Abstract:

Understanding geologic risks that could hinder successful geologic CO_2 capture and storage (CCS) in a prospective area is imperative before moving forward with a storage project. Containment of injected CO_2 requires the storage formation, top seal, and fault seals to be of sufficient quality, but the stratigraphic overburden must also be characterised thoroughly in order to appreciate the entire storage system fully. Two CO_2 storage prospects are located within the Smeaheia, 4 km east of the Troll East offshore gas field along the west coast of Norway. Above the idealised Jurassic storage units are the Cretaceous and Tertiary overburden strata, which could provide either secondary seals or conduits to flow if containment of the CO_2 were to fail. Of particular interest are the Quaternary sediments, which lie above the Upper Regional Unconformity (URU), and preserves many pockmarks and glacial features. Since pockmarks are indicators of paleo-fluid seepage, the distribution of pockmarks on the seabed and within the Quaternary interval, can provide insight towards how buoyant paleo-fluids may have migrated through the subsurface and help determine if parts of the overburden geology could act as a secondary seal for any leaking CO_2 injected into the Smeaheia storage prospects. To achieve this, pockmarks and other overburden features are interpreted from high-quality 3D seismic data, and statistics are gathered and analysed to understand the distribution of the pockmark geometries and map their areal densities. The seabed surface hosts a total of 679 pockmarks and can be divided into three groups; (A) medium pockmarks with a mean width of 77 m, (B) large pockmarks with a mean of 129 m, and (C) giant pockmarks with a mean width of 214 m. An additional 2476 buried pockmarks are identified on six older seismic horizons under the seabed down to the URU. These horizons are dominated by medium-sized pockmarks with mean widths between 75 to 81 m, while large pockmarks increase in size with depth and have mean widths ranging from 122 to 191 m. It is proposed that the formation of large and mega pockmarks are associated with significant expulsion events and occasionally correlate with interpreted seismic pipes, while the ubiquity of the medium-sized pockmarks suggests that they may have formed in the wake of more significant expulsion events or from more passive buoyant fluid build-ups within the Quaternary stratigraphy.
Furthermore, quadrat and kernel density maps are used to display pockmark density distribution. These density maps, together with qualitative observations from the available 3D seismic data below the URU, suggest that there are two main domains for pockmarks-forming fluid sources, east and west of the Øygarden Fault Complex (ØFC). Pockmarks east of the ØFC appear to originate from basement-rooted faults along the footwall of the ØFC, while pockmarks west of the ØFC could have multiple points of origin. Most of the pockmarks west of the ØFC are present between Top Sele Fm and Top Shetland Gp horizon subcrops under the URU, which are also above a dense network of Tertiary polygonal faults and deeper WNW-ESE rending faults associated with a Late Jurassic to Early Cretaceous rifting event. No data was available to determine whether the buoyant fluids that formed the pockmarks were biogenic or thermogenic, and no hydrocarbons were encountered by the two wells drilled in the Smeaheia fault block. However, the Cretaceous and Tertiary layers subcroping the URU are all westward-dipping, suggesting that buoyant thermogenic fluids may have migrated up-dip from the NW or WNW from the Troll area. Additionally, mapped mega-scale glacial lineations (MSGL) and plough mark trends correlate with pockmark longest axis azimuths, which shows that glaciers may have played a vital role in triggering pockmarks formation at Smeaheia. Overall, it is evident that the Quaternary interval has periodically been compromised by buoyant fluid migration, implying that the Quaternary and underlying overburden strata might work poorly as a secondary seal for CO_2 sequestration at Smeaheia over geologic timescales.