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Subsidence and uplift history of hyperextended margins and a self-consistent mechanism of depth-dependent thinning of the lithosphere

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Most geometries, structural styles, sedimentary architectures and subsidence histories of deep water continental rifted margins cannot be explained solely by a pure shear uniform stretching model or by a simple shear model. Depth-dependent kinematic models can reproduce some of the geological observations in these rifted margins, but there is a controversy regarding the mechanism for depth dependency. In particular, previous models cannot explain the tectonic subsidence in deep-water area of many basins. Specifically, instead of a monotonic curve, many subsidence curves in natural basins display two phases of subsidence separated by a quiescent or even an uplift phase where shallow water conditions (carbonate and salt deposition) were predominant. This is particularly true for hyperextended margins like the North Atlantic conjugate Iberia-Newfoundland, part of the South Atlantic margin, the fossil Alpine Tethys and hyperextended Mauléon basin in the western Pyrenees (SW France). We propose a new self-consistent mechanism that can induce both the aforementioned non-monotonic tectonic subsidence history and the depth-dependent thinning in a normal lithosphere of different ages and of rheological properties consistent with strain rate and temperature. This mechanism generates dynamic uplift away from isostatic equilibrium. It originates from the rapid initial subsidence of a rigid keystone crustal block (H-block) in the mantle. If, because of time dependent rheological behavior, block H cannot thin by an amount consistent with isostatic balance, a difference in the vertical pressure gradient is generated below it compared to the surrounding areas. The lower gradient of pressure initiates a buoyant instability that drives the hot (less dense) asthenospheric mantle flow upward. The upwelling of the asthenospheric mantle focuses below block H. The magnitude of the uplift and the duration of this dynamic balance while rifting are primarily related to (1) the composition and the (2) thermal age of the lithosphere. We test the proposed mechanism in numerical experiments varying age and thickness of the lithosphere, rates of extension, fixed minimum erosion and fixed source term of sediment to simulate marine incursions. The development of this unsteady flow of asthenospheric mantle can have important implications in the subsidence/uplift and thermal history of basins related to the evolution of continental rifted margins.

Keywords: Rifting, Continental Margins, Subsidence history, Depth-dependent stretching