HAVE NNE-SSW TRANSCURRENT SHEAR ZONES ALWAYS BEEN SINISTRAL IN THE VARISCAN BASEMENT?

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Abstract

Traditionally, the NNE-SSW shear zones have been considered mainly as sinistral transcurrent faults throughout their entire evolution, from late Variscan times to Alpine, in the Variscan basement. This is not in agreement with their PT evolution, nor with the expected orientation of the major compressive stresses (subvertical NNE and NE) by the end of Variscan Orogeny. The PT record suggests evolution during crustal uplift, most probably by Local Decrease of the Variscan Chain. If this relation is not accompanied by break up of the Variscan Range, compressional is induced by the fitting roots of the mountain belt. The variation in the orientation of the stress field, together with post-collisional thrusting and folding, would be responsible for the observed geometry and kinematics of the Variscan transcurrent shear zones that would then further be complicated by opaque kinematics: direct NNE-SSW and NW-SE systems, and conjugate sinistral NNE-WSW to ESE-WNW families.

Resumo

Os accidents tecônicas NNE-SSW que afloram o norte Variscano têm sido geralmente considerados como falhas transversais esquerda do tipo de leva a norte, em tempos anti-varisco. Tal não se afigura, contudo, consistente com a sua evolução PT, nem com a orientação esperada para as inferências de compressão máxima (entre NNE e NE) estabelecidas durante os diferentes estágios da Orogenia Variscana. O registro PT sugere um processo evolutivo diferente do encaixe crustal, muito provavelmente associado à recuperação tecônica da Cordilheira Variscana. Se este relato não for acompanhado pela ruptura da Cordilheira Variscana, os dois condicionamento para a descontinuidade do Arquean e subpostos indicados pela assimetria diastotal do domo de relevo da cordilheira mantinham-se. A variação da orientação do campo de stress pode explicar o dobramento pós-colisional derivado da superposição da direção das variáveis norte-sul e easter-southerly, que poderiam ser consideradas como continuas do norte Variscano e do NW-SE, a família conjugada coaxal NNE-WSW a ESE-WNW.

Introduction

In NW Iberia, the Variscan kinematics are cut by a prominent, statistically self-affine, fracture network that comprises distinct families of accidents with a dominant transcurrent movement, whose geodynamic meaning can only be accurately evaluated when both geological mapping in appropriate scales are produced and a multidisciplinary approach is considered in their characterization. A complete evaluation of the geodynamic conditions that favoured the earlier and earlier propagation of this fracture network (usually designated as late-variscan network) must take into account at least two distinct events: (1) the NNE-SSW network must have been active in the late Variscan (e.g., Gutiérrez & Mateus, 1994), and references therein; (2) NW-SE open folding, upwarping or facing outwards symmetrically relative to the granite core of the orogen; (3) late orogenic thrusts verging outwards symmetrically relative to the core of the orogen; and, finally, the late ductile (earlier) to brittle (later) subvertical shear zones. The fracture network can be grouped into distinct families striking close to NW-SE, NNE-SSW, ESE-WNW to E-W, and ESE-WNW.

Recent evaluation of the geometry and kinematics of the above-mentioned shear zones in several domains of NE Portugal, allowed a comprehensive characterization of the late Variscan deformation events, which includes also the available data concerning the PT deformation conditions of the earlier post-collisional granitoid intrusive and the PT evolution of some major transcurrent shear zones (e.g., Mateus et al., 1995, 1996; Mateus et al., 1995). Because Variscan Variscana break was at a high angle to the NW-SE striking of the mountain belt, and will take place sometime prior to c. 210 Ma (the age of evoportite that lie top of Triassic red beds), it is clear that tectonic recovery of the orogenic chain occurred in a nearly confined space. This will induce a particular stress field that enables the uplift of the granite core and, simultaneously, the development late folds and shear zones, as shown by the analogical modelling recently performed in laboratory (Pires & Mateus, submitted). This will favour also a more or less complex evolution of the fault structures: early ductile to semi-ductile shear zones (first stages of the isostatic recovery), grading gradually into brittle, as the crust is exhumed and cooled by uplift. The major goal of the present extended abstract concerns therefore this general geodynamic scenario, focusing in particular the evolution of the most prominent and best studied system of shear zones, i.e., the one of average NNE-SSW direction.
The NNE-SSW transcurrent shear zones

There is usually a clear conformity between the earlier emplaced post collisional granite batholiths and the late Variscan deformation events typified by: 1) polecyclically generated and emplaced batches of anatectic melts, remobilizing distinct mineral formations (and sometimes distinguishing late-magmatic magnetosfomination); and 2) the development of transcurrent shear zones whose trace often controls the geometry of the igneous bodies that comprise the highly deformed granite facies (e.g. Reesy, 1969; Mateus, 1986). Regional, heterogeneous, near-E-W ductile left-lateral shear zones are frequently located at the margin of the earlier emplaced batholiths, denoting the mechanical instabilities caused by the polyphase granite emplacement.

Further deformation appears to be concentrated within thermally (frequently) narrow (<3 mm thick) soft sedimentary bands that regularly establish the contact with the strongly deformed metasedimentary rocks. Strain variations across these tectonic contacts consist either on: 1) cleavage development within intensely deformed strata; 2) gradual changes from regional to local, polyphase, structures; 3) sporadic occurrence of asymmetric folds which are sheared parallel to the cleavage plane; and 4) development of NNE-SSW (locally NE-SW), right-lateral, semi-ductile shear zones which form narrow corridors of intense non-axial deformation, typically conjugate of the ubiquitous left-lateral E-W (on average) shear zones.

When NNE-SSW (NE-SW) shear zones are not subject to late reactivation if brittle regime, the original C-D fabrics are preserved, and microscopic examination of oriented samples reveals the presence of several microstructures attributable to cyclic, continuous-discontinuous yielding mechanisms at the grain scale during presence of late-magmatic fluids under the most probable average P-T conditions of 3.5 kbar and 450-500°C (Bürg & Lauter, 1978; Bédnarz et al., 1979; Ignelzi & Choukroune, 1980; Mateus et al., 1985). The subsequent evolution of these structures records the progressive transition from asthenospheric to sedimentary conditions of deformation, being thus consistent with the continuous uplift that occurred immediately after the earlier post collisional granite emplacement. According to the available data, the earlier seismic events (responsible for the generation of proto-)mylonite rocks occurred in crustal levels of moderate depth (<8-10 km) under temperatures ranging from 300 to 350°C and global pressures lower than 3 kbar. Induced by crustal uplift, most probably isotropic recovery, anomalously for regions and consequent surface anomalies will develop, favoring significant fluid pumping into the NNE-SSW structures in the course of their late development towards wider domains of synorogenic granites and, therefore, enabling the polyphase precipitation of hydothermal siliceous aggregates. Strain concentration fractures tips should thus promote the development of local stress fields that may lead to fracture interaction, securing their coherence before the emplacement period of latest granite bodies (270 Ma); during this general evolution, the geothermal gradient should decrease from an average value of 55°C/km to 40°C/km (Godinho, 1974; Mateus, 1986).

At this point, it should be emphasized that kinematic criteria of earlier diapiric movement of NNE-SSW (to NE-SW) shear cones exist at most places; notable cartographic examples can be found at NE Trás-os-Montes (e.g. shear Zone labelled 1 in fig.1). Note also that the most common characteristics of fault-planes detected along these tectonic accidents are typically related to the fault segments reactivated in the course of the Alpine Orogeny, namely during the kinematic events that took place in Plio-Quaternary times (e.g. Mateus & Barriga, 1987).

Late Variscan shear zones; kinematical analysis

Considering only the late Variscan record, a logical kinematic solution is possible for all families of shear zones present in the Variscan basement of Northern Portugal. NE to NW走向 would be deformed conjugates to the sinistral ENE to ESE fissions, denoting an orientation for Eocene to Pliocene relative movements.

Considering only the early Variscan record, the solution for ENE to WNW orientations among the conjugates may have a simple explanation that takes into account the early development of the vertical transcurrent shear zones. The initial Variscan shearing is correlative of the earliest Variscan folding, since rocks experienced flattening, the earliest structures should rotate, and the initial acute angle between the conjugates should grade into obtuse views. This is clear for the ESE-WNW (older, ductile to semi-ductile, and rotated sinistral conjugate) and ENE-WSW (younger and non-rotated sinistral conjugate) systems. Unfortunately, the relative chronological relationships between the NNE-
SSW and NW-SE families are not so obvious, regardless the common ducile corridors related to the latter shear zones. If the NW-SE system predated the development of the NNE-SSW shear, then they could all result from the same stress field (ENE to NE). Otherwise, a more elaborate solution is required, i.e., that the rotation of σ1 occurred during or immediately after the deformation regime change from transpressional (oblique E-W collision - Dias & Ribeiro, 1991) to pure shear (confined isostatic recovery) by the end of the Variscan Orogeny. In this perspective, σ1 thould lie near ENE during the initial stages of late Variscan evolution, rotating subsequently towards NE (fig. 2). During this gradual rotation, the relative chronology inferred for the ESE-WNW and ENS-WSW systems remains valid and an elegant explanation for the development of thicker and longer quartz infillings along NW and NE shears is achieved. Therefore, the reactivation of NNE-SSW structures as left-lateral strike-slip faults should have occurred mainly by Moscovian (post-Caledonian) times, under a regional stress field characterized by regional compressive trajectories near N-S.

Conclusions

The laterally continued isostatic recovery of the Variscan chain enabled the uplift of the granitic Variscan massifs, and, simultaneously, the development of late faults and shear zones, favouring also a more or less linear evolution of the latter structures: early ducile to semi-ductile shear zones (first stages of the isostatic recovery), grading gradually into brittle, as the tectonic isostatically and cooled by uplift. The age, geometry and early kinematics of folds and of all the shear zones are compatible with a stress field with σ1 striking between ENE and NE. A possible rotation of σ1 from ENE, typical of the final stages of the Variscan oblique collision, towards NE in the latest stages of the isostatic recovery, should be considered in order to explain some of the characteristic features exhibited by the most common shear-zones that form this typical late Variscan network and that were not subsequently reactivated; discordant NW-SSW and NW-SE systems, and conjugate sinistral ENE-WNW to ESE-WNW families.

This tectonic network in NW Iberia is clearly asymmetric and the prevailing system, displaying an average NNE-SSW direction, records a long and complex evolution, being slightly more developed in the area of the Variscan Orogeny until recent times (Dias & Ribeiro, 1994). According to the available results, the whole geometry and relative extension exhibited by these structures are mainly due to their late reactivation as left-lateral strike-slip faults in Alpine times, under a regional stress field characterized by regional compressive trajectories near N-S. 

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References

Fig. 1 - Sketch map with late Variscan finite, main faults and emplaced plutons, granitic core of the mountain belt in NE Portugal. Contact metasediments. Tectonic zones marked with 1 and 2 have the same geometry but opposite kinematics; shear zone 2 has taken up all the Alpine tectonic movement, while shear zone 1 preserves the late Variscan dextral kinematics.

Fig. 2 - Cylindrical representation of the mean azimuths of shear zone families, and rotation of both shear zones and maximum compressive stress during Variscan late-to-post-collisional stages.