GEOPARK VESTJYLLAND

ANNEX 2

GEOLOGICAL HERITAGE

APPLICATION FOR GEOPARK WEST JUTLAND

TO BECOME A UNESCO GLOBAL GEOPARK

TITLE | Application for Geopark West Jutland to become UNESCO Global Geopark, Annex 2 - Geological Heritage

PUBLISHED BY | Geopark West Jutland, Rådhusgade 1, DK-7620 Lemvig, Denmark – November 2016

CONTACT | mail@geoparkvestjylland.dk and +45 40 54 71 98

WEBPAGE | www.geoparkvestjylland.dk

EDITOR | Thomas Holst Christensen, Geopark West Jutland

LAYOUT | Lars Holm Christensen, Holstebro Kommune

PHOTOS | Søren Raarup, Geopark West Jutland/Complot Media – in special cases other photographers are mentioned in connection with the individual pictures

GEOLOGICAL GRAPHICS | Grethe Storgaard, Graphic designer, Department of Geoscience, Aarhus University, Denmark

AUTHORS | Nicolaj K. Larsen, PhD - Associate Professor, Department of Geoscience, Aarhus University, Denmark

James Richard Wilson, PhD, dr. scient. – emeritus, reader, Department of Geoscience, Aarhus University, Denmark

Søren Raarup, Volunteer at Geopark West Jutland with great insights into local geology and cultural history, Thyholm, Denmark

Mads Kjærstrup, Geologist, Ringkøbing-Skjern Forsyning, Denmark

Anette Petersen, Geologist, GEON, Denmark

Tove Damholt, PhD, Geologist, GEON, Denmark

COPYRIGHT | Geopark West Jutland – can be quoted stating Geopark West Jutland as source

LAG LOKALE AKTIONS GRUPPER

LEADER

Den Europæiske Landbrugsfond for Udvikling af Landdistrikterne: Danmark og Europa investerer i landdistrikterne

Application for Geopark West Jutland to become UNESCO Global Geopark

Annex 2 – Geological Heritage

November 2016

LIST OF CONTENTS

Geological heritage 6

B.1. General geological description of the proposed Geopark 6
B.2. List and short description of geological sites 19
B.3. Details of the Geological sites 22
B.4. List and description of other sites of natural, cultural and intangible heritage interest 24

References Annex 2 and Geosites (Supplement B3). . 30

SUMMARY

Geopark West Jutland and its suite of glacial landforms and sediments has been subject to scientific scrutiny for more than a century. Already in the beginning of the 20th century state geologist Niels Viggo Ussing presented a very comprehensive analysis of the landscapes in the geopark area. He advocated that the landscapes were glacial landforms and identified, amongst other features, the Main Stationary Line as a marked boundary in the landscape between a hilly glacial landscape and flat outwash plains. Since then the conceptual glacial landscape model has been discussed and challenged, but it remains the backbone of our current understanding. The variety of glacial landforms and sediments is demonstrated in a pedagogical form and on an international scale Geopark West Jutland ranks among one of the best locations to study the impact of the Scandinavian ice sheet on landscape development.

B. GEOLOGICAL HERITAGE

B.1. GENERAL GEOLOGICAL DESCRIPTION OF THE PROPOSED GEOPARK

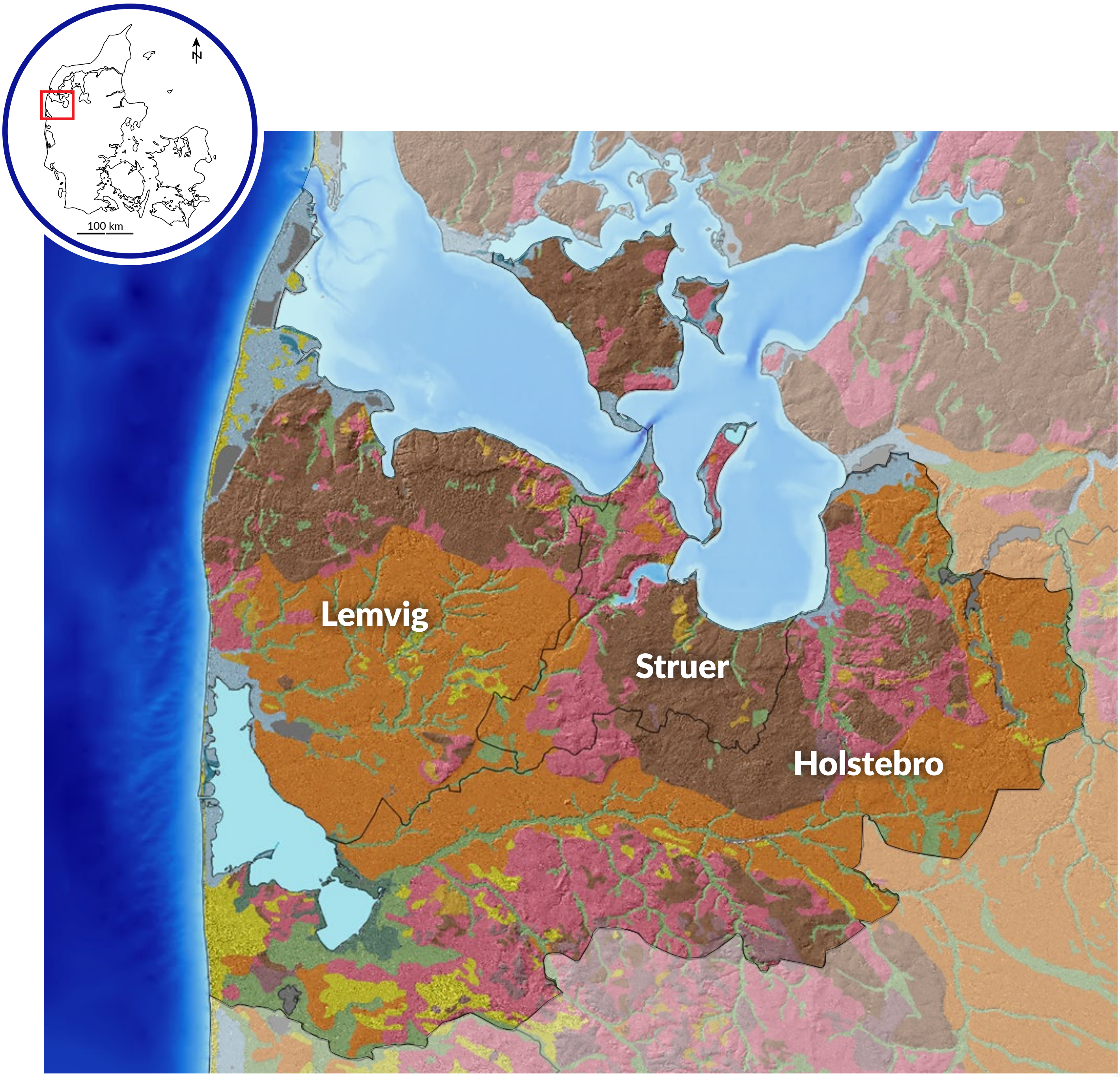


Fig. B1 *Geopark West Jutland is situated in the Central Denmark Region and occupies an area of 4,759 km2 which includes the land area of Lemvig, Struer and Holstebro municipalities of 1,560 km2. Map source: Kort og Matrikelstyrelsen (2009) and GEUS (2011).*

B. GEOLOGICAL HERITAGE

Geopark West Jutland
– a world class ice age landscape
During the Quaternary period of Earth history, enormous ice sheets sculpted the impressive ice age landscapes that form the core of Geopark West Jutland (GPWJ). These landscapes mark the final period when the Earth was in a deep freezer and when the Scandinavian Ice Sheet extended from the mountains of Norway down to Denmark. In addition to the ice age landscapes there is a series of other landforms that developed after the end of the ice age by rivers and coastal processes, as well as by the powerful westerly winds that characterize the west coast of Denmark. There are also remains of older geological deposits from the Tertiary and the Quaternary in some of the cliffs.

The unique glacial landscape in western Jutland was mapped over 100 years ago by the geologist N.V. Ussing who identified, amongst other features, the Main Stationary Line as a marked boundary in the landscape between a hilly glacial landscape and flat outwash plains.

This landscape developed as a result of repeated ice ages that each contributed to its formation. It was, however, during the last ice age – the Main Advance that took place 23.000 - 21.000 years ago when the ice reached its maximum extent – that most of the landscape in GPWJ was formed.

A brief account of the geology of the GPWJ area is presented here.

The Northern European Lowland – the Danish Basin
Since the Permian, about 250 million years ago, GPWJ has been part of a large sedimentary extensional basin that covered the whole of Denmark, the North Sea, northern Germany and the Baltic. Thick sequences (6-7 km) of sedimentary rocks, primarily sandstone, claystone and limestone were deposited here during the Mesozoic and Cenozoic. Towards the end of the Cenozoic the basin became filled up and Denmark finally became a land area during the Miocene.

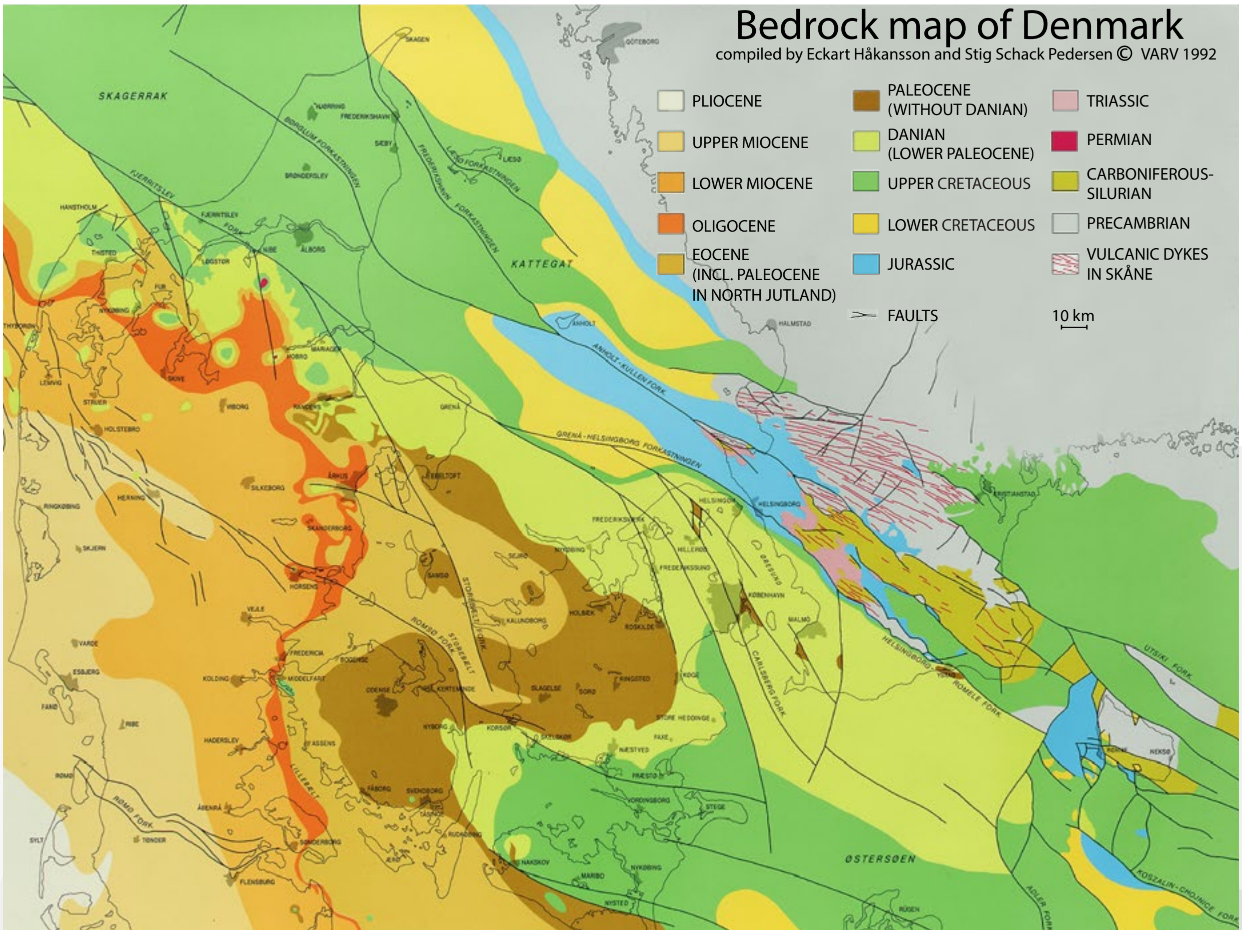


Fig. B2 *Pre-Quaternary map of Denmark (Heilmann-Clausen & Surlyk 2010).*

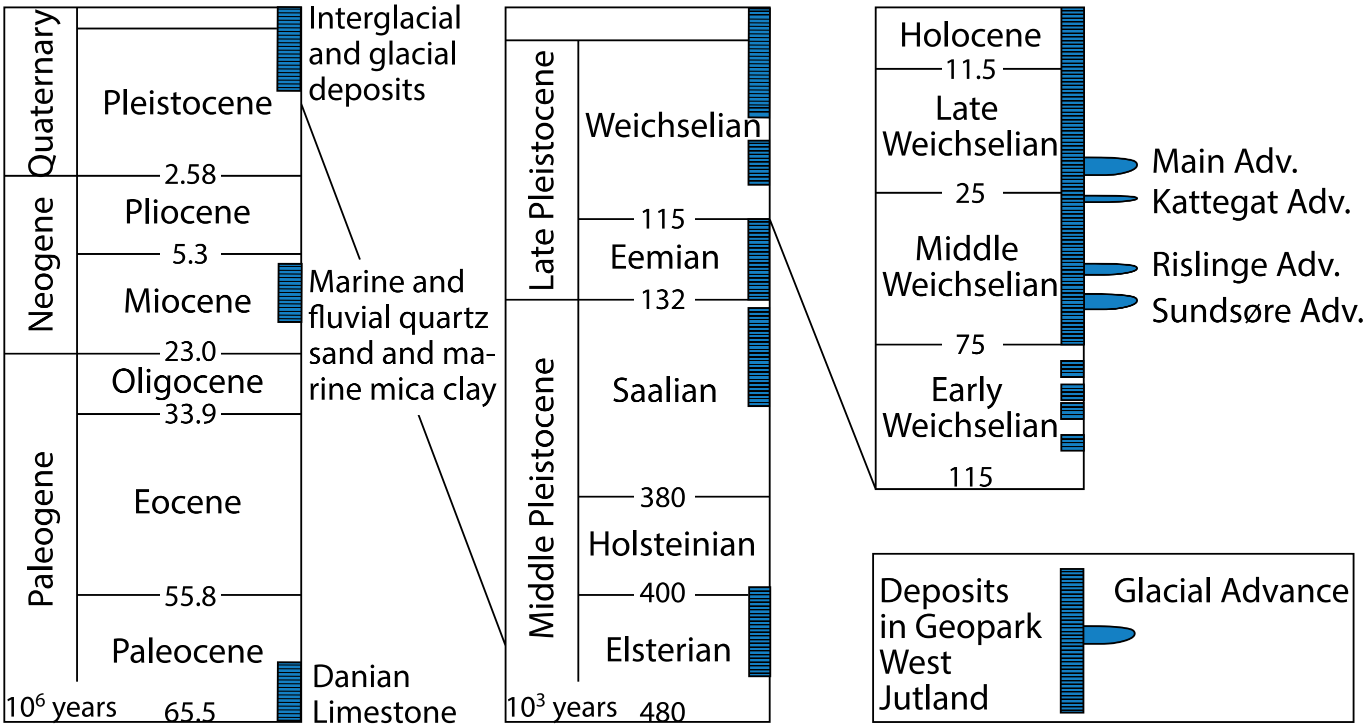


Fig. B3 *Stratigraphic scheme showing the layers that are exposed in Geopark West Jutland.*

At the present time, the pre-Quaternary surface of Denmark (excluding the island of Bornholm) consists of sedimentary rocks from the Lower Cretaceous to the Upper Miocene. Upper Cretaceous and Danian limestone comprise the surface in northern Jutland, Djursland and eastern Zealand. Younger deposits of fine-grained plastic clay and marl from the Paleocene and Eocene epochs make up the surface in eastern Jutland, Funen and west Zealand. In central and western Jutland the surface comprises sandy, silty and clay-rich deposits from the Oligocene and Miocene. The overall distribution of pre-Quaternary deposits, with the oldest in the north and the youngest in the south, bears witness to the fact that the Fennoscandian Marginal Zone has been elevated and eroded in the Cenozoic (Fig. B2). The reason for this Neogene uplift is unclear, but it reflects either tectonic events or extensive erosion of the Norwegian mountains by glaciers and meltwater which gave rise to isostatic elevation.

The pre-Quaternary deposits in GPWJ consist of a series of Miocene formations of micaceous marine clay and marine fluviatile quartz-rich sand (Fig. B3). In addition to these there are exposures of Danian limestone and Paleocene and Eocene plastic clay and marl where salt domes have elevated the overlying sediments and formed sub-surface, circular, dome-shaped structures (Fig. B2).

Quaternary glacial and interglacial periods

The average global temperature has gradually fallen through the past 60 million years, and about 2.58 million years ago a new era started - the Quaternary - that is characterized by cold glacial intervals and warm interglacial periods. During the glacial intervals, extensive ice sheets developed in the northern hemisphere, in particular in North America, Scandinavia and the Himalayas.

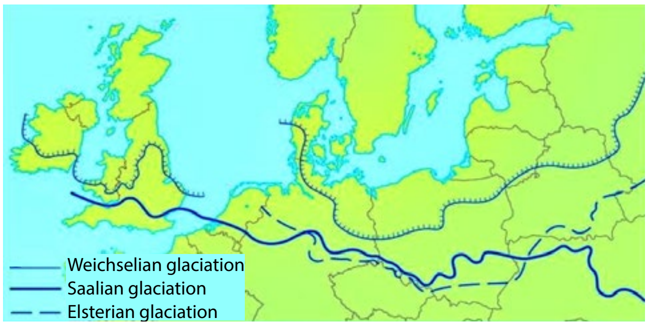


Fig. B4 *Maximum extent of the Scandinavian icecap in connection with the three last ice ages: Elsterian, Saalian and Weichselian (after Wienberg-Rasmussen, 1966).*

The existing icecaps in Antarctica and Greenland became considerably larger. During periods when the ice sheets reached their maximum extents, about 30% of all the continents were covered by glaciers, which resulted in a drop in worldwide sea level by 120-130 m. These repeated decreases in sea level meant that land areas became larger and there was connection between areas that are today separated by the sea, such as Denmark and England. During the interglacial periods the ice sheets melted partially or completely and the climate was similar to – or warmer than – that of today. At the start of the Quaternary the glacial periods lasted for about 40.000 years, but about 800.000 years ago the duration of the ice ages increased to about 100.000 years. This meant that the ice sheets had time to grow even larger. The three most recent ice ages - Elsterian, Saalian and Weichselian - were therefore those that covered the largest areas in Northwest Europe and when all or most of Denmark was covered by the Scandinavian Ice Sheet (Fig. B4).

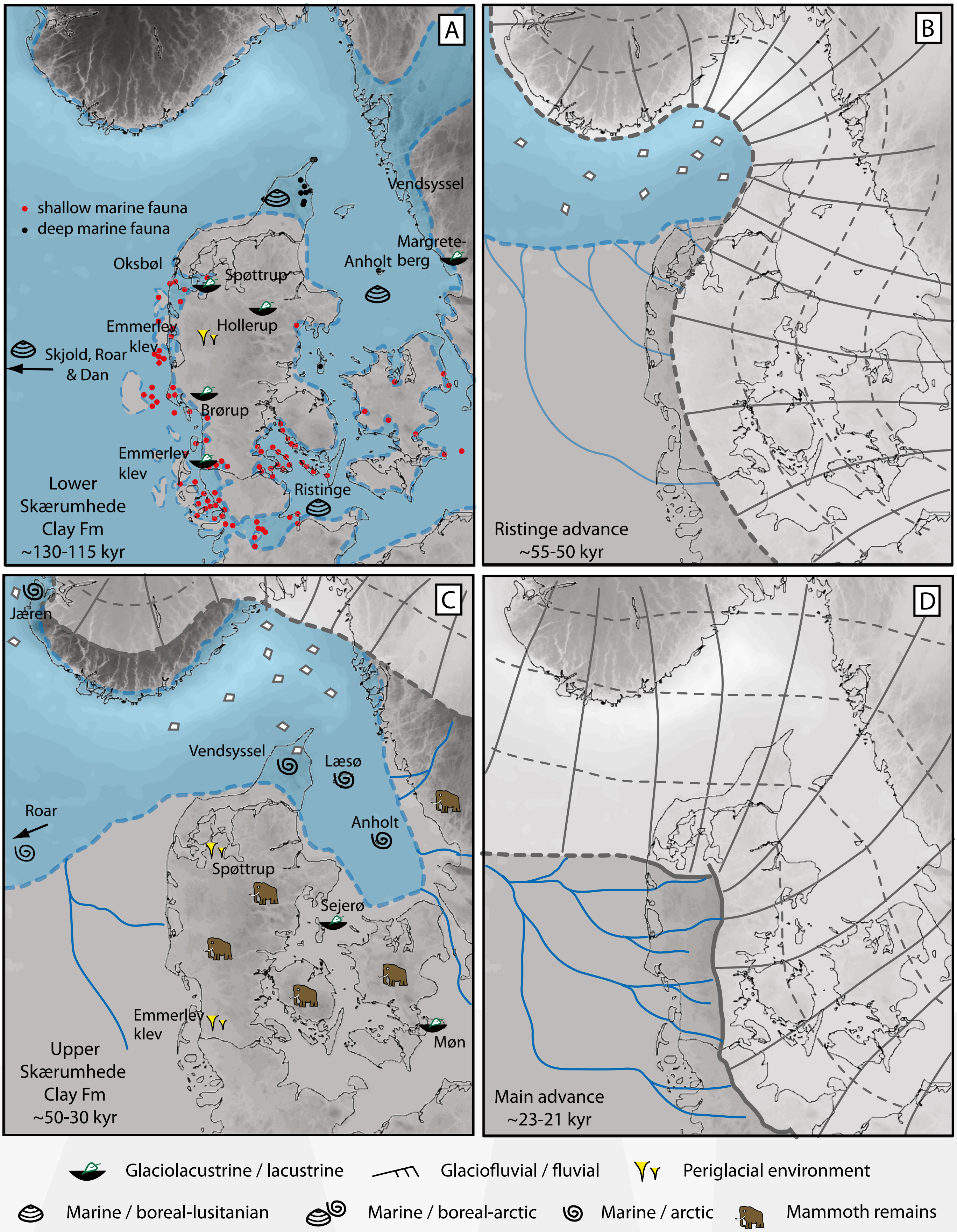
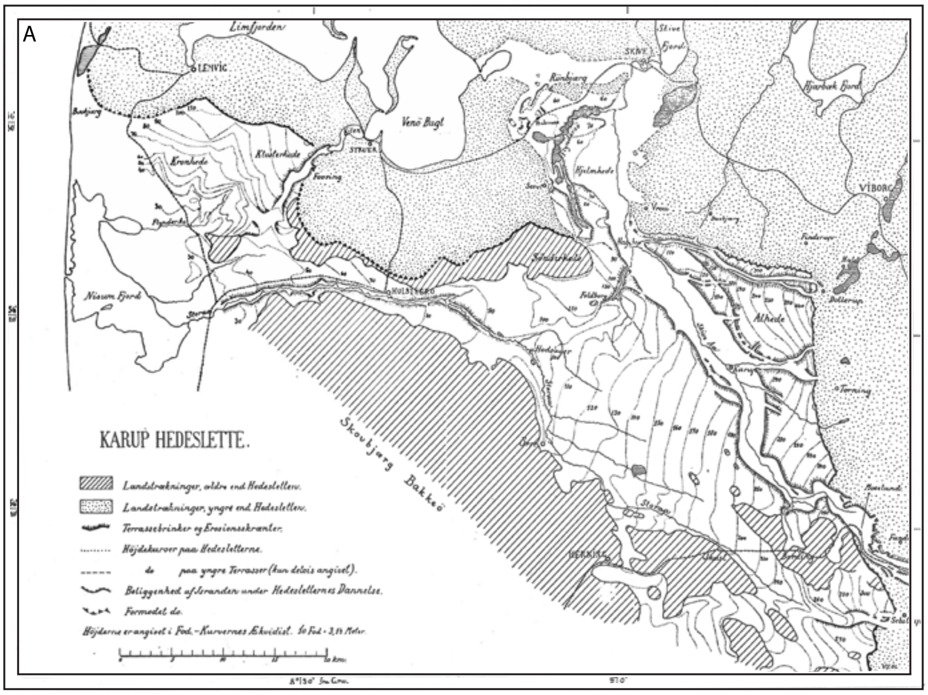


Fig. B6 *A) Eemian interglacial, B) Ristinge Advance, C) Mammoth Steppe, D) Main Advance*



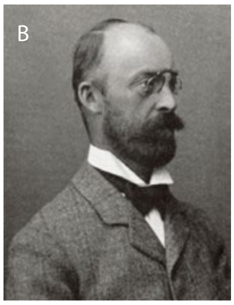


Fig. B7
A) *The Main Stationary Line in Western Jutland (Ussing 1903).*
B) *Geologist N.V. Ussing (1864-1911) mapped the Main Stationary Line and described the glacial land¬scapes in Western Jutland (Larsen 2012).*

Most of the landscape in GPWJ developed during the last (Weichselian) ice age and the following Holocene interglacial period that started 11.700 years ago. There are, however, many localities where older Quaternary deposits (of Elsterian and Saalian age) can be studied, and there are also a few places where marine or lacustrine deposits from the Holsteinian or Eemian interglacial periods are exposed (Fig. B3).

The Weichselian glaciation

Most of the landscapes and surface layers in GPWJ were formed in connection with the Weichselian glaciation that lasted from 115.000 until 11.700 years ago. During this ice age the climate varied from extremely cold (stadials) to relatively warm (interstadials). Throughout most of the Weichselian Denmark was ice-free and the landscape consisted of tundra plains where, amongst other animals, mammoths, woolly rhinoceros, wild horses and bison grazed. Even though there are no archaeological discoveries of mankind from this period, it seems likely that the large mammals were hunted by Neanderthals. It was cold and there was permafrost, which meant that the landscapes from previous ice ages were smoothed out by soil creep; ice wedges and associated polygons developed. The Scandinavian Ice Sheet only reached the Danish area during the coldest periods of the Weichselian. Based on these climatic variations this ice age has been subdivided into the Lower, Middle and Upper Weichselian.

Early and Middle Weichselian (115.000 to 25.000 years ago)

When the Weichselian ice age started 115.000 year ago the Scandinavian Ice Sheet began to expand in the Norwegian mountains when small glaciers and ice caps coalesced to form a large ice sheet. Denmark was a tundra plain, and in the early Weichselian the cold climate was replaced by two warmer periods (interstadials) when a more temperate fauna and flora became re-established in the area. Traces of these interstadials are found in, for example, old lake deposits in the hill islands in western Jutland and in the famous bog at Brørup where the interstadial was first recognized; it is now called the Brørup interstadial. Marine clay with drop-stones that was deposited in northern Jutland contains an arctic fauna, which bears witness to the sea becoming colder when the Scandinavian Ice Sheet reached the coast in southern Norway and glaciers calved into the Skagerrak.

Glaciers from the Scandinavian Ice Sheet reached Denmark for the first time between 70.000 and 50.000 years ago in the Middle Weichselian (Fig. B6). The first ice came from the north in connection with the Sundsøre Advance about 65.000 to 60.000 years ago, and the next ice came from the east about 55.000-50.000 years ago in connection with the Ristinge Advance (also called the Old Baltic Advance). The maximum extent of the Sundsøre Advance is not known in detail, but it is believed to have reached past the northern part of Skovbjerg hill island. The following Ristinge Advance from the east reached well into western Jutland. It is difficult to assess the maximum limit of these advances since no terminal moraines have been found. It is therefore not known whether, for example, the Ristinge Advance covered the whole of Denmark or if there was a narrow strip in western Jutland that remained ice-free. Deposits from the Ristinge Advance have been found in several localities in southern Jutland, western Jutland and in the Limfjord area. All in all this means that the traditional view that the hill islands in western Jutland represent Saalian glacial landscapes needs to be revised, since many of them were overrun by ice during the Middle Weichselian.

After these Middle Weichselian glacial advances, Denmark became a tundra plain for more than 20.000 years. This dry, cold, barren plain extended to England, Sweden and large parts of Siberia. This tundra plain is referred to

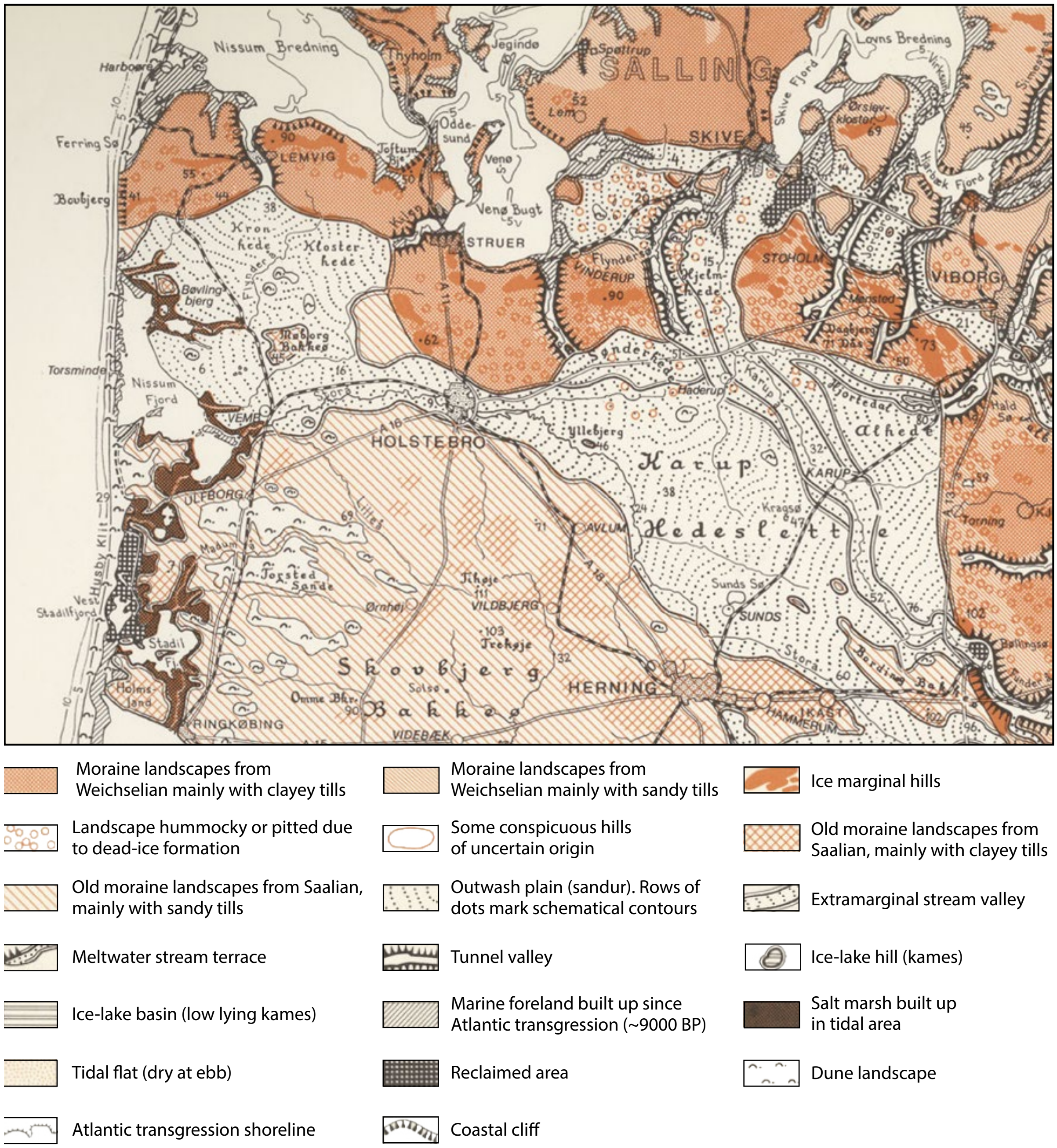


Fig. B8 *Glacial morphological map of Western Jutland (after Smed 2012).*

as the Mammoth Steppe after the countless numbers of mammoth tusks and teeth that have been found in, for example, western Jutland. Unfortunately, none of these finds in western Jutland have been dated. During the long periods of time in the Early and Middle Weichselian when Denmark was ice-free the landscape was subjected to periglacial conditions that resulted in "smoothing" of the landscape as a result of alternating freezing and thawing. This is evident in, for example, Skovbjerg hill island that stands out as an undulating, elevated area without any clear terminal moraines or other obvious glacial landscape features.

The temperature fell towards the end of the Middle Weichselian and the Scandinavian Ice Sheet spread southwards over Denmark in connection with the Kattegat Advance 29.000 – 27.000 years ago. No glacial landscapes remain from this advance, but deposits from this event can be studied in, for example, the Bovbjerg profile in the form of till and deposits from glacial lakes.

Late Weichselian (25.000 to 11.700 years ago)
When the Scandinavian Ice Sheet reached its maximum extent 23.000 - 21.000 years ago, glaciers advanced over Denmark to the Main Stationary Line (MSL) where it formed a marked boundary in the landscape. The eastern part of Denmark was later covered by ice from the Young Baltic Advance 19.000 – 18.000 years ago, but these glaciers did not reach western Jutland. This means that the landscape and glacial deposits from the Main Advance are preserved in GPWJ. The MSL was mapped in the early 1900s by state geologist N. V. Ussing who published a map in 1903 based on the topography and nature of the surface deposits (Fig. B7). He based his interpretation of

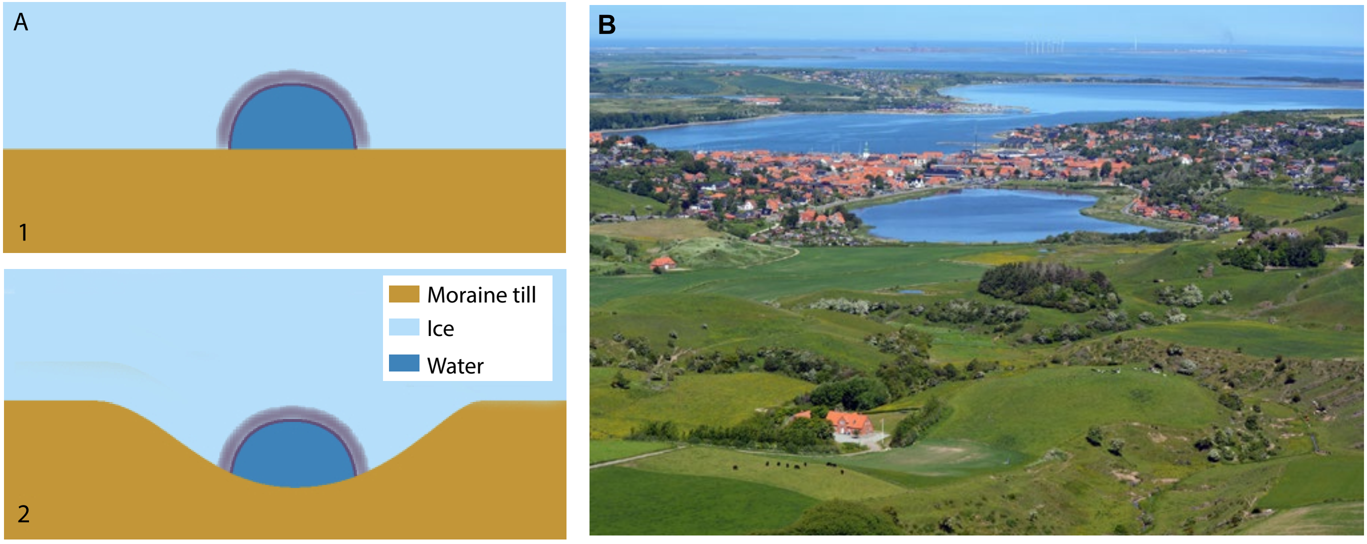


Fig. B9
A) *Two stages in the formation of a tunnel valley by meltwater erosion below a glacier (Krüger, 2012).*
B) *Tunnel valley at Lemvig with a view over the fjord (Photo: Lemvig.eu).*

the location of the MSL on a clear change from an undulating glacial landscape with marked terminal moraines or a zone of dead ice landscape, to the flat outwash plains ahead of the ice front.

It was originally thought that the MSL defined the maximum extent of the ice in Denmark, but, as mentioned above, recent studies have shown that during the Middle Weichselian glaciers covered a large part of western Jutland, including the hill islands. However, considering the Scandinavian Ice Sheet as a whole, it reached its maximum extent 23.000 – 21.000 years ago which is when it formed the MSL in Denmark.

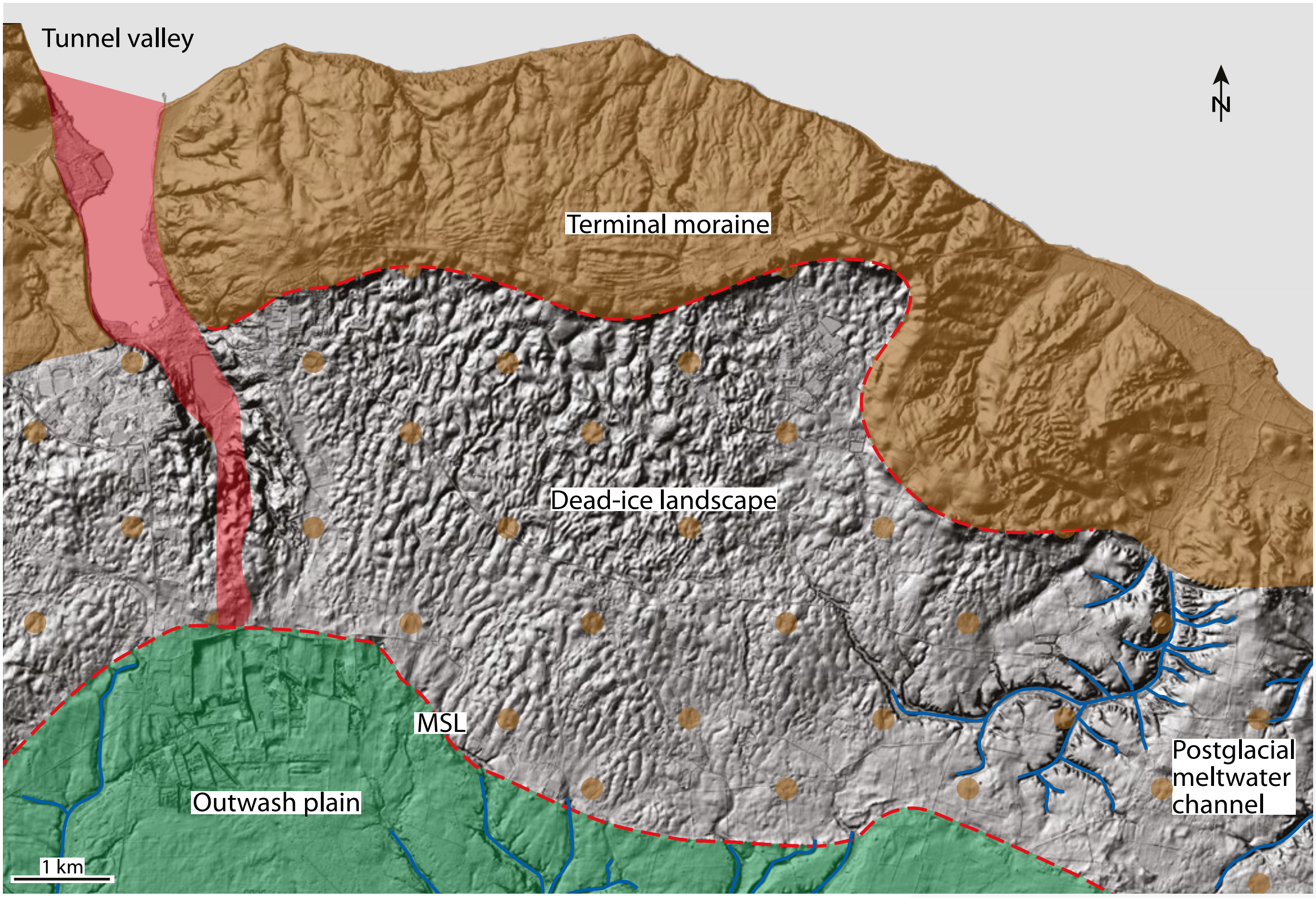


Fig. B10 *Glacial geological map of the area east of Lemvig showing the complex landscape around the Main Stationary Line. Map source: Kort og Matrikelstyrelsen (2009).*

Fig. B11 *The Continental period represents the interval from the end of the last ice age until the beginning of the Holocene when elevation of the land took place faster than rise in sea level and Denmark was linked to Sweden and England (Noe-Nyggard et al., 2012).*

One of the most characteristic forms of landscape in western Jutland is the meltwater plains (outwash plains) that developed when the ice was at the MSL (Fig. B8). Meltwater flowed from the ice towards the west and south and deposited huge amounts of sand and gravel. The heathlands of Kronhede, Klosterhede and Sønderhede are all fan-shaped areas of outwash deposits whose top points are at Lemvig, Struer and Sevel where large volumes of meltwater flowed out from glacier portals. Before reaching the ice front the meltwater had flowed under the glaciers in large channels that eroded deep sub-glacial valleys – so-called tunnel valleys (Fig. B9).. These are expressed in the landscape today by fjords or large elongate lakes. There are four tunnel valleys in the GPWJ area - at Lemvig, Struer (Kilen), lake Hellegård Sø and at the Stubbergård sø - Flynder Sø lakes.

Ussing was the first, over 100 years ago, to recognize the connection between the focal point of the fan-shaped outwash deposits and the end of a tunnel valley that was perpendicular to the ice front. Since then there has been discussion as to whether meltwater could carve out these 30 to 40 km long, 2 to 5 km wide and between 100 and 300 m deep tunnel valleys, or whether they could represent older river valleys from the Tertiary controlled by sub-surface neotectonic movements. Modern research has, however, shown that it is possible for meltwater to erode deep valleys below recent glaciers, and most researchers now consider that tunnel valleys were formed primarily by sub-glacial meltwater erosion.

During the general melting of the ice at the MSL, there were periodic glacial re-advances that formed hill-hole pairs, which are hills with closely spaced sub-parallel ridges lying a short distance from their source depressions. Good examples of hill-hole pairs can be seen at Nørlem and Bjerrum arch. In GPWJ, a characteristic dead-ice landscape developed between the MSL and the terminal moraine ridges during a re-advance with many small hills and depressions with no natural drainage that are now occupied by small lakes or bogs (Fig. B10). Continued retreat of the ice meant that the meltwater found a new route to the North Atlantic via Limfjord, and that the large outwash plains in western Jutland dried out. Deep meltwater valleys that cut down into the flat outwash plains south of the MSL are today visible as dry gullies in the landscape.

Even though the ice was retreating, it was still cold in Denmark and the landscape was subjected to periglacial processes. This is evident in the landscape as ice wedges and associated polygons. There was also extensive aeolian activity on the outwash plains, and until vegetation took a firm grip on the landscape several areas of inland sand dunes were formed.

When the ice melted away in late glacial times the load on the crust was reduced and it gradually began to rise again. In northern Jutland this took place slower than the elevation in sea level, which resulted in large parts of northern Jutland becoming inundated by the sea. When the rate at which the ice melted decreased, the rise in crustal level became dominant and we entered the Continental period when Denmark was linked to both England and Sweden. This phase continued into the following Holocene interglacial period (Fig. B11).

Holocene (11.700 years ago to the present)

A significant rise in temperature marked the transition between the Weichselian glaciation and the present interglacial period. This increase in temperature is best documented in ice cores from Greenland, but has also been detected in, for example, lake deposits in western Jutland where there is a steady increase in temperate plant species approaching the Holocene. This gradual increase in temperature culminated at the Holocene temperature maximum about 9.000 – 5.000 years ago. During this interval the remaining portions of the North American ice cap melted away which led to an eustatic sea level rise that again took place at a faster rate than the isostatic uplift of the crust. This resulted in the low-lying parts of Denmark again being flooded by the sea. This is evident in northern Denmark as extensive low-lying flat areas and marked old coastal cliffs that reach up to 13 m above present sea level in northern Denmark. These marine deposits and the coastal cliffs are named after the snail Littorina littorea that was prevalent at that time (Fig. B12).

In GPWJ the base of the Littorina cliffs is about 2 m above present sea level. Between the Littorina cliffs and the present coastline there is a wide variety of forms of coastal landscapes, including beach ridges, spits and la-

Fig. B12
A) *Extent of the Littorina Sea during the Atlantic period 9.000-5.000 years ago (after Aaris-Sørensen, 1988).*
B) *View of the Littorina coastal cliff at Engbjerg (Photo. Søren Raarup).*

goons. These combine to form the characteristic features of the west coast of Jutland. The development of these landforms reflects the interplay of a combination of factors, especially the powerful action of waves, coast-parallel currents, and the availability of sandy sediments that comprise much of the surface and sub-surface in Western Jutland. When the North American ice cap had finally melted away about 5.000 years ago, sea level ceased to rise and crustal elevation took over once again and Denmark essentially took on its current appearance. Elevation of the land continues today; northern Jutland is rising at a rate of about 1.8 mm per year whereas southern Denmark is more or less in balance. However, since the global rise in sea level is currently about 3.2 mm per year, the Danish area is overall subjected to a relative increase in sea level.

Some of the youngest sediments and landscapes in GPWJ are the characteristic and striking sand dunes that are developed along the entire west coast of Jutland from Skagen in the north to Skallingen in the south, a distance of about 300 km. Sand dune formation commonly starts with primitive dunes that may develop into crescent-shaped barchan dunes. Free growth of sand

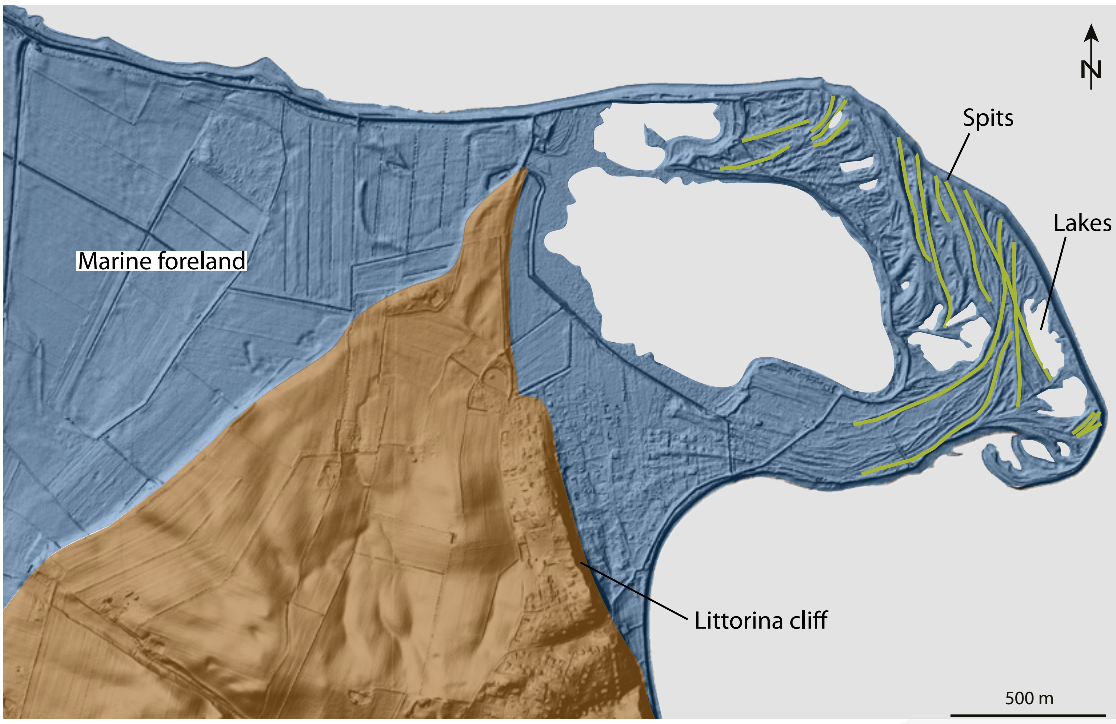


Fig. B13 *Coastal landscape at Gjeller Odde. Map source: Kort og Matrikelstyrelsen (2009).*

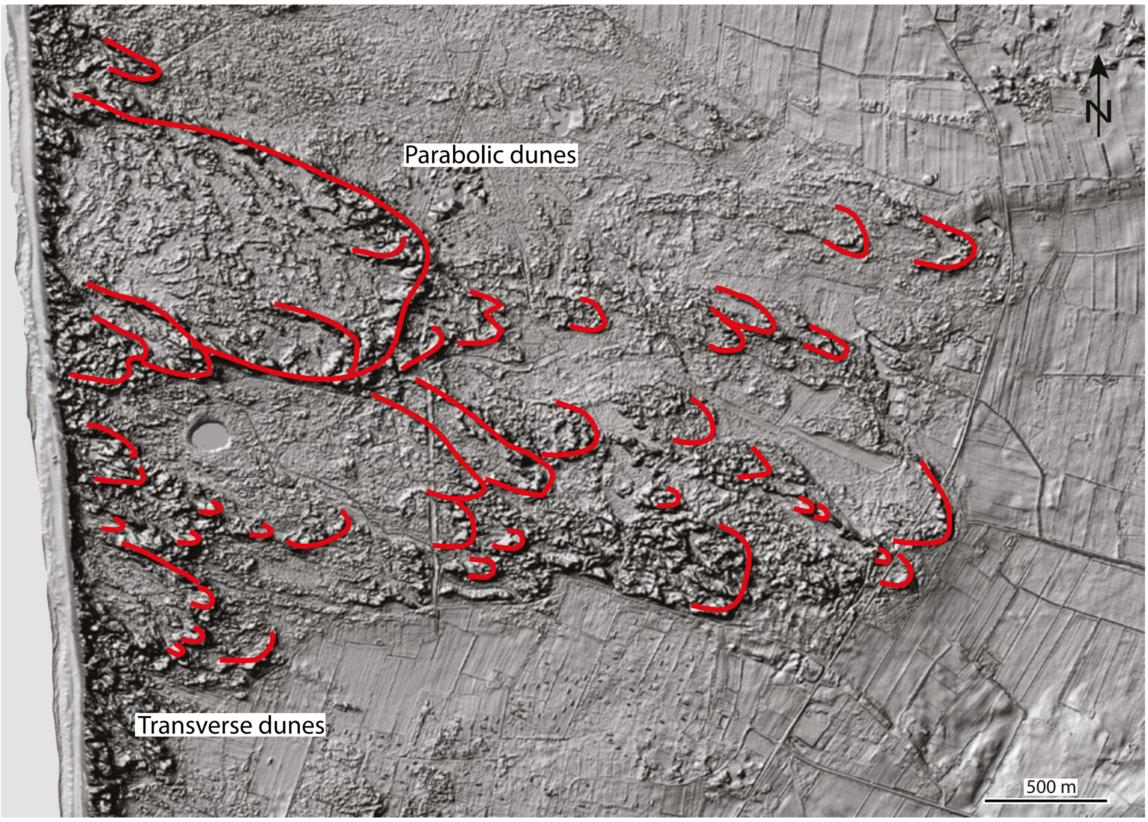


Fig. B14 *Dune landscape at Husby Klitplantage plantation. Map source: Kort og Matrikelstyrelsen (2009).*

dunes in Denmark is generally inhibited by vegetation and transverse dunes are developed. If a hole develops in the vegetation on a sand dune, extensive wind erosion can take place and a dune hollow can develop. Continued erosion can result in the development of a parabolic dune. In historic times, wind-blown erosion has increased as a result of the clearing of vegetation together with greater storm activity, and many of the dunes can be dated to the Stone and Bronze Ages. Renewed wind-blown sand activity from ca. 1550-1650 to ca. 1900 had catastrophic consequences for farmers who lived near the west coast.

Fig. B15A *Bovbjerg lighthouse (Photo: Lemvig.eu).*

The Bovbjerg profile – a key locality in Geopark West Jutland

Bovbjerg may be the only place in the world that exposes a section through an entire glacial landscape series with a terminal moraine and source depression (hill-hole pair) and its associated outwash plain. This provides an opportunity to get a three-dimensional impression of the MSL that marks the maximum extent of the ice sheet in the Late Weichselian.

The Bovbjerg profile was first described by E. M. Nørregaard in 1912 and later, more detailed studies, have shown that the profile includes both glacial and meltwater deposits from several glacial and interglacial periods. The oldest glacial deposits are from the Elsterian ice age, whereas the youngest were deposited in connection with the Kattegat Advance and the Main Advance during the Late Weichselian (Fig. B15).

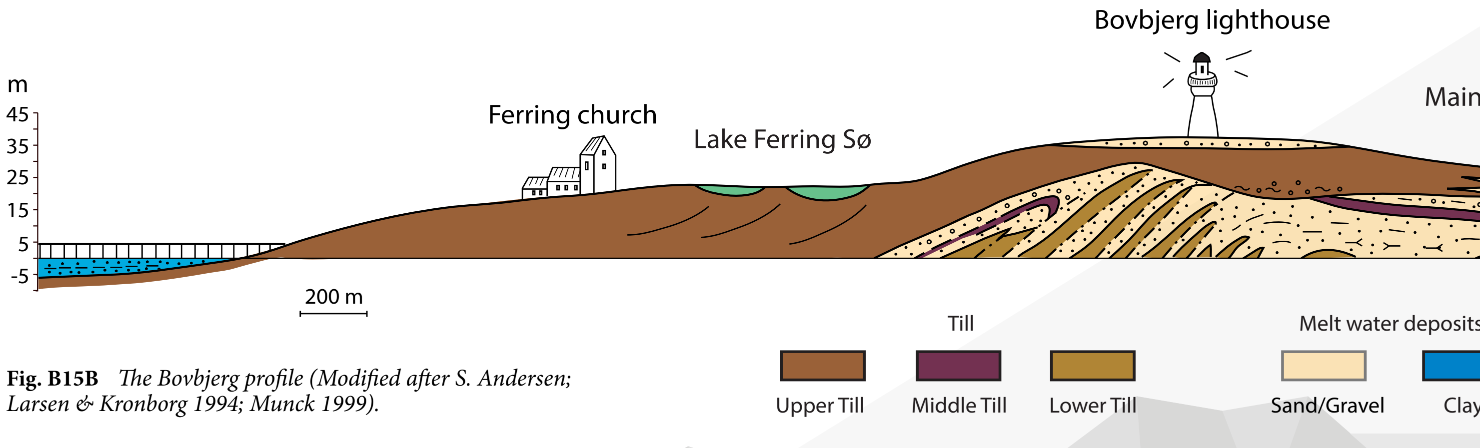


Fig. B15B *The Bovbjerg profile (Modified after S. Andersen; Larsen & Kronborg 1994; Munck 1999).*

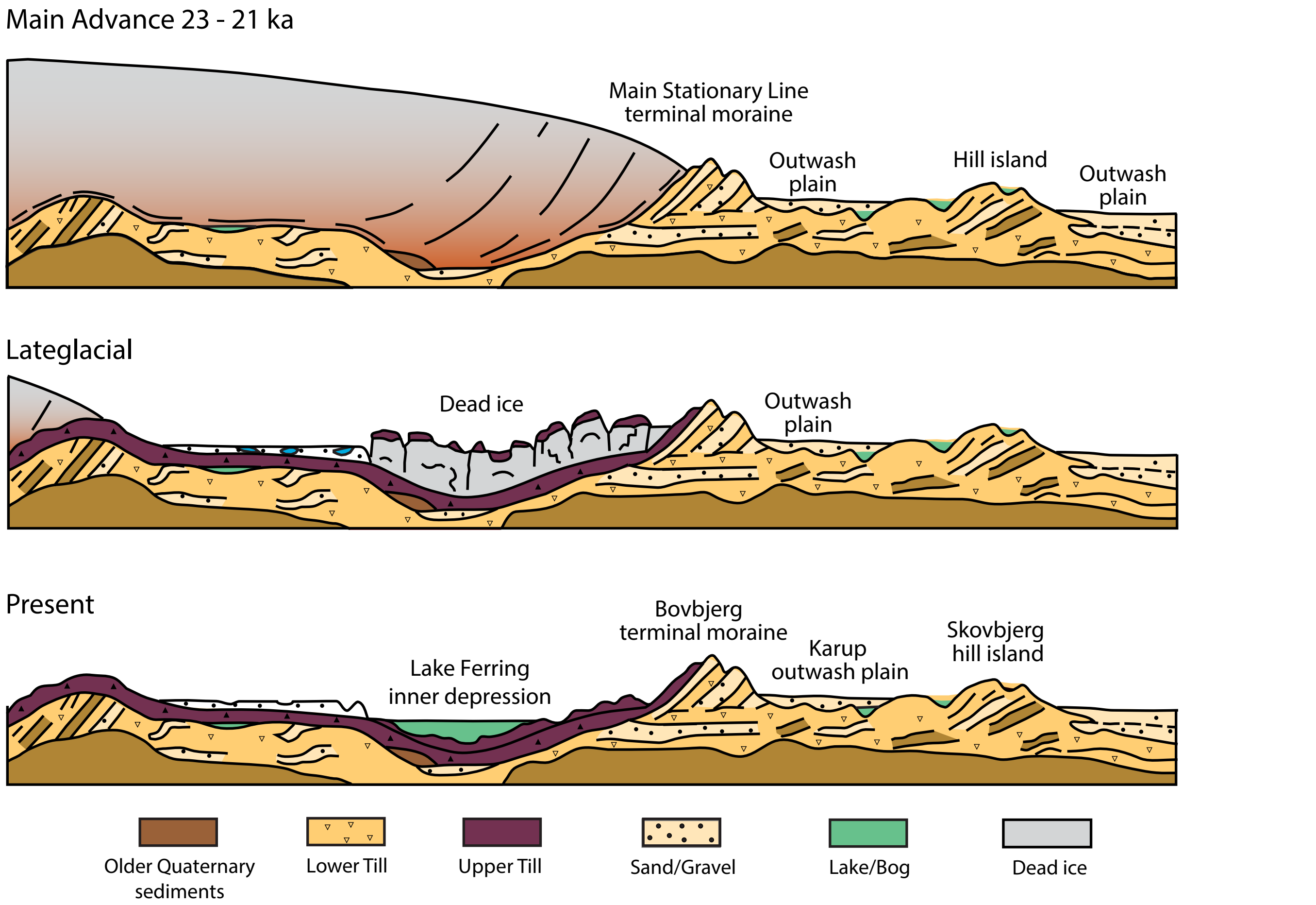
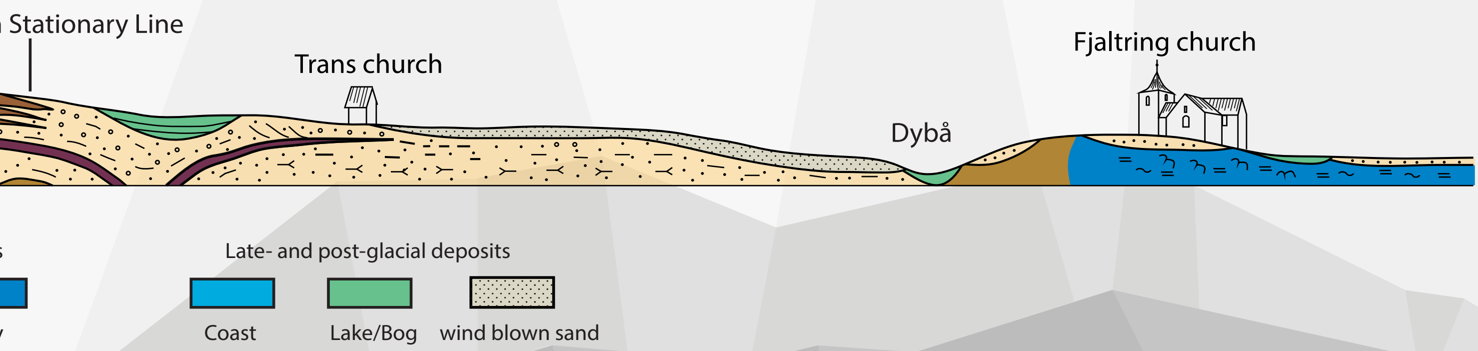


Fig. B16 *Conceptual landscape model for Bovbjerg with an inner depression, terminal moraine and outwash plain (after Houmark et al., 2005)*

The landscape around Bovbjerg has provided inspiration for the subdivision and interpretation of a glacial landscape system (Fig. B16). During the Last Glacial Maximum (LGM) the Scandinavian Ice Sheet reached the MSL where it formed a terminal moraine composed of up-thrust sheets of older glacial and interglacial sediment that derived from the source depression (hill-hole pair). There are many examples of glaciotectonic deformation with dislocated sediments in GPWJ, but Bovbjerg is unique in that it offers a view into the moraine that marks the MSL. In front of the MSL a large outwash plain was formed that extended all the way down to the so-called hill islands that represent older glacial landscapes from Middle Weichselian and/or Saalian times.



B.2. LIST AND SHORT DESCRIPTION OF GEOLOGICAL SITES

The most important geological sites in GPWJ have been selected and described by geologists Mads Kjærstrup, Anette Petersen, Tove Damholdt and school teacher Søren Raarup in cooperation with docent emeritus J. Richard Wilson and associate professor Nicolaj Krog Larsen, Department of Geoscience, Aarhus University. These authors selected the figures in cooperation with Grethe Storgaard, Department of Geoscience, Aarhus University, who prepared the illustrations. The text was translated from Danish to English by J. Richard Wilson.

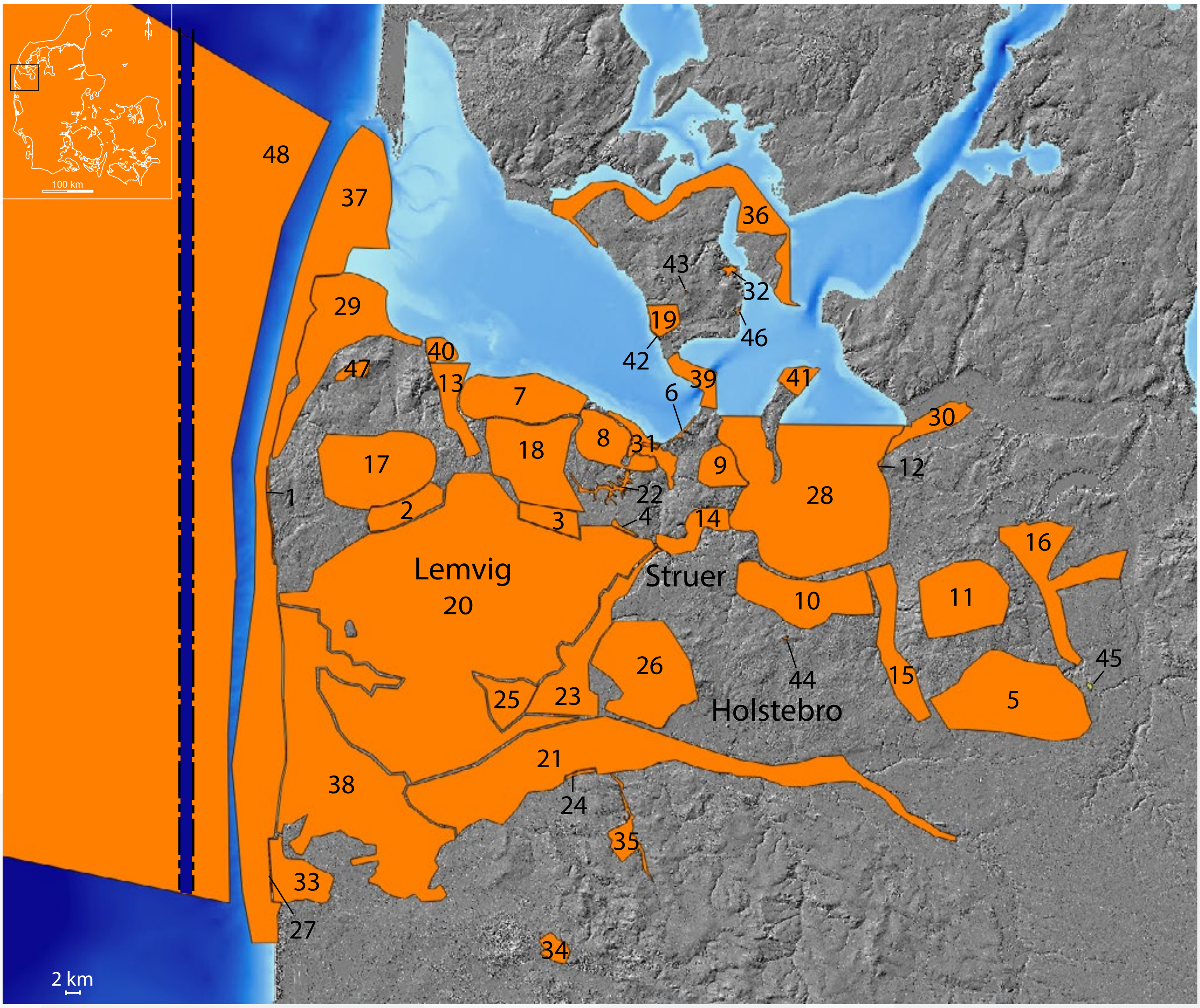


Fig. B17 *Locations of the geological sites in Geopark West Jutland. Map source: Kort og Matrikelstyrelsen (2009).*

No.	Name	Description	Geological importance
1	The Bovbjerg profile	Cliff profile. Section through the glacial sequence around the Main Stationary Line	NGI 76, NCL 80 and Geosite 4-4
2	Lomborg	Terminal moraine at the Main Stationary Line	NGI 75
3	Fabjergkirkevej	Main Stationary Line and prehistoric traces	NGI 75
4	Skodborg Huse	Terminal moraine at the Main Stationary Line	Local importance
5	Salshøj - Sønderhede	Outwash plain in front of the junction between two lobes in the Main Stationary Line	Local importance
6	Toftum Bjerge	Coastal cliff with deposits from several glaciations. Terminal moraine formed by a Weichselian glacial re-advance	NGI 74 and NCL 85
7	Nørrelem - Nørre Nissum - Kamstrup	Marked terminal moraine formed by glacial re-advance following the Main Advance	NGI 75 and NCL 84
8	Bjerrumbuen	Marked terminal moraine with several kames	Local importance
9	Breinholtbuen	Small terminal moraine and outwash plain	Local importance
10	Gimsing - Handbjerg	Terminal moraine from a glacial re-advance and an inner depression	Local importance
11	Ryde - Sevel	Terminal moraine formed by a glacial re-advance with superimposed landscape forms	Local importance
12	Nygård Hage	Coastal cliff with deposits from two glaciations	Local importance
13	Lem Vig	Tunnel valley with outwash fan deposits	NGI 75 and NCL 84
14	Kilen - Hornet	Winding tunnel valley between Venø Bugt and Klosterheden	Local importance
15	Hellegård tunnel valley	Tunnel valley with thresholds and basins	Local importance
16	Stubbergård Sø - Flyndersø	Pitted outwash plain - Hjelm Hede. Tunnel valley	NGI 64
17	Lomborg - Bonnet - Heldum	Undulating moraine landscape with dead ice features and a terminal moraine formed as a result of glacial re-advance.	NGI 75
18	Nørre Nissum - Fabjerg	Undulating moraine landscape with dead ice features between the Main Stationary Line and a terminal moraine formed during glacial re-advance	NGI 75
19	Odby till plain	Till plain from the last glacial advance in the Weichselian	Local importance
20	Klosterhede - Kronhede	Two outwash plains	NGI 75
21	The Storå valley	From outwash plain to postglacial river valley	NGI 77
22	Trælborgdalen	Periglacial valley	Local importance
23	Fousing valley	Lateglacial periglacial valley	Local importance
24	Burlund	Erosional cliff testifying to the extensive late glacial melt water runoff from Main Stationary Line	NGI 77
25	Møborg hill island	Hill island. Gravel pit profile with traces from three glaciations	Local importance
26	Linde hill island – Sir Lyngbjerg	Part of a hill island in connection with the moraine landscape behind the Main Stationary Line	Local importance
27	The Græm profile	Cliff profile of a hill island. Postglacial wind-blown sand	Local importance

No.	Name	Description	Geological importance
28	Venø Bugt	Inner depression from a re-advance after the main Weichselian advance	Local importance
29	Veserne - Plet - Engbjerg	Marine foreland. Littorina cliff	NGI 76 and NCL 80
30	Sønder Lem Vig - Geddal Enge	Marine foreland. Littorina cliff	Local importance
31	Remmerstrand - Resen Kær	Marine foreland. Littorina cliff	Local importance
32	Hellerød Kær	Marine foreland. Erosional valleys	NGI 71 and NCL 87
33	Husby Klitplantage	Sand dune landscape. Well-developed parabolic dunes	Local importance
34	Sønder Vosborg Hede	Heath with inland sand dunes and parabolic dunes on a hill island	NGI 77
35	Idom Å and Ormstrup Hede	River valley. Open heathland on a hill island	NGI 77
36	Skibsted Fjord - Kås Bredning	Coastal landscapes of the Limfjord	NGI 71 and NCL 87
37	Vestkysten	Simplification and barrier coast. The dynamic coast – coastal erosion and protection	NGI 76, NCL 80 and Geosite 4-4
38	Nissum Fjord	Coastal lagoon and the river Storåen delta. Marine foreland	"NGI 75 (northeast corner) NGI 77 (southeast corner)"
39	Oddesund	Coastal landscape. Spits, beach ridges and beach lakes	Local importance
40	Gjellerodde	Coastal landscape. Cuspate foreland	NGI 75 and NCL 84
41	Venø - Nørskov Vig	Coastal landscape. Cuspate foreland	NGI 72 and NCL 87
42	Odby Klint	Coastal cliff with Danian limestone and flint and evidence of three glaciations	NGI 73 and NCL 86
43	Bjørndal limestone quarry	Abandoned limestone quarry	Local importance
44	Hjerm limestone quarry	Abandoned limestone quarry and mine now used for storeing and maturing of cheese	Local importance
45	Sevel limestone quarry	Abandoned limestone quarry with ruins of lime-kilns	NGI 64
46	Søndbjerg Strand	Coastal cliff with Miocene deposits	NGI 72 and NCL 87
47	Hygum Bakke - Kildeplads Engbjerg	Well field – ground water extraction for drinking water. Possible terminal moraine	NGI 76
48	The underwater landscape Jyske Rev	Drowned glacial landscape modified by marine erosion and deposition. Continuation of the Main Stationary Line in the North Sea	Offshore areas are not classified

* NCLxx - National Coastal landscapes
NGIxx - Site of National Geological Interest
Geosite - Site of international geological importance

Fig. B18 *List of the 48 geosites in Geopark West Jutland with a short description and their designation according to the official Danish lists of Sites of National Geological Interest and National Coastal Landscapes.*

B3. DETAILS OF THE GEOLOGICAL SITES

In the table below (Fig. B19) details of the 48 geosites are shown with the geological and natural designations of the sites. The table also shows if public interpretation is available in the form of information panels and/or printed or digital information material and whether the geosites are being used for educational purposes and geotourism. A detailed description of the 48 geological sites is included as Supplement B3 in Annex 1.

I. Geology and Landscape - 1.1 Territory

Note 1 - List of Geological sites (items 1.1, 3.1, 3.2, 3.3 and 3.4)

		Scientific importance		Public Interpretation			
No.	**Name**	**Geology/ landscape***	**Nature****	**Panel**	**Print/ web**	**Edu- cation**	**Geo- tour- ism**
1	The Bovbjerg profile	NGI 76, NCL 80 and Geosite 4-4	NCA	+	+	+	+
2	Lomborg	NGI 75				+	+
3	Fabjergkirkevej	NGI 75		+	+	+	+
4	Skodborg Huse	Local importance			+	+	
5	Salshøj - Sønderhede	Local importance		+	+	+	+
6	Toftum Bjerge	NGI 74 and NCL 85	"Coastline is part of NAT28 2 NCAs"	+	+	+	+
7	Nørrelem - Nørre Nissum - Kamstrup	NGI 75 and NCL 84	"Coastline is part of NAT28 3 NCAs"	+	+	+	+
8	Bjerrumbuen	Local importance		+	+	+	+
9	Breinholtbuen	Local importance		+	+	+	+
10	Gimsing - Handbjerg	Local importance		+	+	+	+
11	Ryde - Sevel	Local importance				+	+
12	Nygård Hage	Local importance		+	+	+	+
13	Lem Vig	NGI 75 and NCL 84	"Coastline is part of NAT28 1 NCA"	+	+	+	+
14	Kilen - Hornet	Local importance	NWR and 1 NCA	+	+	+	+
15	Hellegård tunnel valley	Local importance	2 NCAs	+	+	+	+
16	Stubbergård Sø - Flyndersø	NGI 64	"NAT41 2 NCAs"	+	+	+	+
17	Lomborg - Bonnet - Heldum	NGI 75		+	+	+	+
18	Nørre Nissum - Fabjerg	NGI 75		+	+	+	+
19	Odby till plain	Local importance			+	+	+
20	Klosterhede - Kronhede	NGI 75	NAT 224 and 65 and 1 NCA	+	+	+	+

21	The Storå valley	NGI 77		+	+	+	+
22	Trælborgdalen	Local importance		+	+	+	+
23	Fousing valley	Local importance	Part of NCA		+	+	+
24	Burlund	NGI 77			+	+	+
25	Møborg hill island	Local importance		+	+	+	+
26	Linde hill island – Sir Lyngbjerge	Local importance		+	+	+	+
27	The Græm profile	Local importance		+	+	+	+
28	Venø Bugt	Local importance	NAT62 and 1 NCA	+	+	+	+
29	Veserne - Plet - Engbjerg	NGI 76 and NCL 80	NAT28 and NWR	+	+	+	+
30	Sønder Lem Vig - Geddal Enge	Local importance	NAT32	+	+	+	+
31	Remmerstrand - Resen Kær	Local importance	1 NCA	+	+	+	+
32	Hellerød Kær	NGI 71 and NCL 87	NAT28 and NWR	+	+	+	+
33	Husby Klitplantage	Local importance	NAT74	+	+	+	+
34	Sønder Vosborg Hede	NGI 77	NAT64 and NCA	+	+	+	+
35	Idom Å and Ormstrup Hede	NGI 77	NAT64 and NCA	+	+	+	+
36	Skibsted Fjord - Kås Bredning	NGI 71 and NCL 87	NAT28, NCA and NWR	+	+	+	+
37	Vestkysten	NGI 76, NCL 80 and Geosite 4-4	NAT28, NCA and NWR	+	+	+	+
38	Nissum Fjord	"NGI 75 (northeast corner) NGI 77 (southeast corner)"	NAT65, NWR and 2 NCAs	+	+	+	+
39	Oddesund	Local importance	NAT28 along western coast	+	+	+	+
40	Gjellerodde	NGI 75 and NCL 84	NAT28	+	+	+	+
41	Venø - Nørskov Vig	NGI 72 and NCL 87	NWR	+	+	+	+
42	Odby Klint	NGI 73 and NCL 86	NAT28	+	+	+	+
43	Bjørndal limestone quarry	Local importance		+	+	+	+
44	Hjerm limestone quarry	Local importance		+	+	+	+
45	Sevel limestone quarry	NGI 64		+	+	+	+
46	Søndbjerg Strand	NGI 72 and NCL 87		+	+	+	+
47	Hygum Bakke - Kildeplads Engbjerg	NGI 76		+	+	+	+
48	The underwater landscape Jyske Rev	Offshore areas are not classified	NAT219-220-247	+	+	+	+

Fig. B19 *List of geological sites showing their scientific importance/designation, availability of interpretation material, use for educational purpose and geotourism*

* NCLxx - National Coastal landscapes
NGIxx - Sites of National Geological Interest
Geosite - Site of international geological importance
** NATxx - Natura2000 site
NWR - Nature and Wildlife Reserve
NCA - Nature Conservation Area - Designation can be based on values for natural beauty, nature, cultural heritage, scenery, research and recreational use

B4. List and description of other sites of natural, cultural and intangible heritage interest

The cultural and natural heritage of Geopark West Jutland is strongly influenced by the landscape and its geological history. Some of the most immediate examples of this are the early settlement patterns along the Main Stay Line where the early settlers found soil that was light enough for them to cultivate with their relatively primitive implements and yet contained enough clay for them to harvest a decent crop.

The North Sea, the Limfjord and other inner waters have changed dramatically since the ice melted away but have been a source of food and a shipping route with enormous importance for the development of the whole region and its people. The market towns Lemvig, Struer and Holstebro expanded considerably when the Harboøre-Agger isthmus was breached and the North Sea became accessible. Shipping however also faced many challenges and the story of the geopark is also the story of the Iron Coast with shipwreck disasters and the birth of the Danish National Sea Rescue Service.

The intangible heritage of the area such as "The spirit of West Jutland" has certainly been shaped by the harsh conditions along the coast and on the outwash plains and hill islands. For centuries the land south of the Main Stay Line was open and almost devoid of forests and most of it was covered by heath with meadows along the rivers, lakes and lagoons. The land was excellent for grazing and the raising and export of steers was a major source of income. It also gave local people an outlook when they travelled to the markets in the south.

Wind and water has shaped the landscape in many highly visible ways. If you look at a tree in West Jutland you will almost always be able to tell where West is. As sand drift became an increasing problem the great plantations of the region were planted with stretches of heath and dunes in between. The river valleys shaped by meltwater are also significant landscape elements and together with the many meadows, beaches, lagoons and underwater reefs and other sites the region as a whole is very rich in nature which can also be seen from the many Natura 2000-sites, nature and wildlife reserves and nature conservation areas.

All of the above has led to the identification of 48 sites of natural, cultural and intangible heritage interest that are in so many ways linked to the geological heritage. A detailed description of each site is included as supplement B4 in Annex 1.

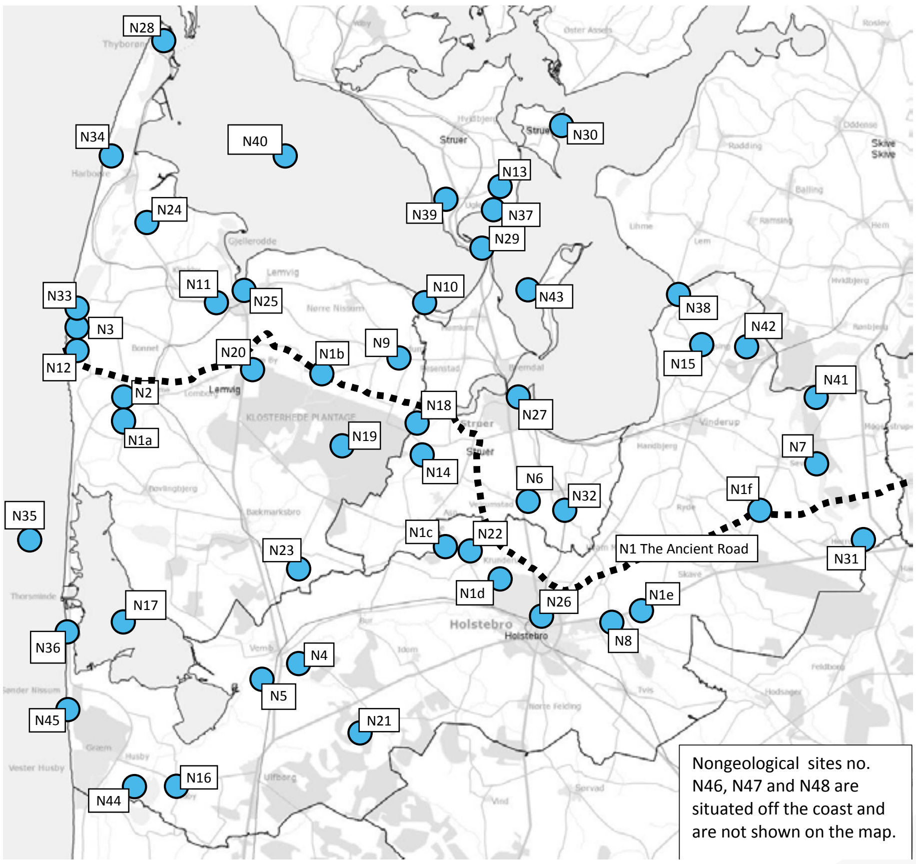


Fig. B20 *Map with positions of the non-geological sites of natural, cultural and intangible heritage interest. Sites no. N46, N47 and N48 are situated in the North Sea along the coast and have not been shown on the map.*

Fig. B21 *List of the 48 non-geological sites in Geopark West Jutland with a short description of their natural, cultural and intangible heritage values. A comprehensive description of each site is provided in Annex 1, Supplement B4.*

No.	Non-geological site	Short description
N1	The Ancient Road	Clear traces of prehistoric habitation along the Main Stationary Line marked by barrows and evidence of an ancient road passing through the entire geopark from the North Sea coast to Viborg in the east.
N1a	Barrows at Rammedige	Fifteen of originally 60 Stone and Bronze Age barrows constructed along the Ancient Road with an associated legend of a treasure to be found.
N1b	Barrows along Fabjerg Kirkevej	A fine example of how not only barrows but also Middle Age churches were built along the Main Stationary Line and the Ancient Road.
N1c	Mangehøje	The name means “Many barrows” which is in agreement with the 13 pre-served barrows on the site. Also found here are traces of the Ancient Road that are very visible as parallel wheel tracks in the landscape together with an old milestone.
N1d	Døeshøjene	A group of 27 preserved barrows of which one has been archaeologically ex-cavated revealing four graves from the older Bronze Age. There is also an old legend associated with the Barrow Langemette that will give visitors a challenge.
N1e	Single Grave Barrows at Mejrup Kirkeby	Five barrows from the Single Grave Culture (2800 – 2400 B.C.) during the New Stone Age when major changes in agriculture took place.
N1f	Salshøj	A group of barrows on top of a terminal moraine where valuable archaeo-logical finds which are now in the National Museum in Copenhagen have been made. The site also has evidence of some of the old road system.
N2	Rammedige	Rammedige is an earthwork from the Iron Age that is believed to have been constructed in the period between 100 and 400 A.D. In 2011 a full-scale model of 30 m of the rampart and trench was built, and the conti-nuation of the now removed part of Rammedige was marked by a series of posts.
N3	Bovbjerg Lighthouse	Bovbjerg Lighthouse has many functions. In addition to its role as an active lighthouse it is a cultural and exhibition centre as well as a cafeteria. It is run by a group of local enthusiastic volunteers under the watchful eye of a “Lighthouse Auntie”. It is located at the top of Bovbjerg cliff that is the most important geosite in Geopark West Jutland.
N4	Skærum Mill	Historical site which today houses the Folk University Centre (Danish Uni-ver-sity Extension Centre) and a number of unique exhibitions on art, cul-tural history, geology and a historical forest.
N5	Nørre Vosborg	The more than 700 year old manor house Nørre Vosborg was thoroughly reno-vated between 2004 and 2008. It is Denmark´s best documented man-or house with a close connection to the history of the local area. The house is now a centre consisting of a hotel, restaurant and course facilities.
N6	Ausumgaard	Ausumgaard is one of the few manors that survived the so called slaughter of estates around the year 1800 and is today working to become a Power Hub for production and innovation of high quality locally based food prod-ucts.
N7	Stubber Monastery and cattle pen	Historical ruin of a former monastery belonging to the Order of Saint Bene-dict with a nearby example of an ancient livestock pen and traces of the Drovers’ Road
N8	Tvis Mill and Monastery	Scant remains of the foundations of a large Cistercian monastery and an old water mill located between two watercourses of river Tvis Å. Holstebro munic-ipality is establishing a new Tvis Mølle Nature Laboratory for school children, citizens and guests on the site which will also serve as a geopark visitor centre.
N9	Gudum Monastery and Klo-stermølle	The village of Gudum (God´s Home) was an important traffic junction and spiritual centre in the Middle Ages. Today there are the remains of two nunner-ies and a restored watermill (Klostermølle). The local population are very active and have been involved in restoring the mill, have established a series of paths (Kløverstier) and have amongst a number of projects rebuilt the former school into a new parish hall.

No.	Non-geological site	Short description
N10	Åmølle	The watermill at Åmølle is about 500 years old and is conserved as one of the most interesting water mills in Denmark. The mill has the only surviving intact example of a Roman drive in Northern Europe. It is located on raised sea floor close to the terminal moraine at Toftum Bjerge. It has been reno-vated and is being run by volunteers.
N11	Heldum Church	A very fine example of the 51 Norman ashlar churches in the geopark. Heldum Church is quite small and unlike many of the other churches it has not changed much since it was built just before 1200.
N12	Trans Church	Norman ashlar church on the west coast. The church has been excavated revealing remains of the previous wooden church and finds of German coins from the late Middle Ages bearing witness to trading connections with the Hanseatic League.
N13	Søndbjerg Church	Norman ashlar church. One of few magnate churches built with a tower. The foundation has Runic in-scriptions telling about who financed and who built the church. The church also tells stories of a late Middle Age fire, legends and ballads and even an earthquake.
N14	Fousing Church	Fousing church dates back to around 1200 and was built in the Norman style with later extensions. The church has a very interesting link to geology because of the many large blocks of rhomb porphyry that have been used for its construction.
N15	Ejsing Church and Landting	Ejsing church is a Romanesque ashlar church with an unusual number of large late Gothic additions. The church represents the story of how local squires influenced the church.
N16	Staby Church	A Norman ashlar church that is famed for its apse with two unique four leaved clover shaped windows and six arched arcades supported by 7 col-umns. Another special feature is the presence of many ashlar blocks of dark reddish-brown “iron sandstone” which sometimes are laid in continuous rows.
N17	Nissum Fjord Nature Park	Nissum Fjord is a natural site of international importance which is also rich in cultural history closely linked with the landscape. Importantly, the site is also the home of the NIssum Fjord Network, a community based organisation working to establish a nature park as a means to promote local deve lopment and tourism.
N18	Kjærgårdsmølle	In addition to the history of Kjærgaard watermill this site has a dramatic geological history as Kilen tunnel valley, and was also an important settle-ment in the younger Stone Age with ancient roads and sunken roads. There is a Nature School and the area has been administered in a successful co-operation between Lemvig and Struer municipalities, Nørre Nissum Tea-chers Training College and the Nature Agency since 1977.
N19	Klosterheden	Klosterheden is the common name for both Klosterheden and Kronheden Plantations with a total area of 6.400 ha making it the third largest woodland area in Denmark. The area is rich in ancient monuments and contributes to the story of the succession of plants from the end of the last ice age until today. It also provides insights into the development of local fauna including the site where beavers have been reintroduced to Denmark.
N20	Rom Airfield and World War II	During World War II the Germans build an airfield for fighter planes with hangars, a hospital and bunkers on the outwash plain just south of Lemvig. After the war the airfield was used as a refugee camp for up to 9,000 refu-gees from Eastern Prussia. The site is part of the story of World War II in the geopark.
N21	Stråsø Plantation	In 1891 the Danish state started buying land in this area in order to plant trees to reduce the effect of windblown sand and to produce timber for the region. The plantation gradually expanded up to 1940-42. Part of the area is designated Natura 2000 with heaths, inland sand dunes, mulberry and oak scrubland and a strip along river Idom Å that is one of the cleanest and most undisturbed water-courses in Denmark.

No.	Non-geological site	Short description
N22	Sir Lyngbjerg	Sir Lyngbjerg is a site of high scenic value with a long history as a location for public meetings, celebrations and debates on democracy and freedom, gathering thousands of people. The area has a historical route with eight memorial stones erected over a period of 100 years celebrating events of national importance, royal persons and local people of high regard. The story of the local geology is also communicated.
N23	Møborg Bavnehøj	Møborg Bavnehøj (beacon) is one of many high points in Geopark West Jutland from where there is an excellent view of the surrounding landscape. The beacon is a good example of how the formation of the landscape and cultural history are connected, and how communication can be carried out in cooperation with local volunteers.
N24	Hygum Hill	Hygum Hill is really a former water tower in an area that contains 36 bar-rows and remains of German fortifications from Wold War II. There is a fine view of the landscape and the site has excellent opportunities for infor-mation on where we get our water from.
N25	Lemvig Market Town	Lemvig is a Middle Age market town at the base of a bay with a harbour and road connections to its hinterland which has made the town an important trading centre – especially after 1825 when the Aggertange isthmus was breached and Lemvig gained access to the North Sea. The surrounding area consists of fertile till soil.
N26	Holstebro Market Town	Market town and trading centre located at a crossing point over the Storå river where several roads converge. Holstebro is a cultural centre with modern industry and educational facilities.
N27	Struer Market Town	Struer is a young town that developed as a result of industrialisation in the 1800s with a harbour and railway connections. It was a further development of an old market place and a landing site on the beach. The town evolved around a brick works.
N28	Thyborøn	Thyborøn and the surrounding landscape on the spit Harboøre Tange bear witness to dynamic events and attempts by mankind to tame them. This is an excellent example of an "engineered landscape". Thyborøn is also home to three information centres on landscape formation, nature and cultural history.
N29	Oddesund	Historically Oddesund has formed a very important connection between north and south. The locality is important in a cultural historical context with ferries, bridges, fishing, fortifications and an eccentric recluse. The location has considerable recreational value and there are plans to make it an experience and communication centre.
N30	Jegindø harbour	Jegindø harbour involves the history of fishing in Limfjord and its develop-ment from "sjægten" (a primitive fishing boat with a sail unique to Limfjord used until about 1900) to motorised fishing boats with modern mussel-dredgers and special boats to collect longline cultured mussels.
N31	Sevel Kalkværk (Lime-works)	Sevel Kalkværk (Lime-works) is run by a group of volunteers and is one of the communication sites for the geopark. The story told is about the quar-rying of limestone since 1873 until 1960 and the geological explanation for why the quarry exists.
N32	Hjerm Limestone Mine	Hjerm limestone mine provides an opportunity to communicate geology in a first rate combination with cultural history, nature and food produce. The mine, that is part of Geosite nr. 44, has become a home for bats in one section, and a store far the maturing of cheese in another.
N33	The groynes at Ferring	The steep cliffs at Bovbjerg and Ferring are a result of hundreds of years of coastal erosion. Groynes were built perpendicular to the coast in 1875 to reduce this erosion. This was the beginning of the coastal defence system along the Danish West Coast.
N34	Flyvholm Sea Rescue Station	The underwater landscape along the west coast – the so-called "Iron Coast" – has been closely connected with many dramatic shipwrecks through the years. Part of the story concerns the efforts made to save the lives of the crews. Flyvholm Sea Rescue Station was the start of the National lifeboat service.

No.	Non-geological site	Short description
N35	Submarine Stoneage settle-ments	The oldest discoveries of Stone Age settlements in the area under the re-sponsibility of Holstebro Museum were made off the west coast. These finds serve to emphasize the dramatic changes in the landscape that have taken place since the last ice age.
N36	HMS St. George and HMS De-fence	Marine archaeological finds of international significance from the largest shipwreck catastrophe on the west coast of Jutland in 1811 when two Eng-lish vessels of the line stranded offshore from Thorsminde and 1408 drowned. The story of this tragic event will be told at a new stranding mu-seum in Thorsminde opening in 2017.
N37	St. Mauritii spring	The Holy Spring St. Mauritius on the beach at Serup dates back to the Mid-dle Ages. The name comes from a Roman legionary who became a saint.
N38	Sønderlem Vig and Geddal Tidal Meadows	This site tells the story of the enclosure and draining of a near-coast area to provide more agricultural land and the wide variety of interests that are involved. The area is a valuable nature area with Natura 2000 status and a possible future nature park.
N39	Odby village	From the agrarian development in the Viking age to the industrial age; the role of geology. Odby village provides a good illustration of the special infield-outfield system.
N40	Natura 2000 site no. 28 Agger Tange, Nissum Bredning, Skib-sted Fjord and Agerø	This is the largest single natural area of international significance in Geopark West Jutland. About 85% of the area is maritime with considerable value for recreation and communication.
N41	Part of Natura2000 site no. 41 Hjelm Hede, Flyndersø og Stubbergaard Sø	This is a varied, naturally infertile area with unspoiled nature in interplay with cultural landscape elements and the potential for a range of experi-ences. The Outdoor Museum Hjerl Hede that is located just west of lake Flyndersø is a splendid communication centre with many visitors.
N42	Natura2000 site no. 61: Skånsø and Tranemose	A heathland and plantation area with a very clean lake with water lobelia plants. The lake developed in a dead ice hole (kettle hole). There is also a small bog and a rather overgrown area where peat used to be extracted.
N43	Natura2000 site no. 62 Venø and Venøsund	Nørskov Vig on the northern tip of Venø island, Venøsund (Venø sound) and the tidal meadows on the mainland west of Venø have considerable natural value with a rich birdlife and many stony reefs. The inhabitants of the island are keen to protect these assets in a sustainable fashion.
N44	Natura2000 site no. 72 Husby Sø	Of the entire Natura 2000 area it is only lake Husby Sø that is part of Ge-opark West Jutland. The lake has a rich flora and fauna and bears witness to land reclamation projects during and after World War II.
N45	Northern part of Natura2000 site no. 74: Husby Klit	This Natura 2000 site contains valuable sand dune landscapes. Together with Husby Klitplantage (plantation) the area has considerable potential for open air activities and communication regarding cultural history and nature.
N46	Natura2000 site no. 219 Sand banks off the coast from Thy-borøn	The three areas comprise sandbanks and stony reefs that rise from the floor of the North Sea. These areas are the objects of current investigations and are of considerable research interest. They are also of interest from a marine archaeological viewpoint.
N47	Natura2000 site no. 220 Sand banks off the coast from Thor-sminde	
N48	Natura2000 site no. 247 Thy-borøn Stenvolde	

A detailed description of all the 48 non-geological sites is provided in Annex 1, Supplement B4 to this application.

REFERENCES ANNEX 2 AND GEOSITES (SUPPLEMENT B3)

Aaris-Sørensen, K. 1988. Danmarks Forhistoriske Dyreverden. – Gyldendal.

Andersen, S., 1993. Geologisk Det – Det mellemste Jylland, Bovbjerg - Engbjerg, s. 209-215. Geografforlaget, Brenderup.

Andersen, S. T., 1995. Kulturlandskabet i geologisk perspektiv. På opdagelse i kulturlandskabet, s. 9-12. Gyldendal.

Binderup, M. 1994. Kystens geologi. Naturen ved kysten - kap. 2 side 13-22, Miljø- og energiministeriet, Skov- og Naturstyrelsen.

Binderup, M. 2012. Nutidens kyster og klitter. Naturen i Danmark – Geologien, kap. 17 side 395-436, Gyldendal.

Clemmensen, L.B., Murray, A., Heinemeier, J., de Jong, R., 2009. The evolution of Holocene coastal dunefields, Jutland, Denmark: A record of climate change over the past 5000 years. Geomorphology 110, 236-237.

COWI, 2014. Grundvandsmodel for Engbjerg kortlægningsområde.

COWI, 2014. Hydrostratigrafisk og grundvandskemisk modelrapport, kortlægningsområde Engbjerg.

Danish Coastal Authority website, http://kysterne.kyst.dk/kystbeskyttelsesmetoder.html (accessed august 2016)

Danish Coastal Authority website, http://kysterne.kyst.dk/kystbeskyttelsesstrategi.html (accessed august 2016)

Ditlevsen, C, 1994. Geologisk Set – Midtjylland, Odby Klint, side 200 - 201. Geografforlaget. Brenderup.

Ditlevsen, C, 1990, En kvartærstratigrafisk undersøgelse på Thyholm. Dansk geol. Foren., Årsskrift for 1987-89, side 55-69. København.

Frandsen, K-E., 1983. Vang og tægt, studier over dyrkningssystemer og agrarstrukturer i Danmarks landsbyer 1682-83. s. 4-38, 228-232, 247-249. Bygd, Esbjerg.

GEUS, 2011. Geologisk kort over de overfladenære jordarter. "Jordartskort 1:200.000". GEUS rapport 2011/19

Gravesen, P., Nilson. B, Pedersen, S. S., Binderup, M., 2011. Low- and intermediate level radioactive waste from Risø, Denmark. Location studies for potential disposal areas. Report no. 9. Limfjorden.

Hansen, Kjeld. Folk og fortællinger fra det tabte land – Midtjylland. http://www.dettabteland.dk/midtjylland.htm (accessed July 2016)

Heilmann-Clausen, C., Surlyk, F. 2010. Koralrev og lerhav. Naturen i Danmark – Geologien, kap. 10 side 181-226, Gyldendal.

Houmark-Nielsen, M., 2003. Signature and timing of the Kattegat Ice Stream: onset of the Last Glacial Maximum sequence at the southwestern margin of the Scandinavian Ice Sheet. Boreas 32, 227-241.

Houmark-Nielsen, M., 2007. Extent and age of Middle and Late Pleistocene glaciations and periglacial episodes in southern Jylland, Denmark. Bulletin of the Geological Society of Denmark 55, 9-35.

Houmark-Nielsen, M., 2010. Extent, age and dynamics of Marine Isotope Stage 3 glaciations in the southwestern Baltic Basin. Boreas 39, 343-359.

Houmark-Nielsen, M., Kjær, K.H., 2003. Southwest Scandinavia, 40-15 kyr BP: palaeogeography and environmental change. Journal of Quaternary Science 18, 769-786.

Houmark-Nielsen, M., Knudsen, K.L., Noe-Nygård, N., 2012. Istider og mellemistider. Naturen i Danmark – Geologien, kap. 13 side 255-302, Gyldendal.

Houmark-Nielsen, M., Krüger, J., Kjær, K.H., 2005. De seneste 150.000 år i Danmark - Istidslandskabet og naturens udvikling. Geoviden - Geologi og Geografi 2, 1-20.

Jensen, J.A. 2003. Sandflugt i 8000 år. FRAM, pp. 156-159.

Jensen, J. B., 1983. Geologisk Set. Det – Det mellemste Jylland, Toftum Bjerge, s. 202-204. Geografforlaget, Brenderup.

Jensen, J.B., 1984. Sen-Elster smeltevandsler - en mulig ledehorisont i Vestjylland. Dansk Geologisk Forening, Årsskrift for 1984, 21-35.

Jensen, J.B, Leth, J.O., Borre, S., Nørgaard-Pedersen, N., 2010. Model for potentielle sand- og grusforekomster for de danske farvande. GEUS rapport 2010/23.

Jørgensen, M., 1985. Geologisk Set – Det mellemste Jylland, Kronhede, s. 205-208. Geografforlaget, Brenderup.

Jørgensen, M., Niebe, P., Petersen, K. S., Pedersen, S. S. 1990. Geologisk Set – Det mellemste Jylland, Skovbjerg Bakkeø, s. 215-223. Geografforlaget, Brenderup.

Jørgensen, F., Sandersen, P.B.E., 2006. Buried and open tunnel valleys in Denmark - erosion beneath multiple ice sheets. Quaternary Science Reviews 25, 1339-1363.

Kolstrup, E., 2004. Stratigraphic and environmental implications of a large ice-wedge cast at Tjæreborg, Denmark. Permafrost and Periglacial Processes 15, 31-40.

Krabbe, J., 1977. Bjørndal Kalkværk, egnsindustri gennem 200 år. Egnshistorisk forening for Thyholm og Jegindø, side 19-25. Hvidbjerg.

Kristensen, M. et al. 2015. Miocæn 3D, opdateret 2015. Den rumlige geologiske model. GEUS rapport 2015/90.

Kronborg, C., Mejdahl, V., 1989. Thermoluminescence dating of Eemian and Early Weichselian deposits in Denmark. Quaternary International 3/4, 93-99.

Kronborg, C., Mikkelsen, M., Thomsen, K, 2000. Vestjylland bliver til: Det kvartære landskab. Mellem Hav og Hede, s. 16-27. Aarhus Universitetsforlag.

Krüger, J. 2012. Nutidens landskab. Naturen i Danmark – Geologien, kap. 16 side 361-394, Gyldendal.

Larsen, G. 2012. Udforskningens historie. Naturen i Danmark – Geologien, kap. 2 side 25-40, Gyldendal.

Larsen, G., Kronborg, C. 1994. Geologisk Set – Midtjylland, Brenderup

Larsen, N.K., Knudsen, K.L., Krohn, C.F., Kronborg, C., Murray, A.S., Nielsen, O.B., 2009. Late Quaternary ice sheet, lake and sea history of southwest Scandinavia - a synthesis. Boreas 38, 732-761.

Larsen, N.K., Krohn, C.F., Kronborg, C., Nielsen, O.B., Knudsen, K.L., 2009. Lithostratigraphy of the Late Saalian to Middle Weichselian Skaerumhede Group in Vendsyssel, northern Denmark. Boreas 38, 762-786.

Larsen, S.N., Nielsen, B.O., Toft, S. 2007. Moserne og de ferske enge. Naturen i Danmark – Det åbne land, kap. 4 side 119-166, Gyldendal.

Leth, J. O. 2003. Nordsøen efter istiden – udforskningen af Jyske Rev. Geologi – nyt fra GEUS nr. 3.

Leth, J.O. et al, 2014. Den danske havbund. Geoviden – geologi og geografi nr. 2.

Madirazza, I. 1968. Mønsted and Sevel salt domes, North Jutland, and their influence on Quaternary morphology. Geol. Rundsch. 57, side 1034-1066.

Madirazza, I. 1975. The geology of Vejrum salt structure, Denmark. Bull. Soc. Denmark, vol. 24, pp. 161-175.

Mathiassen, T., 1948. Studier over Vestjyllands oldtidsbebyggelse. Kapitel 2, side 10-32, plancher 1-25. Gyldendal.

Madsen, V. 1921. Terrainformerne på Skovbjerg Bakkeø. Medd. Fra Dansk geologisk Forening. Bd. 6 nr. 5.

Miljøministeriet, 2008. Kortlægning af grundvandsressourcen i og nord for Klosterhede Plantage, Dokumentationsrapport, 22-27

Milthers, K., 1935. Landskabets udformning mellem Alheden og Limfjorden. Danmarks Geologiske Undersøgelse 2, 1-32.

Milthers, K., 1948. Det danske Istidslandskabs Terrænformer og deres Opståen. Danmarks Geologiska Undersøgelse lll, 233.

Mortensen, P.H. 2003. Klitplantagernes oprindelse. FRAM, pp. 112-118.

Munck, F. (1999): Kvartærgeologisk kortlægning af Bovbjergklinten. Unpubliced MSc Thesis, Aarhus University, Denmark.

Møller, J. T., 2000. Engang en del af havet: Fjorde og søer i Ulfborg herred. Mellem Hav og Hede, s. 36-58. Aarhus Universitetsforlag.

Naturstyrelsen, 2010. Marin råstof- og naturtypekortlægning i Nordsøen 2010.

Naturstyrelsen, 2011. Natura 2000-plan 2010-2015. Husby Klit. Natura 2000-område nr. 74. Habitatområde H197

Naturstyrelsen, 2012. Forslag til Natura 2000-plejeplan for Naturstyrelsens arealer i Natura 2000-område nr. 74 Husby Klit.

Naturstyrelsen, 2012. Forslag til Natura 2000-plejeplan for Naturstyrelsens arealer i Natura 2000-område nr. 64 Heder og klitter på Skovbjerg Bakkeø, Idom Å og Ormstrup Hede.

Naturstyrelsen, 2014. Redegørelse for Engbjerg – Afgiftsfinansieret grundvandskortlægning.

Noe-Nyggard, N., Knudsen, K.L., Houmark-Nielsen, M. 2012. Fra istid til og med jægerstenalder. Naturen i Danmark – Geologien, kap. 14 side 303-332, Gyldendal.

Odgaard, B., Dalsgaard, K., Kristensen, G. 2014. Landskabets tilblivelse. Nørre Vosborg i tid og rum, bind 1, pp. 25-34, Aarhus Universitetsforlag.

Pedersen, S.A.S., Petersen, K.S., Rasmussen, L.A., 1988. Observations on glaciodynamic structures at the Main Stationary Line in western Jutland, Denmark, In: Croot, D.G. (Ed.), Glaciotectonic: Forms and Processes. Balkema, Rotterdam, pp. 177-183.

Petersen, K.S., Kronborg, C., 1991. Late Pleistocene history of the inland glaciation in Denmark, In: Frenzel, B. (Ed.), Klimagechichtliche Probleme der letzen 130.000 Jahre. Palaoklimaforschung, pp. 331-342.

Petersen, K.S., Rasmussen, L.A., Pedersen, S.A.S. 1992. Middle and Late Pleistocene glacial geology of western Jutland, as exemplified by the Ulfborg map sheet. Sveriges Geologiska Undersökning, Ca 81, pp. 225-232.

Raarup, S. 2013. Dødbjerg – en geologisk perle på Thyholm. Gang i lokalsamfundet.

Rasmussen, E. S., 2010. Neogen – Da Danmark steg op af havet. Geoviden 2010/3, side 12-19. GEUS.

Rasmussen, E. S., Dybkjær, K., Piasecki, S., 2010. Lithostratigraphy of the Upper Oligocene – Miocene succession of Denmark. GEUS 2010, Bull. 22.

Sandicani, H., 1986. Geologisk Det – Det mellemste Jylland, Venø, s. 194-199. Geografforlaget, Brenderup.

Sjørring, S., 1981. Pre-Weichselian till stratigraphy in western Jutland, Denmark. Meded. Rijks Geol. Dinst 34-10, 62-68.

Smed, P., 2012. Landskabskort - Midtjylland. Geografforlaget, Brenderup.

Sundberg, P.S. 2000. Resultater fra Ulfborg projektet – påvisning af Eem strandflade. Geologisk Nyt 4/2000.

Surlyk, F., 2006. Naturen i Danmark – Geologien, kap. 10 side 186-190. Gyldendal.

Thomsen, E., 1995. Danmarks geologi fra Kridt til i dag. Århus geokompendier nr. 1, kap. 4, side 45-60. Geologisk Institut, Aarhus Universitet.

Wienberg Rasmussen, H. 1966. Danmarks Geologi, Gjellerups liniebøger, Gjellerup.

Ussing, N.V., 1903. Om Jyllands hedesletter og teorierne for deres dannelse. Det Kgl. danske Vid. Selsk. Forh. 4, 1-53.

Ussing, N. V., 1907. Om Floddale og Randmoræner i Jylland. Kgl. Danske Vidensk. Selsk. Forhandlinger, 4. 161-213.

Ødum, H., 1926. Studier over Daniet i Jylland og paa Fyn, side 126-136, Tavle I, Tavle II. Danm. Geologiske Unders., II Rk. 45.

GEOPARK
VESTJYLLAND