DELIVERABLE D1.1 - REPORT ON THE IDENTIFICATION OF SECONDARY RESOURCES IN EUROPE AND SOUTH AFRICA AND BRIEF DESCRIPTION OF THEIR WASTES

Lead Partner: EDM

<table>
<thead>
<tr>
<th>Writer</th>
<th>Reviewed by CHALMERS</th>
<th>Approved by Coordinator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carlos Rosa/Daniela</td>
<td>Petr Koran / Jakub Heller</td>
<td>Christian Ekberg</td>
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<td>Lobarinhas/Marisa Gomes</td>
<td></td>
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<td>Edgar Carvalho</td>
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Coordinator: Christian Ekberg
Coordinating Organisation: CHALMERS
Project start date: 01/01/15
Project duration: 36 months

Project co-funded under ERA-MIN programme

<table>
<thead>
<tr>
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<tr>
<td>RE</td>
<td>Restricted</td>
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<tr>
<td>CO</td>
<td>Confidential (only for ENVIREE partners)</td>
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### Version control table

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<th>Author(s)</th>
<th>Brief description of changes made</th>
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<td>First release</td>
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<td>DIAMO-GEAM; CGS; Boliden; Chalmers; AGH; EDM; IST-ID</td>
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<td>1.3</td>
<td>29/03/2016</td>
<td>CHALMERS</td>
<td>Final version, signatures</td>
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### Project information

<table>
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<tr>
<th>Project full title:</th>
<th>ENVIronmentally friendly and efficient methods for extraction of Rare Earth Elements from secondary sources</th>
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<tr>
<td>Acronym:</td>
<td>ENVIREE</td>
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<tr>
<td>Funding scheme:</td>
<td>Research project</td>
</tr>
<tr>
<td>Programme and call</td>
<td>2nd ERA-MIN Joint call</td>
</tr>
<tr>
<td>Coordinator:</td>
<td>Ch. Ekberg</td>
</tr>
<tr>
<td>Start date – End date:</td>
<td>01/01/15 – 31/12/17 i.e. 36 months</td>
</tr>
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<td>Coordinator contact:</td>
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</tr>
<tr>
<td>Online contacts:</td>
<td>To be specified</td>
</tr>
</tbody>
</table>

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1 EXECUTIVE SUMMARY

This report is Deliverable D1.1 “Report on the identification of secondary resources in Europe and South Africa and brief description of their wastes to evaluate the potential for containing REE; wastes availability, and sample location” of the Work Package 1 – Assessment of Available Materials and Their Characterization, as defined in the Project Proposal and Detailed Work Plan, which delivery was planned for the Month 12 of the ENVIREE Project.

A large number of sites having mine tailings, mostly from abandoned mine sites, but also from mines in operation, were initially identified in the Czech Republic, South Africa, Sweden, Poland and Portugal by the local project partners. It was then necessary to conduct a bibliographic review to characterize the abandoned mine sites in order to define those with more potential to contain REE in the tailings and therefore be considered for the ENVIREE project. This work focused initially on the volume of the tailings body/bodies that was obtained from data published by the mine operators at the time the mines were in production, or from present data produced by some project partners or national agencies. This information was integrated with the mineral paragenesis indicated for each mined deposit in order to define the mine sites that have more potential to contain REE in their tailings. This information was compiled in a table (site selection criteria table in annex I) and prioritized to define the most appropriate sites to be sampled. Also, in order to guarantee that the information produced during the sampling campaigns was consistent among all partners, and more important, among sites and materials sampled, EDM has defined and shared with the project partners a template of a Site and Sampling Characterization Report that should be completed for each selected site. This template was created exclusively for this project taking account the main characteristics of the tailings but can be used in another sampling campaigns (annex II). It is important to note that information regarding the REE content of the mineralization is scarce or inexistent, since the exploitation of those mines was targeted at other commodities than REE and the mine operators were not considering the potential of the mineralizations to contain REE elements. The samples from mines in operation were made available by the mine operators but their REE content was not deeply characterized.

This procedure narrowed the initial identified sites to a selection of the most promising sites to provide material to be processed in the subsequent phases of the project. These sites were then characterized in detail with respect to the geology of the mine area; the mineralogy and modes of occurrence of the mineralization; type of ore, grades and processing methods; and period of mining activity. This information was compiled in a Site and sampling characterization report that was produced for each mine site and gathers the relevant information for each site in a single document.

The sampling campaigns were aimed to obtain representative samples that characterize the tailing bodies. Therefore, to fulfil this objective and after site inspection, it was necessary in some cases to collect several samples from different places of the tailings; from different vertical positions of the tailings; and from different tailing bodies. In order to have representative samples, each sample weighted approximately 5 kg. The samples were sent to IST-ID in Portugal for processing (grinding and homogenization) and chemical characterization. Additional chemical characterization was conducted at AICU in Romania.

The geochemical results were used to define which samples have higher REE content, and these were then selected to be bulk sampled. Approximately one ton of material from the selected sites is going to be prepared in the BRGM facilities to be processed in WP2.

In the following chapters is presented by country, the identification of secondary resources in Europe and South Africa, characterization of the sites, description of their wastes and sample locations.
2 CZECH REPUBLIC

2.1 Identification of Secondary REE Site

In the Czech Republic, the potential source of REE to be investigated are tailings from Dolni Rozinka uranium mine (Rozna deposit, figure 1) suggested by DIAMO-GEAM company operating the mine (member of Industrial Users Group of ENVIREE project).

Basic information about the deposit is given below in Table 1:

Table 1: Details of the Dolni Rozinka mine

<table>
<thead>
<tr>
<th>Location:</th>
<th>Dolni Rozinka, 55 km north-west of Brno, Czech Republic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposit:</td>
<td>The uranium hydrothermal deposit in metamorphic rocks</td>
</tr>
<tr>
<td>Economic reserves:</td>
<td>1,800 megatons &quot;U&quot; (ore in sight)</td>
</tr>
<tr>
<td>1997 &quot;U&quot; sales:</td>
<td>300 megatons (uranium concentrate)</td>
</tr>
<tr>
<td>Total &quot;U&quot; sales from the start:</td>
<td>approx.17,670 megatons of yellow cake</td>
</tr>
<tr>
<td>Number of employees:</td>
<td>550</td>
</tr>
<tr>
<td>Total depth of the mine:</td>
<td>1,200 metres</td>
</tr>
</tbody>
</table>

![Figure 1: Location of Rozna mine in Dolni Rozinka (CZ)]

2.2 Sampling and site characterization

2.2.1 Rozna

The Rozna deposit was discovered in 1956 by radiometric exploration and sampling of radon in soil. It is the largest deposit of uranium ore in the Moravia and one of the most important deposits in the Czech Republic (location in Figure 1). Exploitation at Rozna started in 1957. The uranium deposit Rozna (active mine) is localised in a formation of metamorphosed sedimentary - effusive rock of Precambrian age, nowadays mostly gneisses. Uranium mineralisation occurs in graphitized zones of large faults (the length of tens of km).

The wall rocks are biotite- and hornblende gneiss with abundant intercalations of ortho- and para-amphibolite, quartzite and marble. The spatial localization of ore zones is to a large extent controlled by the mineral composition of surrounding rocks and by their physico-mechanical properties. The rock complex of the Rozna deposit mostly consists of Moldanubian rocks represented by gneiss in different level of migmatisation, and amphibolite (see the deposit scheme in Figure 2).
The ore occurrences are bonded to the Rozna - Olsi anticline, about 12 - 15 km long. The saddle part of the anticline is formed by intensively metamorphosed gneisses, the wing parts by gneisses and amphibolites. The axial plane of the fold is overcast eastwards; due to it, both wings dip 45° – 65° westwards. The maximum width of the fold wings is 1.5 - 2.5 km. The deposit Rozna is localised in the western wing of the anticline. The anticline wings are complicated by flexures, which influence the building of ore-bearing structures and control the location of individual ore knots of the deposit. Dislocations of fault character form the main ore-bearing structures. Their morphology and spatial location is strongly connected with the fold fabric. The dislocations are both strike- and diagonal.

Strike (longitudinal) faults are developed in all deposits; the dip of these dislocations mostly conforms to the dip of rock strips or transects them at an acute angle. Their spatial distribution is therefore influenced by the orientation of anticline wings. The uranium mineralisation is bonded to main strike dislocations and connected higher-level structures. Based on their origin they can be described as tectonic zones and linked veins. The thickness of zones is mostly several metres, exceptionally up to 25-30 metres. They reach up to 10 km in longitude. Zoned fillings consist mostly of broken surrounding rocks with a small amount of vein minerals (calcite, graphite, and pyrites). In some cases, the dislocation zones are filled with aplite or carbonate dikes. Uranium mineralisation is spatially bonded to hydrothermally altered parts of chloritized rocks.

Due to the presence of minerals of temporally different mineral assemblages, and the variety of textural ore types, the uranium ores are complex. The ores were formed during metasomatic processes, what is reflected by their disseminated or veiny-disseminated character. The following six stages of mineralisation (assemblages) were recognised:

1. graphite - pyrite (pre-Variscan)
2. quartz - sulphide (pre-Variscan)
3. carbonate (siderite) - sulphide (late Variscan)
4. calcite - chlorite - uraninite (late Variscan, 270 + 15 Ma)
5. calcite - pyrite (late Variscan)
6. albite - chlorite - coffinite (USiO4) (Kimmeridgian orogeny, 190 + 15 Ma)

The development of uranium minerals is closely connected with metasomatic chloritisation of biotite gneisses. Biotite and to some extent also potassium feldspars are replaced by chlorite, albite, hydromuscovite and sericite. Pitchblende and coffinite occur as massive aggregates, often with colloform structure. Coffinite usually replaces pitchblende along aggregate margins and fissures. In some parts, coffinite also replaces primary montroseite (uranil vanadate). Pitchblende is often associated with selenides, which are bonded to carbonate veins, forming in them nests up to several tens of centimeters in size. Selenides are mostly represented by berzelianite (Cu2-xSe) and umangite (Cu3Se2); less common are eskebornite (CuFeSe2), clausthalite (PbSe), bukovite (Tl2Cu3+xFexSe4-x -
named after a nearby locality Bukov), klockmannite (CuSe), eucairite (CuAgSe), ferroselite (FeSe₂), crookesite (Cu₇(Tl,Ag)Se₄), and tyrrelite ((Cu,Co,Ni)₃Se₄).

The ores of Rozna ore field developed in several stages; the changes connected with younger mineralisation processes overprinted the older ones, giving rise to complex zone of altered rocks. The changes of original rocks along tectonic zones with graphite - pyrite mineralisation are graphitisation, pyritisation and silicification. The aureoles of altered rocks often range tens meters into the footwall as well as hangingwall rocks. Their spatial extent is greater than any of the ensuing ones. Graphite and pyrite replace mafic minerals, above all biotite.

Changes of wall rocks along carbonate (siderite) - sulphide veins of the pre-ore stage manifest themselves by intensive bleaching. The rocks gain pale yellow or light grey colour and the laminar texture turns to massive texture.

The hydrothermal changes consist in removal of Si, Fe, Na and influx of water, K, Ca, Mg, H₂CO₃. Their effects can be observed no more than 1 - 2 metres from the vein. The resulting low-T potassium metasomatism was not suitable for uranium precipitation, as it was responsible for unfavourably low reduction capacity and acidification of the rocks.

Changes of the original rocks along the veins of the calcite-chlorite-uraninite stage are visible only microscopically. They manifest themselves by intensive chloritisation and carbonatisation in the immediate vicinity of the vein. Chlorite makes pseudomorphs after biotite; biotite and plagioclase are replaced by carbonate. The chloritisation caused also increase in Fe and Mg and removal of K and Si. The alteration of rocks connected with the youngest mineralisation stage (albite - chlorite - coffinite) is easily visible as reddening of the rocks. This alteration starts to occur 1,5 - 2 metres off the vein. There, biotite is replaced by muscovite, chlorite, and carbonate. The feldspar grains gain red tint, the acidity of plagioclase increases, and on the rims they are replaced by pure, transparent albite. Maximum intensity alterations revealed by total replacement of the gneisses by quartz, albite, fluorite, and montmorillonite. Original uranium minerals are replaced by coffinite, quartz, radioactive harmotome (rich in radium), clay minerals and uranophane. The composition of such rocks gives evidence of influx of sodium, calcium, and carbonic acid, and removal of potassium, iron, magnesium and silicium. They display positive correlation of sodium and uranium levels. The abundance of this sodium-metasomatism controlled mineralisation increases with depth from the surface. From the mining point of view this phenomenon is considered disadvantageous, as it indicates removal of uranium from main mineralised zones and its secondary re-dispersion.

Mining and processing

Mining takes place in one deep mine, with the dressing of mined ore at a chemical-processing unit, which is close to the mine. Uranium content in mined ore is 0,1 - 0,5 %. The final product of the processing unit is uranium concentrate (NH₄)₂U₂O₇; "yellow cake", which is reprocessed at other unit abroad. The processing scheme is in Figure 3.
Figure 3: Processing scheme of Rozna mine.

Mine water and surface water contaminated by uranium and radium represent the greatest danger to the environment during uranium ore mining. Protection of the natural environment against contaminated water consists in cleaning all water from the mine surface (rain water, process water and sewage water) and mine water before it is discharged in the environment. The average annual volume of cleaned water is about 2 million cubic metres.

The cleaning operation in decontaminating plants is based on precipitation of uranium and radium salts, followed by their extraction with ion exchange resins. Radium is precipitated as radium-barite, which is disposed in the tailings ponds (Figure 4), and uranium is processed to yield uranium concentrate ("yellow cake", ammonium or sodium diuranate). Water treatment process is in Figure 5.
The samples suggested for analyses by ENVIREE included:

- Water from tailing ponds (500,000 m³ available);
- Tailings (14 mil. m³ available in the tailing ponds).

According to valid Czech legislation, both selected materials are classified as nuclear materials. Handling of such materials is limited to holders of special license. Another license is needed for exporting such material.
Due to the connected time risk for ENVIREE project, the materials from Rozna mine have been excluded from ENVIREE priority materials at this stage. Basic characterization may take place later during the project depending on costs required for transporting the materials through a professional company holding the necessary licenses.
3 SOUTH AFRICA

3.1 Identification of Secondary REE Sites

A list of sites in South Africa with potential for REE-containing secondary materials has been compiled (Table 2).
<table>
<thead>
<tr>
<th>Source</th>
<th>Name</th>
<th>Geographic location</th>
<th>Occurrence/identification (mine name)</th>
<th>Geological/geographical information</th>
<th>Geological background/type of Deposit/characteristics</th>
<th>Paragenesis</th>
<th>Content of REE*</th>
<th>Characteristics (mineralogy, homogeneity etc.)</th>
<th>Availability (estimated quantity)</th>
<th>Access to the site</th>
<th>Probability of high REE content associated with other known elements</th>
<th>Old mining and milling information</th>
<th>Details of processing routes</th>
<th>Details on industrial production (ongoing operation or operation stopped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>North West Province, South Africa: 26°54'53.53”S 26°23'52.34”E</td>
<td>Dominion Reef Mine</td>
<td>Wastes from gold/uranium mining</td>
<td>Quartzite, quartz pebble conglomerate with gold and pyrite mineralisation</td>
<td>Tailings</td>
<td>Tailings cover 65 Ha</td>
<td>Accessible</td>
<td>Au, U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cyanide + CIP, Possible amalgamation with Hg in early stages of mining, U extraction by acid leach.</td>
<td>Non-operational (to be confirmed)</td>
</tr>
<tr>
<td>2</td>
<td>Mpumalanga, South Africa: 25°34'53.30”S 28°59'3.28”E</td>
<td>Database entry 1044912</td>
<td>Wastes from fluorspar/tin mining</td>
<td>REEs substitute up to 0.5% of the Ca in the fluorite lattice (Crocker, 1974, quoted in Coetzee, 1976)</td>
<td>Small amount</td>
<td>Accessible</td>
<td>Sn, F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sn,F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Limpopo, South Africa: 24°51'12.46”S 27°54'48.52”E</td>
<td>Tooyskraal Fluorspar Mine</td>
<td>Wastes from Fluorspar mining</td>
<td>Rhyolite</td>
<td>Allanite reported (crocker, 1974)</td>
<td>Accessible</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>North West Province, South Africa: 25° 2'16.20”S 27°46'17.47”E</td>
<td>Ruigtepoort Fluorspar Mine</td>
<td>Wastes from Fluorspar mining</td>
<td>Rhyolite</td>
<td>Large residue deposits reported</td>
<td>Accessible</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>North West Province, South Africa: 25° 0'41.34”S 27°41'5.40”E</td>
<td>Slipfontein (Big Ben)</td>
<td>Wastes from Fluorspar mining</td>
<td>Rhyolite</td>
<td>Bastnaesite reported (Crocker, 1974)</td>
<td>Accessible</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td></td>
<td>Currently in production, extracting fluor spar from dolomite hosted deposit,</td>
</tr>
<tr>
<td>6</td>
<td>North West Province, South Africa: 25°42'40.86”S 26° 5'27.15”E</td>
<td>Witkop Fluorspar Mine</td>
<td>Wastes from fluor spar mining</td>
<td>Dolomite</td>
<td>Wastes cover 96 Ha - northern site - as well as a number of deposits 4km to the south east.</td>
<td>Accessible</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F</td>
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</tr>
</tbody>
</table>

**Table 2. Identified secondary REE sites in South Africa**
<table>
<thead>
<tr>
<th>Source</th>
<th>Geographic location</th>
<th>Geographic information</th>
<th>Tailings information</th>
<th>Old mining and milling information</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>North West Province, South Africa: 25°44'27.78&quot;S 26° 2'56.67&quot;E</td>
<td>Database entry 1168218</td>
<td>Wastes from Fluorspar mining</td>
<td>F</td>
</tr>
<tr>
<td>8</td>
<td>Northern Cape, South Africa: 28°42'47.00&quot;S 20°27'41.00&quot;E</td>
<td>Pegmatites around Kakamas</td>
<td>Wastes from pegmatite mining</td>
<td>Large number of small waste piles</td>
</tr>
<tr>
<td>9</td>
<td>Northern Cape, South Africa: 28°45'11.44&quot;S 20°40'37.67&quot;E</td>
<td>Baviaanskrantz</td>
<td>Wastes from pegmatite mining</td>
<td>Waste piles along a 7.5km line</td>
</tr>
<tr>
<td>10</td>
<td>Northern Cape, South Africa: 28°42'34.19&quot;S 19°29'19.78&quot;E</td>
<td>Strykraal</td>
<td>Wastes from pegmatite mining</td>
<td>Scattered waste piles over about 90 Ha</td>
</tr>
<tr>
<td>11</td>
<td>Northern Cape, South Africa: 28°23'26.25&quot;S 20°0'47.94&quot;E</td>
<td>Pegmatites in the Riemvlassaak Conservancy (Murasi and Japie Mines)</td>
<td>Wastes from pegmatite mining</td>
<td>Access limited to 4WD vehicles/foot</td>
</tr>
</tbody>
</table>

**Note:**

<table>
<thead>
<tr>
<th><strong>Characteristics</strong> (mineralogy, homogeneity etc.)</th>
<th><strong>Availability (estimated quantity)</strong></th>
<th><strong>Access to the site</strong></th>
<th><strong>Interest (content) for other elements</strong></th>
<th><strong>Probability of high REE content associated with other known elements</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Paragenesis</td>
<td>Wastes cover 17 Ha</td>
<td>Accessible</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td><strong>Characteristics</strong> (mineralogy, homogeneity etc.)</td>
<td><strong>Availability (estimated quantity)</strong></td>
<td><strong>Access to the site</strong></td>
<td><strong>Interest (content) for other elements</strong></td>
<td><strong>Probability of high REE content associated with other known elements</strong></td>
</tr>
<tr>
<td>Granitic pegmatite</td>
<td>Large number of small waste piles</td>
<td>Accessible</td>
<td>Feldspar, Beryllium, Rare Earths</td>
<td></td>
</tr>
<tr>
<td>Granitic pegmatite</td>
<td>Waste piles along a 7.5km line</td>
<td>Accessible</td>
<td>BERYLLIUM, TANTALUM/NIOBIUM, BISMUTH, RARE EARTHS</td>
<td></td>
</tr>
<tr>
<td>Granitic pegmatite</td>
<td>Scattered waste piles over about 90 Ha</td>
<td>Accessible</td>
<td>BERYLLIUM, BISMUTH, RARE EARTHS, MICA</td>
<td></td>
</tr>
<tr>
<td>Granitic pegmatite</td>
<td>Access limited to 4WD vehicles/foot</td>
<td>Accessible</td>
<td>RARE EARTHS, TANTALUM/NIOBIUM, URANIUM, BERYLLIUM, ROSE QUARTZ (GEMSTONE), FLUORSPAR, FELDSPAR</td>
<td></td>
</tr>
</tbody>
</table>

**Source:**

7. Database entry 1168218
8. Pegmatites around Kakamas
9. Baviaanskrantz
10. Strykraal
11. Pegmatites in the Riemvlassaak Conservancy (Murasi and Japie Mines)
<table>
<thead>
<tr>
<th>Name</th>
<th>Geographic location</th>
<th>Occurrence/identification (mine name)</th>
<th>Geographic background/type of Deposit/characteristics</th>
<th>Paragenesis</th>
<th>Content of REE*</th>
<th>Characteristics (mineralogy, homogeneity etc.)</th>
<th>Availability (estimated quantity)</th>
<th>Access to the site</th>
<th>Interest (content) for other elements**</th>
<th>Probability of high REE content associated with other known elements</th>
<th>Information on exploited deposits and targeted metals</th>
<th>Details of processing routes</th>
<th>Details on industrial production (ongoing operation or operation stopped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 12</td>
<td>Northern Cape, South Africa 29°3'11.00&quot;S 21°46.00&quot;E</td>
<td>van der Kloff Pegmatite</td>
<td>Wastes from pegmatite mining</td>
<td>Granitic pegmatite</td>
<td></td>
<td></td>
<td>Waste piles covering about 1 Ha</td>
<td>Accessible</td>
<td>FELDSPAR, MICA, FLUORSPAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source 13</td>
<td>Northern Cape, South Africa: 28°30'12.68&quot;S 21°144.74&quot;E</td>
<td>McTaggart's Camp</td>
<td>Wastes from pegmatite mining</td>
<td>Granitic pegmatite</td>
<td></td>
<td></td>
<td>Numerous waste piles</td>
<td>Accessible</td>
<td>Fluorspar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2 Sampling and site characterization

3.2.1 North West Province and Limpopo (fluorspar and gold/uranium mining sites)

A field visit to a selection of the fluorspar and a gold/uranium site in the North West Province has been undertaken and samples collected. These site localities are shown on Figure 6.

![Google Earth Image showing Sampling site localities.](image)

### Slipfontein

<table>
<thead>
<tr>
<th>Site features</th>
<th>Material sampled</th>
</tr>
</thead>
</table>
| The site has a large shallow open pit area, surrounded by coarse residue material. The waste rock consists of vesicular brecciated material and vein quartz containing significant amounts of iron oxide (Figure 7). | Two samples collected from the base of the waste rock pile:  
  1. RES-SLIP1 Breccia  
  2. RES-SLIP2 Vein quartz |
**Zeerust area**

<table>
<thead>
<tr>
<th><strong>Site features</strong></th>
<th><strong>Material sampled</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The site includes a large waste rock dump containing a mix of coarse and fine</td>
<td>RES-ZEE1 contains a mix of the fines and the different coarse materials present on</td>
</tr>
<tr>
<td>material. The coarse material comprises a mix of banded ironstone and mineralised</td>
<td>the site.</td>
</tr>
<tr>
<td>dolomite, with vein fill material composed of fluorspar, rhodochrosite, calcite</td>
<td></td>
</tr>
<tr>
<td>and a needle-like crystalline mineral (Figure 8, 9).</td>
<td></td>
</tr>
</tbody>
</table>
Figure 8: Fluorspar mineralisation in dolomite from the Zeerust Area, North West Province, showing preferential replacement in stromatolite structures.

Figure 9: Typical large fluorspar mine residue deposit from the Zeerust area, North West Province.
Witkop Fluorspar Mine

<table>
<thead>
<tr>
<th>Site features</th>
<th>Material sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>This is a large operational fluorspar mine, with a processing plant (Figure 10).</td>
<td>Three Samples were collected: 1. RES-WIT1 Older mine tailings 2. RES-WIT2 Current mine tailings 3. RES-WIT3 Fluorspar product, for comparison with tailings.</td>
</tr>
</tbody>
</table>

Figure 10: Sampling mine residue at the operational Witkop Fluorspar Mine: North West Province

Dominion Reef Gold/Uranium Mine

<table>
<thead>
<tr>
<th>Site features</th>
<th>Material sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>This is a large – 1.3MT tailings facility on a mine which is in the process of being reopened by Shiva Uranium. There is a plan to reprocess these tailings for their gold and possibly uranium content in future. Samples were collected using a hand auger, attempting to sample deeper (&gt;1m) less oxidised material (Figure 11).</td>
<td>Two samples were collected: 1. RES-SHIVA1 Collected off the top of the tailings pile. 2. RES-SHIVA2 Collected by augering into a face exposed by past tailings reclamation on the side of the tailings pile.</td>
</tr>
</tbody>
</table>
3.2.2  Northern Cape Province – Pegmatite mining sites

A field trip was undertaken to a pegmatite province in the Northern Cape Province with the objective of sampling a representative group of abandoned mines with potentially REE-Containing wastes. The major minerals mined in this area were feldspar, micas and rose quartz, with minor, but, in some cases economically important, production of rare earths, tantalum, niobium, uranium and fluorspar. The locations of the sites are shown on figure 12 and 13.
Four sampling sites were identified and sampled:

1. Baviaanskranzt Pegmatite near Kakamas;
2. Murasie Pegmatite in the Riemvasmaak Conservancy area;
3. Pegmatites near Kuboos, close to the Gariep River between Kakamas and Pofadder; and
4. The two Sidi Barani Mines south of Kenhardt
These were selected as they were relatively large mines, with some residues and could represent the diversity of lithologies in the Kakamas area.

**Baviaanskrantz**

The Baviaanskrantz mine consists of a number of deep excavations into the pegmatite body, with waste piles comprised of a quartz, feldspar, muscovite float on larger waste rock boulders. Some epidote was observed on the feldspars. A sample of waste rock (RES-BK1) was collected close to the old mine workings (Figure 14).

**Murasie Pegmatite**

The Murasie Pegmatite is located in the Riemvasmaak Conservancy. Pegmatite was mined from an outcrop on a hilltop, with other similar mines located in the vicinity (Figure 15). A number of different waste types were identified on the site and 4 samples collected:

- RES-MUR1: Coarse material at the surface of the residue deposit.
- RES-MUR2: Dark coloured fine waste material.
- RES-MUR3: Light coloured fine waste material.
- RES-MUR4: Brown-coloured fine waste material.
Kuboos area

In the Kuboos area a large number of residues from small abandoned pegmatite operations were identified (Figure 16 and 17).

Figure 15: The Murasie Pegmatite Mine.

Figure 16: Small mining operations covering a large area - Kuboos.
Samples were collected to represent the different lithologies as follows:

- RES-KUB1: Coarse waste material.
- RES-KUB2: Fine waste material.
- RES-KUB3: Purple-coloured material from localised diggings.
- RES-KUB4: Material with substantial iron staining.
- RES-KUB5: Sample collected at a pegmatite in the southern part of the pegmatite field.

**Figure 17:** Granitic bodies in the Kuboos area. Small mining operations can be seen at the base of the hill in the foreground.

**Sidi Barani**

The Sidi Barani Pegmatite was selected as it is in a different area and geological setting from the others sampled. Two open pits were identified (Figure 18). The materials mined were characterised by large feldspar and rose quartz crystals with some interstitial mica. A shear zone with extensive mica development was also noted on the site (19).

Two mines, known as Sidi Barani 1 and Sidi Barani 2 were visited and sampled. The material mined and the waste materials appear similar at both sites.
Figure 18: Sidi Barani #1 open pit.

Figure 19: Mica-filled shear zone at Sidi Barani #1
The following samples were collected:

- RES-SID1: Fine material collected inside the #1 Pit, including a green-coloured precipitate.
- RES-SID2: Fine material collected from the waste pile at the #1 Pit.
- RES-SID3: Waste collected from the waste pile at the #2 Pit.

3.3 Sample handling and analysis

Coarse samples have been dried, crushed to approximately 8mm size, homogenised and a 5kg split prepared for analysis. The fine tailings samples – Witkop Fluorspar and Dominion Reef Au/U – have been dried and a 5kg split prepared.

A notable feature of all of the sites sampled has been the variable particle size and extreme heterogeneity of the waste materials. This is typical of mines where vein-type deposits have been mined. A similar characteristic has been noted by EDM at the Portuguese field sites.

The large number of samples renders it impractical to send large samples to Portugal for analysis, while the heterogeneity of the samples needs to be addressed. The samples collected will therefore be screened for REEs using a handheld XRF instrument (to assess heterogeneity) and by ICP-MS and possibly laboratory XRF analysis early in 2016. It is also envisaged that additional potential REE sites will be visited and sampled during 2016.
4 SWEDEN

4.1 Identification of Secondary REE Sites

Two sites with REE in tailings from mining operations belonging to Boliden Mineral AB are known.

- Aitik copper mine
- New Kankberg gold mine

The Aitik ore is an open pit low grade porphyry copper mine operated since 1968 and currently run at an annual capacity more than 36 Mton. The capacity is planned to be increased to 45 Mton per year and the current life length is calculated to 2045. Boliden Aitik is situated outside the town of Gällivare in the very north of Sweden (see Figure 20).

The New Kankberg ore is currently mined at an annual capacity of around 400 kton with underground mining. The mining started 2012 and the gold grade is around 4 g/t with some additional value in tellurium. Around 31 kton tellurium was produced in 2014. The current expected life length is to 2023. Kankberg is located in the Boliden Area (see Figure 20).

Figure 20: Location of Aitik copper mine (upper point) and New Kankberg gold mine (lower point)

General information about New Kankberg is given in the table below.
<table>
<thead>
<tr>
<th>Geographic/geographical information</th>
<th>Tailings information</th>
<th>Old mining and milling information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geographic location</strong></td>
<td>Content of REE*</td>
<td>Information on exploited deposits and targeted metals**</td>
</tr>
<tr>
<td><strong>Occurrence/identification (mine name)</strong></td>
<td>Availability (estimated quantity)</td>
<td>Details of processing routes</td>
</tr>
<tr>
<td><strong>Geological background/type of Deposit/characteristics</strong></td>
<td>Access to the site</td>
<td>Details on industrial production (ongoing operation or operation stopped)</td>
</tr>
<tr>
<td><strong>Paragenesis</strong></td>
<td>Interest (content) for other elements**</td>
<td></td>
</tr>
<tr>
<td><strong>Northern Sweden</strong></td>
<td><strong>New Kankberg</strong></td>
<td><strong>Au, Te (Bi) is recovered. Some Nb is in the tailing (20 ppm)</strong></td>
</tr>
<tr>
<td><strong>Mineralization located in andalusite formation</strong></td>
<td><strong>REO content around 640 ppm in tailings. Around 80% LREO and 20% HREO</strong></td>
<td><strong>Au, Ag, Te</strong></td>
</tr>
<tr>
<td><strong>Small amount of sulphides, gold and tellurium minerals monazite</strong></td>
<td><strong>Around 500 kton tailings per year</strong></td>
<td><strong>Gravity, flotation, cyanide leaching, tel</strong></td>
</tr>
<tr>
<td><strong>Au, Te</strong></td>
<td><strong>Accessible</strong></td>
<td><strong>500 kton per year mined</strong></td>
</tr>
</tbody>
</table>

*Table 3: Identified secondary REE source from Sweden*
4.2 Sampling and site characterization

4.2.1 The Aitik mine

The ore is transported by trucks to in-pit crushers and from there to the mill with conveyor belts. The grinding is done in two lines with fully autogenous grinding in two steps. The flotation is carried out in two parallel lines with totally 13 cells of 160 m³ in each line. The four last cells are normally run for desulphurisation but the first two of these can be run as extra scavenger. The concentrates from the roughers are cleaned in four steps after some regrinding and the first cleaner tail is combined with the desulphurisation concentrate to a “high sulphur product” that is planned to be deposit separately from the bulk tailing in the future. Details of the flowsheet are given in figure 21.

Figure 21: Flow sheet of Aitik mine operation.

Originally was it believed that the REE was associated to the apatite (0.7 – 1%) in the tailing. Flotation tests revealed that only about half of the REE content can be found in apatite and the rest in other minerals and monazite is one of them.

A picture from Google Earth is shown below (figure 22). The open pit is about 5 km long and 1 km wide. The tailing pond area is around 5 km wide and 10 km long.

Roughly 700 Mton has so far been stored in the tailing pond and around 1300 Mton more is currently planned to be stored until year 2045.
4.2.2 The New Kankberg mine

The New Kankberg mine is mined underground and transported, around 10 km, by truck to the Boliden concentrator. The ore is crushed to below around 250 mm before grinding in two stages. Gold is floated along with tellurium and the gold is recovered by hot cyanide leaching from the flotation concentrate. The cyanide leaching residue is going to the tellurium plant where tellurium is recovered. The residue from the tellurium plant is going back to cold cyanide leaching together with the flotation tailing. The tailing is going with tailings from the other ores (four complex sulphide ores) to the tailing pond.

Flotation tests have been carried out on the flotation tailing from New Kankberg to find out if the REE can be recovered. The results indicate that most of the REE is in monazite. The sample investigated contained 2916 ppm REO. The distribution was around 19 % HREE and 81 % LREE.

Sample from the flotation tailing has been delivered to the ENVIREE project.

A view of how the ore looks like with access ramp is shown in the figure 23.
Underground view of the mine.

Figure 23: New Kankberg mine
5 POLAND

5.1 Identification of Secondary REE Sites

In Poland four sites of mining tailing, which could possibly contain REE have been identified:

- Source 1 - KGHM Polska Miedz - Zelazny Most
- Source 2 - ZGH Boleslaw - Boleslaw
- Source 3 –KiZPS Siarkopol - Tarnobrzeg
- Source 4 - Kopalnia Staszic w Rudkach – Rudki

For the identified sources the following information has been gathered: geographic location, geological background, paragenesis, content of REE, estimated quantity of tailings, access to the site, content of other elements, exploited deposits and targeted metals, details of processing routes, details on industrial production (ongoing operation or operation stopped)

The data on the identified sources has been shown in table 4 and sent to ENVIREE partners for discussion.
<table>
<thead>
<tr>
<th>Name</th>
<th>Geographic location</th>
<th>Geographical/geographical information</th>
<th>Tailings information</th>
<th>Old mining and milling information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 1</td>
<td>SW Poland 51°30' 54,86&quot; N 16°12'18,61&quot; E</td>
<td>KGHM Polska Miedź Wastes from copper ore enrichment</td>
<td>Tailings: 29 mln Mg per year</td>
<td>Cu, Ag, Au, Pb, Zn, Fe, Mn, Ti, As, Co, Ni, V, Mo, Cd, Pt</td>
</tr>
<tr>
<td>Source 2</td>
<td>S Poland 50°16'52,99 N 19°29'56,19&quot; E</td>
<td>ZGH Bolesław Wastes from enrichment of zinc and lead ores</td>
<td>Tailings: 2.6 mln Mg per year</td>
<td>Zn, Pb, Fe, Cd, Cu, As, Sh, Ni, Ge, Mn, Ag, Ba, Cr, Mo</td>
</tr>
<tr>
<td>Source 3</td>
<td>SC Poland 50°31'36,13&quot;N 21°42'20,63&quot; E</td>
<td>KIZPS Siarkopol Wastes from sulfur ore enrichment</td>
<td>Tailings: 33 mln Mg</td>
<td>S, Sr, Na, Mg, K, Fe, Mn, Co, Ni, Zn, Cd, Pb</td>
</tr>
<tr>
<td>Source 4</td>
<td>SC Poland 50°89'14,49&quot;N 21°09'29,00&quot; E</td>
<td>Kopalnia Staszic w Rudkach Wastes from pyrite uranium mine tailings of low grade ore and post flotation tailings from ore processing</td>
<td>Tailings: 1.5 - 2 mln Mg</td>
<td>Fe, S, U, Ba, Mn, Pb, Ti, Zn, Th, Sc, Y, Ni, V</td>
</tr>
</tbody>
</table>

**Notes:**
- **REE:** Rare Earth Elements.
- **INAA:** Inductively Coupled Plasma Mass Spectrometry.
- **Tailings:** Solid residues from processing.
- **Access to the site:** Indicates whether the site is accessible for mining and milling operations.
- **Interest (content) for other elements:** Indicates the potential for other elements in the tailings.
- **Details on industrial production:** Indicates the state of production (ongoing or stopped).
- **Closed in 1972:** Indicates the closure date of the site.
After the analysis and discussion of the data from the possible sites, by all ENVIREE partners, 2 sites were selected to be sampled in Poland:

- Source 1 - KGHM Polska Miedz - Zelazny Most
- Source 4 - Kopalnia Staszic w Rudkach - Rudki

Location of these two sites is shown in figure 24.

5.2 Sampling and site characterization

5.2.1 KGHM Polska Miedz - Zelazny Most

The mining company, owned by KGHM Polska Miedz, exploits one of the world’s biggest copper ore deposits in mines “Rudna,” “Lubin,” and “Polkowice–Sieroszowice”. The considered mining area is located in the southern part of Poland in the Lower Silesia region, covering an area of about 468 km2.

Due to the scale of mining operations performed there and the location of copper smelters and refineries, the region is often called the Legnica–Glogow copper district (LGCD).

The copper ore deposit operated by KGMH in Poland dips monoclona at the depth form a few hundred meters to 1500 meters in depth. Copper minerals are hosted by three main lithological Zechstien rock types: sandstone, shale and dolomite. Four base copper sulphides are most common in the ore: chalcocite, bornite, chalcopyrite and covellite. The KGHM deposit is considered as a
stratabound deposit occurring in sedimentary rocks with varied thickness up to over a dozen meters. In the ore sequence many faults are occurred with displacements up to several dozen meters. The Geological profile of copper ore deposit in Fore-Sudetic Monocline was shown in figure 25.

![Geological profile of copper ore deposit in Fore-Sudetic Monocline](image)

Figure 25: Geological profile of copper ore deposit in Fore-Sudetic Monocline (PL)


Due to an average 1.7% content of copper in the exploited Polish deposits, enrichment process is necessary. During the process, copper minerals are separated from worthless material by inducing them to gather in and on the surface of a froth layer. The process entails crushing and grinding the ore to a fine size, subjected to flotation with the addition of flotation agents in flotation cells, after which the concentrate is thickened, filtrated and dried. As a result, the concentrate contains the amount of copper that can be processed further in a smelter.

Wastes formed during the floatation enrichment of copper ores are currently deposited in the Żelazny Most reservoir. The Żelazny Most tailings pond is the largest mineral waste repository in Europe and one of the largest in the world, covers an area of 13.94 km². Żelazny Most reservoir was built in 1974 to collect flotation tailings from three local copper-ore enrichment facilities, for the storage of groundwater from the Lubin-Glogow mines, and to be used to facilitate flotation of sulfides during ore processing and transport of the gangue. The total volumes of wastes and water present in Żelazny Most are estimated to be 476 mln m³ and 7.5 mln m³, respectively. The annual deposition of flotation tailings varies from 20 to 26 million tons.

Żelazny Most tailings pond is shown in pictures 26-29.
During the period 3rd June 2015 to 6th June 2015, the team of AGH took 10 subsamples from, Zelazny Most tailings pond. The location of taking subsamples is shown in figure 30.
The subsamples were delivered to AGH laboratory, air dried at 40°C and made averaged. The prepared sample of 5 kg was sent to IST-ID on 22/06/2015.

5.2.2 **Kopalnia Staszic w Rudkach - Rudki**

The Rudki area is one of the most interesting historical metal ore mining sites in Europe. Originally, hematite (c-Fe2O3) of Rudki found useful applications in the Neolithic for body, weaponry, pottery and product colouring as a mineral dye. During the Roman period, but especially from the 1st through 4th century, the hematite ore was mined for smelting of pig iron in numerous primitive furnaces. This mineral deposit was re-discovered in 1922 by a geologist Jan Samsonowicz, and extraction of iron ores, i.e. hematite and deeper occurring siderite (FeCO3), was resumed in the twenties of the 20th century. During 1933–1969, pyrite and marcasite (FeS2) were mined from a depth of at least 450 m for production of sulfuric acid. In 1952 uranium mineralization was found and pitchblende (partly altered uraninite UO2) ore was mined until 1968.

Physiographically, the study area lies in the northern part of the Debno Valley that separates the Łysogory range in the south and the western part of the Pokrzywianski range in the north. The bedrock of the Debno Valley is built of Ordovician and Silurian clayey shales, siltstones and graywackes. In contrast, the towering Łysogory range consists primarily of middle/upper Cambrian quartzites and quartzitic siltstones and sandstones with clayey shale interbeds whereas the Pokrzywianski range is...
composed of lower and middle Devonian quartzitic sandstones and siltstones, and dolomites, with subordinate limestone, clayey shale and tuff interbeds. This is shown in figure 31. No sedimentary sulfate minerals (gypsum, anhydrite) occur in these rock formations.

Figure 31: Geologic map of the Rudki area with a simplified cross-section


In general, bedrock lithology is in conformity with geomorphology, which means that hard rocks (quartzites and dolomites) build heights whereas soft rocks (clayey shales) form depressions. In places, these two ranges are laterally faulted. The most distinctive is the deep-rooted Łysogory fault that extends nearly north-south through the small town of Rudki. This fault hosts a pyrite-hematite-siderite-uranium mineral deposit. Most of the study area is blanketed by glacial tills, fluvioglacial gravels, sands and silts, in places by loesses that form ravines reaching a few meters deep.

During nearly 50 years of operation of the mine "Staszic" pyrite ore exploitation ranged from several to several tens of thousands tons. In total, in the years 1925-1973 were excavated 4 million tons of pyrite ore, 1.5 million tons of hard rock ore and 0.8 million tonnes of hematite ore.

Pyritic rocks, which exploitation was started in the sixties of XX century, was initially used for the production of sulphuric acid and later as a flux in copper smelters "Legnica" and "Głogów". In the years 1965-1969 the exploitation reached the level of approx. 140-170 thousand tons, and hematite hundred tonnes. Raw rocking ore was processing in the plant, built in the sixties and the ore after crushing and grinding was subjected to flotation. From the feed to the process containing not less than 17% S was obtained pyritic concentrate containing approx. 40% S.

Pyrite ore was sent to recipients in the rough (sometimes using a manual sorting). In the fifties in the "Staszic" mine, uranium ore (pitchblende) was also exploited in small quantities co-occurring among
the earthy varieties of pyrite and marcasite. This with no enrichment was sent to the former Soviet Union.

Post-processing waste (post-flotation tailings) heaps in Rudki are located in the immediate vicinity of the buildings of the former mine and processing plant. The area of the tailings heaps, in the most parts after the reclamation, is approximately 23.5 hectares.

The tailings material was also used for the reclamation to fill the pits after the open-pit exploitation of the upper parts of the deposit.

In 12 May 2015 the team of AGH took 6 subsamples from the reclaimed tailings ponds in Rudki. The location of sampling in Rudki is shown in figure 32, exact sub-samples location in figure 33. During the reclamation process in seventies of XX century, the 40-60 cm layer of soil from a nearby heal was put over the tailings. In some other places of old tailings ponds the covering layers consist of stones. Therefore the sampling was possible on the area covered by soils but not by stones.

The pictures of sampling process are shown in figures 34-37.

Figure 32: The location of sampling in Rudki
The subsamples were delivered to AGH laboratory, air dried at 40°C and made averaged. The prepared sample of 5 kg was sent to IST-ID on 21/05/2015.
6 PORTUGAL

6.1 Identification of Secondary REE Sites

The main task of EDM in this project was the selection of tailings from old mines with favourable conditions to contain REE.

To this mission were considered all the records of Portuguese old mines and in particular the 180 abandoned old mines of which EDM is responsible for the environmental rehabilitation, and through these data was made a pre-selection of sites whose deposits show favourable mineralogical paragenesis to the occurrence of REE. This selection comprised several types of deposits: aplite-pegmatites, massive sulphides, radioactive and alkaline complexes. In this first phase it were identified 86 sites that occur mainly in the norther-central Portugal and have the potential to containing REE (figure 38).

Figure 38: Distribution of the 86 old mine sites with favourable conditions to contain REE

After this initial evaluation, the sites were ordered according to the mine size (volume of exploited material), which will give an idea of the volume of tailings, and grades of the mineralization or geochemical analyses of the tailings material. This screening resulted in the selection of 12 sites that were subsequently ordered by potentiality. This ranking was shared with the ENVIREE partners for further discussion in order to select the sites to be sampled in Portugal, and included in the list of project sites to be initially screened for REE.
Table 5: Ranking of the 12 proposed Portuguese sites

<table>
<thead>
<tr>
<th>Name</th>
<th>Geographical location</th>
<th>Occurrence/identification (mine name)</th>
<th>Geological background/ type of Deposit/ characteristics</th>
<th>Paragenesis</th>
<th>Tailings information</th>
<th>Characteristic (mineralogy, homogeneity etc.)</th>
<th>Availability (estimated quantity)</th>
<th>Access to the site</th>
<th>Interest (content) for other elements</th>
<th>Probability of high REE content associated with other known elements</th>
<th>Old mining and milling information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 1</td>
<td>NE Portugal</td>
<td>Covas</td>
<td>Tungsten mineralization associated with skarn, massive sulphides and iron oxides; occurs in metassedimentary and metaquartzitic formations (Silurian)</td>
<td>Scheelite, ferberite, albite, apatite, quartz, pyrite, pyrrhotite and arsenopyrite</td>
<td>ΣREE&lt;sup&gt;(1)&lt;/sup&gt;: 28.5-194ppb (in AMD from tailings); ΣREE&lt;sup&gt;(1)&lt;/sup&gt;: 65.7-748.4ppm (philitic and quartzophilitic lithologies near and equivalent to Covas deposit)</td>
<td>Tailings E2 to E4 to 226 000 m&lt;sup&gt;3&lt;/sup&gt;; Tailing E5 84 000 m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Accessible</td>
<td>W</td>
<td></td>
<td></td>
<td>Information on exploited deposits and targeted metals</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 metassediments</td>
<td>Cassiterite, wolframite, gold</td>
<td>Potential indicated by academic preliminary studies</td>
<td>To be defined after visiting the site</td>
<td>Accessible</td>
<td>Sn, W, Au</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source 3</td>
<td>NE Portugal</td>
<td>Cabração</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source 4</td>
<td>N Portugal</td>
<td>Beça</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source 5</td>
<td>Central Portugal</td>
<td>Ribá Gaia</td>
<td>Alluvial type deposit from pegmatitic veins with cassiterite, COLTAN; hosted in granites</td>
<td>Cassiterite, Ilmenite, COLTAN</td>
<td>Potential indicated by academic preliminary studies</td>
<td>To be defined after visiting the site</td>
<td>Accessible</td>
<td>Sn, COLTAN (Nb, Ta)</td>
<td></td>
<td></td>
<td>Information on exploited deposits and targeted metals</td>
</tr>
</tbody>
</table>

Legend:
- ΣREE<sup>(1)</sup>: Sum of rare earth elements detected
- W: Tungsten
- Sn, W, Au: Sn and other target elements
- Sn, Nb, Ta: Sn and other target elements
- Information on exploited deposits and targeted metals
- Details of processing routes
- Details on industrial production (ongoing operation or operation stopped)
<table>
<thead>
<tr>
<th>Name</th>
<th>Geographical location</th>
<th>Occurrence/identification (mine name)</th>
<th>Geological background/ type of Deposit/characteristics</th>
<th>Paragenesis</th>
<th>Content of REE</th>
<th>Characteristics (mineralogy, homogeneity etc.)</th>
<th>Availability (estimated quantity)</th>
<th>Access to the site</th>
<th>Interest (content) for other elements</th>
<th>Probability of high REE content associated with other known elements</th>
<th>Information on exploited deposits and targeted metals</th>
<th>Details of processing routes</th>
<th>Details of industrial production (ongoing operation or operation stopped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 6</td>
<td>NE Portugal</td>
<td>Cumieira</td>
<td>Alluvial type deposit from quartz veins and pegmatitic apophysis</td>
<td>Cassiterite, COLTAN arsenopyrite, pyrite</td>
<td>Stratiform tourmalinite: ( \text{REE}^{[1]} : 394.2 \text{ppm} ); Potential indicated by academic preliminary studies</td>
<td>To be defined after visiting the site</td>
<td>Accessible</td>
<td>Sn, COLTAN (Nb, Ta)</td>
<td>Sn, Nb, Ta (placer)</td>
<td>hydrogravity, washing</td>
<td>stopped</td>
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<td>Source 7</td>
<td>N Portugal</td>
<td>Vieiros</td>
<td>Pegmatitic system in schists and phyllitic formations</td>
<td>Cassiterite, arsenopyrite, pyrite, tantalite</td>
<td>Potential indicated by academic preliminary studies</td>
<td>Small tailings (&lt;10,000 m³) of shale and quartz</td>
<td>Accessible</td>
<td>Sn, Ta</td>
<td>Sn, Ta (quartz veins)</td>
<td>stopped</td>
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<tr>
<td>Source 8</td>
<td>S Portugal</td>
<td>S. Domingos</td>
<td>Massive sulphides; exploited for Cu, Zn and S</td>
<td>Pyrite, sphalerite, chalcopyrite, galena, arsenopyrite &amp; sulfosalt</td>
<td>High-tech metals identified. ( \text{REE}^{[2]} : 69.08 - 229.85 \text{ppm} ) (soils). ( \text{REE} ) only La, Ce, Nd, Sm, Eu, Yb, Lu, Sc.</td>
<td>Tailings, mine wastes, slags and rubbles (&gt;100,000 m³)</td>
<td>Accessible</td>
<td>Au, Re, Sb, Se, Bi, As, Mo, Ge, Zn, Cu, Pb</td>
<td>Cu, Zn, S (massive sulphides)</td>
<td>leaching, roasting, Cu cementation</td>
<td>stopped</td>
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<tr>
<td>Name</td>
<td>Geographical information</td>
<td>Tailings information</td>
<td>Old mining and milling information</td>
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<td>Source 9</td>
<td>Central Portugal Qta Bispo (rad)</td>
<td>Located in the contact of a granite with an enclave of metasediments. These enclaves show contact metamorphism and consist of clay-micaceous schists, brown in color. Can be ferruginous and altered. Autunite, torbernite and black minerals of uranium</td>
<td>Tailings (1 500 000 ton; max height 37m)</td>
<td>Accessible</td>
<td>U, Ra</td>
<td>U, Ra (veins)</td>
<td>in situ leaching</td>
<td>stopped</td>
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<tr>
<td>Source 10</td>
<td>Center Portugal Ervideira (rad)</td>
<td>Smoked quartz in veins, with “basic rock” hosted by altered granite</td>
<td>Tailings from pit and trench (500 ton, 1.5 m height)</td>
<td>Accessible</td>
<td>U, Ra</td>
<td>U, Ra (veins)</td>
<td>The ore was not processed in the mine site</td>
<td>stopped</td>
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<td>Source 11</td>
<td>Center Portugal Mestras (rad)</td>
<td>Porphyritic coarse, with two mica granite, cut by fractures with smoked and amethyst quartz and chalcedony. Mineralization consists of secondary uranium minerals, predominantly of disseminated metatorbernite in the lode and in the altered granite</td>
<td>Tailings (5000 ton, 3m height)</td>
<td>Accessible</td>
<td>U, Ra</td>
<td>U, Ra (veins)</td>
<td>The ore was not processed in the mine site</td>
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<td>Name</td>
<td>Geographical information</td>
<td>Tailings information</td>
<td>Old mining and milling information</td>
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<td>Source 12</td>
<td>S Portugal, Monchique</td>
<td>Nepheline Syenite massif of Cretaceous age, hosted by shales of Paleozoic age</td>
<td>Nepheline Syenite Quarry in operation</td>
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<td>Paragenesis: Feldspar, nepheline, pyroxen (aegirina and augite). Accessory minerals: Apatite, sphene, fluorite, pyrochlore, rutile, zircon, turmaline, wholerite</td>
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<td>Characteristics (mineralogy, homogeneity etc.): To be defined after visiting the site</td>
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<td>Information on exploited deposits and targeted metals:</td>
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1. Dias (2011) – Análise estrutural e paragenética de produtos litológicos e mineralizações de segregação metamórfica: Estudo de veias hiperaluminosos e protólitos poligênicos Silúricos da região da Serra de Arga (Minho); PhD Thesis; Universidade do Minho, Braga
4. EDM (2007) – Mina da Ervideira: Relatório Final; EDM internal report
5. EDM (2007) – Mina de Mestras: Relatório Final; EDM internal report
After the analysis and discussion of the data from the possible sites, by all ENVIREE partners, 3 sites were selected to be sampled in Portugal:

- **High priority:**
  - Covas;
  - Cumieira;
- **Low priority:**
  - Ervideira-Mestras.

After the site selection was completed the sampling campaign started to be planned (Task 1.2).

### 6.2 Sampling and site characterization

During the month of May, a team formed by three members of EDM staff and two members of IST-ID staff completed the field work for sampling and characterizing the tailings of the selected areas.

For Portugal were defined the tailings of Covas, Cumieira and Ervideira-Mestras old mines. The sampling campaign included two additional sites given their close proximity to the sites defined in the project, and therefore did not brought additional costs, and also because they have high potential to contain REE. These sites are Cabração and Verdes.

All these sites are nowadays abandoned mines and located on northwest of Portugal with exception of Ervideira-Mestras that is located on the centre of Portugal (Figure 39).

For each of these sites the Site and Sampling Characterization Report (in Annexe III) was completed.

![Figure 39: Location of the two areas: A – Covas, Cumieira, Verdes and Cabração; B – Ervideira-Mestras](image)

All the sampled areas are characterized individually below.
6.2.1 Covas

The Covas tailings represents 30 years (1954-1984) of mining focused in tungsten mineralization (mainly scheelite and minor wolframite) exploited by underground mining works.

This deposit consists of several lenticular skarn levels (each 1-3 metres thick) hosted by schists and occur near a two mica granite of medium grain (figure 40). The skarn levels are constituted essentially by zones of massif sulphides (pyrrhotite, pyrite, arsenopyrite and chalcopyrite) with associated wolframite, scheelite and ferberite pseudomorphs after scheelite. The mineralization also comprises apatite, muscovite, chlorite and quartz.

![Figure 40: Geological sitting of Covas area (C. Teixeira, 1962)](image)

The ore processing was by electromagnetic, hydrogravitic, roasting and flotation methods.

These tailings and the mining area were rehabilitated by EDM. The works included slope stabilization, modelling and limiting the tailings areas, reducing the pluvial infiltration, maintenance of natural processes of chemical neutralization.

After an initial recognition of the Covas tailings, 3 zones were defined and 13 sub-samples were collected (figure 41):

- Zone A – fine grained material - 4 samples;
- Zone B – main zone with material from de processing plant - 8 samples;
- Zone C – material from drainage of tailings - 1 samples;
The macroscopic inspection suggests that the samples of zone C and zone B are interesting, namely samples COV B3 and COV B4. These samples were collected on the same location but the samples look very different. COV B4 is laminated showing millimetric layers with different colours and grain size, whereas COV B3 was more homogeneous in terms of colour. Additionally, samples COV B5 and COV A1 and COV A2 from zone A are also considered to be of interest.

### 6.2.2 Cumieira

Cumieira consisted of an alluvial deposit located on a plateau that has formed by weathering and accumulation of the surrounding rocks. The deposit varies in thickness from few centimetres up to 3 meters and comprises clasts of schists, quartz, granite and aplite-pegmatite. This area was initially exploited for Sn (cassiterite) and later for Nb-Ta (COLTAN) and was active between 1927-1966. The cassiterite occurred in rounded or angular grains concentrated in layers of the elluvial deposit supported by a clay matrix. The ore processing was essentially made by hydrogravitic processes and, more rarely, by electrostatic separation in industrial facilities away of the mining area.
The deposit overlays Silurian units formed by polygenic psamo-pelitic formations with quartzite, black schists with phosphate nodules, lidites and exotic psamitic lithologies (figure 42).

Figure 42: Geological setting of Cumieira area (C. Teixeira, 1962)

Two areas with tailing were identified. One area consists of fine material (sand size) and is located next to the old washing plant (tailing D). The other area is bigger than the previous one and comprises several piles of mostly coarse material (tailings A, B and C). Five sub-samples were collected (figure 43):

- CUM A1: fine grey material, probably results from water drainage;
- CUM B1: coarse material from a pile of tailings;
- CUM C1: coarse material from a pile of tailings;
- CUM D1: fine yellowish material collected at the base of the washing plant;
- CUM D2: fine yellowish material collected at the base of the washing plant.
Macroscopic inspection of the tailings material suggests that CUM D2 and CUM D1 samples are appropriate for the project. Additionally, the homogeneity of the tailings and the volume also suggest the tailing body “D” could be further processed in the project.

6.2.3 Ervideira-Mestras

Ervideira-Mestras were exploited for U (metatorbernite) between 1919-1962 in open pit and underground works, and the ore processing method was physical. The mineralization occurs in polyphasic veins with smoked and milky quartz, and amethyst. The veins trend N-S, NNW-NE, are sub-vertical and 1-1.5 meters in thickness. They are hosted in basic rocks and in two mica coarse granite (figure 44).
Given the paragenesis of this mineralization a full chemical characterization is needed in order to evaluate its potential for REE and radioactive elements.

### 6.2.4 Cabração

This area was not included in the sampling plan defined by ENVIREEE but due to the proximity to the sampling sites and its potential in REE it was decided to visit and sample the site.

At Cabração, pegmatite veins were sourced from proximal granitic batholits and were exploited for Sn (cassiterite) and Nb-Ta (COLTAN), between 1943-1992. The ore processing method is unknown. The aplite-pegmatite intrudes rocks of Silurian age that consist of polygenic psam-o-pelitic formations with quartzite, black schists with phosphate nodules, lidites and exotic psamitic lithologies (Figure 45). The tailings were later exploited for industrial minerals and are reduced to a small volume (Figure 46) of fine grained material with light colour. Therefore, only one sample was collected in this site (CAB A1).
The reduced volume of tailings indicate that this site is not the most appropriate for the project.

6.2.5 Verdes

Like Cabração this area was not initially defined in the sampling plan. Verdes were exploited between 1947-1975 for Sn (cassiterite) and W (wolframite) in underground mining works. The cassiterite occurs disseminated in aplite-pegmatite veins and the wolframite is hosted in veins that intrude the aplite-pegmatite. The ore processing was by electromagnetic and hydrogravitic, methods.
The veins are hosted by Silurian units formed by polygenic psamo-pelitic formations with quartzite, black schists with phosphate nodules, lidites and exotic psamitic lithologies (figure 47).

The Verdes tailings are fine grained and characterized by light colour (figure 48). One sample was collected (VERDES A1) in the single tailing body identified.

Figure 47: Geological setting of Verdes area (C. Teixeira, 1970)
The visual inspection of the tailings material suggests the existence of monazite, which is a mineral that typically contains REE in its crystalline structure. Additionally, the size of the tailings indicates that this site is appropriate for ENVIREE and can eventually be considered for the next phase of the project.
7.1 Annex I – Table of Criteria for Site Selection
<table>
<thead>
<tr>
<th>Name</th>
<th><strong>Geological/geographical information</strong></th>
<th><strong>Tailings information</strong></th>
<th><strong>Old mining and milling information</strong></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Geographic location</td>
<td>Occurrence/identification (mine name)</td>
<td>Geological background/type of Deposit/characteristics</td>
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</table>
7.2 Annex II – Site and Sampling Characterization Report Template
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 metallogenetic province:
________________________________________________________________________
________________________________________________________________________

Mineralization type:
________________________________________________________________________
________________________________________________________________________

Host and outcropping rocks:
________________________________________________________________________
________________________________________________________________________

Exploitation period:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Type(s) of ore processing:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Evidence for neoformation/weathering:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Mine drainage:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Sampling team:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
**Tailings:**

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**Homogeneity (grain size, composition, etc):**

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<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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### Tailings/waste sampling:

**Used equipment:**

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**No. samples collected:**

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**Samples id:**

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<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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Sampling grids and photos (scheme):

Observations:

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7.3 Annex III – Site and Sampling Characterization Reports for the Portuguese Sites
**Site and Sampling characterization report**

**Date:** 14 / 05 / 2015

**Time:** 10:23 am

**Weather conditions:**
Cloudy and foggy

**Mining site:**

**Name:** Covas

**Location:** Vilares, Caminha, Viana do Castelo

**Type of ore (grade and tonnage):**

Skarn exploited for tungsten ( wolframite and scheelite)

**Regional geology and metallogenetic province:**

The mining site is located in the tectono-stratigraphic Galiza and Trás-os Montes Zone in the Parautochthonous unit, called Central Minho Unit from Silurian age. The mine occurs in an antiform of pelitic schists and impure marble. This sequence is intruded by the Covas granite (+/- 320-310 Ma) and the Arga granite (+/- 305 Ma). Both granites are sin-tectonic to deformation phase D3.

**Mineralization type:**

Skarn type. The carbonate units (impure marbles) host the mineralization. The mineralization is stratiform to lenticular consisting of tungsten mineralization ( scheelite, wolframite, ferberite), cassiterite, sulphides ( arsenopyrite, chalcopyrite, sphalerite, pyrite, pyrrhotite), apatite, chlorite, muscovite and quartz.

**Host and outcropping rocks:**

The host and outcropping rocks are metassedimentary formations of Silurian age, consisting of pelitic schists, impure marbles and quartzites. There are also abundant aplitic-pegmatitic veins and the Covas granite.

**Exploitation period:**

First mining exploitation was by open pit between 1950-1964. From 1964 until 1984 the exploitation was underground.

**Type(s) of ore processing:**

Electromagnetic, hydrogravitic, roasting and flotation.

**Evidence for neoformation/weathering:**

Locally there are neoformation 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.
Tailings:

5 bodies of tailings divided by 3 main parts: COVAS A (E1), COVAS B (E234 - 3 bodies at different elevations and with flat tops) and COVAS C (E5). The approximate volume for COVAS B is 226000 m$^3$ and for COVAS C is 84000 m$^3$. The COVAS A is approximately 10000 m$^3$. The tailings are well integrated in the landscape being in some places densely vegetated.

Homogeneity (grain size, composition, etc):

COVAS A: light brown to cream and orange colours, heterogeneous, grain size ranging between silt to cobbles with high content of micas and lithic fragments of pegmatite and schist.

COVAS B: dark grey, red, orange, yellow, cream and light brown colours, in some places layered. Heterogeneous in terms of grain size (clay to clasts up to 20 cm long) and composition (clays, and clasts of schists and pegmatite).

COVAS C: orange very fine grained material capped by oxidized crusts with orange and yellow colours. On top occur scattered coarser fragments of schists.

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<tr>
<th>Tailing bodies ID</th>
<th>Height (m)</th>
<th>Shape</th>
<th>Area (m$^2$)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVAS A</td>
<td>= up to 3 m</td>
<td>Irregular</td>
<td>= 5500 m$^2$</td>
<td>COVAS A: mainly light brown to orange coarse sand with silt grain size fraction and low content of fragments coarser than 10 cm. In some places is compact and consolidated. Major fragments are aplites, granites and micaschists. The finer portion has higher content of micas.</td>
</tr>
<tr>
<td>COVAS B</td>
<td>= up to 10 m</td>
<td>Irregular</td>
<td>= 25000 m$^2$</td>
<td>COVAS B: in the bottom is characterized by yellow, red, orange silt-sandy material with thinner darker muddy levels, on the top has coarser sand material with major clasts, light brown to cream colours, locally compacted and consolidated.</td>
</tr>
<tr>
<td>COVAS C</td>
<td>= up to 2 m</td>
<td>Irregular</td>
<td>= 10000 m$^2$</td>
<td>COVAS C: Corresponds to fine tailing. The material is fine grained orange material with strong component of silt grain size, well compacted being difficult to dig. Locally is capped by thin oxidized crusts.</td>
</tr>
</tbody>
</table>
Tailings/waste sampling:

**Used equipment:** hammer, shovel, hoe, gloves, plastic bags

**No. samples collected:** 11

**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>
</tr>
</thead>
<tbody>
<tr>
<td>COVAS A FORNO</td>
<td>COVAS A1</td>
<td>-</td>
<td>1 m</td>
<td>0,05-2 mm</td>
<td>Angular</td>
<td>COVAS FORNO: fine ashes, black to dark grey, from the building where was the roasting process. See Figure 2.</td>
</tr>
<tr>
<td></td>
<td>COVAS A1.1</td>
<td>0,5 m</td>
<td>0,05-0,6 mm</td>
<td>Angular</td>
<td></td>
<td>COVAS A1.1: fine (silt) to coarse sand with fragments portions with gravel grain size, light brown, homogeneous with predominant micas. See Figure 3.</td>
</tr>
<tr>
<td></td>
<td>COVAS A1.2</td>
<td>0,5 m</td>
<td>0,06-2 mm</td>
<td>Angular</td>
<td></td>
<td>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. See Figure 4.</td>
</tr>
<tr>
<td></td>
<td>COVAS A2</td>
<td>-</td>
<td>0,30 m</td>
<td>0,06-0,6 mm</td>
<td>Angular</td>
<td>COVAS A2: composite sample collected in 2 places separated 10 m each and between 2 grinding rails. Coarse grain size (sand) with rare coarser fragments. Light brown to cream colors. See Figure 5.</td>
</tr>
<tr>
<td></td>
<td>COVAS A3</td>
<td>Surface</td>
<td>0,05-2 mm</td>
<td>Angular</td>
<td></td>
<td>COVAS A3: fine grain size (fine to medium sand), heterogeneous with orange, brown and yellow colors. In some places is well consolidated. See Figure 6.</td>
</tr>
<tr>
<td></td>
<td>COVAS A4</td>
<td>-</td>
<td>0,30 m</td>
<td>0,06-0,6 mm</td>
<td>Angular</td>
<td></td>
</tr>
<tr>
<td>COVAS B2</td>
<td>-</td>
<td>0,4-0,5 m</td>
<td>0,2-6 mm</td>
<td>Angular to subangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COVAS B3</td>
<td>-</td>
<td>0,5-1 m</td>
<td>0,2-6 mm</td>
<td>Angular to subangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COVAS B4 (rock)</td>
<td>-</td>
<td>Surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COVAS B5</td>
<td>-</td>
<td>0,5-0,8 m</td>
<td>0,2-2 mm</td>
<td>Angular to subangular</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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. Soil at top. See Figure 10.

**COVAS B3**: mainly coarse grain size (medium sand) with larger fragments up to fine gravel, orange, yellow and brown colors, heterogeneous. On top is red brown friable layer, below is coarser than the previous, yellow with minor dark grey layers intercalated. The bottom is darker than the top layer, similar to COVAS B1a. See Figure 11.

**COVAS A4**: coarse grain size (fine sand), light brown, cream and white colors, heterogeneous. The bottom is well consolidated and corresponds to the protolith. See Figure 7.

**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. See Figure 9.

**COVAS B1b**: fine grained dark grey mud probably is roasting ashes. This layer shows millimetric planar structures. See Figure 9.

**COVAS B1c**: very fine grain size (silt), dark brown (with burnt aspect), consolidated but easy to disaggregate. See Figure 9.

**COVAS B1d**: this layer is coarser than the previous (B1c, B1b, B1a) (medium to coarse sand), light brown to white colors, difficult to dis aggregate, with white coarser clasts (medium to coarse gravel) easily broken. See Figure 9.

**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. Soil at top. See Figure 10.

**COVAS B3**: mainly coarse grain size (medium sand) with larger fragments up to fine gravel, orange, yellow and brown colors, heterogeneous. On top is red brown friable layer, below is coarser than the previous, yellow with minor dark grey layers intercalated. The bottom is darker than the top layer, similar to COVAS B1a. See Figure 11.
| COVAS C (continuation) | COVAS B4: rock sample with approximately 30 cm x 10 cm x 7 cm with fine grained material consolidated. Shows laminar textures, probably corresponding to the material at bottom of settling tank. See Figure 12. |
| COVAS B5: mainly coarse sand material with larger fragments of aplit (?) up to 5 cm, light brown color, heterogeneous, hard and difficult to dig. See Figure 13. |
| COVAS C1: Very fine banded material (clay to silt grain size) with millimetric to centimetric orange and yellow layers, showing oxidation crusts. Homogeneous sample with presence of micas. Coarse schist fragments on the top. See Figure 15. |
**Sampling grids and photos (scheme):** A sampling grid was not defined due to the size, distribution and number of tailing bodies. The sampling distribution at each body tailing is represented at Figure 1.

![Figure 1 – Sampling location](image1)

![Figure 2 – a) Old mine oven; b) COVAS FORNO sample](image2)
Figure 3 – Sub-sample COVAS A1.1 local

Figure 4 – Collecting sub-sample COVAS A1.2.
Figure 5 – Sample COVAS A2 local

Figure 6 – Sample COVAS A3 local
Figure 7 – Sample COVAS A4 local

Figure 8 – COVAS B Tailing view
Figure 9 – Profile for COVAS B1 sample (Sub-samples, bottom to top: COVAS B1a, COVAS B1b, COVAS B1c, COVAS B1d)
Figure 10 – Sample COVAS B2 local

Figure 11 – Sample COVAS B3 profile
Figure 12 – Rock sample COVAS B4

Figure 13 – Sample COVAS B5 local
Figure 14 – View to COVAS C tailing top

Figure 15 – Sample COVAS C1
**Site and Sampling characterization report**

**Date:** 13/05/2015  
**Time:** 5 pm  
**Weather conditions:** Sunny with no wind

**Sampling team:** Carlos Rosa, Daniela Lobarinhas, Marisa Gomes, Isabel Paiva, Isabel Dias

**Mining site:**

**Name:** Cumieira  
**Location:** Serra de Arga, Caminha, PORTUGAL

**Type of ore (grade and tonnage):**

Tin and Nb-Ta minerals from quartz veins and pegmatitic veins.

**Regional geology and metallogenetic province:**

The mining site is in the tectono-stratigraphic Galiza and Trás-os Montes Zone in the Parautochthonous unit called Central Minho Unit from Silurian age. In this unit is the allochthonous massif – Arga massif with +/- 305 Ma - sin-tectonic to D3.

**Mineralization type:**

Placers deposits near quartz veins and pegmatitic apophysis. The placers have different thicknesses from centimetres up to 3 m above bed-rock.

**Host and outcropping rocks:**

Micaschists of Silurian age

**Exploitation period:**

The mine was exploited between 1927 and 1966 for Sn and Nb-Ta from elluvial deposits. Since 1950, the main target exploitation was Nb-Ta concentrates.

**Type(s) of ore processing:**

hydrogravitc, washing, electrostatic separation

**Evidence for neoformation/weathering:**

The tailings do not show any evidence of weathering.

**Mine drainage:**

The area is characterized by seasonal rivers between October to April. All seasonal rivers flows to the Coura River. There is a seasonal river near the tailings with no visual evidences of contamination.
Tailings:

Several scattered tailing piles, approximately 12 piles, with different grain sizes and areas. The thicknesses are variable but not higher than 1.55 m.

Homogeneity (grain size, composition, etc):

The piles are heterogeneous and mainly characterized by schist and granite coarse fragments (between 1 mm to 15 cm) and angular shapes.

<table>
<thead>
<tr>
<th>Tailing bodies ID</th>
<th>Height (m)</th>
<th>Shape</th>
<th>Area (m²)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUM A</td>
<td>0.30 m</td>
<td>Irregular</td>
<td>&lt; 1</td>
<td>CUM A: fine to coarse grained (clay to sand), dark grey, with biotitic minerals, located in the runoff zones which brings the fine material from coarse tailings located to SW.</td>
</tr>
<tr>
<td>CUM B</td>
<td>Up to 0.8 m</td>
<td>Irregular</td>
<td>5 m x 5 m = 25 m²</td>
<td>CUM B: mainly characterized by coarse grains up to +/- 10 cm, heterogeneous, with micaschists, quartz, spotted schists (andalusite?).</td>
</tr>
<tr>
<td>CUM C</td>
<td>Up to 0.8 m</td>
<td>Irregular</td>
<td>6 m x 3 m = 18 m², 6 m x 3 m = 18 m², 1 m x 1 m = 1 m², 2 m x 2 m = 4 m²</td>
<td>CUM C: fine grained material, heterogeneous, with quartz and schist fragments. Constituted by 4 piles with different areas where the pile 2 m x 2 m is equivalent in grain size to CUM B.</td>
</tr>
<tr>
<td>CUM D</td>
<td>1.55 m</td>
<td>Irregular</td>
<td>10 m x 10 m = 100 m²</td>
<td>CUM D: it is the tailing from the hydrogravitic plant. Coarse sand on the top in the opposite side of the water shed, heterogeneous, mainly with quartz and schist fragments.</td>
</tr>
</tbody>
</table>
Tailings/waste sampling:

**Used equipment:** bags, shovel, hoe, gloves

**No. samples collected:** 5

**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>
</tr>
</thead>
<tbody>
<tr>
<td>CUM A</td>
<td>CUM A1</td>
<td>-</td>
<td>0.30 m</td>
<td>0.002 – 0.2 mm</td>
<td>Angular</td>
<td><strong>CUM A1:</strong> 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. See Figure 2 and 3.</td>
</tr>
<tr>
<td>CUM B</td>
<td>CUM B1</td>
<td>-</td>
<td>Surface</td>
<td>0.06 – 200 mm</td>
<td>Angular to subangular</td>
<td><strong>CUM B1:</strong> mainly coarse grains (cobbles grain size) with fine material (silt to fine sand), heterogeneous. The materials are schists, micaschists, spotted schists (andalusite?), quartz and minor occurrences of aplites. See Figure 4 and 5.</td>
</tr>
<tr>
<td>CUM C</td>
<td>CUM C1</td>
<td>-</td>
<td>0.50 m</td>
<td>0.06 – 6 mm</td>
<td>Angular</td>
<td><strong>CUM C1:</strong> coarse material (mainly above 2 mm grain size) with some clay material; dark brown, heterogeneous.</td>
</tr>
<tr>
<td>CUM D</td>
<td>CUM D1</td>
<td>-</td>
<td>0.20 m</td>
<td>0.06 mm</td>
<td>Angular</td>
<td><strong>CUM D1:</strong> fine material (silt) without coarse grains, homogeneous, well sorted; light brown with lots of micas. See Figure 7.</td>
</tr>
<tr>
<td></td>
<td>CUM D2</td>
<td>-</td>
<td>0.10 m</td>
<td>0.06 – 0.2 mm</td>
<td>Angular</td>
<td><strong>CUM D2:</strong> Similar to CUM D1, well sorted. The grain size is more coarse than CUM D1. See Figure 8.</td>
</tr>
</tbody>
</table>
**Sampling grids and photos (scheme):** A sampling grid was not defined due to the size, distribution and number of tailing bodies. The sampling distribution at each body tailing is represented at Figure 1.

![Sampling location](image1.png)

**Figure 1 - Sampling location**

![Collecting sample](image2.png)

**Figure 2 – Collecting CUM A1 sample**
Figure 5 – Collecting CUM B1 sample

Figure 6 – View for CUM C tailing
Figure 7 – Sub-sample CUM D1 sampling local

Figure 8 – Sub-Sample CUM D2 sampling local
Site and Sampling characterization report

Date: 15 /05/2015

Time: 11:00

Weather conditions:
Sunny

Mining site:

Name: Ervideira-Mestras (Ervideira sector)  
Location: Gradiz, Aguiar da Beira

Type of ore (grade and tonnage):
Metatorbernite in weathered basic rock and vein of smoked quartz, both hosted by two mica granite.

Regional geology and metallogenetic province:
The mining site is in central Portugal in the tectono-stratigraphic Central Iberian Zone (CIZ). The CIZ contains abundant granitic intrusions and metasedimentary units of Pre-Cambrian and Paleozoic ages. In the mine area occur several types of granites that host mainly quartz veins with uranium mineralization.

Mineralization type:
Veins with basic rock and quartz (smoky) emplaced in a two mica granite. The vein is approximately 1 m wide, strikes N15ºE and dis 80º W. The mineralization is mainly metatorbernite hosted by the basic rock.

Host and outcropping rocks:
The host rock to the mineralization is a basic rock and quartz that infills a fault zone. The fault and the infill rocks are hosted by a two mica granite.

Exploitation period:
The advanced exploration started in 1919 with development of 6 mine shafts and a trench 250 m long. In 1955 the main shaft was deepened.

Type(s) of ore processing:
The ore was not processed at the mine site.

Evidence for neoformation/weathering:
No evidences

Mine drainage:
No evidences of mine drainage
**Tailings:**

The tailing body is totally integrated in the landscape. Most of the tailing was moved to fill the trench and shafts. A very small tailing occurs next to a small pit.

**Homogeneity (grain size, composition, etc):**

Very coarse clasts of quartz and quartz breccia containing basic rock and metatrobernite.

<table>
<thead>
<tr>
<th>Tailing bodies ID</th>
<th>Height (m)</th>
<th>Shape</th>
<th>Area (m²)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERVIDEIRA</td>
<td>1</td>
<td>Small mound</td>
<td>1 m² (visible)</td>
<td><strong>ERVIDEIRA:</strong> The tailings consist only of a small mound of large clasts of quartz and quartz breccia with elements of basic rock and different generations of quartz veins. The tailings were moved to fill the trenches and shafts excavated during the exploitation. However, the tailings material is accessible to be samples and can be excavated to provide a large amount of material, up to 500 ton.</td>
</tr>
</tbody>
</table>
Tailings/waste sampling:

**Used equipment:** gloves, shovel, hoe and plastic bags

**No. samples collected:** 2

### 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>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ERVIDEIRA</strong></td>
<td>Ervideira 1</td>
<td>-</td>
<td>Surface</td>
<td>1-30 cm</td>
<td>Angular</td>
<td>Ervideira1: The tailings are completely covered by moss.</td>
</tr>
<tr>
<td></td>
<td>Ervideira 2</td>
<td>-</td>
<td>0.8 m</td>
<td>Fine fraction 1-5 mm; Coarse fraction 2-5 cm</td>
<td>Angular</td>
<td>Ervideira2: Mixture of fine grained and coarse material. The coarser clasts (up to 5 cm long) are typically coated with metatorbernite and consist mainly of quartz and basic rock, but some granite clasts are also present.</td>
</tr>
</tbody>
</table>
Sampling grids and photos (scheme): No grid was defined since each tailing body was sampled only at one site.

Figure 1 – Ervideira tailings
Site and Sampling characterization report

Date: 27/05/2015
Time: 11:00
Weather conditions: Sunny

Sampling team: Carlos Rosa, Rui Pinto

Mining site:
Name: Ervideira-Mestras (Mestras sector)
Location: Gradiz, Aguiar da Beira

Type of ore (grade and tonnage):
Metatorbernite and autonite hosted in veins of smoked quartz, ametiste and chalcedony that infills a fault zone emplaced in a two mica granite.

Regional geology and metallogenetic province:
The mining site is in central Portugal in the tectono-stratigraphic Central Iberian Zone (CIZ). The CIZ contains abundant granitic intrusions and metasedimentary units of Pre-Cambrian and Paleozoic ages. In the mine area occur several types of granites that host mainly quartz veins with uranium mineralization. Approximately 500 m to the North of Mestras, and along the same fault zone, occurs the Luz mine, also for U - Ra.

Mineralization type:
Polyphasic veins with quartz (smoky, ametist, chalcedony) emplaced in a two mica granite. The vein is approximately 1,5 m wide, strikes N-S and is sub-vertical. The mineralization is mainly metatorbernite and autonite hosted by the quartz and at the contact of the quartz veins with the granite. Quartz crystals of variable sizes (up to 5 cm) are abundant.

Host and outcropping rocks:
The mineralization is hosted by a quartz vein emplaced in a fault zone, hosted by a two mica granite.

Exploitation period:
There was an initial exploitation period from 1919-1924 for Ra, and a subsequent phase 1955-1958 for U. During the initial phase 2 shafts of 20 m deep each and approximately 30 m apart were excavated. The shafts were connected by two levels of adits. A 30 m long trench was also excavated. During the second phase the site was intensely explored, several drill-holes were made and more shafts and adits were excavated along the veins. The mining depth has reached level -65 m.

Type(s) of ore processing:
The ore was not processed at the mine site.

Evidence for neoformation/weathering:
No evidences

Mine drainage:
No evidences of mine drainage
Tailings:

The tailing body is approximately 5 000 ton, is integrated in the landscape and there are no evident risks of collapse or erosion. However, part was taken presumably by local people. The tailings body is marked with signalization alerting not to remove the tailings material from its place.

Homogeneity (grain size, composition, etc):

The tailing consists mainly of intermediate and fine grained material (coarse sand) of quartz and granitic composition, mixed with coarse material. Relatively abundant very coarse clasts of quartz, quartz breccia and granite containing metatorbernite and autonite.

<table>
<thead>
<tr>
<th>Tailing bodies ID</th>
<th>Height (m)</th>
<th>Shape</th>
<th>Area ($m^2$)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mestras</td>
<td>Up to 3</td>
<td>Irregular</td>
<td>~1300 $m^2$</td>
<td><strong>MESTRAS</strong>: The tailings consist of an irregular mound covered with small vegetation that reaches a maximum height of 3 m. The tailing front was excavated and the material was probably taken by local people. The tailings are heterogeneous in terms of grain size, there is a coarse fraction (clasts can be up to 30 cm long) an intermediate fraction (clast sizes range from 1 cm to 10 cm) and a fine fraction of coarse sand. The clasts in all fractions are of granite and quartz (smoky, ametist, chalcedony) showing abundant crystals. Metatorbernite and rare autonite are abundant coating the clasts surfaces.</td>
</tr>
</tbody>
</table>
Tailings/waste sampling:

*Used equipment*: gloves, shovel, hoe and plastic bags

**No. samples collected**: 2

<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>
</tr>
</thead>
<tbody>
<tr>
<td>MESTRAS</td>
<td>Mestras 1</td>
<td>-</td>
<td>Surface</td>
<td>5-30 cm</td>
<td>Angular</td>
<td><strong>Mestras1</strong>: Coarse material that covers the tailings.</td>
</tr>
<tr>
<td></td>
<td>Mestras 2</td>
<td>-</td>
<td>0.8 m</td>
<td>Fine fraction 1 mm – 5 cm;</td>
<td>Angular</td>
<td><strong>Mestras2</strong>: Mixture of fine grained and material of intermediate size that occurs under the coarse material of sample Mestras1.</td>
</tr>
</tbody>
</table>

![Graphic symbol diagram]
Sampling grids and photos (scheme): No grid was defined since each tailing body was sampled only at one site.

Figure 1 – Mestras tailings

Figure 2 – Mestras tailings
Site and Sampling characterization report

Date: 13/05/2015

Time: 4 pm

Weather conditions: Sunny without wind

Mining site:

Name: Cabração
Location: Breia, Ponte de Lima, Viana do Castelo

Type of ore (grade and tonnage):

Tin and Nb-Ta minerals from aplite-pegmatite veins.

Regional geology and metallogenetic province:

The mining site is in the tectono-stratigraphic Galiza and Trás-os Montes Zone in the Parautochthonous unit called Central Minho Unit from Silurian age. In this unit is the allochthonous massif – Arga massif with +/- 305 Ma sin-tectonic to D3.

Mineralization type:

Aplite-pegmatite veins with N-S to N40W azimuth, subvertical. There are minor quartz veins crossing the main veins containing gold. The mineralization is Tin and Nb-Ta minerals. The accessory minerals are petalite, spodumene, amblygonite, lepidolite and zinnwaldite.

Host and outcropping rocks:

The host rocks are mainly micaschists from Silurian age.

Exploitation period:

The mine site is inside of the Cabração Mine Field but there is no old mine area/concession on the visited local. The exploitation period is difficult to precise but during 1930 to 1950 there was large volume of permits request for the mine field.

Type(s) of ore processing:

Unknown

Evidence for neoformation/weathering:

No evidence of neoformation/weathering processes.

Mine drainage:

No visual evidence of mine drainage.
**Tailings:**

The mine site has small tailing body well integrated in the landscape, covered by low vegetation. This tailing is represented by a centimetric layer of tailings residues above the outcrop.

**Homogeneity (grain size, composition, etc):**

**CABRACAO A:** fine to coarser grain size, cream to light brown colors, heterogeneous with large content of micas and fragments of micaschists (hosting rocks).

<table>
<thead>
<tr>
<th>Tailing bodies ID</th>
<th>Height (m)</th>
<th>Shape</th>
<th>Area (m²)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABRACAO A</td>
<td>≈ 0,5 m</td>
<td>Irregular</td>
<td>≈ 20 m x 17 m = 340 m²</td>
<td><strong>CABRACAO A:</strong> the tailing is a centimetric layer with fine to coarse grain size (from sand to medium gravel), cream to light brown colors. The fragments are mainly micaschist.</td>
</tr>
</tbody>
</table>
### Tailings/waste sampling:

**Used equipment:** gloves, shovel, auger, plastic bags

**No. samples collected:** 1

### 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>
</tr>
</thead>
<tbody>
<tr>
<td>CABRACAO A</td>
<td>CABRACAO A1a</td>
<td>-</td>
<td>Surface</td>
<td>0.06 – 0.6 mm</td>
<td>angular</td>
<td><strong>CABRACAO A1:</strong> fine to coarse grain size between silt and medium sand, light brown color with micas. See Figure 2.</td>
</tr>
</tbody>
</table>
**Sampling grids and photos (scheme):** No grid was defined since each tailing body was sampled only at one site.

![Sampling location](image)

**Figure 1 – Sampling location**

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![Collecting sample CABRACAO A1a with auger; Right) sample CABRACAO A1a local](image)

**Figure 2 – Left) Collecting sample CABRACAO A1a with auger; Right) sample CABRACAO A1a local**
**Site and Sampling characterization report**

**Date:** 14/05/2015

**Time:** 17:40

**Weather conditions:** Sunny

**Mining site:**

**Name:** Os Verdes

**Location:** Amonde, Viana do Castelo

**Type of ore (grade and tonnage):**

Tin and tungsten from aplite-pegmatite veins.

**Regional geology and metallogenetic province:**

The mining site is in the northwest sector of Portugal in the tectono-stratigraphic Galiza and Trás-os-Montes Zone in the Parautochthonous unit called Central and Occidental Minho Unit from Silurian age (Wenlock-Llandovery age). In the middle of the Minho Unit is the Arga massif (+/- 305 Ma) sin-tectonic to D3.

**Mineralization type:**

Quartz veins from aplite-pegmatite for cassiterite and wolfram mineralization. Has also breccia cemented by quartz and pegmatites with cassiterite. The mineral assemblage is cassiterite, wolframite and gold.

**Host and outcropping rocks:**

The host rocks are metassediments with possible intercalations of volcanic to volcaniclastic rocks with abundant sulphides from Central and Occidental Minho Unit (Arga Unit - Silurian age).

**Exploitation period:**

The mine was exploited in 1947 to 1975 for cassiterite and wolframite with underground mining works.

**Type(s) of ore processing:**

Electromagnetic, hydrogravitic

**Evidence for neoformation/weathering:**

No evidences

**Mine drainage:**

No evidences of mine drainage

**Sampling team:**

Carlos Rosa, Daniela Lobrinhas, Marisa Gomes, Isabel Paiva, Isabel Dias
Tailings:

In this mine site is difficult to identify the tailing body because is totally integrated in the landscape. The tailing is a one large ellipsoid body following the slope/hillside.

Homogeneity (grain size, composition, etc):

VERDES A: fine to coarse light brown grained size material, homogeneous and mainly composed by micas.

<table>
<thead>
<tr>
<th>Tailing bodies ID</th>
<th>Height (m)</th>
<th>Shape</th>
<th>Area (m²)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERDES A</td>
<td>≈ 50</td>
<td>Ellipsoidal shape with major axis trending N-S</td>
<td>≈ 17000 m² (Estimated in ArcGis)</td>
<td>VERDES A: fine to coarse sand, cream to white, with larger fragments of aplites and schists. On the top of the tailing, the grain size is mainly coarser sand. This tailing is similar to the Cumieira by the distribution of the granulometry.</td>
</tr>
</tbody>
</table>
Tailings/waste sampling:

**Used equipment:** gloves, shovel, hoe and plastig bags

**No. samples collected:** 2

**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>
</tr>
</thead>
<tbody>
<tr>
<td>VERDES A</td>
<td>VERDES A1</td>
<td>-</td>
<td>0.5-0.8 m</td>
<td>0.06-0.2 mm</td>
<td>angular</td>
<td><strong>VERDES A1:</strong> Fine grain size (fine sand, similar to beach sand), cream to white, compacted. All the material as large portion of micas. See Figure 2.</td>
</tr>
<tr>
<td></td>
<td>VERDES GALERIA 2</td>
<td>-</td>
<td>Surface</td>
<td>-</td>
<td>-</td>
<td><strong>VERDES GALERIA 2:</strong> Rock sample of fine grained white aplite with oxides. The mineral assemblage is mainly micas and quartz. Hard to break.</td>
</tr>
</tbody>
</table>
Sampling grids and photos (scheme): No grid was defined since each tailing body was sampled only at one site.

Figure 1 – Sampling location

Figure 2 – VERDES A1 sample location