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OROGEN-PARALLEL TECTONIC TRANSPORT DURING CONTINENTAL COLLISION. EXAMPLES AND MODELS

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Kinematic analysis of ductile deformation in terranes amalgamated during continental collision has stressed that orogen-parallel displacements commonly occurred at some stage of the tectonic evolution (e.g. see review in Vauchez and Nicolas 1991). Although the geometric and kinematic patterns produced by such deformation may be very similar, they reflect very different lithospheric behavior and geodynamics from belt to belt. Three orogenic belts of different ages in which orogen-parallel displacements have accomodated a large part of the lithospheric deformation are described below. In each case: 1) collision between two continental plates is regarded as the main geodynamic process responsible for mountain building, and 2) pieces of the upper mantle or of the lower crust give information on the general behavior of the lithosphere.

The Brasiliano/Pan-African Dom Feliciano belt (DFB, southeastern Brasil) developed during a long-lasting convergence of the Kalahari craton (South Africa) and the Rio de La Plata craton (South America; Porada 1979; Fragoso-Cesar 1980). The tectonic evolution of this belt (Tommasi and Fernandes 1990, Fernandes et al. 1991) involves: 1).development around 850 Ma of an early magmatic arc and of a back-arc basin on the margin of the South American plate , 2) collision between this magmatic arc and the Kalahari craton, and 3) during the Brasiliano/Panafrican orogeny (ca. 600 Ma), closure of the back-arc basin resulting in the development of a late magmatic arc and finally in the tectonic incorporation of upper mantle peridotite within the crust. From a kinematic point of view, the DFB is characterized by tectonic transport of terranes normal to the trend of the belt during the early stages of its evolution. Following the suturing of the two continents, orogen-parallel movement associated with granitoids emplacement became dominant, especially within the eastern, more internal, domain of the orogen. The peridotites although largely retrogressed during the late stage of deformation, locally retain evidence of an early high-temperature lithospheric flow tranverse to the belt. Evidence of this history has been totally erased in the surrounding crustal rocks by later events.

The Southern Appalachians were formed on the eastern margin of the North American plate during late Paleozoic time as a consequence of the convergence of Laurentia and Gondwana. Several micro-plates, originally situated outboard of the eastern margin of Laurentia, were squeezed between the two continents and form a complex assemblage of exotic terranes of different age and nature (see review by Dallmeyer 1991). The kinematic pattern reflects a long-lived transpressional convergent margin. It is characterized by a systematic partition of tectonic displacements into movements respectively transverse in the western and central domains, where possible remnants of oceanic crust have been incorporated into the continental crust assemblage, and longitudinal in the eastern (more internal) domain (Vauchez, 1991). Strain partitioning occurred during successive early and late Carboniferous tectonothermal events. At each stage, the location of transverse and longitudinal motions was similar, although the evolution of the thermal regime in the different domains was significantly different.

The Betic Cordillera of southern Spain formed during the Miocene Alpine orogeny as a result of the convergence of Eurasia and Africa that ended with the collision of the Iberian, Alboran and African plates. During the main collisional stage, large masses of peridotite resulting from earlier rifting were incorporated into the continental crust of the internal domain. Although the Betic Cordillera has been considered as a classical example of thrust and nappe tectonics, recent studies of the ductile deformation in the internal domain point out that the kinematics during the continental collision was dominated by orogen-parallel motions (see review in Vauchez and Nicolas 1991). Moreover a detailed study of the Ronda peridotite massif (Tubia and Cuevas 1986) has clearly shown that an asthenospheric flow direction parallel to the Iberian plate boundary, recorded during the rifting stage,was followed by a lower but still high temperature (>900° C) lithospheric flow which accomodated orogen-parallel displacements during the continental collision. The kinematic pattern in crustal rocks of the internal domain, both immediately adjacent to the peridotite and exposed far from these massifs, is in close agreement with longitudinal movements during the main high-temperature metamorphism. Finally, it should be noticed that an early high-pressure/low-temperature metamorphic event has been characterized in the internal domain, suggesting that rapid crustal loading occurred during the first stage of the collision, probably related to the integration of the peridotite into the continental crust.

These three examples display some similar trends of evolution, but also significant differences. The main similarities are: 1) a preferential localisation of longitudinal movements within the internal part of the belt where a greater crustal thickening may be expected. This suggests a possible link between the buoyancy forces developed in response to crustal thickening and the initiation of orogen-parallel displacement, and 2) a complex geometrical pattern of the shear zones which have accomodated belt-parallel movement; with partition of this movement in flat-lying and steeply dipping strike-slip faults, both types trending parallel to the structural grain. However, the timing of orogen-parallel displacement during the tectonic evolution, and the tectonic process responsible for the introduction of mantle rocks in the crust differ widely from belt to belt. In the Dom Feliciano belt, the integration of the peridotite to crustal formations was related to tranverse thrusting due to the closure of the marginal basin; orogen-parallel movement became dominant only after this late evolutionnary stage and probably represents an intracontinental deformation. In the southern Appalachians, orogen-parallel motions occurred at each stage of the evolution in association with tranverse motions that are responsible for the introduction of pieces of oceanic crust in the continental assemblage during the early stages of the evolution. In the Betic Cordillera, longitudinal motion occurred even before the collision during the pre-orogenic rifting stage, and was dominant at the time of the addition of the peridotite to the orogenic assemblage.

Finally, the occurrence of orogen-parallel movement at some stage of a continental collision is a very common event. Different evolutions may lead to this situation depending on the angle of convergence between the continents, and the structure and the geometry of the continents margin. Satisfactory geodynamic models require the integration of kinematic data for each stage of the tectonothermal evolution into a self-consistant mechanical system. Special attention should be devoted: (1) to kinematic data giving clues on the process that led to the incorporation of mantle rocks to the orogenic assemblage, since they usually reflect <the lithosphere behavior for at least a part of the orogen, and (2) to the seismic anisotropy

that likely reflects the large scale deformation fabric of the frozen upper mantle developed during orogenic processes.

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