# Structural evolution of the onshore/offshore Atlas system of Morocco

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A review of most industry reflection seismic surveys across the flanks and plunges of the High and Middle Atlas system provides new constraints for models of this foreland mountain range. The Atlas system is discordantly superimposed on the Paleozoic structural grain. Thus, the Mesozoic/Tertiary re-activation of earlier Paleozoic structures is limited to a few late Paleozoic Triassic strike-slip faults.

An overall north-northeast striking Triassic rift system is segmented by transfer faults, and overlain by a Late Triassic/Earliest Jurassic much less faulted sag basin that is associated with widespread plateau basalts. Middle and Upper Jurassic rifting is a distinctly separate event that only rarely coincides with Earlier Triassic rifts. The role of Paleozoic/Early Mesozoic strike-slip faulting and its reactivation amphasized by so many authors appears to be more limited and complex .

Onshore, salt tectonics are active from the Jurassic to the Quaternary. The compressional deformation and/or inversion of the Atlas Mountains begins during the Upper Cretaceous and is active until today. A low-relief folded belt forms in its earlier evolution, and is followed in late Miocene-Pleistocene time by the high relief forming event responsible for the uplifts of both, the Atlaș and the Anti-Atlas systems.

Striking features of the Atlas system are the near-absence of a flexural foredeep-like depression; its intersection with the Atlantic passive margin, its extension into the oceanic domain, intermittent mantle-derived volcanism from the Triassic into the Quaternary, a complex interplay of basement-involved deformation, inversion and décollement tectonics and finally widespread salt tectonics which often overprint and camouflage deeper tectonic patterns.

# Melt segregation and migration during deformation of anisotropic partially molten rocks

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Understanding dynamics of orogen roots implies a better knowledge of the role of partial melting in the mechanical behaviour of deep crustal rocks. In migmatitic terrains, melt occupies sites created by the heterogeneous deformation at a metric scale, such as hinge of folds, foliation-parallel veins or shear zones. The flow of the melt is driven by the pressure gradients so that the sites of low pressure are the sinks of melt. In order to understand the mechanisms of melt accumulation in metric structure such as a fold, analogue modelling has been performed with partially molten paraffin wax. The solidus of the wax is at 50°C and its liquidus at 75 °C. During the experiments, the wax layer is at 60±2°C and contains 15 to 20 % of liquid. The liquid is homogeneously distributed within the whole layer. The viscosity contrast between the liquid and the solid matrix is about of ten orders of magnitude.

The pervasive foliation of high-grade metamorphic rocks has also been taken into account. Before deformation, the layer is molded by pouring liquid wax in a rectangular mold. During the solidification of the wax, a weight is then applied at the surface of the mold. This process generates a horizontal planar intrinsic anisotropy.

The wax layer is embedded between two 68/70 paraffin layers. An upper layer of sand overlies these layers and is used as a load to increase the vertical stress. Initially, the layers are 250 mm long, 150 mm wide and 35 mm thick. The finite horizontal shortening is of 36 %. The average deformation rate is $3 \times 10^{-6}$ $s^{-1}$. The 68/70 paraffin layers are softer than the wax layer and act as a solid medium for the development of the fold. During the experiment, a part of the liquid moves from the microscopic porosity of the wax to the outside of the layer in large accumulation sites. At the onset of shortening, many microscopic dilatant veins filled with the liquid open in the horizontal foliation. These veins are long (40–50 mm) and thin (<1 mm). This development is favoured by the mechanical anisotropy of wax.

During the development of the fold, the veins acquire a sigmoidal shape which results from their rotation and shearing in the limbs. This process involves deformation of the solid wax around and between nearby veins. The liquid segregates from these deforming areas into the opening veins because the liquid flows down the pressure gradients. The veins are concentrated in the concave side of the fold and in the limbs. The enlargement of the veins implies an increasing heterogeneity. When the shortening is higher than 25 %, the fold becomes asymmetric. One of the limbs thus defines a reverse shear zone in which the veins are deformed. According to their position and orientation with respect to the shear planes, their aperture increases or decreases. The closing veins expel the melt toward the sides of the model, perpendicularly to the shortening direction. These veins are therefore obliterated. Next, a shear band may develop when the vein density is locally around 15 %. Finally, our experiments show that during the main part of the shortening, an important horizontal melt migration occurs through interconnected veins toward the lowest pressure vertical sides of the model. The flow of melt is guided by the mechanical anisotropy. On the other hand, upward melt migration occurs through the shear band only after 30 % of shortening. Melt segregation and migration are highly strain-dependent mechanisms since the stress field within the folded layer is heterogeneous and changes during the progressive deformation.

# A series of friction new bearings for seismic insulation

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The study describes in detail the composition and operating principle of six movable bearings for seismic insulation and also emphasises the most important characteristics of the respective systems; for example, the economical competitiveness with all other existing conventional or base insulation systems, the considerable decrease in the absorbed seismic energy and in the psycho-physical discomfort of the inhabitants of the building during an earthquake and the ease of maintenance.

The main principles of seismic insulation systems when using the proposed movable bearings are:

1. interruption of the solidarity between the building and the foundation-soil complex;
2. laying of movable bearings with sliding or rolling friction.

As regards their composition and the operating principle, the bearings may be classified as follows:

- mechanical
- natural
- mixed.

The centring and locking of the building after an earthquake, when using the first type of bearings, are not automatic because they occur by means of the activation of special electronically powered devices. The natural bearings are suitable for carrying out the self-centring of the building and, finally, the mixed ones are suitable for both centring the building automatically and also for mechanically safeguarding it against the danger of resonance.

# Self-centring aseismic system with double natural frequency

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The proposed system is based on the following operations:

1. interruption of the solidarity between the building and the foundation-soil complex;
2. laying of multidirectional movable elastic bearings with sliding or rolling friction.

This application confers the building with the main properties of centring after an earthquake and of doubling the natural frequency of vibration during an earthquake.