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Background seismicity monitoring prior to CO_2 injection in the Horda Platform: The HNET project

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Abstract

As a contribution to national and European greenhouse gas emission-reduction targets, Norway is developing a full-scale Carbon Capture and Storage value chain project (Longship) aiming to start operations in 2024. Building on decades of experience with CO_2 sequestration offshore Norway, an industrial joint venture, the Northern Lights JV DA, is currently developing and constructing the CO_2 storage facility at the Aurora site located to the southwest of the Troll field on the Norwegian Continental Shelf (NCS). The storage site has a design capacity of 1.5 Mt CO_2 per year over 25 years for the initial demonstration phase and has ambitions to increase the injection rate to 5 Mt per year in a subsequence phase. The target storage units are at 2500-3000m depth within the lower Jurassic Johansen and Cook Formations within a large gently dipping fault block on the Horda platform, bounded by the Svartalv fault to the west and the Tusse fault to the east. Storage potential was confirmed by drilling the 'EOS' verification well (31/5-7) completed in January 2020.

To support this project and to help assess the long-term integrity of this CO_2 storage site, the HNET project (a CLIMIT Demo project started in 2018), has evaluated a range of passive seismic monitoring strategies to investigate the nature of background seismicity in the Horda platform region. The main objective is to develop an improved understanding of past and present seismicity, to support seismic hazard and risk assessment prior to CO_2 injection. The catalogue of seismicity recorded by the Norwegian National Seismic Network (NNSN) since 2001 has been analysed statistically to reveal a moderate rate of seismicity in the Horda platform, with a b-value (the slope of the earthquake frequency plot) of close to 1, indicating normal tectonic strain behaviour. The magnitude of completeness for the Horda platform region is M_L=1.5, confirming that the NNSN catalogue is complete for earthquakes larger than this. We can also characterize the historical seismicity data to show that the accumulated seismic moment release over the last 20 years is equivalent to a single earthquake of M_L=4.1 and that the annual probability of occurrence of an earthquake with M_L=4.0 is ~7% in the Horda platform region. This value varies in the surrounding region, increasing to ~12% in

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nearby offshore regions and reducing to ~5% in the onshore region to the east of Horda platform. The NNSN catalogue data also indicates very low rates of seismicity in the region around the Aurora injection site (Fig. 1). Further work is needed to understand these regional variations in seismicity levels and to improve the detection levels for the offshore regions. Various actions have therefore been taken to improve the azimuthal coverage and to reduce the detection threshold for seismicity in the Horda platform. Firstly, a new broadband seismic array (HNAR, Fig 1) was deployed in March 2020 on the Holsnøy island to the east of the Horda platform. Secondly, we have worked on integrating a limited number of offshore geophones from the Permanent Reservoir Monitoring (PRM) systems on the Grane and Oseberg oil/gas fields with the NNSN seismic stations. In this study we show how integration of offshore and onshore seismic stations, along with use of array processing methods have significantly reduced the location uncertainty of the earthquakes in the area of interest. For example, several NNSN uncatalogued earthquakes could be detected by employing array processing. To further improve and evaluate the rates of seismicity close to the Aurora injection site, three broadband ocean bottom seismometers (OBS) have been deployed south west of the Troll field in October 2021. These autonomous OBS stations will monitor seismicity at the Aurora site for approximately one year. The recorded data will be retrieved in 2022 and will then be investigated for assessing possible previously undetected seismicity close to the CO_2 injection site. Further integration of these new offshore nodes with the existing onshore and offshore seismic arrays should then enable an improved baseline of natural seismicity prior to injection start in 2024.

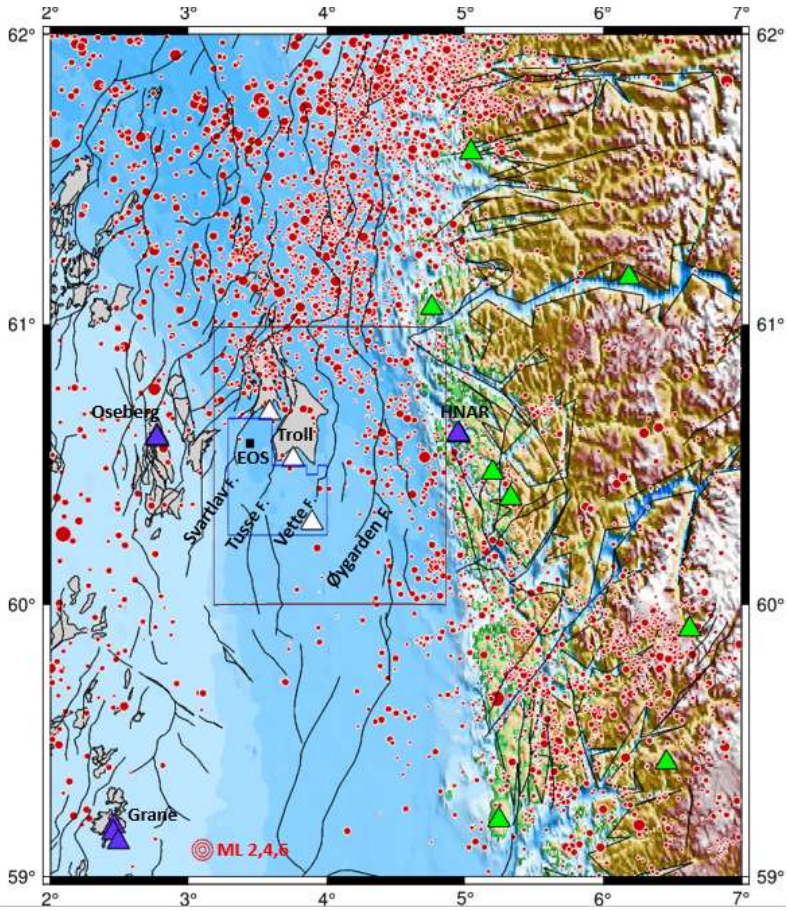

Figure 1. *Background seismicity monitoring in the Horda platform region (red rectangle) around the Aurora exploitation license (blue polygon). Red dots show seismic events detected by integration of broadband stations from the NNSN (green triangles) with new stations using a limited set of offshore geophones from the Grane and Oseberg fields and the onshore HNAR Broadband array (blue triangles). The white triangles show the location of OBS deployed in late 2021.*

Keywords: CO_2 storage, Earthquakes, Seismic risk, Passive seismic monitoring