Sample Processing Methods for Recovery of Indicator Minerals

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Exploration 07 Workshop 3
Indicator Mineral Methods in Mineral Exploration
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INDICATOR MINERALS

Physical Characteristics:
- Occur mainly in host rock
- Visually and chemically distinct
- Moderate to high density
- Silt to coarse sand-sized (0.10 to 2.0 mm)
- Survive weathering
- Survive clastic transport
SAMPLE MEDIA

- Stream sediments
- Shoreline/beach sediments
- Glaciofluvial (esker) sediments
- Till
- Eolian sediments
- Laterite, regolith
- Float cobbles & boulders

![Till](image1)

![Stream sediments](image2)

![Esker sand](image3)

![Beach sand](image4)

![Deflation sediments, pisolith lag](image5)
SAMPLE PROCESSING

• Reduce sample volume
• Recover heavy mineral fraction
• Reduce volume of heavy mineral fraction to examine
• Recover & analyze indicator minerals

10 to 40 kg sample

10s to 1000s indicator mineral grains
Sample Weight

Example: till samples from glaciated terrain

<table>
<thead>
<tr>
<th>Location</th>
<th>Till Texture</th>
<th>Weight (kg)</th>
<th>&gt;2 mm Clast (kg)</th>
<th>Liquid Light fraction (g)</th>
<th>Magnetic fraction (g)</th>
<th>Non-mag fraction (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thompson Ni Belt</td>
<td>silty sand</td>
<td>15</td>
<td>3</td>
<td>105</td>
<td>36</td>
<td>48</td>
</tr>
<tr>
<td>Sudbury-N. Rim</td>
<td>sand</td>
<td>15</td>
<td>6</td>
<td>403</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Timmins Au camp</td>
<td>silty sand</td>
<td>12</td>
<td>2</td>
<td>320</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>Timiskaming kimberlite field</td>
<td>silty sand</td>
<td>10</td>
<td>1</td>
<td>377</td>
<td>22</td>
<td>36</td>
</tr>
<tr>
<td>Northern Alberta</td>
<td>clay</td>
<td>67</td>
<td>2</td>
<td>1235</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

Suggested till sample weights:
- Sandy material, 10 to 25 kg
- Clay-rich material, 25 to 50 kg
GENERALIZED FLOWSHEET

0.5-1.0 kg split for geochemical analysis & archive

Bulk sediment sample: 10 to 40 kg

Lithology examination >2 mm or >1 mm

Sieve <2 mm or <1mm

< 2mm

Preconcentration

jig, spiral, shaking table, Knelson Concentrator, DMS, or pan

Final concentration

heavy liquids, and/or magstream

Magnetic fraction: Examine or store

Heavy Fraction: Ferromagnetic Separation

Nonferromagnetic fraction: Dry sieve to specific size fractions

Indicator mineral selection

Indicator Mineral Identification:
1. Examine & photograph
2. Chemical analysis: electron microprobe, LA-ICP-MS, ion microprobe

Store under-/oversized fractions
**STEP 1**

Disaggregate & homogenize

**STEP 2**

Screen off gravel fraction

- >4 mm (5 mesh)
- >2 mm (10 mesh)
- >1 mm (20 mesh)
- Retain gravel for pebble counts

(Cement mixer)

(Sedimentation net)

Mineral Services Canada
STEP 3: PRECONCENTRATION

Size Screening
  • Silt to very coarse sand (0.01 to 2.0 mm)

Density Separation
  • Jig, wheel
  • Pan
  • Spiral separator
  • Dense media separator (DMS)
  • Shaking table (Wilfley table)
  • Knelson Concentrator
**Panning**

- Oldest recovery method for indicator minerals
- Pan shaken sideways in circular motion
- Heavy minerals sink, light minerals rise
- Size range: silt to sand sized mineral grains

**Advantages:**
- Field or lab-based operation
- Inexpensive, reduces shipping costs
- Recovers silt-size precious & base metals minerals
- Can be used in combination with other preconcentration methods

**Disadvantages:**
- Slow
- Dependent on experience & skill of operator
- Consistent personnel required to pan
STEP 3: PRECONCENTRATION

Spiral concentrator

- Recovers heavy minerals \( \sim \text{SG} \geq 3 \)
- Stainless steel bowl with ribs that form spiral
- Bowls spins, water sprays, grains move up in spirals
- Water washes light minerals down
- Heavy minerals travel up to central opening, collected in container behind bowl
- Heaviest minerals recovered first

Advantages:
- Fast if sample is sandy
- Field or lab-based operation
- Inexpensive, reduces shipping costs
- Recovers indicator minerals across broad size range, from silt-sized precious & base metals to sand size

Disadvantages:
- Dependent on experience & skill of operator
- Lower density threshold variable
- Some loss of heavy minerals
- Slow if sample is clay-rich
STEP 3: PRECONCENTRATION

**Knelson Concentrator**

- Centrifugal separator, rotating bowl with rings
- Originally designed for recovery of gold
- Modified 3” version recovers heavy to moderately heavy minerals
- Slurry forced outward & upward under centrifugal force
- Slurry fills rings on cone wall, heavy minerals concentrate in rings

**Advantages:**
- Moderate cost
- Field or lab-based operation
- Field based reduce shipping costs

**Disadvantages:**
- Lower size limit 0.25 mm, does not recover silt-size precious or base metal minerals
- Lower density threshold ~3.2, resulting in loss of moderately heavy minerals, greater loss for coarser (>0.5 mm) material
STEP 3: PRECONCENTRATION

Shaking (Wilfley) Table

- <2 or <1 mm fraction processed
- Table with riffles, shakes sideways
- Heavy minerals ride across top of table
- Light minerals across bottom of table

Advantages:
- Recovers broadest size range of indicator minerals from silt to sand size (0.1-2.0 mm)
- Recovers broad spectrum of indicator mineral species, including precious & base metals, kimberlites, U
- Moderate cost
- Pan preconcentrates for precious & base metals
- Well established & widely used method

Disadvantages:
- Some coarse heavy minerals lost during tabling
- Table operator requires experience
- Consistent personnel required to operate table
STEP 3: PRECONCENTRATION

Dense Media Separator (DMS)

- <2 or <1 mm fraction processed
- Fed into ferrosilicon solution, SG 3.1
- Heavy minerals spin to outside of column, light minerals in middle of column, heavy minerals collected at base

Advantages:
- Fast
- Density settings checked daily
- Not operator dependent
- Use for recovery of kimberlite indicator minerals

Disadvantages:
- Higher cost
- Lower size limit: 0.3 mm
- No recovery of silt-size precious & base metals
STEP 4: FINAL CONCENTRATION

- Preconcentrate (step 3) further processed using heavy liquids
- Exact separation at a specific density, light minerals float, heavy minerals sink

- **Heavy liquids commonly used:**
  - Methylene iodide (MI) $SG=3.3$
  - Tetrabromoethane (TBE) $SG=2.96$
  - Na-polytungstate  $SG \ 2.82-2.95$

- **Diluted MI**  $SG=3.2$
  Lower limit for kimberlite indicator minerals is 3.2, to include Cr-diopside and forsteritic olivine
STEP 5: REMOVAL OF FERROMAGNETIC MINERALS

Purpose: reduce volume of material to examine for indicator minerals

- Hand magnet
- Magnetic Separator
- Fe-Nd dry magnetic separator
STEP 6: ADDITIONAL PROCESSING

Purpose: reduce picking volume & time
• Sizing, e.g. 0.25-0.5 mm; 0.5-2.0 mm
• Magnetic susceptibility (paramagnetic separation)
• Magstream

Paramagnetic separation:
• Non paramagnetic (e.g. diamond, olivine)
• Weakly paramagnetic (e.g. pyrope garnet, Cr-diopside, olivine)
• Moderately paramagnetic (e.g. Cr-spinel)
• Strongly paramagnetic (e.g. Mg-ilmenite)

Carpco magnetic separator
STEP 6: ADDITIONAL PROCESSING

Magstream magnetic separator:
- Gravity (& magnetism) used to separate heavy minerals
- Fluid with high SG used, e.g. SG 3.1
- Fluid spins, magnet on outside of tube
- Heavy minerals concentrate on outside of tube (e.g. oxides, Fe-almandine)
- Light minerals concentrate on inside of tube (e.g. CPX, pyrope)
- Used to separate similar looking Fe-rich almandine from E-garnets prior to indicator mineral selection

Till heavy mineral concentrate containing abundant orange Fe-rich almandine that may be misidentified as E-garnet
STEP 7: INDICATOR MINERAL SELECTION

- Visual identification of possible & probable indicator minerals using binocular microscope
- Grain morphology & surface textures: binocular microscope, SEM
- Examine entire HMC or portion (normalize to full weight HMC)
- Select indicator minerals for chemical analysis
STEP 8: MINERAL CHEMISTRY

- Confirm visual mineral identification, evaluate grade, genesis or alteration
- Mount & polish grains (25 mm epoxy mounts)
- Mounting technique and polishing crucial steps
- Quantitative major & trace element analysis: SEM, EMP, LA-ICP-MS, SIMS
- Examples of the application of mineral chemistry data:
  Bill Griffin, Herman Grütter

Mineral grains mounted for analysis

K. Gibbs

H. Thorliefson
STEP 8: MINERAL CHEMISTRY

Electron microprobe analysis (EMP):
• Determines element concentrations in % to ppm range
• Target key locations within single mineral grain
• Beam width 5 µm

Electron microprobe (EMP)

Mineral grains mounted for analysis
KIMBERLITE MINERAL CHEMISTRY

**Mg-ilmenite**

**Garnets**

Also discrimination plots for olivine, Cr-diopside...
Step 8: Mineral chemistry

Laser Ablation ICP-MS (LA-ICP-MS):
- Determines element concentrations in ppm-ppb range
- Target key locations within single mineral grain
- Beam width 30 to 50 µm

Pyrite framboid with laser ablation pits

LA-ICP-MS, CODES
INDICATOR MINERAL FEATURES

Relative Abundance

Kimberlite A

Kimberlite B

Grain Surface

Kelyphite rims (k) on Cr-pyrope

SD-042

SD-043

SD-043
INDICATOR MINERAL FEATURES

Grain shape

Gold grain shape classification scheme (DiLabio, 1990)

Pristine  Modified  Reshaped

Increasing glacial transport distance
Visible gold grains in till, Pamour Mine, Timmins:

- Gold grains fine sand to silt sized
- Most grains <50 \(\mu m\)
- Typical of Archean quartz vein-hosted lode gold deposits
QUALITY CONTROL

• QC program mandatory for indicator mineral processing & analysis as outlined in “Mineral Exploration Best Practices Guidelines” in Canada

• Dictated in Canada by National Instrument 43-101

• Tour heavy mineral processing and picking labs

• Use blanks, field duplicates, spiked samples, repick ~5-10%

• Use same/similar labs for duration of project to allow comparison of results over several batches/years

• Report raw counts, as well as normalized counts

• Report indicator mineral abundances with respect to sample weight for interpretations on maps, figures etc..., e.g. 100 grains/10 kg
QUALITY CONTROL

Mineral Exploration Best Practices Guidelines:

• **Sampling**
• **Sample security**

• **Sample preparation** (processing):
  - Indicator mineral spikes - oxides & silicates, laser etched & SEM photos;
  - Diamond spikes- laser etched & SEM photos
  - Density beads

• **Analysis & Testing** (Indicator mineral picking):
  - Indicator mineral spikes - oxides & silicates, laser etched & SEM photos
  - Diamond spikes- laser etched & SEM photos
  - Repicking by another mineralogist within the lab
  - Resubmit 5-10% of concentrates for re-picking

• **Analysis & Testing** (Mineral chemistry analysis):
  - Analyze certified reference standards
QUALITY CONTROL

Things that can screw up your results....

• Sample tampering in the field (unsecured sample storage)

• Contamination/carry over in the field from equipment (e.g. dirty shovels)

• Contamination during sample processing: carry over from one sample to the next within your batch or another client's samples

• Indicator minerals lost during processing

• Indicator minerals missed during examination/selection
**COMMON INDICATOR MINERALS**

- Gold grains (Au)
- Native copper (Cu)
- Kimberlite indicator minerals
- Platinum Group minerals (PGM)
- Sulphide minerals
- Metamorphosed massive sulphide minerals - e.g. gahnite
- Magmatic Ni-Cu-PGE minerals
- Scheelite (W)
- Cassiterite (Sn)
- Cinnabar (Hg)
- Fluorite, topaz (F)
- Uranium minerals
- Rare earth element (REE) minerals

- May be recovered from same heavy mineral concentrate, depends on processing methods used
- Selected from sample all at same time, or during re-examination

![Topaz](image1.png)
![Gahnite](image2.png)
![Gold, native copper, pyromorphite](image3.png)
![Pentlandite](image4.png)
• Indicator minerals are rugged, easily recovered heavy minerals. Recovery methods exploit mineral size, density and magnetic characteristics.

• Various processing methods available, methods used will depend on: cost, number of samples, survey location, time frame to obtain results.

• Mineral abundance, chemistry, shape, surface features may provide important information about the bedrock source, including style of mineralization, grade, alteration as well as distance of transport from source.

• Quality control essential to monitor during all phases of processing, mineral selection and analysis.

• Commercial labs now offer a range of indicator mineral processing, selection and analytical services.

• Broad range of indicator mineral species can now be recovered, allowing exploration for a wide range of deposit types using the same samples.
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SELECTED REFERENCES


