CHAPTER VII

G R A N I T I S A T I O N

GENERAL CONSIDERATIONS

The granitic rocks of Almora have been considered as a product of granitisation. Almost all the previous workers, Sarkar et al. (1965) and Pande and Powar (1968) have suggested a metasomatic origin of these rocks. In fact, Pande et al. (1963) have called all the gneissic rocks of the Almora nappe as migmatites, and Vashi (1966), Desai (1968), Merh (1968) etc. have further supported the above view. Merh and Vashi (1965) have described in details the migmatitic origin of the Ranikhet gneisses. The author finds himself in full agreement with the previous workers, and he too believes that the gneisses and gneissic granites of Almora area, represent granitised schists - their mineralogical and textural variation suggesting different stages of granitisation in place and time.

The various gneissic bands of Almora area, in all probability represent early F_1 fold cores. The exact nature of the small lenses of gneisses in the central and north-eastern part is not clear, but the southernmost band i.e. Chaunsali band, which is in fact a part of the Ranikhet-Siahidevi-Mukteswar band, has been taken as a reclined fold core by Merh and Vashi (1965). The most conspicuous granitic exposures of Almora proper, viz., the Dyolidanda hill, forming a horse-shoe shape outcrop, looks like a relatively less tight reclined F_1 structure. This particular gneissic granite occurrence is most striking and somewhat different in structure, texture and mineralogy from the main Chaunsali band to its south. The author has come to the conclusion that both have identical origin, except that the two indicate granitisation at different energy levels.

Granitisation generally takes place in the same environment as that of the high grade metamorphism, and most gneisses form under conditions of amphibolite or granulite facies. The transformation could be brought about by ionic diffusion in solid state, action of metasomatic solutions, magmatic emanations from a contemporary magmatic body or by the permeation of rock with granitic migma (or magma) produced by anatexis.

In the Almora area, the transformation of schists into gneissic granites, appears to have been brought about by a process of slow permeation and progressively increasing metasomatic action of emanations rich in alkalies. The chemical data has shown that the granitisation process involved considerable enrichment in alkalies - the addition having taken place in two stages - sodic followed by potassic. The relative proportions in which the Na_2O and K_2O got fixed in the process of granitisation, not only depended on the length of time of granitisation, but also the tectonic levels at which the fixation took place. The soda rich gneisses indicate a relatively shallower depth of granitisation as compared to the potash rich gneisses and gneissic granites.

The various stages of the granitisation as shown by the textural and mineralogical changes appear to be rather different for the gneissic bands (the Chaunsali band and the other smaller ones) from those of the Dyolidanda gneissic granites. The sequences of changes were essentially controlled by the plutonic conditions.

The various bands of augen gneisses, which are relatively richer in Na_2O, indicate granitisation of rocks farther from the deep seated source of emanations. The sequence of changes leading to the porphyroblastic gneisses, could be summarised as under:-

(1) Appearance of a little plagioclase in the ground mass.

(2) Increase in the total plagioclase content; development of augens of plagioclase; appearance of microcline in the groundmass.

(3) Appearance of porphyroblasts of potash-felspar; mostly microcline showing traces of carlsbad twinning; the microcline often tending to replace the plagioclase augens.

On the other hand, the Dyolidanda hill gneissic granites are richer in potash and reveal a different course of felspathisation, which comprised following stages:-

(1) Appearance of a little plagioclase in the groundmass.

(2) Development of augens of both felspars - orthoclase and plagioclase, the former predominating.

(3) Appearance and progressive proliferation of orthoclase porphyroblasts, leading to obliteration of the foliation.

Unlike the Ranikhet and Majkhali area, where Vashi (1966), and Desai (1968) found that plagioclase formed first and was later on extensively replaced by microcline, in the Almora area the replacement phenomenon is much less pronounced. In the Chaunsali gneissic band and in the other smaller lensoid gneissic bands, the evidence of microcline replacing plagioclase is not uncommon, but so far as the gneissic granites of Almora proper (Dyolidanda hill) are concerned, they reveal a metasomatism which was dominated by K_2O from the very beginning.

EVIDENCES OF GRANITISATION

Megascopic evidences

The contacts of the gneisses with the flanking schists are rather transitional, and with a gradual increase of felspar content, the schists grade into gneisses. The size and amount of felspars too increase. The gradual increase in the grain size of the rock as a whole and of the felspars in particular, clearly indicates a metasomatic origin.

Further, the presence of relict schist bands and layers of quartzite (Plate VII.1) inside the gneisses, typically illustrates the phenomenon of "ghost stratigraphy",

PLATE VII.1

Relict quartzite layer within gnesses
(Loc. Dyolidanda hill)

and demonstrates that the framework of the host rock remained coherent throughout the transformation.

Microscopic evidences

Thin sections reveal a gradual transformation of schists into gneisses. The metasomatic growth of the felspar porphyroblasts is fully established on the basis of the following textural criteria:-

(i) The felspar augens and porphyroblasts show a steady and gradual increase in size, with increasing felspar content of the rock.

(ii) The augens and porphyroblasts contain abundant inclusions of muscovite, biotite, quartz and plagioclase.

(iii) The porphyroblasts very often show rims of fine to medium grained quartz, crowded all along their borders, suggesting the segregation of SiO_2 around the metasomatically developed felspars. Many of such quartz grains are partly or fully included in the porphyroblasts.

(iv) Well formed garnets in gneisses and gneissic granites, indicate that the enclosing rocks were derived from originally garnetiferrous mica-schists.

Chemical criteria

The chemical analyses of a few selected samples from both the bands (i.e., Chaunsali and Dyolidanda hill bands), when plotted on various diagrams, give an idea of the chemical changes undergone by the rocks during the different stages of granitisation. The chemical study fully supports the various textural, structural and mineralogical evidences of granitisation for both the bands discussed earlier in this chapter.

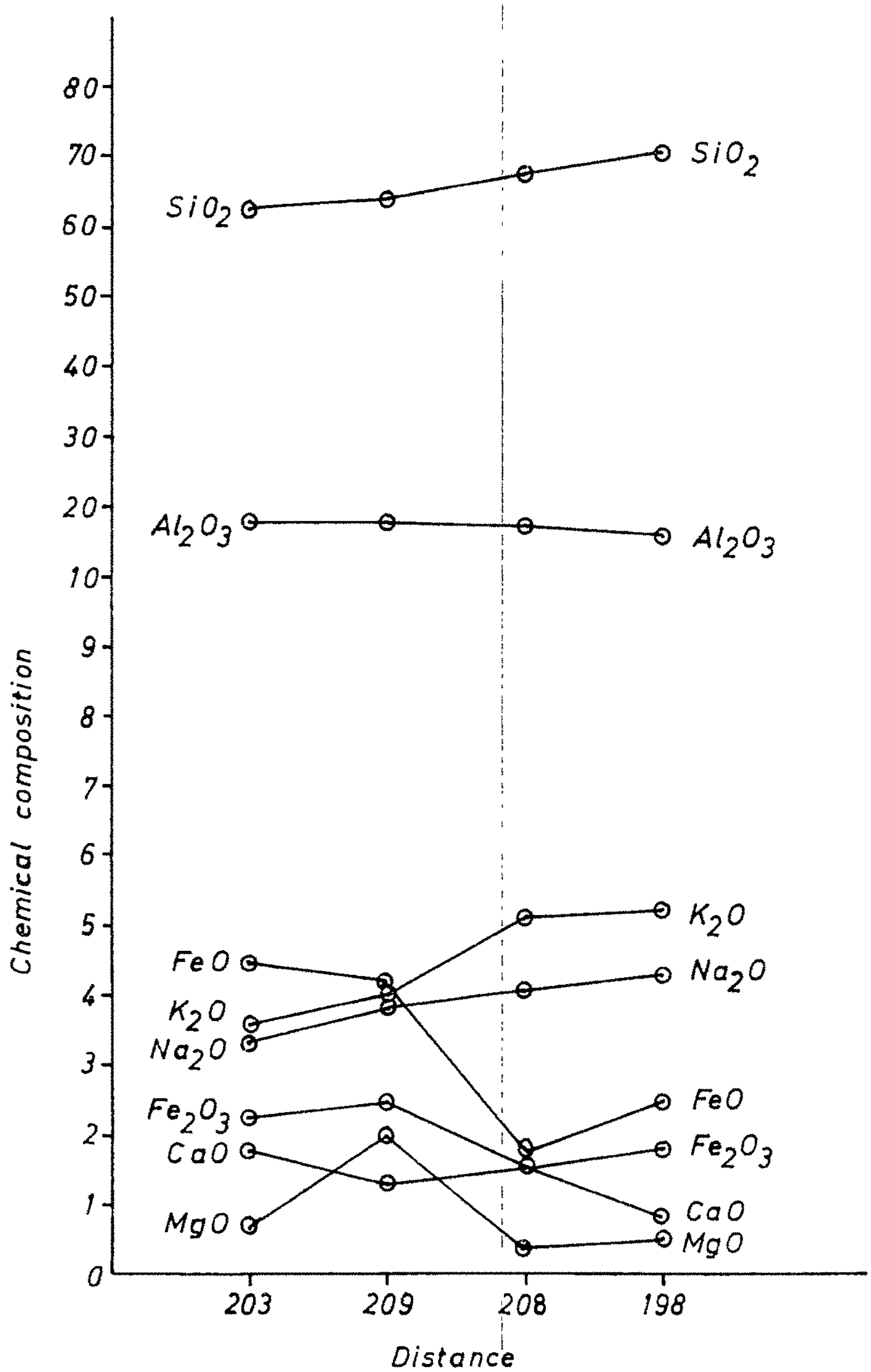
Variation diagrams

The trends of the various percentages of SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, K_2O, Na_2O and CaO from felspathic schist to porphyroblastic gneiss and gneissic granite of Dyolidanda hill, when plotted on variation diagram (Table VII.1 and Fig.VII.1), show enrichment in potash content right from the initial stages that steadily increases with increasing felspathisation. The silica content shows a marginal and gradual increase. The increase in potash and silica content in the final stages i.e. in gneissic granite variety suggests a rather marked addition. CaO and other mafic oxides show a decline.

The chemical data of the selected rocks of Chaunsali band reveals that during transformation of felspathic schist

Fig. VII. 1.

Variation diagram : Dyolidanda hill band



203 - Felspathic schist

209 - Augen gneiss

208 - Porphyroblastic gneiss

198 - Gneissic granite

TABLE VII.1

Chemical analyses of the gneissic rocks of Dyolidanda hill band

Rock type	Felspathic schist		Augen gneiss			Porphyroblastic gneiss		Gneissic granite		
Sp.no.	203	80	82	204	209	208	81	186	198	71
SiO_2	63.47	68.97	60.30	66.90	64.20	68.20	69.86	71.90	70.90	69.87
TiO_2	00.78	00.69	00.07	00.79	00.78	00.09	00.38	00.36	00.09	00.52
Al_2O_3	18.22	17.17	24.51	17.61	17.52	17.11	17.87	12.62	13.61	12.66
Fe_2O_3	02.28	03.04	01.00	01.14	02.40	01.60	01.18	01.09	01.84	01.49
FeO	04.50	02.72	01.99	03.25	04.58	01.79	01.73	03.29	02.55	03.50
MnO	00.87	00.46	00.09	00.88	00.86	00.28	00.43	00.58	00.58	00.68
MgO	00.72	01.50	01.33	01.26	01.14	00.40	01.09	00.38	02.63	00.76
CaO	01.82	01.26	00.98	02.10	00.98	01.61	01.87	00.84	00.84	01.96
Na_2O	03.34	03.06	06.67	03.07	04.36	04.14	03.25	03.60	04.34	04.08
K_2O	03.68	01.16	03.74	02.68	03.49	05.11	02.17	04.99	05.24	06.06
P_2O_5	00.09	00.08	00.02	00.13	00.09	00.08	00.08	00.39	00.08	00.25
Total	99.77	100.11	100.68	99.81	100.40	100.41	99.91	100.04	100.70	100.03

Niggli values										
si	249.5	315.7	209.8	283.00	247.1	302.1	330.8	364.1	291.8	300.2
al	42.30	46.43	50.10	43.90	39.72	44.68	48.87	37.69	32.84	32.22
fm	28.46	32.96	15.45	26.42	31.18	15.69	19.88	23.71	32.60	24.73
c	07.54	06.32	03.76	09.64	04.16	07.71	09.66	04.86	03.95	09.28
alk	21.70	14.29	30.69	20.04	24.94	31.92	21.59	33.74	30.61	33.73
c/fm	00.26	00.19	00.24	00.36	00.13	00.49	00.48	00.20	00.12	00.37
Values for Osann's diagram										
C	03.18	02.83	01.33	03.92	01.81	02.74	03.62	01.95	01.76	03.70
Al	17.68	20.78	17.77	17.89	17.32	15.90	18.30	14.82	14.62	12.84
Alk	09.14	06.39	10.90	08.19	10.87	11.36	08.08	13.23	13.62	13.46
Marmo diagram										
K_2O mol.	02.63	-	02.64	01.91	02.46	03.59	-	03.71	03.48	04.19
Na_2O mol.	03.58	-	07.31	03.30	04.73	04.38	-	04.06	04.37	04.25

Analyst A.N.Shah

to porphyroblastic gneiss the Na_2O played a major role. The Na_2O content is dominant in felspathic schist and augen gneiss. But in the porphyroblastic gneiss, it registers a slight decline with concomitant increase in potash content (Table VII.2 and Fig.VII.2). This fact illustrates late arrival of potash and its replacement of Na_2O. Also the SiO_2 content shows a very slight increase.

Von Wolff's Q-L-M diagrams

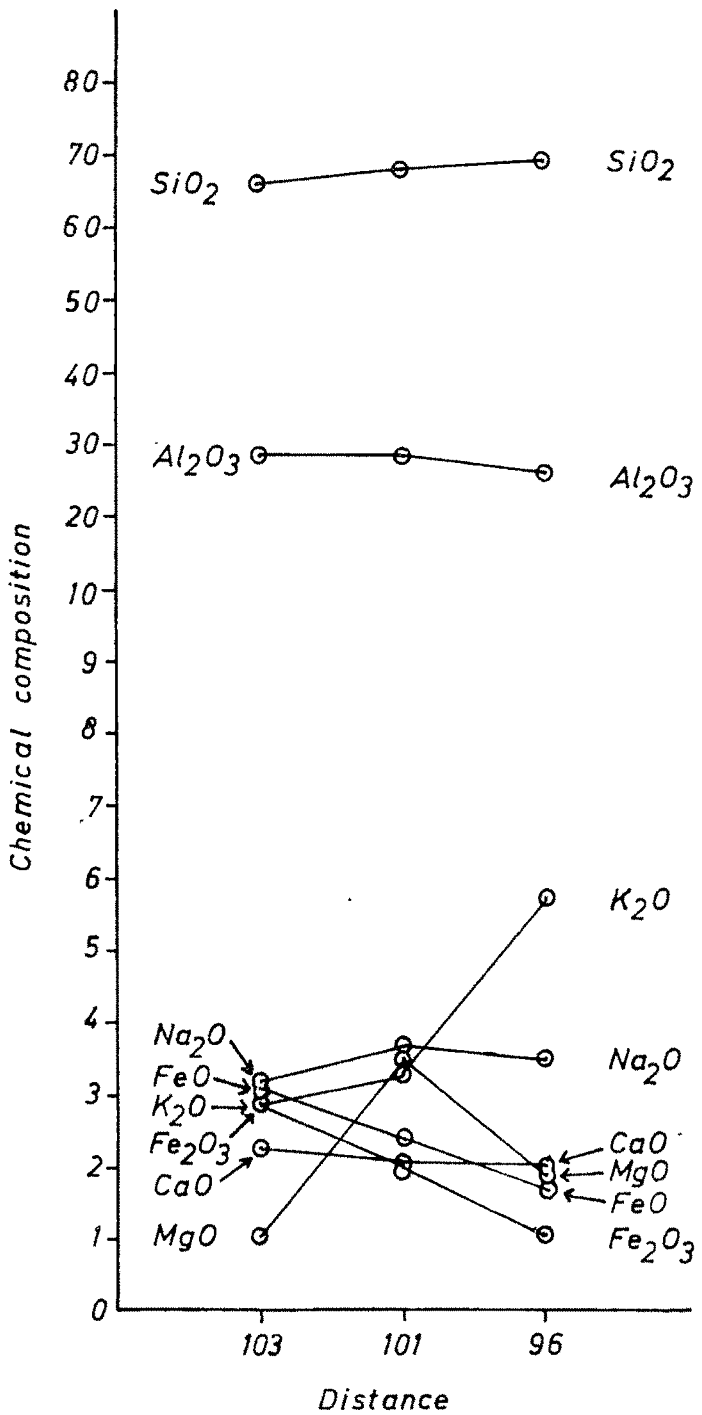
Q-L-M values were also calculated from the analyses (Tables VII.3 & VII.2) of both the gneissic bands, and were plotted on Von Wolff's Q-L-M diagram (Figs.VII.3 & VII.4).

The rocks of Dyolidanda hill band show decrease in quartz percentages from felspathic schist to porphyroblastic gneiss, and increase in leucocratic constituents. But the gneissic granites show increase in Q values. This suggests significant addition of silica during the final stages.

The rocks of Chaunsali band show decrease in quartz percentages and increase in leucocratic constituents from the felspathic schist to porphyroblastic gneiss. This indicates that during the transformation there was only a limited external supply of silica and appreciable addition of alkalies. Thus, the free quartz of the schist was used up in the formation of felspars.

Fig. VII. 2.

Variation diagram: Chaunsali band



103 - Felspathic schist

101 - Augen gneiss

96 - Porphyroblastic gneiss

TABLE VII.2

Chemical analyses of the gneissic rocks of Chaunsali band

Rock type	Felspathic schist	Augen gneiss	Porphyroblastic gneiss	
Sp.no.	103	101	96	99
SiO_2	65.68	68.03	69.22	72.50
TiO_2	00.87	00.60	00.17	00.48
Al_2O_3	18.25	17.18	15.21	12.57
Fe_2O_3	02.30	02.05	01.09	00.83
FeO	03.18	02.42	01.70	01.60
MnO	00.29	00.62	00.23	00.52
MgO	00.95	03.52	01.50	00.50
CaO	02.78	01.89	02.04	00.98
Na_2O	03.23	04.28	03.54	04.98
K_2O	02.86	03.27	05.74	05.55
P_2O_5	00.03	00.06	00.06	00.06
Total	100.42	100.92	100.50	100.57
Q-L-M (Von Wolf's diagram)				
Q	30	23	21	19
L	58	57	71	78
M	12	20	08	03
Niggli values for Marmo diagram				
si	265.8	252.3	303.7	-
al	43.45	38.06	39.22	-
K_2O mol and Na_2O mol				
K_2O	02.06	02.24	03.98	03.88
Na_2O	03.46	04.42	04.60	05.24
For AKF diagram				
A	51.72	32.23	23.67	-
K	14.56	14.45	37.18	-
F	33.70	53.32	39.13	-

Analyst A.N.Shah

Fig. VII. 3.

Von Wolff's Q - L - M diagram for gneissic rocks of Dyolidanda hill band.

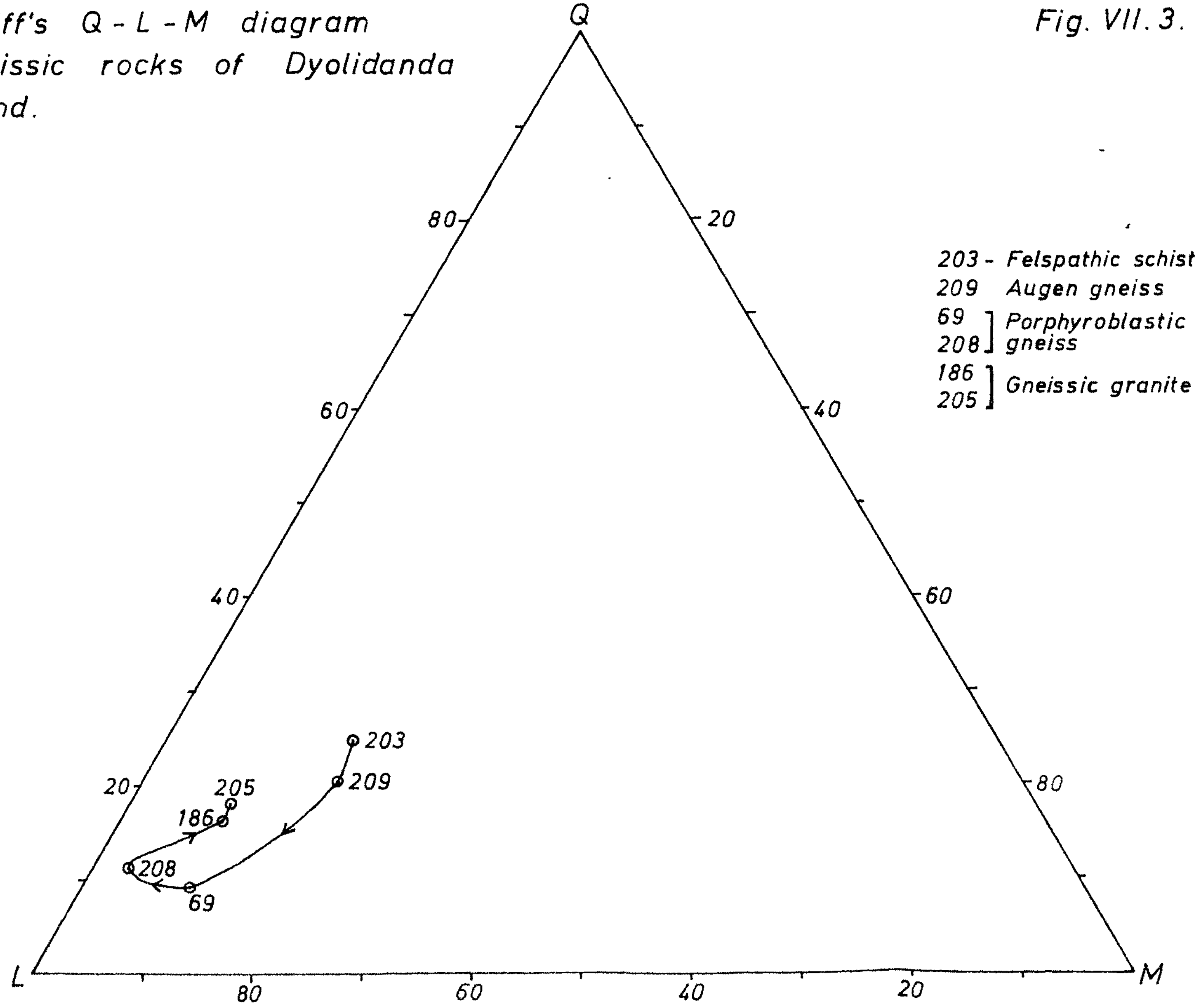
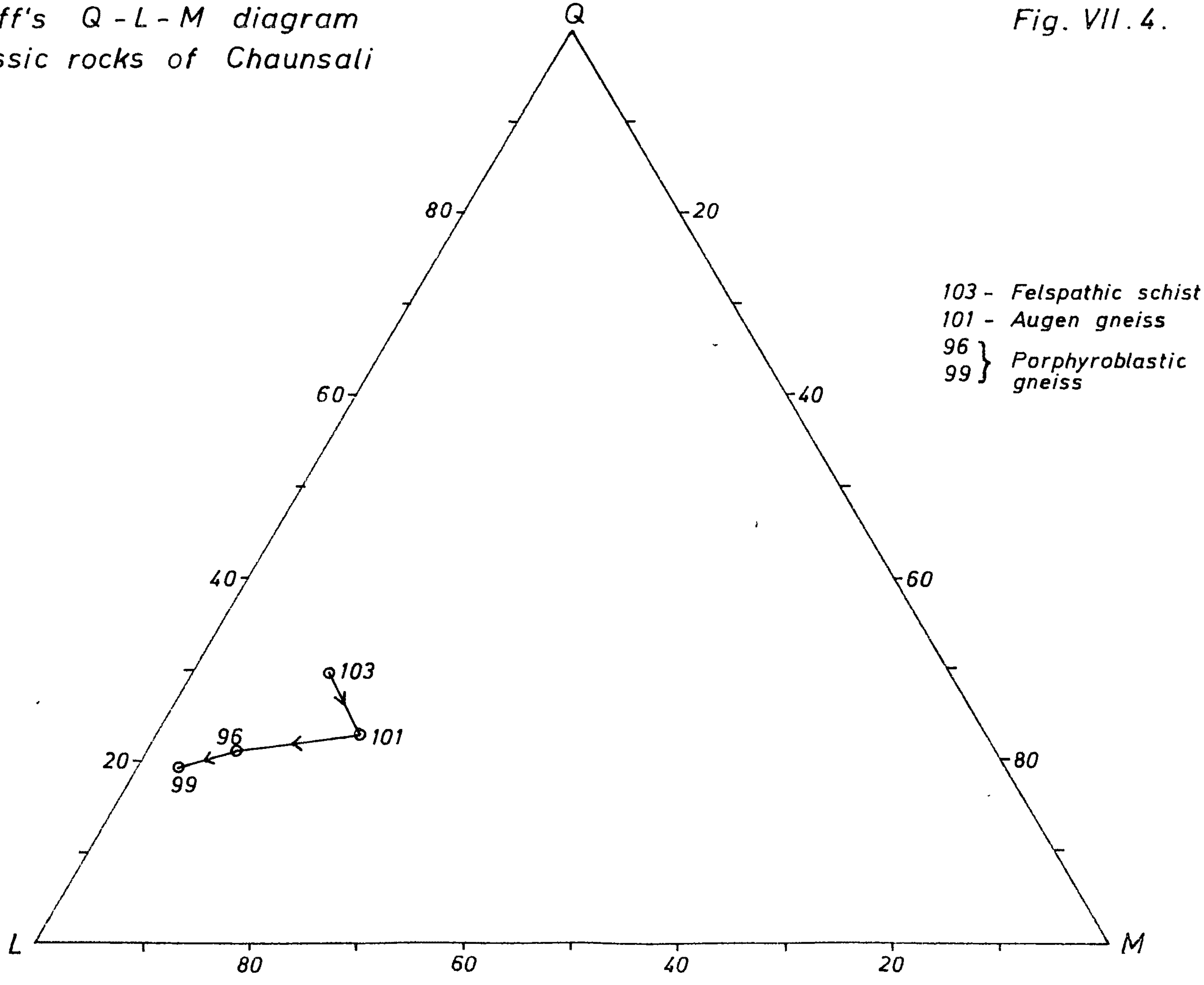


Fig. VII.4.



Von Wolff's Q - L - M diagram for gneissic rocks of Chaunsali band.

TABLE VII.3

Chemical analyses of the gneissic rocks of Dyolidanda hill band

Rock type	Felspathic schist	Augen gneiss	Porphyroblastic gneiss		Gneissic granite	
Sp.no.	203	209	69	208	186	205
SiO_2	63.47	64.20	65.84	68.20	71.90	68.00
TiO_2	00.78	00.78	00.07	00.09	00.36	00.28
Al_2O_3	18.22	17.52	12.87	17.11	12.62	18.61
Fe_2O_3	02.28	02.40	03.55	01.60	01.09	01.09
FeO	04.50	04.58	05.23	01.79	03.29	02.30
MnO	00.87	00.86	00.09	00.28	00.58	00.37
MgO	00.72	01.14	01.26	00.40	00.38	00.27
CaO	01.82	00.98	02.38	01.61	00.84	01.40
Na_2O	03.34	04.36	03.74	04.14	03.60	03.56
K_2O	03.68	03.49	04.94	05.11	04.99	04.36
P_2O_5	00.09	00.09	00.04	00.08	00.39	00.07
Total	99.77	100.40	100.01	100.41	100.04	100.31
Q-L-M (Von Wolf's)						
Q	24	20	09	11	17	19
L	58	62	81	86	74	73
M	18	18	10	03	09	08

Analyst A.N.Shah

Mehnert's graphs

Following Mehnert (1968) the values of Na_2O Wt. % were plotted against K_2O Wt. % (Tables VII.1,VII.2 and VII.4). From these graphs (Figs.VII.5 and VII.6), it becomes clear that the rocks of Dyolidanda hill band show a sharp rise in potash content from felspathic schists to gneissic granites, while in the Chaunsali band the increase in potash from felspathic schist to porphyroblastic gneiss is rather gradual.

Hejtman's diagram

Fig.VII.7 shows graphically the ratio of principal felspar oxides (Na_2O, K_2O and CaO) and simultaneously their relations to MgO, $FeO+Fe_2O_3+MnO$ and K_2O in the Dyolidanda hill rocks (Table VII.4). The graphical representation follows the example of B. Hejtman (1956, p.59). This diagram very clearly suggests the transformation of schist into gneisses and gneissic granite. The numbered points indicate the graphical position of Na_2O, K_2O and CaO ratios for a base of 100, while the points of the arrows indicate the ratio of $FeO+Fe_2O_3+MnO$, MgO and K_2O. The arrows thus represent the relationship between the two groups of oxides, for different stages of granitisation. It is interesting to note the progressive swing in the direction of the arrows. In felspathic schists,

Mehnert's graphs.

Fig. VII. 5.

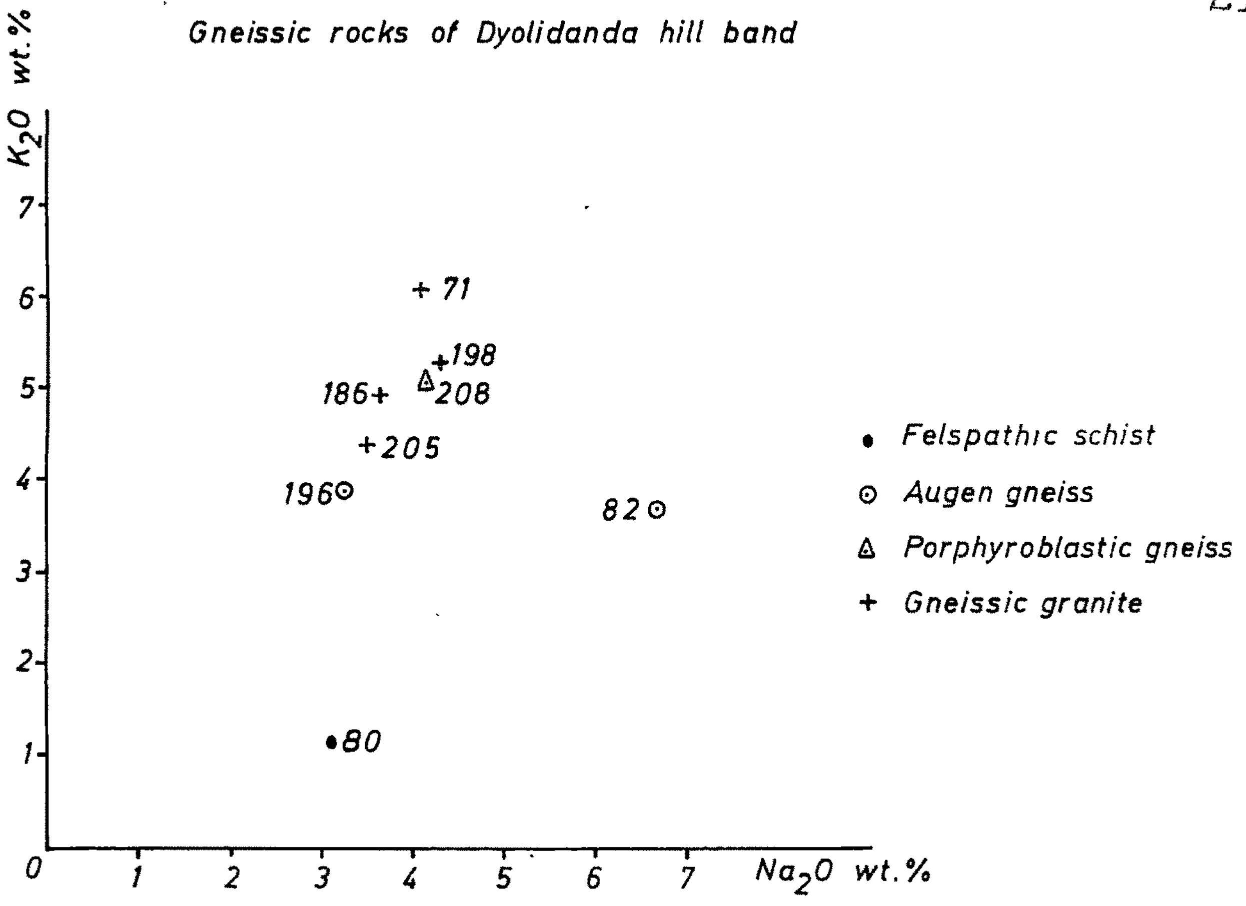


Fig. VII. 6.

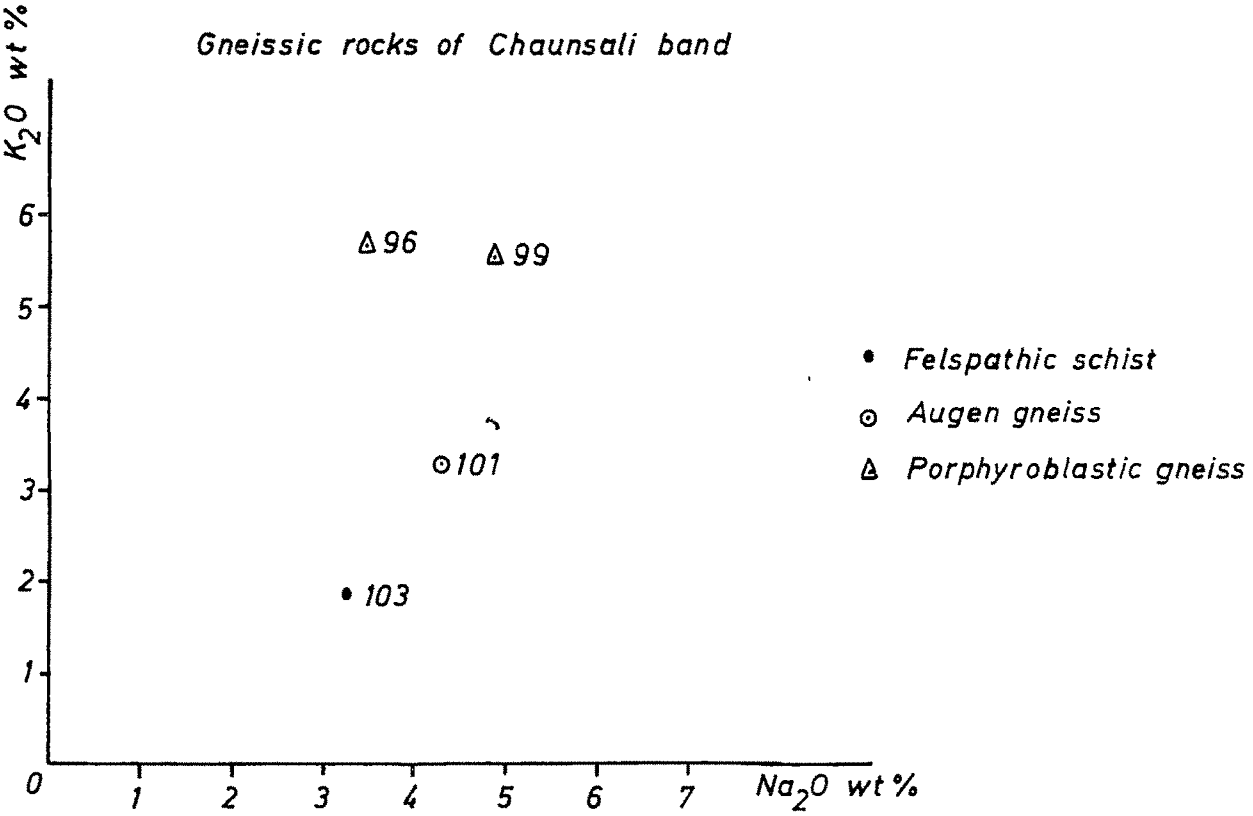


TABLE VII.4

Chemical analyses of the gneiss rocks of Dyolidanda hill band

Rock type	Felspathic schist		Augen gneiss		Porphyro-blastic gneiss	Gneissic granite	
Sp.no.	3	203	204	196	208	205	71
SiO_2	62.58	63.47	66.90	69.80	68.20	68.00	69.87
TiO_2	00.16	00.78	00.79	00.82	00.09	00.28	00.52
Al_2O_3	19.87	18.22	17.61	15.21	17.11	18.61	12.66
Fe_2O_3	02.50	02.28	01.14	01.99	01.60	01.09	01.49
FeO	05.17	04.50	03.25	01.80	01.79	02.30	03.50
MnO	00.27	00.87	00.88	00.86	00.28	00.37	00.68
MgO	01.20	00.72	01.26	00.36	00.40	00.27	00.76
CaO	02.30	01.82	02.10	02.24	01.61	01.40	01.96
Na_2O	03.25	03.34	03.07	03.21	04.14	03.56	04.08
K_2O	02.86	03.68	02.68	03.86	05.11	04.36	06.06
P_2O_5	00.02	00.09	00.13	00.08	00.08	00.07	00.25
Total	99.98	99.77	99.81	100.23	100.41	100.31	100.03

For Hejtman's diagram

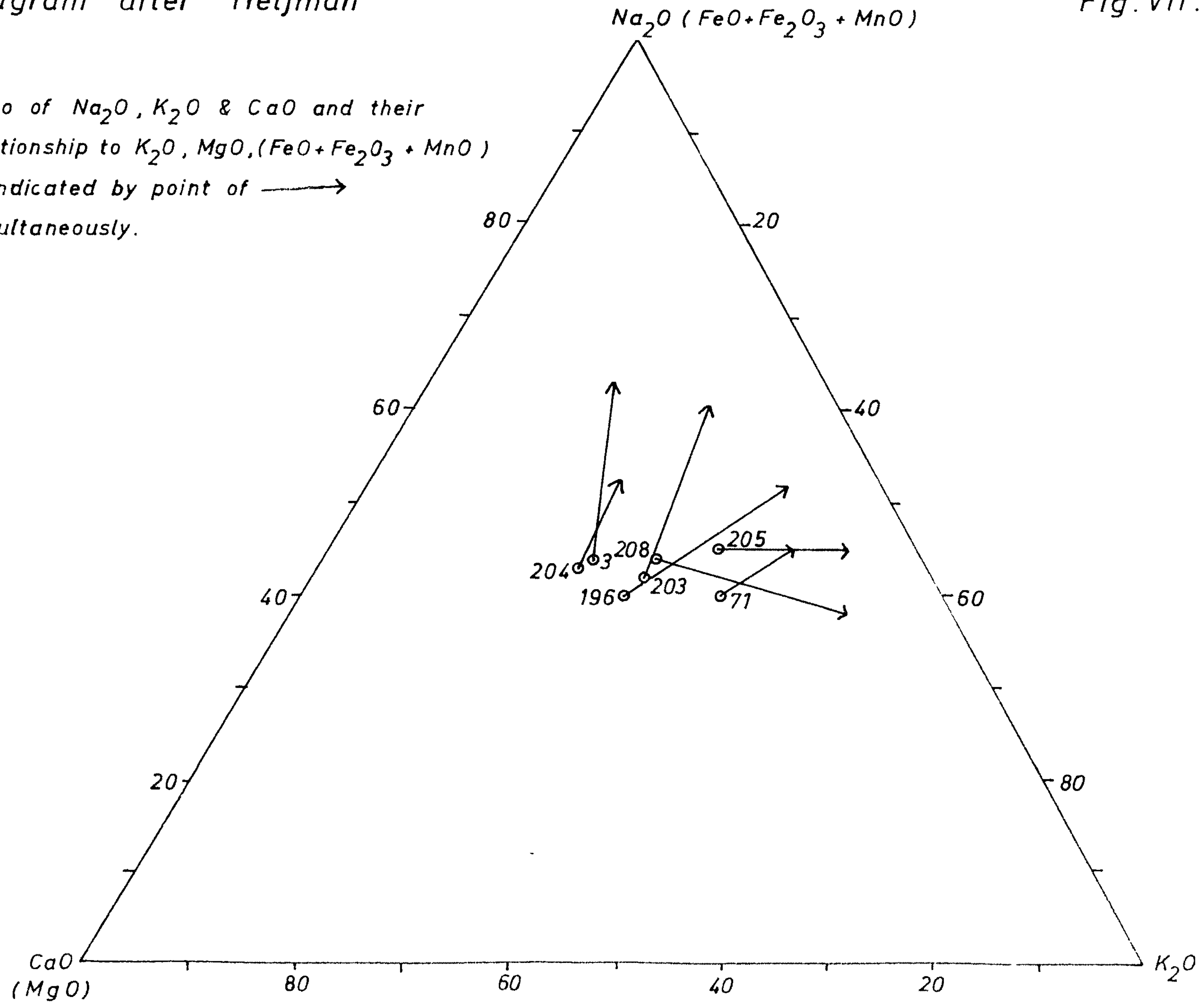
K_2O	25	31	30	24	36	36	39
Na_2O	44	42	40	43	44	45	40
CaO	31	27	30	33	20	19	21
FeO+ Fe_2O_3+ MnO	63	61	52	52	38	45	45
MgO	20	12	09	25	10	07	12
K_2O	17	27	39	23	52	48	43

Analyst A.N.Shah

Diagram after Hetjman

Fig. VII. 7.

⊙ = Ratio of Na_2O, K_2O & CaO and their relationship to K_2O, MgO, ($FeO + Fe_2O_3 + MnO$) is indicated by point of ⟶ simultaneously.



it points toward mafic content, indicating its richness in soda and mafic constituents. On the other hand, in the gneissic granite, the arrow points towards K_2O apex, indicating potash enrichment and gradual decrease of mafics.

Marmo's diagrams

(i) $K_2O:Na_2O$ mol.: The mol. values for K_2O and Na_2O of the analyses of 3 gneissic rocks from Chaunsali band and 9 gneisses and gneissic granites from Dyolidanda hill band (Tables VII.1 and VII.2), when plotted on standard diagram (Fig.VII.8) prepared by Marmo (1955) ideally show that all these gneisses and gneissic granites fall within the synkinematic field.

(ii) Niggli values: Niggli values of si and al for the gneisses and gneissic granites (Tables VII.1 & VII.2) from both the bands when plotted on standard diagram (Fig.VII.9) of Marmo (1955) again confirm their synkinematic origin.

c/fm-al-alk diagram of Niggli

The niggli values of the gneisses and gneissic granites (Table VII.1) of Dyolidanda hill band, when plotted on c/fm-al-alk diagram of Niggli (A. Johannsen, 1937) (Fig.VII.10) show that the felspathic schist, augen gneiss

Table 30 : Amino acids in Tissues Medium as inf ced by aline added Per cally i tura Cel spension.

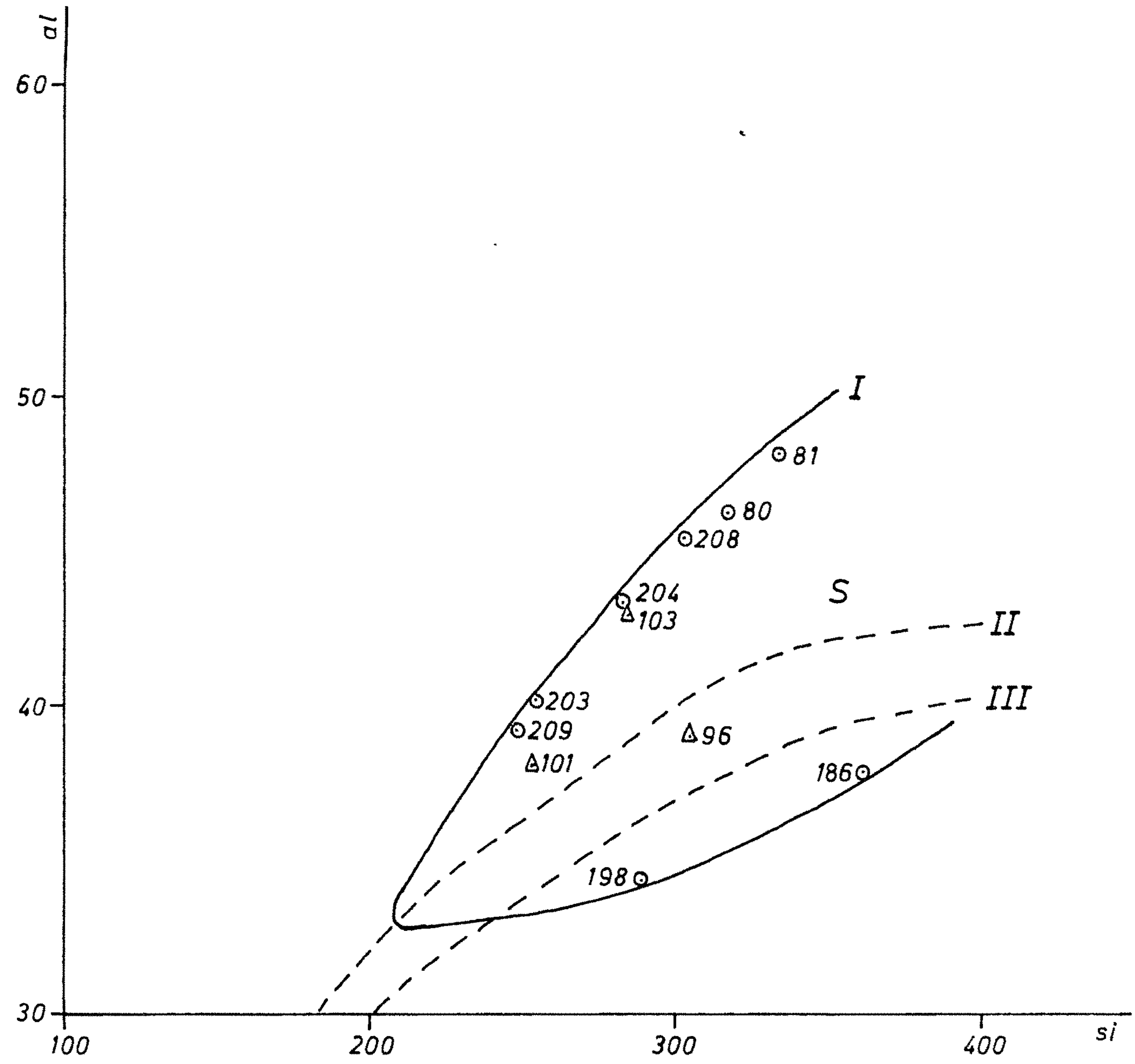
Inoculum : 1000± 40 mg ue by fresh w (Dry at 50 mg) in 50 MS medi

incubation : 4 weeks at 2°C in light

Amino acids	Initial		on C		L aline ad after 1 week			er 2 wee	after 3 weeks	
	Tissue (µgm/100 mg dry wt)	Medi (µgm/	Tissue (µgm/100 mg dry wt)	edium gm/ml)	Tissue n/100 mg / wt)	Med (µgm/	Ti (µgm/ dry	g (µg	Tissue (µgm/100 mg dry wt)	Medium (µgm/ml)
Orrithine	420.3	-	-	-	-	-			-	-
Phenylalanine	710.6	17	-	-	-	-			-	-
Histidine	1681.2	21	500	-	-	-			-	-
Proline	-	-	6750	520	320	5	25	9	7200	432
Alanine	710.6	17	-	-	-	-	5		-	-
Serine + Threonine	-	60	350	2.4	-	-			-	-
Aspartic acid	1260.9	-	-	-	-	-			-	-

Fig. VII. 9.

Diagram for synkinematic gneissic rocks of Dyolidanda hill and Chaunsali bands. (Marmo)

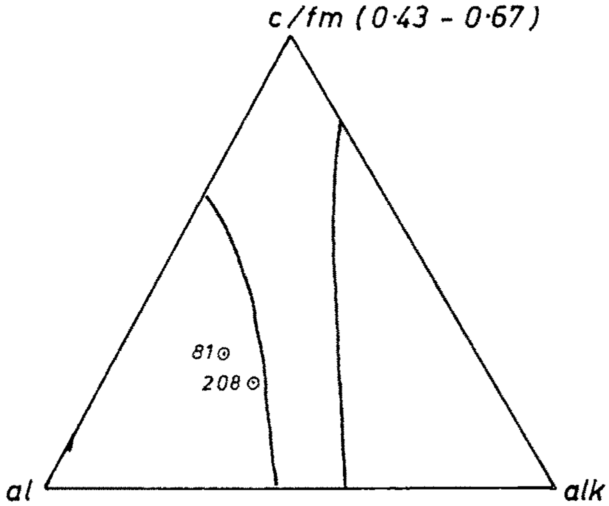


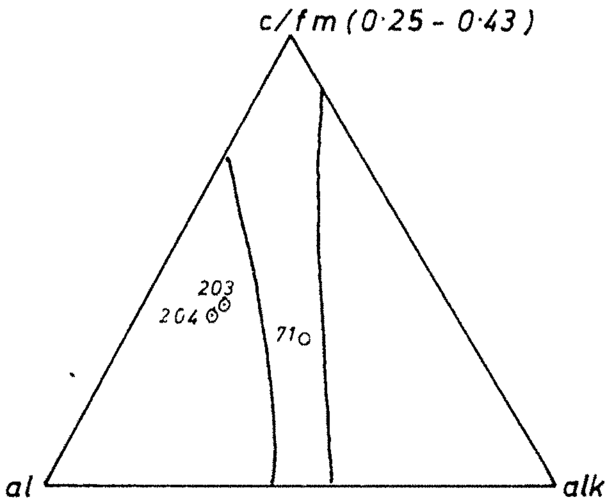
⊙ Gneissic rocks of Dyolidanda hill band.

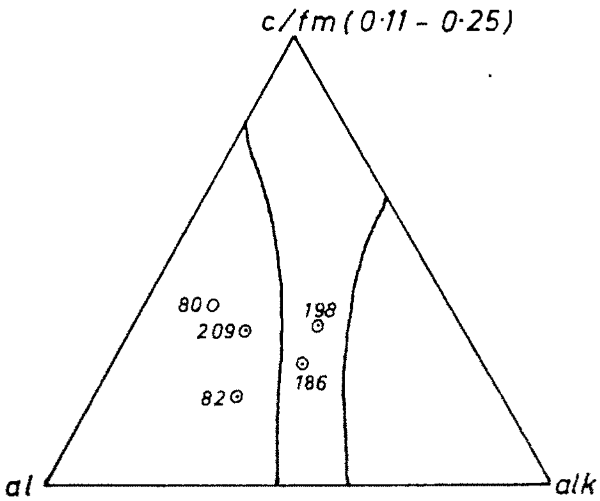
△ Gneissic rocks of Chaunsali band.

Fig. VII. 10.

c/fm — al — alk diagram of Niggli







and porphyroblastic varieties of gneisses fall in the metamorphic field and the gneissic granites fall into the eruptive field. Though the gneissic granites (on the basis of field evidences and petrography) have been found to be metamorphic in origin, they show chemical character of an eruptive granite indicating that they are deep seated rocks, granitised at higher energy level. Sadashivaiah (1962, p.53) has also arrived at similar conclusions for the Archean granites and gneissic rocks of Munirabad area in Mysore State.

Osann's C-Al-Alk diagram

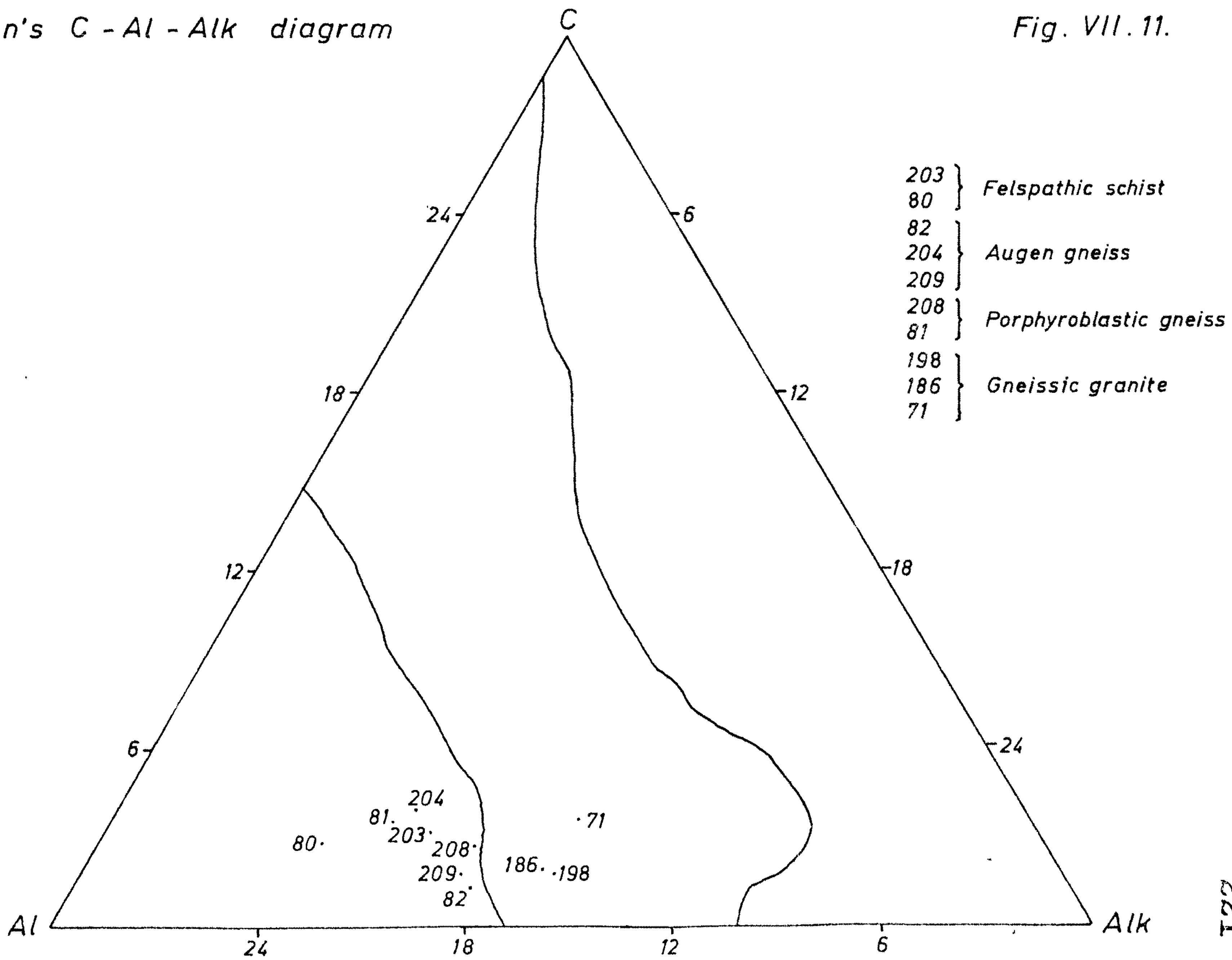
The chemical data of gneisses and gneissic granites of Dyolidanda hill band (Table VII.1) when plotted on Osann's C-Al-Alk diagram (Fig.VII.11), clearly brings out the fact that the gneissic rocks are metamorphic in origin.

MECHANISM AND CAUSES OF GRANITISATION

The granitisation appears to have closely synchronised with the regional metamorphism, the two allied phenomena ultimately associated with obscure plutonic processes operating in the geosynclinal depths. Read (1957, p.88) has defined granitisation as "the

Osann's C - Al - Alk diagram

Fig. VII. 11.



process by which solid rocks are converted to rocks of granitic character without passing through a magmatic stage. According to him, regional metamorphism and granitisation are genetically connected.

The granitisation in the study area also appears to be closely connected with the regional metamorphism at geosynclinal depths. The rocks which now occupy the cores of early isoclinal folds represent the sediments from the deeper levels nearest to the theatre of granitisation. These were granitised easily by the emanations rising from depths, the passage of such rising emanations being facilitated by the metamorphic (axial-plane) foliation.

The gneisses and the gneissic granites of the area do not suggest injection of any granitic melt - magmatic or migmatic, as there are few evidences to show any injection of a molten material. On the other hand, various criteria point towards a gradual metasomatic alteration of schists into gneisses, the transformation perhaps having been brought about by the passage through solid rocks of a stream of interchanging constituents. The various textural and mineralogical features of the rocks indicate the possibility of metasomatism brought about by the mechanism of solid diffusion.

Obviously, the important controlling factors in solid diffusion are temperature and pressure. Heat results in increased diffusion. Stresses promote solid diffusion because they increase pore spaces. Shearing distorts the crystal lattice and so promotes ionic migration.

Reynolds (1947, pp.409-411) has suggested three possible ways in which ions may migrate through a solid (crystalline) medium.

(i) Through spaces in the lattice, if the lattice is sufficiently open and the migrating ions are of appropriate size.

(ii) From one lattice point to another within the crystal mesh. This type of diffusion occurs when the atoms in a crystal are in a state of rapid thermal vibrations. At a certain temperature, these vibrations become so large that ions may break away and wander through lattices.

(iii) Through zones of atomic disorder, lattices are composed of minute blocks which are not perfectly aligned. These mosaic structures give rise to atomic disorder at the junctions of mosaic units. Atomic disorder is also found along the boundaries of closely packed crystal grains. Orogenic stresses create pronounced atomic disorder.

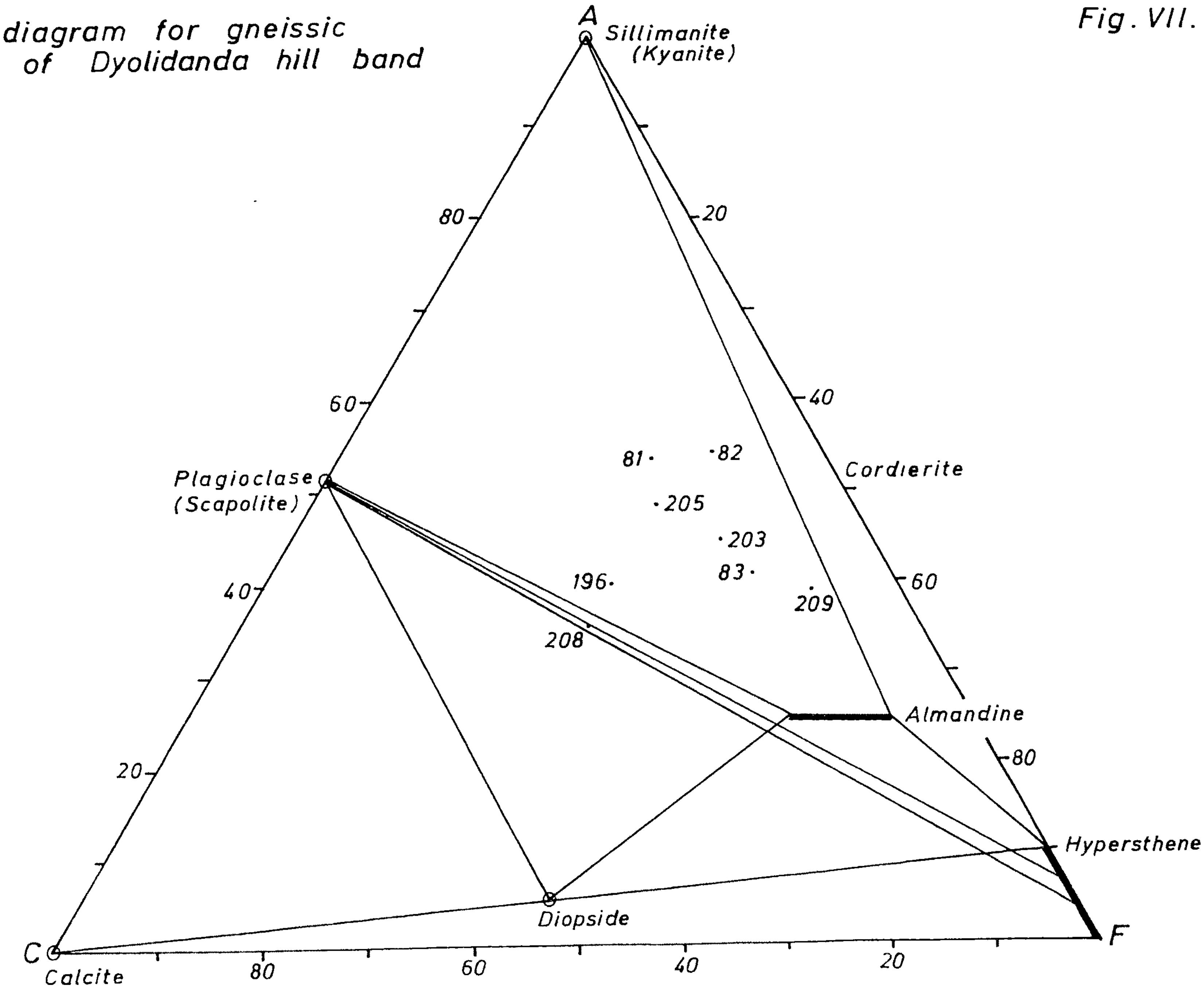
The pattern of progressive alkali increase, as shown by the granitic rocks of the area, fully supports the view put forth by Lapadu-Hargues (1945) that regional metamorphism leading to granitisation consists of a progressive calc-alkali influx. He found that with increasing grade, there is an influx of alkalis from deeper zones. In the lower grades, there is an accession of soda, in higher grades the accession of alkalis continues with potash dominating. Both alkalis come from the same deep source - the soda moving farther. The smallest ions migrate the farthest, the potassium ion, for example being large is confined to the internal zones. The dependence of migration on atomic radii, is of considerable significance in the process of granitisation.

Applying the above criteria, the Almora gneissic rocks of metasomatic origin could be classified into two main groups each representing distinct plutonic conditions of origin and characterising granitisation at different energy levels. The fixation of soda which travelled faster and farther as compared to potash, into the meta-morphic rocks at relatively shallower levels, gave rise to the augen bearing gneisses. In these, the potash-felspar is quite subordinate, just managed to reach and that too fairly late. On the other hand, the gneissic granites of the Dyolidanda hill, rich in potash felspar, and that too mostly orthoclase-perthite, clearly represent a deepseated granitised rock, where the dominant alkali was potash.

The felspars provide very good indications of the metamorphic conditions under which the granitised rocks originated. While the plagioclases typically reveal their development in an environment of medium grade metamorphism, the potash felspars suggest their fixation under metamorphic conditions of upper part of the amphibolite facies or even beyond. The plots of the chemical analyses of gneisses and gneissic granites of Dyolidanda hill, when plotted on ACF diagram (Fig.VII.12,Table VII.5) indicate the amphibolite-granulite transitional facies of Turner (1968, p.327), while AKF diagram after Turner and Verhoogen (1962,p.550) (Fig.VII.13,Table VII.5) indicates the sillimanite-almandine-orthoclase sub-facies of the upper part of the amphibolite facies. Heier (1957,1961) and Guitard et al. (1960) who investigated the relationship between triclinicity data and the geological position of rocks with metamorphic facies series, found that the alkali felspars of high temperature origin belonging to granulite

ACF diagram for gneissic rocks of Dyolidanda hill band

Fig. VII. 12.



Amphibolite – granulite Transitional Facies

Fig. VII.13.

AKF diagram for gneissic rocks of Dyolidanda hill band

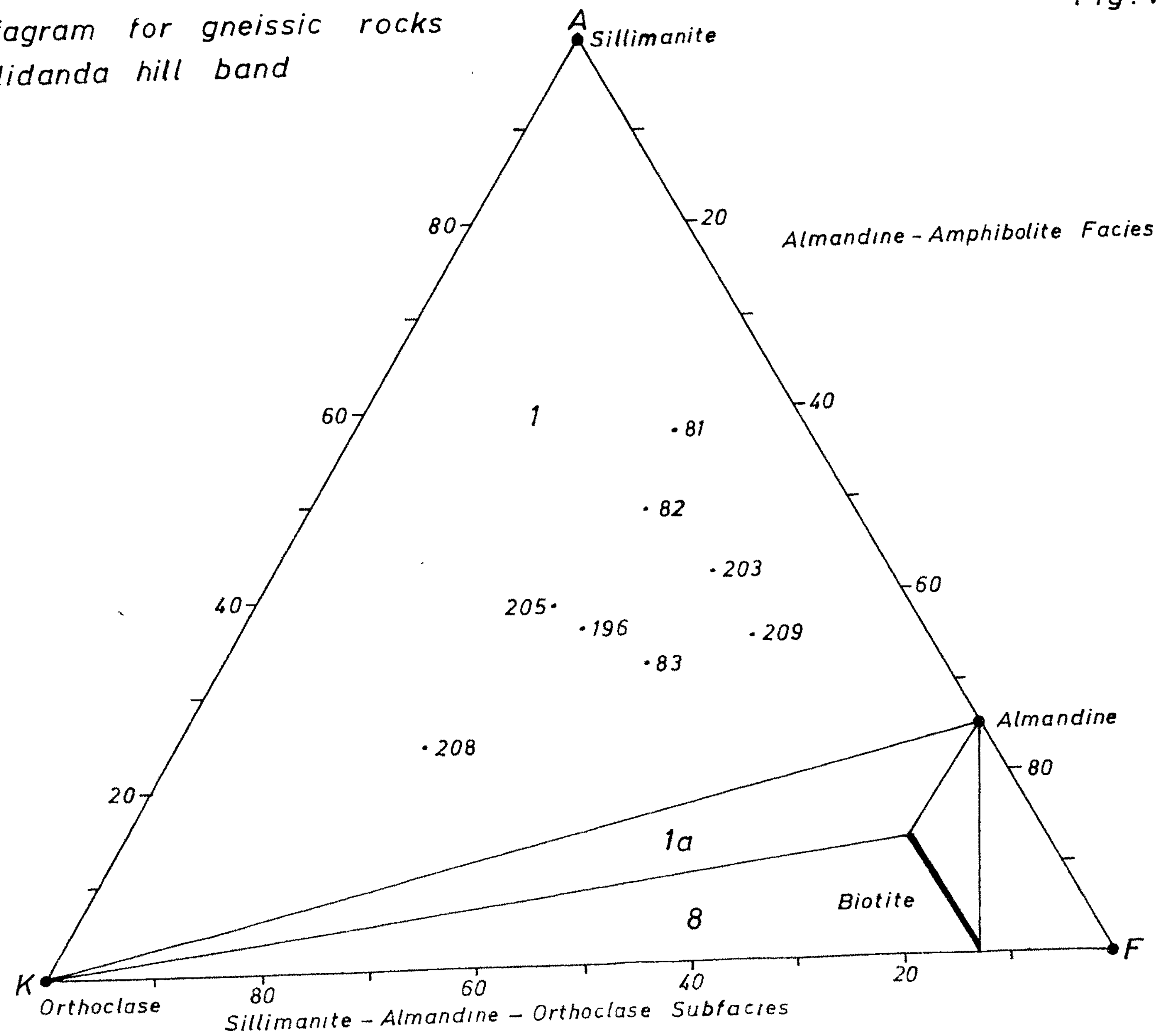


TABLE VII.5

Chemical analyses of the gneissic rocks of Dyolidanda hill band

Rock type	Fels-pathic schist	Augen gneiss			Porphyro-blastic gneiss		Gneissic granite	
Sp.no.	203	82	196	209	81	208	83	205
SiO_2	63.47	60.30	69.80	64.20	69.86	68.20	69.20	68.00
TiO_2	00.78	00.07	00.82	00.78	00.38	00.09	00.06	00.28
Al_2O_3	18.22	24.51	15.21	17.52	17.87	17.11	17.41	18.61
Fe_2O_3	02.28	01.00	01.99	02.40	01.18	01.60	01.22	01.09
FeO	04.50	01.99	01.80	04.58	01.73	01.79	01.37	02.30
MnO	00.87	00.09	00.86	00.86	00.43	00.28	00.08	00.37
MgO	00.72	01.33	00.36	01.14	01.09	00.40	01.91	00.27
CaO	01.82	00.98	02.24	00.98	01.87	01.61	01.12	01.40
Na_2O	03.34	06.67	03.21	04.36	03.25	04.14	03.43	03.56
K_2O	03.68	03.74	03.86	03.49	02.17	05.11	04.56	04.36
P_2O_5	00.09	00.02	00.08	00.09	00.08	00.08	00.23	00.07
Total	99.77	100.68	100.23	100.40	99.91	100.41	100.59	100.31
For ACF diagram								
A	44.24	54.70	38.90	38.85	53.91	33.34	40.05	47.70
C	14.14	10.14	27.67	08.83	17.61	33.33	13.63	18.63
F	41.62	35.16	33.43	52.32	28.48	33.33	46.32	33.67
For AKF diagram								
A	42.88	48.93	36.78	35.53	57.18	23.61	33.45	39.10
K	16.75	19.63	31.61	16.63	12.61	52.78	27.87	33.30
F	40.37	31.44	31.61	47.84	30.21	23.61	38.68	27.60

Analyst A.N.Shah

facies show little triclinicity, whereas in the amphibolite facies those of high triclinicity predominate.

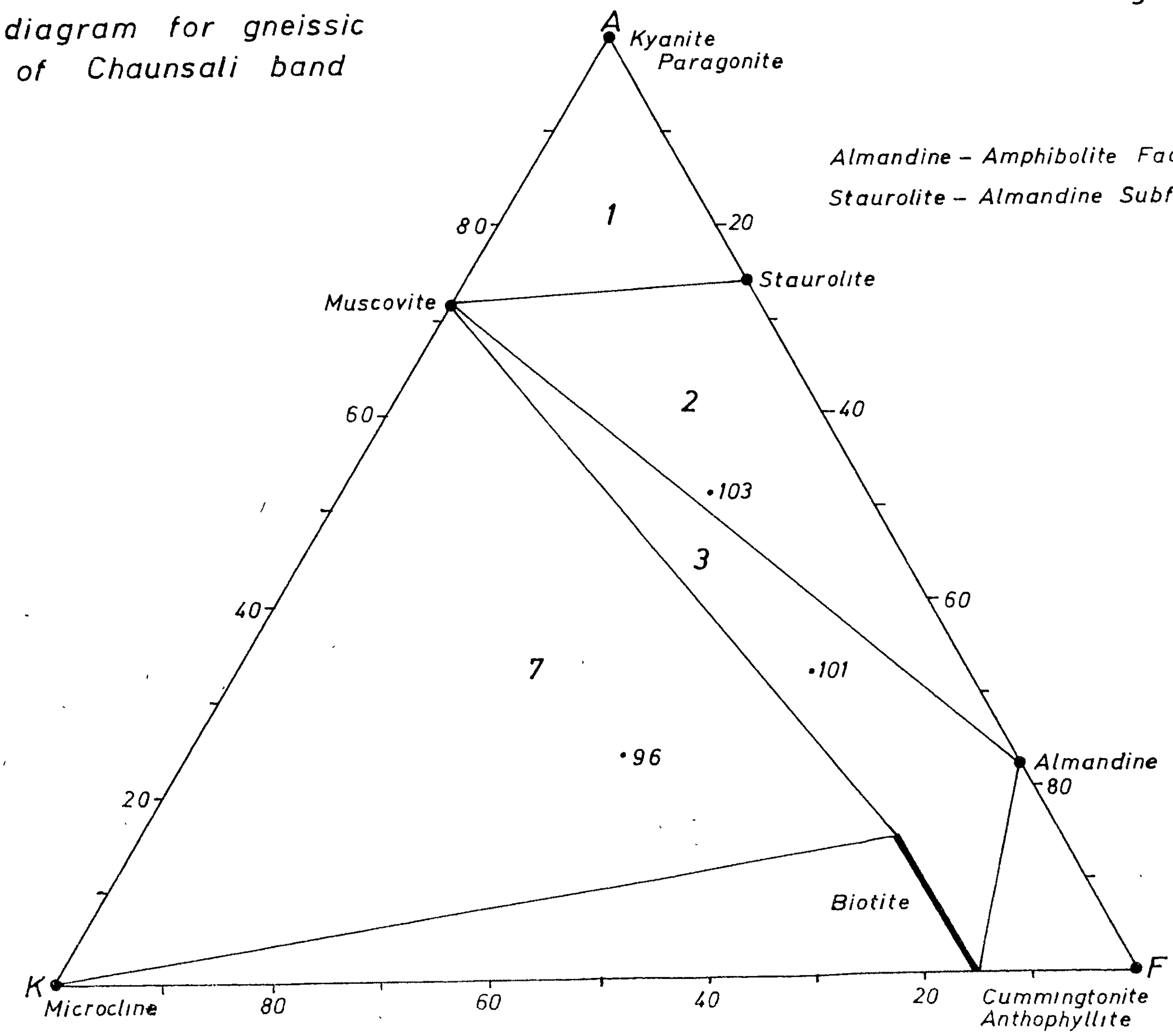
The microcline porphyroblasts of the augen gneisses of the study area frequently exhibit relict carlsbad twinning, and this feature might indicate that originally they may have been orthoclase having developed at high temperatures and later inverted to microcline with their tectonic uplift to regions of moderate depths. Similar phenomenon has been observed and discussed by Chaudhary and Narayan Rao (1966) who investigated granitic rocks of Assam. Optical studies carried out by them revealed that, "The presence of orthoclase and the optical behaviour of the twinned/patchily twinned/untwinned microcline grains suggest that the original K-felspar that crystallised first was of monoclinic form - orthoclase and the latter transition to microcline occurred during late kinematic orogenic movements." The predominance of orthoclase-perthite in the gneissic granites on the other hand, is indicative of their origin under conditions of high metamorphic grade - characterising at least the upper part of the amphibolite facies, because orthoclase microcline transition takes place at that stage. According to Pande and Powar (1968) also, the gneissic granites of

Dyolidanda hill (their Almora granites) represent sillimanite-almandine-orthoclase sub-facies of the almandine-amphibolite facies of Turner and Verhoogen (1962).

It is therefore reasonable to conclude that in the Almora area, granitised rocks represented by the gneissic bands and the gneissic-granite hill respectively represent products of granitisation at two distinct metamorphic and structural levels. While the former comprise granitised metasediments in a moderately high metamorphic environment, equivalent to that of the almandine and staurolite zone of amphibolite facies. The plots of chemical analyses of representative samples of gneisses of Chaunsali band when plotted on AKF diagram (after Turner and Verhoogen, 1962) suggest that they originated under staurolite-almandine sub-facies of Amphibolite facies (Fig.VII.14, Table VII.2). On the other hand, the gneissic granites of Dyolidanda hill represent a much deepseated product, having been lifted up rather abruptly as a "rootless" fold core. While on one hand the various big and small gneissic bands might have risen up gradually as folded anticlinal cores, the Dyolidanda rock appears to have been uprooted from depth

Fig. VII. 14.

AKF diagram for gneissic rocks of Chaunsali band



and pushed up suddenly. It is this difference in the cooling history subsequent to the development of orthoclase porphyroblasts that is reflected in the degree of inversion of orthoclase to microcline. According to Mehnert (1968, p.106) the formation of microcline is favoured in slowly cooled rocks and that of orthoclase in rocks of an intermediate cooling rate.

From the above discussion, it becomes quite clear that all the gneissic rocks of the Almora area, represent products of granitisation, the transformation having been brought about by alkali rich emanations. The author does not agree with the opinion of Heim and Gansser (1939) who have considered these rocks as ortho-gneisses. The other previous workers like Sarkar et al. (1965) and Pande and Powar (1968) have invoked a migmatitic origin. So far as the augen bearing and porphyroblastic gneiss bands are concerned, there is not much of doubt in respect of their slow transformation, but in case of the Dyolidanda gneissic granite, the author has to add something more to the opinions of the previous workers. Sarkar et al. (1965) have called this rock mass as a "granite body mantled by granite gneisses' in which gradation variation is noticeable from the schists through granite gneisses to the granites." They have reported haphazard orientation of the relics of metasediments within the granite indicating local mobilisation of granite. Pande and Powar (1968, p.61-62) have on the other hand described this hill mass as "NW-SE trending concordant sheet-like" pluton, incorporating both meta-sedimentary and magmatic components and being the result of upward permeation of granitic material. The present author is in broad agreement with the opinions of the previous workers, but in the matter of details, he considers that the Dyolidanda gneissic granite mass did not get granitised "in situ", but comprises a patch of folded "ultra migmatites", that originated under a much more deepseated environment than that shown by the rocks within which it is at present situated. It is quite possible that during the upliftment of this granitised mass, some mobilization and homogenisation took place, but the overall structural and textural pattern of the band has remained unobliterated.

Another interesting aspect of the gneissic rocks of the study area including both the varieties - plagioclase rich and orthoclase rich, is the fact that they originated during and after the main folding event F_1. The textural and mineralogical evidences clearly show that the axial plane foliation S_1 provided the most accessible channels for the granitising emanations. The augens have grown forcing apart the foliae. The porphyroblasts grew even after the folding, thus cutting across the foliation. It is therefore quite logical to assume that granitisation was initiated before the F_1 folding. It was quite predominant during the folding and its porphyroblastic phase outlasted the same. In the neighbouring areas. Vashi (1966), and Desai (1968) have shown that felspars continued to grow even during and after the F_2 folding. But in the Almora area, the author has not come across any such evidence. On the other hand, the effects of F_2 folding is recorded in the gneisses and gneissic granites in the form of twisting and bending of micas and felspar porphyroblasts. Thus, it is reasonable to assume that so far as the gneissic rocks of the study area are concerned, they represent products of granitisation that affected them before, during and immediately after the main isoclinal folding, and in this respect, they can be considered "synkinematic". The chemistry plotted on the diagrams of Marmo, also supports the above contention.

In a region of active orogeny, where sediments have been subjected to high temperatures and different types of stresses, ideal conditions would exist for initiating such processes. Thus, regional metamorphism and granitisation form a connected sequence of events closely related to the orogeny. The nature of the ultimate source of the emanations, though undoubtedly being in the deep-seated parts of the geosyncline, is yet to be properly understood. Some believe that sources of granitising emanations are the palingenetic granitic magma, while others suggest a chemical "squeezing" of K, Na, Si, O at deeper levels and their subsequent upward migration. Whatever may be the ultimate source of the granitising emanations, it is almost universally agreed that the downwarping of the sialic crust forming the roots of the fold mountains, on touching the hot simatic substratum leads to the generation of granitising emanations. Whether it is wholesale melting, selecting fusion or ionic dissociation is a matter of conjecture.