DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2006/12

Kortlægning af grundvandsmagasiner i Vejle Amt 2004

Erik Skovbjerg Rasmussen

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE
MILJØMINISTERIET

GEUS

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Kortlægning af grundvandsmagasiner i Vejle Amt 2004

Sammenfatning

Denne rapport indeholder en tolkning af 2 seismiske linier (Thyregod og Viuf) skudt i Vejle Amt i 2004. Endvidere indeholder del 2 en afrapportering af arbejdet, som pågår med at opstille en ny litostratigrafi for den miocene lagserie i Danmark.

Den seismiske linie ved Thyregod viser at Billund deltaet kiler ud lige vest for Thyregod og at der øst herfor ikke er de store tykkelser af sand på dette stratigrafiske niveau. Bastrup sandet er veludviklet vest for Thyregod, men har formentligt en noget varieret mægtighed øst for byen.

Den seismiske linie ved Viuf indikerer at der er en kile ved Almind, som tilhører Hvidbjerg sandet (del af Billund sandet). En korrelation til en nærliggende boring, Christiansminde, hvor der er gennemboret en forholdsvis tyk Miocæn lagserie, indikerer at der findes et gruslag på 10 til 15 m tilhørende Hvidbjerg Led og Kolding Fjord Formationen.

Nye resultater fra naboamterne Ringkøbing og Århus antyder at der måske skal revideres på den miocæne stratigrafi. Nogle af de dybereliggende store grundvandsmagasiner ligger måske ubeskyttet i dele af det centrale Jylland. Dette har stor betydning for udpegning af beskyttelsesområder her, samt for hele kortlægningsarbejdet af grundvandsmagasiner i det centrale Jylland.

Arbejdet med opstillingen af en ny litostratigrafi blev påbegyndt i 2004 og der er nu defineret 5 formationer og 5 led. Disse enheder er markeret med fremhævet skrift nedenunder.

Vejle Fjord Formationen er revideret og opdeles nu i **Vejle Fjord Sand Led** og **Vejle Fjord Ler** Led. **Brejning Ler** Led opgraderes til **Formation**. Klinting Hoved Formationen defineres formelt. Ribe Formation revideres og inddeles i 2 nye led; **Hvidbjerg Led** og **Billund Led**. Arnum Formationen inddeles i 3 nye led, nemlig **Vandel Silt Led**, Sdr. Vium Led og NN Led. Odderup Formationen kommer til at inkludere Stauning Led og det kulførende Fasterholt Led. De øvre miocæne lag inddeles i **Hodde -, Gram – and Marbæk Formationerne**. Gram Formationen kommer også til at inkludere Glaukony Ler Led.

Indledning

Denne rapport indeholder en tolkning af 2 seismiske linier, der er skudt i 2004. Den ene linie er øst – vest løbende linie skudt mellem Thyregod og Vonge den anden repræsenterer en nord – syd gående linie ved Viuf, nord for Kolding.

Endvidere er der en afrapportering af arbejdet med at lave en nye litostratigrafisk inddeling af den miocæne lagserie i Danmark. Definitionen af de litostratigrafiske enheder er på engelsk, da dette er den formelle måder at gøre det på.

Geologisk ramme

De Paleogene og Neogene sedimenter, der blev aflejret for 65 til 5 millioner år siden i det østlige Nordsø bassin består hovedsageligt af ler og sand. Kalkaflejringer kendes fra den tidligste del af perioden.

Paleogenet, der dækker det geologiske tidsrum fra 65 millioner år til 23 millioner år, startede med aflejring af koldtvandskarbonater. Altså, sedimenter dannet i det hav eller på havbunden i det hav som de levede i. I den østlige del af Danmark består disse karbonater hovedsageligt i form af bryozor banker og koral rev. For omkring 62 millioner år siden ændredes dette aflejringsmønster markant således at der i den resterende del af Paleogen aflejredes overvejende lerede sedimenter, som stammede fra nedbrydningen af de landområder, der omkransede den daværende Nordsø. Aflejringen skete på forholdsvist dybt vand.

For ca. 23 millioner år siden, ved begyndelsen af den periode geologerne kalder Miocæn, blev der land i det område vi i dag kender som Danmark. Landet var på det tidspunkt karakteriseret ved store deltaer og kystsletter, som byggede ud i Nordsøen fra bjergene i nord (Norge). Udbygningen af deltaer og kystsletter dominerede de første 7 millioner år af Miocæn perioden (Fig. 1). I løbet af disse 7 millioner år skete der tre markante udbygninger af deltaer, hovedsageligt fra Norge. Den første deltaudbygning nåede helt ned til Sønderjylland. Herunder aflejredes tykke sandlag kendt som Ribe Formationen. I det centrale Jylland aflejredes i en periode tykke sandlag som er blevet kaldt Billund sandet Fig. 1). Efter aflejringen af Ribe Formationen steg havet og overvejende lerede sedimenter tilhørende Arnum Formationen blev aflejret. Havet nåede ca. ind til Silkeborg området. Herefter rykkede landet igen søværts mod sydvest og sandrige deltaaflejringer blev afsat i form af Bastrup sandet. Udbygningen af Bastrup sandet nåede ikke så langt sydvest på som Ribe Formationen. En ny stigning af havet, betød at landet igen rykkede tilbage til Silkeborg området. Udbygningen af deltaer kulminerede ved overgangen fra Nedre til Mellem Miocæn, hvor store sumpområder medførte aflejringer af tykke brunkulslag i Midtjylland (Fig. 2). Disse lag er kendt som Odderup Formationen.

For ca. 15 mio. år siden, i begyndelsen af Mellem Miocæn, skete der en markant ændring mod et varmere klima der førte til at havniveauet steg og oversvømmede store landområder omkring Nordsøen. Dette store hav kaldes populært for "Gram Havet". De geologiske vidnesbyrd fra dette hav er aflejringer af marine, til tider fossilholdige, lerbjergarter kendt som Hodde og Gram Formationerne. Under denne varme periode (det midt miocæne klimatiske optimum) lå kystlinien formodentligt lidt nord for Limfjorden langs en forkastningszone kaldet Fjerritslev Forkastningen (Fig. 3). Dette er dog kun ét forslag, måske var kystlinien placeret væsentligt nordligere, og havet dækkede måske store dele af det nuværende Sverige helt op til Göteborg. Vi ved det ikke helt præcist, fordi senere istider over Danmark har slettet alle spor af Gram Havet i Nordjylland og Skagerrak–Kattegat området.

I den sidste del af Miocæn begyndte kysten igen at bygge ud i Nordsøen. Denne udbygning skete både fra nord og fra øst (Fig. 4). Ved Miocæns afslutning lå kystlinien helt ude i den centrale del af Nordsøen (Fig. 5) der langsomt var ved at være fyldt op af de nedbrydningsprodukter som igennem Miocæn var blevet eroderet bort fra de norske fjelde og de centraleuropæiske bjergkæder.

Litostratigrafi

De nyere undersøgelser af den øvre oligocæne – miocæne lagserie har vist at den tidligere litostratigrafiske opdeling er for simpel. Derfor vil der i nærværende undersøgelse blive benyttet en litostratigrafi for den miocæne lagserie, der er kraftig revideret (Dybkjær et al. 1999; Rasmussen et al. 2002)(Fig. 6 og 7).

Den ældste litostratigrafiske enhed er Vejle Fjord Formationen. Den nederste del af Vejle Fjord Formationen, Brejning Led, henregnes til oligocænet, så den miocæne lagserie starter med Vejle Fjord Leret. Vejle Fjord Leret efterfølges af Vejle Fjord Sand og Hvidbjerg sand. I det centrale og vestlige Jylland er der kortlagt et større deltakompleks, som er samtidig med Vejle Fjord Formationen. Dette benævnes Billund sand. I det sydlige Jylland aflejredes et meget sandrigt system, som er en videre udbygning af Billund deltaet, men som dog er isoleret fra Billund deltaet. Dette sandrige system hedder Ribe Formationen. Over disse enheder, der overordnet tilhører Vejle Fjord Formationen, kommer Arnum Formationen, der hovedsageligt består af lerede sedimenter. Den nederste del af Arnum Formationen, som består af sandrige sedimenter benævnes Kolding Fjord sand. De minder meget om Vejle Fjord Formationen, men er yngre og udgør ikke en del af Vejle Fjord systemet. I de nordlige og østlige egne af Jylland kiler der sig et sandlag ind i den lerede del af Arnum Formationen. Dette lag benævnes Bastrup sand. I forbindelse med en ny kystudbygning i den øverste del af Arnum Formationen aflejredes finsand rigt på tungmineraler. Disse sandlag kaldes for Stauning sand. Over Arnum Formationen følger den sandrige Odderup Formation. Herover træffes kun lerrige sedimenter i Jylland. Disse lag er kendt som Hodde Formationen og Gram Formationen.

Der er endnu ikke konstrueret et prækvartært kort over de miocæne formationer, som omtalt ovenfor, men den overordnede fordeling af de miocæne og pliocæne i det danske område er vist i Rasmussen (2004). Her ser man at de Miocæne lag bliver ældre mod øst og nordøst. Dette er en konsekvens af den markante neogene og kvartære hævning og erosion.

Data

De 2 seismiske linier, Thy1 og Vi1 danner basis for nærværende rapport. Derudover er der anvendt data fra boringerne: Brande DGU 104.1964 og Christiansminde DGU 124.529.

Seismisk tolkning

THY1(Fig. 8, 9 og10)

Der er erkendt 3 sekvenser i den miocæne lagserie: Sekvens B, C og D (Fig. 9). Det seismiske signal er dårlig under topografiske højdeområder.

Basis af sekvens B er placeret ved en højamplitude og kontinuerlig reflektor, som kan følges regionalt. Generelt er sekvens B karakteriseret ved et parallelt til subparallelt reflektionsmønster. I den nederste del af sekvensen ses en mere høj amplitude, gennemgående reflektor. I den vestlige del erkendes en kile, der er karakteriseret ved et clinoformt reflektionsmønster, der hælder mod øst. Der ses et klart pålap på kilen (Fig. 9). I den østlige del af sekvensen sker der en gradvis tilsløring af det parallelle reflektionsmønster.

Sekvens C er defineret ved en kontinuerlig, højamplitude reflektor. Herover følger en tynd zone karakteriseret ved et parallelt reflektionsmønster. Dette følges af et lavamplitude, subparallelt reflektionsmønster. Den øverste del af sekvens C er karakteriseret ved et parallelt reflektionsmønster, der dykker mod sydøst. Sekvensen bliver tyndere mos øst.

Basis af sekvens D er placeret ved en kontinuerlig, lavamplitude reflektor. Den nederste del af sekvens D er karakteriseret ved et parallelt til subparallelt reflektionsmønster. Mod øst bliver signalet meget svagt inden for sekvensen.

Den øverste del af den seismiske sektion er delvist transparent og den øvre grænse af sekvens D kan ikke erkendes.

De seismiske linier kan korreleres til en vandforsyningsboring ved Brande (Fig. 9). Denne boring gennemborer en tyk øvre til nedre miocæne lagserie omfattende Gram, Hodde, Odderup, øvre Arnum og Bastrup sandet. Sekvens B er ikke gennemboret, men tolkningen i området (Rasmussen 2004) indikerer at sekvensen kan korreleres til Vejle Fjord Formationen og for kilen mod vest til Billund sandet. Det klinoforme reflektionsmønster i Sekvens C Korrelerer til sandet sedimenter tilhørende Bastrup sandet (Fig. 9). Tolkningen tyder dog på at Bastrup sandet kiler ud mod øst og er formentligt noget tyndere mod øst end i boringen ved Brande. Sekvens C korrelerer veksellejrende lerede og sandede sedimenter fra øvre Arnum og Odderup formationerne. Ifølge boringen kan den blå horisont tolkes til at repræsenter sekvensgrænsen mellem Sekvens D og E (Rasmussen 2004). Over sekvensgrænsen følger lerede sedimenter fra Hodde og Gram Formationerne.

VUF(Fig. 11,12 og 13)

Der er erkendt 2 sekvenser i den miocæne lagserie: Sekvens B og C (Fig. 12). Disse bliver dog skarpt skåret omkring skudpunkt 450.
Basis af sekvens B er placeret ved en højamplitude og kontinuerlig reflektor. Sekvens B karakteriseret ved et parallelt til klinoformt reflektionsmønster (Fig. 12).

Sekvens C er defineret ved en kontinuerlig, men svag reflektor. Herover følger et delvist transparent reflektionsmønster. I den øverste del erkendes et mere højamplitude, subparallelt reflektionsmønster. Den øvre grænse er svær at erkende, men er placeret, hvor der sker en ændring af reflektionsmønsteret mod et transparent til kaotisk reflektionsmønster.

De seismiske linier kan korreleres til Christiansminde boringen (Fig. 12). Denne korrelation indikerer at den øverste del af sekvens B og nederste del af sekvens C er karakteriseret ved grusede aflejringer. Disse lag tolkes til at tilhører Hvidbjerg sandet/Billund sandet og Kolding Fjord Formationen og at det klinoforme reflektionsmønster afspejler en søværts progradering af kystlinie og efterfølgende transgression. Den øverste del af gruslaget tilhører sandsynligvis den nederste del af Kolding Fjord Formationen. De lerede aflejringer herover tolkes til Nedre Arnum Formation.

Sammenfatning af seismisk tolkning

På baggrund af nærværende undersøgelse samt tidligere tolkning af seismiske data i Vejle Amt og data indsamlet i de andre jyske amter, er der fremstillet et temakort, der gør rede for udbredelsen af potentielle miocæne grundvandsmagasiner i Jylland. I vise områder er data af en sådan kvalitet og tæthed at tykkelsen og udbredelsen kan angives ret nøjagtigt (Hansen og Rasmussen 2004).

På figurerne 14, 15 og 16 er vist udbredelsen af Billund og Bastrup sandet. Endvidere er der angivet, hvor et parallelt klinoformt reflektionsmønster er identificeret.

Konklusion

Den seismiske linie ved Thyregod viser at Billund deltaet kiler ud lige vest for Thyregod og at der øst herfor ikke er de store tykkelser af sand på dette stratigrafiske niveau. Bastrup sandet er veludviklet vest for Thyregod, men har formentligt en noget varieret mægtighed øst for byen.

Den seismiske linie ved Viuf indikerer at der er en kile ved Almind, som tilhører Hvidbjerg sandet (del af Billund sandet). En korrelation til en nærliggende boring, Christiansminde, hvor der er gennemboret en forholdsvis tyk Miocæn lagserie, indikerer at der findes et gruslag på 10 til 15 m tilhørende Hvidbjerg/Billund Led og Kolding Fjord Formationen.

Resultaterne i nærværende rapport samt tidligere og parallelt kørende projekter i Ringkøbing og Århus amter viser at der eksisterer store grundvandsmagasiner i central Jylland og dermed i den vestlige del af Vejle Amt. Kortlægningsarbejdet efter miocæne grundvandsmagasiner i den resterende del af amtet, er stadig mangelfuldt og behøver en yderligere indsamling af data, f.eks. boringer og seismik.

Nye resultater fra naboamterne Ringkøbing og Århus antyder at der måske skal revideres på den miocæne stratigrafi. Nogle af de dybereliggende store grundvandsmagasiner ligger måske ubeskyttet i dele af det centrale Jylland. Dette har stor betydning for udpegning af beskyttelsesområder her, samt for hele kortlægningsarbejdet af grundvandsmagasiner i det centrale Jylland.

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Figurliste

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Fig. 2: Palæogeografisk rekonstruktion af af Danmark for ca. 15 millioner af år siden i Miocæn.

Fig. 3: Palæogeografisk rekonstruktion af af Danmark for ca. 12 millioner af år siden i Miocæn.

Fig. 4: Palæogeografisk rekonstruktion af af Danmark for ca. 10 millioner af år siden i Miocæn.

Fig. 5: Palæogeografisk rekonstruktion af af Danmark for ca. 7 millioner af år siden i Miocæn.

Fig. 6: Korrelationspanel af boringer fra Sønderjylland og det centrale Jylland.

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Fig. 16: Sammensat kort over sandrige enheder i Billund og Bastrup sandet. Bemærk at et parallelt klinoformt reflektionsmønster er angivet med henholdsvis røde og gule streger.

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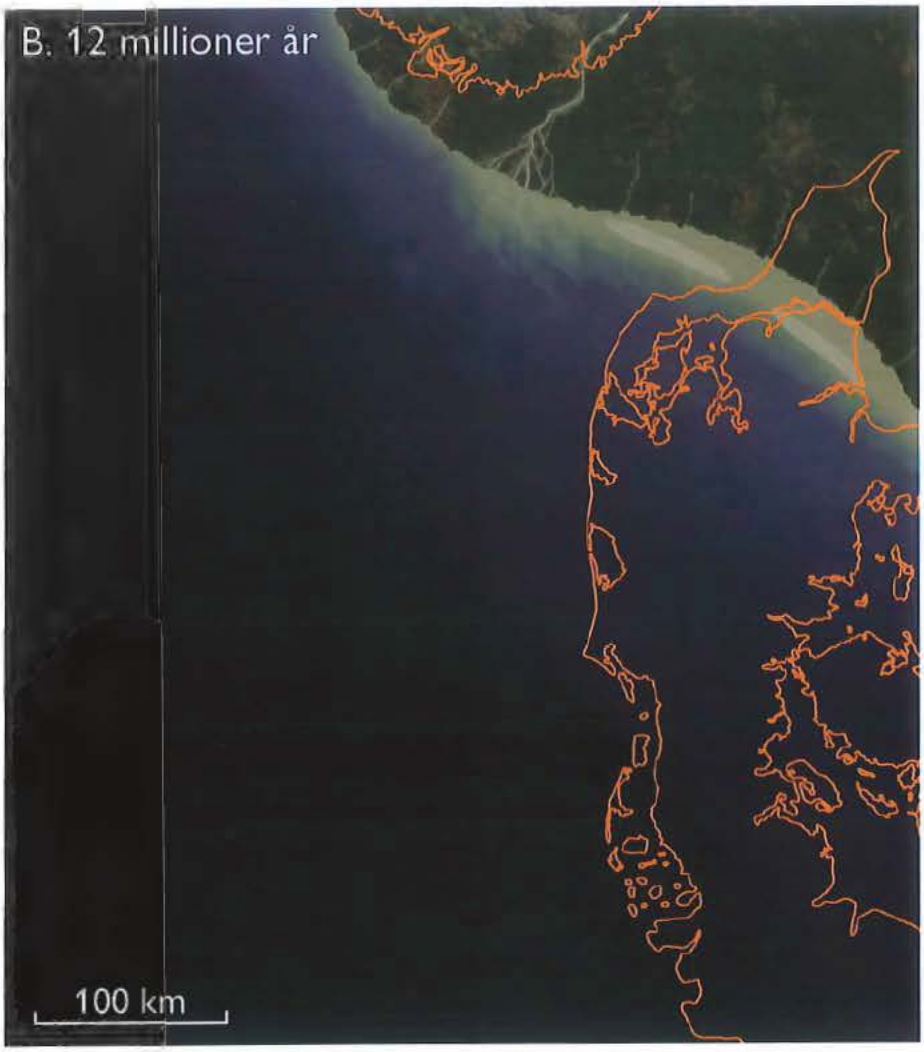
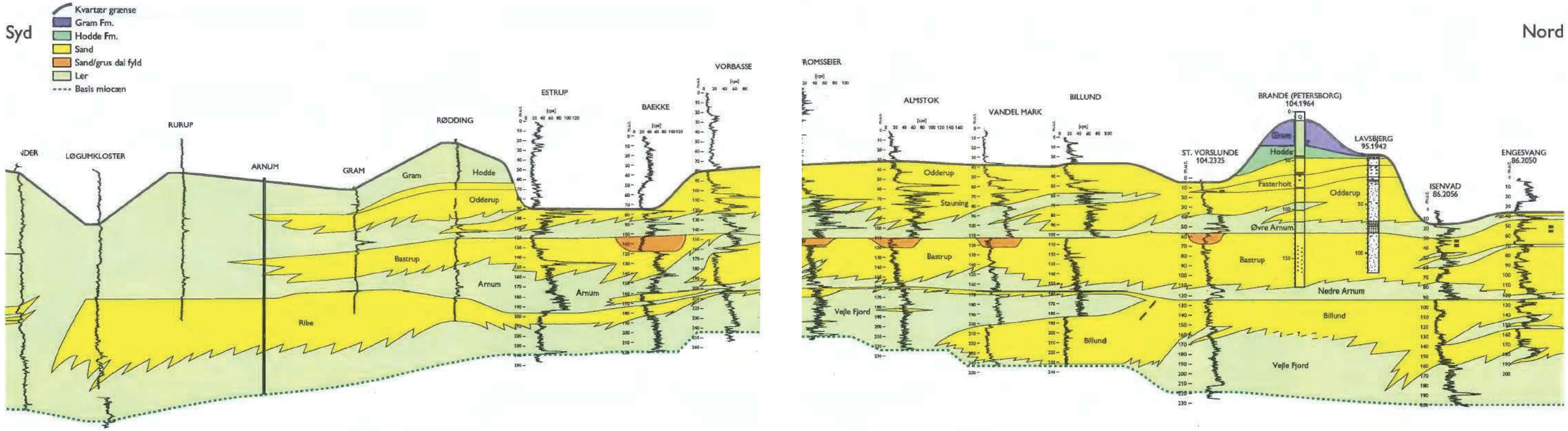


Fig. 3: Palæogeografisk rekonstruktion af af Danmark for ca. 12 millioner af år siden i Miocæn.

Fig. 4: Palæogeografisk rekonstruktion af af Danmark for ca. 10 millioner af år siden i Miocæn.

Fig. 5: Palæogeografisk rekonstruktion af af Danmark for ca. 7 millioner af år siden i Miocæn.



F'g. 6: Korrelationspanel af boringer fra Sønderjylland og det centrale Jylland.

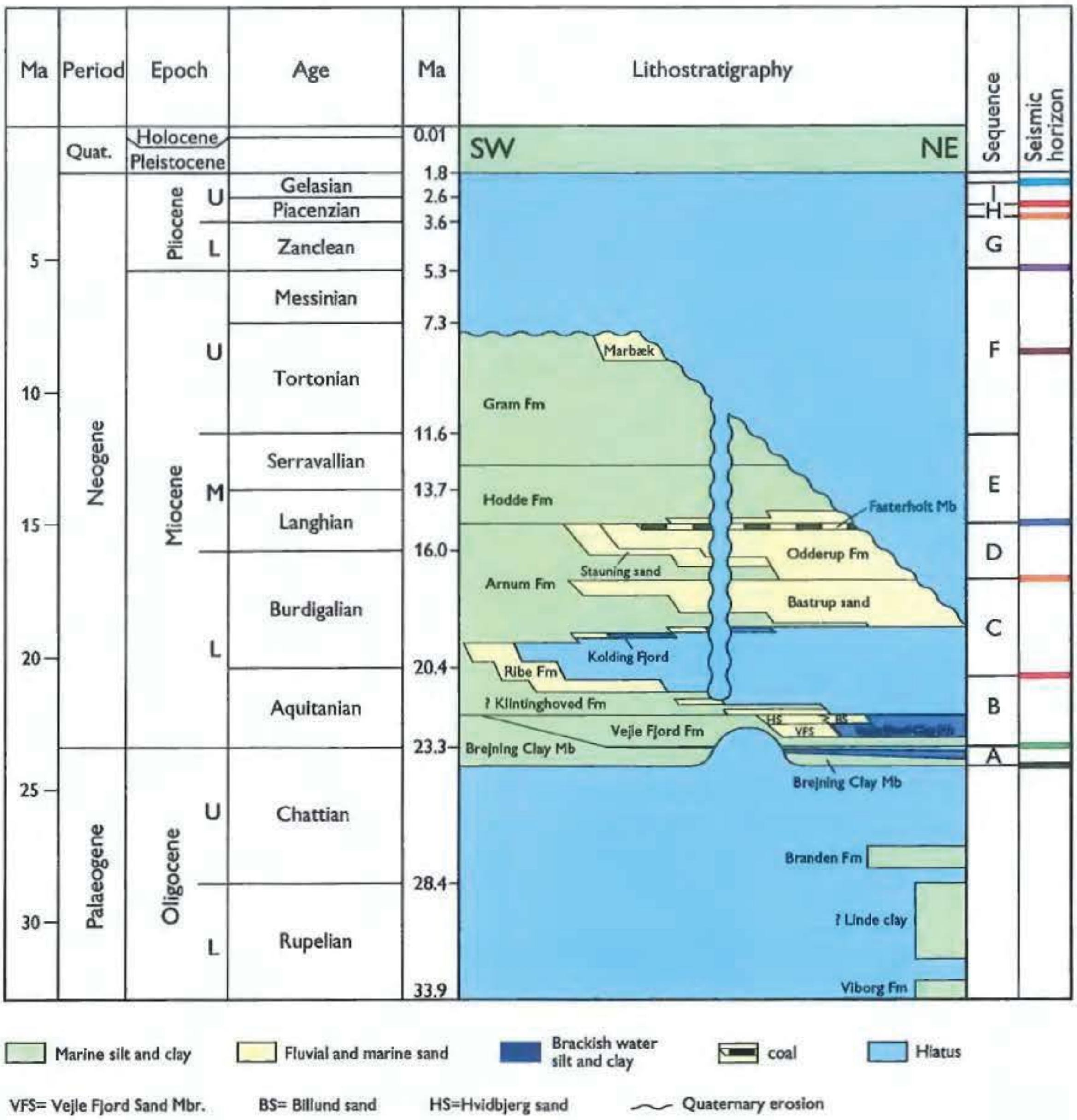


Fig. 7: Revideret litostratigrafi for den øvre oligocæne – miocæne lagserie. Bemærk at i kolonnerne til højre er angivet sekvenser og farvekode på seismiske nøglehorisonter.

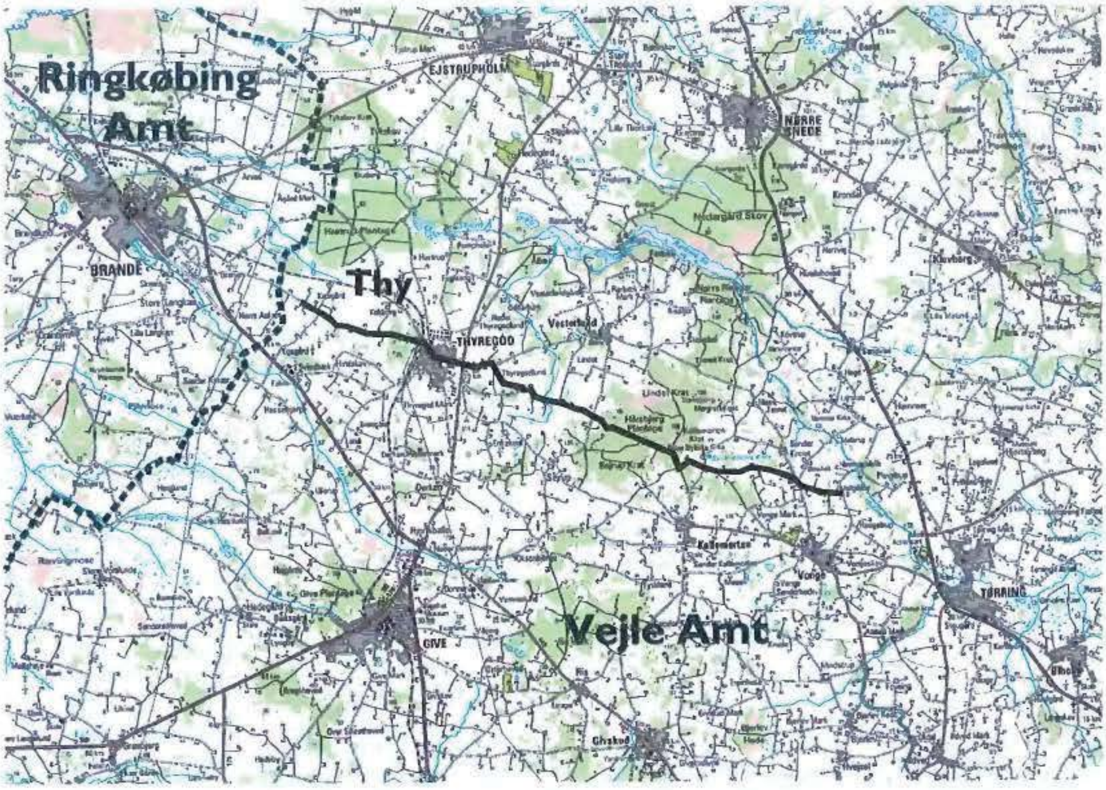


Fig. 8: Kort, der viser placeringen af den seismiske linie ved Thyregod (THY1).

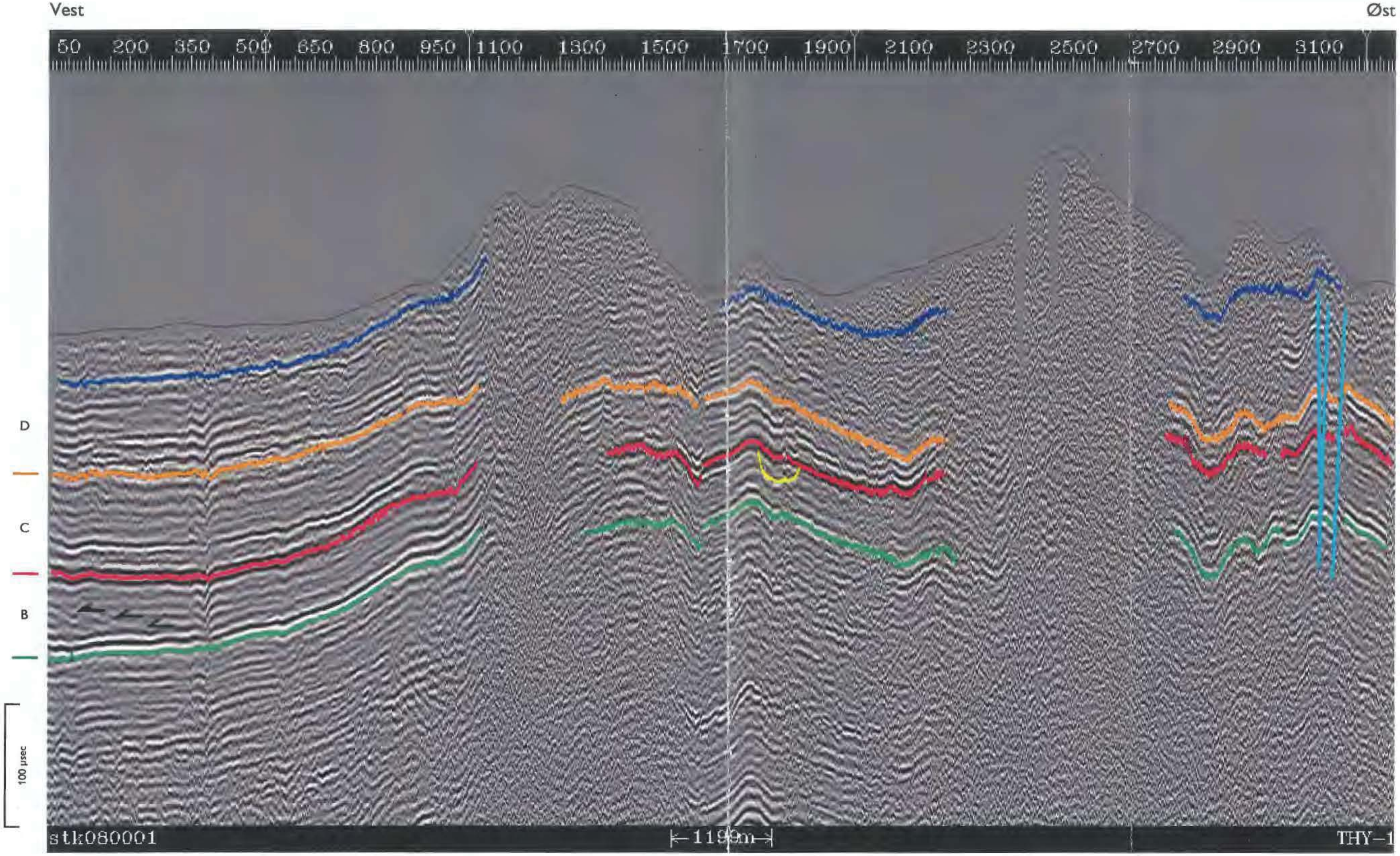


Fig. 9: Øst – vest gående seismisk linie (THY1) ved Thyregod.

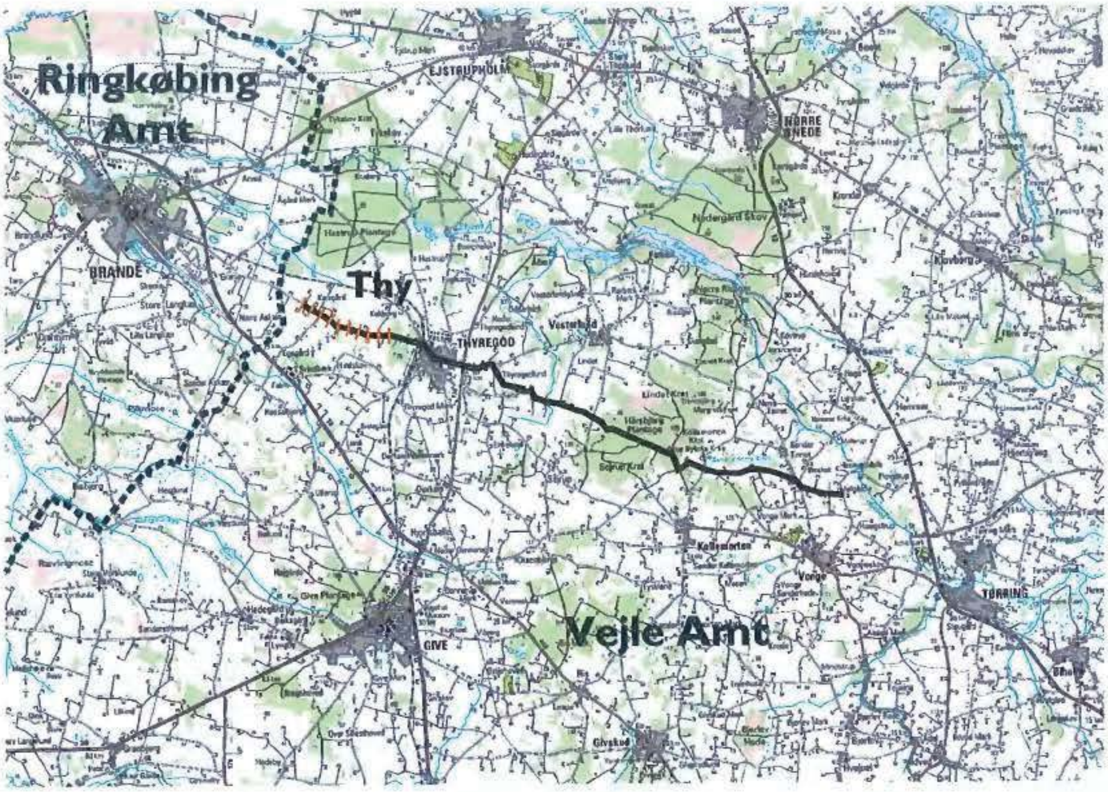


Fig. 10: Kort, der viser hvor der er identificeret parallelt klinoformt reflektionsmønster i Bastrup sandet.

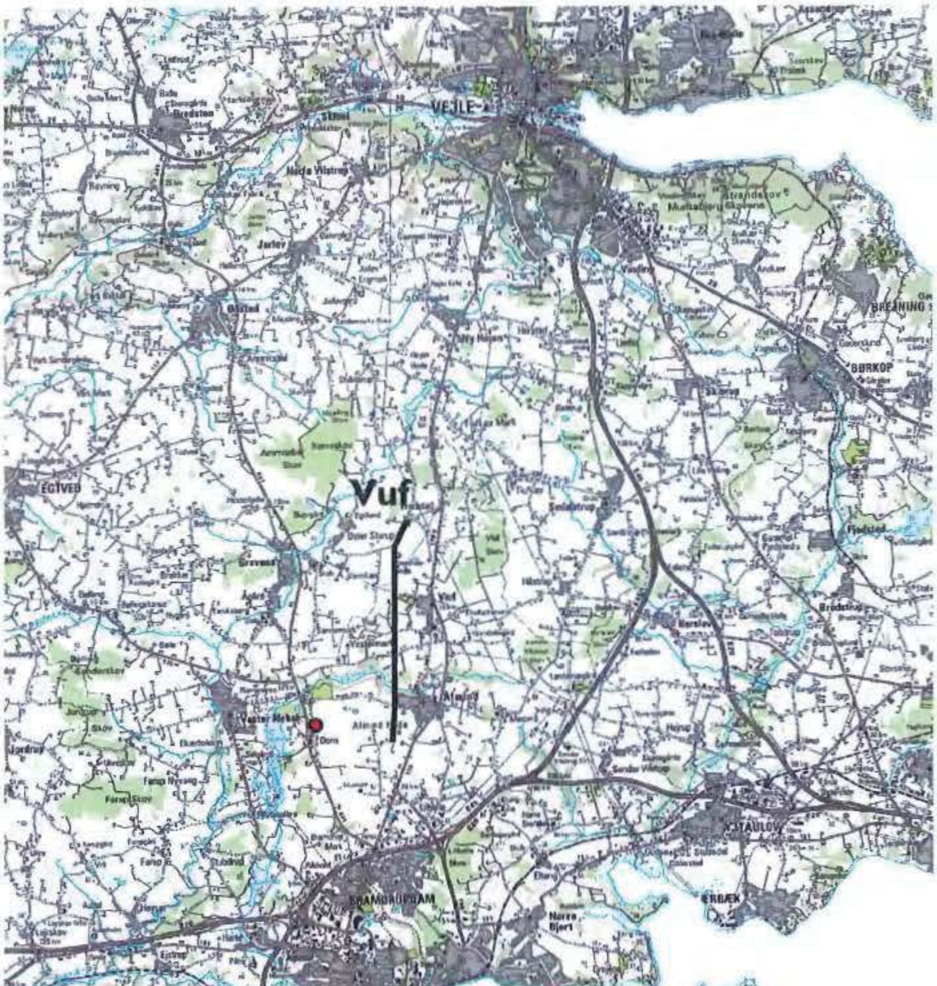


Fig. 11: Kort over placeringen af den seismiske linie (VUF1) ved Viuf og boringen Christiansminde ved Dons.

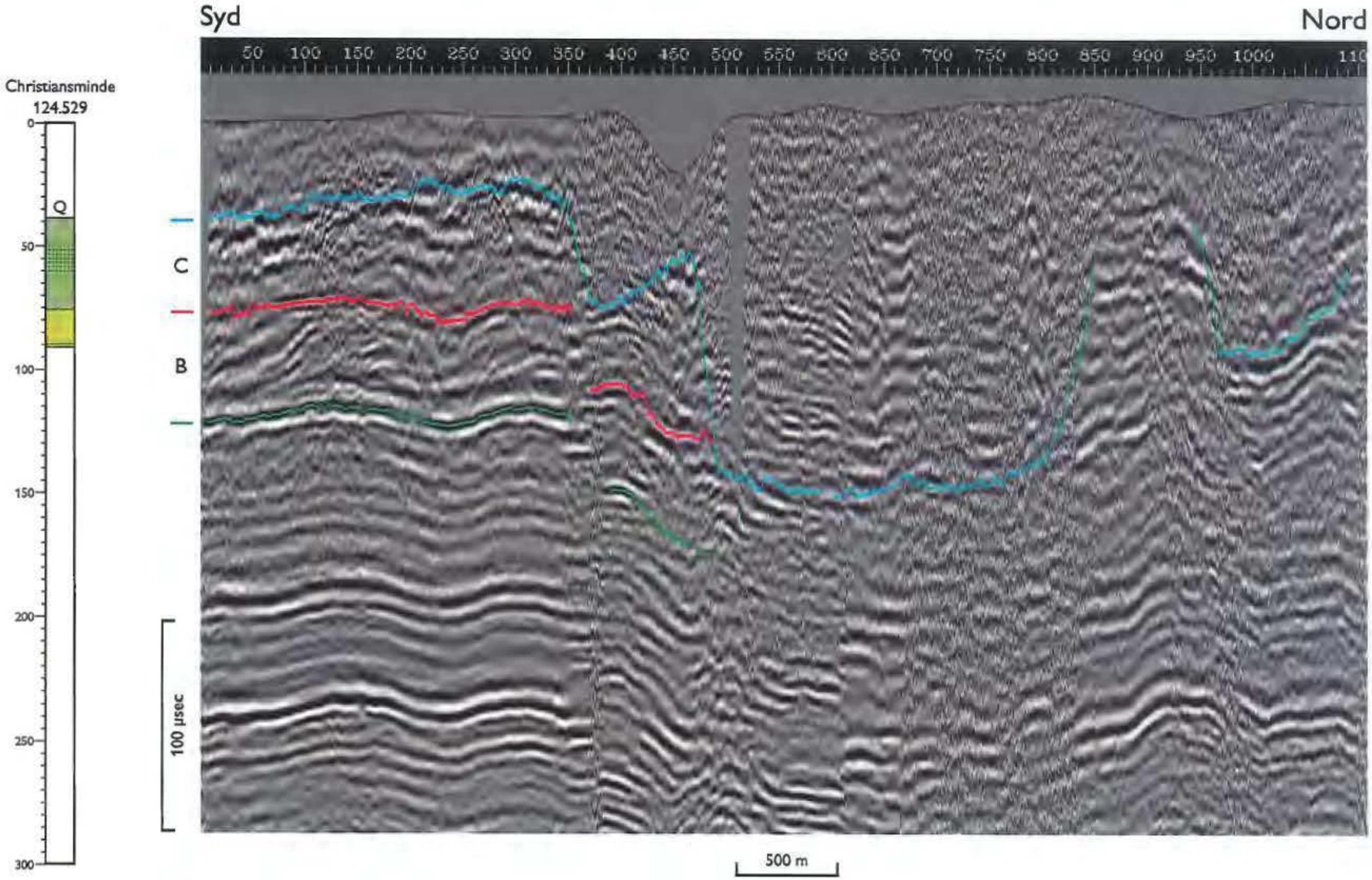


Fig. 12: Nord – syd gående seismisk linie (VUF1) ved Viuf.

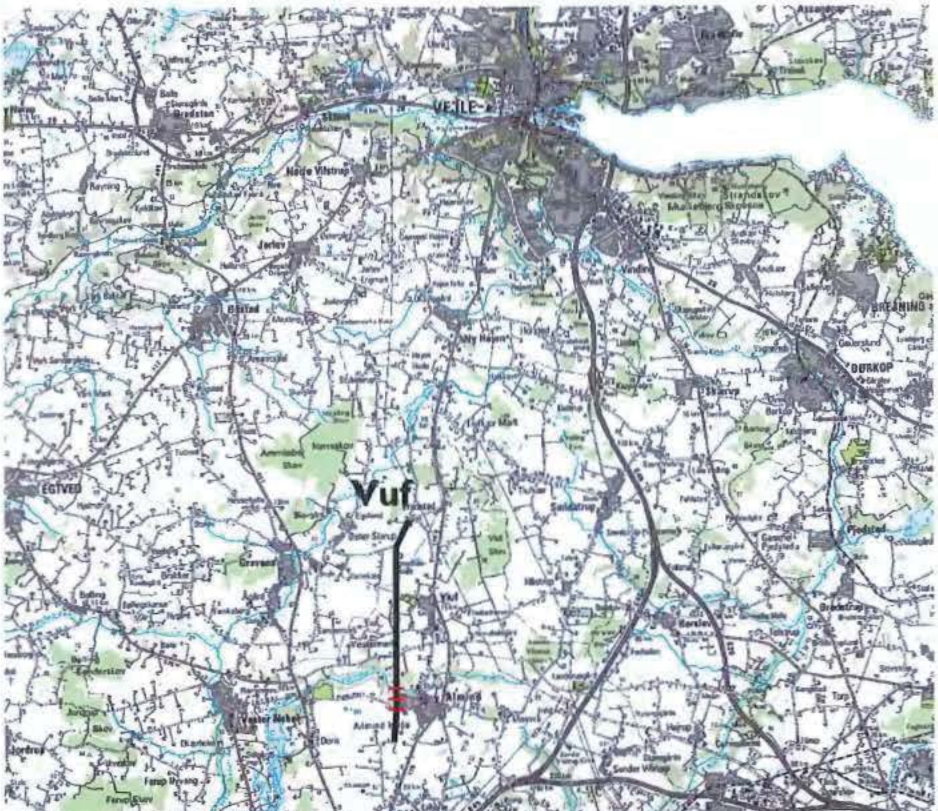


Fig. 13: Kort, der viser hvor der er identificeret parallelt klinoformt reflektions-mønster i Hvidbjerg/Billund sandet.

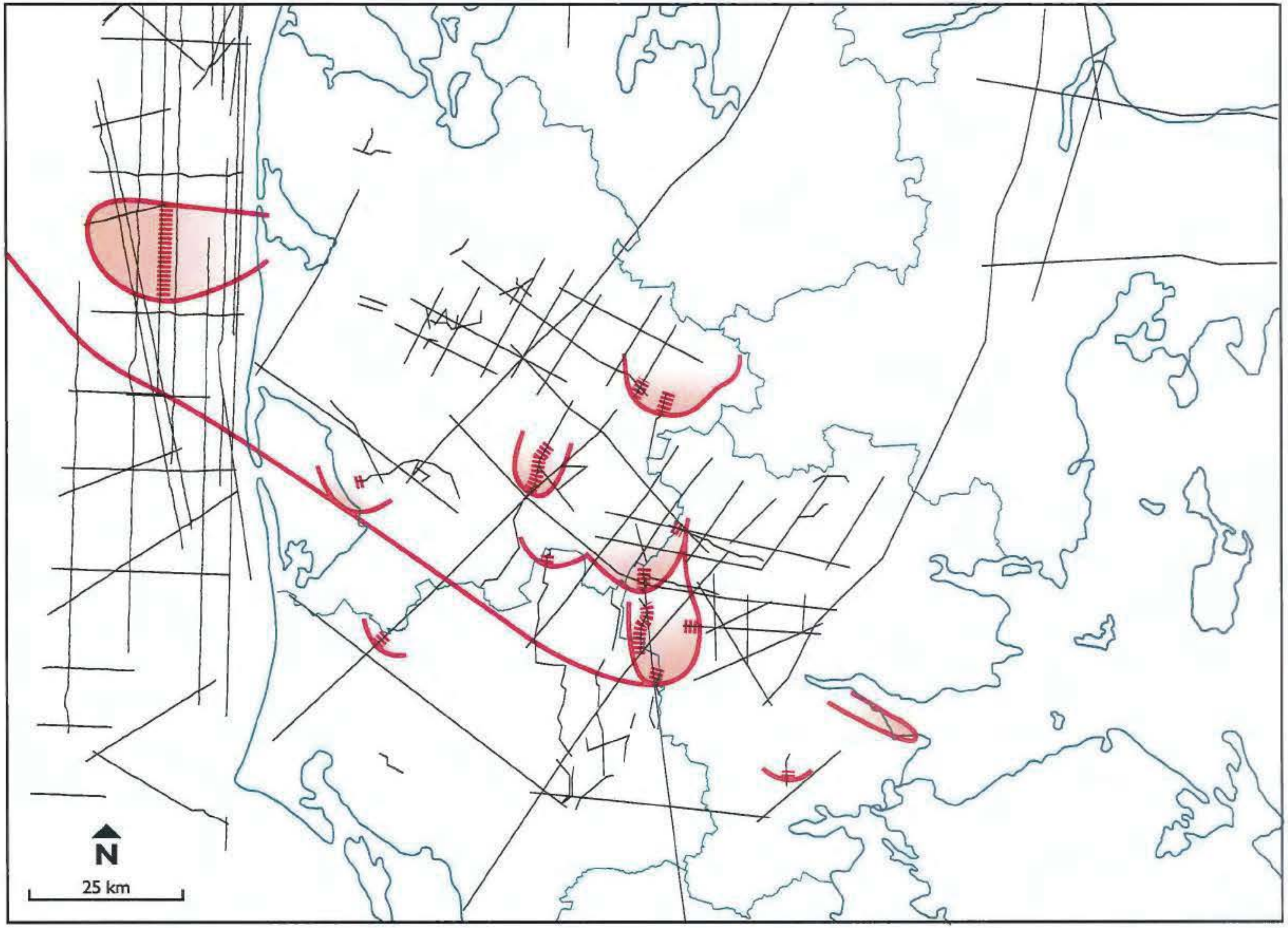


Fig. 14: Kort over deltalober og oddekomplekser i Billund sandet (sekvens B), samt placeringen af kystlinien under den sidste fase af Billund sandet. Bemærk at et parallelt klinoformt reflektionsmønster er angivet med røde streger på figuren.

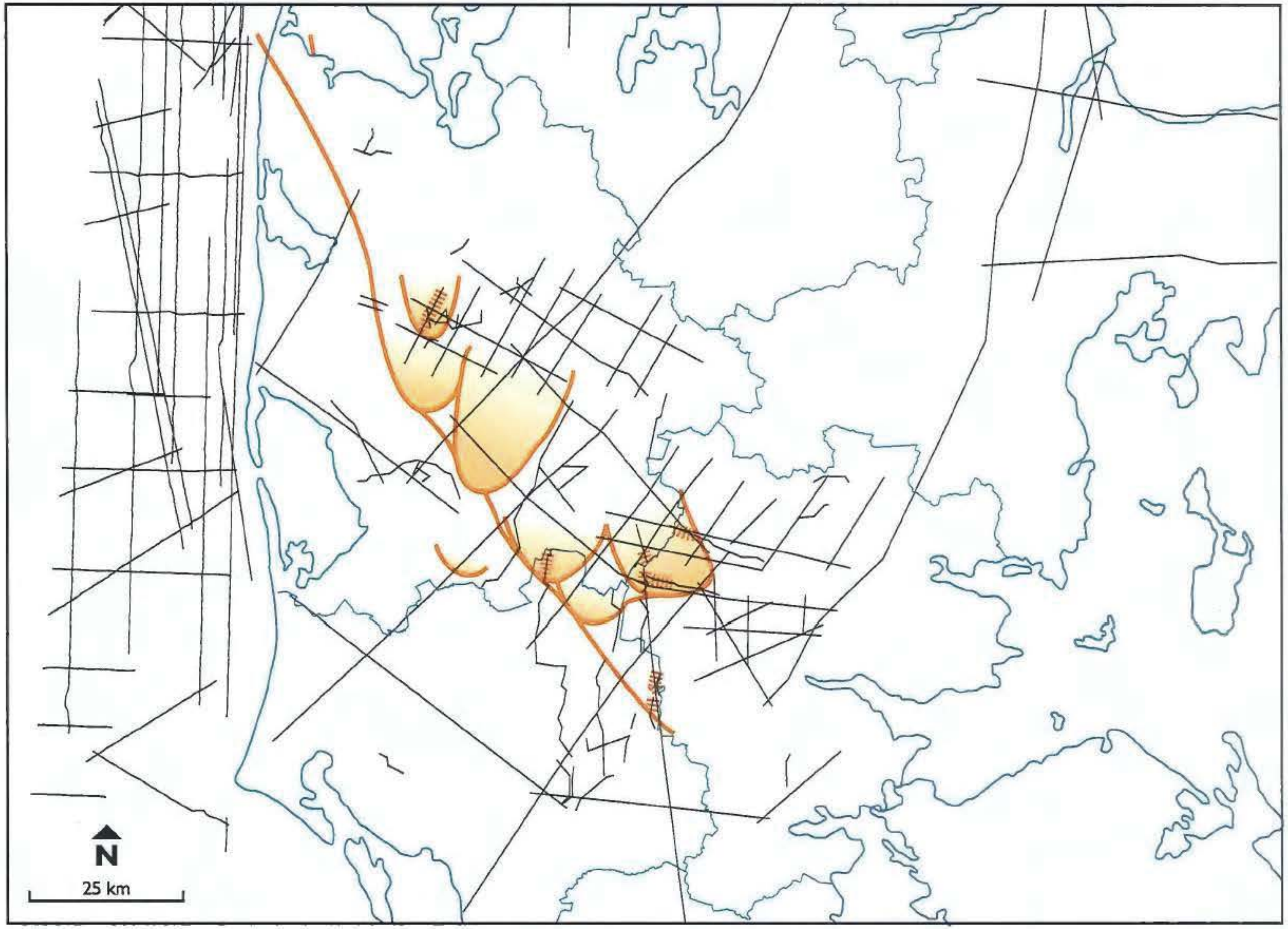


Fig. 15: Kort over deltalober i Bastrup sandet (sekvens C), samt placeringen af kystlinien under den sidste fase af Bastrup sandet. Bemærk at et parallelt klinoformt reflektionsmønster er angivet med gule streger på figuren.

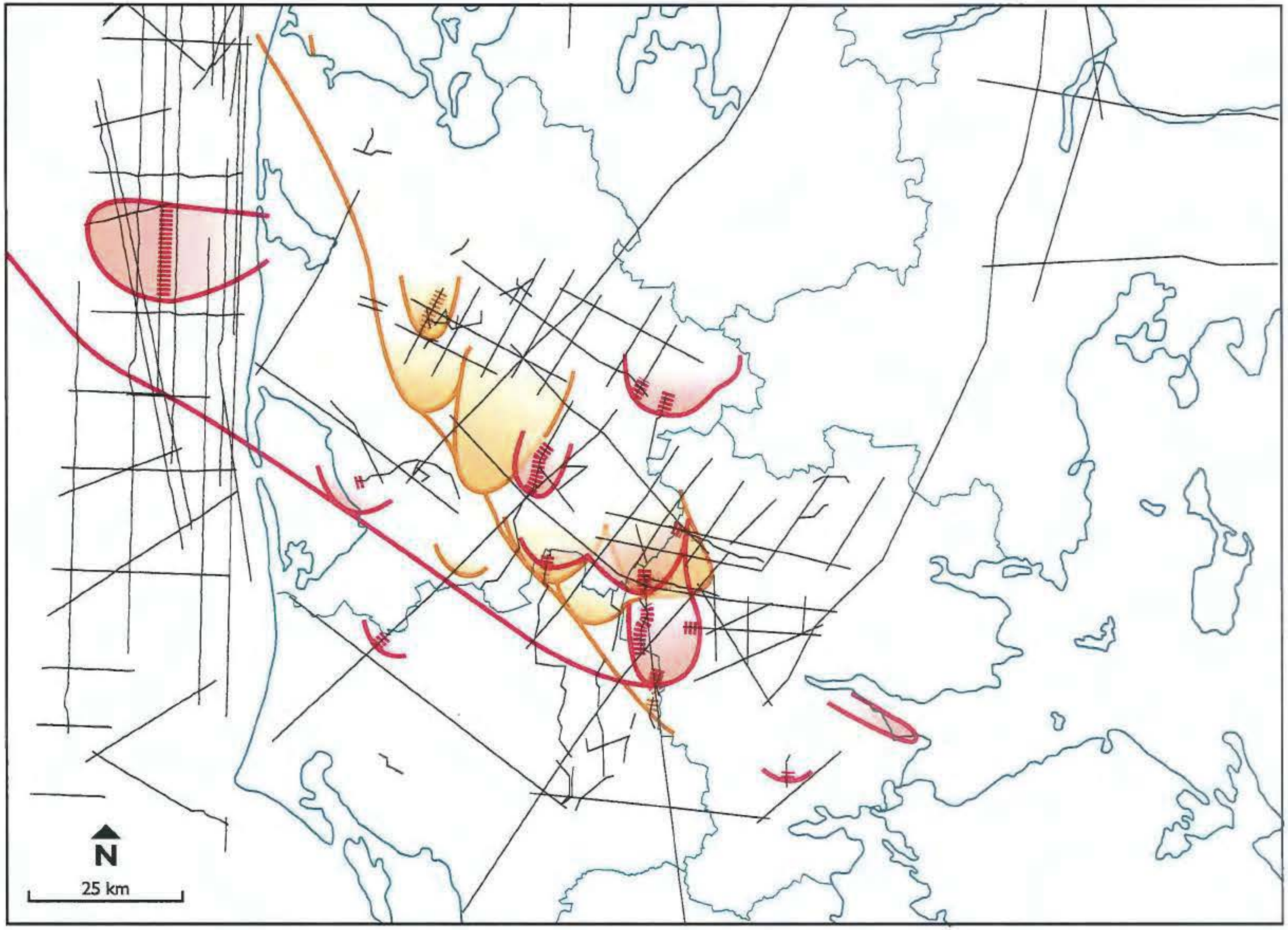


Fig. 16: Sammensat kort over sandrige enheder i Billund og Bastrup sandet. Bemærk at et parallelt klinoformt reflektionsmønster er angivet med henholdsvis røde og gule streger.

Uppermost Oligocene – Miocene lithostratigraphy of Denmark

Forord

Denne raport er en afrapportering af det arbejde, der pågår med at definerer den Øverste Øvre Oligocæn – Miocæn litostratigrafi i Danmark. Der er nu defineret 5 formationer og 5 led. Disse enheder er markeret med fremhævet skrift i abstraktet nedenunder. Det er planen at de sidste enheder skal defineres i løbet af 2005

Preface

This part of the report is a preliminary report on the definitions of Uppermost Upper Oligocene – Miocene lithostratigraphic units in Denmark. So far 5 formations and 5 members have been defined. These units are indicated in bold in the abstract below. The work of defining lithostratigraphic units will continue in 2005.

Abstract

This paper provides an updated and revised lithostratigraphic scheme for the uppermost Upper Oligocene – Miocene succession in Denmark. The shallow marine and deltaic deposits of the Lower Miocene are subdivided into 6 formations. The **Vejle Fjord Formation** is revised and is subdivided into the **Vejle Fjord Sand Member** and **Vejle Fjord Clay Member**. The **Brejning Clay Member** is upgraded to **Formation**. The Klinting Hoved Formation is defined formally. The Ribe Formation is revised and includes now two new members: the **Hvidbjerg Member** and the **Billund Member**. The Arnum Formation is subdivided into three new Members the **Vandel silt Member**, Sdr. Vium Member and NN Member. The Odderup Formation includes the Stauning Member and the coal bearing Fasterholt Member. The fully marine Middle and Upper Miocene deposits is subdivided into the **Hodde -, Gram - and Marbæk Formations**. The Gram Formation also includes the Glaucony Clay Member.

Geological setting

The depositional basin of the eastern North Sea area covered by the present-day Denmark, was bounded towards the northeast by the Fennoscandian Shield (Bertelsen 1978; Vejbæk 1997), (Fig. 1). The transition to the basin was the southeast – northwest trending Sorgenfrei-Tornquist Zone. The basin was subdivided into two subbasins: the Norwegian-Danish Basin and the North German Basin with the east-southeast – west-northwest striking Ringkøbing-Fyn High separating the subbasins. The Ringkøbing-Fyn High is further segmentated into a number of north – south trending elements e.g. the Rødding Graben and

Brande Trough. These structural element were formed during the Permian rift tectonics and later reactivated in the Jurassic and during the Late Cretaceous and Early Paleocene inversion tectonics (Ziegler 1991; Liboriusen et al. 1986; Mogensen and Jensen 1994). Reactivation of some of the older structures occurred in the Oligocene as well as in the Miocene (Rasmussen 2004a).

During the Paleogene fine-grained sediments of mainly deep marine origin were deposited in the basin (Heilmann-Clausen et al. 1985). A general sea-level lowstand and tectonic reorganisation during the Oligocene resulted in erosion or non-deposition in the area, especially in the central and southern part of the area. In the northern area prodeltaic wedges of the Viborg and Branden Formations were laid down. In the latest part of the Oligocene resumed transgression resulted in the deposition of glaucony-rich clay (Fig. 2A). This was followed by deposition of deltaic and coastal-plain sand and clayey deposits in the Early Miocene (Fig. 2B – I). Three major progradation of the coastal plain occurred during the Early Miocene. The third and final progradation was characterised by extensive coal sedimentation (Fig. 2I). Upon the deposition of the dominantly terrestrial deposits of the Lower Miocene marine clayey sediments dominated the middle and Upper Miocene (Fig. 2K, L).

Late Pliocene – early Quaternary tilting of the whole eastern North Sea area (Japsen and Bidstrup 2000) combined with periodical growth of icecaps in the northern hemisphere resulted in strong erosion of the substratum

Lithostratigraphy

The former lithostratigraphic subdivision of the uppermost Oligocene – Miocene succession in Denmark was based on studies of outcrops, pits and in a few cases boreholes (Sorgenfrei 1958; Larsen and Dinesen 1959; Rasmussen 1956, 1961; Christensen and Ulleberg 1973; Koch 1989). The first overall lithostratigraphic scheme of the Miocene was constructed by Rasmussen (1961) later revisions of this scheme has been performed by Buchardt-Larsen & Heilmann-Clausen (1988) and Michelsen (1994). The new subdivision is based on the present 25 new boreholes (Fig. 3, 4, and 5), high-resolution seismic data (Fig. 6) and the restudy of outcrops and pits in Jylland (Fig. 7). The correlation and dating of the succession is based on the principles of sequence stratigraphy and dinoflagelatte stratigraphy. This allowed a much more detailed and confident correlation of the succession.

Vejle Group

Brejning Formation (Fig. 9)

New Formation

History. This formation corresponds to the Brejning clay Member of the Vejle Fjord Formation of Larsen and Dinesen (1959).

Name. The formation is named the after town of Brejning at Vejle Fjord.

Type locality. The Formation is exposed at the seabed in the eastern part of the Skansebakke Profile at Brejning. The section at Brejning was described by Larsen and Dinesen (1959). Other exposure of the formation is found at Sanatoriet, Fakkegrav, and Juelsminde in the Vejle fjord area, Jensgård at the mouth of Horsens Fjord. Periodically the Formation crop out at Søvind, Sønder Vissing, and Ølst clay pit.

Thickness. The (-0,4 m - -4,65)

Lithology. The Brejning Formation consists of greenish to brown, glaucony-rich clay with scattered pebbles. In the upper part there is an increased content of organic matter and sand.

Boundaries. The Brejning Clay rest with a sharp and erosional boundary on the marly, Eocene søvind Marl Formation. The boundary is intensively bioturbated. The upper boundary is characterised by a distinct change in lithology from clay to gravel at most localities. However, the boundary may be more transitional, e.g. at the type locality, where the boundary towards the overlying Vejle Fjord Clay is recognised by the absence of glaucony.

Distribution. Same as the Vejle Group.

Geological age. Late Oligocene, Chattian (Dybkjær and Rasmussen 2004).

Vejle Fjord Formation (Fig. 10)

Redefined

History. The Vejle Fjord Formation was defined by Larsen and Dinesen (1959). The formation was originally defined from the base of the Brejning Clay Member to the top of the Vejle Fjord Sand Member (Larsen and Dinesen 1959). For practical reasons (see above) the Brejning Clay Member is excluded from the Vejle Fjord Formation.

Name. The Formation is named after Vejle Fjord in East Jylland.

Type locality. The cliff of Skansebakke at Brejning on the southern side of the Vejle Fjord

Thickness. The is 9 m at the type locality Skansebakke and 13 m a Dykjær. In boreholes up to 90 m has been penetrated e.g. at Stensig.

Lithology. The formation consists of dark brown, cleyey silt with a high content of organic matter. Locally fine-grained, yellowish sand is intercalated in the formation.

Boundaries. The lower boundary is often characterised by a gravel layer. It may also be marked by a marked decrease in the content of glaucony.

Distribution. The formation is distributed most of central and southern Jylland.

Geological age. Aquitanian (Dybkjær and Rasmussen 2000).

Subdivision. The formation is subdivided into two members: The Vejle Fjord Clay Member and The Vejle Fjord Sand Member.

Vejle Fjord Clay Member (Fig. 10)
History. The Vejle Fjord Clay Member is defined by Larsen and Dinesen (1959).

Name. The named is after the two outcrops at Vejle Fjord: Skansebakke and Brejning Hoved.

Type locality. The Member is exposed at the type locality at Skansebakke, Brejning.

Thickness. The Vejle Fjord Clay is 6 m at Skansebakke, but the thickness is up to 31 m in the borehole of Remmerslund. The thickness of the Vejle Fjord Member is up to 70 m in the Brande Trough.

Lithology. Brownish to black, micareous, silty clay with some fine-grained sand. Laterally it pass into a heterolitic tidal influenced sediments in the northeastern part and towards the southwest it pass into hommucky cross-stratified, fine-grained sand alternating with wave-influenced heterolithic beds.

Boundaries. Same as the Vejle Fjord Formation.

Distribution. The Vejle Fjord Clay Member is present in most Jylland and the north and eastern boundary follows the lower boundary of the Miocene deposits.

Geological age. Aquitanian (Dybkjær and Rasmussen 2000; Karen Dybkjær..)

Vejle Fjord Sand Member (Fig. 10)
History. The Vejle Fjord Sand Member is defined by Larsen and Dinesen (1959).

Name. The named is after the two outcrops at Vejle Fjord: Skansebakke and Brejning Hoved.

Type locality. The Member is exposed at Skansebakke, Brejning Hoved, and Sanatoriet.

Thickness. The thickness at Skansebakke is 17 m, Brejning Hoved ca. 12 m and at Sanatoriet 7 m.

Lithology. The Vejle Fjord Sand consists of alternating layers of fine-grained, velsorted, yellowish sand and brownish clay.

Boundaries. The formation overlies the Vejle Fjord Clay Member and the boundary is placed where the first occurrence of an extensive sand layer occurs. The upper boundary is characterised by a change from yellowish sand alternating with thin silt layers to clean white sand of the Hvidbjerg member.

Distribution. The Vejle Fjord Sand Member is present along the coast of Vejle Fjord and has been penetrated by the Morsholt borehole south of Odder.

Geological age. Aquitanian (Dybkjær and Rasmussen 2000; Karen Dybkjær pers. Comm.)

Ribe Formation

Hvidbjerg Sand Member (Fig. 11)

New Member

History. The white sand at Hvidbjerg was studied by Larsen and Dinesen (1959). The Hvidbjerg Sand was not included in the Vejle Fjord Formation due to a different heavy mineral association.

Name. The Hvidbjerg Sand Member is named after the Outcrop at Hvidbjerg Strand on the south coast of Vejle Fjord.

Type locality. The Formation is exposed at Hvidbjerg on the south coast of the Vejle Fjord. Other exposures in the Vejle Fjord area are the Sanatoriet, Fakkegrav, and Dykær. At Pjedsted west of Fredericia. In the Lillebælt area at Hindsgavl, Børup and Rønshoved. The sand crops out at one locality in the Limfjord area at Søndbjerg.

Thickness. The Thickness is 24 m at Hvidbjerg. In the Lillebælt area it reaches 13 m but at most outcrops it is rarely thicker than 6 m.

Lithology. The Hvidbjerg Sand consists of white, fine- to medium grained sand with a few pebble lags. Thin light brown clay layers occur locally. Deposition took place in storm dominated shoreface environment, at Hvidbjerg as a part of a spit system.

Boundaries. The formation overlies the Vejle Fjord Clay Member and is marked by a change from black, organic-rich clayey silt to white sand. At Hvidbjerg the lower boundary is erosive. The upper boundary is erosive and normally overlain by a gravel layer

Distribution. The member is present in east Jylland and has been found at Søndbjerg in north-west Jylland. The member probably has a patchy distribution along a NW-SE trend across Jylland.

Geological age. Aquitanian (Dybkjær and Rasmussen 2000; Karen Dybkjær pers. Comm.)

Billund Member (Fig. 12)
New Member

Name. The Billund Member is named after sand-rich deposits found in boreholes in the area around the town of Billund.

Type locality. The Formation was penetrated in the borehole DGU 115.1371 at Vandel Mark where 28 m of sand were encountered from 203 m to 231 m.

Thickness. The thickness of the Billund Member is 28 m in the Vandel Mark borehole. In the borehole, DGU 114.1857 drilled at Billund, the thickness is 50 m and the maximum thickness of 70 m has been found in the Isenvad borehole DGU 86.2056.

Lithology The member composed of Fine-grained sand and medium- to coarse-grained sand. Pebbely horisons are common in the upperpart. The fine-grained sand occurs in the lower part of the member or in distal lobes. The sand was deposited in a wave-dominated delta and delta slope environment.

Boundaries The lower boundary is defined were a changes from clayey, organic-rich silt sediments of the Vejle Fjord Clay Member is superimposed by sand. Locally, e.g. at Billund the sand is overlying Eocene Søvind Marl.

Distribution The Billund Member is distributed in central Jylland and northwestwards into the North Sea just west of Ringkøbing.

Geological age The Billund Member is of Aquitanian in age (Dybkjær pers. Comm.).

Klintinghoved Formation

History. The Klintinghoved Formation was included in the stratigraphic of Rasmussen 1961. However, the formation has never been defined formally. Sorgenfrei (1940) described the molluscan fauna of the Klintinghoved Clay and briefly mentioned the Klintinghoved Formation in a later publication (Sorgenfrei 1958).

Arnum Group

Kolding Fjord Formation (Fig. 13)

History. Sand and organic-rich clayey sediments exposed at Lillebælt was studied by Radwanski et al. 1975, Rasmussen 1995 and Friss et al. 1998. These studies inferred that the sediments were a part of the Vejle Fjord Formation. However, a biostratigraphic study by

Dybkjær and Rasmussen 2000, revealed that the sediments were significantly younger than the Vejle Fjord Formation and of same age as the Arnum Formation (Rasmussen 1966; Piasecki 1980).

Name. The Kolding Fjord Formation is outcropping at a number of localities: Rønshoved, Hagenør, Børup and Galsklint in the Lillebælt and Kolding Fjord area.

Type locality. The Formation is exposed at Rønshoved on the south side of Kolding Fjord.

Thickness. The Formation is 12 m thick at Rønshoved and 8 m at Hagenør.

Lithology. The formation composed of white to yellow, fine- to medium-grained sand with a few thin, brown clay layers. The basal part of the Formation consists of a gravel layer up to 1 m thick.

Boundaries. The lower boundary is erosive and characterised by a distinct changes from sand deposits of the Ribe Formation (Billund and Hvidbjerg Members).

Distribution. The formation is found in east and central Jylland.

Geological age. The formation is of early Burdigalian in age (Dybkjær and Rasmussen 2000).

Subdivision. Hagenør member.

Vandel Member (Fig. 14)
New member

History.

Name. The member is named after the Village of Vandel east of Billund.

Type borehole. The Vandel Mark (DGU 115,1371) where it was penetrated at 111 -96 m.

Thickness. The thickness rarely exceeds 15 m as was the case at the type boring Vandel Mark.

Lithology. The member composed of grey to white silt, with a high content of heavy minerals. It might contain clasts of reworked reddish Eocene clay.

Fossils. No fossils

Boundaries. The lower boundary is defined by a sharp transition from grey sand to grey to white silt.

Distribution. The member is distributed in central Jylland with maximum thickness around the Billund area.

Geological age. Late Burdigalian is suggested as it is intercalated in the Lower Arnum Formation.

Bastrup Formation (Fig. 15)

New formation

Name. The formation is named after the village of Bastrup south of Vamdrup.

Type section. The borehole DGU 133.1298, Bastrup, 84-110 m below surface.

Thickness. The thickness is 26 m in the Bastrup borehole, but has a maximum thickness of 44 meter in St. Vorslunde borehole (104.2325).

Lithology. The Formation consists predominantly of grey, medium- to coarse-grained sand with intercalated gravel layers. Locally dark brown, organic-rich silty mud is present. Deposition took place in fluvial and deltaic environments. The intercalated mud represents floodplain deposition.

Boundaries. The lower boundary is either sharp e.g. at Bastrup or gradational as in the Almstok borehole (Fig.). In the Bastrup borehole, the lower boundary is placed where grey mud is sharply overlain by grey medium-grained sand. In boreholes where a more gradational development occurs, the boundary is marked by the change from alternating sand and mud layers to clean sand. A gravel layer is also common at the base of the Bastrup member. In the Bastrup borehole the lower boundary is characterised by a distinct decrease in gamma log response. In other boreholes the lower boundary may be represented by a minor decrease in gamma log response followed by a consistent decrease in gamma log response upwards.

Distribution. The formation is present in southern and central Jylland. Towards the north-east the formation is truncated and it pinches out towards the south-west.

Geological age. Early to late Burdigalian (Dybkjær pers. Comm.)

Odderup Formation

Stauning Member

History. The Stauning Member was recognised as fine-grained sand layers with a high content of heavy minerals interbedded in the Arnum Formation in a number of boreholes in south and central Jylland (Knudsen 1998). On gamma logs the sand beds are characterised by extreme high readings. Exploitation for these sands with heavy minerals was intensive during the last part of the decay of 1990 in the Stauning area.

Name. The Stauning Member is named after village of Stauning, were the member is subcropping Quaternary deposits.

Type borehole. A complete succession of the Stauning Member is penetrated in the borehole DGU 115.1371 at Vandel Mark.

Thickness. The thickness is up to 37 m.

Lithology. The member is characterised by grey to blackish, fine-grained sand occasionally with a very high content of heavy minerals. Medium-grained to pebbly sand may occur, especially in central Jylland.

Boundaries. The lower boundary is defined at the base of the first significant fine-grained sand layer with a high content of heavy minerals.

Distribution. The Stauning Member is found in southern, central en western Jylland.

Geological age. Early Miocene, Burdigalian (pers. Comm. Stefan Piasecki).

Måde Group

Hodde Formation (Fig. 16)

History. The Hodde Formation was defined by Rasmussen 1961).

Name. The formation is named after the village of Hodde where the formation was shortly exposed in connection with the construction of Karlsgårde Channel.

Type locality. The formation is exposed at Lille Spåbæk near Ørnhøj, south of Holstebro.

Thickness. The formation is 9.6 m (13.8 – 23.4 m) in the Hodde-1 borehole (DGU 113.33).

Lithology. The formation consists of darkbrown, organic-rich silty clay with thin sand linses. The basal part of the Formation composed of a thin gravel layer. In the upper part of the formation laminated silty clay are common and glaucony may occur.

Boundaries. The lower boundary is sharp and defined by a gravel layer overlying the sandy deposits of the Odderup Formation.

Distribution. The Hodde Formation is distributed in southern and western Jylland. The Formation is locally distributed as far east as Bording and Give in central Jylland in depressions associated with salt structures.

Geological age. Serravalian (Piasecki 1980; 2003)

Gram Formation (Fig. 17)

Redefined

History. The Gram Formation is defined by Rasmussen (1956). In the original definition of the Gram Formation the formation includes three members: The Glauconite Clay, the Gram Clay and the Gram Sand.

Name. The Gram Formation is named after the town of Gram.

Type locality. The Formation is exposed at the old pit of Gram brickwork, currently the Midtsønderjyllands Museum of Gram.

Thickness. The thickness is c. 25 m but in the borehole of Tinglev (DGU 168.1378) 119 m was penetrated (Piasecki 2001).

Lithology. The Gram Formation consists of darkbrown clay. The lower part of the Formation is greenish due to high content of Glaucony. In the upper part a few fine-grained sand layers are intercalated in the formation. Siderite concretions are common at some levels.

Boundaries. The Lower boundary is defined by the change from dark to blackish silty clay somtines laminated clay of the Hodde Formation to Greenish darkbrown clay with a high content of Glaucony.

Distribution. The Gram Formation is distributed in southern and western Jylland. The Formation is locally distributed as far east as Bording and Give in central Jylland in depressions associated with salt structures.

Geological age. The Gram Formation is of Serravallian to Tortonian in age (Piasecki 1980; Piasecki et al. 2001, 2003).

Subdivision. The Gram Formation includes the Glaucony Clay Member, which forms the lower part of the Formation.

Glaucony Clay Member

Marbæk Formation (Fig. 18)

History. Sands outcropping at Marbæk Cliff and Sjælborg, north of Esbjerg and sandy sediments in the upper part of the Sæd borehole (DGU x) have with some uncertainty been referred to be of Pliocene in age (Jørgensen 1945). New studies of these sections (Piasecki 2003) however, indicate that these deposits are of Tortonian in age.

Name. The Formation is named after the coastal cliff at Marbæk, northwest of Esbjerg.

Type locality. The Formation is exposed at Marbæk Cliff.

Thickness. The Marbæk Formation is 16 m thick. At Gram Brickwork pit 1.5 m of the formation is exposed at the bank of the brook.

Lithology. The formation consists of white and reddish fine- to medium-grained sand with few intercalations of thin coarse-grained sand or gravel layers. The sand shows parallel lamination with subordinate cross-bedding and hummocky cross-stratified beds are common. Double clay layers may occur.

Boundaries. The lower boundary is defined where alternating thin clay and sand layers of the Gram Formation is overtaken by amalgamated sandbeds.

Distribution. The formation is distributed in southwestern Jylland.

Geological age. The Marbæk Formation is of Tortonian in age (Piasecki 2003)

Summary and conclusion

Based on the above a new lithostratigraphic scheme has been constructed (Fig. 19). The uppermost Upper Oligocene – Miocene succession is subdivided into 9 formations, which includes both the marine and terrestrial deposits.

The shallow marine and deltaic deposits of the Lower Miocene are subdivided into 6 formations. **The Vejle Fjord Formation is revised** and is subdivided into the **Vejle Fjord Sand Member** and **Vejle Fjord Clay Member**. The **Brejning Clay** Member is upgraded to **Formation**. The Klinting Hoved Formation is defined formally. The Ribe Formation is revised and includes now two new members: the **Hvidbjerg Member** and the **Billund Member**. The Arnum Formation is subdivided into three new Members the **Vandel silt Member**, Sdr, Vium Member and NN Member. The Odderup Formation includes the Stauning Member and the coal bearing Fasterholt Member. The fully marine Middle and Upper Miocene deposits is subdivided into the **Hodde -, Gram – and Marbæk Formation**. The Gram Formation also includes the Glaucony Clay Member.

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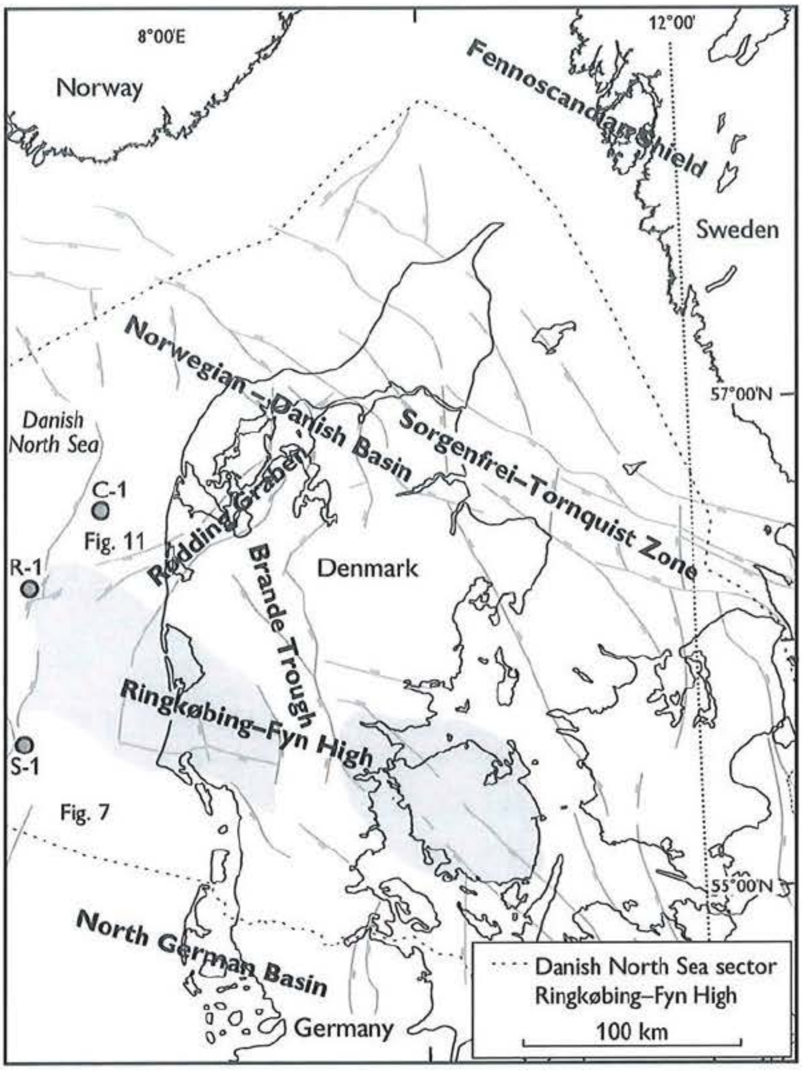

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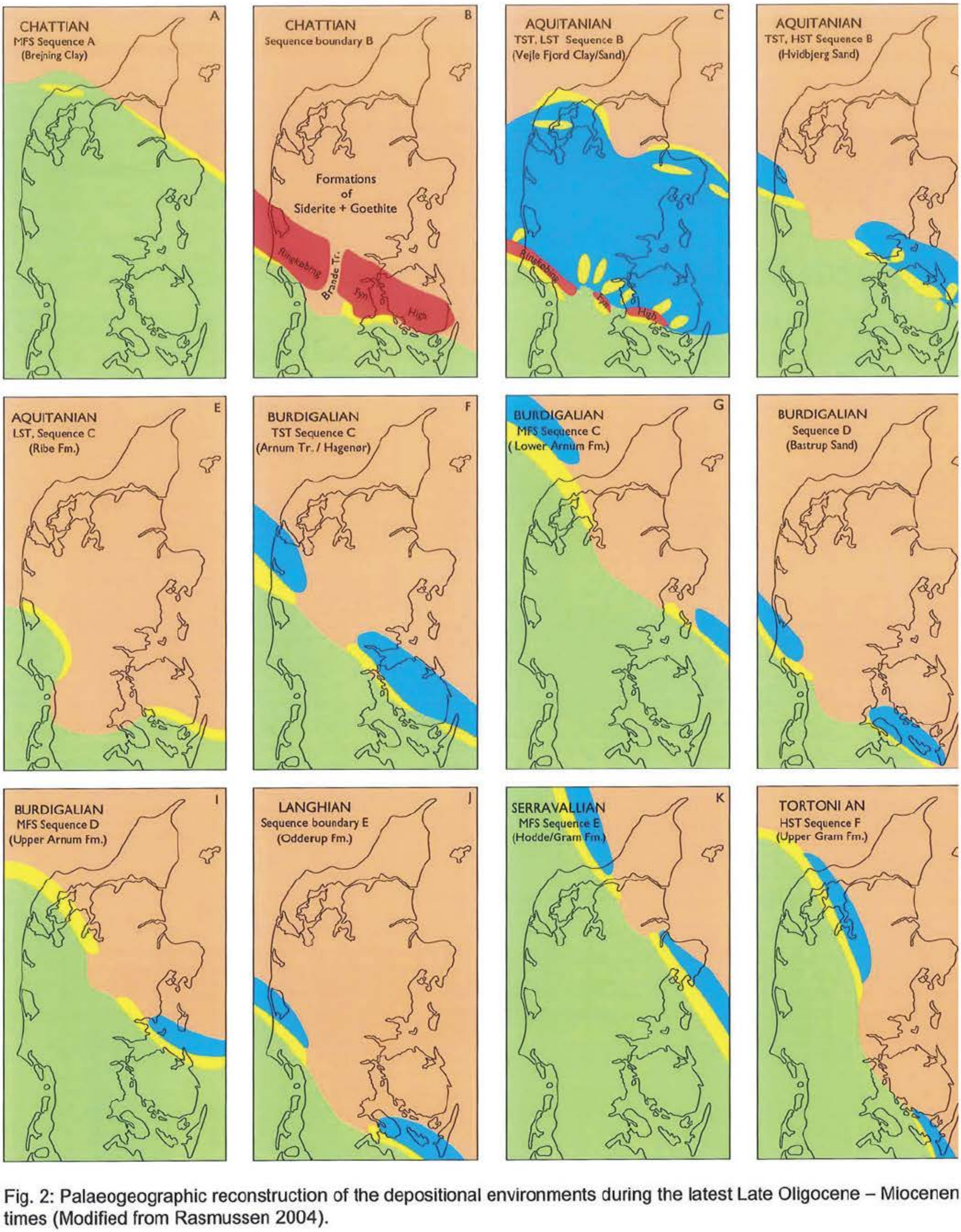

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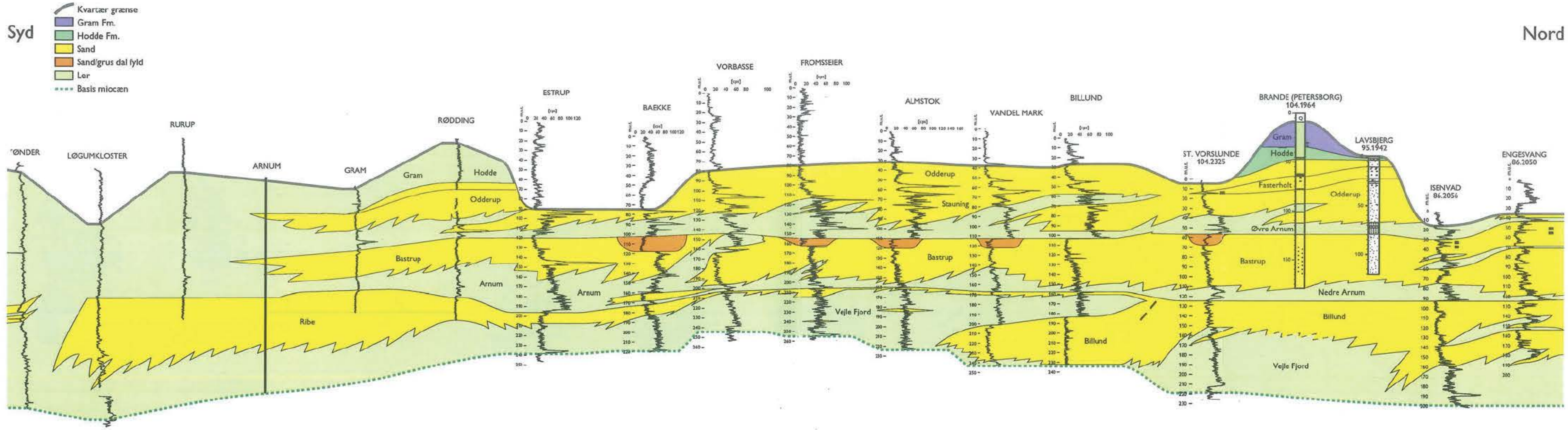

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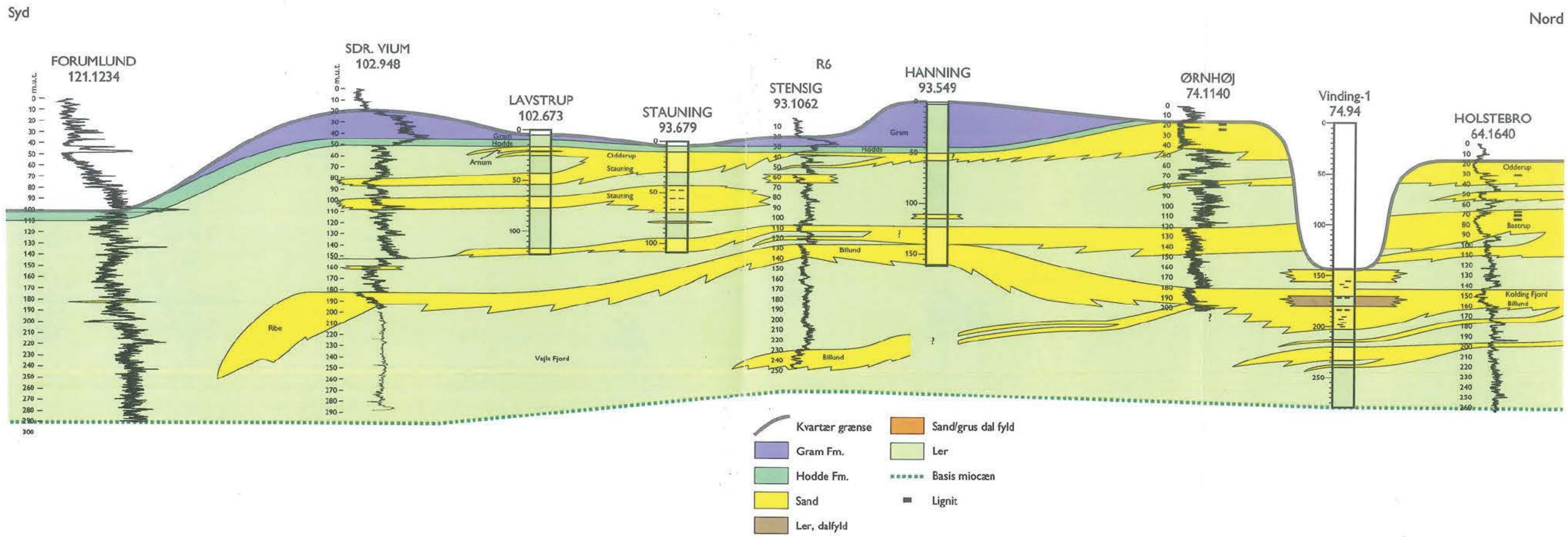

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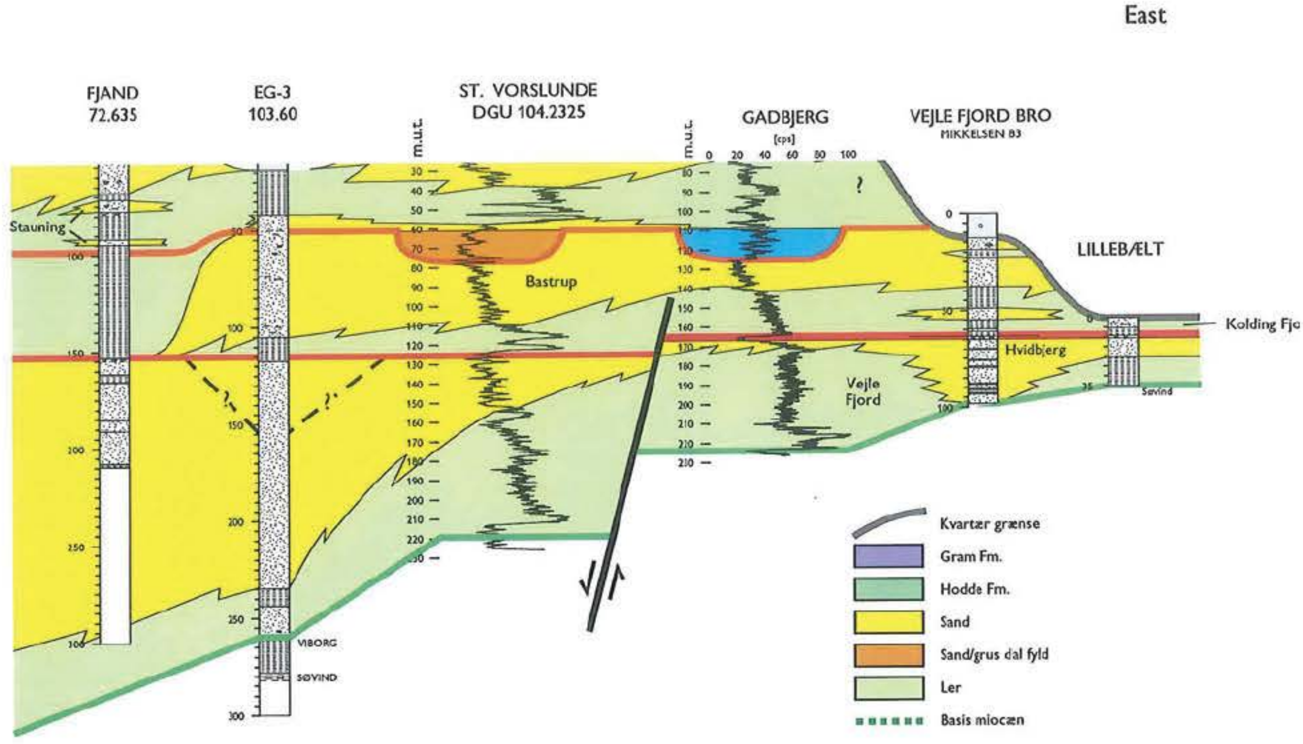

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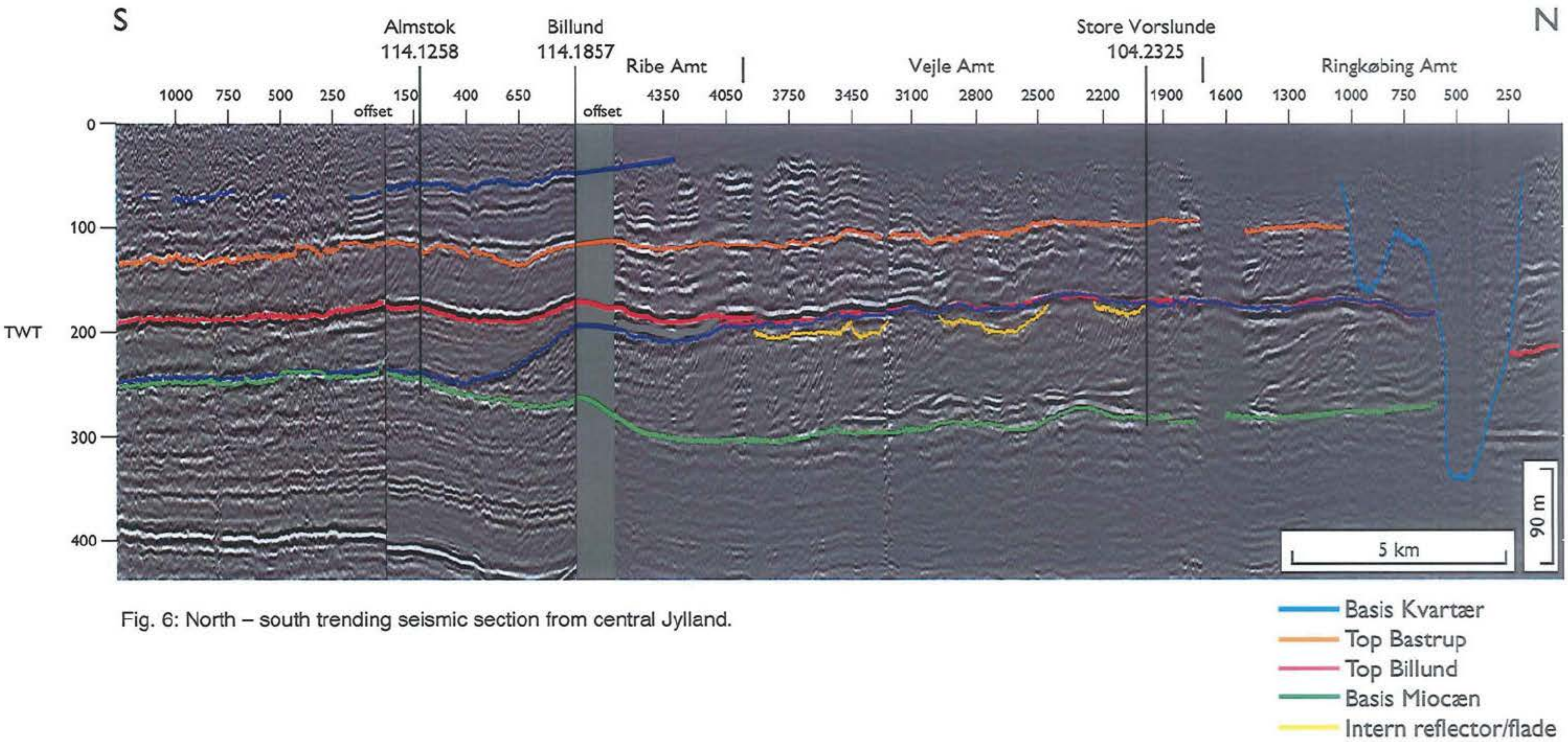

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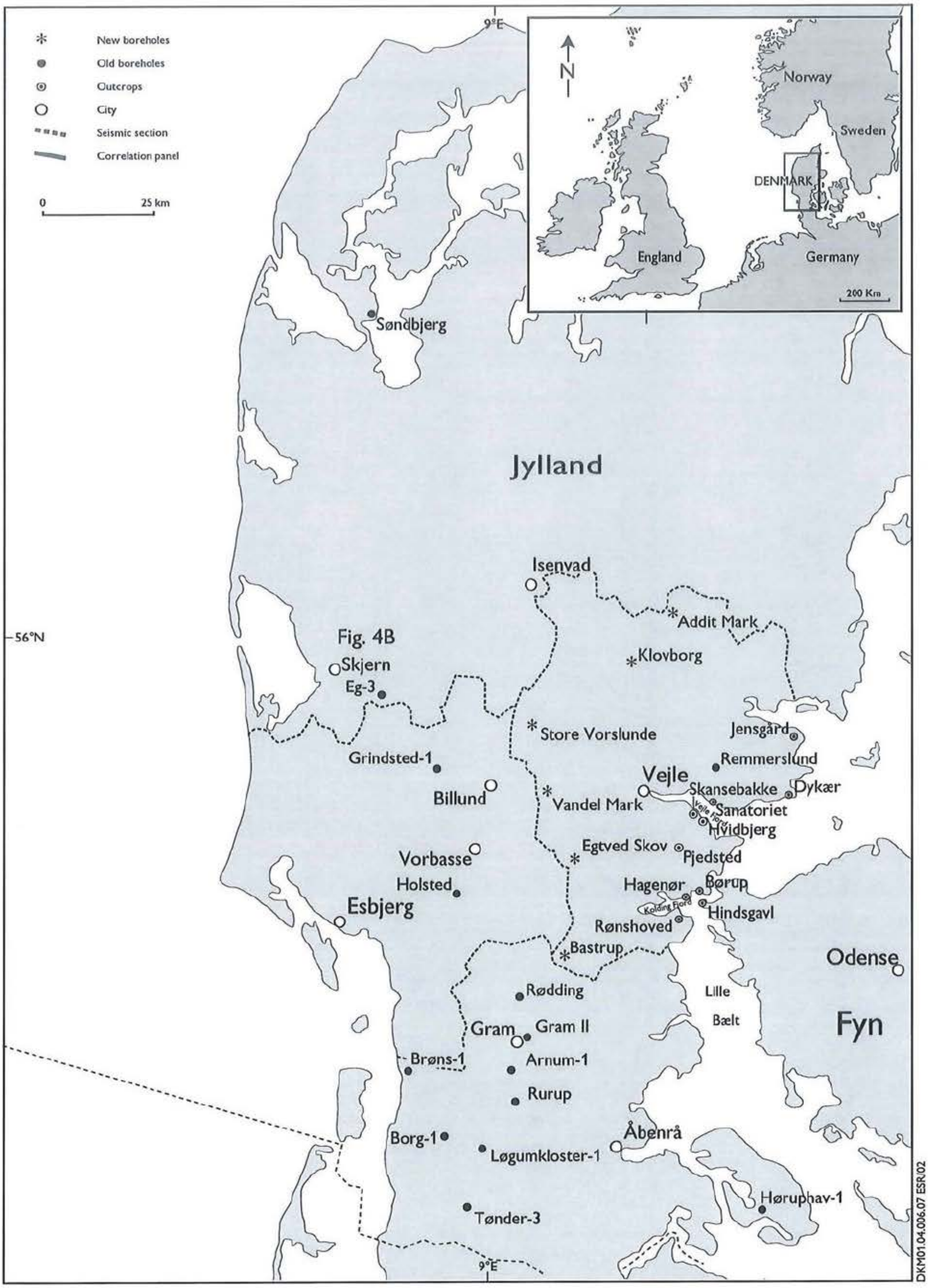

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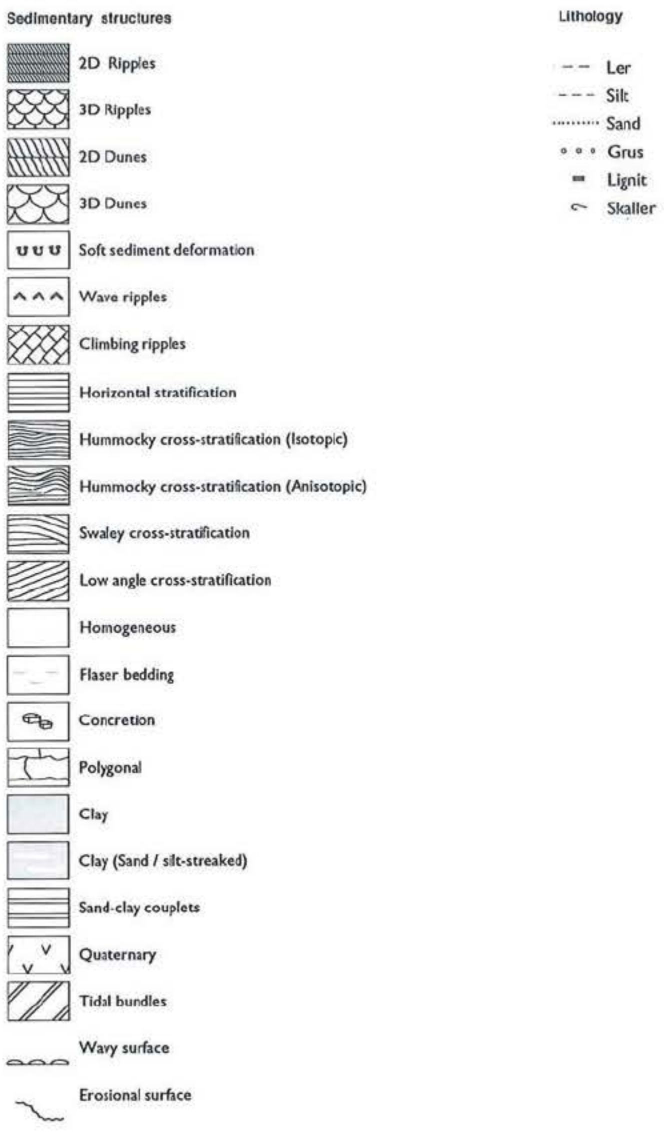

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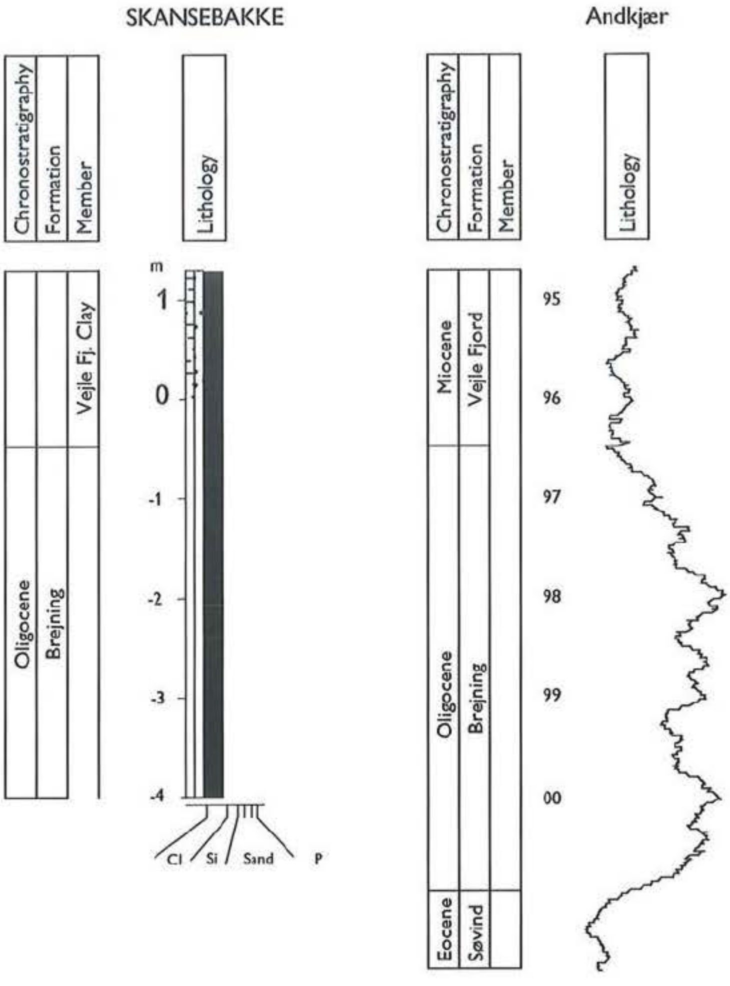

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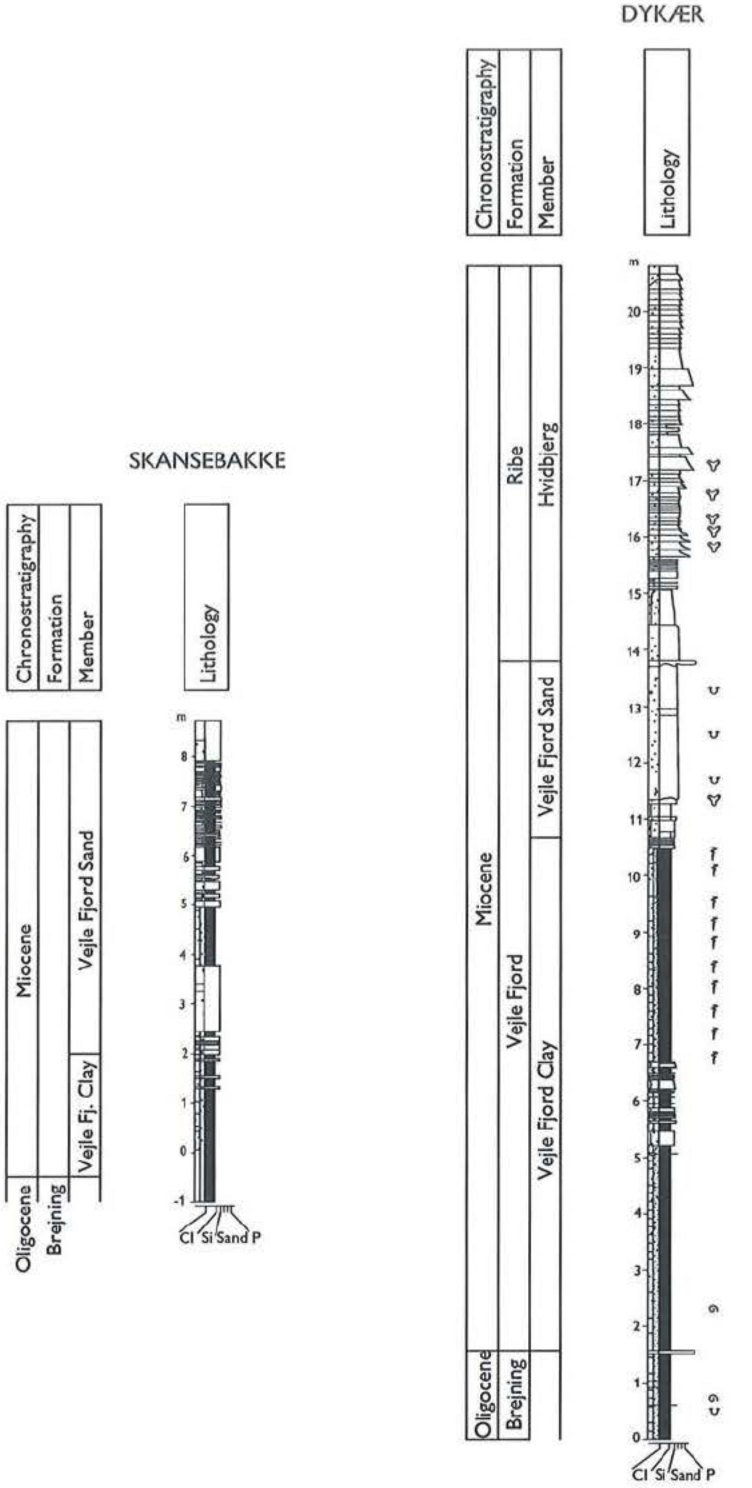

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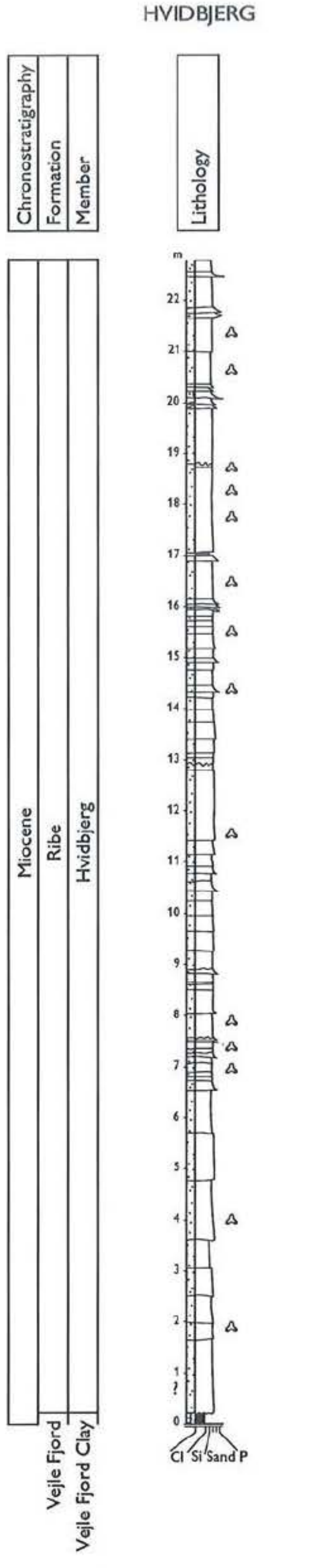

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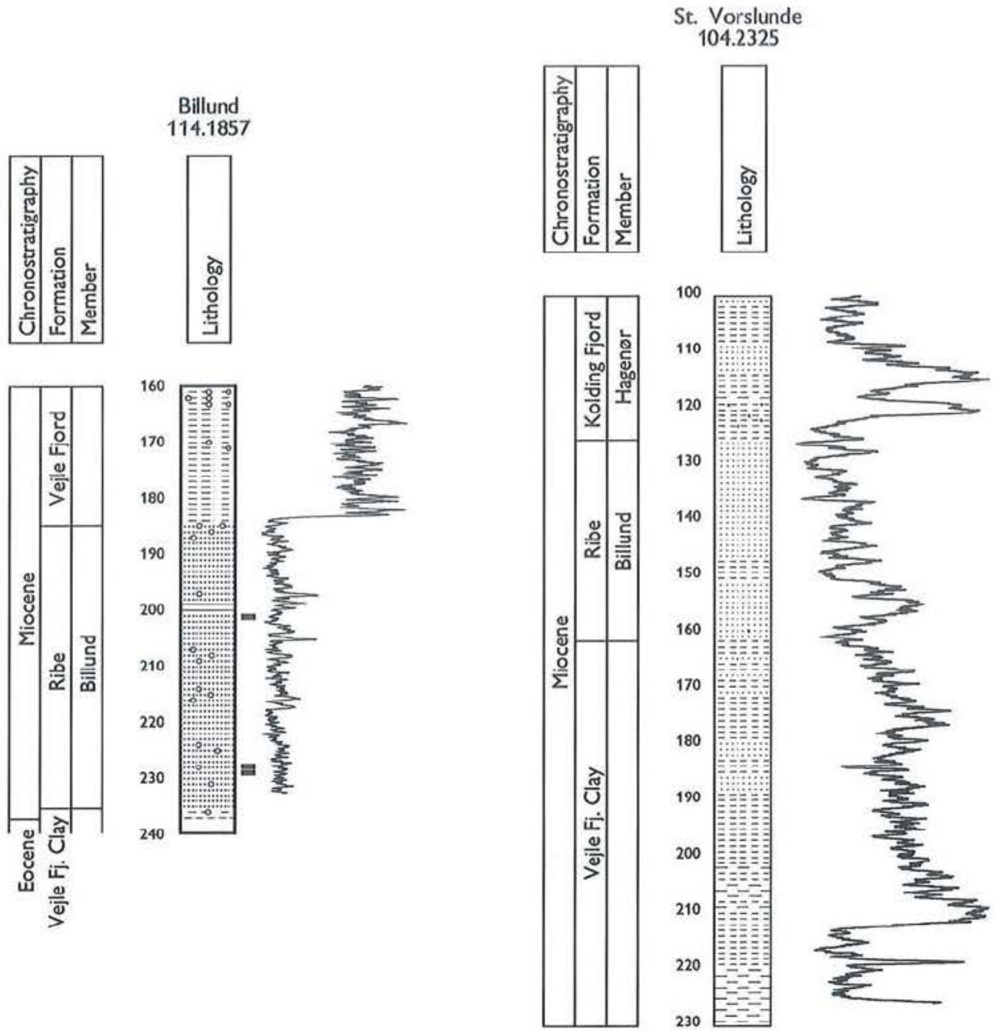

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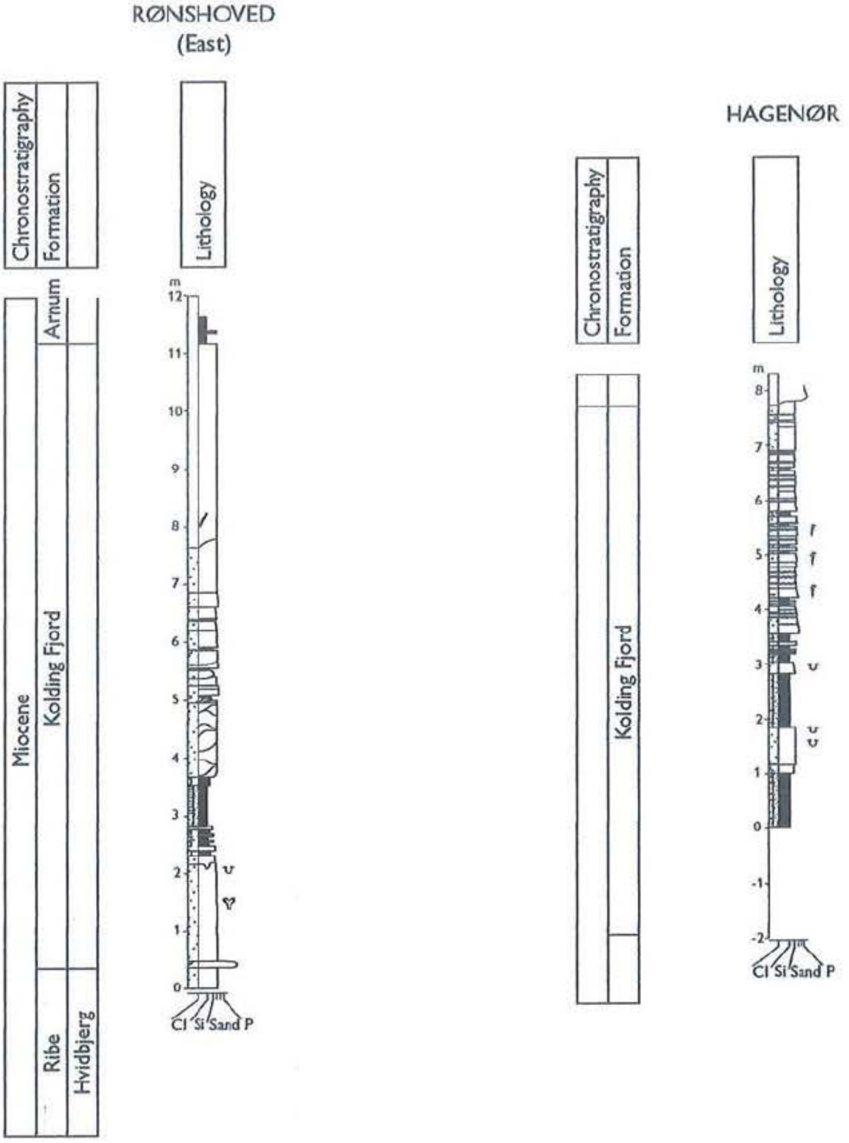

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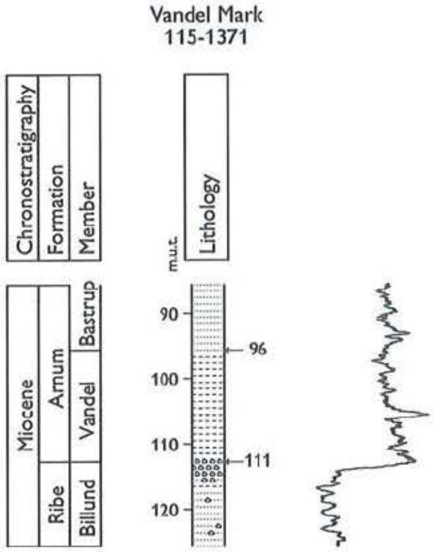

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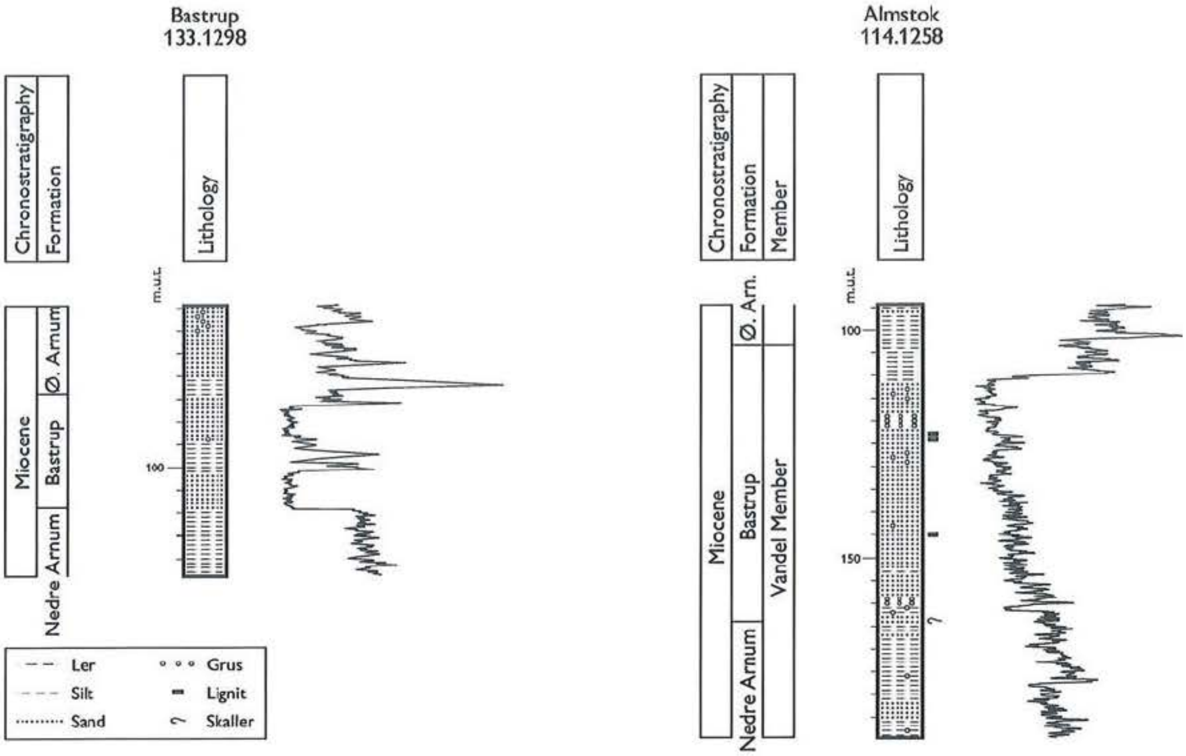

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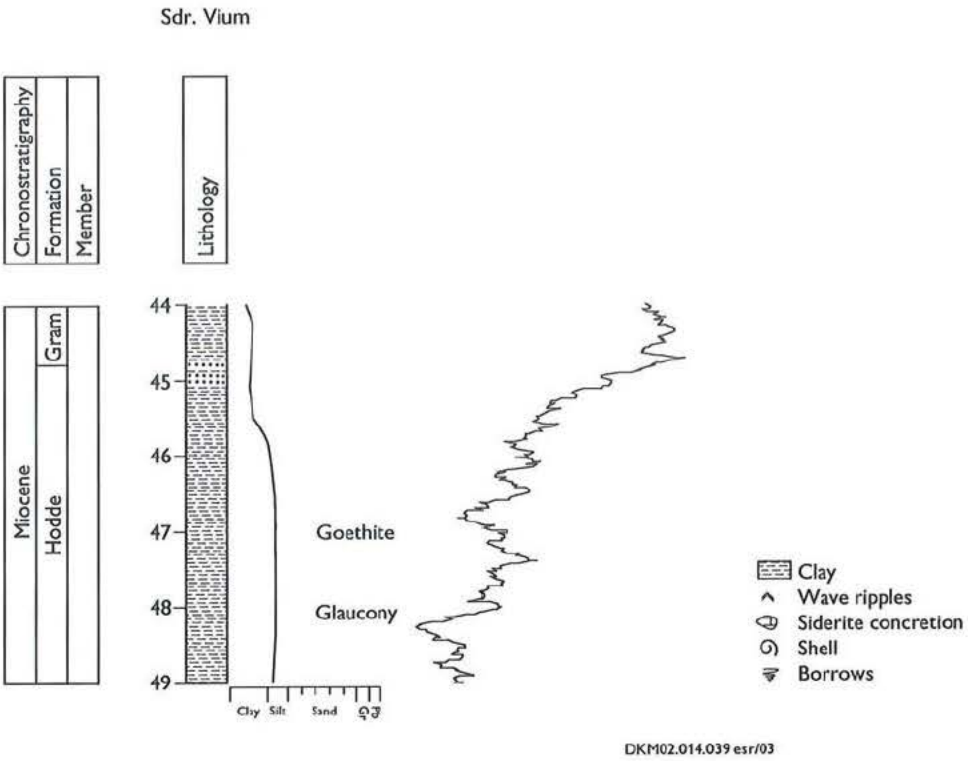

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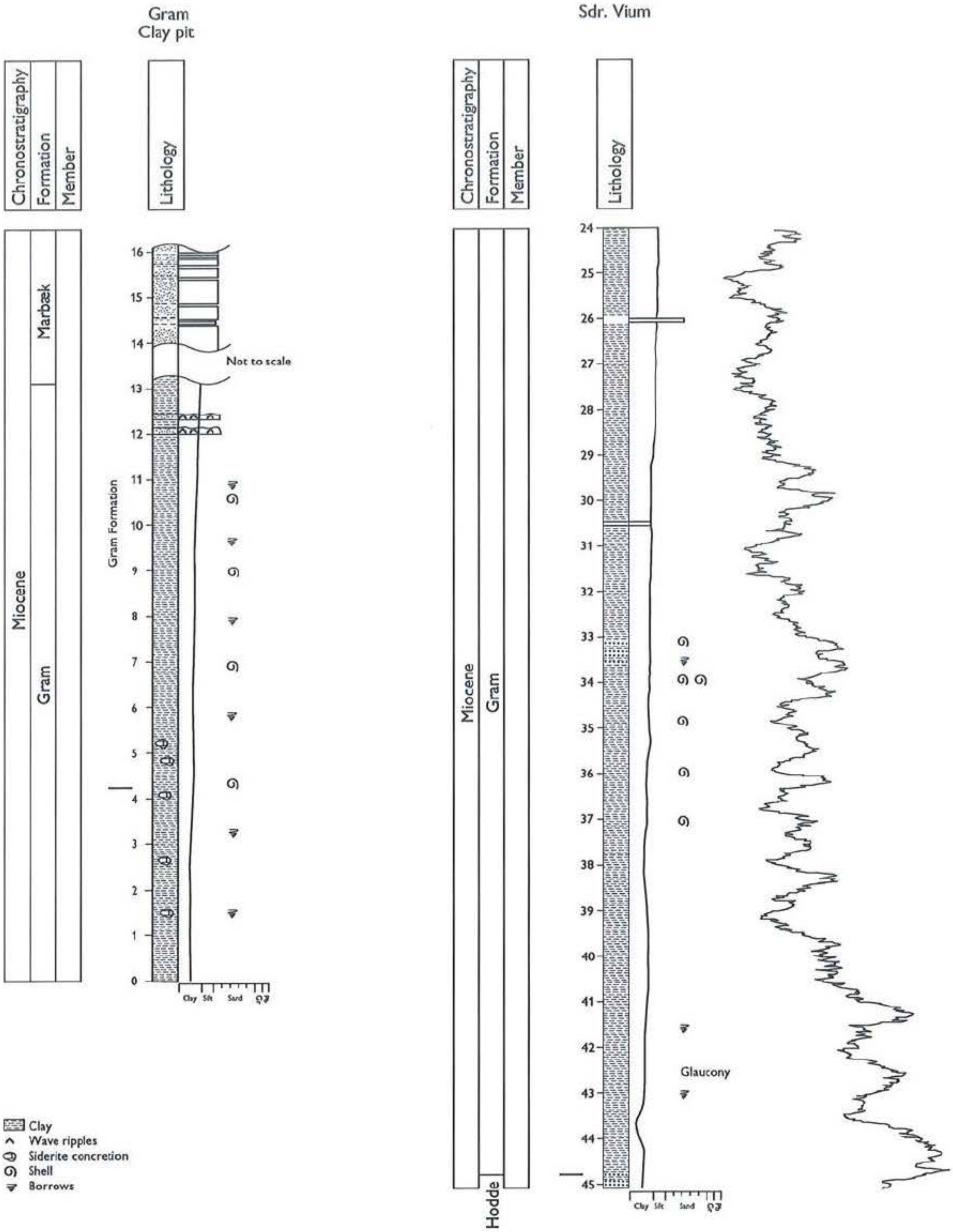

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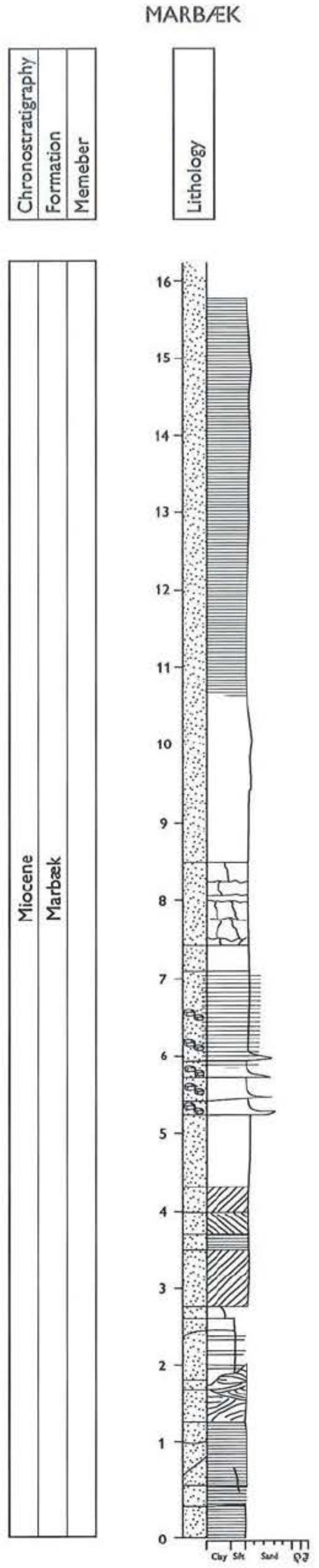

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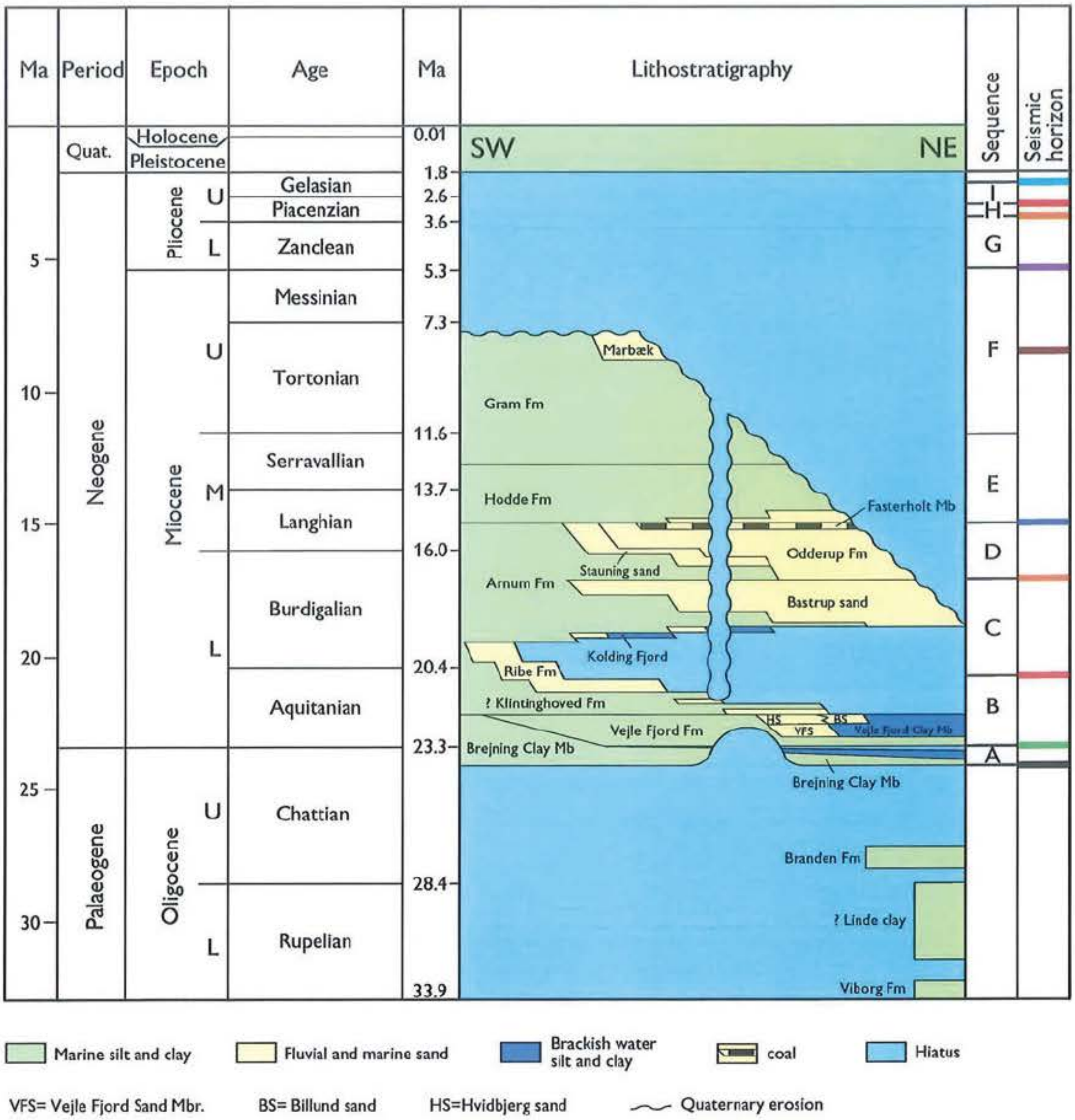

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