Thyborøn Area

Overview of the geological conditions in the Thyborøn urban- and harbour area

GeoAtlas Live Documentation
Report 1, 2018-07-12

This report gives a brief overview of the geological setting and conceptual interpretation of the Thyborøn Harbor Area and eastern part of the urban area. The terrain surface in the model area has been modified into a 1m grid cell version in order to represent the local geology and harbor infrastructure in the best possible way. Similarly, the recent fill layers, Postglacial organic layers and glacial Quaternary layers have been mapped in detail and interpolated into a 1m grid cell model.

The Pre-Quaternary layers are not shown in the 1m model, as it is focused on the uppermost 40 meters in the area. The Pre-Quaternary layers have previously been interpreted in the regional 25m model for the Thyborøn area (see separate documentation) and are used to adjust the lower boundary of the model.

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1 Introduction

This note gives a brief overview of the geology of the Thyborøn harbor model area (1m). All available geological datasets (drillings, geophysical surveys, maps) have been imported into the modelling software GeoScene-3D and visualized in Geos web based GeoAtlas Live platform. For more information, see here (Danish) or here (English).

The extend of the model area is illustrated in Figure 1.

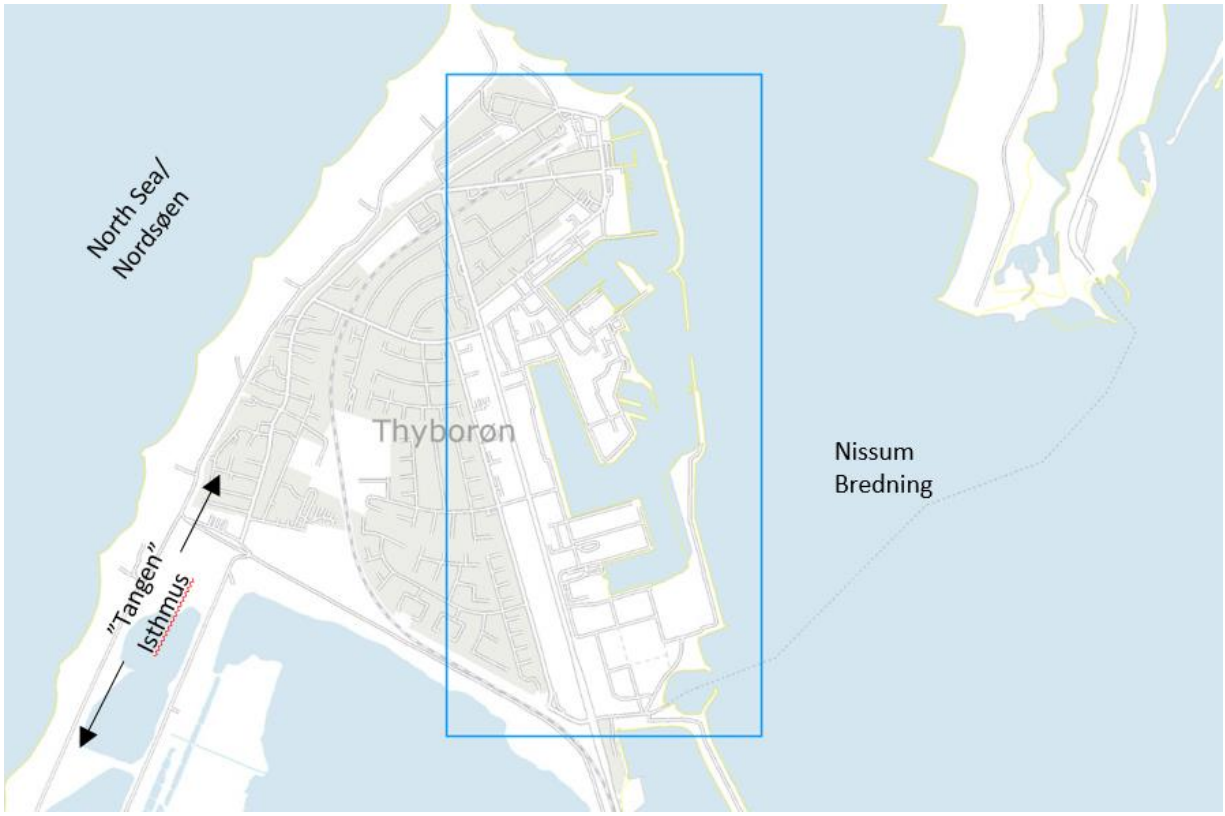

Figure 1. Extend of the Thyborøn Harbor Model Area (1m) covering the harbor area and the eastern part of the urban area.

The lithological units present in the area were interpreted and correlated on a local scale based on the depositional history and urban development.

The sedimentary units interpreted in the conceptual geology were setup in the modelling software. The upper surfaces covering the recent, postglacial and glacial deposits, were interpolated with a 1m cell size in the model area.

2 Geological setting and history

2.1 Pre-Quaternary structural geology and deposits

Structurally, the model area is positioned in the Danish Basin along the margin of the Ringkøbing-Fyn High (RFH). The RFH is a structural ridge orientated NV-SE consisting of elevated crystalline bedrock. The margin of this high is marked by a system of subparallel fault lines trending NV-SE that runs just to the south of the Thyborøn urban area, see Figure 2.

Along this structural system, migration of deep-seated Permian evaporates is triggered along the fault lines, as the evaporates (rock salt) is less dense than the sedimentary strata above and will migrate upwards along the weak zones along the fault lines, migrating close to the surface at Thyborøn.

During the upward migration, the evaporates have transected and up-folded the sedimentary strata superposing it, forming the Rønland Saltdiapir (salt dome). The salt-tectonic processes have uplifted the pre-Quaternary surface in the area below Thyborøn, elevating the rock salt to about level -95 and the pre-Quaternary surface to level -75m. The area with uplifted pre-Quaternary sediments is seen on a regional scale in Figure 2.

At Thyborøn the only remaining part of up-folded strata above the evaporates is a thin cover rock consisting of Cretaceous limestone, that forms the pre-Quaternary surface at Thyborøn and Harboøre. In the surrounding area, the pre-Quaternary deposits consist of clay -and sand deposits of Miocene age.

The deposits forming the pre-Quaternary surface in the area are shown in Figure 2.

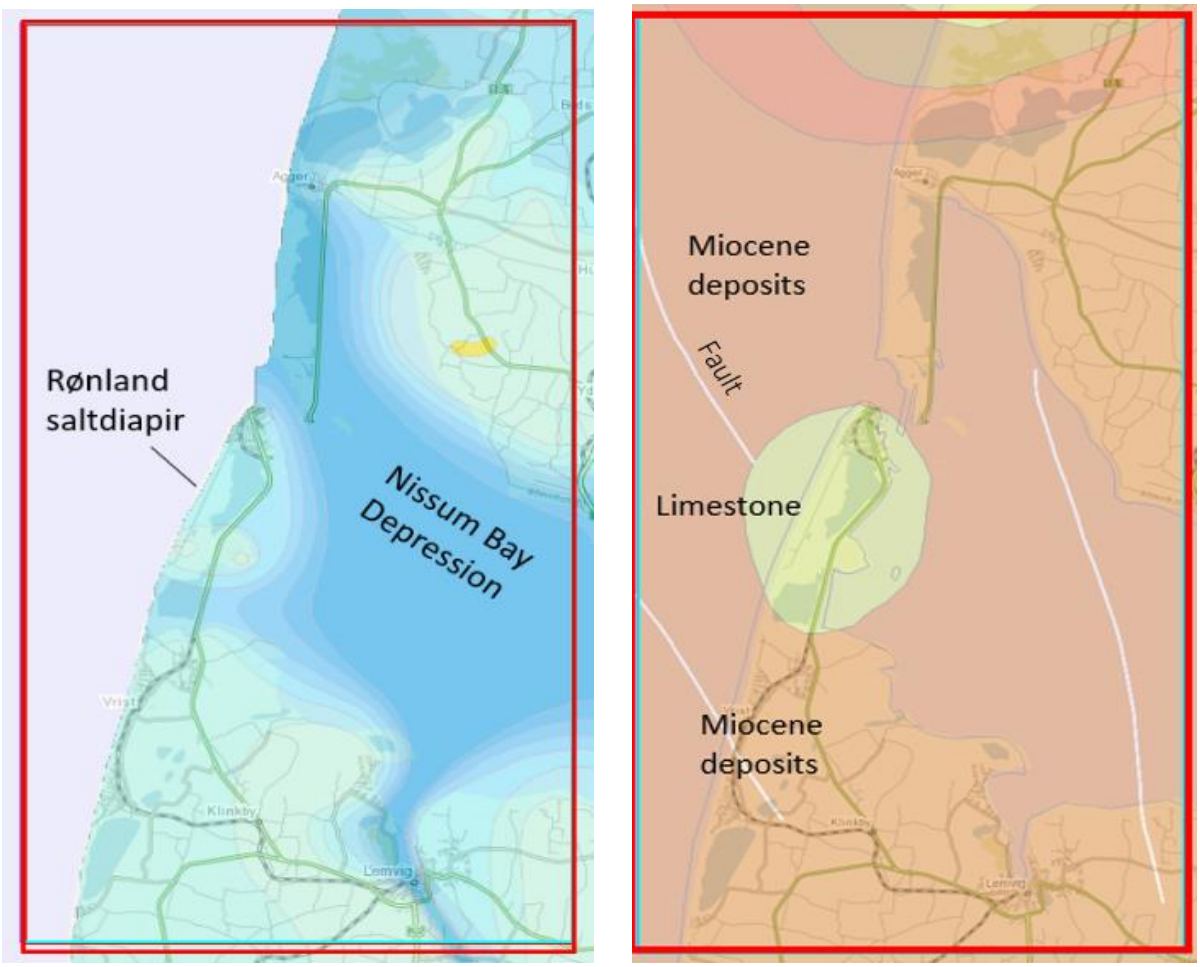

Figure 2. A) Elevation of the pre-Quaternary surface at Thyborøn and surrounding area, blue colors denotes low elevation, green and yellow colors denotes high elevation. Note the Nissum Bay depression and the elevated pre-Quaternary surface at Rønland/Thyborøn. B) Distribution of pre-Quaternary deposits at Thyborøn and surrounding area. The area is dominated by deposits of Miocene age (orange color) but in a circular area in the Thyborøn-Rønland area, the pre-Quaternary subsurface consists of Cretaceous limestone marking the extent of the salt dome. Note the white lines representing fault lines in the area. From /1/

2.1.1 Permian deposits

The Permian deposits in the area consist of rock-salt (halite) anhydrite, clay and minor sand layers that were deposited in shallow marine basins in an arid, subtropical climate. The evaporation from the basins led to deposition of salt on the seabed, that to some degree have been interbedded with clay and sand layers.
In the Danish Basin, the evaporites have been buried by younger sediments of e.g Cretaceous and Miocene age. The salt is less dense than the overlying deposits and has been mobilized by later tectonic activity at fault zones, enabling it to migrate upwards creating dome-structures.

2.1.2 Cretaceous deposits

The Cretaceous chalk was deposited as skeletal carbonate mud in a marine environment.
The Cretaceous chalk consists of fine-grained skeletons or skeletal fragments of algal coccolithophores with minor silt sized components e.g. bryozoans or marine invertebrates. The chalk is regularly bedded with only minor flint beds.

2.1.3 Miocene deposits

In the area surrounding the salt-dome, the pre-Quaternary geology consists of mica rich clay –and sand deposits of Miocene age. The Miocene deposits represent a period of alternating marine and deltaic/fluvial deposition in the Danish Basin due to tectonic and climatic variation. The clay deposits representing marine sedimentation in a fully marine or near shore environment.

The sand deposits represent deltaic or fluvial deposits prograding into the Danish Basin from the north. Two major deltaic formations are represented in the model area, the Billund -and the Bastrup Formations. The lowermost part of the Miocene deposits is represented by the clay-dominated Vejle Fjord Formation, that makes up the pre-Quaternary surface to the north in the model area.

The Miocene deposits are tilted towards the SW due to the general structure of the Danish Basin, in the model area. The Miocene deposits are influenced by the salt tectonics at Rønland however and the deposits have subsided along the margins of the salt structure.

2.2 Quaternary deposits

The Quaternary deposits in the surrounding area are represented by two clay tills and four layers of meltwater sand, however in the Thyborøn Harbour area, the upper meltwatersand unit is not present.

The two till layers are interpreted to represent two major glaciations during the Weichelian period, namely from the north (lower till) and from the northeast (upper till). The glacial deposits form major ice marginal ridges to the south in the Lemvig area and to the north at Vestervig.
The extent of the glacial ice sheets during the Weichelian glaciation is shown in Figure 3

The glacial deposits are thin above the salt dome at Thyborøn, but increase dramatically in magnitude in a circular area around the dome (circular depression) indicating that major salt-tectonic movements took place at the dome during this period.

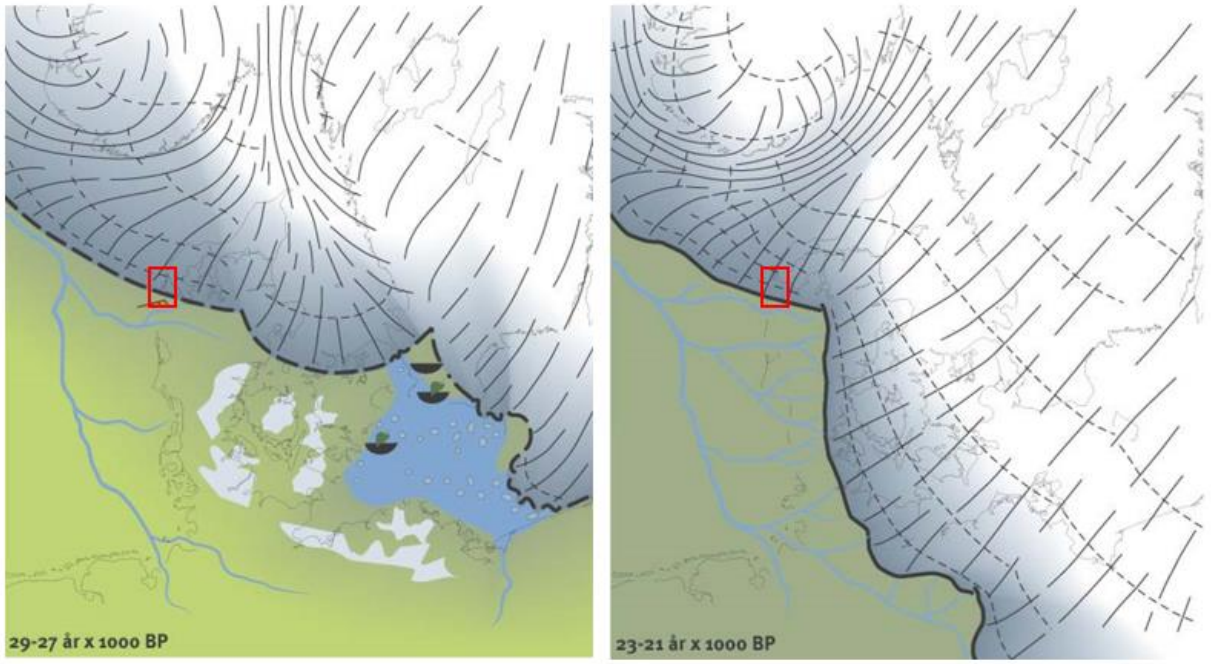

Figure 3. Extent of glacial ice sheets during A) Ice sheet expanding from a northern direction, associated with the lower till, B) Ice sheet expanding from a NE-direction, associated with the upper till. From /2/.

2.3 Postglacial and Recent deposits

The postglacial sediments consist of marine clay (Agger ler), marine sand, organic deposits (gyttja) and Aeolian sand.
The postglacial development has been elaborately described by Elkær (1985).

The marine clay is deposited during the postglacial marine transgression in the area. The clay is quite thin above the salt dome but in accordance with the glacial sediments, the magnitude increases in the circular depression around the dome indicating continued salt-tectonic movements in the area during the postglacial period.

The marine sand is deposited during the buildup of the barrier system that forms the present day land areas at Thyborøn (Harboøre and Agger Tange). The system is believed to have been deposited from the Postglacial to historic time and is thus a quite recent deposit (Holocene). The sand deposits show only little influence from salt tectonics.

Along the coastline Aeolian sand is deposited at present day. Fill deposits at Thyborøn consist primarily from sand pumped up from the Limfjorden area or from glacial sand deposits at Jyske Banke in the North Sea. The distribution of the postglacial deposits is shown in Figure 4.

Figure 4. Distribution of Postglacial deposits, primarily marine clay and sand deposits (blue colors) and Aeolian sand (yellow color). Red square marks the extent of the 1m model. From /1/.

3 Conceptual geology

The stratigraphy of the Thyborøn Harbor area is divided into a pre-Quaternary sequence, a glacial Quaternary sequence and a Postglacial sequence. The interpretation resulted in a model consisting of 5 Quaternary layers and 6 Postglacial layers. The pre-Quaternary layers are not part of the 1m model. An overview of the stratigraphy is given in Table 1.

The conceptual interpretation is illustrated in a conceptual profile orientated W-E showing the general geological settings and structures of the Thyborøn Harbor Model (1m), Figure 5.

Table 1. Overview of the stratigraphy in the Thyborøn Model Area. The stratigraphy includes glacial and postglacial Quaternary sediments including recent fill and aeolian sands.

No.	Name	Lithology code (DK)	Age	Description	Occurrence in model area
1	Aeolian sand	ES,S	Recent	Sand, fine-medium	In costal dunes
2	Fill	O,S,L	Recent	Sand, medium, sl. gravelly	Probably mainly marine sand from Limfjorden
3	Upper Marine sand	HS,DS, S	Recent	Sand, medium, w. gyttja and clay	Local occurrence in "Limfjord Barriers" area
4	Gyttja/organic dep.	HP.P, HL, L	Postglacial	Gyttja and Peat	As lenses at Thyborøn, as minor layers at barriers
5	Marine sand	HS,DS, S	Postglacial	Sand, medium	Regionally distr., silt, gyttja in upper part
6	Marine clay	HL,DL, L	Postglacial	Clay, fat ('Agger-clay')	Regionally distr., silt and sand lenses in upper part
7	Upper meltwater sand	DS, S	Glacial	Sand, fine-medium	Only local distribution
8	Upper clay Till	ML, L	Glacial	Clay Till, gravelly, sandy	Regional distribution
9	Intermediate meltwater sand	DS, S	Glacial	Sand, medium-coarse, gravelly	Regional distribution, occurs as lenses in ice marginal ridges
10	Lower clay Till	ML, DL, QL, L	Glacial	Clay, fat-sandy	Regional distribution, upper part is sandy clay
11	Lower meltwater sand	DS, GS,S	Glacial	Sand, medium-coarse, gravelly	Regional distribution, locally contains mica-sand

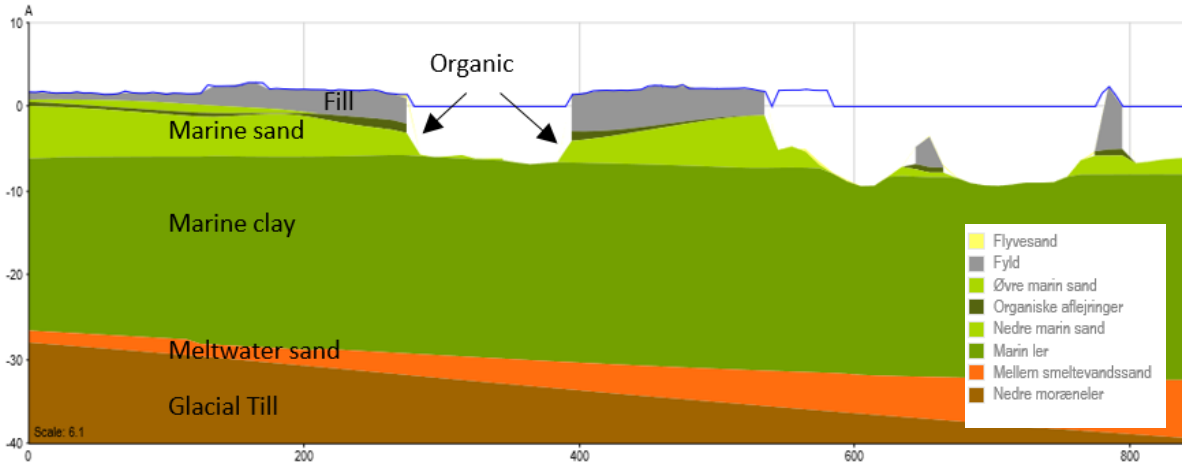

Figure 5. Conceptual profile SW-NE transecting the local geological model (1m) for the Thyborøn Harbour Area. Note the thin layer of organic sediments covering the marine sand and is found below the fill sediments in the harbor and urban area.

4 Description of the Quaternary sediments

The Quaternary stratigraphy in the Thyborøn Harbor area consists of a glacial and a postglacial sequence. The glacial sequence comprises three layers of meltwater deposits of mainly sand and gravel interbedded with two layers of glacial till. The glacial sequence rests mainly on top of Miocene deposits, but in the Thyborøn-Harboøre area it rests partially on Cretaceous chalk.

The glacial deposits are in the coastal /isthmus areas superseded by postglacial marine clay (Agger ler) and marine sand that in the rim along the Nissum Bay may be covered by organic deposits. Along the coastal strip bordering the North Sea, it may be covered by aeolian sands. In the build-up areas and at infrastructure (roads, harbors) recent fill deposits are locally present.

4.1 Aeolian sediments

The aeolian deposits are presently being deposited along the coastline of Jutland due to the strong influence of westerly winds and re-deposition of marine sand.

The Aeolian deposits consists of medium- to fine sand interbedded with local layers of peat.
The layer occurs along the coastline in elongated dunes, generally 4-8m high. The layer of aeolian sand is very thin in the model area, and occurs only locally except for the dunes in the NW-most part.

4.2 Fill deposits

The fill consists primarily of marine sand extracted from the seabed or glacial sand extracted from Jyske Rev. The fill thus consists of sand, fine medium, locally slightly gravelly.

The fill occurs in the build-up areas and harbor areas of Thyborøn. In the harbor area the fill in the breakwater structures and harbor infrastructure reaches 5-6 m in the eastern part – and 4-5 m in the western part of the harbor area. In the eastern part of the urban area, the fill reaches 2-3m. It wedges out to about 1m towards the west.

4.3 Postglacial organic deposits

The postglacial organic deposits include both terrestrial and marine deposits of peat, gyttja or organic clay. The terrestrial deposits are distributed locally along the coastline, at places interbedded with marine sand.

In the Thyborøn 1m model, the organic sediments are found stretching from the western coastline towards the lagoon area towards the east (Nissum Bredning). It is primarily found in the central and eastern part of the model area. In the western and southern area, the layer may be discontinuous or missing completely.

The organic layer is about 0,2-0,3m in thickness in the urban area. In the harbor, the layer locally reaches 1m in thickness, often underlying the fill deposits of the harbor infrastructure.

4.4 Postglacial marine sand

The postglacial marine sand was deposited in a high-energy marine environment during a phase of marine transgression in the area; the upper part of the layer may represent recently deposited or re-deposited sediments.

The layer consists of medium sand that in the upper part may be interbedded or overlaying organic sediments.

The layer occurs in the entire isthmus area ("tangen") and is present in the entire model area except from the easternmost part of the seabed (Nissum Bredning) and in the Thyborøn Channel.

The thickness is about 6-8m in the urban area, thinning in the harbor area in the east to 3-4m. In parts of the harbor channels, the layer is missing completely.

4.5 Postglacial clay ("Agger ler")

The postglacial clay was deposited in a low-energy marine environment with clay sedimentation in protected bay areas. The layer consists of clay with high plasticity that may be interbedded with sand layers in the upper part.

The clay occurs in the whole of Nissum Bay Area, along the isthmus and in the entire Thyborøn 1m model area. In the western part of the area the thickness reaches about 20m, and in the eastern part it reaches 25m.

4.6 Upper meltwater sand

The upper meltwater unit is interpreted to have been deposited during the late glacial period when the glacial ice in the area was melting. The layer consists of medium- to fine sand.

The upper meltwater-sand does not occur in the model area.

4.7 Upper clay Till

The upper till unit is interpreted to have been deposited during an ice-advance from the NE during the mid Weischselian and is associated with ice marginal complexes along the southern shore of the Nissum Bay at Lemvig and Klinkby.

The layer consists of sandy-gravelly clay till and is widely distributed in the surrounding area, however in the model area it occurs only in a very limited area in the northern part of the model area with a thickness about 2,5m.

4.8 Intermediate meltwater sand

The intermediate meltwater sand unit is interpreted to have been deposited by the NE-ice.
The layer consists of medium-coarse or gravelly sand and is widely distributed in the glacial landscape and in the isthmus area at Thyborøn. The layer is dipping towards the northeast in the Thyborøn Harbor model. It is very thin or completely missing in the western part of the area, but increases in thickness towards the east where it reaches a thickness about 10m.

4.9 Lower clay till

The unit is interpreted to have been deposited by an ice-advance from the north, but it may contain deposits from older glaciations. The layer consists of high plasticity-sandy clay till, and is distributed in the most part of the model area, especially in the Nissum Bay depression.

In the Thyborøn 1m model area, the layer is dipping towards the northeast. The layer thickness varies from about 20m in the west to about 30m in the east.

4.10 Lower meltwater sand

The lower meltwater sand unit is interpreted to have been deposited sub-glacially by the NE-ice sheet.
The layer consists of medium-coarse sand or gravelly sand, and is distributed in the glacial landscape north- and south of the Nissum Bay and in the isthmus area to the north of Thyborøn.

The layer is dipping towards the northeast, is present in the northern part of the model area and is missing in the central- and southern part. The thickness of the layer varies between 5-10m.

5 References

/1/ GEUS, map service.

/2/ Houmark-Nielsen, M. et al., 2005: De seneste 150.000 år I Danmark, istidslandskabet og naturens udvikling. Geoviden, GEUS.