Finite Element Modelling of Tertiary to present day stress fields in the Iberian Peninsula.

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The stress field in the Iberian Peninsula from E. Tertiary onward is very well documented by a large number of (paleo)-stress studies. These show that the intraplate stress field changed rapidly in type, orientation and magnitude in response to the opening of the Atlantic Ocean that caused differential motion between Iberia, Africa and Eurasia. Superposition in time and place of the stresses transmitted from the active plate boundaries to the interior created locally varying stress fields in the Iberian Peninsula, which are accompanied and recorded by deformation of the plate interior. Iberia was still linked to Africa when oblique collision with Eurasia, which started during L. Cretaceous- E. Paleogene, created a stress field in which Shmax (maximum horizontal compression) is oriented NNW-SSE. Shmax rotated to N-S or NNE-SSW during Paleocene-Eocene and is accompanied by major deformation in the Pyrenees and off-shore Cantabria. The main deformation front was relocated to the southern part of Iberia (the Betics) during M. Miocene and collision with Africa caused an uniaxial compression, with Shmax again NNW-SSE. The Valencia Trough opened east of the microplate and readjusted the stressfield during L. Miocene to extension in the Valencia area and to strike slip in the interior of the plate. Finally, from L. Pliocene to present, the ongoing convergence between Africa and Eurasia/Iberia produced a compressional stress field which is oriented NNW-SSE again.
We used the finite element method to model the first order variations in the Iberian plate stress field, which result from changes in the distribution of active plateboundary processes, linked with paleogeographical reconstructions of the Iberan Peninsula and the western Mediterranean. We compared the results with observations. Similar models that have been applied to other regions were able to predict relative magnitudes and direction of the principal stresses, but could not reproduce absolute values and local states of stress. A better knowledge of the latter is required for the successful prediction of failure or fault-reactivation and for quantifying the effects of larger scale processes like plate-driving mechanisms on stresses and deformation in sedimentary basins. To take into account many of the first order stress sources, we included the additional stress source of lateral density variations (i.e. topography and crustal thickness variations). This allowed us to incorporate the ridge push force as an intraplate force rather than as a boundary force and to take into account buoyancy forces associated with continental margins.
In a first approach, we modelled the stress fields for four different timeslices in Tertiary to present day without including the lateral density variation effects. The orientations of maximum compression of these advanced models are in agreement with the observations, the local state of stress, however, is not.
When taking into account the stresses induced by lateral density variations in the model for the present day setting, the resultant stress field is in close agreement with observations (focal mechanism solutions, bore-hole breakout data and fault-slip data of quaternary faults). The modelling indicates that the present day stress field in Iberia is the resultant of predominantly ridge push force of the opening of the Atlantic and collisional forces to the southern plate boundary. The direction of the collisional force exerted by Africa was established from several plate-motion reconstruction models (NUVEL-1) and preliminary GPS data from N. Africa-Iberia. Since the ridge push force has been calculated accurately using the lateral density variations method and because the orientation of the present day stress field is well known, we deduced that the magnitude of the collisional force associated with the Iberian-African collision is off the order of 10-20 MPa.