

Pingos in Denmark: A comparison between pingo remnants in the Netherlands and circular depressions in South Jutland

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Introduction: Pingo's are ice-cored hills that form under conditions of permafrost, presumably as a result of hydrostatic groundwater pressures in partially frozen upper aquifers. Although permafrost was present in most of north-western Europe during the Late Weichselian, no studies have focussed on the possible presence of pingo remnants in Denmark. This is strange, since permafrost conditions were also present in Denmark during the Weichselian, west of the maximum ice extent. Moreover, circular depressions are observed in Denmark, similar to those in the Netherlands.

Results from Drenthe, the Netherlands

Two Dutch pingo remnants are used as reference for the Danish circular depression. The DEM and the bathymetric maps show the morphology of the different depressions, while the LOI and pollen diagrams show the infilling of all the circular depressions.

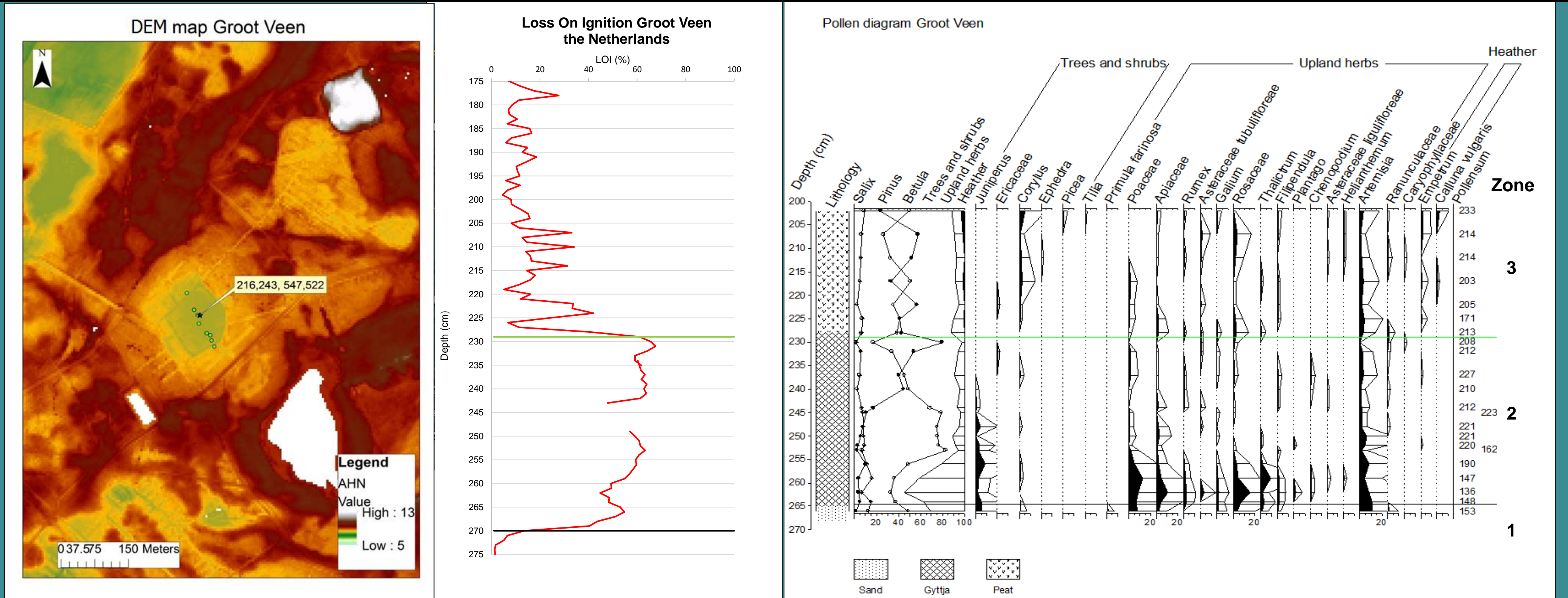


Figure 1 (from left to right): Digital Elevation Map (DEM), Loss On Ignition and Pollen diagram (preliminary dataset) of the Groot Veen pingo remnant. The LOI diagram is subdivided into different zones based on organic matter content. Bottom to top: **Black line** represents the start of increased organic accumulation during the Bolling-Allerød interstadial, **Green line** marks the end of the warm Bolling-Allerød interstadial. The Pollen diagram is subdivided into different pollen zones, based on Hoek (1997, 2008). Since the timing of the changes in vegetation composition appears to be synchronous with the climate changes recorded, the same colors were used as in the LOI diagram.

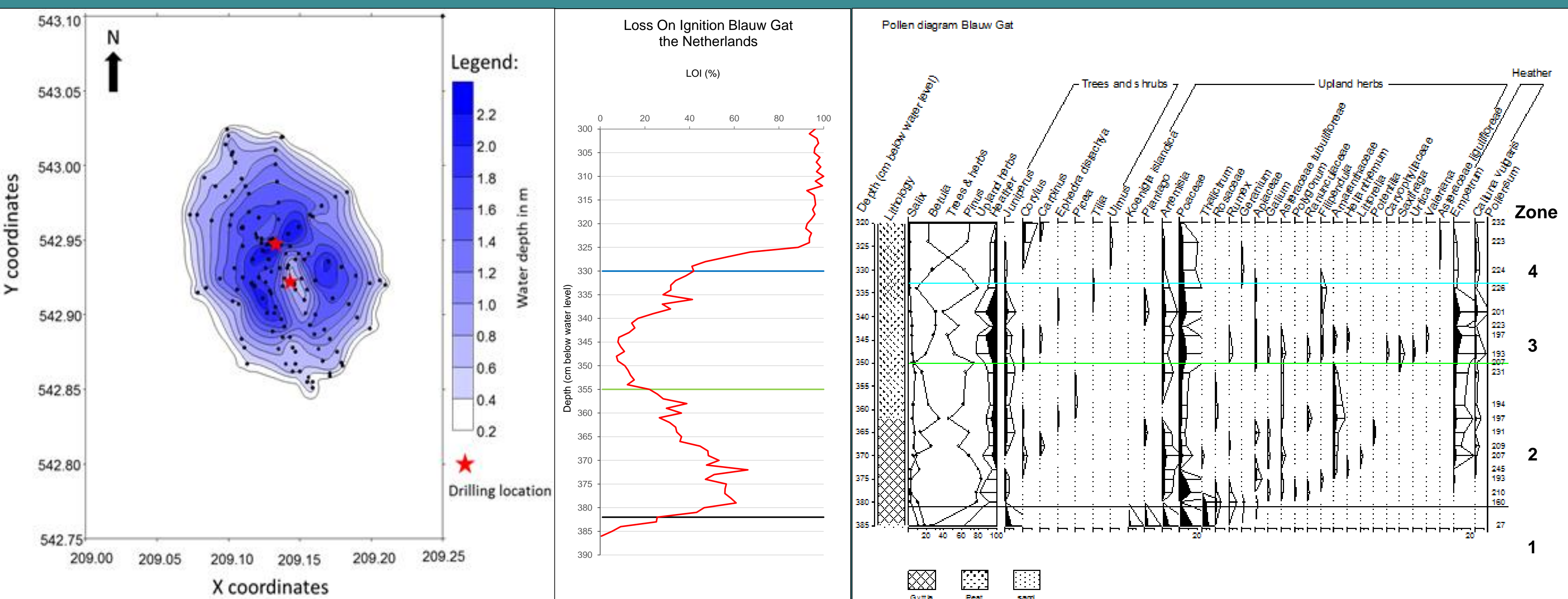


Figure 2 (from left to right): Bathymetric map, Loss On Ignition and Pollen diagram of the Blauw Gat pingo remnant. The LOI diagram is subdivided into different zones based on organic matter content. Bottom to top: **Black line** represents the start of increased organic accumulation during the Bolling-Allerød interstadial, **Green line** marks the end of the warm Bolling-Allerød interstadial, the **Blue line** marks the end of the cold Younger Dryas stadial and the start of the warm Holocene. The Pollen diagram is subdivided into different pollen zones, based on Hoek (1997, 2008). Since the timing of the changes in vegetation composition appears to be synchronous with the climate changes recorded, the same colors were used as in the LOI diagram.

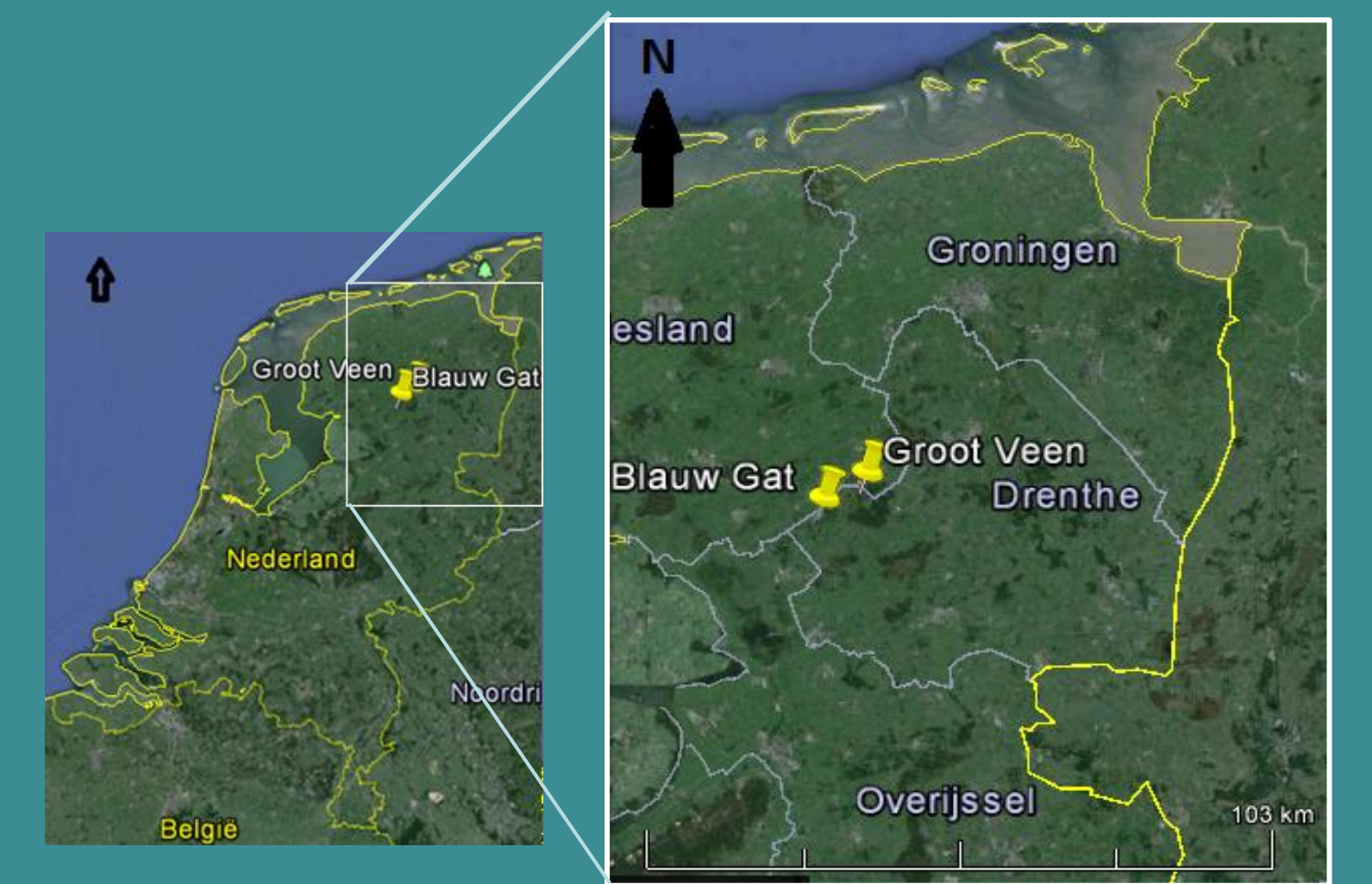


Figure 3 Location of Dutch pingo remnants. Source: google.earth

Results from South Jutland, Denmark

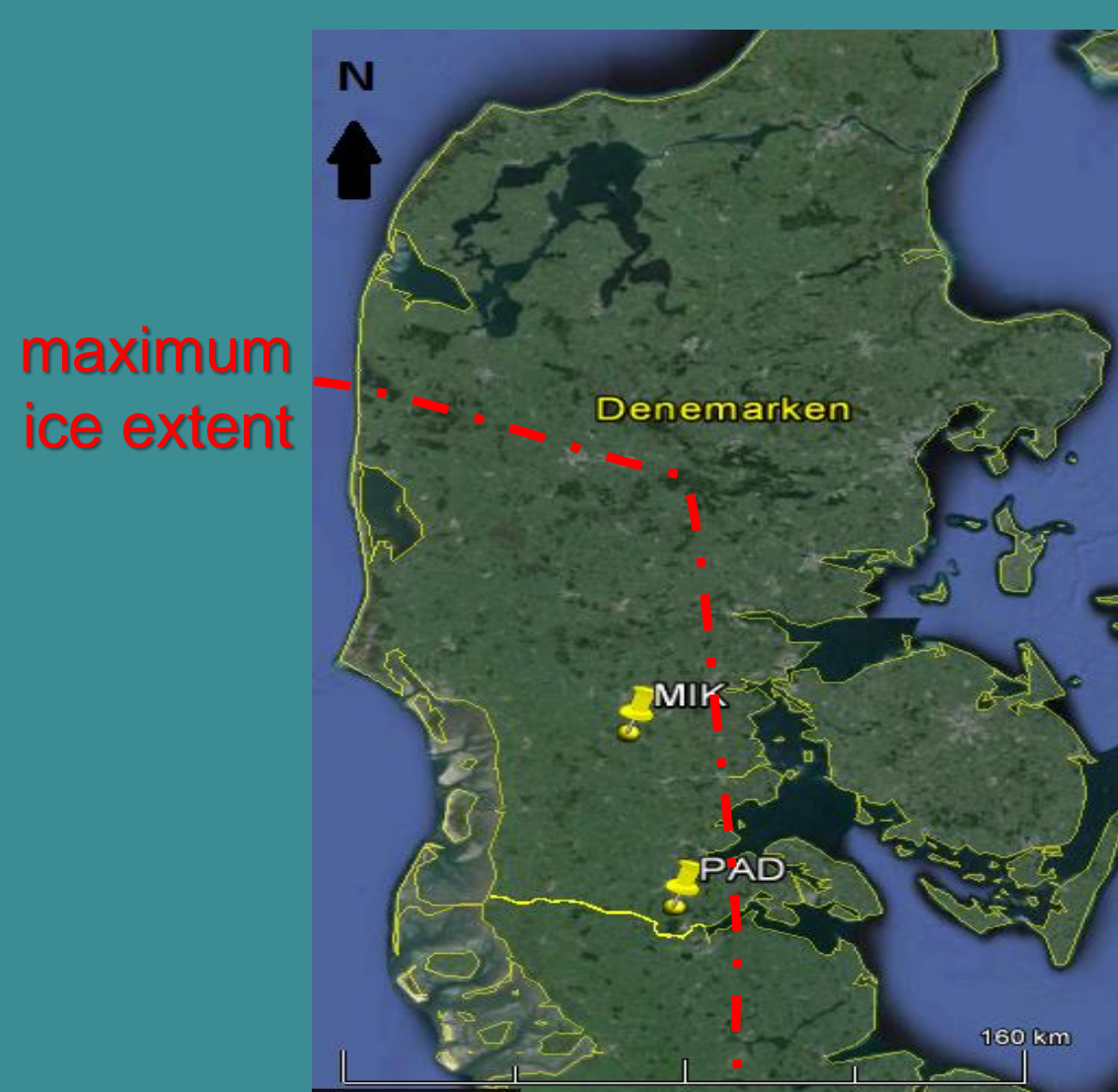


Figure 4 Location of Danish circular depression. Source: google.earth

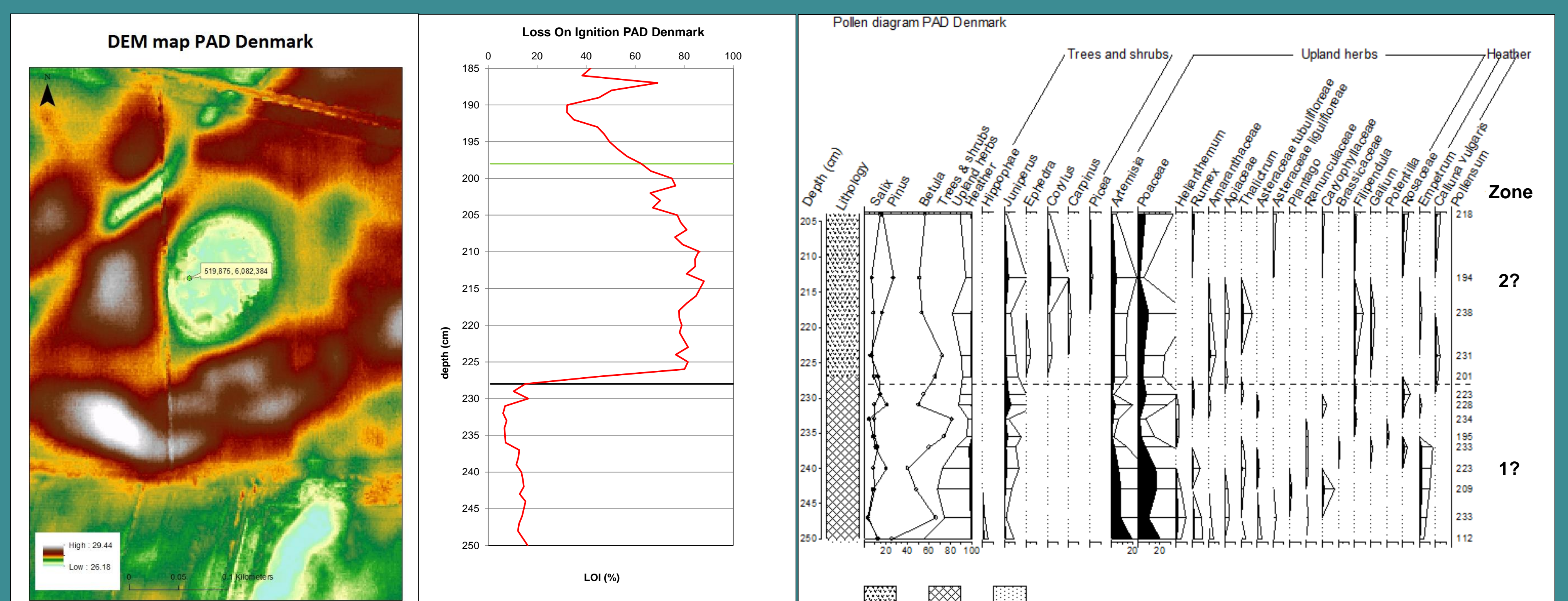


Figure 5 (from left to right): Digital Elevation Map (DEM; source: Mette Bendixen, University of Copenhagen), Loss On Ignition and Pollen diagram (work in progress!) of the PAD depression. The LOI diagram is subdivided into different zones based on organic matter content. Bottom to top: **Black line** represents the start of increased organic accumulation during the Bolling-Allerød interstadial, **Green line** marks the end of the warm Bolling-Allerød interstadial. The Pollen diagram is also divided into different Dutch vegetational zones, based on Hoek (1997, 2008).

Discussion:

- Morphologically the PAD depression is very similar to the pingo remnants in the Netherlands.
- The LOI diagrams of the Netherlands are similar to the LOI diagram of Denmark. Although less variation is present in the Danish diagram, the same trends can be observed.
- The determined vegetational zones do not exactly match the LOI zones
- The palynology clearly shows the presence of Bolling-Allerød interstadial (B/A) followed by the Younger Dryas (YD) and Holocene (H), which is supported by the comparison of the LOI with the NGRIP record.

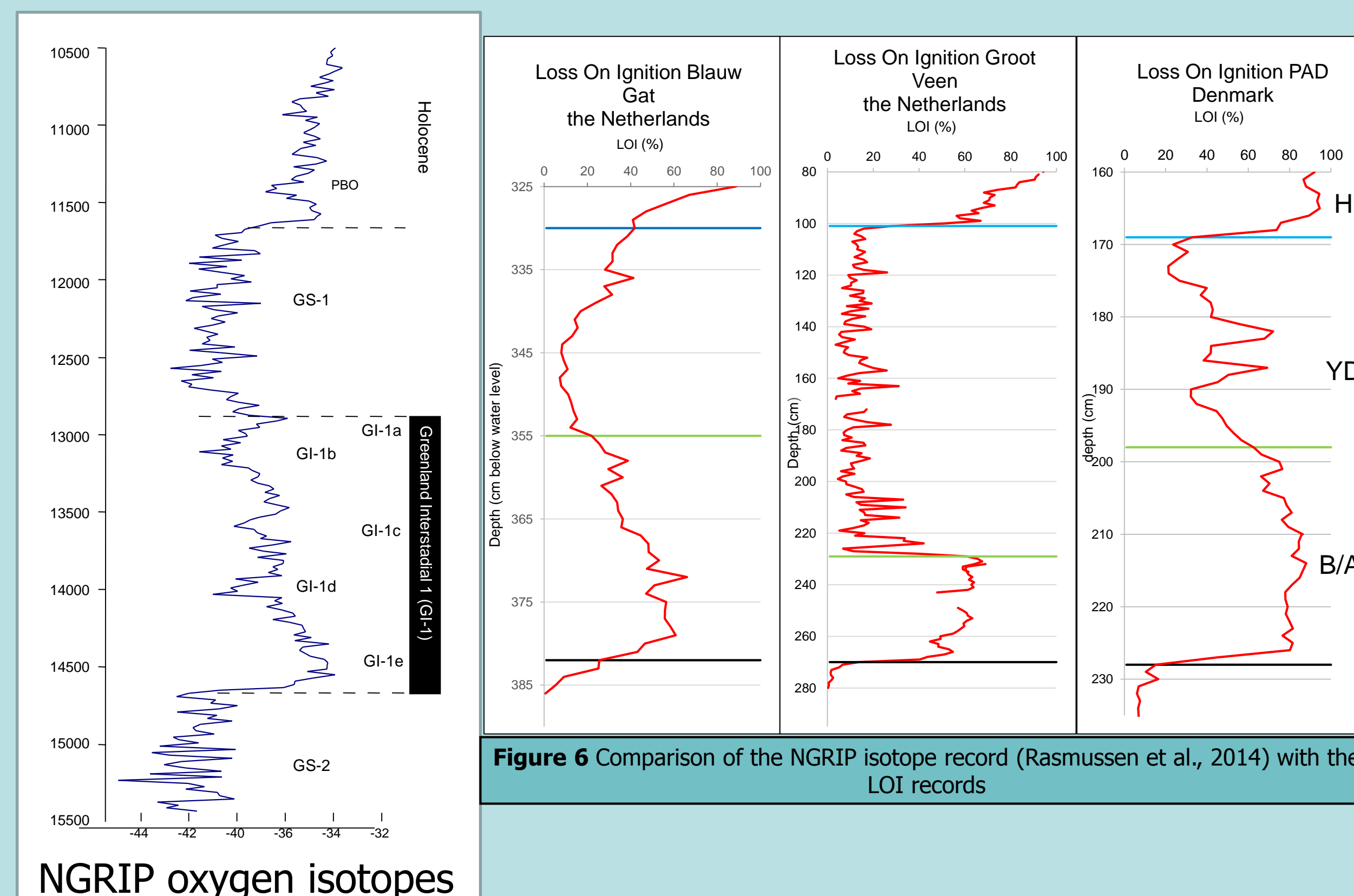


Figure 6 Comparison of the NGRIP isotope record (Rasmussen et al., 2014) with the LOI records

Conclusion:

The circular PAD depression in Denmark has many of the same characteristics (morphology, palynology and LOI), as the pingo remnants in the Netherlands. This might indicate the presence of pingo remnants in Denmark, close to the German border.