Geol. Bull. Univ. Peshawar, Vol. 25, pp. 77-84, 1992

Alkali-feldspar from Koga syenites, Ambella grantitic complex, NW Pakistan

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ABSTRACT: *The Koga syenites are intruded by at least two carbonatite intrusions, having different Na/K ratios. The carbonatite with high Na/K ratio has produced Na-fenites, while the other formed K-fenites. XRD study of low albite indicates that changes occur in the structural state of albite with increasing grade of fenitization. The Na-feldspar in the unfenitized rocks is low albite, while in the fenitized rocks is anomalous low albite. The degree of orderness increases with the increasing intensity of fenitization. The K-feldspar is maximum microcline in both the fenitized and unfenitized rocks. The tie lines between the co-existing Na- and K-feldspars deviate from the generally agreed magmatic trend.*

INTRODUCTION

Feldspar are the most important minerals in igneous, metamorphic and metasomatic rocks. In metasomatic rocks fenitic feldspars are formed as a result of K and Na fenitizing fluids emanating from the carbonatites and/ or ijolites. A considerable work has been carried out on the chemistry and structure of the magmatic feldspars but very little has been published on the metasomatic feldspars; especially on their structural state.

Siemiatkowska and Martin (1975) have suggested that the fenitic albite in the Mississagi quartzite, Sudbury area, Ontario, is well ordered and has 2Q(131)-2Q(131) values (Cu K radiation), close to the values proposed for ordered pure albite by Martin (1969). While albite in the Loe Shilman is anomalously low albite, (Mian & Le Bas, 1988). The authors also observed that the co-existing Na-and K-feldspars showed some deviation from normal tielines present in the coexisting igneous feldspars given by Wright (1967). Mian & Le Bas, (1988) demonstrated that the K-feldspars and anomalously low albite constitute reverse zonation in contrast to the temprature gradient. The reverse zonation in Loe Shilman fenites has been interpreted as the result of superimposed fenitization by later ankeritic carbonatite (Mian & Le Bas, 1988).

The Koga syenites were intruded by sporadic intrusions of carbonatite and minor ijolites. Two types of fenites are dominanted in the area: one is potassium fenite and the other is sodium fenite. There are some rocks in which both types of fenitization can be observed: these results from the K- and Na-fenitization of syenites and nepheline syenites at Koga. The most dominant minerals are alkali feldspars which occur as perthite, albite rimed around perthite, and veins of albite and microcline both within the whole-rock and in perthite of the protolithic syenites and nepheline syenites.

GEOLOGICAL SETTING

The Koga syenites occupy the eastern part of the Ambella granitic complex of the alkaline igneous province, north west Pakistan. It is located near Koga village at about 35 K.m from Mardan. The syenitic rocks constitute an oval-shaped body (about 40 sq. km) and are emplaced in Chinglai gneisses to the east and granites and syenites in the north and west (Fig. 1). The rock units of Koga are alkali-syenites, nepheline-syenites, ijolites, carbonatites and fenites.

The Koga syenites and carbonatites were first reported by Siddiqui et al., (1968). Chaudhry et al., (1982) described the preliminary petrology and chemistry of these

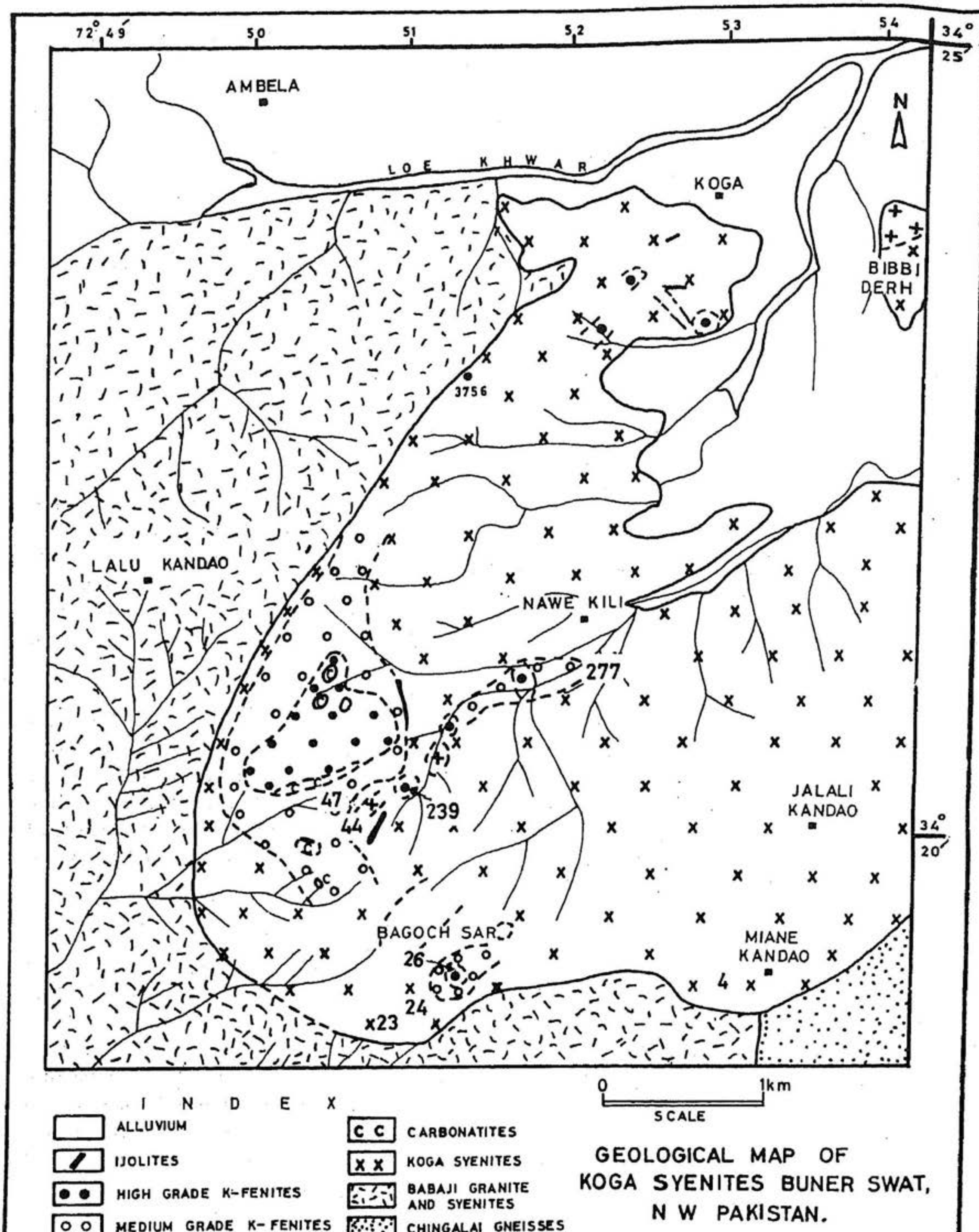

Fig. 1. Geological map of Koga syenite (after Siddiqui et al., 1968).

rocks and suggested the emplacement of magmas along a weak zone developed south of Main Mantle Thrust in a sequence as Babaji Soda granite, pulaskite, nephelinitic syenites, foyaite, sodalite syenite, and carbonatites followed by the formation of fenites. Rafiq (1987) suggested the generation of such magmas by partial melting of the lower crust, contiminated during the later phases by an influx from the activated upper mantle and progressive desilicification of the magmas which lead to the formation of the quartz syenite, syenite and feldspathoidal syenites. Le Bas et al., (1986) has given the preliminary petrography of the Babaji and Koga syenites and on the basis of Rb-Sr isotopic ratios he has suggested an age of 315$\pm$15 Ma for the former and 297$\pm$4 Ma for the latter.

PETROGRAPHY

Detailed petrography of Koga granite, syenites, ijolites, carbonatites and fenites is discussed in another paper (Jabeen & Mian, in prep.). We present petrographic accounts related to alkali-feldspars.

The granite, syenites and fenites are mostly composed of albite, microcline, perthite, pyroxene, amphibole, biotite, ore, zircon and apatite. The most dominant felsic mineral in unfenitized rocks is perthite, which is medium-grained and occurs as subhedral to enhedral crystals. Na-pyroxene is a common mafic mineral which is fine- to medium-grained, subhedral and is yellowish-green in colour. Na-amphibole in unfenitized rocks is taramite, which is fine- to medium-grained with a paleochroic scheme of α = yellowish-brown β = greenish-brown and γ = bluish-green. Biotite also occurs in the form of needles.

In the least fenitized rocks a rim of albite (Table 1) around perthite is formed. The K-feldspar (Table 2) within perthite becomes turbid and this turbidity increases upto medium grade fenites. Pyroxene is medium-grained and yellowish-brown in colour. It is corroded and altered along the margins, and cleavages. Amphibole shows zoning with a taramite core and kataphorite margine in the low and medium grade fenites.

TABLE 1. ANALYSES OF NA-FELDSPAR FROM KOGA SYENITES

Analysis No.	1	2	3	4	5
Sample No.	K-4	K7P1	K34P1	K34P2	K25
SiO_2	68.499	67.727	67.935	68.801	67.609
TiO_2	00.000	00.000	00.057	00.031	00.134
Al_2O_3	19.374	19.478	19.571	19.426	19.366
FeO^T	00.000	00.177	00.059	00.155	00.322
MgO	00.000	00.092	00.011	00.000	00.014
CaO	00.021	00.217	00.183	00.063	00.049
Na_2O	10.269	10.871	10.973	10.733	10.903
K_2O	01.391	00.024	00.173	00.082	00.132
Total	99.609	98.704	99.013	99.314	98.662
			No. of oins on the basis of 32 Oxygens		
Si	12.033	11.970	11.971	12.050	11.970
Ti	00.000	00.000	00.008	00.004	00.018
Al	04.012	04.058	04.065	04.010	04.041
Fe	00.000	00.026	00.009	00.023	00.048
Mg	00.000	00.024	00.003	00.000	00.004
Ca	00.004	00.041	00.035	00.012	00.009
Na	03.498	03.725	03.749	03.644	03.743
K	00.312	00.005	00.040	00.018	00.030

TABLE 2. ANALYSES OF K-FELDSPAR FROM KOGA SYENITES

Analysis No.	1	2	3	4	5
Sample No.	K-4	K-7	K25	K34	K19
SiO_2	64.431	64.327	64.247	64.384	64.385
Al_2O_3	18.419	17.867	18.641	18.381	18.758
Fe_2O_3	00.146	00.046	00.061	00.171	00.017
MgO	00.058	00.000	00.141	00.211	00.216
CaO	00.126	00.101	00.033	00.107	00.000
Na_2O	00.538	00.484	00.481	00.838	00.574
K_2O	16.639	16.578	16.155	15.993	16.497
Total	100.357	99.403	99.759	100.085	100.447
		No. of oins on the basios of 32 Oxygens			
Si	11.924	12.000	11.887	11.906	11.877
Al	04.018	03.928	04.063	04.006	04.079
Fe^{3+}	00.023	00.015	00.009	00.026	00.003
Mg	00.016	00.000	00.039	00.058	00.059
Ca	00.025	00.200	00.007	00.021	00.000
Na	00.193	00.175	00.172	00.300	00.205
K	03.929	03.945	03.811	03.773	03.882

In medium and high grade fenites the rim of albite around perthite becomes double. A characteristic feature noticed is that the albite rim around one perthite grain is in optical continuity with the albite of the adjacent perthite and the rim around the another perthite is in optical continuity with the albite of the first grain. Such a rim of albite around perthite is also observed in nepheline syenites of south Greenland (Stephenson, 1976), in the fenites of north and south Ruri (Dixon and Collins, 1977) and in Sillai Patti fenites (Mian, 1986). The nature and behavior of the two rims is not fully understood. Different suggestions are given only for the single rim around perthite as follows:

1. The albite rim is formed due to unmixing and recrystalliztion of the initial homogeneous feldspar in the presence of sufficient supply of volatile materials (Tuttle and Bowen, 1954). The outcoming albit crystallized around the adjacent grain of perthite (Butt, personal communication).
2. This behavior of the rim may be due to the Carlsbad twinning of albite within the rim.

These suggestions can explain the behavior of one rim around perthite but the behavior of the double rim is difficult to explain therefore, interpretted as the result of fenitizing fluids emanating from carbonatite intrusions.

In low and medium grade fenites K-feldspar is turbid. Such a turbidity in the feldspar is also observed in the syenitic fenites of Sokli, Finland (Vartiainen and Woolley, 1976) and in Kangankunde Carbonatite, Malawi (Woolley, 1969). Woolley (1969) suggested that this turbidity may be the result of a change in the ratios of alkalies in feldspars. The turbidity increases up to medium-grade fenites and again decreases in the high grade fenites. In high grade fenites these feldspar are fresh, very coarse-grained and occur in the Cape rock on the top of the carbonatite at Naranji Kandau.

In high grade fenites K-feldspar and perthite are fresh, very coarse-grained, subhedral to euhedral. Medium-grained K-feldspar shows microcline twinning. However, twinned or un-twinned small grains of albite are also present in the coarse-grained perthite. Pyroxene shows zoning in the high grade fenites. Where the relic yellowish-green pyroxene is surrounded by the yellowish-brown pyroxene, the dusty brown rim around the relict green pyroxene is interpreted as the reaction rim between the original pyroxene of the protolith and fenitizing fluids. Even the core of zoned pyroxene is dusty at places. The fenitic pyroxene shows the trend of evolution from acmitic to diopsidic or hedenburgitic component in contrast to the magmatic trends. (Mian & Jabeen 1990). The amphibole in high grade fenites is magnesio-orfvedsonite and shows iron-leaching along the cleavages.

X-RAY POWDER DIFFRACTION DATA OF FELDSPARS

About 100 samples were used for the X-ray differaction study of feldspar. Selective X-ray diffraction data is given (Table 3). Feldspar was separated from the other minerals and then analysed. There were problems in distinguishing between low albite and acmite because the (331) and (330) planes of acmite have 2θ value 42.6 which could interfere with the 2θ value of (060) of the low albite. The peak position was measured at the estimated centre line of the top 1/3 of the peak. Pure CaF2 was used as a standard for the XRD work. Three X-ray powdered patterns for (204) and (060) were run for each sample using Cu Kα radiation at 1 per min for one run and 1/4 per min for two runs. The error calculated is based on the minimum and maximum of the three diffraction patterns (see Table 3).

2θ values for ($\bar{2}$04) and (060) planes of alkali-feldspars are plotted (Wright,1968). The plot (Fig.2) shows albite in unfenitized rocks has a 2θ (060) value of 42.40 and in the low grade fenites the value ranges from 42.40 to 42.50. In medium grade fenites these values range between 42.5 to 42.55 while in the high grade fenites these range between 42.55 to 42.80. This increase from 42.40 to 42.8 shows that the albite of high grade fenites, (especially in the sodium fenites), is more ordered as compared to the albite of low grade fenite, (particularly from albite in unfenitized rocks). This suggests that the albite in the highly fenitized rocks formed at a temperature lower than the albite present in the unfenitized rocks. In contrary to (060) little variation is present in ($\bar{2}$04) values which range between 50.10 and 50.16.

The K-feldspar plots mostly within the field suggested for maximum microcline. The tielines can be drawn between the coexisting Na- and K-feldspars but these tielines deviate from the generally agreed magmatic trend (Wright, 1967). The deviation of the tielines from the magmatic trend is also observed by Mian and Le Bas (1988) in Loe Shilman fenites.

DISCUSSION

The XRD data of low albite in the Koga syenites indicates that changes occur in the structural state of albite with increasing grade of fenitization. Magmatic albite or unfenitized albite (k-4) from Koga syenites plots as normal low albite (Fig.2) having a 2θ value of 42.40 for (060) plane whilst, albite from fenites of Koga plots as anomalous low albite. The 2θ value for (060) is 42.50 in the low grade fenites and reaches upto 42.80 in the high grade fenites.

The degree of orderness also increases with the increasing grade of fenitization. The magmatic albite and albite from low grade fenites are less ordered whilst, high grade fenites are relatively highly orderd (e.g Cape rocks of the Naranji Kandau carbonatite, which indicate a low temperature gradiant near the intrusion). Generally the highest temperatures within a fenite environment are proximal to the source of fenitization. At Koga the low temperature albite proximal to source of fenitization is obtained. This is due to the fact that the albite was initially present as magmatic albite in the Koga syenites, forming at higher temperatures of 800 -1000°C (Mian pers. commun.). The temperature of the carbonatites at Koga, Shilman and Silai Patti is determined by Mian and Le Bas (in prep.) as 350-500°C. This suggests that the albite which was proximal to the source of fenitization has been most affected by the low tempertature (350-500°C) fenitizing fluids. The orderness of albite decreases as the temperature and intensity of fenitization decreases. As a result the low grade fenites and unfenitized rocks preserved orignal less ordered (magmatic) low albite (Fig.2).

TABLE 3. XRD DATA OF FELDSPAR FROM KOGA SYENITES

Anal. No.	1	2	3	4	5	6
Sample No.	K-4	Kn-277A	Kn-24	K-26	Kn-23	K-10
K-feldspar						
2θ(060)	41.750 ±00.010	41.770 ±00.010	41.850 ±00.010	41.810 ±00.015	41.800 ±00.020	41.860 ±00.025
2θ($\bar{2}$04)	50.600 ±00.015	50.460 ±00.020	50.600 ±00.010	50.660 ±00.015	50.500 ±00.010	50.610 ±00.015
Na-feldspar						
2θ(060)	42.400 ±00.025	42.410 ±00.030	42.500 ±00.010	42.520 ±00.025	42.550 ±00.010	42.570 ±00.025
2θ($\bar{2}$04)	51.100 ±00.020	51.100 ±00.015	51.150 ±00.010	51.160 ±00.015	51.100 ±00.030	51.170 ±00.015
Anal. No.	7	8	9	10	11	12
Sample No.	Kn-26	Kn-57	Kn-239	Kn-47	Kn-44	Kn-45
K-feldspar						
2θ(060)	41.850 ±00.025	41.800 ±00.010	41.800 ±00.015	41.800 ±00.025	41.800 ±00.025	41.750 ±00.025
2θ($\bar{2}$04)	50.600 ±00.025	50.500 ±00.015	50.560 ±00.010	50.600 ±00.015	50.550 ±00.015	50.500 ±00.015
Na-feldspar						
2θ(060)	42.600 ±00.015	42.620 ±00.010	42.660 ±00.015	42.700 ±00.020	42.750 ±00.015	42.800 ±00.010
2θ($\bar{2}$04)	51.100 ±00.010	51.150 ±00.015	51.160 ±00.020	51.100 ±00.010	51.100 ±00.010	51.100 ±00.010

Anlyses No.1 alkali-feldspar from unfenitized rocks.
Analyses No.2 alkali-feldspar from low grade fenites.
Analyses No.3-5 alkali-feldspar from medium grade fenites.
Analyses No. 6-12 alkali-feldspar from high grade fenites.
Values in brackets are errors for each sample.

CONCLUSION

1. the magmatic alkali feldspars in the Koga syenites are low albite and maximum microcline whilst, fenitic Na-feldspar is anomalous low albite.
2. The degree of orderness also increases with the increasing grade of fenitization.
3. In the low grade fenites albite has retained its original magmatic structure whilst, in the high grade fenites it has become more ordered.
4. The tielines between the co-existing Na- and K-feldspar deviat from the generally agreed magmatic trend.

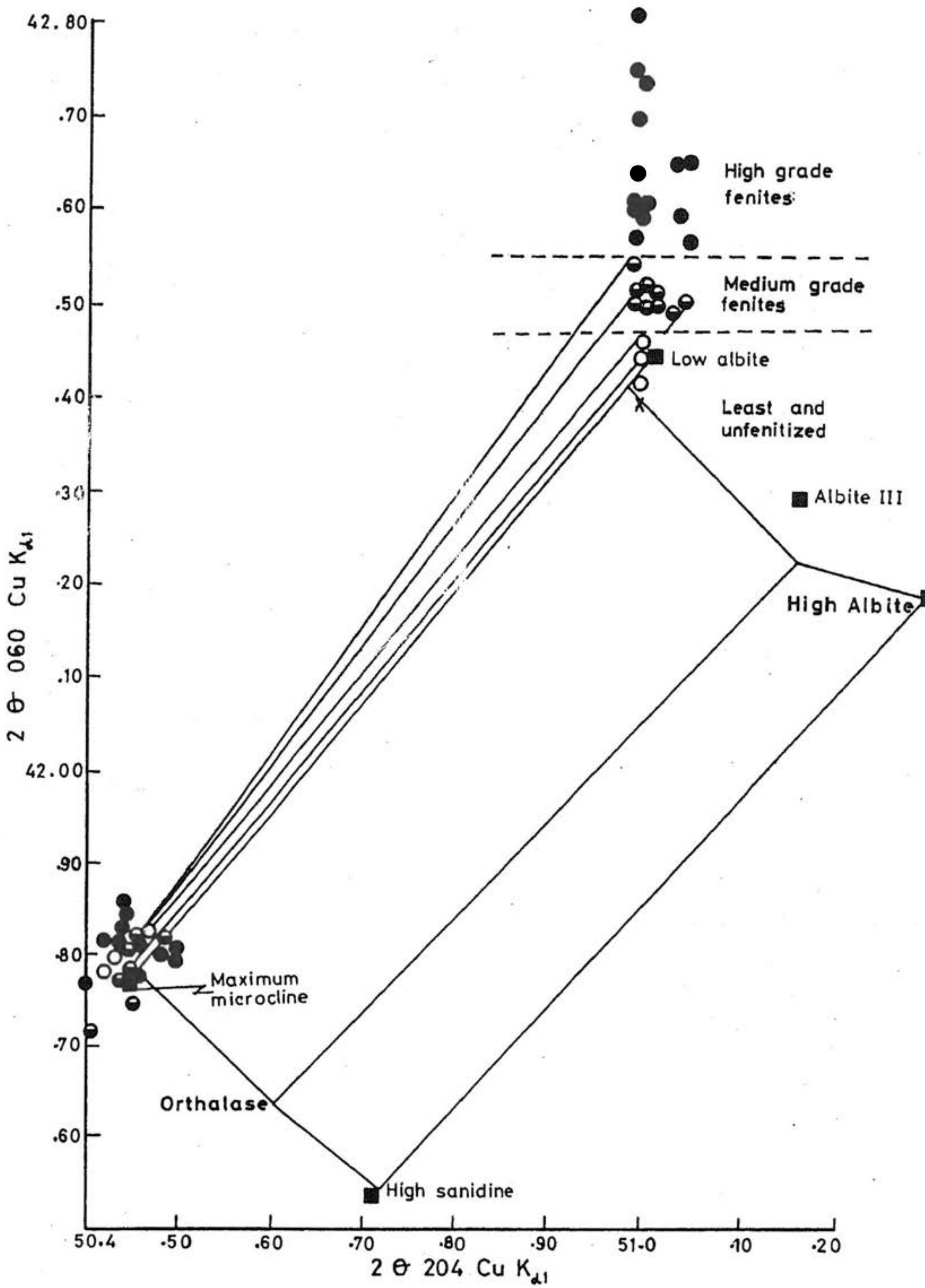

Fig. 2. The structural state of Na-feldspar and K-feldspar in Koga syenites showing low albite of fenitized rocks plots as anomalously low albite. The tie lines between maximum microline and anomalously low albite deviate from the tie line existing between magmatic maximum microcline and low albite (after Wright, 1968). X = magmatic albite; open circles = albite from low grade fenites, half filled circles = albite from medium grade fenites, filled circles = albite from high grade fenites.

Aknowledgments: The data presented in this paper constitutes a part of M.Pill. thesis of Nusrat Jabeen. We would like to thanks Drs.M.j.Le Bas and Mike Patterson for fruitful discussion and critical reading of the manuscript. NCE in Geology provided analytical facilities.

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