Ceramic raw materials in Portugal: characteristics and potential

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LNEG in the Portuguese government

The Portuguese government entities related with geology, mining and exploration:

• Laboratório Nacional de Energia e Geologia (LNEG) *(Geological Survey)*
  Geological mapping, geological, geochemistry and geophysical databases, exploration R&D projects
  *Portuguese Geological Survey* since 1848. www.lneg.pt

• Direção Geral de Energia e Geologia (DGE) *(Mining authority)*
  Mineral exploration and exploitation permit licenses, administrative processes, and legislation. www.dgeg.pt

• Empresa de Desenvolvimento Mineiro (EDM)
  Rehabilitation programs for inactive abandoned mines. www.edm.pt
Common clay, special clay and kaolin: Total production (1999-2014)

All tonnage and value production data are from DGEG
Geology

Portugal, a small country with a great and diverse geology!

Variscan basement:

- Galicia Trás-os-Montes Zone (GT)
  - (Upper, Intermediate and Lower Allochthonous Complexes, Parautochthon Complex)
- Central Iberian Zone (CIB)
- Ossa Morena Zone (OMZ)
- South Portuguese Zone (SPZ)

Mesocenozoic Basins:

- Lusitanian (L)
- Algarve (A)
- Tagus-Sado (T)

Maps adapted from LNEG/SGP 1992, Ribeiro et al. 2010
Common clays

Potential geological units for ceramic clays:

**Paleozoic and Early Mesozoic**

**Upper Jurassic**

**Cretacic**

**Cenozoic**

**Paleogene**

**Neogene**

**Pliocene and Quaternary**

*Figure from Pais et al. 2012*
The main minerals observed are **illite**, **kaolinite** and **quartz** and less frequently **smectite**, varying the order of importance of these minerals.

Accessory minerals: feldspar and iron oxides and hydroxides.

**Carbonates** are a less frequent phase in the common clays exploited in Portugal.
Common clays
Present main exploitation clusters

Clay pits and occurrences database (1964-2010)

Ramalhal – Outeiro da Cabeça
Aguada – Anadia
Juncal

Porto
Aveiro
Leiria
Lisboa
Faro

Main exploitation clusters
- Cenozoic
- Mesozoic
- Paleozoic
- Precambrian
- Intrusives

50km
Juncal
Ramilhal – Outeiro da Cabeça
Special clay (ball-clay)

The known deposits are located in a limited area in the central western zone of Portugal (Pliocene and Pleistocene age).

The ball clays sector is very advanced in which concerns the knowledge about the deposits, extraction technologies, quality control and rational utilization of resources.

- Composition: kaolinitic with illite and organic matter. Very fine grain and high plasticity. Color: white, grey and black.
- Used as raw materials for whiteware ceramics: sanitary, tableware, refractories and floor and wall tiles.
- Known reserves are about 2 Mt (Pombal and Leiria areas).
Portugal is rich in kaolin for ceramic uses.

Geologically diverse origin:

- Sedimentary deposits of different ages (large resources)
- Primary deposits formed by hydrothermal processes and weathering of granitic rocks.
- Arkoses have recently become a relevant resource due to their content in kaolin - besides k-feldspar and silica sands.

The kaolin subsector has shown a great dynamism with the aims of increasing quality levels, diversifying uses and penetrating in foreign markets.
Main target kaolin exploitation areas in the Lusitanian basin, N and S of Aveiro
Typical composition fields for raw materials with application in whiteware and red construction ceramics

**Construction clays**
ri = Italian illite-chloritic clays; rp = Portuguese const. clays

**Whiteware** (based on European ceramic raw materials)
w = English kaolins; w' = French kaolins; w'' = German kaolins; wp = Portuguese kaolins

adapted from Fabbri & Fiori 1985

Portuguese kaolins composition is similar to other European kaolins
Estimated reserves based only on information of Exploration permits (EP) and Required exploration permits (REP) (2014)

Required exploration permits: 87,059,926 t
Exploration permits: 9,311,641,41 t

Total kaolin: ~100,000,000 t

Total area EP and REP: 394 km²
  CM: 68 km²; APP's: 326 km²

Potencial area = 2049 km²
  Lower Cret.: 996 km²; Mio-Plio-Q: 1054 km²

Considering that the potential area is more than 5x the considered area, besides that in most REP's and EP's only a small fraction of the area concerns the calculation of reserves, the tonnage of raw material will be considerably higher!
Quartz and feldspar are very common minerals in Portugal. Occurrences with economic value are Qz-Fsp vein structures. The North and Central Portugal regions are those where such structures are more abundant, being associated with granitic massifs and the Paleozoic metasedimentary rocks that form their wall rock.
LNEG exploration and research

A few recent case studies carried out concerning ceramic raw materials
A kaolinite content increase opposite to illite is noted in the deposits south of Mondego river.

Typological columns were used to identify and characterize the raw materials of the main clay resources exploration areas.

Typological column concept: column based on the typology of the units or productive formations, from the lithostratigraphic column.

Chart of Clay Resources in the Lusitanian basin and Inner basins.
Main identifying characteristics of two typological units

For each unit were defined:

Expected interval ranges for mineralogical composition, grain size (clay, silt, sand) and ceramic parameters (PI, dry and fired BS, water absorption)

Illite is the prevailing clay mineral, the higher % of non-clay minerals (upper unit) is reflected in lower PI and BS.
Example of another typological column south of Mondego river...

Remarks:
High kaolinite content, PI and BS, which are higher in the sample containing interstratified clay minerals (in red)
Clay resources mapping in a inner basin (NE of Coimbra, Central Portugal)
Clay resources mapping in the Lusitanian basin (Torres Vedras – Bombarral, N of Lisbon)
Areas of probable clay resources occurrence were delimited, which do not outcrop but have high probability of occurrence at economically viable exploitation depths (<10m).

These areas were defined based on: outcrops stratigraphic correlation, drill cores and, indirect, local information.
The Gonçalo aplite-pegmatite field

Dozens of acid and basic dykes, sills, veins, etc. and at the same time is the richest in structures with lithium. These are intruding mainly a porphyritic biotite granite.
Final remarks

- In Portugal there are resources for ceramics in quantity and quality.
- There are political conditions and tradition to ensure the continuity & sustainability of the mining activity.
- The Portuguese ceramics cluster provides in a structured and organized manner, good conditions for existing companies and settlement of new ones.
- Exploitation of the raw materials is made according good environmental practices.
- In Portugal we have the material conditions, will and skilled people.
The Gonçalo aplite-pegmatite field

- 3 different mineralization types occur:
  - Geochemically evolved **lithium sills** with quartz, k-feldspar, albite, muscovite, *lepidolite*, *petalite*, montebrasite, topaz, etc.,
  - Less evolved **tin sills** with quartz, k-feldspar, albite, muscovite, *rare lepidolite*, montebrasite, topaz, apatite, beryl, cassiterite, columbite-tantalite, etc.
  - **Mixed sills** having an intermediate composition and being located between the others, corresponding to a transition phase.

- Structure:
  - Sub-horizontal with a tabular form
  - Thickness: few cm to 10m; average: 3,5m

- Resources: 540 000 m³ (maximum quarry front of 10m)
LNEG contribution

The main issue is the definition of areas for extractive industry, mainly at the municipalities level.

Therefore, presently one of the most important contributions is at a territorial planning and management level.
To solve this main issue:

- Geological mapping of potential areas
- Highlight the geological units that reveal more potential for the different raw materials extraction, which have been and may be, the target of exploitation
- Define general ceramic typology of the deposits / geological units
- Technological aid to industrials on the exploitation activity and materials’ characterization and beneficiation.
Some of the players in the Portuguese ceramic industry

Mining and ready made bodies producers

Installed consuming companies
Portugal is a friendly mining country with a long mining tradition!

Obrigado!

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