3D imaging of clay tectonic deformations in the Kortrijk Formation through (ultra-)high-resolution acoustic and seismic reflection profiling in the Princess Elisabeth Zone, offshore Belgium

Hakan SARITAS* 1, Thomas MESTDAGH 1, Harisma ANDIKAGUMI 2, Ruth PLETS 1, Tine MISSIAEN 1, Marc DE BATIST 2, Bruno STUYTS 3, Hans PIRLET 1

1 Flanders Marine Institute (VLIZ), Ostend, Belgium; 2 Department of Geology, Ghent University, Ghent, Belgium; 3 Acoustics & Vibrations Research Group, Vrije Universiteit Brussel, Brussels, Belgium

In the Princess Elisabeth Zone (PEZ), on the Belgian Continental Shelf, new offshore windfarms (with a total capacity of up to 3.5 GW) will be built in the coming years. The substrate of this zone consists of a thin Quaternary cover overlying Early Eocene (Ypresian) clays that are part of the Kortrijk Formation. Clay tectonic deformations, manifesting as faults and folds, are known to exist in this formation since the 1980's (Henriet et al., 1983; Henriet et al., 1988), yet potential repercussions for the design, installation and operation of the planned windfarms in the PEZ have not been studied so far. The cSBO-project "Clay Tectonics" (2023-2025), funded by VLAIO through the Blue Cluster, therefore aims to investigate this topic through a combination of geophysical measurements, geological analyses and geotechnical simulations.

A first, essential step in this evaluation is the acquisition of adequate geophysical data for imaging and characterizing the clay tectonic deformations. Several surveys have therefore been performed in the PEZ, to acquire high-resolution sparker seismic reflection profiles and ultra-high-resolution parametric sub-bottom profiling data over four tightly spaced grids (called Block A, B, C and D). The location of these study areas and the survey strategy were carefully selected, based on previously known geological/geophysical factors (e.g. variations in deformation style, Quaternary cover thickness, bottom penetration, presence of identifiable reflectors, Palaeogene subcrop stratigraphy) and practical constraints (e.g. available shiptime, parcel division of the PEZ). This has resulted in >1,000 km of high-quality 2D seismic/acoustic profiles. The processing of these data adopted a particular focus on optimizing the visualisation of the clay tectonic features.

The next step encompasses integrating the processed 2D seismic and acoustic profiles per survey block into (pseudo-)3D sub-bottom volumes. These cubes should allow to properly reconstruct the 3D distribution and characteristics of the deformations, which will be important knowledge for the development of the new offshore windfarms. Preliminary tests performed for Block B (a 2.5 x 2.5 km network of 39 SW-NE and 38 NW-SE 2D profiles, intersecting at approximately 50 m) show promising results, clearly revealing a set of SW-NE trending normal faults. Relevant fault characteristics (e.g. dip, orientation, displacement, length) can readily be obtained from the generated 3D seismic volume and the derived structure and time maps, down to a depth of ~40 m below the seabed. Below this depth multiples obscure the interpretation, despite applying multiple suppression methods (such as surface related multiple elimination, pre-stack deconvolution and zero offset demultiple) in the data processing phase. That said, the adopted geophysical data acquisition, processing and integration methodology can be considered successful in creating a 3D visualization of the clay tectonic features in Block B. Future work will focus on automating the interpretation workflow and applying this approach to the other blocks

(Blocks A, C and D) as well, from which the observations will continue to feed into the geological analyses and geotechnical evaluation of clay tectonic deformations in the PEZ.

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