

## Axinites from the contact skarns of the Meldon aplite, Devonshire, England

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**SUMMARY.** Chemical analyses, optical properties, and specific gravities are presented for nine axinites. A reciprocal substitution relationship is demonstrated between Mg and  $Mn^{2+}$ , and a linear variation diagram is constructed between refractive indices and the  $(Fe^{2+} + Fe^{3+} + Mn^{2+} + Ti)$  ions calculated on the basis of  $16(O,OH)$ . The composition of these axinites is independent of the composition of their host rocks; their colour appears to be independent of the  $Fe^{2+}/Mn^{2+}$  ratio for the range of iron and manganese values of the specimens investigated.

THE Meldon aplite, near Okehampton, Devonshire, is a sodium- and lithium-rich aplite dyke about 60–80 ft in thickness, which occurs three-quarters of a mile north-west of the main Dartmoor granite (Worth, 1920). In the Meldon aplite quarries (commonly known as the granulite quarries), south of the main Railway Quarries, it forms contact skarns with a basic doleritic dyke to the south, with the calc-flintas (metasedimentary rocks with alternating calcareous and siliceous bands) to the north-east, and with the calcareous shales to the north-west. Samples were collected from each of the skarns to find whether any relation existed between the composition of the axinites and the composition of the rocks within which they are developed.

*Chemistry.* The samples MN122, MN133, M80, M175, and M2 were obtained from the skarns of the basic rocks (dolerite). Three samples, MN211, HM, and MN18a were separated from the skarns of the calc-flintas. The sample M127 was chosen from the skarn of the calcareous shales. The minerals were separated from the associated calcite, prehnite, diopside, actinolite, sulphides, etc., by combined heavy-liquid and magnetic methods and chemically analysed by standard wet-chemical techniques: boron was determined by the titrimetric method of Kramer (1955). The results are given in table I, where these analyses have also been recalculated on the basis of  $16(O,OH)$ . A general deficiency in Si is found; this is accompanied by a general excess in the  $(Al + Ti + Fe^{3+})$  group. Thus significant substitution of Si by Al is considered to be taking place. The formula given by Berman (1937),  $(Ca, Fe^{2+}, Mn)_3Al_2BSi_4O_{15}OH$  has been modified accordingly to



In the present analyses, no reciprocal relationship can be shown between  $Fe^{2+}$  and  $Mn^{2+}$ . There is, however, such a relationship between  $Mg^{2+}$  and  $Mn^{2+}$  and this is

TABLE I. *Axinite analysis and physical properties*

Analyst: MN18a and M2 R.A.H.; all others M.N.C.

	MN127	M211	M175	M80	MN122	H.M.	MN133	MN18a	M2
SiO <sub>2</sub>	42.53	42.08	41.53	41.44	41.55	42.13	41.78	42.47	41.73
TiO <sub>2</sub>	0.18	0.15	0.31	0.50	0.25	0.20	0.24	0.19	0.23
Al <sub>2</sub> O <sub>3</sub>	18.57	18.90	18.11	18.03	18.25	18.52	18.41	18.47	18.57
Fe <sub>2</sub> O <sub>3</sub>	0.97	0.55	1.03	0.38	0.70	0.58	0.61	1.19	0.77
FeO	6.92	6.73	6.61	8.04	6.58	6.39	6.27	6.57	6.59
MgO	2.03	0.41	0.07	0.08	1.97	2.83	2.15	2.08	0.90
CaO	20.37	20.12	20.00	20.21	21.18	20.49	20.91	19.93	20.14
Na <sub>2</sub> O	0.24	0.25	0.13	0.35	0.15	0.18	0.13	0.00	0.05
K <sub>2</sub> O	0.09	0.13	0.07	0.17	0.05	0.08	0.07	0.21	0.04
MnO	1.34	3.13	4.87	4.14	1.90	1.25	1.96	1.46	3.42
H <sub>3</sub> O <sup>+</sup>	1.46	1.44	1.41	1.42	1.52	1.51	1.49	1.61	1.58
H <sub>2</sub> O <sup>-</sup>	0.07	0.06	0.07	0.08	0.12	0.06	0.10	0.07	0.05
B <sub>2</sub> O <sub>3</sub>	5.76	6.24	6.17	5.64	6.20	6.22	6.27	5.87	5.89
Total	100.53	100.19	100.38	100.48	100.42	100.44	100.39	100.12	99.96
$\alpha$	1.675	1.677	1.678	1.678	1.676	1.675	1.676	1.676	1.678
$\beta$	1.683	1.684	1.685	1.684	1.683	1.682	1.683	1.682	1.686
$\gamma$	1.688	1.690	1.691	1.690	1.687	1.686	1.688	1.686	1.690
2V <sub><math>\alpha</math></sub>	73°	75°	72°	74°	75°	76°	76°	—	74°
D	3.31	3.30	3.29	3.28	3.30	3.30	3.31	3.31	3.31

*Numbers of ions on the basis of 16(O,OH)*

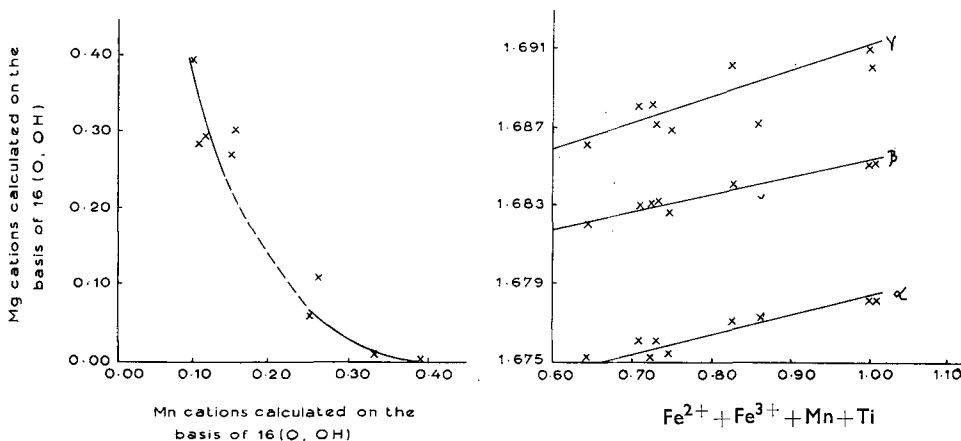
B	0.929	1.013	1.010	0.929	1.003	0.999	1.012	0.948	0.970
Si	3.976	3.957	3.938	3.953	3.897	3.922	3.908	3.970	3.947
Al	0.024	0.043	0.062	0.047	0.103	0.078	0.092	0.030	0.053
Z	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Al	2.044	2.052	1.962	1.980	1.915	1.954	1.939	2.007	2.007
Fe <sup>3+</sup>	0.069	0.038	0.073	0.028	0.050	0.040	0.043	0.089	0.056
Ti	0.013	0.017	0.022	0.036	0.017	0.014	0.017	0.027	0.017
Y	2.126	2.107	2.057	2.044	1.982	2.008	1.999	2.123	2.080
Mg	0.283	0.058	0.002	0.011	0.276	0.393	0.300	0.290	0.127
Fe <sup>2+</sup>	0.541	0.529	0.524	0.641	0.516	0.497	0.491	0.514	0.519
Mn	0.106	0.249	0.391	0.335	0.151	0.098	0.155	0.116	0.261
Na	0.044	0.045	0.024	0.064	0.027	0.032	0.024	—	0.011
Ca	2.049	2.022	2.032	2.066	2.129	2.044	2.096	1.998	2.037
K	0.011	0.016	0.008	0.021	0.006	0.009	0.008	0.025	0.006
X	3.034	2.919	2.981	3.138	3.105	3.073	3.074	2.943	2.961
OH	0.910	0.903	0.892	0.903	0.952	0.988	0.930	1.005	0.998

demonstrated in fig. 1. If, as appears probable, a reciprocal relationship also exists between Mn<sup>2+</sup> and Fe<sup>2+</sup> in other axinites (Deer, Howie, and Zussman, 1962), then two replacement series must be distinguished; in one the substitution of Fe<sup>2+</sup> for Mn<sup>2+</sup> and in the other (present analyses) of Mg for Mn<sup>2+</sup>.

Although these axinites were separated from rocks of very different original composition they do not show any marked chemical differences. Furthermore no relation

between the iron, manganese, or calcium contents of the host rocks and the axinites can be determined. Howie (1968) suggests that this lack of correlation may be due to the fact that axinites are not formed by the simple reconstitution of the host rock but by the metasomatic introduction of large amounts of  $\text{MnO}$ ,  $\text{FeO}$ , and  $\text{B}_2\text{O}_3$ . Geochemical studies of the host rocks of these axinites confirm this view.

*Optical and physical properties.* The refractive indices and specific gravities of the Meldon axinites are given in table I; the former were determined by the single variation method, using sodium light, and estimated as accurate to  $\pm 0.001$ . Carstens (1965) was able to split four axinites into heavy and light fractions and found that the heavier



FIGS. 1 and 2: FIG. 1 (left). The relationship between Mg and Mn in Meldon axinites. FIG. 2 (right). The refractive indices of axinite in relation to  $(\text{Fe}^{2+} + \text{Fe}^{3+} + \text{Mn}^{2+} + \text{Ti})$  ions on the basis of  $16(\text{O}, \text{OH})$ .

fractions, which were slightly richer in  $\text{FeO}$  and  $\text{MnO}$ , had the higher refractive indices. This suggests dependence of refractive indices on  $\text{FeO}$  and  $\text{MnO}$ , but any study of the refractive indices of axinite with chemical composition must also take into account both  $\text{Fe}_2\text{O}_3$  and  $\text{TiO}_2$ . Therefore in fig. 2 the refractive indices have been plotted against the  $(\text{Fe}^{3+} + \text{Mn} + \text{Fe}^{2+} + \text{Ti})$  contents calculated on the basis of  $16(\text{O}, \text{OH})$ . A moderate correlation is shown by this diagram. The suggestion by Tröger (1952) that the refractive indices increase with an increasing  $\text{Fe}/\text{Mn}$  ratio is not supported by the present work.

Although the work of Carstens (1965) indirectly indicates a correlation between the  $\text{FeO}$  and  $\text{MnO}$  content and specific gravity, the present work does not support this relationship. This lack of correlation between specific gravities and composition and between optic axial angles and composition (table I) is attributed here to the chemical inhomogeneity of the axinites. This possibility is supported by the further separation into fractions of pure fractions as reported by Carstens (1965).

No correlation between the  $\text{Fe}/\text{Mn}$  ratio and the depth of colour has been found in these axinites, none of which is rich enough in manganese to bring in the yellow or orange-red colours seen in the manganoan variety (tinzenite). However, a petrographic

study shows that the Meldon specimens containing manganese dioxide or carbonaceous inclusions or both are generally darker in colour.

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