Geophysical Research Abstracts
Vol. 20, EGU2018-17159-1, 2018
EGU General Assembly 2018

New insights into crustal- and basin-scale processes in the Porcupine Basin, offshore Ireland, from travel-time tomography of active-source seismic data

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The Porcupine Basin is a Mesozoic failed rift located in the North Atlantic margin (SW Ireland). Here, we present two sets of tomographic images obtained with travel-time tomography of two different active-source seismic data sets: ocean bottom seismic (OBS) data and long-streamer data. The study provides new insights into geological processes that occurred at different scales and geological stages during the formation of the Porcupine Basin.

OBS-derived images show the Vp structure of the uppermost lithosphere and the geometry of the Moho across and along the basin axis, providing insights into formation processes that occurred during lithospheric extension in the Mesozoic. In particular, these tomographic results together with neighboring seismic reflection lines provide crustal stretching (βc) estimates of $\sim$2.5 in the north at 52.5N and > 10 in the south at 51.7N. These values suggest that no crustal embrittlement occurred in the northernmost region, and that rifting has potentially reached crustal breakup in the southern part of the study area. Tomographic images reveal that mantle velocities decrease across the basin axis from east to west. These variations occur in a region where βc is within the range at which crustal embrittlement and serpentinisation are possible (βc 3-4). Across the basin axis, the lowest seismic velocity in the mantle spatially coincides with the maximum amount of crustal faulting, indicating fault-controlled mantle hydration. Mantle velocities also suggest that the degree of serpentinisation, together with the amount of crustal faulting, increases southwards along the basin axis. Seismic reflection lines show a major detachment fault surface that grows southwards along the basin axis and is only visible where the inferred degree of serpentinisation is > 15 %. This is consistent with laboratory measurements that show that at this degree of serpentinisation, mantle rocks are sufficiently weak to allow low-angle normal faulting.

In contrast, the long-streamer tomographic image shows the Vp structure of the post-rift section in much more detail than OBS-derived images providing insights into basin-scale processes that occurred after lithospheric extension during the Cenozoic. The tomographic image reveals faster vertical velocity gradient in the center of the basin than in the flanks. This variation together with a relatively thick sediment accumulation in the center of the basin suggests higher overburden pressure and compaction compared to the margins. This suggests fluid flow driven by differential compaction towards the margins of the basin. The model also reveals two prominent vertical velocity anomalies located at the western margin of the basin, coinciding with the location of a reactivated basin-bounding fault. Comparing the corresponding time-migrated seismic section with the tomographic model, we observe that the hanging wall of the basin-bounding fault is not significantly affected by major normal faulting and yet is associated with comparatively lower seismic velocities. This result together with exploration well data suggests high effective porosities within the hanging wall suggesting potential overpressured areas. Our results suggest that the western basin-bounding fault is acting as a barrier for fluid migration causing overpressured areas over the western flank.