

Copenhagen Area

Overview of the geological conditions in the Copenhagen area and surrounding areas

GeoAtlas Live Documentation
Report 1, 2018-07-12

This report gives a brief overview of the geological setting and conceptual interpretation of the Copenhagen area and the surrounding area.

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

The mapped layers in the Copenhagen model are briefly described by occurrence, thickness and sedimentology.

GeoAtlas Live Documentation

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1 Introduction

This report gives a brief overview of the geology of the Copenhagen area. All available geological datasets (drillings, Geophysical surveys, maps) have been imported into the modelling software GeoScene-3D. The lithological units present in the area were interpreted and correlated on a regional scale based on the depositional history and urban development.

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

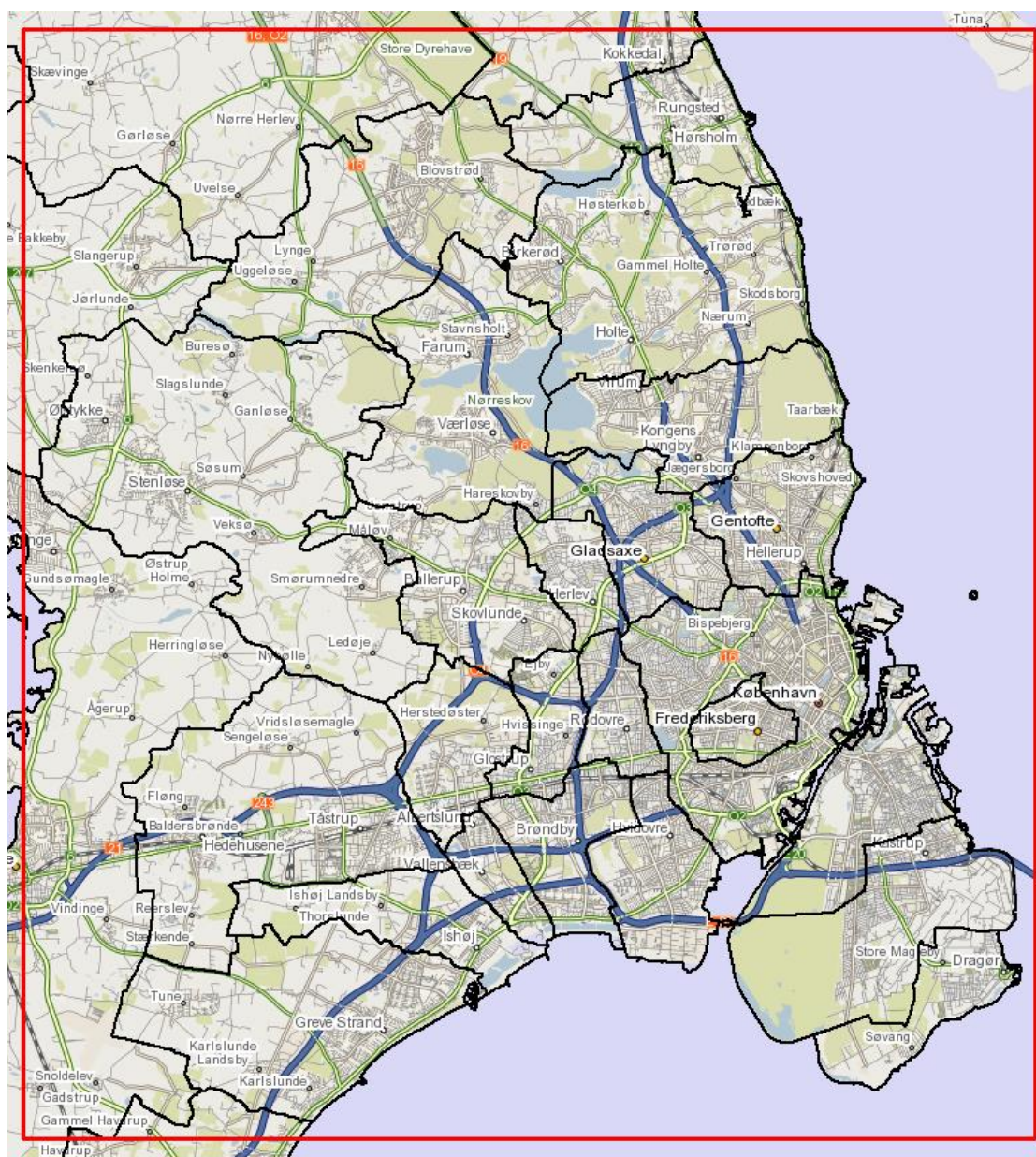


Figure 1 Extent of the Copenhagen Model area.

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

2 Geological setting

The geological setting in the Copenhagen 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 are briefly described below:

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

The pre-Quaternary layers are primarily limestone sediments of Cretaceous (Maastrichtien) or Tertiary/Danien age (Bryozoa Limestone and Copenhagen Limestone). Greensand deposits of Selandien age may occur locally.

The pre-Quaternary sediments are to the south transected by a number of fault lines trending NV-SE where the most prominent are the Carlsberg Fault to the east and the Roskilde Fjord Fault to the West, see Figure 2. The pre-Quaternary strata is gently folded with fold-axes trending NV-SE and Selandien greensand deposits occurring in the synclines.

To the north the W-E trending buried valley system of Sønderødalen is defined by subparallel fault lines.

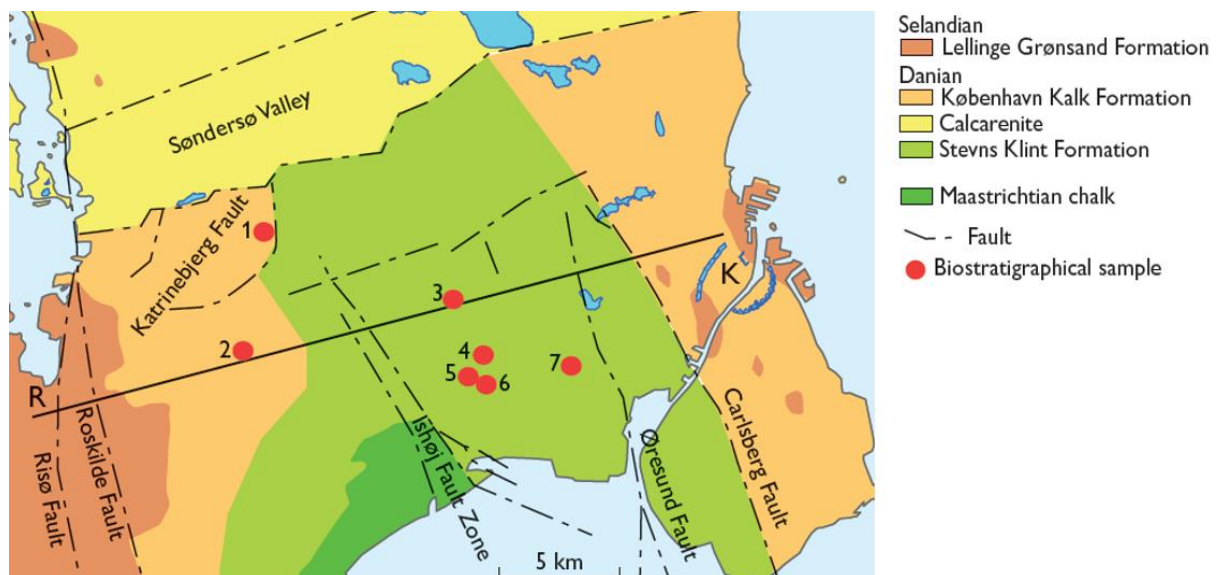


Figure 2. Map of the Pre-Quaternary sediments and fault lines in the Copenhagen area. Note NW-SE trending fault lines south of the Sønderødalen that transect the area trending W-E. Also note the distribution of Copenhagen Limestone east of the Carlsberg Fault and along the Roskilde Fjord Fault. From /1/

2.2 Quaternary deposits

The Quaternary glacial sequence consists of 5 layers of glacial sediments, consisting of three layers of meltwater sand interbedded with two layers of glacial till. The glacial sediments are to various degrees overlain by a layer of Postglacial organic sediments or by a layer of recent fill.

The Quaternary sediments fill out deep NV-SE trending valley systems (E.G. Rådhusdalen) in the southern part of the area and the W-E trending Sønderødalen in the northern part. Glacial deformations or ice marginal complexes occur as concave lines or ridges trending SW-NE associated with the upper till. An older system trending NW-SE associated with the lower till is found at Hillerød, at Valby Bakke and along the island of Amager and

along the coastline of Svanemøllebugten. The two main ice streams forming the glacial landscape in the region are illustrated in Figure 3.

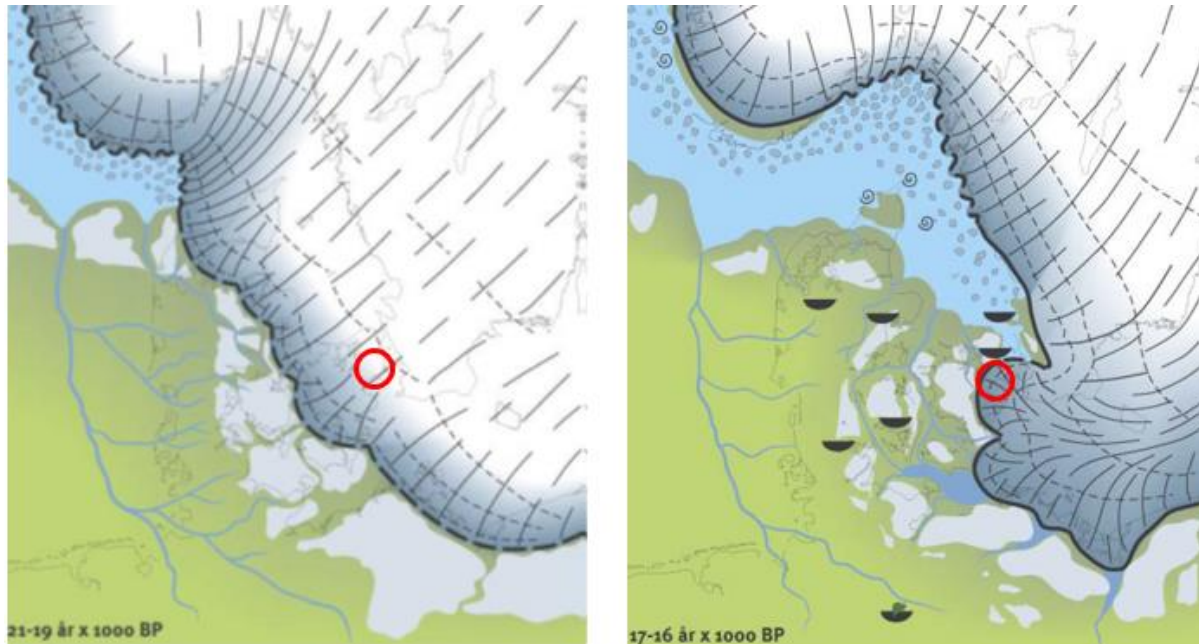


Figure 3. Ice marginal lines formed during A) Ice flowing from a NE-direction B) Ice flowing from a SE-direction. Red circle marks extend of the model area. From /2/.

3 Conceptual geology

The stratigraphy of the Copenhagen area is divided into a Pre-Quaternary sequence and a Quaternary sequence, the resulting interpretation resulted in a 13-layer model consisting of 6 pre-Quaternary layers and 7 Quaternary layers.

An overview of the stratigraphy is given in Table 1.

The conceptual interpretation is also illustrated in two conceptual profiles W-E (Figure 4) and N-S (Figure 5) showing the general geological settings and structures in the region.

Table 1. Overview of the stratigraphy for the Copenhagen area. The stratigraphy includes Cretaceous, Tertiary and Quaternary sediments including Postglacial organic sediments and Recent fill.

No	Name	Lithology	Chronology
1	Fill	O,S,L	Recent
2	Postglacial_Organic	P, T, FP, FT, L, S O	Postglacial
3	Upper Meltwatersand	DS, HS,GS,S	Glacial/ateglacial
4	Upper Till	ML, DL, DI, i, I	Glacial
5	Middle Meltwatersand	GS, DG,S,g	Glacial
6	Lower Till	ML, DL, DI, I, i	Glacial
7	Lower Meltwatersand	DS, DG,S,g	Glacial
8	Greensand	PS, PK, PL, s	Selandien
9	Upper Copenhagen Limestone	KK, K	Late Danien
10	Middle Copenhagen Limestone	KK, K	Late Danien
11	Lower Copenhagen Limestone	KK, K	Late Danien
12	Bryozoan limestone	BK, K	Danien
13	Chalk	SK, K	Cretaceous

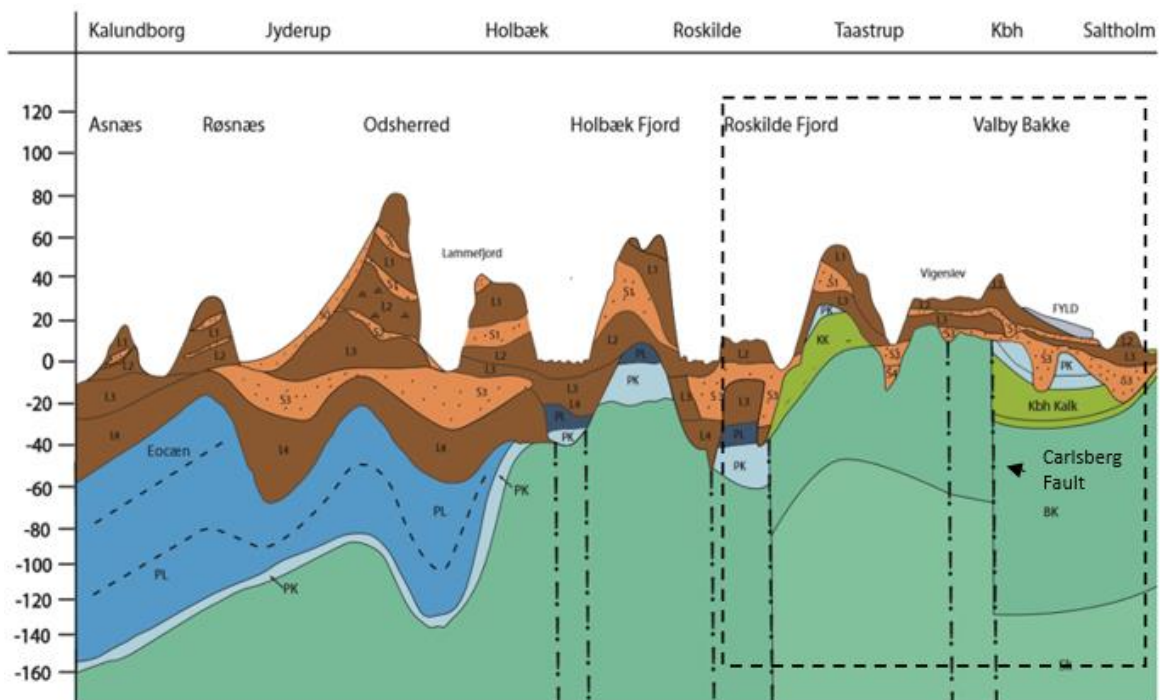


Figure 4. Conceptual profile W-E. Note the down faulted block east of the Carlsberg Fault with Copenhagen Limestone and greensand deposits covering the Bryozoan Limestone. The block between the Carlsberg Fault and the Roskilde Fjord Fault is uplifted and tilted with Late Danien and Selandien rocks covering the western part of the block. Ice marginal complexes are seen at Valby Bakke and at Roskilde Fjord, buried valleys (Rådhusdalen) are seen to the east. Dotted square marks the extent of the Copenhagen model.

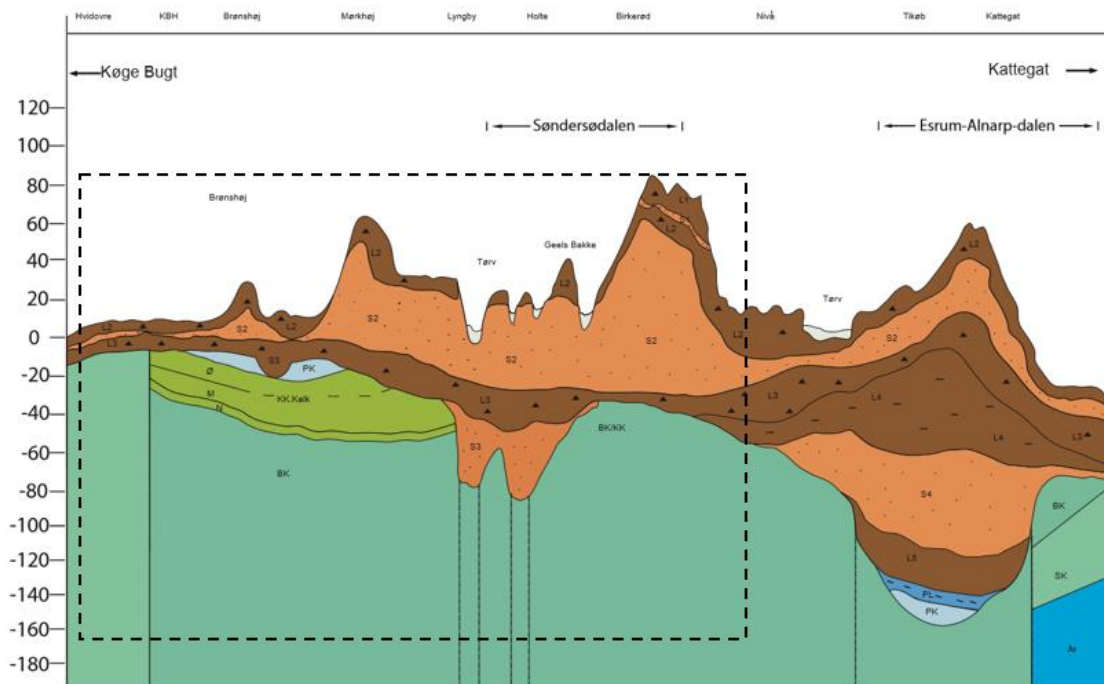


Figure 5. Conceptual profile S-N. Note Cretaceous chalk below the Quaternary sediments to the south. Copenhagen Limestone and local greensand deposits are found in the central Copenhagen area to the north this stratigraphy is transected by fault lines along the Søndersø Valley. Major ice marginal complexes are found at Mørkhøj in Gladsaxe and to the north of Søndersødalene at Holte, Birkerød and Hillerød. Note the accumulation of meltwater sand in the Søndersø area. Extent of the Copenhagen model is shown with a dotted square.

4 Description of the Pre-Quaternary sediments

The pre-Quaternary deposits consists of Cretaceous chalk (Skrivekridt), Tertiary limestone of Danien age (Bryozokalk) and Late Danien limestone (København kalk), except for a small area to the south at Køge Bugt with Cretaceous chalk (Skrivekridt). The pre-Quaternary surface west of the Carlsberg Fault is represented by bryozoan limestone (Bryozokalk), to the east of this the pre-Quaternary surface is represented by Copenhagen Limestone (København Kalk). These deposits also dominate to the north of the Søndersø Valley.

Greensand deposits occur along synclines superseding the Copenhagen Limestone or along the Roskilde Fjord Fault.

4.1 Selandien greensand

The greensand was deposited in a nearshore marine environment. The lower boundary to the Copenhagen Limestone is sharp and erosive. The lowermost part of the deposits consists of 10-30 cm of hardened, conglomeratic marl rich in the greenish mineral glauconite and fossils. The conglomerate is superseded by marl or sandy marl that transcends into silty or clayey marl.

The deposits are quite thin in the Copenhagen area max. 6 meters, but at Roskilde Fjord it may reach 30m.

4.2 Copenhagen Limestone

The Copenhagen Limestone was deposited as carbonate mud in a shallow marine environment.

The Copenhagen Limestone is a silty and sandy marine limestone with varying degrees of indurations by calcite cementation or silicification, containing layers and nodules of flint.

The entire Copenhagen Limestone formation is between 40-45 m thick and is subdivided lithologically into three subunits, upper, middle and lower Copenhagen Limestone.

4.2.1 *Upper Copenhagen limestone*

The upper Copenhagen limestone (UCL) is horizontally bedded with layers of different hardness and thickness from a few centimeters up to 1 m. Flint occurs in beds of 0.2 to 0.4 m thicknesses, occasionally up to 1 m in thickness.

The upper subunit is approximately 14 to 16 m thick in the Copenhagen area. The upper 3 m is assumed to be influenced by glaciers to a variable degree. Locally, the UCL unit is very thin or completely missing.

4.2.2 *Middle Copenhagen limestone*

The middle Copenhagen limestone (MCL) is irregularly bedded due mainly to bioturbation and is characterized by being nodule-rich with burrows being preserved as irregular flint filled nodules. It is characterized by a lower frequency of strongly indurated limestone layers and flint bands compared to the upper and lower Copenhagen Limestone.

The middle subunit is approximately 15 to 18 m thick in the Copenhagen City area.

4.2.3 *Lower Copenhagen limestone*

The lower Copenhagen limestone (LCL) is regularly bedded and relatively rich in clay. It is described as laminated and dark, mainly caused by a fairly high content of glauconite and pyrite.

The most common occurrence of flint in the LCL is in the form of dark nodules as layer parallel bands of irregular flint nodules. Flint layers are commonly 0.2 to 0.4 m thick.

The lower subunit is approximately 4 to 5 m thick in the Copenhagen area.

4.3 Bryozoan limestone

The boundary between the LCL and the bryozoan limestone is marked by a hardground or a massive flint bed.

The bryozoan limestone consists of sand to silt sized skeletal fragments of bryozoans mixed with subordinate amounts of lime mud and clay. The bryozoan limestone is typically developed as 100-200 m long

mounds, 5-15 m in height. The limestone contains substantial amounts of silicifications and flint occurs as both light grey or black irregular nodules of various sizes.

The bryozoan limestone is 50-60 m thick in the Copenhagen area, and was deposited during the early Danian period. Bryozoan limestone overlies Cretaceous chalk.

4.4 Cretaceous chalk

The boundary between the bryozoan limestone and the chalk is developed as a hardground. 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.

5 Description of the Quaternary sediments

The Quaternary stratigraphy of the Copenhagen area consist of a glacial and late glacial sequence comprising three layers of meltwater deposits of mainly sand and gravel interbedded with two layers of glacial till. It rests mainly on top of Danian limestone.

The glacial deposits are superseded by postglacial organic deposits and/or recent fill.

5.1 Fill deposits

The fill consists of a mixture of different lithologies including organic deposits, sand, gravel and/or clay, sometimes mixed with building materials of various kind.

The fill layer is generally between 2-6 meters in the central part of Copenhagen, greater thickness is reached in the harbor areas and at former limestone quarries.

5.2 Postglacial organic deposits

Postglacial deposits are widely distributed below fill in the lower lying areas around lakes, depressions, former marine surfaces, in the nearshore areas and in channels and moats.

The postglacial deposits consist of both marine and freshwater deposits, often rich in organics, of sand, silt, clay, gyttja or peat. Thicknesses are typically less than 1 m.

5.3 Upper sand unit

This unit consists of both glacial and late-glacial sandy deposits.

The upper meltwater unit consists mainly of fine to coarse-grained sand and gravelly sand with some silt and clay. The thickness is about 1 meter in the southern part and about 5m in the northern part. The deposit is frequently found on Amager, the city center, along the Øresund coast, in Søndersødal and in local depressions in the northern part.

5.4 Upper till unit

The upper till unit consist of clayey till but locally it may consist of sandy or gravelly clay till. The unit often contains stones and boulders. The till is generally pre-consolidated and is interpreted as deposited from lodgement at the base of the glacier. The upper 1-2 meters, however, are locally less consolidated, and is interpreted as a melt-out till. The unit is dominantly clayey. Locally it may be absent in the area.

5.5 Middle meltwater sand unit

The middle meltwater unit consist of pre-consolidated silty, fine grained sand to unsorted gravelly sand or gravel. Local occurrences of silt and clay are interbedded with the sand. The meltwater sand and gravel are generally very dense. The unit is about 5-10m thick in the southern part of the area, including the central Copenhagen area, in the northern part and the Sønderødalen the thickness is 15-20m.

The middle meltwater unit is locally absent, e.g. in some areas where the upper and lower till unit constitute a contiguous layer.

5.6 Lower till unit

The lower till unit consist of sandy and gravelly clay till, locally described as sand- or gravel till, containing large amounts of stones and boulders. The unit is generally heavily pre-consolidated, has relative low natural moisture content. It is known to contain considerable amounts of stones and boulders.

Glacial floes of limestone and lenses of sand are frequently found in the till unit, and it locally contains re-worked organic interglacial or interstadial deposits.

The unit is found in the depressions in the central part of Copenhagen, in parts of Amager and at Valby Bakke and Vibenshus Runddel, west of Nørrebro and west of Frederiksberg. To the north it is present in the Sønderød Valley.

5.7 Lower meltwater sand unit

The lower meltwater unit consists of fine- to coarse-grained sand and gravel, often with large amounts of limestone and flint. The meltwater sand and gravel are generally very dense.

The unit is mainly found in the buried meltwater valleys in the area especially in Rådhusdalen in the central part of Copenhagen and parts of Amager. To the north the lower sand unit is present in the valley systems in Gentofte and Lyngby and in the Sønderød Valley.

6 References

/1/ Jacobsen, P.R. et al., 2016: Structures and stratigraphy of Danien limestone, eastern Sjælland, Denmark. GEUS.

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