Workshop 3
Indicator Mineral Methods in Mineral Exploration
Sunday, September 9, 2007
Association of Applied Geochemists (AAG)
Convenors:
Harvey Thorleifson, MGS & Beth McClenaghan, GSC
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
<th>Company</th>
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<tbody>
<tr>
<td>9:00</td>
<td>Introduction</td>
<td>Harvey Thorleifson</td>
<td>MGS</td>
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<td>9:30</td>
<td>Survey design</td>
<td>Chris Benn</td>
<td>BHPB</td>
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<td>Processing methods</td>
<td>Beth McClenaghan</td>
<td>GSC</td>
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<td>10:50</td>
<td>Mineral Chemistry</td>
<td>Bill Griffin</td>
<td>GEMOC</td>
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<td>11:20</td>
<td>QA/ QC</td>
<td>Mary Doherty</td>
<td>ALS Chemex</td>
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<td>Discussion</td>
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<td>Lunch</td>
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<td>Precious metal exploration</td>
<td>Dave Kelley</td>
<td>Zinifex</td>
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<td>1:20</td>
<td>Diamond exploration</td>
<td>Herman Grütter</td>
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<td>Base metal exploration</td>
<td>Stu Averill</td>
<td>ODM</td>
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<td>2:20</td>
<td>Lab: field sampling</td>
<td>Mike Michaud</td>
<td>ODM</td>
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<td>Exploration: India</td>
<td>Dean Pekeski</td>
<td>Rio Tinto</td>
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<td>Public sector: Minnesota</td>
<td>Harvey Thorleifson</td>
<td>MGS</td>
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<td>3:50</td>
<td>Discussion</td>
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Indicator Mineral Methods in Mineral Exploration: Introduction

Harvey Thorleifson
Minnesota Geological Survey
Mineral exploration

- Direct inspection
- Remote detection
Remote detection

- Exploration geophysics
- Exploration geochemistry
- Indicator mineral methods
Remote detection

- Exploration geophysics
- Exploration geochemistry
  - Chemical signal
- Indicator mineral methods
Remote detection

- Exploration geophysics
- Exploration geochemistry
  - Chemical signal
- Indicator mineral methods
  - Clastic signal
Chemical signal

- Transported by aqueous &/or gaseous processes
- Detected in media such as A horizon, B, horizon, vegetation, or gases
Clastic signal

- Transported by mechanical processes
- Detected by sampling clastic sediments that have undergone minimal modification
Clastic sediments
Indicator minerals

• Ideally:
  - Coarse-grained
  - Specific to exploration target
  - Visually distinctive
  - Readily recovered
  - Adequately abundant
  - Adequately resistant
Indicator mineral methods

- Drift prospecting
- Drift exploration
- Tracing float
- Boulder tracing
- Stream sediment geochemistry
- Loaming
- Overburden sampling
- Till geochemistry
- Indicator mineral tracing
Indicator mineral surveys

- Exploration, mapping, research
- Regional reconnaissance
- Follow-up
- Assessment of geophysical targets
- \textit{In situ} mineral chemistry
Objective

• Region or target

• Commodity or commodities
Media

- Stream sediments
- Shoreline sediments
- Glaciofluvial sediments
- Till
Spacing & layout

• Can vary by orders of magnitude
  – 10’s of km
  – 1 km
  – 0.1 km

• Layout
  – Grid
  – Transect
Ranch Lake, NWT,
pyrope grains in till

(McClenaghan et al., 2001)
Phase 1 ice flow
Bedrock source

Phase 2 ice flow

Phase 3 ice flow

Dispersal Vector
Resultant Vector
Resultant Dispersal Fan

(Stea, 2001)
James Bay Lowland

Stream sediments derived from till

(Kong et al., 1999)
Size

• Samples on the order of 10 litres
  - Expected frequency ~ 1 indicator mineral per litre of sand
  - May require 5 to 50 litres of sand
  - % sand varies
Collection

- Road access, aircraft
- Exposures, shovel, excavator
- Large volume & weight
- Field concentration e.g. panning
- Field screening e.g. remove gravel
Field observations

• Boulders
• Striations
Processing

- **Disaggregate**
- **Screen gravel**
  - >2 mm (10 mesh)
  - >1 mm (20 mesh)
  - >4 mm (5 mesh)
- **Retain gravel for lithology**
Pre-concentration

- **Density**
  - Jig, table, pan, spiral, wheel
  - Heavy liquid

- **Size**
  - medium to very coarse sand

- **Magnetism**
  - Reject non-paramagnetic
Concentration

• Heavy liquids
  - Methylene iodide (MI, 3.3)
  - Diluted MI (e.g. 3.2)
  - Tetrabromoethane (TBE, 2.96)
  - NaPolyW (variable)

• Superpanner
• DMS
• Magstream
Ferromagnetics

- Separator
- Hand magnet
Classification

- **Processing of nonferromagnetics**
  - Reduce picking time
  - Add information
  - Sizing
    - E.g. 0.25-0.5 mm; 0.5-2.0 mm
  - Magnetic susceptibility
  - Magstream
The graph illustrates the percentage of different iron oxides in relation to their magnetic susceptibility.

- **Ferroilmenite** shows a peak in percentage at lower magnetic susceptibility.
- **Manganooan Ilmenite** has a peak in percentage at stronger magnetic susceptibility.
- **Picrorilmenite** exhibits a peak in percentage at weaker magnetic susceptibility.

The data is sourced from McCallum and Vos, 1993.
Background

• Many aspects of processing are governed by regional heavy mineral background
Picking/panning

- Identification of possible & probable indicator minerals
- Recovery
- Morphology
- Spikes
- Re-picks
Gold grains

• Number
• Morphology
• Mass
• Composition
Oxidized Till
n = 469

Predicted Assay vs. Gold (ppb, nonmagnetic concentrate)
Oxidized Till
n = 469

Gold Grains / 10kg

Gold (ppb, nonmagnetic concentrate)
Sulphides

• Rare coated grains in aerated sediments
• Fresh sulphides in sediments obtained by drilling
Scheelite

• Lamping under short-wave ultraviolet
Base metal indicators

- e.g. resistates such as gahnite
**Kimberlite indicator minerals**

- Cr-pyrope
- Mg-ilmenite
- Cr-spinel
- E-garnet
- Cr-diopside
- Olivine
- Diamond
Morphology
Mineral chemistry

• Mount & polish grains
• Semi-quantitative analysis
• Quantitative major element analysis
• Mineral classification
• Trace element analysis
<table>
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<tr>
<th>Mean:</th>
<th>TiO₂</th>
<th>Cr₂O₃</th>
<th>FeO</th>
<th>MgO</th>
<th>CaO</th>
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<td>0.58</td>
<td>1.34</td>
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<td>G2</td>
<td>1.09</td>
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<td>G4</td>
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<td>8.01</td>
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<td>15.94</td>
<td>7.47</td>
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</table>
Prairie; Chrome Pyrope; \( n = 342 \)
DIAMOND INCLUSION CHROMITE

$\text{Cr}_2\text{O}_3$ (wt\%) vs. MgO (wt\%)

GURNEY AND MOORE, 1993
TANZANIA

Diamondiferous

Barren

$T_{Ni}$ (°C)

Griffin and Ryan, 1993
Interpretation & follow-up

1992 PRAIRIE ULTRA-LOW DENSITY INDICATOR MINERAL RECONNAISSANCE
Peridotitic Garnets (0.25–2.0 mm) in 30 kg Till

GSC, 1993
OF 2745, Fig. 3
**Indicator mineral surveys**

- Objective
- Media
- Spacing
- Size
- Collection
- Processing
- Pre-concentration

- Concentration
- Ferromagnetics
- Classification
- Picking
- Morphology
- Mineral chemistry
- Interpretation & follow-up
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