CERTIFICATE

Certified that the dissertation entitled "CARBONATITES OF NEWANIA, DISTRICT UDAIPUR-RAJASTHAN, INDIA" being submitted by Mr. L. Palaniappan in partial fulfilment for the award of M.Tech. degree in Applied Geology of the University of Roorkee is an authentic record of the student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

October 15, 1976

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October 15, 1976

(L.PALANIAPPAN)

CONTENTS

PREFACE

Long back in 1884, before the carbonatite were recognized as petrologically and economically significant type of rocks P.N.Bose,while investigating the geology of the Narmada valley between Nimawar and Kawant near Dei, came across these carbonate rocks, and the observation which he made became the first ever recorded description of a carbonatite.

He observed masses of yellowish-altered calcareous siliceous rocks forming the crest of basalt-covered ridges. He has noted;

1. " that these rocks were more resistant to weathering and erosion than basalts.
2. that they were not bedded
3. contained no fossils
4. that they were fine grained but crystalline
5. that they were markedly calcareous with local nests and patches of trappean-looking substance- the igneous origin of which manifests under the microscope
6. the outcrop distribution is lenier and straight
7. that they were locally associated with highly altered and intensely hardened shaly and siliceous rocks.

He finally concludes that there can be very little doubt that ... the rocks under notice have been severed and forced up from the infratrappean beds by intrusive rocks. They have been most effectively baked being rendered quite crystalline .... and portions of them would appear to be converted into trappean substance.

In fact his suggestion that these were famed due to remobilization of infratrappean rocks has come to stay as one of the possible modes of origin of carbonatites. After several decades Sukeswala and Udas(1963) identified the same rocks described above as carbonatites.

Later in (1889) Hogbom, Brogger W.C.,(1921) identified these rocks as of magmatic origin.The carbonatites are now defined as carbonate rich rocks of apparent magmatic derivation or decent.

Carbonatites occur as both intrusives and extrusives,they may crop out as lava flows,dykes,sills,stocks and plugs.Carbonatites usually occur in distinctive petrographic association with more or less characteristic chemical composition.~~with~~ They are usually associated with rocks such as ljolites, Nephelinites,and contain significant concentrations of (Na +K),P,Ti,Sr Zr,Nb,Mo,Ba,REE,Th, in comparison with sedimentary limestone,otherwise they are difficult to be recognized and differentiated.

The significance of carbonatites increased several fold on the discovery of many rare earth containing occurrences in

South Africa during the second world war. Large contents of pyrochlore(Niobium rich mineral), Rare Earth minerals, the ce subgroup, and thorium deposits in these rocks accelerated prospecting operations for carbonatites.

Several occurrences of carbonatites of varying dimensions have been reported from several countries. In India they were found to occur in the states of Rajasthan, Andhra Pradesh, Tamil Nadu and Karnataka. The fluorite deposits at Ambadongar are associated with carbonatites. The Newania carbonatites in the present area of study bears much apatite but has been estimated to be uneconomical for exploitation, for the present.

TERMINOLOGY

Though the significance of carbonatites have been appreciated for quite sometime, from the recognition of their economic importance, many a student of Geology are yet inadequately acquainted with the nomenclature and terminology of this group of rocks. A brief definitions of carbonatites and their associated rocks are given below.

CARBONATITE: Any carbonate rich rock of apparent magmatic derivation or decent.

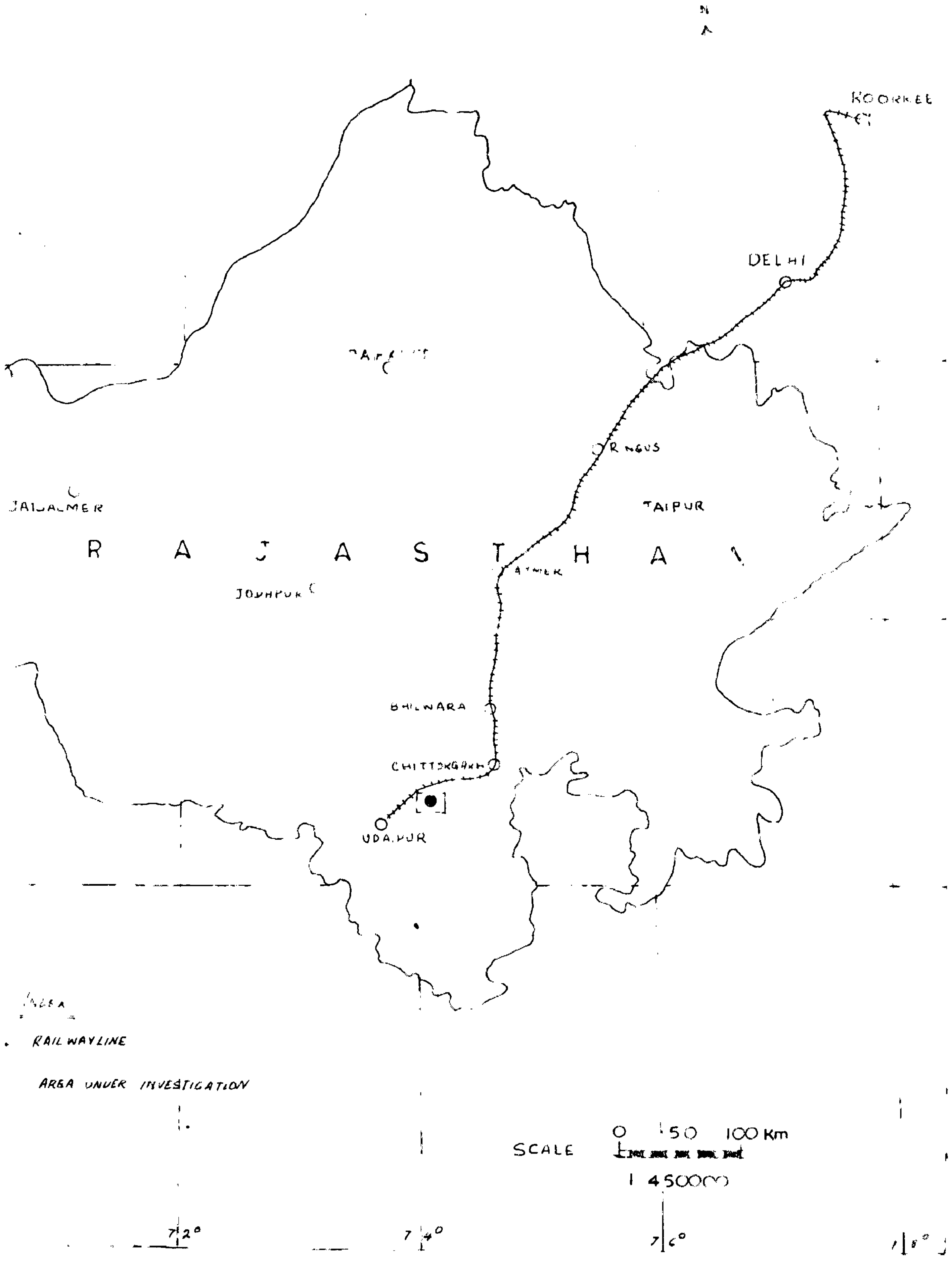
SOVITE: A carbonatitic rock with more than 80% calcite and 20% of other carbonates species and accessories, variable in grain size.

RAUHAUGITE: Dolomitic equivalent of the above. More than 80% dolomite 20% others.

FENITE: Any rock in the immediate vicinity of the carbonatites which have undergone metasomatism.

THERMAL SHOCK ZONE: A crushed and breccicted belt of in situ rocks forming a ring around the mobilized carbonatite rocks.

LOCATION MAP



CHAPTER - I

INTRODUCTION

LOCATION AND ACCESSIBILITY

The area of investigation selected by the author lies between the villages of Kikawas and Newania, Vallabhnagar Taluk Udaipur district, Rajasthan. The area lies 28 km. north-east of Udaipur city having latitude 24°38'22' and longitude 78°5'44". The actual area of detailed study covers an area of five kilometres by two kilometres 10 sq.km. lies within latitudes 24°35'N to 24°45'N ; Longitude 74°0' to 74°13'E. The area is covered by Survey of India Quarter Inch sheet No.45L. The work was done on the carbonatite outcrops which forms a plug between the villages Kikawas-Newania about 6 km. south east of Vallabh-nagar, connected by a cart track. A fair-weather road connects Udaipur and Fatehnagar which passes through Vallabhnagar.

PHYSICAL GEOLOGY

The area presents a mature stage with a plain topography bearing abundant soil cover. There are several hillocks in the northern and North-eastern part of the area, most of quartzites the schists being eroded to form depressions and valleys.

At Kikawas the carbonatites are found in a slightly depressed topography while near Newania they seem to be elevated to form a dome-like structure. Characteristic limestone weathering is seen in these outcropslarge sink holes,pitted surfaces and solution cavities.

Ephemeral streams, their tributaries and distributaries of small dimensions run in the area,with inter connecting nallahs. Among the several irrigation canals in the area one such cuts across the carbonatite outcrop north of Newania village,on its way to Randers.The canals are unlined,dry most of the year,which provides an ideal exposure for study.

The climate is typical of semi arid terrains being very hot during the day and cool at night.July,August and September are the rainy months. During the hottest months of April,May and June the temperature ranges from 30° - 40°C. November, December,and January are the winter months.

Soil cover is very thin in the area insufficient to support certain plant crops.The vegetation flourishing the area are stunted shrubs, and plants.Among trees mangoe trees are common. Mangifera indica, Tamarind trees,fig trees and plantains are commonly found. Vegetation on the carbonate rocks are negligible except for grasses with fibrous roots.

PREVIOUS WORK

The outcrop of carbonatites in the present area of investigation has been previously worked upon by several workers from as early as 1934.

Gupta(1934) has, while investigating the area indicated that these rocks as aravalli limestone in his geological map. Heron too mentioned it as limestones of aravalli age (1953).

Recently K-Ar dating of the amphiboles found in Newania gave the age of 759 ± 25 million years.This was done by T.Deans,Overseas Geological Survey,London.

Dar,K.K.,(1964) in his description of the likely carbonatite occurrence in India has given that a highly folded calcareous granulitic rock occurs in a large post-Aravalli granite intrusive. He however,tentatively named it as crystalline limestone.He suggested that they could be Sovite or Haematitic Sovites containing calcite chlorite,biotite,apatite,quartz, magnetite and minerals of pyrochlore affinities.

Phadke,A.V. and Jhingran,A.G.(1968) gave an account of the Geological setting,mineral assemblages,geochemistry of the carbonatites,fenites.and granites.They gave a very brief account of the country rocks,granites, the fenitization and fenitized zone, and the carbonatite rocks which they grouped into three classes. They also gave data on chemical analysis which tend to support that these rocks are related to metasomatic processes of apparent magmatic origin.Trace elements were determined qualitatively and the results of which also supported their view.

Their chemical and spectrographic analysis data has been reproduced here elsewhere for comparison.

Yadav(1969) worked in the area.His view was that the carbonate rocks were not carbonatites,but remobilized sedimentary carbonates rich in phosphorous and iron,which has later reconstitued themselves as apatites and titanomagnetites.His arguments and evidences favours the biotite granites to be younger than the carbonate rocks and that the granites have been intruded into the carbonate rocks which remained as a xenolith. Due to Alkali metasomatism sodic-pyroxenes and amphiboles have developed.

Yadav has collected much bore-hole data to support his views.He has given an idea of the possible reserves of apatites in the outcrop.

THE PRESENT SCOPE OF STUDY

Though many previous investigators in the area have described the carbonate outcrop of Kikawas-Nawanamone gave an account of the detailed mineralogy of the carbonatite rocks.

Further none gave due importance to the metasomatic processes that have given rise to the Reibeckite syenites or fenite as the author prefers to call them.In fact every investigator has given a vague idea.

Although qualitative spectroscopic studies on the carbonatites have been done (Phadke and Jhingran,op.cit.) yet no quantitative trace element determinations have been made.

In view of the above the author was given the area to find solutions,to the extent possible,within the limited time available.

The author during his first field outing which lasted for 10 days during June '75 got acquainted with the area,studied the carbonatite outcrops and prepared a map 1:50 metres scale by the pacing and compass method. Along the traverses taken perpendicular to the direction of linear extension of the whole outcrop,the author collected samples at fifty metres interval which gave nearly 70 samples.

Detailed mineralogical and textural variation in the carbonatite outcrops were recorded in the map and data regarding features like bedding,joints and foliation were also plotted.

During the second field visit the author spent 10 days collecting systematic samples in the fenitized region,to study their variation. And on the spot acid,alizarin reds test were done to confirm many observations previously made. The author was able this time to go down several wells to study the fenitization structures and collect samples.

Laboratory studies includes thin section studies, X-ray diffraction studies, staining, chemical analysis of 15 samples and trace element studies, and Radiometric studies.

The author on the basis of his work done in the field as well as in the laboratories within the department and without has given the substance of his study in the following pages.

Since the author did not have the time to study the geology and stratigraphy of the area, he has completely relied on the works of previous geologists who have done good work in this respect.

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CHAPTER - II

GEOLOGICAL SET UP AND LITHOLOGY

The most predominent country rocks of the area under study belong to the Aravalli Age, consisting of quartzites and schists, within which the granites occur. The origin of the granites are still being discussed while Gupta (1934) considered these granites to be part of the pre-cambrian shield rocks or the banded gneissic complex over which the aravalli rocks were deposited unconformably. Dar (1964), Phadke and Jhingran(1968) considered these granites to be post Aravalli i.e. emplaced later in the quartzites schistose rocks.

A table representing the stratigraphic sequence suggested by the various authors including those of P.K.Yadav(1969) has been reproduced from P.K.Yadav(1969) M.Sc.(Tech.) dissertation. [TABLE A.]

TABLE - A

TABLE SHOWING GEOLOGICAL SUCCESSION ACCORDING TO VARIOUS WORKERS

Gupta (1934)	Heron (1953)	Sharma (1953)	Dar (1964) Phadke and Jhingran (1968)	P.K.Yadav (1969)
		Soda pegmatites and soda syenites	-	Recent alluvium fine grained carbonate veins soda-amphibole gneisses
		Quartz vein		Quartz vein
		Pegmatites and aplite veins	Carbonatites	Pegmatite veins aplite veins
		Granites	Granites	Ultala granites
		Basic rocks		Basic sills now Amphibolites
Shales slates and mica schists	Shales Slates and Mica schists	Bhadesar Quartzites, Kanoj and Khardeologrit Khairmalta amygdaloid		
		Ranthambhore Quartzites Thick shales slates and phyllites	Aravalli Quartzite and schists	
Thin ferruginous lime stone	-	Thin ferruginous lime stone	-	Ferruginous marble with apatite and chlorite schists
Basal Quartzites	Basal Quartzites	Thin Basal Quartzites and volcanic beds	-	Alternative schists and Quartzites
B.G.C.	B.G.C.	B.G.C.		

The base of the Aravalli rocks have not been exposed in the area (Yadav,1969) and the succession starts with quartzites and schists alternations.These Aravalli formations has also been intruded by basic rocks like Amphibolites. The general dip of the Aravalli formations are N70° with local variations.

The lithological description of the carbonatite and the associated rocks have been given below.

These can be conveniently grouped into

1. calcite rich Sovites
2. Dolomite rich Ranhangites
3. Haematitic sovites+Ranhangites interalations

Sovites are widespread,as individual outcrops,scattered all over the outcrop.They are mostly greyish or greenish grey in colour,mostly coarse grained Ranhangites are coarse grained pale pink or greyish colour present all throughout the outcrop, but the mixture of these two rock sovites and ranhangites are the most common within the plug. Usually these are also associated with iron oxides which gives their diagnostic appearence. These rock comprises the major area of the outcrop. Those also include their fine grained counterparts which are found to occur as distinct intrusive bodies within the fenitized zone and sometimes within the main carbonatite outcrop.

Apatite veins are found in all these rocks.The strike, and dip directions of all the carbonatite rocks are nearly the same except the fine grained sovitic and ranhantic carbonatites which have larger dip amounts. The strike direction varies from

N260°-N20°.

The following table gives an account of the joints in the carbonatites.

No.	Strike direction	dip direction	dip amount	frequency /sq.metr.
1	N281	N110	76°	2
2	N18°	N108°	84°	7
3	N22°	N110°	65°	4
4	N-S	N90°	71°	2
5	N10°	-	vertical	5
6	N340°	N250°	68°	2
7	N312°	-	vertical	7
8	N261°	-	vertical	9

UNTALA GRANITES

These are coarse grained leucocratic rocks sometimes appearing like pegmatites. These are found to be exposed at Vallabhnagar in the Berach river beds. It is also exposed near the Agricultural Research farm campus about 4 kilometres west of Kikawas, and also exposed in the Newania canal cutting but the greater part of the area is covered by soil cover.

Pegmatite veins, apatite veins and schlierens of quartz are also found within these granites at some places, near the Research farm rest house abundant calcite veins are found to traverse the rock, those are highly folded and fractured. The granites exposed here are of the medium grained equigranular types, when compared to those exposed at Vallabhnagar.

Apatite veins that are found in the granites seems to be highly folded unlike those found in the carbonatites, more branching and offshoting veins are found more frequently in these granites.

At Randera xenoliths of chlorite schists of small dimensions are seen, but the author was not able to observe any xenoliths of carbonate rocks within the granites. The attitudes ofof these schistose xenoliths approximate their counterparts found in the carbonatites at Kikewas-Newania.

The following table gives the major joints as recorded by the author. at Vallabhnagar and A.R.F.campus.

No.	Strike	dip direction	dip amount	frequency
1	N 297	N 27	72°	9
2	N 332	N 62	87°	2
3	N 272	N2°	67°	4
4	N 364	–	vertical	8
5	N 194	–	vertical	3
6	N 24°	N294°	76°	3

CHLORITE SCHIST

The chlorite schist are found to occur scattered throughout the plug of carbonatite within it but not without. These rocks have similar trend as the main carbonatite rock.

These rocks are biotite chlorite schist, and these have undergone tremendous stressconditions which has resulted in the brecciation and fracturing of the rock, this is evident in all exposures came across by the author. They are also highly jointed, the frequency of jointing is very high and interval of jointing less than a few centimetres. Being highly friable and foliated rocks, the foliation stricktly parallel to those of the carbonatite rocks and the apatite veins contained in them.

Deep green to yellowish green in colour the rock contains laths and fibres of chlorite, aggregates of biotite laths both distinctly pleochroic, with accessory quartz, plagioclase orthoclase, rounded grains of apatite with appreciable quantities of calcite, dolomite and siderite which become essential in come samples.

These rocks occur as disconnected bands within the main carbonatite plug, three such bands can be made out. The maximum dimensions of these rock exposures are about 105x50 metres.

The strike direction of these rocks varies from N 345°- N 10° with amount of dips ranging from 11°-28° direction

N75° - N100°. The following table gives the various prominent joint directions in the biotite-chlorite schist.

Strike direction	Dip direction	Amount of dip	Frequency per sq.metre
N 282°	N18°	vertical	12
N 17°	N107°	86°	3
N 86°	N356°	72°	5
N 342°	N 72°	Vertical	9
N 172°	N 262°	79°	3

Leaching of Iron carbonate has given rise to an earthy covering of the rocks. Interval of jointing varies from 10-30 cms. The author considers these rocks as xenoliths of aravalli schist which has undergone an advance degree of brecciation, metasomatism and carbonization.

APATITE VEINS

The Apatite veinsconstitutes more than 80% apatites with accessory magnetites, siderites and ankerites. These occur as probably fillings in joints which are mostly in accordance with the lineations in the souites and Rauhaugites, and they also intersect the country rocks unconformably at varying angles. The veins vary in strike from N 354-N32°, having a dip ranging from North to N 110° and no systematic variation in their attitude has been noted.

Individual veins differs much in dimensions. They are usually straight regular veins sometimes pinching out giving a lenticular appearence. Their contract with the host rocks are scrupulously straight on either side of their long dimensions. The individual veins vary from a few millimetre to several centimetres mostly 3-7 centimetres but rarely to widths of 12 centimetres, their average is 4 cms. Depth persistance do not exist to more than 4 metre's as evident from the bore hole data, presented by Yadav(1969) in his dissertation(p.61) and they thin out below this depth.

The strike extension conforms with the nature of the exposure of the carbonatite rock. They are found to extend the whole length of the bald domelike individual exposures. They commonly have strike extensions of 3-4 metres.

Their occurrences are highly scattered without any preferential concentration in localized areas. The majority of the veins are tabular and lenticular in plan as well as section. They also thin downwards. In a few instances network of these veins are observed and in many instances folded, in which case their shape and sizes become smaller, pinching and swelling. Distinct small scale fractures are found in the veins which form conjugational sets of joints.

Apatite is the major constituent of most of the veins, and they occur as medium to coarse hexagonal, polygonol, ovoid or elongated grains. Magnetite is found as fine grained patchy aggregates within the veins, with rounded grain boundaries.

Other constituents are, an appreciable amount of siderite, ankerite and dolomite.

The apatite veins show a very sharp transition from vein material to the host rock material. The veins stand out prominently against weathering as compared to the carbonatites. The author did not attempt to determine the chemical transitional nature of the apatite vein-host rock contact.

THE FENITE

These rocks are Reibeckite syenites, which has resulted from metasomatism of the country rock, granites. These rocks are found to occupy the outer fringe or margin of the main carbonatite plug. These fenitized rocks are not profusely exposed, due to soil cover. They are also found within the plug.

The rocks are essentially of K-felspars- large crystals of microcline with reibeckite. The original schistocity of the rock has been preserved to an appreciable extent, but their trend and attitudes of the rocks varies due to minor faulting-fracturing and rotation.

The rocks have strikes ranging from N340°-N20° and dips ranging from 18°-34°, linearly extended outcrops of average dimension 20-50 metres found if exposed. Abundant Rauhaugite and haematitic Rauhaugite ~~and~~ veins are found intruding bedding planes in conformity with the bedding plane lineation.

As mentioned earlier exposures of these rocks are rare beyond 300-400 metres outwards from the boundry.Even within the zone the soil covering consists of fragments of the rock,pebble sized.

Weathering is prominent in these rocks.The abundant fractures joints and other weak planes serves as an efficient plumbing system which has resulted in many wells being dug within this zone.

Schlorens of quartz are found abundantly distributed in these rocks,well crystallized. Similarly pegmatic veins are seen to traverse these rocks exposed in the Nowania canal cuttings. Due to tremendous stresses the fenites has developed boudinage systems with oval shaped fénites forming the boudins surrounded by the fine grained carbonatite material.

The following table gives the major joints,strike and dip direction and the dip amount plus their frequency.

No.	Strike	Dip direction	dip amount	Frequency per 1 sq.mtr.
1	N352°	-	vertical	20
2	N77°	N167°	72°	9
3	N196°	N 287°	84°	3
4	N241°	-	vertical	16
5	N263°	-	vertical	21
6	N 346°	N256°	63°	5
7	N9°	N 279	86°	3
8	N164°	N 260	89°	6

C H A P T E R - III

PETROGRAPHY

This Chapter deals with the detailed laboratory studies mainly petrographic, mineralogical and staining studies carried out by the author, on all rock types associated with the carbonatite body. More than 102 samples were systomatically collected in 10 traverses made porpondicular to the trend of the carbonatite plug covering the fenitized zone on either end. 42 thin sections were prepared representative of all rock types. Five polished sections were prepared to study the opaque minerals found in abundance and seven rock slices were made of 1 mm. thick for staining. The details of various laboratory investigations includes

1. megascopic studies
2. thin section studies
3. polish section studies
4. staining
5. determination of modal composition of fifteen samples

The author has sub-divided the rocks investigated in the area into the following groups.

CARBONATITES
- { SOVITES, HAEMATITIC SOVITES }
- { RAUGHAUGITES, HAEMATITIC RAUGHUGITES }
- SIDERITIC-ANKERITIC CARBONATITES
- APATITE VEINS

COUNTRY ROCKS
- { CHLORITE BIOTITE SCHIST, EPIDOTE-BIOTITE GRANITE }
- PEGMATITE VEINS
- REIBECKITE FENITES

SOVITES (Sample No.24/634,24/640)

These rocks are made up of more than 80% calcite with ascesory Haematite,magnetite,apatite,amphiboles,sphene,biotite, phlogopite,graphite etc.

MEGASCOPIC CHARACTERS

The granularity of the rocks in hand specimen varies considerably from coarse grained to medium grained,equigranular or having granulitic characters. Colour ranging from pale grey-pale pink or brownish iron stained,containing essentially calcite with ascesory dolomite and siderite.The ascesory magnetites are found as discrete ovoid grains scattered all over. Pyrites and graphites has also been observed in hand specimens. Amphiboles are found as blades having vitreous lustre sometimes radiating the specific gravity low, and readily efferverses with acid and gets stained very fast. The magnetites have been altered to limonite having an earthy appearance. The dolomites are found as regular bands and cross cutting veins.

MICROSCOPIC CHARACTERS

Equigranular rock with mosaic or granulitic texture.

MINERALOGY

Calcite - Colourless in thin section with clean rhombohedral grain boundaries,twinning sometimes present with perfect cleavages and strong dispersion and birefringence$.Uniaxial and optically negative easily identified with Alizarin Red S stain.

Dolomite: Colourless, partings and cleavages nearly absent rhombohedral grain boundaries are usually rounded off. Strong dispersion, varying quantities of ironoxides has given a slightly brownish shade. Sometime clear pink which may be due to Mn substitution in the lattice.

Apatites: These are found in clusters of ovoid grains, their long axis usually oriented in a particular direction. Moderate relief, colourless to light grey. The calcites are found to enclose these grains. These are also found to have inclusions of magnetite under varying degree of replacement.

Magnetites: Found widespread as irregular aggregates usually of anhedral grains, corroded outlines found included in apatite grains and with rims of calcite hallos which seem to replace them too. Found to vary within 3%.

Chlorite: These are found as flakes, fibres and blades having random orientation. Moderately strong pleochroism.

colourless

pale green

brownish green

These are found to replace brown biotite and being replaced by carbonates.

Biotites: Being colourless to pale brown,found in fibrous from form. Sometimes also as wide blades,pleochroism is from pale brown to dark brown. The basal cleavages are perfect. The plates clean serated edges which are sometimes replaced by carbonates(later).

Amphiboles: It is the Na rich variety Reibeckite, light green or pale bluish colours.Basal and prismatic sections perfect. Prominently pleochroic.Pleochroic scheme

γ - light green	γ - pale green
β - purple	β - dark green
α - dark blue	α - bluish green

Cleavage distinct,dispersion strong.Extinction angle 15-28°
Sometimes extinction being replaced by carbonates.

HAEMATITIC SOVITE

These are similar to sovites in every respect except that the rock has been contaminated by iron oxides,haematitic dust,occupying partings and intergranular spaces of the calcite grains.

RAUHAUGITES AND HAEMATITIC RAUHAUGITES

MEGASCOPIC CHARACTERS

Those group of rocks includes those that have essential dolomites upto 80% with other accessory constituents.The term includes a variety of rocks more often medium to fine grained than coarse grained. The colour xx varies from pale pink - greenish grey to earthy. Most rocks of this group have accessories of magnetite, apatite, amphiboles, siderites, ankerites, and calcite. The rocks found in the fenitized zone contain much biotite.

The haematitic rauhaugites are deeply stained with iron oxides, while the magnetites are found widely scattered, here too flakes of biotite, amphiboles, pyrite, sphene are seen; weathering is more prominent with bald outcrops due to exfoliation and spheroidal weathering.

MICROSCOPIC CHARACTERS

Dolomite - Colourless to turbid grey and dark brown, the haematitic variety being opaque. Hexagonal rhombohedral form in the colourless varieties, with even rounded off grain boundaries. Mosaic texture with non interlocking grains showing symmetrical extinction are common.

Siderite: Strong relief, colour ranging from brown to opaque brown, found as patches and streaks, sub-hedral grains and as dark brown interstitial fillings. Symmetrical extinction with respect to parting. Alters to limonite and goethite, replacing dolomite through partings and grain boundaries.

Ankerites are usually associated with siderites in the area, identified only by x-ray powder diffraction.

Magnetites: These are found as granular aggregates occurring in clusters and more often scattered opaque and have rounded grain boundaries also found in aggregates along veins and fractures. These have been altered to limonite and comprises less than 2% of the rock.

Apatite: Colourless,moderate relief-ovoid granular sporaidic as well as clusters, along veins of small dimensions 0.5 - 1 mms. often surrounded by fine grained carbonates. Sometimes coated with brownish iron oxide rims.Found to comprise less than 2% of the rock.

APATITE VEINS

MEGASCOPIC CHARACTERS

The apatites are pale brown to dark brown colours with thread like bands of magnetite and siderite and some ankerite, pearly lustre with numerous microfractures,magnetite grains very fine grained and scattered throughout the rock. The weathered surface is dark and earthy due to disintegration of the iron minerals and siderite.The apatite grains are microscopic in size. The amount of magnetite varies from 1 - 3%-

MICROSCOPIC CHARACTERS -

Apatite content is more than 70%. Apatite nearly equigranular but seems to have been elongated in a particular direction by their long axes. Their grain size varies greatly less than 0.5 mm - 0.8 mm. These are different from those apatites found in the carbonatites, they are not oval in form, but seems to have well crystallized hexagonal forms are common while most of them sub-hedral(Refer Microphotograph No. 21). Moderate relief with pitted or mottled appearence with second order bluish grey polarization colour. Microscopic rounded grains of magnetites are also found scattered. Usually found as relicts within the apatite grains. Individual grains shows partings.fractures and cleavages.The microscopic evidence suggests that the magnetite were earlier in the paragenetic sequence than the apatite.

BIOTITE-CHLORITE -SCHIST

MEGASCOPIC CHARACTERS

The rock is medium to fine grained and consists of essential chlorite,biotite and replaced carbonate minerals plagioclase and quartz.leaf green in colour. In a few specimens schistosity is not distinct, cut sections across the lineation shows augen-like features of carbonate minerals,weathered, forming the eyes while chlorite and biotite flex around it in a spindle form. Rounded magnetite grains are found as clusters and also scattered. Weathering of the iron minerals has given an earthy appearence to the schist.

MICROSCOPIC CHARACTERS

Foliation is well revealed microscopically with preferential orientation of chlorite, biotite and calcite in a particular direction (Refer Microphotographs No. 15 & 16). Chlorites are fibrous prismatic form - pale green exhibiting distinct pleochroism. Biotite too shows pleochroism. Their pleochroic schemes are given below.

Chlorite: colourless - pale green - pale green

Biotite: Pale yellow-orange yellow - clove brown

The chlorite and biotite pioms are of on average 0.2 - 0.3 mm. in length. They are found in radiating aggregates and also occurring along with calcites which has crystallized along veins varying in dimensions from thread-like to those 2 mm in width. Much magnetite and iron ox oxide minerals makes the minerals stained in certain patches.

The texture gives us an impression that it may have been caused by flowage. The rocks as a whole have been subjected to cataclastic metamorphism.

Biotite: As laths,well developed basal cleavages, serrated edges,kinked to different degrees,puckering significant being replaced by chlorite and carbonate minerals.

Magnetite: Found as granular aggregates and irregularly scattered,replaced by chlorite and carbonates.

Apatite: Few oval shaped grains are found in these rocks often roplaced by carbonates.

EPIDOTE-BIOTITE -GRANITE

MEGASCOPIC CHARACTERS

Equigranular leucocratic rock with essential quarty, orthoclase,plagioclase(albite) with accessory biotito, epidote,phologopite. Gneissic texture is poorly developod.

Quarty is coarse grained,greyish colour,sometimes inter grown with k-felspar to give a myrmekitic contact.The biotite found as regular streaks.Plagioclase found as platy ledge shpped bodios.

Quartz - Present as large grains with rounded grain boundaries bearing much inclusions.

Plagioclase - Found as platy ledge shaped bodies with distinct polysynthetic twinning with large number of lamellae. Anorthite content 10 - 30%.

Two generation of plagioclase have been identified. The first has given rise to epidote as alteration product, these are larger grains. The later generation are diagnostically smaller in dimensions with less intensive twinning without signs of alteration(Refer microphotograph No. 19).

Epidotes (Clinozoisites) - Moderate relief light green colour and strong dispersion, occurs as granular crystals at plagioclase margins. It shows anamolous yellowish blue polarization colours.

K-felspar - Colourless with irregular outline sometimes with carlsbad twinning. Sericitization of these felspars common. Kaolinization is overwhelming in certain samples which leads to the suggestion that chemical weathering has palyed a significant role. Minor constituents like phologopite, sericite and secondary calcite are also observed.

FENITES - RIEBECKITE SYENITES

MEGASCOPIC CHARACTERS

These rocks vary widely in their granularity, texture and mineralogical composition. Being leucocratic rocks, their grain size differs abruptly within short distances from coarse to fine grain and vice-versa. Gneissic texture is well preserved which is derived from the original granite by the orientation of pink felspars and sodic amphiboles in a preferred direction. There is near absence of quartz, contains accessory biotite,phologopite,magnetite.Apatite and carbonates. Carbonatization of the rock has taken place observable in certain samples when carbonate veins 1 - 3 mm in width is seen to traverse the rock. The dgree of metasomatism so evidenced by the increasing quantity as well as dimensions of the amphibole. The results and effects of shock metamorphism are not visible in hand specimens.

MICROSCOPIC CHARACTERS

K-FELSPARS - MICROCLINE

The essential minerals in these rocks are the colourless microclines with distrinct reticulate twinning.They vary from 0.5 mm - 3 mm in diameter.

Two generations of microclines have been identified.the older ones,are very coarse grained and these are being altered to fibrous riebeckite,sericitization is also prominent, the microclines are cloudy with murky appearence(Ref.Microphoto graph No.25-30).

The second generations of which has recrystallized probably by the reconstitution of the felspars, comparatively smaller in size,clear and fresh looking with distinct sharpe grain boundaries and brilliant reticulate twinning.

<u>Orthoclase</u>: These are found as large grains which have been appreciably affected by cataclastic metamorphism. They exhibit bursh extinction with inclusion of carbonates in the form of spots. The carbonates are found to fill in many microfractures within orthoclase crystals. These are often more cloudy sometimes exhibiting microperthitic texture.

<u>Amphibole-Riebeckite</u> - Identified easily by their characteristic dark blue and yellowish green colour exhibiting diagnostic pleochroism.

Pleochroic scheme being: α - pale blue
β - indigo blue
γ - yellowish grey

Absorption being $\alpha > \beta > \gamma$

These are mostly subhedral prismatic grains with well developed (110) cleavage with clean edges sometimes splintery in the case of large prismatic ones.

The asbestiform variety is also present, where they occur as fibrous radiating aggregates, mostly found at places where deformation has been appreciable and along fractures. These Na-rich amphiboles vary in grain size 0.25 mm in width when platy and 2 mm when prismatic, part of them have also been subjected to stresses. They replace microcline and orthoclase and being replaced by later carbonates.

Biotite: These are found in appreciable quantities, brown colour, pleochroic.

Pale green – brown

with perfect basal cleavages and is under final stages of replacement by riebeckites and k-felspars. The grain contacts of reibeckite with biotite are penetrative, sharp and clean. Biotite often exhibits kinking and forms trails as a result of stress.

Carbonates: Carbonatization has taken place in the rocks to an extent such that they efferverce with acid. Several ~~r~~ veins of carbonates traverse the rock. Carbonates form interstitial cement in the mylonitized patches, non-crystalline, hazy appearence with extremely irregular outline. These veins are usually of microscopic dimensions.

Other Accessory Minerals: Other accossory minerals found are a few grains of aegirine, apatite grains resembling those in the carbonatites but slightly larger, magnetite very small grains, sericite, phologopite.

The degree of crushing has been observed to increase in samples taken near the contact, similarly brush extinction is prominent. A few grains of amphiboles have also been subjected to crumpling.

Pegmatite veins - These are found in the granites and fenites in the form of veins, patches, schlierens etc. The milky quartz are dominent over the felspars - microcline.

Kankar - Several occurrences of such residual deposits are observed especially near the canal as well as in the depressed portion of the plug near Kikawas village.

	A
Mineral	68
Microcline	–
Orthoclase	–
Albite	–
Quartz	–
Biotite	–
Phølogopite	–
Chlorite	–
Amphibole (Reibeckite)	–
Total Carbonates	–
Apatites	44
Epidotes	–
Iron minerals	[illegible]

TABLE SHOWING MODAL ANALYSIS OF VARIOUS ROCK OF THE AREA

Mineral	628	607	609	621	634	640	684	685	686	669 A	669 B	3	4	5	6
Microcline	-	-	-	-	-	-	-	-	-	31.5	33.2	28.4	32.0	16.8	18.3
Orthoclase	-	-	-	-	-	-	-	-	-	16.4	18.1	40.7	28.5	48.6	40.8
Albite	-	-	-	-	-	-	-	-	-	6.2	5.7	3.6	6.3	4.7	5.1
Quartz	-	-	-	-	-	-	-	-	-	19.8	18.3	-	-	-	-
Biotite	-	-	1.6	-	-	-	-	-	-	13.3	14.6	7.4	10.6	7.4	10.6
Phlogopite	1.2	-	-	-	7.2	-	-	-	-	5.2	4.9	1.2	-	-	-
Chlorite	0.5	-	-	-	-	-	-	-	-	1.4	0.8	-	-	-	-
Amphibole (Reibeckite)	6.21	-	8.3	0.2	1.2	1.7	-	-	-			14.0	17.6	19.8	18.6
Total Carbonates	84.6	88.3	80.4	80.7	96.0	97.4	89.0	2.3	-	2.5	1.0	4.4	3.1	2.5	3.6
Apatites	2.7	5.1	6.7	1.6	2.1	1.9	3.7	80.3	44.8	0.8	1.9	0.9	1.1	.5	1.2
Epidotes	-	-	-	-	-	-	-	-	-	2.6	2.4	-	-	-	-
Iron minerals	4.7	6.2	6.0	7.5	-	0.5	6.4	7.2	5.6	-	-	-,1	.1	.8	1.3

CHAPTER - IV

FENITIZATION

The process of fenitization consists the metasomatism of rocks of varied composition, local or widespread, in the immediate vicinity of carbonatitic rocks. The metasomatic processes tend to find a new equilibrium product which depends on the chemical composition of the generated mobile component and the rock undergoing metasomatism.

The Newania carbonatitic complex consists of a large number of haematitic rauhaugite bodies intruded or emplaced into a pre-fenitized zone forming a ring of various thickness around the main carbonatitic body. It is found between 100-200 metres away from the contact. The carbonatitic intrusions in this fenitized zone vary in dimensions, from thin veins ranging from 2-25 cm width, and plug like bodies which stand out in relief. These intrusive bodies are relatively more dipping than those of the main carbonatite plug. They are sometimes found conformable with the bedding planes of the fenitized rocks, but in most cases the attitude of the fenitized rock has been displayed, rotated and has become unconformable with the rock found away from this zone.

Fenitization has occurred to varying degrees,very prominent around the contact margins and becoming less so outwards.The rocks that have been fenitized are the biotite-epidote-granite gneiss,of post Aravalli age. The country rocks outside the fenitized zone are the Banded Gneissic Complex(B.G.C.).

Within the fenitized zone the carbonatites frequently enclose xenoliths of the host rocks of very small dimensions. The fenites at the immediate vicinity of the contact shows very significant fracturing and shattering,these represents the thermal shock zone,field study,megascopic and microscopic investigations conclusively support this.This shock zone forms a ring of about 25-100 metres around the contact.

The Fenites are reibeckite syenites and are unmistakably metasomatic and the transformations at its extreme were not even as great as to cause a complete destruction of the original characters of the rock. The foliation of the original rocks are marked well in outcrops as well as in hand specimens.

Boudinage structures have been observed in well cutting No.6.The total depth so far dug was 25 metres. At a depth of 16 metres from the surface the author was able to observe these structures. The foliation with the boudinages were more or less conformable with the surrounding rocks. The ~~six~~

axis of the boudins were sometimes rotated. These structures are post fenitization (Refer Fig. 2 and field photograph No. 6).

Fenitization has also taken place on the xenoliths of chlorite Biotite schists, which are found as disconnected bands, and patches within the main carbonatite plug. In this case the transformation has been complete mineralogically in a few instances. Though the original foliation of the rock has been retained distinctly. Complete replacement of most silicates, recrystallization of chlorite, and the biotites replaced.

MICROSCOPIC STUDIES

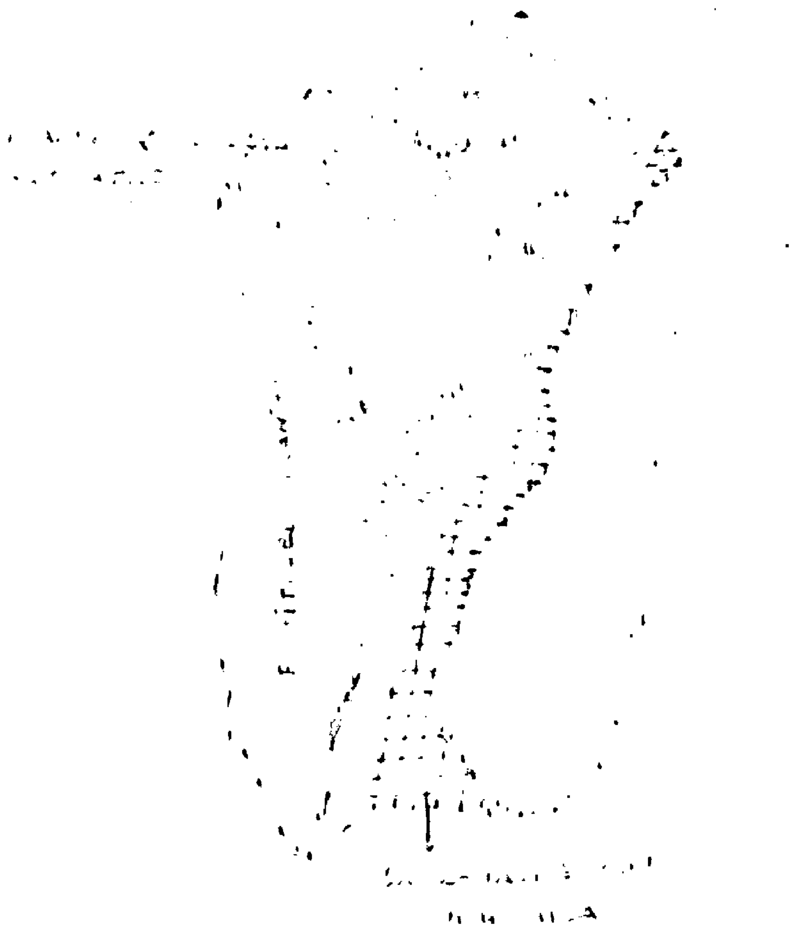
The most characteristic newly formed minerals are the bluish green reibeckite and fresh-looking microcline occurring in various proportions.

The sodic-amphiboles forms a feathery radiating fine needles which sometimes penetrates into crystals of felspars. They are also found arranged parallely. The prismatic grains with distinct cleavages are mostly fresh and prominent replacing felspars.

The marked reconstitution of the rock is marked by the development of Alkali Felspars-microcline as crystals of varying sizes but always fresher than the original mosaic.

In certain cases the felspars show a vague patchy extinction, vaguely defined boundaries, suggesting replacement of

FIG 2 SHOWING XENOLITHS OF FENITIZED GRANITE IN
FINE GRAINED CARBONATITE VEINS



earlier granular crystals of older felspar. Abundant inclusions of micas are found within felspars - sericitization and large prismatic amphiboles are found replacing the potash felspar.It should be noted that the near absence of silica and very little amount of plagioclase felspar represents the degree of metasomatism.

The biotites are brownish,which are distinctly pleochroic. It is sometimes the original biotite which undergoes replacement.These along with older reibeckite plates forms trails denoting stress conditions.

Other dark minerals that have been introduced are magnetite crystals rounded aggregates,very rarely cubic form and apatite grains mostly ovoid in form and secondary vein fillings of calcite and dolomites,and intergranular fillings.

Quartz disappears due to replacement by the K-felspar and Na amphiboles.Evidences of replacement of quartz are difficult to trace but the significant variation in silica content of these rock and the country rock provides evidence of the transformation that has occurred.

The most prominent texture of these rocks are the mortar texture,which sometimes appears to be resembling a porphyritic texture.Even within single large crystals of felspars,different parts of it has been crushed.

The presence of carbonate in the rock is not clear how they are related to fenitization but in certain cases are found as vein filling giving a secondary character.

The xenoliths of chlorite-biotite-schist as mentioned earlier have been subjected to intense cataclastic metamorphism.The quartz and felspar grains have been crushed,have become cloudy,and reddish due to haematitite dust.In many cases the carbonates have replaced the above said minerals retaining their form.Chlorite and biotite seems to be fresh in certain samples.Linear orientation of these minerals are marked which sometimes appears to be flow texture.

Complete replacement and subsequent recrystallization of dolomite has taken place with fresh recrystallized chlorite flakes oriented in a random fasion in the carbonates. This clean fresh chlorite leads us to the conclusion that these may have recrystallized from the biotite of the original schistose rock.

Haematization of the rock has rendered the minerals of the rock reddish (Refer Microphotograph 13).

It has been observed through thin section studies that the degree of metasomatism or fenitization has direct relations with the distance of the rock from the carbonatite contact. It is surprising and fortunate that such a marked variation can be observed within a distance of about 200 meters away outwards from the intrusive contact.

Descriptions of thin sections made from rocks available from four different spots in the fenitized zone are given below to convey the systematic variations found in petrographic characters. Along with it the variations in the petrochemistry of the rock has also been presented. Microphotographs of each thin section described have been presented at the back.

SAMPLE No.24/668/3 45 metres away from contact.

1. Significant stress conditions denoted by:
   - (a) significant fragmentation of felspar and amphiboles.
   - (b) undulatory extinction shown by large microcline crystals but not the smaller ones.
   - (c) trails of biotite and reibeckite
   - (d) kinking in biotites
   - (e) presence of microfracturing in the rock later filled by carbonates. Inter granular fillings of carbonates are also present, in patches and blades of reibeckites are

found occurring along fractures. Pressure shadows in felspars are common. Magnetite and apatite grains are being corroded. Addition of $FeO+Fe_2O_3$, MgO, MnO, Na_2O, K_2O and P_2O_5 with decrease in SiO_2 is observed.

SAMPLE No.24/668/6 10 metres away from contact.

Shows very marked modification due to its proximity with the contact. All minerals have been subjected to fragmentation. The biotites, small in dimensions are oriented in all directions. The larger grains of amphiboles are being replaced by carbonates which forms rims around them. The felspars are very cloudy with indistinct outlines. The reibeckites show pressure shadows.

Depletion of silica is very well marked while the addition of K_2O, Na_2O, $FeO+Fe_2O_3$ are significant.

SAMPLE No.24/668/ 1 and 2

These were collected from the northern contact of the plug with granites, approximately at the same distance away as sample No.3 and 6 from the contact. Here the degree of metamorphism and metasomatism are nearly the same.

Appreciable addition of Na_2O, Al_2O_3 and deplotion of silica is marked (Refer Fig.3). Marked addition of $CaO+MgO$ has also taken place which may have been due to introduction of these at a later stage.

A small amounts of $FeO+Fe_2O_3$ and P_2O_5 have been added, which may be due to the introduction of magnetite, apatitite and haematite dust.

SAMPLE No.24/668/4 195 metres away from contact

The degree of cataclastic metamorphism suffered is less as evidenced by lesser degree of granulation.Here it is found in patches.

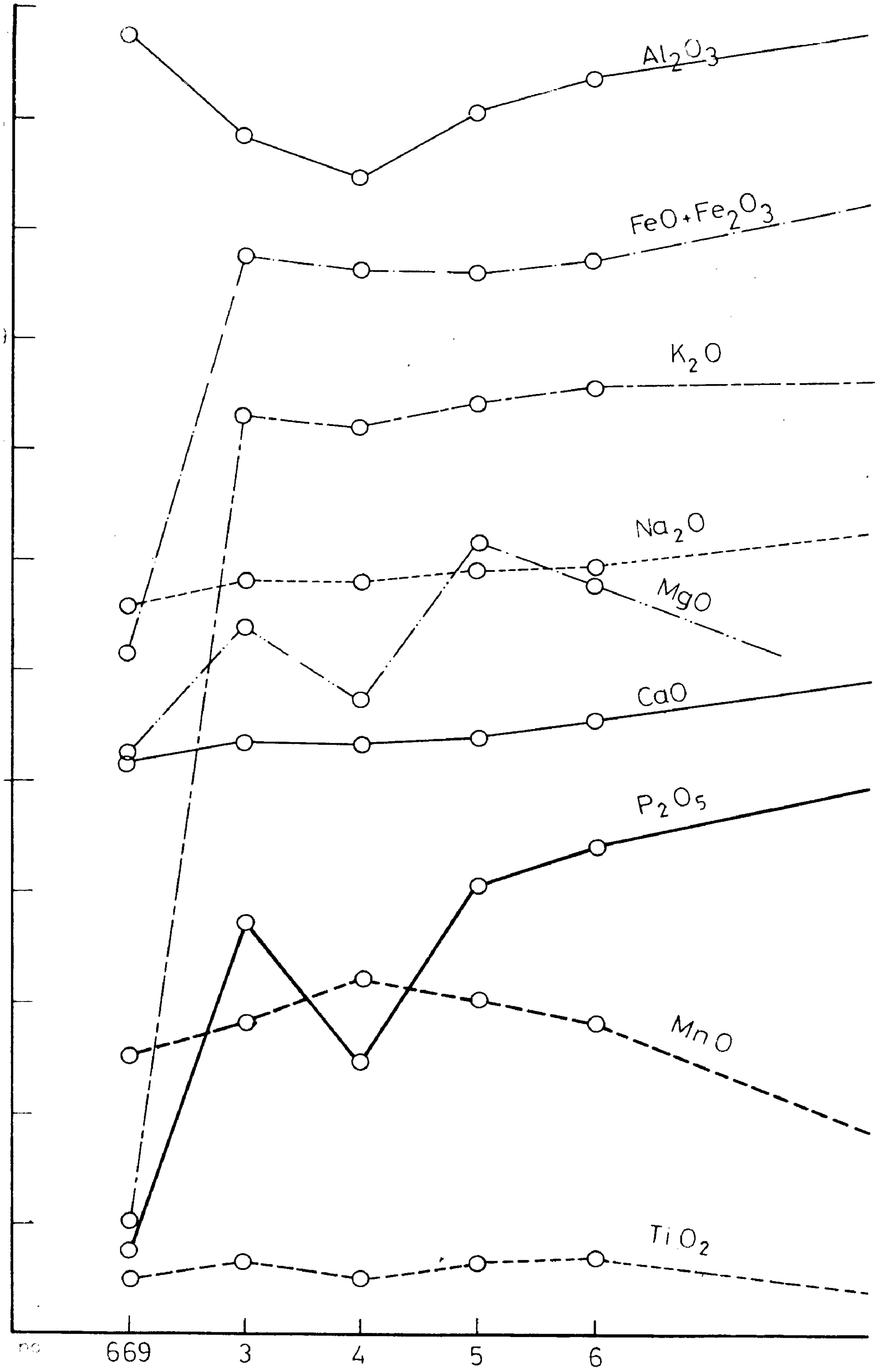
Recrystallization of microcline is more prominent with most of the constituents have clean bounderies.Mostly the sodic-amphiboles are of small dimensions subhedral prismatic grains with 2 sets of perfect cleavage presence of carbonate minerals insignificant.

Addition of $(FeO+Fe_2O_3)$,K_2O,P_2O_5,MnO is observed and depletion of SiO_2 and Al_2O_3 has taken place.This sample marks the outermost exposure of the fenitized zone available for study.

SAMPLE No.24/668/5 62 metres away from contact.

The modification is slightly less in extent than that of No.3,. The k-felspar orthoclase are larger and cloudy, the mortar texture confined only to grain bounderies and isolated patches.

The presence of silica as veins and schlierens most of them crystalline milky,massive,also beautifully crystallized bearing amphibole needles within them has been observed in the fenitized zone(refer diagram 4).These are also accompanied by



Variation of various element oxides in the Fenitized rocks with respect to the Granites

FIG. 4

SHOWING THE RELATIONSHIP BETWEEN DIFFERENT MINERALS AS OCCURING IN THE FENITIZED ZONE

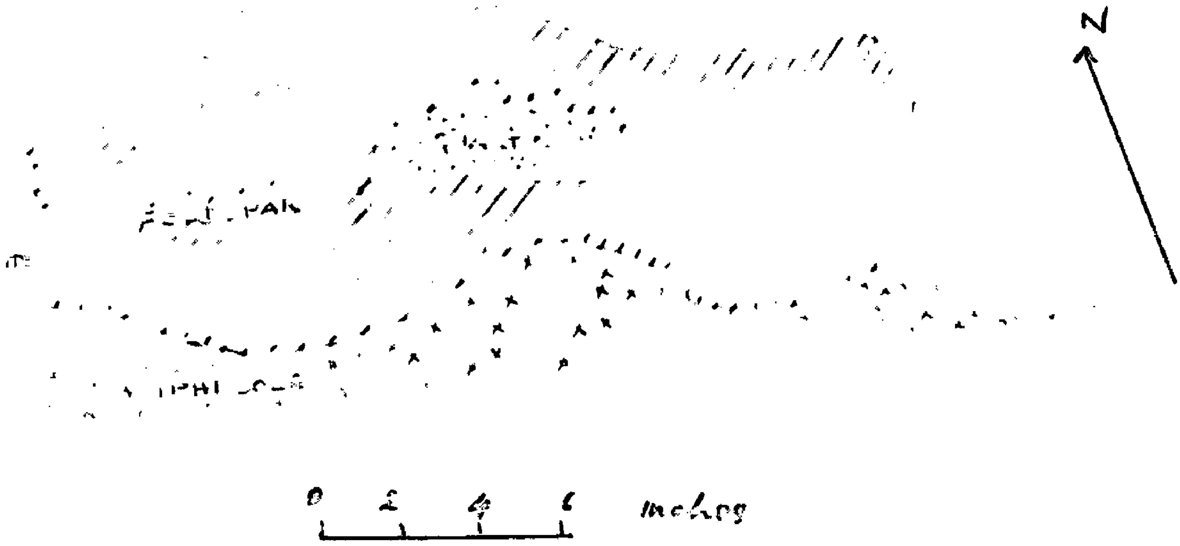
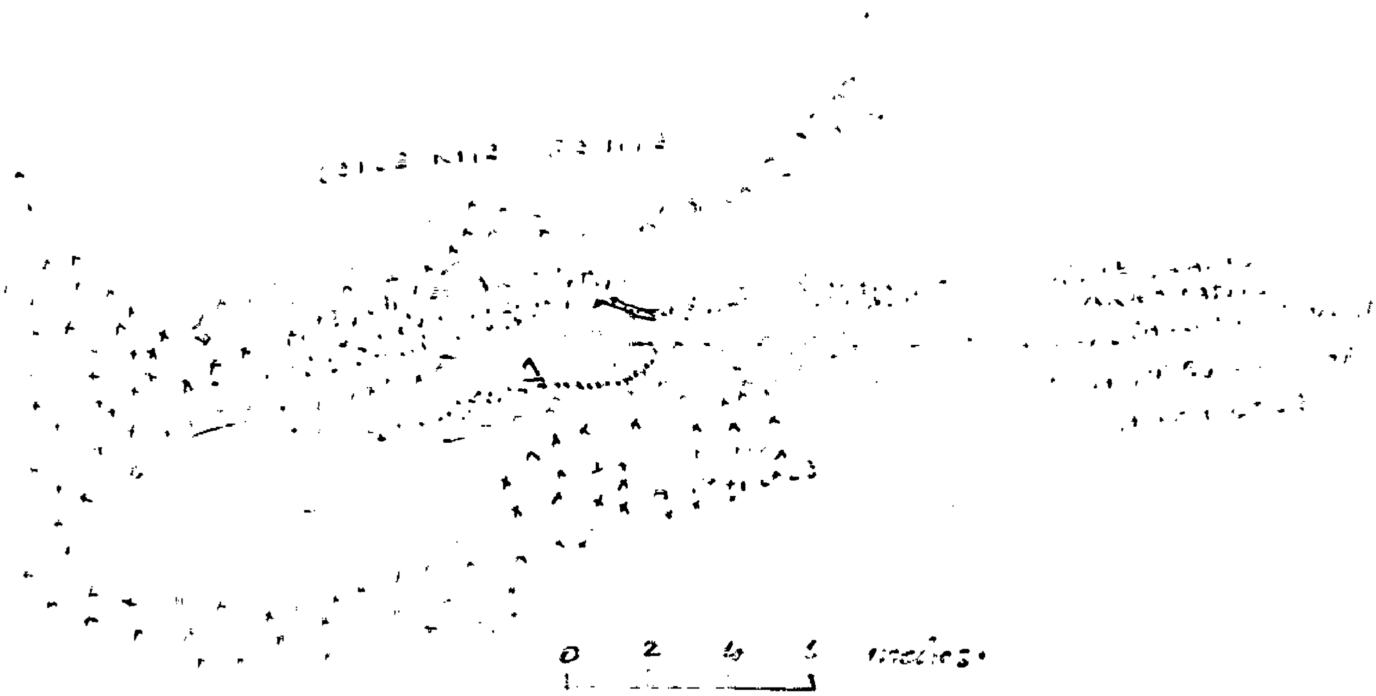


FIG. 4a



SHOWING RELATIONSHIP OF FINE GRAINED CARBONATITE VEINS AND THE FENITIZED ROCKS.

patches of amphibole minerals along with them. Sometimes these quartz are found to be enclosed within large felspar masses. Refer Fig. 4 & 4a.

These could be released silica, during metasomatism, deposited as free quartz enclosing needles of amphibole which were also forming simultaneously.

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CHAPTER - V

CHEMICAL VARIATION IN THE ROCKS

With the view of getting an elaborate and detailed account of the various processes that has taken place in the rocks eleven(11) samples representing different rock types associated with the carbonatite body were selected for chemical analysis, while another four samples of the fenitized rocks collected at different distances away from the carbonatite contact were chemically analysed to observe whatever variations they may show. The discription of the samples taken for chemical analysis are given in the accompanying table (No. I).

From the samples collected from the field 100 grms. of rock were taken, broken to pea size with a steel hammer, washed well by brushing till earthy material goes off, dried for a day, finally crushed in a steel pestal and motar to -200 mesh. The whole rock was reduced to the size of -200 mesh.

The analysis were made by an analyst of the Metallurgical Engineering Department but CaO, MgO determinations were done by the author by E.d.t.a. titration. Other element's oxides were determined by classical methods.

TABLE. 1

List of Rock type analysed with the Sample numbers

1)	24/607	Rauhaugites
2)	24/609	Rauhaugites
3)	24/621	Rauhaugites
4)	24/628	
5)	24/634	Sovites
6)	24/640	Sovites
7)	24/684	Apatite veins
8)	24/685	Apatite veins
9)	24/686	Haematite siderite vein
10)	24/669A	Untala biotite-epidote granite
11)	24/669B	Untala biotite-epidote granite
12)	24/668/3	Reibeckite fenites
13)	" 4	Reibeckite fenites
14)	" 5	Reibeckite fenites
15)	" 6	Reibeckite fenites

Results of chemical analysis have been given in the accompanying table (No. 2) and variation in the chemical analysis have been given in graphic representation from Fig. (5) to (8).The quality and nature of variation of the element oxides have been discussed below.Chemical analysis data given by Phadke and Jhingran(1968) have been given in table(3) for comparison and have been discussed elsewhere.

TABLE NO. 3

	Untala Granite gneiss%	Fenitic syenite %	Carbonatites (1)%	(2)%	(3)%	Sedimentary limestone
SiO_2	70.35	55.63	7.95	16.84	2.23	2.50
Al_2O_3	15.50	12.60	2.05	2.60	p.nil	p.nil
FeO	1.52	1.61	p.nil	1.78	8.91	p.nil
Fe_2O_3	2.47	10.16	14.46	12.78	9.70	2.18
CaO	2.86	1.60	37.69	27.95	27.46	30.46
MgO	0.70	3.14	3.08	5.97	10.95	20.63
Na_2O	4.60	4.60	1.04	0.78	0.13	0.04
K_2O	p.nil	7.32	p.nil	p.nil	p.nil	p.nil
Total loss on ignition corrected for FeO content only	0.82	1.43	32.20	17.07	39.31	44.11
BaO	0.60	0.76	0.61	p.nil	p.nil	p.nil
MnO	0.03	0.03	0.68	1.24	0.76	0.07
TiO_2	0.21	0.12	0.15	0.10	p.nil	p.nil
R.earth oxides	p.nil	p.nil	p.nil	5.94	p.nil	p.nil
$(Nb+Ta)_2O_5$	p.nil	p.nil	p.nil	p.nil	p.nil	p.nil
ThO_2	0.01	0.01	0.01	0.04	0.01	0.01
P_2O_2	0.14	0.92	0.69	7.41	p.nil	0.04
F	p.nil	p.nil	p.nil	p.nil	p.nil	p.nil
Cl'	0.01	p.nil	P.nil	0.04	0.01	0.01
Total S as SO_3	p.nil	p.nil	p.nil	p.nil	p.nil	p.nil
CO_2	p.nil	1.12	27.23	13.60	37.10	41.71
$-H_2O$	0.08	0.25	0.45	0.20	0.34	0.15
$+H_2O$ (by difference)	0.74	0.06	4.52	3.27	1.86	2.26

SiO_2 Content

This serves as a good indicator of variation within the different rocks. It has an average range of 1.85 -2.00% in the Rauhaugites, 3.05 - 3.87% - Sovites, 0.86-1.04% apatites, 49.28 - 52.32% - fenites and 66.72-71.47% in the granites. A more or less gradual decrease in SiO_2 content from Sovites through Rauhaugites to Apatites can be observed. The one high value of SiO_2 in the Rauhaugites may be due to the presence of much amphibole or due to error in analysis.

TiO_2 Content

Being a very diagnostic chemical constituent in the carbonatites, are found to vary between 0.10 - 0.56%. These could be localized in the magnetites associated with the rocks and a few grains of sphene. No sharp variation in their contents have been found between Sovites, Rauhaugites and Fenites. But since the apatite veins bear relatively more magnetities occurring in clusters, they seem to have higher values of TiO_2.

Al_2O_3 Content

These range between 11.94% - 13.74% in the reibeckite fenites, much less than the country rocks - granites having values above 14.0% obviously due to the large concentration of alumino silicates in them. They vary from 1.78 - 2.66 in the various sovites and rauhaugites nearly absent in apatite veins. The variation of $K_2O + Al_2O_3$ against SiO_2 has been given in Fig. (5).

<u>$FeO + Fe_2O_3$</u>

Ranges from 8.18 - 14.57 in the rauhaugites and of average 7.90 in the sovites, 16.0% in the apatite veins and siderite. Average is around 10% in the fenites. Iron oxides are mainly localized in the magnetite grains in the apatite veins, and rauhaugites while they may also be due to haematite contamination and stains in rauhaugites sovites and fenites.

FeO and Fe_2O_3 values for the metasomatized rocks are higher due to liberation of iron oxide on oxidation and leaching which might have later been transported in solution permeating the brecciated rock contaminating them.

<u>MgO content</u>

Having a range between 9.95 - 16.61% in the dolomitic carbonatites, decrease in range to 3.64- 3.94% in the sovites becomes insignificant in apatites veins and varies from 2.38-4.76 % in the fenites. The MgO content in rauhaugites is obvious, but those in fenites may be due to partial post-tectonic dolomitization of the rocks.

<u>MnO content</u>

Not much variation is observed in the rocks except a few rocks in which they are higher especially 24/686.

Ca O Content

Boing of high range in the sovites 43.34 - 44.86%.It lowers to a range of 25.10 - 35.06 in the rauhaugites where the Ca CO_3 contents varies within 15% of the rock. Less in apatite veins, averaging 17% significant in siderite carbonatites and insignificant in fenites.

Na_2O Content

It averages to 4.7 in the fenites.4.0% in the granites and very less in carbonatites.The higher values in fenites are due to the increase in the Na amphibole contents of the rock.

K_2O Content

These are definitely higher in the fenitized rocks while they are very insignificant in the carbonatites less than 0.3% in the granites.The increase in the fenitic rocks may be due to a definite decrease in the silicate content.

P_2O_5 Content

Ranges from 2.41 % - 8.03% in the rauhaugites 2.26 - 2.93 in sovites, 44 - 46% in apatite veins. Very less in fenites 0.49 - 0.88 and insignificant in untala granites. The apatites are mainly hydroxy-apatites as confirmed by x-ray analysis.

CO_2 content

These were found to vary according to the carbonate contents of the rock. The H_2O content of the rock can be got by difference.

RELATIVE VARIATION

SiO_2 Vs(K_2O+ Al_2O_3+ Na_2O)

The variation of K_2O, Al_2O_3, Na_2O with SiO_2 have been tested. Graph(5) shows a gradual increase in the total values of the three oxide with respect to silica. This shows a sympathetic relationship between the proportion of the three oxides and silicondioxide.

(CaO+MgO) Vs (FeO+Fe_2O_3)

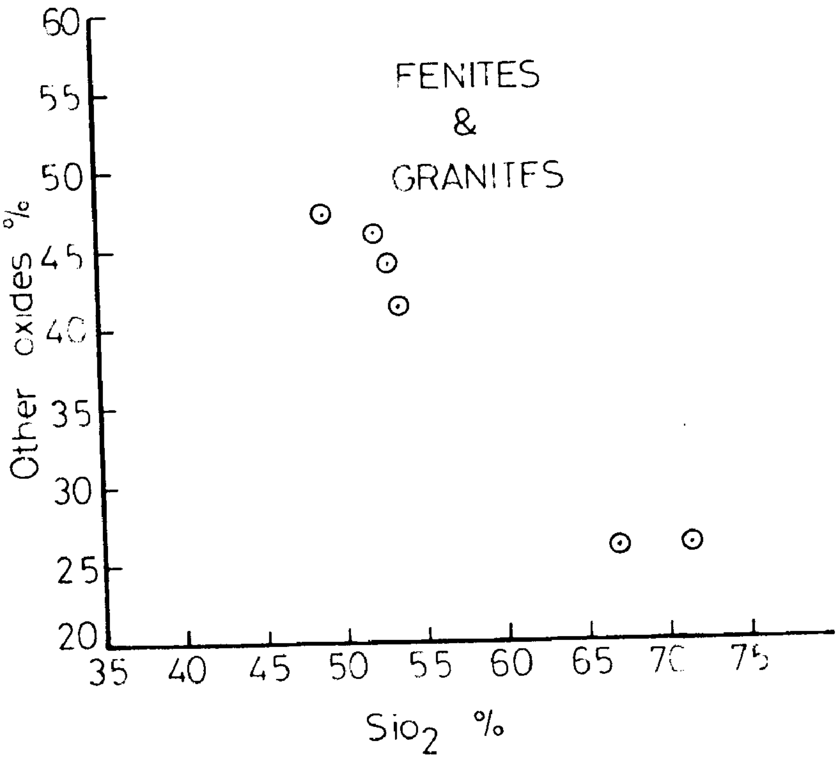
The iron oxides seems to be low in the rauhaugites, very less in the sovites and high in the apatite veins, appreciable in the siderites. Fig. 6

($CaCO_3$+$MgCO_3$ +$FeCO_3$) Vs P_2O_5

Here the variation of P_2O_5 in relation to the total carbonates have been given. P_2O_5 values for rauhaugites are very high, less in sovites and siderites. Fig. 7

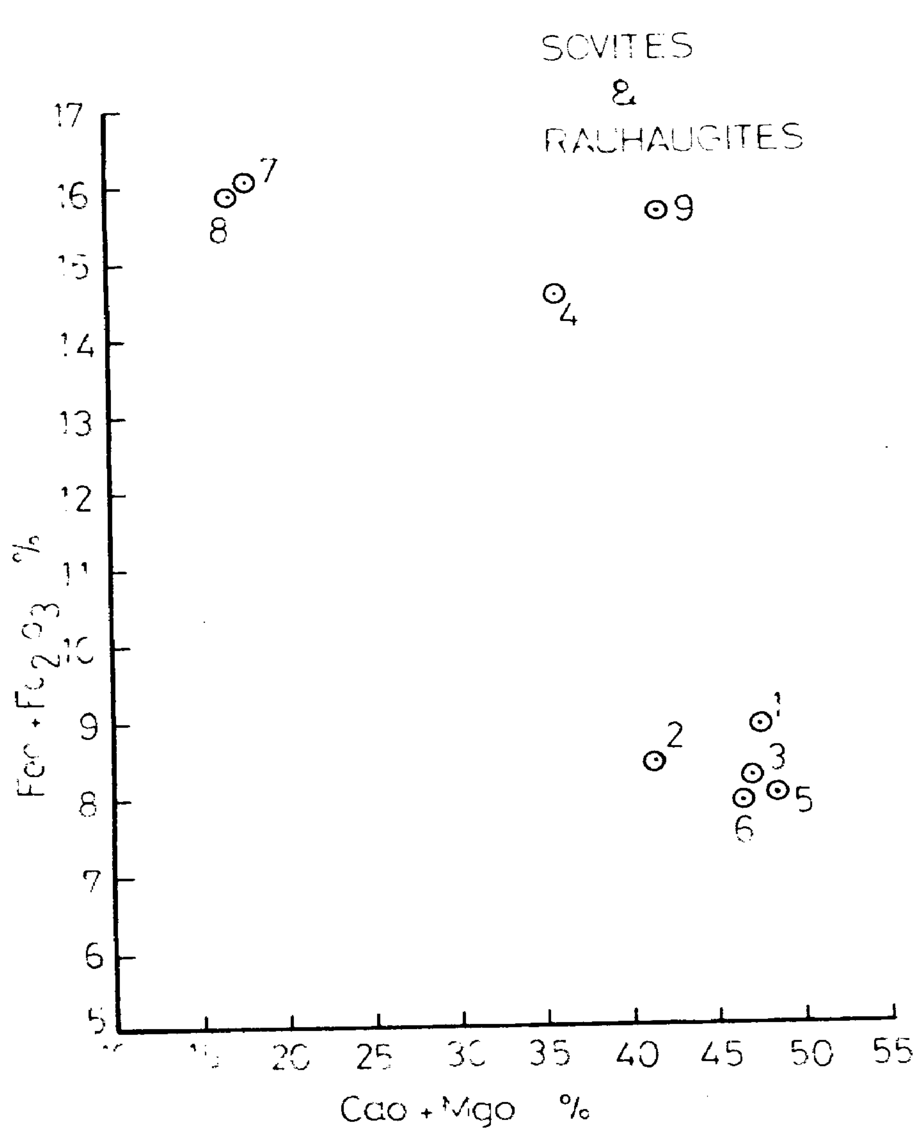
(CaO +MgO) Vs SiO_2

SiO_2 varies much in relation to CaO+MgO in rauhaugites, slightly less in sovites and very less in apatites. Fig. 8



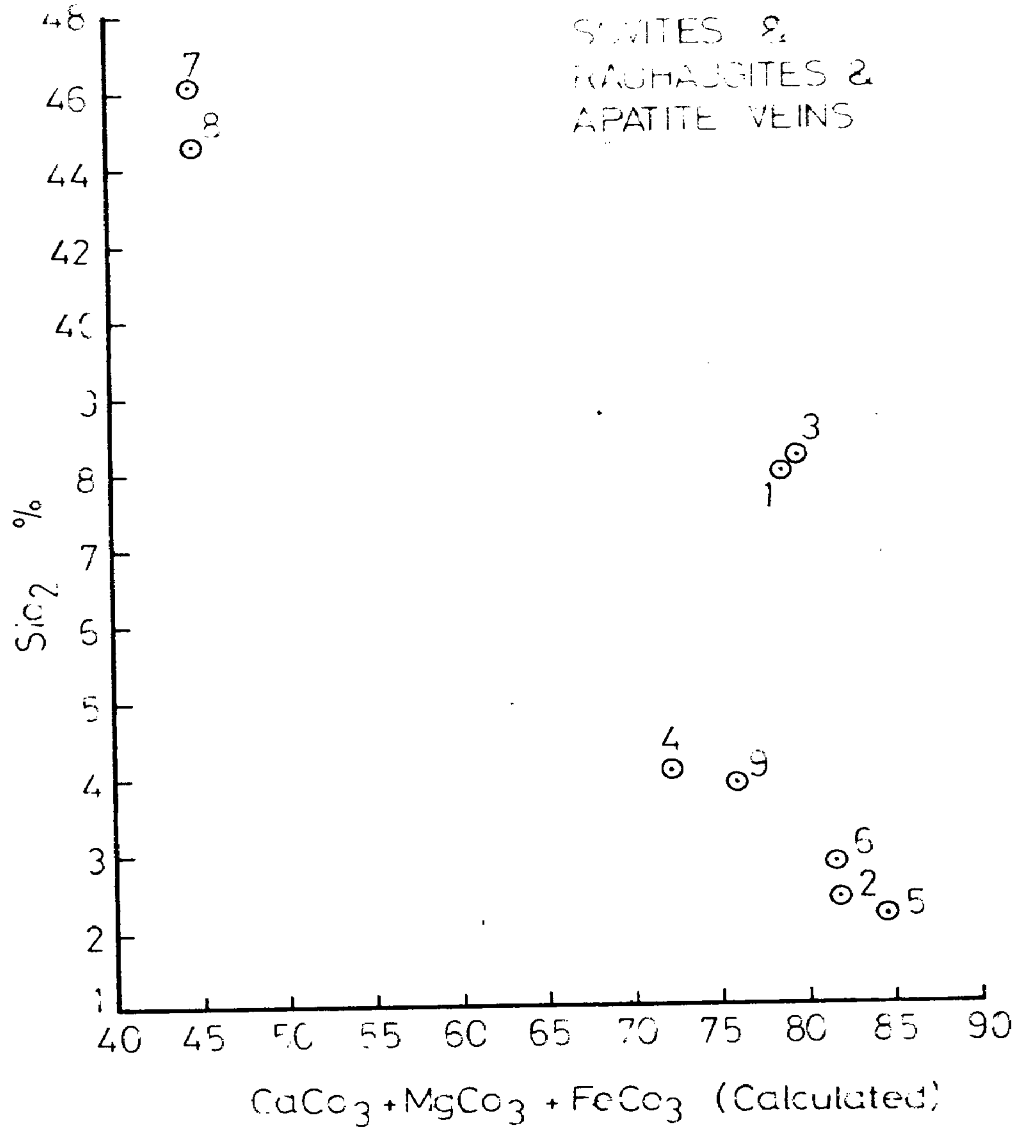
Chemical variation of other oxides with respect to Silica in the Fenites and Granites.

Fig 6



⊙ Sample no.

Fig.7



Chemical variation diagram between various elements oxides in the different rock types of Newania.

CHAPTER - VI

TRACE ELEMENT STUDIES

The author's sincere intension was to subject the various rock types associated with the carbonatites of Kikawas-Newania at least for fourteen important diagnostic trace elements but he could not succeed in getting proper laboratory facilities. This restricted the scope of the study. Hence the author has to be satisfied with whatever trace element determination that could be done with the Emission Spectrometer tailored specially for the I.P.E. requirements at Dehra Dun which the author could finally avail himself.

Four samples (powder) were analysed. They are 24/607, 24/609, 24/627 and a limestone from Khetri which has been hinted as a carbonatite.

The analysis were done on the Compact Atom Counter-Model 66 -004. Experimental details are as follows:

A.C. Arc current 8 amperes

Pre-exposure time 2 minutes

Exposure time 10 minutes

The counts were calibrated against 'SQ' standards in graphite matrix. The following table gives the results. (Table 4)

TABLE: 4

RESULTS OF TRACE ELEMENT ANALYSIS IN PPM.

in A° detected	3039.06	3132.59	3273.96	3453.50	4289.72	3185.2	4554.6	2417.7	3414.0
Sample No.	Ge	Mo	Cu	Co	Cr	V	Ba	B	Ni
24/607	23	25-50	50	10-25	100	100	100	50	50
24/609	25	50	100	25	100	100	100	100	25
24/627	20	50	30	10-25	100	50	10	50-100	25
K.L.St.	25	100	100	25	100	100	100	100	23
Average carbonatite of Gold(1363)	-	42	1	17	-	-	-	-	8

As can be seen from the above table, comparing with the average ppm. contents of the observed elements in average carbonatites as given by Gold(1963) and the qualitative spectrographic analysis table of Phadke and Jhingran(1968) given it would be seen that the results of the present analysis are somewhat erratic but since this is the first quantitative analysis done by any investigator the author feels they should be reported.

These results when compared to those of Phadke and Jhingran (1968) (refer table 5).

Phadke and Jhingran		Present result
Cu	- Moderate	60 ppm
Co	- Moderate	25 ppm
V	- Moderate	85 ppm
Ba	- Moderate	85 ppm
Mo	- Moderate to strong	45 ppm
Cr	-	60 ppm

Thus the author is not deriving any conclusion on the basis of trace element results given here.

-

QUANTITATIVE SPECTROGRAPHIC ANALYSIS OF TRACE ELEMENTS [illegible] ROCK TYPES AROUND NEWANIA, RAJASTHAN

FIELD NO.		Ba	Ce	Co	Cr	Cu	Dy	F	Ga	La	Li	Mn	Mo	Nb	Nd	Pb	Pr	[illegible]	[illegible]	Sr	Ti	V	Y	Yb	Zr
AVP	1	M	X	X	M	M	X	X	M	X	M	M		X	X	M	X	M	X	M	M	M	M	F	M
"	2	M	X	X	M	M	X	X	M	X	M	M	X	X	X	M	X	M	X	M	M	M	M	F	M
"	3	M	X	X	M	M	F	F	M	X	M	M	X	X	X	X	X	M	X	F	M	M	X	X	X
"	4	M	X	M	M	F	X	F	M	X	M	M	X	X	X	X	X	M	X	M	F	M	X	F	X
"	5	M	X	M	M	M	X	M	M	X	S	M	X	M	X	X	X	M	M	S	M	M	M	F	M
"	6	M	X	X	M	M	X	X	M	X	M	M	X	X	X	M	X	M	X	M	M	M	M	F	M
"	7	F	X	M	F	F	F	X	M	X	M	S	X	S	X	X	X	X	X	F	M	M	X	F	X
"	8	M	X	M	M	M	F		[illegible]	X	F	M	X	M	M	X	M	X	X	S	M	M	X	F	X
"	9	M	X	M	M	M	F	F	X	X	F	M	M	M	X	X	X	X	X	S	M	M	X	F	X
"	10	F	X	M	M	M	F	X	X	X	X	M	X	X	X	X	X	X	X	M	M	M	X	F	X
"	11	M	X	M	M	M	[illegible]	X	X	X	F	M	X	X	X	X	X	X	X	VVS	M	M	X	F	X
"	12	F	X	M	M	M	[illegible]	X	[illegible]	X	F	M	[illegible]	M	X	X	X	X	X	M	M	M	M	F	X
"	13	M	X	M	S	M	F	M	X	X	S	M	X	X	X	X	X	X	M	M	M	M	M	F	M
"	14	M	X	X	M	M	X	X	X	X	M	M	F	X	X	X	X	X	M	M	M	M	M	M	M
"	15	F	VS	X	X	M	M	F	X	VS	M	M	[illegible]	[illegible]	S	X	M	X	X	F	F	M	X	X	X
"	16	M	X	X	M	M	M	F	[illegible]	F	VS	[illegible]	X	[illegible]	X	X	X	M	M	S	M	M	X	F	X
"	17	M	X	M	M	F	F	F	X	X	S	M	[illegible]	M	X	[illegible]	X	[illegible]	X	S	M	M	X	F	X
"	18	M	X	X	F	F	X	X	X	X	X	M		X	[illegible]	[illegible]	[illegible]	X	X	F	M	M	X	F	X
"	19	M	X	X	F	F	X	X	X	X	F	M		X	X	[illegible]		X	X	F	M	M	X	F	X
"	20	F	X	X	F	F	X	X	X	X	F	M	X	[illegible]	X	X	X	[illegible]	X	F	F	M	X	F	X

X - not detected, M - moderate, V - Very strong, A[illegible] 1 to 2 Intale granite gneiss, AVP[illegible] to 17 Carbonatites
F faint, S - strong, VVs Very very strong, AVP[illegible] to [illegible] [illegible] [illegible], AVP/16 to 20 Sedimentary Limestone/dolomites

[REPRODUCED FROM PHADKE + JHINGREN 1968]

TABLE. 5

The study was carried out with the sole view of finding out minerals and mineral assemblages not reported by provious workers and identification of the various carbonate species assemblages which otherwise would have to be determined by conventional staining methods.

Megascopic description of the samples choosen for study are given below:

1.	24/628/XI	- Contact schistose rock-green fine grained
2.	24/628/X2	- Contact fine grained carbonate rock-brown
3.	24/628/x_3	- Coarse grained buff coloured carbonate rock
4.	24/622/X_4	- Brownish band - carbonate rock coarse grained
5.	24/622/X_5	- Greyish carbonate rock-coarse grained
6.	24/621	- Fine grained melanocratic carbonatite dyke
7.	24/607	- Coarse grained brown to pink carbonatite
8.	24/609	- Massive coarse grained leucocratic carbonatite
9.	24/627	- Coarse to medium grained carbonatite-grey
10.	24/668	- Feslpathic fenite-coarse grained-gneissic
11.	24/669	- Granite country rock, coarse grained
12.	24/670	- Pegmatitic rock in the granites-pink coarse grained.
13.	24/685	- Vein from the carbonatite rocks(Newania)

SAMPLE PREPARATION

The rocks were crushed by hammer to pea size, washed with soap and water to remove surface material and dried in the sun for a day. 60 grams of those are sampled and crushed in a diamond

CHAPTER - VII

X-RAY STUDIES

X-ray diffraction studies were carried out on fifteen(15) samples of the various carbonatite,associated felspathic fenites and the country rock granites.on a limited scale.These also includes two carbonate rock samples found associated with the Khetri Copper deposits. The studies were done at the Institute of Petroleum Exploration,Dehra Dun with a General Electric X-ray Diffractometer using Cu K_α radiation operating at 36 KV power 15m A,with electronically controlled self recording.

Area of Powder specimen covered by x-ray	- 5 x 5 mm
Scanning speed	2° 2θ/m
Chart speed	24 inch/hr
Time constant	0.5 sec.
Copper target - nickle filters	1.5405

All powder pack sample was run from 2° - 50 with a scanning speed of 2°/m. All patterns were obtained at 22°C room temperature.

The study was carried out with the sole view of finding out minerals and mineral assemblages not reported by previous workers and identification of the various carbonate species assemblages which otherwise would have to be determined by conventional staining methods.

Megascopic description of the samples choosen for study are given below:

1.	24/628/XI	- Contact schistose rock-green fine grained
2.	24/628/X2	- Contact fine grained carbonate rock-brown
3.	24/628/x_3	- Coarse grained buff coloured carbonate rock
4.	24/622/X_4	- Brownish band - carbonate rock coarse grained
5.	24/622/X_5	- Greyish carbonate rock-coarse grained
6.	24/621	- Fine grained melanocratic carbonatite dyke
7.	24/607	- Coarse grained brown to pink carbonatite
8.	24/609	- Massive coarse grained leucocratic carbonatite
9.	24/627	- Coarse to medium grained carbonatite-grey
10.	24/668	- Feslpathic fenite-coarse grained-gneissic
11.	24/669	- Granite country rock, coarse grained
12.	24/670	- Pegmatitic rock in the granites-pink coarse grained.
13.	24/685	- Vein from the carbonatite rocks(Newania)

SAMPLE PREPARATION

The rocks were crushed by hammer to pea size, washed with soap and water to remove surface material and dried in the sun for a day. 60 grams of those are sampled and crushed in a diamond head steel motar to 200 mesh. 60 grams were reduced to -200 mesh B.S.

Instances where different portions of the rock are to be investigated separately, they were crushed till the required portions are liberated, washed, handpicked then crushed. The various minerals that have been identified in the deffractoÿgrams have been given below. Conversion from 2θ to d values were done directly with the help of conversion tables given by Carner(1966) for certain minerals. Others were identified from x-ray power data given by Kostov(1968).

Mineral	2θ	θ	d	hkl	I
1	2	3	4	5	6
Dolomite	30.90	15.425	2.90	104	VS
	44.60	22.3	2.0?	202	W
	40.80	20.4	2.21	113	S
	37.20	18.6	2.42	110	W
	23.80	11.9	3.73	102	W
	44.95	22.475	2.01	202	S
	41.1	20.55	2.19	113	S
	37.35	18.675	2.41	110	W
	35.30	17.65	2.54	105	W
	33.50	16.75	2.67	006	W
	24.0	12.0	3.70	102	S

VS - VERY STRONG, S - STRONG, W - WEAK, VW - VERY WEAK.

1	2	3	4	5	6
Calcite	23.5				
	29.7	14.85	3.04	104	VS
	35.9	17.95	2.50	110	VW
	39.5	19.75	2.29	113	VW
	43.4	21.7	2.10	202	W
	47.5	28.75	1.91	108	S
	48.5	24.25	1.81	116	S
Siderite	32.0	16.0	2.78	104	VS
	38.5	19.25	2.85	110	W
	41.7	20.85	2.13	113	S
	42.2	21.1	2.13	113	S
	50.7	25.35	1.800	204	VW
	52.4	26.2	1.736	108	W
Apatite	21.90	10.95	4.09	200	VW
	25.90	12.95	3.44	002	W
	27.70	13.85	3.22	102	W
	31.75	15.875	2.81	211	VW
	32.00	16.00	2.79	112	VS
	32.90	16.45	2.72	300	S
	34.1	17.05	2.62	202	VW
	46.9	23.45	1.94	222	S
	49.2	24.6	1.85	213	VW

1	2	3	4	5	6
Reibeckite	28.5	14.25	3.13		S
	19.6	9.8	4.529		VW
	10.5	5. 25	8.429		VS
	10.6	5.3	8.345		S
Microcline	45.6	22.8	1.99		W
	42.0	21.0	2.16		S
	27.7	13.805	3.22		VS
	21.0	10.5	4.18		W
Quartz	42.7	21.35	2.12	200	W
	40.5	20.25	2.287	102	VW
	36.6	18.30	2.45	110	S
	26.7	13.35	3.34	101	VS
	20.9	10.45	4.25	100	VW
	45.6	22.80	1.98	201	W
	42.4	21.20	2.131	200	VW
	40.25	20.125	2.242	211	VW
	39.5	19.75	2.28	102	S

1	2	3	4	5	6
Orthoclase	30.5	15.25	2.93	222	S
	29.6	14.80	3.007	131	S
	25.7	12.85	3.466	112	S
	24.9	12.45	3.57	221	VW
	21.1	10.55	4.24	201	S
	13.85	6.925	6.52	020	W
	23.45	11.725	3.79	130	W
	15.0	7.50	5.87	111	W
	22.5	11.25	3.94	111	VW
	24.3	12.15	3.62	131	VW
	26.6	13.3	3.33	220	VS
Albite	13.85	6.925	6.39	001	S
	22.75	11.375	4.03	201	W
	23.5	11.75	3.78	111	S
	24.25	12.125	3.68	130	S
	27.9	13.95	3.20	002	VS
	28.05	14.025	3.179	220	VS
Hornblende	42.0	21.0	2.151		VS
Haematite	33.2	16.6	2.69	104	VS
	49.6	24.8	1.83	204	S

SAMPLE NO. 24,607

2.05 DOLOMITE

2.19 DOLOMITE

2.42 DOLOMITE

2.54 DOLOMITE

2.67 DOLOMITE

2.90 DOLOMITE

3.[illegible] [illegible]

5.[illegible] [illegible]

4. 2.[illegible] DOLOMITE

35 2.67 DOLOMITE

35 2.90 DOLOMITE

2.07 3.04 CALCITE

DOLOMITE

DOLOMITE

DOLOMITE

DOLOMITE

APATITE

DOLOMITE 30 9

APATITE

ARAGONITE

48 6 1 67 CALCITE

41 7 1 91 CALCITE

43 2 2 10 CALCITE

SIDERITE

CALCITE 39 5 2 29 — CALCITE

SIDERITE

DOLOMITE 35 9 2 50 — CALCITE

AROGONITE

— SIDERITE

30 9 2 38 — AROGONITE

— CALCITE 29 4 3 04

— REIBECKITE 28 3 51

— AROGONITE

26 5 3 40

23 5 5 86

AROGONITE

REIBECKITE 19 6 4 55 REIBECKITE

— REIBECKITE 10 5 8 42 — REIBECKITE

4 / 5 / 91 BIOTITE

QUART
BIOTITE

QUART

420 2 15

QUART
QUART
ALBITE

38 75 2 32

QUART

35 75 2 54 DOLOMITE

3 [illegible] 91
30 95 [illegible] DOLOMITE
30 5 [illegible] ORTHOCLASE
2 [illegible] ORTHOCLASE
[illegible] — REIBECKITE
27 7 3 [illegible] — MICROCLINE
26 6 3 33 ORTHOCLASE
25 [illegible] ORTHOCLASE
25 [illegible] ORTHOCLASE
[illegible] 3 62 ORTHOCLASE
[illegible] 3 79 ORTHOCLASE
[illegible] ORTHOCLASE
[illegible] MICROCLINE
9 7 4 52 REIBECKITE

15 0 5 81 ORTHOCLASE
13 6 [illegible] 52 ORTHOCLASE
6 52 ORTHOCLASE

10 6 8 42 — REIBEC[illegible]
9 0 9 82

MICROCLINE

QUARTZ

QUARTZ

QUARTZ

QUARTZ

ORTHOCLASE

ORTHOCLASE

ALBITE

MICROCLINE

ORTHOCLASE

QUARTZ

ORTHOCLASE

ORTHOCLASE

249 210

222 215

401 224

415 265

412 269

270

279

304

ALBITE

25 15

107 826

HEMATITE

SIDERITE

CALCITE

C H A P T E R - VIII

STAINING

Staining served as an important tool in the present context of investigation, with which identification of calcites and dolomites have been made simple and less cumbersome.

Since the proportion of calcites and dolomites alone leads to the classifying of the rock as sovite or rauhaugite, staining was done on (a) outcrops exposed in the area of investigation, (b) on polished surfaces and (c) specially prepared rock slices in the laboratory.

Alizarin Red S organic stains were employed for the purpose. For approximate determination in the field 0.1 gm.of Alizarin Red S was added to 1:1 dilute Hcl, packed in a special acid polythene bottle which releases only drops of acid on pressing.

Freshly broken surfaces of the outcrops were tested. It was found that calcite rich rocks efferverse very readily attaining a reddish pink stain within a few seconds, while dolomites and dolomite rich rocks effervesce less readily, becoming stained only after several minutes (might be due to over exposure). Several parts of the outcrops were thus tested while mapping.

In the laboratory rock slices 0.5 mm thick were prepared for 7 samples and the staining solution was prepared as follows.

Dissolving 0.1 gm of Alizarin Red S in 100 ml.of 0.2% Hcl.

The slices were then etched in dilute Hydrochloric acid. checked often under a binocular microscope whether etching has produced sufficient relief.They were then put into the stain solution till sufficient contrast is attained. Usually it took about 3 minutes for calcites to stain reddish,while dolomites remain unstained or become pale pink on long exposures.

The proportions of calcite were then done usually under a binocular microscope.The results are given below:

No.	Sample No.	Calcite%
1	24/600	14.0
2	24/607	17.0
3	24/609	21.0
4	24/634	86.0
5	24/640	82.0
6	24/686	6.0
7	Limestone from Khetri	9.0

The difference gives the percentage of other carbonates and silicates.

-

CHAPTER - IX

RADIOMETRIC STUDIES

RADIOACTIVITY

Every element has a preferred ratio of r neutons and protons and if an isotope contains such number of protons and neutrons that their ratio differs from the preferred ratio the neucleus becomes unstable. Probably tremondous energies were required to build up and hold these nuclei together in the very early stages of the earth's history. Such elements transmutates spontaneously to another element to attain stable configuration, releasing energy in the process, in the form of alpha or beta particles, accompanied by electromagnetic radiation (gamma). The disintergration results in the formation of a new element if it too happens to be radioactive, it disintegrates again to attain stability. This may go on covering a few elements giving a radioactive series.

It has been established that the rate of radioactive disintegration(dNt/dt) of atoms of a given element at any instant of time (t) is proportional to the number (Nt) of atoms present at that instant i.e.

$$-\frac{dNt}{dt} = \lambda . Nt$$

Where λ is the disintegration or decay constant, which represents the fraction of atoms that disintegrate in a unit time. Its value is fixed for any given element and persist in the most diverse environments.

All elements having their atomic number more than 83 are unstable and therefore, radioactive but a few having lesser At.nos. are also radioactive.

It is customary to express energy in terms of electron volts(ev), millions of electron volts(Mev). An electron volt is the kinetic energy acquired by an electron falling through a potential difference of 1 volt and is equal to 1.6×10^{-12} erg. Natural alpha particles usually have energies of several Mev: beta rays range from fractions of an ev to several Mev, and most natural gamma rays have energies of the order of 1 Mev.

Alpha Decay

The energy of an alpha particle is always discrete, carries considerable energy, stopped by thin sheet of paper, only 30 microns thick surface layer of rock or mineral specimen is effective for examination.

Beta Decay

A neutron disintegrates to a proton and electron. The former remains in the nucleus and the later(β particles) leaves the nucleus penetration, few millimeters in rocks. Beta decay is associated with the emission of neutrinos(a light particle of mass less than 1/100th of an electron, possess no electric charge. Penetrative power of neutrino matter is about a million times that of gamma rays. Due to its negligible mass and neutral charge, it produces no ionization) of different energies and the total energy available is shared between the beta particle and the neutrino. Therefore the beta spectrum is continuous. Greatest penetration of energetic beta particles is a few mms. in rocks.

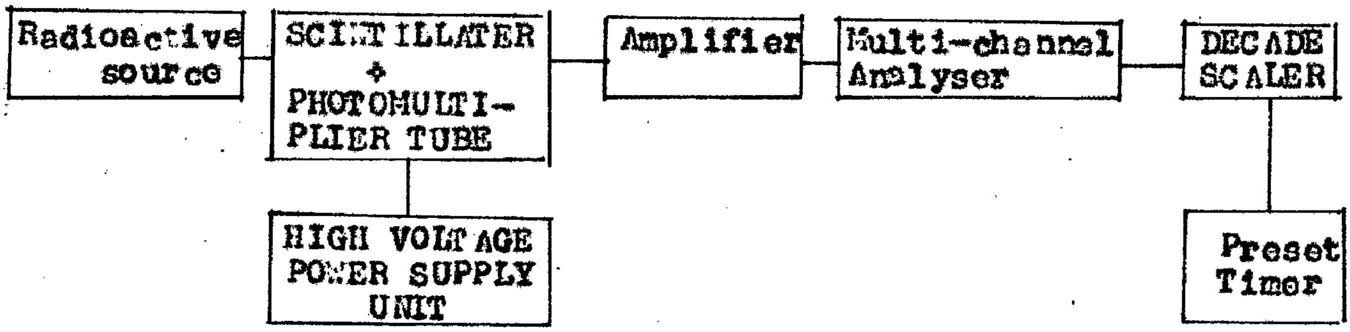
Gamma Rays

The nuclei of radioactive elements after emitting or radiation are in an excited state. When the excited nucleus changes into ground state, the excess energy is emitted in the form of electromagnetic radiation, similar in nature to light rays and x-rays having same velocity but higher energy.

At any point in space, a gamma ray quantum travels with the velocity of light ($C = 3 \times 10^{10}$ cm/sec) and with frequency determined by its energy. Its wavelength λ (= c/γ) usually varies between 10^{-9} cm. The energy of gamma quanta is given by $E_r = hv = \frac{hc}{\gamma}$ where $h = 6.63 \times 10^{-27}$ erg. sec. is the Planck's constant. Gamma ray spectrum is a line spectrum, however one and the same element emits more than one monochromatic line with widely differing energies. Electromagnetic radiations originating within the atom but outside the nucleus are called x-rays.

The carbonate rocks of Newania were suspected to be carbonatites by K.K. Dar (1964), solely on the basis of their radioactive nature. But no subsequent investigators have paid heed for the nature of radioactivity. Six powdered samples (<200mesh) of the carbonatite rocks were studied using a gamma ray spectrometer.

The Basic components of Gamma Ray Spectrometer and their functions are given below:



The scintillator consists of a thallium activated sodium iodide crystal("phosphor") which gives a burst of light when struck by gamma ray.

The photomultiplier tube produces electrical pulses for each burst of light that impinges on it.becomes effective under high voltages.

Pulses produced by the photomultiplier tube is amplified by an amplifier unit.

Every element emit energy radiation of characteristic peaks of count rate, at characteristic wave length.Hence to record count rates coming from different element sources at different wavelength a multichannel analyser is provided with the Spectrometer.In the present instrument 530 channels can be analysed simultaneously.

A preset timer is provided to count all discret pulses arriving during a desired interval of time.

Facilities to store counts arriving in the various channels to give a total count value at the end of the preset time is also present. Total number of counts in each channel were automatically printed by Teleprinter device.

The instrument was calibrated by using a standard sample of Cesium 137. The six powder samples of equal weight were counted under the same geometrical conditions as the standard with respect to the scintillation counter.

The plots of the no. of counts per 1000 secs. Vs. Channel number for only four samples have been given since nearly all eight plots showed the same number and quality of peaks.

The peak of standard Cesium 137 was at the 386th channel which is equivalent to an energy of 661 Kev. The plots gave peaks at the

1. 52nd channel = 89.05 Kev
2. 21st channel = 35.96 Kev.
3. 10th channel = 17.124 Kev.

as given by $\frac{661}{386} \times 52$ and so on

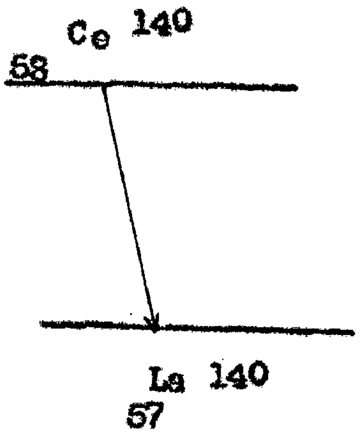
The energy 17.24 Kev. corresponds to an x-ray peak while the other 2 are photopeaks.

The results were matched with standard curves for niobuim, uranium, cerium etc. and it was found that the two peaks correspond to those of Ce (Cerium) which gives three peaks at with cerium disintegrating to give Lanthanum

0. 923 mev.

0. 815 mev.

0.328 mev.



The results obtained from plots are

1. 17.124 Mev
2. 35.96 Mev.
3. 89.06 Mev.

The first corresponds to an x-ray peak while the other two corresponds to the two out of the three peaks for cerium.

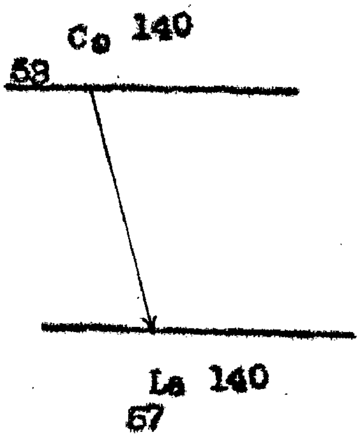
Conclusion

The samples represent all varieties of carbonatites 24/609, 24/621, 24/622, 24/632, 24/641 and 24/660. All of those were found to be radioactive, the most possible source element being Cerium $_{58}Ce^{140}$ disintegrating to Lanthanum. They seem to with cerium disintegrating to give Lanthanum

0. 923 mev.

0. 815 mev.

0.328 mev.



The results obtained from plots are

1. 17.124 Mev   x ray peak
2. 35.96 Mev.   } photo peaks
3. 89.05 Mev.

The first corresponds to an x-ray peak while the other two corresponds to the two out of the three peaks for cerium.

Conclusion

The samples represent all varieties of carbonatites 24/609, 24/621, 24/622, 24/632, 24/641 and 24/660. All of these were found to be radioactive, the most possible source element being Cerium $_{58}Ce^{140}$ disintegrating to Lanthanum. They seem to contain the same radioactive element in approximately some concentration, since equal amounts of samples were taken.They emit the same amount of radioactive energy in all samples. This may suggest that the carbonatites have radioactive elements more or less uniformly distributed in all the varieties which leads us nowhere in confirming the paragenetic sequence of the different varieties of carbonatites.

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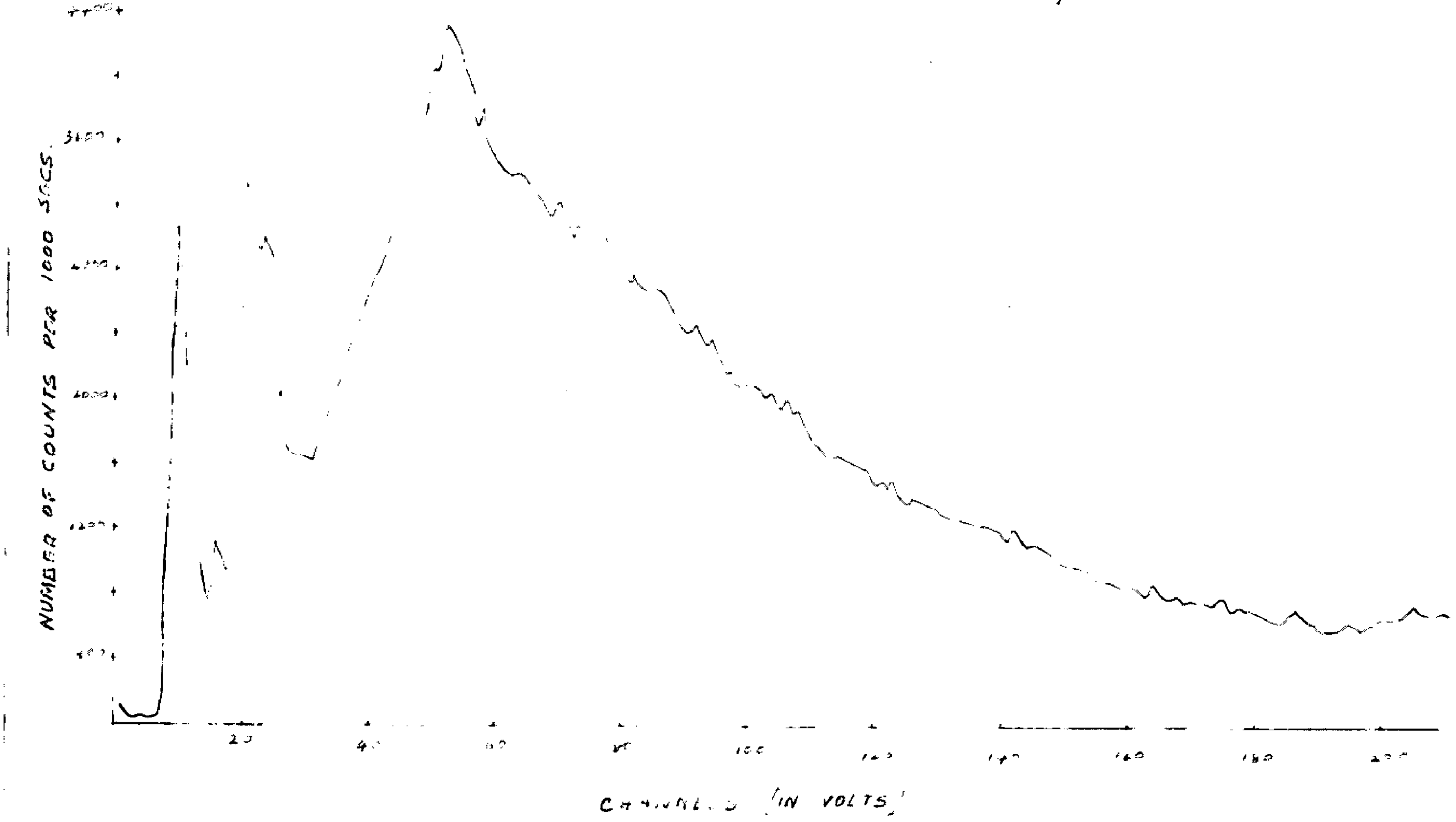
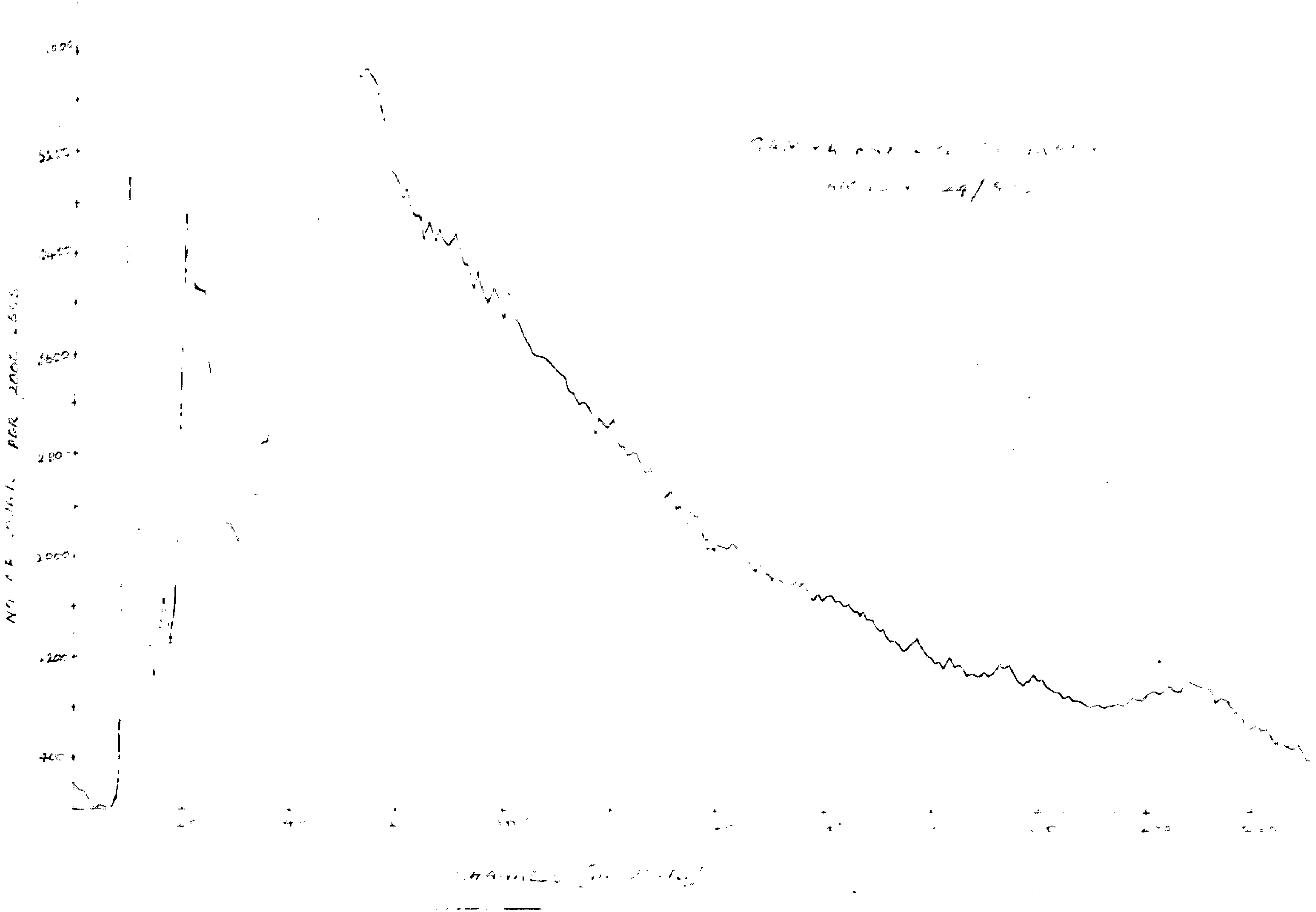
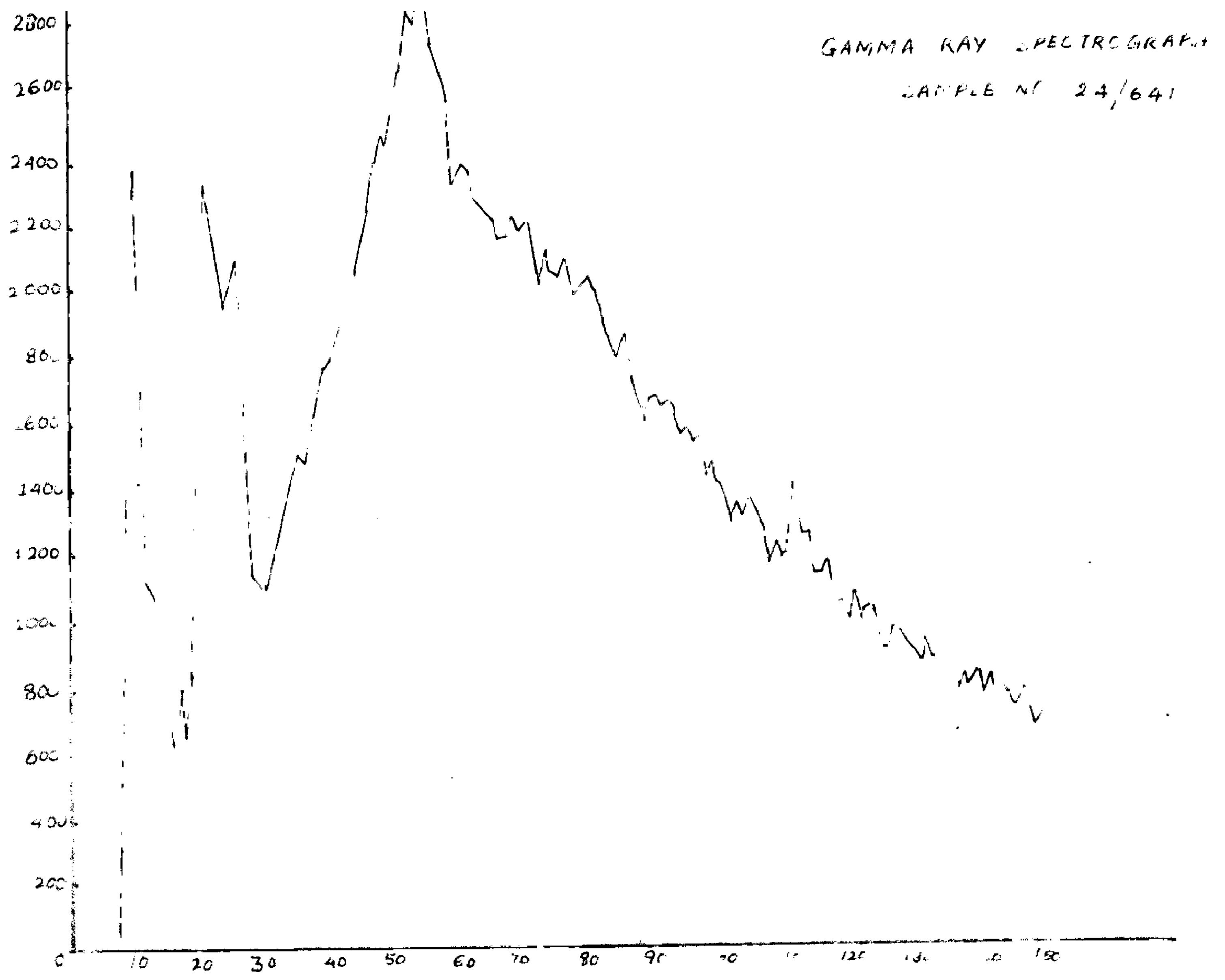
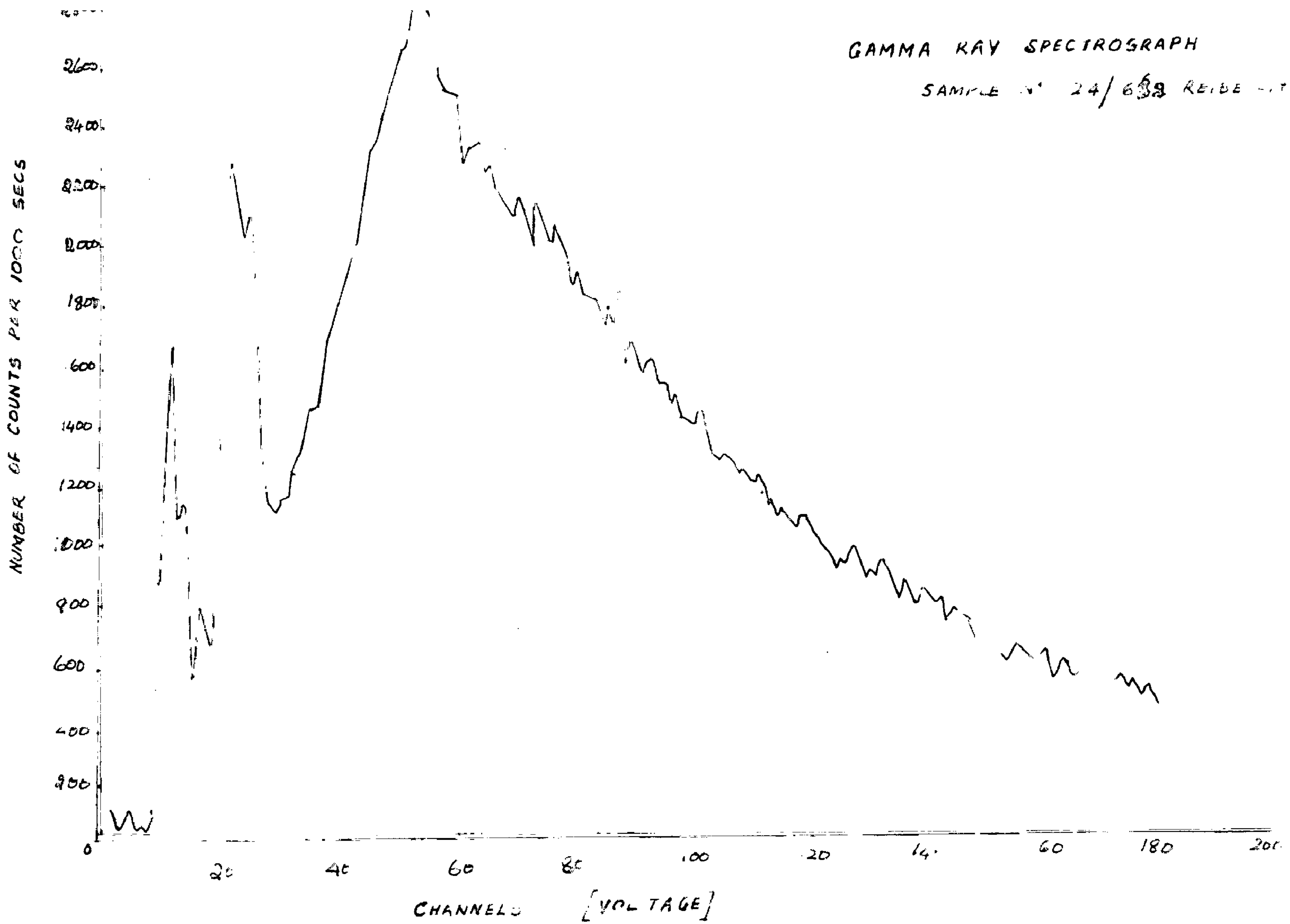
GAMMA RAY SPECTROGRAPH




PER
2000


GAMMA RAY SPECTROGRAPH
SAMPLE NO 24/641
2800
2600
2400
2200
2000
600
1400
1200
800
600
200
0
10
20
30
40
50
60
70
80
90
120
150


GAMMA RAY SPECTROGRAPH
SAMPLE Nº 24/6
REIBE
NUMBER OF COUNTS PER 1000 SECS
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
20
40
60
80
100
120
14.
60
180
200
CHANNELS [VOLTAGE]

CHAPTER - IX

DISCUSSION

The carbonate rocks of Kikawas-Newani has lead different investigators to interpret them differently. Gupta has grouped these rocks with the Aravalli suite of rocks(1934). Heron(1953) saw no significance as he mapped them as Aravalli Schists and biotite schists. K.K.Dar(1964) suggested these to be an occurrence of carbonatites stated in this paper, at Newania a highly folded calcareous granulitic rock which may be sovite or haematitic sovite but has been tentatively named crystalline limestone containing calcite, chlorite, biotite, apatite, quartz, magnetite and a mineral of pyrochlore-microlite affinities occurs in a large post-aravalli granite intrusive.

Phadke and Jhingran (1968) have shown these to be carbonatite rocks having alkaline magmatic affinities. They have also given a vague grouping of the intrusive carbonatites of the area as

1. Greenish grey to dark brown carbonatite bodies containing medium to coarse grained dolomite, calcite, ankerite and siderite.

These are actually the haematitic sovites and rauhaugites mentioned by the author.

2. Dark brown dykes of carbonatites. These are probably the cone sheets of fine grained haematitic rauhaugite and sovite with magnetites and biotites as accessory.

3. Calcite veins traversing all rocks.

These third group of calcite veins are very minor in spatial extent, but no previous worker has mentioned the occurrence of haematite rich veins in the main outcrop of carbonatite near Kikawas village NNW of the temple.

Yadav.P.K.(1969, p.67) has mentioned that he did not find any structures like cone sheets, stocks and plugs, which the present work has brought to light, of the presence of cone sheets and plugs.

He further argues that a central carbonatite core enclosed by a ring complex of felspathoidal rocks, which are necessary to prove a carbonatite as suggested by Tuttle and Githins, Smith(1956) are not found at Newania, the above shows that Yadav has misinterpreted the observations he had made in the field. He has in fact observed that he has not found any dark brown carbonatite but that some brown coloured, carbonate bands occur in the granite and granite marble contact, some of these dipping 30° -80° towards the main marble. These were actually the intrusions of fine grained carbonatite within the fenitized rocks.

The presence of these haematitic sovite-rauhaugite cone sheets or dikes within the fenitized zone as distinguished from the main plug may lead to the suggestion that these two have been emplaced from different centres of magmatic activity, the fine grained carbonatites intruded from shallower depths as compared to the carbonatites in the main plug, however some interconnected weak planes tapped these centres which must have resulted in these rocks (fine grained carbonatites) finding their way within the main plug. However, the depth of the carbonatitic magma generation and the nature of intrusion, whether through a single conduit or several, remains to be investigated.

While discussing fenitization of the five generalized zones of fenitization given by Heinrich (1966) only the first three can be found at Newania. They are

1. The shatter zone, with metasomatic veinlets, marginal alteration (thermal shock zone-von Eckermann (1948)
2. Fenite with relict quartz (Quartz syenite zone)
3. Potash Felspar - Ægerine Fenite zone (Alkali syenite zone)

Zone No. 2 is is absolutely or nearly absent due to the intensive metasomatism of the contact granites, which has resulted in near complete elemination of quartz. However, Zone No. 3 is the most predominant. Ægerine in the 3rd zone is represented by Reibeckite and a little hornblende which have formed in preference to Ægerine due to favourable pressure temperature conditions which are governed by depth factor, which causes a variation in the results of fenitization with similar carbonatites and similar wall rocks,such as preponderence of amphiboles over pyroxenes Heinrich (1966).

The 4th and 5th Zones given above involves desaturation or nephelinization,which is absolutely absent,it could be due to the fact that the SiO_2 content of the original host rock(Biotite-Epidote granite) were present in excess of that subtraced during the initial stages of fenitization which would otherwise result in Nephelinization of the rocks in the terminal stages of fenitization process,Von Eckermann(1948).

The factors responsible for variation in the results of fenitization are,according to Dawson(1964a):

1) Major variations in composition of carbonatites magmas especially in proportions of the ions K^{+}, Na^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+} and Mn^{2+} which apparently have different rates of reactivity with wall rock.

2) Different types of wall rock. ~~Taxthoxatowm~~

To the above Heinrich(1966) has added that with similar carbonatites and similar wall rocks the result of fenitization may vary with the pressure temperature environment,such as preponderence of amphiboles over pyroxene,thus his contribution to to a third factor.

3) Depth and temperature at which the solution reacts with the wall rock.

Having the above in view the carbonatite magma at Newania had higher proportions of K^{+}, Na^{+}, Fe^{+} which had higher rates of reactivity with the wall rock as evidenced by addition of the above contents in the wall rock causing characteristic modifications and the depth-temperature environment was such that the development of amphiboles far overwhelms those of pyroxenes.

Felspathization has been a pre-carbonatitic alteration, which has suffered post-fenitization brecciation but these rock have not undergone any significant degree of carbonatization.

Saether(1958) has calculated that that at Fen Na_2O Al_2O_3, CaO, K_2O and CO_2 have been added by 2% to the original gneiss to produce fenite, while SiO_2 has been removed by 8%. At Newania $Na_2O + Al_2O_3 + CaO + K_2O + CO_2$ have been added upto an average of 44% and SiO_2 removed by 24%. This signifies the intense degree of fenitization that has taken place.

The presence of bounds ins of fenitized rock in the fine grained in the well cuttings roughly 10 metres deep, which the previous workers were unable to observe since the wells are being dugged recently.

Considering the suggestion made by Yadav(1969) that the sedimentary carbonates have been regenerated by the high temperatures produced by the intrusion of granite into them

(Anatexis),it leads us to the question as to why then the petrographic and petrochemical differences between the main carbonatite body and the fine grained carbonatites with the fénite zone? They are supposed to be from the same material suffering anatexis at the same depth.

Further if we take that the granites have been intruded into the carbonatites,it should be evidenced by intrusive features of all scales,microscopic,mesoscopic and megascopic though megascopic evidneco,in the form of apophyses of fenitized granite occurrence at 60 metres depth(from bore hole data) Yadav(1969) has been reported,it is not convincing.

Cataclastic metamorphism of the xenolithicchlorite schist bands within the main plug of carbonatites proves that the carbonatites are younger than granites and have been intruded into the granitic and schistose rock.

Carbonatites are usually associated with alkaline rocks like Ijolites. Urtites,Nephelenites,and in an idealized carbonatitic ring complex the main rock units found outwards - inwards would be as given by Heinrich (1966).

1. Fenite
2. Nephelene Syenite
3. Urtite
4. Ijolite
5. Melteigite
6. Carbonatite.

Similarly at Koratti,Tamil Nadu(Barodin et al.,1971) the carbonatites are flanked in the east by syenites and on the west by pyroxenites. At Jogipatti,nearby,they occur within syenite massed in the form of lenses.They also with crystalline limestone which have as different geological setting and mineralogical assemblages.But as in the present area such alkaline rocks are not observed,which should be noted.

Further it is interesting to note that carbonatite rocks are found in intrusive complexes usually occupy only 10% or less of the total area of the peralkaline rocks (Heinrich 1966). In view of the above observation King et al.while investigating the volume of the cenozoic volcanic material in Eastern Uganda and and western Kenya estimated them to be 30,000 cu.kms.in which Nephelinites were the dominant rocks.They also projected the area occupied by ijolites,carbonatites and also associated rocks to a depth of 10 kms.giving a total volume of 1200 cu.kms. It was found only 2.5% are intrusive ijolites while 0.5% were carbonatites.

Thus at Newania if we consider it as a carbonatite differentiated from an Alkaline magma,it would represent the 0.5% of the total volume of Alkaline magma to give this much differentiated,but unforunately no other alkaline differentiates are found present. This leads to the conclusion that these carbonatites have not originated by direct differential crystallization from a dense fluid magma of Alkaline affinities.

By processing the evidnecos already available the Newahia carbonatites could be the result of recrystallization of remobilized phosphate and iron rich sedimentary carbonate rock at depth.

Pure microscopic examinations of the carbonatite samples did not show the presence of any identifiable rare-earth minerals but a possibility is there that they might have been overlooked due to their rarity or due to their being sub-microscopic but these do not prove that these are not carbonatites. Sethna(1971) has mentioned that though he could not detect any diagnostic minerals in thin sections of the carbonatites of Ambadongar, Gujarat, trace element analysis has proved the presence of rare-earth contents.

Dean and Powell(1968) has noted that individually high contents of an element like phosphorous, stontium or barium (in the case of Newania phosphorous and Titanium) cannot be regarded as diagnostic of carbonatites but collective enrichment of several elements like the most characteristic niobium, cerium, Lanthanum, strontium, barium, phosphorous would definitely be in favour of a carbonatitic origin.

Unfortunately the author was not able to do trace element analysis done for the above six important diagnostic elements. Hence no conclusion could be drawn in these lines. However, cerium has been found present in appreciable amounts in all the carbonatites through radiometric studies.

The nature of occurrence of the apatite veins sometimes cross-cutting relationships with covites,rauhaugites and associated carbonatites within the main plug,their texture and numeralogy,they appear to be low temperature,fracture filled bodies They must be post tectonic since they are found in almost all varieties of carbonatites.They also have invariably sharp transitional contacts with the host rocks.

Concentration of high volatiles during late stage crystallization would have kept the residual liquid rich in phosphorous iron and titanium,titanomagnetite,must have begum crystallizing till it is joined by apatite,which is evidenced by the inclusions of magnetite which the apatite seems to be partly replacing. Apatite ~~cyr~~ crystallized till phosphorous was depleted,later subjected to filter pressing,which has caused the universal characteristic of rounded ovoid grains of apatite in the deposit, some magnetite accompanied the apatites.

It has been found that the habit of apatite varies with their conditions of formation, apatite crystals according to experimental studies by Wyllie et. al.(1962) co-existing in equilibrium with liquid or vapours were small and equant whereas those precipiated from a liquid during quenching formed ascicular prisms exhibiting a variety of parallel and skeletal growths. When an acqueous vapour phase is present it tends to form stubby hexagonal prisms,when a liquid phase is present the apatite crystals are similar but with increasing temperature they become somewhat larger and better formed. Maximum elongation ratio 3:1, whereas those precipitated from a liquid during a quench are greatly elongated to the C axis 20:1.

In view of the above the apatite crystals found in the present area were small and equant with maximum elongation ratio 5:1 (Refer micro-photograph No. 21). This supports the author's view that these apatites were formed from fluids in equilibrium with them. However, the pitted surface of nearly all apatite grains remains to be explained.

carbonatitic varieties have been given,

1. Emplacement of sovites
2. Emplacement of rauhaugites with siderite and Ankerite which resulted in internal metasomatic alteration i.e. photogopitization and development of apatite and amphiboles.
3. Intrusion of core sheets into fenitized rocks.However detailed trace element and rare earth determination have to be done to confirm the above.

The carbonatites of the area are rheomorphic in nature remobilization and emplacement of phosphorous and iron rich carbonate rocks at depth.

Metasomatism has been a pre-carbonatite alteration which has suffered post fenitization brecciation.The feinites are result of carbonatitic emplacement and not the result of intrusion of granitic host rocks.

Study of apatites has led to the suggestion that they could possibly be fracture fillings at low temperature pressure,in origin.

Kaolinization,sericitization and carbonation of the fenitized rocks are late stage alterations.

Finally the presence of abundant cerium earths in all varieties of carbonatites of the area also supports the authors views.

CHAPTER - XI

CONCLUSION

On the basis of field observations and laboratory investigations the author has been led to derive the following conclusions.

Field occurrences suggestive of emplacement by intrusion of the carbonatite rocks exposed at Kikawas-Newania are as follows:

1. Several fine grained carbonatite bodies dipping relatively more steeper inwards which differ in composition and texture.

2. A main carbonatite plug collared by a ring of metasomatized rock.

3. Pressure of thermal stock zone around the central core.

The carbonatites have been classified into four groups.

a) Calcite Sovites

b) Dolomitic Rauhaugites

c) Haematitic sovites and Rauhaugites with siderites, Ankerite in various proportions.

d) Cone sheets of haematitic sovites and rauhaugites fine grained.

A paragenetic sequence(tentative) of the various carbonatitic varieties have been given,

1. Emplacement of sovites
2. Emplacement of rauhaugites with siderite and Ankerite which resulted in internal metasomatic alteration i.e. photogopitization and development of apatite and amphiboles.
3. Intrusion of core sheets into fenitized rocks.However detailed trace element and rare earth determination have to be done to confirm the above.

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No.1 Shows the numerous outcrops of carbonatite rocks of the main plug. Joints trending NE of the photograph can be clearly seen in almost all outcrops.

No.2 Boudins of Fenitized rock enveloped by fine grained melanocratic rock which has been weathered above as well as in between.

No.3 Haematitic Rauhaugite rock with patches of coarse grained sovites, bearing an apatite vein in line with the apparent Sovite lineation.

No.4 Sovite-Rauhaugite rock slightly ~~sit~~ foliated and folded upper part of photograph.

No.5 Vertically jointed sovite rock with perfect bands of dolomite rich rock. Arrow.

No.6 Fine grain carbonatite veins in the fenitized zone with xenoliths of fenitized rock. The boulder were dug out from a well.