Geological Screening of Kriegers Flak North and South

Geological seabed screening in relation to possible location of windfarm areas

Jørn Bo Jensen & Ole Bennike



GEOLOGICAL SURVEY OF DENMARK AND GREENLAND DANISH MINISTRY OF CLIMATE, ENERGY AND UTILITIES

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Client Danish Energy Agency

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1. Dansk Resumé

Energistyrelsen har bedt GEUS om at udføre en geologisk screening af de potentielle havvindmølle parker Kriegers Flak 2 Nord og Syd. Undersøgelsen har resulteret i en generel geologisk beskrivelse og en geologisk model for området. Studiet er baseret på eksisterende data og er tænkt som baggrund for en vurdering af områdernes geologiske egnethed som vindmølleparker, samt som baggrund for eventuelle fremtidige tolkninger af seismiske data, geotekniske undersøgelser og arkæologisk screening.

I studiet har vi benyttet en kombination af publicerede artikler og rapporter, samt GEUS-arkiv data, til at vurdere den generelle geologiske udvikling i de potentielle havvindmølle områder Kriegers Flak 2 Nord og Syd.

Som en del af studiet præsenterer vi data, som er relevant for en efterfølgende arkæologisk screening.

Kriegers Flak 2 Nord, har en relativ flad havbund med vanddybder på 20 – 35m. Havbunden består af Danien kalk dækket af få meter moræne med sten og et pletvis dække af få meter vekslende sand og dyndet sand. Generelt vurderes området til at være egnet til vindmølle fundering.

Krigers Flak 2 Syd har en hældende havbund med vanddybder fra 20m i nordvest til 45m i sydøst imod Arkona bassinet. Havbunden består af Kridttids kalk dækket af få meters moræne, som udgør fundamentet for et kileformet sandlegeme, der i vestlige del opnår tykkelser på op til 35m og aftager i tykkelse mod øst til at blive få meter tykt. Generelt vurderes området som egnet til vindmøllefundering. Den østlige tyndere del af kilelaget har stigende indehold af ler, og dynd, hvilket der bør være fokus på.

Den geologiske opbygning samt vanddybder over 20m, indikerer at der ikke er arkæologiske interesser i områderne.

2. Summary

The Danish Energy Agency has requested that GEUS undertakes a geological screening study of the Kriegers Flak North and South potential offshore wind farm (POWF) areas. The study has resulted in a general geological description and establishment of a conceptual geological model for the understanding of the area. The study is based on existing data and is to be used as a background for the evaluation of geological suitability of the areas as wind farm sites and a background for future interpretations of new seismic data, geotechnical investigations, and an archaeological screening.

In this study we have used a combination of published work, GEUS archive seismic data and sediment core data to assess the general geological development of the southwestern Baltic Sea area, including the Kriegers Flak North and South POWF.

Information on the existing Kriegers Flak OWF has been presented including the general geology, soil types and geotechnical characteristics.

As part of the geological desk study, we present a relative late glacial and Holocene sealevel curve for the area and describe the development that is relevant for an archaeological screening.

The general geological description includes the complete geological succession from the underlying pre-Quaternary geological framework, the pre-Quaternary surface, glacial deposits, the deglaciation and late glacial and Holocene deposits.

A surface sediment map has been compiled by a combination of Emodnet seabed substrate maps from the German and Swedish zones and the latest version (2020) of the Danish 1:100.000 seabed substrate map.

Details of the geology are presented from the Kriegers Flak North and South POWF areas and has been interpreted and described on the basis of existing knowledge, seismic profile sections modified from Baltic Pipe investigations and scientific seismic lines as well as vibrocores.

In the south-western part of the Baltic Sea, studies of late glacial and early Holocene shore level changes have formed the basis for evaluation of the potential for finding submerged settlements in the wind farm areas. We consider the early and mid-Mesolithic time to be the most likely for findings.

It is concluded that it will be possible to establish a windfarm at Kriegers Flak 2 North POWF, due to its flat seabed (20 – 35m below present sea-level (bsl.) and thin-skinned Holocene sediments on top of till and Danian limestone.

It is concluded that the Kriegers Flak 2 South POWF is probably geotechnically suited for Wind- turbine foundations with some focal points.

It is however also recommended to acquire an open grid of shallow seismic data and few vibrocores, combined with geotechnical investigation, as a low-cost pre-investigation, before next step of decisions and comprehensive studies.

The geological setting and water depths above 20m indicates no risk for archaeological interest in both areas.

3. Introduction

GEUS has been asked by the Danish Energy Agency to provide an assessment of the seabed in the Kriegers Flak 2 North and South potential offshore wind farm areas (POWF), located north and south of the exsiting Kriegers Flak Offshore Wind Farm (OWF). The assessment consists of the establishment of a conceptual geological model based on existing data as a background for evaluation of the suitability for windfarm establishment and a marine archaeological screening (Figure 3.1).



Figure 3.1 Overview map of the southwestern Baltic Sea with location of Kriegers Flak OWF (polygon with purple dashed lines), and the potential wind farm locations Kriegers Flak 2 North and Kriegers Flak 2 South (polygons with yellow dashed lines). The red dashed lines show the Exclusive Economic Zone (EEZ). The bathymetry is from Emodnet Bathymetry (https://www.emodnet-bathymetry.eu/).

4. Data background

As a basis for the desk study, existing background papers and reports have been used together with primary data from the GEUS Marta database (<u>https://www.geus.dk/produkter-ydelser-og-faciliteter/data-og-kort/marin-raastofdatabase-marta/</u>), which is the national main archive of shallow seismic data and vibrocore data (Figure 4.1). In addition, data not included in the Marta database have been used. These data comprise boomer, pinger and vibrocore data from the Baltic Pipe project as well as boomer, airgun and vibrocore data from the Institute for Baltic Sea Research Warnemünde (IOW) and airgun and sediment echosounder data from Stockholm University.

4.1 Background reports and papers

Detailed information about The Baltic Pipe offshore pipeline transect is reported in Rambøll (2020). The Baltic Pipe transect crosses the Kriegers Flak 2 North POWF and the studies provide vital information from seismic transects and vibrocorings,.

In a geological desk study offshore Bornholm (GEUS 2021 a), the general geology of the region has been presented and existing seismic facies units have been described.

In the report Geological desk study Bornholm Windfarm cable transects (GEUS 2021 b), information about the Kriegers Flak North POWF location is reported.

Results from the existing Kriegers Flak OWF includes seismic- (Rambøll 2013) and geotechnical investigations (Geo 2013).

The Arkona Basin geology has been a subject for scientific investigations in Lemke (1998), with description of seismic facies and a combined distribution and thickness map of late glacial clay.

Additional scientific investigations of the southwestern Baltic Sea have in the past focused on the late- and postglacial development. A few papers describe the southern margin of the Arkona Basin including the Kriegers Flak 2 South POWF location (Jensen, 1993, Jensen et al. 1997, Jensen et al. 1999).

4.2 GEUS archive shallow seismic data and sediment cores

The Marta database includes available offshore shallow seismic data and core data in digital and analogue format (Figure 4.1). An increasing part of the seismic lines can be downloaded as SGY files from the web portal.

As seen on Figure 4.1, the Marta database contains a lot of archive data, but only sparse information is available from the Kriegers Flak 2 North and South POWF.

However, the existing seismic lines collected by the Baltic Pipe project (but not in Marta) provides information within, and close to, the potential wind farm areas. The acquired data include side scan, sediment echosounder and boomer data.

In our study we have further included archive data from Stockholm University (Tom Floden, airgun and sediment echosounder data) used for general mapping in the Arkona Basin by Lemke (1998) as well as scientific data from an IOW R/V Humboldt cruise from 1994 (boomer and airgun data).

The existing coring's are all vibrocorings with up to 6m penetration. Most of the vibrocores relate to the Baltic Pipe project and the Humboldt 1994 cruise. Core descriptions are in general available in the Marta database, while no samples have been preserved.



Figure 4.1 Distribution of Marta database seismic data and core data in the study area as well as IOW corings and Stockholm University (Tom Floden) airgun data used for general mapping in the Arkona Basin by Lemke (1998). The location of the proposed Wind farms Kriegers Flak 2 North and Kriegers Flak 2 South is indicated by polygons with yellow dashed lines. The red dashed lines show the EEZ. The bathymetry is from Emodnet Bathymetry (https://www.emodnet-bathymetry.eu/).

5. Pre-Quaternary geology of the south-western Baltic Sea

Detailed pre-Quaternary descriptions of the Bornholm and Arkona Basin region has been presented in geological desk studies offshore Bornholm GEUS (2021 a) and Arkona Basin cable transects GEUS (2021 b).

The southwestern Baltic Sea is crossed by the 30-50 km wide WNW-ESE-trending Sorgenfrei–Tornquist Zone that separates the Baltic Shield, the Skagerrak-Kattegat Platform and the East European Precambrian Platform in the northeast from the Danish Basin in the southwest (Figure 5.1). The Sorgenfrei–Tornquist Zone has been active during several phases after the Precambrian. The lineament is characterised by complex extensional and strike-slip faulting and structural inversion (Liboriussen et al. 1987; Mogensen & Korstgård 2003; Erlström & Sivhed 2001). The old crustal weakness zone was repeatedly reactivated during Triassic, Jurassic and Early Cretaceous times with dextral transtensional movements along the major boundary faults.



Figure 5.1 Position of the Bornholm area in the Tornquist Zone between the Baltic Shield/East European Platform and the Danish Basin/NW European craton (Graversen 2004, 2009).

The pre-Quaternary surface is presented in Figure 5.2, where the Kriegers Flak region show Upper Cretaceous chalk and Danien limestone, bounded by faults related to the Ringkøbing Fyn High.



Figure 5.2 Bedrock geology in the Kriegers Flak area. From Varv (1992), with location of Kriegers Flak OWF (polygon with purple dashed lines), and the potential wind farm locations Kriegers Flak 2 North and Kriegers Flak South 2 (polygons with yellow dashed lines). The red dashed lines show the EEZ.

The general geological development of the study area has resulted in a characteristic pre-Quaternary surface topography (Binzer & Stockmarr 1994) (Figure 5.3).

The combined present bathymetry and pre-Quaternary surface topography shows that only a thin Quaternary top unit of a few metres to about 30m thickness can be expected in the mapped areas. Unfortunately, the Krieger Flak 2 South and North areas are not mapped in relation to pre-Quaternary surface topography. The expectation is however that the northern part of the Arkona Basin follows the same pattern, while increasing Quaternary sediment thickness is observed in the southern part of the Arkona Basin (Lemke 1998).

The seabed sediment map in Figure 7.1 shows large areas with exposed pre-Quaternary seabed sediments offshore Bornholm and in the near shore northern Fakse Bay area. Kriegers Flak 2 North POWF shows only a thin Quaternary top unit of a few metres above Danien limestone while Kriegers Flak 2 South POWF shows 10 – 30m Quaternary glacial (Till) and late glacial sand-clay above Upper Cretaceous chalk.



Figure 5.3 Pre-Quaternary surface topography in metre above sea level (Binzer & Stockmarr 1994). Location of Kriegers Flak 2 North and Kriegers Flak 2 South POWF is shown with black dashed lines. The red dashed lines show the EEZ.

6. Quaternary geology of the south-western Baltic Sea

Four Late Saalian to Late Weichselian glacial events, each separated by periods of interglacial or interstadial marine or glaciolacustrine conditions, have been identified in the southwestern Baltic region. The thickness of Quaternary sediments in the region can exceed 100m in the basins (Jensen et al. 2017). The Scandinavian Ice Sheet reached its maximum extent in Denmark about 22000 years BP followed by stepwise retreat.

The Bornholm region was probably deglaciated shortly after 15000 years BP. Moraine ridges on Rønne Banke and Adler Grund trending parallel to the former ice margin resemble ridges reported southeast of Møn (Jensen 1993). They may mark short-lived re-advances during the winter, formed during the general retreat of the ice margin. An interpretation of the general deglaciation pattern is presented in Lange (1984).



Figure 6.1 Ice margin readvance stage model from Lange (1984).



After the deglaciation, a glaciolacustrine environment with icebergs, the Baltic Ice Lake, was established (Figure 6.2).

Figure 6.2 Illustration of a glaciolacustrine depositional environment.

Quaternary sedimentation in the Fakse Bay, Arkona- and Bornholm Basins, has been intensively studied in relation to the development of the late- and postglacial Baltic Sea phases (Jensen et al. 1997, 1999), because of the well-preserved Baltic Ice Lake clay and the Yoldia Sea and Ancylus Lake clay, as well as the brackish to marine Littorina Sea clay and mud deposits. The Holocene history was documented by Andrén et al. (2000).

6.1 Palaeogeography of the deglaciation of Denmark

The knowledge about the general deglaciation and postglacial history of the southwestern Kattegat and the western Baltic can be presented in a series of palaeogeographical maps (Figure 6.3 a and b):

- About 18000 years ago, the deglaciation from the largest glacier extension (Main Stationary Line) in Jutland had reached a stage where the ice margin roughly followed the Swedish west coast, the present Zealand northern coastline, extending southward along the western part of the Great Belt and with the distal margin found in the northernmost part of Germany. In this early phase, the deglaciated Kattegat region still was not isostatically adjusted and the relative sea-level was high with sea covering major parts of northern Jutland.
- At the next stage, about 16000 years ago, the ice margin had retreated to the Øresund region and the western part of Skåne leaving an ice lobe that covered the southern part of Zealand and followed the present southern coastline of the Baltic Sea. The ice margin was directly connected to the Kattegat marine basin by a broad meltwater channel, which at this stage was affected by an initial relative sealevel regression, while local lakes were under development along the ice margin in the south-westernmost Baltic Sea, e.g. in Køge Bugt.
- A controversial stage of the deglaciation was reached about 15000 years ago, as the ice margin retreat had reached central Skåne. For this stage, only limited information has so far been available about the present offshore area, but investigations in Polish waters combined with data from German and Danish waters show that the ice margin must have been situated west of Bornholm and a large lake started to be

dammed in front of the ice sheet with connection through the Great Belt to the Kattegat, which at that time was increasingly affected by a regression. Apart from meltwater flow from the glacier area west of Bornholm, major meltwater contributions were provided by German and Polish rivers as proved by the existence of major late glacial delta and beach barrier deposits in Fakse Bay and South of the island of Møn (Kriegers Flak South POWF).

- The initial damming of The Baltic Ice Lake was followed by a regression, before a second damming occurred followed by a major discharge event (For relative sealevel changes see Figure 8.1 and Figure 8.2). The last and most extensive Baltic Ice Lake damming took its maximum about 12000 years ago, when minor channels drained the lake through the Great Belt and Øresund and only a small land bridge separated the Baltic Ice Lake from the sea in south-central Sweden. Under the second damming, reactivation and substantial beach barrier deposition continued in Fakse Bay and South of the island of Møn (Kriegers Flak South POWF). Further retreat resulted in a catastrophic discharge event in south-central Sweden with the water level in the lake dropping about 25m.
- About 11500 years ago, a strait was established through south-central Sweden, and the Baltic basin was transformed into a marine basin called the Yoldia Sea. This name comes from an arctic bivalve species called Portlandia (Yoldia) arctica, which is found in sediments deposited during this time. The postglacial eustatic sea-level rise surpassed the rate of glacio-isostatic rebound in the southern Kattegat and the lowest postglacial relative sea-level was reached about 35m below present sea-level. Curves of sea-level changes are shown in Figure 8.1 and Figure 8.2.
- Continuous glacio-isostatic uplift of south-central Sweden closed the connection to the ocean and the last lake phase of the postglacial Baltic, called the Ancylus Lake, was established, The stage is named after a fresh-water gastropod, Ancylus fluviatilis, which lives in rivers and in the coastal zone of large lakes. Due to damming, the lake reached a maximum water level about 10200 years ago with only a narrow drainage pathway through the Great Belt into the southern Kattegat. Here the initial transgression had resulted in the formation of a rather large lagoon/estuary basin, partly blocked by transgressive coastal barriers. Remains of this system are preserved on the sea floor as it is reported by Bennike et al. (2000) and Bendixen et al. (2017).

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Figure 6.3 a and b. Palaeogeographical maps showing the development of the Danish area from c. 18000 to c. 7000 years BP. Modified from Jensen et al. (2003).



- About 10000 years ago, the Ancylus Lake water level dropped about 9m within a
 few hundred years. The traditional opinion was that the drainage was through the
 Great Belt. However, investigations in the southern Kattegat, the Great Belt as well
 as at the thresholds Gedser Reef Darss Sill, south-east of Langeland and in the
 south-western Kattegat show that only a small lake level fall, in the order of a few
 metres, could be provided by this drainage route. Moreover, for the time of drainage, calm lake and estuarine sedimentation is recorded in the Great Belt and southwestern Kattegat.
- The calm lake sedimentation was followed by a gradual transgression and change into brackish conditions about 9400 years ago, and a fully marine environment was reached in the Great Belt 9100 years ago, marking the beginning of the Littorina transgression.
- About 8000 years BP, the transgression had reached the Darss Sill Gedser Reef area.
- And about 7000 years BP, also the western part of the Baltic Proper was marine.

6.2 The basic Quaternary conceptual geological model in the Southwestern Baltic, based on data from the Bornholm region

The Quaternary conceptual geological model for the region, builds on a network of seismic data from the Marta database as well as scientific data collected during the last few decades, mainly in connection with the EU BONUS project: Baltic Gas. A seismic stratigraphy was developed, and core positions were selected and followed by an Integrated Ocean Drilling Program (IODP 347).

During IODP Expedition 347 in October 2013, cores were recovered at Site M0065 (Figure 6.5, Figure 6.6 and Figure 6.7) in the Bornholm Basin, with an average site recovery of 99%. The water depth at the coring site was 84.3m, with a tidal range of <10 cm. A total depth of 73.9m below seabed was reached before bedrock was encountered. Piston coring was used to recover the clay lithologies before switching to a combination of open hole and hammer sampling to maximize recovery in the more sandy lithologies. No samples were recovered from the lower part and only the upper 49.2m could be described.

The obtained sediment sequence was divided into lithostratigraphical units by Andrén et al. (2015).

A conceptual geological model based on the combination of seismic data and core data was established by Jensen et al. (2017). Results from the rest of the southwestern Baltic Sea shows that the model is valid for the whole region and hence it forms the basis for the interpretations in this study.



Figure 6.4 Map of the southwestern Baltic Sea with location of IODP site M0065 (yellow star) in relation to the Kriegers Flak 2 North and South POWF (polygons with black dashed lines). P21 is the location of seismic line from Mathys et al. (2005). The red dashed lines show the EEZ.

Five seismic units were described, all separated by unconformities (Figure 6.5).

The Crystalline basement and Sedimentary bedrock, Unit V, as well as the Glacial Unit IV, were mainly identified on deeper seismic airgun data, whereas details of the late- and post-glacial more soft deposits are best seen on the sediment echo-sounder profiles (Figure 6.6).

The bedrock distribution follows the deeper structures shown in Figure 5.1 and the glacial deposits follows the regional glaciations.

The late- and postglacial Units III–I were deposited in basins with a changing shore-level. The shore-level changes are well described in the southwestern Baltic Sea (Figure 6.5) (Andrén 2000 and Uscinowicz 2006), and a close match can be expected between shore-level lowstands and allostratigraphical unconformities.



Figure 6.5 Stratigraphical subdivision of the Bornholm Basin (Jensen et al. 2017). The seismic Units I–V represent allostratigraphical formations, some of which are divided into members, all bounded by unconformities. Mappable lithostratigraphical formations (informal) are identified within the allostratigraphical framework and Baltic Sea stages as well as the general Baltic Sea shore-level changes are correlated with the established allostratigraphy.

6.2.1 Unit IV Glacial deposits

The glacial deposits drape the pre-Quaternary irregular surface. Unit IV is usually 10–20m thick, but in the Christiansø Ridge zone, crystalline basement rocks are sometimes found at the seabed, whereas the unit is more than 50m thick in the strike-slip fault basins. The upper reflector is an irregular unconformity, and the internal configuration is mostly chaotic except in some of the strike-slip fault basins, where internal unconformities exist. The glacial deposits consist of diamicton and glacial outwash sediments, as documented in the IODP 347 sites (Figure 6.6) and Andrén (2014).

The distribution of glacial sediment facies is in general chaotic with alternating sections of clast-rich muddy diamicton and parallel-bedded, medium grained sand with cm- to dm-scale laminated silt and clay interbeds as seen in IODP site 66. However, IODP site 65 is located in a strike-slip fault basin, where there is a clear subdivision into a lower diamicton member (IVb) and an upper outwash member (IIIa), separated by an unconformity.



Figure 6.6 Seismic line across Site M0065 (Jensen et al. 2017). Original interpretation of the seismic transect: Airgun data (A) and Atlas parasound data (B) (Andrén 2014), as well as sediment documentation for sites 65 and 66. The interpretation (C) follows the classification in seismic units described in Figure 6.5. The location of the IODP sites are shown in Figure 6.4.

6.2.2 Unit III Late glacial glaciolacustrine deposits

The glaciolacustrine sediments cover the irregular unconformity of the glacial deposits in the Bornholm Basin, except in the topographically high Christiansø Ridge area, where Unit IV is truncated or absent, indicating erosion. In the basin areas, a strong upper reflector marks the top of the glaciolacustrine deposits, which in general drape the underlying topography with a thickness of 10–20m. An increased thickness of more than 50m is found in the minor strike slip fault basins (Figure 6.6). The internal reflection configuration also varies through the basin.

Unit III is divided into three subunits:

• IIIc is the lowest unit characterized by greyish brown clay with weak lamination by colour and few silt laminae in mm scale, large intervals dominated by massive to contorted appearance; numerous interspersed, grey clay/silt intraclasts of mm to cm scale, very well sorted.

Unit IIIc corresponds to Baltic Ice Lake sediments deposited in front of the retreating Weichselian glacier and represents an early stable phase of the glaciolacustrine environment. The parallel reflectors and rhythmically layered clay, seen all over the Bornholm Basin, are interpreted as varved glaciolacustrine clay. The upward decrease in grain size from silty clay to clay and the decreasing frequency of sand laminations indicate that the ice front became more and more distal to the Bornholm Basin.

- IIIb is the middle unit and consists of dark grey, homogenous clay. It is a basin-wide intermediate zone consisting of homogeneous clay that can be related to the first Baltic Ice Lake drainage that occurred during the late Allerød (Figure 6.7). This drainage led to a 10m drop in water level and to the formation of unconformities in the shallow parts of the southwestern Baltic Sea (Jensen et al. 1997; Bennike & Jensen 1998, 2013; Uscinowicz 2006). The relatively deep Bornholm Basin was covered by water even after this drainage event and the unconformity seen in shallow areas is replaced by a basin-correlative conformity. However, the water level drop in the Bornholm Basin is reflected in the changes in internal reflector configurations and the lithological shift to homogeneous clay.
- Illa is the upper unit and consists of greyish brown, silty clay with parallel lamination, downwards coarsening to fine- to medium-grained sand with laminated silt; lowermost few metres massive, medium-grained sand with few dispersed pebbles and detrital carbonate in all grain sizes up to fine gravel. The indistinct lamination in formation Illa, combined with homogeneous and contorted sedimentary structures, as well as clay intraclasts, may indicate slumping in an unstable sloping environment with high sedimentation rates. This could be due to piano key neotectonics (Eyles & McCabe 1989) that led to reactivation of minor, along-basin, strike-slip faults.

The sediments in unit III are barren of diatoms, foraminifers or ostracods and the depositional environment is interpreted as a glacio-lacustrine environment. The sandy sediments in the lowermost part of the retrieved succession represents a proximal glaciolacustrine environment.



Figure 6.7 Examples of lithostratigraphic units, Hole M0065A. A. Unit I. B. Unit I. C. Unit II. D. Subunit IIIc. E. Subunit IIIb. F. Subunit IIIa.

6.2.3 Unit II Early postglacial transition clay

Unit II conformably drapes the glaciolacustrine sediments in the Bornholm Basin with a rather constant thickness of about 4m. The seismic characteristics of Unit II are closely spaced parallel reflectors with upward decreasing amplitude. A strong reflector is seen at the upper boundary. In the minor strike-slip fault basins, local thickening of the unit, on-lapping and erosional truncation is observed. This is probably due to synsedimentary down-faulting of the basins and relative uplift of the margin (Figure 6.6).

At IODP site 65, which is in one of the minor strike-slip fault basins, Unit II is 4m thick and consists of grey to dark grey clay. In the lowermost part (formation IIb) homogeneous brown clay is observed, gradually changing upwards to grey clay with intervals of black spots and specks. The uppermost part of the clay (formation IIa) is laminated by colour with very fine dark grey iron sulphide-rich, 2–3mm thick lamina. The density of laminae decreases downwards. The basin-wide clay drape indicates accumulation of Unit II in a deep-water basin with only weak bottom currents. Previous studies in the Bornholm Basin (Kögler & Larsen 1979; Andrén et al. 2000) documented the same lithological sequence. It has been interpreted to represent deposition in the Yoldia Sea (the lowermost homogeneous part) and Ancylus Lake clay (AY) deposition (the uppermost laminated part). Sulphide migration downwards from the upper organic-rich sediments is a likely explanation for the diagenetic iron sulphide enhanced laminations.

6.2.4 Unit I Mid- and late postglacial marine mud

In the central Bornholm Basin, northeast of the Christiansø Ridge, the basin infill of the youngest Unit I have an asymmetrical external wedge shape and the sediment echo-sounder data show complex internal reflection patterns (Figure 6.6). Frequent low amplitude, concave and internal on-lap parallel reflectors dominate the major synsedimentary down-faulting zone. In the minor strike-slip fault basins, we established three allostratigraphical members (Ic, Ib and Ia; Figure 6.5). These members show asymmetrical bundled on-lap infill of the basins and the bundles are bounded by reflectors representing internal unconformities and correlative conformities.

The complex reflection pattern indicates that late postglacial down-faulting resulted in episodic, synsedimentary deposition in the strike-slip basins and that sub-recent to recent sedimentation is still asymmetrical with sedimentation in the southern central basin and erosion at the north-eastern margin of the basin. Transport of sediments from the Arkona Basin west of Bornholm into the Bornholm Basin and along the southern basin margin is a likely process for the observed deposition of sediments as a wedge-shaped contourite.

At IODP site 65, Unit I is ~7m thick (Figure 6.6). The unit consists of well-sorted, dark greenish grey, organic-rich clay with indistinct colour lamination due to moderate bioturbation. The general stratification is overprinted by intervals of black layers with sharp bases. Scattered shell fragments are found down to the lowermost transition zone to Unit II, where about 10cm of non-bioturbated clay with prominent mm-thick laminae is found. Organic debris is common (possibly algal or plant debris) and large centric diatoms are found. Some silt and sand are also present. The boundary to Unit I is gradual. The organic-rich clay, with bioturbated indistinct lamination and intervals of black layers, indicates more oxic conditions during the midand late Holocene in the Bornholm Basin than in the central Gotland Basin. The lowermost laminated transition zone may represent an initial anoxic phase, similar to the anoxic phases reported in the Gotland Deep (e.g., Zillen et al. 2008).

6.3 The Arkona Basin geological background information

The Arkona Basin region is mainly situated in German and Swedish Exclusive Economic Zones (EEZ), and only very limited information is available from the GEUS archives.

From the Baltic Pipe project we use information about the Bornholm Wind Farm 1 and 2 (GEUS 2021 b) as well as longer stretches along the planned cable transects (GEUS 2021 a) including the Sweedish zone (transects B and C). The available information includes side scan, sediment echosounder and boomer data reported in Rambøll (2020).

In addition, we have included archive seismic data from Stockholms University (Tom Floden) used for general mapping in the Arkona Basin by Lemke (1998) and scientific papers (Moros et al. 2002, Mathys et al. 2005).

6.3.1 Arkona Basin stratigraphy

The Arkona Basin sediment stratigraphy is presented in Moros et al. (2002) and Mathys et al. (2005). Comparing Figure 6.8 and Figure 6.10 with the stratigraphical subdivision of the

Lithostratigr. units of Arkona Basin sediments	Biostratigraphy (core 202170)	Stages of the Baltic Sea´s history	Ages in cal. ka BP (Biörck, pers. comm.)
scaments	Diatoms with brackish wate and freshwater taxa	er Post-Littorina	
F	Diatoms with marine and brackish water taxa	Littorina	
***** Sef	marine foraminifera	Littorina Transgres	sion 6.475±50
ES de	freshwater fossils	Ancylus Lake II	10.2
D D	(Cladocera)	Ancylus Lake I	ston 10.2
C Sbc	barren of fossils	Yoldia Sea	sion 10.6
B Sch	1	Yoldia Lake Billingen-2 drain	11.6
AII		Baltic Ice Lake II	
alin ilin kacanganan kanan	\bigvee	Billingen-1 drain	nage ****** 12.8
AI	barren of fossils	Baltic Ice Lake I	

Bornholm Basin (Jensen et al. 2017), the same units are observed representing the Baltic Ice Lake and younger sediments with similar characteristics.

Figure 6.8 Link between the lithostratigraphic units, the sandy layers, biostratigraphic information observed in Arkona Basin sediments and the known stages of the Baltic Sea's history



Figure 6.9 Lithological logs from profile P21 (Figure 6.10).



Figure 6.10 (a) Original seismic profile 21 with indication of an acoustic turbidity zone; (b) Seismostratigraphic interpretation of profile 21, SF = seafloor from Mathys et al. (2005). Location see Figure 6.4.

6.3.2 Arkona Basin sediments

The well-established stratigraphy for the Arkona Basin was used by Lemke (1998) in a substantial monograph about the late- and postglacial development of the western Baltic Sea region. The study is based on airgun data acquired by Tom Floden (University of Stockholm), supplemented by sediment echosounder data and 6m vibrocores.

The till surface of the basin is the oldest unit exposed at the seabed, with a patchy appearance in the marginal north-western part of the Basin (Figure 7.1). The till surface topography has a maximum depth of 75m below present sea-level (bsl.) in the central part of the basin, while the EEZ transect in the northern margin has a maximum depth to the till surface of 55m bsl., shallowing up to about 40m bsl. in the Kriegers Flak 2 South POWF area (Figure 6.11).



Figure 6.11 Till surface topography by Lemke (1998). Location of Kriegers Flak 2 South is shown with yellow dashed lines. The red dashed lines show the EEZ.

The till surface is covered by late glacial and Holocene clays and mud in the central parts of the Arkona Basin, changing to proximal sandy coastal deposits in the shallow western margin of the basin (Kriegers Flak 2 South POWF).

The combined mapped thickness of the late glacial clays (Figure 6.12) is up to 12m in the central and northernmost areas, while the thickness in the northern EEZ transition area is ranging from 10m in the east, to 0m in the west, with an average of about 4m.

Unfortunately, the thickness of proximal sandy coastal deposits in the shallow western margin of the Arkona Basin (Kriegers Flak 2 South POWF) has not been mapped in detail by Lemke (1998) (Figure 6.12), but a comparison of till surface topography (Figure 6.11) and late glacial surface topography (Figure 6.13) shows a thickness of up to 30m. Detailed information about Kriegers Flak 2 South POWF area follows in chapter 9.2.



Figure 6.12 Thickness of late glacial clays by Lemke (1998). Location of Kriegers Flak 2 South POWF is shown with black dashed lines. The red dashed lines show the EEZ.



Figure 6.13 Late glacial surface topography by Lemke (1998). Location of Kriegers Flak 2 South POWF is shown with yellow dashed lines. The red dashed lines show the EEZ.

Mapping of the Holocene mud distribution (Figure 6.14) show that an up to 10m thick mud unit is deposited in the central part of the Arkona Basin. In the Kriegers Flak 2 South POWF area the thickness of Holocene mud is between 0 and 2m in the easternmost part, while a thin sandy layer is expected in the westernmost part.



Figure 6.14 Thickness of Holocene mud by Lemke (1998). Location of Kriegers Flak 2 South POWF is shown with black dashed lines. The red dashed lines show the EEZ.

6.4 Fakse Bay geological background information

In the Fakse Bay the seabed shows evidence of both the rise of the Baltic Ice Lake and the transgression of the Littorina Sea. As the Baltic Ice Lake reached its highest water level at about 11500 years BP, the coastline of Fakse Bay was found at a level about 13 metre lower than today.



Figure 6.15 Presentation of the geological development of Fakse Bay from Jensen and Nielsen (1998). A: Barrier – lagoon system which was formed by the Baltic Ice Lake around 13000 years BP. B: The persisting rise of the lake level resulted in a westward migration of the barrier – lagoon system and reached its maximum about 11500 years BP at a level 13m below present sea level. C: With the drainage of the ice lake the Fakse Bay became dry land at about 11200 years BP. D: The transgression of the Littorina Sea caused a drowning of the former coast lines and a new spit system was formed about 6500 years BP

Later, a lake was again formed in the Baltic basin: the 'Ancylus Lake'. The Ancylus lake lasted from 10600 to 8400 years BP, which coincides with the 'Continental Period', when sea level was still low. The following rise of the global sea level resulted in a renewed inflow of marine waters in the Baltic basin, this time through the Danish Belt Sea, and the 'Littorina Sea' was formed.

The moraine cliffs along the Baltic Ice Lake were exposed to erosion. Clay and silt were transported into deeper waters, whereas sand, fine gravel and coarse gravel primarily contributed to the formation of beach deposits. In the following time a coastal barrier system developed, which resulted in the damming of a local lake (Figure 6.15 and Figure 6.16 A). After lowering of the water level in course of the Yoldia Sea period (11200-10600 years BP), parts of the local sea became dry land. As the Littorina Sea (Stone Age Sea) had reached the older coastal formations from the Baltic Ice Lake period, the coastal processes were reactivated and continued to further develop the old barrier system. Later this system was

inundated. Leeward of the elevated moraine cliffs, a system of spits developed, which likewise were gradually inundated (Figure 6.15 and Figure 6.16 B). Today this fascinating puzzle of drowned coastlines and lagoon sediments still exist on the seafloor.



Figure 6.16 Palaeogeographic maps from Jensen and Nielsen (1998), which shows (A) the barrier island and lagoon system during the high stand of the Baltic Ice Lake and (B) The spit system formed when the sea level of the Littorina Sea was approximately 10m lower than present time.

The Fakse Bay fossil barrier lagoon system is preserved at the seabed (Figure 7.1) in the western and central part of the bay, while the Kriegers Flak 2 North POWF area is in an intermediate till zone, exposed to erosion or bypassing of clay and silt, that was transported into the deeper Arkona Basin and deposited as the Baltic Icelake Clay.

7. South - Western Baltic Sea surface sediments

A surface sediment map has been compiled by a combination of Emodnet seabed substrate 1:1M (<u>https://www.emodnet-geology.eu/data-products/seabed-substrates</u>) from the German and Swedish zones and the latest version (2020) of the Danish 1:100.000 seabed substrate map (Figure 7.1).

In the Arkona Basin, the upper seabed consists of a thin layer of Holocene mud and Baltic Ice Lake Clay, turning into patchy till and Baltic Ice Lake clay in the westernmost zone north of Kriegers Flak.

In the Danish outer Fakse Bay and in the Kriegers Flak 2 North POWF, Upper Cretaceous chalk or Danian limestone is covered by a few metres of till and thin patchy metre scale layers of postglacial freshwater- and marine clays, sand, and mud.

Southeast of Møn, Upper Cretaceous chalk is covered by a few metres of till with basin infill of late glacial sands, silt and clay, followed by patchy thin layers of Holocene metre scale layers of Postglacial freshwater- and marine clays, sand, and mud.

The Kriegers Flak 2 South POWF is dominated by late glacial sand with thin Holocene top layers.



Figure 7.1 Seabed substrate map from Kriegers Flak North and South POWF areas base on a combination of Emodnet 1:1M and Danish 1:100.000 2020 version. POWF areas black- and EEZ red dashed lines.

8. Dynamic late glacial and Holocene shoreline history

After the last deglaciation, the south-western Baltic Sea region was characterised by highly fluctuating water levels (Figure 8.1). Transgressions were interrupted by two abrupt forced regressions, the first at c. 12800 years BP and the second at c. 11700 years BP. Prior to these regressions, the Baltic Ice Lake was dammed by glacier ice in south-central Sweden. In the Kriegers Flak South POWF and Rønne Banke region, the water level reached a maximum around 20m below present sea level during the Baltic Ice Lake stages (Figure 8.1). After the retreat of the Scandinavian Ice Sheet, the dam was broken twice, and the water level dropped by 20-25 metres over a few years. In Early Holocene, during the Yoldia Sea Stage, water level reached a minimum at around 40-45m below present sea level. During this period there was a land bridge from Bornholm to the continent, which allowed red deers, aurochs and hunters to invade Bornholm. A horn-core of an aurochs found on the sea floor south-west of Bornholm dates to this period. From around 10800 to 10200 years BP the water level increased rapidly, and pine forests in the region were submerged. The rapid increase was followed by a short period with relatively stable water level at around 9000 years BP. Soon, the Water level continued to rise, and at c. 7000 years BP marine waters inundated the region, which mark the beginning of the Littorina Sea Stage. During the past 6000 years, the water level has increased a few metres only. The global eustatic sea level rise has surpassed the glacio-isostatic uplift of the region, and fossil shorelines and landscapes are now submerged.

In the Fakse Bay and Køge Bugt region, the water level reached a maximum around 13m below present sea level during the Baltic Ice Lake stages (Figure 8.2). The difference between the Rønne Banke region (and Kriegers Flak South POWF) and the Køge Bugt region (and Fakse Bay), as can be seen from (Figure 8.1), is caused by higher glacio-isostatic uplift in the Køge Bugt region than in the Rønne Banke region. According to the presented curve, the water level reached a minimum between 35 and 40m below present sea level. During this period, all of Køge Bugt was dry land.

The Kriegers Flak 2 North POWF area is located between Køge Bugt and Kriegers Flak 2 South POWF with intermediate relative water level changes.

The deeper parts of the Arkona Basin have been continuously submerged after the last deglaciation, but the shallow water areas in the Kriegers Flak 2 South POWF developed coastal barrier deposits (Figure 6.3 a and b) with dry land for long periods after the last deglaciation of the region.



Figure 8.1 Shoreline displacement curve for the Rønne Banke region south-west of Bornholm. The curve is based on radiocarbon dating of samples collected from vibrocores (Table 1).



Figure 8.2 Shoreline displacement curve for the Køge Bugt region. The curve is based on radiocarbon dating of samples collected from vibrocores (Table 1).
Selected radiocarbon ages from	n the cable route region
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Core/ site	N. lat. °	E. long.	Laboratory number	Material	Deprh (m)	Age (¹⁴C years BP) ¹	Cal. age (years BP) ²
Marine							
7250/26	54.821	12.523	AAR-2647	Mytilus edulis	26.3	7090±90	7530
282080	54.845	13.925	KIA-26266	Mytilus edulis	46.5	6675±35	7141
Lake deposits							
548021-1	55.64	12.292	Ua-57758	Salix polaris	15.81	12863±47	15373
200540	54.725	12.766	AAR-2637	B. nana, S. herbacea	27.7	12700±110	15132
520002	55.145	12.398	AAR-1313	Salix polaris	18.7	12440±150	14605
212860	54.248	14.74	AAR-4058	Salix sp.	21.0	12400±90	14530
258000	54.750	13.765	KIA-21680	Cladium	45.2	10980±55	12896
Køge Havn			Beta-488168	Terr plant	9.04	10480±40	12536
257910	54.786	14.59	AAR-8837	Phragmites	29.9	10120±90	11695
222810	54.457	15.156	KIA-9342	Scirpus, Pinus	35.9	9930±45	11337
222820	54.483	15.172	KIA-9343	Pinus, Betula Albae	36.1	9740±55	11177
526015-1	54.949	15.362	Ua-57754	Betula Albae	44.6	9581±59	10934
526030-4	55.135	14.641	Ua-57755	Lycopus, Ranunculus	35.3	9593±51	10938
222810	54.457	15.156	KIA-9341	Menyanthes, Phragmites	34.5	9365±50	10583
548021-1	55.64	12.292	AAR-29111	Cladium mariscus	12.92	9361±35	10577
5775/01	54.913	13.05	AAR-1923	Cladium	44.3	9360±90	10574
BP09 ext 11	54.946	14.744	Beta-560826	Populus	23.0	9240±30	10407
526189	54.806	14.5	Ua-4863	P. sylvestris, Betula	24.4	9230±85	10404
Køge Sønakke			K-5099	Homo sapiens	8.0	8250±85	9227
Køge Nordhavn	55.469	12.228	K-4779	Wood peat	7.5	8090±90	9007
RAM-05-09	54.942	14.754	Beta-560827	Cladium, Scirpus	19.6	8070±30	9002
258010	54.920	13.151	KIA-21682	Phragmites	46.3	7880±50	8522
Køge Havn	a sub-relative and		AAR-24741	Corylus, fish weir	8.7	7450±32	8267

¹ Radiocarbon ages are reported in conventional radiocarbon years BP (before present = 1950; Stuiver & Polach (1977)). ² Calibration to calendar years BP (median probability) is according to the INTCAL20 and MARINE20 data (Reimer *et al.* 2020).

Table 1 Selected radiocarbon ages from the cable route region.

9. Details from Kriegers Flak North and South POWF

In the following sections, detailed data will be presented from Kriegers Flak 2 North and South POWF, described on the basis of existing knowledge and profile sections modified from Baltic Pipe investigations (Rambøll 2020) and scientific surveys (Lemke 1998). The interpretations are based on boomer and sediment echosounder data as well as vibrocores.

The Kriegers Flak 2 POWF's are located north and south of the existing Kriegers Flak OWF. Kriegers Flak 2 North has a rather flat seabed with a gentle southward dip, ranging from 20 to 35m bsl. (Figure 9.1).

Kriegers Flak 2 South shows a shallow western seabed platform 15 - 20m bsl. interrupted by a central rather steep eastward sloop down to about 30m bsl., followed by a gentle eastward dipping seabed from 30 to about 45m bsl., in the easternmost part (Figure 9.1).



Figure 9.1 Bathymetric map of the Kriegers Flak 2 North and South POWF areas (yellow dashed lines). Kriegers Flak *OWF* (Purple dashed lines) *as well as EEZ* (*red dashed lines*) are indicated.

The surface sediment map (Figure 9.2) shows a north-western area dominated by till in the shallower part of the Kriegers Flak 2 North POWF, followed by muddy sand in the deeper south-eastern part of the POWF area.

In Kriegers Flak 2 South POWF the shallow western platform and the central eastward slope is represented by medium-fine sand at the seabed, gradually changing into muddy sand and sandy mud in the easternmost part of the POWF area.



Figure 9.2 Seabed sediment map from the Kriegers Flak 2 North and South POWF areas (black dashed lines) based on a combination of Emodnet 1:1M and Danish 1:100.000 2020 version. Kriegers Flak OWF (purple dashed lines) as well as EEZ (red dashed lines) are indicated. For details, see Appendix B.

9.1 Kriegers Flak 2 North geology

A combination of the sediment distribution map (Figure 9.2) together with 3 profiles from the Baltic Pipe studies, profiles E - F, G - H and N - M (Figure 9.4, Figure 9.5 and Figure 9.6) and a few vibrocore logs (Figure 9.6) gives a general indication of the expected seabed geology in the Kriegers Flak 2 North POWF area.

9.1.1 Baltic Pipe profile E – F

The profile has a west-northwest – east-southeast orientation crossing the southernmost part of Kriegers Flak 2 North (Figure 9.3). The Profile shows that the deepest easternmost part from 35m bsl. to the westernmost part about 25m bsl., has up to 10m till covered by about 5m Baltic Ice Lake clay (highest level of Baltic Ice Lake clay about 30m bsl.) and a top unit of 2 - 4m Holocene muddy sand.

The till unit thins to the west to be a few metres thick on top of Danien limestone. Till with boulders is observed around 25m bsl., with a patchy coverage of a few metres of Holocene sands and muddy sands.



Figure 9.3 Upper figure: Surface sediments in the outer Fakse Bay region. Location of Baltic Pipe profile section *E* - *F* is indicated. Lower figure: Interpretation of Baltic Pipe seismic profile *E* - *F* with indication of Kriegers Flak 2 North crossing. For details, see Appendix C.

9.1.2 Baltic Pipe profile G – H

The orientation is northwest – southeast, and the profile is crossing the central part of Kriegers Flak 2 North (Figure 9.4). It confirms the general picture from the description of profile E – F (Figure 9.3) and documents that in general the seabed consist of a few metres of Holocene sand and muddy sand on top of a few metres of late glacial clay and till overlying sedimentary bedrock consisting of Danien limestone.



Figure 9.4 Upper figure: Surface sediments in the outer Fakse Bay region. Location of Baltic Pipe profile section G - H is indicated. Lower figure: Interpretation of Baltic Pipe seismic profile G - H with indication of Kriegers Flak 2 North crossing. For details, see Appendix D.

9.1.3 Baltic Pipe profile N – M

The profile has a north – south orientation, just west of Kriegers Flak 2 North (Figure 9.5). The Bedrock is very close to the seabed, with only a few metres of variations of till, late glacial clay, Holocene freshwater sediments, sandy mud and muddy sand on top of it.

Consultation with the bedrock map in Figure 5.2 shows that the bedrock below the thinskinned quaternary sediments along profile N - M consists of Upper Cretaceous chalk.



Figure 9.5 Upper figure: Surface sediments in the outer Fakse Bay region. Location of Baltic Pipe profile section N - M is indicated. Lower figure: Interpretation of Baltic Pipe seismic profile N - M with indication of Kriegers Flak 2 North crossing. For details, see Appendix E.

9.1.4 Vibrocore logs from Krieger Flak 2 North POWF

The profiles presented above (E - F, G - H and N – M), are Baltic Pipe boomer survey lines and the seismic interpretations shown in Figure 9.3, Figure 9.4 and Figure 9.5 has been documented by vibrocores located along the lines, with lithological descriptions similar to Figure 9.6 representing profile N – M.



Figure 9.6 Vibrocore logs along profile N – M crossing Kriegers Flak 2 North POWF.

9.2 Existing Kriegers Flak Windfarm

As background for establishment of the existing Kriegers Flak OWF a detailed seismic grid was acquired (Rambøll 2013) followed by 17 geotechnical boreholes including CPT's (GEO 2013). The boreholes were drilled to the target depth between 70 m 50 m below seabed.

The OWF pre-investigation area encompasses the Danish part of the Kriegers Flak bank. Water depths across the Kriegers Flak pre-investigation area vary approximately between 15 m to 30 m (Figure 9.7).

The Kriegers Flak OWF is composed of a rather complex sequence of glacial deposits, as well as Lateglacial and Postglacial deposits, all overlying the Cretaceous Limestone.

The Postglacial and Lateglacial deposits consist of sand and clay and are in general less than 4 metres thick. The deposits are generally loose/soft and have locally organic content (gyttja).

The glacial deposits mainly consist of stiff to very stiff clay till or dense to very dense sand till and vary in thickness approximately between 20 m to 40 m. The till is generally intersected by meltwater layers/lenses of clay and sand.

The Cretaceous Limestone is found in all boreholes except borehole KF-BH006 (glacial deposits not penetrated). The Prequaternary bedrock is made of Maastrictian Limestone deposited during the Late Cretaceous period. This deposit occurs very widespread in NW-Europe, in the Kriegers Flak area mainly as a muddy, white limestone with many nodules and thin layers of dark grey/black flint. The upper part of the limestone is locally showing evidence of glacial deformation.



Figure 9.7 Bathymetry and borehole locations Kriegers Flak OWF. Red stippled line combines boreholes KF–BH002, KF-BH004, KF-BH011 and KF-BH015 and shows location of geological profile in Figure 9.9. For regional bathymetry see Figure 3.1

9.2.1 Details on soil types

Detailed sidescan and shallow seismic studies of the Kriegers Flak Bank (Rambøll 2013) combined with surface samples and borings (GEO 2013) show that the seabed surface sediments, with only few minor exceptions, consist of postglacial sand and gravel, as well as glacial clay with stones exposed at the seabed (Figure 9.8).

On top of a rather uniform Upper Cretaceous limestone, the glacial deposits form the core of Kriegers Flak Bank while late- and postglacial clays and sands onlaps the flanks and a central depression. The general geology, soil types and geotechnical characteristics is presented in a west-east profile (Figure 9.9) combined with selected boreholes (KF-BH002, KF-BH004, KF-BH011 and KF-BH015) (Appendix N) and a table with geotechnical results (Tabel 2).

9.2.1.1 Postglacial marine sand

The top unit of marine sand and gravel has been deposited during the Postglacial transgression.

The top unit mainly consists of non-graded sand deposited during the Postglacial. In large parts of the central part, it occurs in thicknesses less than 1 m, while in the outermost boreholes and in a central bank the thickness is 1.3 - 4.5 m (KF-BH002 Appendix N).



Figure 9.8 Surface sediment and borehole locations Kriegers Flak OWF. Red stippled line combines boreholes KF–BH002, KF-BH004, KF-BH011 and KF-BH015 and shows location of geological profile in Figure 9.9. For regional seabed sediment map see Figure 7.1



Figure 9.9 Geological west – east profile with location of boreholes KF–BH002, KF-BH004, KF-BH011 and KF-BH015. Location of profile see Figure 9.7 and Figure 9.8

9.2.1.2 Glaciolacustrine freshwater deposits

In Lateglacial time thinly laminated freshwater clay was deposited in the Baltic Ice Lake basin and sand in the coastal zone.

In borehole KF-BH011 (Appendix N) there have been observed medium sand on top of glaciolacustrine clays (Tabel 2) which are rich in silt and fine sand laminae or streaks. These laminated clays have been deposited on top of siltier Lateglacial meltwater deposits and clay tills and are interpreted as varve deposits in the Baltic Ice Lake.

9.2.1.3 Meltwater clay, silt and sand

These units have been deposited in ice-free environments during the melting of the glacier responsible for Prior tills.

The Upper and Lower till units both includes meters of medium plasticity meltwater clay, and sand probably deposited during the melting of an earlier glacial advance. The Lower Till is covered by varying thicknesses of medium to high plasticity clay or poorly graded sand. The clay often contains varve-like, thin silt and sand laminae, pointing to a meltwater or glaciola-custrine origin (Appendix N).

9.2.1.4 Upper Glacial unit (mostly Till)

The Upper Till has been deposited during an Upper Weichselian glacial advance.

The Upper Till is very similar to the Lower Till. The boundary between the upper and Lower Till has introductory been assessed based on water contents and/or strengths measured by the pocket penetrometer; see borehole KF-BH004, KF-BH011, KF-BH015. The water contents of the Upper Till are in most of the mentioned boreholes higher than the water contents of the Lower Till. An inverse pattern has been registered in the strengths measured by the pocket penetrometer, indicating lowest strengths in the Upper Till (Tabel 2). A rough indication of the boundary between the Upper Till and Lower Till has been made in Figure 9.9. In most of the area this unit has been intersected by several meltwater layers or lenses with thicknesses between 0.1 m and 15.1 m.

9.2.1.5 Lower Glacial unit (mostlyTill)

The Lower Till unit has probably been deposited during a Middle Weichselian glacial advance. The top of this unit appears to be quite planar, occurring at levels around -35 m to - 45 m over most of the area.

All boreholes in the area have penetrated this often silty or medium plastic clay till that locally shows inclined limestone layers and smears. In most of the boreholes the pocket penetrometer indicates high or maximum values of undrained shear strengths (Tabel 2). In all boreholes the Lower till is resting directly on top of the limestone.

9.2.1.6 Limestone

Prequaternary rock composed of muddy, white limestone with many dark grey/black flint nodules and thin layers. Locally the upper part shows evidence of glacial deformation.

In the entire area the Prequaternary rock is made of Maastrictian Limestone deposited during the Late Cretaceous period. This deposit occurs very widespread in NW-Europe, in the Kriegers Flak area it appears mainly as a muddy, white limestone with many dark grey/black flint nodules and thin layers. The upper part of the limestone is locally showing evidence of glacial deformation. This unit has been found in the bottom of all boreholes.

9.2.1.7 geotechnical characteristics

Laboratory classification tests and advanced tests have been listed and related to the corresponding geological soil unit to present the geotechnical parameter variation (Tabel 2). Based on this typical values, ranges of the geotechnical parameters have been identified and tabulated.

The values presented cover all encountered soil units including post- and late Glacial units as well as Glacial and Cretaceous units.

Parameter	Unit	Marine and Glacio-la- custrine sand	Glacio- la- custrine freshwater clay and silt	Upper till	Melt- water clay	Lower till	Lime- stone
Water content (w)	%	10-81	22-82	7-26	18-57	7-32	19-37
Bulk density (γm)	Mg/m ³	1.7-2.1	NA	2.1-2.7	1.7-2.0	2.1-2.6	1.6- 2.1
Medium grain size (d_{50})	mm	0.178-0.6	0.002	0.002- 0.364	0.002	0.007- 0.128	NA
Uniformity coef. (U)	-	1.6-3.9	NA	2.2- 64.4	NA	NA	NA
Dry density (Max/Min)	Mg/m ³	1.45/2.0	NA	NA	NA	NA	NA
Clay fraction (<0.002 mm)	%	NA	49-63	6-38	46	12-36	NA
Plasticity index (Ip)	%	NA	22-37	6-25	12-36	6-21	NA
Carbonate cont. (Ca)	%	0.8-8	7-23	1-22	13	2-26	NA
Undrained Shear Strength (C_u)	kPa	15	NA	47-620	19-56	137-1235	50- 2046
Friction Angle (ϕ')	De- gree	37	NA	NA	NA	NA	NA
Unconfined Compression Strength (σ_c)	kPa	NA	NA	NA	NA	NA	99- 4091

Tabel 2 Geotechnical results

It shall be noted that the boundary between the upper and Lower Till is not clearly defined in all boreholes. The boundary in each borehole has been established based on geological description, index tests and CPT results. Due to the above uncertainty in the boundary the geotechnical classification of these two "formations" are therefore subject to uncertainties.

The form of presentation is not a statistical work up of all data for the individual parameters leading to determination of characteristic design values for each soil type. The presentation of data is prepared as guide to get a quick overview of the geotechnical parameter variation for each geological soil type to be used only for initial engineering purposes.

9.3 Kriegers Flak 2 South POWF geology

The previous sections describing the general geology of the southwestern Baltic Sea and the Arkona Basin have revealed, that the Kriegers Flak 2 South POWF is located at the margin of the Arkona Basin (Lemke 1998). The bedrock geology is represented by Upper Cretaceous chalk and the glacial till deposits are dominated by ice margin readvance marginal ridges following the general deglaciation pattern.

The till surface topography has a maximum depth of 75m below present sea-level (bsl.) in the central part of the Arkona Basin, shallowing up to about 40m bsl. in the Kriegers Flak 2 South POWF area (Figure 6.11).

The till surface is covered by late glacial and Holocene clays and mud in the central parts of the Arkona Basin, changing to proximal sandy coastal deposits (Jensen et al. 1997) in the shallow western margin of the Arkona Basin, i.e. in the Kriegers Flak 2 South POWF area.

Unfortunately, the thickness of proximal sandy coastal deposits in the Kriegers Flak 2 South POWF area has not been mapped in detail by Lemke (1998) (Figure 6.12), but a comparison of till surface topography (Figure 6.11) and late glacial surface topography (Figure 6.13) shows a thickness of up to 30m. Detailed information about the Kriegers Flak 2 South POWF area, is provided in the following and illustrated by a set of seismic profiles and vibrocore data (see Figure 9.10 for locations).



Figure 9.10 Kriegers Flak 2 South POWF (dashed black lines) surface sediment map with location of seismic profiles (pink dashed lines) and vibrocores (red dots). The red dashed lines show the EEZ.

9.3.1 Baltic Pipe profile O – P

Baltic Pipe sparker profile O – P (Figure 9.10) is located just east of Kriegers Flak 2 South POWF, in the marginal area of the Arkona Basin. The seismic profile in Figure 9.12, combined with a few vibrocores (Figure 9.11) document that the bedrock consists of Upper Cretaceous chalk found at a level of 50 - 65m bsl. A thin till unit covers the bedrock with a thickness between 0 and 5m and is followed by Baltic Ice Lake clay in a lower and an upper unit, with a combined thickness of between 5 and 10m. Then follows an early Holocene, freshwater transition, organic clay – silt, 0 - 2m thick covered by an uppermost unit of marine Holocene sandy mud to muddy sand, 3 - 4m thick.



Figure 9.11 Vibrocore logs along Baltic Pipe profile O – P. See Figure 9.9 for legend.

The geological succession along the Baltic Pipe profile O - P probably represents what can also be expected in the easternmost part of Kriegers Flak 2 South POWF.



Figure 9.12 Baltic Pipe sparker profile O - P (upper figure) and geological interpretation (lower figure). Vibrocore positions are marked with red lines. For location, see Figure 9.10. For details, see Appendix F.

9.3.2 Seismic lines crossing Kriegers Flak 2 South POWF

A series of archive boomer and airgun seismic lines crosses the Krigers Flak 2 South POWF area. These data have been collected for scientific purposes and has been reported in Jensen et al. (1997) and Lemke (1998). The main conclusion is that the till surface was covered by an up to 35m thick wedge of late glacial proximal sandy coastal beach barrier deposits, that developed between Møn and Rügen in connection with two late glacial Baltic Ice Lake high stand periods, interrupted by two abrupt forced regressions; The first at c. 12800 years BP and the second at c. 11700 years BP (Figure 8.1 and Figure 8.2). The high stands reached a level of about 20m bsl. with progradation from west into the Arkona Basin on top of clay sediments in the basin. The prograding units represent the present eastward dipping seabed slope into Arkona Basin.

The combination of Boomer and airgun seismic lines gives good general information of the deeper till and bedrock units (airgun lines 231 (Figure 9.14), 241 (Figure 9.17) and 211 (Figure 9.19)) as well as more detailed information of the late glacial and Holocene deposits (Boomer lines 232 (Figure 9.13), 242 (Figure 9.15), 252 (Figure 9.18) and 222 (Figure 9.20)).

The surface of the Upper Cretaceous chalk is dipping to the south and east from about 20m bsl. north and west of Kriegers Flak 2 South POWF to between 30 and 55m bsl. in the POWF area. The bedrock is covered by till ranging in thickness from a few metres to more than 15m, due to the development of ice marginal ridges (airgun lines 231 (Figure 9.14), 241 (Figure 9.17) and 211 (Figure 9.19)).

The late glacial Baltic Ice Lake deposits follows the general pattern in the southwestern part of the Baltic Sea, as described in section 6.1 and 6.2, but the lower and upper glaciolacustrine deposits changes facies from clay deposits in the Arkona basin (Figure 9.11 and Figure 9.16) to fine to medium sand coastal sediments, deposited in a wedge structure, on the margin of the Arkona Basin (Boomer line 252, Figure 9.18).

Only a very few vibrocores have been taken and they consist of fine to medium late glacial sand on the wedge and glaciolacustrine clay at the foot of the wedge, but they only penetrate maximum 6m into the uppermost part of the late glacial deposits. The seismic lines indicate that the late glacial wedge deposits reaches a maximum thickness of up to 35m (Seismic line 252, Figure 9.18) south of Kriegers Flak 2 South POWF, with an internal reflection pattern indicating prograding sandy costal deposits (about 25m thick) above basin clay (about 10m thick).

In the Kriegers Flak 2 South POWF area (seismic profiles 231 (Figure 9.14), 242 (Figure 9.15), 211 (Figure 9.19) and 222 (Figure 9.20)), the late glacial deposits mainly include the upper prograding sandy costal deposits (about 25m thick) on top of Till as seen from the internal reflection pattern.

Early Holocene, freshwater, fine-grained, organic rich sediments (0 - 3m thickness) are located in the Arkona basin (Profile O – P, Figure 9.9) and inside the POWF at the foot of the prograding unit (seismic profiles 231 (Figure 9.14) and 242 (Figure 9.15)) as well as in depressions west of the POWF (seismic profiles 232 (Figure 9.10), 252 (Figure 9.18)).

The final Holocene transgression of the region resulted in erosion of the older sediments and redeposition of sand and muddy sand on top of the palaeo late glacial coastal deposits.

In the Kriegers Flak 2 South POWF area only about 1m of Holocene sand is located on top of late glacial sand, while depressions west of the POWF may hold up to 5m of Holocene sand.

Muddy sand and sandy mud represent subrecent to recent sedimentation in the Arkona Basin and the shallow waters close to Møn, with a typical thickness of 1 - 3m (seismic profiles 231 (Figure 9.15), 242 (Figure 9.15) and 252 (Figure 9.18)).



m b.s.l

Glacial

till

Upper

Cretaceous



Postglacial

transition

10 km

Upper Glacio-

lacustrine

Lower

Glaciolacustrine



Figure 9.14 Airgun profile 231 and geological interpretation. For location, see Figure 9.10. For details, see Appendix H.

Postglacial

marine mud

Postglacial

marine

Postglacial

marine sand





Figure 9.15 Boomer profile 242 and geological interpretation. For location, see Figure 9.10. For details, see Appendix I.



Figure 9.16 Vibrocore logs along Boomer profile 242, from Jensen et al. (1997).



Figure 9.17 Airgun profile 241 and geological interpretation. For location, see Figure 9.10. For details, see Appendix J.



Figure 9.18 Boomer profile 252 and geological interpretation. For location, see Figure 9.10. For details, see Appendix K.





Figure 9.19 Airgun profile 211 and geological interpretation. For location, see Figure 9.10. For details, see Appendix L.



Figure 9.20 Boomer profile 222 and geological interpretation. For location, see Figure 9.10. For details, see Appendix M.

10. Key geological conditions

The screening has revealed geological conditions and sediment characteristics that may have implications for the assessment of wind farm foundation conditions. The following key geological characteristics are shortly discussed here:

- Chalk bedrock
- High-lying over-consolidated glacial sediments
- Meltwater clay
- Marine dynamic sand deposits
- Soft silty marine clays and gyttja
- Peat layers
- •

With reference to Velenturf et al. (2021), some of the possible implications of these geological conditions are described below:

Soft sediments can imply a risk for low geotechnical strength and be a challenge for the foundation design. At the seabed, soft sediments can potentially be unable to bear large loads from e.g. a jack-up rig during construction.

Marine dynamic sand deposits may imply migrating erosional and depositional bedforms that can change the seabed topography over the operational lifetime of an OWF site in terms of scouring or burial of e.g. piles or cables.

Clay deposited in lakes in front of the retreating glacier has not been over consolidated and may be very soft, with similar challenges as younger soft sediments.

The old glacial deposits may represent over-consolidated and strong sediments, which generally can provide a difficulty during construction e.g. for driving piles. They may also comprise more specific hard, potentially heterogeneous, coarse lag deposits (gravel to boulders) that can be difficult to penetrate and may lead to refusal of foundation infrastructure or damage of equipment. Near the seabed, a hard, heterogeneous surface can make it more difficult predict scour behavior.

The chalk bedrock is characterised by varying degrees of weathering, leading to significant variation in properties ranging from those typical for stiff soil to soft rock.

In Table 10-1 an overview of sediment types met in the screening area and potential critical geotechnical conditions and general foundation suitability is given.

Table 10 -1

Sediment type	Critical geotechnical conditions/challenges	Foundation suitability
Marine sand	n.a.	Well suited
Marine clay/soft		
mud	Low geotechnical strength	Not well suited if thick
Peat	High compressibility, low geotechnical strength	Not well suited
	Low geotechnical strength if not overconsoli-	
Meltwater clay	dated	Not well suited if thick
	Overconsolidated and potentially heterogene-	
	ous. Can contain coarse lag deposits, boulder	
Moraine clay/till	stones and dislocated slabs of older sediments	Potentially problematic
	Provides a hard substrate for emplacement of	
	seabed infrastructure (e.g., drilled piles). How-	
	ever, may be weathered with lower strengths	
Chalk bedrock	at the interface with Quaternary sediments	Potentially problematic

Kriegers Flak 2 North POWF is a rather flat area, located in the outer Fakse Bay at water depths of 20 – 35m. The area is dominated by Danian limestone covered by a few metres of till, with boulders and patchy coverage of a few meters of Holocene sands and muddy sands. The sediment distribution indicates that the Quaternary sediment succession will be well suited for foundation, while the Danian limestone, if weathered, may be potentially problematic.

Kriegers Flak 2 South POWF has a seabed slope, from 45 to 20m bsl. and the Cretaceous limestone and till is covered by an up to 35m thick wedge of late glacial proximal coastal sands prograding south-eastward into the Arkona Basin over the basin clay.

The seabed slope must be considered, while the wedge sand in general is considered well suited for foundation. The easternmost slope foot however consists of more than 10m of soft late glacial clay and Holocene muddy sand to sandy mud, not well suited for foundation. Below the sand wedge complex few meters of till is followed by Cretaceous chalk. The till is well suited for foundation while the Cretaceous chalk, if weathered, may be problematic.

11. Archaeological interests

In addition to geotechnical interests in a conceptual geological model and detailed understanding of the geology of the Kriegers Flak 2 North and South POWF areas, it is also important for an archaeological screening to understand the development and distribution of land and lake/sea after the last deglaciation.

The initial period after the deglaciation was characterised by highstand water-level in the south-western Baltic Sea. The region was deglaciated around 16000 to 15000 years ago and major parts of the Kriegers Flak 2 North and South POWF were covered by the glaciolacus-trine Baltic Ice Lake. This corresponds to the archaeological Hamburg culture or Hamburgian (15500–13100 years BP) – a Late Upper Palaeolithic culture of reindeer hunters.

The highstand period was followed by an abrupt regression and development of an erosional unconformity at around 12800 years BP. During this lowstand period the water level was about 40m below present sea level and reed plants were growing in parts of the Arkona Basin. Major parts of the Kriegers Flak region would have been dry land during this lowstand. However, the low-stand period was short-lived and followed by a rapid transgression. A new low-stand period is dated to c. 11700 years BP, and this time the water level was c. 40–45m below present sea level and Bornholm was a peninsula connected to mainland Europe (Figure 10.1). Again the POWF would have been exposed, but this second low-stand period was also short-lived and soon followed a new fairly rapid transgression. The second low-stand period corresponds to the early part of the Maglemose Culture.



Figure 10.1 Late glacial and Holocene general palaeogeography in the Danish area and related archaeological cultures. The maps are from Jensen et al. (2003).

The shallow-water parts of the Kriegers Flak 2 North and South POWF have been dry land for long periods during the late glacial and Early Holocene. Submerged archaeological sites from the Maglemose, Kongemose and Ertebølle Cultures are for example known from Meck-lenburg Bay off northern Germany (Schmölcke et al. 2006; Hartz et al. 2011; Lübke et al. 2011), from Køge Bugt and near Amager. Submerged fishing constructions made of hazel rods and dated to 9000-8400 years BP have been reported from Hanö Bugt off Skåne (Hansson et al. 2018). Due to the fluctuating and dynamic shoreline history in the southern Baltic Basin, it is possible to find submerged landscapes and archaeological sites from throughout the Holocene, but we consider the early and mid-Mesolithic time to be the most likely for findings. The chances to find submerged archaeological sites are probably small in areas with a long fetch and high energy environment. The chances are higher along the east coast of Møn and Zealand, which is protected from the dominating westerly winds.

12. Conclusions

In this study we have used a combination of published work, archive seismic and sediment core data, to assess the general geological development of the south-western Baltic Sea region, including the Kriegers Flak 2 North and South POWF. Detailed information has been acquired from the GEUS Martha database, supplemented by a few lines from The Baltic Pipe offshore pipeline transect, which are passing through and close by the Kriegers Flak 2 North and South POWF as well as from scientific studies (Jensen et al. 1997). The seismic transects and vibrocorings from various sources has all been vital for the understanding of the area.

A geological description of the areas has been provided and a conceptual geological model for the development of the south-western Baltic Sea area has been presented.

A surface sediment map has been compiled by a combination of Emodnet seabed substrate map for the German and Swedish zones and the latest version (2020) of the Danish 1:100.000 seabed substrate map.

Information on the existing Kriegers Flak OWF has been presented including a geological model based on detailed seismic studies (Rambøll 2013) and boreholes (GEO 2013) The Kriegers Flak OWF is composed of a rather complex sequence of glacial deposits, as well as Lateglacial and Postglacial deposits, all overlying the Cretaceous Limestone.

The general geology, soil types and geotechnical characteristics is presented in a west-east profile (Figure 9.9) combined with selected boreholes (Appendix N) and a table with geotechnical results (Tabel 2).

The planned Kriegers Flak 2 North and south POWF will include Upper Cretaceous chalk and Danien limestone bedrock, followed by glacial and late glacial clays and sands. The western margin of the Arkona Basin is dominated by late glacial basin clays and proximal shallow costal platform sands, as well as Holocene sand and sandy mud, while outer Fakse Bay has a base of glacial till, with a thin patchy coverage of late glacial and Holocene sand and muddy sands.

As a result of the geological desk study, it has been possible to present a relative late glacial and Holocene sea-level curve for the area and to describe the development relevant for an archaeological screening.

Data are presented from the Kriegers Flak 2 North and South POWF areas, and the interpretations are described on the basis of existing knowledge and profile sections (Figure 9.3 to Figure 9.6) modified from the Baltic Pipe project investigations (Rambøll 2020) and scientific airgun and boomer seismic lines as well as vibrocores (Figure 9.10 to Figure 9.17).

Several focal points and recommendations are relevant for the future geotechnical and archaeological evaluation of the areas:

12.1 Focal Points and recommendations Kriegers Flak 2 North POWF

- Kriegers Flak 2 North POWF is a rather flat area, located in the outer Fakse Bay at water depths of 20 35m. The area is dominated by Danian limestone covered by a few metres of till, with boulders and patchy coverage of a few metres of Holocene sands and muddy sands.
- Despite few datapoints and no geotechnical evidence. It is concluded that the Kriegers Flak 2 North POWF flat seabed (20 35m bsl.), with thin skinned Holocene sediments on top of till and Danian limestone, will be an area where it is possible to establish a wind farm.
- The geological setting and water depths above 20m indicates no risk for archaeological interest.
- Only few seismic lines cross the area and few nearby vibrocores. We have no geotechnical data form the area. However, the succession of geological units indicates that the area is rather uniform in its geological setting.
- It is recommended do acquire an open grid of shallow seismic data and few vibrocores, combined with geotechnical investigation, as a low-cost pre-investigation, before next step of decisions and comprehensive studies.

12.2 Focal Points and recommendations Kriegers Flak 2 South POWF

- South of Møn, in the north-western margin of the Arkona Basin, the seabed slope shallows up westwards, from 45 to 20m bsl. and the Cretaceous limestone and till is covered by an up to 35m thick wedge of late glacial proximal coastal sands prograding south-eastwards into the basin over the basin clay.
- In the Kriegers Flak 2 South POWF area the late glacial deposits mainly include the upper wedge, indicating prograding sandy costal deposits (about 25m thick) on top of Till.
- Detailed studies of the existing Krigers Flak OWF show a similar seabed geology as Kriegers Flak 2 South POWF and offers boreholes as well as geotechnical properties of the individual geological units, that can be transferred to similar units in the Kriegers Flak 2 South POWF
- It is concluded that the Kriegers Flak 2 South POWF is probably geotechnical suited for wind turbine foundation.
 - 1. It should however be considered that the POWF includes a seabed slope in the eastern part of the area from 20m- to 45m bsl.
 - 2. A late glacial fine to medium grained sand wedge, with a thickness of up to 35m, covers till and Cretaceous chalk in the westernmost part of the area
 - 3. At the easternmost slope foot, more than 10m of late glacial clay and Holocene muddy sand to sandy mud, covers till and Cretaceous chalk.

- The chances to find submerged archaeological sites in the Kriegers Flak 2 South POWF is small due to water depths above 15 – 20m and lack of postglacial deposits.
- Only few seismic lines cross the area and few vibrocores with no geotechnical information.
- It is recommended do acquire an open grid of shallow seismic data and few vibrocores, combined with geotechnical investigation, as a low-cost pre-investigation, before next step of decisions and comprehensive studies.

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Appendix A: Bathymetry and location of Kriegers Flak 2 North and South POWF



Appendix B: Seabed sediments and location of Kriegers Flak 2 North and South POWF



Appendix C: Profile E - F
















Appendix H: Kriegers Flak 2 South Profile 231



Appendix I: Kriegers Flak 2 South Profile 242





Appendix J: Kriegers Flak 2 South Profile 241

10 km	





Glacial

Upper Cretaceous

Appendix K: Kriegers Flak 2 South Profile 252



Appendix L: Kriegers Flak 2 South Profile 211







Appendix N: Existing Kriegers Flak Boreholes KF-B002, KF-BH004, KF-BH011 and KF-BH015.

В	oreho	le:	KF-Bł	1002			Coc	ordinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum: V	NGS 84 UTM :	Zone 32 N - D	VR 90		♦ HS ▼ SPT(S) 20 40 60	SPT(C)	Carbonate	2 16 %	2 4 6 8 PCPT Tip Resistance (MPa)	
	Sample	•	Lab	specimen	Sea Leve -2	abed el (m): 1.8	Not	tes:		Core Runs and			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 2.0 MPa	* Loss on Igr 2 4 (w Moisture Co	nition 6 8 % ntent	 — 20 40 60 80 ● Point Load Strength I_{s 50} 0.1 0.2 0.3 0.4MP 	Other Tests
	ype		ype		Bou (I	ndary m)	/ 60	Gеоlоду			res	ation		Tor Vane Fall Cone	w _s Sat. Moistur w _P Plastic Limit w _L Liquid Limit	e Content	Relative Density (Mg/m ³) e_{min} e_{max}	tests tests sts Conductivit pple Shear
Drill tool	No. and t	Depth (m	No. and t	Depth	Depth	Elevation	Graphic L	Description of <i>layers</i> and details	Deposit Age	TCR (%) SCR (%) RQD (%	Fissu	Inpul	• mact 00	800 kPa	W _P W ↓ 10 20 3	w _s w _L · → - ∞ 40 %	■ Bulk Density (Mg/m ³) □ Dry 16 18 20 22	Grain size Chemical Cyclic Tes Cyclic Tes Uhermal C Direct Sim Direct Sim Direct Sim
Div rotary drilling	1-LB 2-B	- 0 - - - - - - - - - - - - - - - - - -	2.1D 1.1D 1.2D 1.3D 1.4D 1.5D 1.6D	0.00-1.50 0.20 0.60		22.2		SAND, medium, non graded, gravelly, w. shell fragments, light yellowish brown 0.15 becoming grey, w. plant remains 0.20 angularity: subrounded 0.60 w. 50 mm black peat layer	Ma Pg									
	3-LB 4-B	2				-23.3	$\frac{1}{1} \frac{1}{1} \frac{1}$	SAND, medium - coarse, non graded, gravelly, sl. calcareous, w. plant remains, grey	Ma Pg				2					
K		Ē	-4.1D	2.50	2.3	-24.1		CLAY, very silty, sl. gravelly, calcareous, grey	Mw Lg									
	5-1VV				3.0	-24.8	 	SAND, fine - medium, graded, sl. gravelly, calcareous, w. clay lumps, grey	Mw Lg									
		. 3	5.2D 5.3D 5.4D	3.10 3.20-3.35	•			CLAY, very silty, sl. sandy, calcareous, grey	Mw Lg									
	6-TW	-	5.5D 5.1U		3.6	-25.4 -25.6		SAND, fine - medium, poorly graded, sl. gravelly, calcareous, w. few clay lumps, brownish grey	Mw Lg GI Gc									
	7-TW		6.1D 6.2D 6.3D 6.4D 6.5U	4.10 4.25-4.50	-		- 	CLAY TILL, sandy, gravelly, sl. calcareous, brownish grey 3.75 - 3.95 silty 3.95 - 5.40 w. limestone grains					•					
	<u>_</u>	- 5	^{-7.1D} 7.2U	5.05 5.15-5.40			oʻl ¦ l` oʻl ¦ l` oʻl ¦	4.85 - 4.95 w. silty parts							•			•
μı		-		-				Borehole Log: KF-BH002		Drilled:	TBH	I/KHH		Date:	2013-06-01	Report N	No.: 1	
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Во	reho	le:	KF-BH	1002			Cor	ordinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum	: WGS 84 UTM	Zone 32 N - D	VR 90		♦ HS ▼ SPT(S) ▼	SPT(C)	Carbonate	2 16 %	– 2 4 6 8 PCPT Tip Resistance (MPa)	
S	Sample	•	Lab	specimen	S Le	eabeo vel (m -21.8	1 1):	Geology		Core Runs and - Core Quality			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa strength	* Loss on Igr 2 4 (w Moisture Co w _s Sat. Moisture	nition 6 8 % ntent e Content		Other Tests
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation (m)	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%) SCR (%) RQD (%)	Fissures	Induration	 △ Pocket Pen ▲ ● Lab Vane ◇ F ● Intact UU 5 200 400 600 	all Cone	W_P Plastic Limit W_L Liquid Limit W_P W H — $- \oplus$ 10 20 3	w _s w _∟ • ⇔− 60 40 %	e _{min} e _{max} <u>1.6</u> 1.7 <u>1.8</u> 1.9 ■ Bulk Density (Mg/m ³) □ Dry 1.6 1.8 2.0 2.2	Grain size distrib Chemical tests Cyclic Tests Thermal Conduc Direct Simple Sh Oedometer
rilling (continued)	8-TW	- 6	-8.1D 8.2U	6.10 6.25-6.55	6.* - - -	27	o; 	CLAY TILL, silty, sandy, gravelly, calcareous, brownish grey 6.10 w. 35x60 mm granite gravel	GI Gc				6	A	• • • • • • • • • • • • • • • • • • •			
Dry rotary o	9-TW	- 7	F 10 1D	7 70			o · o							······································				
	11-B	- 8	T 11 1D	8.50		3 -30		SAND, medium, non graded, sl. gravelly,	Mw Gc	-			8				8	
	12-LB ⁻	- - - - 9 - -	12.1D 12.2D 12.3D 12.4D 12.5D 12.6D	8.90 9.20 9.40	- - - - - -			calcareous, grey								1.		
Geobor-S	13-B	- 10	12.0D 12.7D		- - - - - - - - - - - - - - - - - - -	2 -32	· · · · · · · · · · · · · · · · · · ·	CLAY silty st sandy st calcareous dark grey	Mw. Gc.		_		10					
		- - - - - - - - - - - - - - - - - - -								67								
	15-TW	-	- 15.1D 15.2D	11.75	12.	0 -33		11.75 - 12.00 w. iron sulphides		60	_				©			
1				\sim				Borehole Log: KF-BH002		Drilled:	TBH	/KHH		Date:	2013-06-01	Report N	No.: 1	-
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E	Boreho	le:	KF-E	H002	2		(Coor	dinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum: V	VGS 84 UTM	Zone	32 N - D	/R 90		♦ HS ▼ SPT(S) ▼	7 SPT(C) 80 N		onate	12 16	2 % PCPT Tir	4 6 Resistance	8 (MPa)	
loc	Sample ad A	(m)	La	o specii	imen	Seab Level -21. Bound (m	dary		s: Geology	osit	Co Cor (%)	re Runs and e Quality	ssures	duration	UCS(Y) ■ 0.5 1.0 1.5 Undrained shear △ Pocket Pen ▲ □ ● Lab Vane ◇ F ● Intact UU	UCS 2.0 MPa strength For Vane	* Loss 2 w Moist w _s Sat. N w _P Plasti w _L Liquic w _P	s on Igr 4 ure Co Vloistur ic Limit d Limit W	nition <u>6</u> 8 ontent re Conte t W _s W _L	% ──20 % ● Point 0.1 Relative e _{min} 1.6	40 60 Load Stren 0.2 0.3 Density (M 1.7 1.8	80 gth I _{s 50} 0.4MPa lg/m ³) e_{max} 1.9 a^{3}	Other Lests ical tests Tests Simple Shear meter
Drill to	No. al	Depth			Depth	Depth	Eleva	Grapr	Description of layers and details	Depc Age	TCR	SCR RQD	نتُّ 1	<u> </u>	5 200 400 600	800 kPa	10	20 :	30 40	■ Bulk D □ Dry % 1.6	1.8 2.0	2.2	Grain Chem Cyclic Direct Direct Triaxié
Geobor-S (continued)	16-C ⁻⁷	_ 12 	15.3 15.4 15.6 15.7 16.1) 12.10) 12.20) 12.20) 12.20	10 20-12.40 50				11.90 - 12.00 w. many sand streaks	Mw Gc									X 				•
	17-C					13.3 -	35.1		12.90 w. diagonal fracture 12.95 w. diagonal fracture 13.00 becoming very silty 13.05 w. 20 mm silt laminae CLAY TILL, sandy, gravelly, calcareous, olive brown	GI Gc	50		-								~		
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B	orehol	le: I	KF-BH	002			Cool	rdinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum:	WGS 84 UTM	Zone	32 N -	DVR 90)		♦ HS ▼ S	PT(S)	SPT(C) 🗙	Carbona	te 12 16	3 %	– 2 PCPT Tir	4 6 Resista	8 nce (MPa)		
	Sample		Labs	specimen	Seal Level -21	bed (m): .8	Note	es:		Cor Core	e Runs and e Qualit	y			□ UCS(Y 0.5 1 Undrained	0 00) ■ .0 1.5 shear	UCS 2.0 MF	× Paw	Loss on 2 4 Moisture	Ignition 6 8 Content	<u> </u>	- 20 ● Point 0.1 Polativ	40 60 t Load Str 0.2 0.3	rength $I_{s 50}$ 3 0.4 MPa	Other	Tests
II tool	. and type	pth (m)	· and type	pth	Boun (n	svation (r	aphic Log	Geology	eposit Je	.R (%)	CR (%)	Fissures		Induration	 △ Pocket ● Lab Val ● Intact U 	Pen ▲ ne ◇ U	Tor Vane Fall Cone	e w _e W _P W _L	Plastic Lir Liquid Lin W _P	nit nit ww _s w ⊕-⇔—		e _{min} 1.6 ■ Bulk D	<u>1.7 1.8</u> 9ensity (M	···· e _{max} <u>3 1.9</u> Ig/m ³)	ain size distribut emical tests clic Tests	ermal Conductiv ect Simple Shei dometer axial
Dri	Ž	ස 42	Ž	De	De	ш	Ö	Description of <i>layers</i> and details	Pi Pi Pi	10	S S	1	- 5 1 -	5	200 4	0 600	800 kF	°a ′	10 20	30 40	0 %	1.6	1.8 2.0) 2.2	త్రేరే	
Geobor-S (continued)			37.1U - 37.2D	42.60-42.75 42.90				42.15 w. 50x50 mm echinoderm 42.80 - 42.95 w. many 1-2 mm grey marl flasers	Ma Ct											●						
	38-C	- - - - - - - - - - - - - - - - - -		-		-				50					44							Mr. M. M.	>	44		
	39-C	- - - - - - - - - - - - - - - - - - -	- 39.1D	44.90 -		-		45.10 w. 1 mm grey marl flaser 45.30 - 45.40 w. vertical fracture		80					46					© 			>			
	40-C	- - - - - - - - - - - - - - - - - - -		-						77										 						
			41.1D	47.85			-	Borebole Log: KE-BH002		Dril	led [.]	TR	H/KF	 -			Date	20	13-06-0	1 Rep	ort N	l				
1			-	-()		-	Project: 36642 Kriegers Flak		Pre	pared	: LTI	R/LF	J			Date:	20	13-06-0	3 Encl	No.				-	
	Ľ	-)			Remarks:		Che	ecked	JSI))				Date:	20	13-06-0	3 Rev	:				1	
v	v w	w	. G	E O . D	к	P				Арр	orovec	: LA	R				Date:	20	13-08-0	B Page	e:		8	/ 12	-	

В	oreho	le: I	KF-BH0	02			Coo	ordinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum:	WGS 84 UTM	Zone 3	82 N - D\	/R 90		♦ HS ▼ SPT(S) 20 40 6	▼ SPT(C)	Carbonat	e 12 16 %	– 2 PCPT Tip	4 6 8 Resistance (MP	a)	
	Sample		Lab spe	ecimen	Sea Leve -2	abed el (m): 1.8	Not	Geology		Core a Core	e Runs and Quality			□ UCS(Y) ■ 0.5 1.0 1 Undrained shea	UCS .5 2.0 MPa	* Loss on le 2 4 w Moisture C w _s Sat. Moistu	gnition 6 8 % Content ure Content	— 20 • Point I 0.1 (Relative	40 60 80 Load Strength I _s 0.2 0.3 0.4M Density (Mg/m ³	⁵⁰ Othe	er Tests
	Ō		Q		Bou (ndary m)	′ 	Georogy	1		1	ŝ	ion	△ Pocket Pen ▲ ● Lab Vane ◇	 Fall Cone 	w _P Plastic Lim	nit 	e _{min}	e _{ma}	sts	e Sh
Drill tool	No. and typ	Depth (m)	No. and typ	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%) RQD (%)	Eissure	Indurati	Intact UU 200 400 60	00 800 kPa	W _L Liquid Lim W _P 	nt w w _s w _L ⊕ ↔ <mark> </mark> <u>30 40 %</u>	1.6 ■ Bulk De □ Dry 1.6	I.7 1.8 1.9 nsity (Mg/m ³)	Grain size di Chemical tes Cvclic Tests	Thermal Cor Direct Simple Oedometer Triaxial
(pai		- 48						47.90 w. light grey burrows	Ma Ct					48						48	
ontinu		-			-																
-S -S		F																			
sobor	-	F			1												•				
Ŭ		49]																
Ħ	42-C	È.			-					73											
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H		50]									50						50	
E		ţ			1																
E		Ē			-																
B	43-C	Ē								83	7						•				
		51			-			51 10 w few 1-2 mm marl flasers													
		E	-43 1D 5	1 40]			51.30 w. 8 mm marl seam													
		F	40.10		1																
		Ē]							-									
		52			1									52		•				52	
	44-C	Ē]					77											
		F			-														\leq		
		Ē]			52 80 - 53 85 w 20 x 50 mm black flint nodule											>		
		53			1																
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		F			-																
	45-C	È]					80	23						•				
				~			_	Borehole Log: KE-BH002		Drille	ed:	TBH	/KHH		Date:	2013-06-01	Report N	No.: 1			
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j.	w w	w	. G E	0.1	ок					Арр	roved:	LAR			Date:	2013-08-08	B Page:		9 / 12	-	

Boreh	nole	: K	F-BH(002			Coo	rdinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum:	WGS 84 UTM	Zone	32 N -	DVR	90		♦ HS	▼ SP1	(S) ▼	SPT(C)	×	Carbo	nate	12 1	6 %	– 2 PCPT	4 Tip Res	6 8 istance (I	, MPa)		
Sam	ple		Lab s	pecimen	Sea Leve -2	abed el (m): 1.8	Not	es:		Cor	re Rur and e Qua	is itv			0.	UCS(Y) 5 1.0 ained s	1.5	UCS 2.0 MPa	* • • •	Loss o 2 4 Moistur	n Igi	nition 6 8 ontent	<u> </u>	- 20 • Po 0.1	40 int Load 0.2	60 80 Strength 0.3 0.4	h $I_{s 50}$ 4MPa	Other Test	s
					Bou	ndary		Geology	1			·	~	E	△ Po	ocket Pe	en ▲ To	or Vane	W _s X W _P I	Plastic	Limit	re Coni t	tent	Relat	Ive Den	sity (ivig/i	m') •	Shea	
Drill tool No. and type		Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	RQD (%)	Fissures	Induratio	● La ● In 5 20	tact UU	♦ Fa	all Cone 800 kPa	w _L I	Liquid L W _P I 0 20	Limit w — ⊛	/w _s w ≻ → 30 4	/L 0 %	e _{min} <u>1.6</u> ■ Bulk □ Dry 1.6	<u>1.7</u> Density 1.8	<u>1.8</u> 1.9 (Mg/m ³) 2.0 2.	9 (1) 9 (1)	Grain size dis Chemical test Cyclic Tests Thermal Conc Direct Simple	Oedometer Triaxial
(pa		54						LIMESTONE, muddy, white (continued)	Ma Ct				F		54										\square		54		
-95		55						54.10 - 54.00 W. T MIN Man Hasers		93											•								
		56								90		20			56							•					56		
		58	47.1U	57.80-58.10				57.00 - 58.00 w. many 1-2 mm man flasers							58			•			-@@			8			58		
		59		- - - - - - - - - - - - - - - - 						87																			
		•		-														++	$\left \right $						+++	+++	+		
49-1	-		0							93		40																	
1				\sim	1			Borehole Log: KF-BH002		Dril	lled:	T	BH/	KHH				Date:	20	13-06-	-01	Rep	ort N	lo.: 1					
	-		_)			Project: 36642 Kriegers Flak		Pre	epare	d: L	. (R/	LFJ				Date:	20'	13-06-	-03	Encl	No.	:					
	-	1	<u> </u>	. ~	/			Remarks:		Che	ecke	1: J	SP AD					Date:	20	13-06-	-03	Rev	:			10 () -			
w v	v v	Ν.	G	E O . D) К	-				Abb	prove	a: L	AR.					Date:	20	13-08-	-08	Pag	e:			10 / 12			

Bor	ehol	e: k	KF-BH	002			Coo	ordinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum:	WGS 84 UTM	Zone	32 N -	DVR 9	0		♦ HS	▼ SPT	[(S) ▼	SPT(C) 🗙	Carbo	nate	; 12 1	6 %	– 2 PCPT	4 Tip R	6 esistan	8 ce (MPa		
Sa	mple		Lab	specimen	Sea Leve -2	abed el (m): 1.8	Not	les:		Cor	re Run and e Quali	s			Undr	UCS(Y) 5 1.0 ained s	1.5	UCS 2.0 MP	a w	Loss c 2 4 Moistur	, on Ig I re Co	nition 6 ontent	8 %) 40 pint Lo	0 60 bad Stre 2 0.3	80 ength I _{s 50} 0.4MPa	Othe	er Tests
					Bou	ndary	,	Geology	1					Ч		ocket Pe	en ▲ To	or Vane	W _s W _P	Sat. Mo Plastic	Distu Limi	ire Con it	itent	Rela		ensity	(ivig/m²)	tributi	Shea
Drill tool	ואט. מווע ואףכ	Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	Tuu (%)	20 mcci - 5	Induratio	● In	tact UU	♦ Fa	800 kP	w _L	Liquid I W _P 	Limit W — @	t vw _s v → → — 30 4	v∟ 1 10 %	e _{min} <u>1.6</u> ■ Bulk □ Dry 1.6	6 <u>1.7</u> C Dens	7 <u>1.8</u> sity (Mg 32.0	··· e _{max} <u>1.9</u> //m ³) 2.2	Grain size dis Chemical test Cvclic Tests	Thermal Cond Direct Simple Oedometer Triaxial
) (pé		60			-			LIMESTONE, muddy, white (continued)	Ma Ct						60												60		
C C C C C C C C C C C C C C C C C C C	0-C		-49.1D	61.00						90																			
	1-C	- - - - - - -								93		D			62							•					62	-	
		63						63.55 - 63.90 w. few 1 mm marl flasers							64							•					64		
	2-C	- 65			• • • • • • • • • • • • • • • • • • • •					80																			
	3-C	-			-					93		0	E																
1				\sim	1			Borehole Log: KF-BH002		Dril	led:	TE	3H/k	<hh< td=""><td></td><td></td><td></td><td>Date:</td><td>20</td><td>13-06</td><td>-01</td><td>Rep</td><td>ort N</td><td>lo.: 1</td><td></td><td></td><td></td><td></td><td></td></hh<>				Date:	20	13-06	-01	Rep	ort N	lo.: 1					
(-	-	-()			Project: 36642 Kriegers Flak		Pre	pareo	I: LT	R/L	_FJ				Date:	20	13-06	-03	Enc	I No	:					
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Γ	Boreho	ole:	KF-Bł	1002		C	Coor	rdinates (m): E: 742,996.9 N: 6,100,896.8 Grid & Datum:	WGS 84 UTM	Zone 3	32 N - I	DVR 9	D		♦ HS ▼ SPT(S) ▼ 20 40 60	SPT(C)	Carbonate	12 16 %	– 2 PCPT Tir	4 6 Resistar	8 nce (MPa)			
	Sample	9	Lab	specimen	Seab Level -21	ed (m): .8	Note	25:		Core a Core	e Runs and Qualit	v		-	□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shears	UCS 2.0 MPa	* Loss on Ig 2 4 w Moisture Co	nition 6 8 % ontent	- 20 ● Point 0.1	40 60 Load Str 0.2 0.3	80 rength I _{s 50} 0.4MPa	Oti	her T	ests
	0		0		Bound	dary		Geology	1		I	u		5	△ Pocket Pen ▲ T	For Vane	w _p Plastic Limi	t	e lu	e Density	(Mg/III)	stribut ts	ductiv	She
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation Craphic Loc	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	T Fissire	- 5	5	 Lab Valle Intact UU 200 400 600 	800 kPa	w _L Liquid Limit w _P w I ——€ 10 20	′w _s w _L ► Ə− 30 40 %	0 min 1.6 ■ Bulk D □ Dry 1.6	<u>1.7 1.8</u> ensity (Mo <u>1.8 2.0</u>	g/m ³) 2.2	Grain size dis Chemical tes	Cyclic Tests Thermal Con	Direct Simple Oedometer Triaxial
(pen		- 66			-			65.95 - 67.10 w. many 1-2 mm marl flasers LIMESTONE, muddy, white (continued)	Ma Ct						66						66			
contin		Ē	- 53.1D	66.50				, , , , ,																
or-S (Ē																						
Geot		67																						
E	54-C	É								97														
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E	55-C	Ē								20	0	,					e							
		69	- 55.1D	69.00				69.00 - 69.70 w. 1-2 mm marl flaser				E.					Ð							
1.180																								
9I-0I-		Ē																						
/ 2013		70			70.0 -	91.8	-	w. fossil						•••	70		●				70			
29.7																								
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17 17 17																								
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8 9-2	1			-				Borehole Log: KF-BH002	<u> </u>	Drill	ed:	TB	H/KHI	H		Date:	2013-06-01	Report N	No.: 1					
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Bore	hol	e: K	(F-BH	004			Coo	rdinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum: W	'GS 84 UTM 2	Zone 32	2 N - D	/R 90		♦ HS ▼ SPT(S) 20 40 60	7 SPT(C)	Carbonate	2 16 %	2 4 6 8 PCPT Tip Resistance (MPa)	
San	nple		Lab s	pecimen	Sea Level -21	bed (m): .0	Note	es:		Core ai Core (Runs nd Quality			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa	* Loss on Ign 2 4 6 w Moisture Col	ition 8 8 % ntent	20 40 60 80 ● Point Load Strength I _{s 50} 0.1 0.2 0.3 0.4MPa Relative Density (Md(m ³)	
Drill tool No. and type	;	Depth (m)	No. and type	Depth	Depth Uepth	Elevation (u	Graphic Log	G e o l o g y Description of <i>layers</i> and details	Deposit Age	TCR (%)	SUR (%) RQD (%)	Fissures	Induration		For Vane Fall Cone	w_{s} sat. Molecular w_{p} Plastic Limit w_{L} Liquid Limit w_{p} w $h \Theta$ 10 20 3	w _s w _L → - 0 40 %	e _{min} [Grain size distribut Chemical tests Cyclic Tests Thermal Conductiv Direct Simple She: Oedometer Triaxial
/ rotary drilling (co <i>ntinued)</i>	D-B	7	9.2D	6.10	7.3	-27.1		brown CLAY TILL, medium plasticity, silty, sl. sandy, gravelly, calcareous, brown (continued) CLAY, medium plasticity, silty, calcareous, laminated, w. iron sulphides, grey 6.05 - 6.10 w. many 1-5 mm fine sand laminae, w. black specks, w. odour	Mw Gc)						
	₩ 2-B	8	11.1D 11.2D 11.3D 11.4D 11.5U 11.6U	7.40 7.50-7.70 7.70-7.90	8.6	-29.6	o` ` o` ` o` ·	CLAY TILL, medium plasticity, sandy, gravelly, calcareous, w. limestone grains, brownish grey	GI Gc					Δ 8		©			
	LB B	9	- 12.1D 12.2D 12.3D 12.4D 12.5D - 13.1D - 13.2D	8.80 9.50 - 9.70 -		-		 SAND, medium, non graded, sl. gravelly, non calcareous, grey 8.80 angularity: subangular-subrounded 9.30 becoming fine, well graded, silty, gravelly 	Mw Gc							©			
15-1	w	- 11	- 15.1D 15.2D 15.3D	11.40	-	•				13		-							
1				\sim	1			Borehole Log: KF-BH004		Drille	ed:	TBH	/KHH		Date:	2013-05-28	Report N	lo.: 1	
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	-	-		\sim		-		Remarks:		Cheo	ked:	JSP			Date:	2013-05-29	Rev :		
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E	Boreho	le:	KF-B	1004	_	Coc	ordinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum:	WGS 84 UTM	Zone 32 N - D	VR 90		♦ HS ▼ SPT(S) 20 40 60	SPT(C)	Carbonate	12 16 %	PCPT Tip Resistance (MPa)	
	Sample	9	Lab	specimen	Seabed Level (m) -21.0	No [*]	tes:		Core Runs and Core Quality			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa	* Loss on Ig 2 4 w Moisture Co	nition 6 8 % ontent	— 20 40 60 80 • Point Load Strength I _{s 50} 0.1 0.2 0.3 0.4MPz Relative Density (M/m ³)	Other Tests
	type	(L	type	1	Boundary (m)	/ Log	Geology	i.	(9)	ures	Iration	△ Pocket Pen ▲ ⁻	Tor Vane Fall Cone	W_{p} Plastic Limit W_{L} Liquid Limit W_{p} W	t w. w.	e _{min} e _{max} 1.6 1.7 1.8 1.9	e distribu Il tests ests Conductiv mple She ter
Drill too	No. and	Depth (r	No. and	Depth	Depth Elevatio	Graphic	Description of layers and details	Depos Age	TCR (% SCR (% RQD (%	SSIL	חpuן 5 1	5 200 400 600	800 kPa	10 20 €	+ ↔ 	■ Bulk Density (Mg/m ³) □ Dry 1.6 1.8 2.0 2.2	Grain siz Chemicz Cyclic Ti Thermal Direct Si Oedome Triaxial
tinued)		12			12.4 -33.4		SAND, medium, non graded, sl. gravelly, non calcareous, grey (continued)	Mw Gc				12					
or-S (con	16-C				12.8 -33.8		CLAY TILL, sandy, gravelly, calcareous, dark grey	GI Gc									
Geob	17-C	- - - -	- 17.10 17.1D	D 13.05			CLAY, high plasticity, silty, calcareous, organic, w. few shell fragments, w. iron sulphides, dark grey	Fw Is	80				<u> </u>	* +•		↓ 51 ¶ □	
			- 17.20 17.30 17.40 17.50	13.30 13.45-13.70	-		CLAY, high plasticity, calcareous, w. many silt and fine sand laminae, brown	Mw Gc				•		60			
		- 14	17.60 17.7D 17.8D 17.9D	13.85	-							14		×		14	
	18-B						14.30 - 15.80 w. many fine to coarse, non graded, grey sand layers										
		- - -															
	19-C	-							47								
		16	- 19.1D	16.15					47					⊢ ⊛	<u>5</u>		
		- 17			17.3 -38.3												
	20-C						CLAY TILL, sandy, gravelly, calcareous, grey	GI Gc	67								
Γ	1			- ~			Borehole Log: KF-BH004		Drilled:	TBH	I/KHH		Date:	2013-05-28	Report N	No.: 1	
	(_	-	-(Project: 36642 Kriegers Flak		Prepared:	LTR	/LFJ		Date:	2013-05-30	Encl No.]
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E	Boreho	ole:	KF	-BH	004			Coo	rdinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum:	WGS 84 UTM	Zone 3	2 N - D'	/R 90		♦ HS ▼ SPT(S) 20 40 60	SPT(C) 80 N) ×	Carbonate	2 16 %	PCPT Tip	4 6 8 Resistance (MPa)	
	Sample	e		Lab s	pecimen	Seab Level -21	ed (m): 0	Note	es:		Core a	e Runs Ind Quality			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 2.0 MPa	a w	Loss on Igr 2 4 0 Moisture Co	ition <u> 8 8 %</u> ntent		40 60 80 Load Strength I _{s 50} 0.2 0.3 0.4MPa	Other Tests
						Bound	dary		Geology			Quality		5	△ Pocket Pen ▲	Tor Vane	W _s W _P	Sat. Moistur Plastic Limit	e Content	Relative	Density (Mg/m ³)	s Shea
Drill tool	No. and type	Denth (m)		No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%) RQD (%)	Fissures	1 Induratio	 ● Lab Vane ◆ ● Intact UU 5 200 400 600 	Fall Cone	w _L	Liquid Limit $W_P \qquad W$ $I \odot$ 10 20 3	w _s w _L ↔ → → 0 40 %	e _{min} 1.6 1 ■ Bulk De □ Dry 1.6	.7 1.8 1.9 nsity (Mg/m ³) .8 2.0 2.2	Grain size dis Chemical test Cyclic Tests Thermal Cont Direct Simple Oedometer Triaxial
(pər		- 18	8				-	<u></u>	CLAY TILL, sandy, gravelly, calcareous, grey (continued)	GI Gc					18						18	5
ebor-S (continu	21-C		2	1.1U	18.85-19.10	-	- - - -				93							•				
ŏ		1	9	1.2D	19.15]	-									•						
H		-	2	1.3U	19.20-19.45		-	.0														
H		-	2	1.4D 1.5D	19.60		-												*			
		-	2	1.6D		1	-	. <u>.</u>	19.85 w. 30x60 mm granite gravel													
		- 20	0				-		20.10 w. 100x140 mm granite stone						20			•			20	
		E					-	.°														
	22-C	2	1			20.7	41.7		LIMESTONE, muddy, white (glacial disturbed) 20.70 - 21.25 w. clay till parts, many gravels (granite and flint)	Ma Ct	50		-									
	23-C	2:	2			21.8	42.8		LIMESTONE, muddy, white	 Ma_Ct	80	0			22			•		<u>}</u>	22	
		2	3 2	3.1D	23.00				22.80 - 22.90 w. 80x100 mm dark grey to black flint nodule									•	>			
	24-C										60											
	1		1	1		1		Í	Borehole Log: KF-BH004		Drille	ed:	TBH	I/KHF		Date:	20)13-05-28	Report N	No.: 1		
	(-	•	_	-()			Project: 36642 Kriegers Flak		Prep	ared:	LTR	/LFJ		Date:	20	013-05-30	Encl No	.:		
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E	orehol	le: I	(F-BH	1004		(Coor	rdinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum:	WGS 84 UTM	Zone	32 N	- DVI	R 90		♦ HS ▼ SPT(S) 20 40 60	▼ SPT(C) 80 N	×	Carbon	ate 12	16 %	PCPT	4 Tip Resi	6 8 stance (MF	a)	
	Sample		Lab	specimen	Sea Leve -2	bed I (m): I.0	Note	25:		Co	re Ru and e Qu	ins ality			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa	*	Loss or 2 4 Moisture	Ignition 6 Conten	t 1 1 1 1 1 1	- 20 ● Pc 0.1	40 bint Load 0.2	60 80 Strength I. 0.3 0.4N	50 Pa	her Tests
	Ø		υ		Bour (r	ndary n) ∣	- 1	Geology	1		1		Ś	on	△ Pocket Pen ▲	Tor Vane Fall Cone	W _P	Plastic L	imit	nieni	e		l e	stribut	e Sher
loc	d typ	(E	nd typ	_		, tion	ic Loc		osit	(%)	(%)	(%)	ssure	durat	 Intact UU 		WL		w w _s	WL	1.6	<u> </u>	1.8 1.9	size di cal tes	I ests al Cor Simpl
Drill to	No. ar	Depth	No. ar	Depth	Depth	Elevat	Graph	Description of layers and details	Depc Age	TCR	SCR	RQD	Ë,	J L	200 400 600	800 kP	-	10 20	30	- 40 %			(Mg/m ⁻)	Grain : Chemi	Cyclic Therm Direct Oedor Triaxiz
∋d)		24						LIMESTONE, muddy, white (continued)	Ma Ct						24							, 1.0		24	
ontinue		Ē																						_	
r-S (c		F																							
Geobc	25-C	25			-			24.80 - 24.95 w. dark grey to black fractured flint		77		0							۲						
		-																							
		F			-	_	Г																		
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					1			Borehole Log: KF-BH004		Dri	lled:		TBH	/KHH		Date:	20	013-05-	28 Re	eport l	No.: 1				
			[-()			Project: 36642 Kriegers Flak		Pre	epare	ed:		LFJ		Date:	20	013-05-	30 En	ICI NO	.:			_	
3	\sim	-	<u> </u>	- ~		-		Remarks:		Cn An	ecke	ed:	1255			Date:	20	113-05-	29 Re	ev :			E / 0	_	
	ww	W	. G	E O .	DK	1	L			1 vh	piuv	eu.				Dale.	20	515-00-		iye.			5/9		

В	oreho	le: k	⟨F-Bŀ	1004			Coo	rdinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum:	WGS 84 UTM	Zone	32 N	- DVI	R 90		♦ HS ▼ SPT(S)	▼ SPT(C)		nate	— 2 % PCPT Ti	4 6 8 Resistance (MPa)
	Sample		Lab	specimen	Sea Leve -2	abed el (m): 1.0	Not	es:		Co	re Ru and e Qu	uns ality			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 5 2.0 MPa	* Loss of 2 4	on Ignition 6 8 re Content		40 60 80 t Load Strength I _{s 5} 0.2 0.3 0.4MP	
	0		0		Bou	ndary		Geology	1		1		6	u	△ Pocket Pen ▲	Tor Vane	w _s Sat. W w _P Plastic	Limit			stribut ts ductiv
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	RQD (%)	Fissures	1 Induratio	Lab Vane Intact UU 200 400 600	Pail Cone	W _L Liquid W _P <u>H</u> 10 2	Limit ww _s w _i - 	e _{min} 1.6 ■ Bulk D □ Dry 1.6	1.7 1.8 1.9 uensity (Mg/m³) 1.8 2.0 2.2	Grain size dis Chemical test Cyclic Tests Thermal Con Direct Simple Oedometer Triaxial
ied)		30			-			LIMESTONE, muddy, white (continued)	Ma Ct						30				3	3	
Geobor-S (continue	28-C	- - - - - - - - - - - - - - - - - - -	28.1U	- 30.95-31.15 - -				31.50 - 31.75 w. dark grey to black flint nodules 31.95 w. 1 mm marl flaser		87		50						© 			
	29-0	- - - - - - - - - - - - - - - - - - -		-						83		10						•			
	21.0	34	30.1U	33.90-34.15 _				33.80 - 33.85 w. dark grey to black fractured flint34.25 - 34.45 w. 1 mm marl flasers				40			34			09 0 0 0		3	
	31-0	- - - - -		-	-					83											
					1			Borehole Log: KF-BH004		Dri	lled:		TBH	/KHH		Date:	2013-05	-28 Repo	ort No.: 1		
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E	oreho	le: k	(F-BH	004			Coo	rdinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum: WGS 84 U	TM Zor	ne 32	N - D\	/R 90		♦ HS ▼ SPT(S) ▼	SPT(C)	×C	arbon	ate	16 %	PCPT	4 Tin Re	6 sistance	8 (MPa)			
	Sample		Lab s	pecimen	Sea Leve -2	abed el (m): 1.0	Not	ies:	(Core I an ore C	Runs d Juality			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 2.0 MPa	* Lo 2 w Mo	oss or 4 oisture	Ignition 6 Conten	<u>8 %</u>	20	40 2000	60 ad Strenç 0.3	80 gth I _{s 50} 0.4MPa	Othe	er Tes	sts
	0		0		Bou	ndary		Geology				6	u	△ Pocket Pen ▲	Tor Vane	w _s Sa w _P Pla	at. Moi astic L	sture Co imit	ntent	Rela	tive De	nsity (M	g/m°)	stributi	ductiv Shea	
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	1%) OCF		RQD (%)	Fissure	Indurati	● Intact UU	800 kPa	w _L Lic	quid Li W _P I	mit ₩ ₩ _s - @ - ↔ - 30	w _L ┨ 40 %	■ Bull	<u>} 1.7</u> ∢Densi	<u>1.8</u> ty (Mg/m 2 0	1.9 1 ³)	Grain size dis Chemical tes Cvolic Tests	Thermal Con Direct Simple	Oedometer Triaxial
ed)		36		-	-			LIMESTONE, muddy, white (continued) Ma C	t				<u> </u>	36									36			
oor-S (continu	32-0	•		-	-					2	0															
Geo		- - - -		-	-			flint	0.	5								•								
		-		-				37.50 - 37.55 w. dark grey to black fractured flint										•								
	-	38		-										38									38			
	33-C	-		-					8	3																
																						-				
		39		-																	_					
		Ē		-																						
	34-C							39 80 - 41 15 w many 1 mm marl flasers	9	0	57							•								
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		-	34.1U 34.2D	40.25-40.45 40.45 -																	++-			•		
		-																								
		41		-														۲								
	35-C	Ē		-				41.30 - 41.40 w. black fractured flint	7	7	-									5	\pm					
		-																								
				\sim				Borehole Log: KF-BH004		rille	d:	TBI	-I/KHH		Date:	2013	3-05-2	28 Re	port l	No.: 1						
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		1						Remarks:	С	hec	ked:	JSF) 		Date:	2013	3-05-2	29 Re	v :					1		
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Bore	hole	e: K	F-BH	004			Coo	rdinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum: W	/GS 84 UTM	Zone	32 N	- DV	R 90		♦ HS ▼ SPT(S)	▼ SPT(C)	X (Carbon	ate	16 0	2 PCPT T	4 in Resi	6 istance	8 (MPa)	
San	nple		Lab s	pecimen	Sea Leve -2	abed el (m): 1.0	Not	es:		Co	re Ru and e Qu	ins alitv			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 2.0 MPa	* 2 w M	Loss on 2 4 Noisture	Ignitio 6 Conte	n 8 %	— 20	40 nt Load 0.2	60 8 I Streng 0.3 0	30 th I _{s 50}).4MPa	Other Tests
					Bou	ndary		Geology						E	△ Pocket Pen ▲	Tor Vane	W _s S W _P P	Plastic L	sture C imit	ontent	Relati	ve Den	sity (ivig	/m ⁻)	S Shea
type	:	Ê	type	1	0	n) 	Log		it	()	(9)	(%)	ures	Iratio	 ● Lab Vane ◆ ● Intact UU 	Fall Cone	W _L L	iquid Lii.	mit ww.	W	e _{min} 1.6	1.7	1.8 1	e _{max}	Conce als ests ter ter
I tool and		oth (r	and	oth	oth	vatio	phic		e	R (%	R (%	6) Q	Fiss	Indu				I		–	Bulk	Density	/ (Mg/m ^²	³)	emice emice entral
D TI		Del	Ň	De	De	Ele	Ö	Description of <i>layers</i> and details	Ag	10	SC	R S	1 (5 1	5 200 400 600	800 kPa	1(0 20	30	40 %	b Dry 1.6	1.8	2.0 2	2.2	
(pər		42						41.90 - 42.10 w. many 1-2 mm marl flasers	Ma Ct						42									42	
ontinu	Ę	-		_															۲						
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eopo	Ē			-																					
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		46	37 1D	46 20											46				0					46	
			01112	10.20														_							
								46.60 - 46.70 w. few 20-30 mm dark grey to																	
								black flint nodules					_												
	-	47		-				47.00 w. vertical fracture											۲						
38	-C	-								90											+		+=		
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		-																				ΗŤ			
1	-				1		Ĩ	Borehole Log: KF-BH004		Dri	lled:		твн	/KHH		Date:	201	3-05-2	28 R	eport	No.: 1				
(-		-	-()			Project: 36642 Kriegers Flak		Pre	epare	ed:	LTR	/LFJ		Date:	201	3-05-3	30 E	ncl No	.:				
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E	Borehole: KF-BH004 Coordinates (m): E: 745,999.6 N: 6,102,700 Grid & Datum							id & Datum:	WGS 84 UTM	Zone 32	N - DV	R 90		♦ HS ▼ SPT(S)	▼ SPT(C)	Carbonate	; 12 16 %	2 4	6 8 esistance (MPa)			
	Sampl	e		Lab spe	cimen	Se Lev	eabe vel (n ∙21.0	d N 1):	otes:			Core R and	uns I			□ UCS(Y) ■ 0.5 1.0 1.	UCS 5 2.0 MP	* Loss on Ig 2 4 w Moisture C	nition 6 8 % ontent	− 20 40 • Point Lo 0.1 0.2	$\begin{array}{c} 60 & 80 \\ \hline \\ ad Strength I_{s 50} \\ 2 & 0.3 & 0.4 \\ \hline \\ \end{array}$	Other Tests
						Во	unda	ry	Geology		1			(A)	ы	△ Pocket Pen ▲	Tor Vane	w _s Sat. Moistu w _P Plastic Lim	ire Content it	Relative D	ensity (Mg/m [°])	stributi ts ductivi e Shea
Drill tool	No. and type	Depth (m)		No. and type	Depth	Depth	Flevation	Graphic Log	Description of <i>layers</i> and details	S	Deposit Age	TCR (%) SCR (%)	RQD (%)	Eissure 15	Indurati	 Intact UU 200 400 60 	00 800 kPa	w _L Liquid Limit w _P v h ——e	t vw _s w _L → → → <u>30 40 %</u>	1.6 1.7 ■ Bulk Dens □ Dry 0 1.6 1.8	7 <u>1.8 1.9</u> sity (Mg/m ³) 3 <u>2.0 2.2</u>	Grain size dis Chemical tess Cyclic Tests Thermal Con Direct Simple Oedometer Triaxial
UB:18	39-C	-48	9 9			50.0	0 -71		LIMESTONE, muddy, white (continued) 49.00 - 50.10 w. few 1 mm marl flasers	5	Ma Ct	100	54					e				
31 UA-51 & US-FIT / 30042 KKIEGERS FLAN.GFJ / 2019-10-10									Borehole Log: KF-BH004 Project: 36642 Kriegers Flak			Drilled Prepa	: red:	TBH/ LTR/	/KHH LFJ		Date: Date:	2013-05-28 2013-05-30	Report I Encl No	No.: 1		-
5	C	-			C	Γ			Remarks:			Check	ed:	JSP			Date:	2013-05-29	Rev :			-
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E	oreho	ole:	KF-B	H011		Coc	ordinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone 32 N - D	VR 90		♦ HS ▼ SPT(S)	SPT(C) 80 N	Carbonate	2 4 6 8 PCPT Tip Resistance (MPa)	
Drill tool	Sample No. and type	Depth (m)	No. and type	specimen	Seabed Level (m): -20.4 Boundary (m) Levation (m)	Graphic Log	Geology Description of <i>layers</i> and details	Deposit Age	Core Runs and Core Quality (%) SCK (%) SCK (%)	Fissures	Induration	UCS(Y) UCS(Y) UCS(Y) Undrained shear △ Pocket Pen ▲ ○ Lab Vane ◇ Intact UU	UCS 2.0 MPa strength Tor Vane Fall Cone	* Loss on Ignition 2 4 6 8 $^{\circ}$ w Moisture Content w _s Sat. Moisture Content w _p Plastic Limit w _L Liquid Limit w _P w w _s w _L H e + -1 10 20 30 40 $^{\circ}$		Grain size distribution Chemical tests Cyclic Tests Thermal Canductivity Direct Simple Shear Dedometer Trianki
Dry rotary drilling	1-LB	- 0 - - - - - - - - - - - - - - - - - -	-1.1D -1.2D -1.3D	0.10 0.30 0.40	0.2 -20.6		SAND, medium, non graded, yellowish brown SAND, medium - coarse, non graded, gravelly, grey SAND, fine - medium, non graded, grey	, <u>Ma Pg</u> Ma Pg Ma Pg	-							
TTTTTT	2-LB	- - - - - - - - - - - - - - - - - - -	2.1D	1.50-2.00 2.25								2				•
	3-LB	- 3	- 3.1D - 3.2D - 3.3D - 3.4D	3.20 3.40 3.70 3.85	3.3 -23.7		CLAY, medium plasticity, silty, w. many 1-2 mm fine sand laminae, grey	Fw Lg								•
	4-LB	- 5	-4.1D -4.2D	4.90 5.10			5.00 - 6.15 becoming brown									
	1			- ~			Borehole Log: KF-BH011		Drilled:	JW	J/ELF		Date:	2013-05-20 Report	No.: 1	
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В	oreho	ole:	KF-B	H011		Coc	ordinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone	32 N - C	VR 90			SPT(C)	Carbonat	e 12 16 %	PCPT Tip Resista	8 Ince (MPa)	
	Sample	•	Lab	specimen	Seabed Level (m): -20.4	No			Cor core	e Runs and Quality	,		□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MP	* Loss on I 2 4 w Moisture 0 w _e Sat. Moist	gnition 6 8 9 Content ure Content) 80 rrength I _{s 50} 3 0.4MPa / (Mq/m ³)	Other Tests
l tool	and type	oth (m)	and type	oth	Boundary (m)	phic Log	Georogy	posit e	R (%)	R (%) D (%)	Fissures	Induration	 △ Pocket Pen ▲ ⁻ ○ Lab Vane ◇ I ● Intact UU 	For Vane ⁻all Cone	w _P Plastic Lin w _L Liquid Lim w _P	nit it w w _s w _∟ ⊕ ⇔ —	e _{min} 1.6 1.7 1.4 ■ Bulk Density (N	 e _{max} <u>8 1.9</u> 1g/m ³)	in size distribu emical tests lic Tests rmal Conduct ect Simple She dometer
Dril	° Ž	Der	, S	Dep	Ele,	Gra	Description of <i>layers</i> and details	De	TC	S DR	1	51	5 200 400 600	800 kP	a 10 20	30 40 %	6 Dry 6 1.6 1.8 2.0	0 2.2	Gra Che Dire
ontinued)	5-LB	- 6	-5.1D	6.30	6.2 -26.6 6.5 -26.9		CLAY, medium plasticity, silty, calcareous, grey	Mw Lg					6			0		6	
ng (c		E	-5.2D	6.60	6.7 -27.1		CLAY TILL, silty, sl. sandy, calcareous, grey	GI Gc											
/ rotary drilli		7	⁻ 5.3D	6.85		ام' ¦ ا	SAND, fine, poorly graded, clayey, slity, calcareous, grey CLAY TILL, sandy, sl. gravelly, calcareous, arev	GI GC							•			2.6	2
ลิโ	0 714/						groy												
ЯI	6-1VV	Ē	-6.1D	7.60	7.8 -28.2	 									•			▫┤╺	
ЯI		Ē	6.3U	7.80 7.85-8.05	-7.8 -28.2	<u> </u>	SAND, medium - coarse, non graded, grey								●				
ł		8	Γ			- 	CLAY TILL, Sandy, gravelly, calcareous, grey	GIGC					8					8	
ν ν	7-C	Ē							41				A		•				
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3				-			Borenoie Log: KF-BHU11		Drill					Date:	2013-05-20		NU T		
		-)		Project: 30042 Kriegers Flak		Cha	pared:				Date:	2013-03-22)		
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E	orehol	e: I	KF-BH	011			Coo	ordinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone 32 N -	DVR 9	90		♦ HS ▼ SPT(S) ▼ 20 40 60	7 SPT(C)	×	Carbo	nate	16 %	2 PCPT 1	4 in Res	6 8 istance (} MPa)	
	Sample		Lab s	pecimen	Sea Leve -2	abed el (m): 20.4	Not	ies:		Core Run and Core Quali	s tv			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 2.0 MPa	* w	Loss o 2 4 Moistur	n Ignition 6 e Conten	<u>8 %</u>	- 20 ● Poi 0.1	40 nt Load 0.2	60 8 Strengt 0.3 0.	0 h I _{s 50} 4MPa	Other Tests
					Bou	indary	/	Geology	1		· .		Ч	△ Pocket Pen ▲ T	for Vane	W _s W _P	Sat. Mo	listure Co Limit	ntent	Relati	ve Der	Isity (IVIg/	(m ⁻)	Shea
_	l type	Ê	I type	1			Log		it	(%)	(%)	μ Π	uratio	 ● Lab Vane ◇ F ● Intact UU 	-all Cone	WL	Liquid L W _P	imit wws	W	е _{тіп} 1.6	1.7	1.8 1.	e _{max} : 9	ze dis al test ests imple iter
rill toc	o. and	epth (o. and	epth	epth	levatic	raphic	Description of <i>layers</i> and details	epos ge	CR (9			Indu				ŀ—		-F	Bulk	Density	/ (Mg/m ³))	rain si hemici herma irect S edome
	z	_ 12	z			ш	0	CLAY TILL, sandy, gravelly, calcareous, grev			r 1	5 1	1 5	200 400 600 12	800 kPa		10 20	30	40 %	1.6	1.8	2.0 2.	2 12	
inued		-			-		<u> </u>	(continued)																
(cont	11-C	F		-	-		<u> </u>			30					A									
obor-S		Ę			-		<u> </u>																	
Geo		13		-	13.1	-33.5	<u> </u>	SAND fina madium non aradad calcorroup	May Co	-														
		-			-		· · ·	brown	WW GC															
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	12-TW	-	- 12.1D	15.50	-		· · · · · .				_													•
	13-C	Ē			15.7	-36.1		CLAY TILL, silty, sandy, gravelly, calcareous.	GI Gc	56														
		-		-	-		<u> </u>	grey						16			۲						16	
	-	-			-		<u> </u>																	
	14-C	Ē		-	-		<u> </u>	16.50 - 16.90 sl. sandy. w. few gravels		100	_													
		-	14.1D 14.2D	16.70	-		 										۲							
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		-			1			Borehole Log: KF-BH011		Drilled:	J۷	VJ/E		· · · · · · ·	Date:	20)13-05-	20 Re	port N	No.: 1				
		-	-	-()			Project: 36642 Kriegers Flak		Prepareo	d: LT	R/L	.FJ		Date:	20)13-05-	22 En	cl No.	.:				
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	N W	W	. G	ΕΟ.[о к	-				Approve	d: LA	١R			Date:	20)13-08-	08 Pa	ge:			3 / 12		

Bore	nole	: K	F-BH	011			Coo	ordinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone	32 N	- DVI	R 90		<	>HS ▼ SPT(S) ▼	SPT(C)	Carbonat	e 12 16 %	– 2 4 6 8 PCPT Tip Resistance (MPa)	
Sam	ple		Lab s	pecimen	Sea Leve -2	abed el (m): 0.4	Not	tes:		Cor	re Ru and e Qua	ins ality				□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa	* Loss on I 2 4 w Moisture (gnition 6 8 % Content	− 20 40 60 80 • Point Load Strength I _{s 50} 0.1 0.2 0.3 0.4MPa Point's Density (Ma(m ³))	
Q			Ō		Bou (ndary m)		Geology	1				ŝ	ion		△ Pocket Pen ▲ 1	For Vane	W _P Plastic Lin	nit		istribut sts nductiv e Shea
Drill tool No. and typ		Depth (m)	No. and typ	Depth	Depth	Elevation	Graphic Loo	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	RQD (%)	Fissure	Indurat	- 5	 Intact UU 200 400 600 	800 kPa	W _L Liquid Linn W _P <u> </u> — — 10 _ 20	n w w _s w _L ● ← <mark>–</mark> <u>30 40 %</u>	1.6 1.7 1.8 1.9 ■ Bulk Density (Mg/m ³) □ Dry 1.6 1.8 2.0 2.2	Grain size d Chemical te: Cyclic Tests Thermal Coi Direct Simpl Oedometer Triaxial
(pen	E	18		-	-		_o_ 	CLAY TILL, silty, sandy, gravelly, calcareous, grey (continued)	GI Gc						1	8					
It-S (contin	c			-	-		- - - - - - - - -	18.40 - 18.45 w. limestone parts 18.40 - 18.70 sl. gravelly		67											
90 17- 9	сŢ	19		-	19.1	-39.5	 			100											
		-	17.1D 17.2D	19.20			_	CLAY, medium plasticity, very silty, calcareous, brown	Mw Gc										- ×		•
			17.3D 17.4D 17.5U	19.50-19.75			Ξ	19.10 - 19.70 w. sand streaks								•)		
18-	c -			-			Ξ	19.70 - 19.90 w. iron sulphide stains		30											
		20		-						50					2	0					
				-	20.5	-40.9															
	F						 	grey	GIGC												
		21		-			 														
10.							 			100											
	Ŭ -	. –	19.1D 19.2D	21.60			 			100								• I 1	×	2.4	<u>8</u>
	Ē	22	19.3D 19.4D	21.85-22.10 -			 									2	•	•			
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20-		23		-			 			87											
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			_	. (Borebole Log: KE-BH011		Dril	led [.]		JW.	J/ELF			Date [.]	2013-05-20) Report I	No.: 1	
(-	•(Project: 36642 Kriegers Flak		Pre	pare	ed:	LTF	R/LFJ			Date:	2013-05-22	2 Encl No		
1	1076	-		\sim)			Remarks:		Che	ecke	ed:	JSF	>			Date:	2013-05-22	Rev :		
w	N N	ν.	G	E O . D	к	-				App	orov	ed:	LAF	२			Date:	2013-08-08	B Page:	4 / 12	

В	oreho	ole:	KF	BHO)11			Coo	rdinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum: WG	GS 84 UTM 2	Zone	32 N	- DVR	90		♦ HS ▼ SPT(S) ▼ 20 40 60	SPT(C)	×	Carbona	ate	16 %	PCPT Ti	4 6 p Resistar	8 nce (MPa)	
	Sample		L	_ab sp	becimen	Se Leve -2	abed el (m): 20.4	Note	es:		Cor Core	e Ru and Qua	ns lity			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shears	UCS 2.0 MPa	* 2 w N	Loss on 2 4 Voisture	Ignition 6 Content	8 %	— 20 6 ● Poin 0.1 Polativ	40 60 t Load Str 0.2 0.3	$\frac{80}{0.4 \text{MPa}}$	
	0			0		Bou	undary	,	Geology					6	uo	△ Pocket Pen ▲ T	or Vane	W _P F	Plastic Li	imit	neni		e Density	(ivig/iii)	stribut ts ductiv
Drill tool	No. and type	Depth (m)		No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	RQD (%)	Fissure	1 Indurati	Lab varie	800 kPa	W _L L	Liquid Lii WP L	mit ww _s -	w∟ − 40 %	■ Bulk D Dry 1.6	<u>1.7 1.8</u> Density (Mo <u>1.8 2.0</u>	g/m ³)	Grain size dis Chemical tes Cyclic Tests Thermal Con Direct Simple Oedometer Triaxial
ed)		_ 24				24.1	44.5		LIMESTONE, muddy, white	Ma Ct						24								24	
Geobor-S (continue	21-C	- 25				•		, , , , , , , , , , , , , , , , , , ,	24.95 - 25.05 w. black flint nodules		60		0							O					
	22-C	- 26									57														
	23-C	27	- 23	8.1D	27.50						60									•					
		- 28				- - - - - - - - - - - - - - - - - - -			27.90 - 28.10 w. vertical fissures 28.15 - 28.25 w. black flint nodules							28								28	
	24-C	- 29				- - - - - - - - - -					63														
	1	1	Г		\sim	1			Borehole Log: KF-BH011		Dril	led:	J	WJ/	ELF		Date:	201	13-05-2	20 Re	port I	No.: 1			
		-		_	'()			Project: 36642 Kriegers Flak		Pre	pare	d: L	.TR/	LFJ		Date:	201	13-05-2	22 En	cl No	.:			
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ġ	N W	W		GI	ΕΟ.Ι	D K	-				Арр	prove	ed: L	AR.			Date:	201	13-08-0	08 Pa	ge:		5	/ 12	

E	oreho	le: k	KF-BH	011			Coo	rdinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone 3	32 N	- DVR	90		♦ HS ▼ SPT(S) 20 40 60	SPT(C) 80 N	Carbona	ite 12 16 %	– 2 4 PCPT Tip Re	6 8 sistance (MPa)	
	Sample		Lab s	specimen	Sea Leve -2	abed el (m): 0.4	Not	es:		Core Core	e Ru and Qua	ns Ility			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa	* Loss on 2 4 w Moisture	Ignition 6 8 % Content	 — 20 40 ● Point Loa 0.1 0.2 ■ Polative De 	60 80 ad Strength I _{s 50} 0.3 0.4MPa	
	0		0		Bou	ndary	1	Geology	1				s	uo	△ Pocket Pen ▲	Tor Vane	w _P Plastic Li	mit	e lunu		stribu ts ductiv
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	RQD (%)	Fissure:	1 Indurati	Lab Varie V r Intact UU 200 400 600	800 kPa	w _L Liquid Lir W _P h — —	nit ww _s w _L •	I.6 1.7 Bulk Densi Dry 1.6 1.8	<u>1.8</u> 1.9 ity (Mg/m ³) <u>2.0</u> 2.2	Grain size dis Chemical tes Cyclic Tests Thermal Con Direct Simple Oedometer
(pa		_ 30 -			-			LIMESTONE, muddy, white (continued)	Ma Ct						30				E	30	
Geobor-S (continu	25-C	- - - - - - - - - - - - - - - - - - -	-25.1D	30.50	-			30.70 - 30.75 w. black flint layer		53		0						©			
		-																			
	26-C	32								60					32					32	
		-																			
		33																			
	27-C	-								80									-> -		
		34	-27.10					34.05 w. few 1-3 mm marl flasers and seams							34					34	
	28-C	35								37											
		1	-	-	1		T.	Borehole Log: KF-BH011	1	Drill	ed:	J	WJ/	ELF		Date:	2013-05-2	0 Report I	No.: 1		
		_	-	-()			Project: 36642 Kriegers Flak		Pre	pare	d: L	.TR/I	LFJ		Date:	2013-05-2	2 Encl No	.:]
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В	orehol	e: K	(F-BH	011			Coo	rdinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum: W	/GS 84 UTM 2	Zone 3	32 N	- DVR	90		♦ HS ▼ SF	PT(S) ▼	SPT(C)	X Ca	rbonat	te 12 1	6 % P	— 2 CPT Tip I	4 6 Resistance	8 (MPa)		
	Sample		Lab s	pecimen	Sea Leve -2	abed el (m): 0.4	Not	es:		Core Core	e Rui and Qua	ns lity			UCS(Y) 0.5 1. Undrained) ■ 0 1.5 shear s	UCS 2.0 MPa	* Los 2 w Moi	ss on l 4 sture (gnition 6 8 Content	8 % (- 20 2 Point L 0.1 0	0 60 .oad Stren .2 0.3	80 gth I _{s 50} 0.4MPa	Other	Tests
	d)		cD		Bou	ndary m) I	_ 1	Geology			1		s	uo	△ Pocket F	Pen ▲ To	or Vane	w _P Plas	stic Lin	nit	tont	e		le.	stribu its	She
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SCR (%)	RQD (%)	Fissure	1 Indurati	 Intact UI 200 40 	U 10 600	800 kPa	W _L Liqu W	uid Lim V _P 	iit w w _s v ⊕ ⊕ — <u>30 4</u>	v _L	1.6 1 Bulk Der Dry 1.6 1	<u>.7 1.8</u> nsity (Mg/r <u>.8 2.0</u>	1.9 n ³) 2.2	Chemical tes Cyclic Tests Thermal Con	Direct Simple Oedometer Triaxial
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Во	rehol	e: K	(F-BH	011			Coo	rdinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone 3	32 N	- DVR	90		♦ HS ▼	SPT(S)	▼ SPT(C)	X Ca	arbona 8	te 12	16 %	2 PCPT T	4 ip Resi	6 8 stance (B (MPa)	
s	ample		Lab s	pecimen	Sea Leve -2	abed el (m): 0.4	Not	es:		Core 2 Core	e Rui and Qua	ns lity			UCS 0.5	S(Y) ■ <u>1.0 1.</u> ed shea	UCS 5 2.0 MPa	* Lo 2 w Mo	oss on 4 Disture (Ignition 6 Conten	10 //	- 20 ● Poir 0.1	40 nt Load 0.2	60 8 Strengt 0.3 0	th $I_{s 50}$ $\frac{4MPa}{(m^3)}$	Other Tests
	0		0		Bou	ndary		Geology	1		1		6	ы		et Pen ▲	Tor Vane	w _s Sa W _P Pla	astic Lir	nit	ment	Relativ	le Den	sity (ivig	(111)	stribut Shee
_	l typ∈	Ê	I type	1		5	Log		÷	(%	(%	(%	siures	urati	 Lab Intac 	tuu	Fail Cone	w _L Liq	quid Lin w _P	nit ww.s	W	• _{min} 1.6	1.7	1.8 1	.9	ests con con eter
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Dri	N	e d	Ň	De	De	Ē	ö	Description of <i>layers</i> and details	Š Č	4	Š	<u>ک</u> 1	5	1	5 200	400 60	0 800 kPa	10	20	30	40 %	1.6	1.8	2.0 2	.2	
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0) S-		-	33. ID	42.50				42.60 - 42.90 w. vertical fissure					C													
eobor		-			1			42.65 - 42.70 w. black flint layer																		
.Ö		43]																					
		-						43.15 w. 5 mm man seam																		
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В	orehol	e: K	(F-BH0 ⁻	11			Cool	rdinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone 3	32 N ·	DVR	90		♦ HS ⊽	7 SPT((S) ▼	SPT(C)	X Ca	rbonat	ite	16 0	2 4 PCPT T	4 in Resi	6 8 stance (8 (MPa)	
	Sample		Lab spe	ecimen	Sea Leve -2	abed el (m): 0.4	Note	es:		Core	e Rur and	IS iity			□ UC: 0.5	S(Y) 1.0	■ 1.5	UCS 2.0 MPa	* Los 2 w Mois	ss on I 4 sture (Ignition 6 Conter	n 8 % nt	20	40 nt Load 0.2	60 8 Strengt 0.3 0	0 th I _{s 50} .4MPa ,	Other Tests
					Bou	ndary		Geology		Cole	Qua	ity		c		ted Sn ket Per	iear s 1 ▲ To	or Vane	w _s Sat.	Moist	ture C mit	ontent	Relati	ve Den	sity (Mg	/m³)	Shear
	ype	_	ype		(m) _	60-						Ires	atio	● Lab	Vane	♦ Fa	all Cone	w _L Liqu	uid Lim	nit		e _{min}		10 1	e _{max}	o alst Sets Piple (
tool	and 1	m) ti	and 1		£	ation	hic L		oosit	%) 2	%) 2	%	issu	ndur		100			w	P — —	ww _s ∙⊕-⊖		■ Bulk	Density	(Mg/m ³	3) 3)	nical mal (omete
Drill	Ň	Depi	No.	Dep	Dep	Elev	Grap	Description of layers and details	Dep Age	TCF	SCF		ш 5	 1 (200	400	600	800 kPa	10	20	30	40 %	□ Dry	1.8	2.0 2	2	Cher Cher Direction
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ntinue	07.0				1																						
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Boreh	ole	: K	F-BH	011			Coo	rdinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum: WGS	84 UTM Z	Zone 3	2 N -	DVR	90		♦ HS ▼ SPT(8 20 40	S) ▼ SPT(C)) 🗙	Carbo	nate	16 0	2 6 PCPT 1	4 Fin Resis	6 8 stance (M	Pa)				
Samp	ble		Lab s	pecimen	Sea Leve -2	abed el (m): :0.4	Not	les:		Core a Core	e Rur Ind Qual	s			□ UCS(Y) 0.5 1.0	■ UCS <u>1.5</u> 2.0 MPa	a w	Loss o 2 4 Moistur	n Ignitio	on 8 9 ent	← 20 ← Poi 0.1	40 int Load 0.2	60 80 Strength 0.3 0.41	I _{s 50} MPa	Other Tests			
			0		Bou	ndary		Geology			1		0	uo	△ Pocket Pen	Tor Vane	W _s W _P	Sat. Mo Plastic	listure (Limit	Content	Relat	ive Dens	sity (Mg/m	stributi	ts Shea			
Drill tool No. and type		Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of <i>layers</i> and details	Age	TCR (%)	SCR (%)	rad (%)	LISSURG	Induration	 Lab vane Intact UU 200 400 	♦ Fail Cone 600 800 kP	w N	Liquid L W _P	-imit ww — ⊕- €	's WL → −	e _{min} <u>1.6</u> ■ Bulk □ Dry	1.7 Density	<u>1.8 1.9</u> (Mg/m ³)	Grain size dis	Chemical test Cyclic Tests Thermal Con Direct Simple Oedometer Triaxial			
୍ୱି	Ē	54						LIMESTONE, muddy, white (continued)	la Ct	-		1	5 1	3	54							1.0	2.0 2.2	54				
-1-1 Geobor-S (continue		55 _	41.1D 41.2D	- 55.10				54.50 - 54.60 w. 1-2 mm marl flasers 54.55 w. few silicified parts 54.70 - 55.00 w. 1-2 mm marl flasers 54.80 w. 8 mm marl seam 54.95 w. slickenside		18		2							• • •						•			
42-0		56		-	-			55.90 - 56.00 w. 90 mm black flint nodule		73					56									56				
		57		-	-					80		17																
		58		_	-			57.75 - 58.10 w. 1-2 mm marl flasers		00					58									58				
			43.1U	58.42-58.60 _	-			58.30 - 58.55 w. many 1-2 mm marl flasers 58.50 w. few 3-5 mm marl seams											•									
		59		-	-			58.90 - 58.95 w. black flint nodules		67																		
	_		_	\cdot				Borehole Log: KF-BH011		Drille	ed:		NJ/E	 LF		Date:	20	13-05-	-20 F	Report	No.: 1							
(_		-	• (Project: 36642 Kriegers Flak		Prep	are	d: L ⁻	rr/Lf	=J		Date:	20	13-05-	-22 E	Encl No).:							
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Bore	ehole	e: K	(F-BH	011			Coo	rdinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone 3	32 N -	DVR 9	0		♦ HS	▼ SP	T(S) ▼	SPT(C	C) 🗙	Carb	onate	e 12	16 0	2 6 PCPT 1	4 in Resis	6 8 stance (MF	Pa)	
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San	nple		Labs	specimen	Sea Leve -2	abed el (m): 0.4	Not	es:		Core 2 Core	e Run and Quali	s y			0. Undr	UCS(Y) 5 1.0 ained s	■ 1.5 shear s	UCS 2.0 Mi	Pa w	Loss 2 Moistu	on lo 4 ure C	gnition 6 Conten	8 %	← 20 6 ● Poi 0.1 Polati	40 nt Load 0.2	60 80 Strength I 0.3 0.4M	s 50 <u>APa</u>	Other Tests
			0		Bou	ndary		Geology	1		I		,	uo		ocket P	en ▲ T	or Van		Plastic	c Lim	nit	neni	e la	ve Dens	ing (ing/in	stribut	ts ductiv e Shei
Drill tool No. and type		Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of layers and details	Deposit Age	TCR (%)	SCR (%)	T Fissure	5 1	Indurati	 Ini 20 	tact UU	600	800 kl	Pa	Liquid W _P I-	Limi \ 6 20	it w w _s ⊕- ↔ - 30	w∟ − 40 %	■ Bulk	1.7 Density 1.8	1.8 1.9 (Mg/m ³) 2.0 2.2	Grain size di	Chemical tes Cyclic Tests Thermal Con Direct Simple Oedometer Triaxial
ed)		60		-				LIMESTONE, muddy, white (continued)	Ma Ct						60												60	
nuituo 45 S-Jo	5-C	- - -						60.45 - 60.90 w. 1-2 mm marl flasers		90	2	3																
Seobc		61		-				60.80 - 60.85 w. many 3-5 mm mark seams																				
			45.1U	61.10-61.25				61.25 - 61.65 w. silicfied parts														•						
				-																								
46	6-C	62								63					62												62	
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47	7-C	-		-						100	Ę	3																
		64						63.55 w. 5 mm marl seam 63.65 - 63.85 w. grey flint nodules, w. silicified parts				E			64												64	
				-				64.15 w. 5 mm marl seam																				
		- - -	47.1U	64.35-64.55			0	64.20 - 64.65 w. 3-6 mm marl seams 64.50 - 64.60 w. few silicified parts 64.65 - 64.80 w. few light grey flint nodules, w.				ŀ																
48	3-C	65		-				very silicified parts		60																		
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E	Boreho	ole: I	KF-BH	011		Co	oordinates (m): E: 755,000.5 N: 6,103,100.2 Grid & Datum:	WGS 84 UTM	Zone 32	2 N - D\	/R 90		♦ HS ▼ SPT(S)	SPT(C) 80 N	Carbonate	12 16 %	PCPT Tip Resistance	8 e (MPa)	
	Sample	•	Lab	specimen	Seabe Level (-20.4	ed No m): k	otes:		Core ar	Runs nd			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 2.0 MPa	* Loss on Ig 2 4 w Moisture Co	nition 6 8 % ontent	− 20 40 60 • Point Load Strem 0.1 0.2 0.3	80 igth I _{s 50} 0.4MPa	Other Tests
					Bound	ary	Geology	1		J		ц	△ Pocket Pen ▲	Tor Vane	w _s Sat. Moistu w _P Plastic Limi	re Content t	Relative Density (N	/lg/m³)	tributi ts Shea
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%)	SUR (%) RQD (%)	Fissures	Induratio	 ■ Lab Vane ♦ Intact UU 5 200 400 600 	Fall Cone	w _L Liquid Limit W _P W I e 10 20	/ w _s w _L → → → 30 40 %	e _{min} 1.6 1.7 1.8 ■ Bulk Density (Mg/r □ Dry 0 1.6 1.8 2.0	e _{max} <u>1.9</u> m ³) 2.2	Grain size dis Chemical test Cyclic Tests Thermal Cont Direct Simple Oedometer Triaxial
ued)		_ 66					LIMESTONE, muddy, white (continued)	Ma Ct					66					66	
Geobor-S (contin	49-C		^{-49.1D}	66.60			66.55 w. 2x40 mm light grey marl seam		30	0						•			
	50-C			-					87	27			68					88	
		- - - - - - - - - - - -	50.1U	- 69.00-69.20 -												B			
		70		-	70.0 -9	0.4							70					70	
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E	Boreho	ole:	KF-BH	1015		Coc	ordinates (m): E: 759,002.1 N: 6,108,399.5 Grid & Datum: WGS 84 UTM	1 Zone	e 32 N -	DVR 9	0	♦ HS ▼ SPT(S) 20 40 60	SPT(C)	Carbonate	12 16 %	2 4 PCPT Tip Re:	6 8 sistance (MPa)	
	Sample	9	Lab	specimen	Seabed Level (m): -19.4	Not	tes:	Co Co	ore Runs and re Qualit	s y		□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa	* Loss on Ig 2 4 w Moisture C	Inition 6 8 % ontent	 — 20 40 ● Point Loa 0.1 0.2 Relative De 	60 80 d Strength I _{s 50} 0.3 0.4MPa	Other Tests
ill tool	o. and type	apth (m)	o. and type	epth	Boundary (m) evation	aphic Log		CR (%)	CR (%)	Eiceurae	Induration	 △ Pocket Pen ▲ ○ Lab Vane ♦ Intact UU 	Tor Vane Fall Cone	W_{p} Plastic Limit W_{L} Liquid Limit W_{p} V H e	it t v w _s w _L → → → –	e _{min} 1.6 1.7 ■ Bulk Densi		ain size distribu nemical tests cclic Tests ermal Conducti termal Conducti tect Simple She edometer
ة T	Z 1-LB	۵ ٥	Ž	<u> </u>	 	5	SAND medium non graded sl gravelly Ma Po	P	00 E	<u>د</u> 1	5 1	<u>- 5 200 400 600</u>	800 kPa	10 20	30 40 %	1.6 1.8	2.0 2.2	
tary drilling			1.1D 1.2D	0.10 0.30-0.50	-		June 1 June 2 June 2 <td>1</td> <td></td> <td></td> <td></td> <td>Δ</td> <td></td> <td>•</td> <td></td> <td></td> <td>2.9</td> <td>54</td>	1				Δ		•			2.9	54
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E	Boreho	ole:	KF-B	H015		Coo	ordinates (m): E: 759,002.1 N: 6,108,399.5 Grid & Datum:	WGS 84 UTM	Zone 32 N -	DVR 9	90		♦ HS ▼ SPT(S) ▼ 20 40 60	7 SPT(C)	X (12 16 %	PCPT	4 Tip Resi	6 8 stance (MF	Pa)	
	Sample	9	Lab	specimen	Seabed Level (m) -19.4	No):	tes:		Core Run and Core Qual	s tv			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 2.0 MPa	* L 2 w N	Loss on Igr 2 4 Noisture Co	nition 6 8 %	— 20 ● P0 0.1	0 40 oint Load 1 0.2	60 80 Strength I. 0.3 0.4M	50 1Pa	Other Tests
					Boundary	y	Geology			.,		n	△ Pocket Pen ▲ T	for Vane	w _s S w _P P	Sat. Moistur Plastic Limit	e Content	Rela	ative Den	sity (Mg/m°	() (tributi	Shea
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth Elevation	Graphic Log	Description of <i>layers</i> and details	Deposit Age	TCR (%) SCR (%)	КОП (%)		Induratio	 ○ Lab Vane ◇ F ● Intact UU 200 400 600 	-all Cone 800 kPa	w _L Li	iquid Limit w _P w ├─── ⊕ 0 20 3	'w _s w _L - → - 30 40 %	e _{min} <u>1.0</u> ■ Bull □ Dry	6 1.7 k Density 6 1.8	1.8 1.9 (Mg/m ³) 2.0 2.2	Grain size dis	Chemical test Cyclic Tests Thermal Conc Direct Simple Oedometer Triavial
ed)	5-TW	6	5.1U	6.15-6.40	-	. <mark> </mark>	CLAY TILL, silty, sandy, sl. gravelly,	GI Gc		İ			6			•					6	
ontinu		Ē	5.2U	6.40-6.57	-	 	calcareous, grey (continued)						Δ									
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E	Boreho	le:	KF-B	H015			Coo	rdinates (m): E: 759,002.1 N: 6,108,399.5 Grid & Datum:	WGS 84 UTM	Zone 32 N - D	VR 9	0		♦ HS ▼ SPT(S) ▼ 20 40 60	SPT(C)	Carbonate	12 16 %	PCPT Tip Resistance (MPa	a)	
	Sample	•	Lal	o specimen	Sea Leve -1	bed I (m): 9.4	Not			Core Runs and Core Quality	r			□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear	UCS 2.0 MPa	* Loss on Igr 2 4 w Moisture Co w Sat. Moistur	nition 6 8 % ontent re Content	 → 20 40 60 80 ♦ Point Load Strength Is 0.1 0.2 0.3 0.4Mi Relative Density (Mg/m³) 	Other	r Tests
	be		e		Boui (I	ndary n)	<u>b</u> o	Georogy			v d			 △ Pocket Pen ▲ T ● Lab Vane ◇ F 	or Vane all Cone	w _P Plastic Limit w _L Liquid Limit		e _{min} e _{max}	distribu ests ts	ple She
Drill tool	No. and ty	Depth (m)	No and th	Depth	Depth	Elevation	Graphic Lo	Description of <i>layers</i> and details	Deposit Age	TCR (%) SCR (%) ROD (%)		5 1	5	 Intact UU 200 400 600 	800 kPa	w _P w ↓ → ⊕ 10 <u>0</u> 20 3	$W_{\rm S} W_{\rm L}$ $- \Rightarrow - \mathbf{I}$ 30 40 %	1.6 1.7 1.8 1.9 ■ Bulk Density (Mg/m³) □ □ □ Dry 1.6 1.8 2.0 2.2	Grain size Chemical t Cyclic Test	Thermal C Direct Sim Oedometer Triaxial
(pənu		12			-	-	<u> </u>	CLAY TILL, silty, sandy, sl. gravelly, calcareous, grey (continued)	GI Gc					12					12	
Continue of the contract of th	11-TW 12-C	- 13	= 11.11 11.21 11.31) 13.30 J 13.35-13.55 J 13.55-13.75	· · · · · · · · · · · · · · · · · · ·	- - - - - - - - - - - - - - - - - - -		13.20 - 13.75 very silty		7						 €1 ⊙				
	13-TW 14-C	- 15 - 15 	13.11 13.21 13.31 13.31 13.41	0 15.00 0 15.15-15.35 J		- - - - - - - - - - - - - - - - - - -		14.70 - 15.80 very sandy		30						© 0			•	
	15-TW 16-C	- - - - - - - -	15.1	J 16.35-16.55	16.2	-35.6		CLAY TILL, silty, sandy, gravelly, calcareous, grey 16.55 - 16.80 w. black stone	GI Gc	57	_					•			1 6	
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E	oreho	le: k	KF-BH	015		(Coor	dinates (m): E: 759,002.1 N: 6,108,399.5 Grid & Datum:	WGS 84 UTM	Zone 3	2 N - D'	VR 90		♦ HS ▼ SPT(S) 20 40 60	▼ SPT(C)	Carbonate	; 12 16 %	2 4 6	8 e (MPa)	
	Sample		Lab s	pecimen	Sea Leve -19	bed I (m): 9.4	Note	295:		Core a Core	Runs nd Qualitv			□ UCS(Y) ■ 0.5 1.0 1.5	UCS 5 2.0 MPa	* Loss on Ig 2 4 w Moisture Co	inition 6 8 % ontent	 ── 20 40 60 ♦ Point Load Strer 0.1 0.2 0.3 	80 ngth I _{s 50} 0.4MPa	Other Tests
					Bour	ndary		Geology	1				5	△ Pocket Pen ▲	Tor Vane	w _s Sat. Moistu w _P Plastic Limi	ire Content it	Relative Density (N	/ig/m²)	Shea
Drill tool	No. and type	Depth (m)	No. and type	Depth	Depth	Elevation	Graphic Log	Description of layers and details	Deposit Age	TCR (%)	SCR (%) RQD (%)	Fissures	Induratio	 ■ Lab Vane ◆ Intact UU 5 200 400 600 	Fall Cone	w _L Liquid Limit W _P w I ——e 10, 20	t vw _s w _L > - → - 30 40 %	Emin 1.6 1.7 1.8 Bulk Density (Mg/r Dry 1.6 1.8 2.0	1.9 1.9 1.3 1.9 2.2	Grain size dis Chemical test Cyclic Tests Thermal Cont Direct Simple Oedometer Triaxial
ontinued)		_ 18 _ _						CLAY TILL, silty, sandy, gravelly, calcareous, grey (continued)	GI Gc					18					18	
Geobor-S (c	19.0	- - - - 19										_								
	10-0		18.1D 18.2D 18.3D 18.4D 18.5U	19.30 19.45-19.70			9 			50						● ⊢ - ●	×			•
	19-C	20			20.2	-39.6		CLAY TILL, silty, very sandy, gravelly,	GI Gc	70		-		20					20	
							. 	20.20 - 28.20 very sandy								• •				
0 00.24	20-C	-	-20.1D	21.50				21.50 - 21.70 w. black stone		55				Δ		•				
	1	- - 22	20.2D 20.3D 20.4D											22					22	
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					1			Borehole Log: KF-BH015	·	Drille	ed:	SKA	VELF		Date:	2012-05-13	Report I	No.: 1		
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E	Boreho	ole:	KF-B	H015		Coc	rdinates (m): E: 759,002.1 N: 6,108,399.5 Grid & Datum: WGS	84 UTM Z	2one 32 N - D\	/R 90		♦ HS ▼ SPT(S) 20 40 60	▼ SPT(C)	X Carbonate	PCPT Tip Resistance (MPa)	
Drill tool	No. and type	Depth (m)	Vo. and type	specimen	Seabed Level (m): -19.4 Boundary (m) to to to to to to to to to to to to to	Graphic Log	Geology Description of <i>layers</i> and details	Age	Core Runs and Core (%) XOD (%)	Fissures	Induration	□ UCS(Y) ■ 0.5 1.0 1.5 Undrained shear △ Pocket Pen ▲ ◎ Lab Vane ◇ I ● Intact UU	UCS 2.0 MPa strength Tor Vane Fall Cone	* Loss on Ignition 2 4 6 8 9 w Moisture Content w _s Sat. Moisture Content w _p Plastic Limit w _p W w _s w _L $H \rightarrow e \rightarrow H$ 10 20 20 40 8	− 20 40 60 80 Point Load Strength I _{s 50} 0.1 0.2 0.3 0.4MPa Relative Density (Mg/m ³) e _{min} [e _{max} 1.6 1.7 1.8 1.9 Bulk Density (Mg/m ³) Dry	orten size distribution Offenical tests Orolio Tests Thermal Conductivity Direct Simple Shear Dedometer Trixial
seobor-S (continued)		_ 24	22.2U 22.3U 22.4U 22.5U 22.6U 22.7U	23.95-24.20			CLAY TILL, silty, very sandy, gravelly, G calcareous, grey (continued) 24.20 - 24.35 w. black stone	GC GC								•
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	24-C ⁻	_ 26	24.1L 24.2L 24.3L	26.25-26.50 26.50-26.75 26.75-27.00					100					↔ @0	26	
	25.0	27	24.4	27.00-27.30		·										
	25-C	- 28	9		28.2 .47.6		LIMESTONE, muddy, white M	la Ct	100							
	27-C				-		29.70 - 29.85 w. many black flint nodules		33 0						*	
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Bore	ehole	e: K	(F-BH	015			Coo	rdinates (m): E: 759,002.1 N: 6,108,399.5 Grid & Datum: WGS 84 L	JTM Zo	one 3	2 N - C	VR 90)		♦ HS ▼ SPT(S) ▼ 20 40 60	SPT(C)		onate	2 16	6 %	— 2 PCPT Tip	4 6 Resista	8 nce (MPa)	
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						Boundary		Geology		Cole	Quality		Ę		Poc	ket Pe	n ▲ T	or Van	e w	Sat. Plas	Moist tic Lin	ure C nit	ontent	R	elative	Densil	ty (Mg/r	n³) 🗄	s noun	Shear
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	36-C]	43						43.20 - 43.25 w. black flint nodules 43.50 - 43.60 w. black flint nodule 43.70 - 43.75 w. black flint nodule		57		-			4													44		
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Geological survey of Denmark and Greenland (GEUS) Øster Voldgade 10 DK-1350 Copenhagen K Denmark GEUS is a research and advisory institution in the Danish Ministry of Climate, Energy and Utilities