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Title of article Temperature/pressure, and mixed-volatile equilibria attending metamorphism of staurolite-kyanite-bearing assemblages, Esplanade Range, British Columbia

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Columbia

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TABLE 6. Electron microprobe analyses of garnets from the Esplanade Range, B.C.

	CV113 cores	CV113 rim	CV114 cores	CV114 rim	Gh115 cores	Gh115 rim	Gh117 cores	Gh117 rim	Gh123 cores	Gh123 rim
SiO ₂	37.0	37.3	36.3	36.8	36.9	36.9	36.9	36.7	37.2	37.0
Al ₂ O ₃	20.7	21.0	20.5	20.6	21.5	21.6	21.3	21.1	20.7	20.7
FeO ^a	29.3	34.7	31.0	34.9	34.1	35.6	31.7	32.0	33.6	34.6
MnO	4.7	0.6	7.9	1.6	2.5	1.9	4.2	5.2	1.9	1.5
MgO	1.2	3.1	1.8	2.9	2.9	3.1	1.7	2.2	3.0	3.0
CaO	<u>7.7</u>	<u>4.2</u>	<u>1.8</u>	<u>0.4</u>	<u>2.7</u>	<u>2.0</u>	<u>4.7</u>	<u>3.3</u>	<u>3.2</u>	<u>2.3</u>
Sum	<u>100.6</u>	<u>100.9</u>	<u>99.7</u>	<u>97.2</u>	<u>100.6</u>	<u>101.1</u>	<u>100.5</u>	<u>100.5</u>	<u>99.6</u>	<u>99.1</u>

Number of ions on basis of 12 oxygens

Si	2.98	2.98	3.00	3.04	2.96	2.95	2.97	2.96	3.00	3.01
Al	<u>0.02</u>	<u>0.02</u>	<u>0.00</u>	<u>-</u>	<u>0.04</u>	<u>0.05</u>	<u>0.03</u>	<u>0.04</u>	<u>-</u>	<u>-</u>
	<u>3.00</u>	<u>3.00</u>	<u>3.00</u>	<u>3.04</u>	<u>3.00</u>	<u>3.00</u>	<u>3.00</u>	<u>3.00</u>	<u>3.00</u>	<u>3.01</u>
Al	<u>1.94</u>	<u>1.95</u>	<u>1.97</u>	<u>2.00</u>	<u>1.99</u>	<u>1.99</u>	<u>1.99</u>	<u>1.99</u>	<u>1.97</u>	<u>1.98</u>
Fe	1.97	2.32	2.12	2.41	2.29	2.38	2.13	2.16	2.27	2.35
Mn	0.32	0.04	0.55	0.11	0.17	0.13	0.29	0.35	0.13	0.10
Mg	0.14	0.37	0.22	0.36	0.34	0.37	0.20	0.27	0.36	0.36
Ca	0.66	0.36	0.16	0.04	0.23	0.17	0.41	0.29	0.28	0.20
Sum of Fe +										
Mn + Mg + Ca	3.09	3.09	3.05	2.92	3.03	3.05	3.03	3.07	3.04	3.01

End member proportions

Alm.	64	75	70	83	76	78	70	70	75	78
Spess.	10	1	18	4	6	4	10	11	4	3
Pyr.	5	12	7	12	11	12	7	9	12	12
Gross.	21	12	5	1	7	6	13	10	9	7

Analyses in weight per cent, a denotes total Fe as FeO

TABLE 6 continued

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TABLE 6. Electron microprobe analyses of garnets from the Esplanade Range, B.C.

	Gh129 cores	Gh129 rim	CV150 cores	CV150 rim	CV204 cores	CV204 rim	Jh348 cores	Jh348 rim	CV99* average	CV107* average
SiO ₂	37.1	37.4	37.2	37.6	37.1	37.2	37.9	38.1	37.1	37.6
Al ₂ O ₃	20.8	20.8	20.9	21.0	20.9	21.1	21.3	21.2	19.4	21.1
FeO ^a	31.1	30.7	30.2	31.6	31.1	32.2	29.8	31.9	29.3	30.9
MnO	3.5	1.7	3.6	0.7	2.8	1.2	5.3	2.4	4.9	5.2
MgO	2.2	2.8	1.3	2.6	1.5	3.0	1.5	2.0	1.7	1.6
CaO	6.6	6.1	7.6	6.3	6.7	5.1	7.2	6.6	5.7	4.2
Sum	101.3	99.5	100.8	99.8	100.2	99.8	103.0	102.2	98.1	100.6

Number of ions on basis of 12 oxygens

Si	2.96	3.00	2.98	3.01	2.99	2.98	2.98	3.00	3.05	3.02
Al	0.04	-	0.02	-	0.01	0.02	0.02	-	-	-
	3.00	3.00	3.00	3.01	3.00	3.00	3.00	3.00	3.00	3.02
Al	1.92	1.97	1.96	1.98	1.97	1.98	1.95	1.97	1.88	1.99
Fe	2.08	2.06	2.02	2.11	2.10	2.16	1.95	2.10	2.02	2.07
Mn	0.24	0.12	0.24	0.05	0.19	0.08	0.35	0.16	0.34	0.35
Mg	0.26	0.34	0.16	0.31	0.18	0.36	0.18	0.23	0.21	0.19
Ca	0.56	0.52	0.65	0.54	0.58	0.44	0.61	0.56	0.50	0.36
Sum of Fe + Mn + Ca	3.14	3.04	3.07	3.01	3.05	3.04	3.09	3.05	3.07	2.97

End member proportions

Alm.	66	67	66	70	69	71	63	69	66	70
Spess.	8	4	8	2	6	3	11	5	11	12
Pyr.	8	11	5	10	6	12	6	8	7	6
Gross.	18	18	21	18	19	14	20	18	16	12

*Analysis by C.D.S. Devries

Alm. = Almandine; Spess. = spessartine; Pyr. = pyrope; Gross. = grossular

TABLE 7. Electron microprobe analyses of biotites from the Esplanade Range, B.C.

	<u>CV113</u>	<u>CV114</u>	<u>Gh123</u>	<u>Gh129</u>	<u>CV150</u>	<u>CV204</u>	<u>CV214</u>	<u>Jh348</u>	<u>Jh365</u>	<u>CV99</u>	<u>CV107</u>	<u>Gh115</u>	<u>Gh117</u>
SiO ₂	36.0	35.7	36.9	36.7	35.6	36.2	36.3	36.2	36.6	-	-	36.5	35.9
TiO ₂	1.4	1.2	1.5	1.5	1.5	1.5	1.1	1.3	1.3	1.7	1.8	1.6	2.1
Al ₂ O ₃	19.0	19.3	18.8	18.8	18.4	18.5	19.3	18.5	17.1	18.7	19.0	18.9	17.7
FeO ^a	17.8	21.6	18.3	16.1	17.2	17.3	17.2 ^b	19.4	15.1	19.8	20.0	19.1	22.8
MnO	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	0.1	-	-	<0.05	0.1
ZnO	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-
MgO	11.8	9.4	11.3	12.7	11.9	12.2	11.8	11.0	14.1	9.5	9.3	11.2	9.5
CaO	<0.06	0.1	<0.06	<0.06	0.1	<0.06	<0.06	<0.06	0.3	-	-	-	0.1
Na ₂ O	0.3	0.2	0.4	0.4	0.4	0.2	0.4	0.2	0.1	-	-	0.3	0.1
K ₂ O	8.5	8.0	8.8	8.6	8.5	8.8	8.4	8.6	7.7	-	-	9.2	9.8
BaO	<0.09	<0.09	<0.09	<0.09	<0.09	0.1	<0.09	<0.09	<0.09	-	-	-	-
Sum	94.8	95.6	96.0	94.1	93.6	94.8	94.6	95.3	92.4	-	-	96.8	98.0

Number of ions on anhydrous basis of 22 oxygens

Si	5.43	5.42	5.51	5.49	5.44	5.46	5.46	5.48	5.57	-	-	5.44	5.42
Al	2.57	2.58	2.49	2.51	2.56	2.54	2.54	2.52	2.43	-	-	2.56	2.58
Sum	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	-	-	8.00	8.00
Al	0.81	0.87	0.81	0.80	0.75	0.75	0.88	0.77	0.64	-	-	0.75	0.76
Ti	0.16	0.14	0.17	0.17	0.17	0.17	0.12	0.12	0.15	-	-	0.17	0.17
Fe	2.24	2.74	2.28	2.01	2.20	2.18	2.16	2.45	1.92	-	-	2.38	2.88
Mn	-	0.01	-	-	-	-	0.01	0.01	0.01	-	-	0.00	0.01
Zn	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg	2.65	2.13	2.51	2.82	2.71	2.74	2.65	2.48	3.20	-	-	2.49	2.13
Sum	5.86	5.89	5.77	5.80	5.83	5.84	5.82	5.86	5.92	-	-	5.79	5.82
Ca	-	0.02	-	-	0.02	-	-	-	0.05	-	-	-	-
Na	0.09	0.06	0.12	0.12	0.12	0.06	0.12	0.06	0.03	-	-	0.09	0.04
K	1.64	1.55	1.68	1.64	1.66	1.69	1.61	1.66	1.50	-	-	1.75	1.68
Ba	-	-	-	-	-	0.01	-	-	-	-	-	-	-
Sum	1.73	1.62	1.80	1.76	1.79	1.76	1.73	1.72	1.57	-	-	1.84	1.92

Analyses in weight per cent; ^a denotes total Fe as FeO. ^b wet chemical analyses gives FeO = 14.98; Fe₂O₃ = 2.47

TABLE 8. Electron microprobe analyses of muscovites from the Esplanade Range, B.C.

	CV113	CV114	Gh123	Gh129	CV150	CV204	CV214	Jh348	Jh365	CV99	CV107	Gh115	Gh117
SiO ₂	45.6	46.4	46.6	46.3	45.5	45.8	45.6	45.7	45.8	-	-	46.1	46.4
TiO ₂	0.3	0.3	0.3	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.6
Al ₂ O ₃	36.7	37.1	36.1	35.7	35.3	35.0	36.4	36.4	32.5	-	-	36.0	33.2
FeO ^a	1.0	1.2	1.0	1.0	0.9	1.1	1.1	1.2	3.8	1.3	1.4	0.9	3.2
MnO	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	<0.05	<0.05
ZnO	<0.1	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-
MgO	0.6	0.6	0.6	0.8	0.7	0.8	0.9	0.9	1.5	0.8	0.7	0.6	1.1
CaO	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	-	-	-	-
Na ₂ O	2.2	1.7	1.9	1.5	1.6	1.4	1.6	1.6	0.7	-	-	1.9	1.0
K ₂ O	8.2	8.6	8.5	9.2	8.9	9.3	8.9	9.0	10.0	-	-	9.0	10.6
BaO	0.2	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.1	-	-	-	-
Sum	94.8	96.1	95.2	95.2	93.8	94.1	95.0	95.3	94.7	-	-	94.8	96.1
<u>Number of ions on anhydrous basis of 22 oxygens</u>													
Si	6.05	6.08	6.16	6.14	6.13	6.15	6.06	6.06	6.22	-	-	6.13	6.21
Al	1.95	1.92	1.84	1.86	1.87	1.85	1.94	1.94	1.78	-	-	1.87	1.79
Sum	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	-	-	8.00	8.00
Al	3.79	3.81	3.78	3.72	3.73	3.70	3.76	3.75	3.42	-	-	3.77	3.45
Ti	0.03	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.03	-	-	0.03	0.06
Fe	0.11	0.13	0.11	0.11	0.10	0.12	0.12	0.13	0.43	-	-	0.10	0.36
Mn	-	-	-	-	-	-	-	-	-	-	-	-	-
Zn	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg	0.12	0.12	0.12	0.16	0.14	0.16	0.17	0.18	0.30	-	-	0.12	0.22
Sum	4.05	4.11	4.04	4.04	4.02	4.03	4.08	4.11	4.18	-	-	4.02	4.09
Na	0.57	0.43	0.49	0.39	0.42	0.36	0.41	0.41	0.18	-	-	-	-
K	1.39	1.44	1.43	1.56	1.53	1.59	1.51	1.52	1.73	-	-	0.49	0.26
Ba	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	-	-	1.53	1.61
Sum	1.97	1.87	1.93	1.96	1.97	1.96	1.93	1.94	1.92	-	-	2.02	2.07

Analyses in weight per cent, ^a denotes total Fe as FeO.

TABLE 9. Electron microprobe analyses of chlorites from the Esplanade Range, B.C.

	CV113	CV114	Gh115	Gh117	Gh123	Gh129	CV204	Jh348	Jh365	CV99	CV107	CV214
SiO ₂	24.9	25.2	25.5	25.8	24.7	25.5	25.4	25.6	-	-	-	-
Al ₂ O ₃	23.8	22.9	23.5	21.6	23.2	23.2	23.3	23.0	22.3	23.4	23.1	24.2
FeO ^a	22.1	25.7	24.5	28.6	22.5	19.7	21.2	25.5	19.4	26.1	25.5	21.6
MnO	<0.04	-	<0.04	0.2	<0.04	-	<0.04	0.2	0.2	-	-	-
ZnO	<0.05	-	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	-	-	-
MgO	<u>16.8</u>	<u>13.7</u>	<u>16.6</u>	<u>14.5</u>	<u>16.5</u>	<u>18.1</u>	<u>17.8</u>	<u>15.8</u>	<u>19.8</u>	<u>14.0</u>	<u>13.0</u>	<u>16.9</u>
Sum ^b	87.5	87.5	90.1	90.7	86.9	86.5	87.7	90.1	-	-	-	-

Number of ions on anhydrous basis of 28 oxygens

Si	5.16	5.31	5.18	5.33	5.17	5.26	5.21	5.24	-	-	-	-
Al	<u>2.84</u>	<u>2.69</u>	<u>2.82</u>	<u>2.67</u>	<u>2.83</u>	<u>2.74</u>	<u>2.79</u>	<u>2.76</u>	-	-	-	-
Sum of IV Cations	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	-	-	-	-
Al	2.95	3.00	2.81	2.59	2.89	2.92	2.87	2.79	-	-	-	-
Fe ⁺²	3.82	4.53	4.16	4.94	3.94	3.41	3.64	4.36	-	-	-	-
Mg	5.18	4.31	5.03	4.46	5.14	5.58	5.45	4.82	-	-	-	-
Mn	-	-	-	<u>0.03</u>	-	-	-	<u>0.03</u>	-	-	-	-
Sum of VI cations	<u>11.94</u>	<u>11.84</u>	<u>12.00</u>	<u>12.02</u>	<u>11.97</u>	<u>11.91</u>	<u>11.95</u>	<u>12.00</u>				

All analyses in weight per cent. a denotes total Fe as FeO. b Bence Albee corrections made assuming H₂O⁺ = 12.0 weight per cent.

TABLE 10. Electron Microprobe analyses of oxide minerals from the Esplanade Range, B.C.

	Ilmenites							Magnetite Rutile		
	<u>CV99</u>	<u>CV113</u>	<u>CV114</u>	<u>Gh123</u>	<u>CV150</u>	<u>CV204</u>	<u>CV214</u>	<u>Jh432</u>	<u>Jh365</u>	<u>CV150^b</u>
TiO ₂	53.3	52.5	54.2	52.9	53.2	52.8	52.6	53.6	0.1	98.0
Al ₂ O ₃	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	0.2	0.6	<0.2
FeO ^a	46.3	46.8	44.2	47.8	47.3	47.1	46.1	45.6	92.2	0.3
MnO	0.6	0.3	1.8	0.3	0.3	0.3	1.3	-	<0.04	-
MgO	0.1	0.2	0.03	0.2	0.2	0.2	0.2	0.2	<0.02	<0.02
ZnO	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	-	-
Sum	100.3	99.8	100.23	101.2	101.0	100.4	100.5	99.6	92.9	98.3

Recalculated analyses^c

Fe ₂ O ₃	-0.9	0.3	-3.0	1.0	0.1	0.3	0.5	-2.5	68.1	-
FeO	<u>47.1</u>	<u>46.6</u>	<u>46.9</u>	<u>46.9</u>	<u>47.2</u>	<u>46.8</u>	<u>45.6</u>	<u>47.8</u>	<u>30.9</u>	-
Total	100.2	99.8	99.9	101.3	101.0	100.4	100.6	99.4	99.7	-

Molecular proportions of end members

Hematite	.0089	.0026	-.0281	.0093	.0013	.0029	.0094	-.0208	-	-
Ilmenite	1.0089	.9974	1.0281	.9907	.9987	.9971	.9906	1.0208	-	-
Magnetite	-	-	-	-	-	-	-	-	.9971	-
Uvospinel	-	-	-	-	-	-	-	-	.0029	-

^a denotes total Fe calculated as FeO

^b rutile also contains 0.3 - 8.4% Nb₂O₅ not included in average analyses

^c analyses recalculated according to scheme of Carmichael, I.S.E., 1967, in

The iron-titanium oxides of salic volcanic rocks and their associated

ferromagnesium silicates: Contr. Mineralogy and Petrology, v. 14, p. 36-64.

TABLE 11. Electron microprobe analyses of staurolites from the Esplanade Range, B.C.

	<u>CV113</u>	<u>CV114</u>	<u>Gh115</u>	<u>Gh123</u>	<u>CV150</u>	<u>CV204</u>	<u>CV214</u>
SiO ₂	27.5	28.3	27.0	27.4	27.7	27.4	27.2
TiO ₂	0.7	0.6	0.5	-	0.6	0.6	0.6
Al ₂ O ₃	54.6	54.6	54.6	53.8	54.3	54.6	53.7
FeO ^a	13.1	12.6	13.7	13.6	12.8	12.5	13.4
MnO	0.1	0.2	0.2	0.1	0.1	0.1	0.3
ZnO	0.4	1.2	-	0.2	0.7	0.7	0.3
MgO	<u>1.7</u>	<u>1.4</u>	<u>1.7</u>	<u>1.8</u>	<u>1.9</u>	<u>1.8</u>	<u>2.0</u>
Sum	98.1	98.9	97.7	96.9	98.1	97.8	97.5

Number of ions on basis of 30 cations

Si	7.76	7.95	7.65	7.82	7.82	7.76	7.73
Al	<u>0.24</u>	<u>0.05</u>	<u>0.35</u>	<u>0.18</u>	<u>0.18</u>	<u>0.24</u>	<u>0.27</u>
	<u>8.00</u>						
Al	17.93	18.03	17.88	17.92	17.88	17.98	17.71
Ti	<u>0.15</u>	<u>0.13</u>	<u>0.11</u>	-	<u>0.13</u>	<u>0.13</u>	<u>0.13</u>
	<u>18.08</u>	<u>18.16</u>	<u>17.99</u>	<u>17.92</u>	<u>18.01</u>	<u>18.11</u>	<u>17.84</u>
Fe	3.09	2.96	3.25	3.25	3.02	2.96	3.18
Mn	0.02	0.05	0.05	0.02	0.02	0.02	0.07
Zn	0.08	0.25	-	0.04	0.15	0.15	0.06
Mg	<u>0.72</u>	<u>0.59</u>	<u>0.72</u>	<u>0.76</u>	<u>0.80</u>	<u>0.76</u>	<u>0.85</u>
	3.91	3.85	4.02	4.07	3.99	3.89	4.16

 Analyses in weight per cent. a denotes total Fe as FeO.

 Bence-Albee correction made assuming 2.00 weight per cent H₂O in staurolite.

TABLE 12. Electron microprobe analyses of plagioclase feldspars
from the Esplanade Range, B.C.

<u>Sample</u>	<u>An</u>	<u>Or</u>	<u>Range in An (spots)</u>
CV 99	18	0.3	15 - 21
CV 113	21	0.2	19 - 24
CV 114	4	0.2	3.5 - 6
Gh 115	22	0.3	19 - 24
Gh 117	14	0.3	11 - 21
Gh 129	31	0.2	26 - 36
CV 150	31	0.2	25 - 34
CV 204	21	0.2	19 - 24
CV 214	30	0.2	22 - 35
Jh 313A	8	0.2	3.0 - 17
Jh 313B	24	0.3	22 - 27
Jh 348	22	0.3	17 - 27
Jh 365	2	0.2	0.5 - 3.5
Gh 123	25	0.2	24 - 26

An = anorthite; Or = orthoclase. Analyses in molecular per cent. Range in An include all spots giving satisfactory analytical totals.