Sampling and Site Selection and Sampling Criteria

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Marcoule, France, 23rd October 2015
1. Site selection for ENVIREE project
2. Geological/Tailings architecture constraints
3. Sampling Procedures and techniques
SITE SELECTION FOR ENVIREE PROJECT
Screening process of Portuguese secondary sources of REE

- Database with all old mines
- Portuguese old mines
- Pre-selection of sites whose deposits show favorable mineralogical paragenesis to the occurrence of REE
- REE potential
- Were identified 86 sites. Most of them occur at northern-center of Portugal
- Pre-selection 86 sites
- 10 sites
- Mine size → Volume of tailings
- Ore grades
- Geochemical analyses of tailings material (if available)

Selection of 10 favorable sites to discuss relevance with project partners
<table>
<thead>
<tr>
<th>Name</th>
<th>Geographic location</th>
<th>Occurrence/identification (mine name)</th>
<th>Geological/geographical information</th>
<th>Tailings information</th>
<th>Old mining and milling information</th>
<th>Details on industrial production (ongoing operation or operation stopped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 1</td>
<td>NE Portugal</td>
<td>Covas</td>
<td>Tongsten mineralization associated with skarn, massive sulphides and iron oxides; occurs in metasedimentary and metatquartzitic formations (Silurian)</td>
<td>Tailings E2 to E4 - 226 000 m³; Tailings E5 84 000 m³</td>
<td>Accessible</td>
<td>W (Skarns)</td>
</tr>
<tr>
<td>Source 2</td>
<td>NE Portugal</td>
<td>Verdes</td>
<td>Quartz veins, breccia cemented by quartz and pegmatites with cassiterite; occurs in very deformed Silurian metasediments</td>
<td>To be defined after visiting the site</td>
<td>Accessible</td>
<td>Sn, W, Au</td>
</tr>
<tr>
<td>Source 3</td>
<td>Central Portugal</td>
<td>Ribé Gaia</td>
<td>Alluvial type deposit from pegmatic veins with cassiterite, COLTAN, hosted in granites</td>
<td>To be defined after visiting the site</td>
<td>Accessible</td>
<td>Sn, COLTAN (Nb, Ta)</td>
</tr>
<tr>
<td>Source 4</td>
<td>NE Portugal</td>
<td>Cumieira</td>
<td>Alluvial type deposit from quartz veins and pegmatic apophysis</td>
<td>To be defined after visiting the site</td>
<td>Accessible</td>
<td>Sn, COLTAN (Nb, Ta)</td>
</tr>
<tr>
<td>Source 5</td>
<td>N Portugal</td>
<td>Vieiros</td>
<td>Pegmatitic system in schists and phyllic formations</td>
<td>Small tailings (=10.000 m³) of shale and quartz</td>
<td>Accessible</td>
<td>Sn, Ta</td>
</tr>
<tr>
<td>Source 6</td>
<td>S Portugal</td>
<td>S. Domingos</td>
<td>Massive sulphides; exploited for Cu, Zn and S</td>
<td>Tailing, mine wastes, slags and rubble (&gt;100.000 m³)</td>
<td>Accessible</td>
<td>Cu, Zn, S (massive sulphides)</td>
</tr>
<tr>
<td>Source 7</td>
<td>Central Portugal</td>
<td>Qta Bispo (rad)</td>
<td>Located in the contact of a granite with an enclave of metassediments. These enclaves show contact metamorphism and consist of clay-micaeous schists, brown in color. Can be ferruginous and altered.</td>
<td>Tailings (1 500 000 ton; max height 37m)</td>
<td>Accessible</td>
<td>U, Ra</td>
</tr>
<tr>
<td>Source 8</td>
<td>Center Portugal</td>
<td>Ervideira (rad)</td>
<td>Smoked quartz in veins, with &quot;basic rock&quot; hosted by altered granite</td>
<td>Tailing from pit and trench (500 ton, 1.5 m height)</td>
<td>Accessible</td>
<td>U, Ra</td>
</tr>
<tr>
<td>Source 9</td>
<td>Center Portugal</td>
<td>Mestradas (rad)</td>
<td>Porphyritic coarse, with two mica granite, cut by fractures with smoked and amethyst quartz and chaledony.</td>
<td>Tailing (5000 ton, 3m height)</td>
<td>Accessible</td>
<td>U, Ra</td>
</tr>
<tr>
<td>Source 10</td>
<td>S Portugal</td>
<td>Monchique</td>
<td>Nepheline Syenite massif of Cretaceous age, hosted by shales of Paleozoic age.</td>
<td>To be defined after visiting the site</td>
<td>Accessible</td>
<td>Nepheline Syenite</td>
</tr>
</tbody>
</table>

**List of Portuguese sites**
GEOLOGICAL/TAILINGS ARCHITECTURE CONSTRAINTS
Mining wastes

Definition

*Mining wastes* are mining-related by—products of two types:

(a) *mining-and-quarrying extraction wastes* which are barren soils removed from mining and quarrying sites during the preparation for mining and quarrying and do not enter into the dressing and beneficiating processes, and

(b) *mining-and-quarrying dressing and beneficiating wastes* which are obtained during the process of separating minerals from ores and other materials extracted during mining-and-quarrying activities.

https://stats.oecd.org/glossary/detail.asp?ID=3077
Mining wastes

- Mining wastes heterogeneity
  - Waste pile configuration
  - Type of mine wastes
  - Neoformation minerals (secondary mineralization)
The wastes are accumulated in one or several sites with different distributions according with the local landuse management by the mine operator/regulator.

http://www.lneg.pt/CienciaParaTodos/edicoes_online/diversos/boa_pratica/texto

http://www.lneg.pt/CienciaParaTodos/edicoes_online/diversos/boa_pratica/texto
Waste pile spatial distribution/organization
Type of mine wastes

There are different types of mine waste materials which vary in their physical and chemical composition, their potential for environmental contamination, and how they are managed at mine sites. Types of mine waste include:

**Overburden**: Overburden includes the soil and rock that is removed to gain access to the ore deposits at open pit mines. It is usually piled on the surface at mine sites where it will not impede further expansion of the mining operation – moving large volumes of material is expensive. Overburden generally has a low potential for environmental contamination, and is often used at mine sites for landscape contouring and revegetation during mine closure.
There are different types of mine waste materials which vary in their physical and chemical composition, their potential for environmental contamination, and how they are managed at mine sites. Types of mine waste include:

**Waste rock:** Waste rock is material that contains minerals in concentrations considered too low to be extracted at a profit. Waste rock is often stored in heaps or dumps on the mine site, but may be stored underwater with tailings if it contains a lot of sulphide minerals and has a high potential for acid rock drainage formation. Waste rock dumps are generally covered with soil and revegetated following mine closure, although there are cases of waste rock being re-mined due to an increase in mineral market prices or improvements in extraction technology.

http://www.groundtruthtrekking.org/Issues/MetalsMining/MineTailings.html
There are different types of mine waste materials which vary in their physical and chemical composition, their potential for environmental contamination, and how they are managed at mine sites. Types of mine waste include:

**Tailings**: Tailings are finely ground rock and mineral waste products of mineral processing operations. Tailings can also contain leftover processing chemicals, and are usually deposited in the form of a water-based slurry into tailings ponds (sedimentation lagoons enclosed by dams built to capture and store the tailings), although offshore tailings disposal has been successful in some cases. Tailings dams are discussed in further detail below.

http://www.groundtruthtrekking.org/Issues/MetalsMining/MineTailings.html

There are different types of mine waste materials which vary in their physical and chemical composition, their potential for environmental contamination, and how they are managed at mine sites. Types of mine waste include:

**Slags:** Slags are non-metallic by-products from metal smelting, and were historically considered to be waste. Slags are largely environmentally benign, and are being used increasingly as aggregate in concrete and road construction.

http://www.groundtruthtrekking.org/Issues/MetalsMining/MineTailings.html

Type of mine wastes

- Waste rock
  - $\Delta$ host rocks

- Ore
  - $\Delta$ grade; $\Delta$ mineralization type

Source: Lundin Mining

http://www.sec.gov/Archives/edgar/data/1377085/000120445908001113/exh991.htm
Type of mine wastes

Vale Pião mine

W, Sn mineralization in quartz veins
Type of mine wastes - Tungsten (W) mines

Composition variability of tailings related to the geological diversity of the mineralizations.

**Bejanca**

**Mineralization type:** tungsten mineralization ( wolframite), cassiterite

**Host rock:** granite

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**Argozelo**

**Mineralization type:** tungsten mineralization ( scheelite, wolframite, ferberite), cassiterite, sulphides ( arsenopyrite, chalcopyrite, sphalerite, pyrite)

**Host rock:** pelitic-siltitic schists, quartzwackes

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**Covas**

**Mineralization type:** skarn type with tungsten mineralization ( scheelite, wolframite, ferberite), cassiterite, sulphides ( arsenopyrite, chalcopyrite, sphalerite, pyrite, pyrrhotite), apatite, chlorite, muscovite and quartz.

**Host rock:** pelitic schists, impure marbles and quartzites.
Type of mine wastes

Bejanca
Type of mine wastes

Argozelo

A – coarse grained of silicate composition
B – pyrite deposit, sulphides rejected from mineral processing
C – fine grained of silicate material
Type of mine wastes

Covas

- Site selection for ENVIREE project
- Geological/Tailings architecture constrains
- Sampling procedures and techniques
Neoformation minerals (secondary mineralizations)

S. Domigos mine – massive sulphides mine (Cu, Zn, Pb)
SAMPLING PROCEDURES AND TECHNIQUES
Sampling procedures and techniques

- Site and sampling characterization (report)
- Sampling techniques vs Sample type
- ENVIREEE sampling
Site and sampling characterization

Mining site

- Sampling and Date
- Mining site ID
- Type of ore (including grades and tonnage)

Geological characterization

Exploitation characterization

After mining conditions

Site and Sampling characterization report

- Date: __/__/____
- Time: __:__
- Weather conditions:

Mining site:
- Name: __________________ Location: __________________
- Coordinates: __________________ Projection System: __________________
- Type of ore (grade and tonnage):

Regional geology and meteorologic province:

Mineralization type:

Host and outcropping rocks:

Exploitation period:

Type(s) of ore processing:

Evidence for reformation/weathering:

Mine drainage:
Site and sampling characterization

### Tailings

<table>
<thead>
<tr>
<th>Tailing bodies ID</th>
<th>Height (m)</th>
<th>Shape</th>
<th>Area (m²)</th>
<th>Description</th>
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Homogeneity (grain size, composition, etc.)
Site and sampling characterization

## Sampling

### Tailings/waste sampling:

**Used equipment:**

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**No. samples collected:** ______

**Samples ID:**

<table>
<thead>
<tr>
<th>Tailing body ID</th>
<th>Sample Ref.</th>
<th>Sub-sample Ref.</th>
<th>Depth (m)</th>
<th>Grain size</th>
<th>Grain shape</th>
<th>Observations</th>
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**Geological/Tailings architecture constrains**

**Sampling procedures and techniques**
Observations
Site selection for ENVIREE project

Geological/Tailings architecture constrains

Sampling procedures and techniques

Sampling techniques vs Sample type
Commodity: W

Type of deposit: skarn

Mineral paragenesis: skarn type with tungsten mineralization (scheelite, wolframite, ferberite), cassiterite, sulphides (arsenopyrite, chalcopyrite, sphalerite, pyrite, pyrrhotite), apatite, chlorite, muscovite and quartz.

Exploitation type: Open pit and underground

Evidence for neoformation/weathering: Locally there are neoformations of sulphates and sulphur

Mine drainage: Mainly infiltration and runoff from tailings. There is a small lake downstream one of the tailings where the water is treated before it drains to the local streams.

Ore processing: Electromagnetic, hydrogravitic, roasting and flotation

Activity: 1950 - 1984

Tailings

Accumulated in well defined areas
Large volume
Heterogeneous composition
Extremely reactive (generates AMD)
Covas sampling

- Area with tailing bodies
- Sampling sites

84,000 m³

5,500 m³

226,000 m³
Covas sampling

COVAS A1-1
Fine to coarse material – silt and sand grain size and some portions of gravel. Light brown colour and homogeneous composition

COVAS A1-2
Similar to COVAS A1-1. Characterized mainly by silt to fine sand grain size with low content of coarser grains. This sample was collected 2.5 m to N of COVAS A1-1

Composite sample COV A1
**Covas sampling**

**COVAS A3**: fine grain size (fine to medium sand), heterogeneous with orange, brown and yellow colors. In some places is well consolidated.
**Covas sampling**

**COVAS A4:** coarse grain size (fine sand), light brown, cream and white colors, heterogeneous. The bottom is well consolidated and corresponds to one of the host rocks.
COVAS sampling

**COVAS FURNACE**: fine ashes, black to dark grey colour, from the building where the roasting process was made.
**Covas sampling**

**COVAS B1a:** fine (silt) to coarse grain size (medium sand) with orange, dark red and yellow colours, heterogeneous. It is the bottom level of a layered sequence.
**Covas sampling**

**COVAS B1b:** fine grained dark grey mud, probably corresponds to roasting ashes. This layer shows milimetric planar structures.
**Covas sampling**

**COVAS B1c:** very fine grain size (silt), dark brown (with burnt aspect), consolidated but easy to disaggregate.

![Image of Covas sampling site with area and sampling sites highlighted.](image-url)
**Covas sampling**

**COVAS B1d:** this layer is coarser than the previous (B1c, B1b, B1a) (medium to coarse sand), light brown to white colors, difficult to disaggregate, with white coarser clasts (medium to coarse gravel) easily broken.
Covas sampling

**COVAS B2**: similar to COVAS B1d. Coarse grain size (coarse sand to fine gravel), cream to light brown and orange colors. Sample has lithic elements, mainly pegmatite-aplite with fragments ranging from 1 to 5 cm or larger. Cemented material (silicious) for being hard and difficult to dig. The soil at top was removed.
Covas sampling

COVAS B3: mainly coarse grain size (medium sand) with larger fragments up to fine gravel. Heterogeneous material with orange, yellow and brown colors. Is defined 3 types of material from top to bottom: fine to medium grain, red brown layer; coarser than the previous, yellow with minor dark grey layers intercalated; material darker than the top layer, similar to COVAS B1a.

COVAS B4: consolidated sample with approximately 30cmx10cmx7cm with fine grain size. Shows laminar textures, probably corresponding to the material at bottom of settling tank.
Covas sampling

**COVAS B5**: mainly coarse material (sand) with larger fragments of aplite(?) up to 5 cm, light brown color, heterogeneous, hard and difficult to dig.
Covas sampling

**COVAS C1:** Very fine banded material (clay to silt grain size) with milimetric to centimetric layers with orange and yellow colors, showing oxidation crusts. Homogeneous sample. Coarse schist fragments on the top.
ENVIREE sampling - CUMIEIRA

**Commodity:** Sn, Nb, Ta

**Type of deposit:** Placers deposits near quartz veins and pegmatitic apophysis (primary source). The placer have different thicknesses from centimetres up to 3 m above bed-rock.

**Mineral paragenesis:** cassiterite, columbite, tantalite, quartz, minor sulphides

**Exploitation type:** surface exploitation and minor underground works

**Evidence for neoformation/weathering:** The tailings do not show any evidence of weathering

**Ore processing:** hydrogravitic, washing, electrostatic separation

**Activity:** 1927 – 1966

**Tailings**

- Disperse over a large area
- Heterogeneous (grain size and composition)
- Extremely poorly sorted
- Non-reactive

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**Legend:**

- **Zn** Undifferentiated Silurian Units
- **Y4** Granite
- **9af** Quartz veins
- **tap** Aplite-pegmatite veins

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[Map Image: 500m scale map with geological features labeled]
Cumieira sampling

Area with tailing bodies
- Sampling sites

~ 55,000m²
**CUM A1**: fine dark grey grained material (silt to fine sand), homogeneous. Some dark intercalations (probably organic material) and dark soil in the bottom. This sample is from rain runoff near the road.
**Cumieira sampling**

**CUM B1:** mainly coarse grains (cobble grain size) with fine material (silt to fine sand), heterogeneous. The materials are schists, micaschists, spotted schists (andalusite?), quartz and minor occurrences of aplites.
**Cumieira sampling**

**CUM C1**: coarse material (mainly above 2 mm grain size) with some clay material; dark brown, heterogeneous
Cumieira sampling

**CUM D1**: fine material (silt) without coarse grains, homogeneous, well sorted; light brown with lots of micas

**CUM D2**: Similar to CUM D1, well sorted. The grain size is more coarse than CUM D1
**ENVIREE sampling - VERDES**

**Commodity:** Sn, W, (Au)

**Type of deposit:** Quartz veins from aplite-pegmatite for cassiterite and wolfram mineralization. Has also breccia cemented by quartz and pegmatites with cassiterite

**Mineral paragenesis:** Cassiterite, wolframite and gold.

**Exploitation type:** Underground

**Evidence for neoformation/weathering:** The tailings do not show any evidence of weathering

**Ore processing:** Hydrogravitic, electromagnetic

**Activity:** 1947 – 1975
Verdes sampling

- Area with tailing bodies
- Sampling sites

~ 17,000m²
Verdes sampling

Area with tailing bodies

Sampling sites

Site selection for ENVIREE project
Geological/Tailings architecture constrains
Sampling procedures and techniques
Verdes sampling

VER A1: Fine grain size (fine sand), cream to white, very homogeneous

Area with tailing bodies
Sampling sites
Summary

- **Mining wastes**
  - Characteristics of mineral deposit and processing methods
  - Waste pile configuration
  - Tailings heterogeneity

- **Sampling (representative samples)**
  - Sampling techniques according sample type
  - Number of samples vs complexity of the tailings
  - Simple or composite samples
Thanks for your attention!

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