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Evidence for extreme crustal thinning and mantle exhumation in the Western Pyrenees-Bay of Biscay

S. JAMMES (1), G. MANATSCHAL (1), and L. LAVIER (2)

(1) CGS-EOST, Strasbourg, France (suzon.jammes@illite.u-strasbg.fr), (2) University of Texas Institute for Geophysics, Jackson School of Geosciences, Austin, Texas 78759, USA

The Bay of Biscay represents a V-shaped oceanic basin that opened in Aptian-Albian time within a transtensional setting. During the opening of the Bay of Biscay, several rift basins (e.g. Parentis, Mauleon, Cantabrian basins) formed in front of this propagating ocean. During the subsequent Pyrenean compression in Late Cretaceous to Oligocene time, the basins to the south (e.g. Mauleon and Cantabrian) were strongly reactivated while to the north (e.g. Parentis) the reactivation was minor. Our investigations in two of these basins, the offshore Parentis basin and the onshore Mauleon basin, show evidence for extreme crustal thinning and local exhumation of lower crustal or mantle rocks associated with the formation of these basins.

The Mauleon basin, exposed onshore in the western Pyrenees, was partly reactivated during the Pyrenean compression, which has the advantage that deeper parts of the basin are exposed and can be mapped. Our field investigations show that the base of this basin was formed by mantle peridotites and lower crustal rocks that were exhumed, reworked and overlain either by extensional allochthons, today preserved in “chaînons Béarnais”, or upper Aptian to Albian sediments. The stratigraphic record of extreme crustal thinning is documented by up to 900 m of Albian conglomerates reworking Palaeozoic metasediments. Structures that documented the exhumation and supporting the existence of top-basement detachment faults are exposed in the Labourd massif where shear zones observed in lower crustal granulites are overprinted by brittle fault zones and infiltrated by sediments.
In contrast the Parentis basin is an offshore basin, slightly reactivated but covered by geophysical surveys and well data. These data show evidence for extreme crustal thinning, an important asymmetry of the basin and only little evidence for normal faulting. To the north of a major E-W fault (named the Ibis fault) the basin is characterized by a sag geometry whereas to the south the interaction of extensional processes and salt tectonics makes seismic interpretations more difficult. We suggest that the southern part of the basin is floored by a slightly reactivated detachment fault that caps the basement and account for the extreme crustal thinning. Deformation in the overlying Albian sediments is interpreted as being related to gravitational gliding toward the centre of the basin probably associated with salt tectonics. These interpretations are compatible with field observations made in the Mauleon basin.

Based on these observations and in agreement with new results from the Iberia-Newfoundland margins and paleomagnetic investigations we propose a new evolution model for the formation of the Cretaceous basins within the Pyrenean domain. In this model extreme crustal thinning results from a polyphase tectonic evolution in which there is a strain partitioning between strike-slip, decollement and detachment systems. To test the physical realism of our conceptual model, we developed a numerical model in which we superpose two major kinematic phases. We initiate with a strike-slip dominating phase that last for about 10 Ma, before we change to an extension dominated phase for another 20 Ma. This model is in line with new plate tectonic reconstructions proposed for the Iberia plate and can reproduce the major structural observations observed in the field and on seismic sections, i.e. asymmetric basin architecture with a sag geometry in the north and an exhumed top-basement detachment system in the south.