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Quantifying the contribution of shallow subsurface processes to (sub)surface movement in the Groningen gasfield area

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Surface and shallow subsurface deformation

Land subsidence due to natural and human-induced processes occurs on different time-scales and depth-intervals. The negative impacts of land subsidence are manifold and the design of efficient measures mitigating land subsidence requires the **quantification of the individual processes** that contribute to total (sub)surface movement and reliable techniques for monitoring surface elevation changes at high resolution, spatial and temporal scales.
The ultimate goal of this research is to model and quantify shallow subsurface processes such as **oxidation** and **compression** occurring in the Holocene sequence (surface level up to 8m depth). Additionally intermediate depth processes such as the **extraction of groundwater** from Pleistocene (8m – 100m depth) aquifers will be modelled.
Within the overall DeepNL project this will contribute to a surface elevation model, combined with reservoir models and InSAR observations.

Causes of deformation

Shallow (sub)surface deformation rates are strongly influenced by (phreatic) groundwater level, loading, subsurface lithology and other properties. Variations and fluctuations of these parameters lead to:

- Primary and secondary (creep) compression
- Oxidation of organic matter
- Shrinkage and swelling of clay and peat

These processes cause cm-scale fluctuations in (sub)surface deformation, resulting in net subsidence rates of several mm/yr.

Monitoring sites Nieuwolda

Two monitoring sites are developed in Nieuwolda in the south-east of Groningen (fig. 1&2), for measuring and monitoring the shallow subsurface processes. One site is focused on surficial clay governing mainly shrinkage and swelling and overall compression, whereas the other site is focused on surficial peat governing oxidation and overall compression.
Monitoring instruments involve groundwater monitoring wells, extensometers with anchors positioned at different geohydrological boundaries for measuring relative deformation of different layers (fig. 4), a transponder for InSAR observations, and further meteostation devices such as moisture content devices, thermometers, and precipitation and evapotranspiration monitors. Both sites are currently used for agriculture which differs from the standard grassland monitoring sites, which will provide new insights. These are the first shallow measuring sites in the Groningen gas field area.

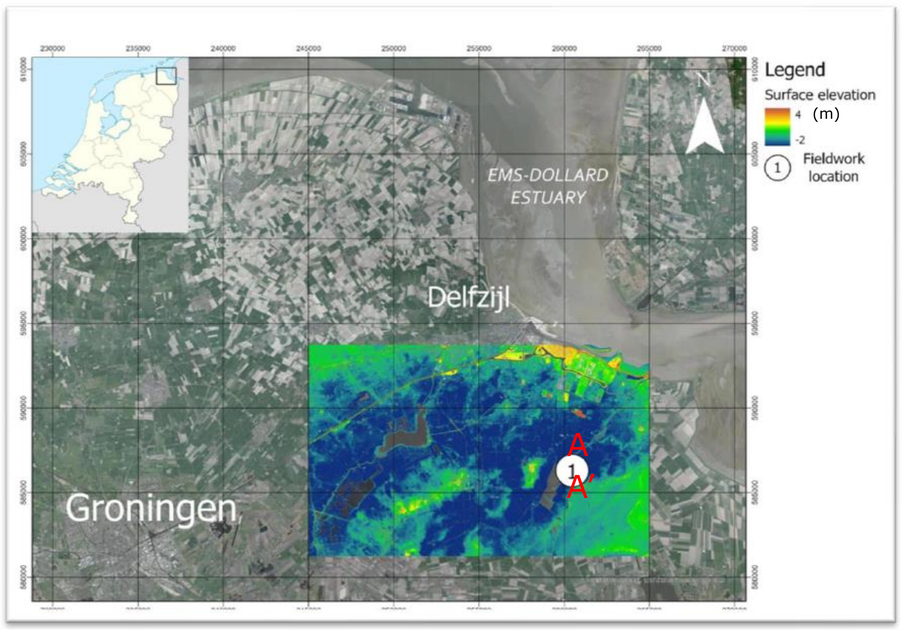

Fig. 1 Low elevation fieldwork location in Nieuwolda Groningen

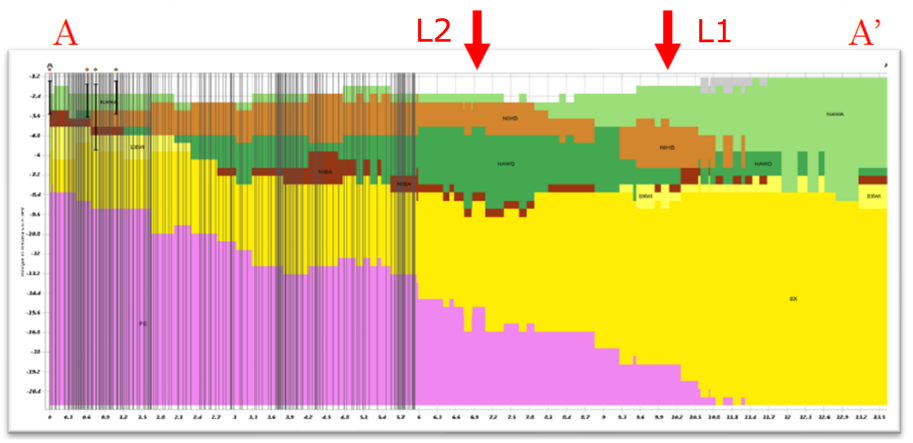

Fig. 2. Schematic cross section of fieldwork location in Nieuwolda, Groningen

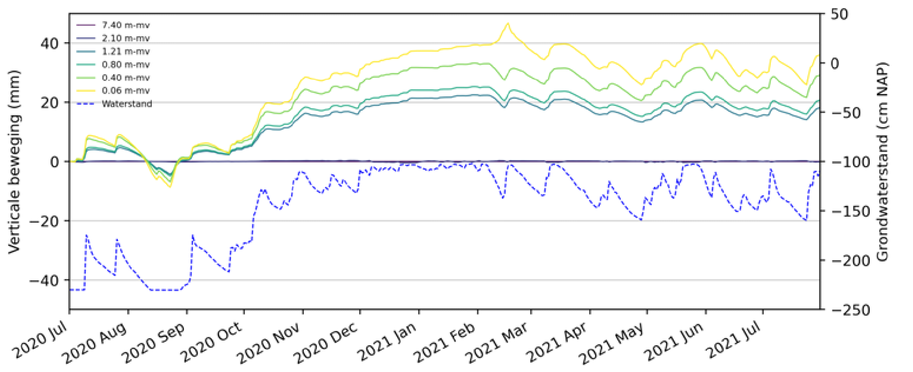

Fig. 3 Extensometer results of reference plot in Aldeboarn, Friesland: Vertical movement of the extensometer anchors in peat and clay layers in reaction to phreatic groundwater level fluctuations on a yearly base, NOBV jaarrapportage 2020-2021

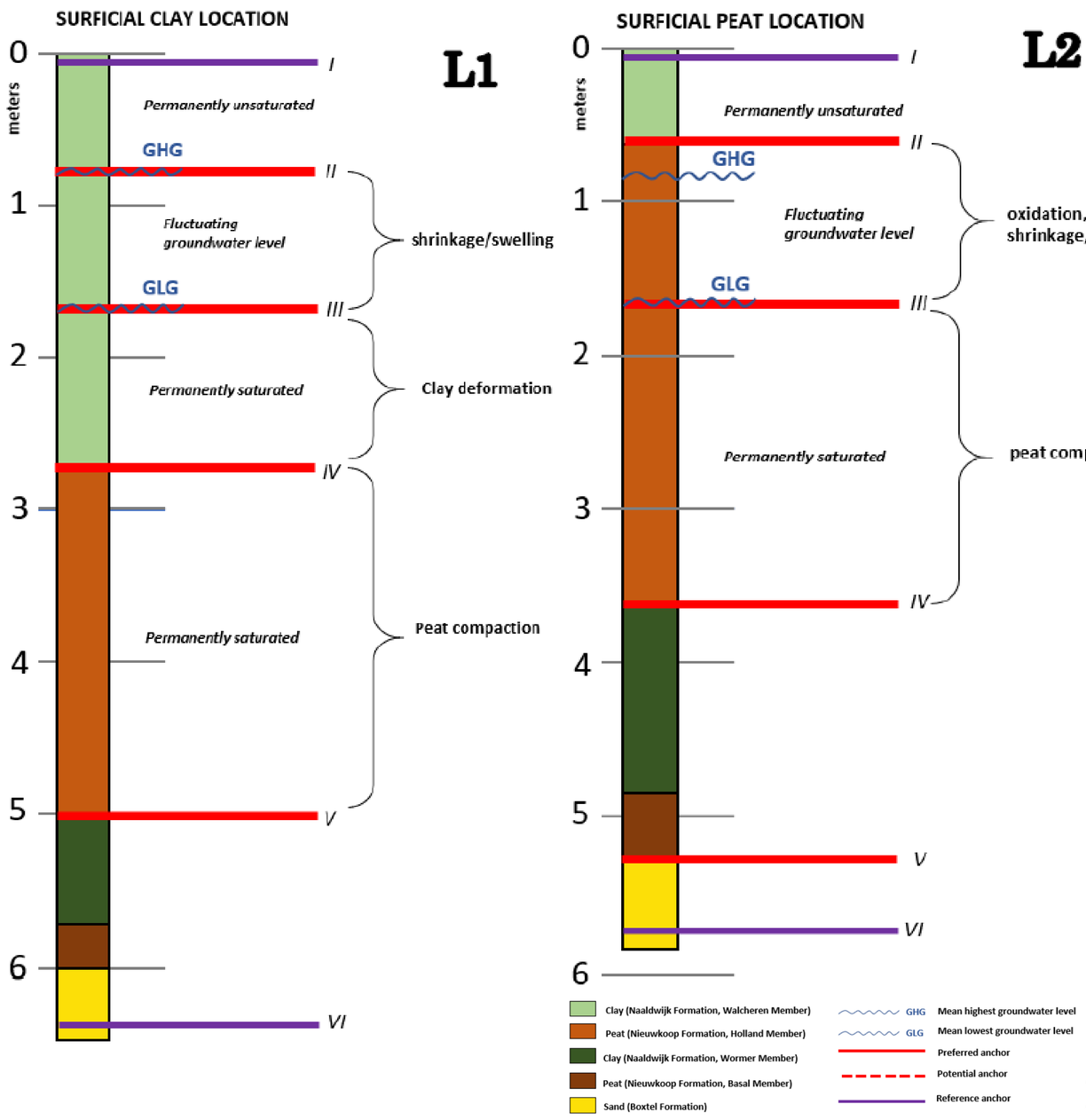

Fig. 4 Schematic overview of two extensometer sequences (in meters w.r.t. the surface) varying in lithological build-up, with their anchor positions and corresponding measuring purposes

Future monitoring and modelling

In order to quantify shallow subsurface processes over time on a regional scale, modelling is essential. Compression modelling based on the a,b,c-isotache method (Den Haan, 1994) and oxidation modeling (based on organic versus mineral content) will be performed over a period from 1959 until present. Measurements will serve as validation for these models and quantification on a local scale (fig. 3). In addition, the contribution of groundwater extraction from Pleistocene aquifers to (sub)surface movement will be modelled using iMOD coupled to SubCR. These model outputs will give new insights in the contribution of shallow and intermediate depth processes to subsurface movement in the Groningen gasfield area.

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