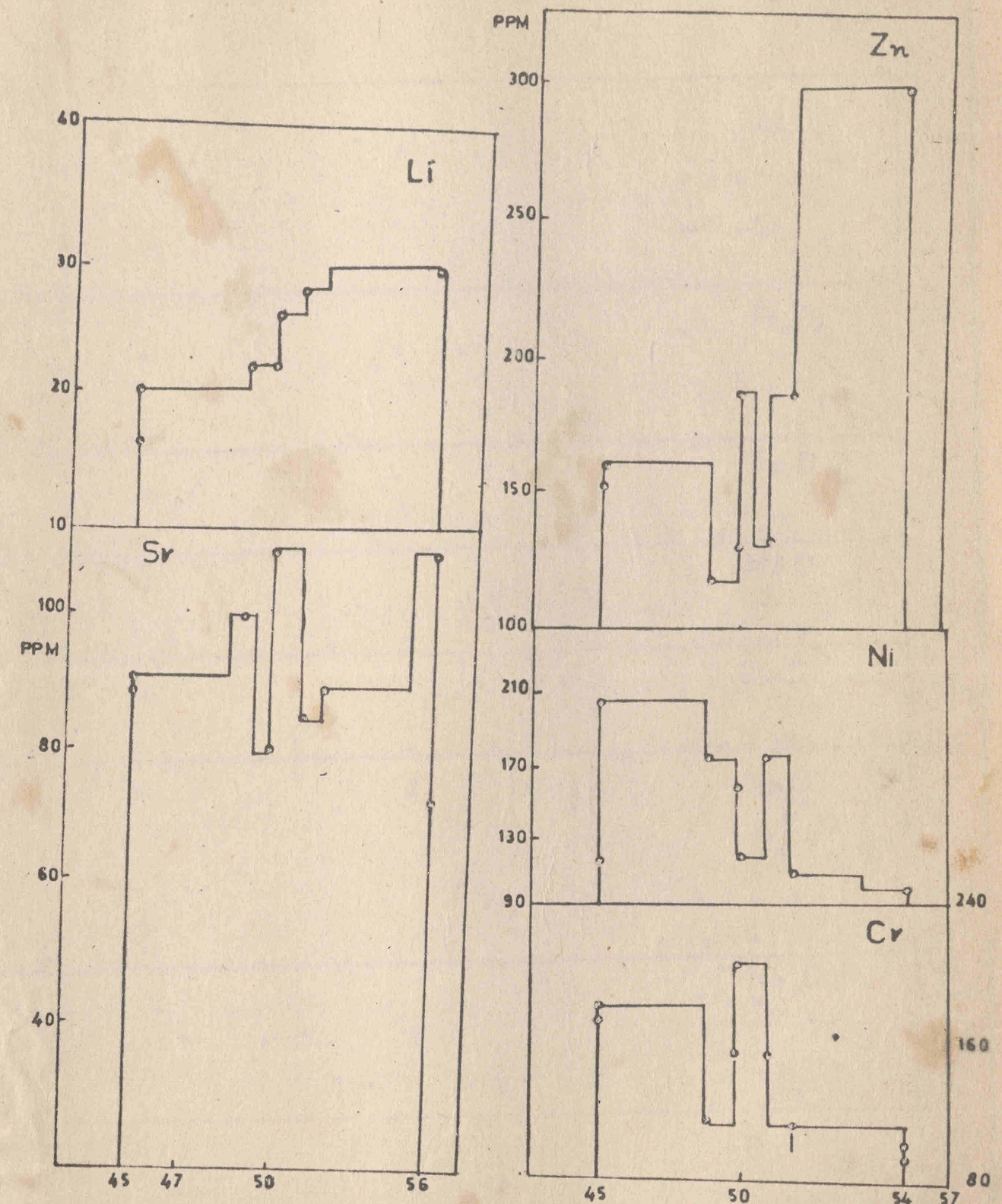


(c) — Mg Wt%

Ni v/s Mg FOR THE TRAP ROCKS OF GULABGARH AREA, UDHAMPUR DISTT.

PLATE - 47A

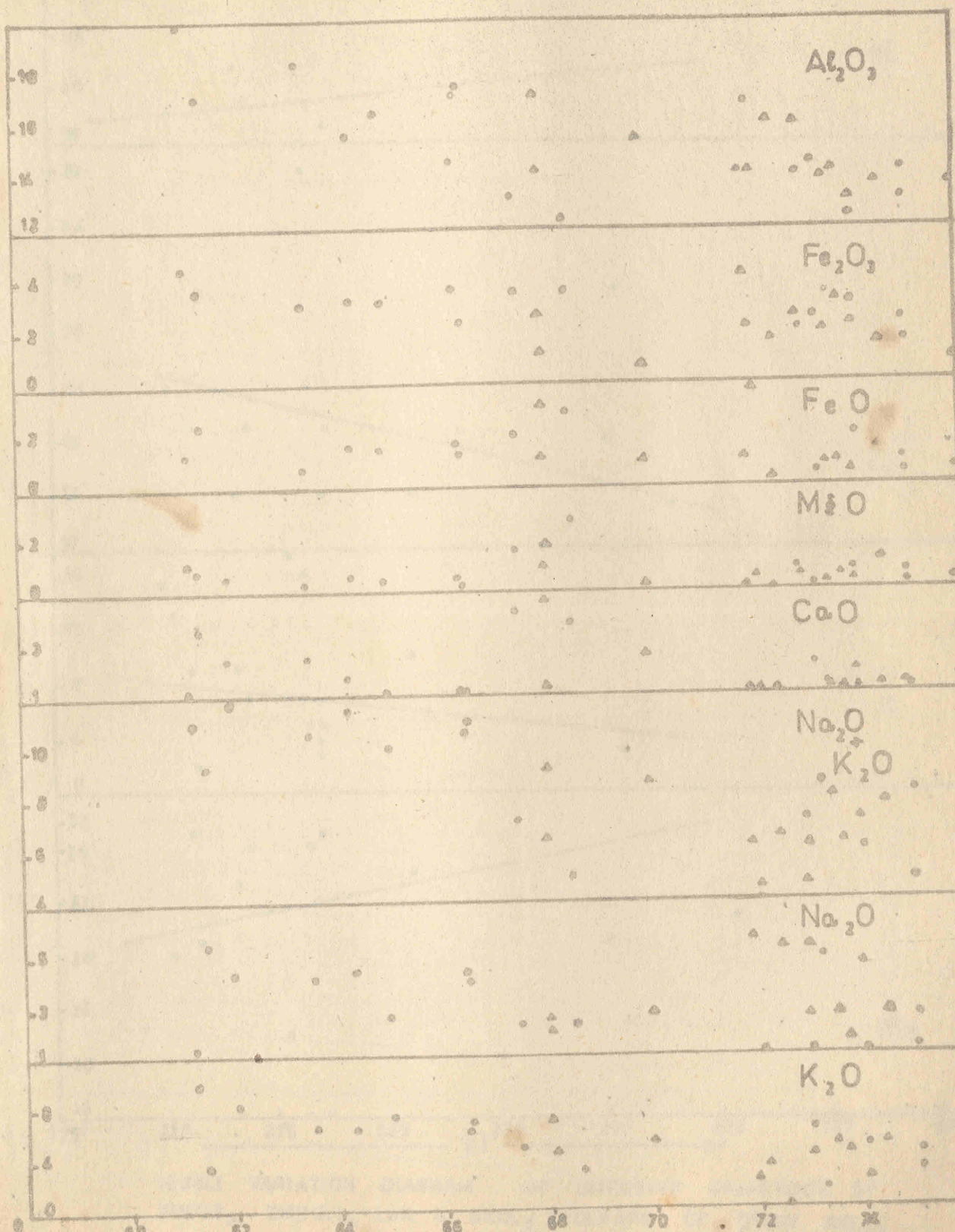
Fig. No.



DISTRIBUTION OF Cr, Ni, Zn, Li, Sr, OF PANJAL TRAP ROCKS WITH RESPECT TO SiO_2 OF STUDY AREA, UDHAMPUR DISTT.

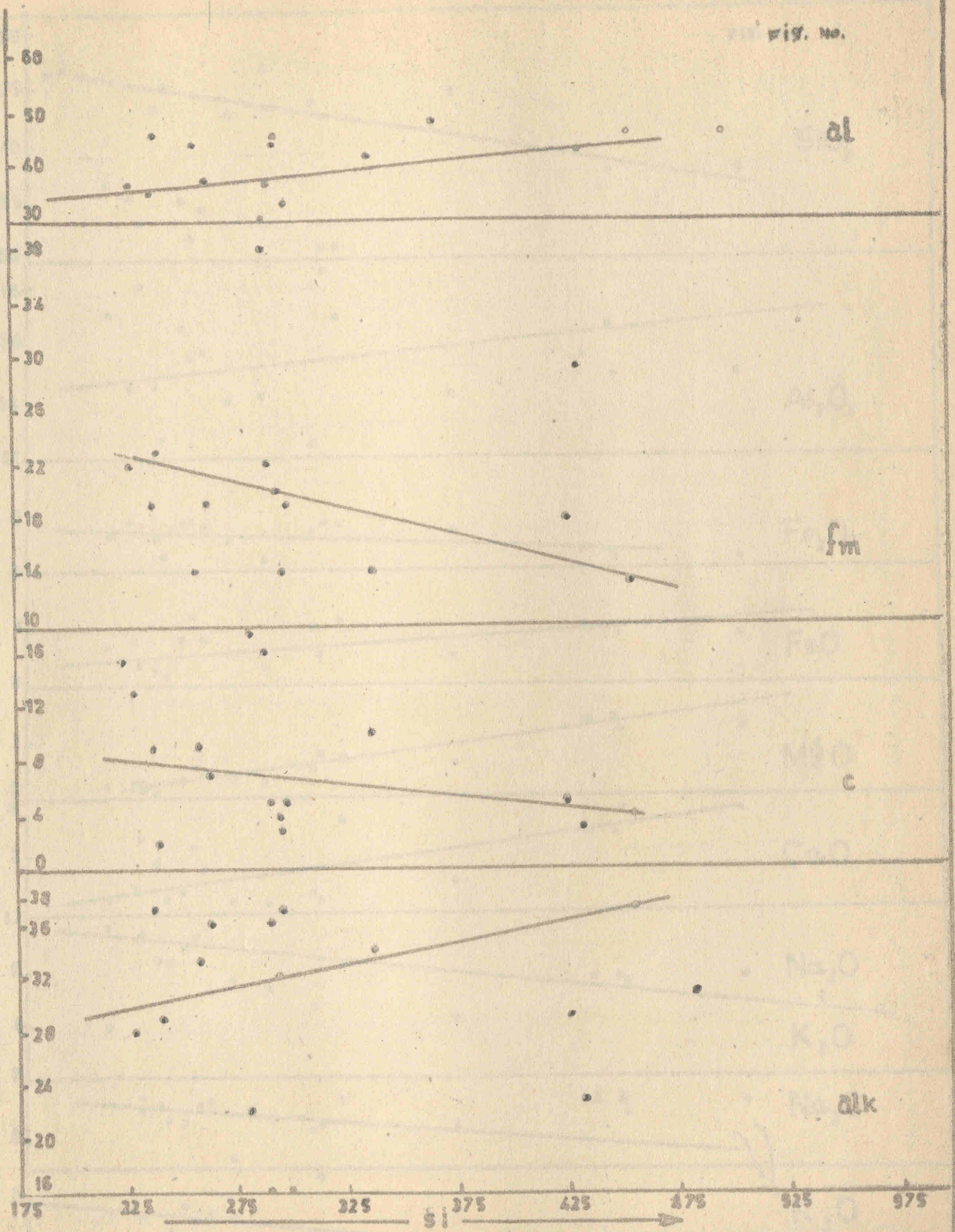
PLATE-48

Fig. No.



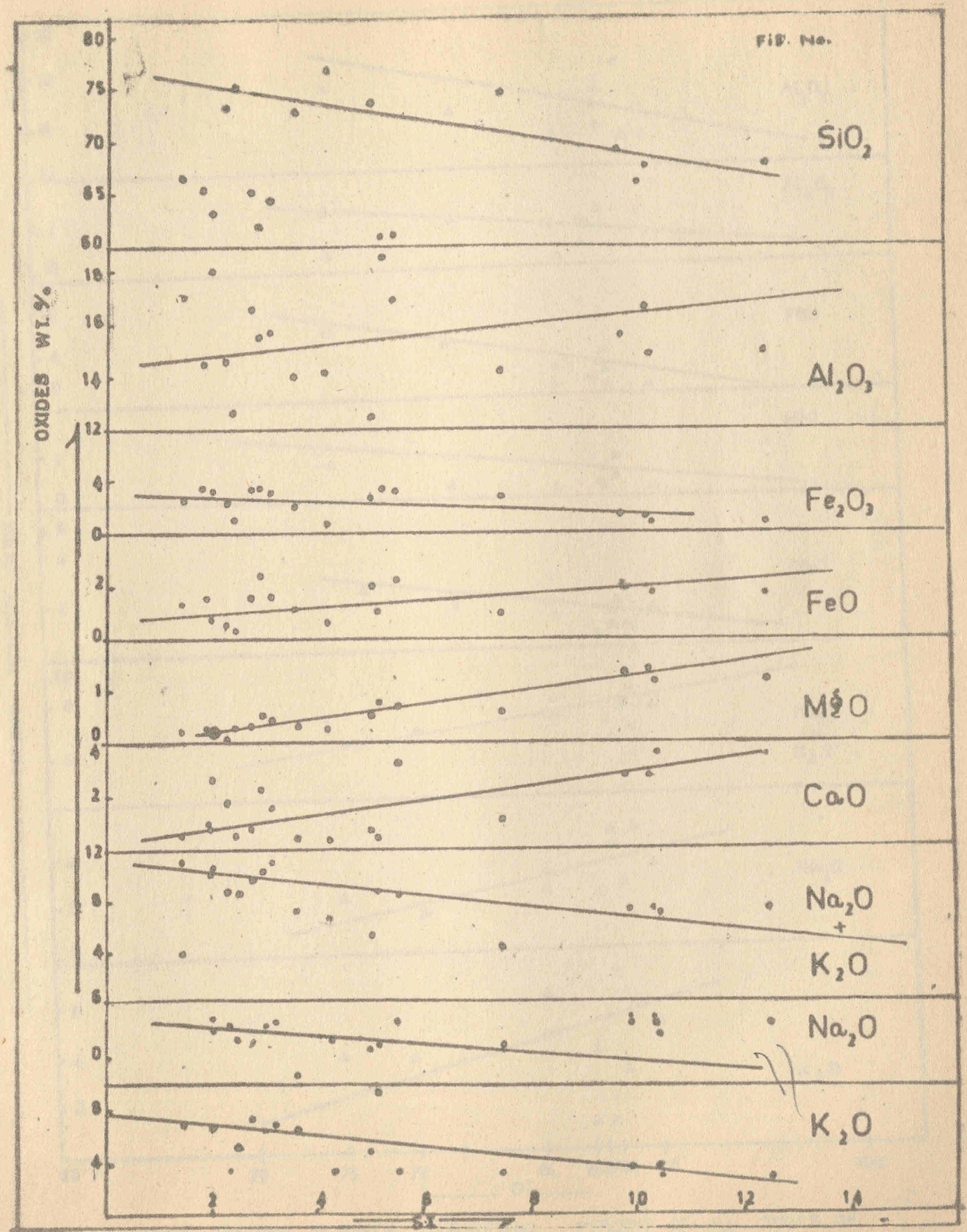
INTRUSIVE GRANITOID ROCKS MARKED BY ● & GNEISSOES GRANITES MARKED BY △ VARIATION DIAGRAM BETWEEN SILICA & OTHER OXIDES OF ROCK SAMPLES OF STUDY AREA.

PLATE-49



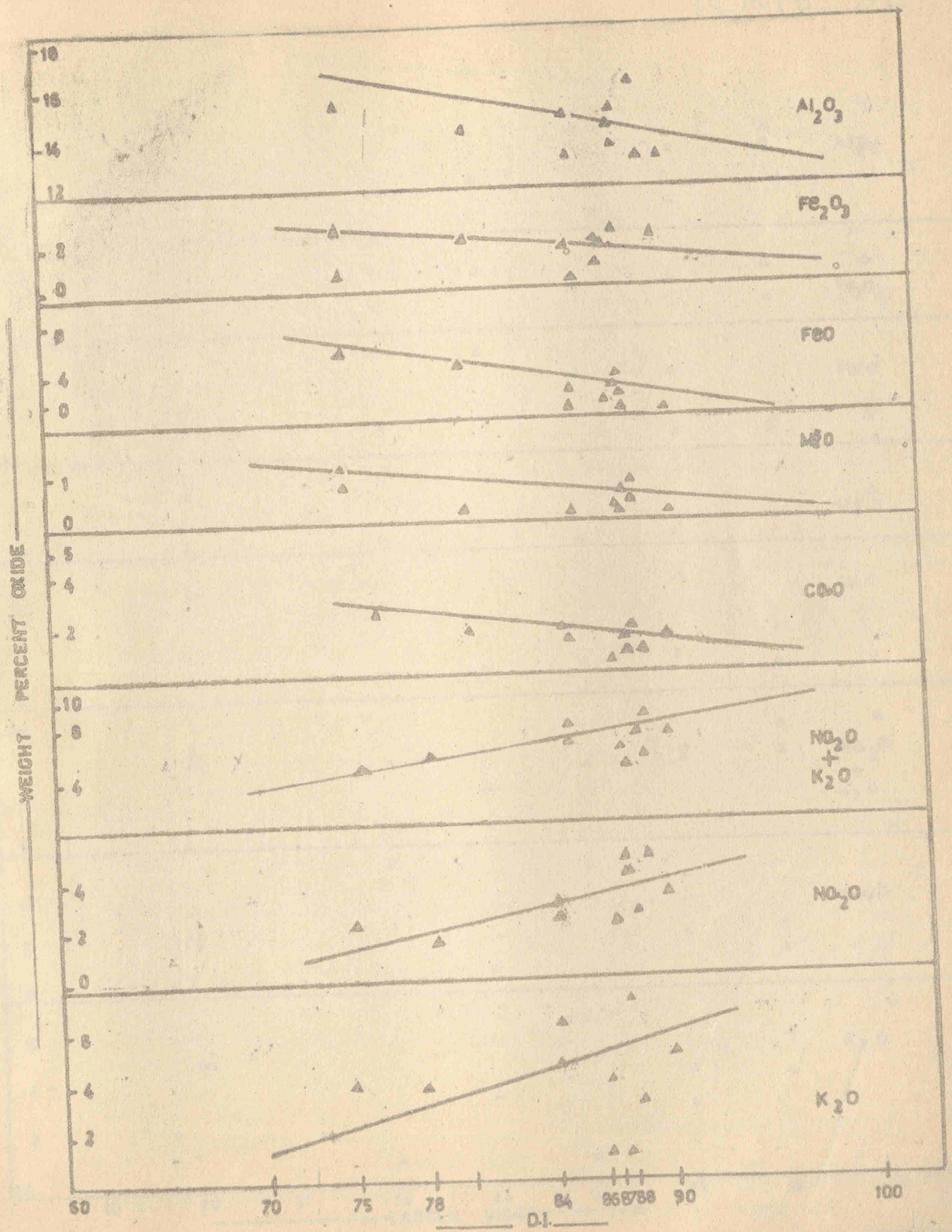
NIGGLI VARIATION DIAGRAM OF INTRUSIVE GRANITOIDS OF KHOUR, SHIDOUL, LAR & DEOL, DEOLMARG OF STUDY AREA, UDHAMPUR – DISTT..

PLATE-50



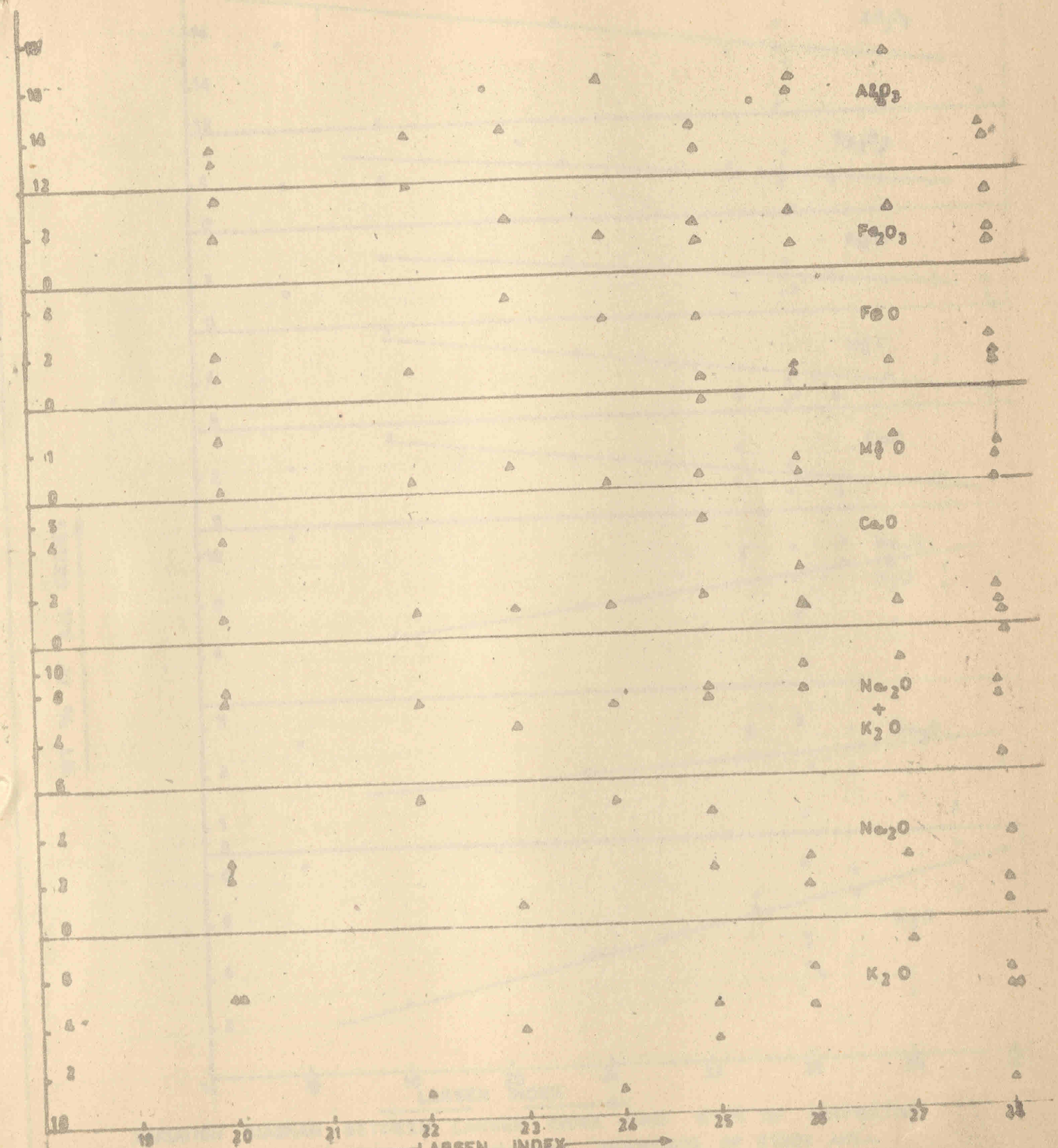
VARIATION DIAGRAM BETWEEN S.I. & WT. % OXIDES OF ANALYSED SAMPLES OF INTRUSIVE GRANITOIDS OF STUDY AREA.

PLATE - 51



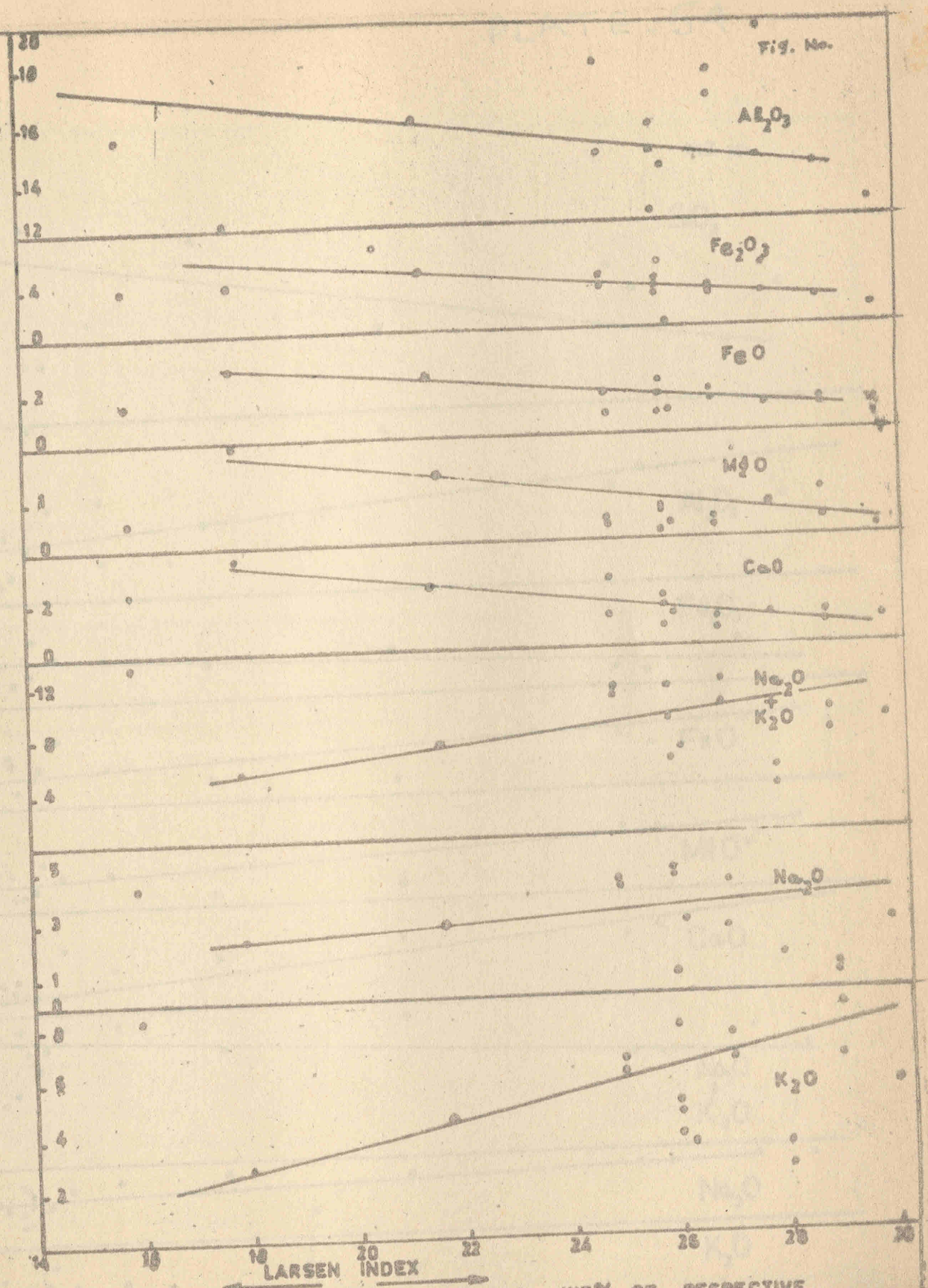
VARIATION DIAGRAM BETWEEN D.I. & WEIGHT PERCENT OF ALL OXIDES OF GNEISSOSE ROCKS OF SALKHALA GROUP, SOUTHERN PIRPANJAL OF STUDY AREA.

PLATE - 52



VARIATION DIAGRAM BETWEEN LARSEN INDEX & RESPECTIVE OXIDES OF PARA — GNEISSES & GNEISSOSE GRANITE OF SUPRASS, NOACH, TUKSUN LOCALITIES OF STUDY AREA.

PLATE-53



VARIATION DIAGRAM BETWEEN LARSEN INDEX AND WT.% OF RESPECTIVE OXIDES OF INTRUSIVE GRANITOIDS OF STUDY AREA.

PLATE - 54

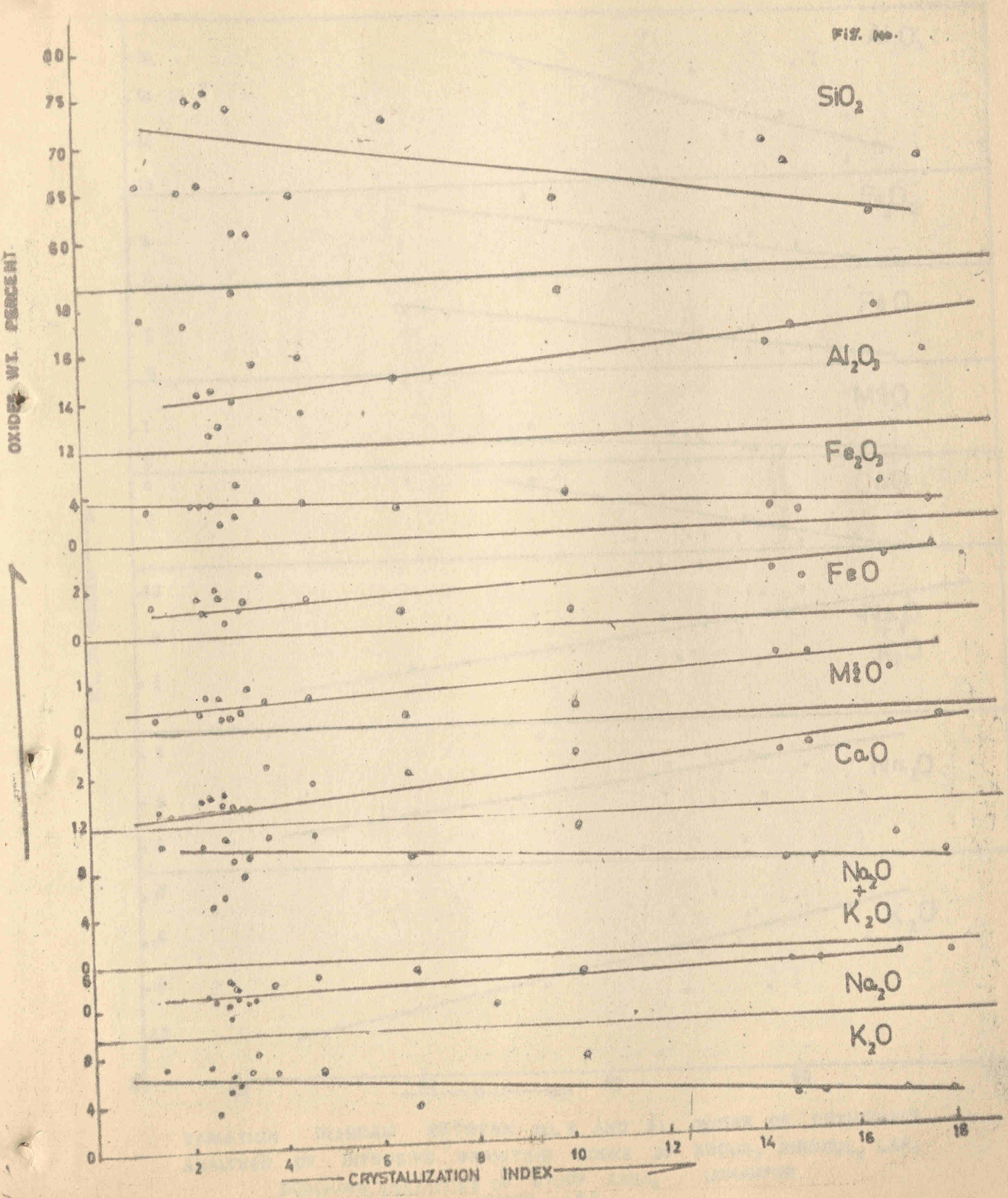
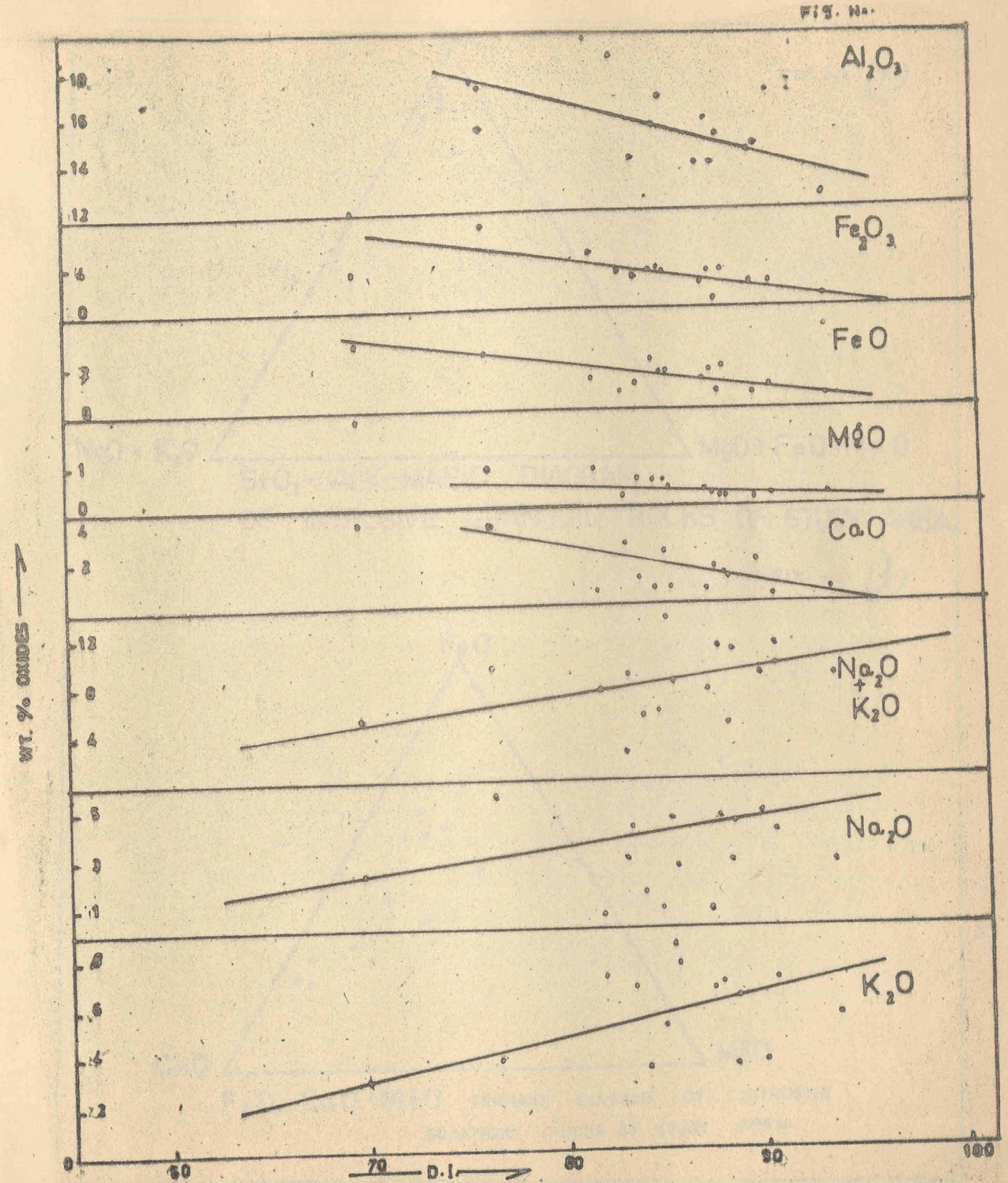


Fig. No.
OXIDES WT. PERCENT
80
75
70
65
60
18
16
14
12
4
0
2
0
1
0
4
2
12
8
4
6
0
8
4
0
SiO2
Al2O3
Fe2O3
FeO
MgO
CaO
Na2O + K2O
Na2O
K2O
2
4
6
8
10
12
14
16
18
CRYSTALLIZATION INDEX

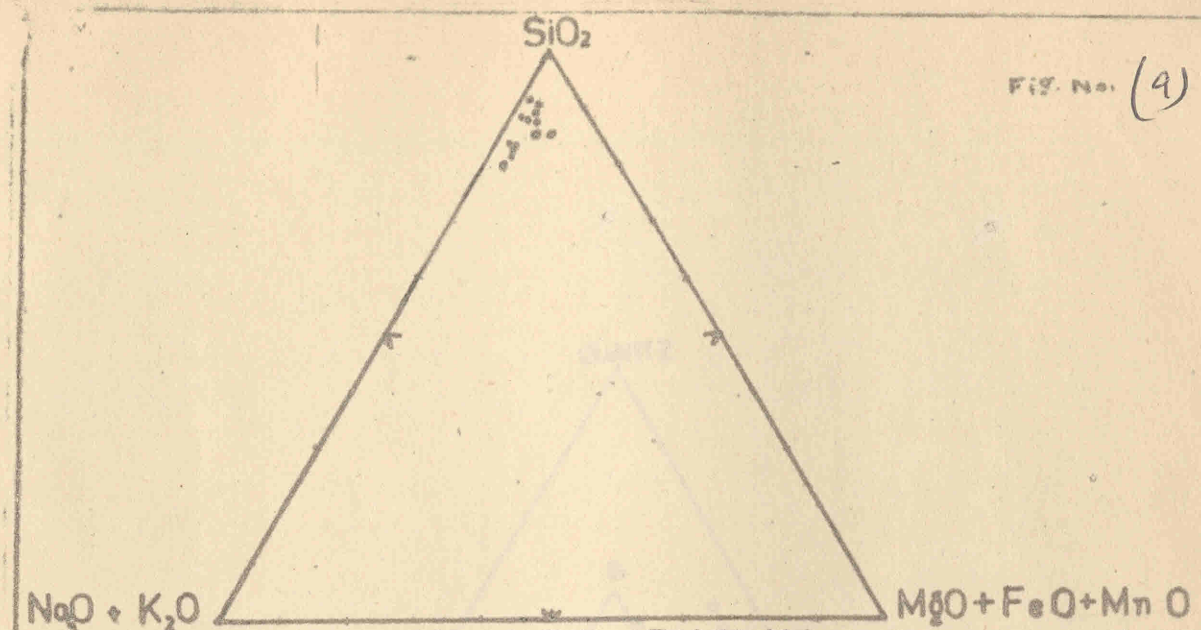
PLATE-55



VARIATION DIAGRAM BETWEEN D.I. & AND ALL OXIDES OF CHEMICALLY ANALYSED OF INTRUSIVE GRANITOID ROCKS OF KHOUR, SHIDOUL, LAR, DEOLMARG, LOCALITIES OF STUDY AREA, UDHAMPUR DISTT. – J & K.

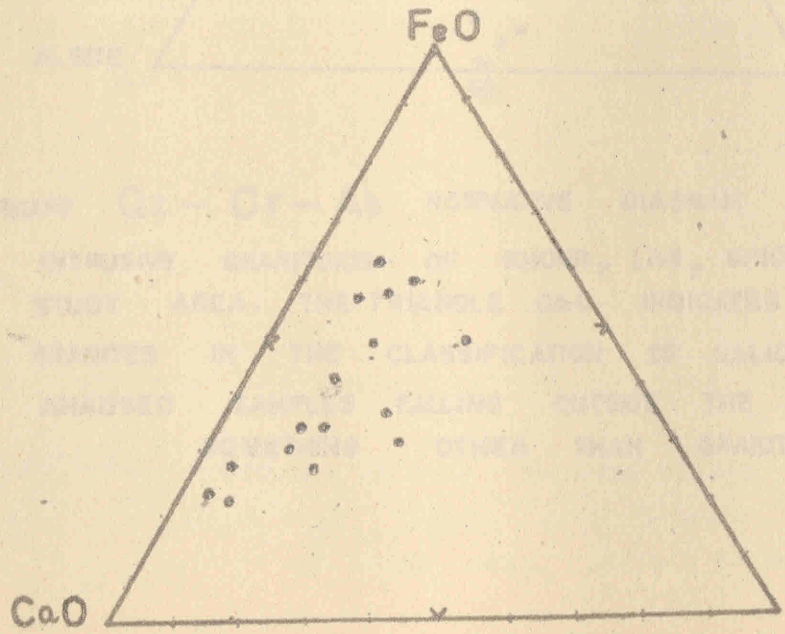
PLATE-56

Fig. No. (9)



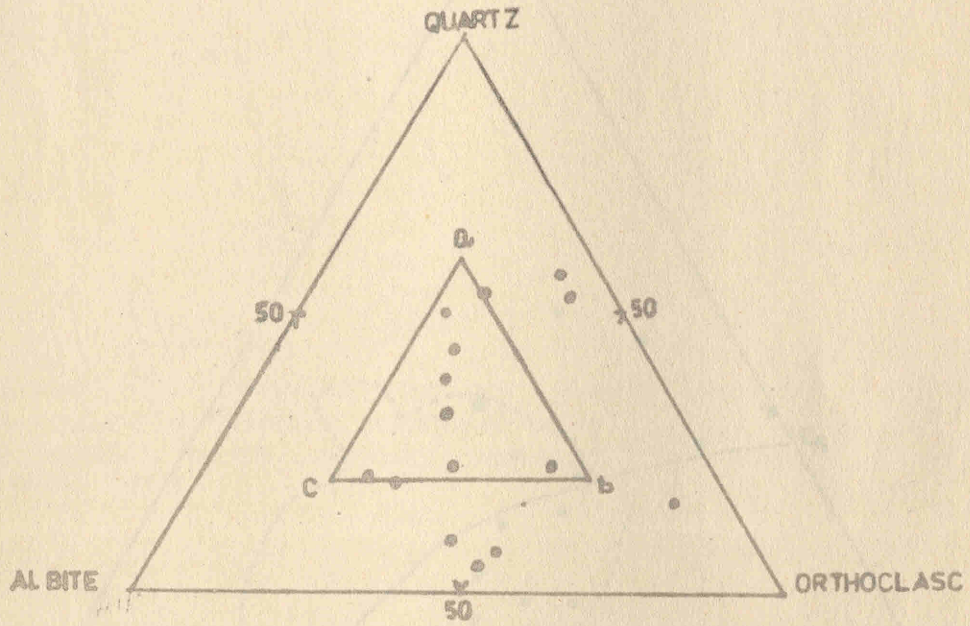
SiO_2 – ALK–MAFIC DIAGRAM
OF INTRUSIVE GRANITOID ROCKS OF STUDY AREA.

Fig. No (8)



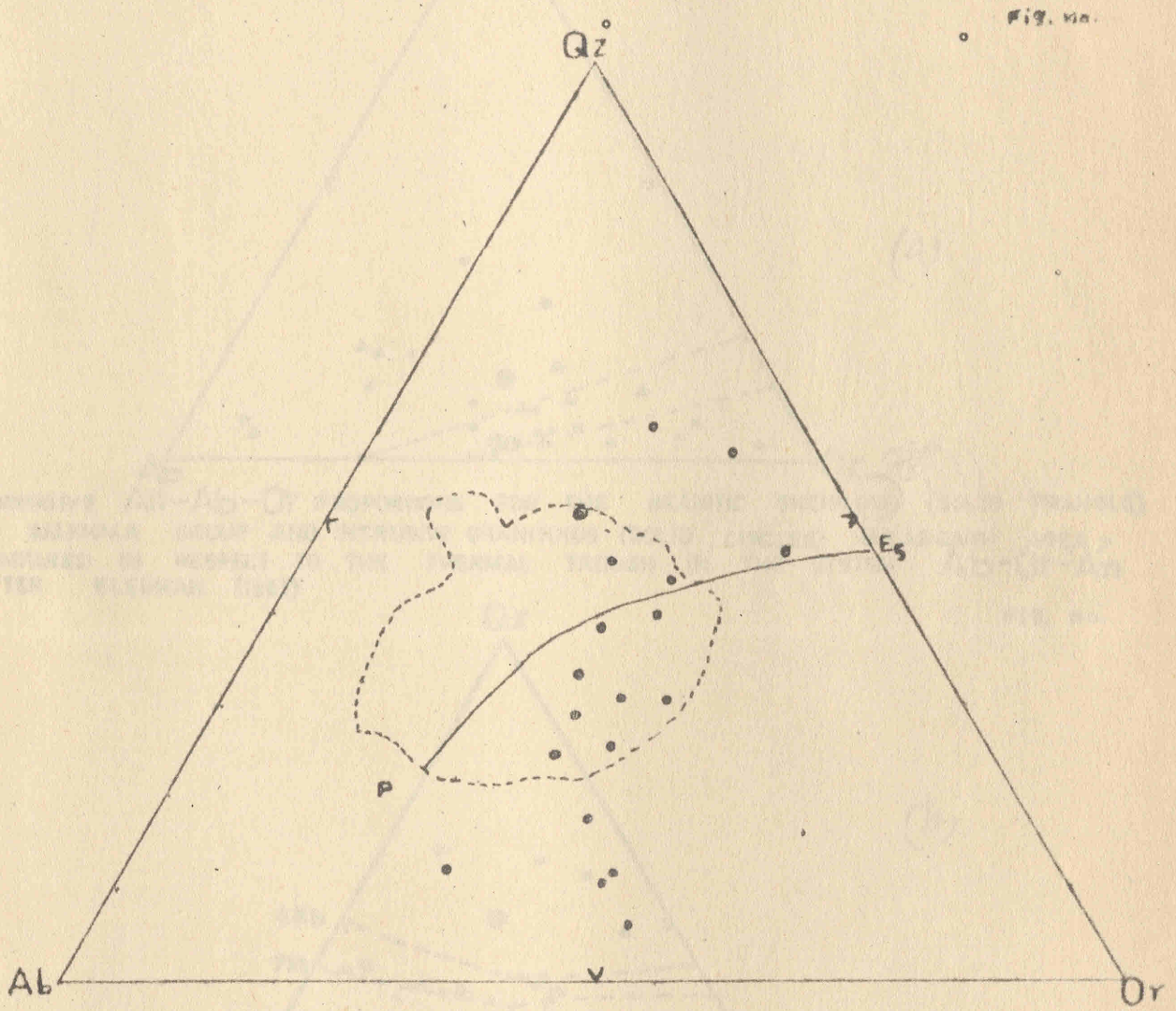
FeO–CaO–MgO TERNARY DIAGRAM OF INTRUSIVE GRANITOID ROCKS OF STUDY AREA.

PLATE-57



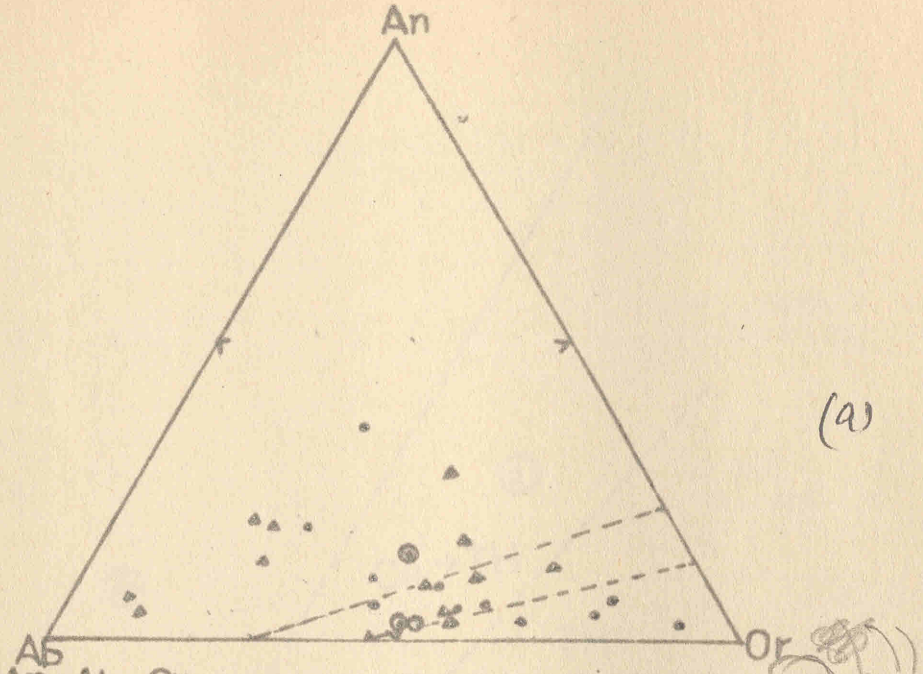
TERNARY Qz – Or – Ab NORMATIVE DIAGRAM SHOWING PLOTS OF INTRUSIVE GRANITOIDS OF KHOUR, LAR, SHIDOUL etc. VILLAGES OF STUDY AREA. THE TRIANGLE QbC INDICATES THE COMPOSITION OF GRANITES IN THE CLASSIFICATION OF SALIC ROCKS AND PLOTS OF ANALYSED SAMPLES FALLING OUTSIDE THE AREA Q b C IS SOMETHING OTHER THAN GRANITE.

PLATE-58



Ab-Or-Qz NORMATIVE DIAGRAM SHOWING PLOTS OF INTRUSIVE GRANITOID ROCKS OF KHOUR, LAR, SHIDOUL, DEOLMARG LOCALITIES OF STUDY AREA. (AFTER WINKLER, 1974).

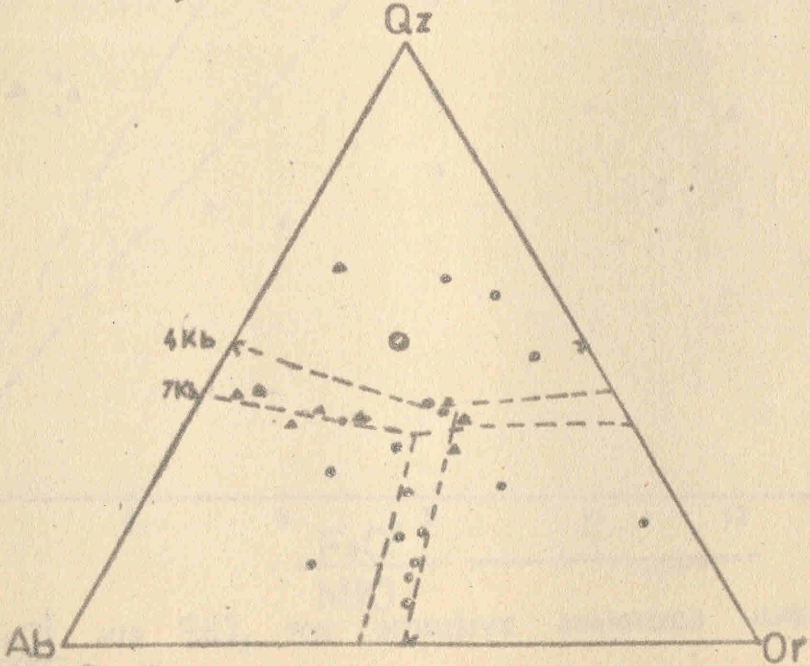
PLATE-59



(a)

NORMATIVE An-Ab-Or PROPORTIONS FOR THE GRANITIC GNEISSOSE (SOLID TRIANGLE) OF SALKHALA GROUP AND INTRUSIVE GRANITOIDS (SOLID CIRCLES) GULABGARH AREA, COMPARED IN RESPECT TO THE THERMAL TROUGH IN THE SYSTEM Ab-Or-An AFTER KLEEMAN (1963)

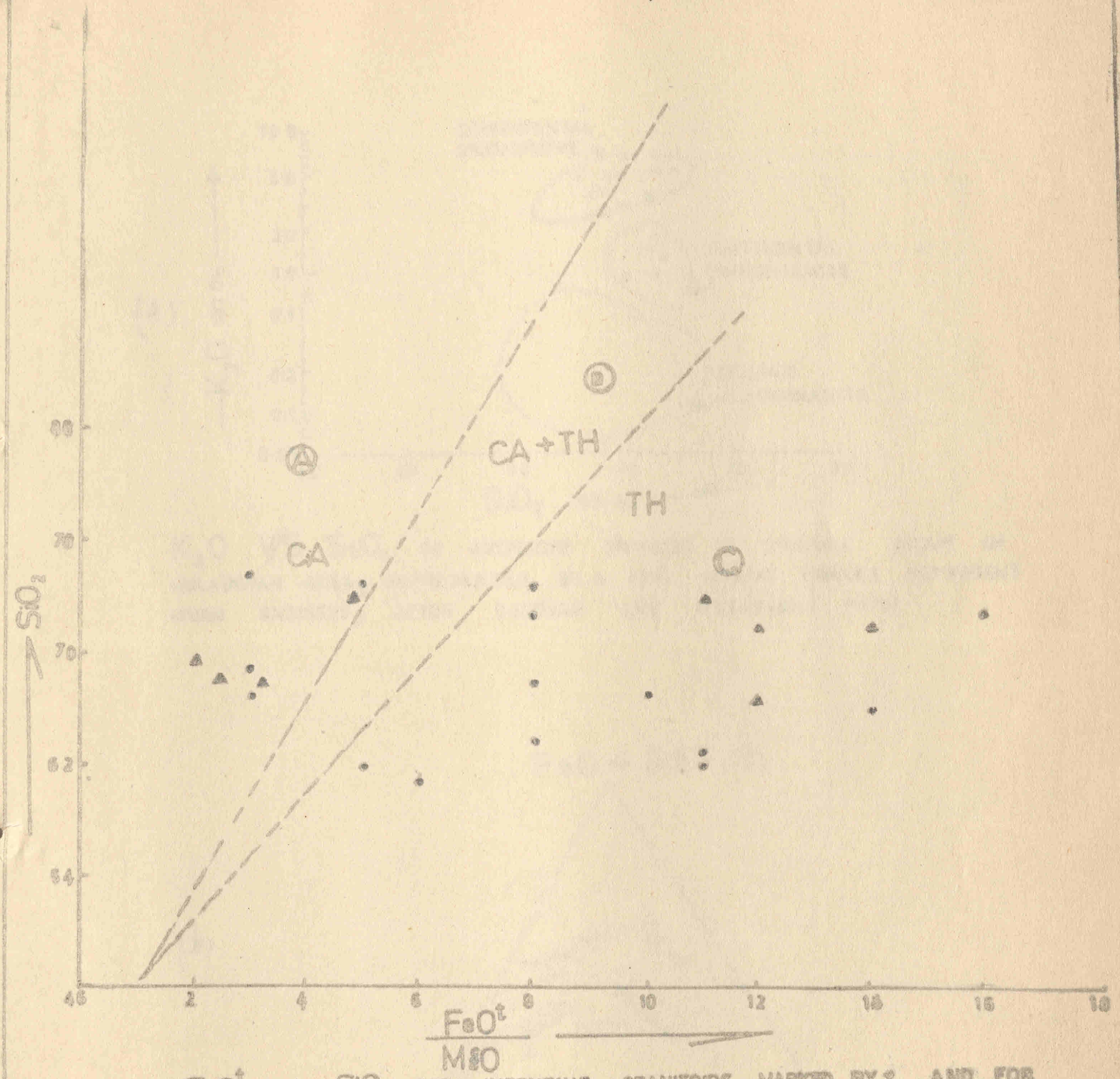
Fig. No.



(b)

NORMATIVE Ab-Or-Q PROPORTIONS FOR THE GNEISSOSE GRANITES (SOLID TRIANGLE) OF SALKHALA GROUP & GRANITOIDS (SOLID CIRCLES) OF GULABGRAH AREA, RELATIONSHIP WITH COTECTIC BARS OF WATER PRESSURES OF 4Kb & 7Kb. AFTER (VON PLATTEN 1965)

PLATE. 61 Fig. No.

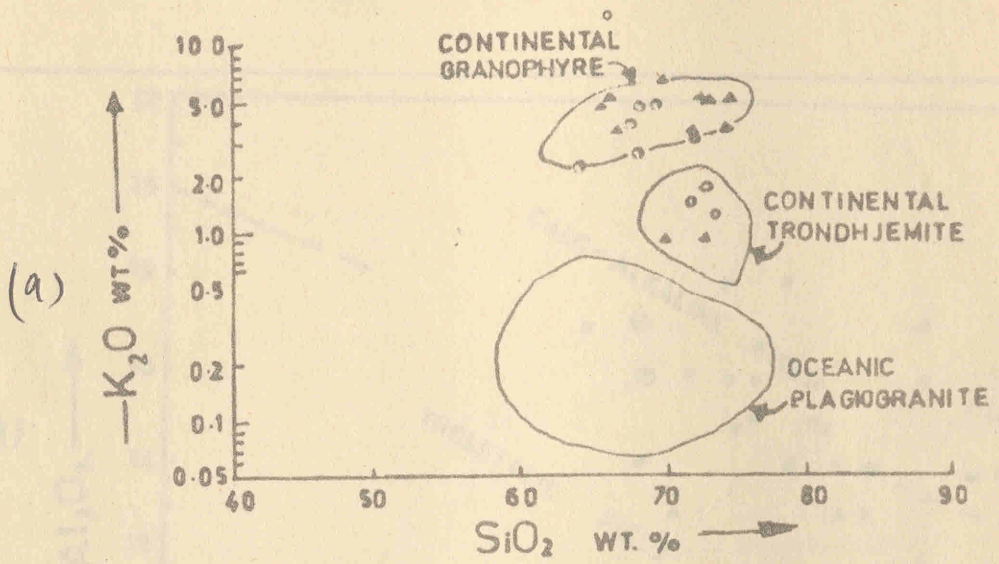


PLOT OF $\frac{FeO^t}{MgO}$ V/S SiO_2 FOR INTRUSIVE GRANITOIDS MARKED BY ● AND FOR GNEISSOSE GRANITE MARKED BY ▲ OF STUDY AREA, GULABGARH, UDHAMPUR DISTT. (AFTER MIYASHIRO 1974).

INDEX - CA CALC - ALKALINES
TH THOLEIITE

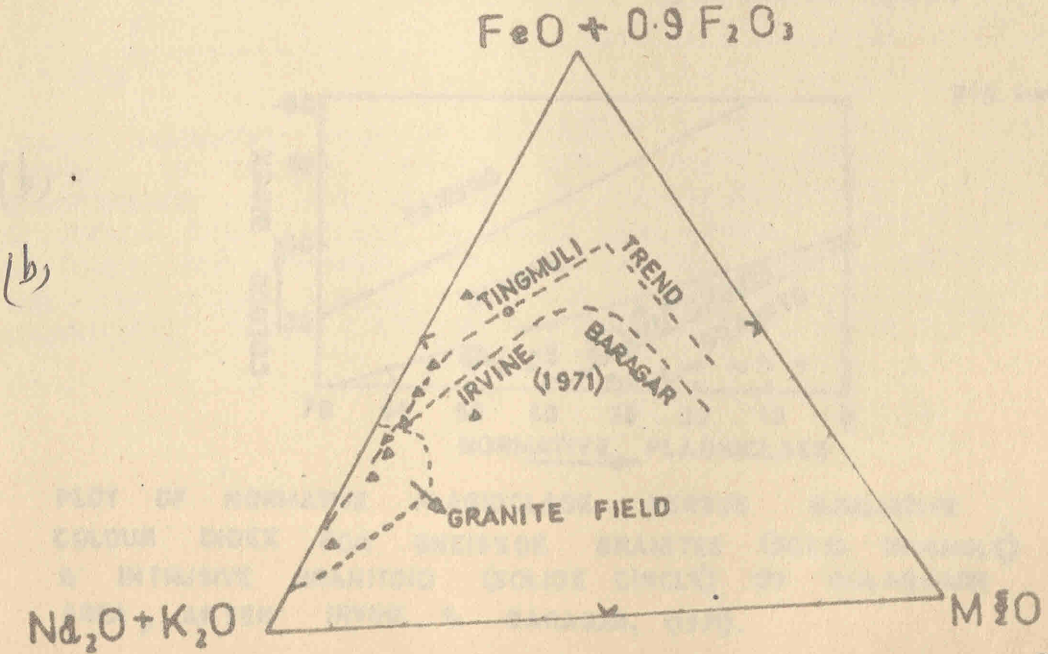
PLATE 62

(a)



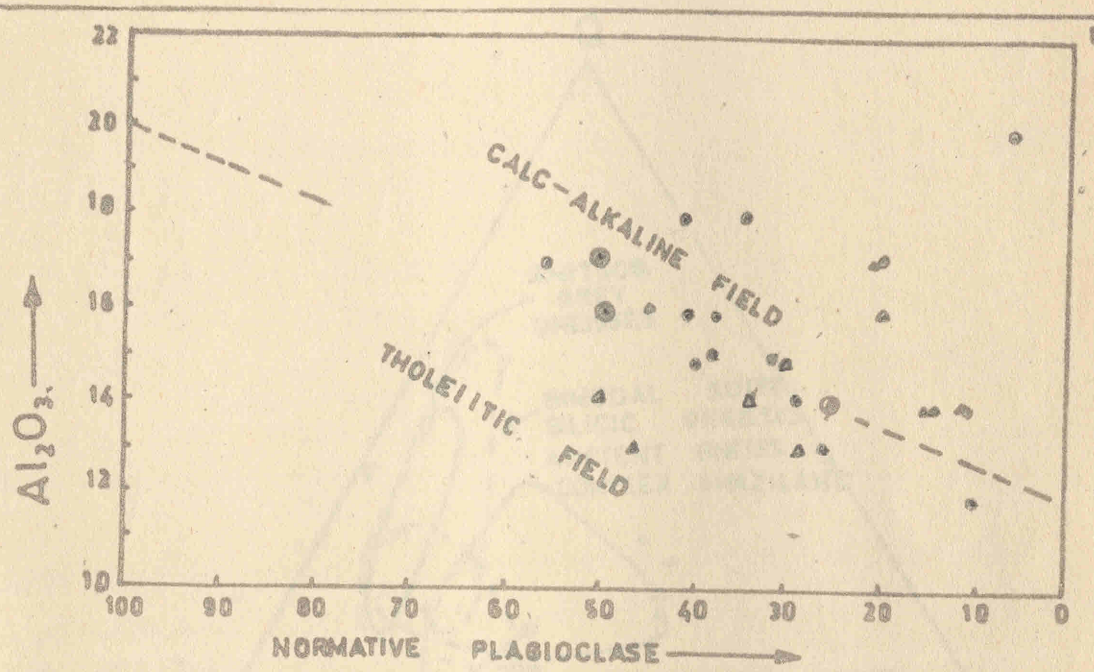
K_2O V/S SiO_2 OF GNEISSOSE GRANITES OF SALKHALA GROUP OF GULABGRAH AREA, REPRESENTED BY Δ AND HOLLOW CIRCLES REPRESENT UIVAK GNEISSES, AFTER COLEMAN AND PETERMAN (1975).

(b)

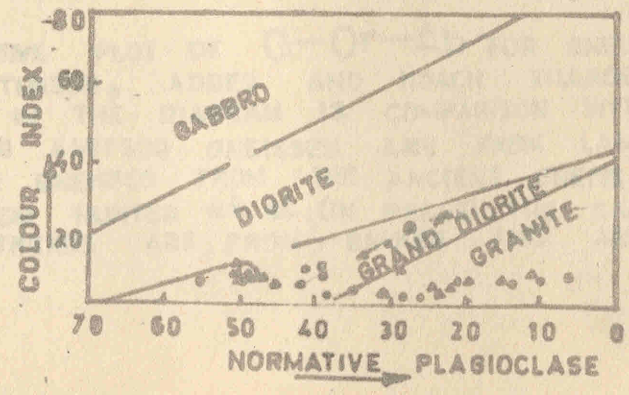


AFM TRIANGULAR PLOT OF GNEISSOSE GRANITES OF SALKHALA GROUP OF STUDY AREA SHOWING TINGMULI TREND.

PLATE 63

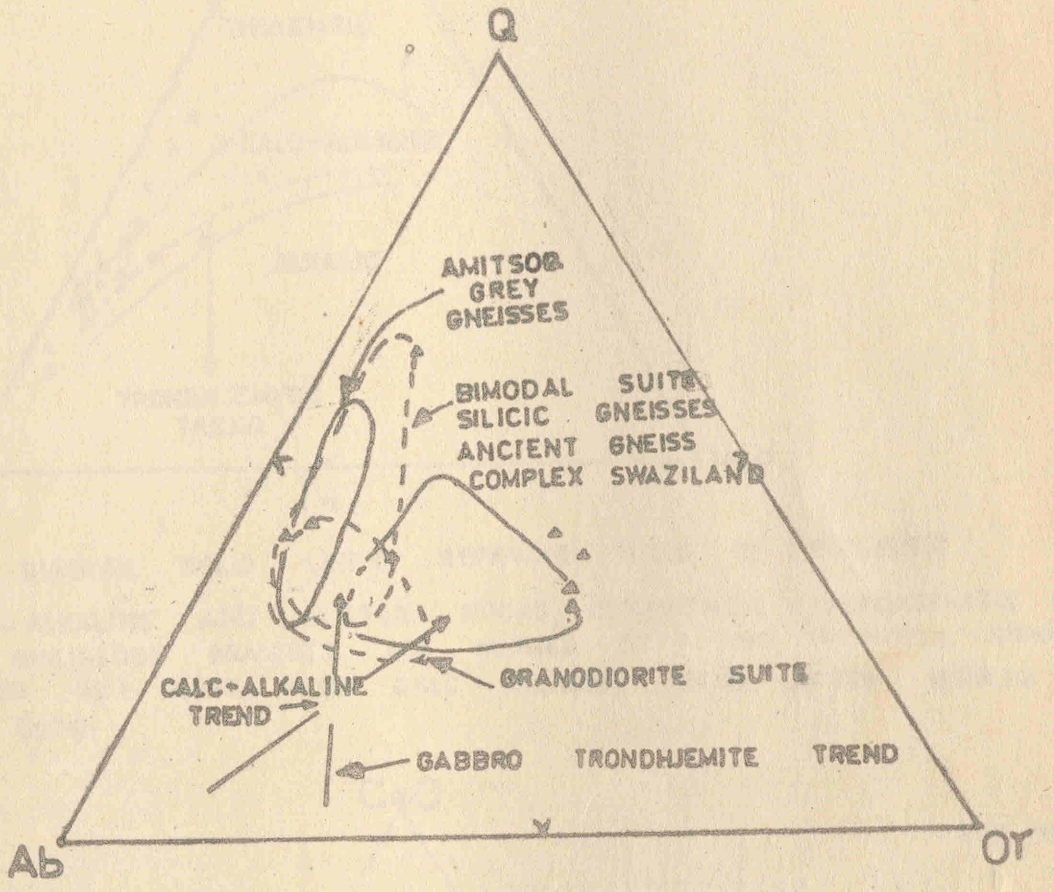


PLOT OF NORMATIVE PLAGIOCLASE VERSUS Al_2O_3 FOR GNEISSOSE GRANITES (SOLID TRIANGLE) & INTRUSIVE GRANITOIDS (SOLID CIRCLES) OF GULABGARH AREA, UDHAMPUR DISTT.



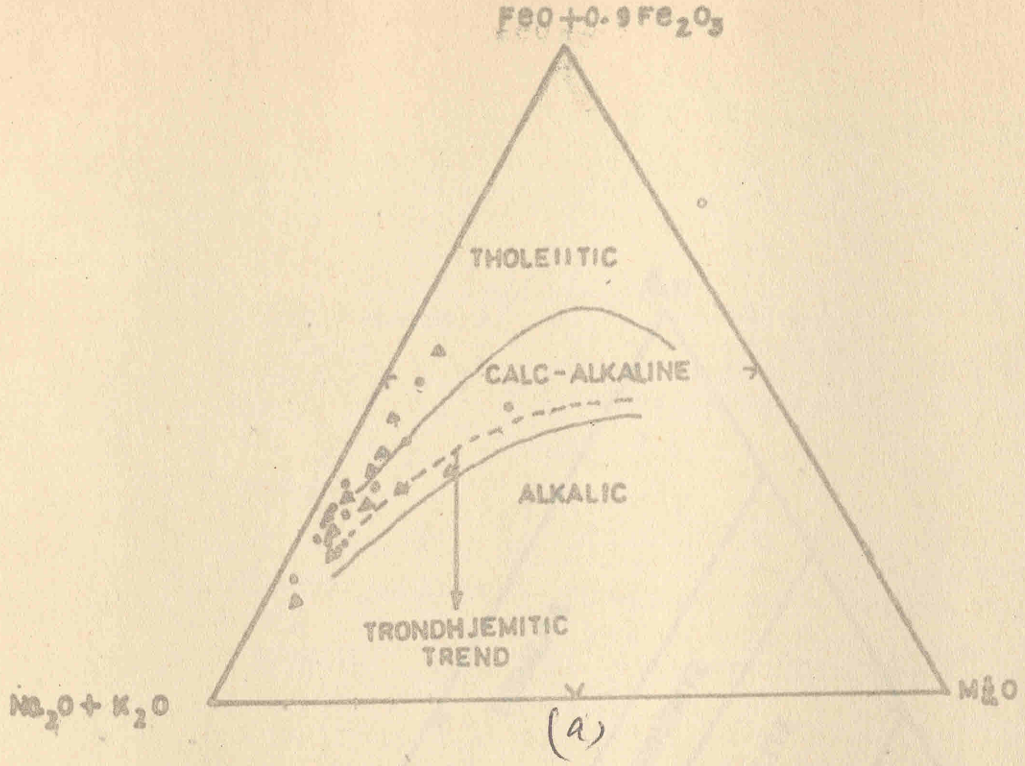
PLOT OF NORMATIVE PLAGIOCLASE VERSUS NORMATIVE COLOUR INDEX FOR GNEISSOE GRANITES (SOLID TRIANGLE) & INTRUSIVE GRANITOID (SOLIDE CIRCLE) OF GULABGARH AREA, AFTER IRVINE & BARAGAR, (1971).

PLATE. 64



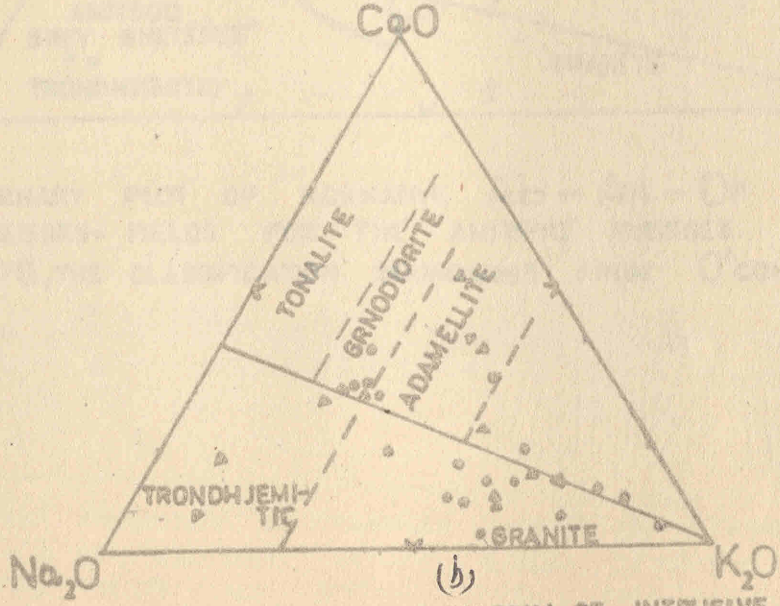
TERNARY NORMATIVE PLOT OF Q—Or—Ab FOR GNEISSOSE GRANITES & GNEISSES OF TUKSUN, ADBES AND NOACH VILLAGES OF STUDY AREA. ORNAMENTATION IN THE DIAGRAM IS COMPARISON WITH UIVAK GNEISSES. THE FIELDS FOR AMITSOQ GNEISSES ARE FROM LAMBERT & HOLAND (1976), AND THOSE FOR GNEISSES FROM THE ANCIENT GNEISS COMPLEX IN SWAZILAND ARE FROM HUNTER et al; (IN PRESS). THE CALC—ALKALINE AND TRONDHJEMITE TRENDS ARE FROM BARKER AND ARTH (1976).

PLATE 65



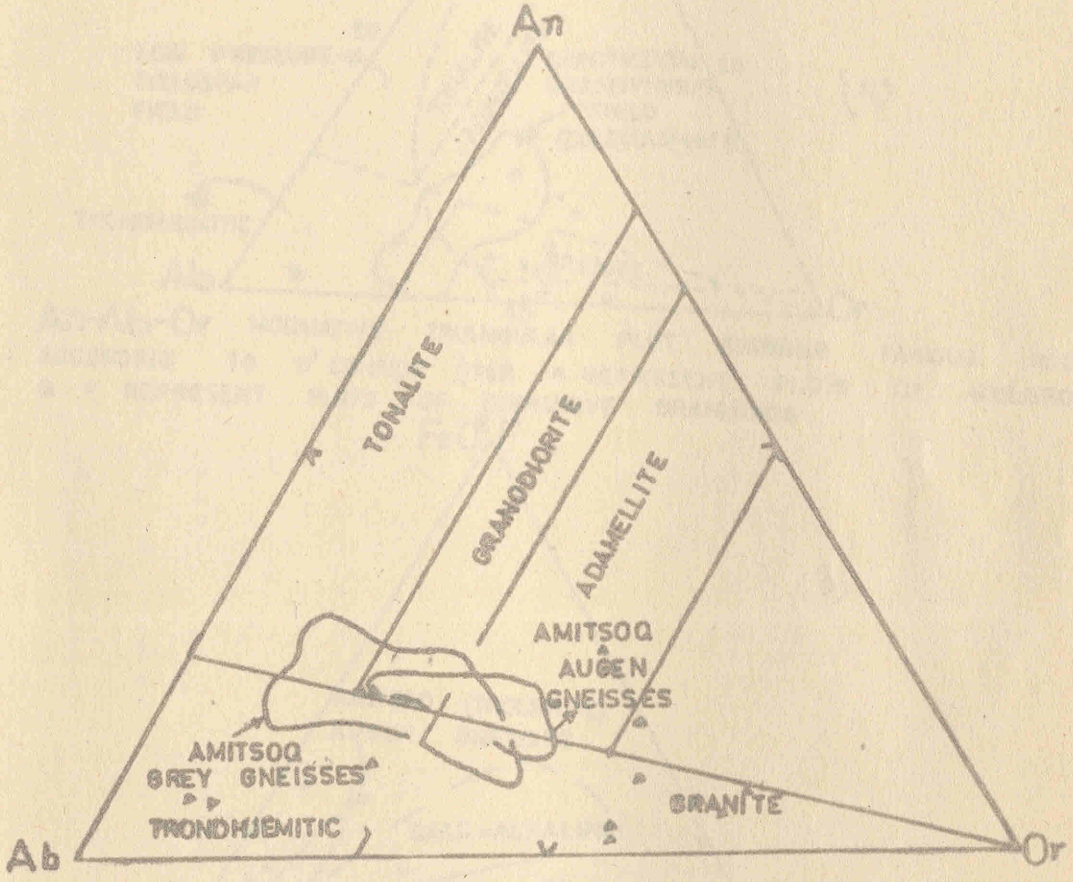
AFM DIAGRAM SOLID LINES SEPARATE FIELD OF THOLEIITIC CALC – ALKALINE AND ALKALIC ROCKS, CONTINENTAL TRONDHJEMITIC TREND. THE GNEISSOSE GRANITES ARE MARKED BY ▲ AND INTRUSIVE GRANITES MARKED BY ● PLOTS SHOW CALC – ALKALINE TREND. AFTER BARKAR & ARTH (1976).

Fig. No.



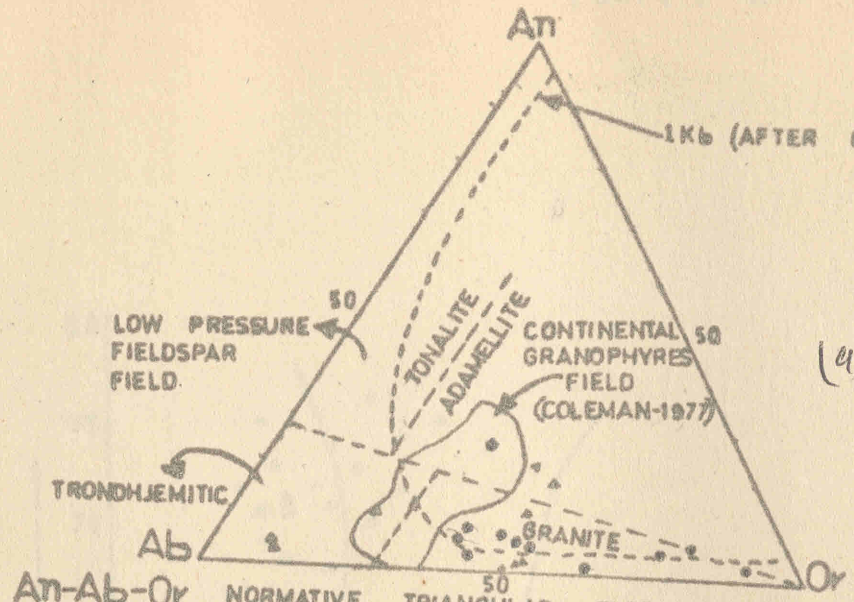
$CaO - Na_2O - K_2O$ TERNARY VIARIATION DIAGRAM OF INTRUSIVE GRANITOID (SOLID CIRCLES) AND FOLIATED GNEISSOSE GRANITE OF SALKHALA GROUP OF GULABGRAH AREA. THE FIELD DIVISIONS OF ROCKS ARE AFTER GLIKSON (1979).

PLATE-65a



TERNARY PLOT OF NORMATIVE Ab – An – Or FOR THE SALKHALA GNEISSES. FIELDS FOR THE AMITSOQ GNEISSES ARE FROM MCGREGOR (1975), THE CLASSIFICATION BOUNDARIES FROM O'CONNOR (1965).

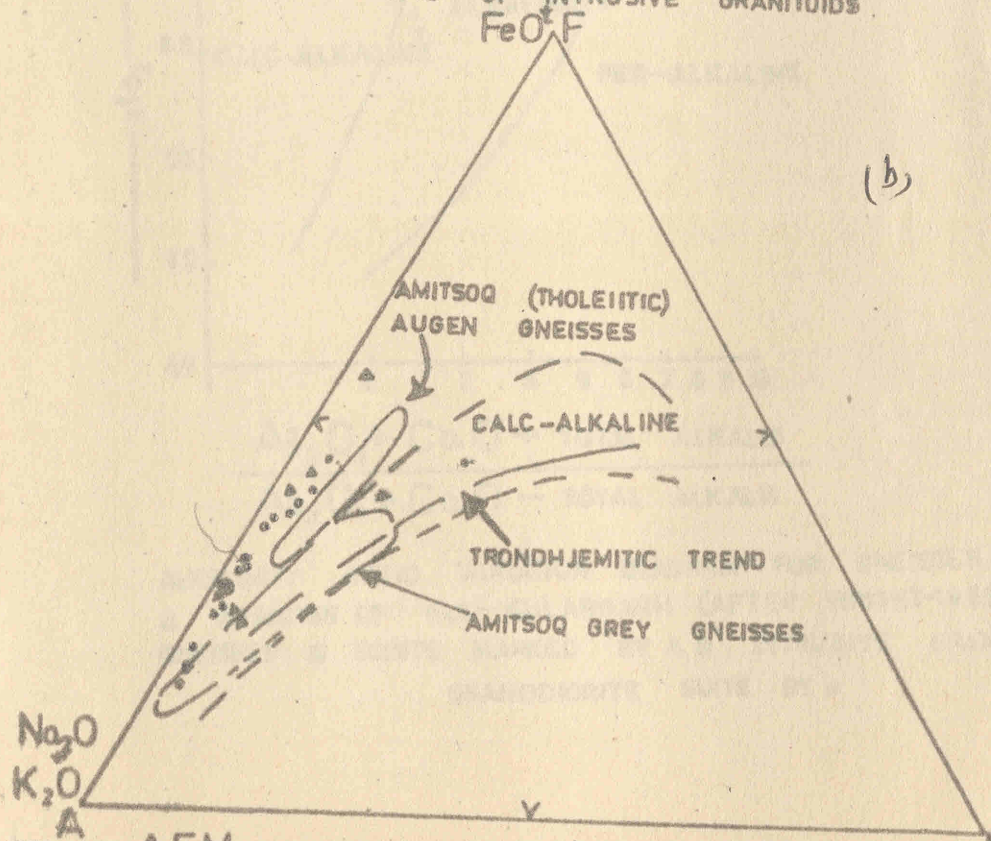
PLATE-66



(a)

An-Ab-Or NORMATIVE TRIANGULAR PLOT SHOWING VARIOUS ROCK TYPES ACCORDING TO O'CONNOR (1965) ▲ REPRESENT PLOTS OF GNEISSOSE GRANITES & ● REPRESENT PLOTS OF INTRUSIVE GRANITOIDS

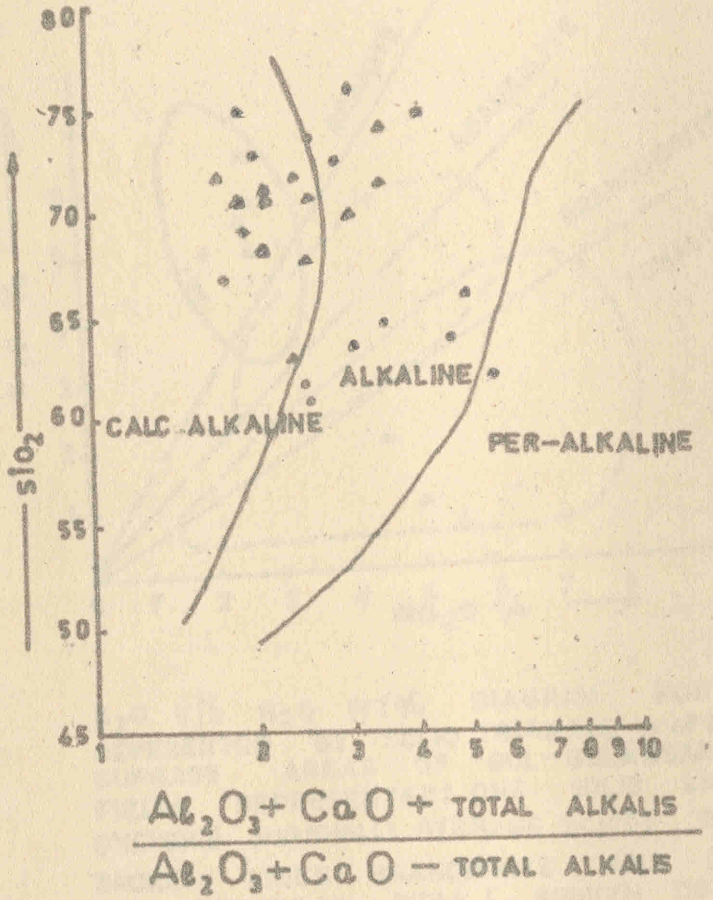
Fig. No.



(b)

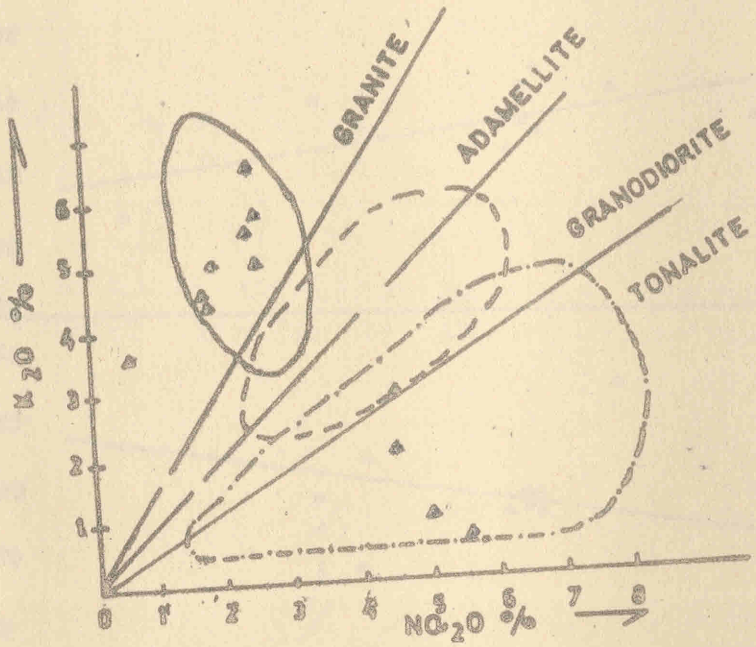
TERNARY AFM PROJECTION OF ANALYSED SAMPLES OF INTRUSIVE GRANITOIDS MARKED BY ● & OF GNEISSOSE GRANITES MARKED BY ▲. THE OTHER FIELDS SHOWN IN THE FIGURE ARE AMITSOQ AUGEN & GREY GNEISSES FROM MCGREGOR (1975). THE THOLEIITIC & CALC-ALKALINE FIELDS & TRONDHJEMITIC TREND ARE FROM BARKER AND ARTH (1976).

PLATE - 67



ALKALINITY RATIO VARIATION DIAGRAM FOR GNEISSES & GRANITES OF GUL – GULABGARH (AFTER WRIGHT-1969) GNEISSES & SCHITS MARKED BY Δ & INTRUSIVE GRANITE – GRANODIORITE SUITE BY •

PLATE - 68

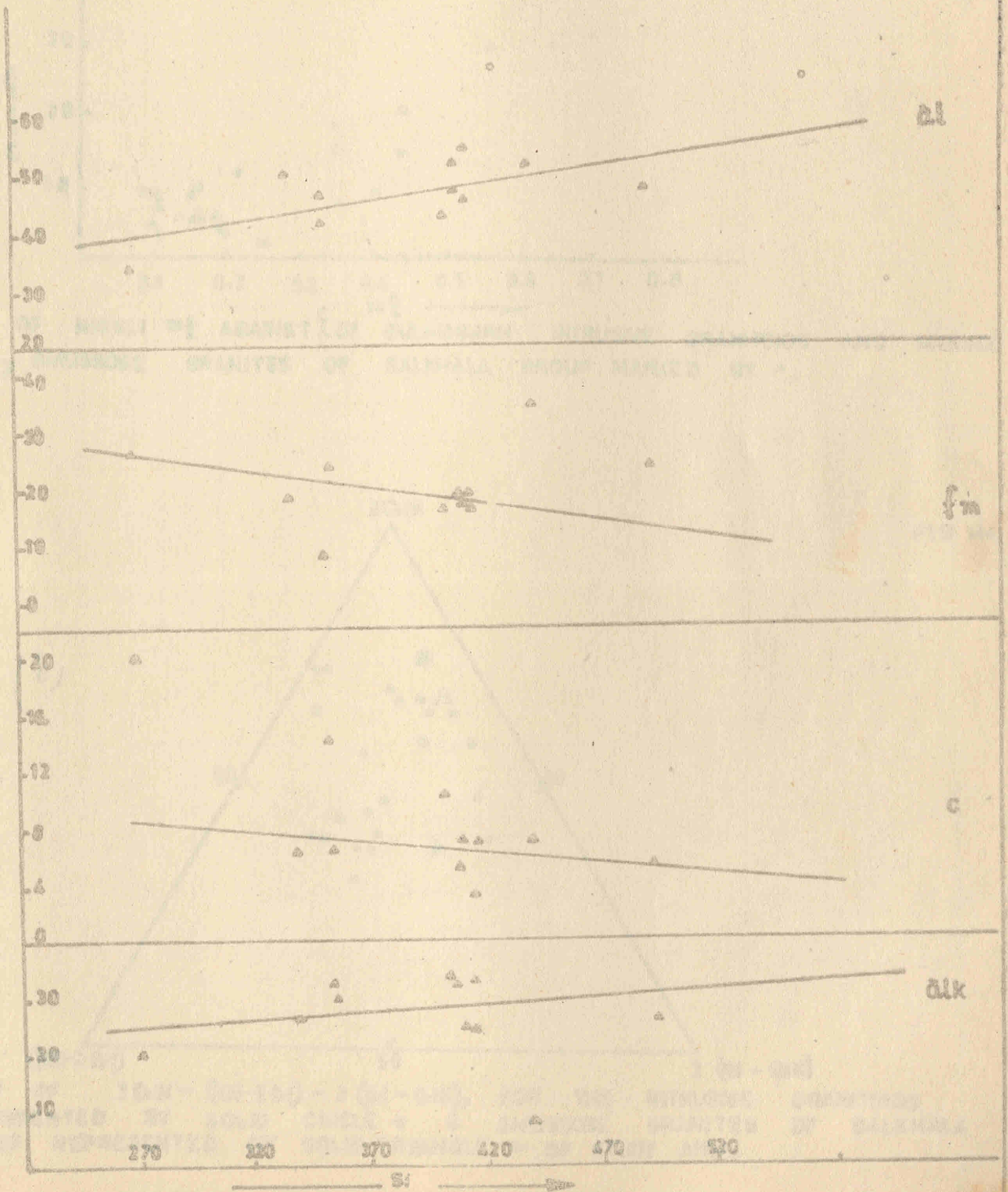


K_2O V/S N_2O WT% DIAGRAM FOR THE GNEISSES REPESENTED BY SOLID TRIANGLE ▲ OF NOACH, TUKSUN, SUPRASS AREAS OF GUL-GULABGARH UDHAMPUR-DISTT. FIELDS REPRESENTED: ONE SOLID LINE K-RICH PARA-GNEISSES JAVANHALLI AVERAGE SCHIST BELT KARNATAKA; BROKEN LINES GRANODIRITE AND GRANITIC GNEISSES OF PENINSULAR INDIA; BROKEN DOTTED LINES TONA-LETIC AND TRONDH-JEMATIC PEBBLES OF DHARWAR CONGLOMERATES. (NAQVI et al., 1980)
PRESENT AREA OF STUDY: 1. K-RICH PRRAGNEISSES
2. GRANODIORITE & GRANITE-GNEISSES

(9)

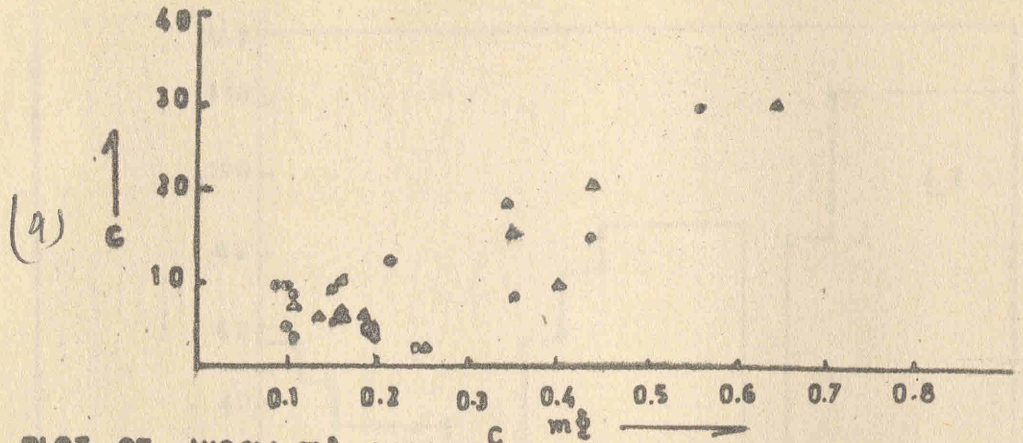
PLATE 70

Fig. No.



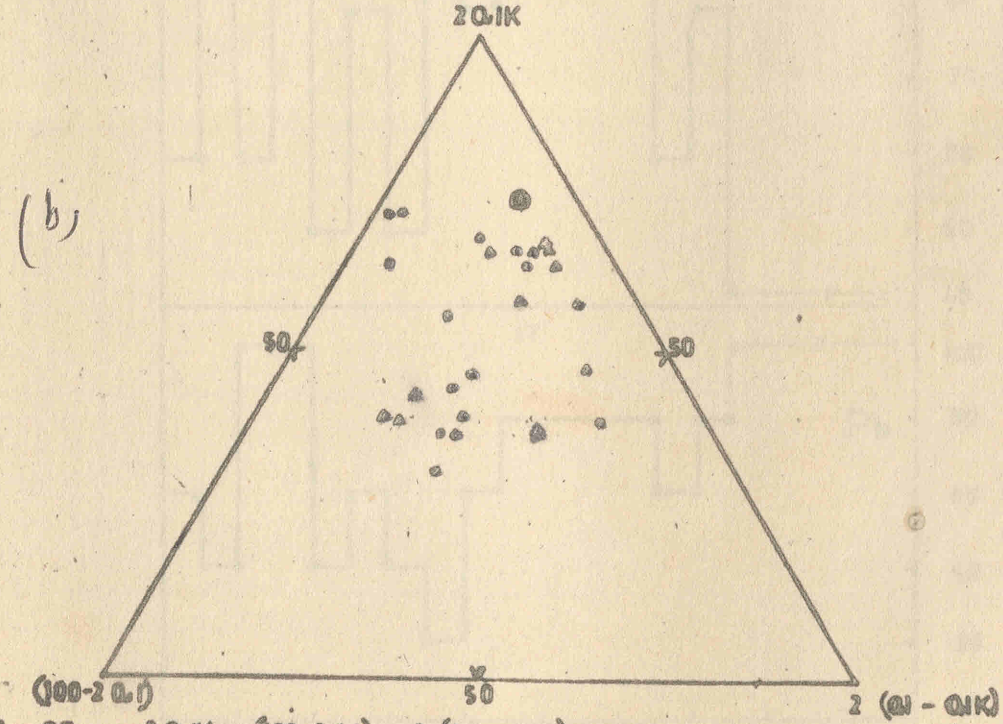
NIGGLI VARIATION DIAGRAM OF GNEISSOSE GRANITE AND GNEISSES ROCKS OF SALKHALA GROUP OF STUDY AREA.

PLATE-71



PLOT OF NIGGLI $\frac{c}{mg}$ AGAINST $\frac{c}{mg}$ OF GULABGARH INTRUSIVE GRANITOIDS AND MARKED BY ○, GNEISSOSE GRANITES OF SALKHALA GROUP MARKED BY △.

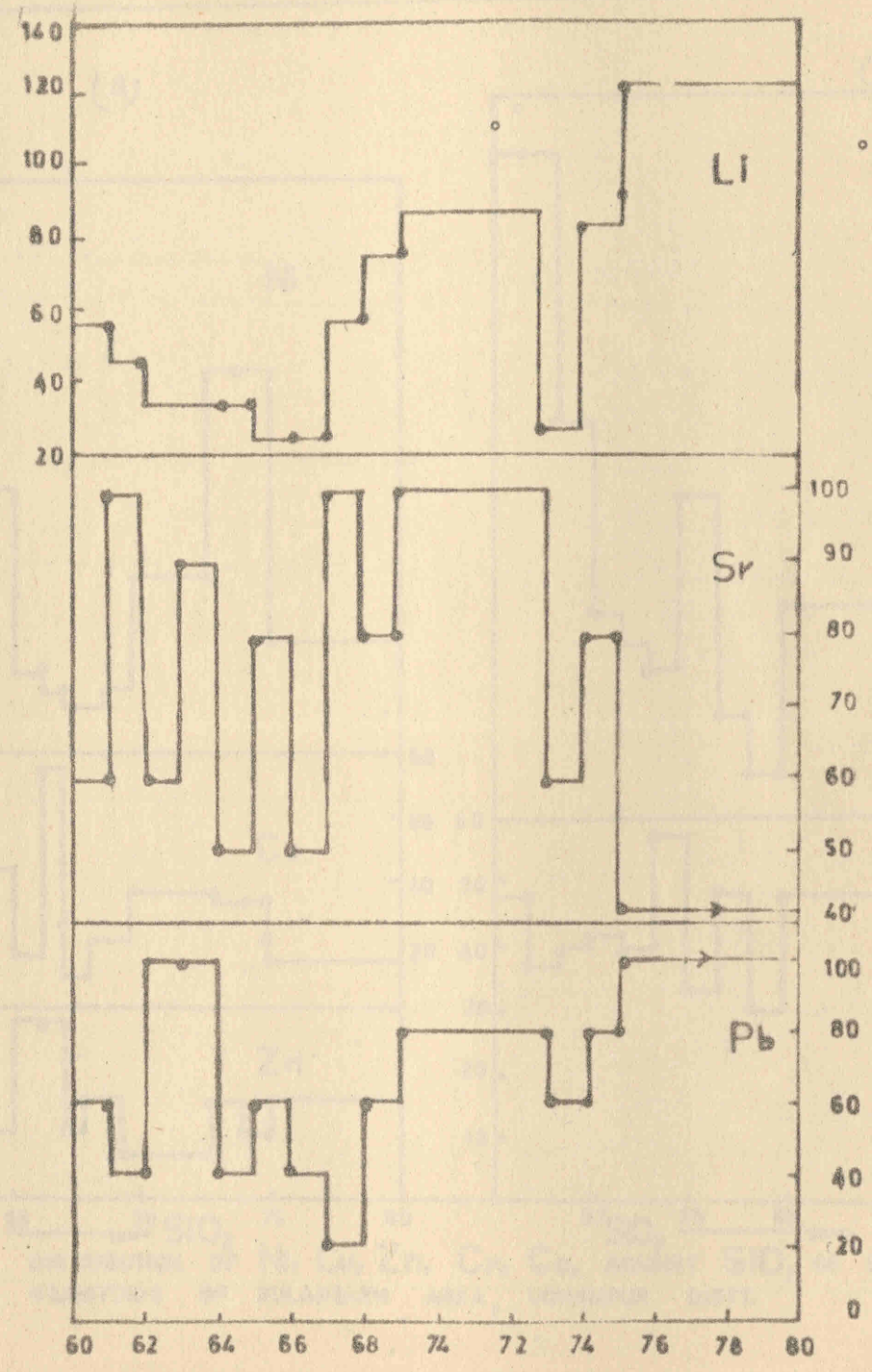
Fig. No.



PLOT OF $2Q.IK - (100-2Q.I) - 2(Q.I - Q.IK)$, FOR THE INTRUSIVE GRANITOIDS REPRESENTED BY SOLID CIRCLE ○ & GNEISSOSE GRANITES OF SALKHALA GROUP REPRESENTED BY SOLID TRIANGLE △ OF STUDY AREA.

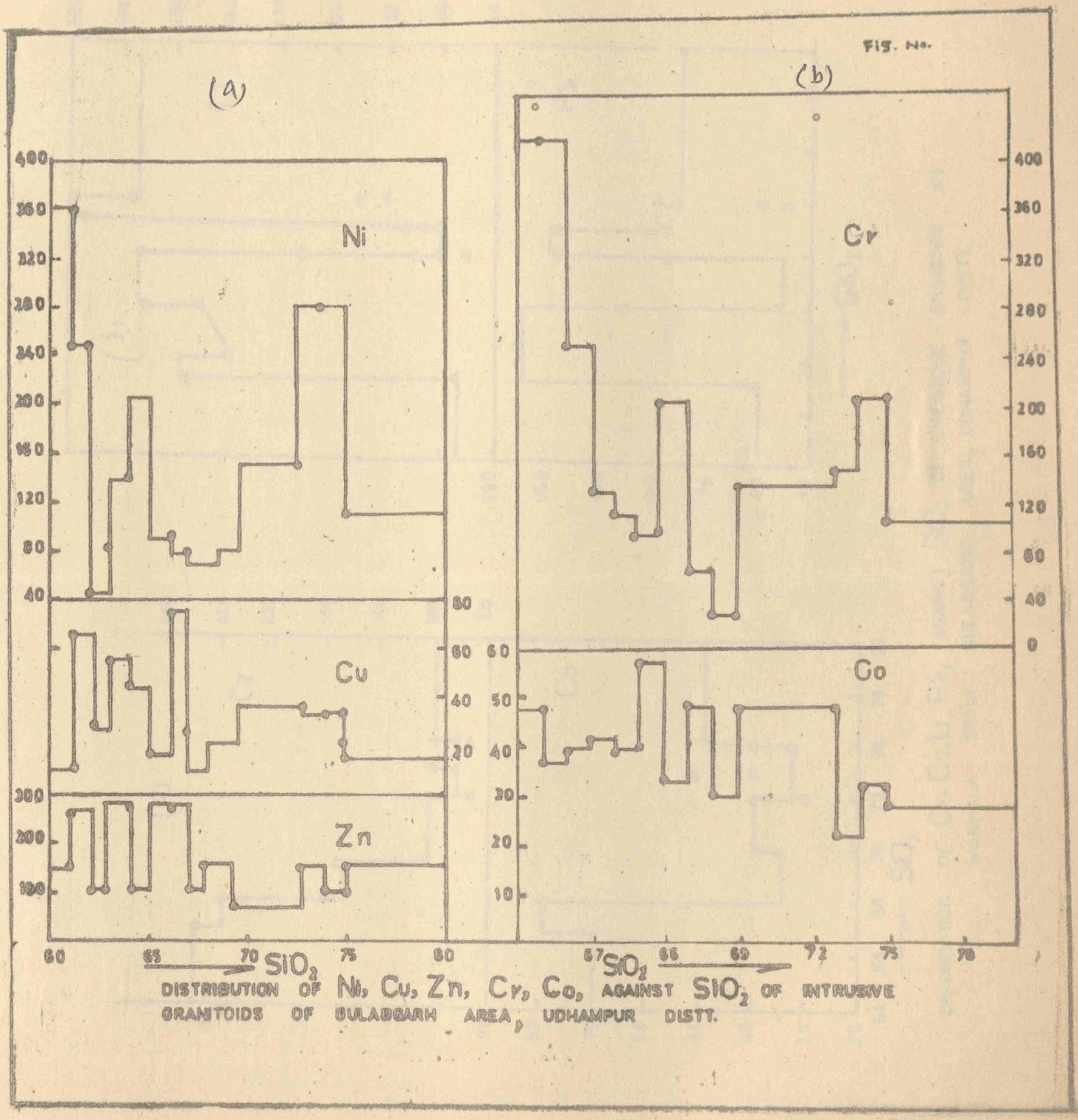
PLATE-72

Fig. No.



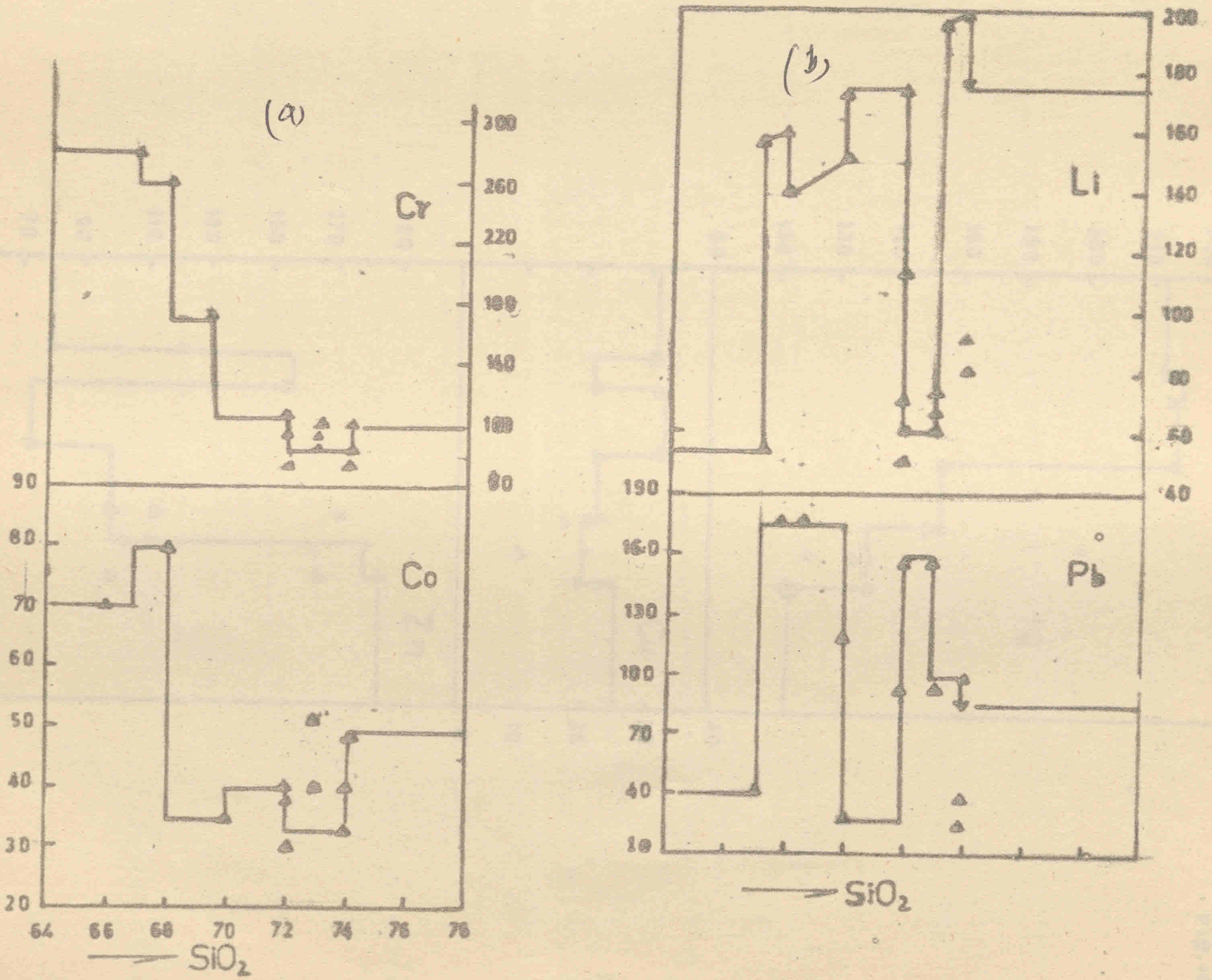
DISTRIBUTION OF Li^{++}, Sr^{++}, Pb^{++} AGAINST SiO_2 OF INTRUSIVE GRANITOIDS OF GULABGARH AREA, UDHAMPUR DISTT.

PLATE-T3



DISTRIBUTION OF Ni, Cu, Zn, Cr, Co, AGAINST SiO_2 OF INTRUSIVE GRANITOIDS OF SULABGARH AREA, UDHAMPUR DISTT.

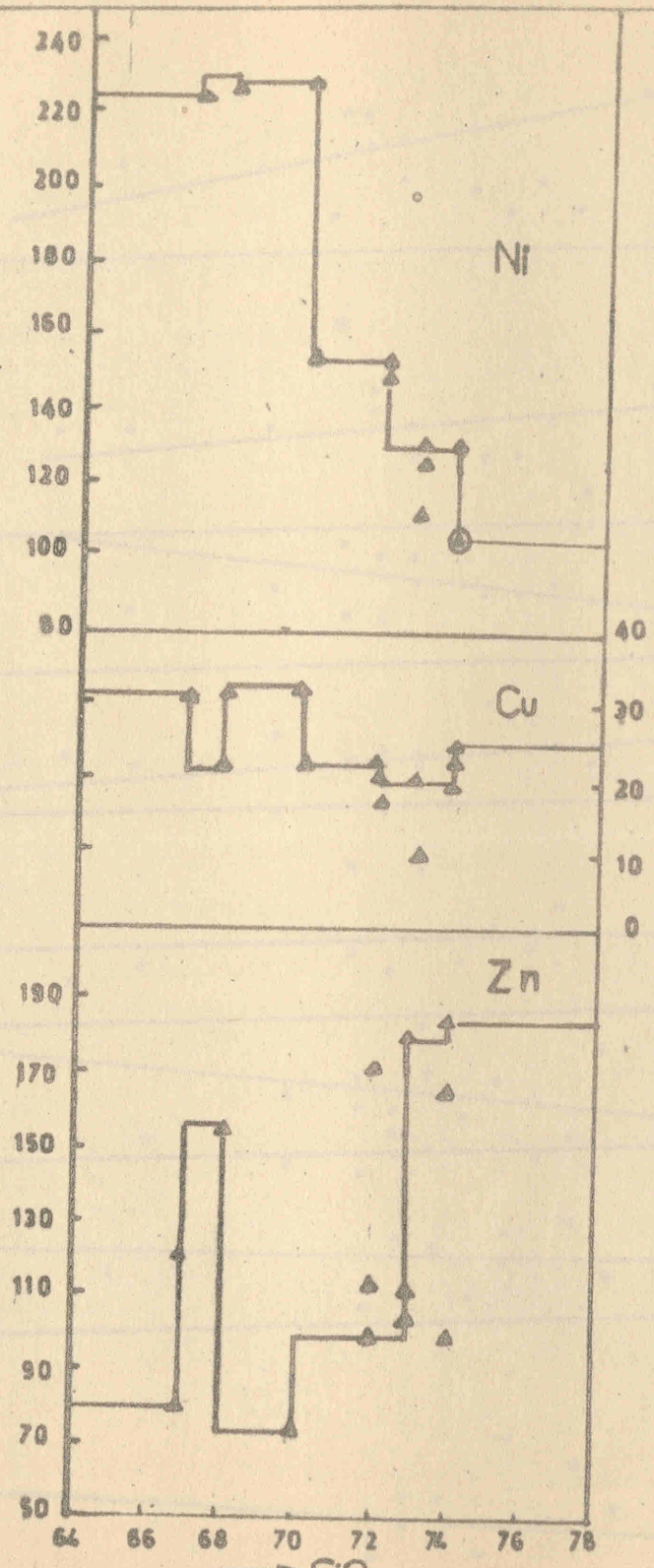
PLATE - 74



DISTRIBUTION OF Cr, Co, Li, Pb, AGAINST SiO_2 OF GNEISSOSE GRANITES OF SALKHALA GROUP GULABGARH AREA, UDHAMPUR DISTT.

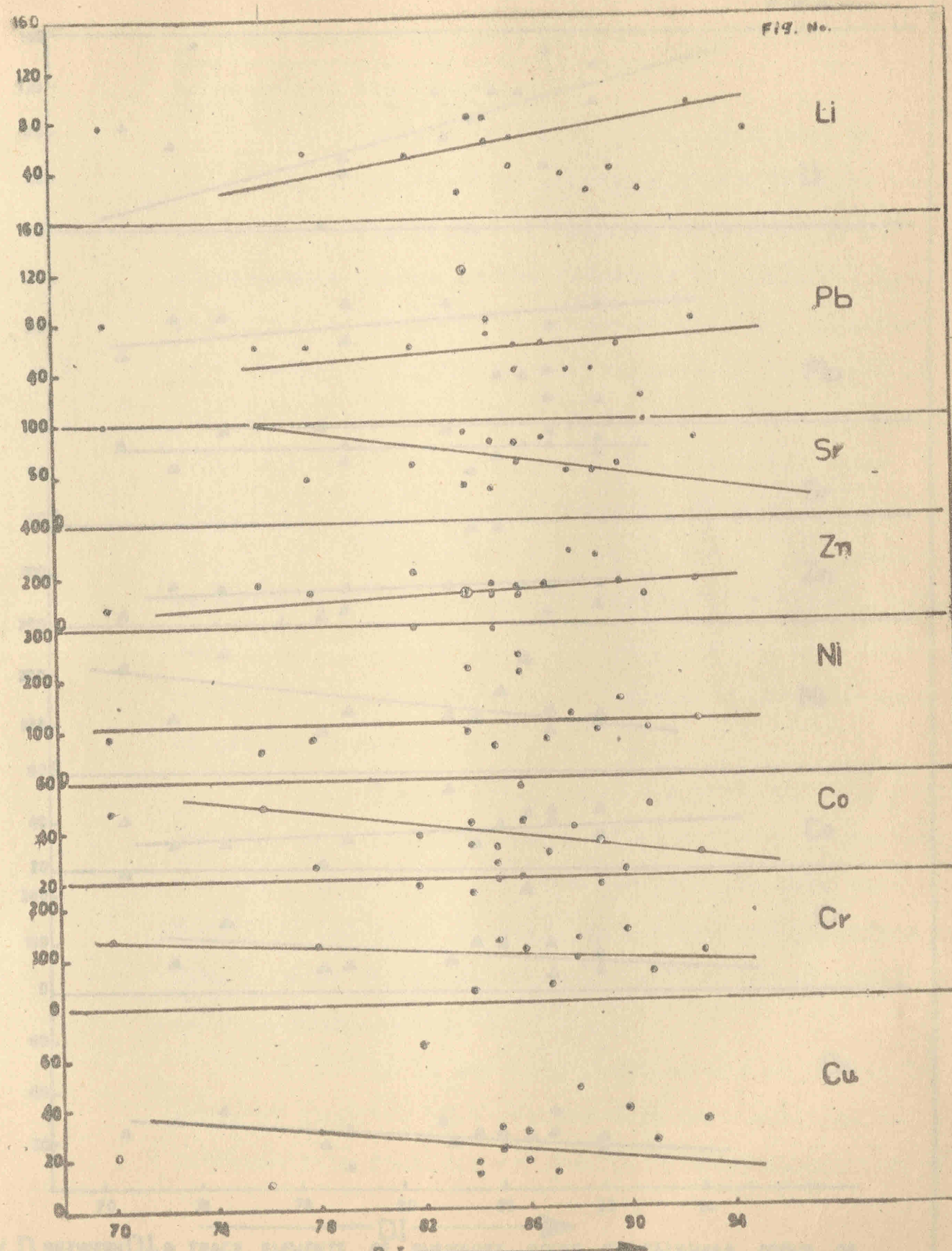
PLATE-75

Fig. No.



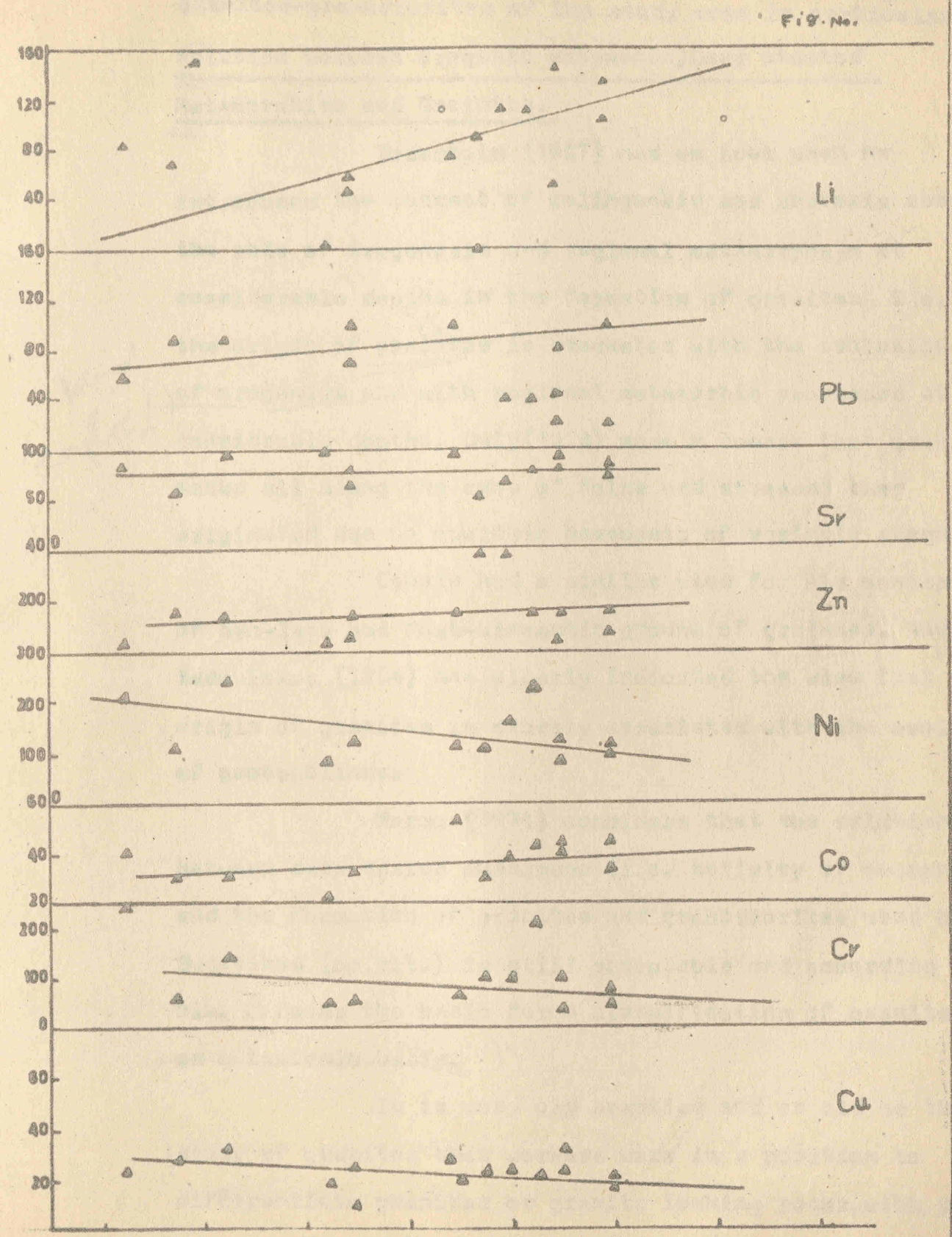
DISTRIBUTION OF Ni, Cu, Zn, AGAINST SiO_2 OF GNEISSOSE GRANITES OF SALKHALA GROUP GULABGARH AREA, UDHAMPUR DISTT.

PLATE-76



V.D. BETWEEN D.I. & TRACE ELEMENTS OF INTRUSIVE GRANITOIDS OF STUDY AREA.

PLATE-77



V.D. BETWEEN D.I & TRACE ELEMENTS OF GNEISSOSE ROCKS OF SALKHALA GROUP, OF STUDY AREA.

CHAPTER - VIII

CLASSIFICATORY MODELS OF GRANITOIDS

This chapter presents theoretical as well as pragmatic classificatory models of granites of classic areas in general and granites-granodiorites of the study area in particular.

Relation between orogenic movements, Deep seated Metamorphism and Graintes.

Sederholm (1907) had an idea when he introduced the concept of palingenesis and anatexis about the role of Orogenesis and regional metamorphs-m at considerable depths in the formation of granites i.e. the origin of graintes is bracketed with the evolution of orogenies and with regional metamorhic processes at considrable depths. Daly(1914) made a remark that granites occur all along the axes of folds and stressed they originated due to orogenic movements of variable strength.

Eskola had a similar view for his conceptions of Syn-late and Post-kinematic groups of graintes. Recently, Sudovickov (1964) has clearly indicated the view that the origin of granites is closely associated with the evolution of geosynclines.

Marmo (1971) considers that the relationship, between deep seated phenomena (i.e. activity of geosyncline) and the formation of granites and granodiorites used by Sudovikow (op.cit.) is still acceptable and according to him, it forms the basis for a classification of granites on a tectonic basis.

It is very old practice and as old as the study of granites that workers were in a position to differentiate granites or granite looking rocks, with var-ied

compositional difference between granite types, into different groups.

Holmberg (1858) observed that there are older gneissose and younger massive granites, similar to one observed by the author in this study area and Wilk(1876) discussed its genetic problems. Sederhom (1891) also distinguished between the older usually greyish and gneissose granite rich in plagioclase and the younger pink granite rich in microcline in Finland. Then further granite investigations, in eastern and northern Finland gave rise to a third group of granites which are older than rapakivi and which have a composition close to that of granites of the second group but have many features common with the rapakivi granites(e.g. Sederholm,1928). Granites or granite looking rocks of different ages, derived from different sources having different setting with country rocks, have led Eskola (1932) to divide the granites into three magmatectonic groups which was later on accepted fully by Bowen (1947). These magmatectonics are :-

1. Synkinematic Granites

These granites are formed at an early stage of an orogenic cycle. That is those granites or granite looking bodies have which formed before the first pre-Cambrain orogeny started and it includes older Archaean granites of Fennoscandia including many primary

gneisses and hardly any non-oriented rocks at all belong to this group. These granites form concordant (with country rock) intrusions and is easily comparable with granites of Sederholm's group I. Eskola considers that these synkinematic rocks which donot have true granite composition had derived from Juvenile magmas but this does not mean that actual granites among them are likewise magmatic. Later on, this was expressed by him that potash feldspar of synkinematic granites may be of metasomatic origin. In a similar manner gneissose granites, of Noach, Abbas and Tuksun areas of present study which have conformable contacts with the slaty lithounit of Salkhala group are proposed by the author to belong to this group.

Further acid, and coarse grained rocks containing large porphyroblasts of potash feldpar, mostly microcline in matrix of granodiorite composition are common within the areas characterized by the presence of argillaceous schists and gneisses. The synkinematic rocks form large and fairly homogeneous masses. Synkinematic granites, often occur in huge batholiths which donot have sharp contact with the country rocks but show gradational contacts with schists and phyllites but there can be a sharp contact in case there is a composition difference between the batholith and country rocks e.g. amphibolite. In all probability, the contacts of batholith with country

rocks tend to be concordant which is a characterstic feature of Synkinematic granites. These batholiths have certain features in common, such as the banding of alternating acid (granitic) and more basic (pelitic to amphibotitic)portions see (Pl.16 Fig. e & f) of the study area in the Salkhala Group belt.

Bott (1957) remarked that Dartmoor batholith of England is not a homogeneous mass but infact largely comprises tonalites, adamellites and granodiorites and true granites if any in this group have formed due to recrystallisation due to potash metasomatism which have led to the formation Microcline, thus producing the present rocks. A similar phenomenonis observed in Synkinematic areas of Finland or any other pre-Cambrian areas.

Buddington (1959) from his studies with the granites of North America related the structures of granite pluton with depth of emplacement. For example, he concluded that granites emplaced in the epizone are almost wholly discordant; those granites emplaced in the mesozone are complex; those which are common in most basement complexes from Pre-Cambrian to early Cretaceous age are partly concordant and partly discordant, finally those granites which are emplaced in the catazone are predominantly concordant which is the characterstic feature of rocks being regarded as synkinematic type. Another charactertic feature of

synkinematic granites is that these rocks are highly metamorphosed sediments or igneous bodies by later geological events. Whitten (1959) has investigated the composition of Donegal Granite in Eire. He found that in the " granite" mainly of granodiorite composition with minor change in composition.

Marmo (1962) who studied granites of Sierra leone, to south of the Kangari Hills, concludes that there is a large area composed of apparantely homogeneous, gneissose, sykinematic rock granites and detailed study of this batholith showed very well marked nonhomogeneity. For example large and homogeneous diorite bodies are enclosed by synkinematic granodiorite with local patches of granite composition and the contacts between the diorite and granodiorite are gradational over wide area.

Chemical and Mineralogical Characters of Sykinematic group of Rocks.

Marmo (1962) the chemical analysis of Sykinematic sialic rocks of sierra leorie as shown as SiO_2 ranges from 76.16 % 68.38% and Al_2O_3 from 14.07 to 16.25 in granodiorite while Soda content varies from 5.89 to 4.27 and Potash content varies from 0.72 to 1.59 and in all probabilities RiO_2 is less than 1 % Lyakhovich and Chervinskaya (1965) who studied the Ukraine and the Russian Platform and according to them the synkinematic rocks of these areas have the high content of sphene, apatite and magnetite as

well as the presence of apatite with pleochroi-c cores and rounded grains of zircon indicate the important role played by sedimentary material in the formation of these old granites. There is heterogeneity in acid rocks as these rocks show varying distribution of magnetite. Synkinematic granites indicate considerable variation in the mafic constituents e.g. Mg, Fe, and Ca

Chemical composition of the synkinametic Sialic rocks (Wt %).

(After Marmo, 1962 p.29, 1963 P.31.)

	Quartz diorite Sierra Leone	Grano-diorite east of Makera Sierra Leone	Grano-diorite Sierra-Leone.	Gulabgarh Salkhala Group Present study area Granite	Granodiorite.
SiO_2	76.16	69.85	68.36	73.30	69.05
TiO_2	0.01	0.19	0.33	0.42	0.48
Al_2O_3	14.07	15.48	16.25	14.42	15.83
Fe_2O_3	1.06	0.71	1.04	2.19	1.97
FeO	0.05	1.90	2.38	1.26	1.73
MnO	0.13	0.10	0.04	0.17	0.09
MgO	0.13	2.93	1.08	0.45	0.94
CaO	1.75	2.95	3.48	1.03	2.39
Na_2O	5.89	5.54	4.27	2.65	3.46
K_2O	0.72	1.87	1.59	3.79	3.74
P_2O_5	0.06	0.26	0.16	0.31	0.25

It is worthnoting that potash feldspar of synkinematic granites is younger than the other consituents of the rock. And true granite composition is occasional and usually the granite composition is attained only due to granitization. Among the most acid members such a sequence is quartz diorite and it is only granite which is younger than other acid variants of Batholith (Raguin, 1957).

Cannon (1965) while discussing the granites of the British Guiana concluded that some of the synkinematic rocks there have acquired granite composition probably through granitization which is in itself a result of potash-metasomatism.

Roubalt D LaRoche, 1965; Chin et al.1963 concluded that the hetrogeneous structure of the pluton is the process of granitization mainly in situ.

According to Marmo (1971) microcline is always younger than any other consituent of the rock, occurring almost as infilling of fissures or in the interstices of the other mineral grains of the rock. He believed that the granite in the fractured zones has caused granitization in the environment or the granite has been produced by an accumulation of potassium present in the ancient sediments transported towards the fractured area ie. the regions of low pressure.

Synkinematic rocks contain mostly porphyroblasts of potash(feldspar) microcline of high triclincity

in large number than the potash feldspar but oligoclase and quartz may occur there in a similar way. The porphyroblast may vary in shape and size in such rocks some porphyroblasts are rounded or irregularly shaped, but they may develop well defined crystal faces. But one thing is clear as envisaged by Somonen (1948) while describing granitization of granodiorite, that the synkinematic intrusions of southern Finland as magmatic and the content of the alkalies especially K_2O has increased as a secondry phenomena and according to him such alkali increases is especially typical of the gneissose varieties. And the apparent gneissosity is in his opinion caused by mechanical processes.

Biotite is another mineral which is typical of synkinematic rocks which are called biotite granites or one mica granites. The presence of biotite may be attributed to the granitization of mainly peltic and arkosic sediments if the phenomenon is accepted. The biotite of synkinematic granite is characteristically dirty greenish in colour and is strongly pleochroic. Brownish biotite is more characterstic of the rocks of diorite or quartz diorite rocks. Synkinematic granites also contain muscovite in addition to biotite what is normally called two mica granite. Almost similar mineralogical and Chemical assemblages occur in the metamorphic belt of Salkhala group and the accessories appear to be of same mineral

assemblages as outlined above in the foregoing paras. The brief account of the main features of the synkinematic granites of the study area can be summed up in the following lines:-

1. The rocks of such group are non-homogenous.
2. These are concordant with the country rocks.
3. These rocks show gradational contacts with argillaceous schists, gneisses and phyllites and do not show sharp contact.
4. Granitization due to metasomatism is another feature of these rocks which is responsible for attaining present true granite composition among other acid members of the group and even then these granites are subordinate to quartz diorite, granodiorite etc.
5. Shortly the rocks are neo-magmatic but later on rendered gneissose by subsequent crystallisation and regional metamorphism.
6. The chemical mineralogical assemblages as outlinad above.

The examination of thin section and field evidences of the gneissose granites of Salkhala group of study area conform very much with the characters of synkinematic granites as described above. These rocks are distributed around Noach, Tuksun, Adbes and suprass in a strict direction showing concordant relationship with the slate, phyllites and schists of northern belt of Angrala and just north of Baddar in the field by observing the thick quartz vein wedging along the foliation of phyllites and slate (Pl.15 Fig.e).

The granite rocks in this belt show conspicuous evidence of grantization which is substantiated when the common feature of fedspathization is noticed in thin sections viewed under microscope together with albilization (Pl.23 Fig. b).

There is clear gradation of schists with gneisses as such later don't show contacts all with the country (pl.15 Fig. d) rocks and finally it is discovered that the microcline is always younger than any other constituent of the rock, occuring as porphyroblasts and also occur as interstitial (pl.24 Fig. a).

And the accessories found in such rocks of Salkhala group of pre-cambrian age are mostly magnetite, euhedral sphene, euhedral apatite and little epidote as welll These rocks are showing granitoid texture(Pl.24 Fig.f) as such appearto be magmatic initially of course derived (PL-22 Fig b) as secondary magma due to anatexis. This conforms with the observations of Simonen (1948) for synkinematic granites of southern Finland. Migmatites found locally around Tuksun nala are infact injection gneisses which are produced when quartz feldspathic material permeats through the metasedimentaries.

Late-Kinematic Granites

This group of rocks belong to relatively late stage of orogenesis. As Wagmann(1930) has pointed out that they often behave as diapiric like intrusion in the axial culmination of old mountain chain and it is equivalent of group II of Sederholm. Eskola(1932) concluded that the Late-Kinematic granites are much close to the final crystallisation differentiation in overall composition. According to him they are also uniform potash-rich granites, though they contain almandite or cordierite that have never been entirely dissolved.

Eskola (1955) revised his earlier opinion and remarked that these are typical eutectoid granites which are common in this group and among them "metasomatic types with preserved ghostly relics or old design of stratification are fairly common." Also,"they are probably always mixed with rocks formed by metasomatic replacement. They have a liquid phase from which the crystalisation has taken place in a truly magmatic way".So in (1960) he prefered to use Serokinematic instead of Late-Kinematic

Marmo(1971) remarked that most of the late-Kinematic graintes are pink or grey, fine grained to medium grained and mostly aplitic consisting of microcline-albite-quartz assemblages.

These are rarely gneissose but may contain ghost like relics inheriting gneissose structure. Eskola (1950) concluded that true granite composition is the most common among granites belonging to this group. They have similar characteristies with the disharmonious granites of Walton(1955) and are known to be indentical with the serorgenic granites of Wahl(1936). They are probably late orogenic graintes of Saksela (1936) and Read's intrusive granites are also of Late-Kinematic graintes.

Polkanov (1955) while discussing mainly granites considered here as late and Post-Kinematic was against the widening of the conception of granite and stressed that this name should be used only for magmatic origin. Perin and Roubault pointed out that texture of magmatic origin is the characterstic only of the so-called late and post kinematic granites, whileas the texture of

the Synkinematic granites on the other hand is very characteristic of granitized rocks. As concluded by Eskola, the process of hydrothermal granitization of synkinematic rocks may be contemporaneous with the formation of late-kinematic granite bodies. This possibility has been approved by Verdananz (1957) and his opinion is based on Potassium/argon age determinations carried out by Polevaga(1956) and by Gerling (Polkanov,1955) Who confirmed the mica age for Synkinematic rocks in the ukraine as 1800 m.y but the microcline age of the same rocks is only 1500 m.y. In the late-kinematic granites,both muscovite and microcline gave the same age of 1500m.y. Marmo(1958) had confirmed this hypothesis on a petrological basis.

The field characteristics of Late-Kinematic granites are that these rocks cut the older formations discordantly including synkinematic gneisses and granodorites. They may form bosses and stocks of considerable size or dykes of varying lengths. But none of these occurrences possess chilled margins. For example in sierra leone and at Pohjaslathi, the

dykes are composed of pink , fine grained aplitic granite and it cuts any kind of rock from granodiorites to gabbro. The Late-Kinematic granite of Sula Mountains in Sierra leone, does not contain only potash feldspars but also contains albite in excess of microline accompained by large amount of epidote which corresponds to granodiorite of albite epidote facies of Ramberg (1952).

The sharp contacts and effects of granitization are other characterstics of Late-Kinematic granites. The Late-Kinematic granites in the northern cameroons may also belong to the age of 500 m.y." the granites ultimes of French geologists (Koch, 1959). These granites contain microcline albite granites and sometimes skialithic remnants in abundance. The most typical mineral compositions of granites which characterizes the Late-Kinematic group of rocks is that microcline is in excess of Plagioclase, rich in albite, quartz and micas. The micas comprise muscovite and biotite, the latter is often present as either along or together with muscovite. The triclinicity of the microclines belonging to this group is very high about

0.9 Marmo, Mikkola,(1955), Marmo and Permingeat (1957). Perthite may or may not be present because most of the late-Kinematic granites of Finland examined by Marmo(1971) contain microcline which is very weekly perthitic or non-perthitic. The intensely perthitic microcline is however present in some syenites and mozonites and these rocks have been some times described as Late-Kinematic group of rocks.

Another conspicuous feature of the microcline of Late-Kinematic granites is that they contain very small amounts of Sodium or they may almost be without it which has a direct imprint on high Triclimcity of on microcline.

Microcline and other constituents in Late-Kinematic are almost found at the same time but, their microcline which forms interstices or sometimes occur along the grain boundaries is younger than other constituents.

Epidote bearing acid rocks are pink rather buff coloured granites in the field and these are called as albite-Microcline-epidote bearing granodiories.

Wilkman (1931) has termed such rocks as unakites and are found in Finland. It consists of pure microcline, albite, quartz, epidote and some chlorite. Micas are rare. From these characteristics of Late-Kinematic granites mentioned in forgoing pages, it is likely that granites of almost non-foliated type of Khor, Shidoul, Lar, area of study may belong to Late-Kinematic on the basis of following lines.

1. These are intrusives having discordant relationship against the country rocks, called Tanawals.

2. These are homogeneous in their mineralogical compositions with only one difference that is regarding quantity of each constituent and this variation in quantity of universal constituent gives rise to different rocks types forming granitoids.

3. These granites have perthitic feldspars with undulose quartz (Pl.3/ Fig. e).

4. There is small outcrop of pink or buff coloured granite in Shidoul top and on the right bank of Khour nala, which is just like pluton having discordant

relation with the country rock and it contains big grains of epidote in large number alongwith sphene and albite, microcline microperthite, (Pl. 26 Fig. d).

PL 34 Fig e

5. These granitoids show sharp contact with the country rocks and near north of Lar village enroute Gulabgarh the grey white colourd granites are finer than the rocks found in the centre of pluton, thus showing chilling effect along the walls of the country rocks which were cold at the time of emplacement of these granites which must have been relatively hot causing chilling effect locally.

6. Microcline Plagioclase(fresh ones)-quartz-epidote and even sphene, Magnetite and little micas together with altered hornblende are found in these rocks which from the above established mineralogy of Late-Kinematic granites found elsewhere in the world it is convincing to believe such granites to be very close to late-kinematic and as such is being proposed by the author.

7. These granites show granitoid texture which is conspicuous as straight and sharp contacts found between few sides of quartz and perthites or between perthites of

different composition (Pl.29 Fig. d&f). Which is an evidence to show that they are essentially crystallised from melt and later on these have been subjected to other events leading to metasomatic processes.

Post-Kinematic Granites.

According to Eskola(1932) Post-Kinematic granites are those which are emplaced when all movements have ceased that is, these must essentially be younger and without any stress evidences and is represented best by the rapakivi granites in Finland. Eskola considers Tertiary granites e.g. the granite of Baveno, Switzerland belong to the same class and in chemical composition these granites are true granites and can hardly be distinguished chemically from Late-Kinematic graintes. Laying much emphasis on rapakivi graintes which according to Sederholm (1928) are formed due to the assimilation of preexisting rocks by rapakivi. Later on, Eskola (1955) concluded that the rapakivi plutons are the purest magmatic granites. The presence of orthoclase is chief characterstic of Post-Kinematic granites.

Simonen (1948) outlined some features described as post-kinematic have in common e.g. the potash feldspar is of inferior triclincity and is to a large extent orthoclase and if microcline occurs, it is usually younger than other constituents forming interstitial infillings or minute veinlets and it may also occur patch wise in the orthoclase, the plagioclase is typically oligoclase, the femic minerals are represent by iron rich varities of biotite, sphene, epidote. Marmo (1975) according to whom, the most of the post-kinematic granites are actually orthoclase-oligoclase granites , all of them containing

orthoclase of different triclinicity and also patches of young microcline show well crosshatching. The microcline of microcline granites is, however, perthitic according to him. However, Solderholm (1928) linked these granites under Post-Kinematic classification with his III group of granites which are slightly younger than rapakivi granites.

Chayes (1950) after he studied the granites of westerly and Bradfor, Rhode Island containing orthoclase, concluded that these granites are somewhat uniform in composition and the simplest explanation for such homogeneous rocks according to Marmo (1971) would be their formation by direct crystallisation from a magma of approximately the similar composition. And also microcline-albite granites with extremely uniform composition can be thought to have been formed by crystallisation from hydrothermal solutions as quoted by Marma (1971). Post-Kinematic granites are also reported from Alpine region by Eskola (op.cit.) and also from the Alps and Himalayas by Gysin (1948,1956). The Tertiary granite of skye, likewise contains perthitic and nonhomogeneous triclinic orthoclase and according to Tuttle (1952) the potash feldspar is mostly coarse perthite or orthoclase cryptoperthite etc.

Also coarse microperthite(over 65%) and quartz thus representing single feldspar granites are

reported by wager et. al.(1965) from the Granites of Skye. There are also granites in skye which contain basic plagioclase, quartz and orthoclase which Harker (1904) did not believe as true granites but instead hybrid rocks which must have originated by the degestion of basic rock by acid magma and he called this rock"marscoite". Another typical variety of granite is rapakivi which show inset of Potash grains envoloped by a shell of oligoclase but in the study area of Khour and Sihdoul, ther are porphyroblastic granodiorites, which contain oligoclase rims enveloping potash feldspar (Pl.32 Fig.b&d) and here the potash feldspar is of orthoclase perthite or microcline perthite.Another characterstic feature of Post-Kinematic granites is that these are cutting across the country rocks or early formed granite body. From the above discussion, it seem improbable for the author to discriminate between Post-Kinematic and late-kinematic group of rocks from the study of the granitoid outdrops of the study area because there is hardly any appreciable difference between the two and what appears that dykes,veins of leucogranites found around Lar village of apilitic veins cutting across the granitoids of intrusive nature are more akin to Post-Kinematic type of rocks. These rocks are found to be younger than intrusive Late-Kinematic granites. It may be mentioned that the non-foliated granitoids cut across

by diabase dykes near right bank of Shidoul-nala And also fresh leucocratic aplitic vein is seen cutting along the gneissose rocks of Syn-Kinematic granites near north west of Adbes village. These veins contain fresh orthoclase showing carlsbad twinning (Pl.24 Fig.f) Plagioclase crystals without much of sericitization and quartz grains without undulosity. These features point towards its freshness in nature and appears to have escaped further deformational events so in brief, the granitoids of the study area fall into two broad categories.

1. Syn-Kinematic Granites (Southern unit of Salkhala of Pre-Cambrian age group).
2. Intrusive Granitoid of Khour etc. as undifferentiated Late and Post-Kinematic group of Granites.

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Walton (1960) gave a model which explains fully, the granite problem so far as granitization of Syn-Kinematic granites and especially the origin of Late-Kinematic microcline-albite granites are concerned. This he named as anatectic model, but it does not explain well the formation of the most of the post-kinematic orthoclase bearing granites which could have been formed from late stage hydrothermal solution. Therefore the presence of water in the magmatic evolution of granites has received considerable attention of Tuttle and Bowen

(1958) on the basis of experiments under hydrothermal conditions conducted by them and they concluded that the sodium feldspar, as a component of perthite in same granitic rocks, has formed by unmixing during cooling indicating thereby that the rock crystallised at a temperature above the solvus in the binary system $NaAlSi_3O_8$ - $KAlSi_3O_8$. According to them, the temperature of crystallisation was higher than 600°C, perhaps as high as 900°C. Tuttle and Bowen remarked that the perthite could survive in the rocks which is suggestive of either extremely rapid cooling (op. cit) or due to the presence of water vapour which helps in the separation of Na feldspar from K-feldspars beyond the perthite stage and, therefore ,can act temperature indicator of their formations. As pointed out believed by them that many granites contain discreet plagioclase crystals, in the potash feldspar, as also noticed in study area (Pl 34 Fig. a), have recrystallised subsequent to magmatic crystallisation and the sodium content in potash feldspar is a measure of actual and final temperature at which crystallisation took place rather than the temperature of magmatic crystallization and the the amount of solid solution is a direct measurement of temperature the minimum temperature at which feldspar could have formed under equilibrium condition. Thus they classified granites into two broad groups.

I. Hypersolves granites which are characterised by the above absence of plagioclase except that where it occurs

as a component of perthite. This feature is observed in granitoid intrusive rocks and gneissose granites of Salkhala Group of study area (Pl. 32 Fig. d), which contain only one feldspars i.e., perthites.

II. Subsolvus granites which are characterised by both perthitic potash feldspars and plagioclase feldspars, of study area as seen in (Pl. 32 Fig. a).

Group-II can be further divided into three subgroups on the basis of albite content of the alkali feldspar.

A. with more than 30% Ab in solid solution.

B. with 15-30% Ab in solid solution.

C. with less than 15% Ab in solid solution.

This is a genetic classification in the sense that Groups *I and II A can be considered high temperature rocks and therefore owe their origin to crystallisation from anatectic magma and whileas those granites, which have been formed due to crystallisation or recrystallisation or in otherwords due to replacement, an origin of metasomatism fall in group IIC. The laboratory studies have revealed that it is not probable that the two feldspars having the compositions of feldspars of plagioclase and microcline of the group II C granites could have crystallised direct from a silicate melt. These differences suggest that the hypersolvus granites are magmatic derived from secondary melt whereas Group II C granites are metasomatic. Similar results have been obtained in the petrological study in respect of

intrusive granitoids and gneissose granites of study area. Keeping in view the principles of experimental work of Tuttle and Bowen (op. cit.) regarding the origin of granitic rocks, the granitoids of the study area have been classified into two groups.

I. Hypersolvus: These include intrusive granitoids exposed near east of Dandhala and north east of Khour village.

II. Subsolvus : A : Gneissose granites of Salkhala Group
B : Central part of Non-foliated granite granodiorite pluton.
C : Marginal area of non-foliated Intrusive Granitoids.

From the study of thin sections of intrusive granits it is evident that perthitic microcline grows at the cost of untwinned orthoclase (Pl.32 Fig. d) and it is possible only according to Marmo (1956 a), if (1) the crystallisation of of granite takes place at a relatively low temperature and below that temperature the microcline cannot survive(below 525°C), and (2) simultaneously the accumulation of crystallising material is sufficiently slow similar to metasomatic processes. It is a fact that in K-feldspars, the albite component decreases propertionally to the increasing tricunicity (op. cit.). From these argurments Marmo(op.cit.) considered such granitic rocks, rich in higly triclinic microcline to fall into the II C category of Tuttle and Bowen and he confirmed that Late-Kinematic granites of Eskola which frequently form migmatites readily fall into this group.

The Hypersolvus granites e.g.the younger granites of Nigeria, are rich in perthitic orthoclasse of varying triclinicity as the only feldspar except for the deuteric lamellae of albite forming interstitial or along the contacts of two perthites or any two crystals which look to be of later generation, must have formed after the main crystallisation of the rock was completed(Pl.32 Fig. a) and new called one feldspar granite by various ptrographers. The granites of central Khour and Shidoul village are bought into II A of the sub-solvus granites are also represented by rapakivi granites of Alpine mountains, Eskola(1956). They appear to be suitable examples of magmatic granites. Here the word"magma" is always refered in the thesis to correspond to secondary magma which has been formed due to anatexis. For all practical purposes the secondary remelted magma behaves like a parent magma with difference in their composition.

The post-Kinematic and Late-Kinematic granites containing perthitic microcline and plagioclase and no orthoclase, would belong to II B. The number of microcline-albite granites mostly of Late-Kinematic nature belong to group II C.

Group II C : Thus the petrological classification proposed by Marmo (1971) offers satisfactory principles to classifying the granitic rocks of the study area, which seem to be consistent with the grouping proposed by

Tuttle and Bowen (op. cit.), on experimental basis.

Lastly Marmo (1971) in his classification considered the following groupings.

(1) Hypersolvus granites are magmatic in a way that water is active during melting of the material.

(2) Group II A and possibly also II B may be explained on the basis of "Walton model" of Anatexis.

(3) Group II C includes granites of metasomatic origin. These groupings are almost the same expresed by Tuttle and Bowen (op. cit.) with only minor changes. In the light of classification of Marmo (1971) all granites of study area older and younger ones can be nicely classified.

Saksela (1936) while mapping in northern Finland drew the classification of granites on the basis of age and petrological characters. Thus, he divided the granites into synorogenic and Late-Orogenic groups which follow exactly the classification of Hogbom (1928) who used term syntectonic for the older granites which are concordant and the term Late-tectonic for the younger granites which are intrusive and discordant and independent of pre-existing tectonics. This classification is fully in agreement with the field evidencees of granites and gneissose granites of study area. The Syntectonic term can be applied to pre-Cambrian, concordent, gneissose granites and Augen gneisses etc. of northern limit of Salkhala Group, whileas

Late-tectonic term can be used for intrusion of younger granites which appear true granites and also are discordant to prexexisting country rocks, i.e. Tanawals of possibly of Lr - M Cambrian(?) age. These younger granites are found in and around Khour, Shidoul, Lar and Deolmarg villages of study area. However, the Dykes and veins of leucogranites of still younger age, found in the north east of Lar village also being grouped in late tectonic group of Hogbom(op cit).

Before Saksela proposed his classification, Wahl (1936) gave a similar classification. He thought that an area, which was once affected by an old mountain chain, the principal part of which had been removed by erosion, two kinds of granites are to be found. The older granites have the appearence of gneissose granite but according to him , they have i.e. older granites have been intruded into the surrounding partly sedimentary and partly volcanic material during early stages of orogenies and have attained the present stage of gneissose character due to subsequent periods of orogenies and he named such old granites as "Primorogenic". The younger granites considered by Wahl as "Serorogenic" are mostly pegmatitic and are intimately connected with and form part of migmatites. According to him, primorogenic granites are mostly granodiorites, whileas his serorogenic granites are mostly microcline granites. Later on Wahl (op. cit) introduced his third group of granites corresponding to third and fourth groups of sederholm, which he

called post-orogenic granites. Wahl's classification seems to be quite appropriate for similar rocks occuring in this field. Because in the area, older granites of Salkhala group are more foliated and exhibit gneissose-granitoid texture (op. cit.) and pegmatitic variety of graintes of somewhat younger age found in the north of Salkhala belt around Khour, Lar, Shidoul, Deolmarge villages are non-foliated However, the young granites seem to have undergone a mild regional metamorphism evinced by the presence of epidote and also later events of metasomatism including hydrothermal stage of alteration. This is in full agreements with Fuch's (1975) terminology as "Metagranites" which show epizonal charactors.

Then with the advent of idea of palingensis and metasomatism, Kennedy (1938) classified igneous bodies into volcanic and plutonic associations. According to him, the volcanic association is basic dominantly effusive, truly magmatic and non orogenic and whileas, plutonic association is granitic and granodioritic, associated with processes of assimilation and with the orogenic movement.

French school of geologists recognised three groups of granites viz. Syn.-, late-, and post-kinematic granites. Raguin (1966) felt that granites of cratonic region must have been formed due to reactivation of the granitic material within cratons, and proposed five-fold classifications:.

1. Orogenic Syn-Kinematic granites.
2. Orogenic Post-Tectonic granites.
3. Subvolcanic granites.
4. Granites associated with lopoliths (differentiation products from a gabbro)
5. Granites of cratons.

Walton's remark (1955) is more plausible in the sense that in regionally metamorphosed terrains, like the one observed in the study area, there is strong evidence of granitization, i.e. Soda and K-metamsomatism responsible for the albitization and for the development of replacement perthite and later is held responsible for feldspathisation phenomenon respectively. But he stressed that magmatic emplacement is not excluded in such regionally metamorphosed terrain. Therefore, Walton's model seems very convincing . That is true granites or granite like bodies were initially crystallised from the same secondary magma derived as a result of anatexis which have calcalkline affinity. (Pl.07 Fig.—) whose last differentiates like quartz-feldspathic material intrude the metasedimentaries along foliation. Thus early formed granites show concordent relationship all along strike direction in the field. These concordant intrusives in Salkhala Group were subjected to orogenic movements subsequent to their emplacement thus rendered a typical gneissose character in them on regional scale. And also due to huge later intrusion of quartz feldspathic

material, the metasediment arround Suprass village were subsequently converted into paragneisses which appears a local phenomenon. This litpar-lit injection of quartzo-feldspathic material of relatively younger age into pre-existing phyllites or schists, giving rise to injection gneisses. The Augen gneisses show boudinage structure (Pl. 16 Fug. a).

The possibility of quartzofeldspethic material to a higher levels, manage to permeate through the foliation of country rocks like phyllites schists due to their higher mobilitily under Hydrothermal conditions. The same gneissose granite is understood to have undergone retrogression due to thrusting which occurred during Alpine Himalayan orogeney, thus with the release of pressure along strike direction, temperature falls and that is why early formed biotite mineral is altered to fresh chlorite which is conspicuous by noticing specks of biotite streaks included in fresh chlorite with knotted structure (Pl. 22 Fig. a).

Also the biotites and muscowites are randomly oriented through foliation, is not preserved very well in the sections examined by the author (Pl. 21 Fig. f) Granitoid texture is visible, showing typical gneissose character (Pl. 22 Fig. c).

Much later than the period of first intrusion, there occurred another intrusion which cut across through the Tanawals and must have uplifted the overlying Tanawals

which were thought to have been removed by subsequent erosion. These massive and pegmatitic varieties of granites have sharp contact (Pl. 7) Fig. 7)) and minerals have straight contacts or sharp contact (Pl 30 Fig. b) which will go in favour of neo magmatism. And it is possible that during crystallisation all must not have been true granites or granodiorites, though differentiation of parent magmatic calc-alkaline magma is felt to have occureed at the time of its emplacement. But due to later events of granitisation by way of K-metasomatism and Na-metasomatism (op. cit.) which could take place simultaneously resulting in the formation of present state of granitoids. These granites are stated to have been subjected to mild metamorphism due to Himalayan orogeny resulting in microcline-albite-epidote facies of rocks, that is perhaps the reason which might have tempted Fuchs(1975) to use the term"metagranites" instead of intrusive granitoid rocks used by the present author. There are still younger leucogranitic dykes or veins through the early emplaced granite which is also supported by Fuchs (57) for the rocks of this area. The above described phenomena which is supposed to have taken place after the solidfication of varying differentiates of parent magma. Actually all this explanation involves a considerable amount of imagination concerning various phenomena, which are accessible to the observation of author particularly

those classifications based on tectonics, distinct minerology, and petrology of quartz in question. However it may not be difficult for author to use Hogboom's classification (op. cit.), or refined classification of Saksala and extend their views safely to granitic exposures of Gulabgarh area. One can with the above mentioned paramerters, comparatively, safely construct petrological classification of granites which run almost parallel to Eskola's Syn-, Late-, and post-kinematic-granites.

The writer of this thesis has also made an attempt to classify both foliated gneissose granites and non-foliated intrusive granites of study area on the basis of chemical data of analysed rock samples. Various chemical based diagrams after O'Connor (1965), modified form of Cox et al. (1979) and Naqvi et al. (1980) have been drawn and the description of each diagram is placed on the opposite page of respective diagram. The diagram of O'Connor (op. cit.) represents the igneous and metamorphics of both localites. And Cox's diagram gives an idea of the various varieties of volcanites and plutonites present in the study area. Lastly, Naqvi's diagram takes care of gneissose rocks of metamorphic belt of Salkhala Group.

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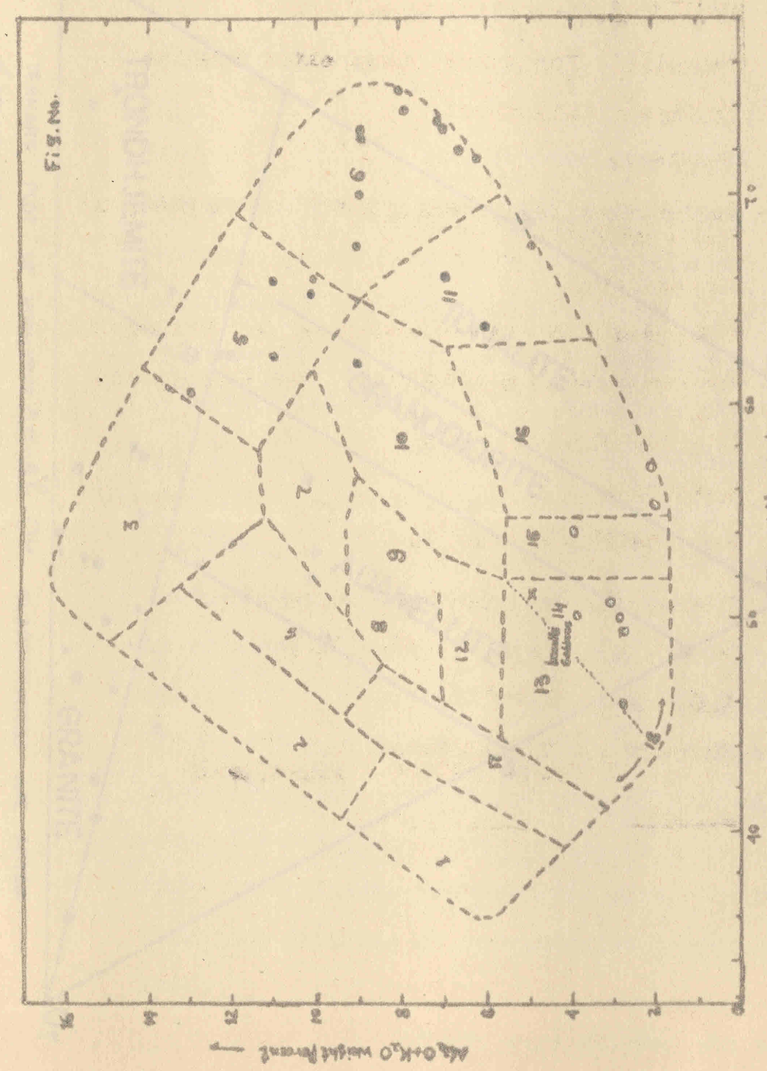
Fields of Chemical Classification after Cox(et al,)

1. Nephelenites or Ijolites
2. Phonolitic Nephelenites and Ijolite Nephelene Syenite.
3. Phonolitic Nepheline Syenites.
4. Phonolitic Tepherites (Nepheline Syenites)
5. Trachytes (Syenites)
6. Rhyolites
7. Benmoorites (Monzo-diorites) Syenites, or Syno- diorite.
8. Mugearites.
9. Trachybasalts (Monzo- gabbros or Syno-gabbros)
10. Trachy andesites - Latites or Monzonites.
11. Dacites (Granodiorites)
12. Hawaiites
13. Alkali-Olivine Basalt.
14. Tholeiitic or Sub-alkaline Basalts.
15. Basaltic- andesites (Diorites)
16. Andesited (Diorites)
17. Basanites & Tepherites. (Theralites & Essexites)
18. Picrite Basalts.

PLATE-78



NOMENCLATURE OF THE COMMONER IGNEOUS ROCKS BASED ON THEIR SILICA AND ALKALI CONTENTS (MODIFIED FROM COX, BELL AND PARKHURST 1979). SPILITES SAMPLE FROM BADDAR MARKED BY X TRAP SAMPLES MARKED BY • AND GRANITE SAMPLES MARKED BY ○

PLATE-79

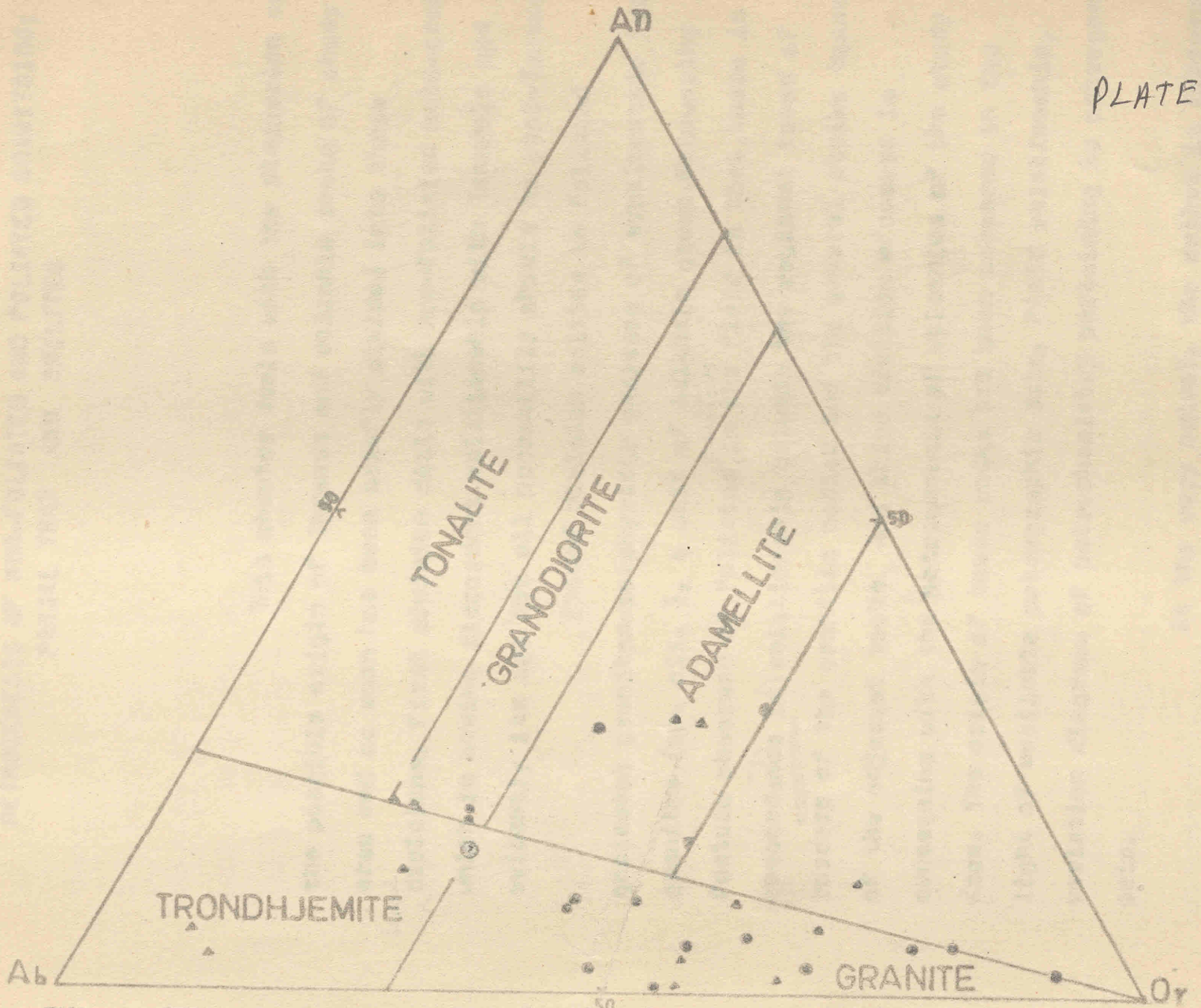


FIG: TERNARY PLOT OF NORMATIVE An–Ab–Or CLASSIFICATIONS ARE AFTER O'CONNOR (1965) ▲ REPRESENTED BY GNEISSES & SCHISTS ● REPRESENTED BY GRANITOID ROCK SUITE OF GULABGARH AREA.

CHAPTER - IX

PETROGENESIS OF NON-FOLIATED AND FOLIATED GRANITOIDS; PANJAL TRAP AND SPILITES

This chapter deals with the discussion on the possible origin of Igneous and volcanic rocks of study area and as such has been briefly divided into three broad divisions. First division deals with non-foliated meta-granite, which is having discordant relationship with Tanavals and evidently its age for all probability should be post-Tanaval.

Second division relates to foliated gneissose granites-porphyritic gneisses of syn-kinematic type granites (op. cit.), a unit of Salkhala group. Noteworthy feature observed of foliated granitoids in the field is that there is concordance in relationship between the regional trend of borders of the granitic bodies and the general strike trend of the adjacent rocks. And third division ofcourse is concerning with the petrogenesis of volcanics of the study area. The origin of these rocks has been assessed in the light of available petrographic data, field relationship, variation diagrams of petrochemistry pertaining to petrogenesis.

At the very outset, the author is impressed by the fact that granites and granodiorites make up at least 95% of all the plutonic rocks. The theory of fractional

crystallization of (Bowen) suggests that magmatic differentiation of basaltic parental magma can generate granitic and granodioritic residual magma upto 5 %. Jackson expects the percentage of granitic and granidioritic magma to approach 10 percent on differentiating of primary basaltic magma. So in view of this, one fails to find substantial amount of basic or ultrabasic rocks in orogenic belts which equally holds true for this Kashmir Himalayan orogenic belt.

Daly (1933) says," The igneous rocks of the globe belong chiefly to two types: granite and basalt. To declare the meaning of the fact, that one of these dominant types is intrusive and the other is extrusive, is to go a long way towards outlining petrogenesis in general. It is also an interesting feature to note that along the orogenic belts, there is preponderance of granite-granodiorite suite."

Barth (1962) believed that there did not occur magmas in the continents since the birth of earth. But till now the huge acidic magmas, responsible for the origin of at last 90% earth crust is being generated in the depths of geosynclines by differential melting. In the terrain, the igneous plutons locally are emplaced in two different ways, ie. they are emplaced essentially as liquid magmas or as solid bodies and in between two extreme, there may be the possibility of a transition phase which may be partly a viscous phase containing already crystallised material within it.

So these assumptions lead us to understand that magmatic origin means crystallising direct from parent magma (Sensu stricto) due to decreasing temperature. Likewise it can be otherway round that increasing temperature may cause the earlier crystallised bodies, to remelt again, thus forming a secondary magma in the geological cycle. This secondary magma is called"palingenetic" magma which upon crystallisation again gives rise to the same prexisting crystalline rocks of identical mineralogical or chemical composition.

There exists a close relationship between volcanism and plutonism(Kennedy and Anderson,1938) in relation to their chemical composition. And it is remarked by workers that acidic variety of volcanics such as rhyolites-dacites present in the orogenic areas find absence of acidic equivalents of plutonic rocks. Even many granites are not visibly found with surface flows,leaves some doubt as to such granites, if found in such areas , a magmatic origin can be linked with. But then such granites must have been formed due to granitization etc.

Also their mode of occurrence is confined to different tectonic enviorments.For example, granitic magmas may be generated predominantly in regions of compression during orogenic periods. During such episodes, ascent of magma to the surface may be difficult. Reversely the same thing many not be true in case of basaltic conditions of

magma, generated under tensions and under low pressure, and reach easily to the surface of extrusion.

The literature on the subject is profound. The authors has, however, restricted to some classic works, viz., Winkler (1958), Wyllie and Tuttle (9158, 1959, 1961), Winkler (1965), Von platen (1965), Winkler (1967) and James and Hamilton (1969).

The earlier views about the origin of geanites were divided into two schools of thoughts. One school of thought believed that the granitic rocks are derived directly from "primary magma" after crystallisation but this appears not be have justified the voluminous presence of granitic rocks within the earth crust.

Equally the phenomenon of granitization, is known to be responsible for the occurrence of few granitic bodies especially in orogenic belts. Barth (op. cit.) remarked that regional metamorphism and granitization are chief characterstics of the orogenic belts. Though this origin satisfies the room problem for such enormous bodies in the field. Later Winkler (1958) found on experimental basis, that there is possibility of sediments and derived crystalline rocks getting remobilized and start melting in the deep geosynclines. He concluded that remelting of deep seated rocks takes place at relatively low temperature 650°C at 4 to 5 Kb pressure.

Sederholm (1893, 1897, 1907) was the first worker who had this idea of remelting within the earths crust and used the term "Anatexis". His view was supported by Hutton, Lyell, Durocher, Dana.

Michel-Levy, Barrois, Lacroix Termier and others used the conceptions of granitization or feldspathisations of rocks. The term anatexis introduced by Sederholm (1907) literary meant, remelting of sediments or Sialic crust near tectogens to form secondary magma of granitic composition. These are called neomagmas (Good speed) and the amount of melt generated in this way shall depend upon the temperature, the chemistry of the country rocks or wall rocks and also important is the availbility of water and other volatile substances. The formation of secondary magma capable of intrusions at higher levels in the crust is called palingenesis which implies rebirth of new rock from the melting of previously existing one. But what is the source of heat responsible for the melting of huge sediments of geosynclinal dimension. As simple hot basaltic magma on minor scale can't supply so much wanted heat which can take care of melting of huge sediments. And it remains still to be resolved, if the term anatexis (Sensu stricto) is used for such phenomenon.

However, Barth has expressed that the sediments of arkosic, shale, limestone, evaporites, forming the core of geosyncline help in bringing down the melting temperature and he has concluded that the melt is granitic or granodioritic in composition.

Later on experimental investigation undertaken by Wyllie and Tuttle (1958, 1959, 1961a, 1961b), Winkler (1965) and Von Platen (1965) showed that partial melting begins in clay, shale graywacke and gneissose produce large volume of melt of batholithic dimension in the presence of water and has remarked that as soon as eutectic temperature is reached these rocks mentioned above begin to melt and the resulting melt is in equilibrium with alkali feldspars, plegioclases, quartz and volatiles (gases). The experimental work of many leading petrologists suggests granites formed anatectically cluster near the temperature minium (eutectic) of the system Q_z-O_r-Ab; Von platen (op. cit.) Winkler (1967) and James and Hamilton (1969) have considered the importance of An content in the partial melting of granitic rocks.

Their studies reveal that the addition of "An as a component in the *granite system* produces effect opposite to that of increasing pressure. This implies that more the An contents in parent rocks, the greater the 'Or' content of the remelt formed. Melting investigations on gneissose and granites by such workers have revealed that the first liquid, produced as a result of anatexis (Partial melting) is granitic in composition. It is also concluded experimentally that granitic magma upto An_{39} could be formed by such partial melting (Winkler 1967, Ghose 1974).

Eskola thought the formation of most granites as due to "selective melting of the sial with the soluble combinations of low temperature minerals melting first. According to him quartz and alkali feldspars (orthoclase albite) in the proportion of 1:1:1 combine to form the lowest melting temp. of assemblages of rock-forming minerals and such assemblage is of genetic importance of present day batholith. Krank and Oja (1960) while carrying experiments on the natural rocks in order to confirm if there are any possibilities of anatexis for such rocks. He found the melt being formed at the contact of grain boundaries of quartz/alkali feldspar or quartz/plagioclase grain of quartzofeldspathic rocks. He found first development of glass along those boundries and, therefore, his results are promising for future investigations. Phase relationship in the Q_z-O_r-Ab-An system where H_2O is at a constant pressure has been discussed by Winkler (1967,74) to explan the genesis of granitic magma. The process, involved in understanding the eutectic relationship of these assemblages along the cotectic surfaces, is beyond the scope of this work. However, on this bases, he contructed a diagram with a dotted field in the center which is a field of anatectic melt. If some plots fall outside this field, then those granites rocks are formed as a result of granitization (sodium metasomatism and K- metasomatism) otherwise respective granites are as a result of crystallisation from the neomegma of Goodspeed or antectic magma of Sederholm.

The genesis of the granites or foliated granites of older age of the study area is drawn in the light of foregoing discussion.

Nesbitt(1980) suggested that high grade metamorphic rocks that lack hydrous minerals are the residue after partial fusion of hydrated metamorphic rocks. And compositional difference between the presumptive parents and the residual rocks can be accounted for by extracting liquids of granitic composition which is a anatectic melt. This formation of anatectic magma depends mainly on three factors, namely, geothermal gradient or in other words depth of incipient melting.(ii) The composition of sediments or prexisting gneisses which should correspond to granitic composition i.e. arkose and grayuacke of roughly granitic composition, as (Winkler and co workers) have established the fact that biotite gneisses were formed from grayuacke, and lastly the water content of anatexis melt. And out of three conditions the former and the latter conditions have wider impact on the formation of anatectic magma.

Depth of incipient melting :

Tuttle and England (1955) experimentally concluded that 30°/Km is enough for the remelting of pre-existing rocks and have found that" granitic melting minimum" of 640-660°C is reached at a depth of 20 Km where pressure of 5 Kb is produced. Recent experimental investigations have shown that only 2-3 Km vertical distance separates the

low-temperature facies, (chlorite zone) from the high temperature facies, (sillimanite zone) and even partial anatexis (schreyer et. al. 1964) gave a geothermal gradient of about 65°/Km while working on the Bodenmais ore deposit in Bavarian Forest.

Engel and Engel (1958) found 100°/Km in the northwestern Adirondacks, Johson (1963) found between 50-150/Km in the Scotish Highlands. Mehnert (1968) has inferred that the beginning of melting in orogenic belts is not confined to only 20-25 Km depth but can take place even at much lesser depth of only few Kms.

Geijer (1965) concluded that an atactic magmas are formed within the "heat domes" existing in the core zones mobile belts, which subsequently intrude the core zones of mountains in the form of magma diapirs.

Hall (1971) showed that the formation of granitic rocks in orogenic belts is dependent on geothermal gradient and, therefore, concluded that "Lower the geothermal graddient higher is the water pressure needed for rock melting."

Regarding source rock, much has been said in the preceeding paras and here only the role of water shall have to be discussed briefly. Wagmann (1935), Rambarg (1962) suggest intergranular fluid facilitates the migration of elements.

Later on Bush et al. (1974) experimentally

showed that it is not only along grain boundries that water migrates but also along the cleavages and cracks. It was shown by them that melting takes place even around the inclusions, occurring in the mineral grains between quartz and feldspar contacts etc.

Experiments have shown that increasing pressure increases the solubility of water in the silicate melt, thereby influenced in depressing the melting temprature of granite.

Mehnert (op. cit.); Marmo, (1971) concluded that even small amount of water present in the source rocks can produce partial remelting provided the original composition of geosynclinal sediments or gneisses is suffieiently close to that of granite.

Braun and Fyfe (1970) have remarked that hydroxyl bearing minerals of prexisting gneisses can supply water enough for the formation of melt in absence of free water. From these observations it can be inferred that source of water at the lower crust is draun from hydroxyl bearing minerals and also water is released in the process by many dehydration reactions.

On the whole, there exists an inverse relationship between the temperature and the water content of the crust, i.e. the water content generally decreases as the temperature increases from the surface to deeper levels of the crust. With this principle in mind, one may conclude that the amount of anatectic melt can increase at deeper levels

with increasing temprature or can equally form at higher levels with increasing water content. So if we consider the importance of both the parameters acting simultaneously in the partial remelting, then the anatectic melting is most pronounced in a intermediate zone where the influence of water and tempreture is equally shared.

Present status of Intrusive Granitoids of non-foliated character and their genesis, drawn on the basis of certain field evidences, laboratory investigations and petrochemical diagrams, is given by the writer to propose the possible origin, and author therefore prefers to designate them as metagranites of epizonal character, because of the presence of handsome grains of epidote (Pl.35 Fig.e). Very slight foliation in biotite is conspicuous. The similar view has been expressed by Fuchs (op. cit.). The epidote mineral is seen saggregated in plagioclase laths showing combined albite-carlsbad twinning with An content of 25% and other grains are overridding quartz crystals and biotites crystals . In both the cases the origin seems to be secondary. In former case, the epidote crystals are as a result of decalcification according to the possible reaction with the liberation of low temprature albite and in the later case, the epidote euhedral crystrals are due to deutric alterations.

(1) The field observations reveals that the granite pluton is of local intrusive character and these granites are intruding through Tanavals.(2) These have sharp

contacts with the country rocks, though there is effect on country rocks by way of granitization which is evident with the development of porphyroblast of feldspar (Pl.20 Fig.f). (3) The differentation is conspicuous which is testified by observing coarser grey-pink granites quartz syenite to granodiorite in the center of pluton and finer varieties of fresh appearance granites are along the periphry of pluton. (4) Even within the rock unit there is both coarse and fine varieties which point to act of differentiation or crystal fractionation from the secondary magma formed after selective fusion. (5) There are no rhyolitic varieties of volcanics found any where in the study area. (6) Petrographically, there are two generations of minerals, for example older plagioclase, younger albites; older biotite and younger biotites, older quartz and interstitial quartz as secondary due to post-crystallisation effect etc.

Presence of graphic intergrowth in the marginal area (Pl27 Fig.f) The development of perthitic textures and little myrmekite. Presence of clouded feldspar and sutured texture. (Pl.25 Fig.b) Sharp straight margnis exist between crystals and minerals and also sutured contacts are also not ruled out (Pl.32 Fig. b)Euhedral boundaries of high temperature apatite and magnetite minerals which indicate origin from melt. Bending of biotite, muscovite and plagioclase laths. Deformational twin lamellae what is better called and gliding twins (Pl.32 Fig. a) point to mechanical intrusion of granites.

Presence of undulose extinction in quartz. From the chemistry of these rocks, it shows the uniform composition. From the chemical ternary diagram of O'connor or any other variation diagram on the petrochemistry of these rocks, it is clear that the plots don't fall in basic fields such as diorites, gabbros etc. which clearly indicate that the plution is not a complex and hence the parent magma can't be basaltic or gabbroic (Pl.63 Fig. b).

In the von platen ternary diagram some of the plots remain in the trough of 4Kb and 7Kb (water pressure bare) and others fall outside the trough of eutectic crystallisation from the melt. (Pl. 59, Fig b)

In Winkler ternary diagram some of the plots of plution fall in the anatectic field and these points which fall outside the anatectic field point to the formation as a result of later episodes of granitization after crystallisation of low temperature minerals (Pl. 59 Fig. a). All these points led the writer to conclude that the local pluton of all granite-granidoirite is connected with the anatexis model and these granites must have formed due to crystal fractionation of new magma during cooling history. Even earlier hot melt is produced by anatectic is process of sialic crust in the geosynclines.

From the ternary variation diagram of Tuttle and Bowen, the plots of true granite fall within the small triangle (a,b,c) and other plots out this triangle which they

considered those rocks as other than true granite. By true granite they meant rocks of granitic composition (Pl. 57 Fig. _).

From other diagrams (Pl. 65 Fig. a) the granitic magma formed by anatexis shows calcalkaline affinity. The chief features of calc-alkali series are :- It occurs as pluton, domes or mushroom shaped pluton. It is confined to orogenic (both faulting and folding are prominent), number of intrusions are multiple, vate content of the magmas is high; The mean temperature of differentiation is moderate to low. The character of mineralogy is hydro-quartzofeldspathic. During its intrusion the contact effects are modest to profound thermal and metasomatic, (Saxena et. al. 1977).

Plots of normative feldspars of the granite within the thermal trough indicate magmatic crystallisation at a temprature range between 650°c and 690°c (Kleeman, 1965) and other plots falling outside the thermal trough indicate their present state to have been attained by later history of metasomatism (of sodium and potash) after crystallisation from the granitic magma.

Even petrographically there are conspicuous replacement of plagioclase by low temperature microcline microperthite and orthoclase changing to microcline microperthite which is seen with some relic continued orthoclase or few twined orthoclase within the replacing microcline (Pl. 34 Fig. c).

Also quartz is being replaced by K-feldspars which is called high temperature feldspathisation (Pl. 28 Fig. b,c) caused by potash-metasomatism and albitization is caused at low temperature enviornment at higher levels whereby the albite crystals of younger generation are replacing older plagioclases with increasing An content. The fresh albite crystals are found along the contacts of perthites, thus forming interstices. Almost all granites of lesser Himalaya are due to later granitization and according to (Misch 1949) Naga parbat is one of the classic areas of granitisation. The two processes are different but can also act simultaneously as well on the rocks which have crystallised from the anatectic melt.

The vein and platy perthite are typical of replacement type where the perthitic lamellae are originating from the boundary of the crystals mantled by Sodic plagioclases (Pl. 32 Fig. b). & PL-27, Fig f PL 31 Fig b

Formation of granite under essentially constant P-T conditions which means a rock of non-granitic composition attains granitic composition by addition or removal of mobile components such as K ions and Na ions in the present case. The author is interested to use metasomatic processes, in respect of some granites to have been formed, leading to a process of granitization. By this it is meant that more acid elements such K^{+}, Na^{+}, Si^{++++} get increased in the granite looking rocks which correspondingly remain deficit in ferromagnesian elements.

From the petrographic study of rock slides, the feldspathization and albitization are more conspicuous, for example, existence of quartz crystals in perthites and development of fine albitic lamellae in quartz or in older plagioclase grains are conspicuous features observed in thin sections shown in the micro-photographs. According to Menhert (op.cit.) feldspathization is restricted as due to introduction of K-ions into the pre-existing minerals in solid state which takes place relatively at high temperatures in depth, whileas albitization is caused at higher levels at low temperature with the introduction of Na-ions. into the pre-existing crystals ~~xxx~~. He asserts that heat domes of mountain chains are the sites for feldspathization. According to him, the two processes are different but can act simultaneously as well on the rocks crystallized from the anatectic melt.

Field evidences show the younger leucogranitic veins which cut across the main plutonic mass and probably these leucogranites are the source of alkalis which have metasomatised the pre-existing granite like rocks. This is further supported by the presence of micro-veins of potash and soda cutting across the perthites as shown in the microphotographs (Plates Pl. 28 and figs. a). Pl. 27 and fig a

Now remains the question as to what is the source of these alkalies in the area. To sum up, the following evidences can afford the possible source of alkalies. Mehnert (1968) suggested that albitization is often linked with tectonic disturbances such as thrust planes, faults, joints where large scale alkali migration is possible due to the permeability of these solutions.

The metasediments through which these granites have intruded are essentially arenaceous in composition, though few argillaceous sediments are not ruled out and it is also a fact as clarke (1924) and Pettijohn (1957) remarked that the sodium content of arenaceous sedimentaries is greater than the potash content while as potash content of argillaceous is greater than the sodium content. So it seems possible that these alkalies must have migrated from the pre-existing metasedments, during emplacement of anatectic granites due to high temprature and pressure. The replacement phenomena whereby the K^+ ions or Na^+ ions are liberated during ion exchange phase between the minerals enriched with these elements. Over all, these metasomatic changes are of local importance. The formation of epidote at the cost of hornblende with the formation of biotite (Pl.36 Fig.e) is once again a proof of potash metasomatism i.e. addition of K^+ ions (Marmo, 1971) from the above discussion it appears logical to infer that the granitoids may have originated due to the combined effect of anetexis and granitization(Saitsaari 1951).

The question of origin of epidote is quite interesting. Epidote formation in such rocks is multiple nature(1) $2(2CaO.\ 3(Mg\ Fe)O.\ 2Al_2O_3.6SiO_2) + 2KOH =$

$K_2O.\ 6(MgFe)O.Al_2O_3.6SiO_2.2H_2O + 4CaO.3Al_2O_3\ 6SiO_2.H_2O$

Biotite Zoisite

Barth (1952) remarks that epidote is formed through the process of Saussurization of the anorthite component of plagioclase. This could take place either due to potash metasomatism or be the result of the introduction of calcium into the rock from outside

$4CaAl_2Si_2O_8 + KAlSi_3O_8 + H_2O = 2Ca_2Al_3Si_3O_{12}OH +$

anorthite orthoclase Water Zoisite

$KAl_3Si_3O_{10}OH + 2SiO_2$

muscovite quartz

$3CaAl_2SiO_8 + Ca(OH)_2 = 2Ca_2Al_2Si_3O_{12}OH$

anorthite lime Zoisite

3rd possible origin may be due to deuteric alteration of anorthite because of the presence of epidote grains in plagioclase laths relatively rich in anorthite content (Pl.) Fig.).

$2CaAl_2Si_2O_8 + H_2O + CaCO_3 = 2Ca_2Al_3Si_3O_{12}(OH) + Co_2$

anorthite Epidote

This reaction seems to explain its formation of granites in question because these granites contain excess of potassium in the form of K-bearing minerals such as microcline which becomes perthitic due to introduction of Na^+ ions, liberating K^+ ions due to presence of young interstitial microcline. A similar view is held by

Seitsaari (1951) about the formation of epidotes in Late-kinematic granites.

Emplacement of Granitic Pluton.

By emplacement we mean the attainment of the present position of the pluton. The present position of the intrusive pluton can be ascribed to three possibilities. The pluton may have grown in situ by granitization secondly it may have risen passibly into the previously existing zone of low pressure and thirdly it must have been injected forcefully into its present position.

Regardless of the site of its origin the nature and mechanism of the ascent of neomagma or antectic magma to the site of eruption or intrusion poses a problem and it continues to be the most controversial problem of geosciences. In this connection, an attempt has been made to discuss the emplacement of granitic rocks. An epitomised account is presented below.

Much of the classical work of Balk (1937), Daly (1933) on this subject has become a guiding factor for future workers. Rast (1970) has advanced three possible hypotheses (a) magmas rise due to buoyancy which is inherent in the magma. Its main application is to granitic and other acid magmas and is not always critically accepted. On the basis of calculating viscosity of rising granite bodies Fyfe (1970) believed the existence of glassy matter rather than crystalline state for such bodies. But it is explaining for a situation where they show a clean cross cutting margins.

(b) The gas fluxion and vesiculation causes emplacement of magmas. This hypothesis was introduced by Daly (1911) and was accepted Jaggar (1947) and Rittmann (1962). Graton (1945) objected to the hypothesis, suggesting that the adiabatic expansion of gas would cool the rising magma.

Rittmann (1962) remarked that gas free basaltic magma is denser than the crust, but that it may rise to a level where vesiculation begins and after that as the gas emits, the lowering of density is caused which helps in its ascend. He even goes to this extent that existence of continental fissure eruptions is due to degassing of magmas and hence pleaded for the presence of gases in magmas or neomagmas.

(c) Tectonic squeezing of magmas to the surface, Ramberg (1970) experimenting with $KMnO_4$ solution pointed out that likewise mobile magmas can be squeezed to the surface by collapsing "Super structure". The downward collapse of overlying crust would take the place of magma and, therefore, the mobile magma will get squeezed out producing major dykes, cauldrons etc.

(d) Magmas rise due to the pressure difference between the pressure generated in the process of melting of upper mantle and the pressure over the surface of magma layer.

But above all a question arises as what was the intensity of intrusion whether it was forceful or it was permissive. Out of this Daly used the permissive mode of intrusion which is respresented by cauldron subsidence of blocks into lighter upcoming magma or it may be alike to piecemeal stoping through thermal and buoyant stresses.

According to Balk, the magma was intruded upward with considerable force (forceful intrusion) so that it thrust aside the wall rocks and leaves the impression of movement on these granitic bodies. And according to Knopf (1925) these structural indicators of motion consist of linear minerals which indicate flow lines or platy minerals such as mica, feldspars etc. which would indicate platy flow structures. Also many joints in the margin of the pluton or in the wall rocks were regarded evidences to register movement. The joints were developed due to relative movement of viscous magma against wall rocks which were stationery at the time of its emplacement. But main difficulty is that joints and fractures are possible only in brittle mass and not in plastic mass if these features were assumed to be penecontemporaneous phenomenon and hence these joints and fractures can result after the emplacement and crystallisation of magma is complete.

The effect of gravity on solid bodies has been visualised by Ramberg (1967). So his analysis is based on theortical fluid dynamics and the application of centrifuged scale tends to duplicate the effect of gravity.

In many petrological problem, gravity differentiation is simple answer. e.g. the acidic layer forming the top in the complexes of world.

Hamilton and Myers (1967) remarked that many batholithic plutons were emplaced at shallow depths and actually are covered by roof deposits of their own volcanic activity. However, this appears to create confussion because it is already known fact about the actual depth at the time of intrusion which is certainly not shallow as envisaged by Myers et. al. (op. cit.)However an attempt is made here to present the possible mechanism for the emplacement of granitoids of the study area. It is felt that the magma before emplacement was highly in liquid stage and upward movement of lighter granitic magma against the denser medium of pre-existing solid rocks can nulify the effect of gravity and the movement shall continue till the last drop of silicate melt is in liquid condition. Because the liquid phase is always lighter than solid phase of the same composition. Besides the pressure difference existing in the two horizons alonguith the inherent buoyancy of the melt act as forces which push the melt against gravity.And also due to heat difference, between the rising magma and the wall rocks shall develop cracks in the brittle prexisting rocks which later on with the forceful intrusion, the caving of wall rocks may result in leading to the assimilation of country rocks by the rising anatectic granitic magma.

Petrogenesis of gneissose granites of Salkhala Group:

Metamorphic belt of Salkhala Group is the oldest unit of study area and has undergone polymetamorphism since pre-cambrian times and as such rocks of this belt have undergone many textural and mineralogical changes which baffle the author to arrive at definite conclusion. Therefore, less attention has been paid to this rock type except that petrographic study reveals the following features. Amongst them, is the uniformity in their minerlogy and exhibit typical granitoid textures (Pl.22 Fig. b). It is also observed that the mafic minerals of Granitoid intrusive and the gneissose granites of Salkhala Group are same and so and the plots of the analyses of the specimens of gneissose granite fall in the thermal trough (Pl.59 Fig.—) and these values show lineation with Amitsoq grey gneissose and Nuk gneisses of pre-cambrian age. (Pl.64 Fig.—).

From the ternary diagram of Gilkson, (1979) the plots of gneissose granites don't fall in basic rocks, i.e. the same characters, as found in respect of younger non-foliated rocks, are observed in the foliated rocks of pre-cambrian age. But there is one more characteric feature absorbed in such rocks that there is retrograde metamorphism noticed with the development of fresh chlorite at the cost of biotite mineral. (Pl.22 Fig.c) Here also the two generations of minerals have been found. The retrograde metamorphism may be due to thrusting devloped by Himalayan orogeny.

Because relics of biotite in fresh chloride with preserved cleavages (Pl22 Fig. a) is conspicuous feature. Foliated muscovite laths (Pl.21 Fig. C) at the cost of potash feldspar is yet another proof retrogression together with the presence of perthites which are found at low temperature due to unmixing. The rocks of this group which have suffered much regional metamorphism leading to the formation of mylonitic gneisses, appear to have touched epidote- amphibolite facies of Eskola as evidenced by the presence of mineral assemblages. Rocks of higher metamorphic facies don't occur in the area of study which could give an idea of higher pressure and temperature conditions since the rocks are understood to have undergone reversal metamorphism due to lowering of temprature and pressure. It seems probable to assume the mineral assemblages suited to new parameters of temperature and pressure conditions, resulting in the emergence of green-schist facies. The conclusion arrived at by the author to note the following mineral assemblages coresponding to the two metamorphic facies.

(1) albite+epidote+biotite+magnetic±quartz (albite-epidote-amphibolite facies).

(2) albite+muscovite+epidote+chlorite+magnetic± quartz(green-schists facies).

Apparently from the mineral assemblages, it needs to be mentioned that the tempratures have culminated at lower limit albite-amphibolite facies and have not proceeded further. With the lowering of temperature new set

of minerals due to retrogession appeared as referred in (2) above and can safely be included in the green-schist facies of metamorphism.

Local occurrences of augen gneisses with sporadic thick dykes of amphibolites cutting across the foliation of augen gneisses are met with the strike continuation of gneissose rocks of Salkhala Group (Geological Map.). These occur nearly at places north and north-east of Tukaun located at the water-divide of Tukaum and Angrala nalas.

Under the microscope , in the thin section of augen gneiss, the quartz is often rounded exhibiting sutured margins with faint blue tint along its margin. The feldspar crystals are generally rounded (eyed) but sub-rectangular and shapes of feldspars are also noticed in thin section. These are mostly perthites with relic of untiwinned orthoclase but also pure albite showing glidding twinning and foliation are also present. Also mosaic pattern of rounded crystals of quartz showing texture of quartzite is typically held along foliation (Pl. 22 Fig. d).

Origin : There are various opinions about the origin of Augen gneiss which normally occur all along in Lesser Himalaya, always in the same litho-stragraphic context (Le Fort et.al., 1976) have been expressed by various authors. Two contrast schools of thoughts are known. The one school of thought assigns its origin to magmatometamorphic processes which mean that the pre-existing quartzofelds-

pathic rock has undergone subsequent metamorphism wherein the large rounded grains of potash feldspar have formed due to granitisation *in situ* e.g. metasomatism in which potash material is supplied gradually to its nucleus, or of tectonic emplacement and its origin even ascribed to intrusive granitisation during older orogenies (Saxena 1973).

The other school of thought is drawn from workers who studied its occurrences in central Nepal and proposed its origin to be as volcano-sedimentary which has direct bearing on the paleogeographic and tectonics of the lesser Himalaya.

In the field these formations are characterised by their coarse grain, high feldspathic content, strong schistosity, mineral lineation, intercalations of schists (Pl.16 Fig.c) and quartzites as boudins, presence of amphibolite dyke within it tectonic and metamorphic characters similar to those of the surrounding rocks and lastly the occurrence of bluish round quartz noticed under microscope. All these characters observed in the area of study with minor exceptions as envisaged by le Fort (op. cit.) converge to suggest the ppssibility of a felsic-volcano sedimentary origin. He also does not rule out its possibility to metamorphic "prophyroides" (Lapparent 1909) and partly to metamorphic felsic tuffs.

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Petrogenesis of Panjal Trap

The Panjal trap of the study area occur in two belts. One belt of trap occurs in Para-autochthonous zone overlying the Agglomeratic Slates and other belt of trap occurs in synclines along the Pir Panjal Range. The study of Petrography and petrochemistry of trap rocks has revealed its tholeiitic lineage, which is further characterized by the general absence of olivine mineral, zoned plagioclase crystals and ex-solution-lamellae in Pyroxene crystals. These traps posses normative quartz and normative hypersthene (table) which is confirmatory test of their being tholeiitic in character (Yoder, Tuttle, 1962 and Sood, 1981). Moreover the chemical analyses of these rocks indicate they range from basalt to andesite in character and do not go beyond andesite.

An attempt has been made to discuss the source of tholeiitic magma, as mother magma responsible for the development of traps in the area. There is understood to be general agreement among leading petrologists that basaltic magma is primary, (Turner and Verhoogan, 1962). Now as universally accepted that residual magmas like tholeiite, alkaline-olivine basalt and high alumina basalt exist in the substratum. However the ideas differ whether all these residual magma types are derived from one primary magma or they constitute independent magma types. Detailed discussions on this highly controvertial problem is beyond the scope of the thesis. However a brief review of the contributions of various authors is put across

in order to arrive at general concensus with the incorporation latest findings by various authors todate.

The earliest view was that of Lacroix (1917), later supported by Yoder and Tilley (1962) and Kuno (1968) and they suggested that basaltic magma, generates at great depths by complete melting of peridotite shell. Wagner (1928), Gisolf (1929) and Hurt (1958) believed that fusion of amphibolite at depth would produce the basaltic magma.

Kennedy (1938) regarded the existence of two primary basaltic magmas, namely, tholeiite and olivine basalt and believed that they were derived from lower and upper layers within crustal shell.

Daly (1946) experimented with the "continuous or nearly continuous" sub-crystal layer of vitreous basaltic material and was successful to derive basaltic magma from it. By observing olivine nodules in some basalts of their own interest, Match et al. (1949), Rose et al. (1954) and Bederke (1957) regarded those nodules as torn out fragments of the peridotite shell. Thus they believed that source material for the generation of basaltic magma was peridotite. So with this Noble et al. (1959), Taylor and Nobel (1960), Turner and Verhoogan (1968), Yoder Tilley (op. Cit.) and Kuno (1963), all suggested that ~~it~~ it is peridotite shell of upper mantle where the generation of basaltic magma takes place.

O'Hara (1965, 1967 and b, 1968) experimented under polybasic and polythermal conditions. He concluded that these conditions are necessary for the generation of primary magma and regarded garnet lherzolite as suitable model for mantle composition from which basaltic magma was generated upon partial fusion. Yoder (1974, 1976) proposed that garnet peridotite may be considered as a major mantle material capable of producing various basaltic magmas, by partial melting as a function of depth. This view was earlier held by Hess (1938), Bowen (1947), Kushiro and Yoder (1966) observed from their studies on peridotitic compositions that at 1200°c and pressure of 5-30 Kb(anhydrous). They show a change from plagioclase peridotite-spinel peridotite-garnet peridotite, as a function of increasing pressure. Garnet peridotites are chiefly composed of four minerals : Olivine, Orthopyroxene, Clinopyroxene and garnet (pyrope). From the above sequence it may show increase in density with the result, it shall explain the increase in Seismic velocities which form function of depth. Above all, such a change would suggest that plagioclase would be at least a normative component of liquid produced by partial melting of undepleted peridotitic compositions. Turner and Verhoogan (1968) registered the most reasonable depth of formation of basaltic magma as between 50 to 60 km. and it was concluded by them that the temprature capable of producing such magma at such a depth is of the order of 1200°c to 1500°c.

According to Kuno (1963), the generation of different types of basaltic magmas depends upon the depth where the parent magma generates in the upper mantle. He concluded that residual tholeiitic magma is produced at a "Shallow depth" in the mantle layer; alkali alumina basalt at "intermediate depth" and nepheline basalt at a "greater depth".

Some of the specimens of the trap of study area show normative hydperesthene and other specimens of the trap show hyperesthene and quartz which, according to Sood (1981) modified after Yoder and Tilley (1962), belong to tholeiitic type of basalt which include silica saturated and silica oversaturated varieties of tholeiites. As we know the whole of permian and most of the Triassic periods witnessed the marine conditions in the most parts of Kashmir Himalaya. It is during these periods that extensive prolonged volcanic activity was taking place, Pascoe (1959). Also these is presence of volcanic ash, over the traps of para-autochthonous zone. The similar situation was reported by Bion and Middlemiss (1928). Wadia (1928) confirmed the pyroclastic or volcanic origin of Agglomeratic Slate. Wadia (op. cit.) states that the character of the bedding infers that the lavas must have been of a high degree of liquidity and their eruption and subsequent consolidation must have taken place sub-aerially. From the above discussion and from the binary variation diagrams of petro-chemistry, it

seems possible that the Panjal Traps of Study Area were derived from tholeiitic variety of basalt which formed as a result of partial fusion of the upper mantle at Shallower depths.

Wakhaloo and Mathur (1933), Pascoe (1959) and Wakhloo (1964, 1969) and many patrologist consider the pyroclaste and lavas to have deposited under marine conditions. From the binary diagrams the traps of the Study Area high-alumina basalt which may be due to contamination of wall rocks rich in alumina such as slates etc. Because tholiitic showing high-alumina character is often met with orogenic belts. Similar is the case with the study area.

Bafliaz Volcanics : This formation containing spilites, forms a very small outcrop within the area of study around Baddar village in the west. The description of its origin is beyond the scope of this work. However, it is suggested that this volcanic activity under question appears to have occurred as the initial magma activity under deep water conditions. Yagi (1960) and Cann (1967) have advocated the hypothesis calling for autometamorphism or reaction with sea water at the time when its fresh extrusion of basaltic lava consolidated on the sea floor.

As it is learnt that igneous activity through the geosynclinal sediments is capable of mixing with Na^+ rich connate waters present in the sediments; thus causing

a soda enrichment in the rising magma to produce albite rich rocks Barth (1967) had given the following reaction to explain it

$$Na_2Co_3 + CaAl_2Si_2O_8 + 4SiO_2 = CaCo_3 + 2NaAlSi_3O_8$$

similarly Eskola et al.(1935) presented enrichment of albite in such rock

$$Na_2CaAl_3Si_5O_{16} + Na^+ + Si^{4+} = 2NaAlSi_3O_8 + Ca^{++} + Al^{3+}$$

Even soda enrichment may have caused due to upuard diffusion of sea water, trapped in sea sediments, through the pre-existing igneous rocks and thus has led to the marked development of albite in these rocks

$$CaAl_2Si_2O_8 + (Na,K)_2Co_3 + 4SiO_2 = 2(Na,K,)AlSi_3O_8 + CaCo_3$$

(Tom Keieff, 1941)

Because the outcrop of Bafliaz volcanics is just north of Panjal thrust which was more or less under sea environment before erruption took place and since petrographically the albite -oligoclase feldspar with simple twinning do not shou any sign of alteration which apparantly means that these volcanics have resulted as a primary minerals. From these arguments, the author of this work believes that it was parent magma which must have got enriched in Na^+ content drawn from connate water and sea sediments before the enriched matter got differentiated into spilites and associated rocks. A similar view was expressed by Gupta and Sharma (1973) about the Bafliaz volcanics of Thannamandi area, Distt: Rajouri where huge volcanics of Bafliaz-Keratophyre rocks are exposed in the same strike continuation of the outcrop of spilites of the present study area.

CHAPTER - X

SUMMARY AND CONCLUSIONS

The results arrived at after the study of physiography, tectonics, petrography, mineralogy and petrochemistry in respect of study area, are summarized below:

1- The study area forms southwest part of Kashmir Himalaya and represents Lesser Himalaya on a regional scale. The area is between Matlose in the south to short of watershed in the north whileas, strikewise the area starts from Gul in the east to Badder in the west as shown in the geological map attached.

2- The only prominent range which forms the northern limit of the study area, together with subsidiary ranges, the mention of which has been made in the chapter of Physiography.

3- Stratigraphically, the area comprises almost a sequence starting from Precambrian represented by Salkhala Group to Oligo-Miocene represented by Murree Formation. In between there are other formations though without appreciable fossil content ranging complete Palaeozoic successions with missing strata of Mesozoic and early Cenozoic. The proposed stratigraphy has been built and given at its appropriate place.

4- The area is highly folded and thrusted, the main structural elements have been noticed on a regional scale. The most important thrusts among them is called Murree Thrust separating Murree Formation from para-autochthonous zone of Permocarboniferous sequence. The second equally important tectonic plane in the

north is Panjal Thrust which separtes PreCambrian sequence of Salkhala Group from the para-autochthonous belt in the south. In addition, another tectonic feature of the nature of strike-slip fault has been proposed in the thesis which brings Tanawals into the Salkhala Group along the Shidoul nala in the study area. Besides, there are beutiful folds of both symmetrical and asymmetrical nature found within the Murree Formation and Agglomeratic Slates. Briefly the area of study has been structurally divided from south to north as Murree zone, Para-autochthonous zone, Crystalline zone and Pir Panjal zone.

5- There are both intrusives and extrusives rocks exposed in the study area. The intrusives are acidic varieties of fine and pegmatitic rocks which have been termed as granitoids which comprise granite- granodiorite- Adamellite- quartz- syenite, suite of rocks which have intruded through Tanawals. These seem to have suffered very mild metamorphism which have also been called "metagranites" by Fuchs (op.cit). These have crystallized from the melt which is derived by anatexis of pre-existing rocks of acidic composition. A perusal of Table 9 reveals that these rocks with high silica, alumina and alkali contents have a good comparison with calk-alkaline granites (Nockolds, 1954).

There are reported grey coloured granitoids and pink coloured granodiorites around Shidoul, Dandhala, Khour and Lar villages of study area. The pink/buff colour is due to presence of pink coloured microcline and also due to higher proportion of ferric oxide as impurities in the mineral. Regarding probable age

of these intrusives granitoids, it can only be imagination after noting the rediometric ages conducted on granites occurring elsewhere in the adjestant areas in a regional strike direction. These ages are based on Rb-Sr method and mentioned as follows:

Mandi granite, Himachal Pradesh according to Jager et al.(1971) shows wholerock age as 500 m.y. ± 100 and Mandi Leucogranite Mehta (1975) shows age to be 311 m.y. ± 6. Dalhousie granite on whole rock isochron (Bhanot et al.1974) gives apparent age as 456 m.y. ± 50 whileas Dalhousie Pegmatite (Bhanot et al. 1975) shows an age 350 m.y. ± 50 And in the study area if the Tanawals be presumed as Lr. Cambrian, then it is obvious that these granitoids should be post- Cambrian which fits well with 350 ± 50 m.y.

The aluminous granite belt of the Mandi-Dhauldhar region gives more or less consistent whole rock Rb/Sr dates according to Shams (1983) stated that these granitic rocks are traceable further westwards in Maneshra (Pakistan) where these granites have been observed to intrude into the Tanawal Formation (Shams, 1969; Le Fort et al. 1980). Also Tanawal Formation is considered by them as Post-Hazara and older than Abbottabad Formation which has yielded Cambrian fossils. Therefore, this intrusive phase granite (Shams (op.cit) has been assigned a Cambrian age.

Kaplas granite massif of Doda district (Sharma, 1981) occupying core of NW-SE trending antiformal structure. And granite is emplaced through fossiliferous Bhadarwah Formation which has been assigned a Pre-Devonian age on the basis of their infra-Devonian

stratigraphic position. The granitic rocks in this region are reported to be massive fine grained homogenous to coarse grained porphyritic with aplitic and pegmatitic veins.

The metamorphic rocks undergoing reversal metamorphism represent the Salkhala Group of Pre-Cambrian age and these rocks are understood to have witnessed poly-metamorphism since Pre-cambrian times.

7- The volcanic rocks are represented by Panjal Trap which have suffered little differentiation upto andesites only from the tholeiitic magma derived from shallow depth of the upper mantle. These appear to have erupted under marine conditions related mostly to orogenic belts. What do you mean by this?

8- The granitoids occur both in the foliated and non-foliated form and fall into synkinematic, Late-kinematic and Post-Kinematic types according to Eskola (op.cit.)

9- The granitoids are represented by a Salkhala Group stratigraphically of older age and non-foliated variety occurring strati graphically as Post-Tanawals. The mineralogical characters of these granitoids in question appear to be the same though the feldspars mostly perthitic very quantitatively in two types. Mineralogically, these are composed of alkali feldspars (perthitic) Plagioclases, quartz and biotites, magnetites, ilmenite, apatite are the main accessories.

10- Modal analysis and chemical analysis classify the granitoids into granite-granodiorite- adamellite and quartz syenite. The coarse variety is concentrated in the centre whileas the finer varieties are confined to margins showing intrusive contact effects.

11- The trace element studies in case of granitoids reveal that Pb, Zn, Li and Sr increase with SiO_2 and D.I. whileas other elements like Cr, Ni, Co Cu register decline with the increase of SiO_2 and D.I. The trace elements which are more enriched in the basic rocks of Gulabgarh show a gradual decrease with increasing acidity are Ni, Cr, Pb, Cu and Co.

12- The undulatory extinction, clouding and mortar texture are conspicuous features in quartz and feldspars. The slight bending of biotite suggests a considerable strain undergone by these rocks together with the occurrence of epidote and sphene is noticed in sections of these granitoids. The contacts between crystals are sharp showing direct crystallization from melt and other margins of the same crystals sutured which point to later phenomena of feldspathization, low temperature albitization and silcification due to tectonism of the area which is the post-Consolidation effect.

13- The gneissose granites and augen gneisses show mylonitization where the feldspar and quartz grains are elongated along foliation. The minerals of these rocks show much intensity of deformation caused through ages.

14- The granitoids of the study area are found to be rich in perthites, the microcline-microperthite happens to be the last mineral to be formed in the process. The perthites are mostly of ex-solution type but replacement perthites are also seen in many of the thin sections. The anorthite content decreases from the periphery towards the interior of the granite body.

15- The feldspar granites of high temperature formation, called hypersolvus granites and two feldspar granites of low temperature formation called subsolvus granites have been recorded in the area of study.

16- In the present study, the magma is referred to secondary magma derived as a result of anatexis. In all 44 representative samples from volcanic rock suites and granitoids of rocks of study area have been analysed for their major and trace element studies. After inducting their values in binary and ternary variation diagrams, the corresponding histories and facts about their genetic aspect. Few such diagrams reveal the formation of anatectic magma of granitic composition from where the magmatic differentiation has occurred which is shown by the fields of various binary and ternary variation diagrams. Also the granitoids show calk-alkaline character. Other binary diagrams show combined magmato- metasomatic origin of these granitoids. The origin of volcanic rocks has already been referred to in the foregoing para. The trace element data further reveal a magmatic lineage for these granitoids under reference.

17- Briefly the intrusive granitoids have suffered three phases

of events. First the formation of magma followed by fractional crystallization from the melt during the course of its ascent. Later subsequent metasomatism affected the crystallized rocks from the magma; then lately during Himalayan Orogeny must have affected these rocks which have resulted in the recrystallization producing cataclastic effects followed by the process like silicification and sericitization which are quite evident from the study of these intrusive granitoids.

18. The following minerals of economic importance have been recorded in the area: gypsum, pyrite; gypsum found near Batoi village has revealed CaO = 31.14 % which is recommended for the manufacture of fertilizer and its transparent variety selenite crystals are found in loose carbonaceous material North of Panjal Thrust along the Angrala- Tuksum belt. Sporadic occurrences of pyrites, ochres on minor scale have been found in the country rocks of the study area.

19. The presence of radioactive minerals in granitoids of the study area is reported for the first time by observing radioactivity at Arital as 5 mR. Along thin margin upstream it increases further as we move towards the granite pluton to 8 mR in southern direction movement and 18 mR is recorded near the pegmatitic variety of granites near Khour. These findings reveal that for exact determination of its presence in such acidic rocks, a full scale geophysical study is warranted.

Lastly, though some conclusions have been drawn, yet the limitations of the same cannot be overlooked. And this is obvious as the complexities involved are so great and voluminous work of the author is so large that no single simplicitic solution

can offer a possible explanation to the entire set up.

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LIST OF ILLUSTRATIONS

PLATE : 10

(a) Gondwana and Permocarboniferous Syncline in Gulabgarh Pass. And view of Pir Panjal seen from North.

(Taken from Rec. The Geol. Surv. of Ind. Vol.XXXVII 1909, Part 4 by C.S.Middlemiss)

(b) Panoramic view of the Pir Panjal Range taken from N.W.Kadalbal in the north of range during traverse taken while crossing the Pir Panjal Range.

PLATE NO. - 10



FIG. NO. (a)



FIG. NO. (b)

PLATE # II

(a) A view of snow covered Pir Panjal Range taken from south after having crossed the ranges in this part of country.

(Nickkan Pass)

(b) A view of Glacial near Panjal Top. In the picture, is a photo of my brother Sh.R.L.Koul with labourers.

(c) A view of Gulabgarh pass of Pir Panjal range taken from top of Nakwas in the north.The foreground is locally called Zajimarg.

PLATE NO. 11



FIG. NO. (a)



FIG. NO. (b)

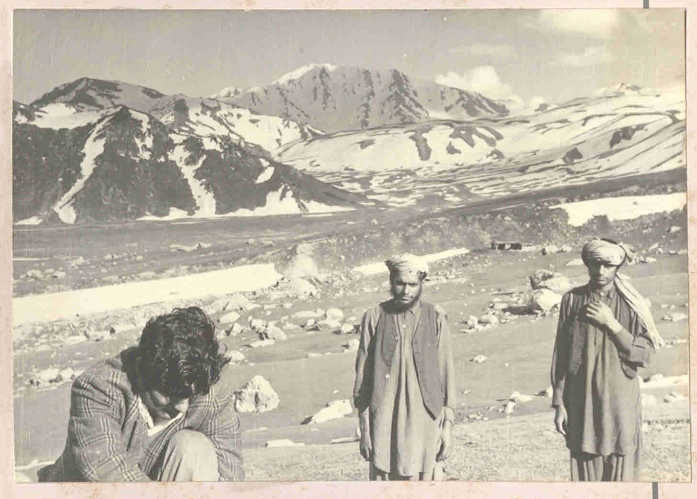

FIG. NO. (c)

PLATE : 12

(a) Anticlinal view Agglomeratic Slate flanked by Panjal Trap on either side near Arital taken from nala.

(b) A view of Baransal nala. In the back ground is view of Burzatophe.

(c) A U type glacial valley near Thinnmarg. In the foreground is a lake formed by melting of glaciers.

(courtesy from Dr.T.R.Sharma)

(d) Same as above but note, the escarpments and cliffs in the ranges.

(courtesy from Dr. T.R.Sharma)

PLATE NO. 12



FIG. NO. (a)



FIG. NO. (b)

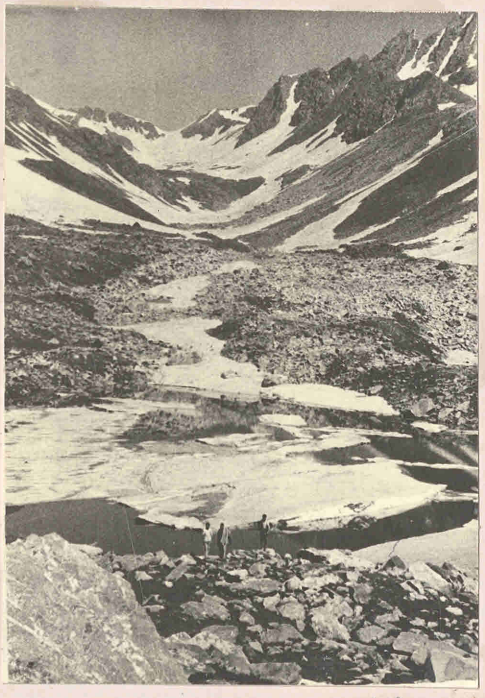

FIG. NO. (c)



FIG. NO. (d)

PLATE : 13

(a) A view of Murree Thrust between Murrees on the left side of Batoi nala and Gamir and Baila Formation on the right side of Batoi nala.

(b) A view of Bansal nala , In the back ground is peack of Burzatophe.

(c) The cross cutting macro veins of quartz in Panjal Trap.

(d) Oscillatory ripple marks in quartzitic material found in north of Batoi village.

(courtesy from Dr.T.R.Sharma)

(e) Shows Symmetrical folds in Murrees.

(f) Shows beautiful Asymmetrical folds in Murree formation In the fore ground is Ans river.

(courtesy from Dr.T.R.Sharma)

PLATE : 14.

(a) A cast of fragmentary pygidium of trilobite Monomorphichus in the quartzite shale sequence.

(b) A Trace fossils of Rosephycus sp. preserved in quartzitic shale sequence.

(c) A Sabal Major plant fossil in purple coloured shale of Murree Formation.

(d) This photograph shows puckering with quartzite bulbs/ boundins on the left bank of Baransal nala.

(e) Site of Selenite twinned crystals found the loose carboneceous material in the Angrala, Tuksun nala section.

(courtesy from Dr.T.R.Sharma)

(f) Kaindora nala section and depicts the contact between Trap and Agglomeratic Slate.

PLATE NO IA

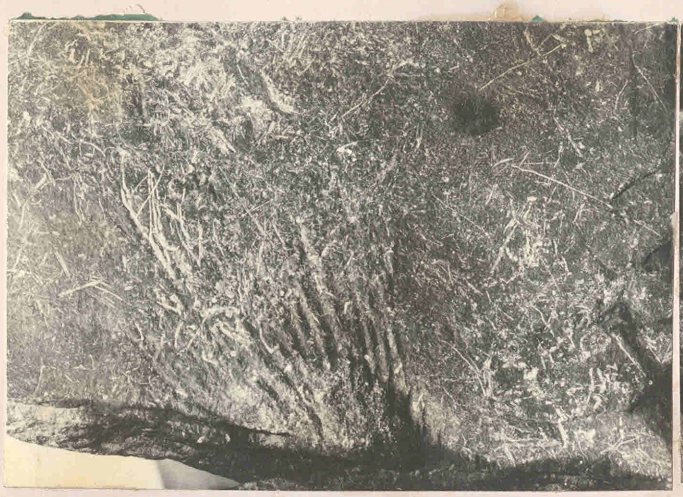

Fig (a)



Fig (b)



Fig (c)



Fig. (d)

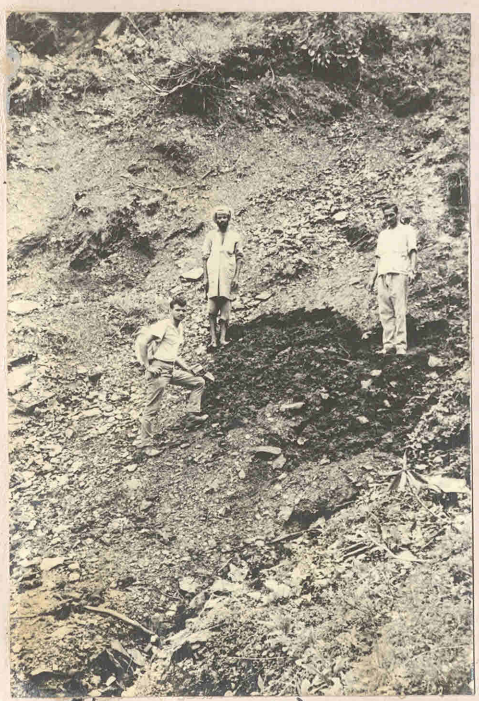

Fig - (e)



Fig. (f)

PLATE : 15

(a) A view of Gulabgarh nala taken from Tuksun.

(b) Shows a quartz vein 12" thick emplaced along foliation of puckered phyllite.

(c) Quartzite within Granite shown with fingure at Doolmarg. Also in the picture is a portable Geiger Muller Counter (G.M.C.) taken in the field.

(d) This shows a gradational contact between ~~phyllite~~ gneiss and schist indicated by hammer.

(e) This is a gneiss along Tuksun nala. Note boudin structure along foliation in gneiss. Its direction E-W steep dip northwards 3"x1" thick. At places, boudins are as big as 4'x1' in and around Tuksun.

(f) Shows vertical Joints in schistose rocks, west of Doolmarg.

PLATE NO - 15

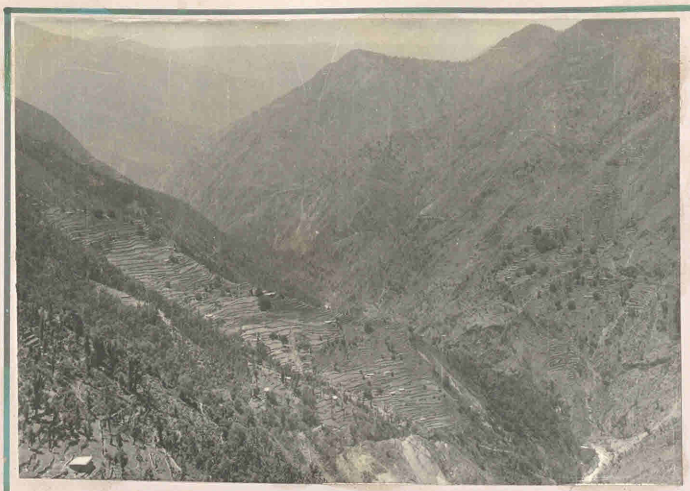

FIG. NO. (a)

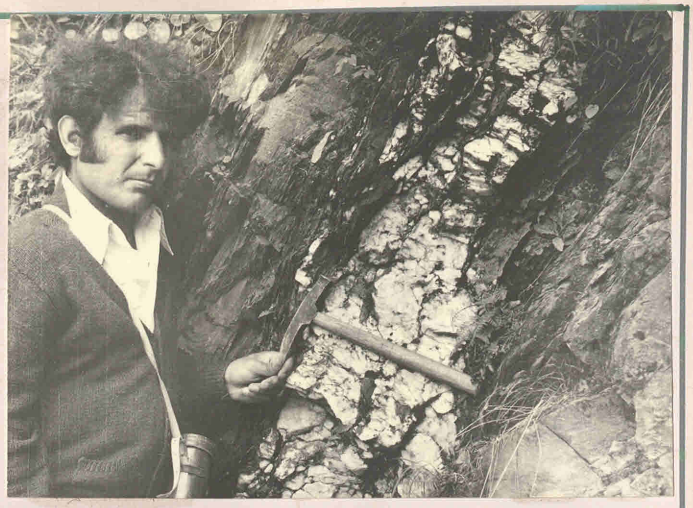

FIG. NO. (b)



FIG. NO. (c)



FIG. NO. (d)

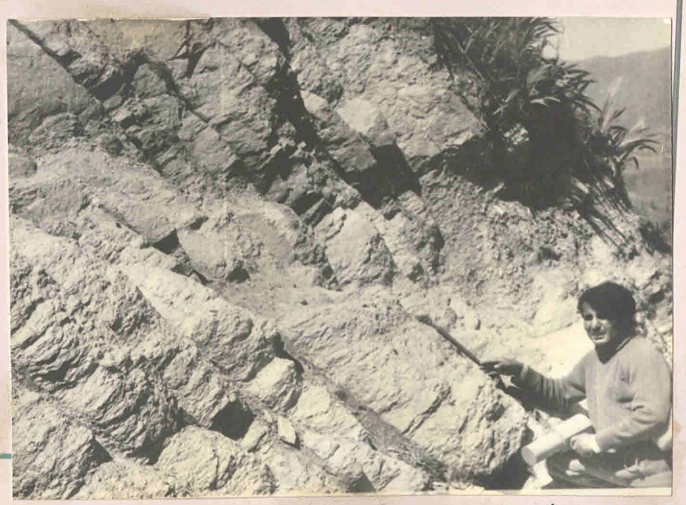

FIG. NO. (e)

FIG. NO. (f)

PLATE : 16

(a) A photograph of Augen Gneiss taken around Tuksun on way to Angrala.

(b) Shows a deep vertical cut trending regional strike be and contact between Gneiss and schist friable, (crushing is too much), near west Deol Marg on way to Noach.

(c) Black rock mobile amphibolite dyken 3½' thick in Augen gneiss found around Tuksun. Such veins have direction N 80 W-S, 80E; Sometimes these are 2" thick also cutting in 1" along above direction.

(d) Photograph is that of augen gneiss located at the water divide between Tuksun and Angrala nalas on way to Khataji Hela.

(e) Boudinage structure in schistose rocks, near Harmtal, north of Deol and between Deol and Deolmarg. Boudins of quartzite in NW-direction.

(f) A beautiful symmetrical fold in Agglomeratic found along the Sildhar Khetaji-Hela section.

PLATE NO. 16



FIG. NO(a)



FIG. NO(b)



FIG NO(c)



FIG NO(d)



FIG NO(e)



FIG NO(f)

PLATE : 17

(a) Photo of Agglomeratic Slate showing warping of beds, Regional altitude is NW-SE strike and northward dip taken from east of Gulabgarh nala.

(b) Out Crop of Conglomeratic phyllite on the left bank of Gulabgarh nala flowing from north west. Hammer and fingure points to quartzitic bulb piece elongated size 3"x1" appox. Ist pieces are also elongated along foliation. In fact all are elongated along foliation-strike direction size of ist goes even to 6"x1½".

(c) A contact between phyllite and light green coloured schist near Hapron village where a sample revealed the presence of chloritoid mineral along a suspected tectonic feature.

(d) Quartz vein across slaty formation near Arital on the left bank of Thinmarg nala.

(e) Photo of granite showing coarse and fine grained variety juxtaposed together with filled veins of reached material direction roughly E-W direction.

(f) Psamite schist with pieces of Quartzite, slate and phyllites. There is a contact with granite of intrusive nature showing sharp contact.

PLATE NO. 17



FIG. NO(a)



FIG. NO.(b)



FIG. NO(c)



FIG. NO.(d)

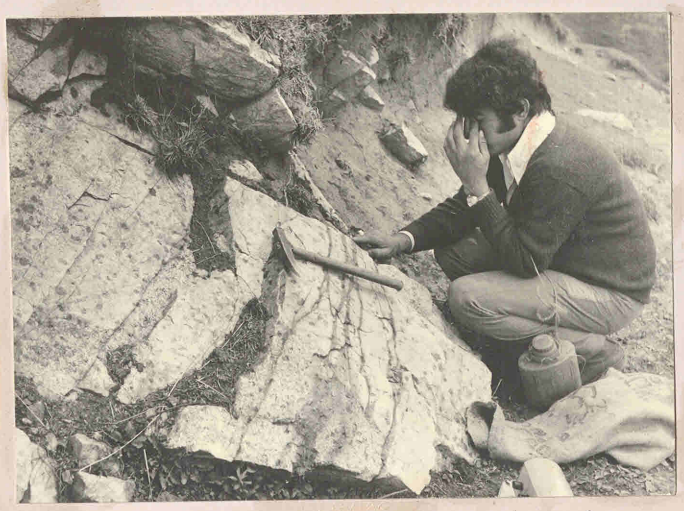

FIG. NO(e)



FIG. NO(f)

Plate : 18

(a) Hybrid rock of trap, with intercalations of agglomeratic slate, Note, the development of spheluritic clinozoisite along the contact between the slate and trap. (XPL 40)

(b) A spheroidal amygdale filled with clouded undulosed quartz crystals showing concertal texture. Note, micro-veins of quartz associated with pyroxenes cutting across the ground mass and spheroidal amygdale. (XPL 40).

(c) Microphotograph showing tectoblastic texture wherein, altered plagioclase penetrates the pyroxene crystal. Note there seems to be a assimilation process whereby early formed pyroxene crystal is being digested by feldspar. (XPL 40)

(d) Besides teclohlastic texture, there are rods of magnetite which show paralled growth with pyroxenes and at places there are radially arranged magnetite rods pointing towards the center of twinned pyroxene in the left below corner. There is a irregular amygdale filled with secondary quartz. (XPL 20)

(e) The field is full of secondary epidote crystals traversed by numerous irregular craks which is subsequently filledwith chalcedony. Along the cracks of epidote there is chemical weathering. (XPL 40)

(f) Microphoto graph shows general view of trap with tectoblasts of altered plagioclase, corroded with groundmass components. One crystal enclosed partly reduced to pigments. One crystal high temperature orthoclase showing carlsbad twinning. These phenocrysts are embadded in a ground mass of fine chloritised plagiocases and augite mixed in a cryptocrystalline material. (XPL 20)

PLATE. NO. 18



FIG. NO. (a)



FIG. NO. (b)

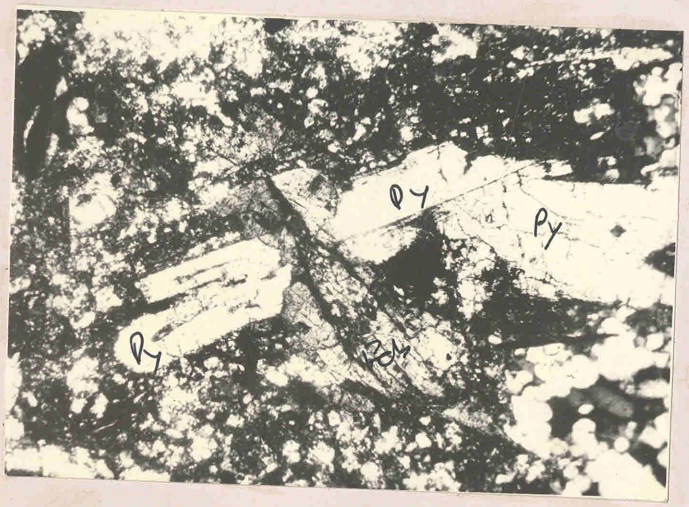

FIG. NO. (c)



FIG. NO. (d)



FIG. NO. (e)

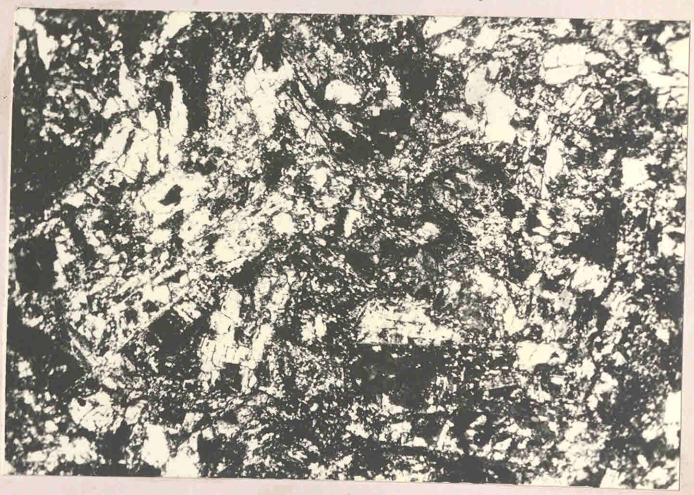

FIG. NO. (f)

PLATE : 19

(a) Microphtograph depicits ovate shaped amygdale filled from the margin to the center as green fibrous material fuschsite (Chrome mica) and ultramarine blue coloured pinninite variety of chlorite of on one cavity. There are inclusions of fine grains of epidote assbciated with bluish coloured variety of chlorite. Note a microvein of epidote material cutting across the gas cavity near the margin. Also microlaths, of albitic-oligoclase clan are randomly oriented suggesting different events of deformation. The gaps between the laths of plagioclase is filled with glassy material.(XPL 20)

(b) Ophitic to subophitic texture is seen in this photograph. There are radiating crystals of plagioclase with characterstic polysymthetic-twinning. (XPL 20)

(c) Subophitic to ophitic texture is not observed because of much alteration. The plagioclase laths randomly oriented are embedded in c crypto-crystalline material. There is a grain of biotite partly cleaved showing simplitictic growth with pyroxene.(XPL 40)

(d) Comb structure conspicuous whreby the undulose (deformed) quartz are interwoven in a vein cutting across the basaltic ground mass cpmprising phenocrysts of ffractured undulosed pyroxene (clino type) and altered plagioclase. The lot of epidote grains seem to be overriding this thick micro-quartz vein, and it appears that quartz crystals are subsequent to epidote and is of secondary origin. (XPL 40)

(e) Mylomitized agglomeratic slate which is depicted by pronounced foliation developed by volcanic ash of black dust. The voids are filled with angular to sub-angular quartz and cherty material.(XPL 10)

(f) More typical slide of agglomeratic slate, in which are cherty material, devatrified glass is volcanic ash of black dust, feldspar grains with inclusions of secondary fine sericite. The margins of angular quartz are with needles of quartz which is a conspicuous thing.(XPL 20)

PLATE NO. - 19

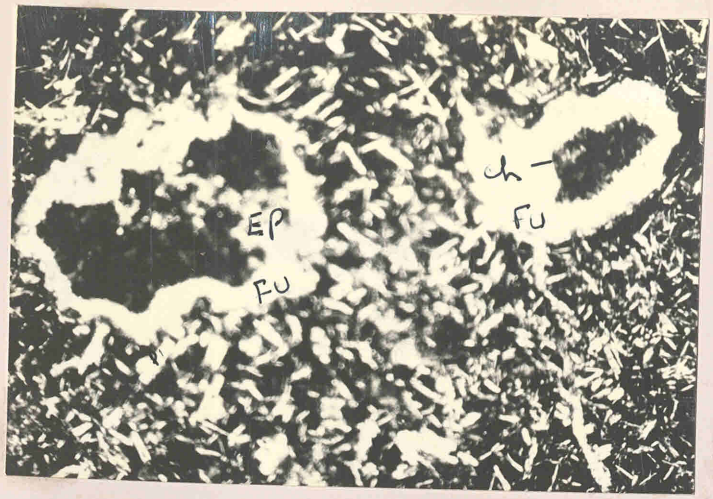

FIG. NO. (a)

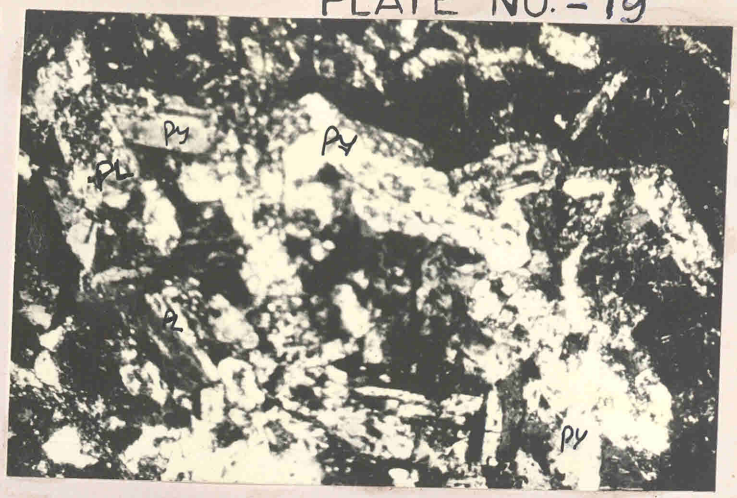

FIG. NO. (b)



FIG. NO. (c)

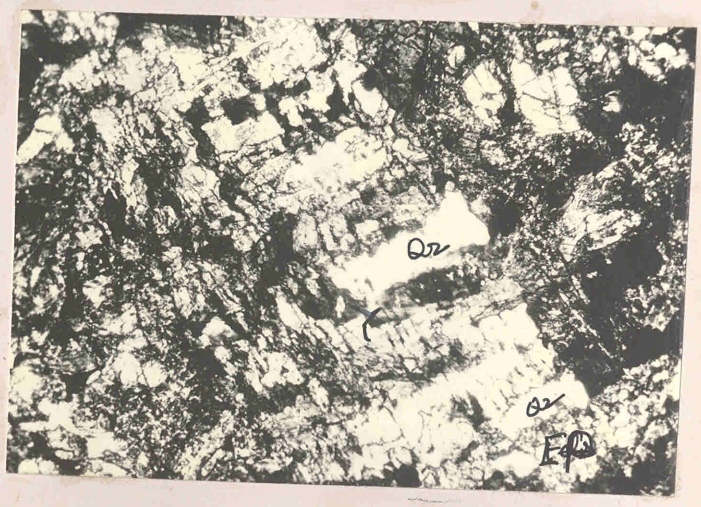

FIG. NO. (d)



FIG. NO. (e)



FIG. NO. (f)

(a) A blast of microcline microperthite contain corroded inclusion of clouded orthoclase sericitized which is having sutured contact with the replacing microcline microperthite. (XPL 40

(b) Here foliation defined by preferred orientation or deformed quartz and undulosed porphyroblasts of plagioclase embedded in quartz sericite matrix. Serrated grain boundaris of flattened grains of quartz highly deformed showing motar texture is suggestive of tectonic activity the rock has witnessed. This is a section of mylomtised gneisse from north of Noach,. (XPL 20)

(c) Fine grained puckered phyllite showing development of microfolds, exhibited by quartz-sericite shreds along the limbs of microfolds Note, minute grains of quartz across the axial plane of folds which is pucker (boudin). (XPL 20)

(d) Mortar texture of quartz showing strain shadow effect crystals of chloritoid beautifully exposed in this section. Porphy blastic texture is more conspicuous in the section whereby large recrystallised, strained quartz and chloritoid crystals, are in petite material of chlorite, sericite and quartz schists Note, Chloritoid and even quartz crystals are undulose inwhich repeated stress conditions are indicated partially sericitized. (XPL 10)

(e) General view of typical medium grained schist ie. quartz-chlorite-sericite schist. (XPL 10)

(f) Shows porphyritic texture; The micro photograph shows the post intrusion effect of cataclastic and crushing on wall rock whereby the sericitic material is permeating through the fractures developed along cleavages of the prophyroblast of feldspar. Also, there are irregular recrystallised quartz showing , undulose extinction, the margins are eaten sericite material. (XPL 20)

PLATE NO. – 20



FIG. NO. (a)



FIG. NO. (b)

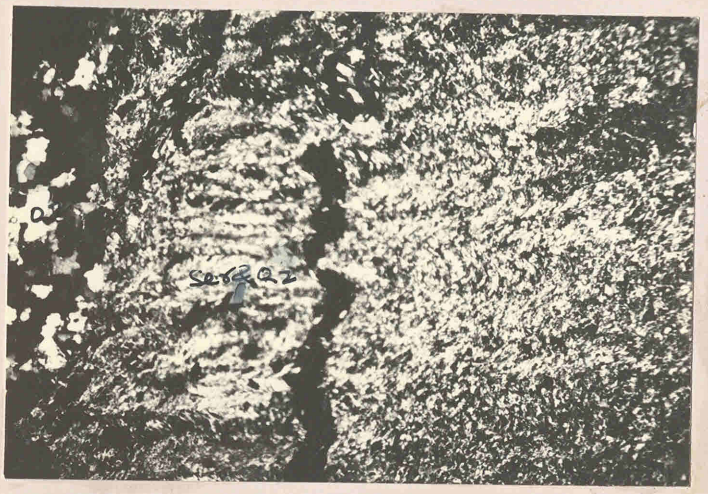

FIG. NO. (c)



FIG. NO. (d) Chltd. = chloritoid



FIG. NO. (e)

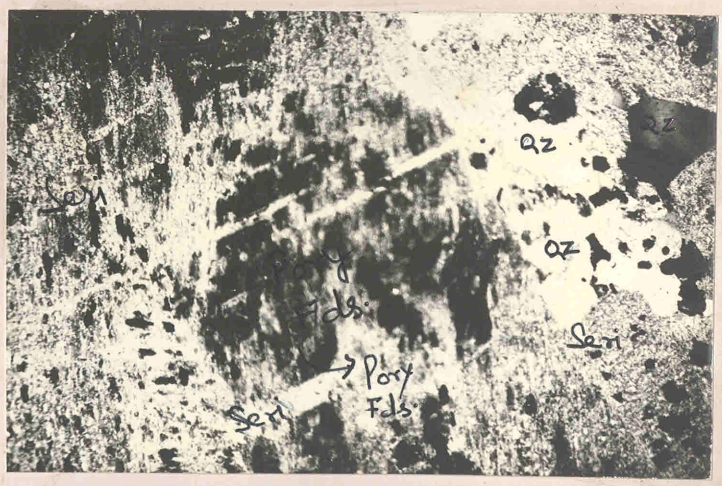

FIG. NO. (f)

PLATE : 21

(a) A slide of amphibolite showing slight foliation and subophitic texture. There are blueish coloured crystals of hornblende called uralite in the section. (XPL 10)

(b) A typical slide of apatite showing a apilitic texture and the minerals are same as found in granite two grains of sericitized orthoclase sutured. Undulosed quartz are present. Plagioclase grains are sericitized Note the feldspars are without clouding and twine plane of carlsbad in orthoclase is slightly bent. (XPL 20)

(c) Elongate foliated, mass of old muscovite without cleavages of primary origin with margins darker. Other muscovite flakes of younger generation with relic cleavages of biotite. There is partial association between younger muscovite and biotite showing simplititic growth. Even biotite is in foliated chlorite (dark in the field). (XPL 40)

(d) Anhedral elongated grain of apatite mineral with irregular crack; along one end a bigger crack has developed which is filled by later aggregate of recrystallised quartz muscovite, little remnants of biotites. Note there is little bending of apatite crystals wrapped by foliated mass of biotite, altered muscovite and fine grain of epidote. (XPL 20)

(e) Porphyroblast of plagioclase with deformed conjugate twin lamellae and other plagioclase crystals with faint and incomplete twin lamellae called gliding twinning. All these plagioclases are wrapped by mass of sericite, biotite and chlorite minerals. Note there is development of albite twin lamellae in quartz grains and there is conspicuous alteration near the edge of old plagioclase grain to young albite with faint twinning. (XPL 40)

(f) Interpentrating bent biotite flakes of two generations. Younger biotite are cleaved of course, slight banding is there and older biotite, show birds eye structure which have parallel growth with fresh muscovite. The older biotites have inclusions of quartz grain and epidote-zoisite assemblages. (XPL 40)

PLATE NO. 21



FIG. NO.(a)

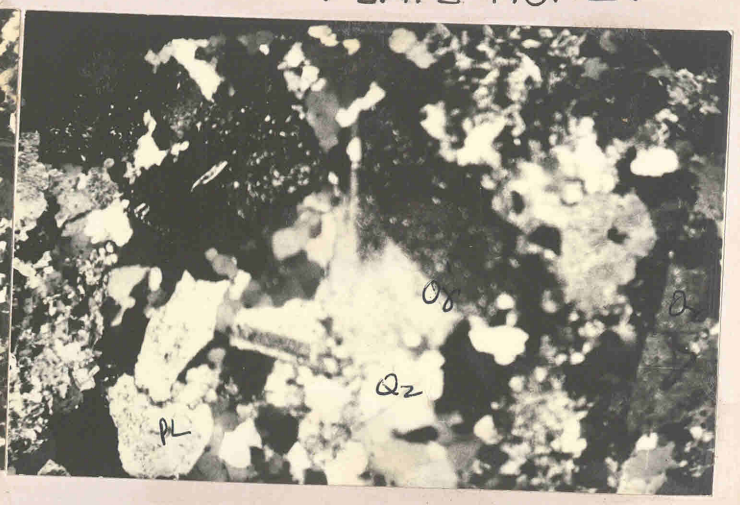

FIG. NO.(b)

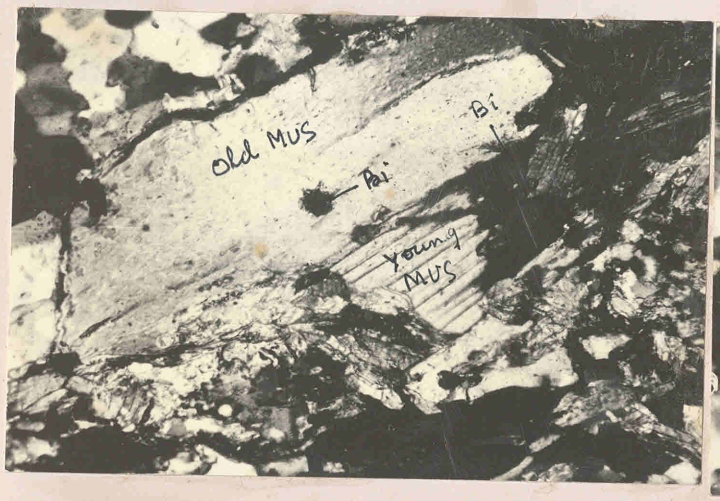

FIG. NO.(c)



FIG. NO.(d)



FIG. NO.(e)



FIG. NO.(f)

PLATE : 22

(a) Crisscross arrangement in chlorite blades showing knotted structure with these cleaved dark green coloured chlorite mass, The chlorite mass contain anhedral epidote and wedge shaped sphene chlorite is associated with muscovite and biotite and this ground mass contain aggrogate mass of epidote grain (dark grey clouded in the field) under polarizer nicol. (PPL 10)

(b) Slide shows typical granitoid texture. Also in the field is an hedral zoned plagioclase crystal, showing sharp contact with the undulosed quartz. (XPL 40)

(c) Two plagioclase grains with combined albite and carlsbad twinning have sharp contact with the blast of perthite and are inclined to the elongation of perthite (not in the field). Note, some relic biotite are in chlorite mass associated with muscovite. Also the albitic twin lamellae are in the stage of development. (XPL 20)

(d) Augen structure whereby highly fractured contorted margined blast of feldspar (perthite) contain inclusions of biotite muscovite and wrapped by flakes of biotite altered to fibrous chlorite as in some crystals of chlorite contain relic biotite. There is case of albitization where older plagioclase is avquiring fresh fine albite lamellae and also a crystal of fresh orthoclase seen in the right of field. (XPL 20)

(e) An view of aggregate quartz crystals is piercing through the perthite plagioclase crystal. Showing incomplete twinning . Foilated grains of biotite have parallel growth with muscovite along the cleavages. (XPL 20)

(f) Two generation of perthites one earlier formed perthite is being replaced by a big new perthite. Clouding of feldspar even quartz grains is there. Note crenulated grains of calcite there with inclusions of anhedral quartz crystal (in extinction position). (XPL 20)



FIG. NO.(a)

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epidotite and [illegible]tited
re is recrystallized
ng along foliation and
tain fractured epidote

plagioclase. Kink bands
llae noticed due to
tains randomly treaky
gregate of zoisite
ing to feldspar
Schistose struct



FIG. NO.(c)



FIG. NO.(d)



FIG. NO.(e)

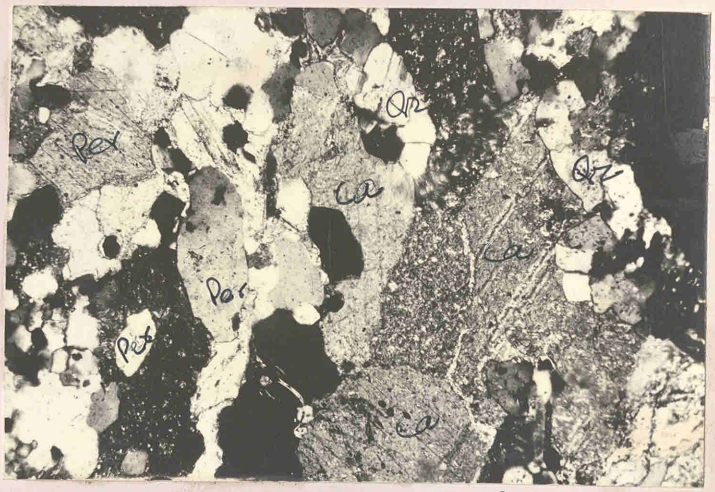


FIG. NO.(f)



FIG. NO.(a)



FIG. NO.(c)



FIG. NO.(d)



FIG. NO.(e)

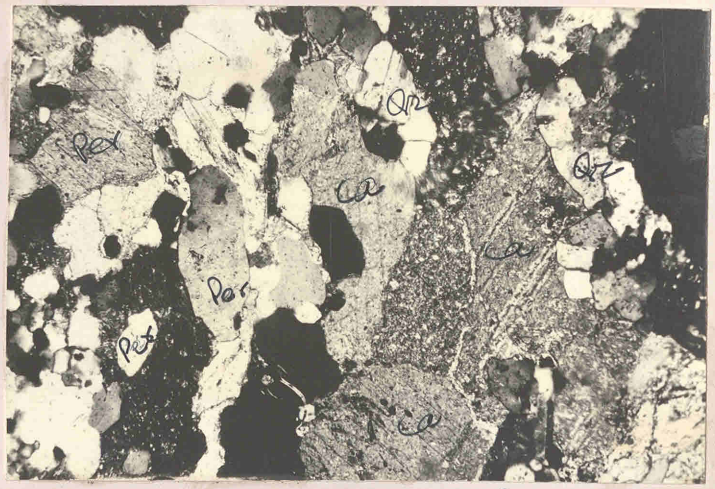


FIG. NO.(f)

PLATE : 23

(a) Porphyroblast of plagioclase grains in foliated mass of sericite streaky epidotite and ~~biotited~~ feathery mass . Note there is recrystallized undulose quartz permeating along foliation and foliated ground mass contain fractured epidote grain. (XPL 20)

(b) Bending in idioblast of plagioclase. Kink bands and fracturing twin lamellae noticed due to later deformation. It contains randomly streaky muscovite-sericite fine aggregate of zoisite in the center. Quartz changing to feldspar exhibiting sutured contacts. Schistose structure is pronounded in the slide. (XPL 40)

(c) A crystal of clouded perthite (? due to exsolution showing relic carlsbad twinning contains sporadic inclusions of rounded quartz grain and rounded grains of plagioclase which are partly Sericitized and clouded. (XPL 20)

(d) A orthoclase perthite, in which carlsbad twin plane is obliterated by the sodic lamellae. Inclusions of oriented plates of plagioclase, broken grains of quartz with some optical continuity. Note one grain of plagioclase crosses the carlsbad twin plane. (XPL 40)

(e) An idioblast of plagioclase lath showing undulosity, poly synthetic twinning and sharp bending towards right. It also contains small inclusions of microcline pods feathery sericite randomly oriented. (XPL 20)

(f) Annealed texture is shown by grains of quartz. And also there is foliated grain of muscovite showing sharp bend and there happens to be inclusions of biotite streakes. Note simplitict growth of muscovite with biotite. There is blast of plagioclase showing slight bending in its twinning. (XPL 10)

PLATE. NO. 23

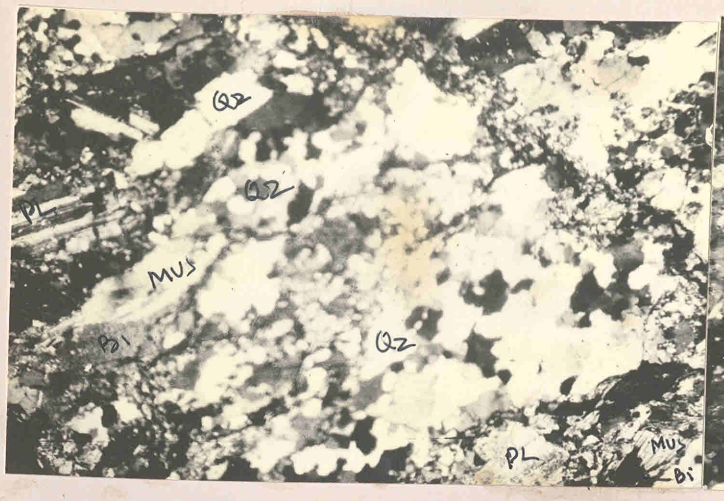


FIG. NO. (f)

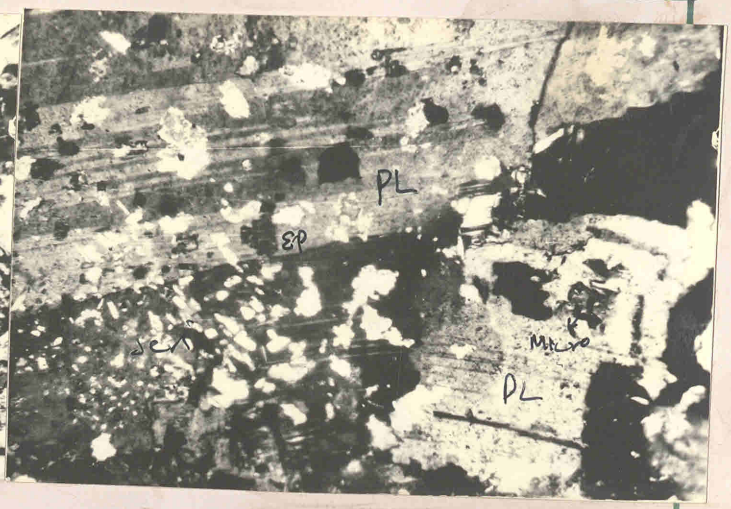


FIG. NO. (e)

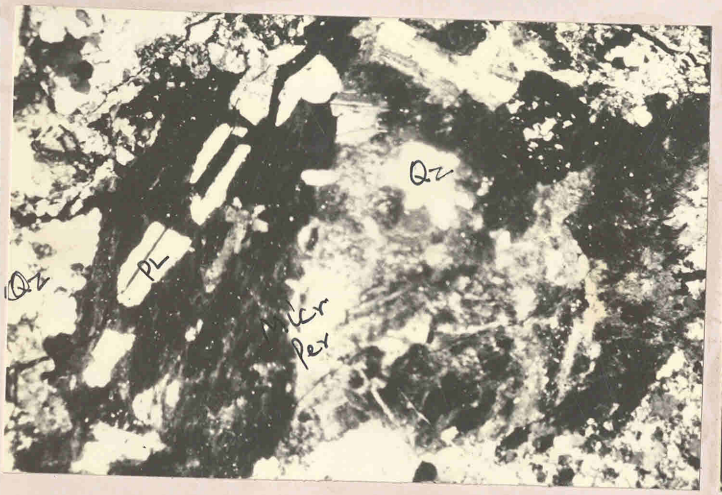


FIG. NO. (d)



FIG. NO. (c)



FIG. NO. (b)

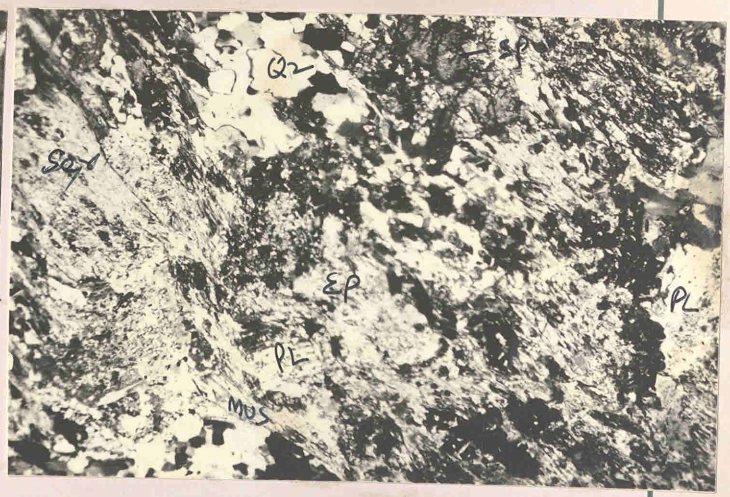


FIG. NO. (a)

PLATE : 24

(a) Microcline microperthite porphyroblast is highly contorted and wrapped by bent flakes of muscobite and contain inclusions of plagioclases. Crack developed due to tectonic feature is filled by recrystallised fine quartz. (XPL 20)

(b) Typical foliation conspicuous. Mortar texture seen whereby, the highly stained (spheluritic) quartz grain is broken into the fine aggregates. The matrix of quartz and fractured, Sericitized, undulosed, plagioclase crystals are wrapped by ~~bent flakes o~~ bent flakes of muscovite . The micaceous material permeat through ~~weak~~ fracture planes of quartz which is case of cataclastic phenomenon. (XPL 10)

(c) Blast of Microcline is enclosing reddles of plagioclase spods and muscovite grains. One big plagioclase lath with fine faint cleavages and partially sericitized along its margin. The microcline is replacing the older plagioclase crystals. (XPL 20)

(d) Clouded untiwinned orthoclase with cleavages preserved contain aggregate mass of quartz and older twinned plagioclase . (XPL 40)

(e) Shows Interperforating plagioclase crystals with the development of microfaults in one big crystal. (XPL 10)

(g) Two anhedral grains of orthoclase which are at right angles to each other in two positions. Typical grainitoid texture in seen in this slide. Chlorite streaky mass contain relic biotite features that biotite is changing to chlorite. (XPL 20)

PLATE NO 24



FIG NO. (a)



FIG. NO (b)



FIG. NO (C)

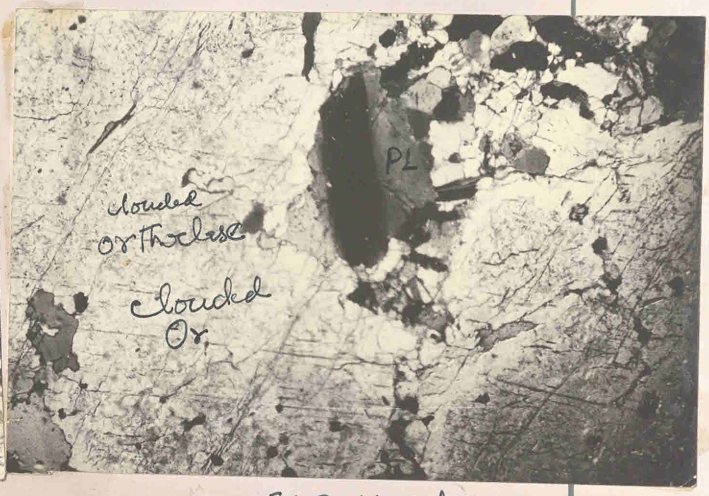


FIG NO (d)



FIG NO (e)

FIG NO (f)

PLATE : 25

(a) This is case of replacement where the older plagioclase is being replaced by microcline of high trichinicity. (XPL 40)

(b) String perthite grading into inter penetrant type. A typical cases of silicification where anhedral, undulosed, quartz is enclosing small grains of clouded plagioclases showing less development of perthite. There are two crystals of biotite one prismatic section is and seen overriding clouded plagioclases and other basal sections and is extenction position in the field. (XPL 20)

(c) A metacryst of half microcline, microperthite of inferior triclinicity. The plagioclase crystals with crenulated margin are found along the contact between other string type perthites below in the field and microcline in the uppor portion. (XPL 20)

(d) Banded or ribbon type perthite which is relatively bright in one corner and the margin of this perthite is having a sutured contact with microcline perthite (not clear) showing relic carlsbad twinning. Note faint development of myrmekite near the margin of microcline microperthite with faint carlsbad composition plane. Also in the field there are grains of shp sphene and iron ore. (XPL 20)

(e) Metacryst of microcline microperthite of inferior triclinicity is mantled by sodic plagioclase fromwhere the sodic lamellae start thereby microcline is being gradually replaced by sodic plagioclase. (XPL 40)

(f) A case of albitization where quartz crystals changeing to albite with fine twin lamellae A deformation is noticed whereby the perthitic microcline and other subrounded grains show undulosity. Also there are secondary fine crystals of quartz to have filled the fracture planes of perthites. (a case of cataclasis) Also in the picture is island of perthite in the sodic plagioclase. (XPL 10)

PLATE NO. 25

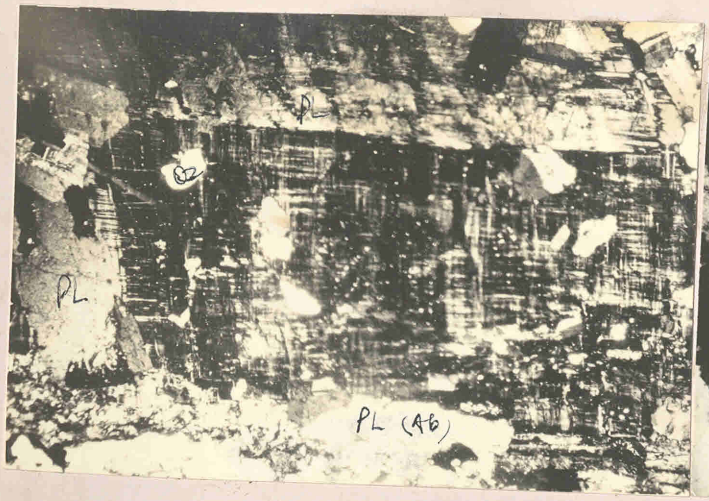


FIG. NO. (a)

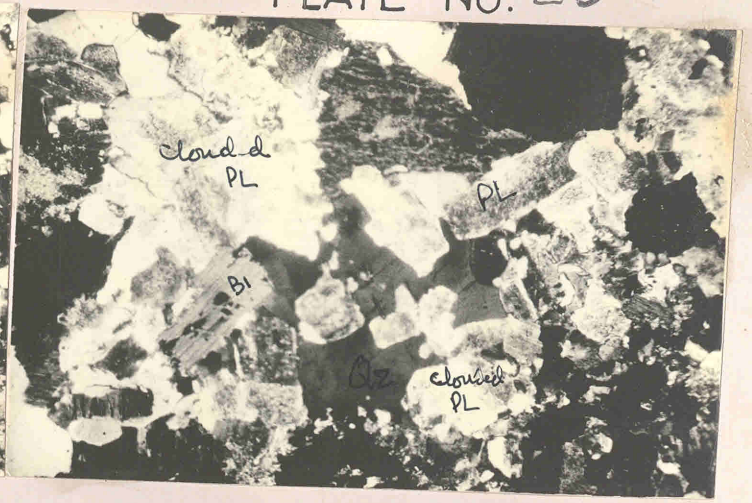


FIG. NO. (b)



FIG. NO. (c)

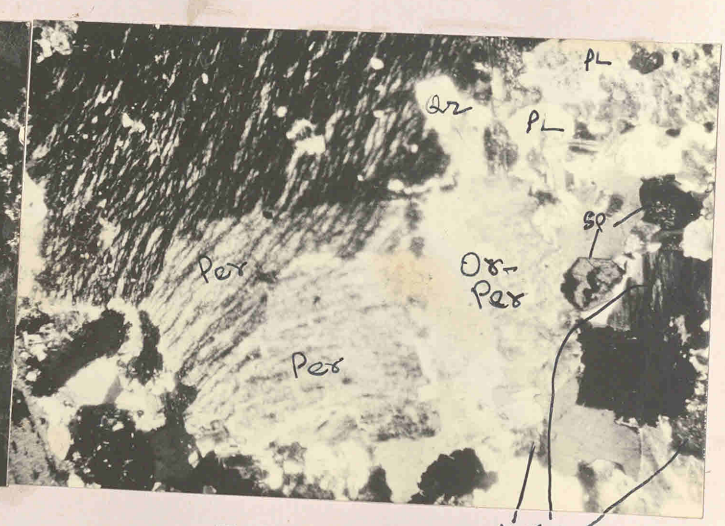


FIG. NO. (d)

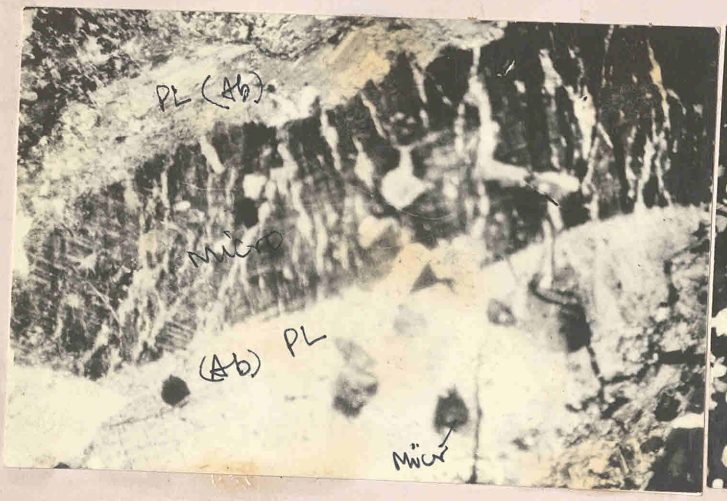


FIG. NO. (e)

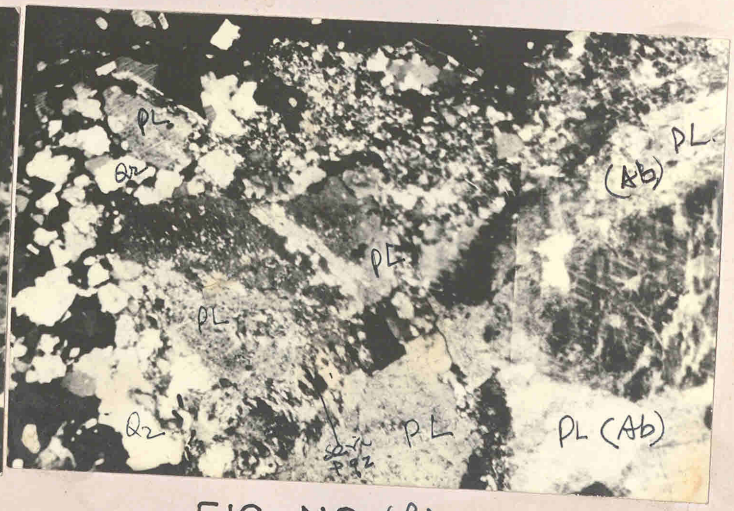


FIG. NO. (f)

PLATE 26

(a) - A case of feldspathization wherein an elongated grain of Quartz is enclosed in Microcline microperthite. Note on elongated bent muscovite in the upper corner right with distinct relic cleavages possibly of biotite. Fine aggregate mass of quartz crystals are along one margin of microcline microperthite which show undulosity. (XPL 20)

(b)- Morter texture, wherein the highly undulose large ragged lenticular quartz porphyroblast is set in a fine grained aggregate crystals of quartz which also show undulosity. Note fine development of albitic lamellae in quartz crystals cemented together through sutured margins. (XPL 20)

(c) Microphotograph shows a cremulated biotite laths with obliterated cleavages showing re-absorption. This lath also contains rounded epidote grains along the cleavages. The background shows clouding in feldspar, view is under polarized light. In the field there is a grain of subhedral sphene with cracks filled with iron dust. (PPL 40)

(d) Clouding of quartz and feldspar, the development of albitic twin in clouded quartz as a result of albitization and feldspathization. A perthite enclosed a deformed plagioclase grain. The field also contains clinozoisite and sphene associated with opaques. (XPL 40)

(e)- Feldspathization is conspicuous, where sutured quartz grains are being replaced, the grey orthoclase perthite replaces them and clouding is conspicuous due to presence of iron dust. (XPL 20)

(f)- Microfaults and bending in plagioclase feldspars fully sericitized. The aggregate of quartz, mica, and fine feldspar grains permeate through the void created due to deformation. (XPL 20)

PLATE NO. - 26

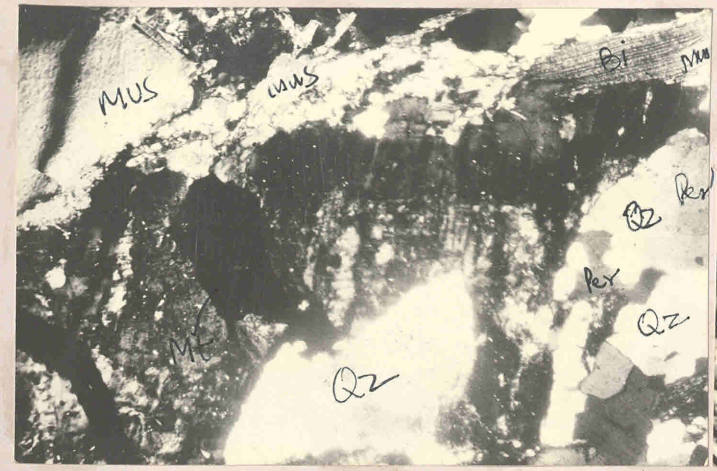


FIG. NO. (a)

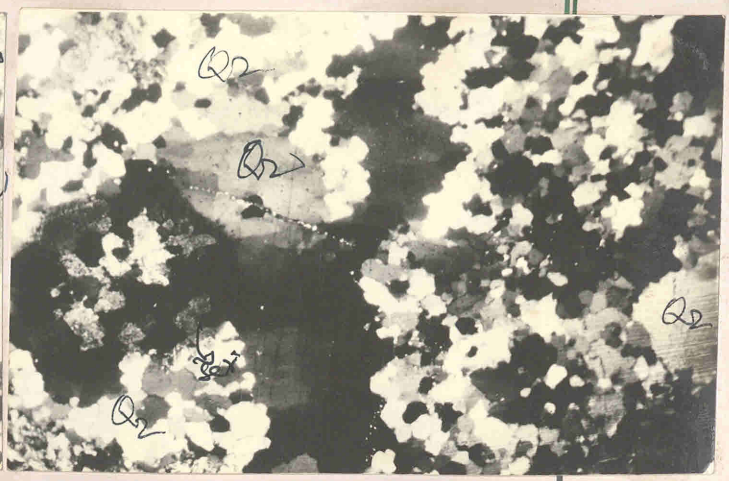


FIG. NO. (b)

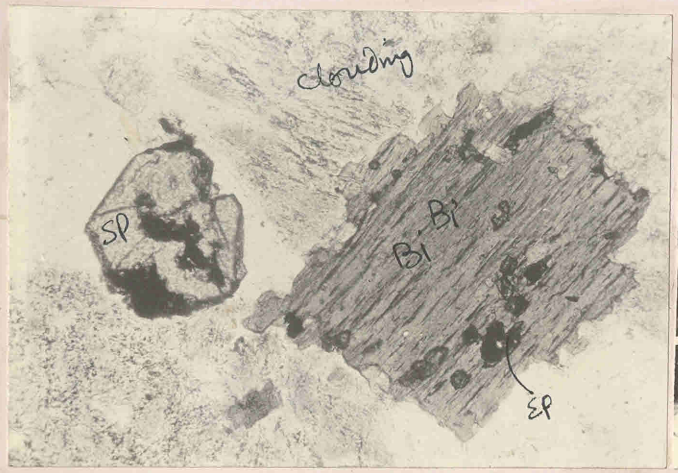


FIG. NO. (c)



FIG. NO. (d)

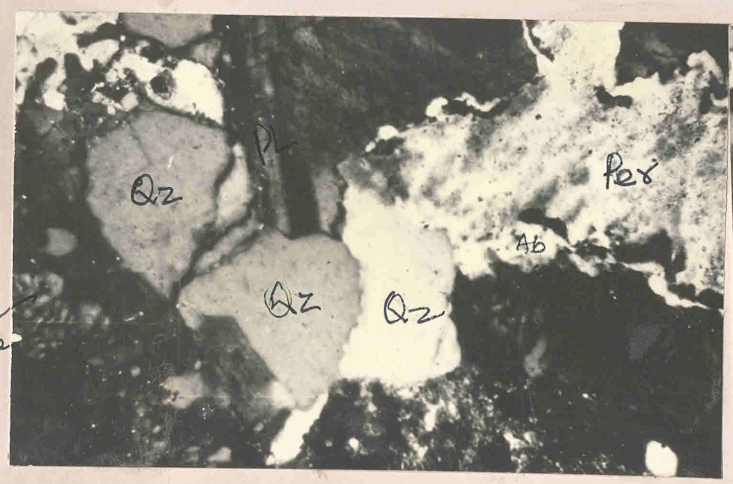


FIG. NO. (e)



FIG. NO. (f)

PLATE- 27

(a) - Herring-bone structure in perthite. Note micro-vein of sodic material cutting across the perthite. (XPL 40)

(b)- Anorthoclase remnant in braid and vein perthite Also a crystal of fine microperthite. It is a sort of exsolution perthite. (XPL 40)

(c)- View of vein perthite grading into braid types. Also a crystal of fine microperthite in the left corner (in grey colour in the photo). (XPL 20)

(d)- View of string and vein penetrating perthite. Note there are remnants of micro cline in one perthite and slight bending in another perthite. Recrystallization of quartz along the contact perthites is noticed. (XPL 20)

(e)- Parallel growth of different string perthites (due to exsolution). There is displacement noticed in sodic lamellae in extinct perthites. (XPL 20)

(f)- Microphotograph of patch perthite, showing remnants of plagioclase in microcline showing thereby that microcline is replacing plagioclase (replacement perthite). There are other grains of microcline-microperthite. Vein type perthite is also noticed. (XPL 40)

PLATE. NO. 27

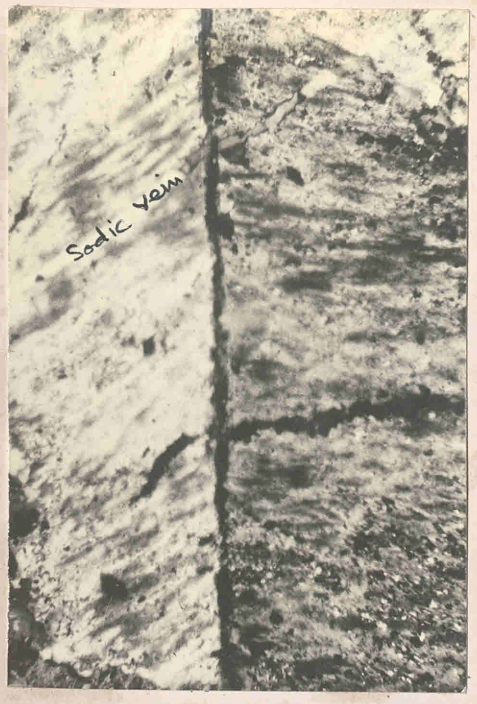


FIG. NO.(a)

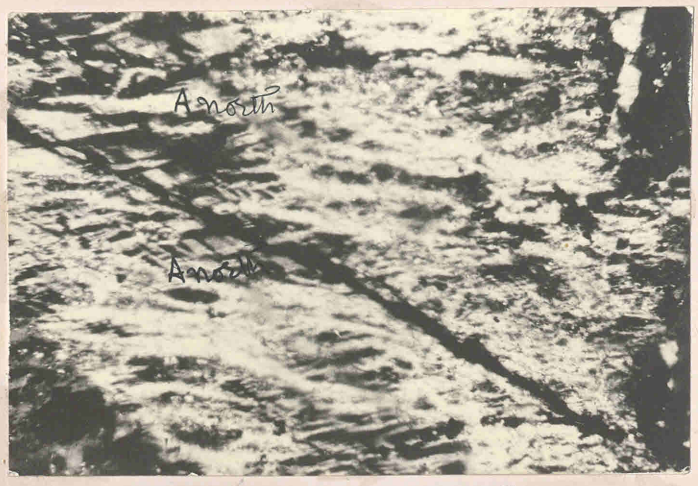


FIG. NO. (b)



FIG. NO. (c)

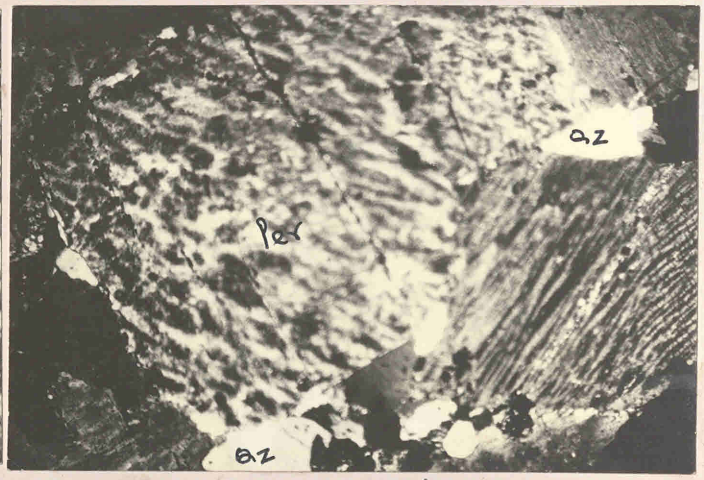


FIG NO. (d)

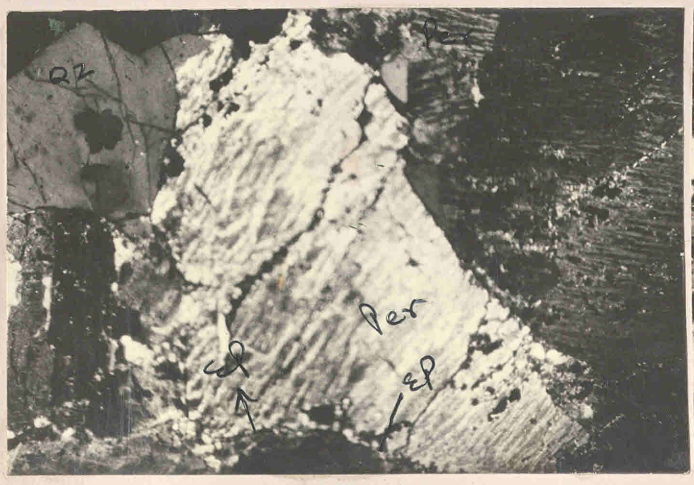


FIG. NO. (e)



FIG. NO. (f)

PLATE- 28

(a) View of film perthite (cryptoperthite) through which microveins are cross cutting the whole crystal. (XPL 40)

(b)- A case of typical feldspathization wherein a big anhedral undulosed quartz crystal with dusty margins is encl sed in clouded perthites. Note how white quartz crystals are gradually being replaced by feldspathic material. Iron dust in whole field is also conspicuous. (XPL 40)

(c)- Fractured undulosed anhedral quartz crystals containing trails of inclusions among which are vermicules that bring a stage of incipient feldspathization and through the cracks the feldspathized material is penetrating. The outer margins of quartz are replaced by clouded perthitic feldspar. (XPL 40)

(d) - String perthite and film perthite of microcline due to exsolution and exsolved plagioclase clouded from where the sodic lamellae begin and are not complete in the crystal. These perthite lamellae are at right angles to the elongation of host crystal. (XPL 90)

(e)- Chess board albite, microcline microperthite with remanants of old plagioclase, microcline enclosing a seggregated mass of mostly epidote and few biotite flakes. Relic of quartz is there associated with other inclusions as a result of reaction. (XPL 40)

(f)- Chess board albite is being replaced by fresh albite which is sericitized with featheary aggregates of sericite (a case of albitization.) (XPL 40)

PLATE NO. - 28

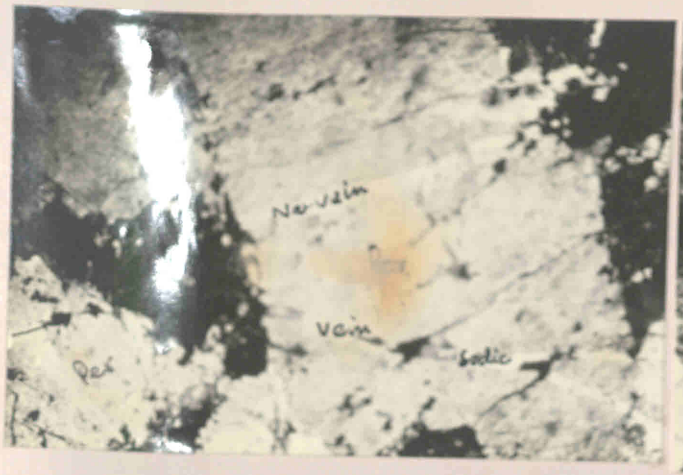


FIG. NO. (a)



FIG. NO. (b)



FIG. NO. (c)



FIG. NO. (d)



Chess board albite FIG. NO. (e)



FIG. NO. (f) chess board

PLATE 29

(a)- String and vein perthite showing replacement phenomena. The contacts between the two different perthites is filled with the sodic plagioclase, later mineral which shows convexity towards the K-perthite on it grows. Also along the contact, a pod of microcline perthite filling interstices. There are fine numerous sodic vermicular plagioclase to have grown in anhedral undulosed quartz crystals. (XPL 20)

(b)- Euhedral crystal of opaques with inclusions of apatite crystals and leucoxene. The margins of opaques are of feathery aggregates of biotite crystals. Clouding of perthite and quartz is conspicuous. (XPL 40)

(c)- A phenocryst of microcline microperthite containing a fully sericitized grain of albite which shows microcline perthite is the last to crystallize. Along the contacts of the two consecutive perthites laths of fresh biotite crystals with distinct cleavages seem to have crystallized from the melt under fluidal conditions. (XPL 20)

(d)- Cross arrangement of biotite flakes with different crystallographic crenulated margins suggestive of re-sorption due to selective melting of parent rock. Also one early formed flake shows a typical magmatic corrosion which is intruding elongated crysta s of quartz showing fracture. (XPL 20)

(e)- Two crystals of biotite flakes with different crystallographic orientations. One biotite crystals showing resorption in the center with the late liberation of quartz and magnetite. Note the iron dust is along one margin of quartz crystal and along the contacts of the crystals, two biotite crystals, magnetite showing parallel growth along the cleavages of biotite lath. (XPL 20)

(f)- Younger biotite lath with distinct cleavages showing kelphytic margin occurs in juxtaposition with fresh albite grain along the contact between the microcline microperthite and plagioclase perthite. (XPL 40)

PLATE NO. - 29

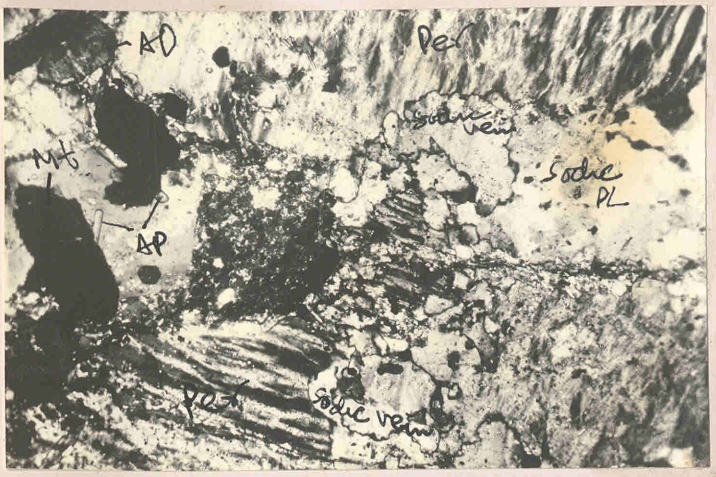


FIG. NO. (a)

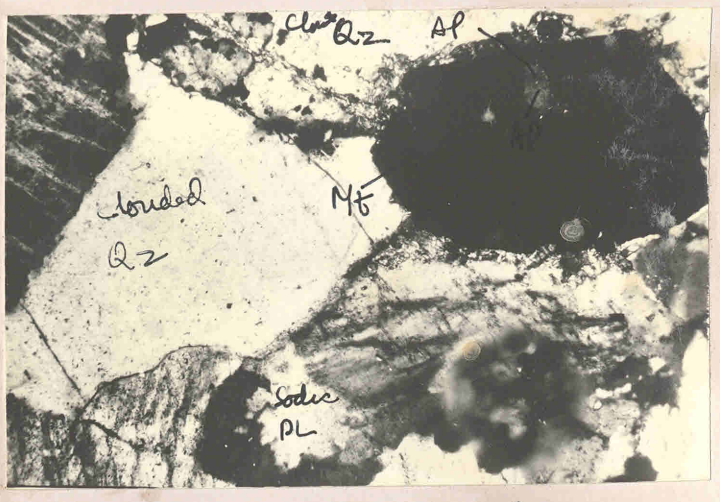


FIG. NO. (b)



FIG. NO. (c)

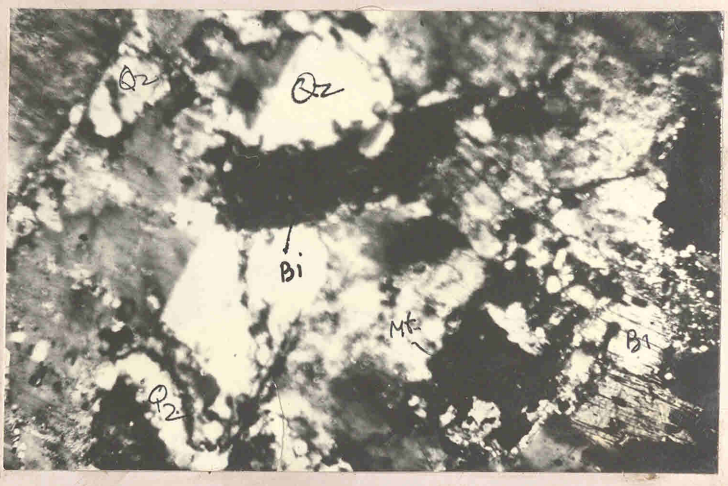


FIG. NO. (d)

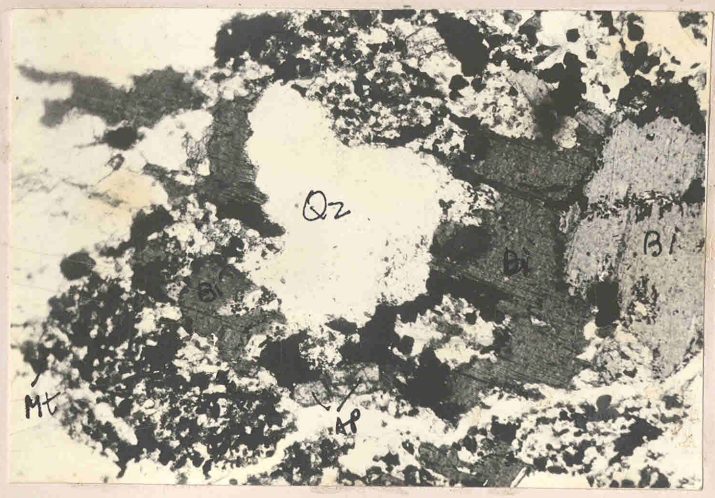


FIG. NO. (e)

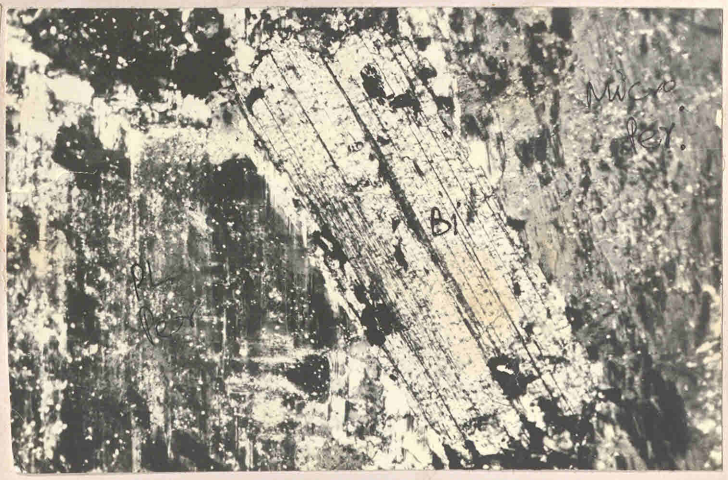


FIG. NO. (f)

PLATE- 30

(a) - Microcline microperthite containing isolated grains of plagioclase with preserved twin lamellae ~~suggesting that plagioclase with preserved twin lamellae~~ suggesting plagioclase is being replaced my microcline (patch type perthite). Myrmekite growth is seen along the contact. (XPL 40)

(b)- Perchitic orthoclase (grey) exsolution with relic carlsbads twinning replacing the plagioclase (white) as is evident from the includions of shreds of plagioclase in the perthithic orthoclase changing the K-feldspar of low triclinicity. (XPL 40)

(c)- Patch perthite in the field. The later is perhaps due to exsolution and bordered and lobes fringes of albite of younger generation due to metasomatism while as the former perthite is due to the replacement. Note there are irregular veins of fine aggregates of epidote in the patch perthite. (XPL 40)

(d)- One feldspar granite showing field of perthites mostly string and vein types each bordered by fringes of sodic plagioclase formed by metasomatism. One perthite crystal is perhaps as a result of exsolution process. (XPL 20)

(e) Vein and patch type perthite in which vein replacing albite pods occur along contact between the patch perthite and perthitic plagioclase. Younger sodic plagioclase is structurally parallel with the perthitic plagioclase on which it grows and exhibits convexity towards early formed perthitic plagioclase. (XPL 40)

~~Composite Perthite~~ composite.

(f)- Patch perthite containing a spindle shaped perthite whose lamellae are at right angles to the elongation of included perthite. Also the margin of this small grain is mantled by the sodic material. (XPL 40)

PLATE NO. - 30



FIG. NO. (a)



FIG. NO. (b)

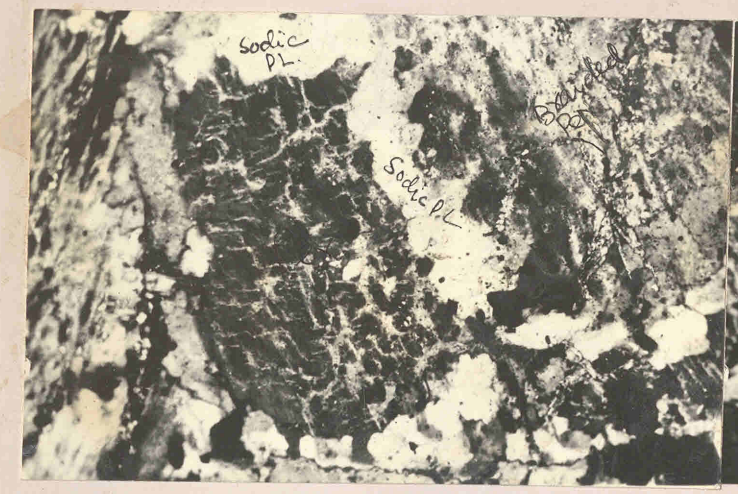


FIG. NO. (c)



FIG. NO. (d)



FIG. NO. (e)

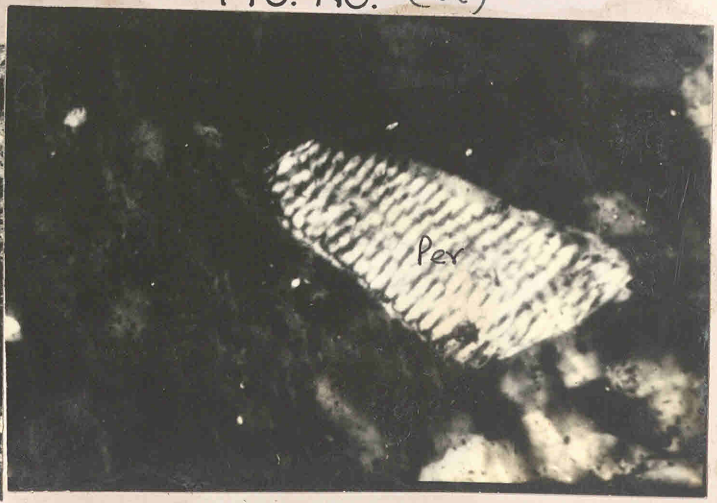


FIG No. (f)

PLATE 31

(a)- Patch perthite showing microcline remnants in plagioclase Twinning in plagioclase inherited from microcline is indistinct. (XPL 40)

(b)- The field shows string and vein type perthites. Some Some sodic lamellae penetrate each other which is worth noting. A rounded grain of perthite is mantled by sodic plagioclase on the one side and show straight margins with undulosed quartz and other perthitic grain where the perthitic lamellae show dislocation causing displacement. The anhedral quartz crystal forms intersititial material. Note another microfault in rounded perthitic grain with remains of microcline (Perthitic microcline) which shows that deformation is post metasomatic change. (XPL 20)

(c)- A typical case of feldspathization wherein a loop shaped quartz is enclosed in the centre of field of patch perthite. (XPL 40)

(d)- Microphotograph shows vein type perthite exhibiting interpenetrating feature. This perthite contains subrounded grain of quartz. (XPL 40)

(e)- Perthites (wavy type or compound type other rounded grains of vein and strong perthite). There is silcification wherein anhedral undulosed quartz crystals occupy the contacts between adjacent perthites. (XPL 20)

(f)- String type lamellae grading into vein type lamellae within the crystal which is mantled by one sodic plagioclase. Note: Faint development of myrmeketic growth in plagioclase in contact with microcline microperthite. (XPL 40)

PLATE NO - 31



FIG. NO. (a)



FIG. NO. (b)



FIG. NO. (c)



FIG. NO. (d)

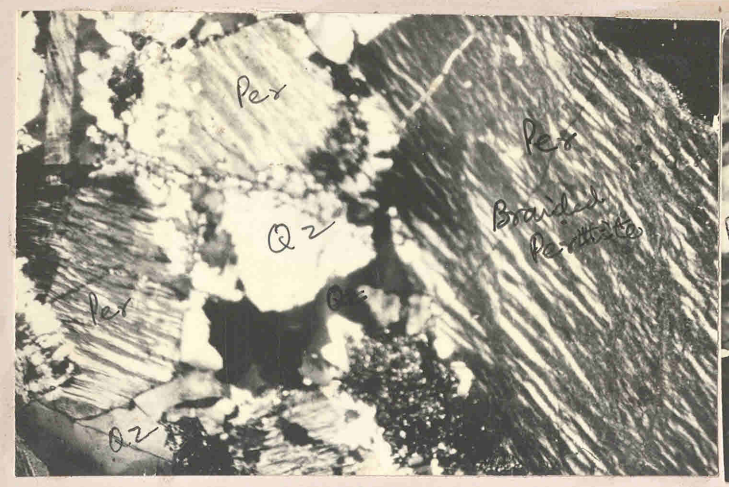


FIG. NO. (e)



FIG. NO. (f)

PLATE. 32

(a)- Replacement of deformed plagioclase by rod and braid perthites and the former is mantled by albite pods. The younger microcline of high triclinicity is replacing the plagioclase and perthites (two feldspar granite.) (xPL 20)

(b)- Single feldspar granite containing different perthites amongst them are spindle shapped vein perthite which shows hering bone structure. (xPL 20)

(c)- Fracturing in perthite with film lamellae grading into string type. along the margin. (xPL 40)

(d)- Perthites showing sutured borders and perthitic development in orthoclase grain with preserved cleavages and another grain showing remnants of microcline in plagioclase. All the grains are mantled by later sodic plagioclases which show later growth with perthites along the margins. Note that there is a fracturing throughout the field. (xPL 20)

(e)- A vein of sodic plagioclase cutting across the sericitized host perthite. (xPL 40)

(f)- Plagioclase perthite (patch type) with topo concentration of opaques and epidote as later minerals. Clouding is conspicuous. (xPL 40)

PLATE NO - 32



FIG NO. (a)



FIG NO. (b)



FIG NO. (c)



FIG NO. (d)



FIG NO. (e)

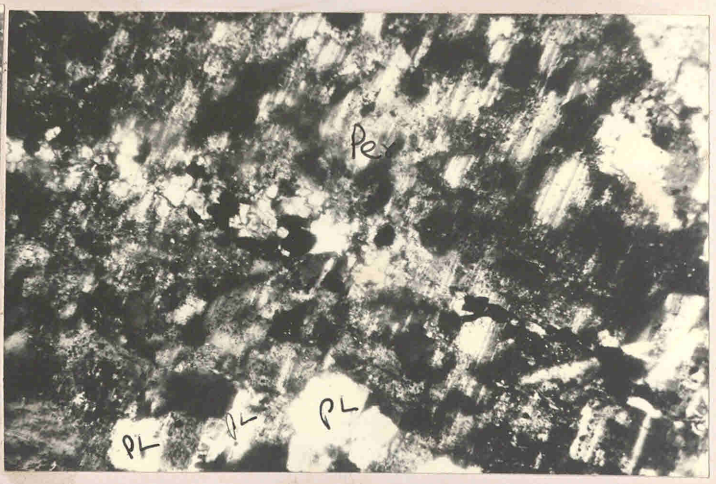


FIG NO. (f)

PLATE. 33

(a)- Patch perthite, plagioclase with distinct discontinuous remnants of orthoclase. P agioclase replacing orthoclase with relic orthoclase cleavages. There are fine scattered grains of epidote. (XPL 40)

(b)- Development of perthites in orthoclase with preserved cleavages latter called orthoclase -perthite with grains of opaques around epidote and quartz as inclusions. Note there is a micro-vein of quartz and opques cutting across the relic cleavages of orthoclase perthite which is proabably later development. (XPL 40)

(c)- Microcline microperthite is replacing plagioclase - perthite showing wavy structure of perthitic lamellae. (XPL 40)

(d)- Cryptoperthite with relic carlsbad's twinning. (XPL 40)

(e)- Vein microcline microperthite with islands of sericitized plagioclase (white coloured). (XPL 40)

(f)- It shows string perthite grading into vein type. The perthitic lamellae are inclined to the main crystal face and extend the boundary of the same crystal face (replacement origin.) (XPL 40)

PLATE NO. 33

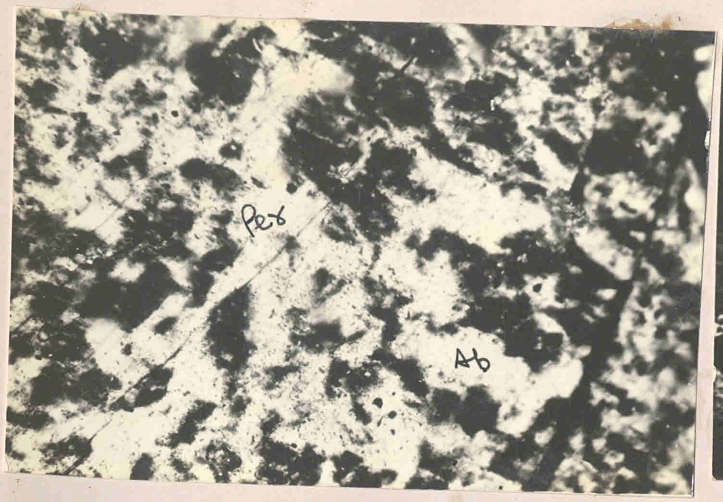


FIG. NO. (a)

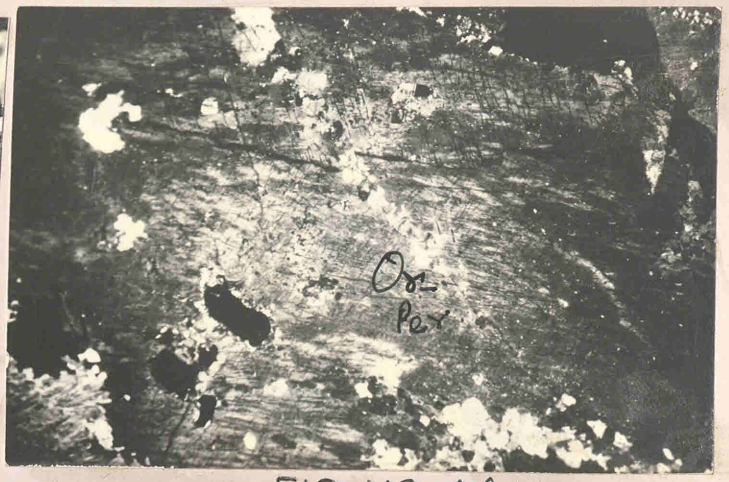


FIG. NO. (b)



FIG. NO. (c)

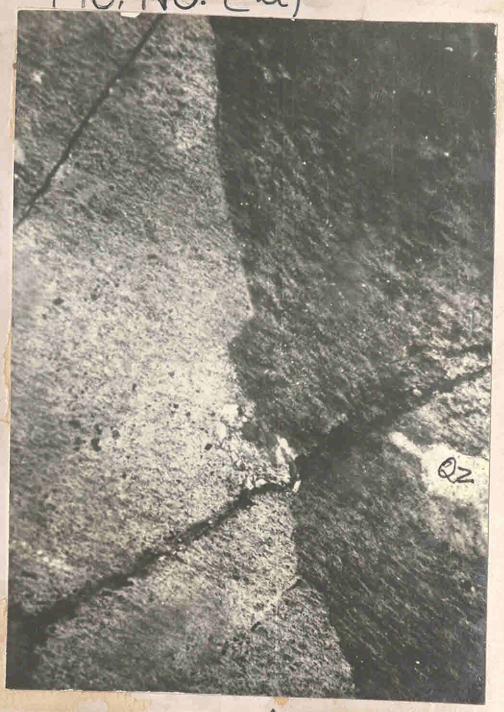


FIG. NO. (d)

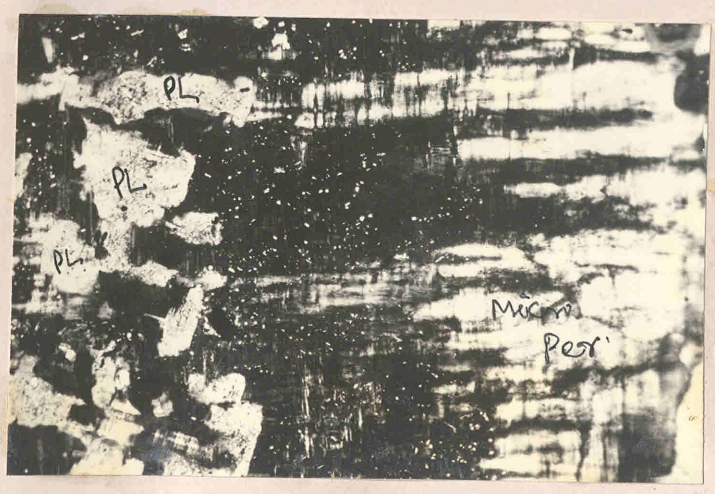


FIG. NO. (e)

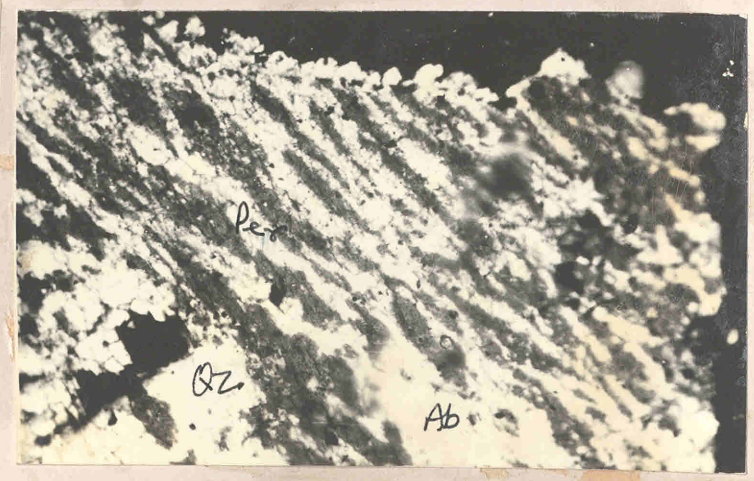


FIG. NO. (f)

PLATE- 34

(a)- Discontinuous rounded elongated clouded grains of plagioclase as inclusions in microcline microperthite. This shows replacement of earlier formed plagioclases. Subsequently irregular and cracked undulosed quartz containing small inclusion of microcline and plagioclase is replacing both plagioclases and microcline. (XPL 20)

(b)- Microcline microperthite of inferior triclinicity contains and island of plagioclase grain zoned one, which is indicated by the sericitization in the core thus showing replacement phenomena. (XPL 40)

(c)- Microcline microperthite with relic carlsbad's twinning showing inversion of old orthoclase into microcline of inferioir triclinicity. This is traversed by numerous irregular cracks filled by leached femic material. Silicification is conspicuous. which is connected with deformation and post consolidation effect. Note the quartz forming intersititial between two perthites, is also fractured and undulosed which is replacing older perthites. (XPL 40)

(d)- Field shows overall view of different perthites which included vein, string and interpenetrant type. (XPL 20)

(e)- Plagioclase perthite contains inclusions of small quartz, epidote grains and fractured clinozoisite. (XPL 40)

(f)- Inset of chess board albite with relict carlsbad8s twinning. The perthites show sutured contacts (older perthite (in extinction) is being replaced by Chess board albite. (XPL 20)

PLATE NO. 34



FIG. NO. (a)

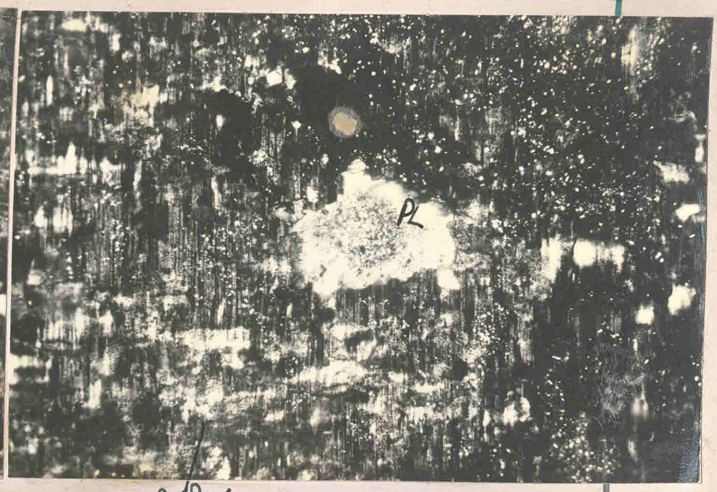


FIG. NO. (b)



FIG. NO. (c)



FIG. NO. (d)



FIG. NO. (e)



FIG. NO. (f)

PLATE- 35

(a)- Development of perthites along the margins fractured orthoclase. Distinct cleavages seen in host orthoclase containing uncleaved biotite lath exhibiting sutured contacts with the perthite. The biotite lath also contains topo concentration of iron ore and anhedral quartz crystal. (XPL 20)

(b)- Clouded perthites seen to have undergone deformation (cataclastic) which causes permeation of aggregate mass of secondary silica and sericite in an irregular fashion. Note a rounded grain of highly undulant quartz surrounded by secondary silica. (XPL 20)

(c)- Overall picture of cataclasis wherein fine aggregate material of secondary silica, mica and epidote permeats through the fracture planes with perthites. Note an irregular quartz grain as a result of silcification along the boundaries of perthites. (XPL 20)

(d)- Mortar texture , where sutured quartz grains show strain shadow effect with crushed and recrystallized grains of quartz. Note along the margins of strained quartz are found as needles of quartz and sericite. (XPL 40)

(e)- A microphotograph shows a cross arrangement of aggregates of epidote, quartz, iron oxide, along the fractured planes of perthites as host mineral. (XPL 40)

(f)- A photomicrograph shows a zoned grain of euhedral epidote. (XPL 40)

PLATE NO. 35

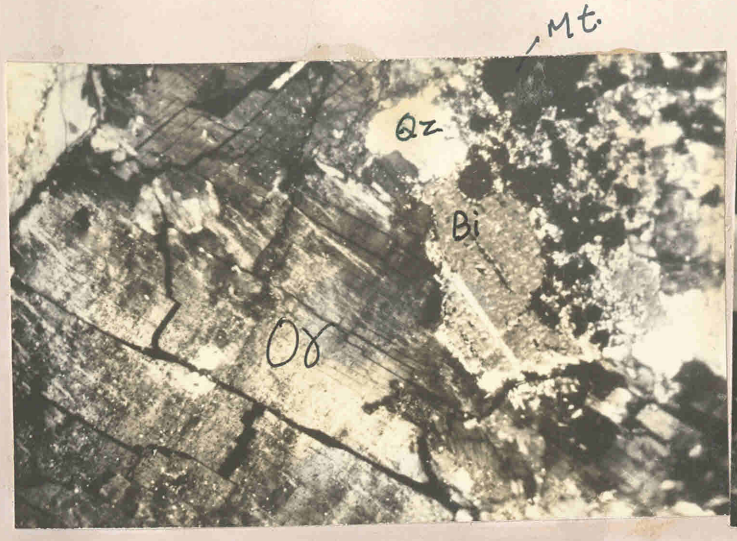


FIG. NO. (a)

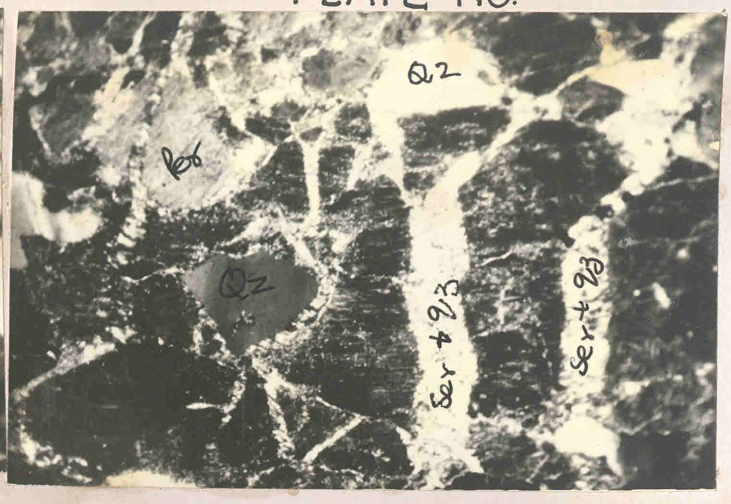


FIG. NO. (b)

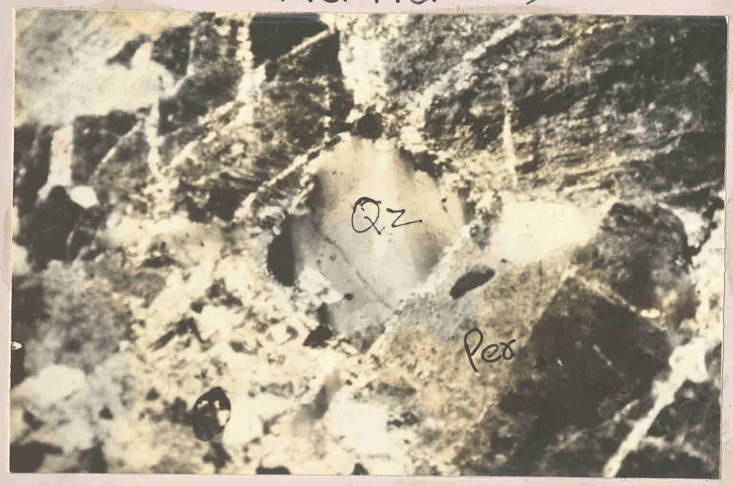


FIG. NO. (c)



FIG. NO. (d)

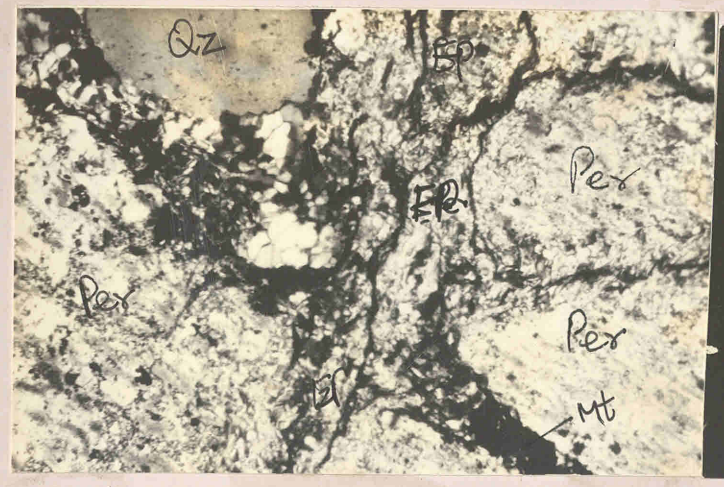


FIG. NO. (e)



FIG. NO. (f)

PLATE- 36

(a)- Slight foliated lath of biotite exhibiting sharp contact with perthite show parallel growth of small laths of chlorite. Note quartz blebs are found as intergrowth with fresh plagioclase in contact with perthite. (XPL 40)

(b)- Re-sorption laths of biotite exhibiting sharp contact with perthite show parallel growth of small laths chlorite. There are pleochroic halos showing sutured contact with quartz and perthite. The sutured quartz form intersititial between the perthite and microcline. The quartz shows much undulosity. (XPL 40)

(c)- Biotite slightly foliated show straight margin with perthites and occur along the contact between perthite and orthoclase. The quartz grains show undulosity. (XPL 20)

(d)- Biotite slightly foliated shows ~~straight~~ Sutured margin with ~~perthites~~ opaques . Dark green mass of anhedral biotite feebly pleochroic is seen to contain rutile needles showing ~~sag~~ pintic structure. The opaques contain partially the euhedral apatite crystals in contact. (XPL 40)

(e)- Heavily fractured hornblende is seen to be associated with replacing biotite which looks to be fresh and cleaved. The chlorite material shows a parallel growth along the cleavages of relativily fresh biotite. Biotite lath also contains opaques.litttle epidote, sphene, in juxta-position. There is also streak of fresh chlorite to have developed within the biotite. (XPL 20)

(f)- Five sided euhedral magnetite is masking the biotite rounded crystal in the centre of the field. This can be ascribed due to the presence of very small grain of biotite within the euhedral magnetite. (XPL 20)

PLATE NO. 36

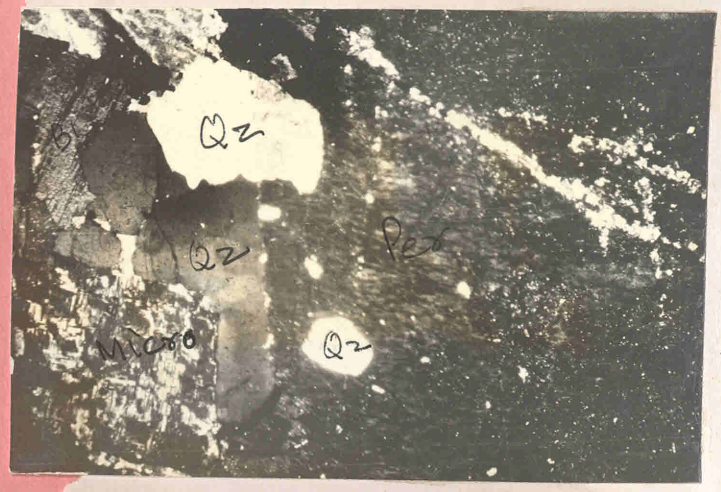


FIG. NO. (c)

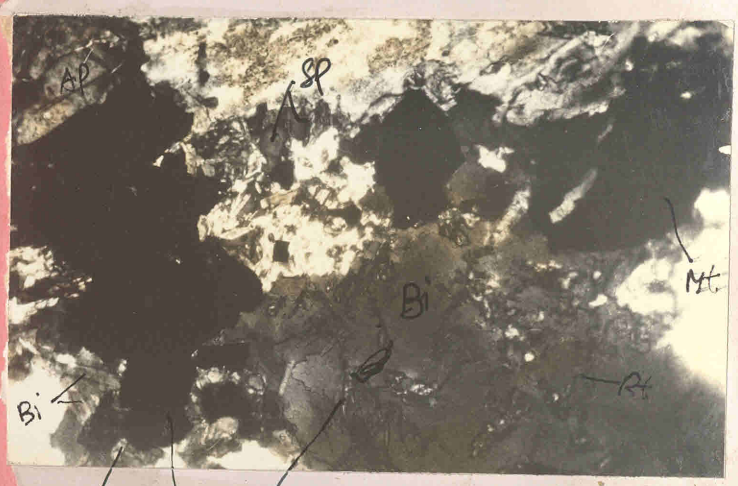


FIG. NO. (d)



FIG. NO. (e)

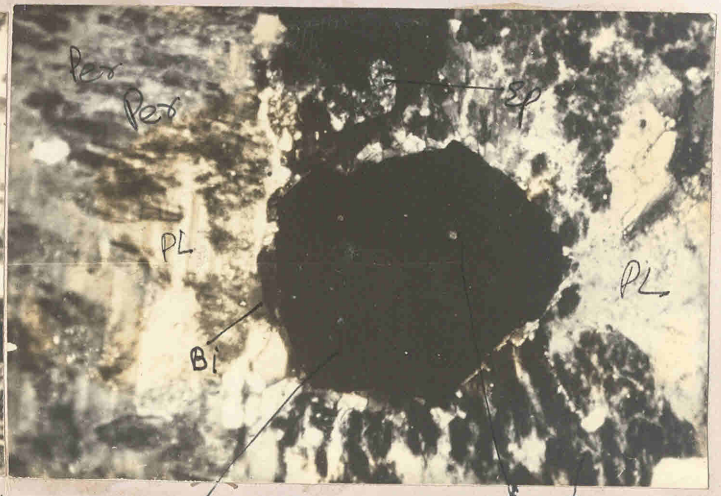


FIG. NO. (f)

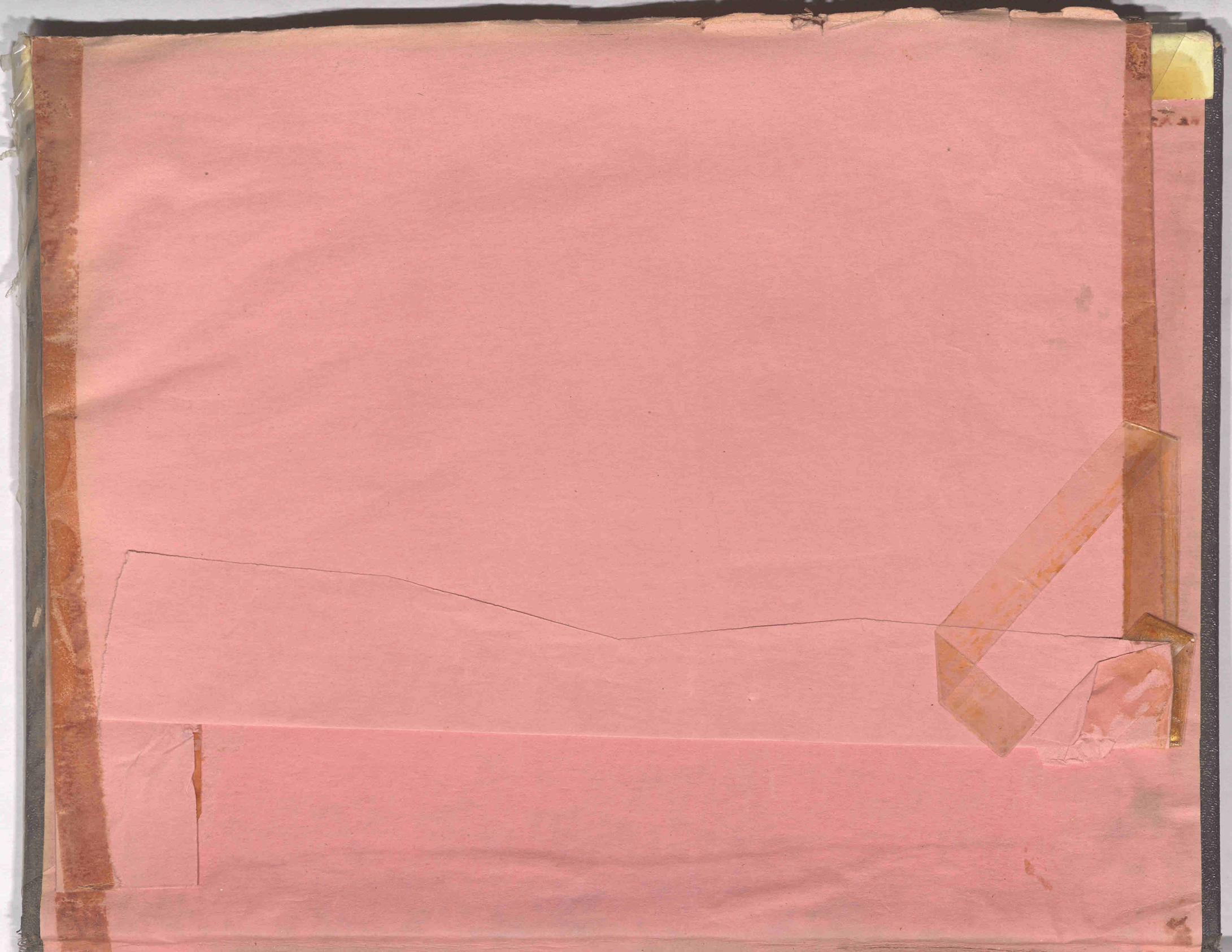
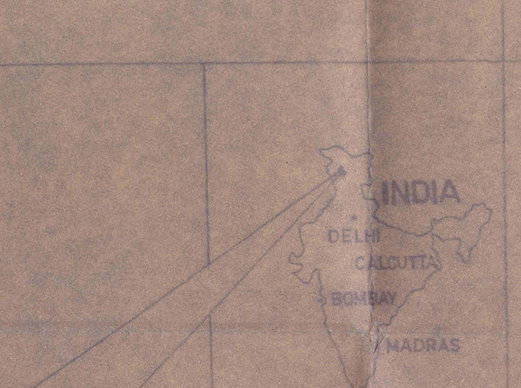


FIG. NO. 2

GEOLOGICAL MAP OF GUL-GULABGARH AREA
DISTRICT UDHAMPUR, JAMMU & KASHMIR





CROSS SECTIONS OF GUL - GULAB - GARH AREA.

VERTICAL SCALE = HORIZONTAL SCALE

A.K.KOUL, 1985.

Fig-4.

