CHAPTER V

MAFIC ROCKS

Occurrences of mafic rocks recorded in the study area are not many, but they offer important clues in unravelling the age relationship of the various metamorphic and igneous episodes of this pre-Cambrian terrain. The author has mapped in all fifteen igneous bodies of large and small dimensions and according to him, they are of the nature of lensoid - sills rather than dykes. In general, these occurrences of mafic rocks are not very extensive and prominent, except in the exposure at the village Kawa where mafic rock forms a very striking and conspicuous hill, within granites. Middlemiss (1921) was considerably attracted to this exposure and he studied the Kawa mafic rock in fair detail. It however appears that he was misled by the freshness of the rock and concluded that Kawa mafic rock and other smaller bodies in the Idar area were younger than the surrounding granites. He thought that the mafic rocks were intruding the granites. The present investigations by the author however have conclusively shown that the granites are younger than the mafic rocks and there are ample field evidences to prove this point. The Kawa hill ideally shows veins of granites cutting the mafic rock.

These mafic rock bodies are seen occurring both in the granitic terrain as well as in that occupied by the calc-gneisses. It is quite probable that many more are there but lie unexposed beneath the soil cover. Generally, these bodies form small lenses 1 to 2 meters thick and of lateral extent never exceeding 100 meters. Of course, the exposures are not so good and never fully give an idea of the total size of the lenses. Full details of the various occurrences have already been given in Chapter III.

Smaller mafic bodies occuring within the low-lying granitic terrain generally show more or less complete hydrothermal alteration and are typical epidiorites. Though the rock is altered yet it preserves the igneous texture. Such occurrences hardly reveal original mineralogy. On the other hand a few bigger masses viz. those of Kawa and Reda have escaped alteration (owing to their large size) and ideally exhibit the original texture and mineralogy. Wherever these mafic rocks have come in contact with later intrusive granite a mixed, hybrid rock type has originated. The Kawa and Satharva hills show such hybrid rocks. The Kawa mafic rock itself is traversed by numerous thin veins of a fine-grained porphyritic mafic rock which has different texture and mineral content. It is so obvious that this fine-grained variety is a late differentiate of the parent mafic magma which gave rise to the coarse grained dolerites and gabbros. Based on above differences the various mafic rock types encountered have been classified into the following four categories:-

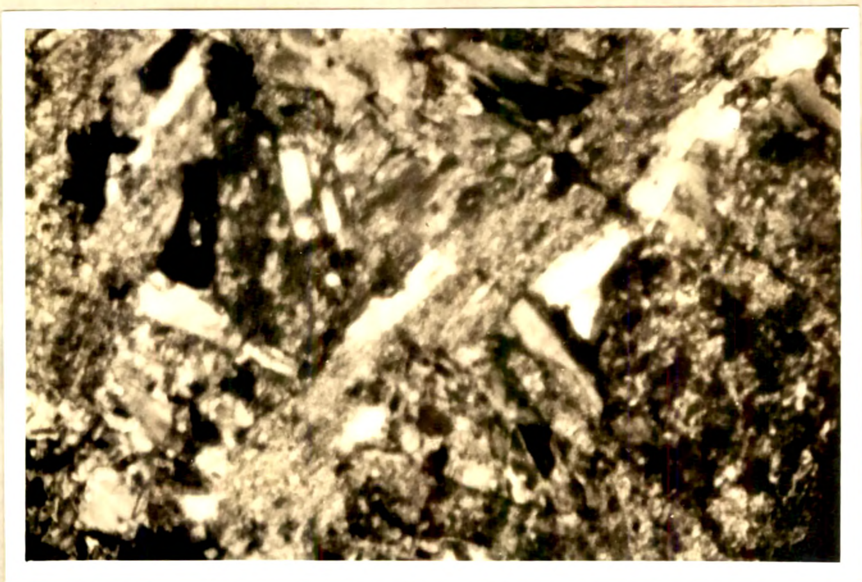
1. Epidiorites,
2. Olivine bearing gabbros and dolerites,
3. Hybrid varieties and
4. Fine-grained andesitic veins.

EPIDIORITES

These hydrothermally altered equivalent of original mafic rocks, in hand specimen are seems to be hard, compact and of dark greenish grey colour. Under the microscope, the rock shows a well preserved sub-ophitic to diabasic texture (Plate-V.1). Occasionally the rock also exhibits a foliation due to parallel orientation of hornblende, biotite and chlorite. This schistocity is obviously due to involvement of the mafic rocks in the folding. The original pyroxene and the plagioclase are more or less altered but still the original texture comprising laths of plagioclase with interstitial spaces filled by pyroxene, is very clearly recognised. The rock is generally medium-grained with plagioclase laths in mafic groundmass. The original minerals are augite and plagioclase which show all stages of alteration to hornblende and chlorite and saussuritisation respectively. In their partly altered forms the epidiorites are seen to consist of following minerals:-

Plagioclase (An_{32-35}) is somewhat less calcic and forms the original constituent of the mafic rock and occurs as stubby, prismatic laths forming a random mass. It shows twinning on albite and carlsbad laws. All stages

PLATE-V.1



Photomicrograph (X60) of epidiorite showing relict texture.

of its alteration to saussurite and sericite is seen. In some cases alteration is so complete that its identification becomes very difficult.

Augite is only occasionally recorded, as in most cases it has completely altered to hornblende and chlorite. The relict and unaltered grains are important because they tell us about original pyroxene of the rock. The mineral is seen occurring interstitially between the criss-cross mesh of plagioclase laths. When unaltered, the pyroxene is colourless, anhedral shows high relief and typical pyroxene cleavage. It has large extinction angle and second order polarisation colours.

Hornblende is a hydrothermal alteration product after pyroxene and occurs in close association with chlorite. It shows usual amphibolitic cleavage and is pleochroic in various shades of green

X = pale green

Y = green

Z = dark green

$X < Y < Z$.

Its extinction angle on (110) cleavage is 18°.

Chlorite occurs as an alteration product of pyroxene and hornblende, and forms the most dominant constituent. It has a light green colour and shows pleochroism from yellowish green to light green.

$X = Y =$ green

$Z =$ yellowish green

$X = Y > Z$.

The mineral has well developed cleavage and occurs as radiating crystals, fibrous tufts and felted mass showing parallel extinction and first order low polarisation colours.

Biotite, Iron oxide, Sphene and Quartz: These minerals occur in a subordinate amount. Biotite forms tiny flakes occurring in close association with chlorite and is obviously derived from the pyroxene. Iron oxide mainly magnetite occurs as scattered patches and also as dusty grains in chlorite. While some magnetite may be the original constituent of igneous rocks, most of the finer grains are released during the alteration of the pyroxene. Sphene forms the tiny irregular grains and is an alteration product after pyroxene and plagioclase. Quartz if at all present, forms stray grains and irregular aggregates and seems to have been introduced by later granites.

OLIVINE BEARING GABBROS AND DOLERITES

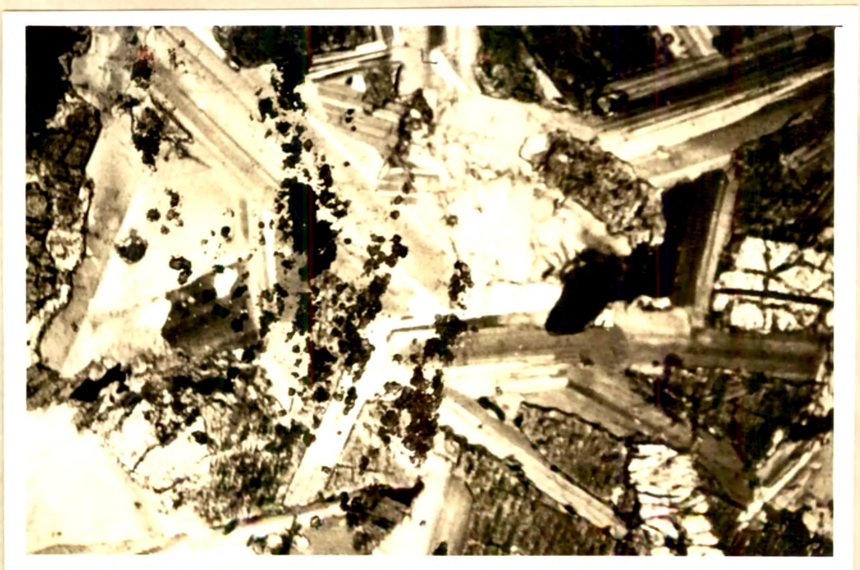
These rocks which are confined to larger exposures of Kawa and Reda are considerably fresh and unaltered, and ideally show the original texture and mineralogy. In hand specimen, the rocks show a dark greenish black colour (Plate-V.2). The grain size varies in various samples from different parts of the same exposure. While the rocks from the central part is mostly coarse and gabbroic, those at the margins are fine-grained and doleritic. In coarser varieties, different minerals like augite, hypersthene, bronzite, olivine, plagioclase and biotite can be identified megascopically.

These rocks show considerable textural and mineralogical variations within the limits of the single exposure at Kawa. The margins as just stated show finer grains and is also different in mineralogy from the central coarser mass. The former shows typical medium grained sub-ophitic texture and consists of plagioclase and augite with occasional olivine. On the other hand the central portion comprising gabbroic rock is seen to contain plagioclase

PLATE-V.2

Fresh and unaltered, olivine bearing gabbro from the central part of a mafic sill (Loc: Kawa).

PLATE-V.3



Photomicrograph (X30) of the olivine bearing gabbros.

and augite with subordinate amount of hypersthene, bronzite and olivine. The orthopyroxene may or may not be present. There are several patches which are richer in plagioclase content and contain smaller proportion of pyroxenes. Almost all varieties show effect of contact metamorphism along the margins, wherever they have come in contact with the later granite, in addition to the usual hydrothermal alteration. Biotite, which is undoubtedly a product of the contact metamorphism due to granites, forms large irregular reddish brown plates scattered all throughout the mass.

The textural and mineralogical variation is more, clearly seen in thin section. Under the microscope, the slices of different samples show quite a wide range in the grain size. Coarser gabbroic variety typically show an equigranular hypidiomorphic, holocrystalline texture comprising laths of plagioclase with interstitial portion occupied by pyroxene (Plate-V.3). Olivine occurs as discrete grains in close association with augite and hypersthene. Finer grained variety shows a sub-ophitic to diabasic texture. The texture in the marginal portions near the contact with the granites is quite often granoblastic comprising an equigranular aggregate of plagioclase and pyroxene with some biotite.

The essential minerals recorded are plagioclase, augite, hypersthene, bronzite and olivine. Biotite, hornblende and chlorite are present as secondary minerals. Iron oxides - mainly magnetite and ilmenite are present in accessory amount.

Plagioclase (An_{48-52}) occurs as large laths (3 mm.) commonly twinned on albite and carlsbad laws. The plagioclase is labradorite with appreciable anorthite content. The plagioclase in the less coarse doleritic varieties confined to the marginal portions, appears to be nearer to andesine with An content about 35 to 38. Inclusions of pyroxene are common in it. Generally the mineral is fresh and unaltered but in the samples collected from margins it shows clouding and saussuritization.

Augite forms subhedral and anhedral colourless grains and mostly occupies space between feldspar laths. In sub-ophitic variety the augite forms big poikilitic grains. It also occurs as inclusions in plagioclase. The mineral shows characteristic high relief, cleavage and second order polarisation colours. Its extinction on prismatic cleavage is 38° to 40°, 2V 60°.

The thermal effect of later granite has resulted into distinct schillerisation of the mineral. Quite likely, that the samples from the immediate vicinity of the contact, which show a rather granoblastic texture, contain diopside instead of augite. The distinction between the two is somewhat difficult but author did find quite a few grains more towards diopside - showing less colouration and length-slow orientation.

Orthopyroxenes are hypersthene and bronzite and are present in coarser variety only. Hypersthene occurs as subhedral grains (1 to 2 mm.) with distinct cleavages. It shows the characteristic pleochroism from pink to pale green

X = pink

Y = yellowish pink

Z = green

$X < Y < Z$.

The mineral is length slow, has lower polarisation colours than augite and shows parallel extinction with cleavage on prismatic face (011). Occasionally grains also show extinction of 10°. It has 2V = 72° and gives biaxial negative figure. In most cases hypersthene is seen altering to biotite and chlorite. Bronzite forms subhedral grains, mostly growing in the interstitial area between other minerals. It typically shows a schiller structure, straight extinction and occasional feable pleochroism with

$$X = \text{pale yellow}$$
$$Y = \text{brownish yellow}$$
$$Z = \text{pale green}$$
$$X < Y < Z.$$

It gives a biaxial positive figure and has a 2V value of 56°. The mineral seems to have formed due to the contact effect of the granite.

<u>Olivine</u> occurs as anhedral grains of variable sizes (1 to 2 mm.). It is more common in the coarser central portion of the outcrops. It is less frequent and of smaller size in the marginal variety. Its grains are colourless and show high relief, prominent fractures and high polarisation colours. The fractures are filled with dusty iron ore. Some olivine grains contain a periphery of augite and ideally illustrate corona structure.

<u>Biotite</u> forms large (2 to 2.5 mm) reddish brown irregular plates with porphyroblastic habit. Its presence indicates contact metamorphism, and is obviously developed

at the expense of the pyroxene by metasomatic addition of potash from the granite. It shows well marked pleochroism from yellow to dark reddish brown

X = yellow

Y = Z = reddish brown

$X < Y = Z$.

Hornblende and Chlorite are the alteration products after pyroxene, formed due to the effects of the granite. Hornblende occurs in close association with the pyroxene grains, shows green colour and its characteristic cleavages. Pleochroism is from pale yellowish green to pale green

X = pale green

Y = green

Z = dark green

$X < Y < Z$.

Chlorite has also identical occurrence and is formed after hornblende. It forms small clusters of stubby prismatic crystals showing one set of cleavage and low 1st order polarisation colours.

Iron oxides viz., magnetite and ilmenite occur as accessory minerals and form small grains scattered all throughout the mass. While the ilmenite appear to the original igneous constituent, the tiny granular magnetite might owe its origin to the hydrothermal products from ferromagnesian minerals.

HYBRID ROCKS

Wherever the granitic material has invaded and assimilated the mafic rocks, interesting hybrid varieties have resulted. Such contamination is generally confined to the contact between mafic rocks and granites. Two main varieties of such mixed rocks have been recognised:

(1) Kawa type gabbro and dolerite transformed metasomatically into almost a granodiorite showing a porphyroblastic growth of 'eye-shaped' feldspar.

(2) Satharva type mafic rocks actually caught up and assimilated by the intrusive granite, resulting into a 'quartz-diorite'.

Almost all instances of hybrid occurrences may fall within the above two categories. The important megascopic and microscopic characters of the two varieties are discussed below.

Kawa Type Hybrid Rock

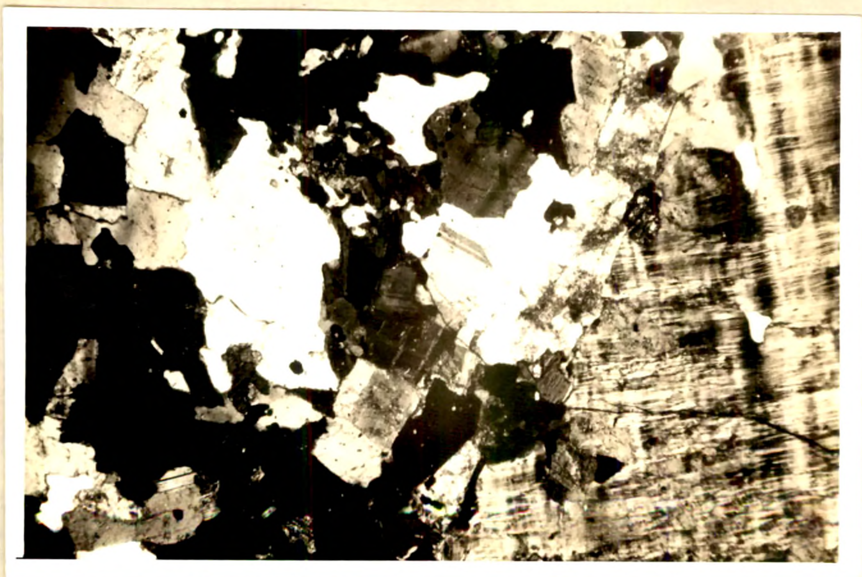
Seen ideally in the Kawa hill, this rock is derived from almost unaltered gabbro and dolerite by a progressive metasomatic action of granitic emanations, rich in potash. In hand specimen the rocks shows a gradual increase of eye-shaped porphyroblasts of potash-feldspar when traced towards the granite. The final product contains a haphazard aggregate of porphyroblasts embedded in a biotitic and hornblendic groundmass quite rich in quartz and feldspar (Plate-V.4).

In thin section the textural and mineralogical changes are more clearly recorded. The pyroxenes of the original mafic rock show a progressive change to hornblende and biotite. All stages of this transformation are recorded. The quartz content shows a progressive increase; also the grain size of this mineral increases towards the granite. The feldspar porphyroblasts are of microcline, and very clearly show their metasomatic growth (Plate-V.5). With the gradual increase of the potash feldspar both porphyroblastic as well as in the groundmass, the plagioclase of the mafic rock changes over to a less calcic variety. The overall texture and mineralogy tends to become granitic and the rock can best be called a porphyritic granodiorite. The minerals present are feldspars, quartz, hornblende and biotite. Of course the relative proportion of the minerals are variable, depending upon the degree of transformation.

PLATE-V.4

Kawa type of hybrid rock showing porphyroblasts of feldspar (Loc: Kawa).

PLATE-V.5



Photomicrograph (X30) of Kawa type hybrid rock showing development of microcline porphyroblasts in the coarse grained groundmass containing quartz, biotite and plagioclase.

Microcline occurs both as phenocrysts and as small grains in the groundmass. The former are big (2 to 3 cm.), eye-shaped grains containing inclusions of plagioclase, hornblende and biotite. The mineral is quite fresh and shows typical cross-hatching. In the groundmass, microcline forms irregular anhedral grains and occurs in close association with hornblende, biotite and quartz forming a typical granoblastic aggregate. It is easily recognised by its low R.I. and twinning.

Plagioclase is of two varieties. In relatively less transformed samples, the original relict plagioclase (An_{45-48}) of the mafic rock is present. It shows considerable alteration (saussuritization). The other plagioclase (An_{14-16}) is of granitic origin, forms small grains and occurs in association with quartz, microcline and mafics. This plagioclase is fresh and clean though contains inclusions of hornblende and biotite.

Quartz content varies, depending on the degree of granitisation. The mineral forms coarse anhedral grains generally confined to the granoblastic mass of the rock, but occasionally it forms bigger grains also.

Biotite is obviously derived from the pyroxenes of the mafic rocks, and the transformation is through an intermediate hornblendic stage. It forms fair-sized (3 mm.) plates and flakes. It is pleochroic from yellowish brown to reddish brown

X = yellowish brown
Y = Z = brown
$X < Y = Z$.

Hornblende forms sub-hedral grains (1 mm.). Two sets of amphibolitic cleavages are typically developed and seen in basal or near basal sections. It is pleochroic in shades of green and shows the pleochroic scheme

X = yellowish green
Y = green
Z = dark green
$X < Y < Z$.

The hornblende is riddled with quartz inclusions and shows very clearly its derivation from pyroxene at one end and its changes to biotite at the other. The mineral shows moderate birefringence and has an extinction angle of about 17° on prismatic cleavage.

The common accessory minerals are apatite, zircon and iron-oxide (magnetite) which occurs as tiny crystals.

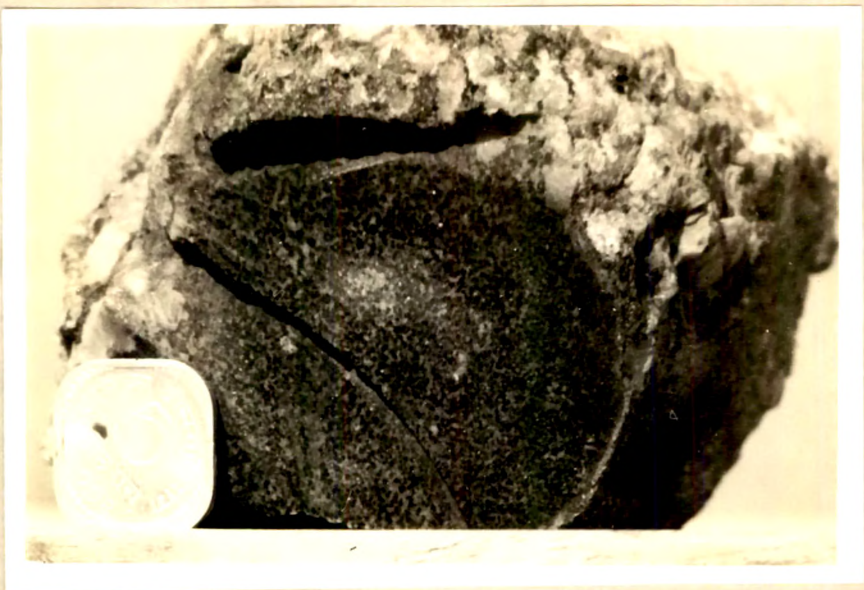
Satharva Type Hybrid Rock

This variety differs considerably from the Kawa hybrid in mode of occurrence and texture. It is a mixed rock of the composition similar to a typical tonalite (= quartz diorite) and forms small patches in the granites. Evidently these represent patches caught up in the granite (Plate-V.6). Nockolds (1934) has called a similar rock by the name 'Tonalite' formed due to contamination of granite with mafic rocks in the Loch Awe of Scotland.

Megascopically, it differs much from Kawa hybrid and is seen to form a dark and massive coarse grained equigranular rock without any phenocrysts. Under the microscope the rock shows a holocrystalline hypidiomorphic texture in which the grain size varies from medium to coarse (Plate-V.7).

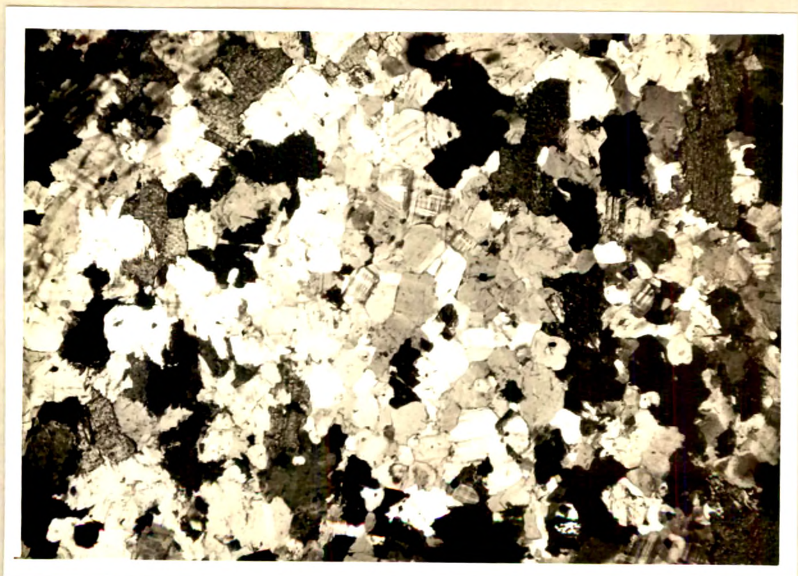
The mineral content comprises feldspar (plagioclase and potash feldspar), quartz, biotite and hornblende. Large subhedral flakes of biotite with hornblende (from which it is seen altering) and well developed laths of

PLATE-V.6



Satharva type hybrid rock caught in the massive granite (Loc: Satharva).

PLATE-V.7



Photomicrograph (X30) of Satharva type hybrid rock showing equigranular texture.

plagioclase occur in close association with interstitial quartz and some microcline. The microcline content is variable.

Feldspar, both plagioclase as well as potash feldspar are present, though the content of the latter is generally subordinate. The plagioclase (3 mm.) is a calcic oligoclase (An_{28}) and is much sericitized. Sometimes a sort of zoning is shown by this mineral with a more calcic core and a thin calcic outer rim. Potash feldspar is generally a microcline and occurs as few interstitial grains. But more granitised type poorer in mafic minerals, show a higher microcline content, and also some orthoclase grains are present.

Quartz occurs as anhedral interstitial grains, and its amount is variable.

Biotite is the predominent mafic mineral and occurs as large flakes (2 mm long). It shows strong pleochroism in shades of brown as under:

$$X = \text{yellow}$$
$$Y \doteq Z = \text{brown}$$
$$X < Y = Z.$$

Its derivation from hornblende is very clearly recorded and almost all stages of alteration of hornblende to biotite are seen. Inclusions of zircon in biotite are common.

Hornblende is the original mafic mineral of the epidiorites, but on account of the contact effect of the granite, shows recrystallisation to distinct well formed crystals of brownish-green hornblende (2 mm.). It is quite fresh except showing a progressive change to biotite. The usual cleavages are well developed and is easily recognised by its characteristic pleochroism and extinction. The mineral has the following pleochroic scheme.

X = pale green

Y = green

Z = dark green

$X < Y < Z$.

It shows an extinction angle of 18° on prismatic cleavage.

Accessory minerals are sphene, apatite, zircon and magnetite. Sphene typically shows lozenge-shaped crystals of brown colour. Apatite forms tiny needles while zircon and magnetite occur as small grains.

ANDESITE

This rock is confined to the Kawa hill only, and is seen as thin veins cutting the main mass of the hill. The veins of this rock hardly exceeds 50 cm. in thickness and show sharp contacts with the dolerite and gabbro. The rock comprises a very fine-grained, greyish green rock containing phenocrysts (1 to 2 cm.) of white feldspar (Plate-V.8). The rock is also seen to contain fragments of the coarser rock.

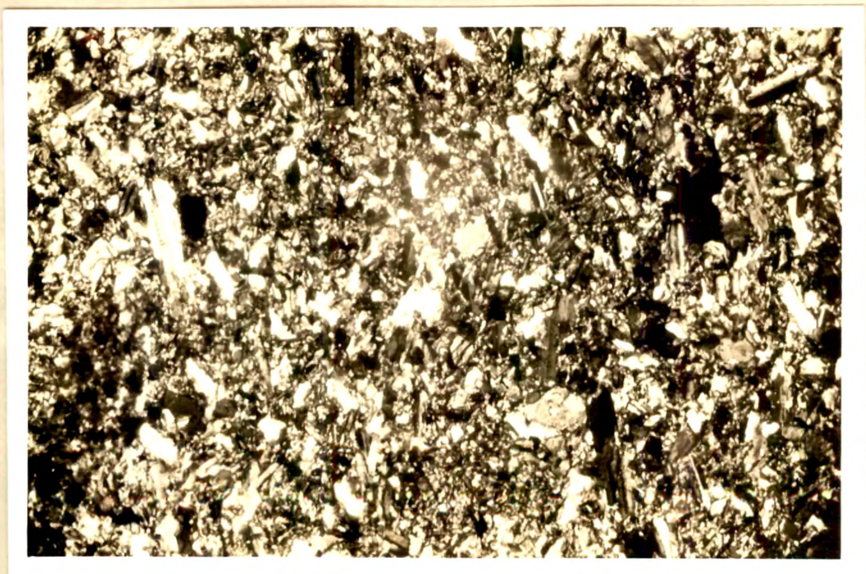
Under the microscope the andesitic composition and nature of the rock is very conspicuous. It shows a fine-grained basaltic texture with rectangular feldspar laths as phenocrysts. The basaltic groundmass consists of brown and green hornblende and biotite with tiny feldspar laths (Plate-V.9). The whole mass shows a somewhat flow structure. The minerals are plagioclase, hornblende, biotite, chlorite and iron ore. Pyroxenes are conspicuously absent.

Plagioclase is an andesine (An_{38-40}) and occurs both as tiny laths in the groundmass and also as phenocrysts. The bigger grains show twinning on carlsbad and albite laws. Some alteration is always there, but not so much as to obscure the properties of the grains. The

PLATE-V.8

Fine-grained porphyritic andesite showing feldspar phenocrysts (Loc: Kawa).

PLATE-V.9



Photomicrograph (X60) of andesite showing fine-grained texture.

smaller laths forming the groundmass also show the two types of twinning and are easily recognised.

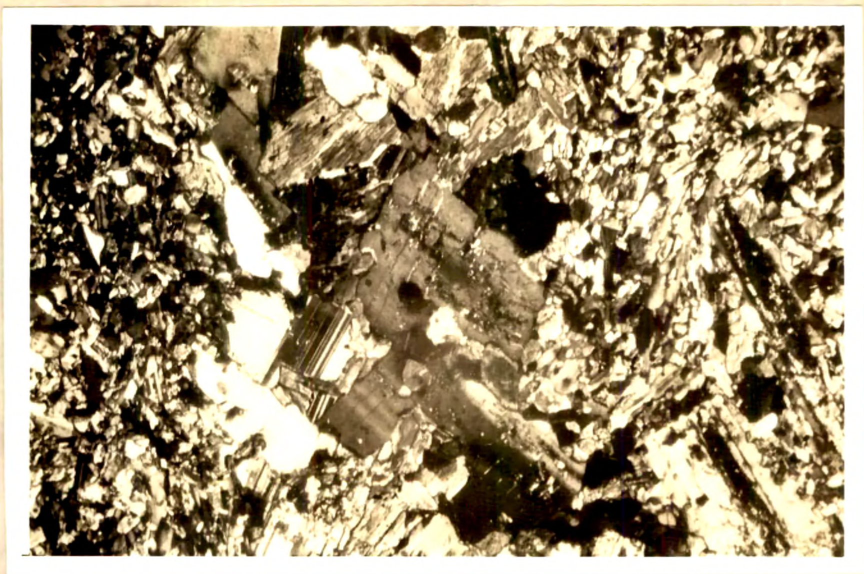
<u>Hornblende</u> together with biotite (which is derived from the former) forms the main mafic content. It occurs as greenish brown small crystals, almost invariably altering to biotite. It is identified by its oblique extinction and polarisation colours. Cleavages are developed but due to the small size of the grains, they are not so conspicuous and striking.

<u>Biotite</u> forms small flakes and is derived from the hornblende. It is quite abundant in some samples. The mineral shows a brownish colour with a greenish tinge and is pleochroic. It is easily distinguished from the hornblende by its pleochroism and straight extinction.

<u>Chlorite</u> occurs as decussate clusters of small flakes. It shows light green colour, one set of cleavage and low polarisation colours - generally greyish blue. The chlorite flakes are fringed with magnetite granules and perhaps represent alteration product of original biotite or hornblende.

[The fragments of coarser dolerites that occur in this rock are typically epidiorite and contain partly

PLATE-V.10



Photomicrograph (X60) showing fragments of doleritic rock in andesite.

altered pyroxene and calcic plagioclase together with the usual hornblende, biotite and chlorite (Plate-V.10)]

Nature of the metasomatic changes

The earliest indication of potash metasomatism is recorded in the appearance of biotite porphyroblasts in the gabbros and dolerites. Another change is of the nature of epidioritization. A most striking fact of this effect of granite on the mafic rocks is that only smaller and thinner sills have been more affected, and the bigger bodies at Kawa and Reda, though completely enclosed within the granitic terrain, have retained their freshness. Even the smaller and altered bodies of epidiorites contain relicts of pyroxene, and the plagioclases are only partly altered to sericite and saussurite. All these point to a restricted hydrothermal activity, and relative paucity of water.

CHEMISTRY

Being modified by the later granites in different ways, the chemistry of these mafic rocks has been rendered quite variable and hence its study has become very interesting. A few salient features relating to the chemical characters of the various derivatives of the original gabbro and dolerite have been worked out a brief account of which is given here.

Mafic rocks completely free from the effects of granite are not recorded and almost all the varieties indicate clear effects of the intruding granite. Even the least affected coarse rock, from the central portion of the Kawa mafic mass, show the early stages of metasomatic action of the granite in the form of the development of biotite. In the Table-V.1 analysis of two samples from Kawa have been given. The specimen No. 6/12 is from the middle parts of the sill and comprises the least altered rock, which has mostly preserved its original mineralogy. The other specimen No. 77/81 is of the rock from the marginal portion of the sill which abounds in biotite porphyroblasts. For the purposes of comparison, analysis of a typical unaltered olivine gabbro from the neighbouring Sirohi area and belonging to this igneous phase, given by Coulson (1933, p.80) has been included in the table.

It is seen that in the Kawa rocks the amount of K_2O content is slightly higher while that of MgO and CaO is less compared to an olivine dolerite unaffected by granite. It is obvious that the metasomatic effects of the granite in the earliest phase, are seen as the appearance and progressive proliferation of biotite.

TABLE-V.1

CHEMICAL ANALYSES OF MAFIC ROCKS

Wt. %	6/12	77/81	36/789 (Olivine gabbro: Coulson)
SiO_2	47.41	47.70	47.02
TiO_2	01.00	01.21	00.36
Al_2O_3	17.84	17.58	20.24
Fe_2O_3	03.55	03.56	01.25
FeO	08.40	08.97	06.34
MgO	07.01	06.19	09.56
MnO	00.14	00.15	00.12
CaO	12.10	09.68	10.54
Na_2O	02.15	02.52	02.32
K_2O	01.06	02.50	00.47
P_2O_5	00.28	00.30	-
TOTAL	100.94	100.36	
si	102.00	106.00	
al	22.63	23.06	
fm	43.59	43.60	
c	27.95	23.07	
alk	05.82	15.28	

Analyst: Paresh Raval　　　　Analyst: Mons.F.Raoult.

The increasing contact metasomatic effect of granite is ideally reflected in the chemical analysis of a set of samples collected across the contact at Kawa and is given in Table-V.2.

The variation diagrams are constructed (Fig.-V.1 & 2) on basis of the chemical data of the Kawa rocks. The diagrams are very illustrative. It is evident from these diagrams that metasomatic changes were brought about by the progressive addition of SiO_2, Na_2O and K_2O and decrease in the content of other oxides.

As has been already discussed, the Satharva hybrid differs from the Kawa hybrid in the mode of formation. At Satharva, a sill of mafic rock is caught up by the later granites and a phenomenon of assimilation has taken place. The chemical analyses of the different samples of various stages of assimilation (Table-V.3) typically reveal the chemistry of the progressive assimilation of the mafic rock into tonalite through contamination. Analysis of a mafic rock from Kawa (25/464), given by Middlemiss (1921) is also included in the table.

Variation diagram (Fig.-V.3) based upon these analyses show the behaviour of the various constituents. The successive stages of the assimilation are represented

TABLE-V.2

CHEMICAL ANALYSES OF MAFIC AND KAWA TYPE HYBRID ROCKS

Wt. %	Mafic rocks		Hybrid rocks	
	6/12	77/81	5/11	4/10a
SiO_2	47.41	47.70	60.49	66.54
TiO_2	01.00	01.21	00.80	00.61
Al_2O_3	17.84	17.58	13.68	15.26
Fe_2O_3	03.55	03.56	04.32	02.03
FeO	08.40	08.97	06.17	03.51
MgO	07.01	06.19	06.51	01.55
MnO	00.14	00.15	00.15	00.09
CaO	12.10	09.68	02.38	04.12
Na_2O	02.15	02.52	02.80	02.84
K_2O	01.06	02.50	03.10	03.25
P_2O_5	00.28	00.30	00.32	00.21
Total	100.94	100.36	100.72	100.01
Larsen Index	-10.65	-06.44	08.20	20.25
Q	-11.35	-18.49	-	-
L	79.60	84.96	-	-
M	31.94	31.58	-	-

Analyst: Paresh Raval

Fig.— V.1

Larsen's diagram: Kawa type hybrid

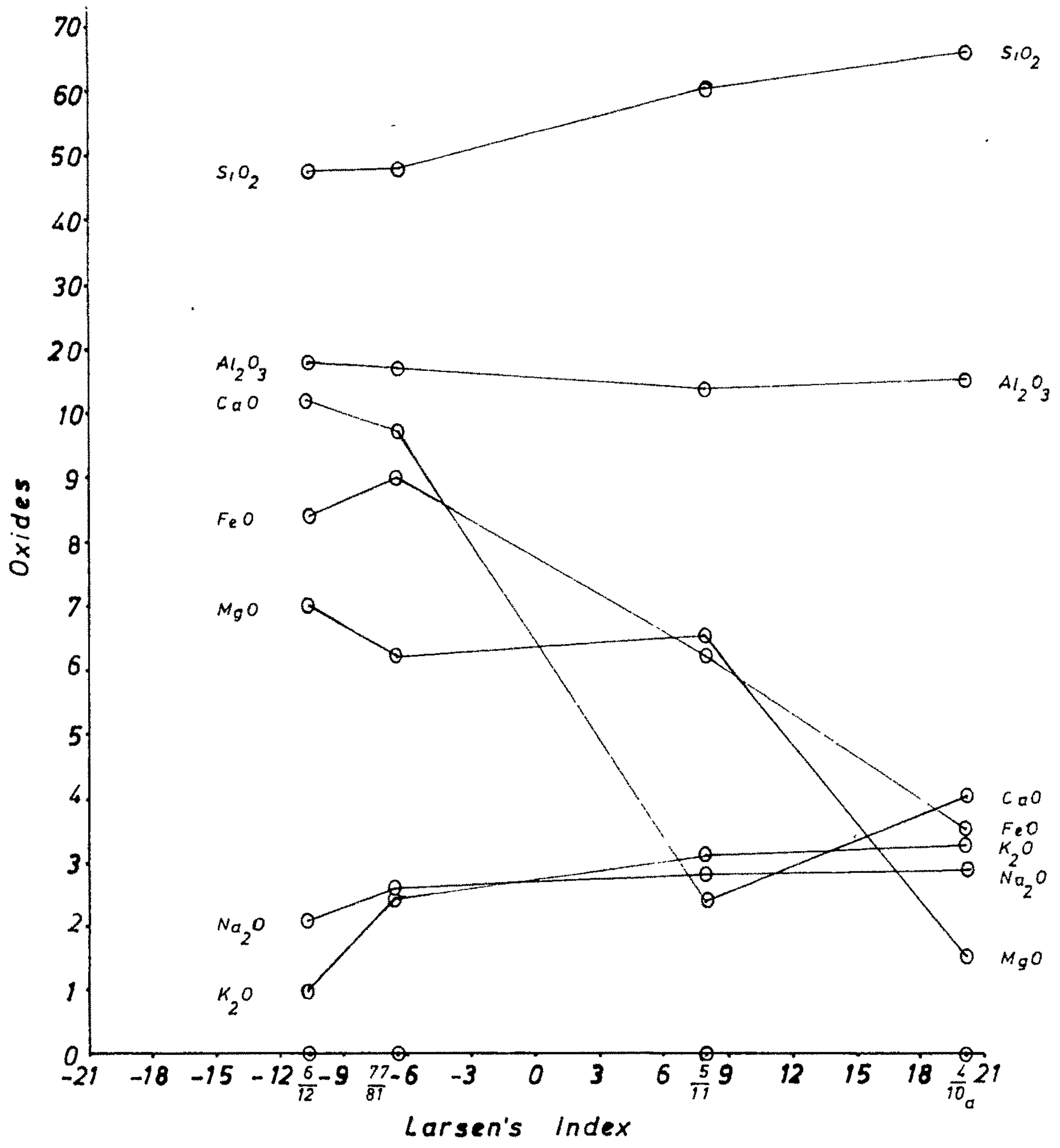
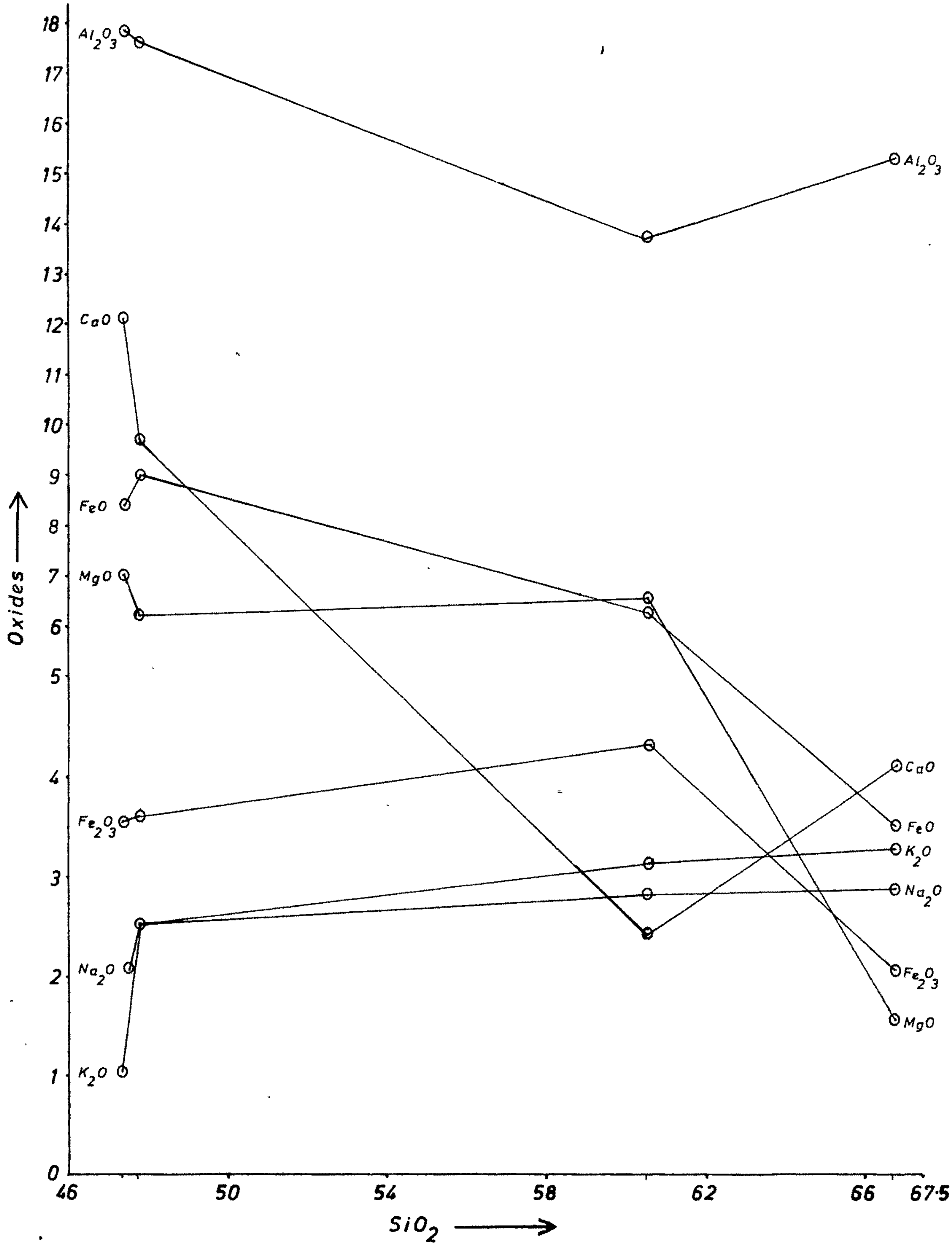


Fig. — V. 2

Harker's variation diagram : Kawa type hybrid



by a substantial enrichment in silica and alkalies with simultaneous overall decrease of Al_2O_3, CaO, Mgo and iron oxides. Other diagrams viz. Simonen diagram (Fig.V.4), Q-L-M diagram (Fig-V.5) and Mehnert's alkali migration diagram (Fig.-V.6) also clearly indicate that the hybrid variety formed due to assimilation of mafic rocks by later intrusive granite and their plots on various diagrams lie in the intermediate field - between acidic and mafic fields.

Chemistry of andesite shows a clear genetic relationship with the main gabbro and dolerite of Kawa. Its chemical composition tallies fairly well with a typical andesite as it can be seen from the Table-V.4.

The rock appears to be a differentiate from the same parent mafic magma, which gave rise to the olivine bearing gabbro and dolerites. As these veins show sharp contacts with main coarser mass and also contain frequent fragments of the latter, it is obvious that the differentiation did not take place 'in situ'. The separation took place at deeper levels and first the olivine dolerite crystallised and later on, the less mafic differentiate intruded them as veins. The genetic relationship between the dolerite and andesite is ideally seen in the diagrams (Figs.V.7,8) based on Nockolds and Allen (1953), and

TABLE-V.3

CHEMICAL ANALYSES OF MAFIC ROCK, EPIDIORITE AND SATHARVA TYPE HYBRID ROCKS

Wt. %	Epidiorite	Satharva Type Hybrid Rocks					Mafic rock (Kawa): Middlemiss
	213/150	598	593	582	581	571	25/464
SiO_2	47.29	57.41	56.64	64.09	62.90	63.70	50.23
TiO_2	00.95	00.80	00.75	00.68	00.64	00.62	01.41
Al_2O_3	17.74	17.84	16.89	15.31	15.28	14.79	16.51
Fe_2O_3	03.81	02.40	02.46	03.16	02.36	02.00	03.83
FeO	07.82	07.16	05.96	04.54	03.97	03.76	08.26
MgO	06.54	01.10	03.98	02.51	01.95	02.02	05.48
MnO	00.80	00.14	00.13	00.11	00.10	00.09	00.14
CaO	09.32	06.10	05.98	05.40	05.54	04.26	09.53
Na_2O	03.41	03.45	03.56	03.72	04.30	03.98	02.07
K_2O	01.71	03.36	03.30	03.29	04.30	04.90	01.04
P_2O_5	00.85	00.30	00.31	00.18	00.21	00.20	00.31
Total	99.99	99.97	99.96	99.99	101.55	100.32	

Q	-	05.69	01.18	12.75	05.08	10.02	01.42
L	-	78.64	76.80	74.08	85.28	78.16	77.92
M	-	15.63	21.90	13.17	09.63	11.65	30.11
si	-	180.00	162.20	210.20	210.00	229.60	124.00
al	-	33.00	29.00	29.50	30.20	31.30	24.00
fm	-	29.90	37.30	32.86	27.30	28.30	44.44
c	-	20.98	18.30	19.00	19.62	15.10	25.19
alk	-	17.00	16.00	18.30	23.00	25.28	06.37

Analyst: Paresh Raval

Fig.— V.3

Variation diagram: Satharva type hybrid

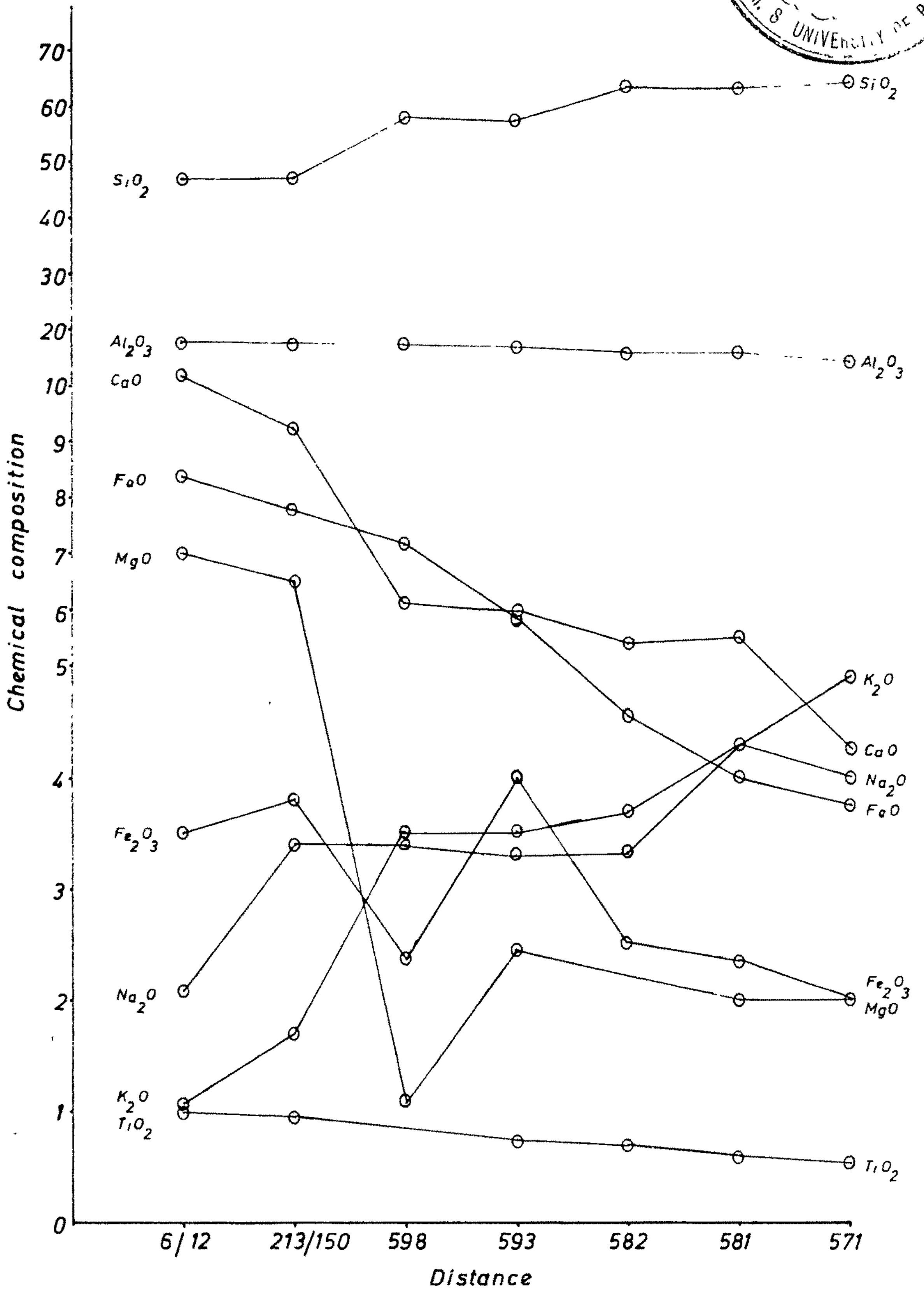


Fig: V. 4

Simonen diagram for plutonic rocks.

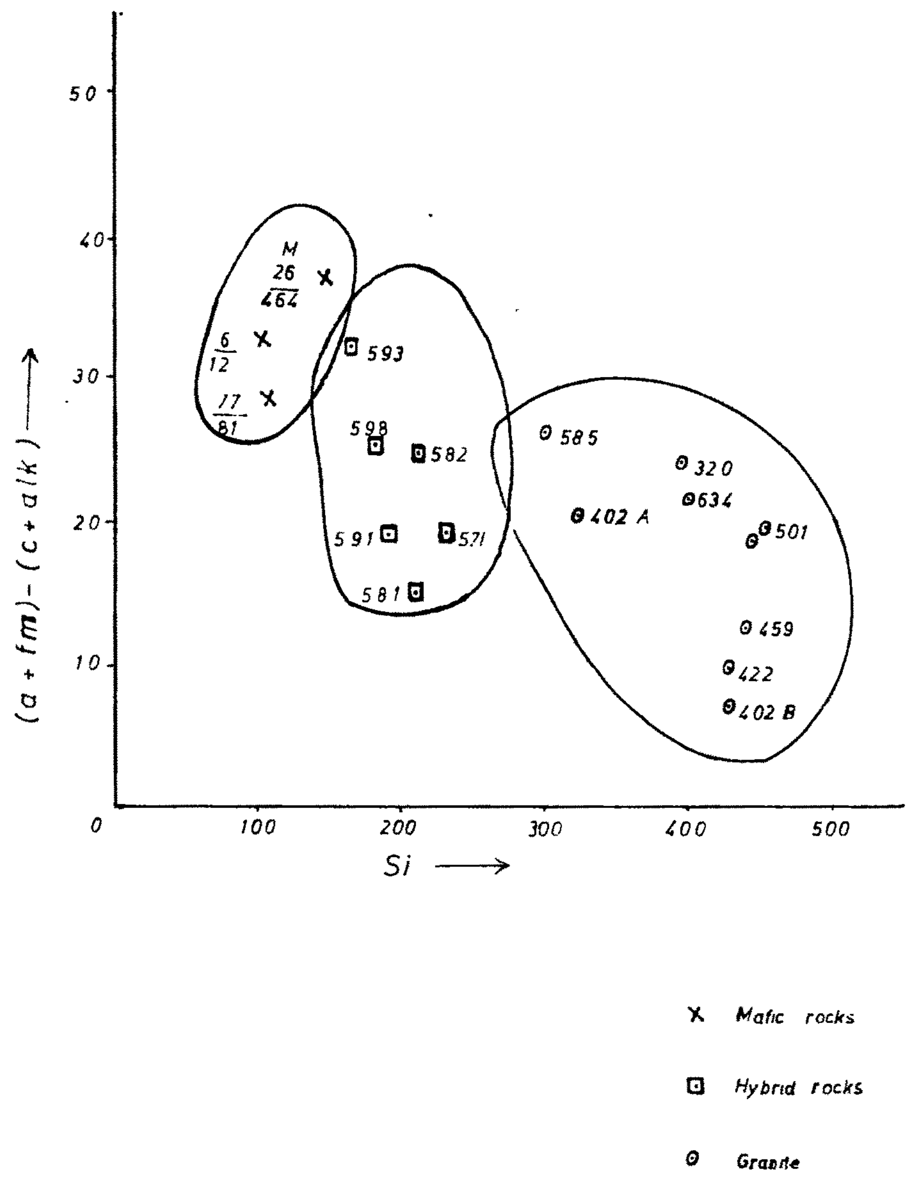
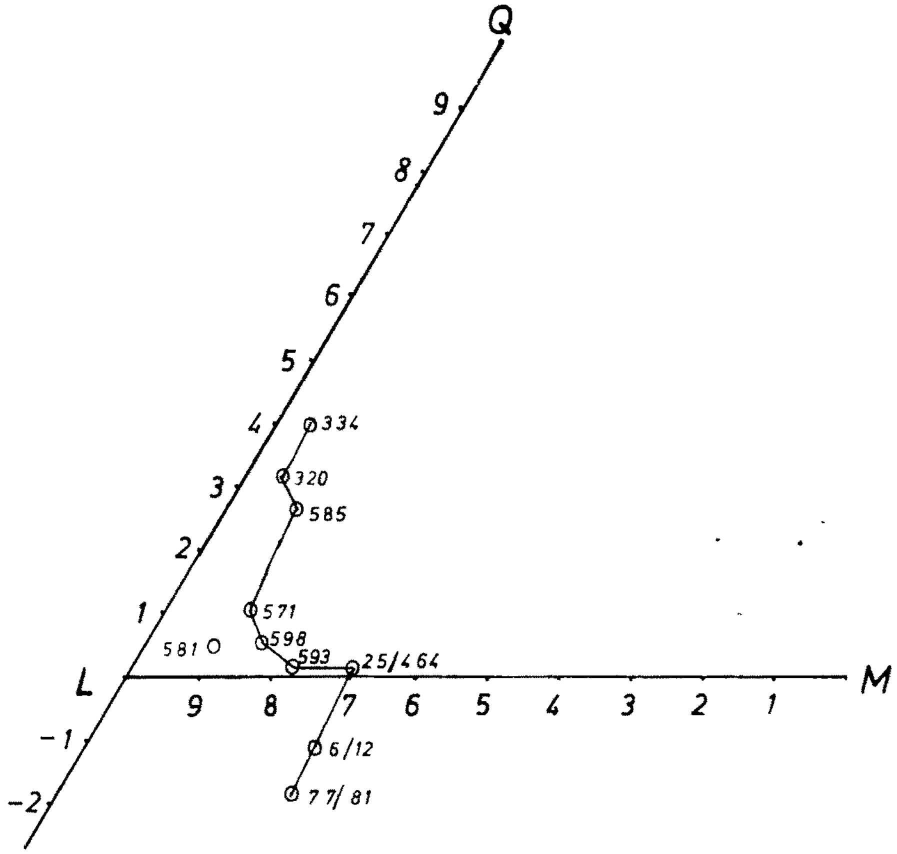


Fig.—V.5



Von Wolff's Q-L-M diagram for mafic, hybrid and granitic rocks

Fig.- V. 6

Mehnert's alkali migration diagram.

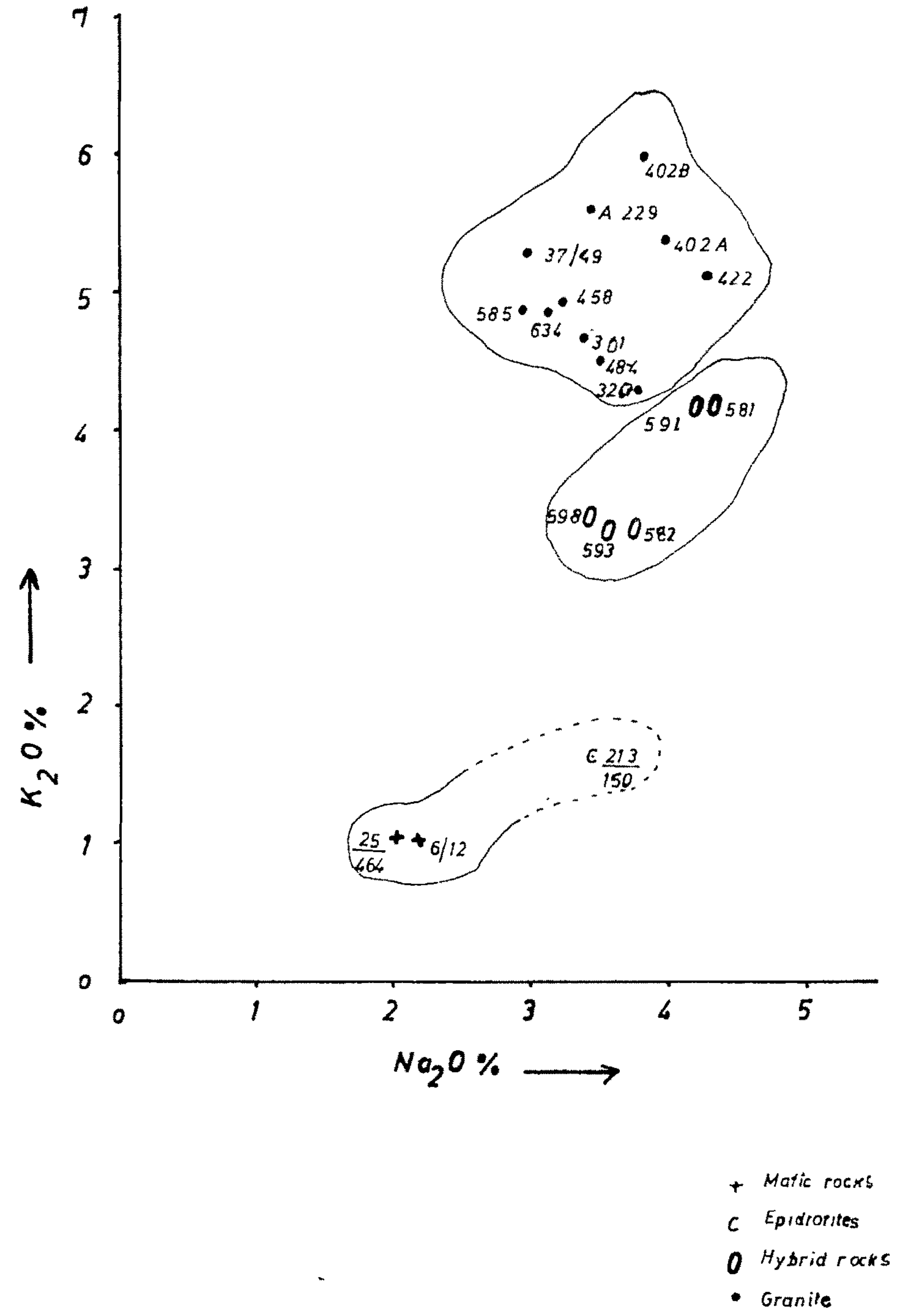


TABLE-V.4

CHEMICAL ANALYSES OF ANDESITIC ROCKS

Wt. %	69/75 (KAWA)	Average Andesite (Source: S.R.Nockolds)
SiO_2	54.50	54.20
TiO_2	01.03	01.31
Al_2O_3	15.93	17.17
Fe_2O_3	03.20	03.48
FeO	06.20	05.49
MgO	04.98	04.36
MnO	00.12	00.15
CaO	06.92	07.92
Na_2O	03.88	03.67
K_2O	02.90	01.11
P_2O_5	00.24	00.28
H_2O	-	00.86
TOTAL	99.90	99.98
si	145.20	-
al	25.03	-
fm	40.44	-
c	19.74	-
alk	14.77	-

Analyst: Paresh Raval (S.R.NOCKOLDS)

Fig. — V.7

Murata's diagram showing differentiation

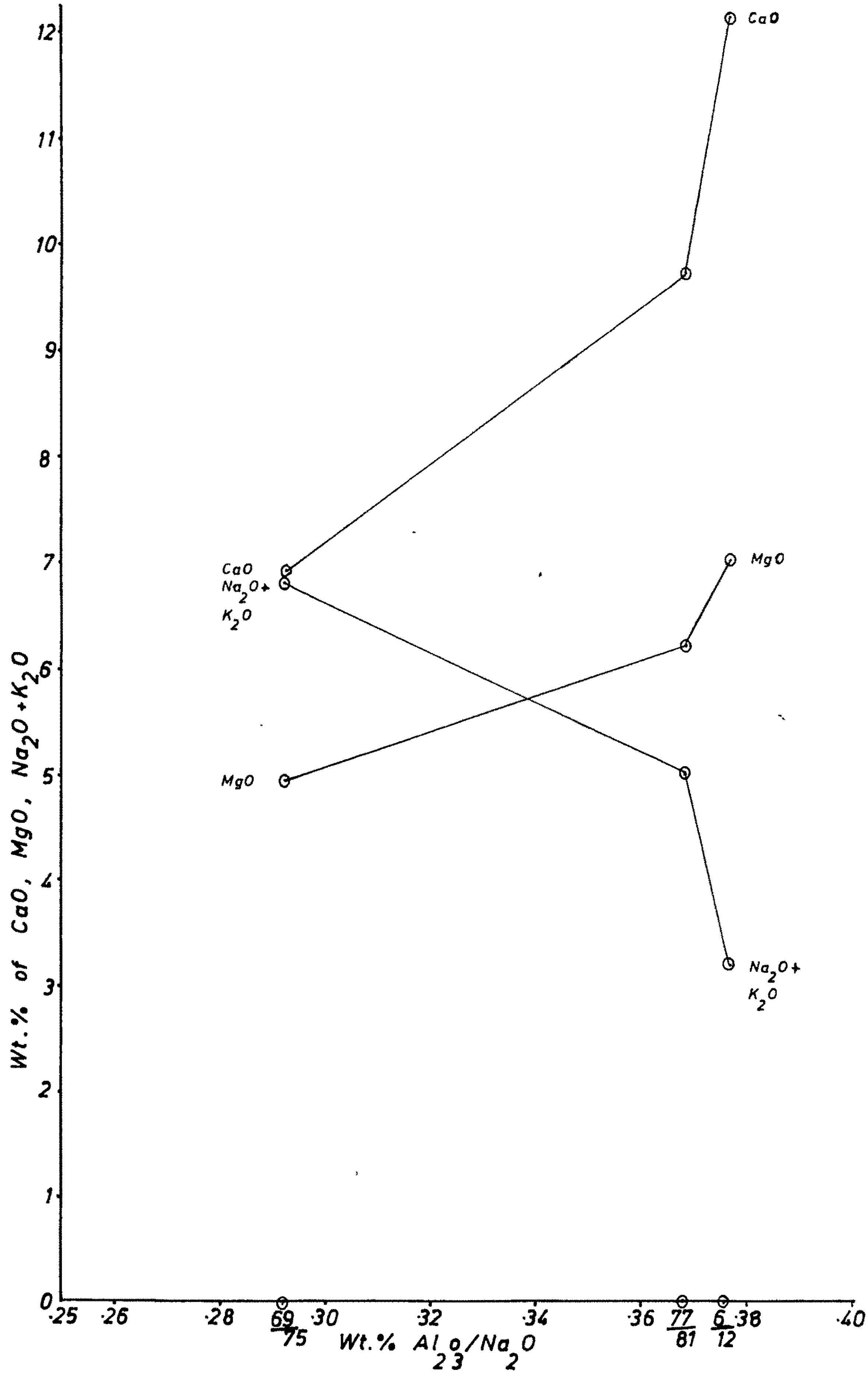
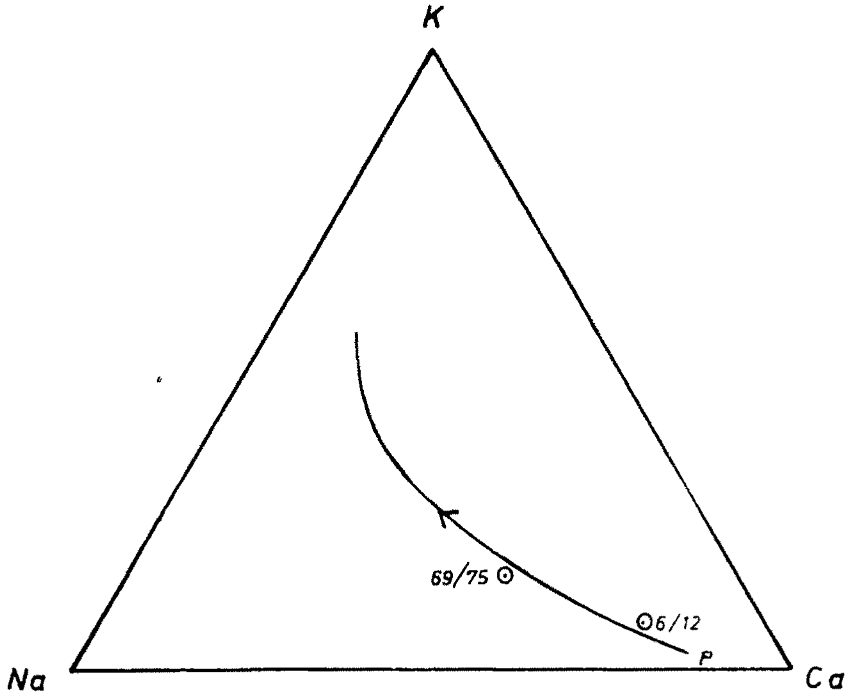


Fig.— V. 8

Nockold and Allen's diagram showing trend of differentiation



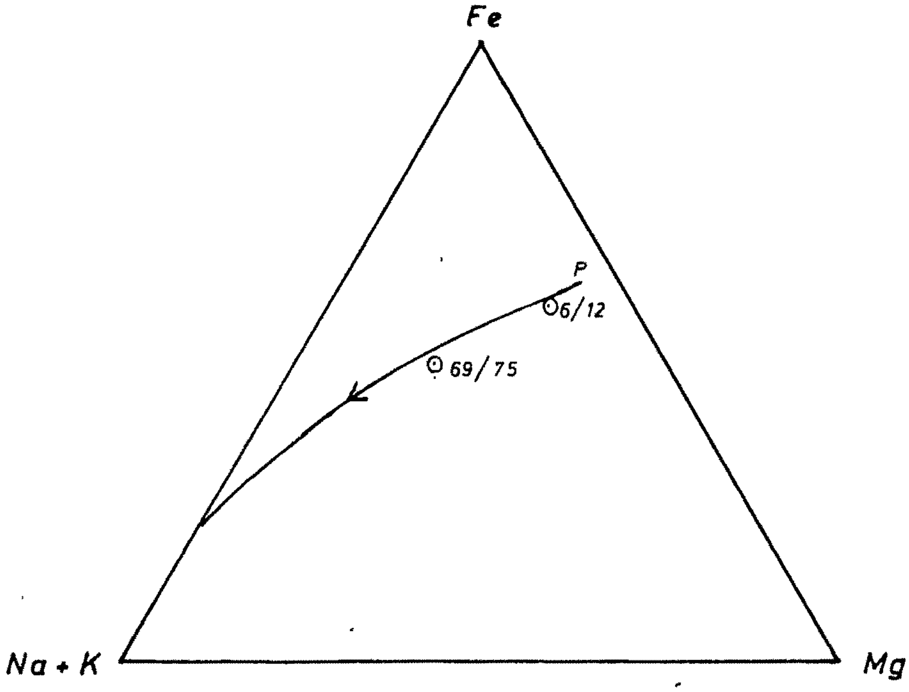
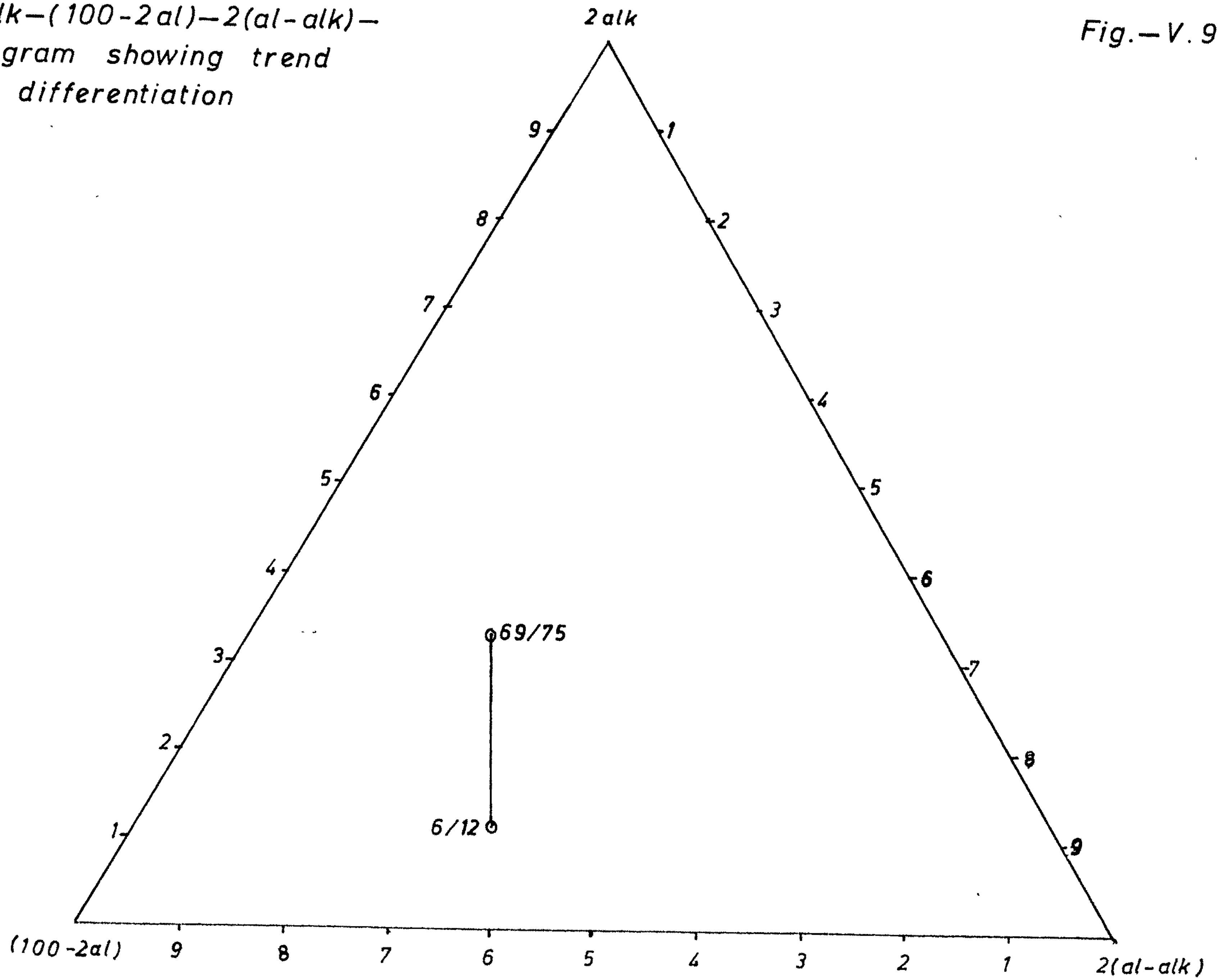


Fig.—V.9

2alk–(100-2al)–2(al-alk)– diagram showing trend of differentiation



Murata (1960). The 2alk, 2(al-alk) and (100-2al) variation diagram (Fig.-V.9) has been constructed from the Niggli values. These diagrams suggest the trend of differentiation, and from which it is evident that the mafic magma that gave dolerites and gabbros, with decrease in Fe, Mg and Ca and with the enrichment of silica and alkalies, produced the andesitic differentiate.

AGE AND CORRELATION

The mafic rock bodies of the study area have been assigned a post-Delhi age by the author. They are more like sills than dykes and taking into account their texture and mineralogy, most of the sills have not been affected by the Delhi folding. It is thus obvious that the mafic magmas were intruded only after the deformational stresses had almost ceased to be effective. Similar rocks from Ambaji (Heron and Ghose, 1938) and Sirohi (Coulson 1933) have been found to be quite often involved in the folding. Accordingly, the entire group of mafic rocks has been considered by various workers as Delhi and post-Delhi in age. Almost all over S.W. Rajasthan and N. Gujarat rock bodies belonging to this mafic igneous activity have been registered in the form of epidiorites, amphibolites and hornblende schists. The obliteration of the original igneous texture depends on the fact whether a sill was involved in deformation or not. The mineralogical changes were caused both by deformation and granite.

In the present area mafic rocks involved in the deformation are almost non-existent except for a few occurrences which show some foliation. Mineralogical changes brought about by the contact metasomatism and also by the assimilation of basic rocks by the invading granite, are the only important clues to the dating of these rocks. Considering the above two facts the author has been able to pin-point the exact age of these mafic rocks as post-Delhi but pre-Erinpura granite.

It is worth mentioning in this connection that Middlemiss (1921) considered the Kawa and Reda occurrences as dyke intrusive into the granites. But he was mistaken. There are ample field evidences to show that the granites of the area are intruding the gabbro and dolerites and are younger. It is quite likely that similar occurrences of the gabbros and dolerites elsewhere in the neighbouring areas of Sirohi, Palanpur and Danta also belong to this pre-Erinpura-granite basic phase. Observations of the author in the present area as well as his brief visits to similar occurrences elsewhere in the neighbourhood has led him to believe that in all probability, epidiorites, olivine bearing gabbros and dolerites all belong to the same mafic igneous phase intruded prior to the Erinpura granites, and show only varying effects of this granite on them. The author found that the famous gabbro masses of Chandravati and Kui (near Abu Road Station), classified by Coulson (1933 p. 79) as post-Erinpura granite, contain abundant veins and patches of granites intruding them and causing a lot of contamination and intermixing. Of course, it is not the intention of the author to suggest that all the olivine bearing dolerites of that region are pre-Erinpura granite. It is quite possible that some of them might be younger than the granite, but this is also equally true that quite a few such bodies considered at present as of post-Erinpura granite age, are in fact older than the granites and belong to the group of Delhi and post-Delhi (but pre-Erinpura-granite) mafic igneous phase.

As regards the andesitic veins on the Kawa hill, these too are older than the granites which is seen cutting it. It has already been stated earlier that the andesitic veins and gabbros and dolerites of Kawa are the products of a common mafic magma differentiated and intruded in succession, but both preceding the granites.