

Studies on manganese-bearing silicate minerals from metamorphosed manganese formations of India. II. Blanfordite, manganoan diopside, and brown manganiferous pyroxene

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SUMMARY. Three members of the pyroxene group, blanfordite, manganoan diopside, and brown manganiferous pyroxene, form important constituents of the manganese silicate rocks (gondite) of the metamorphosed manganese formations of India. The chemical composition of blanfordite is variable within the diopside-acmite series, that of the manganoan diopside corresponds to the diopside end of this series, and the brown manganiferous pyroxenes are related to aegirine-augites. The majority of the blanfordites studied have a composition within the aegirine-augite field, so that compositionally most of the blanfordites and brown manganiferous pyroxenes are similar in spite of the difference in their pleochroic schemes; The chemical composition of blanfordite varies: in association with calc-magnesian metasediments it has a high percentage of diopside, whereas in gondites and pegmatites its composition approaches more towards the acmite end. The blanfordites are often associated with manganiferous amphiboles such as juddite (manganoan magnesioriebeckite) and winchite (richterite-tremolite with blue and pink pleochroism) but never with tirodite. The brown manganiferous pyroxenes, on the other hand, are associated intimately with tirodite (richterite-tremolite with pleochroism in shades of yellow) but never with winchite and juddite.

BLANFORDITE, a manganiferous pyroxene, was first described from metamorphosed manganese formations of India and named by Fermor (1909) after W. T. Blanford of the Geological Survey of India. The mineral has been variously equated by previous workers to manganiferous diopside (Fermor, 1909), aegirine (Bilgrami, 1956; Nayak and Neuvonen, 1963), and aegirine-augite (Zwaan and Plas, 1958; Kilpady, 1960; Deer, Howie, and Zussman, 1963). Manganoan diopside from the metamorphosed manganese formations of Gowari Wadhona, Chhindwara District, Madhya Pradesh, was described by Roy and Purkait (1966, 1968). Brown manganiferous pyroxene was described by Fermor (1909) from Kajlidongri and Kosumbah, India; he related it to schefferite or urbanite. Zwaan and Plas (1958), Roy (1966), and Roy and Purkait (1968) suggested that it belongs to the aegirine-augite group.

Distribution. Both blanfordite and brown manganiferous pyroxenes occur profusely in the regionally metamorphosed manganese silicate rocks (gondites) of the Precambrian Sausar Group of Madhya Pradesh and Maharashtra and the Gangpur

Group of Orissa, India. They are also well distributed in contact metamorphic manganese silicate rocks (kodurites) described from Jothvad, Panch Mahals District, Gujarat, India (Roy, 1966; S. K. Roy, 1967). The formation of blanfordite is generally favoured in such parts of the manganese formation (manganese silicate rocks and oxide ores) as have been invaded by pegmatite dikes and veins. The brown manganiferous pyroxenes are evenly distributed in the gondites, both in association with and in the absence of pegmatites. Both the minerals form large well-developed crystals at the contact of pegmatite bodies. The distribution of manganoan diopside is restricted to those parts of the manganese formations where the gondites are juxtaposed against calc-magnesian rocks, e.g. Gowari Wadhona (Roy and Purkait, 1968) and Sudhan Hurki, Madhya Pradesh.

The *optical properties* of manganoan diopside (table III; Roy and Purkait, 1968) vary within the ranges α 1.670–1.673, γ 1.690–1.702, and $\gamma-\alpha$ 0.020–0.029, $2V_\gamma$ 56–69°; generally the mineral is just perceptibly pleochroic in shades of pale blue, though in varieties with higher refractive indices (Roy and Purkait, 1968), the scheme of pleochroism is distinct, α pale pink, β very pale blue, γ light blue, and is similar to some varieties of blanfordite.

The refractive indices of blanfordite (table II; Bilgrami, 1956; Kilpady, 1960; Roy, 1966; Roy and Purkait, 1968) range: α 1.681–1.767, γ 1.709–1.799, $\gamma-\alpha$ 0.020–0.040, $2V_\alpha$ 50–80°; the pleochroism, α pink to rose pink, sometimes with a violet tint, β pale blue, sometimes with a lilac tint, γ sky blue to deep blue, of the mineral is always very characteristic.

The refractive indices, extinction angle, and optic axial angle of the brown manganiferous pyroxene (table III; Roy, 1966; Roy and Purkait, 1968) range: α 1.713–1.737, γ 1.734–1.758, $\gamma-\alpha$ 0.021–0.029; α : $[001]$ 0–21°; $2V_\gamma$ 77–88°. The pleochroic scheme is: α brown to deep brown, often with a pink tint, β pale brown to yellowish brown, γ yellow with occasional green tinge.

The optical properties indicate that both blanfordite and the brown manganiferous pyroxene belong to aegirine-augite group of the diopside-acmite series. That the brown manganiferous pyroxene cannot be related to schefferite (as suggested by Fermor, 1909) is evident by higher range of refractive indices and higher $2V_\gamma$ values of this mineral. However, their refractive indices, birefringences, and $2V$ values, when plotted against the respective chemical compositions (Fe^{3+} ions per formula unit), do not always agree with the data given by Deer, Howie, and Zussman (1963; vol. 2, fig. 28). In some cases, the refractive indices do not show a consistent rise in values corresponding to rising Fe^{3+} content. The birefringence in particular, always tends to show lower values than is indicated by Deer, Howie, and Zussman (1963). These departures are probably due to variations in the Mg : Fe^{2+} ratio. Since the blanfordites described in this paper contain MnO and little or no FeO, their optical properties are nearer to those of the synthetic $\text{CaMgSi}_2\text{O}_6$ – $\text{NaFe}^{3+}\text{Si}_2\text{O}_6$ series where any $\text{Mg} \rightleftharpoons \text{Fe}^{2+}$ replacement is absent.

X-ray powder data of blanfordite, the brown manganiferous pyroxene, and manganoan diopside from the present study are given in table I.

Chemical composition. A number of specimens of these three minerals, from different localities in the Madhya Pradesh and Maharashtra manganese belt of India, were crushed and cleaned by separation with heavy liquids, isodynamic separator, and hand picking, and were subjected to chemical analysis.

TABLE I. *X-ray powder data for three manganiferous pyroxenes from Madhya Pradesh, India (Cu-K α radiation)*

Blanfordite				Brown manganiferous pyroxene				Manganooan diopside			
<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>
6.441 Å	12	2.146 Å	12	6.441 Å	10	—	—	—	—	2.224	5
—	—	—	—	5.627	5	—	—	—	—	2.216	5
—	—	—	—	5.590	6	2.134	20	—	—	2.158	18
4.424	6	2.132	18	4.447	6	2.106	10	—	—	2.156	18
—	—	2.106	6	4.424	6	2.034	85	—	—	2.140	18
3.212	18	2.036	70	3.218	32	—	—	3.246 Å	20	2.120	10
—	—	—	—	—	—	—	—	3.240	16	2.034	90
3.047	42	—	—	3.027	10	1.829	6	3.008	30	1.843	10
—	—	1.824	6	2.992	46	1.753	22	2.973	20	1.841	10
—	—	1.747	10	2.940	44	1.751	25	2.968	20	—	—
2.920	100	1.743	10	2.895	15	—	—	2.910	12	1.758	20
—	—	—	—	—	—	1.626	25	2.731	5	1.756	16
—	—	1.634	6	—	—	—	—	2.727	5	1.666	10
2.567	12	1.623	12	2.564	15	1.614	28	2.578	12	1.630	18
2.560	12	1.618	14	—	—	1.599	28	—	—	1.626	18
—	—	1.606	12	2.532	15	1.556	10	2.535	30	—	—
2.504	18	1.578	6	2.528	15	1.549	15	—	—	1.593	5
2.501	18	1.575	6	2.508	22	1.546	15	—	—	1.590	5
2.350	96	1.542	12	2.346	100	1.538	8	2.346	100	1.555	7
2.211	6	1.538	12	2.151	15	1.533	8	—	—	—	—
—	—	—	—	2.146	15	—	—	—	—	—	—

The manganooan diopside (table III; also Roy and Purkait, 1968) is uniformly high in CaO (21.97–24.16%) and MgO (14.90–17.13%) and low in Fe₂O₃ (0.44–4.42%) and Na₂O (0.57–2.19%); FeO has only been detected in traces; MnO varies from 1.49% to 3.98%. Published analyses of minerals of diopside–hedenbergite series (Deer, Howie, and Zussman, 1963, vol. 2, table 5) indicate that the manganese content is very low in magnesium-rich members but increases in the more iron-rich members (e.g. manganooan ferrosalite, Tilley, 1949; manganooan hedenbergite, Allen and Fahey, 1957). As they lack FeO and contain MnO, Fe₂O₃, and Na₂O, these diopsides are considered to belong to the diopside–acmite series and the molecular percentages have been calculated accordingly.

The chemical compositions of blanfordite and the brown manganiferous pyroxenes agree more or less with the generalizations of Sabine (1950). In table II, the chemical compositions of blanfordites determined in the present study have been presented. Earlier published chemical compositions have been included in fig. 1. The range of

compositions is: aegirine 82.51–12.49, jadeite 0–23.18, johannsenite 2.19–19.34, diopside 13.34–75.03, and enstatite 0–14.97%.

The chemical compositions of the brown manganiferous pyroxenes are included in table III. It is apparent (cf. table II) that the brown manganiferous pyroxenes are compositionally similar to the blanfordites. They can be expressed as: aegirine 24.64–50.79, jadeite 0–18.78, johannsenite 7.21–23.69, diopside 29.99–47.84, and enstatite 4.02–20.43 (present study; Roy, 1966; Roy and Purkait, 1968). In both blanfordite and brown manganiferous pyroxene, FeO is generally absent or negligible.

Key to fig. 1

Blanfordites

1. Kajlidongri, Jhabua District, Madhya Pradesh, India (Lahiri, unpublished data, 1969).

2. Netra, Balaghat District, Madhya Pradesh, India (R. N. Pal, personal communication).

3. Tirodi, Balaghat District, Madhya Pradesh, India (present investigation).

4. Jothvad, Gujarat, India (S. K. Roy, unpublished data, 1967).

5. Kacharwahi, Nagpur District, Maharashtra, India (present investigation).

6. Tirodi New Quarry, Balaghat District, Madhya Pradesh, India (present investigation).

7. Sitapatore, Balaghat District, Madhya Pradesh, India (present investigation).

8. Ghoriajor, Sundargarh District, Orissa, India (present investigation).

9 and 10. Gowari Wadhona, Chhindwara District, Madhya Pradesh, India (present investigation).

11. Ponia, Balaghat District, Madhya Pradesh, India (Kilpady, 1960).

12. Chikla, Bhandara District, Maharashtra, India (Bilgrami, 1956).

13. Gowari Wadhona, Chhindwara District, Madhya Pradesh, India (Roy and Purkait, 1968).

14. North Tirodi, Balaghat District, Madhya Pradesh, India (Roy, 1966).

X. North Tirodi, Balaghat District, Madhya Pradesh (Nayak and Neuvonen, 1963); aegirine 80.0, jadeite 10.0, johannsenite 6.0, enstatite 4.0%.

Manganoan diopsides

A and B. Sudhan Hurki, Balaghat District, Madhya Pradesh, India (R. N. Pal, personal communication).

C, D, and E. Gowari Wadhona, Chhindwara District, Madhya Pradesh, India (Roy and Purkait, 1968).

Brown manganiferous pyroxenes

P1. Ramdongri, Nagpur District, Maharashtra, India (present investigation).

P2. Netra, Balaghat District, Madhya Pradesh, India (R. N. Pal, personal communication).

P3. Gowari Wadhona, Chhindwara District, Madhya Pradesh, India (Roy and Purkait, 1968).

P4. Tirodi South Hill, Balaghat District, Madhya Pradesh, India (Roy, 1966).

Y. Manganiferous aegirine from metamorphosed Wabush Iron Formation, S.W. Labrador (Klein, 1966, table 10, no. 17A); aegirine 86.67, johannsenite 7.78, enstatite 5.55%.

Z. Manganiferous aegirine-augite from metamorphosed Wabush Iron Formation, S.W. Labrador (Klein, 1966, table 10, no. 16A); aegirine 60.08, jadeite 1.12, johannsenite 18.28, diopside 0.09, enstatite 20.43%.

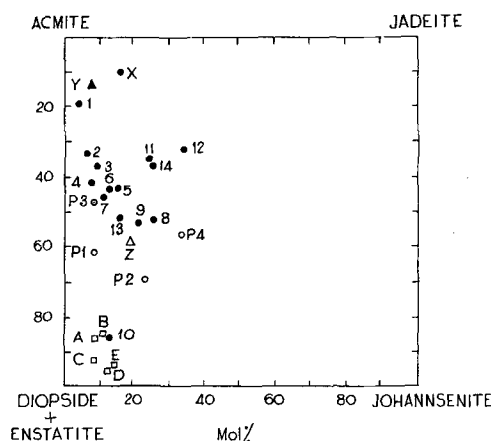


FIG. 1. Compositions, from the present study and from the literature, of: ● blanfordite; ○ brown manganiferous pyroxene; □ manganoan diopside; ▲ manganiferous aegirine (Klein, 1966); △ manganiferous aegirine-augite (Klein, 1966).

TABLE II. *Chemical composition and optical properties of blanfordite (anal. B.P. Gupta).
For localities see the caption to fig. 1*

	1	2	3	4	5
SiO ₂	50.04	51.72	51.20	52.70	50.40
Al ₂ O ₃	2.80	3.68	2.20	2.54	3.44
TiO ₂	0.12	0.53	1.05	0.67	0.18
Fe ₂ O ₃	28.00	23.27	22.00	19.87	18.26
FeO	0.72	0.07	Trace	Trace	0.40
MgO	2.10	4.71	4.33	5.68	5.86
MnO	1.14	1.60	2.74	2.22	2.08
CaO	3.82	5.27	7.70	7.90	10.89
Na ₂ O	9.68	8.07	7.37	7.53	7.41
K ₂ O	0.35	1.02	0.86	0.43	0.54
H ₂ O ⁺	0.58	0.12	0.18	0.24	0.08
H ₂ O ⁻	0.22	0.20	0.62	0.36	0.32
Total	99.57	100.26	100.25	100.14	99.86
<i>Atomic ratios to 6 oxygen</i>					
Si	1.92	1.95	1.95	1.96	1.90
Al	{ 0.08 0.04	{ 0.05 0.11	{ 0.05 0.05	{ 0.04 0.08	{ 0.10 0.08
Ti	0.01	0.02	0.03	0.02	0.01
Fe ³⁺	0.81	0.66	0.63	0.56	0.52
Fe ²⁺	0.01	0.01	—	—	0.01
Mg	0.12	0.26	0.25	0.32	0.33
Mn	0.04	0.05	0.09	0.07	0.07
Ca	0.16	0.21	0.31	0.31	0.44
Na	0.72	0.59	0.55	0.54	0.54
K	0.02	0.05	0.04	0.02	0.03
Z	2.00	2.00	2.00	2.00	2.00
XY	1.03	1.11	1.05	1.05	1.02
W	0.90	0.85	0.90	0.87	1.01
<i>Molecular percentages</i>					
Aegirine	82.51	66.91	63.74	59.37	53.12
Jadeite	—	—	—	—	5.12
Johannsenite	4.15	5.36	9.55	7.37	7.98
Diopside	13.34	16.91	25.54	25.79	33.78
Enstatite	—	10.82	2.17	7.47	—
<i>Optical properties</i>					
α	Pale pink	Pink	Rose pink	Rose pink	Pink
β	Pale blue-green	Deep lilac	Pale violet	Pale blue	Pale blue
γ	Deep blue	Sky blue	Sky blue	Sky blue	Blue
α	1.744*	1.746†	1.739*	1.713‡	1.736*
γ	1.783*	1.785†	1.788†	1.743‡	1.772†
$2V_{\alpha}$	50°	75°	78°	72°	80°

* ± 0.004 .† ± 0.006 .‡ ± 0.005 .§ ± 0.002 .

TABLE II (cont.)

	6	7	8	9	10
SiO ₂	51.44	52.88	49.61	48.66	50.26
Al ₂ O ₃	1.71	1.42	2.97	4.16	1.76
TiO ₂	0.54	0.54	0.45	Trace	Trace
Fe ₂ O ₃	19.71	19.02	15.82	12.44	4.18
FeO	Nil	Nil	Trace	Trace	Trace
MgO	6.49	6.77	5.95	8.72	12.64
MnO	2.49	2.34	6.32	2.20	3.35
CaO	8.99	8.55	11.35	14.22	23.55
Na ₂ O	7.93	7.64	6.76	6.77	1.58
K ₂ O	0.64	0.63	0.29	0.20	0.29
H ₂ O ⁺	0.14	0.16	0.10	0.22	0.24
H ₂ O ⁻	0.38	0.36	0.38	2.06	1.82
Total	100.46	100.31	100.00	99.65	99.67
<i>Atomic ratios to 6 oxygen</i>					
Si	1.94	1.99	1.91	1.88	1.92
Al	{ 0.06 0.02	{ 0.01 0.05	{ 0.09 0.04	{ 0.12 0.07	{ 0.08 0.01
Ti	0.02	0.02	0.01	—	—
Fe ³⁺	0.56	0.54	0.46	0.36	0.12
Fe ²⁺	—	—	—	—	—
Mg	0.36	0.38	0.34	0.50	0.72
Mn	0.08	0.07	0.21	0.07	0.11
Ca	0.36	0.35	0.47	0.59	0.97
Na	0.58	0.56	0.50	0.51	0.12
K	0.03	0.03	0.01	0.01	0.01
Z	2.00	2.00	2.00	2.00	2.00
XY	1.04	1.06	1.06	1.00	0.96
W	0.97	0.94	0.98	1.11	1.10
<i>Molecular percentages</i>					
Aegirine	53.08	51.73	43.01	33.09	12.49
Jadeite	4.84	4.71	5.63	14.30	1.14
Johannsenite	7.49	7.12	19.34	6.60	11.34
Diopside	27.01	26.06	24.60	46.01	75.03
Enstatite	7.58	10.38	7.42	—	—
<i>Optical properties</i>					
α	Pink	Pink brown	Rose pink	Deep pink	Pink
β	Lilac	Deep lilac	Pale violet	Pale lilac	Violet
γ	Blue	Blue	Blue	Blue	Blue
α	1.732*	1.730*	1.728*	1.718*	1.681§
γ	1.770†	1.766†	1.760*	1.748*	1.709*
2V _α	78°	76°	84°	88°	60°

TABLE III. *Chemical composition and optical properties of manganoan diopside (A and B) and brown manganiferous pyroxene (P1 and P2), from Madhya Pradesh, India (anal. B.P.Gupta). For localities see the caption to fig. 1*

	A	B	P1	P2
SiO ₂	52.46	51.78	51.28	52.04
Al ₂ O ₃	1.38	1.88	2.26	1.69
TiO ₂	0.05	Trace	0.48	0.12
Fe ₂ O ₃	4.03	4.42	14.60	11.25
FeO	—	Trace	Nil	Nil
MgO	15.32	14.90	8.93	8.59
MnO	1.75	1.90	2.64	7.74
CaO	22.07	21.97	13.54	13.88
Na ₂ O	2.16	2.19	4.93	4.13
K ₂ O	0.20	0.28	0.47	0.29
H ₂ O ⁺	0.08	0.14	0.10	0.10
H ₂ O ⁻	0.56	0.90	0.90	0.64
Total	100.06	100.36	100.13	100.47
α	Weak but distinct pleochroism in shades of pale blue	Weak but distinct pleochroism in shades of pale blue	Brown Yellowish brown Yellow	Brown Pale brown Yellowish green
β				
γ				
α	1.672*	1.671*	1.721	1.718
γ	1.696*	1.693*	1.744	1.740
α : $[\infty 001]$	—	—	10°	8°
2V _{γ}	68°	66°	80°	84°
<i>Atomic ratios to 6 oxygen</i>				
Si	1.94	1.92	1.94	1.97
Al	0.06	{ 0.08 0.01	{ 0.06 0.04	{ 0.03 0.04
Ti	0.01	—	0.01	0.01
Fe ³⁺	0.11	0.12	0.41	0.32
Fe ²⁺	—	—	—	—
Mg	0.84	0.82	0.50	0.48
Mn	0.05	0.06	0.08	0.25
Ca	0.87	0.87	0.55	0.56
Na	0.15	0.16	0.36	0.30
K	0.01	0.01	0.02	0.01
Z	2.00	2.00	2.00	2.00
XY	1.01	1.01	1.04	1.10
W	1.03	1.04	0.93	0.87
<i>Molecular percentages:</i>				
Diopside	77.76	77.23	47.84	29.99
Johannsenite	5.23	5.69	8.66	23.69
Jadeite	3.99	4.36	—	—
Enstatite	2.37	0.95	4.02	16.14
Aegirine	10.65	11.77	39.48	30.18

* All ± 0.002 .

The calculated molecular percentages of the analysed manganian diopsides, blanfordites, and brown manganiferous pyroxenes have been represented in an acmite–jadeite–johannsenite–diopside (+enstatite) diagram (fig. 1). Fig. 1 shows clearly that the analysed manganian diopsides cluster near the diopside (+enstatite) end of the diagram with little effect of johannsenite and acmite. The blanfordites show a composition in the aegirine-augite field,¹ excepting nos. 1, X, and 10. Nos. 1 and X fall in the compositional field of aegirine and no. 10 falls in the compositional field of diopside. The brown manganiferous pyroxenes, in spite of their difference in pleochroic scheme, exhibit compositions similar to that of blanfordites, confined within the aegirine-augite field. The difference in colour of minerals in the diopside–acmite series has been variously accounted for, e.g. presence of Zr, V, or high content of Mn (Deer, Howie, and Zussman, 1963). It is interesting to note that in one or two cases zoned pyroxene crystals have been detected showing pleochroism characteristic of blanfordite at the core and that of brown manganiferous pyroxene at the rim and vice versa.

Discussion. It has been shown that the optical properties and chemical composition of the manganian diopside indicate that the mineral may be referred to the diopside end of the diopside–acmite series. The blanfordites, selected from different areas and from different mineral assemblages (table IV), exhibit a wide range of composition in the diopside–acmite series, though the majority of these minerals may compositionally be related to aegirine-augites (fig. 1). The brown manganiferous pyroxenes should also be referred to the aegirine-augite field and hence these minerals are compositionally similar to the blanfordites.

Blanfordite occurs in gondite and in pegmatite (at the contact of manganese formation) in the absence of calcite (table IV: I, II, XI–XV, XVIII). In all cases where the blanfordite has been analysed the aegirine percentage is above 50% except assemblage XII, (Roy, 1966) where the aegirine molecule is only 40.36% with corresponding high (23.15%) jadeite molecule. This exception is possibly due to low Fe³⁺ content in the bulk composition. Blanfordite also occurs in the presence of calcite and alkali-bearing minerals. Such assemblages (IV and V) occur in gondite juxtaposed against diopside–forsterite marble and cut across by pegmatite at Gowari Wadhona, Chhindwara District, Madhya Pradesh. The analysed blanfordites in these assemblages have a low aegirine content (33.09 and 12.69%) and correspondingly high diopside content, attributable to the effect of juxtaposed diopside–forsterite marble from which the Ca and Mg were derived. Blanfordite co-exists with manganian diopside in the presence of calcite (assemblages III and VI). In assemblage III (Roy and Purkait, 1968) both blanfordite and manganian diopside have been analysed, the former with an aegirine content of 44.11% and the latter with a diopside content of 86.67%.

Manganian diopside occurs only in the presence of calcite (assemblages III, VI, VII, X); the diopside and aegirine contents vary from 75.15% to 86.67% and 1.11% to 11.77% respectively.

¹ In delineating the aegirine and aegirine-augite compositional fields the nomenclature of Tröger (1952) was followed where the division between aegirine and aegirine-augite was put at 75 mol. % aegirine. This division does not vary much from that suggested by Deer, Howie, and Zussman (1963) restricting the aegirine field to Fe_{0.7}³⁺ to Fe_{1.00}³⁺.

Brown manganiferous pyroxene occurs typically as a constituent of gondite and is also developed as well-formed crystals at the contact of pegmatite and gondite. It occurs both in the presence and absence of calcite (assemblages XIX–XXIV).

Blanfordites and brown manganiferous pyroxenes are compositionally similar though they exhibit characteristically different colour and pleochroism. They rarely if ever coexist as discrete grains, but in one or two cases zoned pyroxenes have been detected with the core exhibiting the pleochroic scheme characteristic of blanfordite and the outer rim that of brown manganiferous pyroxene and vice versa. Blanfordite is associated with juddite (assemblages III, XI, XII) and winchite (assemblages I, II, IV, XIII, XV, XVII), but always with one to exclusion of the other. It is never associated with tirodite. The brown manganiferous pyroxenes, on the other hand, are very often associated with tirodite (assemblages XX, XXII) but never with winchite or juddite. The juddites are manganoan magnesioriebeckites (Roy, 1970) and both winchite and tirodite may be related to richterite–tremolite in composition (Roy, 1969*a* and *b*). The winchites exhibit pleochroism in shades of blue and pink whereas the tirodites are characterized by a scheme in shades of yellow. That the blanfordites are associated with both winchite and juddite, but always one to exclusion of the other, is in conformity with the observations of Ernst (1960) about the relative conditions of formation of magnesioriebeckite and soda-tremolite (*richterite*). Ernst suggested that the formation of magnesioriebeckite is possible under conditions of soda metasomatism involving relatively high P_{CO_2} or low temperature, whereas the formation of richterite is favoured by lower P_{CO_2} or higher temperature.

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