Trace element chemistry of stream water from arctic Greenland reflecting lithology and mineralisation

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Background

Water samples collected at stream sediment localities over large parts of Greenland

Conductivity determined in all samples, $F^-$ and $U^{VI}$ in many
Background

Source: Armour-Brown et al. 1982: South Greenland uranium exploration project
Geology of study area

Palaeoproterozoic orogen
- Reworked Archaean gneiss
- Metasediments/marble
- Granite

Mesozoic-Palaeogene basin
- Basalt
- Picrite
- Sediment

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Black Angel mine (closed 1990)
Carbonate-hosted Pb-Zn sulphide ore with 13.6 mill. t grading 12.3% Zn, 4% Pb, 29 ppm Ag
Geology of study area

Prominent rust zones, elevated Cu in stream sediment
Stream water

Sampling sites
Second or third order streams with catchment areas 20 km²,
one sample per 20 to 30 km²

Many streams are sourced by melting ice and snow

Stream water samples selected for trace element analysis

Pb, Zn, Ag
Sampling, sample treatment and storage at GEUS

- Samples were contained in 100 ml polyethylene bottles with screw cap.
- Bottle and cap were carefully rinsed in the stream and then filled completely with stream water and closed.
- No filtering, no acid.
- Samples were packed into boxes and shipped to Copenhagen.
- The bottles were left at room temperature until they were sent by air mail to Geological Survey of Canada for analysis, 6 or 18 months later.

Any objections to sample treatment?
Sample preparation and analysis at GSC

• Samples were filtered through 0.45 µm Durapore filters and returned to their original container (rinsed with DDW water first).

• A 10 mL sample was removed for conductivity measurement before the samples were acidified to 0.4% with double distilled HNO₃ from Seastar chemicals.

• The samples were left for about 2 weeks prior to analysis by ICP-MS to allow the nitric acid to desorb any elements from container walls.

• ICP-MS was done with a VG PlasmaQuad 2+, calibration against standards in 0.4% HNO₃ also.
Determined elements and concentration levels

Conductivity

Percentiles

μ S / cm
Determined elements and concentration levels

Al, Fe plus 41 trace elements:

\[
\begin{align*}
\text{Al} & \quad \text{Cu} & \quad \text{Li} \\
\text{Pb} & \quad \text{Rb} & \quad \text{Sr} \\
\text{Y} & \quad \text{Zn} & \quad \text{Nd} \\
\text{Be} & \quad \text{Co} & \quad \text{Cr} \\
\text{Mo} & \quad \text{Sb} & \quad \text{Th} \\
\text{V} & \quad \text{Er} & \quad \text{Yb} \\
\text{Fe} & \quad \text{Mn} & \quad \text{Ba} \\
\text{U} & \quad \text{La} & \quad \text{Ce} \\
\text{Pr} & \quad & \\
\text{Ni} & \quad \text{Ti} & \quad \text{Ti} \\
\text{Sm} & \quad \text{Dy} & \\
\text{Ag} & \quad \text{In} & \quad \text{Se}
\end{align*}
\]

% above lower detection limit:

- Red: 100
- Orange: 90
- Green: 70
- Blue: 50
- Light blue: 30
- Black: 0

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Determined elements and concentration levels

![Graph showing percentiles for different elements]

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Determined elements and concentration levels

Correlation coefficients higher than 0.8:

Al-Be   Mn-Co   Y-Co
Al-Co   Mn-Ni   Y-Ni
Al-Ni   Mn-Cu   Y-Cu
Fe-Cr   Mn-Y    Y-REE
Co-Cu-Ni Mn-REE  REE-REE

Highest correlation with conductivity: Sr 0.76

Fe-Mn: 0.46
Determined elements and concentration levels

Comparison with levels in temperate climate

Medians of measured concentrations

*Lahermo et al. 1996: Geochemical Atlas of Finland, part 3*
Regional distribution

Conductivity

- Greywacke N
- Basalt
- Picrite
- Marble
- Greywacke S
- Granite
- Gneiss

<table>
<thead>
<tr>
<th>Conductivity (µS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 180</td>
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<td>120 - 180</td>
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<tr>
<td>80 - 120</td>
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<td>50 - 80</td>
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<tr>
<td>30 - 50</td>
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<td>10 - 30</td>
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<tr>
<td>&lt; 10</td>
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</tbody>
</table>

Simplified Metamorphic Grade

- Northern area, 1995: high metamorphic grade
- Southern area, 1997: low to no metamorphic grade

Rb (µg/L)

- Greywacke N
- Basalt
- Picrite
- Marble
- Greywacke S
- Granite
- Gneiss

<table>
<thead>
<tr>
<th>Rb (µg/L)</th>
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<tbody>
<tr>
<td>&gt; 4.3</td>
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<tr>
<td>3.5 - 4.3</td>
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<tr>
<td>3 - 3.5</td>
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<tr>
<td>1.4 - 3.0</td>
</tr>
<tr>
<td>0.48 - 1.4</td>
</tr>
<tr>
<td>0.18 - 0.48</td>
</tr>
</tbody>
</table>

Simplified Metamorphic Grade

- Greywacke N
- Basalt
- Picrite
- Marble
- Greywacke S
- Granite
- Gneiss
Regional distribution

Cu (µg/L)
- > 6
- 2 - 6
- 0.8 - 2
- 0.4 - 0.8
- < 0.4

Pb (µg/L)
- > 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- 1.2 - 2
- > 2

Be (µg/L)
- < 0.005
- 0.005 - 0.012
- 0.012 - 0.03
- 0.03 - 0.1
- > 0.1

Geology:
- Greywacke N
- Basalt
- Picrite
- Marble
- Greywacke S
- Granite
- Gneiss
Regional distribution

Sb (µg/L)
- > 0.11
- 0.09 - 0.11
- 0.03 - 0.09
- 0.01 - 0.03
- < 0.01

Pb (µg/L)
- > 2
- 1.2 - 2
- 0.8 - 1.2
- 0.5 - 0.8
- < 0.5

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Regional distribution

Zn

µg/L

- > 95
- 43 - 95
- 14 - 43
- 6 - 14
- 3.5 - 6
- 2 - 3.5
- < 2

Pb

µg/L

- > 2
- 1.2 - 2
- 0.8 - 1.2
- 0.5 - 0.8
- < 0.5

Greywacke N

Basalt

Granite

Picrite

Marble

Gneiss

Greywacke S
Hydrogeochemical signatures

Samples are grouped according to main geology of catchment area

Medians of element concentrations for each group are normalised against the corresponding median of all samples
Hydrogeochemical signatures

Greywacke N  Granite

Basalt  Picrite  Greywacke S  Marble  Gneiss

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Hydrogeochemical signatures

Greywacke N

Basalt
Picrite
Gneiss
Marble
Granite

0.1 1 10 100
Al Sr Rb Li U Ba Rb Zn Mo Sb Fe Mn Ni Cu Cr Ti La Ce Pr Nd Sm Eu Dy Er Yb

Greywacke N Greywacke S Marble

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Hydrogeochemical signatures

Greywacke N

<table>
<thead>
<tr>
<th></th>
<th>Greywacke S</th>
<th>Gneiss</th>
<th>mine waste</th>
<th>mine waste</th>
<th>other sites</th>
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</thead>
<tbody>
<tr>
<td>Al</td>
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<td>Gd</td>
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<td>Dy</td>
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<td>Yt</td>
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</tbody>
</table>

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Comparison with stream sediment

- Basalt
- Picrite
- Gneiss
- Greywacke S
- Marble
- Greywacke N
- Granite

Stream water vs. Stream sediment for Rb and Ce.
In the case of Ba, the stream water data distinguishes the marble much better than the stream sediment where only the highest values lie outside the bulk.

There is no correlation between sediment and water for Mn. Only three greywacke localities and one marble locality are anomalous in both media. If the high Mn
No correlation between water and sediment for Cu except for high values in greywacke. This is interpreted as indicative of mineralisation. With regard to Ni, granite and greywacke samples show some correlation. In basalt and picrite Ni is contained in olivine and not expected to contribute to Ni in water.
### Response to mineralisation

#### Stream sediment (mg/kg)

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>Zn</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine waste</td>
<td>3700</td>
<td>10000</td>
<td>c. 100</td>
</tr>
<tr>
<td>Mineralisation</td>
<td>69</td>
<td>669</td>
<td>Pb 3.5 Zn 6.7</td>
</tr>
<tr>
<td>Background (median)</td>
<td>28</td>
<td>97</td>
<td></td>
</tr>
</tbody>
</table>

#### Stream water (µg/L)

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>Zn</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>27, 19</td>
<td>300, 750</td>
<td>Pb c. 100 Zn c. 140</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>8.5</td>
<td>Pb 15.2 Zn 2.3</td>
<td></td>
</tr>
<tr>
<td>0.23</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

- A long suite of trace elements were detected in ICP-MS analysis of stream water from northern West Greenland.
- Many element concentrations range two to three orders of magnitude.
- Regional variations in trace element concentrations can be related to lithological variation and mineralisation.
- Stream water data are complementary to stream sediment data.
- Despite that sample treatment did not follow the book, the results appear reliable and stream water is regarded a useful medium in geochemical mineral exploration in Greenland.