Interplate versus intraplate strike-slip deformed belts: examples from SW Iberia Variscides


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Abstract: A complete transition in tectonic style between pure thrust belts and pure strike-slip belts can be envisaged, both in interplate and intraplate settings, by a combination of thrust and strike-slip components of displacement. The accommodation of shortening components in strike-slip deformation belts has been discussed recently on the basis of two alternative perspectives: (1) the “sub-horizontal attachment model”, where discrete strike-slip faulting of rigid blocks in the schizosphere evolves to continuous movement in plastosphere through a bottom-up driving mechanism controlled by vertical coupling across the lithosphere, and (2) the “accommodation model” that considers decoupling within a heterogeneous and anisotropic plastosphere. Two examples of variable shortening component accommodation in strike-slip deformation belts of the SW Iberia Variscides are reported and discussed. In the Tomar-Badajoz-Córdoba shear zone, an important shortening component is accommodated in flat-lying bends around the horizontal axis within a WNW-ESE flower-structure with sinistral strike-slip component; the geodynamic evolution points to an intraplate setting for this structure. In the N-S, Porto-Tomar-Ferreira do Alentejo, dextral shear zone, the shortening component is restricted to restraining bends around the vertical axis; the geodynamic evolution allows inferring a transform nature for this structure, thus indicating an interplate setting. For these examples, the “accommodation model” is preferred to the “sub-horizontal attachment model”.

Keywords: interplate/intraplate strike-slip deformed belts, kinematics deep structure, vertical coupling/decoupling regimes, SW Iberia Variscides.

Strike-slip deformation belts (SSDB) develop not only at plate boundaries as transform faults, but also in intraplate settings. They have been studied intensively in the last years, both in domains of active tectonics (Teyssier and Tikoff, 1998) and old orogens (Dewey et al., 1998; Storti et al., 2003). Transform faults connect divergent or convergent plate boundaries that can be characterised on the basis of structural and geodynamic criteria. Interplate SSDB connect divergent or convergent intraplate (extended or compressed) belts and, as conjugate belts, contribute to the internal shortening across the orogens and to their arcuate patterns.
The kinematic evolution compatible with dynamic plate tectonics regimes along plate boundaries zones and in intraplate orogens requires that transforms and SSDB should evolve in order to integrate components of convergence (in transpression regimes) or divergence (in transtension regimes), including partitioning of slip and strain. This raises the question of accommodation of dip-slip components of convergence in thrust (transpression) or extension in normal faults (transtension), thus leading to the concept of vertical coupling/decoupling in SSDB and their possible combination as coupling/decoupling modes. In interplate settings, the SSDB total vertical coupling transects the entire lithosphere; partial vertical coupling will be discussed below.

Studies performed in active transforms, namely at the San Andreas Fault, led some authors (Molnar, 1992; Tikoff and Teyssier, 1994; Bourne et al., 1998; Teyssier and Tikoff, 1998) to propose a model where distributed strike-slip faulting across the whole width of the plate boundary movement zone (expressed by geodetic data) passes downward, in the plastosphere, to a continuous ductile shear zone of similar width. On this basis, some authors inferred the presence of sub-horizontal attachment zones accommodating the bottom-up transition from the continuous movement at depth to the discrete strike-slip faulting of rigid blocks in the schizosphere (Tikoff et al., 2004). Models of strain distribution have also been proposed and their results could be used as diagnostic criteria for paleo-transforms in deformed belts (Teyssier and Cruz, 2004).

Other authors (Handy et al., 2005) suggested an alternative model and speak of accommodation zones, where specific deformation mechanisms are active, based on the idea that “weakening and intracrustal decoupling in the viscous crust do not preclude the vertical transmission of normal and shear stresses through the lithosphere” if decoupling is heterogeneous and anisotropic. Such accommodation zones could therefore exist inside the plastosphere and not only at the schizosphere-plastosphere boundary.

Methods

The geodynamic significance of the two SSDB addressed in this paper—the Tomar-Badajoz-Córdoba shear zone (TBCSZ) and Porto-Tomar-Ferreira do Alentejo shear zone (PTFASZ)—must be approached by two independent, though complementary, methods: 1) kinematics and strain analysis of these structures, and 2) seismic imaging of their continuation to depth. Definitive evidence for discontinuity of reference material surfaces eventually displaced by the SSDB and strain distribution must be analysed with caution because, as referred to above, they lead to the controversy between the attachment vs. accommodation zones interpretation. Seismic imaging can only be used in the case of the TBCSZ, because no deep profile exists across the PTFASZ (Fig. 1).
Analysis and results

The major, sinistral TBCSZ corresponds to a transpressive flower-structure located near the Ossa Morena Zone (OMZ)-Central-Iberian Zone (CIZ) boundary (Ribeiro et al., 2007) (Fig. 2). The TBCSZ axial zone (also known as the Axial or Central Unit) is a steep belt, comprising migmatitic ortho- and paragneisses, as well as several amphibolitised eclogite lenses (Simancas et al., 2003). These rocks preserve Cadomian igneous/metamorphic ages (Salman, 2004) and were affected by early Variscan partial melting (in exposures scattered all along the steep axial zone between Crato, west of Portalegre, and SE of Azuaga) related to Lower Paleozoic extensional events. All these features indicate that the high grade rocks preserved inside the TBCSZ represent the reworked Cadomian basement, which was intruded by bimodal rift-related batholiths, with alkaline and inherited calc-alkaline signatures of Lower Paleozoic age.

In the Hinojosa del Valle-Hornachos sector (Burg et al., 1981; Azor, 1997), which was imaged in the IBERSEIS profile (Simancas et al., 2003), the Central Unit steep-structure is replaced by a complex arrangement corresponding to an attachment or accommodation zone. Indeed, from SW to NE, one could observe: 1) the gradual bend of the steep sinistral belt (Central Unit SW margin) to flat-lying foliation domain with top-to-NW shear sense criteria, compatible with the sinistral strike-slip regime, 2) a narrow axial fault zone controlling the development of a Culm basin with a basal conglomerate that includes previously foliated metamorphic pebbles, 3) a flat-lying domain with top-to-SE shear sense criteria, also compatible with the sinistral strike-slip regime in the steep Central Unit NE margin, and 4) the Hornachos fault zone separating the Central Unit from CIZ, characterised by flat-lying axial plane cleavage of recumbent folds facing NE with longitudinal stretching (sub-parallel to the b kinematics axis).

The narrow width of the axial fault zone is not compatible with the strain model for attachment zones as proposed by Teyssier and Cruz (2004), but it should correspond to an incoherent strain boundary (Cobbold et al., 1984); it controls the development Culm basin, besides its subsequent folding as a transpressive sinistral syncline. Consequently, the model of a brittle precursor and broadening to a shear zone (Mancktelow, 2008) is favoured for the TBCSZ nucleation/propagation, valid also for the Hornachos marginal brittle fault. Thus, the concurrent brittle faulting and ductile shearing in the surrounding subs-
zone of concentrated deformation, triggered by predominant strike-slip dextral movement, whose variable width depends on the exposed structural level (≈10 km and ≈2 km in lower and shallow levels, respectively). The PTFASZ is generally straight with the exception of the restraining bend of Oliveira de Azeméis, 30 km SE of Porto, where a significant component of thrusting to south and SW (placing CIZ over the Finisterra Plate) was mapped recently (Romão et al., 2006).

The Finisterra Plate is composed of Neoproterozoic polymetamorphic sequences, very similar in content to those of OMZ to the SE. The composition of some metaconglomerate horizons in the upper part of the slate/greywacke complex in CIZ (Cambrian age) strongly suggests that the Finisterra Plate was the source zone of the clastic sediments towards the Iberian Terrane and implies that both domains were geographically close at the beginning of the Variscan Wilson cycle, before the main plate displacement along the PTFA Transform occurred (Ribeiro et al., submitted). Based on the sigmoidal trajectory of syntectonic granitoids placed along the transform on the eastern side, the dextral displacement accumulated under ductile regime conditions is estimated to be 70±10 km (Ribeiro et al., 1980). Further displacement, developed in brittle regime, must be added; these were accumulated mostly between the Upper Carboniferous and the Lower Permian, when the shear zone kinematics changed from strike-slip to dip-slip (Ribeiro et al., 2007). The existing geophysical (gravimetry and magnetic) data points to a sharp contrast between the two plates separated by the PTFA transform.

Discussion

The geodynamic significance of the two SSBD studied in SW Iberian Variscides can now be evaluated, it being useful to firstly discuss the mutual geometrical relationships between both shear zones. The interference domain between PTFASZ and TBCSZ (SW of Abrantes, figure 2) was recently mapped and leads us to the conclusion that the former shear zone cuts the latter, suggesting a deeper continuity for the first. Kinematical features are also different, PTFASZ having a transform geometry similar to the Trinidad type (Tikoff et al., 2004) where the plate movement is parallel to the plate-boundary (absolute reference frame) and there is coincidence between the lithospheric and asthenospheric boundary, expressing total vertical coupling; this is expressed by both the straight trace of the plate-boundary and by the restraining bending of Oliveira de Azeméis, around the vertical axis. TBCSZ is a transpressive flower-structure with an important compression component across the shear zone, implying the presence of accommodation or attachment zones required by the convergence of two walls represented by thrusts with opposed vergence on both sides of the shear zone. This structural configuration is more similar to the San Andreas type of transform kinematics (Tikoff et al., 2004) with movement oblique to the boundary of the two blocks involved, expressing partial vertical decoupling. This interpretation, supported by the seismic imaging of IBERSEIS
profile (Simancas et al., 2003), is also consistent with a deeper continuity origin for PTFASZ in comparison with TBCSZ.

The interplate nature of the PTFASZ vs. the intraplate nature of the TBCSZ is supported firstly by specific criteria with regard to their kinematics and deep structure and, secondly, by the global framework of their geodynamic evolution during the Cadomian and Variscan Wilson cycles in the SW European Variscides (Ribeiro et al., 2007). In fact, the decay to null value of strike-slip displacement in the NW tip of TBCSZ (SW of Abrantes), due to interference with the active transform displacement across the PTFASZ, remains unexplained in the interplate model for TBCSZ. Nevertheless, it is compatible with intraplate oblique slip in an inherited deep structure by strain partitioning between dip-slip and strike-slip components. This intraplate oblique slip was triggered by the oblique subduction of SPT below OMZ along the SW Iberia suture, whose complex evolution will be the subject of a future publication, although the main thoughts are reported in Ribeiro et al. (2007, 2008).

The history of displacement and its geodynamic significance are distinct in the two SSBD. According to recent geodynamic reconstructions (Ribeiro et al., 2007, and references therein), PTFASZ plays the role of transform, at least since Cambrian until Lower Permian, therefore being related to the opening and closure of the Paleotethys Ocean inside the Armorica-Iberica assemblage and to the closure of the Rheic Ocean between Iberia and Avalonia. TBCSZ seems to obliterate part of a Cadomian suture (Ribeiro et al., 2007; Ribeiro et al., submitted) that evolved into an intra-cratonic rift (aborted at the end of Cambrian), further reworked as an intraplate SSDB during the Variscan orogenesis (Fig. 3). The N-S dextral displacement across PTFASZ is, in fact, compatible with NW-SE shortening in the TBCSZ during convergent regime and NW-SE transtension prior to the divergent regime. During geodynamic evolution, displacements accumulated along TBCSZ are compatible with those in PTFASZ, being controlled by the plate boundary motion during the entire Variscan Wilson cycle. This model includes a small component of extension in PTFASZ that possibly plays the role of a “leaky transform” near the Cambrian-Ordovician boundary (Ribeiro et al., 2007).

![Figure 3. 3D interpretative block diagrams of kinematics and TBCSZ deep structure at the Hinojosa del Valle-Hornachos sector. A) Pre-Culm stage: in the SW branch of the SW TBCSZ (OMZ) the shear sense is top-to-NW; in the NE branch the shear sense is top-to-SE; central brittle fault, B) post-Culm stage: Azuaga fault (A), Hornachos fault (H), Matachel fault (M) and IBERSEIS reflective body (IRB) (Simancas et al., 2003). The upper crust of OMZ and CIZ is gray-shaded.](image-url)
Conclusions

TBCSZ and PTFASZ are two major SSDB with distinct geometry and kinematics whose understanding is critical to a complete reasoning of the geodynamic evolution experienced by the SW Iberian Variscides. TBCSZ obliterates, at least in part, a Cadomian suture and acted as an intraplate SSDB during Variscan times; the shortening component of deformation is accommodated in flat-lying bends around the horizontal axis within a WNW-ESE flower-structure with sinistral strike-slip component. PTFASZ corresponds to a foremost Variscan interplate transform, running N-S and blocking the TBCSZ propagation towards the NW; for this central shear zone, the shortening component is confined to restraining bends around the vertical axis. Thus, the accommodation of shortening components in both SSDB can be ascribed to decoupling within a heterogeneous and anisotropic plastosphere, which means that the “accommodation model” is preferred to the “sub-horizontal attachment model”.

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References


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