CHAPTER VII

M E T A M O R P H I S M

The metamorphic aspects of the area are varied, the rocks having preserved within them an interesting sequence of metamorphic changes. The various rock types have furnished considerable data to enable the author to work out the complete metamorphic history of the area. His investigations have revealed three successive episodes of metamorphism and metasomatism.

(1) Regional metamorphism that synchronised with the Champaner folding.

(2) Contact metamorphism of the regionally metamorphosed rocks, by the granite intrusion.

(3) Migmatisation in the vicinity of the intruding granite mass.

Thus, the Champaner rocks all along the contact zone with granites, show an interesting superimposition of contact metamorphism and contact migmatisation, on the regionally metamorphosed rocks. This superimposition is ideally recorded in the structure, texture and mineralogy of the various rock types.

REGIONAL METAMORPHISM

The effects of regional metamorphism, essentially related with the main Champaner orogeny, are well preserved in the rocks away from the granite. It is obvious that this metamorphism was synchronous with the deformation which folded the Champaner sediments. The main metamorphic foliation of the rocks, is an axial plane cleavage related to this folding and this clearly shows that the metamorphism and deformation were closely connected and proceeded almost hand in hand.

As will be seen from the following account, this metamorphism was of fairly low grade. The foliation that developed is mostly a slaty or phyllitic cleavage such that original sedimentary structures like lamination in shales and ripple marks, current bedding etc. in quartzites are hardly obliterated. The slates and phyllites occasionally show bands of chlorite schists, and it is quite evident in the field itself that these represent zones of more intense shearing. On the other hand, almost all along in the contact aureole of the granite, the recrystallization has transformed the slates and phyllites into coarser rocks with a schistose foliation.

Mineral Assemblages

The regional metamorphism has given rise to a number of mineral assemblages depending on the different parent rock types. The following table summarises these assemblages.

Type of Sediment 1	Metamorphic Equivalent 2	Mineral assemblages 3
Pelitic:		
(i)	Slates and Argillites	Quartz, chlorite, muscovite, stipnomelane (calcite)
	Phyllites	Quartz,chlorite,muscovite, biotite
(ii)	Chlorite Schists	Chlorite, biotite, quartz
	Mica,Chlorite Schists	Quartz, muscovite, biotite, chlorite.

1	2	3
<u>Psammitic</u>:		
(a) Pure	Quartzite	Quartz
(b) Impure	Quartzite	Mostly quartz with chlorite, sericite, iron ores, epidote etc.
<u>Calcareous</u>:		
(a) Pure lime-stone	Marble	Calcite
(b) Siliceous Limestone	Marble	Calcite, Quartz
(c) Argillaceous & siliceous limestones	Calc-Schists	Calcite, quartz, chlorite, tremolite, epidote, mica etc.
(d) Siliceous dolomites	Dolomites	Dolomite, quartz.
(e) Impure dolomites	Dolomites	Dolomite, talc, quartz, tremolite-actinolite.
<u>Graywackes</u>:		
Including Proto-quartzites	Metagraywackes	Quartz, chlorite, sericite, calcite.

From the above mentioned table, it is clear that the various assemblages point to a low grade metamorphism of chlorite grade. In general, the rocks especially the argillaceous, calcareous and dolomitic varieties, point to metamorphic changes governed by low temperature and moderate pressure conditions. Shearing stress was also perhaps quite effective.

The textures, structures and mineralogy of these regionally metamorphosed rocks are on the whole uninteresting. However, a few interesting mineralogical associations have been discussed in detail in the following lines.

The pelites have mostly given rise to slates with incipient crystallisation and development of a slaty cleavage. With somewhat higher grade of metamorphism, the detrital quartz has recrystallized and has formed small lenticles or streaks. The mica and chlorite have also undergone regeneration appearing as somewhat coarser flakes. The schistosity has become more pronounced and the rock has tended to be phyllite or chlorite sericite schist, with chlorite, sericite and quartz as important constituents.

Chlorite-Schists associated with Upper Gandhra Slates

An interesting feature of these rocks is the presence of highly chloritic bands in them. Perhaps, such chlorite rich rocks suggest a local compositional difference in parent sediments. According to Harker (1960, p.215-216) argillaceous sediment devoid of potash, give rise to highly chloritic rocks, Turner (1968, p.280) also attributes the presence of chlorite at the expense of chloritoid and stilpnomelane to the high ratios of Mg/Fe.

It is evident that the regional metamorphism in the Champaner rocks, is generally of chlorite-zone and the mineral assemblages belong to the Green Schist Facies as recorded by Fyfe and Turner (in Fyfe, Turner and Verhoogen, 1958). Turner and Verhoogen (1962), have estimated temperatures of low grade regional metamorphism between 300° to 500° C. and pressure PH_2O = 3000 to 8000 bars.

Presence of stilpnomelane in Gandhra and Jaban Slates

Stilpnomelane has developed in such pelitic rocks which show a very early stage of regional metamorphism and a very poorly developed foliation. Its appearance with sericite and quartz, and a little chlorite typically indicates lowest - temperature sub-facies in the Barrovian facies series (Winkler, 1967, p.97). The stilpnomelane bearing assemblages, therefore belong to Quartz-Albite-Muscovite-Chlorite Subfacies of Green-Schist Facies. Stilpnomelane indicates high Fe/Mg ratio which did not favour the early appearance of chlorite (Turner,1968,p.280). The presence of this mineral and the absence of chloritoid, not only suggests high Fe/Mg ratio but also leads to the conclusion of that the sediments were relatively poor in Al such that no Al was left after the formation of muscovite, to combine with Fe^{2+} to give rise to chloritoid (Winkler, 1967, p.95).

Talc-dolomite Assemblage of Gandhra Pelitic Group

The mineral assemblage derived from the siliceous dolomites, indicate an early stage of metamorphism, and comprise not only the usual tremolite bearing assemblage, but also rocks containing talc-dolomite. Both these assemblages appear to have formed almost at the same time, From the associated pelitic rocks of slate grade, it can be surmised that these two assemblages belong to the Green-Schist Facies.

Tilley (1951) has reported the occurrence of talc as the first silicate phase in his sequence of steps with successive appearance of talc, tremolite, forsterite, diopside, periclase and wollastonite. Turner (1968,p.147) writes that both tremolite and talc could appear simultaneously in the presence of water as a constituent of the gas phase, the reaction involved being as under:

(1) 5 Dolomite + 8 quartz + 1 $H_2O \rightleftharpoons$ Tremolite + 3 Calcite + 7 H_2O

(2) 3 Dolomite + 4 Quartz + $H_2O \rightleftharpoons$

Talc + 3 Calcite + 3 CO_2

According to Turner (1968,p.147), eventually talc, if initially the stable phase, must give way with increasing metamorphism to tremolite, as under:

(3) 2 Talc + 3 Calcite $\rightleftharpoons$

Tremolite + Dolomite + H_2O + CO_2

Thus according to him the assemblage so formed will include tremolite, calcite and dolomite. But in the present case calcite is significantly absent and since both these assemblages occur side by side, somewhat different mode of origin is suggested for the existing assemblages. Winkler (1967, pp.26-27) has shown that such calcite-free assemblages can develop from magnesite - bearing siliceous dolomites, where magnesite and quartz react to form talc according to the following equation:

(4) 3 Magnesite + 4 Quartz + 1 $H_2O \rightleftharpoons$ 1 Talc + 3 CO_2

If the amount of magnesite present in the original rocks is small then only a small amount of talc will be produced by reaction (4). This talc is utilised to produce tremolite as per following reaction:

(5) 2 Dolomite + 1 talc + quartz $\rightleftharpoons$ 1 tremolite + 4 CO_2

According to Winkler (1967, p.26) both the above reactions (4) and (5) proceed at approximately the same temperatures. Thus besides newly formed tremolite, some dolomite and quartz are left over. The above reactions clearly explain the absence of calcite in the tremolite-dolomite-quartz assemblage of Gandhra-Dolomites. The occasional occurrence of a quartz and tremolite free talc-dolomite assemblage suggests that the quartz must have been used up in forming talc from magnesite.

Calc-schists of Undhania

In Undhania exposures, the originally lime-mud segregations in graywackes containing mostly siliceous and argillaceous impurities, after metamorphism have yielded an interesting assemblage of minerals like calcite, quartz, actinolite, chlorite, epidote, muscovite. Harker (1960, p.253) has shown that in low grade of metamorphism of a non-dolomitic limestone, quartz recrystallizes side by side with calcite without any mutual reaction. But if this limestone originally contained some admixture of argillaceous material, the resultant assemblage would contain muscovite and chlorite in addition to calcite and quartz. Such a combination of quartz, chlorite, muscovite with calcite at this grade (chlorite zone) has been reported also by Zen (1960), Turner (1968,p.279,284) and Moorhouse (1964, p.440). Zen has indicated that epidote can also occur along with the above assemblage. According to Winkler (1967, p.100) although calcite alone does not react directly with quartz at this stage or at a somewhat higher temperatures, it enters into the following reaction with quartz in presence of chlorite to give rise to actinolite and epidote.

(6). 3 Chlorite + 10 Calcite + 21 Quartz $\rightleftharpoons$ 3 actinolite + 2 epidote + 8 H_2O + 10 CO_2.

CONTACT METAMORPHISM

The effects of the superimposition of contact metamorphism on the regionally metamorphosed rocks, are seen as progressive recrystallization of slates and phyllites to schists and hornfelses. In the immediate vicinity of the intrusive mass, the schists and hornfelses have been granitised. It is possible to define the contact aureole by delineating a succession of zones of phyllites, mica-schists, hornfelses and gneisses, a feature which is commonly recorded by several workers (Raguin, 1965; Read, 1957).

The hornfelses themselves show the following three progressive zones of contact metamorphism from outer to the inner side of the granite aureole:

A. An outer transition zone of spotted phyllites. In this zone the rocks have retained their original nature of low grade regional metamorphism. The only contact effect shown by these rocks is a slightly coarser grain of biotite and sporadic development of andalusite porphyroblasts. The mineral assemblages, Quartz-muscovite-chlorite-(biotite), and Quartz-muscovite-andalusite-biotite-chlorite, point to Albite-Epidote-Hornfels Facies (Fyfe, Turner, and Verhoogen, 1950, pp. 203-205; Turner, 1968, p.190-193).

B. An intermediate zone of andalusite bearing somewhat hornfelsic rocks in which the typical mineral assemblage is quartz-andalusite-biotite-muscovite. It is in this zone that the country rocks have changed over considerably from their original green schist facies nature and tend to be hornfelsic. Andalusite is found almost throughout, and at a few places, it becomes indeed plentiful.

C. An inner zone of cordierite in which the mineral assemblages are: quartz-muscovite-biotite-cordierite and biotite-cordierite-andalusite-quartz.

This zone shows a high grade of contact metamorphism. Cordierite becomes an important constituent nearer the granite contact, whereas andalusite becomes scarce, except in the second assemblage (Sample No. 408) where it figures as well developed porphyroblasts. This presence of andalusite in cordierite rich hornfelses has been discussed later. But, taking into account the various mineral assemblages - both andalusite and cordierite rich, it is seen that their AKF plots (Plate XXXV) indicate Hornblende Hornfels Facies of Turner (1968). It is further noted that the various plots lie almost along the Andalusite-biotite line in the stability fields 2 and 3 respectively. This suggests that the assemblages comprise stable phases. As expected, the plots of andalusite bearing rock lie in the triangle 2, while those free from andalusite lie in the triangle 3. The presence of biotite and coexistence of andalusite and cordierite, is reflected in the position of the plots which lie in the triangle 4 (Turner, 1968).

According to Truner and Verhoogen (1962,p.510) the mineral assemblages of Albite-Epidote-Hornfels facies are similar to the Green-Schist Facies (of regional metamorphism) as on account of the low temperature of metamorphism, the recrystallization tends to be imperfect.

Regarding the temperature pressure conditions of Hornlende-Hornfels Facies, Turner and Verhoogen (1962,p.520) have suggested a temperature range of 550° to 700°C in the pressure range P_{H_2O} = 1000-3000 bars; at water pressures around 500 bars temperatures would be perhaps 50°C lower.

CONTACT MIGMATISATION

Metasomatism always forms an important process in the contact metamorphism in most of the aureoles along the granite contacts and in the present area also this phenomenon is recognised ideally in the pelitic rocks around Intvada. The investigations have revealed a gradual transformation of phyllites or sericite schists to coarse feldspathic gneisses - the whole phenomenon being known as contact migmatisation. Read and Watson (1963,p.567) have shown that migmatisation also occurs on a local scale in the contact aureoles of certain granites, and according to them (1963, p.523) the rocks formed on account of transfer of alkalies from the granite leading to felds-pathisation or the growth of metasomatic feldspar in the country rocks, could be termed as contact migmatites.

As against the migmatisation and granitisation in terrains of regional metamorphism, where there is a gradual transformation of slates or phyllites to gneisses and granites, the migmatites in the contact aureole, quite often, are separated from the country rocks, by hornfelses or schists containing an inner zone of cordierite, sillimanite and an outer zone of andalusite (Roques, 1941; Read, 1957; Turner and Verhoogen, 1962; Reader and Watson, 1963; Mehnert, 1968; Raguin, 1965). Identical phenomenon is recorded in the present area and the slates and phyllites show a gradual transformation to coarse gneisses. An interesting consequence of a migmatisation in the area is the presence of a highly biotitic fringe along the granite contact. This rock typically characterises a 'basic front' along the margin of the granitisation (Raguin, 1965,p.101).

Interesting features of migmatisation

The author has collected data on the migmatitic gneisses of the area. In the following lines, he has summarised the various features that characterise this phenomenon:

(1) Field characters

(i) Nature of the contact: The contact of the gneisses with the country rocks is rather gradational. While at most places a regular and smooth transition of pelites to gneisses through an intervening zone of hornfelses is recorded, in a portion of the contact the hornfelsic rocks are missing and the gneisses are seen merging outward into coarse mica-schists (S of Poyelli and N of Intvada). But in both the cases thermal effects are indicated by a progressive coarsening of the grain-size. A gradational contact with the schists and hornfelses with gradual increase of feldspar content, towards gneisses, ideally illustrated the progressive alkali metasomatism due to granite.

(ii) Basic front: At several places along the margin of granite and gneisses (migmatites), a thin zone of biotite rich rock is seen to have developed. Some such biotite fringes (viz. S of Kevra) contain in addition numerous porphyroblasts of cordierite and andalusite. This biotite rich rock, typically represents a 'basic front', demonstrating fixation of Fe-Mg expelled from granitised rocks.

The concept of 'basic front' was developed by Reynolds (1947,p.212-13) who found that "the aureole of Fe and Mg enrichment is a basic front, to be explained by the fixation of material that migrated from a central locus, now occupied by granite, at the time, the granite was emplaced". According to Read (1957, p.184,352) "the influx of Na, Ca, Si, into a locus of granitisation results in a complementary expulsion of Al, Fe, Mg, Ca into the surrounding rocks where it builds up a zone enriched in these materials and giving biotite-rich hornfelses and even basic and ultra-basic bodies - the Basic Front". He has further indicated (p.352) that the examples of basic fronts as demonstrating granitisation occur "mostly in regions of non-metamorphic or lowly metamorphosed country rock; and the granites themselves are what I should class as plutons, the high level and late members of my Granite Series".

Occurrences rich in biotite and cordierite flanking the granite bodies, have been observed by many workers and Ragvin (1965, p.101) has described this phenomenon as the most characteristic aspect of the contact aureoles. He writes "The appearance of biotite, is at first sparse and microscopic at the debut of the aureole some distance from the granite, then its growth into bigger flakes and then clusters near to the granite, is the most characteristic aspect of the aureoles. With the development of cordierite, sometimes in great abundance, one can see in these two minerals the mark of the basic front".

Wegmann (1935) has explained the association of cordierite with these basic fronts. According to him magnesium migrates ahead of the migmatite front giving rise to cordierite in abundance; and that this magnesium is not provided by the magma, but by the rock masses already overwhelmed by the migmatisation.

The basic fronts thus clearly show that "in advance of the encroaching granitic 'front' go waves of iron, magnesia, and other unwanted constituents expelled from the country rock itself as its composition is made over that of granite" (Turner and Verhoogen, 1962, pp.365-366).

(iii) Presence of hornfelses: Another feature of contact migmatisation is the presence of thermal aureole around migmatitic borders of granite. Wegmann (1935) has also shown that the formation of silicates of Al, Mg, Fe in the outer aureole is connected to the process of contact granitisation. He has written that "Around the filtering columns' to use an expression of Pierre Termier, an envelope forms with several varieties of enrichments.
In the interior the rocks have a tendency to become potassium feldspar and quartz bearing; they thus effectively immobilize potassium with silica. In the outer parts they stabilize

above all magnesium. The formation of andalusite, cordierite, sillimanite, garnet, etc. is connected with the granitisation."

In the granitic aureole, the processes of the formation of hornfels (including rocks of basic fronts) and of granitisation are connected and inter-related, the latter representing an alkaline front in migmatites (Wegmann, 1931; Raguin, 1965). Turner and Verhoogen (1962, p.362) have observed that "reaction zones on the whole are not so sharply defined at contacts between granitic rocks and sedimentary rocks of the sandstone-shale family. The main constituents of sandstone-quartz, sodic plagioclase, potash feldspar, and mica would already be in equilibrium with most granite magmas. Assimilative reaction consequently would not be expected to occur at sandstone granite contacts. The clay minerals of shales on the other hand are sensitive to temperature changes, so that shales are normally converted by thermal metamorphism to pelitic hornfels (quartz, feldspars, biotite, andalusite, cordierite) for some distance from contacts with large bodies of granite. However, judging from the instability of andalusite and cordierite in the presence of excess potash at all but the highest metamorphic temperatures (cf. Fig. 74, p.519), these minerals would be expected to react with the residual melts of partially crystalline granite magmas to give micas". Therefore, effects generally observed at contacts between granite and shale or sandstone are as observed by Turner and Verhoogen (1962, p.362).

(1) Thermal metamorphism of sediments to hornfelses.
(2) Development of augen (porphyro-blasts) of alkali feldspars by metasomatic replacement of minerals within the country rock.

Because pelitic sediments were highly sensitive to temperature variation, they were converted to only thermally metamorphosed rocks, hornfelses (possibly without much addition of new material from outside) beyond the basic front (biotite-cordierite-andalusite rocks). In other words wherever, metasomatising emanations failed to reach, the rocks were affected largely by the rising temperatures alone giving rise to a zone of hornfelses.

Raguin (1965,p.89), has clearely stated that "ahead of the migmatite front, an aureole is sometimes observed of course more so where the front is pronounced which is the case when the migmatites rise to a sedimentary series little metamorphosed in itself." Mehnert (1968,p.125) has also cited an example of feldspathisation of country rocks in the inner aureole, while outer aureole consisted of spotted slates and hornfelses, around the southern contact of Rand granite in southern Black Forest.

(iv) Resisters: While the pelitic rocks around Intvada were migmatised, the extensions of the same rocks westward (S of Poyelli) show little effects of granitisation. Here the mica-chlorite-schists occur in the core of an anticlinally folded Poyelli Quartzite, the south limb of which abuts against the intrusive granite. Except at a few places where quartzite's continuity is broken due to boudinaging these siliceous rocks have resisted the emanations and have obviously acted as effective barriers not allowing feldspathic solutions to permeate through them. "Pure quartzites are chemically remote from the granites. They are made up of almost one single component, silica, and feldspathization can not take place without considerable influx of material. Highly siliceous rocks are therefore resisters which tend to retain their original characters against migmatisation" (Read and Watson, 1962, p.564).

(2) Microscopic Characters

(i) Progressive enrichment of feldspars: Thin sections of specimens collected across the strike, from phyllites to gneisses, show a progressive increase in content and size of feldspars. First the plagioclase (An_{22}) makes its appearance as small grains. Then with increase in size and amount, it forms augens and ultimately tends to be porphyroblastic. Usually, microcline first appears in the augen bearing variety in the groundmass and then shows a rapid increase. It forms big grains and is also seen replacing the plagioclase porphyroblasts.

The rocks thus amply indicate a process of migmatisation that comprised an early sodic phase followed by a late potassic phase.

(ii) Evidences of potash metasomatism: Following metasomatic changes are ideally seen.

(a) Replacement of plagioclase by microcline: The various thin sections of migmatised rocks, show very clearly a progressive replacement of plagioclase by microcline.

(b) Sericitization of oligoclase, andalusite, and cordierite: Thin sections of gneisses and hornfelses show sericitisation of plagioclase, andalusite and cordierite. This is indicative of introduction of potash during late phase of granite intrusion (William, Turner, Gilbert, 1965,p.134; Moorehouse, 1964,pp.273-274). Winchell and Winchell (1968,pp.276-277) have attributed sericitisation of plagioclase to the alkali metasomatism.

(c) <u>Formation of albite rims around oligoclase</u>: Sericitised oligoclase quite often bears clear rims upto 0.1 mm thick, when it occurs associated with microcline. These rims have been identified as albite, with refractive index slightly lower than the main plagioclase crystal. The twin lamellae uninterruptedly continues across the boundary of the two plagioclases, but they show different optical properties. Many workers have observed such rims at the junction of plagioclase (generally sericitised) and potash feldspars (Harry, 1953; Cheng, 1944; Mehnert,1968). According to Mehnert (p.201-203), albitisation (intergranular albite) mainly occurs at the boundary of plagioclase and potash feldspar, and it results in the development of albite "fringes" and "lobes", or "rims" around older plagioclase. He has also described that the fringes and lobes are often structurally parallel to the adjacent plagioclase crystals on which they have grown. According to him the formation of such rims happen in connection with a secondary transformation of plagioclase. Winchell and Winchell (1968,p.279) have observed that the alteration of feldspar is followed by regeneration of the same or more commonly, a more acid type feldspar and the new feldspar is fresh and glassy, while the old one is more or less permeated with alteration products.

Similar opinion is expressed also by Cheng (1944, p.142-143) regarding clear rims around oligolcase from the migmatites of Betty Hill, Sutherland. According to him, such rims were formed after the general sericitisation, due to hydro-thermal solutions and considered the presence of potash feldspar in the process as quite indispensable.

(3) Chemical Characters

Chemical analyses of a few selected rocks representing various stages of migmatisation (Table VI), when plotted on a number of diagrams, give an idea of the chemical changes undergone by the rocks during the migmatisation.

Variation diagrams: The trends of the percentages of SiO_2, Al_2O_3, Fe_2O_3, FeO, TiO_2, MgO, CaO, Na_2O and K_2O from feldspathic schist to granitoid gneiss and granite clearly reveal the chemical changes that were brought about by

TABLE VI

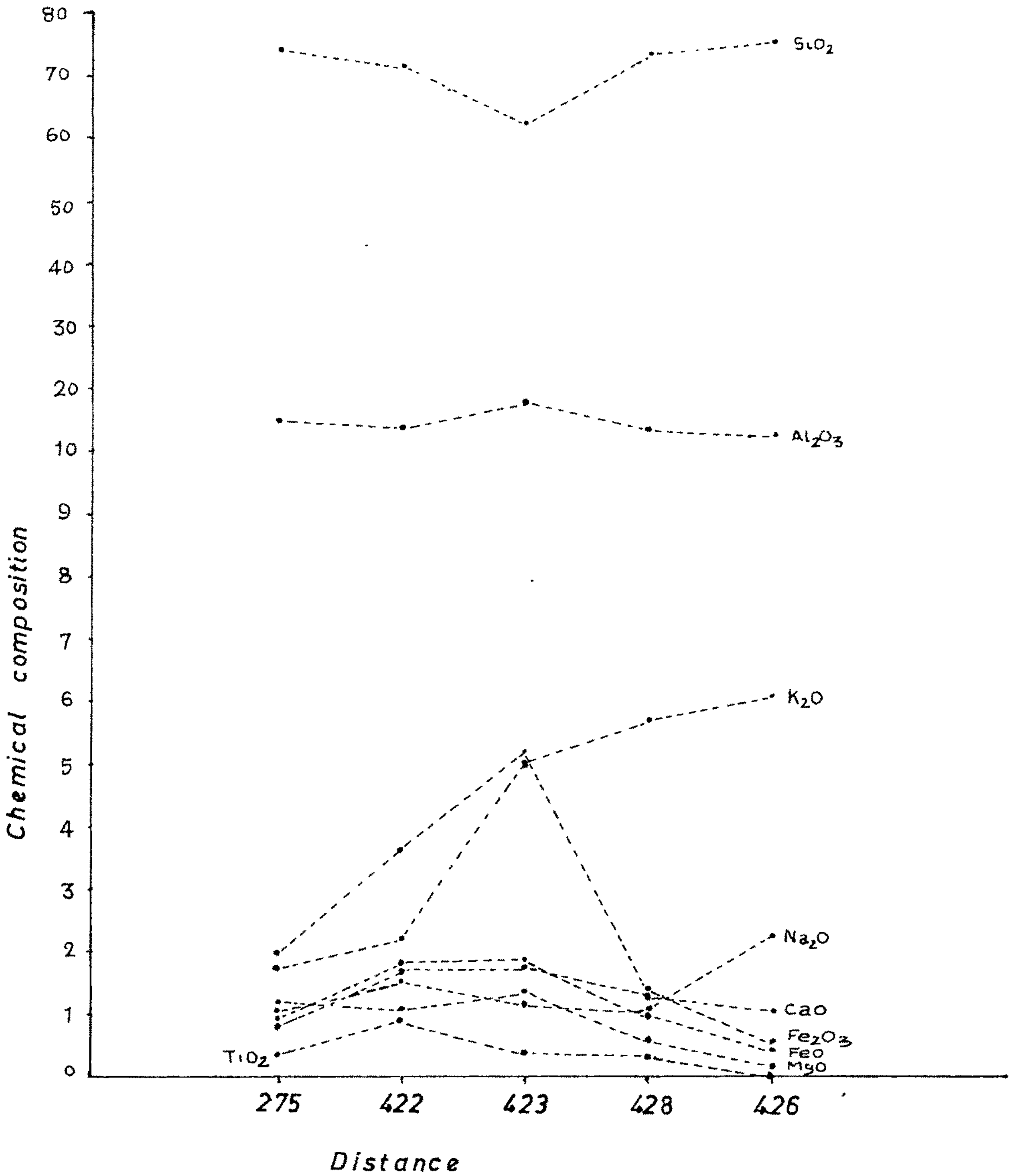
Wt.%	Feldspathic schist 275	Augen-gneiss 422	Porphyro-blastic-gneiss 423	Granitoid gneiss 428	Granite 426
SiO_2	74.65	71.79	62.60	73.73	75.32
Al_2O_3	15.39	14.03	18.31	13.81	13.30
TiO_2	0.95	0.87	0.70	0.24	0.08
Fe_2O_3	2.09	3.65	5.18	1.46	0.59
FeO	0.94	1.81	1.88	1.09	0.48
MgO	1.20	1.13	1.39	0.63	0.16
CaO	0.89	1.75	2.80	1.47	1.12
MnO	0.37	0.93	0.42	0.37	0.02
P_2O_5	0.05	0.05	0.01	0.02	0.04
K_2O	1.77	2.21	5.12	5.75	6.10
Na_2O	0.98	1.67	1.36	1.07	2.32
TOTAL	99.28	99.69	99.77	99.14	99.53

TABLE VII

	275	422	423	426
Q	64.00	55.00	34.00	40.00
L	30.00	33.00	52.00	58.00
M	6.00	12.00	14.00	2.00

Fig. 12

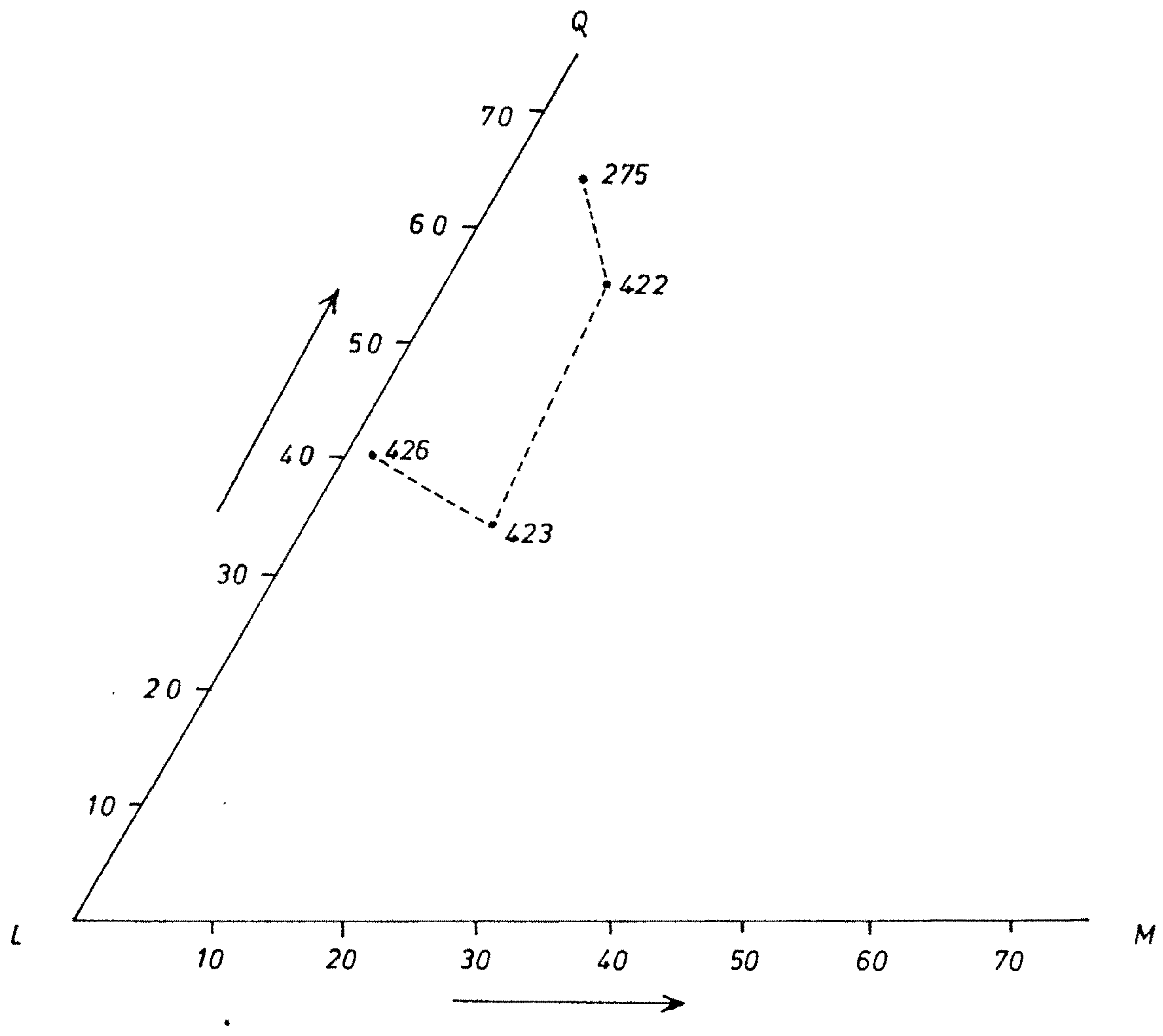
VARIATION GRAPH BASED ON DISTANCE VS. CHEMICAL COMPOSITION



migmatisation (Fig.12). It is seen that the migmatisation occurred in two stages. In the first stage, the process involved general desilication of the rocks and increase in the percentages of rest of the oxides. The peak of this stage is marked by the porphyroblastic gneiss where, CaO, MgO, FeO, Fe_2O_3, Al_2O_3 and Na_2O show the highest concentration and where silica has decreased considerably. As usual, these rocks in the field are characterised by a high biotite content. As observed in the field, beyond this point, towards intrusive granite, biotite gradually decreases in quantity and finally the gneisses merge with the granite both containing only occasionally scattered flakes of this mineral. This fact is reflected in the variation diagram in the form of an increase in silica and potash beyond porphyroblastic gneiss with accompanying decline in CaO, Fe_2O_3, FeO, MgO and TiO_2 towards granite. Al_2O_3 at first decreases but then remains almost constant. Throughout, potash shows a gradual but steady increase.

The process of contact migmatisation in two stages as delineated in the study area tallies well with the results of Reynolds (1946) who found two different processes of reaction leading to granitisation. She found that the

Fig. 13



VON WOLFF'S QLM DIAGRAM.

initial change in rocks of all types includes enrichment in mafic constituents and alkalis and only subsequently are the rocks granitised. Thus, when pelitic rocks come in contact with granite they undergo the following changes: (1) next to the original pelitic rock they become desilicated relative to the other constituents. (2) Towards the granite the previously desilicated rock is granitised, i.e. its composition approaches that of the associated granite. Silica and alkalis, especially K, are added, whilst alumina, the cafemic constituents and the minor constituents TiO_2, P_2O_5 and MnO decrease.

<u>QLM values</u>: QLM values calculated from the analyses of 4 representative migmatitic rocks (Table VII), when plotted on Von Wolff's diagram (Fig.13) reveal that with increasing migmatisation, the free quartz (Q) percentage shows steady decrease while those of leucocratic minerals increase. This indicates that during the transformation, there was only a limited external supply of silica and appreciable addition of alkalis, and thus the free quartz of the schists, for the most part, was taken up in the formation of feldspars.

SKARNS AND ASSOCIATED REACTION ROCKS

In the Jothwad hill (Goldungra) the effect of the contact metasomatism of granite on impure dolomitic limestones and associated rocks has resulted into the formation of interesting mineral assemblages, already described in earlier chapters. These rocks have been described in great detail by Sadashivaiah (1963,pp.303-313). As regards the skarns, he writes (p.310) "The rough zonal distribution of the skarn minerals is related to the falling temperature gradient probably at constant pressure. It is established by Eskola (1922) and Bowen (1940) that the metamorphism of magnesian limestone with excess of silica proceeds in a regular sequence of steps with increasing temperature, starting with tremolite, then diopside tremolite assemblages and finally, rocks containing diopside and wollastonite. But at Jothwad,tremolite-diopside assemblage is first formed, then diopside and finally, a wollastonite assemblage containing diopside. Introduction of fluorine and chlorine during metamorphism has led to the development of phlogopite and scapolite as mineral phases in all the mineral assemblages of the Jothwad area."

According to him (p.312) the "tremolite-bearing assemblages are the first to form and with rise in temperature diopside bearing types developed with the concomitent transformation of earlier tremolite into diopside. With further rise of temperature and at constant pressure, wollastonite bearing calc-silicate rocks developed. The elevated temperature remained for a considerable amount of time with the approach of the later granite giving rise to coarse grained wollastonite bearing types with wollastonite enclosing the earlier formed diopside, garnet, phlogopite and scapolite. The temperature range during the formation of the wollastonite bearing assemblages has been 500°C and 700°C (Bowen, 1940). The assemblage falls into the pyroxene hornfels facies of Eskola".

The piemontite-bearing calc-silicates, obviously were formed from such impure limestones that contained some manganese. As suggested by Sadashivaiah (Sadashivaiah and Tenginakai, 1966,p.71) alkali metasomatism of the lime-bearing rocks led to the displacement of lime resulting in lime-metasomatism which was responsible for the development of calcite and epidote. The presence of MnO in these rocks has aided the formation of piemontite from epidote as a stable mineral phase.

Sadashivaiah (1964) has put forth similar mode of origin for winchite-bearing assemblages also. According to him, these manganese minerals were produced by the metasomatic activity of the emanations from granite in the presence of impure dolomitic limestones.