Pockmarks and fluid migration in the Slyne Basin, offshore west Ireland

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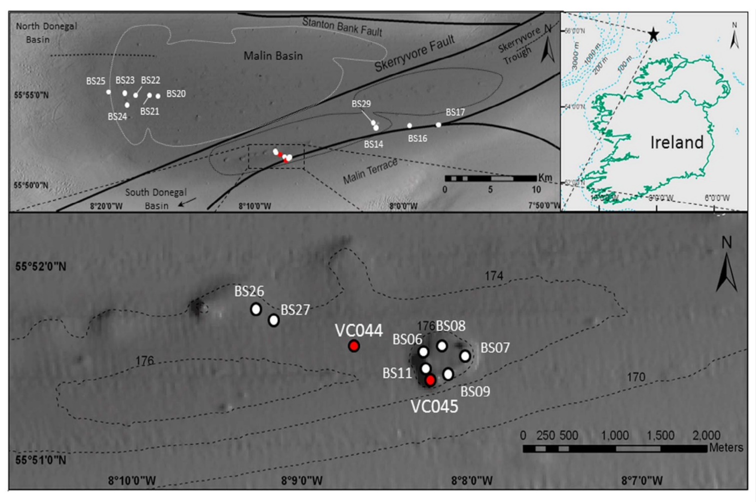
ABSTRACT:

Carbonate mounds, pockmarks, and acoustic features related to fluid flow and/or shallow gas have been recognized on the seafloor in Irish waters (e.g. Shannon et al., 2006; Garcia et al., 2014). In this study, data sets comprising multibeam bathymetry, high-resolution 3D reflection seismic and sub-bottom acoustics have been analysed over about 1306 km2 to investigate fluid flow and seepage in the Slyne Basin, offshore west Ireland. Twenty three pockmarks (262–720 m diameter and 2–6 m depth) could be identified on the multibeam bathymetric data, in water depths ranging of 196–285 m. In addition, acoustic turbid zones have been observed on the sub-bottom acoustic data (3.5 kHz transceiver), occasionally beneath smaller pockmarks, which were not resolved on the multibeam bathymetric data or on the seafloor interpreted on the 3D seismic data. This is most likely due to the limited resolution of the bathymetric and 3D seismic data sets. In the strata beneath the seafloor, more than 1600 paleo-pockmarks (~50–280 m diameter) have been identified along an Intra-Late Tertiary horizon (PmH), at 80–100 ms (TWT) below the seafloor. Well data was tied with the 3D seismic data for age determination of geological unconformities in the Slyne Basin. Various attributes were extracted along the PmH surface and deeper surfaces for better visualization of the spatial distribution of paleo-pockmarks and fault mapping. Pockmarks are abundant at two levels (PmH and seafloor), which may reflect distinct multiple phases of fluid seepage in the basin. Near-distance analysis using the ArcGIS Spatial Analysis tool between the paleo-pockmarks and faults shows correlation coefficient R2 = 0.64, and 1195 pockmarks in close vicinity of faults (within 1 km radius). Kilometre-scale exhumation and erosion of Mesozoic stratigraphy and faulting occurred beneath the Late Tertiary Unconformity (Corcoran & Mecklenburgh, 2005). Extensional fault systems that displace the Late Paleozoic and Mesozoic succession might have facilitated vertical migration of reservoir fluids during the Cenozoic deformation. Structural activity is likely to be the main control of pore fluid mobilization resulting in the formation and distribution of these pockmarks.

EVIDENCES OF SHALLOW GAS AND SEEPAGE IN OFFSHORE IRELAND:



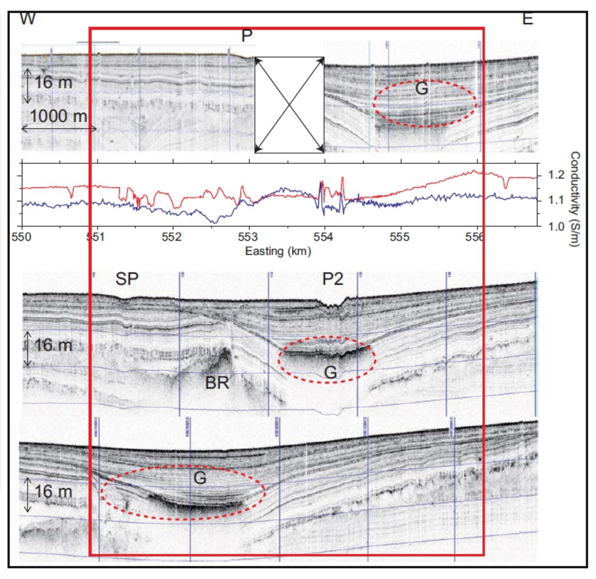
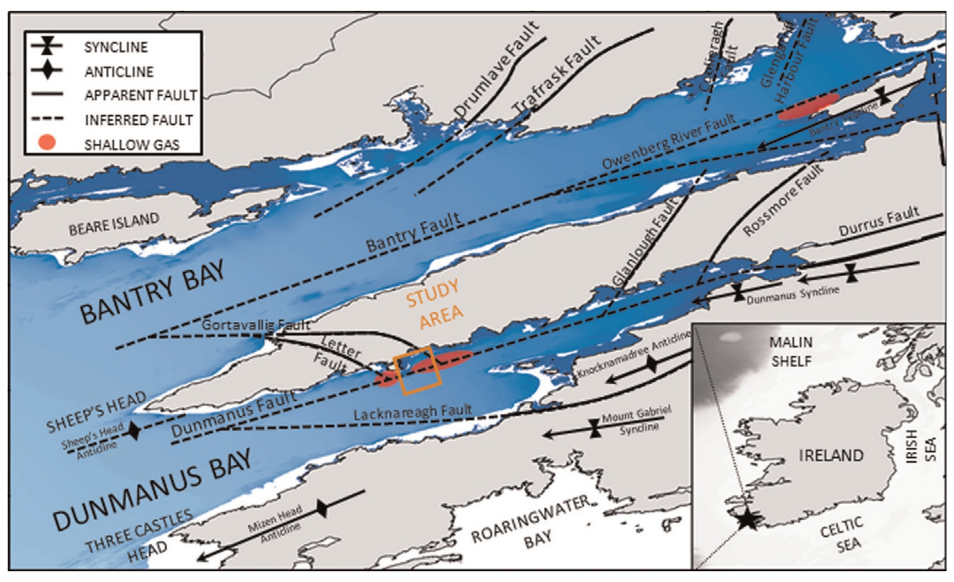
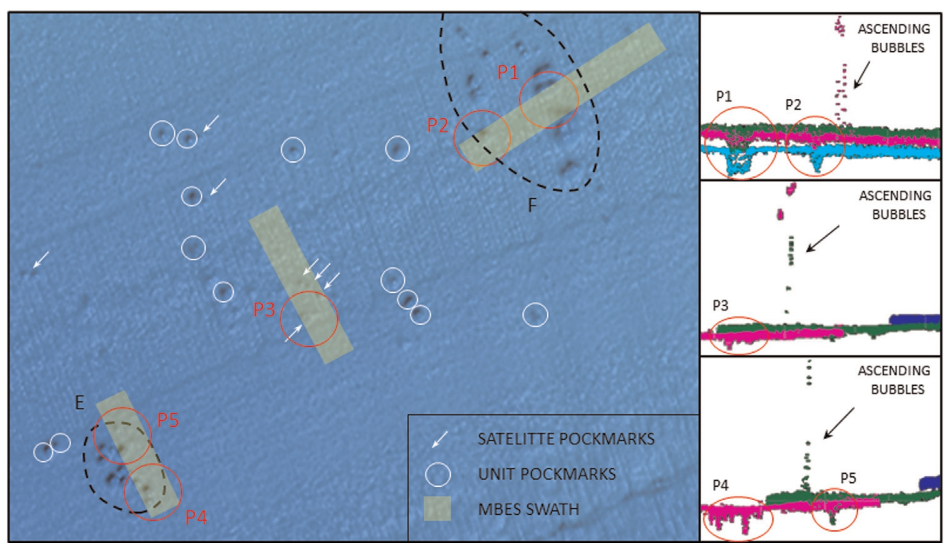


Figure 1 (A)TOP: Pockmark clusters are visible in the Malin Deep micro basin. Skerryvore Fault is marked a with a black dotted line (Szpak et al., 2012).

Figure 1 (B)TOP RIGHT: Gas anomalies in the central part of the Malin basin as observed in the electromagnetic data (EM) and 3 parallel shallow seismic lines (Garcia et al., 2014). Gas accumulation facies (G) are present in the three parallel lines and coincide with the edges of the EM gassy region (C). SP is a small pockmark. The bright reflector (BR) is interpreted as a magmatic intrusion.





Illustrations from Szpak et al., (2015):
Figure 2 (A) TOP RIGHT: Bathymetry of Dunmanus and Bantry Bays with major structural features and shallow gas locations. Major fault in this area, the Dunmanus Fault crosses just north of the pockmark field with minor Gortavallig Fault branching out just 250m north-west from the pockmark field.
Figure 2 (B) BOTTOM RIGHT: Bathymetry illustrating pockmark clusters D to F and individual MBES lines (right panel) with signals ascribed to ascending bubbles in the vicinity of the encircled pockmark features.

SEEPAGE AT SEAFLOOR AND ACOUSTIC RELATED SHALLOW-GAS INDICATIONS IN THE SUB-SURFACE:

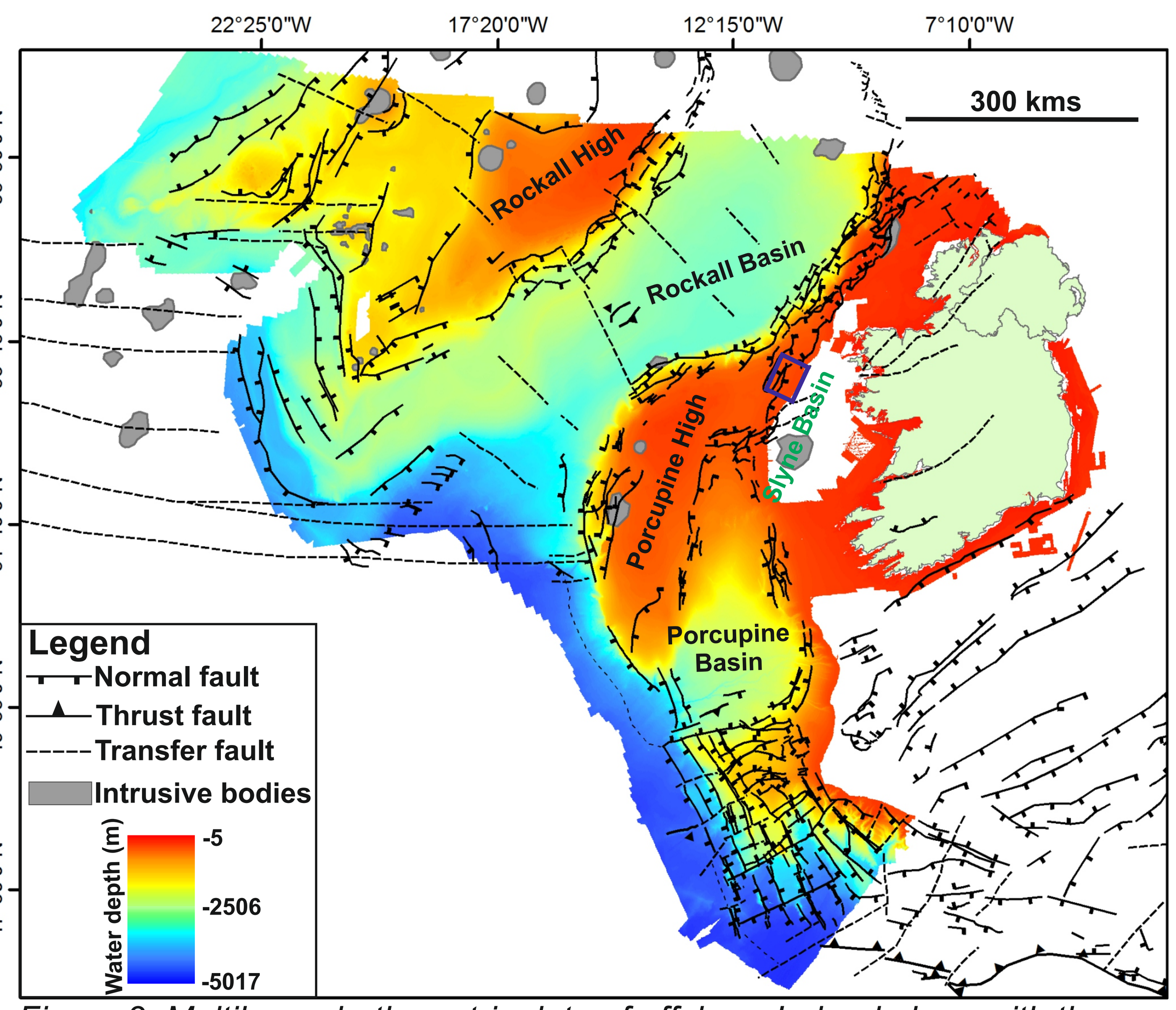


Figure 3: Multibeam bathymetric data of offshore Ireland along with the tectonic elements and intrusive bodies. Note the 3D seismic survey area (shown in blue box) in the Slyne Basin.

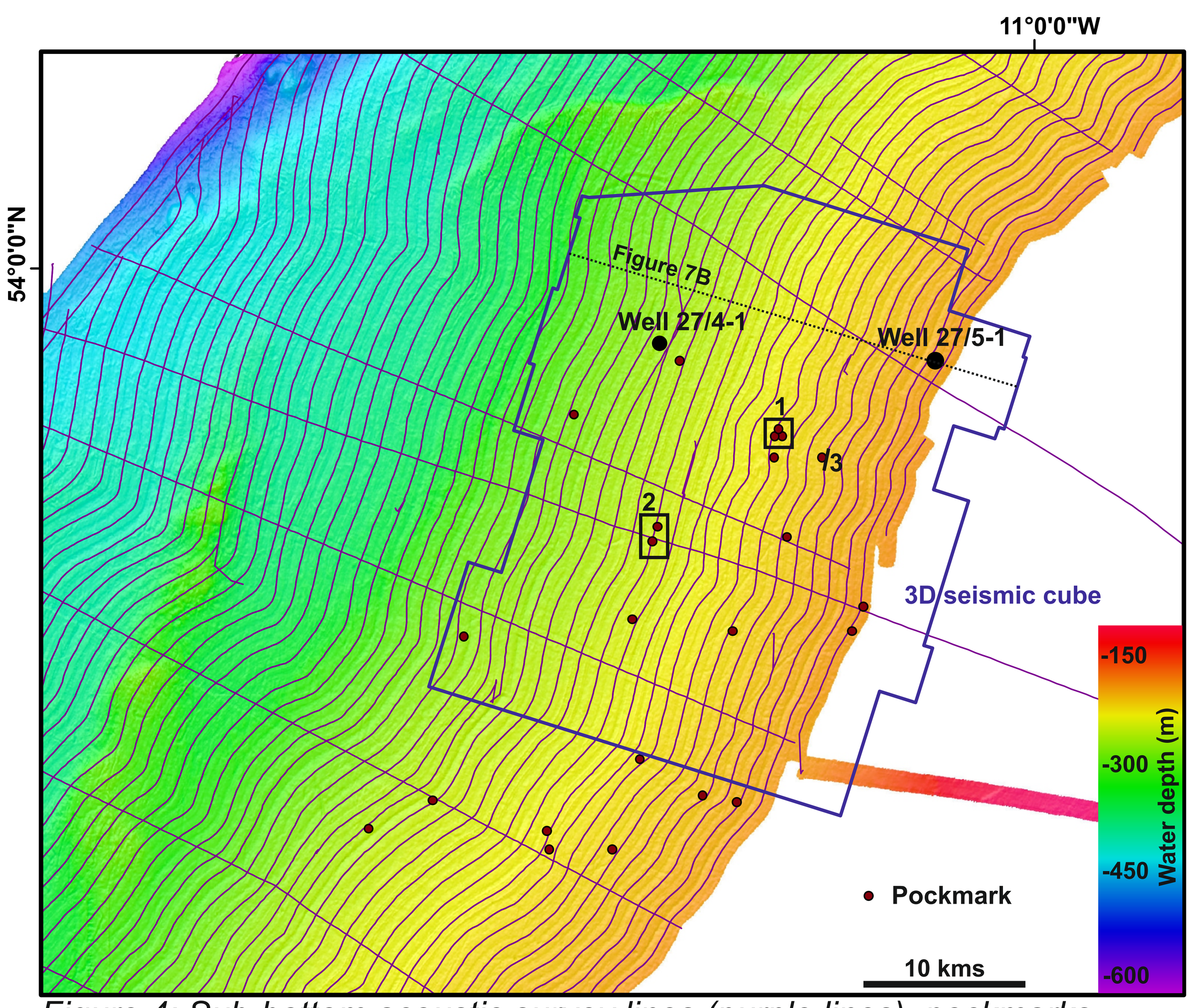


Figure 4: Sub-bottom acoustic survey lines (purple lines), pockmarks interpreted on multibeam bathymetry (seafloor), two well-locations (black dots), 3D seismic survey (blue outline) - also shown in Figure 3.

Evidence of fluid flow on seabed: Pockmarks

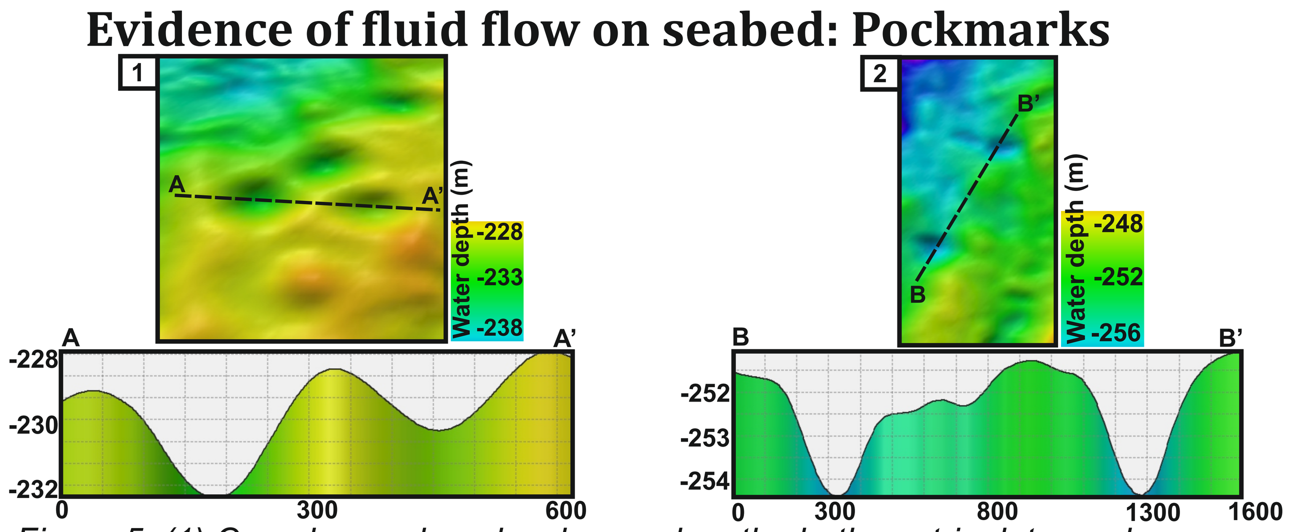
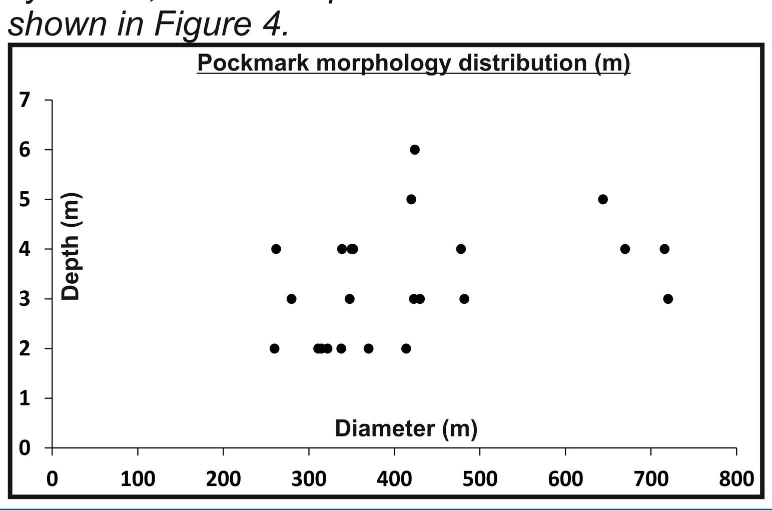


Figure 5: (1) Complex pockmarks observed on the bathymetric data, and cross-profile across two of them shown below. (2) Two individual pockmarks separated by 500 m, and cross profile across them shown below. Locations of (1) and (2) are shown in Figure 4.



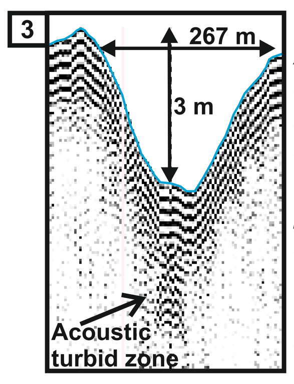


Figure 6: Absorption of acoustic energy by gas-charged sediments beneath pockmark results in acoustic turbid zones. Location shown by 3 in Figure 4.

Acoustic evidence of shallow-gas: Acoustic Turbidity

BURIED POCKMARKS, TURBIDITE CHANNEL SYSTEMS AND FAULTS IN THE SLYNE BASIN

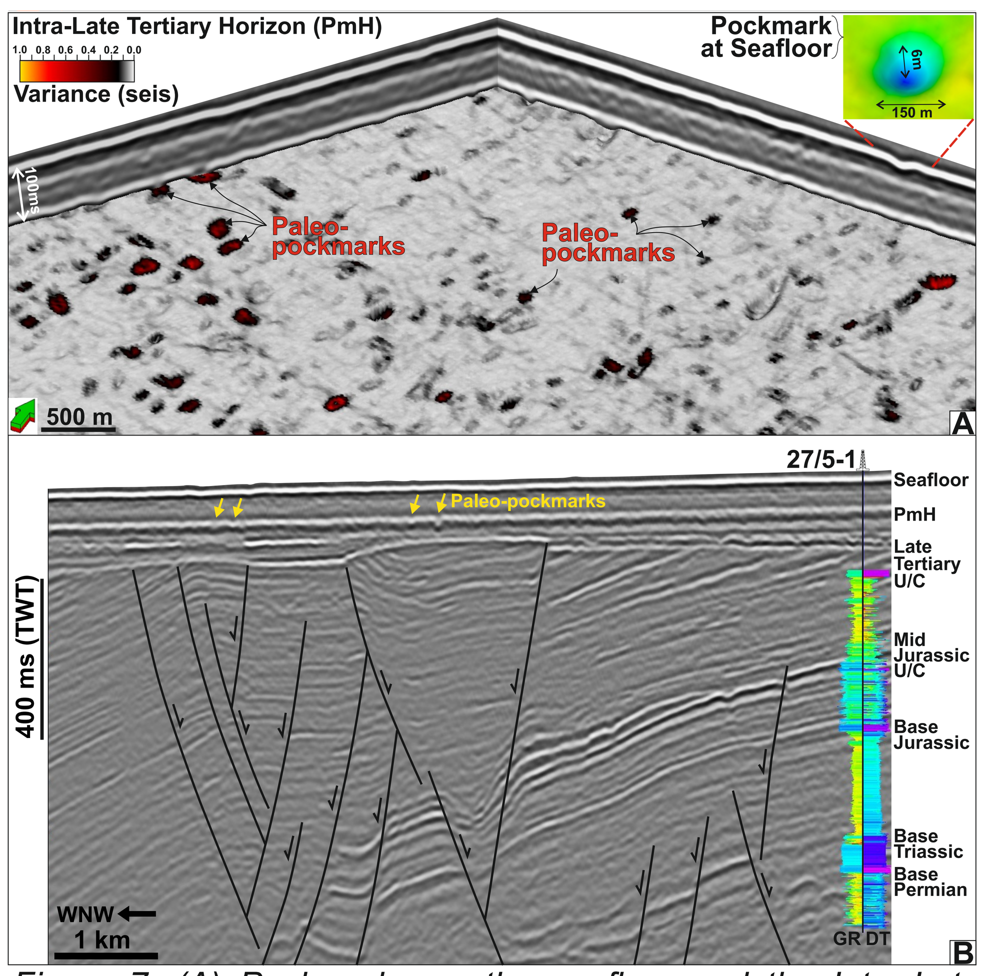


Figure 7: (A) Pockmarks on the seafloor and the Intra-Late Tertiary horizon (PmH). Variance attribute extracted along PmH surface highlights the presence of abundant paleo-pockmarks. Inset box shows morphology and dimension of the seafloor pockmark. (B) Mesozoic strata and normal faults truncate below the Late Tertiary Unconformity (U/C), which suggest enormous uplift and erosion. Paleo-pockmark depressions shown at the PmH. Well data was tied with the 3D seismic data for age determination of geological unconformities in the Slyne Basin. Refer to Figure 4 for location of seismic section.

Channel systems in shallow depths

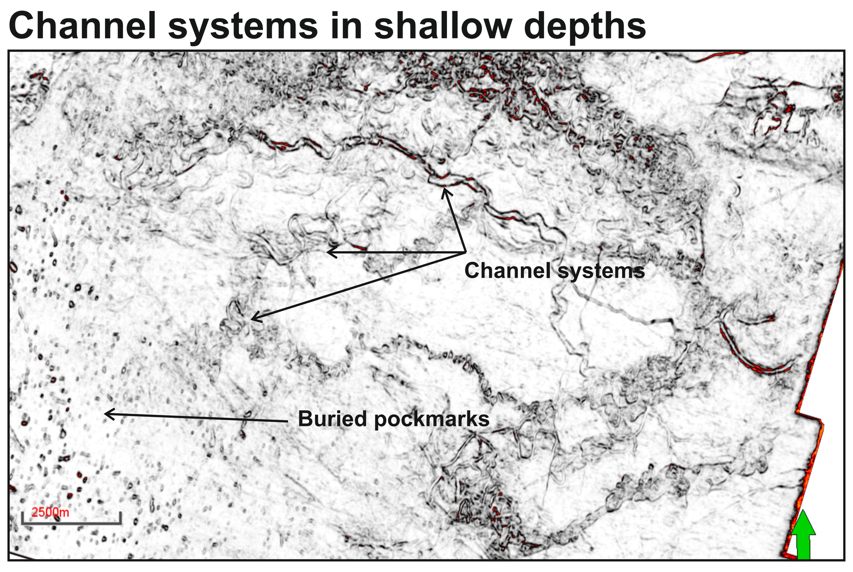


Figure 8: Time slice of seismic variance attribute at -456 ms TWT below seafloor showing extensive channel systems (potential sand reservoirs for NGH), along with buried pockmarks which are evidences of paleo-seepage.

Near-distance analysis between buried pockmarks and faults

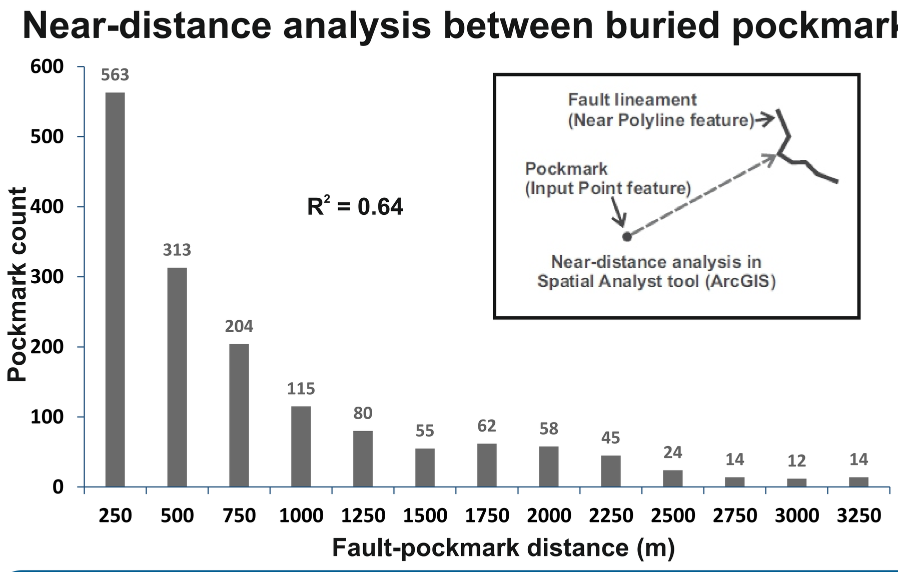


Figure 10: Number of pockmarks plotted as a function of pockmark–fault distance (m), calculated from the near-distance analysis algorithm (with ArcGIS Spatial Analyst Tool). The near-distance analysis determines the shortest distance from one defined feature (pockmarks represented by point-feature) to another type of feature (fault lineaments represented by line-feature). The inset, upper right, illustrates this.

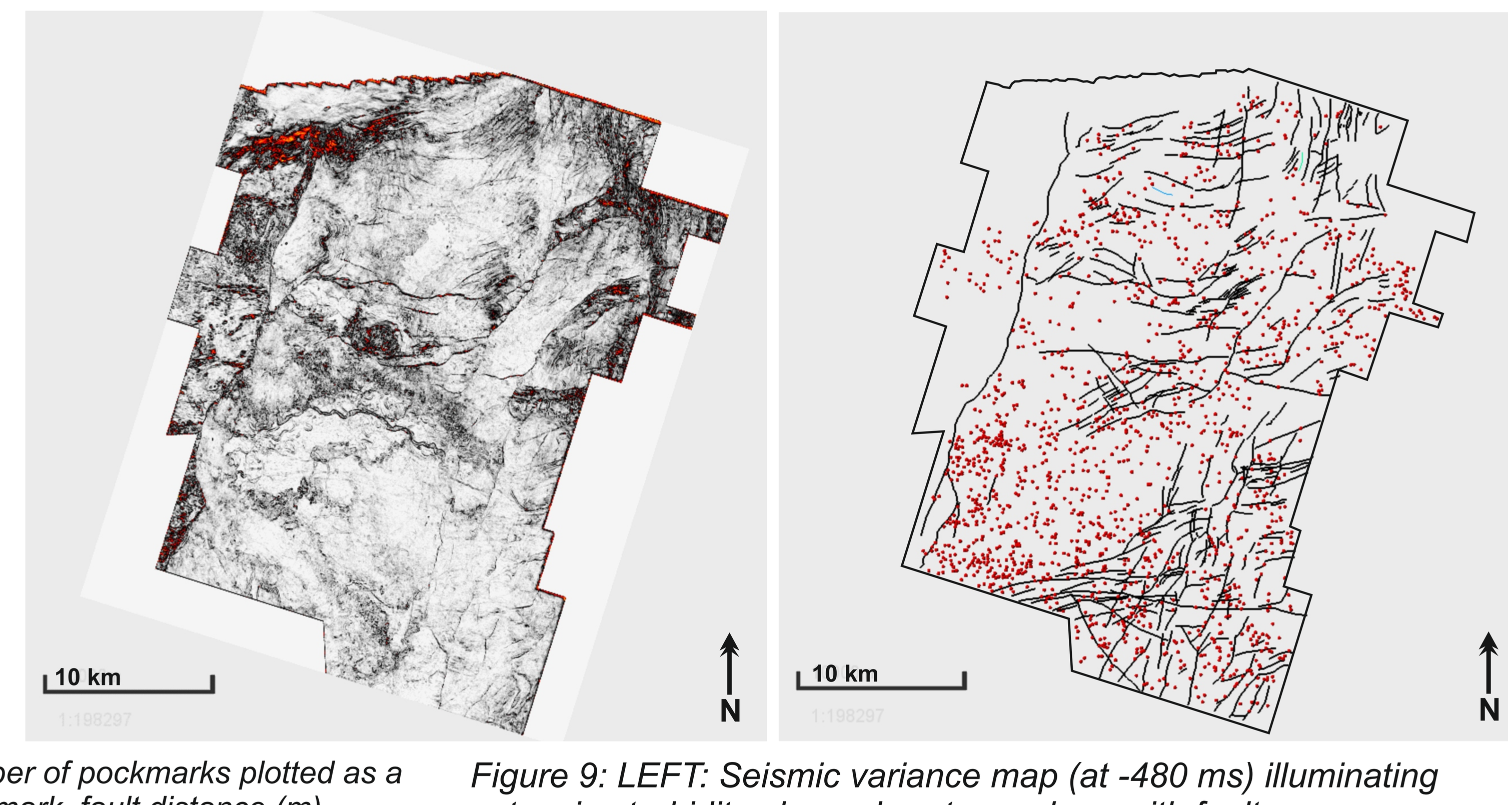


Figure 9: LEFT: Seismic variance map (at -480 ms) illuminating extensive turbidite channel systems along with faults.
RIGHT: Spatial distribution of faults (shown with black lines - interpreted using RMS amplitude and Variance attribute maps) along with buried pockmarks (red dots). Refer to Figure 7B for stratigraphic levels of buried pockmarks, channels, and faults.

Combined presence of fault conduits and potential source rock could be crucial for the formation of pockmarks in Slyne Basin.

FUTURE WORK:

a) Analyse spatial corelation between re-activated faults and buried pockmarks.
b) Delineate turbidite channel systems using seismic attribute workflows extracted along the geological surface.

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Szpak, M.T., Monteys, X., O'Reilly, S.S., Lilley, M.K.S., Scott, G.A., Hart, K.M., McCarron, S.G., Kelleher, B.P., 2015. Occurrence, characteristics and formation mechanisms of methane generated micro-pockmarks in Dunmanus Bay, Ireland. Continental Shelf Research 103, 45-59.

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