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Delamination of oceanic lithosphere in SW Iberia: a key for subduction initiation?

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On the 1st of November 1755, a giant 8.7 magnitude earthquake struck off the coast of Portugal, destroying the city of Lisbon. The seismic event and the following tsunami triggered the interest of philosophers and contributed to the development of modern seismology. In 1969, a 7.9 magnitude earthquake struck in the same region. This was the time when the theory of plate tectonics was developed, and several scientists came to study this margin. Since then, many studies have been dedicated to the Atlantic southwest passive margin of Portugal and several scientists proposed that this region was a case of subduction initiation.

Intriguingly, the epicenter of the 1969 earthquake occurred in a relatively flat abyssal region, far from any known tectonic faults with significant length and surface expression. Previous studies showed the existence of a seismicity cluster precisely in this area at lithospheric mantle depths of ∼50km, in a section of old oceanic (Jurassic?) lithosphere. This seismicity is located below a seismically silent layer, interpreted as a serpentinization front propagating down through the lithospheric upper mantle. Several tomographic models have consistently imaged a fast-velocity anomaly extending up to a depth of 250 km, right below this seismicity cluster. We interpret this anomaly as a lithospheric drip caused by the delamination of oceanic lithosphere. If this is the case, it is the first time that delamination of oceanic lithosphere is identified.

Delamination of continental lithosphere is common due to the high-density contrast between the continental crust and the underlying lithospheric mantle (especially when it is overthickened in orogenic regions), and because there are several weak decoupling layers within continental lithosphere (think of the "Christmas tree strength profiles"). On the contrary, typical oceanic lithosphere is more coherent, with a strong core, lacking major density contrasts and internal decoupling layers. However, if we consider an old and thick (Jurassic) oceanic lithosphere covered by highly altered basalts and water-rich sediments, with an internal weak portion of serpentinized upper mantle that could act as a decoupling layer, then we would have all the ingredients for delamination to occur.

We have tested this hypothesis using simple 2D numerical models with the Underworld code. Preliminary results show that indeed, under certain circumstances, the existence of a serpentinized layer in old oceanic lithosphere may generate horizontal decoupling zones that can lead to the delamination of old oceanic lithosphere. In the present case, due to the proximity to a continental margin and to the Azores-Gibraltar Plate Boundary the process is highly asymmetric and resembles simple models of subduction initiation. We propose that the reactivation of the margin and the hypothetical process of subduction initiation may have been aided by a process of delamination of oceanic lithosphere.

The identification of a first case of oceanic lithospheric delamination will certainly contribute to further our understanding of the dynamics of tectonic plates. Old oceanic lithosphere may be prone to gravitational instabilities, which may play a fundamental role in the process of subduction initiation.

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