Rutile Compositions at the Big Bell Au Deposit as a Guide for Exploration

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Hydrothermal Rutile Formation

\[ K(\text{Fe, Mg, Ti})_3(Si_3 \text{ Al})O_{10}(OH)_2 + S_2 \rightarrow \]

Biota

\[ K(\text{Mg, Fe})_3(Si_3\text{Al})O_{10}(OH)_2 + \text{FeS}_2 + \text{TiO}_2 \]

Phlogopitic biotite

\[ 2(\text{Fe, Ti})_3\text{O}_4 + S_2 \rightarrow \text{Fe}_3\text{O}_4 + \text{FeS}_2 + \text{TiO}_2 \]

Ti Mte

\[ \text{FeTiO}_3 + S_2 \rightarrow \text{FeS}_2 + \text{TiO}_2 \]

Ilmenite

\[ \text{CaTiSiO}_5 + \text{CO}_2 \rightarrow \text{TiO}_2 + \text{CaCO}_3 + \text{SiO}_2 \]

Sphene
Rutile Distribution in Porphyry Systems

- **Propylitic**: Albite + Chlorite + Epidote + Carbonate
- **Phyllitic**: Qtz + Ser + Pyrite
- **Argillitic**: Quartz + Kaolinite + Chlorite
- **Potassic**: Quartz - K-feldspar + Biotite ± Sericite
- **Ore**: Qtz + Ser. + Chl. + K.- feld
**Ionic Radii (Å) of Likely Components of Rutile**

<table>
<thead>
<tr>
<th>Ion</th>
<th>Radius (Å)</th>
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<tbody>
<tr>
<td>W&lt;sup&gt;6+&lt;/sup&gt;</td>
<td>0.62</td>
</tr>
<tr>
<td>Sb&lt;sup&gt;5+&lt;/sup&gt;</td>
<td>0.62</td>
</tr>
<tr>
<td>Cr&lt;sup&gt;3+&lt;/sup&gt;</td>
<td>0.63</td>
</tr>
<tr>
<td>Fe&lt;sup&gt;3+&lt;/sup&gt;</td>
<td>0.64</td>
</tr>
<tr>
<td>Ta&lt;sup&gt;5+&lt;/sup&gt;</td>
<td>0.68</td>
</tr>
<tr>
<td>Ti&lt;sup&gt;4+&lt;/sup&gt;</td>
<td>0.68</td>
</tr>
<tr>
<td>Nb&lt;sup&gt;5+&lt;/sup&gt;</td>
<td>0.69</td>
</tr>
<tr>
<td>Sn&lt;sup&gt;4+&lt;/sup&gt;</td>
<td>0.71</td>
</tr>
<tr>
<td>V&lt;sup&gt;3+&lt;/sup&gt;</td>
<td>0.74</td>
</tr>
<tr>
<td>Fe&lt;sup&gt;2+&lt;/sup&gt;</td>
<td>0.74</td>
</tr>
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Backscattered Electron Images of Rutile

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Cr</td>
<td>2.7%</td>
</tr>
<tr>
<td>W</td>
<td>8.7%</td>
</tr>
<tr>
<td>V</td>
<td>2.5%</td>
</tr>
<tr>
<td>Fe</td>
<td>1.7%</td>
</tr>
<tr>
<td>W</td>
<td>2.9%</td>
</tr>
<tr>
<td>Nb</td>
<td>0.6%</td>
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</table>
Backscattered Electron Images of Rutile

Cr 3.0%
W 3.7%

Nb 1.1%
W 5.2%
Fe 2.6%
Preparation and Analysis of Rutile Grains

- Sample (100 – 150g)
- Crush and size to - 250 + 45μm (if required)
- Separation of heavy mineral fraction (SG>2.9 - Superpanner)
- Clean with HF/aqua regia
- Mount and polish in epoxy resin block
- Analysis of rutile by electron microprobe (major and minor elements)
Location of Big Bell and the Regional Geological Setting

After Chown et al., 1984
Regional Geological Setting, Big Bell

After Barnes, 1996
Big Bell Samples

Pit outline (December 1993)

ORE in floor of pit (200m below surface)

FW

HW

61
60
62
64
63

65

55
56

57
58
59

66 (BRC071)

67 (BRC073)

68 (BRC075)

~ 560m depth

Sample sites (all sample nos prefixed by 1132)
Rutiles – Ore Zone – Big Bell (Sth)

V  0.5%
W  1.7%
Sb 0.8%

V  1.0%
W  2.6%
Sb 1.3%

Inclusion of molybdenite

Bastnaesite

CRCLEME
Rutiles – Ore Zone – Big Bell (Nth)

V 0.4%
W 1.3%
Sb 0.9%

V 0.3%
W 0.9%
Sb 0.9%
Rutile Compositions - Big Bell

V
Ore

Fe
Ore

Altered

Altered

Unaltered

Unaltered

CRCLEME
Rutile Compositions - Big Bell

Graphs showing the distribution of W and Sb in Ore, Altered, and Unaltered samples.
V-Sb-W Rich Rutiles – Big Bell

- Sample sites (all sample nos prefixed by 1132)
- ORE in floor of pit (200m below surface)
- Grid North
- Pit outline (December 1993)
- ~ 560m depth
- FW
- HW
- 65
- 66 (BRC071)
- 67 (BRC073)
- 68 (BRC075)
- 64
- 63
- 62
- 61
- 60
- 60
- 57
- 58
- 59
- 56
- 55
- 69 BBD 19
- 71
- 1000E
- 3000N
- 2000N
- Western Batholith
- Grid North
- CRCLEME
W and V in Rutiles, Big Bell
W and Sb in Rutiles, Big Bell
Trivalent vs Hexavalent and Pentavalent Ions in Rutiles, Big Bell
Coupled Substitutions in Rutile at Big Bell

\[ M^{3+} + (Nb, Sb, Ta)^{5+} = 2Ti^{4+} \]
\[ 2M^{3+} + W^{6+} = 3Ti^{4+} \]
Rutile at Big Bell

- W+V+Sb+Fe in rutile associated with ore
- Coupled substitution – W and Sb balanced by trivalent ions
- Similar rutile geochemistry to Hemlo Au deposit
- W+V+Sb+Fe association in rutile extends for up to 200m footwall
Rutiles – Indicator

V 0.7%
Sb 1.0%
W 1.7%

V 1.2%
Sb 1.8%
W 0.7%

Pyrite inclusions
Rutile Compositions – Regional Deposits
Rutile Compositions – Regional Deposits

**W**
- Fender
- North Fender
- Indicator
- Big Bell

**Sb**
Rutile Compositions – Regional Deposits

- **Fender**
- **North Fender**
- **Indicator**
- **Big Bell**

Graphs showing the distribution of Nb (%).
Features of Mineralization
Big Bell area

<table>
<thead>
<tr>
<th>Deposit</th>
<th>V</th>
<th>W</th>
<th>Sb</th>
<th>Fe</th>
<th>Nb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Bell</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>×</td>
</tr>
<tr>
<td>Fender</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>×</td>
</tr>
<tr>
<td>Nth Fender</td>
<td>×</td>
<td>√</td>
<td>×</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Indicator</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>×</td>
</tr>
</tbody>
</table>
Conclusions

- Rutiles at Big Bell are enriched in V, W, Sb, Fe (cf. Hemlo Au deposit)
- These features commonly present in footwall (up to 200m) and perhaps 30m in hanging wall
- Rutile associated with mineralization at Indicator and Fender also has enriched V, W, Sb and Fe
- Rutile at Nth Fender has elevated W, Fe and Nb, i.e. affected by different fluids than at Big Bell
- Features seen in highly weathered samples ⇒ Big Bell type alteration can be identified in regolith samples
- Rutile geochemistry allows targets to be ranked
V-Sb-W Rich Rutiles – Big Bell

- Sample sites
  (all sample nos prefixed by 1132)

- ORE in floor of pit
  (200m below surface)

- Pit outline (December 1993)

- ~ 560m depth

- Western Batholith
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