

Aarhus City Area

Overview of geological conditions in the central part of Aarhus and Harbour area

GeoAtlas Live Documentation
Report 1, 2018-07-12

This report gives a brief overview of the geological setting and interpretation of the geological model for Aarhus City area and the Harbour area.

The pre-Quaternary and Quaternary stratigraphy and the structural settings of the area are presented by maps and profiles illustrating the complexity of the area.

The mapped layers in the Aarhus City Model are briefly described by occurrence, thickness and sedimentology.

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Contents

1	Introduction	4
2	Geological setting	5
2.1	Pre-Quaternary deposits and elevation of the pre-Quaternary surface	5
2.2	Quaternary deposits and landscapes	7
3	Conceptual model	8
4	Description of the pre-Quaternary sediments	10
4.1	Glimmersand (mica-sand) and Kwartssand (Quarts-sand)	10
4.2	Glimmerler (mica-clay)	11
4.3	Viborg ler (-clay)	11
4.4	Kysing mergel (-marl)	11
4.5	Moesgård ler (-clay)	11
4.6	Søvind mergel (-marl)	11
5	Description of Recent fill deposits	12
5.1	Upper sand-fill deposits	12
5.2	Intermediate clay-fill deposits	12
5.3	Lower sand fill deposits	12
6	Description of the Postglacial sediments	13
6.1	Upper Postglacial Organic Deposits	13
6.2	Postglacial sand	13
6.3	Lower Postglacial gyttja	13
6.4	Postglacial clay	13
7	Description of the late-glacial sediments	14
7.1	Late Glacial Meltwater-sand	14
7.2	Late-glacial Meltwater-clay	14
8	Description of the glacial sediments	14
8.1	Upper glacial floe (Paleocene clay)	14

8.2	Upper glacial meltwater sand/sand-till	15
8.3	Upper meltwater-clay	15
8.4	Upper glacial till	15
8.5	Lower meltwater-clay	15
8.6	Intermediate glacial meltwatersand	15
8.7	Lower glacial floe (Paleocene clay)	15
8.8	Lower glacial till	16
8.9	Lower glacial meltwatersand	16
9	References	16

1 Introduction

This note gives a brief overview of the geology of the Aarhus City Area. All available geological datasets (drillings, geophysical surveys, maps) have been imported into the modelling software GeoScene-3D and visualized in Geo's web based Geotlas Live platform. For more information, see [here](#) (Danish) or [here](#) (English).

The extent of the model area is illustrated below, see Figure 1.



Figure 1 Extent of the Aarhus Model Area.

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

The sedimentary units interpreted in the conceptual geological model were setup in the modelling software. The layers were interpolated with a 25m cell size in order to ensure a high standard of accuracy.

2 Geological setting

The geological setting in the Aarhus area is a result of the pre-Quaternary stratigraphy and the elevation of the pre-Quaternary surface as well as the depositional and erosional history during the glaciations in the Quaternary epoch.

The geological setting and depositional history is briefly described below:

2.1 Pre-Quaternary deposits and elevation of the pre-Quaternary surface

The pre-Quaternary deposits in the Central Jutland area are generally dipping towards the SW due to the overall tectonic settings in the Danish Basin. The pre-Quaternary stratigraphy in the area thereby constitute a sequence where the oldest deposits are found to the east and the youngest deposits are found towards the west due to erosion of the strata.

Oligocene and Miocene deposits primarily represent the pre-Quaternary sediments in the Aarhus area. Deposits of Danien age are locally found in the western part of Brabranddalen (outside the model area) due to salt-tectonic influence, which has caused uplift of deeper-seated sediments.

The deposits of Miocene, Oligocene, and Eocene age are primarily made up by marine clays with high to very high plasticity, but the Miocene deposits may contain local sand- and silt layers.

The distribution of the pre-Quaternary deposits is shown in Figure 2.

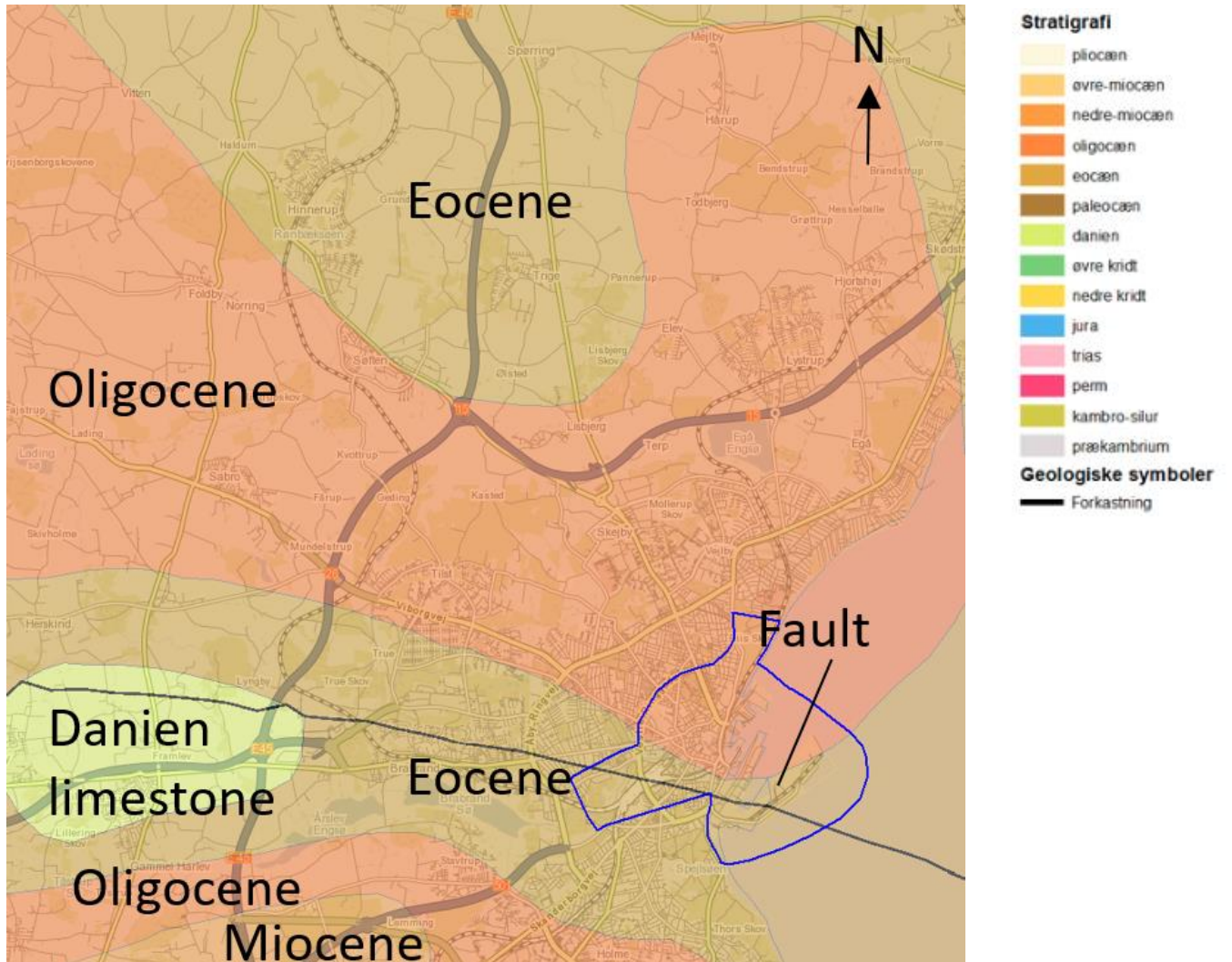


Figure 2. Distribution of Miocene, Oligocene, Eocene and Danien deposits at the pre-Quaternary surface. The sediments are primarily marine clay with high to very high plasticity and minor sand layers. Note the occurrence of Danien Limestone in the western part of the Brabrand valley (outside the model area) and the fault line following the course of valley. Model area is marked by blue polygon. From /1/

The pre-Quaternary surface is transected by multiple, deeply incised valley-systems, that probably represent the orientation of fault lines in the area. The fault lines have been prone to erosion during the Tertiary and Quaternary thus creating valley systems in the pre-Quaternary surface. A map showing the elevation of the pre-Quaternary surface is shown in Figure 3.

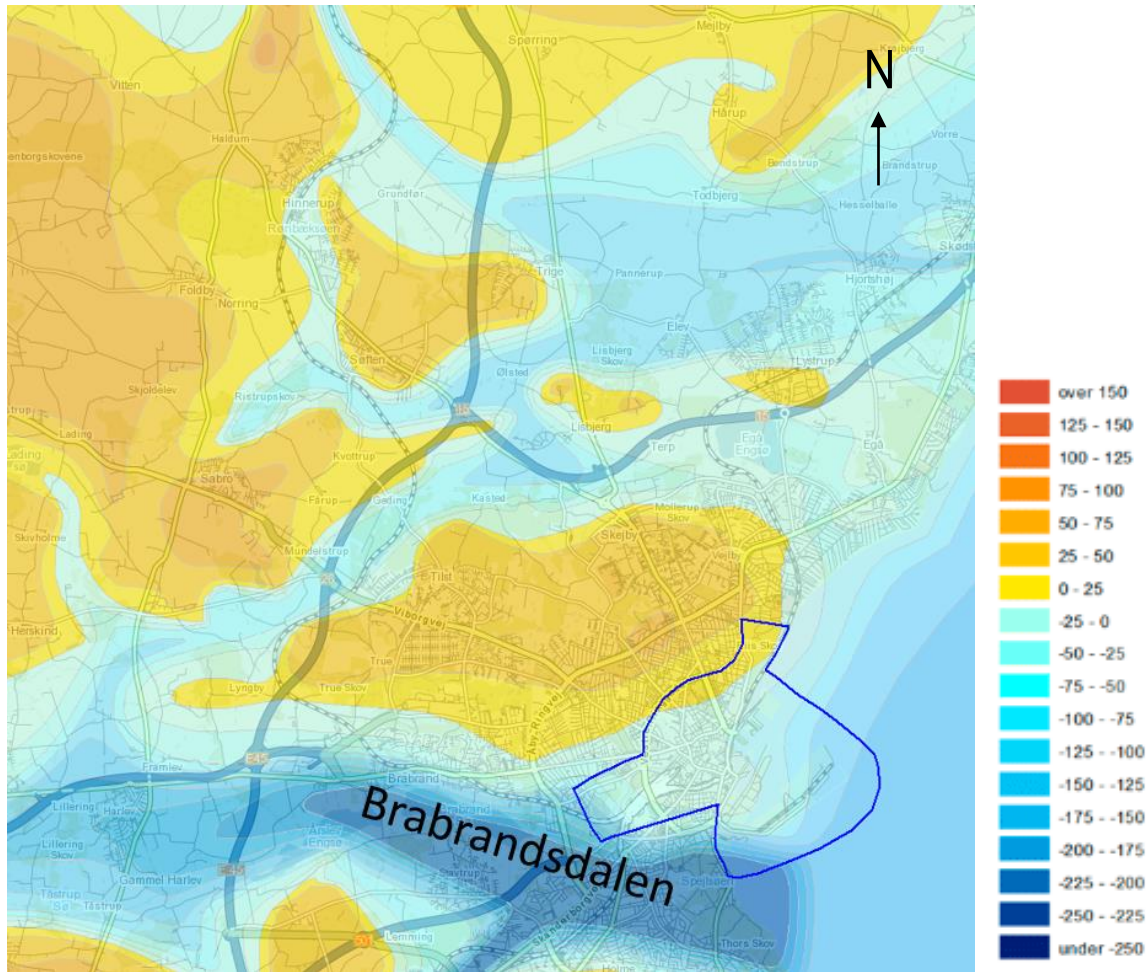


Figure 3. Elevation of the pre-Quaternary surface in the Aarhus model area, a major valley system (Brabranddalen) extends in an E-W direction along a fault system shown in Figure 2. Other valley systems are orientated SW-NE. The valley systems coincide with the buried valley systems in the area. Note the general rise in elevation towards the west. Model area is marked by blue polygon. From /1/.

2.2 Quaternary deposits and landscapes

The Quaternary landscape has primarily been developed during the last glaciation in the area, the Weichselian Glaciation.

During the Weichselian stage in this area, glaciers first advanced from a NE direction. A later advance from a SE direction replaced this advance. Both glacial advances deposited layers of till and meltwater sediments, developed ice marginal lines/complexes and eroded deep systems of subglacial valleys in the area.

The advance of the glacial ice sheet from the NE produced ice marginal lines with a NW-SE orientation and tunnel valleys with an SW-NE orientation. The valley systems developed by the NE-ice may be partially or completely covered by glacial sediments from the later advance from the SE.

The final advance of ice during the Weichselian came from the SE. This advance had its maximum extend to the east and north of Aarhus and produced concave ice marginal lines with SW-NE orientation. Meltwater valleys related to this advance are orientated N-S or NW-SE. During the retreat of the ice sheet towards the

east, major glacial lakes were created in the western part of the deep valley systems due to damming to the west by pre-Quaternary sediments/ice marginal lines and to the east by the retreating ice.

The extent of the NE-advance and the SE-advance is shown in Figure 4.

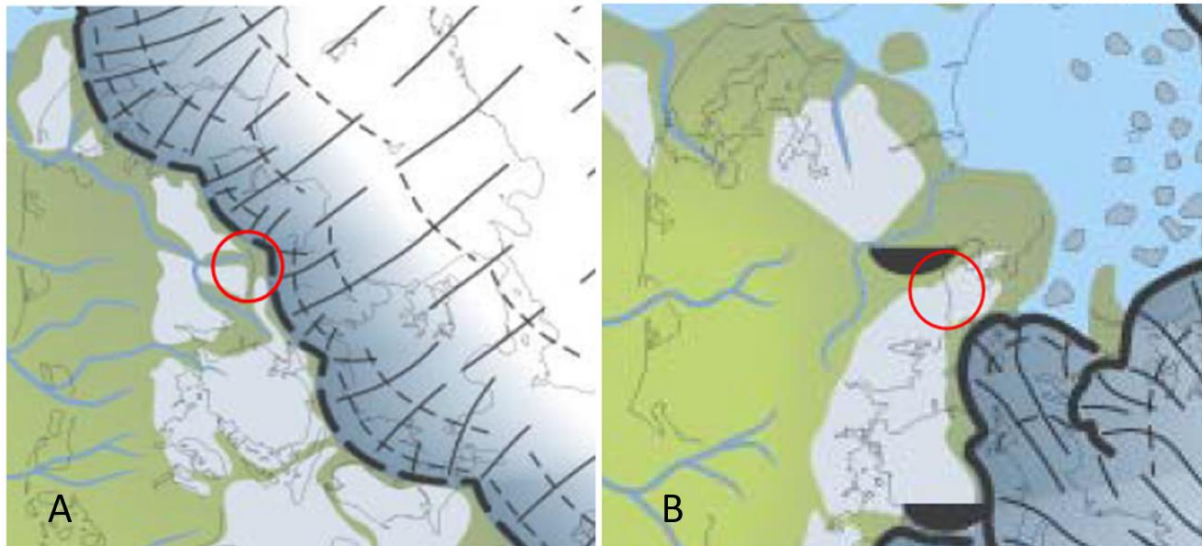


Figure 4. A) Distribution of the NE-ice sheet close to its maximum extent in Jutland, note the NW-SE orientation of the ice marginal lines. B) Distribution of the SE-ice sheet during its advance towards the Aarhus area and Eastern Jutland. The model area is marked by red circles. From [2].

3 Conceptual model

A conceptual model has been set-up, based on the interpretation of the geological setting and all available datasets. The conceptual stratigraphy of the Aarhus City model is divided into 3 recent fill layers, 4 Post-glacial layers, 2 late-glacial layers, 9 glacial layers, including two layers of glacial floe, 2 Miocene layers and 4 Oligocene-Eocene layers.

An overview of the stratigraphy is given in Table 1.

The geological structures and stratigraphy of the area is illustrated in a conceptual profile orientated (SW-NE) transecting the city centre and harbour area (see Figure 5).

Table 1. Overview of the stratigraphy for the Aarhus area. The stratigraphy includes Eocene, Oligocene, Miocene and Quaternary sediments as well as postglacial organic sediments and Recent fill deposits.

No	Name	Lithology (DK)	Chronology
1	Fill-Sand (upper)	O-S, O-G	Recent
2	Fill-Clay	O-S-L, O-S-L	Recent
3	Fill-Sand (lower)	O-S, O-G	Recent
4	Postglacial gyttja (upper)	P, T, FP, FT	Postglacial
5	Postglacial sand	FS, FG, HS, HG	Postglacial
6	Postglacial gyttja (lower)	P, T, FP, FT	Postglacial
7	Postglacial clay	FL, FI, HL, HI	Postglacial
8	Late-glacial sand/gravel	DS, GS, HS, S, G	Late glacial
9	Late-glacial meltwater clay	ML, DL, DI, i, I	Late glacial
10	Paleocene clay (Glacial floe)	IL, PL	Glacial
11	Glacial Meltwater-sand	DS, DG, S, G, MS, MG	Glacial
12	Upper glacial meltwater-clay	DL, DI, I, i	Glacial
13	Upper Glacial Till	ML, I, i	Glacial
14	Glacial Meltwater-clay	DL, DI, I, i	Glacial
15	Glacial Meltwater-sand	DS, DG, S, G, MS, MG	Glacial
16	Paleocene clay (Glacial floe)	IL, PL	Glacial
17	Glacial Till (lower)	ML, I, i	Glacial
18	Glacial Meltwater-sand	DS, DG, S, G, MS, MG	Glacial
19	Glimmersand (Micra-sand)	GS, KS, KG	Miocene
20	Glimmerler (Micra-clay)	GLP	Miocene
21	Viborg ler (clay)	VL, IL	Oligocene
22	Kysingmergel (marl)	KM, IL	Eocene
23	Moesgårdler (clay)	MO, IL	Eocene
24	Søvindmergel (marl)	SL, IL	Eocene

Conceptual Geology, Aarhus-C.

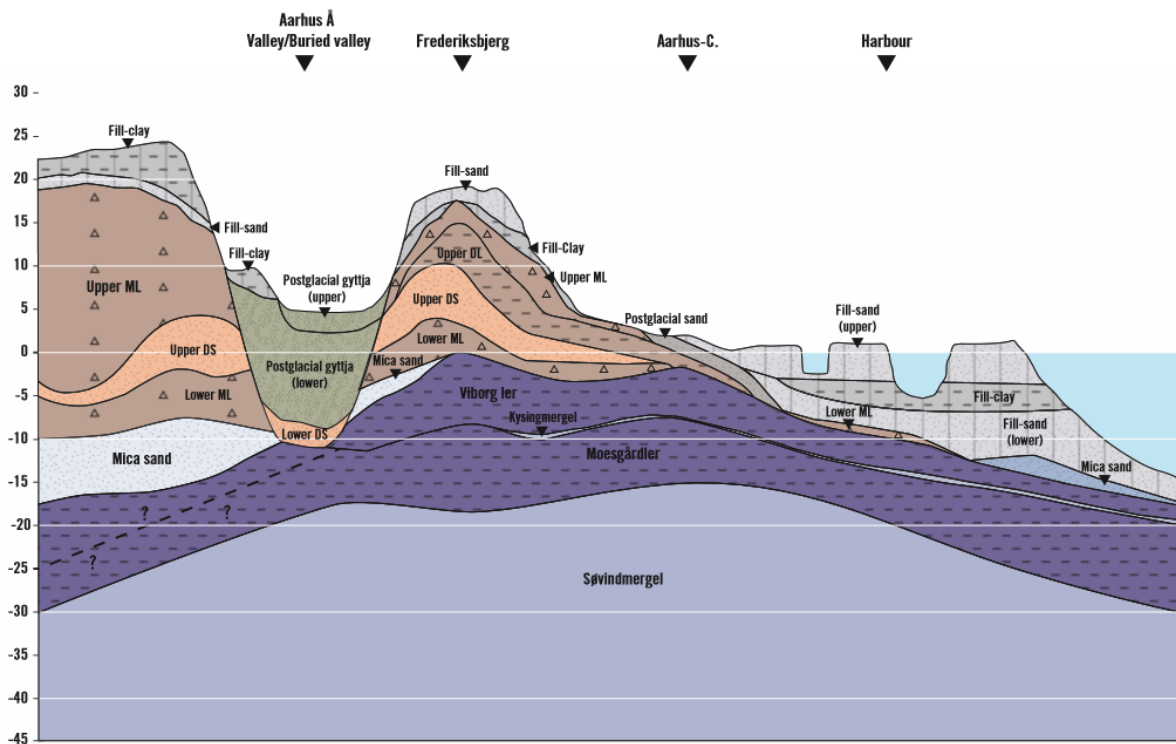


Figure 5. Conceptual profile orientated SW-NE transecting the geological model for the Aarhus C -area. Note the elevated pre-Quaternary deposits in the central part of the area. The pre-Quaternary deposits are only covered by thin Quaternary or postglacial sediments in the harbor area. Also note the valley system stretching from Brabrandsdalen towards the central part of the city, containing Aarhus Å.

4 Description of the pre-Quaternary sediments

The pre-Quaternary deposits consist of marine clay of Palaeocene, Eocene, Oligocene and Miocene age with high to very high plasticity. The Miocene layers does, however, include sand- and silt layers in the upper part.

The pre-Quaternary layers are generally dipping towards the SW, but are locally influenced by tectonics and the distribution of incised valley/buried valley systems that may influence the distribution and/or the elevation of the layer.

4.1 Glimmersand (mica-sand) and Kvartssand (Quartz-sand)

The mica-rich sand is here attributed to the Brejning FM (Øksnerade MB) and/or the Vejle Fjord FM that was deposited during the latest part of the Oligocene period.

The mica-rich sand consists of white to grey-dark, fine-grained sand, often with organic content.

The layer occurs in the hills in the NE- part of the model area, north of Knudrigade/Nordre Kirkegård and east of the "Old town" (Den Gamle By), the thickness varies between 5-15m.

Quartz sand is typically coarser grained and consist almost exclusively of well-rounded grains of quartz.

4.2 Glimmerler (mica-clay)

The mica-rich clay is here attributed to the Brejning FM (specifically the Brejning Clay) and the Vejle Fjord FM that were deposited during the latest part of the Oligocene/early Miocene period.

The clay is brownish with medium-high plasticity to silty-sandy. It is rich in mica, with organic content and no carbonate content.

The layer occurs in the hills in the NE- part of the model area, near Knudrisgade/Nordre Kirkegård and east of the "Old town" (Den Gamle By), the thickness varies between 5-10m.

4.3 Viborg ler (-clay)

The Viborg Clay was deposited during the Oligocene period.

The deposits consist of clay with very high plasticity with some silt specs. The upper part may contain fine sand specs. The sediment contains a slight amount of mica, some organic material but no carbonate content.

The layer extends from the eastern part of the harbour area with a thickness about 2m towards the west, where the thickness increases to about 5m. The layer is absent in Brabrandsdalen and in the northern part of the model.

4.4 Kysing mergel (-marl)

The layer is an internal layer in the Late Eocene Søvind Marl FM.

The marl consists of light-grey marl with very high plasticity and is similar to the Søvind Marl. It has a very high content of glauconite.

The layer occurs in the southern part of the Aarhus Harbour area and parts of the city centre, where it occurs with a thickness about 2m.

4.5 Moesgård ler (-clay)

The layer is an internal layer in the Søvind Marl FM and was deposited during the Late Eocene.

The Moesgård clay is a dark layer with very high plasticity and a low carbonate content.

The layer is found the southern part of Aarhus Harbour area and most parts of the southern part of the city centre, the thickness varies from between 1-2m in the harbour area to between 5- 10m in the urban area.

The layer is absent in Brabranddalen/along Aarhus Å and the northern part of the area, in this area, this is probably due to lack of data

4.6 Søvind mergel (-marl)

The Søvind marl was deposited during the Late Eocene.

The marl consists of light-grey marl with very high plasticity with minor layers or laminae of clay. The uppermost part has a high carbon content and is almost white in colour.

The layer forms the bottom layer in the entire model, the thickness of the layer is not interpreted.

5 Description of Recent fill deposits

The fill deposits have been divided into three layers according to the dominant lithology (sand or clay). The fill deposits are thickest in the harbour area where they are part of the constructions, fill deposits are also found in the central part of Aarhus and adjacent parts of Brabrandsdalen. The fill wedges out towards the outer parts of town.

5.1 Upper sand-fill deposits

The layer consists primarily of sand-fill but may include a mixture of different lithology's including organic deposits, including building materials of various kind.

The layer is found in the entire harbour area, along the edges of Brabranddalen/Aarhus Å and in parts of the northern part of the urban area NW of Knudrisgade/Nordre Kirkegård . The layer is absent in the city centre. The layer thickness varies greatly and in the central and northern part of the harbour area, the thickness varies between 5-10m, thinning towards the former shoreline to 1-2m.

In the areas along Brabranddalen/Aarhus Å the thickness varies between 1-2m, with isolated areas at Åby and Frederiksbjerg with thickness about 5m. In the northern part, thicknesses between 2-5m are seen at Knudrisgade/Nordre Kirkegård

5.2 Intermediate clay-fill deposits

The layer consists primarily of clay-fill but may include a mixture of different lithology's including organic deposits and building materials of various kind.

The layer is found in the central and southern part of the harbour area, along the edges of Brabranddalen/Aarhus Å, at "Den Gamle By" and to the north at Risvang.

The layer thickness varies greatly and in the central and southern part of the harbour area, the thickness varies between 5-10m, thinning towards the former shoreline to 2-5m.

In the areas along Brabranddalen/Aarhus Å, the thickness varies between 1-2m, with isolated areas at Frederiksbjerg with thickness about 5m. In the western part, the thickness reaches 5m at "Den Gamle By" and in the north at Risvang. The layer is absent in the city centre.

5.3 Lower sand fill deposits

The layer consists primarily of sand-fill but may include a mixture of different lithology's including organic deposits, including building materials of various kind.

The layer is found in the eastern part of the harbour area, in Brabranddalen/Aarhus Å, at "Den Gamle By" and in the city centre.

The layer thickness varies greatly. In parts of the harbour area the thickness is between 5-10m, thinning towards the former shoreline to 1-2m.

In the areas in Brabranddalen/Aarhus Å the thickness varies between 1-2m, with isolated areas at Åby and Frederiksbjerg with thickness about 5m. In the western part, the thickness reaches 5m at "Den Gamle By". In the city centre, the thickness varies between 1-5m.

6 Description of the Postglacial sediments

The postglacial deposits are divided into four layers based on their lithological composition (gyttja, sand, clay) and depositional environment, all layers may have an organic content. The deposits are found in the upper part of Brabranddalen, along Aarhus Å and coastal parts of the area, including the harbour area and parts of the city centre.

6.1 Upper Postglacial Organic Deposits

The postglacial deposits consist of both marine and freshwater deposits, mostly gyttja or peat. Postglacial organic deposits are widely distributed in the former tunnel valleys and marine surfaces. They are widespread in Brabranddalen/along Aarhus Å and its extension through the central parts of Aarhus and is also found in the eastern part of the harbour area and adjacent parts of the Aarhus Bay.

The thickness varies between 1-5m in the deeper parts of Brabranddalen/Aarhus Å. The layer wedges out on the steep sides of the tunnel valley. In the central parts of Aarhus the thickness lies between 1-2m. Thin organic layers with a thickness <1m are also seen in the outer part of the harbour below the outer pier.

6.2 Postglacial sand

The postglacial deposits consist of both marine and freshwater sand-deposits, with some organic content. Postglacial organic deposits are widely distributed in the former tunnel valleys and marine surfaces, they are widespread in Brabranddalen/Aarhus Å and its extension through the central parts of Aarhus. It is also found in parts of the harbour area and adjacent parts of the Aarhus Bay.

The thickness varies between 1-10m in the deeper parts of Brabranddalen/Aarhus Å. The layer wedges out on the steep sides of the tunnel valley. In the central parts of Aarhus the thickness lies between 5-10m. The sand deposits in the harbour area are generally about 5 thick, but in the southern part they may reach 10m.

6.3 Lower Postglacial gyttja

The postglacial deposits consist of both marine and freshwater deposits, mostly gyttja or peat. The gyttja deposits are primarily distributed in Brabranddalen and its extension through the central parts of Aarhus along Aarhus Å and is also found in the eastern part of the harbour area and adjacent parts of the Aarhus Bay.

The layer forms a discontinuous layer in the lower parts of Brabranddalen tunnelvalley/Aarhus Å, the layer wedges out towards the steep sides of the tunnel valley. The thickness varies between 1-5m in the tunnel-valley and central parts of Aarhus. Thin organic layers with a thickness about 1m are also seen in the outer, northern part of the harbour below the outer pier.

6.4 Postglacial clay

The postglacial clay deposits consist of both marine and freshwater deposits, with some organic content. The clay deposits are primarily distributed in Brabranddalen/Aarhus Å, along the coastline and in parts of the outer pier in the harbour area.

The deposits generally form local 1-2 thick layers. In the central part of the outer pier it may reach 5m in thickness.

7 Description of the late-glacial sediments

The late glacial sediments are divided into two layers based on their lithological composition (sand/clay) and depositional environment. The deposits are only distributed locally in the area.

7.1 Late Glacial Meltwater-sand

This unit consists of late-glacial sand deposited in both marine and freshwater environments.

The sand deposits consist mainly of fine to coarse-grained unconsolidated sand and can be with some organic content. The layer occurs with a thickness about 1-2m in the central part of Aarhus and in isolated areas at the eastern pier in the harbour area.

7.2 Late-glacial Meltwater-clay

This unit consists of late-glacial-unconsolidated clay deposits, mostly top-till deposits but also includes meltwater clay and silt.

The unit is distributed in parts of the harbour area and locally in the urban areas of Aarhus. It occurs locally in elevated parts of the glacial landscape, but is absent in the tunnel valleys. The thickness varies between 1-5m.

8 Description of the glacial sediments

The glacial sediments are divided into nine layers according to lithological composition and depositional environment. The glacial sequence contains two till (upper/lower) that are related to ice sheets advancing from the NE and SE respectively.

The till units are interlayered by units of meltwater sand and meltwater clay and the upper till unit is overlain by meltwater-clay and sand-till/meltwater-sand. The lower till unit is underlain by a unit of meltwater sand and gravel.

The glacial sequence contains multiple glacial floes represented by Paleocene clay that have been displaced by glaciotectionics.

8.1 Upper glacial floe (Paleocene clay)

The unit consists of glacially displaced Palaeocene clay with high to very high plasticity that may be mixed with various amounts of glacial sediments (till, clay, sand).

The glacial floes occur in the upper part of the glacial sequence and glacial floes of Palaeocene clay occurs at the north-western part of the harbour pier, in the central part of town at Vor Frue Kirke, at "The Old Town" (Den Gamle By) and to the north, just to the east of Knudrsgade/Nordre Kirkegård.

The floes are typically 2-5m in thickness.

8.2 Upper glacial meltwater sand/sand-till

The unit consists of meltwater sand, -silt and -gravel with minor amounts of sandy till or silty till. The unit is consolidated and occurs as a widely distributed layer below the late-glacial meltwater-clay. This means that it occurs in the elevated parts of the glacial landscape but is absent in most tunnel valleys.

The layer occurs in the southernmost part of the model in the costal band south of Frederiksbjerg and the hills at Ole Worms Alle, neat the University Science Park. The thickness varies between 2-5m.

8.3 Upper meltwater-clay

The unit consists of meltwater-clay and meltwater-silt with minor sand lenses.

The unit occurs in parts of Brabranddalen/Aarhus Å near Åbo, in the costal band at Frederiksbjerg, in the hill at the University Hospital (Viborgvej) and in the harbour area.

The thickness varies between 1-6m

8.4 Upper glacial till

The unit is widely distributed in the model area. It consists mostly of consolidated clay till with minor amounts of meltwater-clay. It occurs in most parts of the area except from parts of Brabranddalen, the central parts of town and in the western part of the harbour, where it has a more scattered distribution.

The layer thickness varies between 5-10m in the hill areas to the northwest and west along Brabranddalen/Aarhus Å and along the coast south of Frederiksbjerg. In the remaining areas, the thickness varies between 1-5m.

8.5 Lower meltwater-clay

The unit consists of meltwater-clay and meltwater-silt with minor sand lenses.

The layer occurs especially in the southern part of the model area in the marine and coastal areas south of Frederiksbjerg and along Brabranddalen. The layer also occurs in minor areas in the northern part of the model especially in the area at Nordre Kirkegaard and in the northern part of the eastern pier in the harbour area.

In the southern part, the thickness varies between 5-15m. In the north it varies between 1-5m.

8.6 Intermediate glacial meltwatersand

The unit consists of meltwater sand and -gravel and occurs in primarily in Brabranddalen/Aarhus Å, in the hill areas to the northwest and south and in parts of the harbour area.

In Brabranddalen the thickness reaches 50m in the western part, thinning towards the east. In the hill areas to the northwest and south and the harbour area the thickness varies between 1-5m

8.7 Lower glacial floe (Paleocene clay)

The unit consists of glacially displaced Palaeocene clay with high to very high plasticity that may be mixed with various amounts of glacial sediments (till, clay, sand).

The glacial floes are frequent in the lower part of the glacial sequence and floes of Palaeocene clay occurs especially along the edges Brabranddalen/Aarhus Å towards the city centre, in the area between Nørre Alle

and Nørrebrogade, at Aarhus University (Wilhelm Meyers Alle) and to the north east at Trøjborgvej/Nordre Kirkegaard toward Riis Skov.

The floes are typically 5-15m in thickness.

8.8 Lower glacial till

This unit consists mostly of consolidated clay till with minor amounts of meltwater-clay.

It occurs along Brabranddalen to the southwest and in the hill-areas to the northwest, the unit is absent or occurs only locally in the remaining area that includes most of the city centre and harbour area.

The thickness along Brabranddalen varies between 2-10m. In the hill-areas to the northwest the thickness increases to 60m, especially in the area at Aarhus University along Langelandsgade towards the northwest. In the harbour area the layer occurs only locally with a thickness between 1-2m.

8.9 Lower glacial meltwatersand

The unit consists of meltwater sand- and gravel and occurs primarily in the deepest levels in Brabranddalen, in the hill area at Aarhus University Hospital at Viborgvej towards the west and in an elongate area to the south of Frederiksbjerg, at Marselisborg Havnevej. To the north, the layer occurs along Riis Skov.

The thickness in Brabranddalen varies between 10-15m. In the hill area at Aarhus University Hospital along Viborgvej the layer occurs with a thickness about 5-10m towards the west. To the south of Frederiksbjerg the layer occurs with at thickness of 5-10m at Marselisborg Havnevej. To the north, the meltwater sand occurs with a thickness about 1-5m in the Riis Skov area, wedging out towards the west.

9 References

/1/ Jacobsen, GEUS, map service.

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