DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/35

Luke-1X (14735'6 - 14500 ft), Bryne Formation, Danish Central Graben

Preliminary sedimentological and ichnological core description report

Jussi Hovikoski & Peter Johannessen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

G E U S

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/35

Luke-1X (14735'6 - 14500 ft), Bryne Formation, Danish Central Graben

Preliminary sedimentological and ichnological core description report

Jussi Hovikoski & Peter Johannessen

Released 01.05.2015

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE END ENERGY

G E U S

TABLE OF CONTENTS

1. ABSTRACT

Sedimentological and ichnological properties of the Luke-1X core covering the Middle Jurassic Bryne Formation, Danish Central Graben, were described in order to tentatively interpret its depositional setting. The deposits were divided into 4 main facies associations (FA): The base of the core consists dominantly of m-scale aggradational successions of lenticular bedding, burrow-mottled mudstone, and root-bearing mudstone/muddy sandstone (FA1: lagoon-lagoon margin). At 14700 ft, these deposits begin to intercalate with dm- and m-scale, sharp-based upward-fining successions that consist of extraformational conglomerates, mud-draped cross-stratification, and interbedded sand and mud (FA2: distributary channel – mouth bar complex). Particularly, features such as rythmically mud-draped sigmoidal cross stratification and double mud-drapes as well as trace fossils *Ophiomorpha* and *Teichichnus* are consistent with tidal and brackish water influence in these deposits.

Around 14625 ft, FA2 gradationally grades into m-scale upward coarsening successions of laminated mudstone, interlaminated mud and sand, and lenticular bedding that contains abundant symmetrical ripples (FA3: bay head delta – estuarine embayment). The stratigraphic occurrence of FA3 gradationally above distributary channel deposits (FA2), stressed brackish water trace fossil assemblage and pervasive synaeresis cracks suggest wave reworked, tidally modulated river flood origin for the lamina couplets. In addition, common equilibrium and escape structures, low overall bioturbation intensity as well as biodeformational structures (e.g., “mantle-and-swirl” trace fossils) in mudstone suggest rapid aggradation and low-initial substrate consistency for the mud-layers (i.e., common fluid mud influence).

Near the top of the core, FA3 gradationally grades into a m-scale succession of laminated mud and organic matter, and coal (FA4: bay-offshore). The lack of roots below coal layers and overall facies order suggest that the coal is allochthonous and possibly associated with flooding and temporal abandonment of the bay head delta system.

The observed lagoon-lagoon margin (FA1), distributary channel – mouth bar (FA2), and bay head delta- estuarine embayment (FA3, FA4) sub-environments are all consistent with an overall estuarine embayment complex. Although a detailed assessment of relative sea level change is not possible to do due to lack of regional correlations, the overall gradation from partially subaerially exposed setting (FA1) through tide-dominated environment (FA2) to wave-influenced depositional setting may indicate an overall transgressive setting trend in these deposits.

2. STUDY AREA AND METHODS

The purpose of the study is to describe sedimentological and ichnological properties of the Luke-1X core, Danish Central Graben (Fig. 1), covering the Middle Jurassic Bryne Formation in order to tentatively interpret its depositional setting. For this purpose, the core was described at the Mærsk corelab, 1st–3rd of February 2010. The sedimentological description included descriptions of lithology, grain size, primary and secondary sedimentary structures, bedding contacts and character of bedding, soft-sediment deformation structures, mineralogical accessories and the identification of important stratigraphic surfaces. Ichnological data comprises description of ichnogenera and/or ichnospecies, trace-fossil assemblage, and bioturbation index (BI of Taylor and Goldring, 1993). BI provides a description of the degree to which original sedimentary fabric has been destroyed as a result of biogenic processes. This classification scheme allocates a numerical value ranging from 0 to 6 – the values corresponding to a percentage of bioturbation (cf. Taylor and Goldring, 1993). Undisturbed or non-bioturbated sedimentary fabrics are classified as BI 0 (0 percent reworked), while pervasively bioturbated media (100 percent reworked) are classified as BI 6. Intermediate levels of bioturbation are characterized using BI 1–5 and are defined as follows: BI 1, 1–4 percent reworked; BI 2, 5–30 percent reworked; BI 3, 31–60 percent reworked; BI 4, 61–90 percent reworked; and, BI 5, 91–99 percent reworked (Taylor and Goldring, 1993).

At the time of writing this report, well-log data or data from the side boring Luke-1XA were not available.

3. DESCRIPTION AND INTERPRETATION

The deposits are divided into 4 broad facies associations (FA1-4) based on their sedimentological and ichnological properties. These are described and interpreted below.

FA1: Lagoon - lagoon margin

Description: FA1 is a volumetrically important facies association type occurring in the lower part of the succession (Fig. 2). Its lower contact is gradational when overlying F2A, or sharp when it is overlying itself. The deposits are overlain erosionally by FA1/FA2. FA1 forms m-scale aggradational or upward fining successions that consist of the following elements: 1) the base of the succession consists of sharp- or gradationally-based, dm-scale interval of heterolithic interlamination or lenticular bedding. This facies grades upward into intensively burrow-mottled mudstone (BI 4-6), which is burrowed with monospecific to low diversity assemblage containing

Planolites and indistinct diminutive burrow mottling. It further grades to root-bearing mudstone or muddy very fine grained sandstone in the top of the succession (Fig. 3A). The upper most part of the succession is locally moderately to intensively (BI 2-5) burrowed by low-diversity assemblages that may cross-cut the root-bearing fabric. These assemblages may contain *Teichichnus* and *Diplocraterion habichi* (14684 ft; Fig. 3B); and lined vertical shafts (*Skolithos/Cylindrichnus*) and concentrically laminated subvertical burrow (?*Asterosoma*) (14652 ft). In addition, a possible passively-filled *Thalassinoides* occurs at 14722 ft forming a candidate for *Glossifungites* Ichnofacies demarcated surface.

Interpretation: Rarity of sedimentary structures, locally high bioturbation intensity coupled with fine grain-size suggests dominantly a sheltered low-energy setting. The only sediment structures are present in the lower part of the succession, where intervals of heterolithic lamination and lenticular bedding occur. Although diagnostic features for tidal process are lacking in this facies, the heterolithicity is interpreted to be due to tidal-influence because of the close stratigraphic occurrence with channel facies that show stronger evidence for tidal-influence (FA2; see interpretations below). The ichnological content of the succession points mainly to a very stressed, probably fresh to very low-brackish (monospecific to low-diversity *Planolites* dominated fabric) setting. Moreover, much of the deposits are commonly overprinted with rootlets, which further indicate a shallow subaqueous environment that repeatedly progrades into a subaerially exposed environment in the top of the successions. Considering the above described sedimentological and ichnological characteristics and stratigraphic occurrence of FA1, it is interpreted to represent lagoon-lagoon margin environments within a deltaic-estuarine setting.

The top of the FA1 successions are commonly associated with sharp lithological change and brief appearance of brackish water trace fossil assemblages, which may overprint rootlets (Fig. 2). These surfaces are tentatively interpreted either as Flooding surfaces (autocyclic or allocyclic flooding) or Tidal Ravinement Surfaces (Transgressive Surface of Erosion), in those cases when the erosionally-based overlying facies display clear indications of tidal processes. However, regional correlations are needed to before autocyclic and allocyclic processes can be distinguished with confidence.

FA2: Distributary channel – Mouth bar complex

Description: F2A is a recurring broad facies association type in the lower part of the core (Fig. 2). The deposits form two types of sedimentary successions: 1) erosionally-based, upward fining successions up to 6 m-thick; and 2) dm-scale aggradational units which have sharp or soft sedimentary deformation structures bearing lower contact. The first type of successions overlies root-bearing mud or rhythmic heterolithic interlamination (FA1) in erosion and gradationally grades into mud-dominated heterolithic bedding (FA1/FA3) in the top. The base of the succession consists typically of dm- to m-scale interval of clast-or matrix-supported extraformational conglomerates. This facies is typically unbioturbated, but locally, sporadic robust *Teichichnus* and *fugichnia* were observed (BI 0-3). Lithological accessories include coal fragments. Upward, the conglomeratic facies grades into dm-scale units of cross-stratified or massive, pebbly fine- to coarse-grained sandstone, which is commonly gradationally interbedded with cm-scale, dark grey massive mudstone beds. Bioturbation intensity is fluctuating ranging from unbioturbated to brief intervals of low to moderate (BI 0-3). Recognized trace fossil include common mud- and pebble-lined *Ophiomorpha* (Fig. 3C) and *Teichichnus*. *Ophiomorpha* locally descends from mud-drapes and may have passive heterolithic infill which shows double mud-drapes. Lithological accessories include coal- and mud-clast.

The second type of successions consists of dm-scale intervals that have either a sharp or loaded lower contact, and a gradational upper contact. It is intercalated with laminated dark grey mud at ~145620 ft (FA3; see below), or overlies F2A. It consists of mud-draped sigmoidal cross-stratification (Fig. 3D) or extraformational conglomerates. Very common feature are rip-up mud clasts. The successions are generally aggradational, but contain common upward coarsening intervals.

Interpretation: Sharp-based, m-scale upward fining successions are best interpreted as channel successions. Rhythmically mud-draped sigmoidal cross-stratification and double mud-drapes e.g., in the passively-filled *Ophiomorpha* burrow infill (“tubular tidalite”) suggest tidal influence in these channel deposits. This interpretation is in line with the ichnological data (e.g., *Ophiomorpha*, *Teichichnus*), which suggest brackish water influence in FA2. Moreover, the distribution of burrows suggests that a brief colonization window is associated with mud-drape development. Further considering that the tidally-influenced channel successions grade upward into bay-head delta mudstone (FA3, see below), these deposits are interpreted to represent laterally accreting distributary channel deposits. The second type of succession that forms thin channel-like units that erosionally or non-erosionally (loaded contact) overlie bay head prodelta sediments may represent terminal distributary channels (Olariu and Bhattacharya, 2006) or tidal mouth bars.

At ca. 14670 ft appearing cm-scale, structureless dark mudstone beds are interpreted as fluid mud deposits (i.e., a fine-grained sediment suspension where suspended sediment concentrations are greater than 10 g L^{-1}). This interpretation is supported by thickness of the mud-drapes (> 2 cm), soft sedimentary deformation features, outsized clasts and lack of bioturbation in these beds, which are all consistent with high initial sediment water content and energetic accumulation (e.g., Ichaso and Dalrymple, 2009; see also description of FA3).

FA3: Bay-head delta – estuarine embayment

Description: FA3 is a dominant facies association type occurring in the middle and top parts of the core. It forms subtle, up to 5 m-thick upward coarsening successions. FA3 overlies F2A in gradation and underlies it either in erosion or gradation. From 14618 ft upwards F2A forms a 24 m-thick series of gradationally stacked successions. Ideally, the base of a succession consists of laminated mud, which grades upward into lenticular lamination, and further into wavy bedding and parallel-laminated sand and mud in the top of succession (Figs. 4A-C). Individual mud-lamina thickness increases from ~2 mm to ~1.5 cm from the base to the top in individual successions. Lenticular and wavy-bedding consists of symmetric and asymmetric ripples that displays variably developed foreset off-shoots, bi-directional foreset, irregular lower bounding surfaces, and low relief gutter casts (Fig. 4B). Symmetric ripples become particularly well-developed from 14590 ft upwards in the core. Mud-on-mud erosional contacts, soft sedimentary deformation features and sand-filled subaqueous shrinkage cracks are pervasive throughout the FA3 (Fig. 4A).

Bioturbation intensity appears to be typically low in FA3, but fluctuates locally rapidly (BI 0-4). Recognized trace fossils include common *Teichichnus*, *Planolites,* biodeformational structures (“mantle-and-swirl”; Lobza and Schieber, 1999; Schieber et al., 2003), fugichnia, rare *Thalassinoides* and *Arenicolites* (Fig. 4C). The lack of lihtological contrast hinders the recognition bioturbation particularly in the laminated mud facies. Therefore, the estimated BI is likely lower in places than in reality.

Interpretation: Cm-scale, structure less dark mudstone beds, soft sedimentary deformation features, mud-on-mud erosional contacts and sporadic bioturbation are all consistent with fluid mud accumulation. Particularly, abundant soft sedimentary deformation structures and mantle-and-swirl (muddy-mantle-bearing deformed burrows) trace fossils support this interpretation as they indicate high initial water content of the sediment. Moreover, common robust equilibrium structures (*Teichichnus*) in laminated clay matrix indicate rapid accretion rate for the clay lamina. Furthermore, well-defined *Teichichnus* grades locally to biodeformational structure particularly when the lamina thickness approaches 1 cm (Fig. 4C). These structures lack well-defined burrow wall, show irregular mud-mantle, and diffuse grain size variation between the burrow and the unbioturbated matrix. Such trace fossils are interpreted to result from organisms swimming through fluid-rich substrate (Schieber et al., 2003). The pervasive subaqueous shrinkage cracks are interpreted to represent synaeresis cracks being consistent with tidally-modulated river flood origin for the lamina couplets. This interpretation is in line with the low-diversity *Teichichnus* and *Planolites* dominated ichnofabric, which is typical for a low salinity environment. Although the abundant fluid mud related stress factors likely also decrease the ichnological diversity in these deposits, more specialized feeding structures could be expected to occur locally as brief intervals if the environment was of higher salinity.

The symmetric ripples with foreset off-shoots, bi-directional foresets, and irregular lower bounding surfaces, as well as local low relief gutter casts, indicate common wave-influence in these deposits, particularly from 14590 ft upwards. Locally present asymmetric ripples and mud-draped foresets points further to combined-flow influence.

Considering the above mentioned criteria, upward coarsening nature of the successions and the stratigraphic position of the facies association gradationally above distributary channels and tidal mouth bar deposits (FA2), FA3 is interpreted to represent a bay head delta environment. The wave-dominated intervals are referred as estuarine embayment**,** in order to highlight the process change in the environment.

FA4: Bay offshore

Description*:* FA4 has a single occurrence in the top of the cored interval forming a ca. 9 m-thick succession. It is a gradational facies association type with the FA3 occurring gradationally above and below it. In rough terms, it consists of two main facies: 1) interlaminated mud and organic debris, and 2) coal. In addition to these, brief intervals of deformed organic rich mudstone and bioturbated mudstone exist. The base of FA4 occurs at 14535 ft and is visible as an abrupt increase in bioturbation intensity (BI 3-5) and organic matter content, and decrease in sand content. Upward the deposits grade through interlaminated mud and organic debris to coal layers (Fig. 4DE). Coal seams have typically gradational lower contact, whereas the upper contact is more abrupt. Coal occurs as three 15-150 cm-thick layers, which are interbedded with dm-scale organic rich mudstone intervals. The coal is black and appears as structureless and homogenic. Yellowish (sulphur?) staining occurs rarely. The coal seams appear as unbioturbated, but at 14518 ft there is a single occurrence of *Taenidium*, which rises to the coal interval from the underlying organic rich mudstone. The interbedded organic matter rich mudstone contains locally abundant pyrite. Moreover, outsized clasts and abundant soft sedimentary deformation occur in some intervals. Bioturbation intensity and potential trace fossil are difficult to delineate due to lack of lithological contrast. Probable meandering, diminutive *Planolites* occur at 14519 ft.

Interpretation: Lack of roots under the coal layers suggests that the coal is allochthonous. The increasing bioturbation intensity at the base of FA4 suggests decreasing sedimentation rate, which is interpreted to be due to abandonment of the bay head delta system. The simultaneous disappearance of wave-generated structures could be explained by deepening or autocyclic change in the embayment configuration (a change from an open embayment to a sheltered, oxbow lake-like setting). Tentatively, the combined abandonment of the bay head delta system and minor deepening in the depositional system are considered to be main mechanisms shaping the FA4 development. This interpretation is supported by the following observations: 1) The intergradational facies with coal (interlaminated mud and organic debris) suggests that coal was deposited via sediment gravity flows. Rare synaeresis cracks in lamina couplets suggest distal deltaic-influence for these deposits. Interpretation of periodically energetic deposition is also supported by abundant soft sedimentary deformation and outsized clasts in mudstone intervals.; 2) The gradation from FA4 to FA3 at 14500 – 14510 ft appears to be a normal progradational succession as suggested by the facies order in FA3 (interlaminated sand and mud occur gradationally below wave-ripple bearing lenticular bedding). This further suggests that the facies of FA4 probably represent deeper setting than those of the FA3. Local enrichment of pyrite is inline with this interpretation as it points to probably lowered oxygen levels in FA4. In summary, FA4 is tentatively interpreted to represent oxygen-deficient, bay-offshore deposits below fair weather wave base.

3. DISCUSSION AND CONCLUSIONS

3.1 Depositional Setting and Relative Sea Level Change

The observed lagoon-lagoon margin (FA1), distributary channel – mouth bar complex (FA2), bay head delta- estuarine embayment (FA3, FA4) are all consistent with an overall estuarine embayment complex. Due to lack of regional correlations and highly autocyclic nature of estuarine/deltaic environments the assessment of relative sea level change can only be made in a very tentative manner. Several candidates for flooding surfaces are indicated in the log-profile (Fig. 2). In general, the studied environments grade from alternating root-bearing horizons and lagoonal deposits to tidally-influenced setting, and further in to a wave-influenced embayment setting. This could be easily explained by an overall transgressive trend in the studied deposits. However, despite of the alleged transgression, synaeresis cracks remain pervasive also in the top of the core and trace fossil assemblage as very stressed. In addition to this, the stacked successions of FA3 suggest that facies belts are possibly nearly aggradational in the upper half of the core.

3.2 Future Investigations

- Detailed delineation of depositional environments - particularly depositional controls of organic matter (coal) - and relative sea level change would benefit from microfossil data (e.g., dinocysts). This is particularly the case because fluid mud deposition related stress factors decrease the ichnological diversity in these deposits and thereby complicates ichnology based paleosalinity estimations. Furthermore, well-log data and the side boring Luke-1XA need to be studied before conclusive interpretation of the depositional controls of organic matter (coal) can be made. The presence / absence of roots below coal seams must be reconfirmed in Luke-1XA. This is particularly the case because the observed trace fossil *Taenidium* (14518 ft), would be a reasonable find also in in situ coal layers. Scrutinized paleoenvironmental interpretation would help the prediction of the architecture of the coal layers, their volumetric assessment, and their occurrence in the sedimentary record.
- The facies variation and depositional environments of Luke-1X bear strong similarities with the Rita-1X well, which covers the upper Jurassic Gert Member (Heno Fm.). The biostratigraphic data should be checked when available to confirm the age of these deposits.

REFERENCES

Ichaso, A., and Dalrymple, R., 2009, Tide- and wave-generated fluid mud deposits in the Tilje Formation (Jurassic), offshore Norway: Geology, v. 37, p. 539–542.

Lobza, V., and Schieber, J., 1999, Biogenic sedimentary structures produced by worms in soupy, soft muds: observations from the Chattanooga Shale (Upper Devonian) and experiments: Journal of Sedimentary Research, v. 69, p. 1041–1049.

Olariu, C., and Bhattacharya**,** J., 2006, Terminal Distributary Channels and Delta Front Architecture of River-Dominated Delta Systems: Journal of Sedimentary Research, v. 76 p. 212-233

Schieber, J., 2003, Simple gifts and buried treasures—implications of finding bioturbation and erosion surfaces in black shales: The Sedimentary Record, v. 1, p. 4–9.

Taylor, A.M., and R. Goldring, 1993, Description and analysis of bioturbation and ichnofabric: Journal of the Geological Survey, London, v. 150, p. 141–148.

FIGURE CAPTIONS

Figure 1. Map of the study area showing the location of the studied core.

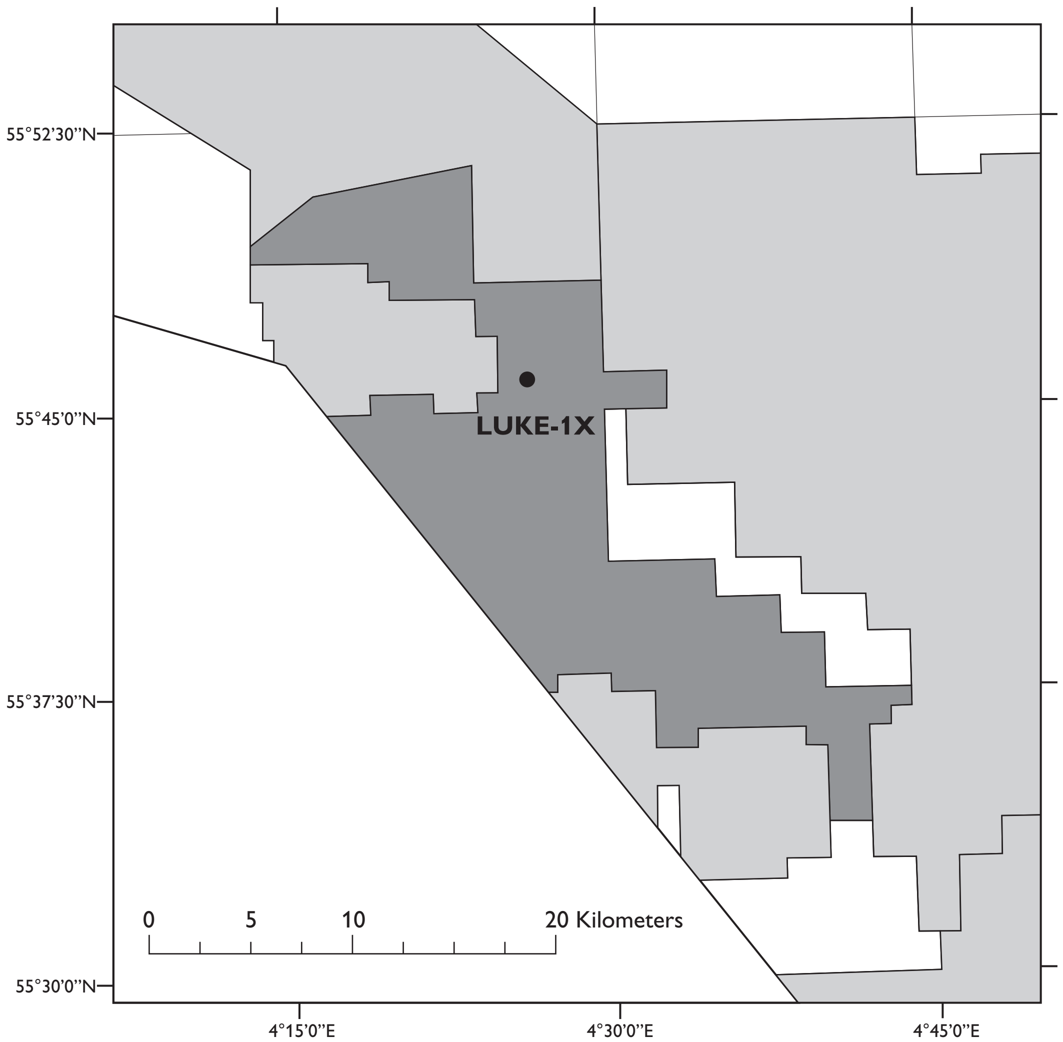
Figure 2. Sedimentological log profile of the Luke-1X (Bryne Fm.) well.

Figure 3. A) Root-bearing, muddy very fine grained sandstone (FA1). rh–rhizolite. 4488.18 m (14725 ft). B) Intensively bioturbated interval marking the top of a FA1 interval. Recognized genera include *Teichichnus* (Te; fuzzy edge, lacks marginal burrow) and *Diplocraterion habichi* (Dh; straight edge with a marginal burrow). The assemblage is interpreted to be associated with a Flooding Surface (white dashed line). 4475.56 m (14683.6 ft). C) Mud- and pebble-lined *Ophiomorpha* (Op) burrowing pebbly fine-grained sandstone (FA2). Burrows descend from a mud-drape (dashed white line) suggesting that a brief opening of colonization window is associated with the mud-drape development. 4462.88 m (14642 ft). D) Mud-draped sigmoidal cross-stratification

(FA2). Note the common mud-clasts. 4456.48 m (14621 ft). E) Structureless massive dark grey mudstone bed interbedded with fine-grained sandstone (top of FA2). The ca. 1.5 cm-thick mud bed layer is interpreted as a fluid mud layer (see text for discussion). 4465.62 m (14651 ft).

Figure 4. A) Interlaminted sand and mud and lenticular bedding (FA3). Note the abundant subaqueous shrinkage cracks interpreted as synaeresis cracks (sy). B) Lenticular bedding (FA3). Note the symmetrical ripples, bi-polar foresets (black arrows) and lamina offshoots (os) suggesting wave-influence. 4431.18 m (14538 ft). C) Laminated mud with *Teichichnus* (Te) that locally grades into diffuse biodeformation structure (ms–“mante-and-swirl”), which lacks clear burrow boundary, displays diffuse grain size variability and mantle development in places. (FA3). 4439.41 m (14565 ft). D) Coal (FA4). Pen (0.6 cm wide) as a scale. 4424.48 m (14516 ft). E) Interlaminated mud and organic matter (dark grey drapes) (FA4). 4421.12 m (14505 ft).

Luke-1X (5504/6-6)



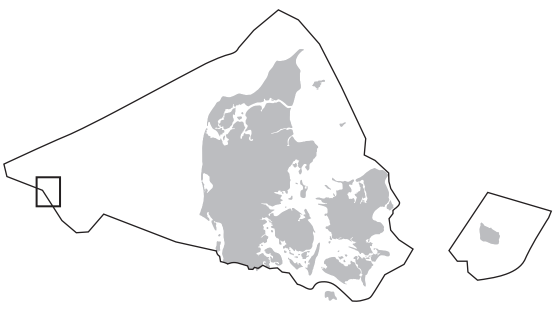
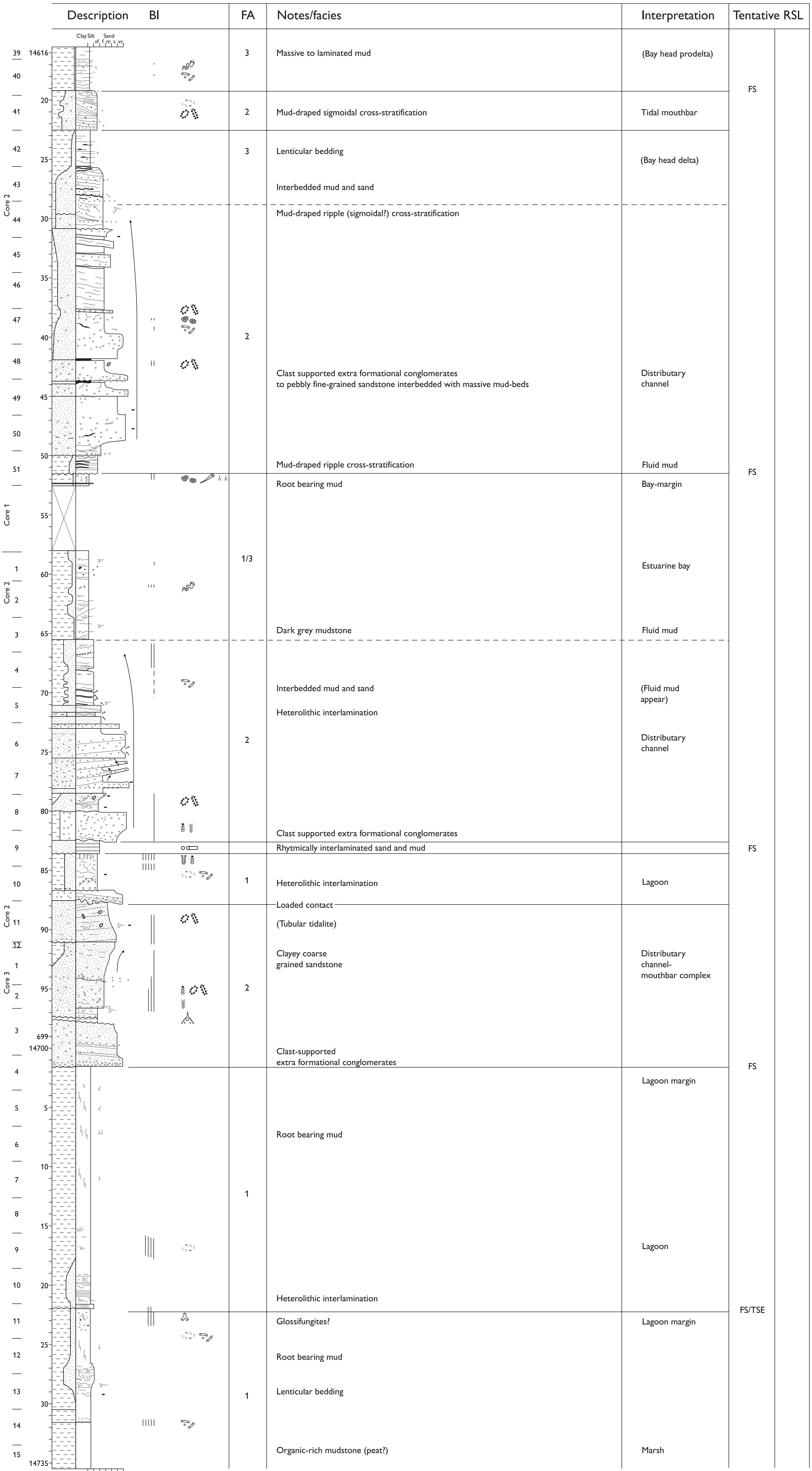


Figure 1



Description
BI
FA
Notes/facies
Interpretation
Tentative RSL
Clay Silt
Sand
vf f m c vc
14616
Core 2
Core 1
Core 3
699
14700
14735
3
Massive to laminated mud
(Bay head prodelta)
FS
2
Mud-draped sigmoidal cross-stratification
Tidal mouthbar
3
Lenticular bedding
(Bay head delta)
Interbedded mud and sand
Mud-draped ripple (sigmoidal?) cross-stratification
2
Clast supported extra formational conglomerates
to pebbly fine-grained sandstone interbedded with massive mud-beds
Distributary
channel
Mud-draped ripple cross-stratification
Fluid mud
FS
Root bearing mud
Bay-margin
1/3
Estuarine bay
Dark grey mudstone
Fluid mud
Interbedded mud and sand
(Fluid mud
appear)
Heterolithic interlamination
2
Distributary
channel
Clast supported extra formational conglomerates
Rhytmically interlaminated sand and mud
FS
1
Heterolithic interlamination
Lagoon
Loaded contact
(Tubular tidalite)
Clayey coarse
grained sandstone
Distributary
channel-
mouthbar complex
2
Clast-supported
extra formational conglomerates
FS
Lagoon margin
Root bearing mud
1
Lagoon
Heterolithic interlamination
FS/TSE
Glossifungites?
Lagoon margin
Root bearing mud
Lenticular bedding
1
Organic-rich mudstone (peat?)
Marsh

Figure 2

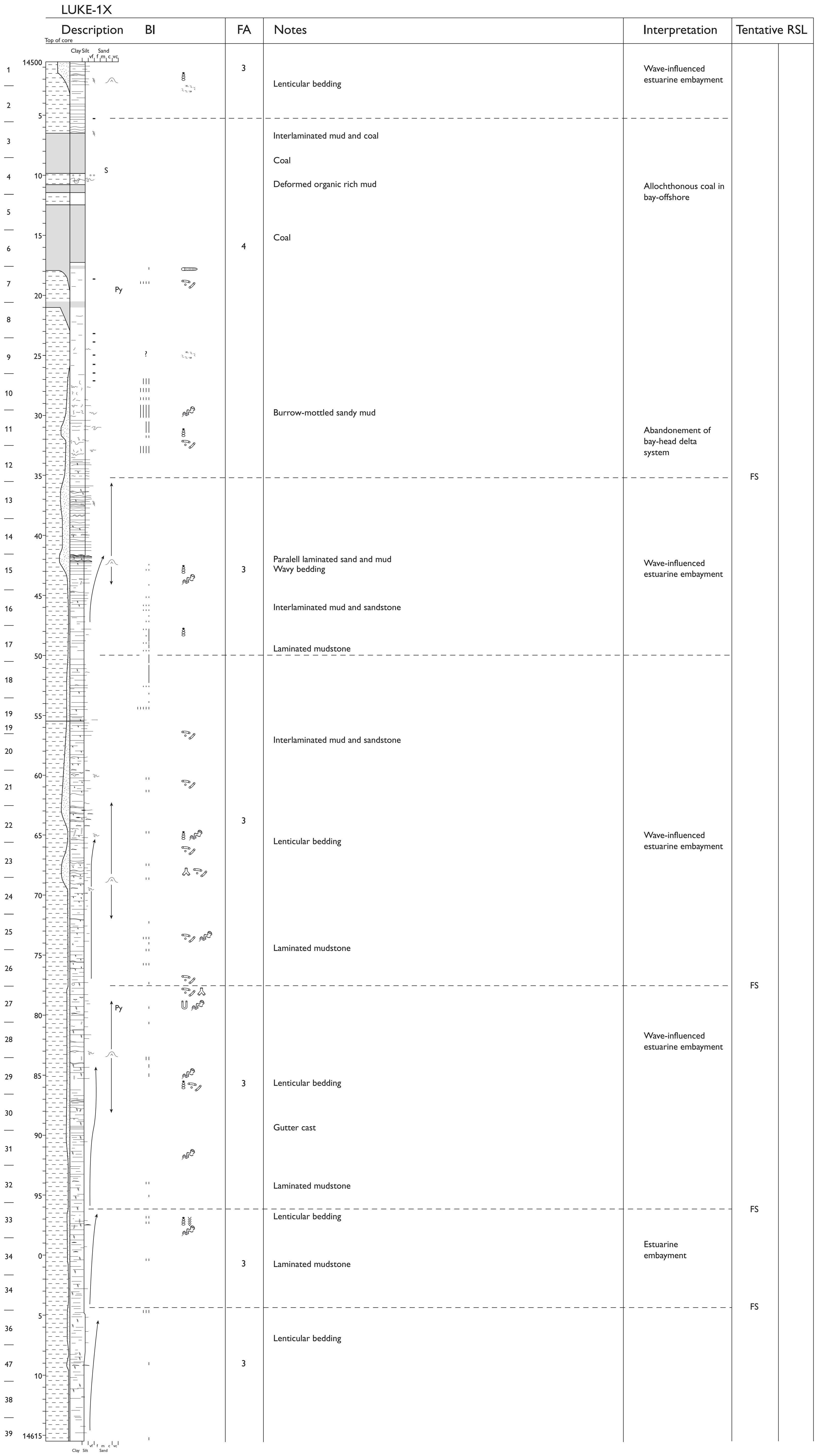


Figure 2 Cont.

Lithology

- Sandstone
- Mudstone
- Muddy sandstone
- Sandy mud
- Conglomerate
- Extraformational clast
- Mud clast
- Coal clast
- Ca-cement

Sedimentary structures

- Low angle cross-stratification
- Trough cross-stratification
- Tangential cross-stratification
- Planar lamination
- Asymmetric ripple cross-stratification
- Symmetric ripple cross-stratification
- Combined flow ripple cross-stratification
- Climbing ripple cross-stratification
- Heterolithic bedding (mud dominated)
- Heterolithic bedding (sand dominated)
- Graded bedding
- Erosive contact
- Contorted bedding
- Loading
- Water escape structure
- Synaeresis crack

Other

- Moullusc (Bivalve shell)
- Bellemnite
- Organic matter
- Py Pyrite
- Fracture
- Fault
- Gl Glauconite
- Trend of the coarsests grain size fraction

Bioturbation Index (BI):

IIIIII	100 %
IIIII	91–99 %
IIII	61–90 %
III	31–60 %
II	5–30 %
I	1–4 %

FS Flooding surface
TSE Transgressive surface of erosion

Biogenic structures

1 *Arenicolites*
2 *Ancornichnus*
3 *Asterosoma*
4 *Burrow motling*
5 *Chondrites*
6 *Curvolithus*
7 *Conichnus*
8 *Cylindrichnus*
9 *Diplocraterion habichi*
10 *Diplocraterion isp.*
11 *Diplocraterion parallelum*
12 *fugichnia*
13 *Gyrolithes*
14 *Helminthopsis*
15 *"Laminites"*
16 *Lockeia*
17 *Macaronichnus isp.*
18 Mantle and swirl
19 *Nereites*
20 *Ophiomorpha irregulaire*
21 *Ophiomorpha* isp.
22 *Palaeophycus herberti*
23 *Palaeophycus tubularis*
24 *Phoebichnus*
25 *Phycosiphon incertum*
26 *Planolites*
27 *Rhizocorallium irregulare*
28 *Rhizocorallium* isp.
29 *Rhizocorallium jenense*
30 *Roots*
31 *Rosselia*
32 *Schaubcylindrichnus frey ("Terebellina")*
33 *Scolicia*
34 *Skolithos* isp.
35 *Spirophyton*
36 *Spreite structures*
37 *Taenidium*
38 *Teichichnus* isp.
39 *Teichichnus rectus*
40 *Teichichnus zigzag*
41 *Thalassinoides* isp.
42 *Zoophycos*

Figure 2 Cont. 2

Figure 3

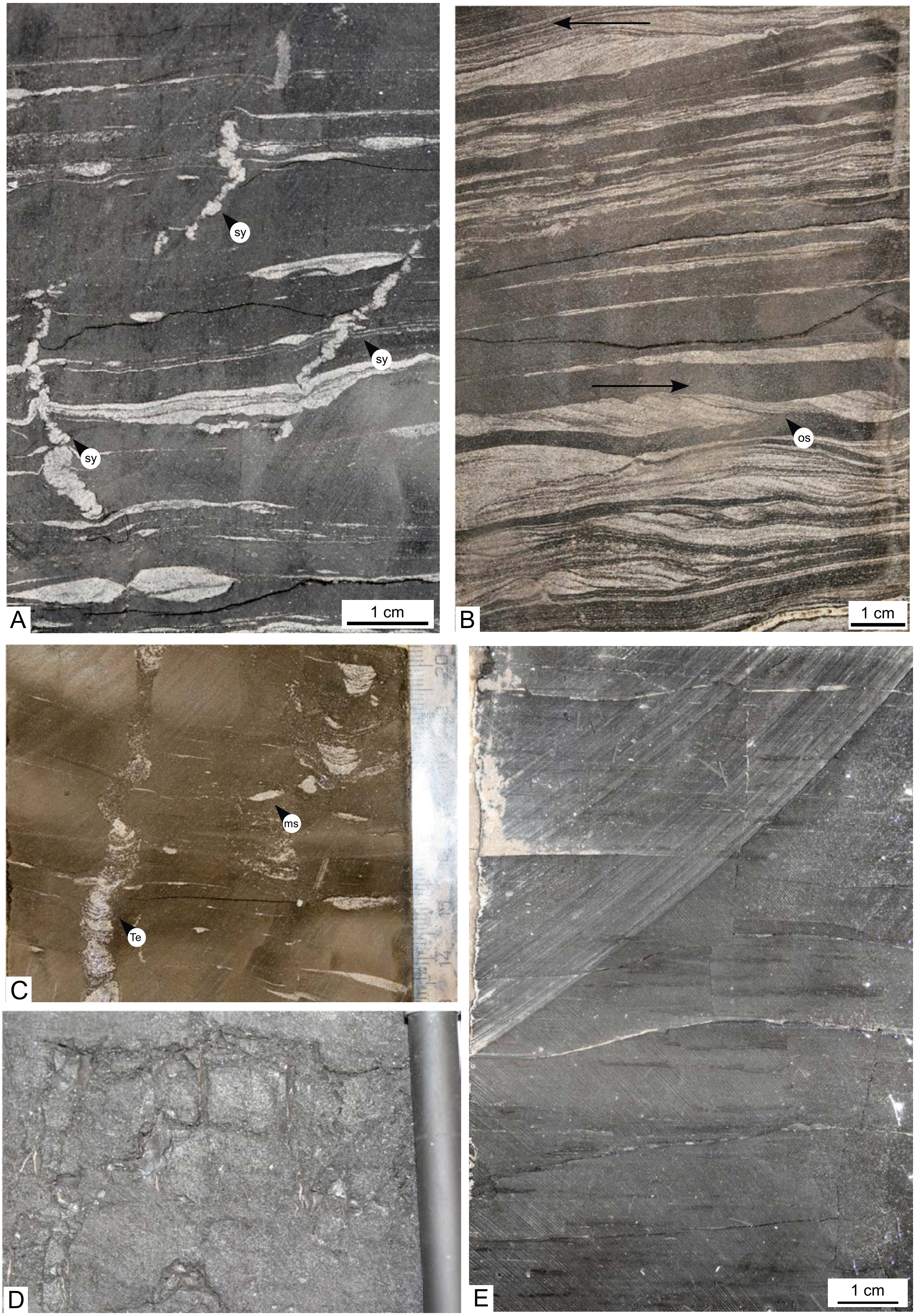


Figure 4