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# MANGANAXINITE FROM THE MESABI RANGE, MINNESOTA

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## ABSTRACT

A new occurrence of the Ca-borosilicate axinite has been identified in a pegmatitic vein cutting metamorphosed Biwabik Iron-Formation on the eastern Mesabi Range, Minnesota. The mineral occurs as grayish-brown patches associated with large anhedral crystals of quartz and K-feldspar and with small amounts of Fe-rich chlorite. The axinite is highly manganoan and corresponds to the formula:

$$H_{0.83}(Ca_{1.85}Mg_{0.04}Fe^{2+}_{0.26}Mn^{2+}_{0.94})(Al_{2.03}Fe^{3+}_{0.01})B_{0.99}Si_{3.98}O_{16}.$$

Determined unit-cell parameters are: $a = 7.161$, $b = 9.190$, $c = 8.978$ Å, $\alpha = 88.26°$, $\beta = 81.80°$, $\gamma = 77.26°$, $V = 570.3$ Å$^3$. Earlier reports of systematic variations in composition between the fine and coarse separated fractions were not verified by microprobe analyses. However, significant variations, particularly in total FeO, MnO, and $Al_2O_3$, exist between different grains.

## INTRODUCTION

During a study of metamorphosed Biwabik Iron-Formation on the Mesabi Range, Minnesota, the calcium borosilicate axinite was identified there for the first time (French, 1968, p. 41, 74). The mineral was collected from the Peter Mitchell pit of the Reserve Mining Company near the town of Babbitt, where it occurs in thin pegmatitic veins that cut the highly metamorphosed iron-formation adjacent to the contact of the Duluth Gabbro Complex (Gundersen and Schwartz, 1962, p. 72–74). The mineral was originally identified by X-ray powder diffraction, and preliminary data on its composition and cell parameters have been presented (French and Fahey, 1968).

In the single specimen collected (specimen MF-62-85), the axinite occurs as irregular dark grayish-brown areas 1–2 cm in size, associated with quartz, K-feldspar, and Fe-rich chlorite. The pink K-feldspar occurs as partly sericitized crystals as much as several cm long which often exhibit graphic intergrowths of quartz. Quartz also occurs in large anhedral grains, and green fibrous chlorite occupies some interstitial areas with the axinite.

The axinite does not have crystal faces. In thin section, it is extensively fractured, both along parallel planes that suggest cleavage and along irregular, closely-spaced surfaces. Definite color differences are observed in the fractured axinite. The more intensely-fractured areas are a deeper yellow-brown in transmitted light, as are isolated areas surrounded by fractures.

## PHYSICAL AND CHEMICAL PROPERTIES

Crushed axinite was separated from the associated minerals by a combination of heavy-liquid and magnetic methods. Two axinite separates of better than 95 percent purity were produced, a $-100+150$ mesh fraction (99+ percent axinite) and a $-150+200$ mesh fraction (96 percent axinite). The contaminant in both cases was green chlorite. The chemical, X-ray, and refractive index data presented here were determined on the coarser, higher purity fraction.

Optical properties, determined by conventional methods in white light are: $\alpha = 1.678$, $\beta = 1.687$, $\gamma = 1.692$ (all $\pm$ 0.003), $2V$ (est.) $= (-)\ 75 \pm 5°$. No significant differences in refractive index were observed between the fine and coarse fractions.

Unit-cell parameters, based on the unit cell of Ito and Takeuchi (1952; see also Peacock, 1937) are: $a = 7.161 \pm 0.002$, $b = 9.190 \pm 0.003$, $c = 8.978 \pm 0.003$ Å, $\alpha = 88.26 \pm 0.03°$, $\beta = 81.80 \pm 0.03°$, $\gamma = 77.26 \pm 0.02°$, $V = 570.3 \pm 0.2$ Å$^3$. The values were obtained from powder diffractograms by measuring about 75 axinite reflections in the range 0–60° $2\theta$ (Cu $K_\alpha$ radiation) and employing a computer program developed by D. E. Appleman and D. R. Wones of the U. S. Geological Survey to reduce the data. $BaF_2$ was used as an internal standard; its $a_0$ value was redetermined as 6.1799 Å, in satisfactory agreement with an earlier determination ($a = 6.2001$ Å; Swanson and Tatge, 1953, p. 70–72).

The chemical composition of the coarse fraction of axinite was determined by conventional gravimetric methods, using techniques described in Hillebrand *et al.* (1953). In determining $B_2O_3$, a minor modification was used. The distillate was brought to pH = 7 using a pH meter instead of the indicator paranitrophenol. After addition of mannitol, the titration (with standard alkali solution) to pH = 7 was again controlled by the meter.

The chemical composition determined was: $SiO_2$ 41.66, $TiO_2$ 0.01, $B_2O_3$ 5.96, $Al_2O_3$ 18.00, $Fe_2O_3$ 0.10, FeO 3.27, MnO 11.66, MgO 0.25, CaO 18.08, $Na_2O$ 0.15, $K_2O$ 0.02, $H_2O(-)$ 0.04, $H_2O(+)$ 1.26, Total 100.46. Using the structural formula: $H(Ca, Mg, Fe^{2+}, Mn^{2+})_3(Al,$

$Fe^{3+})_2BSi_4O_{16}$ (Milton *et al.*, 1962; Deer *et al.*, 1962, p. 320), the composition reduces to:

$$H_{0.83}(Ca_{1.85}Mg_{0.04}Fe^{2+}{}_{0.26}Mn^{2+}{}_{0.94})(Al_{2.03}Fe^{3+}{}_{0.01})B_{0.99}Si_{3.98}O_{16}$$

$$= H_{0.83}(Ca, Mg, Fe^{2+}, Mn^{2+})_{3.09}(Al, Fe^{3+})_{2.04}B_{0.99}Si_{3.98}O_{16}.$$

Significant amounts of $Fe^{3+}$ and $Mn^{3+}$ are apparently not present. The amount of H is slightly low, but not seriously so in comparison with other analyzed axinites (Deer *et al.*, 1962, p. 322–323; Chaudhry and Howie, 1969). According to the nomenclature of Sanero and Gottardi (1968), the composition of the Mesabi material corresponds to manganaxinite.

Previous gravimetric analyses (French and Fahey, 1968) indicated that the fine fraction of axinite had significantly higher total Fe, higher $Fe_2O_3/FeO$, and lower $Al_2O_3$ than did the coarse fraction. These differences are, however, not confirmed by electron microprobe analyses of about 25 grains from each fraction. A significant range of values was observed between individual grains in both fractions for total FeO (2.9–5.6 weight percent), MnO (10.8–14.7 weight percent), and $Al_2O_3$ (12.7–17.3 weight percent), but the average compositions of both size fractions were virtually identical. Furthermore, there was no apparent correlation of composition with color between the light and dark areas of axinite observed in thin section. The close similarity in both refractive indices and unit-cell parameters determined for each fraction also argues against the existence of gross chemical differences.

The reason for the apparent discrepancy between gravimetric and microprobe analyses in the fine fraction is not clear. The presence of minor chlorite in the fine sample is a possible explanation, but the amount present (about 4 percent) does not seem sufficient to produce the observed effects. In view of this uncertainty, the data presented here are for the coarser axinite fraction. This fraction is virtually free of chlorite, and its gravimetrically determined composition is in good agreement with the microprobe analyses.

## CONCLUSIONS

The axinite described from the Mesabi Range, Minnesota, represents a new occurrence of that mineral. The presence of a highly manganoan axinite (manganaxinite) in a vein surrounded by metamorphosed iron-formation and associated with a gabbroic intrusion is noteworthy and suggests that the pegmatite veins containing the axinite were not derived in any significant amount from the iron-formation.

The manganaxinite shows significant variations in composition in

FeO, MnO, and $Al_2O_3$ between different grains in both coarse and fine separated fractions. However, there is no indication of the presence of systematic compositional differences between the coarse and fine fractions.

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