EDINGTONITE: THE FIRST TWO CANADIAN OCCURRENCES

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ABSTRACT

Edingtonite from the Ice River alkaline complex, near Field, British Columbia, is found in nepheline syenite. Its formula, \((\text{Ba}_{9.92}\text{K}_{0.07})\text{Al}_{1.94}\text{Si}_{6.27}\text{O}_{20.66}\cdot 7.34\text{H}_2\text{O}\), is derived from the chemical analysis: \(\text{SiO}_2 36.3, \text{Al}_2\text{O}_3 20.6, \text{BaO} 28.6, \text{K}_2\text{O} 0.32, \text{H}_2\text{O} 12.8\), total 98.62%. Optically it is biaxial negative with \(\alpha 1.535(2), \beta 1.542(2), \gamma 1.545(2), 2\beta 62(5)\) (meas.). Cell refinement yields \(a 9.583(7), b 9.624(7), c 6.527(6)\) Å. The density (g/cm³) is 2.73(2) (meas.), 2.75 (calc.). Crystals average 8x2x2 mm with forms {001}, {110}, and {111} (point group 222). Twinning is common on (110) (lamellar) and penetration. Edingtonite from the Brunswick No. 12 mine, near Bathurst, New Brunswick, is found as a hydrothermal infilling in a series of metasediments. It has the formula \((\text{Ba}_{9.92}\text{K}_{0.07})\text{Al}_{1.94}\text{Si}_{6.27}\text{O}_{20.66}\cdot 7.72\text{H}_2\text{O}\), derived from the chemical analysis: \(\text{SiO}_2 35.9, \text{Al}_2\text{O}_3 20.8, \text{BaO} 29.1, \text{K}_2\text{O} 0.11, \text{H}_2\text{O} 12.5\), total 98.91%. Optically it is biaxial negative with \(\alpha 1.538(2), \beta 1.549(2), \gamma 1.551(2), 2\beta 56(5)\) (meas.). Cell refinement yields \(a 9.551(5), b 9.656(5), c 6.516(6)\) Å. The density (g/cm³) is 2.78(2) (meas.), 2.76 (calc.). Crystals are as large as 45x10x10 mm, with forms {001}, {110}, {111} and {211}, sans trace de macle. L’édingtonite saturée possède huit molécules d’eau. Quatre de ces molécules peuvent être libérées sous vide, deux par chauffage progressif de 50° à 150°C et les deux autres entre 150° et 200°C. L’extraction de ces quatre dernières molécules en deux étapes infirme la structure que l’on attribue actuellement à l’édingtonite. À 30% d’humidité relative et 25°C, l’édingtonite perd en eau (H₂O) un pour cent de son poids.

Keywords: edingtonite, Ice River complex, British Columbia, Brunswick No. 12, New Brunswick, macle, molecules of water, zeolite.

INTRODUCTION

The rare barium zeolite edingtonite, \(\text{Ba}_2\text{Al}_2\text{Si}_6\text{O}_{20}\cdot 8\text{H}_2\text{O}\), has been found in Canada at two occurrences: 1) Zinc Mountain ridge, east side of the Ice River valley, 25 km south of Field, Yoho National Park, Kootenay District, British Columbia, and 2) Brunswick No. 12 mine, 2350 level, East Stope, near Bathurst, Bathurst parish, Gloucester County, New Brunswick. The mineral was first described by Haidinger (1825) from the area of Old Kilpatrick, Dumbartonshire, Scotland; since then, it has been reported from the Böhlet mine, Westergotland, Sweden (Nordenskjöld 1895), near Staré Ransko, East Bohemia, Czechoslovakia (Novák 1970), the Podol’skoye deposit, southern Urals, U.S.S.R. (Ismagilov 1977), Jacupiranga, São Paulo State, Brazil (National Museum of Natural Sciences collection), and the Ice River alkaline complex, British Columbia (Grice & Gault 1981).

GELOGICAL SETTING

The Ice River alkaline intrusive complex consists
of a suite of ijolites, syenites, carbonatites and late-stage pegmatites (Currie 1975) in the Yoho and Kootenay National Parks region of southeastern British Columbia. The complex, approximately 18x6 km in dimension, was emplaced about 245 million years ago into sedimentary rocks of Cambrian and lower Ordovician age. During the mid-Mesozoic, the sedimentary rocks were intensely folded and faulted but the igneous rocks remained relatively unaltered. Edingtonite occurs in isolated zeolite- and carbonate-rich pockets in nepheline syenite. It is a late-stage mineral in these pockets, which were, in themselves, one of the last phases of the complex to form. The mineralogy of the pockets is simple; the major constituents are calcite, natrolite and edingtonite. Occurring rarely are the species ancylite, catapleiite, acmite, pyrite and galena.

The Brunswick No. 12 deposit, about 26 km southwest of Bathurst, New Brunswick, is a massive-sulfide body occurring in sedimentary and volcanic rocks of the Tetagouche Group of Early to Middle Ordovician age (Luff 1977). The area was intensely deformed during the Ordovician and again in Devonian time, resulting in the separation of the sulfide orebody into four zones. Edingtonite occurs in open fractures in veins at the 2350 level of the East Ore Zone. The area in which the edingtonite is found was sheared and fractured as the footwall metasediments were folded around the hanging-wall iron formation. The mineral assemblage of the veins include edingtonite, chalcopyrite, galena, pyrite, sphalerite, barytocalcite, calcite, dolomite, quartz, greenalite and lizardite, and is apparently derived from ascending hydrothermal fluids reacting with massive sulfides, argillites and siliceous tuffs.

**CRYSTALLOGRAPHY**

Edingtonite is orthorhombic, pseudotetragonal. The crystal structure has been refined recently by Galli (1976) in space group \( P2_12_12 \). This refinement has shown Si and Al to have an ordered distribution in the chains, similar to that found in natrolite. This ordering lowers the symmetry of the structure from that determined earlier by Taylor & Jackson (1933), in tetragonal space-group \( P4_2_1_2 \).

Edingtonite crystals from the Ice River are generally well-formed, white, cloudy, pseudotetragonal prisms with good single, or on some specimens, double terminations. Size of the crystals averages 8x2x2 mm; they often form drusy coatings on calcite crystals. The simple morphology includes the forms: prism \( m\{110\} \), two disphenoids \( o\{111\} \) and \( p\{111\} \), and the basal pinacoid \( c\{001\} \) (Fig. 1a). On most crystals, the disphenoids are almost equally developed, giving the morphology a tetragonal ap-

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**Fig. 1.** Idealized drawings of edingtonite. Crystals from a) the Ice River complex, with the following forms: prism \( m\{110\} \), disphenoids \( o\{111\} \) and \( p\{111\} \), and basal pinacoid \( c\{001\} \), and b) the Brunswick No. 12 mine, with the following forms: prisms \( m\{110\} \) and \( n\{101\} \), disphenoids \( o\{111\} \), \( p\{111\} \) and \( r\{211\} \), and basal pinacoid \( c\{001\} \).

**Fig. 2.** Edingtonite from Ice River showing penetration twin [001]. Forms present on each individual are \( o, p \) and \( m \). The width of the twinned crystal is 1 mm.
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TSIE l. DATA FOR EDINGTONITE

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Ice River, B.C.

\[
\begin{align*}
a & = 9.583(5) \\
b & = 9.484(5) \\
c & = 6.370(3) \\
V & = 602(1) \text{Å}^3
\end{align*}
\]

Brunswick No. 12 Mine, N.B.

\[
\begin{align*}
a & = 9.551(5) \\
b & = 9.468(5) \\
c & = 6.516(6) \\
V & = 601(1) \text{Å}^3
\end{align*}
\]

Optical Data:

\[
\begin{align*}
\rho_1 & = 1.535(2) \\
\rho_2 & = 1.545(2) \\
\rho_3 & = 2.58(3) \\
\rho_4 & = 56(5)
\end{align*}
\]

* Powder-diffractometer data, Ni-filtered Cu Kα radiation.

There is a greater difference between \(a\) and \(b\) for the Brunswick mine edingtonite than for that from Ice River. The fact that the Ice River edingtonite is dimensionally closer to a tetragonal cell may explain its propensity for twinning.

**OPTICAL PROPERTIES**

Optical properties of edingtonite from both localities are presented in Table 1. Principal indices of refraction and optic angles were measured on grains illuminated with a sodium vapor lamp (\(λ = 589 \text{ nm}\)). The epitectic overgrowth discussed above and shown in Figure 3 has a lower birefringence than the core (first-order grey to black in comparison to first-order cream to yellow in the (001) section). As the mineral approaches a uniaxial indicatrix, it is likely becoming more nearly tetragonal in symmetry. This is discussed further under Chemical Composition.

**TABLE 1. CRYSTALLOGRAPHIC DATA FOR EDINGTONITE**

<table>
<thead>
<tr>
<th>Ice River, B.C.</th>
<th>Brunswick mine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Cell†</td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>9.583(5)</td>
</tr>
<tr>
<td>(b)</td>
<td>9.484(5)</td>
</tr>
<tr>
<td>(c)</td>
<td>6.370(3)</td>
</tr>
<tr>
<td>(V)</td>
<td>602(1) \text{Å}^3</td>
</tr>
</tbody>
</table>

Optical Data:

\[
\begin{align*}
\rho_1 & = 1.535(2) \\
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\rho_3 & = 2.58(3) \\
\rho_4 & = 56(5)
\end{align*}
\]

† Powder-diffractometer data, Ni-filtered Cu Kα radiation.

**TABLE 2. CHEMICAL* AND DENSITY DATA FOR EDINGTONITE**

<table>
<thead>
<tr>
<th>Ice River</th>
<th>Brunswick mine</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>(average of 7</td>
<td>(average of 6</td>
</tr>
<tr>
<td>(grains)</td>
<td>analyses on 3</td>
<td>analyses on 2</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>35.3</td>
<td>35.9</td>
</tr>
<tr>
<td>K₂O</td>
<td>20.6</td>
<td>20.6</td>
</tr>
<tr>
<td>Na₂O</td>
<td>18.6</td>
<td>18.6</td>
</tr>
<tr>
<td>BaO</td>
<td>0.32</td>
<td>0.11</td>
</tr>
<tr>
<td>H₂O</td>
<td>12.8</td>
<td>12.5</td>
</tr>
<tr>
<td>Total</td>
<td>96.62</td>
<td>96.81</td>
</tr>
</tbody>
</table>

* Analysts: M. Bonardi, Geological Survey of Canada (microprobe), R. Ramik, Royal Ontario Museum (H₂O by TGA).

**TABLE 3. CHEMICAL ANALYSIS OF EDINGTONITE**

<table>
<thead>
<tr>
<th>Elements</th>
<th>Average of 6 analyses</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>20.6</td>
<td>20.08</td>
</tr>
<tr>
<td>Al</td>
<td>18.6</td>
<td>18.21</td>
</tr>
<tr>
<td>K</td>
<td>0.72</td>
<td>—</td>
</tr>
<tr>
<td>Na</td>
<td>7.34</td>
<td>7.22</td>
</tr>
</tbody>
</table>

edingtonite from either locality. With a powder diffractometer and Cu Kα radiation, there was sufficient resolution of peaks to distinguish the orthorhombic symmetry and hence to determine unique \(a\) and \(b\) cell dimensions. Silicon was used as an internal standard for the cell refinement (Table 1).

Symmetry for edingtonite from either locality. With a powder diffractometer and Cu Kα radiation, there was sufficient resolution of peaks to distinguish the orthorhombic symmetry and hence to determine unique \(a\) and \(b\) cell dimensions. Silicon was used as an internal standard for the cell refinement (Table 1).

Fig. 3. Edingtonite from Ice River, transmitted light with crossed polars, (001) section; crystal width is 1 mm. Section shows (001) twin, multiple intergrowths and epitectic overgrowth (e).

pearlance, but careful inspection of the doubly terminated crystals shows the true noncentrosymmetric point-group 222. Crystals are generally complexly intergrown and twinned, with a thin transparent epitectic overgrowth on a cloudy core. Two twin laws have been identified: lamellar (110) and penetration (001) with individuals at 90° (Fig. 2). The overgrowth, as seen in thin section, has a fine lamellar twinning and is oriented with \{110\} parallel to \{110\} of the core (Fig. 3). A good \{110\} cleavage was noted.

Edingtonite crystals from the Brunswick No. 12 mine are very well-formed pseudotetragonal prisms attaining dimensions of 45x10x10 mm. They are white and opaque to colorless and transparent with smooth lustrous surfaces. The morphology of these crystals is more complex than those of Ice River, but no twinning was observed. Forms present include prisms \(m\{110\}\) and \(n\{101\}\), disphenoids \(o\{111\}\), \(p\{\overline{1}1\}\) and \(r\{2\overline{1}\}\), and the basal pinacoid \(c\{001\}\) (Fig. 1b). This edingtonite also has a good \{110\} cleavage.

Single-crystal X-ray precession-camera patterns were not suitable for distinguishing orthorhombic

Fig. 3. Edingtonite from Ice River, transmitted light with crossed polars, (001) section; crystal width is 1 mm. Section shows (001) twin, multiple intergrowths and epitectic overgrowth (e).
silicate hydrates with very little substitution of other cations. On the basis of an edingtonite formula derived from a whole-rock composition, Ismagilov (1977) calculated that edingtonite from the southern Urals contains 4.35 wt.% CaO. In that calculation, it was assumed the plagioclase present is pure albite. No data were given to justify this assumption; therefore, the composition reported must be held in doubt for the present. Both Heddle (1855) and Hey (1934) indicated the presence of calcium in one edingtonite specimen from Old Kilpatrick, but the amount of material was insufficient for a full chemical analysis. The full analysis of Old Kilpatrick edingtonite lists only a "trace" of calcium (Heddle 1855).

In the present study, analyses independent of those given in Table 2 were done by D. Smith, University of Alberta, also using a microprobe with an energy-dispersion spectrometer. There was no significant inhomogeneity in the edingtonite from the Brunswick mine, but a significant, although small, variance was found in the Ice River crystals between the white core and the clear overgrowth discussed above (Fig. 3). No chemical transition is sharp at the overgrowth boundary. This minor amount of potassium appears to affect the crystal structure of the edingtonite overgrowth, making it more nearly tetragonal (i.e., almost optically uniaxial as discussed above). This shift in crystal symmetry is in keeping with the findings of Taylor (1935) for synthetic potassium-edingtonite, which is tetragonal.

Analysis of water in edingtonite has always presented problems. In the literature, the proportion of $H_2O$ in edingtonite ranges from 6.68 to 7.81 $H_2O$ molecules, with the majority of results close to seven. The crystal-structure refinement (Galli 1976) indicated that there are ideally eight $H_2O$ molecules. The problem of low content of reported water was studied by R. Waller, National Museum of Natural Sciences, Ottawa and his results are given in Figures 4 and 5.

Figure 4 shows the relationship between loss or gain of $H_2O$ vs. relative humidity (RH) at 23°C. A sample of Brunswick No. 12 edingtonite, crushed to −40 + 100 and weighing ~300 mg, was placed in a series of desiccators containing saturated salt solutions. The weight of the sample was reproducible for either increasing or decreasing steps. Similar samples of natrolite and quartz served as controls to determine whether adsorption of water onto surfaces was significant. The effect of adsorption was negligible until almost 100% RH, at which point the control samples of quartz and natrolite began to gain weight. The graph shows how readily edingtonite loses or gains structural water even at room temperature. The significance of these results is that any laboratory with less than 80% RH should correct edingtonite

**Chemical Composition**

Analyses of the two specimens (Table 2) were made by microprobe in the laboratories of the Geological Survey of Canada, and the $H_2O$ content was determined by thermogravimetric analysis in the Royal Ontario Museum laboratory. Electron-microprobe analyses were obtained using a Materials Analysis Company instrument (energy-dispersion mode) operating at 20 kV, with a specimen current of ~10 nA (measured on kaersutite) and a counting time of 100 seconds. Because edingtonite loses water readily when heated, samples were mounted in cold-setting epoxy resin. Also, to minimize loss of water due to electron bombardment and high vacuum, a broad, defocused beam of electrons was utilized in analysis. The following analytical standards were used: kyanite (Al), kaersutite (Si,K) and barite (Ba). The simultaneous thermogravimetric–evolved-gas analyses (TGA, EGA) were made on 55-mg samples from each locality with a Mettler TA-1 Thermoanalyzer coupled to an Inficon IQ 200 quadrupole mass-spectrometer.

Table 2 also lists the observed and calculated densities, which agree within the limits of error.

Like other analyzed specimens of edingtonite (Ismagilov 1977, Hey 1934, Novák 1970), the Canadian samples are essentially barium–aluminum

![Graph](image-url)
analytical data for dehydration. Below 10% RH, water loss becomes drastic, and reliable corrections would be difficult. The water contents reported in Table 2 were determined at ~30% RH, which means a loss of 1.0 wt.% H₂O prior to TGA. If this correction is added to Table 2, the resultant formulas (calculated on the basis of 28 oxygen atoms) are:

(Ba₁.₈₉K₀.₀₆)[₁₁₂₅Al₄.₀₈Si₆.₁₁O₂₀.₈西南].̇7.₇₅H₂O (Ice River) and (Ba₁.₉₇K₀.₀₂)[₁₁₂₅Al₄.₁₆Si₆.₀₈O₂₀.₃₇].̇6.₃₃H₂O (Brunswick mine), i.e., close to 8 molecules H₂O.

In order to observe the rate at which structural water is lost, a sample of the Brunswick mine edingtonite was conditioned to 97% RH at 22°C until stable with respect to weight. The sample was then allowed to desorb in 20% RH at 22°C. Figure 5 shows the results: the water loss approaches equilibrium in ten minutes.

The TGA curves (Fig. 6a, b) give additional information on the water in edingtonite. For both localities, the curves are similar, showing that most of the water was lost in three stages. Approximately four molecules of H₂O were lost under vacuum at 25°C. An additional two molecules of H₂O were lost between 50 and 150°C, and the final two molecules were lost between 150 and 200°C. The general features of this TGA curve resemble those of Van Reeuwijk (1972), but the intervals of desorption temperatures given in Figure 6 are considerably lower since the heating experiment was performed under vacuum. Van Reeuwijk (1972) reported 3.0, 2.5 and 1.75 H₂O molecules lost for each of the three intervals of temperature. The EGA curves (relative amounts of evolved H₂O recorded on a mass spectrometer) (Fig. 6a, b) also show approximately equal splitting of the four water molecules.

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**Fig. 5.** Edingtonite from Brunswick No. 12 mine. Weight % H₂O lost from a sample conditioned to 97% RH then allowed to desorb in 20% RH (at 22°C), plotted versus time.

**Fig. 6.** Thermal analyses of edingtonite: thermal gravimetric analysis (TGA) and relative intensity (arbitrary units, measured on a mass spectrometer) of H₂O gas evolved (EGA). a) Ice River, b) Brunswick No. 12 mine.
that are structurally more tightly bonded. In the structure refinement, Galli (1976) noted the existence of two distinct H$_2$O sites, each with a multiplicity of four. One H$_2$O site has fewer ligands and a larger barium–water bond length than the other H$_2$O site (2.832 vs. 2.808 Å). No doubt the H$_2$O more loosely bonded to barium will account for the four molecules lost under vacuum below 25°C. The observation that the four more strongly bonded H$_2$O molecules are lost in two stages leads to the conclusion that they are not structurally equivalent, which contradicts the results of the recent refinement (Galli 1976), or that there is a structural change in edingtonite upon heating. The current neutron-diffraction studies of edingtonite at various temperatures by Å. Kvick and J.V. Smith (pers. comm., 1983) might find a solution to this problem.

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