CHAPTER 5. MINERAL CHEMISTRY

5.1 Introduction

To understand the mineral chemistry, the Electron Probe Micro Analysis (EPMA) was carried out for all important mineral phases present in the calc-silicate rocks with the help of CAMECA SXFive instrument at DST-SERB National Facility, Department of Geology (Center of Advanced Study), Institute of Science, Banaras Hindu University. Polished thin sections of total six calc-silicate rock samples were coated with 20 nm thin layer of carbon for electron probe micro analyses using LEICA-EM ACE200 instrument. The CAMECA SXFive instrument was operated by SXFive Software at a voltage of 15 kV and current 10 nA with a W source in the electron gun for generation of electron beam. Natural mineral standards: fluorite, halite, periclase, corundum, wollastonite, apatite, orthoclase, rutile, chromite, rhodonite, hematite, celestine, barite and pure metal V, Ni, Zn standard supplied by CAMECA-AMETEK used for routine calibration and quantification. A total of 531 points of various mineral phases were analysed. Mineral chemistry of all important mineral phases present within the calc-silicates is discussed in the following sections.

5.2 Calcic-amphibole

Representative analytical data of the calcic-amphibole is listed in the (Table 5.1) and plotted in the (Fig.5.1) All analysed amphiboles can be classified as calcic amphiboles (after Leake,1978).In the nomenclature suggested by Leake (1978), these calcic amphiboles correspond to magnesio-hornblende to actinolite with $(Na+K)_A < 0.5$ apfu, $Ti < 0.5$ apfu.(Table II, Leake et al.,1997). Those amphiboles which are plotted as magnesio-hornblendes contain 6.97-7.34 apfu Si, 0.93-1.24 apfu Al^{tot}, 1.92-1.97 apfu Ca and (Mg / Mg+ Fe^{2+} or X_{Mg})values between 0.66 to 0.73 and actinolites contain 7.5 to 7.74 apfu Si, 0.39-0.82 apfu Al^{tot},1.94-2.01 apfu Ca and X_{Mg} values between 0.75 to 0.78. Sodium and K are present in amounts from 0.02 to 0.22 apfu while Mn and Ti are present in amounts from 0.005 to 0.08 apfu.

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Table 5.1: Representative EPMA analyses of Calcic-amphibole

Rock No.	Prs-10/3	Prs-10/1	Prs-10/8	Rgp-13/2	Rgp-13/5	Bor-10/12	Bor-10/1	Asnd-17/2	Ora-6/1
SiO_2	50.55	52.21	53.84	49.71	51.79	48.97	53.61	47.75	49.33
TiO_2	0.15	0.13	0.073	0.16	0.094	0.31	0.046	0.40	0.27
Al_2O_3	5.51	4.88	2.91	6.35	4.06	6.73	2.29	7.21	6.94
FeO	10.21	9.42	9.28	11.18	10.22	11.59	8.55	12.90	10.48
MnO	0.43	0.68	0.59	0.33	0.19	0.36	0.50	0.49	0.39
MgO	15.58	16.11	17.24	13.92	15.72	14.77	17.35	14.051	15.05
CaO	12.73	12.61	12.96	12.49	12.72	12.41	12.88	12.53	12.62
Na_2O	0.52	0.46	0.31	0.65	0.41	0.60	0.19	0.78	0.60
K_2O	0.43	0.30	0.14	0.68	0.30	0.55	0.108	0.70	0.51
Total	96.16	96.85	97.37	95.52	95.53	96.35	98.81	96.85	96.24
Ions on the basis of 23(O)									
Si	7.27	7.51	7.74	7.34	7.65	7.09	7.76	6.97	7.21
Ti	0.017	0.015	0.008	0.018	0.01	0.034	0.005	0.044	0.03
Al	0.93	0.82	0.49	1.10	0.70	1.15	0.39	1.24	1.196
Fe^{+2}	1.22	1.13	1.11	1.38	1.26	1.40	1.036	1.57	1.28
Mn	0.053	0.084	0.07	0.042	0.0239	0.044	0.061	0.061	0.049
Mg	3.34	3.45	3.69	3.065	3.46	3.18	3.74	3.06	3.280
Ca	1.96	1.94	1.99	1.97	2.014	1.92	1.99	1.96	1.97
Na	0.14	0.12	0.087	0.18	0.119	0.170	0.054	0.22	0.17
K	0.08	0.057	0.027	0.12	0.056	0.102	0.019	0.13	0.095
X_{Mg}	0.73	0.75	0.76	0.69	0.73	0.69	0.78	0.66	0.71

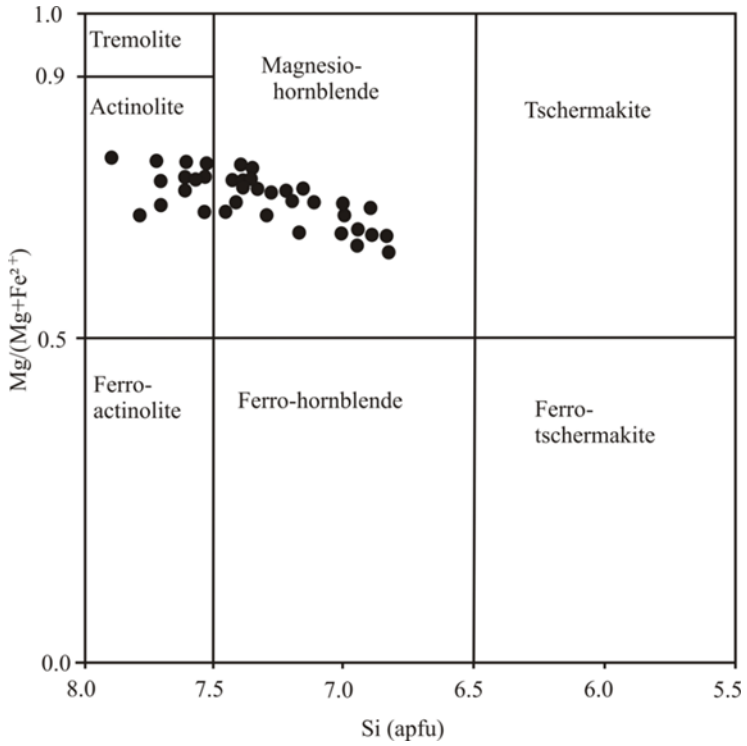

Figure 5.1: Ca-amphibole, classification scheme after Leake et al., (1997).

5.3 Clino-pyroxene

Coarse to medium grained Clino-pyroxene (Cpx) makes most of the groundmass of these rocks. Representative chemical compositions of the analysed Cpx are listed in (Table 5.2).Cpx, here, is essentially a diopside-hedenbergite solid solution, (Wo_{49-50}, En_{36-39}, Fs_{10-13}). The composition is salitic to diopsidic with X_{Mg} ranging between 0.74 and 0.82. The X_{Mg} is showing variation between different samples and also within the same samples because of the variation in bulk rock chemistry.

In these analyses Al is both tetrahedrally and octahedrally co-ordinated. Most of the analysed clinopyroxenes fall in the salitic field in the Ca-Mg-Fe triangular plot (Fig.5.2). Clinopyroxenes contain 1.95- 2.03 apfu of Si, 0.01-0.2 apfu of Al^{tot}, Fe^{3+}0.1-0.2 apfu. Manganese compositions are between 0.007 and 0.02 apfu, Na ranges from 0.007-0.01 apfu and K shows wide variation ranging from 0.0003-0.02 apfu.

Table 5.2: Representative EPMA analyses of Clino-pyroxene

Rock no.	Prs-10/2	Rgp-13/2	Rgp-13/3	Rgp-13/5	Bor-10/1	Ora-6/1	Ora-6/5	Ora-6/6	Ora-6/7
SiO_2	54.71	53.76	51.96	52.43	52.41	52.01	53.7	53.24	52.28
TiO_2	0.032	0.007	0.00	0.019	0.035	0.015	0.012	0.022	0.14
Al_2O_3	5.56	0.57	0.60	0.39	0.74	0.64	0.49	0.57	1.56
Cr_2O_3	0.928	0.043	0.028	0.02	0.04	1.19	0.027	0.066	0.06
FeO	4.37	7.39	8.16	7.59	6.60	7.29	7.16	6.94	7.15
MnO	0.62	0.26	0.60	0.44	0.66	0.22	0.46	0.26	0.44
MgO	10.44	12.90	13.11	13.27	13.87	13.44	13.74	13.96	12.90
CaO	18.53	24.71	24.77	24.85	24.81	24.02	24.91	24.92	24.30
Na_2O	0.16	0.19	0.18	0.11	0.20	0.18	0.11	0.098	0.17
K_2O	4.23	0.00	0.00	0.00	0.001	0.062	0.009	0.009	0.007
Total	99.61	99.87	99.42	99.14	99.40	99.09	100.67	100.11	99.05
Ions on the basis of 6(O)									
Si	2.038	2.01	1.95	1.97	1.95	1.95	1.98	1.97	1.96
Ti	0.0009	0.0001	0.00	0.0005	0.0009	0.0004	0.0003	0.0006	0.004
Al	0.24	0.025	0.026	0.017	0.032	0.028	0.021	0.025	0.069
Cr	0.027	0.001	0.0008	0.0006	0.0011	0.035	0.0007	0.0019	0.002
Fe(ii)	0.13	0.23	0.25	0.23	0.20	0.22	0.22	0.21	0.22
Mn	0.019	0.008	0.019	0.014	0.021	0.007	0.014	0.0084	0.014
Mg	0.58	0.71	0.734	0.745	0.772	0.75	0.75	0.77	0.72
Ca	0.73	0.99	0.997	1.001	0.99	0.96	0.98	0.99	0.97
Na	0.011	0.014	0.013	0.008	0.015	0.013	0.0079	0.007	0.013
K	0.20	0.00	0.00	0.00	0.00	0.003	0.0004	0.0004	0.0003
X_{Mg}	0.81	0.75	0.74	0.78	0.79	0.77	0.77	0.82	0.76
Pyroxene components									
Wo	49.68	50.41	49.39	49.91	49.47	49.11	49.63	49.70	50.08
En	38.95	36.61	36.38	37.11	38.50	38.23	38.11	38.73	37.01
Fs	10.57	12.23	13.56	12.56	11.27	11.96	11.85	11.20	12.22

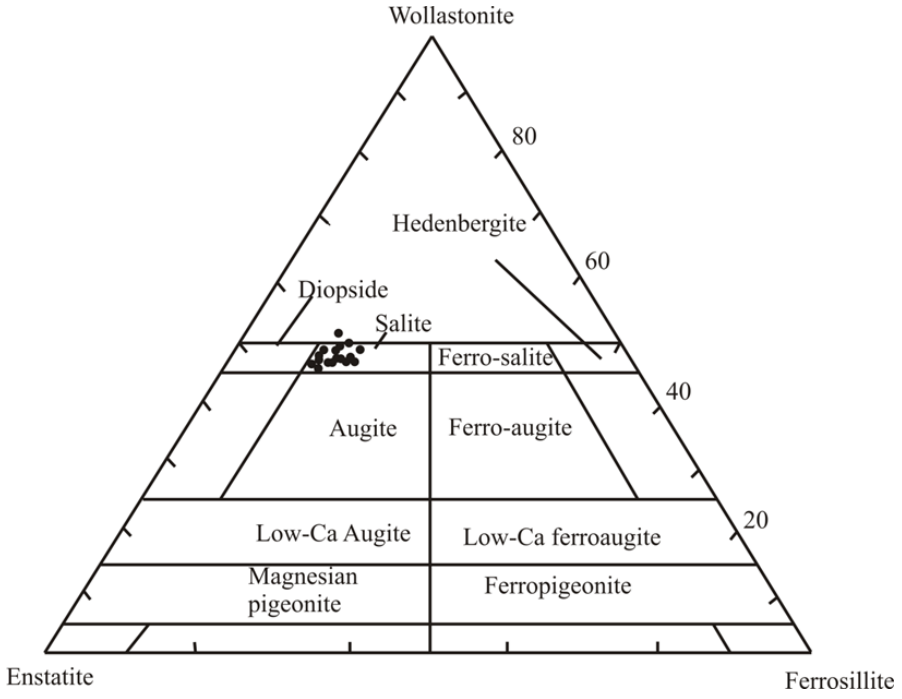

Figure 5.2 : Ca-Mg-Fe triangular plot showing Clino-pyroxene composition.

5.4 Titanite

Titanite contains 0.95 -1.02 apfu Ca, 0.81-0.91 apfu Ti, 0.14-0.39 apfu Al. Mg is below detection limit. A typical titanite has the formula $Ca_{1.02}$ ($Ti_{0.91}Al_{0.19}$ $Fe_{0.006}$) $Si_{0.98}$ ($F_{0.00}$ $Cl_{0.0007}$). Sodium, Mn, K and Ba were measured in amounts 0.00-0.074 wt % oxide concentrations (Table 5.3).

5.5 Microcline

Microcline present within these rocks makes most of the groundmass along with clino-pyroxene. Representative microprobe analyses of the microcline are listed in the (Table 5.4) and have a representative composition of $Or_{94.9}Ab_{5.07}An_{0.00}$. A chemical formula of ($K_{3.8}Na_{0.2}Ba_{0.003}$) ($Si_{11.97}$ $Al_{4.30}$)O_{32} is representative of analysed microcline in these rocks and contain < 3.8 apfu K, Na-content (0.20-0.35 apfu),Al^{tot} (4.02- 4.30 apfu), 11.80-11.97 apfu of Si and 0.003-0.08 apfu Ba.

Table 5.3: Representative EPMA analyses of Titanite

Rock no.	Prs-10/3	Prs-10/6	Rgp-13/2	Rgp-13/4	Bor-10/3	Bor-10/6	Ora-6/4	Ora-6/6	Ora-6/8
SiO_2	30.06	30.74	29.55	30.19	29.15	30.23	32.29	29.79	30.73
TiO_2	37.22	33.74	36.61	35.43	37.09	36.70	35.27	36.76	37.18
Al_2O_3	2.25	4.66	1.66	3.38	1.81	2.15	3.33	2.22	2.63
FeO	0.24	0.28	0.69	0.29	0.38	0.54	0.65	0.38	0.37
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.18	0.00	0.014	0.00	0.058	0.11	0.074	0.074	0.11
CaO	29.10	29.31	28.66	29.14	28.19	28.77	28.02	28.59	29.10
Na_2O	0.038	0.060	0.033	0.03	0.00	0.04	0.00	0.00	0.00
K_2O	0.013	0.012	0.0029	0.01	0.08	0.005	0.08	0.04	0.02
Cr_2O_3	0.042	0.050	0.083	0.05	0.30	0.064	0.07	0.08	0.08
P_2O_5	0.60	0.58	0.54	0.58	0.53	0.59	0.58	0.64	0.59
BaO	0.17	0.38	0.51	0.36	0.31	0.46	0.47	0.10	0.52
ZrO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nb_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.68	0.02	0.56	0.42	0.20	0.59	0.48	0.43
Cl	0.010	0.016	0.01	0.007	0.03	0.00	0.010	0.02	0.012
Total	99.92	100.05	98.38	100.02	98.34	99.85	102.01	99.17	101.7
Ions on the basis of 5(O)									
Si	0.98	0.99	0.97	0.97	0.96	0.98	1.02	0.97	0.98
Ti	0.91	0.81	0.91	0.85	0.91	0.89	0.84	0.90	0.89
Al	0.19	0.39	0.14	0.28	0.158	0.18	0.28	0.193	0.22
Fe	0.0066	0.007	0.019	0.007	0.010	0.014	0.017	0.01	0.009
Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn	0.005	0.00	0.0004	0.00	0.0016	0.003	0.001	0.002	0.003
Ca	1.02	1.01	1.017	1.005	0.99	1.002	0.95	1.005	0.99
Na	0.002	0.003	0.002	0.002	0.00	0.002	0.00	0.00	0.00
K	0.0005	0.0005	0.0001	0.0006	0.003	0.0002	0.032	0.0019	0.0008
P	0.052	0.049	0.047	0.05	0.046	0.0511	0.048	0.055	0.05
Ba	0.002	0.004	0.0067	0.004	0.004	0.005	0.005	0.001	0.006
Zr	0.00	0.00	0.009	0.005	0.006	0.00	0.00	0.00	0.00
Nb	0.00	0.00	0.073	0.087	0.089	0.00	0.00	0.00	0.00
F	0.00	0.07	0.002	0.057	0.044	0.02	0.059	0.050	0.043
Cl	0.0005	0.0009	0.0007	0.0003	0.001	0.00	0.0005	0.001	0.0006

Table 5.4: Representative EPMA analysis of Microcline

Rock no.	Prs-10/1	Prs-10/2	Bor-10/1	Bor-10/2	Ora-6/1	Ora-6/2	Asnd-17/1	Asnd-17/2
SiO_2	64.07	63.32	63.89	64.28	62.18	64.08	63.51	63.96
Al_2O_3	18.6	18.26	18.59	18.63	18.85	18.27	18.25	18.30
FeO	0.037	0.136	0.00	0.045	0.135	0.00	0.06	0.13
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na_2O	0.61	0.56	0.71	0.74	0.978	0.978	0.637	0.55
K_2O	16.02	15.96	15.7	15.55	14.73	15.27	15.84	15.90
BaO	0.7	0.44	0.53	0.16	1.18	0.214	0.53	0.05
Total	100.03	98.67	99.42	99.40	98.05	98.81	98.82	98.90
Ions on the basis of 32(O)								
Si	11.91	11.92	11.91	11.94	11.80	11.97	11.93	11.97
Al	4.07	4.05	4.08	4.07	4.21	4.02	4.04	4.30
Fe(ii)	0.005	0.021	0.00	0.006	0.02	0.00	0.009	0.022
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.21	0.20	0.25	0.26	0.35	0.35	0.23	0.20
K	3.79	3.83	3.73	3.68	3.56	3.64	3.79	3.79
Ba	0.05	0.032	0.038	0.01	0.08	0.015	0.039	0.003
Feldspar components								
An	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ab	5.47	5.06	6.43	6.74	9.16	8.87	5.75	5.08
Or	94.52	94.93	93.56	93.25	90.83	91.12	94.24	94.93

5.6 Biotite

Representative microprobe analyses of the biotite are listed in the (Table 5.5). It has a variable Ti content ranging from 1.42 to 2.22 wt %. The Ti content of biotite present in calc-silicates lying closer to the granitic intrusion is higher than those lying away from it on account of increase in temperature. Their X_{Mg} composition range is between 0.62 to 0.66. The Al^{IV} composition increases with the increase in distance from intrusion (2.44 to 2.58 apfu). On the Al vs. Fe/(Fe + Mg) diagram of Deer et al.,(1992), biotites of these calc-silicate rocks lie in the biotite zone but very near to phlogopite boundary (Fig.5.3) with their Fe/Mg+ Fe ratio ranging from (0.33-0.37 apfu).

Table 5.5: Representative EPMA analyses of Biotite

Rock no.	Prs-10/2	Bor-10/3	Bor-10/5	Bor-10/6	Bor-10/3	Asnd-17/5	Chr-11/7	Chr-12/11
SiO_2	36.38	37.00	37.22	36.86	37.39	36.09	37.09	36.52
TiO_2	2.18	2.22	2.14	1.75	1.59	1.57	1.48	1.42
Al_2O_3	16.06	16.16	15.86	16.47	16.01	15.95	15.74	16.09
FeO	14.45	13.67	13.97	13.32	14.91	14.88	14.38	14.12
MnO	0.36	0.27	0.31	0.17	0.18	0.27	0.34	0.34
MgO	14.54	13.75	14.54	14.77	13.90	14.65	14.09	14.6
CaO	0.00	0.00	0.00	0.00	0.05	0.027	0.04	0.00
Na_2O	0.06	0.10	0.012	0.07	0.06	0.056	0.18	0.11
K_2O	9.11	9.43	9.95	9.55	9.83	9.88	9.51	9.39
BaO	0.41	0.10	0.00	0.00	0.00	0.00	0.051	0.20
F	0.90	0.81	0.90	0.84	0.38	0.40	0.32	0.91
Cl	0.00	0.06	0.006	0.01	0.02	0.02	0.01	0.06
Total	98.63	98.03	99.38	98.57	99.33	98.31	98.11	98.26
Ions on the basis of 22(O)								
Si	5.46	5.55	5.53	5.51	5.56	5.46	5.58	5.50
Ti	0.24	0.25	0.30	0.19	0.37	0.17	0.16	0.16
Al iv	2.53	2.44	2.46	2.48	2.43	2.58	2.41	2.49
Al vi	0.31	0.41	0.23	0.41	0.37	0.30	0.37	0.36
Fe	1.81	1.71	1.73	1.66	1.85	1.88	1.81	1.77
Mn	0.007	0.01	0.009	0.008	0.01	0.035	0.04	0.04
Mg	3.25	3.078	3.22	3.29	3.08	3.30	3.16	3.29
Ca	0.046	0.035	0.04	0.02	0.02	0.004	0.007	0.02
Na	0.02	0.03	0.003	0.021	0.019	0.01	0.05	0.03
K	1.74	1.80	1.88	1.82	1.86	1.90	1.82	1.80
Ba	0.02	0.006	0.00	0.00	0.00	0.00	0.003	0.012
F	0.42	0.38	0.42	0.40	0.18	0.19	0.15	0.43
Cl	0.00	0.016	0.0017	0.002	0.007	0.005	0.004	0.017
X_{Mg}	0.64	0.64	0.65	0.66	0.62	0.64	0.63	0.65

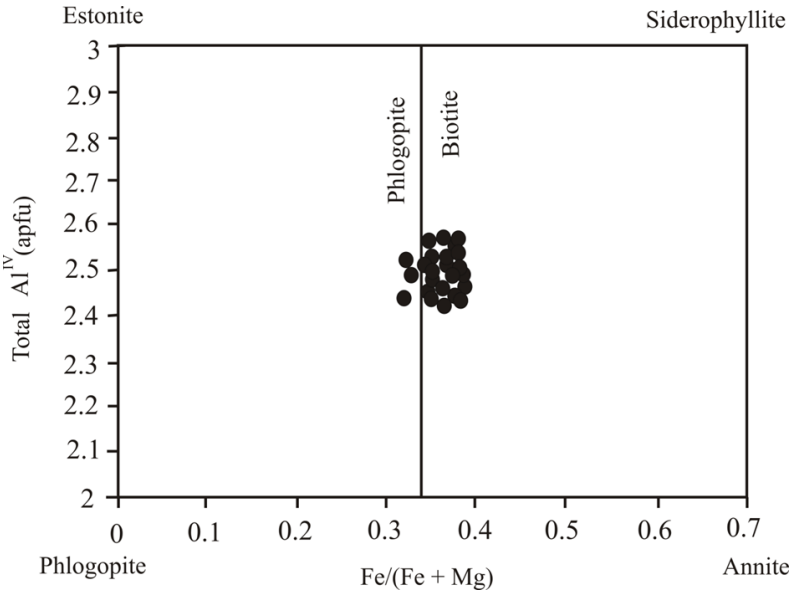

Figure 5.3 : Mica, classification scheme after Deer et al., (1992).

5.7 Epidote

Representative microprobe analyses of the epidote are listed in the (Table 5.6).All epidote analyses contain 2.28-3.18 apfu Si, 2.34-2.54 apfu Al^{tot}, 1.98-2.03 apfu Ca. These epidotes are rich in Fe^{3+}, in these calc-silicates it is in amount 0.46- 0.65 apfu. K was measured at 0.00-0.006 apfu. Manganese is present in amounts of 0.00-0.009 apfu. Na and Mg present are below detection limit.

5.8 Plagioclase Feldspar

Representative microprobe analyses of the plagioclase feldspar from these rocks are listed in the (Table 5.7). Plagioclase feldspars, here, are non-homogeneous with chemical composition not much constant i.e Na contents (An_{22}- An_{61}). They have a composition range from oligoclase to labradorite on the An-Ab-Or ternary diagram (Fig.5.4) with Or content < 8 mole%.

5.9 Scapolite

Representative microprobe analysis of the scapolite is listed in the (Table 5.8). It reveals that these scapolites are Cl-absent calcic-rich meionites. The Ca/(Ca+Na+K) ratios in these scapolites are seen to vary between 0.94 and 1 and the meionite component varies from 93.7% to 99.8%. Analytical totals range from 97 to 99% suggesting CO_2 +H_2O to be about 1 to 3% . F, Cl and SO_3 occur below detection limit.

Table 5.6: Representative EPMA analyses of Epidote

Rock no.	Prs-10/1	Prs-10/2	Bor -10/1	Bor-10/2	Bor-10/3	Bor-10/4
SiO_2	37.38	37.60	38.11	37.57	37.33	37.05
TiO_2	0.03	0.08	0.58	0.04	0.05	0.00
Al_2O_3	26.22	27.19	25.64	27.10	25.65	24.74
Fe_2O_3	9.44	7.83	9.46	8.11	8.93	9.71
MnO	0.32	0.22	0.19	0.14	0.20	0.11
MgO	0.00	0.00	0.00	0.00	0.00	0.00
CaO	23.28	23.48	23.44	23.65	23.55	23.68
Na_2O	0.00	0.06	0.06	0.00	0.00	0.00
K_2O	0.00	0.05	0.00	0.005	0.00	0.06
Total	96.67	96.51	97.49	97.51	96.70	96.43
Ions on the basis of 12.5(O)						
Si	2.62	3.18	2.67	2.76	2.49	2.28
Ti	0.002	0.005	0.03	0.002	0.003	0.00
Al	2.46	2.54	2.38	2.51	2.41	2.34
Fe^{+3}	0.56	0.46	0.56	0.53	0.59	0.65
Mn	0.02	0.01	0.01	0.009	0.014	0.007
Mg	0.00	0.00	0.00	0.00	0.00	0.00
Ca	1.98	1.99	1.98	1.99	2.013	2.03
Na	0.00	0.009	0.009	0.00	0.00	0.00
K	0.00	0.005	0.001	0.001	0.00	0.006

Wt% Fe_2O_3 = Wt%FeO*159.692/(2*71.846) = Wt%FeO*(1.111349275)

Mole Fe_2O_3 = Wt%Fe_2O_3/159.692 = Wt%FeO/(2*71.846)

5.10 Chlorite

Chlorite is present in very few samples and almost in trace amount. Chemical characterisation revealed that they possess composition ranging from pycnochlorite to clinochlore (Fig.5.5). A typical formula of this chlorite is, $K_{0.005–0.01}$ $Na_{0.00–0.13}$ $Fe^{2+}_{1.18\text{-}3.83}$ $Mg_{3.68\text{-}9.21}$ $Mn_{0.01–0.1}$ $Cr_{0.00–0.0009}$ $Al_{2.26\text{-}2.47}$ $Ti_{0.006–0.013}$) · ($Si_{5.62–5.73}$ $Al_{1.83\text{-}3.04}$) · O_{20} (OH) $_{16.}$ Analytical data is presented in (Table 5.8).

Table 5.7: Representative EPMA analysis of Plagioclase Feldspar

Rock no.	Prs-10/1	Prs-10/5	Rgp-13/3	Bor-10/1	Ora-6/1	Ora-6/5	Asnd-17/3	Asnd-17/6
SiO_2	52.73	55.07	60.14	53.04	53.21	61.4	55.07	60.14
Al_2O_3	29.53	27.94	24.35	29.96	28.67	23.7	27.94	24.35
FeO	0.13	0.14	0.00	0.03	0.00	0.15	0.14	0.00
CaO	12.58	10.34	5.72	12.09	11.67	4.53	10.34	5.72
Na_2O	4.34	5.98	8.68	4.70	5.50	8.14	5.98	8.68
K_2O	0.11	0.14	0.21	0.12	0.10	1.35	0.14	0.21
BaO	0.13	0.00	0.00	0.26	0.00	0.05	0.00	0.00
Total	99.57	99.64	99.13	100.23	99.17	99.41	99.61	99.10
Ions on the basis of 32(O)								
Si	9.61	9.97	10.81	9.60	9.72	11.01	9.97	10.81
Al	6.34	5.96	5.15	6.39	6.17	5.004	5.96	5.15
Fe(ii)	0.02	0.02	0.00	0.004	0.00	0.02	0.021	0.00
Ca	2.45	2.006	1.10	2.34	2.28	0.87	2.00	1.10
Na	1.53	2.10	3.02	1.64	1.95	2.83	2.10	3.02
K	0.026	0.03	0.05	0.029	0.024	0.30	0.032	0.048
Ba	0.009	0.00	0.00	0.018	0.00	0.003	0.00	0.00
Feldspar components								
An	61.13	48.45	26.36	58.28	53.64	21.72	48.48	26.38
Ab	38.20	50.73	72.44	40.98	45.76	70.56	50.73	72.45
Or	0.65	0.81	1.19	0.72	0.58	7.71	0.78	1.15

5.11 Apatite

Apatite contains 5.65-5.75 apfu P, 9.60-9.82 apfu Ca, 0.005-0.085 apfu Si and 1.55-1.91 apfu F. Sodium,Fe and Mn are present in trace amount i.e.< 0.04 apfu. Sr, Mg and Cl are below detection limit. Analytical data is given in (Table 5.9).

5.12 Ilmenite

Representative EPMA analyses of ilmenite are given in (Table 5.9). As ilmenite is an opaque mineral and an oxide of iron, it possesses higher amount of Fe i.e. near about 1.88 apfu and 2.005-2.034 apfu Ti. Manganese is nearly 0.057 apfu. Sodium and K are in amount < 0.04 apfu. while Cr and Mg are present in trace amount.

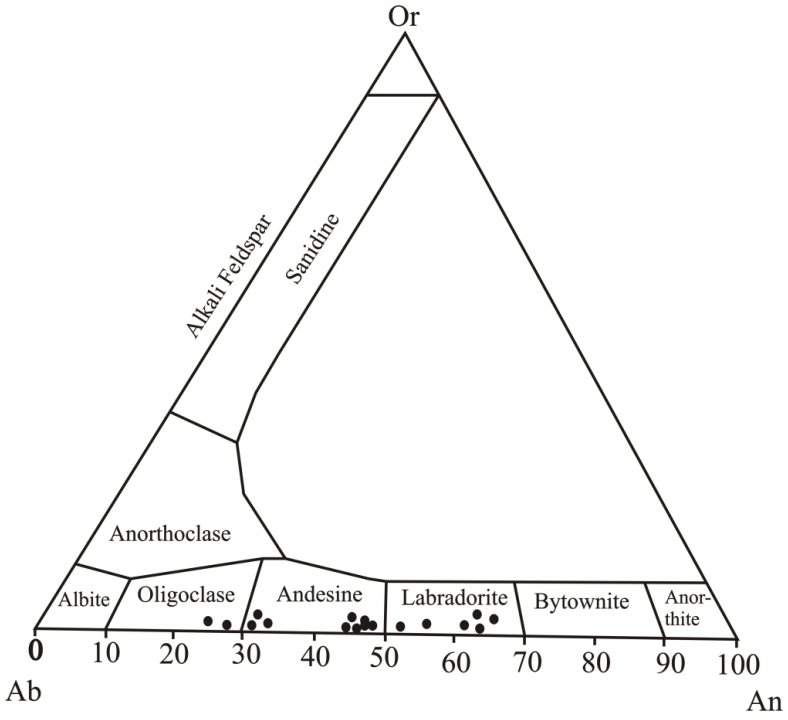

Figure 5.4: An-Ab-Or diagram showing plagioclase feldspar having composition range from (An_{22}-An_{61})

Table 5.8: Representative EPMA analysis of Scapolite and Chlorite

Scapolite					Chlorite				
Rock no.	Bor-10/1	Bor-10/2	Bor-10/3	Bor-10/4	Rock no.	Prs-10/1	Prs-10/2	Prs-10/3	Bor-10/3
SiO_2	43.44	44.16	44.66	42.81	SiO_2	30.3	28.32	26.49	25.35
TiO_2	0.015	0.00	0.00	0.00	TiO_2	0.00	0.09	0.04	0.08
Al_2O_3	31.36	34.74	34.95	34.86	Al_2O_3	18.25	19.03	21.32	19.92
FeO	0.75	0.11	0.02	0.22	Cr_2O_3	0.00	0.00	0.05	0.005
MnO	0.00	0.00	0.00	0.00	FeO	6.36	15.92	25.17	28.22
MgO	0.00	0.00	0.00	0.00	MnO	0.00	0.09	0.30	0.54
CaO	22.89	19.22	19.18	19.08	MgO	32.66	23.72	11.64	12.18
Na_2O	0.00	0.69	0.74	0.86	CaO	0.00	0.00	1.10	0.00
K_2O	0.046	0.00	0.00	0.0038	Na_2O	0.03	0.62	0.13	0.00
F	0.038	0.00	0.00	0.00	K_2O	0.00	0.01	0.02	0.01
Cl	0.00	0.0068	0.0067	0.00	BaO	0.00	0.00	0.00	0.19
					F	0.00	0.00	0.47	0.54
					Cl	0.00	0.00	0.01	0.028
					H_2O*	12.58	11.90	10.60	10.03
Total	98.88	98.92	99.55	97.83	Total	100.18	99.77	97.40	97.09
					O=F,Cl	0.00	0.00	0.20	0.23
					Total	100.18	97.77	97.20	97.32
Ions on the basis of 12(Si,Al)					Ions on the basis of 28(O)				
Si	6.54	6.512	6.73	6.62	Si	5.73	5.65	5.62	5.67
Ti	0.0009	0.00	0.00	0.00	Al^{iv}	2.26	2.34	2.37	2.47
Al	4.171	4.518	4.61	4.6	Al^{vi}	1.83	2.14	3.04	2.82
Fe	0.045	0.0044	0.0018	0.013	Ti	0.00	0.01	0.006	0.013
Mn	0.00	0.00	0.00	0.00	Cr	0.00	0.00	0.008	0.0009
Mg	0.00	0.00	0.00	0.00	Fe^{2+}	1.18	2.73	3.50	3.83
Ca	1.847	1.515	1.548	1.637	Mn	0.00	0.015	0.053	0.10
Na	0.00	0.097	0.099	0.117	Mg	9.21	7.06	3.68	4.03
K	0.0036	0.00	0.00	0.00	Ca	0.00	0.00	0.25	0.00
F	0.0067	0.00	0.00	0.00	Na	0.022	0.13	0.01	0.00
Cl	0.00	0.00	0.00	0.00	K	0.00	0.007	0.01	0.005
					Ba	0.00	0.00	0.00	0.03
Mol%					F	0.00	0.00	0.63	0.75
Meionite	99.83	93.71	94.50	93.75	Cl	0.00	0.00	0.0007	0.021
					OH*	16	16	15.36	15.21
					X_{Mg}	0.88	0.72	0.51	0.51

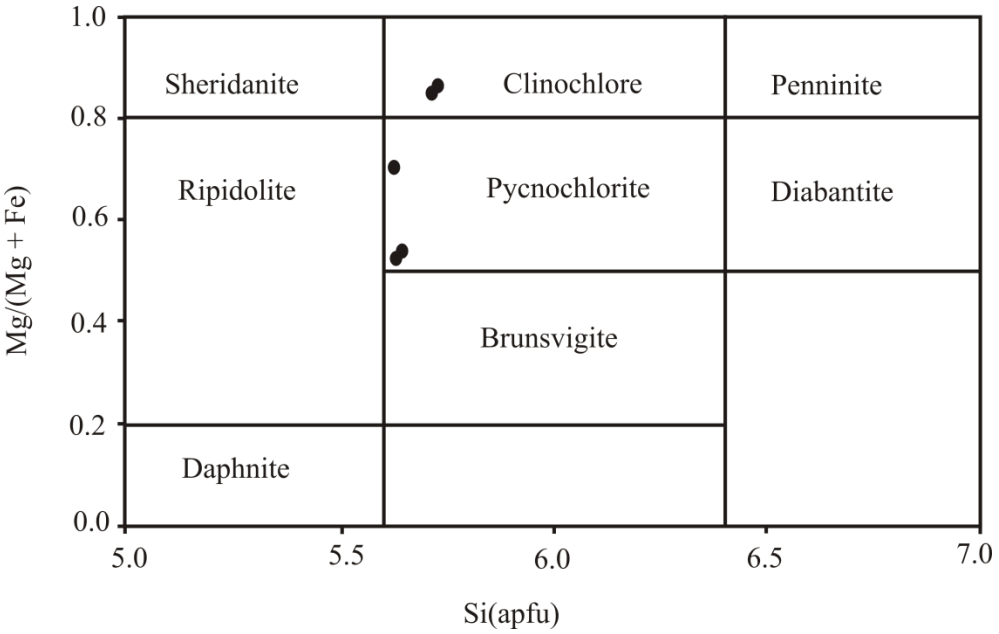

Figure 5.5: Nomenclature and classification of Chlorite (after Hey,1954).

Table 5.9: Representative EPMA analyses of Apatite and Ilmenite

Apatite					Ilmenite			
Rock no.	Prs-10/1	Rgp-13/5	Bor-10/6	Chr-12/8	Rock no.	Chr-12/1	Chr-12/3	Asnd-17/3
CaO	57.14	55.72	56.00	54.76	SiO_2	0.19	0.00	0.00
Na_2O	0.04	0.00	0.11	0.00	TiO_2	52.44	53.33	53.45
SrO	0.00	0.00	0.00	0.00	Al_2O_3	0.00	0.00	0.00
FeO	0.00	0.1	0.23	0.11	Cr_2O_3	0.00	0.01	0.19
MnO	0.00	0.08	0.05	0.08	FeO	44.36	43.99	44.54
MgO	0.00	0.00	0.00	0.00	MnO	1.3	1.24	1.34
P_2O_5	42.71	40.67	41.69	40.95	MgO	0.1	0.08	0.05
SiO_2	0.04	0.36	0.27	0.52	CaO	0.00	0.00	0.00
Cl	0.00	0.00	0.00	0.00	Na_2O	0.40	0.08	0.11
F	3.31	3.51	3.03	3.69	K_2O	0.06	0.02	0.03
	103.24	100.44	101.38	100.11	Total	98.85	98.75	99.71
O≡ F,Cl	1.39	1.47	1.27	1.55				
Total	101.84	98.96	100.10	98.55				
Ions on the basis of 26 (O,OH,F,Cl)					Ions on the basis of 6(O)			
Ca	9.75	9.80	9.74	9.62	Si	0.009	0.00	0.00
Na	0.012	0.00	0.034	0.00	Ti	2.005	2.034	2.023
Sr	0.00	0.00	0.00	0.00	Al	0.00	0.00	0.00
Fe	0.00	0.013	0.031	0.015	Cr	0.00	0.0004	0.0075
Mn	0.00	0.01	0.006	0.011	Fe^{+2}	1.88	1.86	1.87
Mg	0.00	0.00	0.00	0.00	Mn	0.055	0.053	0.057
P	5.75	5.65	5.73	5.68	Mg	0.007	0.006	0.0037
Si	0.006	0.059	0.043	0.085	Ca	0.00	0.00	0.00
Cl	0.00	0.00	0.00	0.00	Na	0.039	0.0078	0.01
F	1.66	1.82	1.55	1.91	K	0.0038	0.0012	0.0019

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