Magnetic fabrics in Portuguese Variscan granites: structural markers of the Variscan orogeny

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1. AIMS

This work focuses on the magnetic fabric of twenty Variscan granitic massifs [Figure 1], from northern and central of Portugal, and considers the Anisotropy of Magnetic Susceptibility (AMS) data obtained in a total of about 750 sampling sites.

In northern and central of Portugal, three main Variscan ductile deformation phases were recognized and described: D₁, D₂, and D₃, being the period of emplacement of granitic magmas generally related to O3 (315-310 Ma).

- D₁ ductile phase produced wide amplitude folds with NW-SE subvertical axial plane and subvertical dextral and sinistral ductile shear zones [Figure 3], forming obtuse angles with the maximum compression direction, ε₁, NE-SW oriented.
- The post-D₁ brittle phase was responsible for the development of conjugate faults (NNW-SEE, NNE-SSW and ENE-WSW), related to a N-S late-Variscan maximum compression.

2. THEORY

The ratio between the induced magnetization, M (expressed in A/m), and the magnetizing field, H (expressed in A/m), is the magnetic susceptibility, k (dimensionless in SI units).

\[ k = \frac{M}{H} \]

In polimeric rocks, the magnetic susceptibility is the sum of the contribution of all rock-forming minerals, so it varies with concentration and composition of those mineral phases, which may include diamagnetic, paramagnetic or ferromagnetic f.i. species.

- The Anisotropy of Magnetic Susceptibility defines a symmetric 2x2-rank tensor originated from a geologic matrix that describes the spatial variation of magnetic susceptibility. This tensor is expressed by the magnitude (eigenvalues) and orientation (eigenvectors) of the maximum (Kₓ), intermediate (Kᵧ) and minimum (Kz) principal axes of magnetic ellipsoid (Kₓ > Kᵧ > Kz) ([Figure 2]).

3. “GRANITES AND YET MORE GRANITES”

The studied granites were classified according to field observations and U-Pb dating of their emplacement relative to the D₃ phase.

<table>
<thead>
<tr>
<th>Granites</th>
<th>Age</th>
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<tbody>
<tr>
<td>Syn-D₁ group</td>
<td>ca. 320-310 Ma</td>
</tr>
<tr>
<td>Late-D₁ group</td>
<td>ca. 310-305 Ma</td>
</tr>
<tr>
<td>Late- to post-D₁ group</td>
<td>ca. 305-290 Ma</td>
</tr>
<tr>
<td>Post-D₁ group</td>
<td>ca. &lt; 290 Ma</td>
</tr>
</tbody>
</table>

4. PARAMAGNETIC OR FERROMAGNETIC GRANITES?

- Despite of different petrographic and geochemical characteristics, K values in the majority of the granites studied range from 20 to 300 × 10⁻⁶ SI units corresponding to reduced- or ilmenite-type granites (paramagnetic behavior). The Pn is generally lower than 8% which reflect its low deformation patterns.
- The oxidized or magmatic-type granites (ferromagnetic behavior) are scarce and are represented by some post-tectonic or post-D₁ biotite-rich granites with K values ranging from 15 to 20 × 10⁻⁶ SI units [Figure 3, green data], which display higher PnS caused by the presence of magmatic in the accessory mineral phases.

5. MAGNETIC FABRIC

Magnetic fabric gives two types of directional data, magnetic foliations (plane normal to Kₓ) and magnetic lineations (trend and plunge of Kᵧ) ([Figure 1]) which provide important information:

- orientation of the magnetic flow;
- relationship between the magma emplacement and tectonics;
- stress field ([Figure 4]).

6. STRUCTURAL MARKERS OF VARISCAN OROGENY

1. Syn-D₁ granites show magnetic foliations and lineations consistent with the syn-D₁ Variscan shear zones ca. N110°-120°, related to NE-SW oriented. The foliations are, mainly, subvertical (> 60°) which may indicate a high thickness of the granitic body and deep rooting: on the other hand, the magnetic lineations exhibit variable plunge ([Figure 1]).

2. Late-D₁ and late- to post-D₁ granites are characterized by foliations and lineations, dominantly NNE-SSW to NNE-SSW oriented ([Figure 4] and 5). The foliations are subvertical (> 60°) and the lineations have, generally, soft plunges.

3. Post-D₁ granites, have, in general, magnetic foliations and lineations associated with important regional post-D₁ brittle structures, which display NNE-SSW trending ([Figure 6]), related to N-S maximum compression. The subhorizontal fabric may suggest a small thickness of the granitic bodies.

4. There is a dominance of weakly dipping lineations (slope <60°), indicating that the feeding zones are deep, which supports the idea of an emplacement at high structural levels.

5. The magnetic fabric of different granites materializes the structural anisotropies found during the evolution of the Variscan orogeny, and points out the rotation of the maximum compression, ε₁, from D₁ phase to late- to post-D₃ phases.

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