HIGH-TECH METALS AND MINERALS IN FINLAND, SWEDEN AND NORWAY
Henrik Schiellerup, NGU, with contributions from SGU and GTK
Fennoscandian high-tech metals and minerals

Battery-critical elements
- Cobalt
- Lithium
- Natural graphite

Magnet metals
- REE

Other
- F, Sc, W, V
- Titanium
Battery critical metals and minerals

- Lithium and cobalt strongly driven by EV development
  - 42% of current Co-production used in battery manufacturing
  - 25% of current Li-production used in battery manufacturing

- Natural graphite dominated by refractory market, but high-quality graphite is needed in Li-ion batteries.
  - 8% of current production of natural graphite is used in battery manufacturing
Rare Earth elements

- REE production remains dominated by China
  - magnets, catalysts, batteries, phosphors etc.
- Different drivers for different elements
- Renewable energy sector major driver for REE-based permanent magnets

Global mine production of REOs, average 2010–2014. European Commision 2017 – based on different sources
Titanium rutile/ilmenite

- Mainly used as an industrial mineral in pigment production
- Metal used in aircraft industry, implants, additive manufacturing etc.
COBALT IN FINLAND, SWEDEN AND NORWAY

- Known deposits: Co resources: 500 000 t
- Known and assumed potential for additional resources
- Co reserves: 1 000 t

- Magmatic Ni-Cu-Co-PGE: Kevitsa, Sakatti, Hitura, Kotalahti (FIN); Kleva (S); Gallujavri, Brattbakken (NO)
- Orogenic Au±Cu, Co: Juomasuo (FIN)
- VMS: Pahtavuoma (FIN); Åsoren, Løkken (NO)
- Polygenetic: Talvivaara, Outokumpu, Kylylahti (FIN)
- Sediment-hosted Cu-Co: Skuterud (NO)
- Unclassified: Venafältet, Lainijaur (SW)
LITHIUM AND REE IN FINLAND, SWEDEN AND NORWAY

- Fennoscandian lithium targets all located in spodumene-carrying pegmatites

- Major REE-deposits are found in carbonatites or agpaitic alkaline complexes in all three countries

- Additional deposit types include
  - hydrothermal and vein-type deposits
  - iron-oxide-apatite deposits
  - granites and pegmatites
  - alkaline rock hosted REE-enriched apatite
NATURAL GRAPHITE IN FINLAND, SWEDEN AND NORWAY

- Deposits of flake graphite found across the whole Fennoscandian shield.
- Production has taken place in both Finland, Sweden and Norway.
- Currently only production in Norway.
- Numerous additional targets.
- Flake-type graphite deposits typically confined to high-grade, multiply deformed, Paleo-Proterozoic supracrustal terranes.
Country perspective - Sweden

- Existing mineral resource estimates* indicate significant potential for critical metals and minerals, including cobalt, lithium, natural graphite, REE, vanadium, tungsten, and fluorspar

- Active exploration for critical metals and minerals

- The Swedish government steps up funding to SGU by 10 MSEK (USD 1.25 million) over the next two years to assess the potential for extraction of innovation critical metals and minerals in both primary deposits and mining waste

* Many of the estimates are historic and not compatible with modern standards (JORC or NI 43-101)
Cobalt and lithium in Sweden

• Historic production from Cu-Co, Ni-Cu-Co and Li-pegmatite deposits (currently no production of cobalt and lithium)

• Ca 25 companies have exploration permits for cobalt or lithium

⭐ Cobalt projects include:
- Kiskama (Cu, Co, Au) – Talga Resources
- Ahmaouma (Cu, Co, Au) – Talga Resources
- Lautakoski (Cu, Co, Au) – Talga Resources
- Lainejaur (Ni, Cu, Co) – Berkut Minerals Ltd.
- Nickel Line (Ni, Cu, Co) – EMX Royalty Corp.
- Slättberg (Co, Ni, Cu) – Sienna Resources Inc.
- Vena (Cu, Co) – Leading Edge Materials Corp.

⭐ Lithium projects include:
- Varuträsk – Critical Metals Ltd.
- Bergby – Leading Edge Materials Corp.
Woxna graphite
Leading Edge Materials Corp.

- Located in central Sweden
- Fully permitted graphite production facility
- Four graphite deposits within trucking distance
- Total measured + indicated mineral resources (NI 43-101): 7.7 Mt @ 9.3% Cg
- The Woxna plant is now maintained on a production-ready basis

Photos: Leading Edge Materials Corp.
Vittangi graphite

Talga Resources

- Located in northernmost Sweden
- Contains the Nunasvaara deposit
- Total Indicated + Inferred mineral resource (JORC): 12.3 Mt @ 25.5% Cg
- Exploration, test mining and processing ongoing
Norra Kärr REE project
Leading Edge Materials Corp.

• Located in south central Sweden
• Peralkaline nepheline-syenite intrusive complex

• Indicated mineral resource (NI 43-101):
  31.1 Mt @ 0.61% TREO
• Probable mineral reserve (NI 43-101):
  23.57 Mt @ 0.59% TREO

• Norra Kärr has a high percentage of the heavy rare
  earths in its REE distribution, with a HREE/total REE ratio
  of 53%
• In addition to REEs, Norra Kärr contains significant
  hafnium (Hf), zirconium (Zr) and nepheline
ACTIVITIES IN HIGH-TECH METALS AND MINERALS IN NORWAY

Natural graphite
Cobalt (nickel, copper)
Titanium
Rare Earth Elements
fluorspar, scandium...
COBALT:
SKUTERUD Co-Cu

- > 6 km long sediment-hosted Cu-Co deposit in South Norway
- Active mining from 1776 to 1898
- Historic production: 1 Mt @ 0.2 % Co
- Claims by:
  - Berkut Minerals/Kobald Mineral Holdings
  - Eurasian Minerals Sweden AB
- Drilling by Berkut Minerals (1200 m)
- Activities in Ni (+Co) brownfields and possibilities in Co-bearing VMS
SKALAND NATURAL GRAPHITE

- The Skaland Grafitt owned Trælen mine is one of three operating graphite mines in Europe
- High quality flake-type deposit
- The Trælen deposit is the richest operating graphite mine in the World: 1,8 Mt @ 31 % graphite.
- Yearly production: 10 kt
- Whole region remains highly prospective with on-going exploration
FEN REE-Nb-Th

- 580 Ma carbonatite in South Norway
- Potentially the largest REE resource in Europe
- Coarse grained rauhaugitic ferro-carbonatites with REE hosted by fluoro-carbonates is the most prospective host
- Additional potential for niobium and phosphate resources.
- Two 1000 m drillcores are currently being extracted from REE-mineralized rauhaugite.
ENGEBØFJELLET RUTILE-Ti + GARNET

- Developed by Nordic Mining ASA
- One of the world’s highest-grade rutile deposits
- Unique due to its substantial content of garnet
- Pre-feasibility study completed October 2017
- Current plans include 16 years of open pit mining followed by underground mining

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<th>3% cut-off grade</th>
<th>Tonnage Mt</th>
<th>TiO₂ %</th>
<th>Garnet %</th>
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231 Mt @ 3.9% TiO₂ and 44% garnet
High-Tech Metals and Graphite Mine development projects and significant deposits

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<th>Project</th>
<th>Commodity</th>
<th>Resource/Reserve</th>
<th>Company</th>
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<td>Kaustinen</td>
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<td>Keliber</td>
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<td>Kuusamo</td>
<td>Au-Co</td>
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<td>Sokli</td>
<td>P, REE, Nb</td>
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<td>Yara/GTK</td>
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High-tech metals and minerals in Finland, Sweden and Norway

• Active production of a number of high-tech commodities, including:
  • Cobalt in Finland; Talvivaara, Kevitsa, Kylylahti
  • Natural graphite in Norway; Skaland grafitt
  • Titanium in Norway; Tellnes

• Important or advanced projects on:
  • Cobalt: Kuusamo (FIN); various (SWE); Skuterud (NO)
  • Lithium: Kaustinen (FIN); Varuträsk, Bergby (SWE)
  • Natural graphite: Woxna, Vittangi (SWE); Pitkäjärvi-Aitolampi, Joutsijärvi (FIN)
  • REE: Norra Kärr (SWE); Fen (NO); Sokli (FIN)
  • Scandium: Kiviniemi (FIN)
  • Titanium: Engebø rutile (NO)

• Additional exploration activity on:
  • Fluorpar, Vanadium, Tungsten, as well as all of the above