A MODEL FOR THE EMPLACEMENT OF THE SERRA DA FREITA GRANITE IN THE GEOTECTONIC CONTEXT OF THE CENTRAL IBERIAN ZONE

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TRABAJOS DE GEOLOGIA

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El granito de Serra da Freita, en la parte central del norte de Portugal, se encuentra dentro de una importante zona de cizalla sinistral que forma parte del sistema de cizalla de Coimbra-Córdoba. La cartografía detallada permite establecer las estructuras asociadas al desarrollo de la zona de cizalla así como la forma del plutón. Se propone un modelo de emplazamiento que relaciona la geometría del plutón con la situación tectónica en que tenía lugar la intrusión. Este estudio se sitúa en un contexto más general con referencia a estudios similares en áreas próximas.

Palabras clave: Granito, Zonas de cizalla.

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The Serra da Freita granite in north central Portugal lies within a major sinistral shear zone, part of the Coimbra-Cordoba shear system. Comprehensive mapping enables structures associated with shear zone development to be recognized and the overall shape of the pluton to be established. An emplacement model is proposed which combines ideas about pluton geometry with the structural setting into which it was intruded. The study is placed in a more regional context with reference to similar work in an adjacent area.

Key words: Granite, Shear zone.

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Structural analysis combined with petrographical and geochemical studies of granites can help to characterize plutonic style. This work shows that correlations of such styles is possible over large areas within one terrane (the Central Iberian Zone). Such an approach may lead to the tectonomagmatic characterization of terranes.

REGIONAL SETTING

The Iberian Arc and the Armorican Massif constitute the Ibero-Armorican Arc, interpreted in terms of continent-continent collision in the Upper Palaeozoic (Matte and Ribeiro, 1975). Two major shear zones delimit this arc (Fig. 1a), the dextral South Armorican (Berthe *et al.,* 1979) and the sinistral Coimbra-Cordoba (Burg *et al.,* 1981). Iberia, lying between these shear zones, is divided into several tectonic zones (Julivert *et al.,* 1972), (Fig. 1b).

Workers in the Central Iberian Zone have reported very similar structural styles in several areas (Iglesias and Choukroune, 1980; Castro, 1985). These are characterized by (i) a clear correspondence between deformation in granitoids and the D2 peak, and (ii) the devel-

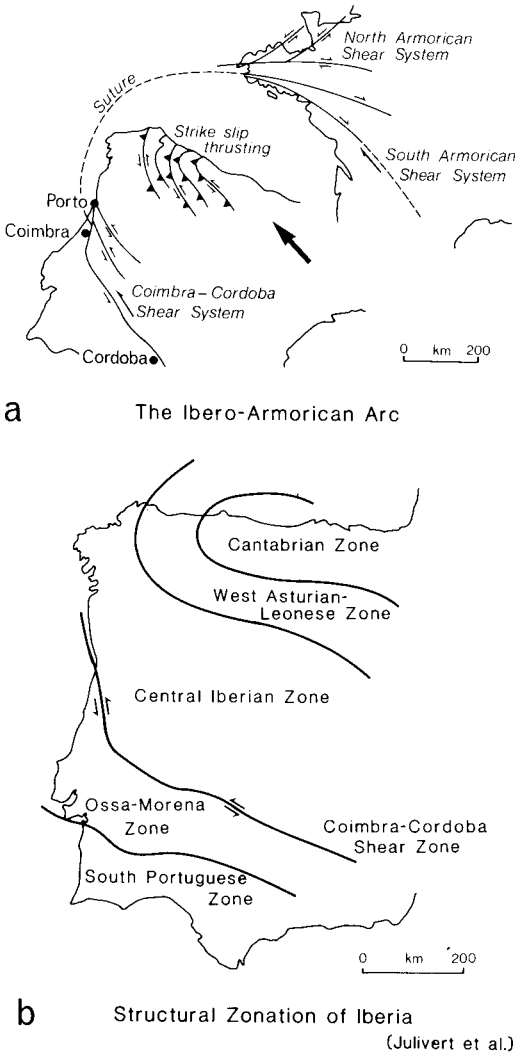

Fig. 1.–a) The Ibero-Armorican Arc showing the positions of the Coimbra-Cordoba and the South Armorican shear zones within this system. b) The structural zonation of Iberian showing the Coimbra-Cordoba shear zone.

opment of C-S fabrics (Lister and Snoke, 1984) which indicate strong components of non-coaxial flow.

The Serra de Freita granite discussed here was intruded into the newly recognized Serra da Freita shear zone, which could be related to the Coimbra-Cordoba sinistral shear-zone (Fig. 2).

LOCAL GEOLOGY

The Serra da Freita is a well exposed plateau approximately 1,000 m above sea level in north central Portugal, situated 5 Km south of Arouca. The country rocks are the Precambrian/Cambrian Beira Schists which crop out over much of northern Portugal; the Serra da Freita pluton is one of a voluminous suite of hyperaluminous leucogranites which are generally regarded as coeval with the main phase of the Hercynian orogeny. The pluton lies in the linear Porto-Viseu metamorphic belt characterized by the presence of a high temperature, low pressure paragenesis of biotite, andalusite, staurolite, and silliminite and a general lack of almandine and kyanite (Fig. 2). The regional geology is described by Pereira *et al.* (1980).

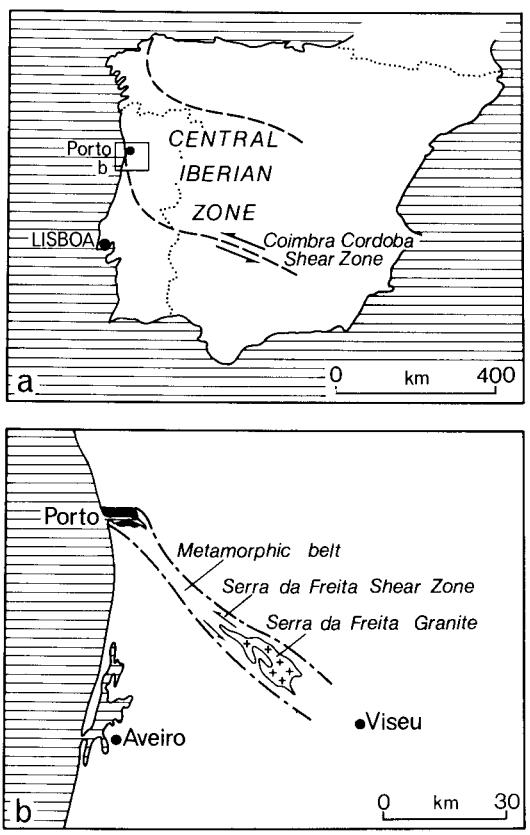

Fig. 2.–The location of the Serra da Freita granite within the Serra da Freita shear zone along the axial region of the Porto-Viseu metamorphic belt.

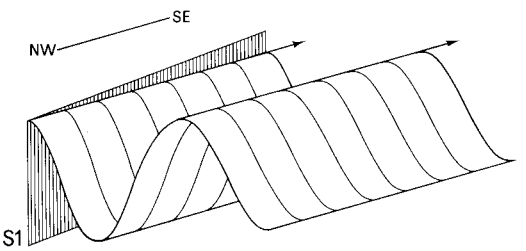

Fig. 3.–F1 fold style.

DEFORMATION

Detailed structural analysis shows the relationships between folding, cleavage, shear zone development and plutonism. The distinction of separate «deformation events» (i.e. D1, D2 ...etc.) within this area tends to be misleading as too rigourous adherence to such a scheme conceals the essential fact that one is dealing with a continuum of deformation, in this case associated with the protracted development of a shear zone.

Early Structures

The first structures recognized are gently SE-plunging upright, or slightly overturned folds (F1), with an associated axial planar slaty cleavage (S1), (Figs. 3 & 4). Their influence on the form of the granite body will be discussed subsequently.

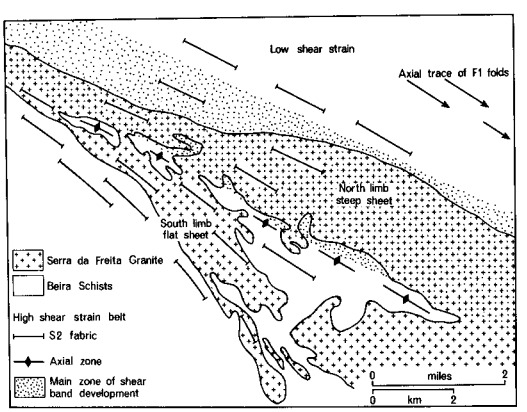

Fig. 4.–Geological sketch map of the Serra da Freita showing the relationship between the granite and its envelope with the main structures discussed in the text.

Shear Zone Structures

Structures formed during the main period of sinistral transcurrent movement are present throughout the area. However, a boundary can be traced along the regional strike south of which strain greatly intensifies (Fig. 4), the Serra da Freita pluton lies within this zone of high shear strain.

Low strain field.–The structures developed at low strain are confined to the northernmost region of the Serra da Freita (Fig. 4). Here F2 folds are moderately to steeply inclined with a penetrative axial planar schistosity (S2), (Fig. 5).

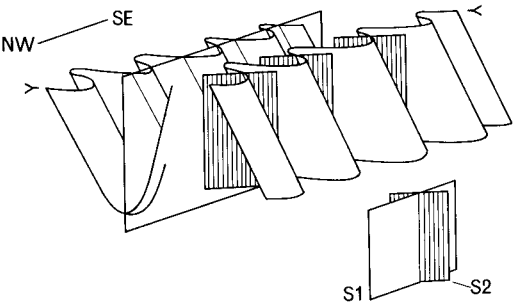

Fig. 5.–F2 fold style formed at low shear strain.

High strain field.–The Serra da Freita granite is intruded into the high strain belt which extends across strike for approximately 6 Km (Fig. 4). S2 in the schists is approximately vertical, with only minor changes in strike over many kilometres caused by intensification and steepening of the fabric within the NW-SE Serra da Freita shear zone (Fig. 6). S2 in the southern limb of the granite is a primary magmatic foliation defined by the preferred orientation of phyllosilicates and feldspars. An associated stretching lineation plunges gently to the north-west and implies transcurrent motion with a component of transpression. Evidence from tension gashes, boudinage and porphyroblast rotation imply a sinsistral direction of translation in the shear zone. F1 and F2 geometry are similar to those described from the Extremadura region (Castro, 1986, page 641, Figure 13), although in the latter case the sense of shear and S2 vergence is dextral.

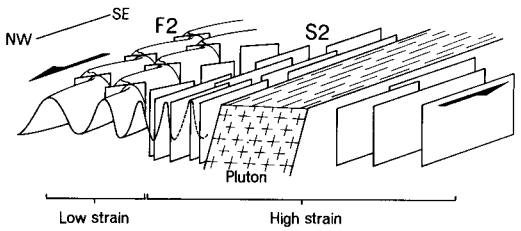

Fig. 6.–Diagrammatic sketch showing the modification of existing structures by increasing shear strain.

Development of ductile shear bands – C-S fabric.–Progressive deformation is marked by the appearance of ductile shear bands which increasingly affect the earlier S2 foliation. These structures occur in a 3 Km wide belt which involves the northern limb of the granite and the schists beyond it (Fig. 4). The C surfaces are small-scale, parallel ductile shear bands recognized in the field as an extensional crenulation cleavage, S2a. These shear bands are generally anticlockwise to the main S2 fabric and show a sinistral sense of displacement (Fig. 7). Its effects become less marked to the south; however, a southern limit to its development cannot be precisely defined. During this phase of the evolution of the shear zone, sinistral transcurrent movement continued, but in a more restricted zone adjacent to the northern contact of the granite.

Late Structures

Tight folds recorded in the schists to the north and south of the granite have axial planar crenulation cleavages (S3) which clearly overprint S2. On the northern side of the granite, S3 dips steeply NE and F3 shows dextral vergence; south of the granite, S3 is inclined to the NW (Fig. 8) and the sense of F3 vergence is sinistral. These structures are interpreted as a conjugate set of crenulations produced by late brittle deformation.

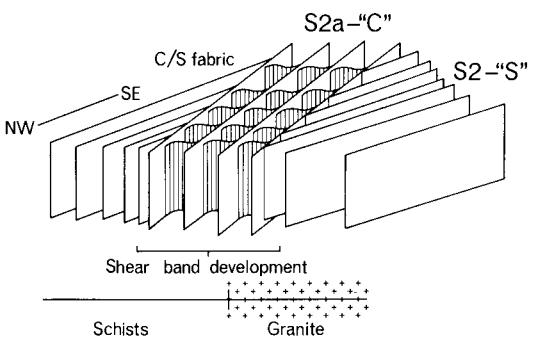

Fig. 7.–The geometry of sinistral shear bands producing a C-S fabric.

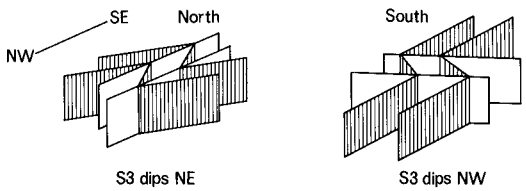

Fig. 8.–Late brittle structures recorded as a conjugate set of crenulations north and south of the granite.

THE STRUCTURE AND EMPLACEMENT OF THE SERRA DA FREITA GRANITE

Pluton Structure

The intrusion shows an apparent symmetry about a strike-parallel axis which divides it into a northern and southern limb shown diagrammatically in Fig. 4. Along this axial zone, the granite overlies the Beira Schists, and in places the contact is almost horizontal, closely following the contour. The northern limb of the granite comprises a steeply inclined sheet which becomes less steeply inclined southwards into the more diffuse southern limb, the granite of which shows complex sinuous contacts with the schists beneath it. A model involving a root zone in the north with flattening towards the south explains the regularity of shape of the northern limb, while the lobate nature of the southern limb and its apophyses can be explained as a cross-section through the base of an undulating but essentially flat-lying sheet. Gently inclined contacts between the granite and the schists beneath demonstrate that an interpretation in which the southern half of the granite consists of subvertical apophyses rooted downwards is not feasible. The cross-section shown on Carta Geologica de Portugal, 1:50,000, Folha 13-D depicts the belt of schists west of Albergaria das Cabras as country rock in a roof pendant situation, the Serra da Freita pluton is shown

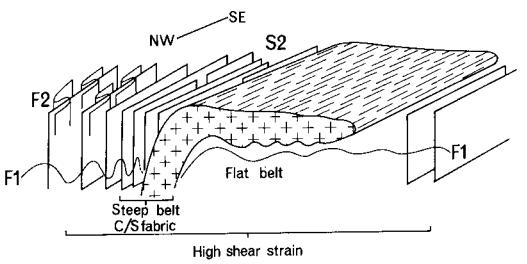

Fig. 9.—Diagrammatic sketch of the emplacement model envisaged for the Serra da Freita granite within the shear system, and its relationships with structures discussed in the text.

as a simple steeply inclined sheet dipping north. However at Albergaria das Cabras, for example, sub-horizontal contacts are well exposed and such a simplistic interpretation is inconsistent with the field data, a summary of which is presented here. The apophyses of the southern limb are, however, continuous with the granite in the northern limb which is rooted downwards.

Tectonic Controls on Emplacement

The granite is inferred to have been intruded into a regime of nearly upright gently plunging F1 folds which may have strongly influenced its overall geometry – the axis about which the pluton shows apparent symmetry is a possible major F1 hinge zone. Emplacement of an inclined sheet took place along an active transpressive shear zone and gravity combined with F1 geometry produced a folded but essentially flat sheet over much of the granite. The main magmatic fabric (S2) present in the southern limb was produced by deformation of a viscous crystal mush during emplacement. As crystallization proceeded, further shortening across the shear zone intensified the fabric and accentuated folding in the flat sheet. The present form of the granite body (Fig. 8) was therefore achieved by a combination of intrusion into folded strata and by shortening and deformation of the consolidating magmatic body. Prolonged shearing responsible for the C-S fabric in the northern limb steepened this part of the intrusion and produced the steep belt towards the end of the shear zone history.

REGIONAL CORRELATIONS AND IMPLICATIONS

This paper presents a model for the relationships between tectonism and plutonism in one part of the Central Iberian Zone. Although the overall sense of shear is dextral, Castro (1985) notes that in Extremadura, F1 folds have vertical axial planes and that the second phase of deformation «consists of shear zones and thrust faults associated with granitic plutonism». It is of particular interest that the Santa-Cruz pluton in Extremadura shows similar geometry to that of the Serra da Freita granite: a steeply inclined granite sheet where deformation is concentrated which is continuous with a less deformed part of the pluton where contacts between the granite and the envelope tend to be gently inclined (Castro, 1986, page 641, Figure 12). In the light of recent discussions about the kinematics of Hercynian deformation in the Central Iberian Zone (Martínez-Catalán & Díez-Balda, 1987) this work hopefully makes a contribution towards regional interpretation.

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