The Mineral Potential in Centro Region of Portugal: Geology, Industry and Challenges

José A. Almeida
José C. Kullberg
Frederico Martins
Vanda Lopes
Alexandra Ribeiro
Critical Raw Materials (EU) 2017

Risk in:
- Sn (Tin)
- Li (Lithium)
- Mn (Manganese)
- Mo (Molybdenum)

Legend:
- Red: Critical raw materials
- Blue: Non-critical raw materials

(The highlighted raw materials are known to occur in the Centro region of Portugal)

Source: European Commission, 2017
Critical Raw Materials

Industries

Defence

Automotive

Metals

Medical Devices

Consumer Electronics

Green Technology

Source: Criticalrawmaterials, 2018
Mineral Resources Abundance:

- Metallic (Tungsten, Lithium, Tin)
- Energetic (Uranium)
- Non-Metallic (Quartz, Feldspar, Kaolin)
- Ornamental Rocks (Granite, Limestone)
Mineral occurrences and deposits

Mineral occurrence = knowledge of a mineral’s trace or evidence that might be economically interesting

Mineral deposit = body with significant dimensions and whose substances within, show interesting economic values; confirmed by mineral resources and reserves calculations

Source: LNEG, 2018

<table>
<thead>
<tr>
<th>Substance</th>
<th>nº ofOccurrences/Deposits</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>409</td>
</tr>
<tr>
<td>Sn</td>
<td>153</td>
</tr>
<tr>
<td>W</td>
<td>116</td>
</tr>
<tr>
<td>Si</td>
<td>78</td>
</tr>
<tr>
<td>Au</td>
<td>51</td>
</tr>
</tbody>
</table>

Legend:
- Anthracite
- Arsenium
- Gold
- Barium
- Beryllium
- Bitumen
- Kaolin
- Copper
- Iron
- Fluorine
- Graphite
- Coal
- Lithium
- Lignite
- Lignite (Tin)
- Cassiterite (Tin)
- Wolframite (Tungsten)
- Chalcopyrite (Copper)
- Gold

Source: LNEG, 2018
Metallic and non-metallic minerals
Occurrences/deposits

**Metallic minerals**
- Granitic rocks
- Metasedimentary rocks
- Structural controlled zones

**Non-Metallic minerals**
- Sedimentary rocks

**Direct relation with Geology**

- Metallic (Tungsten, Lithium, Tin, ...)
- Non-Metallic (Silicon, Salt rock, Kaolin ...)

Source: LNEG, 2018; LNEG, 2010
Critical Raw Materials (CRM) in Centro Region

Potential CRM

- Panasqueira Mine

Source: LNEG, 2018

Legend:
- Ba (Barium)
- Be (Beryllium)
- Mn (Manganese)
- Sb (Antimony)
- Sn (Tin)
- W (Tungsten)

Over 250 W (and Sn) small to medium occurrences/deposits

About 20 (Sb+Mn+Ba+Be) small occurrences/deposits

Over 250 W (and Sn) small to medium occurrences/deposits

Potential CRM
Tungsten (W) and Tin (Sn)

Paiva Tungsten Area

Arouca-S. Pedro Sul

Góis-Panasqueira-Argemela-Segura Belt

Douro Scheelitic Belt

Trancoso-Fig. Castelo Rodrigo Belt

Legend: (deposits)
- Tarouca, 21
- Almendra, 22
- Azevo, 23
- Ragnufte, 24
- Bejanca, 25
- Serra de Bois, 26
- Nave de Haver, 27
- Argemela, 28
- Góis, 29
- Panasqueira, 30
- Mata da Rainha, 31
- Segura, 32
- Sarzedas, 33
- Lagares, 34

W, Sn Potential Areas

Sources: Martins, 2012; LNEG, 2010
### Tungsten (W) and Tin (Sn)

#### WWI & WWII
(major periods of tungsten production in Portugal)

#### Tungsten main deposits
(centro region)

<table>
<thead>
<tr>
<th>Mineral Deposit</th>
<th>Main Substances</th>
<th>Historical Production</th>
<th>Dimension</th>
<th>Potential Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panasqueira</td>
<td>Tungsten</td>
<td>Production of more than 50,000 t of W, (over 100 years)</td>
<td>Large</td>
<td>Proven and Probable Reserves + Indicated Resources= 5.13 Mt with 0.26 % WO$_3$ (total of 13,338 t WO$_3$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bejanca-Bodiosa</td>
<td>Tungsten and Tin</td>
<td>Production of 178 t of WO$_3$ and 184 t of SnO$_2$</td>
<td>Medium</td>
<td>5 mt with 2350 t of WO$_3$ and 3070 t of Sn (1985 Assessment).</td>
</tr>
</tbody>
</table>

Between years 1836 – 1930
Of a total 1793 mines - 530 (30%) exploited tungsten (Portugal)

Sources: LNEG, 2010; Watson, 2014
Other Critical Raw Materials

Beryllium (Be)
Exploited in pegmatites/aplito-pegmatites (as by-product), sources of quartz, feldspar and mica. Viseu district

Niobium (Nb) + Tantalum (Ta)
By-product of tin production (ex. Almendra). Potential in Gonçalo-Vela-Benespera-Belmonte-Sabugal (a) and Sátão-Mangualde-Viseu (b) areas

Tin (Sn)
Potential CRM

Strong relation with tungsten. Panasqueira mine by-product

Li bearing aplitepegmatites in Guarda region, Alvarrões

Sources: LNEG, 2010; Leal Gomes, 2018
Lithium (Li)
Critical metal in the green business

- Lepidolite
- Spodumene and Petalite

Resources >22 Mt
Average grade> 0.4 % Li₂O

Aplitopegmatites can also be source of Tin, Niobium, Tantalum and REE

Only in 2016 arrived at DGEG (Directorate General for Energy and Geology), 30 requests for research and exploration areas. (Investment of 3,8 M€)

<table>
<thead>
<tr>
<th>Designation Area (km²)</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Almendra - Barca de Alva</strong> 343</td>
<td>0,42-0,52 % Li₂O (Barca d’Alva) + 0,05 % Sn, 0,5 % Li₂O (Felin mine) + 0,05 % Sn, 0,16 % Li₂O (Pombal) + 0,05 % Sn</td>
</tr>
<tr>
<td><strong>Argemela</strong> 15</td>
<td>Inferred Resources of 20,1 Mt, 0,4 % Li₂O</td>
</tr>
<tr>
<td><strong>Guarda - Manguade</strong> 1725</td>
<td>Measured Resources of 1,4 Mt, 0,42 % Li₂O</td>
</tr>
<tr>
<td><strong>Massueime</strong> 258</td>
<td>Deposit with: &lt; 150 t Li₂O, &lt; 1500 t Sn</td>
</tr>
<tr>
<td><strong>Segura</strong> 34</td>
<td>Mineralization in lepidolite and REE</td>
</tr>
</tbody>
</table>

Source: Despacho n.º 15040/2016
Uranium (U)
Great mining legacy in the Centro region

- Production ended in 2001
- 3rd biggest reserves in Europe
- The major remediation works in the region are for radioactive old mining areas

Resource Potential in Portugal (2010, LNEG) = 7.558 t U₃O₈

<table>
<thead>
<tr>
<th>Mineral Deposit</th>
<th>Historical Production</th>
<th>Dimension</th>
<th>Potential Resources</th>
<th>Environmental Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ázere (1)</td>
<td>556 t U₃O₈</td>
<td>Small</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Cunha Baixa (2)</td>
<td>600 t U₃O₈ (1979-1985)</td>
<td>Small</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Freixiosa (3)</td>
<td>145 t U₃O₈ (1978-1984)</td>
<td>Small</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Pinhal do Souto (4)</td>
<td>8 t U₃O₈ (1981-1985)</td>
<td>Medium</td>
<td>Ton ‘in situ’ of 770 t U₃O₈</td>
<td>Yes</td>
</tr>
<tr>
<td>Quinta do Bispo (5)</td>
<td>600 t U₃O₈ (1979-1985)</td>
<td>Small</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Urgeiriça (6)</td>
<td>1000 t U₃O₈ (1913-1992)</td>
<td>Small</td>
<td></td>
<td>Yes (in course)</td>
</tr>
</tbody>
</table>

Legend:
• U main occurrences
• U (small/medium) occurrences

Uranium potential areas:
- E – Beira Douro Silurian Belt
- J – Beira Uraniferous Province
- K – Castelo Branco-Penamacor Granitic Area
- L – Nisa Uraniferous Area

Examples of old Uranium mines

Sources: Martins, 2012; LNEG, 2010
Circular economy
Turn mine waste into resource

- Mine waste = extraction, beneficiation and mineral processing
- Causes: Pollution of water, soils and air
- Has: Large potential as a (secondary) resource
- Requires: Characterization (chemistry, physics, mineralogy), volume, grade,..
- Concepts: Recycling, reuse, beneficiation
- Resource maximization and environmental hazard mitigation

Potential areas for beneficiation on tailings in Centro Region: Góis (Tungsten, Tin), Bejanca (Tin, Tungsten), Talhadas (Copper, Lead, Silver) e Braçal (Lead), with volume of tailings between 50.000 - 100.000 m³

Sources: Lèbre and Corder, 2015; Carvalho et al., 2016
**Circular economy**

**Turn mine waste into resource**

**Case study:** Panasqueira mine
- > **8,000,000 m³ tailings** (coarse, crushed and milled waste-rock)
- About 100-200 tons of tailings per day (presently)

Use in road construction (coarse material), bituminous products (coarse and fine material), artificial aggregates (mud), road furniture, polymer-based composite materials (conservation, restoration of buildings, monuments, etc); **(Universities of Beira Interior, Granada and Bologna)**

- **Tailings studies examples (Collaboration of Universities and Companies)**
  - **PT-W** – Biotools for a sustainable supply of tungsten from biodetection to bioleaching and biorecovery **(University of Coimbra)** - Detect and extract tungsten from tailings
  - **ENVIREE** - Environmentally friendly and efficient methods for extraction of rare earth elements (REE) from secondary sources
    - **IST ID (Instituto Superior Técnico for Research and Development), EDM (Empresa de Desenvolvimento Mineiro), and other european partners**

Sources: Castro-Gomes et al., 2012; 2016
An integrated investigation of the Rio tailings - Panasqueira mine (Centre Portugal)

C. Grangeia¹, P. Ávila¹, ², M. Matias¹, E. Ferreira da Silva¹

¹GeoBioTec – Geobiosciences, Geotechnologies and Geomining, University of Aveiro, 3810-193 Aveiro, Portugal (corresponding author; Email address: cgrangeia@ua.pt).
²LNEG –

Geochemistry and Mineralogy of Mill Tailings Impoundments from the Panasqueira Mine (Portugal): Implications f....

Feasibility of alkali-activated mining waste foamed materials incorporating expanded granulated cork
Non-metallic resources in the Centro region

Mainly:
- **Ornamental stone**
- **Industrial minerals**
- **Construction minerals**

Sources: LNEG, 2018; 2010
Non-metallic resources
Production of Centro region

Source: DGEG, 2017a
Centro region mining activity (2017)

The majority of licenses (mining concessions) are related to non-metallic resources.

<table>
<thead>
<tr>
<th>Nº of</th>
<th>Metallic</th>
<th>Non-Metallic</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining Concessions</td>
<td>12</td>
<td>128</td>
<td>140</td>
</tr>
<tr>
<td>Experimental Exploitation*</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Exploration and Research Areas*</td>
<td>30</td>
<td>21</td>
<td>51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nº of companies</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining Concessions</td>
<td>6</td>
<td>27</td>
<td>33</td>
</tr>
<tr>
<td>Experimental Exploitation</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Exploration and Research Areas</td>
<td>17</td>
<td>13</td>
<td>30</td>
</tr>
</tbody>
</table>

Legend:
- Mining Concessions
- Experimental Exploitation
- Exploration and Research Areas

3 license situations:
- ✓ Granted
- ✓ In Publicitation
- ✓ Requested

Source: DGEG, 2018a

*Maximum 5 years period
Portugal strategies for mineral resources

**ESTRATÉGIA NACIONAL PARA OS RECURSOS GEOLÓGICOS | NATIONAL STRATEGY FOR GEOLOGICAL RESOURCES**
- Promotion: sustainability, dynamics, national and regional growth, supply of raw materials
- Development of knowledge and national potential on resources, national propaganda and promotion, economical, social, environmental and territorial sustainability

**(2012)**

**CLUSTER MINERAL RESOURCES**
- Promote knowledge, sustainable economic value of mineral resources.
- Exporting, R&D, Investment, Increase technical, technological and management capacities

59 partners (companies, universities, associations, institutes)

**(2016)**

**GRUPO DE TRABALHO “LÍTIO” | LITHIUM GROUP WORK**
- Increase the Li market in Portugal
- Identification and characterization of Li deposits
- Increase economic value
- Create processing plants

Sources: Resolução do Conselho de Ministros n.º 78/2012, clustermiinalresources, 2018; Despacho n.º 15040/2016
Active mines in Centro region

Companies:

BERALT TIN AND WOLFRAM (PORTUGAL), S.A.
Minas de Cassiterite de César de Almeida Figueiredo & Filho, Lda
Minas de Cassiterite Sobreda, S.A.

José Aldeia Lagoa & Filhos, Lda.
Pegmatitica - Sociedade Mineira de Pegmatites, Lda.
Sociedade Mineira Carolinos, Lda.
Felmica - Minerais Industriais, S.A.

Source: DGEG, 2017b
Mining sector employment in Portugal

Executive, Administratives and Technicians

- More employment related to the metallic sector
- Sector growing from 2011 to 2016

Supervisors and Operatives

- Significant rise between 2009-2010 (metallic sector)

Source: DGEG, 2017c
Exploration and research in Portugal

Rise from 2008 to 2012
(World banking crisis; increase in value of several commodities; investment in the sector)

After 2012 decrease in commodities value

Slight increase since 2015

Boom in lithium demand to contribute for the previous scenario

Investment evolution in exploration and research contracts (1990-2016)

Source: Pais, 2016
Critical raw materials production

Panasqueira mine production (2000-2016)

<table>
<thead>
<tr>
<th>Year</th>
<th>Concentrate Produced</th>
<th>ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WO₃      Sn   Cu</td>
<td>Ore</td>
</tr>
<tr>
<td>2000</td>
<td>1,269     12   132</td>
<td>332</td>
</tr>
<tr>
<td>2001</td>
<td>1,194     23   118</td>
<td>378</td>
</tr>
<tr>
<td>2002</td>
<td>1,179     21   81</td>
<td>346</td>
</tr>
<tr>
<td>2003</td>
<td>1,213     20   99</td>
<td>355</td>
</tr>
<tr>
<td>2004</td>
<td>1,277     50   138</td>
<td>432</td>
</tr>
<tr>
<td>2005</td>
<td>1,405     44   187</td>
<td>574</td>
</tr>
<tr>
<td>2006</td>
<td>1,342     28   235</td>
<td>642</td>
</tr>
<tr>
<td>2007</td>
<td>1,456     48   258</td>
<td>762</td>
</tr>
<tr>
<td>2008</td>
<td>1,684     32   186</td>
<td>782</td>
</tr>
<tr>
<td>2009</td>
<td>1,410     36   164</td>
<td>720</td>
</tr>
<tr>
<td>2010</td>
<td>1,364     25   198</td>
<td>792</td>
</tr>
<tr>
<td>2011</td>
<td>1,399     45   238</td>
<td>905</td>
</tr>
<tr>
<td>2012</td>
<td>1,303     47   228</td>
<td>830</td>
</tr>
<tr>
<td>2013</td>
<td>1,174     103  352</td>
<td>789</td>
</tr>
<tr>
<td>2014</td>
<td>1,131     98   732</td>
<td>775</td>
</tr>
<tr>
<td>2015</td>
<td>799       53   361</td>
<td>518</td>
</tr>
<tr>
<td>2016</td>
<td>926       69   384</td>
<td>643</td>
</tr>
</tbody>
</table>

Source: Almonty Industries, 2016

Baryte production in Portugal

Production ended in 2010

Source: DGEG, 2017d

Lithium production in Portugal

Source: BGS, 2018
Extractive industry in Centro region

Production (t)

- **Metallic Minerals**
  - Metals: Tungsten, Tin, Copper, Titanium

- **Industrial Minerals**
  - Clay, Kaolin, Feldspatic sands, Feldspar, Pegmatites, Quartz, Salt rock

Production (€)

- **Metallic Minerals**
  - (Clay, Kaolin, Feldspatic sands, Feldspar, Pegmatites, Quartz, Salt rock)

- **Industrial Minerals**
  - Metallic Minerals >> Industrial Minerals

Source: DGEF, 2017a
Programmes & Projects
Portuguese and European

- **EUROPEAN UNION (FP6, FP7) e H2020**, related to Europe (including Portugal)
- **POVT** (Territory Valorization Operational Program)
- **POSEUR** (Sustainability and Efficiency in the Use of Resources Operational Program)
- **MAIS CENTRO**
- **CENTRO2020**
- **COMPETE2020**, all related with the Centro Region (Portugal)

FP 6,7 - Framework Program 6,7

Sources: European Commission, 2018; 2018b; Mais Centro, 2018; QREN, 2018; Compete 2020, 2018; Portugal2020, 2018
European research programmes
Portuguese Participation

Sources: European Commission, 2018; 2018b
European research programmes
Portuguese Participation


Projects N°
- METALLIC
- NON-METALLIC
- MIXED
- GEOTHERMAL

H2020 (€)
- EU
- PT

Portuguese research programmes
Centro Region

POVT (2007-2013)

Projects N°

POVT (€)

Remediation of abandoned mining areas

Sources: European Commission, 2018; 2018b; QREN, 2018
Portuguese research programmes
Centro Region

**PT2020 (2016-2018)**

- **Projects Nº**: 4
- **NON-METALLIC**: Remediation of abandoned mining areas

**PT2020 (€)**

- **Projects Nº**: 4
- **NON-METALLIC**: 526,033 €
- **METALLIC**: 27,571,184 €

**MAIS CENTRO (2008-2014)**

- **Projects Nº**: 3
- **METALLIC**: 889,714 €
- **NON-METALLIC**: 17,032,667 €
- **GEOTHERMAL**: 2,439,323 €
- **GEOTOURISM**: 568,664 €

**MAIS CENTRO (€)**

- **Projects Nº**: 4
- **METALLIC**: 889,714 €
- **NON-METALLIC**: 27,571,184 €
- **GEOTHERMAL**: 526,033 €
- **GEOTOURISM**: 568,664 €

Sources: Mais Centro, 2018; Portugal2020, 2018
Portuguese research programmes
Centro Region


Projects Nº

METALLIC
NON-METALLIC
MIXED
ENERGY

32
1
1
1

Centro2020 (€)

21,477,709 €
148,309 €
1,599,990 €
383,678 €


Projects Nº

NON-METALLIC
MIXED
ENERGY

5
1
1
1

Compete2020 (€)

728,598 €
139,222 €
144,396 €

Sources: Centro2020, 2018; Compete2020, 2018
Much less projects (sometimes inexistent) with focus in metallic resources
[Non-Metallic (47) >>>> Metallic (9)]

+ Investment in metallic resources lower than in the non-metallic
[Non-Metallic ≈78 M€ >>>> Metallic ≈22 M€]

‘It’s necessary to change this vision and reinforce the investment in the metallic sector (mainly critical raw materials), reducing the (high) dependency on importation of the European Union’
Considerations

✓ The Centro Region is rich in number and diversity of metallic (and non-metallic) mineral resources

✓ Among the metallic there is:

✓ High potential in Tungsten and Lithium > Tantalum, Niobium, Tin, Rare Earth Elements, Beryllium, Barium (By-products). Tungsten sold as WO$_3$ concentrate from Panasqueira mine

✓ Moderate potential for Tin

✓ Although there are some occurrences of Niobium, Tantalum and Beryllium, more exploration is needed

✓ Existence of old mines (W, Sn, Au) with estimated resources and reserves

✓ High potential for deep deposits (higher costs)

✓ Strong demand in Lithium (growing investment) – Required:

✓ Improved separation of Li metal other elements
✓ Sustainable refining process of Li oxide in Li carbonate for higher economic value in international market

Savannah believes the site in Portugal to be “the largest deposit of spodumene lithium in western Europe.” Mr Archer said: “Portugal could be the first European supplier” of spodumene concentrate, the dominant lithium product to be traded internationally.

References (1/2)

- DGEG – Direção Geral de Energia e Geologia (2017a). Production (Quantities and value) in the Centro region – Mines and quarries
References (2/2)

Thank you!

https://www.interregeurope.eu/remix/