

Table 30. ALKALI FELDSPAR

	1.	2.	3.	4.	5.	6.	7.
SiO ₂	65.76	64.76	64.66	63.66	65.58	64.20	63.68
TiO ₂	0.08	—	—	—	—	—	0.01
Al ₂ O ₃	20.23	19.96	19.72	19.54	19.58	19.10	19.57
Fe ₂ O ₃	0.18	0.08	0.08	0.10	0.21	0.40	0.29
FeO	—	tr.	—	—	—	—	0.24
MgO	0.10	tr.	tr.	—	0.12	—	0.05
BaO	0.63	—	—	—	—	—	0.34
CaO	1.19	0.84	0.34	0.50	0.49	0.34	0.40
Na ₂ O	8.44	5.54	3.42	0.80	5.90	2.60	1.56
K ₂ O	3.29	8.12	11.72	15.60	7.88	12.76	14.21
H ₂ O ⁺	0.37	0.54	0.18	—	0.23	0.72	0.04
H ₂ O ⁻	0.08	—	—	—	0.14	—	0.07
Total	100.35	99.84	100.12	100.20	100.13	100.12	100.46

α	1.528	1.5256	1.5217	1.5188	—	1.5204	—
β	1.533	1.5296	1.5259	1.5230	—	1.5240	—
γ	1.537	1.5326	1.5279	1.5236	—	1.5265	—
2V	78°	82.8°	69.1°	43.6°	—	79.9°	83°-86°
Ext. on (010)	14°	11.7°	9.5°	5.3°	—	7.5°	—
D	—	2.5950	2.5778	2.5632	2.587	2.5771	—

NUMBERS OF IONS ON

Si	11.719	11.750	11.794	11.759	11.825	11.831	11.730
Al	4.249	4.269	4.240	4.254	4.126	4.148	4.249
Fe ⁺³	0.024	0.011	0.011	0.014	0.029	0.055	0.040
Ti	0.011	—	—	—	—	—	0.001
Mg	0.027	—	—	—	0.032	—	0.014
Na	2.916	1.949	1.209	0.286	2.063	0.929	0.557
Ca	0.227	0.163	0.006	0.099	0.095	0.067	0.078
K	0.748	1.880	2.727	3.676	1.813	3.000	3.340
Ba	0.044	—	—	—	—	—	0.024

Z	16.00	16.03	16.04	16.03	16.02	16.03	16.02
X	3.96	3.99	4.00	4.06	4.00	4.00	4.05†

Mol. %	Or	20.0	47.1	68.1	90.5	45.3	75.1	83.1
	Ab	73.6	48.8	30.2	7.1	51.5	23.2	13.7
	An	6.4	4.1	1.7	2.4	3.2	1.7	3.2

1. Sodium-rich orthoclase cryptoperthite, ijolite-nepheline-syenite, Mogok, Burma (Tilley, C. E., 1954, *Amer. Journ. Sci.*, vol. 252, p. 65).
2. Orthoclase micropertthite with white schiller, Burma (Spencer, E., 1930, *Min. Mag.*, vol. 22, p. 291).
3. Orthoclase micropertthite (moonstone), Ceylon (Spencer, E., 1937, *Min. Mag.*, vol. 24, p. 453).
4. Orthoclase, Mogok, Burma (Spencer, E., 1930, *Min. Mag.*, vol. 22, p. 291).
5. Microcline perthite, nepheline-syenite, Korea (Yoshizawa, H., 1933, *Chikyū*, vol. 19, p. 432).
6. Microcline micropertthite, quartz-feldspar-tourmaline pegmatite, Orissa, India (Spencer, E., 1937, *Min. Mag.*, vol. 24, p. 453).
7. Microcline micropertthite, charnockite, St. Thomas' Mt., Madras (Howie, R. A., 1955, *Trans. Roy. Soc. Edinburgh*, vol. 62, p. 725).

† Includes Fe⁺² 0.037.

ANALYSES

	8.	9.	10.	11.	12.	13.	14.	
SiO ₂	64.46	67.27	63.62	63.70	66.97	64.28	64.94	SiO ₂
TiO ₂	—	—	0.08	—	0.04	—	0.00	TiO ₂
Al ₂ O ₃	18.55	18.35	19.12	21.83	18.75	19.19	16.74	Al ₂ O ₃
Fe ₂ O ₃	0.14	} 0.92	} 0.47	0.18	} 0.88	0.09	2.56	Fe ₂ O ₃
FeO	—			—		—	—	—
MgO	0.00	0.00	0.05	0.14	0.00	0.10	0.04	MgO
BaO	—	—	1.56	—	—	0.11	—	BaO
CaO	0.17	0.15	0.05	2.75	0.36	0.11	0.03	CaO
Na ₂ O	0.49	6.45	2.66	7.55	7.88	0.92	0.79	Na ₂ O
K ₂ O	16.07	7.05	12.09	3.75	5.39	15.30	15.33	K ₂ O
H ₂ O ⁺	—	0.08	0.11	0.19	0.01	0.36	—	H ₂ O ⁺
H ₂ O ⁻	0.06	0.08	0.00	—	0.03	—	0.00	H ₂ O ⁻
Total	99.94	100.35	99.81	100.09	100.31	100.46	100.43	Total

—	—	1.5232	—	1.5290	1.5239	1.5192	1.5265	α
—	—	1.5289	—	1.5350	1.5299	1.5228	1.531	β
—	—	1.5296	—	1.5365	1.5308	1.5245	1.5315	γ
—	—	—	—	51°-52°	46°	68.4°	32°-33½°	2V _α
—	—	—	—	6°-8°	—	5.25°	5°	Ext. on (010)
—	—	—	—	2.589	—	2.5661	—	D

THE BASIS OF 32(O)

Si	11.938	12.030	11.770	11.383	11.932	11.852	12.011	Si		
Al	4.050	3.868	4.169	4.598	3.938	4.170	3.650	Al		
Fe ⁺³	0.019	0.124	0.096	0.024	0.118	0.012	0.356	Fe ⁺³		
Ti	—	—	0.011	—	0.005	—	—	Ti		
Mg	—	—	0.013	0.038	—	0.028	0.011	Mg		
Na	0.176	2.236	0.954	2.616	2.722	0.329	0.283	Na		
Ca	0.033	0.029	0.010	0.526	0.069	0.022	0.006	Ca		
K	3.797	1.609	2.855	0.855	1.226	3.599	3.618	K		
Ba	—	—	0.113	—	—	0.008	—	Ba		
Z	16.01	16.02	16.05	16.00	15.99	16.03	16.02	Z		
X	4.01	3.87	3.95	4.03	4.02	3.99	3.92	X		
Mol. %	Or	94.8	41.5	75.5	21.2	30.5	90.5	92.4†	Or } Mol. %	
	Ab	4.4	57.7	23.9	64.8	67.8	8.3	7.2		Ab }
	An	0.8	0.8	0.6	14.0	1.7	1.2	0.4		An }

8. Maximum microcline, pegmatite in grænnaite, Norra Kärr, Sweden (MacKenzie, W. S., 1954, *Min. Mag.*, vol. 30, p. 354).
9. Sanidine, rhyolite, Mitchell Mesa, Texas (Tuttle, O. F., 1952, *Amer. Journ. Sci.*, Bowen vol., p. 553).
10. Sanidine, leucite-nepheline dolerite, Vogelsberg, Germany (Tilley, C. E., 1958, *Amer. Min.*, vol. 43, p. 758).
11. Anorthoclase, inclusions in augite, Euganean Hills, Italy (Schiavinato, G., 1951, *Periodico Min. Roma*, vol. 20, p. 193).
12. Anorthoclase, Grande Caldeira, Azores (Tuttle, O. F., 1952, *Amer. Journ. Sci.*, Bowen vol., p. 553).
13. Adularia, St. Gotthard, Switzerland (Spencer, E., 1937, *Min. Mag.*, vol. 24, p. 453).
14. Amber-yellow feriferous orthoclase, Itrongay, Madagascar (Coombs, D. S., 1954, *Min. Mag.*, vol. 30, p. 409).

† Includes 9.0 mol. per cent. Fe-Orthoclase.

Table 31. PLAGIOCLASE FELDSPAR

	1.	2.	3.	4.
SiO ₂	67.84	67.41	64.10	58.10
TiO ₂	0.00	—	0.00	tr.
Al ₂ O ₃	19.65	20.50	22.66	26.44
Fe ₂ O ₃	0.03	0.07	0.14	0.04
FeO	0.02	—	0.17	0.15
MgO	0.04	0.10	0.25	0.03
CaO	0.00	0.81	3.26	7.84
Na ₂ O	11.07	10.97	9.89	6.48
K ₂ O	0.29	0.36	0.05	1.10
H ₂ O ⁺	0.56	0.15	0.17	0.03
H ₂ O ⁻	0.30	—	0.06	0.06
Total	99.80	100.37	100.75	100.27
α	1.529	1.5283	1.5351	—
β	1.533	1.5327	1.5393	—
γ	1.539	1.5392	1.5437	—
2V	79°(+)	79½°(+)	89°(+)	88°(+)
α' :(010)	—	18½°-19°	11½°	—
D	—	2.619	2.646	—
NUMBERS OF IONS ON				
Si	11.964	11.785	11.267	10.413
Al	4.085	4.225	4.695	5.586
Fe ⁺³	0.004	0.009	0.018	0.005
Mg	0.011	0.026	0.065	0.008
Fe ⁺²	0.003	—	0.025	0.023
Na	3.785	3.718	3.370	2.252
Ca	—	0.152	0.614	1.505
K	0.066	0.080	0.011	0.252
Z	16.05	16.02	15.98	16.00
X	3.87	3.98	4.08	4.04
Mol.%	{ Ab 98.0 An 0.3 Or 1.7	{ 93.5 4.5 2.0	{ 82.5 17.2 0.3	{ 56.0 37.7 6.3

1. Albite, pegmatite, near Court House, Amelia Co., Virginia (Kracek, F. C. & Neuvonen, K. J., 1952, *Amer. Journ. Sci.*, Bowen vol., p. 293).
2. Albite, with quartz and sphene in crevice in amphibolite, Val Devero, Italy (Azzini, F., 1933, *Atti Accad. Sci. Veneto-Trentino-Istria*, vol. 23, p. 45).
3. Glassy oligoclase, pegmatite, Kioo Hill, Kenya (Game, P. M., 1949, *Min. Mag.* vol. 28, p. 682).
4. Andesine antiperthite, two-pyroxene granulite, charnockite series, Madras (Howie, R.A., 1955, *Trans. Roy. Soc. Edinburgh*, vol. 62, p. 725).

ANALYSES

	5.	6.	7.	8.		
	52.96	49.06	44.17	43.88	SiO ₂	
	tr.	—	tr.	—	TiO ₂	
	29.72	32.14	34.95	36.18	Al ₂ O ₃	
	0.84	0.27	0.56	0.08	Fe ₂ O ₃	
	—	—	0.08	0.00	FeO	
	—	0.20	0.00	—	MgO	
	12.28	15.38	18.63	19.37	CaO	
	4.21	2.57	0.79	0.22	Na ₂ O	
	0.13	0.17	0.05	0.00	K ₂ O	
	0.08	0.13	0.84	0.28	H ₂ O ⁺	
	—	0.03	0.17	0.08	H ₂ O ⁻	
Total	100.22	99.95	100.24	100.10	Total	
α	1.560	1.5657	1.574	1.5754	α	
β	1.565	1.5701	1.582	1.5833	β	
γ	1.570	1.5754	1.586	1.5885	γ	
2V	—	89°(-)	78°(-)	76.8°-77.7°(-)	2V	
α' :(010)	23½°	—	—	—	α' :(010)	
D	2.705	—	—	2.749	D	
THE BASIS OF 32(O)						
	9.589	8.990	8.237	8.126	Si	
	6.343	6.942	7.683	7.898	Al	
	0.114	0.037	0.078	0.011	Fe ⁺³	
	—	0.055	—	—	Mg	
	—	—	0.012	—	Fe ⁺²	
	1.477	0.913	0.285	0.079	Na	
	2.383	3.202	3.723	3.844	Ca	
	0.030	0.040	0.012	—	K	
Z	16.05	15.97	16.00	16.03	Z	
X	3.89	4.03	4.03	3.92	X	
Mol.%	{ 38.0 61.2 0.8	{ 22.7 76.3 1.0	{ 7.1 92.6 0.3	{ 2.0 98.0 —	Mol.%	{ Ab An Or

5. Labradorite, Millard Co., Utah (Meen, V. B., 1933, *Univ. Toronto Studs., Geol. Ser.*, no. 35, p. 37).
6. Bytownite, norite, Rustenburg platinum mines, Transvaal (Kracek, F. C. & Neuvonen, K. J., 1952, *loc. cit.*).
7. Anorthite, olivine norite, Grass Valley, California (Kracek, F. C. & Neuvonen, K. J., 1952, *loc. cit.*).
8. Anorthite, calc-silicate rock, Sittampundi complex, India (Subramaniam, A. P., 1956, *Bull. Geol. Soc. Amer.*, vol. 67, p. 317; includes SrO 0.01).

Table 35. NEPHELINE AND KALSILITE ANALYSES

	1.	2.	3.	4.	5.
SiO ₂	44.65	41.88	40.20	38.47	38.48
TiO ₂	0.00	0.03	0.05	0.00	0.05
Al ₂ O ₃	32.03	32.99	32.51	30.81	31.01
Fe ₂ O ₃	0.59	0.74	1.82	1.63	1.12
MgO	0.00	0.00	0.10	0.63	0.00
CaO	0.71	0.78	1.44	0.20	0.03
Na ₂ O	17.25	16.11	10.86	2.09	0.30
K ₂ O	3.66	6.82	12.22	25.65	28.33
H ₂ O ⁺	0.96	0.71	0.00	0.20	0.67
H ₂ O ⁻	0.21	0.03	0.00	0.00	—
Total	100.06	100.16	99.77	99.94	100.00
ε	1.531	—	1.539	1.537	1.533
ω	1.535	—	1.543	1.543	1.539
NUMBERS OF IONS ON THE BASIS OF 32 OXYGENS					
Si	8.585	8.179	8.014	8.044	8.125
Al	7.361	7.595	7.641	7.596	7.720
Ti	—	0.005	0.007	—	0.008
Fe ⁺³	0.085	0.109	0.369†	0.301§	0.180
Mg	—	0.102†	0.030	0.196	—
Na	6.428	6.098	4.198	0.847	0.123
Ca	0.147	0.163	0.308	0.045	0.006
K	0.897	1.699	3.018	6.846	7.635
∑R¶	7.61	8.12	7.92	7.78	7.77
Ne	81.9	76.1	54.7	9.9	96.8
Ks	12.9	23.6	45.3	88.9	1.4
Q	5.2	0.3	—	1.2	1.8

1. Nepheline, phonolite, New Zealand (Tilley, C. E., 1954, *Amer. Journ. Sci.*, vol. 252, p. 65).
2. Nepheline, foyaite, Transvaal (Tilley, C. E., 1956, *Kon. Ned. Geol. Mijnb., Geol. Ser.*, Brouwer vol., p. 403; includes MnO 0.07).
3. Nepheline, potash ankaratrite, Congo (Sahama, Th. G., 1952, *Amer. Journ. Sci.*, Bowen vol., p. 460; includes FeO 0.57).
4. Kalsilite, venanzite, Italy (Bannister, F. A., Sahama, Th. G. & Wiik, H. B., 1952, *Min. Mag.*, vol. 30, p. 46; includes FeO 0.26).
5. Kalsilite, complex phenocryst of kalsilite and nepheline, Congo (Sahama, Th. G., Neuvonen, K. J. & Hytönen, K., 1956, *Min. Mag.*, vol. 31, p. 200. Analysis recalculated after correcting for 10 per cent nepheline, 31.1 atomic per cent K:(K+Na+Ca) in sample; total iron as Fe₂O₃; analysis includes MnO 0.01).

† Includes Mn 0.012.
‡ Includes Fe⁺² 0.096.
§ Includes Fe⁺² 0.045.
|| Includes Mn 0.002.

¶ ∑R = (Na + K + 2Ca)

Table 36. LEUCITE AND PSEUDOLEUCITE ANALYSES

				Numbers of ions on the basis of 6 oxygens			
	1.	2.	3.	1.	2.	3.	
SiO ₂	54.62	54.66	57.42	Si	1.992	1.992	2.034
TiO ₂	0.00	0.17	0.24	Al	0.986	0.995	0.912
Al ₂ O ₃	22.93	23.15	21.85	Ti	—	0.005	0.006
Fe ₂ O ₃	0.26	0.36	1.70	Fe ⁺³	0.007	0.010	0.045
FeO	0.26	0.11	0.00	Mg	—	0.002	0.004
MnO	—	0.01	0.03	Fe ⁺²	0.008	0.003	—
MgO	0.00	0.04	0.07	Ca	0.002	0.004	0.007
CaO	0.08	0.11	0.19	Na	0.047	0.045	0.328
Na ₂ O	0.66	0.63	4.78	K	0.978	0.932	0.606
K ₂ O	21.02	20.04	13.40				
H ₂ O ⁺	0.12	0.36	0.27				
H ₂ O ⁻	0.00	0.05	0.03				
Total	99.95	99.77	100.26				
n	1.509	—	—				

1. Leucite, leucitite, Congo (Sahama, Th. G., 1952, *Amer. Journ. Sci.*, Bowen vol., p. 457).
2. Leucite, giant leucite aggregate, Congo (Sahama, Th. G., 1960, *Journ. Petr.*, vol. 1, p. 146; includes P₂O₅ 0.08).
3. Pseudoleucite, tinguaite, Montana (Zies, E. G. & Chayes, F., 1960, *Journ. Petr.*, vol. 1, p. 86; includes BaO 0.28).

† Includes Mn 0.001, Ba 0.004.

Table 37. SODALITE, NOSEAN AND HÄUYNE ANALYSES

	1.	2.	3.	4.	5.	6.
SiO ₂	36.69	36.70	36.36	36.69	34.04	32.52
Al ₂ O ₃	31.40	32.01	32.09	28.45	28.27	27.61
Fe ₂ O ₃	0.85	0.07	0.07	0.47	—	—
CaO	0.19	—	—	0.63	9.51	6.47
Na ₂ O	25.96	24.79	24.73	23.90	10.39	19.45
K ₂ O	0.23	0.17	0.12	—	5.44	0.28
SO ₃	—	—	—	7.30	10.02	10.46
S	0.38	tr.	0.00	—	—	2.71
Cl	5.64	7.00	6.79	1.05	0.76	0.47
H ₂ O ⁺	0.30	0.36	0.86	—	—	—
H ₂ O ⁻	0.04	0.00	0.12	2.15	0.34	—
	101.71	101.39	101.70	100.64	100.34	99.97
O≡Cl, S	1.39	1.58	1.53	0.23	0.17	0.55
Total	100.32	99.81	100.17	100.41	100.17	99.42
<i>n</i>	1.487	1.487	1.483	—	—	—
<i>D</i>	2.285	2.286	2.278	2.299	—	—

NUMBERS OF IONS ON THE BASIS OF THE 21(O) IN THE 3Al₂O₃·6SiO₂ FRAMEWORK

Si	5.933	5.925	5.894	6.203	6.055	5.998	
Al	5.986	6.091	6.132	5.670	5.927	6.000	12.00
Fe ⁺³	0.102	0.008	0.008	0.060	—	—	
Na	8.138	7.760	7.772	7.834	3.583	6.954	
Ca	0.033	—	—	—	—	—	
K	0.047	0.035	0.025	0.114	1.813	1.279	8.30
Cl	1.546	1.915	1.866	0.301	1.233	0.066	
S	0.115	—	—	—	0.229	0.146	
SO ₄	—	—	—	—	—	—	
OH	0.324	0.380	0.928	0.926	1.336	1.448	2.53
				2.415	0.403		

1. Light grey sodalite, pegmatite cutting nepheline-syenite, Kola peninsula (Fersman, A. E. & Bonshtedt, E. M., 1937, *Minerals of the Khibina and Lovozero tundras*; includes MgO 0.03).
2. White or colourless hackmanite, tinguaitite, Magnet Cove, Arkansas (Miser, H. D. & Glass, J. J., 1941, *Amer. Min.*, vol. 26, p. 437; includes CaCO₃ 0.29).
3. Blue sodalite, associated with colourless hackmanite (anal. 2), Magnet Cove, Arkansas (Miser, H. D. & Glass, J. J., *loc. cit. supra*; includes MnO 0.06, CaCO₃ 0.50).
4. Light blue-grey nosean, ejected block, Laacher See, Lower Rhine (Rath, G. vom, 1864, *Zeits. deutsch. geol. Ges.*, vol. 16, p. 82).
5. Häuyne, häuyne riedenite, Monte Vulture, Italy (Rittmann A., 1931, *Schweiz. Min. Petr. Mitt.*, vol. 11, p. 250; includes FeO 0.69, MgO 0.48, CO₂ 0.4).
6. 'Lazurite', lapis lazuli, central Asia (Brögger, W. C. & Backström, H., 1891, *Zeit. Kryst.*, vol. 18, p. 209).

† Includes Mg 0.007.

‡ Includes Mn 0.008.

§ Includes Fe⁺² 0.103 Mg 0.127.

Table 1. OLIVINE ANALYSES

	1.	2.	3.	4.	5.	6.
SiO ₂	41.07	39.87	34.04	30.56	30.15	25.59
TiO ₂	0.05	0.03	0.43	0.72	0.20	0.61
Al ₂ O ₃	0.56	0.00	0.91	0.09	0.07	6.53
Fe ₂ O ₃	0.65	0.86	1.46	0.10	0.43	31.44
FeO	3.78	13.20	40.37	60.81	65.02	4.64
MnO	0.23	0.22	0.68	3.43	1.01	—
MgO	54.06	45.38	20.32	3.47	1.05	15.83
CaO	0.00	0.25	0.81	1.13	2.18	1.30
Na ₂ O	—	0.04	—	—	—	0.31
K ₂ O	—	0.01	—	—	—	0.28
H ₂ O ⁺	0.05	0.33	0.09	—	—	9.09
H ₂ O ⁻	0.00	0.10	—	—	—	3.74
Total	100.45	100.30	99.11	100.31	100.11	99.36
α	—	1.6626	1.742	1.809	1.827	—
β	—	—	—	1.842	1.869	1.816
γ	—	1.6990	—	1.862	1.879	—
2V γ	—	90°	103°	128°	132°	—
NUMBERS OF IONS ON THE BASIS OF 4 OXYGENS						
Si	0.979	0.997	0.990	0.996	1.002	—
Al	0.016	—	0.032	0.004	0.003	—
Ti	0.001	0.001	0.009	0.018	0.005	—
Fe ⁺³	0.012	0.016	0.032	0.004	0.011	—
Mg	1.920	1.692	0.881	0.169	0.052	—
Fe ⁺²	0.075	0.276	0.983	1.659	1.808	—
Mn	0.005	0.005	0.017	0.094	0.028	—
Ca	—	0.007	0.025	0.039	0.078	—
[Y] ⁶	2.03	2.00†	1.98	1.99	1.99	—
Atomic ratios						
Mg	96.2	86.0	47.3	8.8	2.8	—
Fe ⁺²	3.8	14.0	52.7	91.2	97.2	—

1. Forsterite, metamorphosed limestone, Finland (Sahama, Th. G., 1953, *Ann. Acad. Sci. Fennicae*, 3. *Geol. Geogr.*, No. 31, p. 1).
2. Chrysolite, allivalite, Rhum (Brown, G. M., 1956, *Phil. Trans. Roy. Soc. London*, Ser. B., vol. 240, p. 1. Includes P₂O₅ 0.01, Cr₂O₃ trace).
3. Hortonolite, olivine gabbro, Muck (Tilley, C. E., 1952, *Amer. Journ. Sci.*, Bowen vol., p. 529).
4. Fayalite, porphyritic obsidian, Pantelleria (Carmichael, I. S. E., 1962, *Min. Mag.*, vol. 33, p. 86).
5. Fayalite, fayalite ferrogabbro, East Greenland (Deer, W. A. & Wager, L. R., 1939, *Amer. Min.*, vol. 24, p. 18).
6. Iddingsite, trachybasalt, Gough Island (Gay, P. & Le Maitre, R. W., 1961, *Amer. Min.*, vol. 46, p. 92).

† Includes Na 0.007, K 0.002.

Table 13. PYROXENE ANALYSES

	1.	2.	3.	4.	5.
SiO ₂	57.73	50.08	45.95	54.09	48.34
TiO ₂	0.04	0.64	0.10	0.28	0.08
Al ₂ O ₃	0.95	1.23	0.90	1.57	0.30
Fe ₂ O ₃	0.42	2.34	0.31	0.74	1.50
Cr ₂ O ₃	0.46	—	—	2.03	—
FeO	3.57	27.85	41.65	1.47	22.94
MnO	0.08	0.85	5.02	0.09	3.70
NiO	0.35	—	—	0.03	—
MgO	36.13	15.78	3.49	16.96	1.06
CaO	0.23	1.44	1.43	21.10	21.30
Na ₂ O	—	0.05	—	1.37	0.14
K ₂ O	—	0.02	—	0.15	0.03
H ₂ O ⁺	0.52	—	0.65	0.22	0.46
H ₂ O ⁻	0.04	0.00	0.09	0.08	—
Total	100.52	100.28	99.59	100.64	99.85
α	—	1.707	1.755	—	1.7225
β	—	—	1.763	> 1.66	1.7300
γ	1.670	1.722	1.773	—	1.7505
2V _{γ}	72½°	130°	83°	70°-75°	62½°
D	3.249	—	3.88	—	3.535
NUMBERS OF IONS ON THE BASIS OF 6 OXYGENS					
Si	1.972	1.937	1.972	1.961	1.988
Al	0.028	0.056	0.028	0.039	0.012
Al	0.010	—	0.018	0.029	0.006
Ti	0.001	0.019	0.003	0.008	0.002
Fe ⁺³	0.010	0.068	0.010	0.020	0.046
Cr	0.012	—	—	0.058	—
Mg	1.839	0.910	0.223	0.917	0.065
Ni	0.010	—	—	0.001	—
Fe ⁺²	0.102	0.901	1.495	0.045	0.789
Mn	0.002	0.028	0.183	0.003	0.129
Ca	0.008	0.060	0.066	0.820	0.939
Na	—	0.004	—	0.096	0.011
K	—	0.001	—	0.007	0.001
Mg	93.9	46.9	12.4	50.8	3.3
Fe	5.7	50.0	83.9	3.8	49.0
Ca	0.4	3.1	3.7	45.4	47.7

1. Enstatite, pyroxenite, North Carolina (Hess, H. H., 1952, *Amer. Journ. Sci.*, Bowen vol., p. 173).
2. Ferrohypersthene, hypersthene-diopside-plagioclase hornfels, Oslo district, Norway (Muir, I. D. & Tilley, C. E., 1958, *Geol. Mag.*, vol. 95, p. 403).
3. Orthoferrosilite, thermally metamorphosed iron-rich rock, Manchuria (Tsuru, K. & Henry, N. F. M., 1937, *Min. Mag.*, vol. 24, p. 527).
4. Chrome diopside, kimberlite, S. Africa (Holmes, A., 1937, *Trans. Geol. Soc. S. Africa*, vol. 39, p. 379; includes ZrO₂ 0.12, V₂O₃ 0.07, SrO 0.01, CO₂ 0.26, Ca tr., S tr.).
5. Hedenbergite, California (Wyckoff, R. W. G., Merwin, H. E. & Washington, H. S., 1925, *Amer. Journ. Sci.* 4th Ser., vol. 10, p. 389).

† Includes Zr 0.002, V 0.002.

Table 13. PYROXENE ANALYSES—continued

	6.	7.	8.	9.	10.
SiO ₂	52.92	46.61	49.68	48.90	52.84
TiO ₂	0.50	1.18	0.56	0.12	0.22
Al ₂ O ₃	2.80	3.47	0.78	3.86	0.44
Fe ₂ O ₃	0.85	0.90	3.29	4.65	1.06
Cr ₂ O ₃	0.88	—	—	—	—
FeO	5.57	20.18	18.15	25.35	16.89
MnO	0.15	1.11	0.59	0.51	0.56
NiO	0.10	—	—	—	—
MgO	16.40	7.27	16.19	6.87	23.51
CaO	19.97	17.24	9.90	7.96	4.06
Na ₂ O	0.35	1.04	0.65	0.58	0.19
K ₂ O	0.01	0.27	0.15	0.20	0.00
H ₂ O ⁺	0.10	0.42	0.10	0.57	—
H ₂ O ⁻	0.07	0.04	0.00	0.35	0.22
Total	100.67	99.73	100.04	99.92	99.99

α	1.6818	1.710	1.709	—	—
β	1.6865	1.716	—	—	—
γ	1.7085	1.736	1.738	—	—
2V _γ	49°	52°	28°-30°	—	—
D	—	3.49	—	—	—

NUMBERS OF IONS ON THE BASIS OF 6 OXYGENS

Si	1.929	1.859	1.905	1.941	1.955
Al	0.071	0.141	0.034	0.059	0.018
Al	0.049	0.021	—	0.121	—
Ti	0.014	0.035	0.016	0.004	0.006
Fe ⁺³	0.024	0.026	0.094	0.139	0.030
Cr	0.026	—	—	—	—
Mg	0.891	0.432	0.925	0.406	1.296
Ni	0.003	—	—	—	—
Fe ⁺²	0.170	0.673	0.582	0.842	0.523
Mn	0.005	0.037	0.019	0.017	0.017
Ca	0.780	0.737	0.407	0.338	0.161
Na	0.024	0.080	0.048	0.046	0.014
K	0.000	0.014	0.008	0.010	0.000
Mg	47.6	22.8	45.6	23.3	63.9
Fe	10.7	38.6	34.3	57.3	28.1
Ca	41.7	38.6	20.1	19.4	8.0

- Chromian augite, gabbro, Bushveld Complex (Hess, H. H., 1949, *Amer. Min.*, vol. 34, p. 621).
- Ferroaugite, syenite, South-West Africa (Simpson, E. S. W., 1954, *Trans. Geol. Soc. S. Africa*, vol. 57, p. 126).
- Sub-calcic augite, basalt, Japan (Kuno, H., 1955, *Amer. Min.*, vol. 40, p. 70).
- Sub-calcic ferroaugite, andesite, Japan (Kuno H. & Inoue, T., 1949, *Proc. Japan Acad.*, vol. 25, p. 128).
- Magnesian pigeonite, andesite, Japan (Kuno, H. & Nagashima, K., 1952, *Amer. Min.*, vol. 37, p. 1000).

Table 13. PYROXENE ANALYSES—continued

	11.	12.	13.	14.
SiO ₂	49.72	51.92	64.89	59.38
TiO ₂	0.85	0.77	—	0.04
Al ₂ O ₃	0.90	1.85	26.74	25.82
Fe ₂ O ₃	1.72	31.44	0.57	0.45
Cr ₂ O ₃	—	—	—	0.01
FeO	27.77	0.75	0.04	tr.
MnO	0.98	—	0.01	0.00
NiO	—	—	—	—
MgO	12.69	—	0.00	0.12
CaO	3.80	—	0.00	0.13
Na ₂ O	0.23	12.86	0.05	13.40
K ₂ O	0.12	0.19	0.16	0.02
H ₂ O ⁺	1.27	0.17	0.48	0.22
H ₂ O ⁻	0.08	—	0.06	0.16
Total	100.13	99.95	100.12	99.75

α	1.7137	1.770	1.661	1.654
β	1.7137	1.812	1.666	1.657
	1.7417	1.830	1.676	1.666
2V _γ	0°-12°	—	—	70°
D	3.44	—	3.163	3.43

NUMBERS OF IONS ON THE BASIS OF 6 OXYGENS

Si	1.968	1.986	2.026	1.998
Al	0.032	0.014	—	0.002
Al	0.010	0.069	0.984	1.022
Ti	0.025	0.022	—	0.001
Fe ⁺³	0.051	0.905	0.014	0.012
Cr	—	—	—	0.000
Mg	0.749	—	—	0.006
Ni	—	—	—	—
Fe ⁺²	0.919	0.024	0.001	—
Mn	0.033	—	—	—
Ca	0.161	—	—	0.005
Na	0.018	0.953	0.002	0.874
K	0.006	0.008	0.006	0.001
Mg	39.2	—	—	—
Fe	52.4	—	—	—
Ca	8.4	—	—	—

- Pigeonite, andesite, Scotland (Hallmond, A. F., 1914, *Min. Mag.*, vol. 17, p. 97).
- Aegirine, riebeckite-albite granite, Nigeria (Greenwood, R., 1951, *Bull. Geol. Soc. Amer.*, vol. 62, p. 1151).
- Wine-yellow spodumene, pegmatite, Sweden (Quensel, P., 1938, *Geol. För. Förh. Stockholm*, vol. 60, p. 201; includes Li₂O 7.12).
- White jadeite, serpentinite, California (Coleman, R. G., 1955, *Amer. Min.*, vol. 40, p. 312).

† Includes Li 0.894.

Table 15. AMPHIBOLE ANALYSES

	1.	2.	3.	4.	5.	6.
SiO ₂	58.48	44.89	51.53	47.54	51.40	42.05
TiO ₂	0.03	0.67	0.31	—	0.74	1.48
Al ₂ O ₃	0.57	17.91	5.02	0.20	3.88	14.69
Fe ₂ O ₃ [†]	0.58	0.67	0.82	0.71	3.90	3.21
FeO	7.85	13.31	16.91	47.25	14.91	6.30
MnO	0.27	0.37	0.22	2.14	0.33	0.04
MgO	29.25	18.09	20.84	0.04	11.22	14.91
CaO	0.14	0.40	1.34	0.00	10.17	12.83
Na ₂ O	0.08	1.45	0.65	0.29	1.67	2.01
K ₂ O	0.02	0.05	0.00	0.11	0.09	0.65
H ₂ O ⁺	2.60	2.02	2.15	1.55	1.90	1.53
H ₂ O ⁻	0.20	0.00	0.64	—	0.04	0.09
F	—	—	—	0.01	—	0.5
	100.20	99.87	100.43	99.84	100.25	100.29
O ≡ F, Cl	—	—	—	—	—	0.21
Total	100.20	99.87	100.43	99.84	100.25	100.08
α	—	1.649	1.643	1.686	1.650	1.648
β	—	1.656	1.650	1.709	1.663	1.660
γ	1.632	1.669	1.663	1.729	1.670	1.670
2V _α	80°	—	105°	85°	65°	85°
D	3.01	3.15	3.10	3.597	—	3.16
NUMBERS OF IONS ON THE BASIS OF 24 (O, OH, F, Cl)						
Si	7.885	6.325	7.364	7.968	7.543	6.099
Al	0.090	1.675	0.636	0.032	0.457	1.901
Al	—	1.301	0.209	0.008	0.215	0.611
Ti	0.003	0.071	0.033	—	0.082	0.161
Fe ⁺³	0.058	0.070	0.087	0.088	0.430	0.350
Mg	5.876	3.799	4.438	0.010	2.453	3.224
Fe ⁺²	0.885	1.569	2.022	6.626	1.830	0.764
Mn	0.031	0.044	0.027	0.304	0.040	0.005
Na	0.020	0.396	0.180	0.093	0.474	0.564
Ca	0.020	0.060	0.205	—	1.599	1.994
K	0.004	0.008	—	0.024	0.018	0.120
OH	2.338	1.898	2.049	1.732	1.861	1.480
F	—	—	—	0.007	—	0.229
	7.98	8.00	8.00	8.00	8.00	8.00
	—	—	—	—	5.05	5.12
	6.90†	7.32	7.20	7.15	2.09	2.68
	2.34	1.90	2.05	1.74	1.86	1.71

1. Anthophyllite, serpentinite, outer Hebrides (Guppy, E. M., 1956, *Mem. Geol. Surv. Gt. Britain*; includes Cr₂O₃ 0.04, NiO 0.01, CO₂ 0.08).
2. Gedrite, kyanite-garnet gedritite, Idaho (Hietanen, A., 1959, *Amer. Min.*, vol. 44, p. 539; includes P₂O₅ 0.04).
3. Cummingtonite, oligoclase-biotite schist, Scotland (Collins, R. S., 1942, *Min. Mag.*, vol. 26, p. 254).
4. Grunerite, U.S.A. (Bowen, N. L. & Schairer, J. F., 1935, *Amer. Min.*, vol. 20, p. 543).
5. Actinolite, albite-stilpnomelane-actinolite schist, New Zealand (Hutton, C. O., 1940, *Dept. Sci. and Ind. Res. New Zealand, Geol. Mem.*, No. 5).
6. Hornblende, ultrabasic rock, India (Howie, R. A., 1955, *Trans. Roy. Soc. Edinburgh*, vol. 62, p. 725).

† Includes Cr 0.054, Ni 0.001.

Table 15. AMPHIBOLE ANALYSES—continued

	7.	8.	9.	10.	11.	12.
SiO ₂	44.99	48.10	37.49	45.17	39.68	40.88
TiO ₂	1.46	0.10	0.86	2.11	7.12	0.22
Al ₂ O ₃	11.21	11.05	10.81	7.68	12.81	11.04
Fe ₂ O ₃	3.33	0.67	7.52	14.30	4.04	7.56
FeO	13.17	1.65	25.14	2.81	8.79	17.41
MnO	0.31	—	0.95	0.41	0.16	1.32
MgO	10.41	20.60	1.34	13.44	11.22	5.92
CaO	12.11	12.50	9.77	11.18	11.06	10.46
Na ₂ O	0.97	2.54	2.06	1.35	3.37	3.75
K ₂ O	0.76	1.24	1.91	1.09	1.04	0.78
H ₂ O ⁺	1.48	0.71	2.01	0.19	0.78	1.16
H ₂ O ⁻	0.04	0.11	—	0.06	0.15	—
F	—	1.90	—	0.35	0.33	—
O ≡ F, Cl	100.41	101.17	99.86	100.14	100.55	100.50
	—	0.80	—	0.14	0.14	—
Total	100.41	100.37	99.86	100.00	100.41	100.50

α	1.650	1.613	1.697	1.675	1.685	1.691
β	1.672	1.618	1.713	1.715	—	—
γ	1.681	1.635	1.714	1.735	1.736	1.707
2V _α	(+)	119.5°	16°	—	66°-74°	—
D	—	3.069	—	3.246	—	3.418

NUMBERS OF IONS ON THE BASIS OF 24 (O, OH, F, Cl)

Si	6.669 } 8.00	6.760 } 8.00	6.074 } 8.00	6.728 } 8.00	5.937 } 8.00	0.377 } 3.00
Al	1.331 } 8.00	1.240 } 8.00	1.926 } 8.00	1.272 } 8.00	2.063 } 8.00	1.623 } 3.00
Al	0.629 } 5.13	0.592 } 5.13	0.138 } 5.02	0.076 } 5.30	0.197 } 5.07	0.407 } 5.14
Ti	0.163 } 5.13	0.011 } 5.13	0.105 } 5.02	0.236 } 5.30	0.801 } 5.07	0.025 } 5.14
Fe ⁺³	0.370 } 5.13	0.071 } 5.13	0.917 } 5.02	1.602 } 5.30	0.454 } 5.07	0.886 } 5.14
Mg	2.300 } 5.13	4.315 } 5.13	0.323 } 5.02	2.984 } 5.30	2.501 } 5.07	1.376 } 5.14
Fe ⁺²	1.633 } 5.13	0.194 } 5.13	3.408 } 5.02	0.350 } 5.30	1.100 } 5.07	2.271 } 5.14
Mn	0.039 } 5.13	— } 5.13	0.131 } 5.02	0.051 } 5.30	0.020 } 5.07	0.174 } 5.14
Na	0.278 } 2.35	0.693 } 2.80	0.648 } 2.74	0.390 } 2.38	0.976 } 2.95	1.134 } 3.04
Ca	1.923 } 2.35	1.882 } 2.80	1.696 } 2.74	1.784 } 2.38	1.773 } 2.95	1.748 } 3.04
K	0.144 } 2.35	0.221 } 2.80	0.395 } 2.74	0.208 } 2.38	0.198 } 2.95	0.156 } 3.04
OH	1.462 } 1.46	0.667 } 1.51	2.174 } 2.17	0.190 } 0.36	0.778 } 0.93	1.208 } 1.21
F	— } 1.46	0.845 } 1.51	— } 2.17	0.165 } 0.36	0.156 } 0.93	— } 1.21

- Hornblende, tonalite, Idaho (Larsen, E. S. & Schmidt, R. G., 1958, *U.S. Geol. Surv. Bull.* 1070-A; includes P₂O₅ 0.17).
- Pargasite, metamorphosed limestone, Finland (Laitakari, A., 1921, *Bull. Comm. géol. Finlande*, No. 54).
- Ferrohastingsite, nepheline-syenite, Sweden (Quensel, P., 1914, *Bull. Geol. Inst. Upsala*, vol. 12, p. 146).
- Basaltic hornblende, latite, Colorado (Larsen, E. S., Irving, J., Gonyer, F. A. & Larsen, E. S., 3rd., 1937, *Amer. Min.*, vol. 22, p. 889).
- Kaersutite, cognate xenolith in trachyte (Aoki, K., 1959, *Sci. Rept. Tohoku Univ.*, ser. 3, vol. 6, p. 261).
- Barkevikite, nepheline-syenite, Norway (Kunitz, W., 1930, *Neues Jahrb. Min.*, Abt. A., vol. 60, p. 171).

Table 15. AMPHIBOLE ANALYSES—continued

	13.	14.	15.	16.	17.	18.
SiO ₂	57.73	52.41	53.80	48.51	57.10	48.41
TiO ₂	—	0.45	0.10	1.32	0.35	1.32
Al ₂ O ₃	12.04	0.61	1.37	6.60	6.19	1.81
Fe ₂ O ₃	1.16	14.37	1.89	4.09	8.01	11.25
FeO	5.41	14.82	0.00	9.48	2.69	23.81
MnO	—	1.46	8.69	0.19	0.34	0.75
MgO	13.02	5.07	18.45	14.79	9.13	0.06
CaO	1.04	1.33	5.43	5.60	0.31	1.18
Na ₂ O	6.98	4.94	5.63	6.01	9.77	7.37
K ₂ O	0.68	2.10	1.72	2.20	2.38	1.52
H ₂ O ⁺	2.27	2.02	1.91	1.47	0.50	0.94
H ₂ O ⁻	—	0.10	—	—	0.08	0.13
F	—	0.30	0.36	—	2.69	2.95
O ≡ F, Cl	100.33	99.98	99.88	100.26	101.28	101.50
	—	0.13	0.16	—	1.13	1.24
Total	100.33	99.85	99.72	100.26	100.15	100.26

α	1.606	1.686	1.622	1.639	1.636	—
β	—	—	1.635	1.658	1.644	—
γ	1.627	—	1.641	1.660	1.649	—
2V _α	—	—	66½°	38°	75°	—
D	3.085	—	3.08	—	3.16	—

NUMBERS OF IONS ON THE BASIS OF 24 (O, OH, F, Cl)

Si	7.789 } 8.00	7.924 } 8.00	7.748 } 7.98	7.119 } 8.00	8.021 } 8.02	7.618 } 7.95
Al	0.211 } 8.00	0.076 } 8.00	0.232 } 7.98	0.881 } 8.00	— } 8.02	0.334 } 7.95
Al	1.704 } 8.00	0.032 } 8.00	— } 8.00	0.259 } 8.00	1.025 } 8.00	— } 8.00
Ti	— } 8.00	0.051 } 8.00	0.011 } 8.00	0.145 } 8.00	0.037 } 8.00	0.156 } 8.00
Fe ⁺³	0.118 } 5.05	1.634 } 4.92	0.206 } 5.24	0.452 } 5.28	0.847 } 4.89	1.332 } 4.74
Mg	2.618 } 5.05	1.142 } 4.92	3.961 } 5.24	3.235 } 5.28	1.911 } 4.89	0.014 } 4.74
Fe ⁺²	0.611 } 5.05	1.874 } 4.92	— } 5.24	1.164 } 5.28	0.316 } 4.89	3.134 } 4.74
Mn	— } 5.05	0.187 } 4.92	1.061 } 5.24	0.024 } 5.28	0.040 } 4.89	0.100 } 4.74
Na	1.826 } 2.09	1.448 } 2.07	1.572 } 2.74	1.708 } 3.00	2.660 } 3.13	2.248 } 2.75
Ca	0.150 } 2.09	0.215 } 2.07	0.838 } 2.74	0.880 } 3.00	0.046 } 3.13	0.199 } 2.75
K	0.117 } 2.09	0.406 } 2.07	0.315 } 2.74	0.412 } 3.00	0.425 } 3.13	0.304 } 2.75
OH	2.043 } 2.04	2.036 } 2.18	1.834 } 2.01	1.440 } 1.44	0.469 } 1.66	0.988 } 2.46
F	— } 2.04	0.143 } 2.18	0.163 } 2.01	— } 1.44	1.193 } 1.66	1.468 } 2.46

- Glaucofane, glaucofane schist, Switzerland (Kunitz, W., 1930, *Neues Jahrb. Min.*, Abt. A., vol. 60, p. 171).
- Riebeckite, aegirine-riebeckite syenite, Korea (Miyashiro, A. & Miyashiro, T., 1956, *Journ. Fac. Sci. Tokyo Univ.*, vol. 10, p. 1).
- Richterite, metamorphosed limestone, Sweden (Sundius, N., 1945, *Geol. Förh. Förh. Stockholm*, vol. 67, p. 266; includes BaO 0.30, Cl 0.04, SO₃ 0.19).
- Magnesiokataphorite, theralite, Montana (Wolff, J. E., 1939, *Bull. Geol. Soc. Amer.*, vol. 49, p. 1569).
- Eckermannite, nepheline-syenite, Sweden (Sundius, N., 1945, *Årsbok, Sveriges Geol. Undersök.*, vol. 39, No. 8; includes Li₂O 1.15, ZnO 0.59).
- Arfvedsonite, arfvedsonite-aegirine syenite, east Greenland (Deer, W. A., Howie, R. A. & Zussman, J., 1963 *Rock Forming Minerals*, vol. 2, p. 368, Longmans).

† Includes Ba 0.017.

‡ Includes Cl 0.010.

§ Includes Li 0.650, Zn 0.061.

Table 18. MICA ANALYSES

	1.	2.	3.	4.
SiO ₂	45.24	48.42	49.29	40.95
TiO ₂	0.01	0.87	0.12	0.82
Al ₂ O ₃	36.85	27.16	3.17	17.28
Fe ₂ O ₃	0.09	6.57	21.72	0.43
FeO	0.02	0.81	3.19	2.38
MnO	0.12	—	tr.	tr.
MgO	0.08	tr.	3.85	22.95
CaO	0.00	tr.	0.74	0.00
Na ₂ O	0.64	0.35	0.12	0.16
K ₂ O	10.08	11.23	6.02	9.80
F	0.91	tr.	—	0.62
H ₂ O ⁺	4.12	4.31	7.21	4.23
H ₂ O ⁻	0.46	0.19	4.60	0.48
	100.24	99.91	100.35	100.13
O ≡ F	0.38	—	—	0.26
Total	99.86	99.91	100.35	99.87
α	—	—	1.592	1.546
β	1.586	—	—	1.588-1.590
γ	1.589	—	1.614	1.590
2V _α	46°	—	10°	0°-13°
D	—	—	2.580	2.78

NUMBERS OF IONS ON THE BASIS OF 24 (O,OH,F)

	1.	2.	3.†	4.
Si	6.050	6.597	7.634	5.724
Al	1.950	1.403	0.366	2.276
Al	3.860	2.959	0.213	0.562
Ti	—	0.089	0.014	0.084
Fe ⁺³	0.093	0.672	2.532	0.340
Fe ⁺²	0.002	0.091	0.413	0.276
Mn	0.014	—	—	—
Mg	0.022	—	0.889	4.776
Ca	—	—	0.123	—
Na	0.166	0.092	0.036	0.034
K	1.720	1.952	1.190	1.746
F	0.385	—	—	0.278
OH	3.676	3.916	4.00	3.946

- Rose-muscovite, pegmatite, New Mexico (Heinrich, E. W. & Levinson, A. A., *Amer. Min.*, 1953, vol. 38, p. 25; includes Rb₂O 0.93, Cs₂O 0.20, Li₂O 0.49).
- Muscovite, low grade psammitic schist, Inverness-shire (Lambert, R. St J., 1959, *Trans. Roy. Soc. Edinburgh*, vol. 63, p. 553).
- Glauconite, sandstone, Otago, New Zealand (Hutton, C. O. & Seelye, F. T., 1941, *Amer. Min.*, vol. 26, p. 593; includes P₂O₅ 0.32).
- Phlogopite, marble, New Zealand (Hutton, C. O., 1947, *Trans. Roy. Soc. New Zealand*, vol. 76, p. 481; includes BaO 0.03).

† Includes 0.264 Li.

‡ Includes 0.080 Rb, 0.012 Cs.

§ Nos. of ions calculated on basis of 20 (O) and 4 (OH).

Table 18. MICA ANALYSES—continued

	5.	6.	7.	8.	9.	
	39.14	37.17	35.98	35.03	49.80	SiO ₂
	4.27	3.14	2.35	2.56	0.00	TiO ₂
	13.10	14.60	18.06	20.38	25.56	Al ₂ O ₃
	12.94	3.75	1.47	1.08	0.08	Fe ₂ O ₃
	5.05	26.85	21.56	20.41	0.00	FeO
	0.14	0.06	0.13	0.02	0.38	MnO
	12.75	4.23	7.40	7.11	0.22	MgO
	1.64	0.17	0.15	0.17	0.00	CaO
	0.70	0.15	0.42	0.96	0.40	Na ₂ O
	6.55	8.25	9.09	8.62	9.67	K ₂ O
	1.11	0.85	0.09	—	6.85	F
	2.41	1.35	3.28	3.60	0.38	H ₂ O ⁺
	0.58	—	0.23	0.07	0.50	H ₂ O ⁻
	100.38	100.57	100.21	100.01	102.96	
	0.46	0.36	—	—	2.89	O ≡ F
	99.92	100.21	100.21	100.01	100.07	Total
	1.594	1.610	—	—	—	α
	1.671	1.676	1.644	1.640	—	β
	1.672	1.677	—	1.640	—	γ
	10°-25°	5°	—	—	36°	2V _α
	2.862	—	—	—	2.898	D

NUMBERS OF IONS ON THE BASIS OF 24 (O,OH,F)

	5.	6.	7.	8.	9.	
	5.790	5.972	5.545	5.339	6.750	Si
	2.210	2.028	2.455	2.661	1.250	Al
	0.074	0.736	0.827	1.001	2.834	Al
	0.474	0.379	0.272	0.293	—	Ti
	1.440	0.454	0.170	0.124	0.008	Fe ⁺³
	0.625	3.608	2.780	2.602	—	Fe ⁺²
	0.017	0.007	0.017	0.003	0.044	Mn
	2.811	1.013	1.700	1.615	0.044	Mg
	0.260	0.029	0.025	0.027	—	Ca
	0.199	0.046	0.126	0.282	0.106	Na
	1.236	1.691	1.787	1.676	1.674	K
	0.519	0.431	0.043	—	2.936	F
	2.378	1.446	3.373	3.660	0.344	OH

- Biotite, quartz latite, Colorado (Larsen, E. S., Jr., Gonyer, F. A. & Irving, J., 1937, *Amer. Min.*, vol. 22, p. 898).
- Biotite, granite, Southern California (Larsen, E. S., Jr. & Draisin, W., 1950, *Int. Geol. Congr. Rep. 18th Session, Gt. Britain*, Pt. 3, p. 66).
- Biotite, low grade garnet-mica schist, Inverness-shire (Lambert, R. St J., 1959, *Trans. Roy. Soc. Edinburgh*, vol. 63, p. 553).
- Biotite, garnet-sillimanite-mica schist, Angus, Scotland (Snelling, N. J., 1957, *Geol. Mag.*, vol. 94, p. 297).
- Lepidolite, Varuträsk pegmatite, Sweden (Berggren, T., 1941, *Geol. För. Förh.*, vol. 68, p. 262; includes Li₂O 5.95, Rb₂O 1.97, Cs₂O 1.20).

† Includes Li 3.244.

‡ Includes Rb 0.172, Cs 0.070.

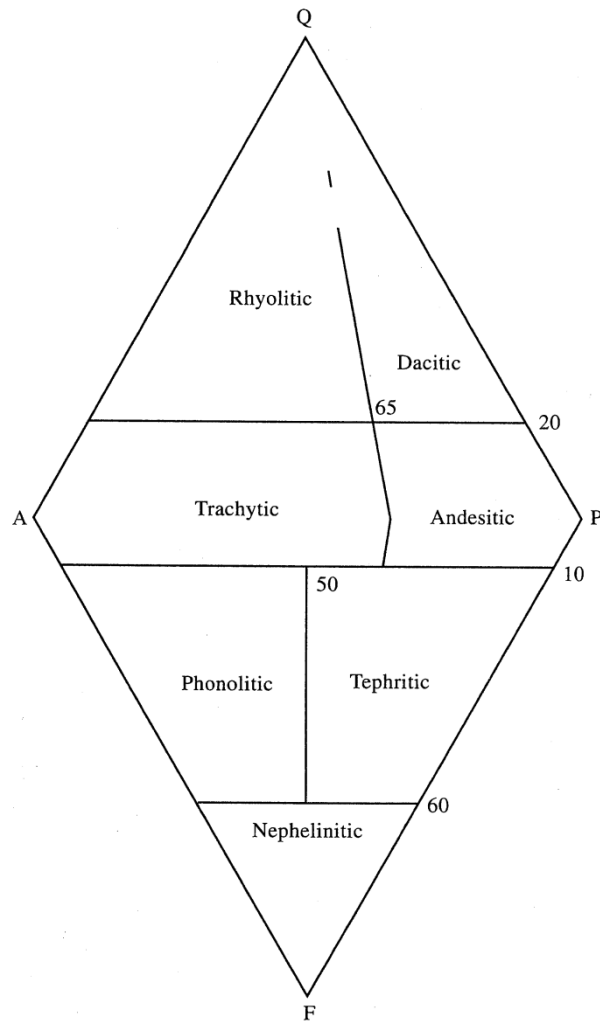
Table 4. GARNET ANALYSES

	1.	2.	3.	4.	5.	6.	7.
SiO ₂	38.03	37.03	38.69	41.52	35.84	35.88	34.48
TiO ₂	—	0.04	0.55	tr.	0.03	—	0.03
Al ₂ O ₃	22.05	8.92	18.17	23.01	20.83	1.13	19.87
Cr ₂ O ₃	—	—	—	0.22	—	27.04	—
Fe ₂ O ₃	0.88	18.34	5.70	1.22	0.65	2.46	0.61
FeO	29.17	2.25	3.78	12.86	1.78	—	0.85
MnO	1.57	1.09	0.64	0.33	33.37	0.03	0.02
MgO	6.49	0.83	0.76	16.64	2.48	0.04	2.07
CaO	1.80	30.26	31.76	4.71	5.00	33.31	37.40
H ₂ O ⁺	—	0.48	0.13	}0.16	—	}0.18	4.65
H ₂ O ⁻	—	0.16	0.06		—		0.23
Total	99.99	99.40	100.24	100.67	99.98	100.07	100.24
n	1.793	1.827	1.7692	1.750	1.787	1.85(±)†	1.702
D	4.08	3.77	3.688	3.782	4.12	3.75	3.35
a(Å)	11.529	—	11.844	—	11.653	—	—
NUMBERS OF IONS ON THE BASIS OF 24 (O)							
Si	5.951 } 6.00	6.043	5.966 } 6.00	5.999 } 6.00	5.808 } 6.00	5.964 } 6.00	5.043 } 6.18
Al	0.049 } —	—	0.034 } —	0.001 } —	0.192 } —	0.036 } —	1.133† } —
Al	4.019 } 1.716	—	3.268 } 3.97	3.912 } 3.99	3.786 } 4.07	0.186 } 3.87	3.416 } 4.05
Cr	0.102 } —	—	—	0.026 } —	—	3.554 } —	—
Fe ⁺³	— } 4.12	2.253 } 3.97	0.662 } 3.99	0.132 } 4.07	0.080 } 3.87	0.308 } 4.05	0.070 } 3.49
Ti	— } —	0.005 } —	0.064 } —	— } —	0.004 } —	— } —	0.003 } —
Mg	1.513 } 0.201	—	0.175 } 3.580	—	0.598 } 0.010	—	0.452 } —
Fe ⁺²	3.818 } 5.84	0.307 } 5.95	0.487 } 5.99	1.552 } 5.90	0.241 } 6.29	— } 5.95	0.104 } 6.42
Mn	0.203 } 5.84	0.151 } 5.95	0.083 } 5.99	0.040 } 5.90	4.581 } 6.29	0.004 } 5.95	0.002 } 6.42
Ca	0.302 } 5.292	—	5.248 } —	0.730 } —	0.868 } 5.934	—	5.858 } —
Almandine	65.4	5.2	8.1	26.1	4.0	—	—
Andradite	2.7	56.9	18.2	3.3	2.2	7.7	—
Grossular	2.5	32.0	69.4	8.9	11.2	2.4	—
Pyrope	25.8	3.4	2.9	60.3	7.9	0.2	—
Spessartine	3.6	2.5	1.4	0.7	74.7	0.1	—
Uvarovite	—	—	—	0.7	—	89.6	—

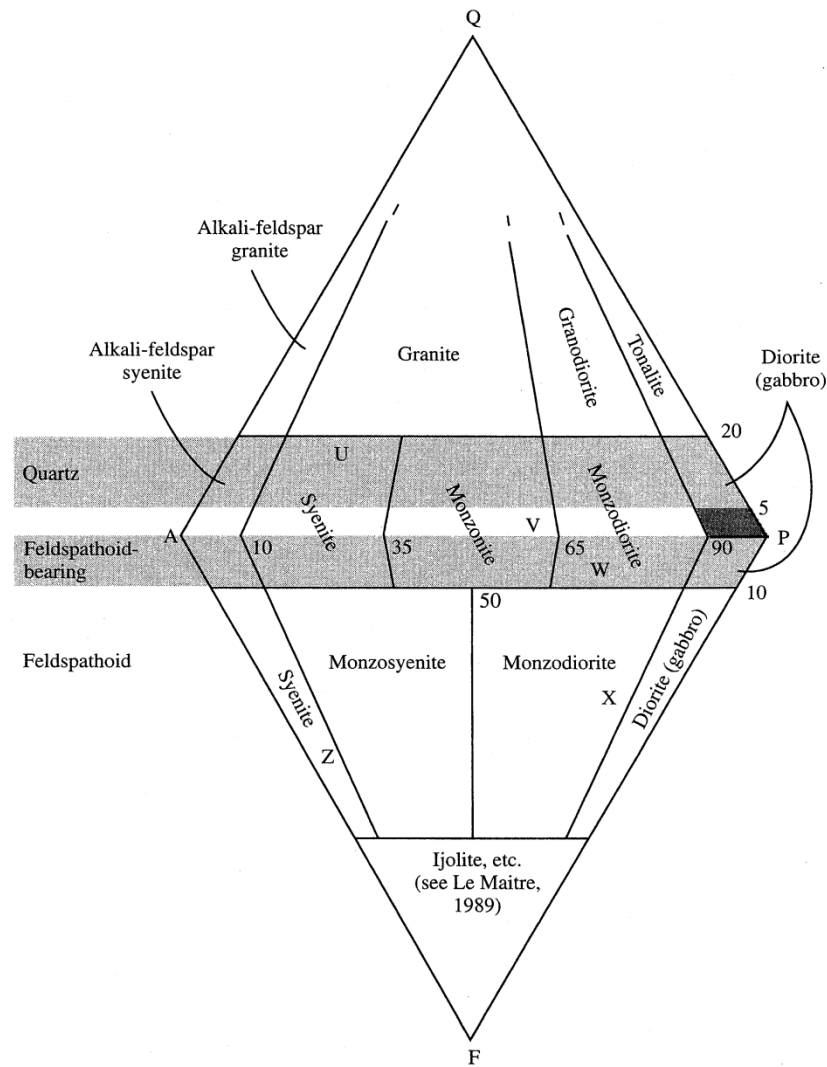
- Almandine, quartz-biotite gneiss, Adirondack Mts., New York (Engel, A. E. J. & Engel, C. G., 1960, *Bull. Geol. Soc. Amer.*, vol. 71, p. 1).
- Reddish brown andradite, metasomatic fissures in thermally metamorphosed andesite, Shap, Westmorland (Firman, R. J., 1957, *Quart. Journ. Geol. Soc.*, vol. 113, p. 205).
- Brownish red grossular, anorthite-clinozoisite-corundum-garnet gneiss, Sittampundi complex, Madras (Subramaniam, A. P., 1956, *Bull. Geol. Soc. Amer.*, vol. 67, p. 317).
- Pyrope, eclogite, Rodhaugen, Sandmore, Norway (Eskola, P., 1921, *Vid. Skrift. I, Mat.-nat. Kl.*, vol. 1, no. 8).
- Golden yellow spessartine, rhodonite-spessartine-pyrrhotite rock, calcisilicate hornfels, Meldon, Devonshire (Howie, R. A., 1965, *Min. Mag.* vol. 34 (Tilley vol.), p. 249).
- Uvarovite, uvarovite-tremolite-tawmawite-pyrrhotite vein, Oütökumpu, Finland (Eskola, P., 1933, *Compt. Rend. Soc. géol. Finlande*, no. 7, p. 26).
- Hydrogrossular, rodingite, Champion Creek, New Zealand (Hutton, C. O., 1943, *Trans. Roy. Soc. New Zealand*, vol. 73, p. 174; includes Na₂O 0.02, K₂O 0.01).

† For green light.

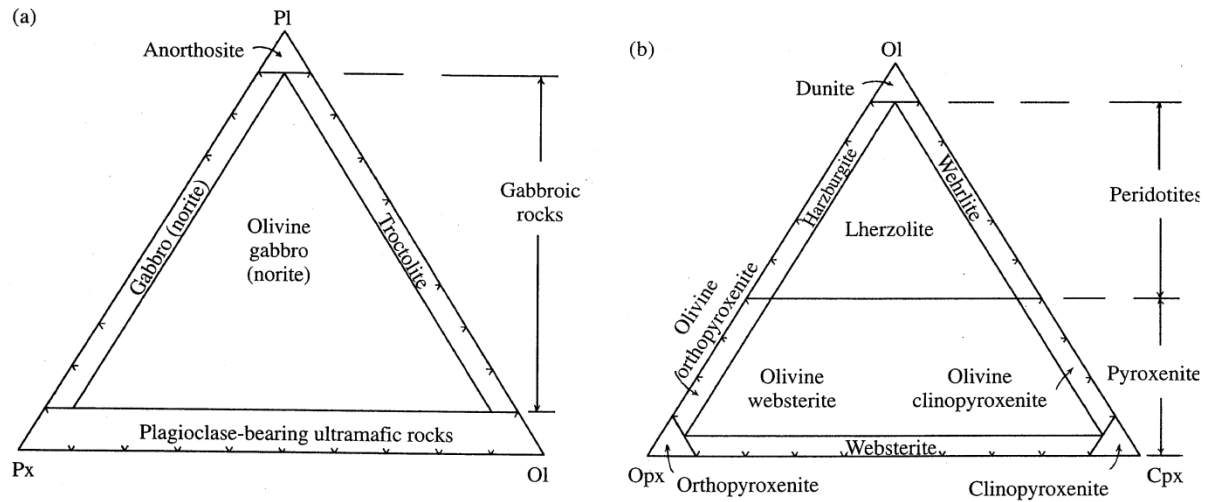
‡ OH/4.



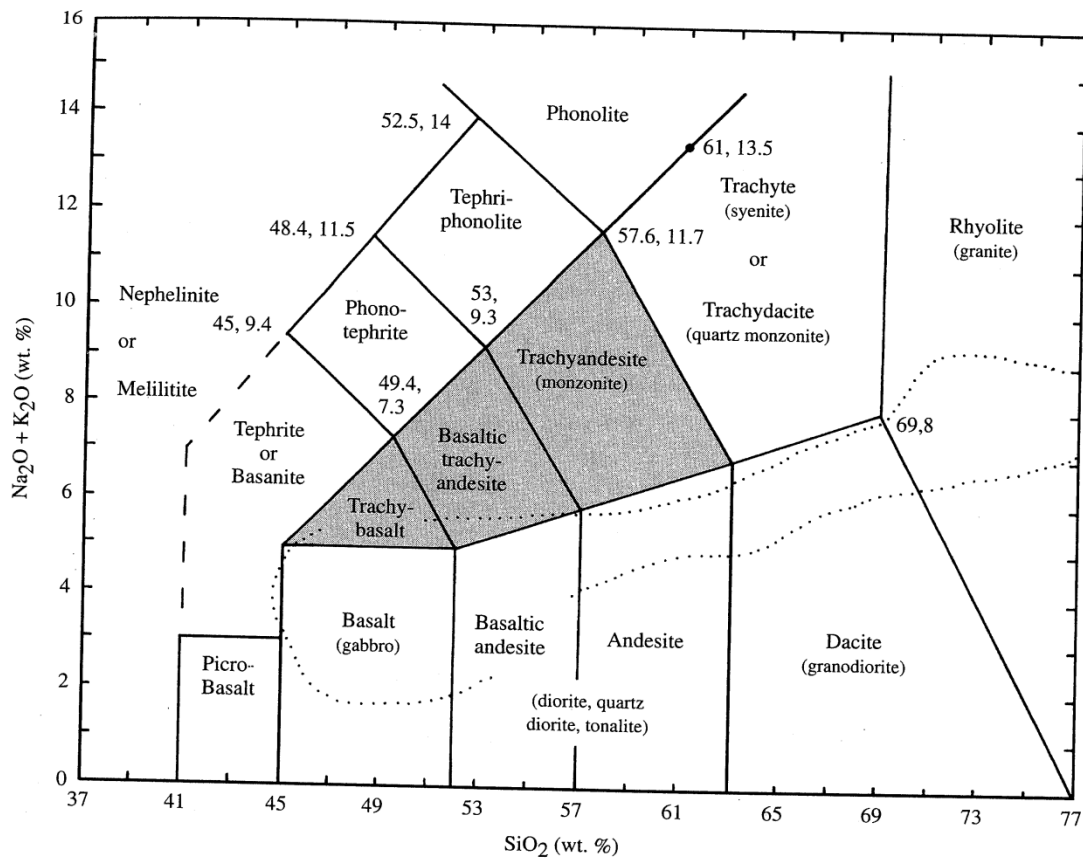
2.13 Preliminary classification of aphanitic and glassy rock types for use in cases in which an accurate chemical analysis is not available. This is a useful classification of rocks in the field or in thin section based upon the proportions of phenocrysts. Some rocks that are chemically rhyolite or dacite (Figure 2.12) contain quartz as the only phenocryst. (Redrawn from Le Maitre, 1989.)



- 2.8 Slightly modified IUGS classification of felsic, phaneritic, magmatic rock types that contain >10 modal % Q (quartz) + A (alkali feldspar) + P (plagioclase) + F (feldspathoids). Coordinates of critical field corners along the A-P join (10, 35, 65, 90) refer to modal percentages of P. Numbers on right side of diagram are modal percentages of Q (5, 20) and of F (10). Mineralogical prefixes on left side of diagram are modifiers to be appended to rock-type names in associated lightly shaded or unshaded fields. For example, a rock whose mode in terms of QAPF plots at U is a quartz syenite, V is a monzonite, W is a feldspathoid-bearing monzodiorite, X is a feldspathoid monzodiorite, and Z is a feldspathoid syenite. Rocks plotting in the small darkly shaded parallelogram near the P apex are **anorthosite** if containing <10% mafic minerals, or, if containing >10% mafic minerals, are gabbro or diorite. **Gabbro** contains plagioclase more calcic than An₅₀ and is further classified according to Figure 2.10a. **Diorite** has plagioclase less calcic than An₅₀. The composition of plagioclase can be approximated in a thin section by optical techniques. In the lower part of the diagram, **ijolite** is a rock composed of nepheline and clinopyroxene; it is essentially a phaneritic equivalent of aphanitic to glassy nephelinite (Figure 2.12). For a supplementary classification of phaneritic felsic rocks (granitoids) containing abundant plagioclase and >20% quartz see Figure 2.9. (Redrawn from Le Maitre, 1989, Figure B.4.)



2.10 IUGS classification of phaneritic mafic and ultramafic rock types. (a) Classification of mafic rocks (see gabbro in Figure 2.8 and its caption) based on the proportions of plagioclase, pyroxene, and olivine. **Norite** has more orthopyroxene than clinopyroxene (see Le Maitre, 1989, p. 17, for details). (b) Classification of **ultramafic** rocks that are composed of orthopyroxene, clinopyroxene, and olivine. For plagioclase-bearing ultramafic rocks see Le Maitre, 1989, Figure B.8. (Redrawn from Le Maitre, 1989.)



Ultrabasic | Basic | Intermediate | Acid

Further subdivisions of shaded fields	Trachybasalt	Basaltic trachyandesite	Trachyandesite
$\text{Na}_2\text{O} - 2.0 \geq \text{K}_2\text{O}$	Hawaiite	Mugearite	Benmoreite
$\text{Na}_2\text{O} - 2.0 \leq \text{K}_2\text{O}$	Potassic trachybasalt	Shoshonite	Latite

2.12 IUGS classification of aphanitic and glassy volcanic rock types. Coordinates of critical points are indicated as, for example, SiO_2 wt. % = 69 and $(\text{Na}_2\text{O} + \text{K}_2\text{O})$ wt. % = 8 at the common corner of the fields of trachyte, rhyolite, and dacite. Rocks plotting in the shaded area may be further subdivided into sodic and potassic rock types as shown in the box below the main part of the diagram. Figure 2.18 shows an alternate classification based on K_2O versus SiO_2 . The distinction between trachyte ($Q < 20\%$) and trachydacite ($Q > 20\%$) is based on the amount of normative quartz, Q , from a recalculation in which $Q + An + Ab + Or = 100$. The amount of normative olivine, Ol , in the rock distinguishes tephrite ($< 10\%$) from basanite ($> 10\%$). Rock-type names for more or less corresponding common phaneritic rocks are indicated in parentheses. Dotted line encloses 53% of the rocks plotted in Figure 2.4. (Redrawn from Le Maitre, 1989.)

Table 2.1 Whole-Rock Chemical Composition of Basalt from the Columbia River Plateau, Sample BCR-1^a

SiO ₂	54.06	Ag	27*	Er	3.63	Nd	28.8	Tb	1.05
TiO ₂	2.24	As	650	Eu	1.95	Ni	(13)	Te	(4.9*)
Al ₂ O ₃	13.64	Au	(0.66*)	F	490	Pb	(13.6)	Th	5.98
Fe ₂ O ₃	3.59	Ba	681	Ga	22	Pr	6.8	Tl	0.3
FeO	8.88	Be	(1.6)	Gd	6.68	Rb	47.2	Tm	0.56
MnO	0.18	Bi	47*	Ge	1.5	Re	0.84	U	1.75
MgO	3.48	Br	(72*)	Hf	4.95	Rh	(0.23*)	V	407
CaO	6.95	Cd	130*	Hg	(7.9*)	S	410	W	(0.44)
Na ₂ O	3.27	Ce	53.7	Ho	1.26	Sb	0.62	Y	38
K ₂ O	1.69	Cl	59	In	92*	Sc	32.6	Yb	3.38
P ₂ O ₅	0.36	Co	37	La	24.9	Se	(88*)	Zn	129.5
H ₂ O ⁺	0.75	Cr	(16)	Li	12.9	Sm	6.59	Zr	190
H ₂ O ⁻	0.81	Cs	0.96	Lu	0.51	Sn	(2.7)		
CO ₂	0.03	Cu	(19)	Mo	(1.6)	Sr	330		
LOI	1.67	Dy	6.34	Nb	(14)	Ta	0.81		
Total	99.93								

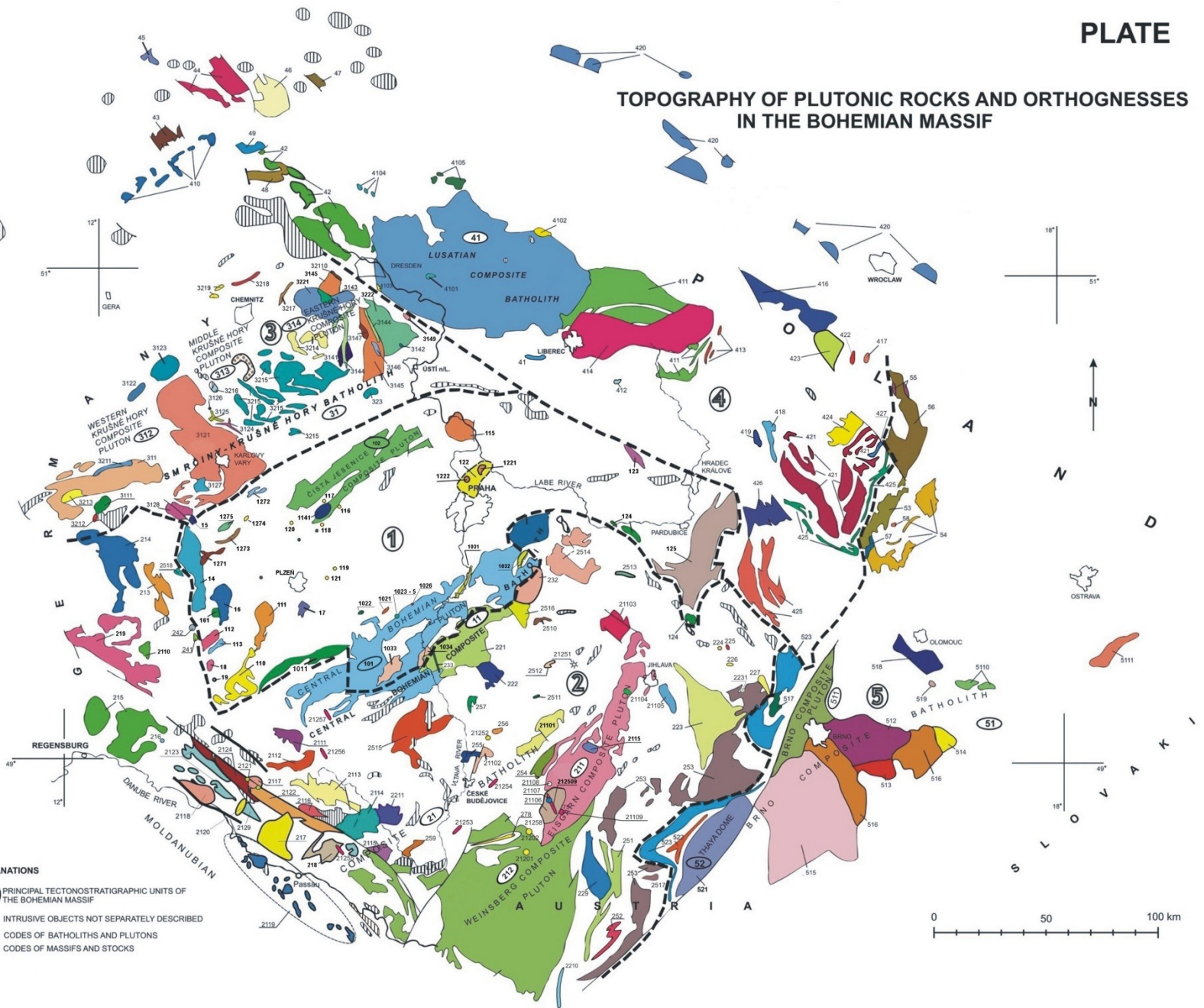
^aMajor element oxides in wt.%. Less certain values in parentheses. *, Trace element concentration in parts per billion (ppb); all other trace elements in parts per million (ppm).

Data from Govindaraju (1989).

Table 2.2 Average Chemical Compositions of Some Common Rock Types (Recalculated Volatile-Free to Total 100%) and Their Normative Compositions^a

	PHONOLITE	SYENITE	TRACHYTE	GRANITE	RHYOLITE	GRANODIORITE	DACITE	DIORITE	ANDESITE
<i>n</i>	340	517	534	2485	670	885	651	872	2600
SiO ₂	57.43	59.63	62.31	71.84	73.95	66.91	65.98	58.34	58.70
TiO ₂	0.63	0.86	0.71	0.31	0.28	0.55	0.59	0.96	0.88
Al ₂ O ₃	19.46	16.94	17.27	14.43	13.48	15.92	16.15	16.92	17.24
Fe ₂ O ₃	2.85	3.09	3.04	1.22	1.50	1.40	2.47	2.54	3.31
FeO	2.07	3.18	2.33	1.65	1.13	2.76	2.33	4.99	4.09
MnO	0.17	0.13	0.15	0.05	0.06	0.08	0.09	0.12	0.14
MgO	1.09	1.90	0.94	0.72	0.40	1.76	1.81	3.77	3.37
CaO	2.78	3.59	2.38	1.85	1.16	3.88	4.38	6.68	6.88
Na ₂ O	7.96	5.33	5.57	3.71	3.61	3.80	3.85	3.59	3.53
K ₂ O	5.36	5.04	5.07	4.10	4.37	2.76	2.20	1.79	1.64
P ₂ O ₅	0.18	0.30	0.21	0.12	0.07	0.18	0.15	0.29	0.21
Q		0.83	5.00	29.06	32.87	22.36	22.73	10.28	12.37
C				0.92	1.02	0.26			
Or	30.96	29.29	29.41	24.50	25.44	16.11	12.82	10.42	9.60
Ab	35.48	44.34	46.26	31.13	30.07	31.73	32.07	29.96	29.44
An	1.50	7.24	7.05	8.04	4.76	17.34	20.01	24.40	26.02
Lc									
Ne	16.50								
Di	6.89	5.35	2.14				0.11	4.67	4.84
Wo	0.73								
Hy		4.16	2.06	3.37	1.34	7.40	5.73	12.56	9.49
Ol									
Mt	4.05	4.41	4.33	1.75	2.14	2.00	3.53	3.63	4.74
Il	1.18	1.60	1.34	0.58	0.54	1.03	1.09	1.80	1.65
Ap	0.41	0.70	0.49	0.28	0.17	0.42	0.34	0.68	0.50

TOPOGRAPHY OF PLUTONIC ROCKS AND ORTHOGNESSES
IN THE BOHEMIAN MASSIF



- EXPLANATIONS**
- ① PRINCIPAL TECTONOSTRATIGRAPHIC UNITS OF THE BOHEMIAN MASSIF
 - ▨ INTRUSIVE OBJECTS NOT SEPARATELY DESCRIBED
 - ②③ CODES OF BATHOLITHS AND PLUTONS
 - 445 CODES OF MASSIFS AND STOCKS

