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Origin of intraplate deformation in the Atlas system of Algeria: from Jurassic rifting to Cenozoic-Quaternary inversions

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Based on the analysis of data from petroleum exploration and a compilation of available paleostress data, this paper aims to discuss the origin of deformation observed in the western and central Saharan Atlas, which is an intraplate foreland fold-thrust belt fringing the Sahara platform. From a general point of view, this intraplate area has recorded the break up of Pangea (upper Triassic), the opening of the Maghrebian Tethys (since the Dogger) and then its closure (Tertiary to present).

However, we show that the Atlas build up occurred during two phases of Late Eocene and Pleistocene-Lower Quaternary ages respectively. These phases are distinct and do not represent end points of a progressive deformation. The development of the Tell accretionary prism, bounding the Mediterranean sea, occurred during Oligocene and Miocene times (i.e., between the two steps of the Atlas building) and is related to subduction rollback of the Maghrebian Tethys. The accretion of this prism to Africa at 18–15 Ma did not generate far stress field in Africa.

So the two periods of strong coupling between Europe and Africa, which correspond to rapid uplifts of the Atlas system, are not collision-related. They can be correlated to the beginning and the end of the development of the western Mediterranean sea (i.e., to the initiation and the cessation of the subduction processes active in the western Mediterranean region).

The use of features of foreland basins to constrain the development of the adjacent orogenic edifices

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The history of foreland basins can provide important insights into the development of the adjacent orogens, e.g., the progress of emplacement of orogenic wedges over the foreland and changes in the taper angle of the wedge. This can supplement the often fragmentary record provided by the complex and incompletely preserved internal parts of orogens. This also applies to depressions (e.g., flysch basins) that form in front of major nappes during stacking of orogenic edifices. Such information should, whenever possible, be incorporated in the interpretation of mountain belts.

The simplest situation is that of flexural basins in front of wedge-shaped loads that advance over an otherwise undeformed foreland. Many studies have shown that in this case at any given moment the deepest part of the basin is located next to the edge of the load, while the basin depth depends on the shape of the load and on the flexural strength of the foreland. This allows, using the migration of the deepest part of the basin and the history of basin subsidence, to gain a better understanding of the relative roles of displacement of orogenic loads and changes in their cross sections.

The situation becomes complicated when the foreland and/or the basin fill are deformed and thrust/fold complexes develop in front of the main orogenic wedge, which thickens the rock pile overlying the foreland. This is equivalent to an extra load, in addition to the main tectonic wedge, but the tectonic thickening actually fills at least a part of the frontal flexural depression. Modelling shows that the net effect is that hardly any space is left for sediment accumulation, despite the advance of the orogenic load over the foreland. Identification of such situations provides insights into the late stages of emplacement of orogenic edifices over the foreland.

Early-Variscan collision and generation of leucogranite melts in the Western Tatra Mountains (S-Poland, W. Carpathians)

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Collisional granites, especially leucogranites, are important elements in the orogenic process and markers of the collisional zones. In the Western Tatra Mountains crystalline basement two structural units could be distinguished: Lower Structural Unit (LSU) and Upper Structural Unit (USU), differing in metamorphic conditions. LSU is formed by mica schists intercalated with the amphibolites ($T = 545–584$ °C; $P = 5–8$ kbar), whereas USU is composed of migmatitic gneisses and amphibolites, graphite quartzites and orthogneisses ($T = 640–780$ °C; $P = 7–9$ kbar). Rocks of LSU are present on both S- and N-sides of the basement, but they differ from each other. Mentioned units form together the inverted metamorphic zonation (Janak 1994, Gawęda and Kozłowski, 1998).

On the N-side of the W-Tatra metamorphic basement the shear zone was established, dipping to SE and deforming the S1 foliation by the younger S2 foliation. The shear zone and fold axes inside the deformed USU were intruded by small leucogranite bodies (called traditionally alaskites). On the S-side of the W-Tatra metamorphic basement the shear zone dipping to NW is present, intruded by the Main Tatra composite granitoid pluton (Kohut and Janak, 1994). Leucogranites were probably older than the Main Tatra Granite (Gawęda et al. 1999). They are fine-grained, poor or lacking in micas, peraluminous in compositions, S-type allochtonous granites. Leucogranites are typical products of dehydration–melting of muscovite at the presence of graphite. The tectonic transport of the leucogranite melt top-to-NW was established in oriented samples. Their geochemical features are typical of syn-collisional continental granites, formed in water deficiency and predominance of CO_2 (from the graphite oxidation) in anatectic fluid.

The geometric discordance between two shear zones and two foliation trends could be interpreted as the trace of the collision of three microplates: A = LSU on the Polish (N) side, B = LSU on the Slovak (S) side, C = USU (delaminated lower crust/upper mantle). The composite collision produced two collision sutures in which the melting of leucogranite magma took place (345 Ma; Gawęda 1995). During the further stages of Tatra basement development the southern zone, dipping to NW, dominated and acted as the pathway for Main Tatra Granite intrusion (cooling ages 300–325 Ma, Janak 1994). In the presented model, the traces of Early Variscan collision could survive only on the N-side, what is consistent with the field observations. Leucogranites from the Western Tatra Mountains have some analogues in other crystalline basements in the Central Western Carpathian Belt and could be used as the proof of the collisional stage in the Pre-Carpathians orogeny development.

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