DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/84

The Lower Palaeozoic sequence in the Slagelse-1 well

Stratigraphical, lithological and geochemical evaluation

Niels H. Schovsbo

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1. Introduction

The Slagelse-1 exploration well was drilled in 1959 on western Zeeland. The well was drilled to test a Zechstein play on the northern flank of the Rinkøbing-Fyn High (Thomsen et al. 1987). The well penetrated 335 m of Lower Palaeozoic sediments and was terminated at 2975 m in the Lower Cambrian Hardeberga Fm.

The purpose of this report is to present an updated stratigraphical, lithological and geochemical evaluation of the Lower Palaeozoic succession in the Slagelse-1 well. The description of the lithological units is based on log response and lithological descriptions of cuttings and cores. 20 samples have been processes and analysed. The analysis includes Total Organic Carbon (TOC) and Rock Eval, Total Carbon (TC) and Total Sulphur (TS) measurements. In addition XRD analyses have been made together with quantitative analyses of quartz content and a qualitative assessment of the mineralogical content. Quantification of the grain-size distribution has been made on 14 samples. In addition, reprocessing of the frequency histograms for 8 vitrinite samples have been made to re-asses the thermal maturity gradient in the Slagelse-1 well.

Geochemical data from previous studies made at GEUS are integrated in the report (Bojesen-Koefoed & Petersen 2001). The presented data are also included in digital version on the attached CD.

The report logs, well information and geochemical data that form part of the GEUS Slagelse-1 well data and log packages together with the seismic line SSl7276 72/001 have been used for preparing this report.

Figure 1. Map showing the location of the Slagelse-1 well. The well was drilled close to Harrested village on Zeeland. The name Slagelse derives from the name of the nearest large town.

2. Well data summary sheet Slagelse-1

Location	Onshore
Longitude	11°22'41.32" E
Latitude	55°22'21.84" N
UTM Zone	32
UTM Easting (x)	650705.0 (m)
UTM Northing (y)	6138978.4 (m)
Well block no.	5511/22-1
Reference point	RT 40.9 m above MSL
Ground level	37.6 m above MSL
TD log	2975.0 m below reference point
TD drill	2974.8 m below reference point
Formation at TD	Hardeberga Fm (Lower Cambrian)
The well is	Vertical
Structure	Slagelse
Spudded	09/03-1959
Completed	21/05-1959
Spud classification	Exploration
Status (completion)	Plugged and abandoned
License	DAPCO
Operator	(STANDARD) GULF
Contractor Rig	EMSCO
HC shows:	No oil or gas shows were reported and the well was classified as dry.
Results:	The well drilled the Lower Palaeozoic sequence from 2640 m below RT and to 2975 m (TD). A total of 16 cores were cut and hereof 10 in the Lower Palaeozoic sequence. Cutting samples were collected with a general spacing of 3 m. The well drilled light to dark green silty mudstone of Silurian age from 2640 and to 2903 m followed by 17 m of green-grey Ordovician mudstone. The top of the Alum Shale was drilled at 2919 m and the base of the formation was reached at 2949 m. Below the Alum Shale a 25 m thick package of mixed siltstone-sandstone lithologies belonging to the Gislöv (top at 2949 m), Læså (top at 2958 m) and Hardeberga (top at 2970 m) formations were drilled.

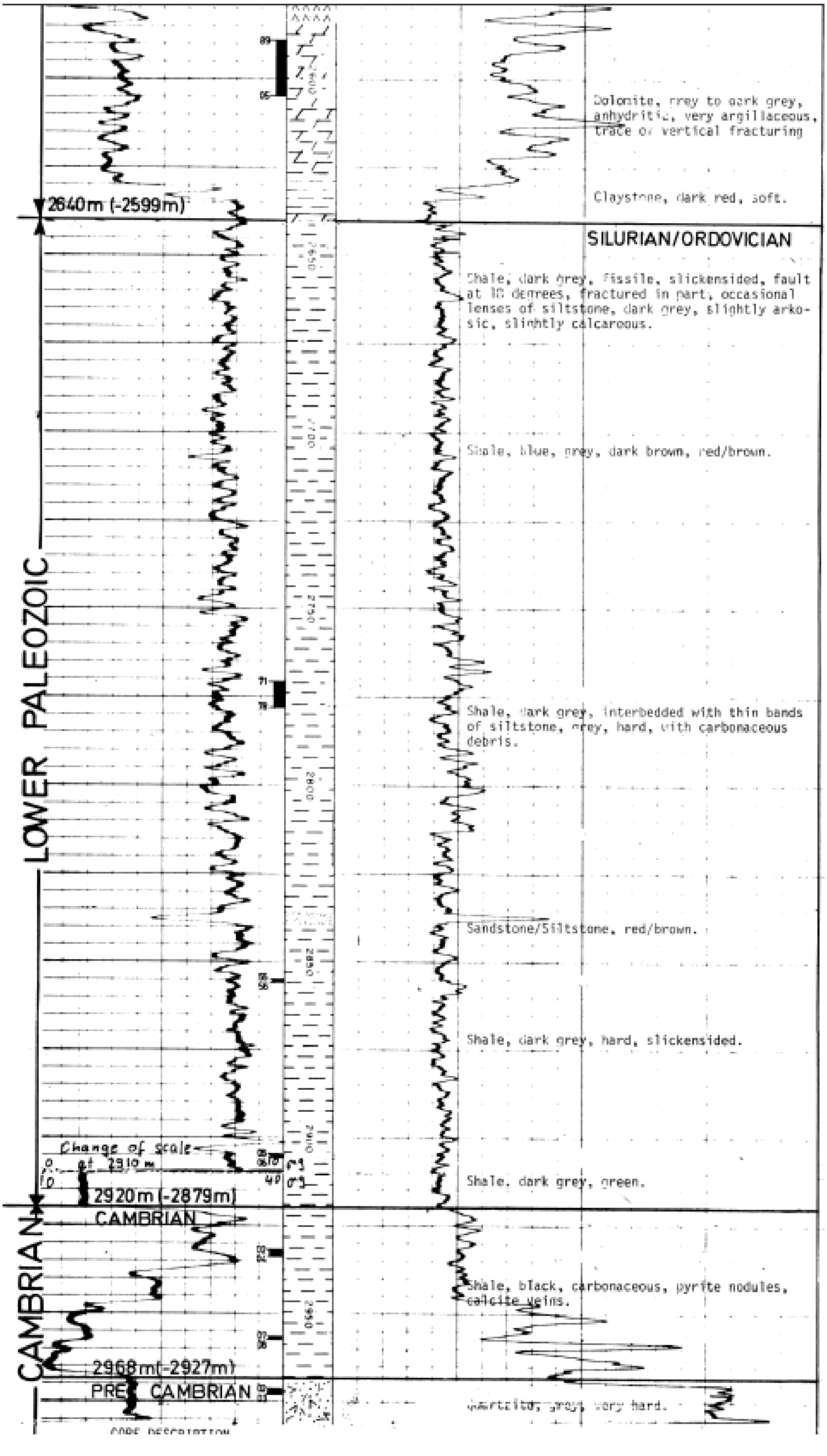


Figure 2. Part of the Slagelse-1 composite log. Cored intervals are indicated on the left side of the lithological column. Note that the ‘Pre-Cambrian’ unit is here interpreted to represent the Lower Cambrian Hardeberga Fm.

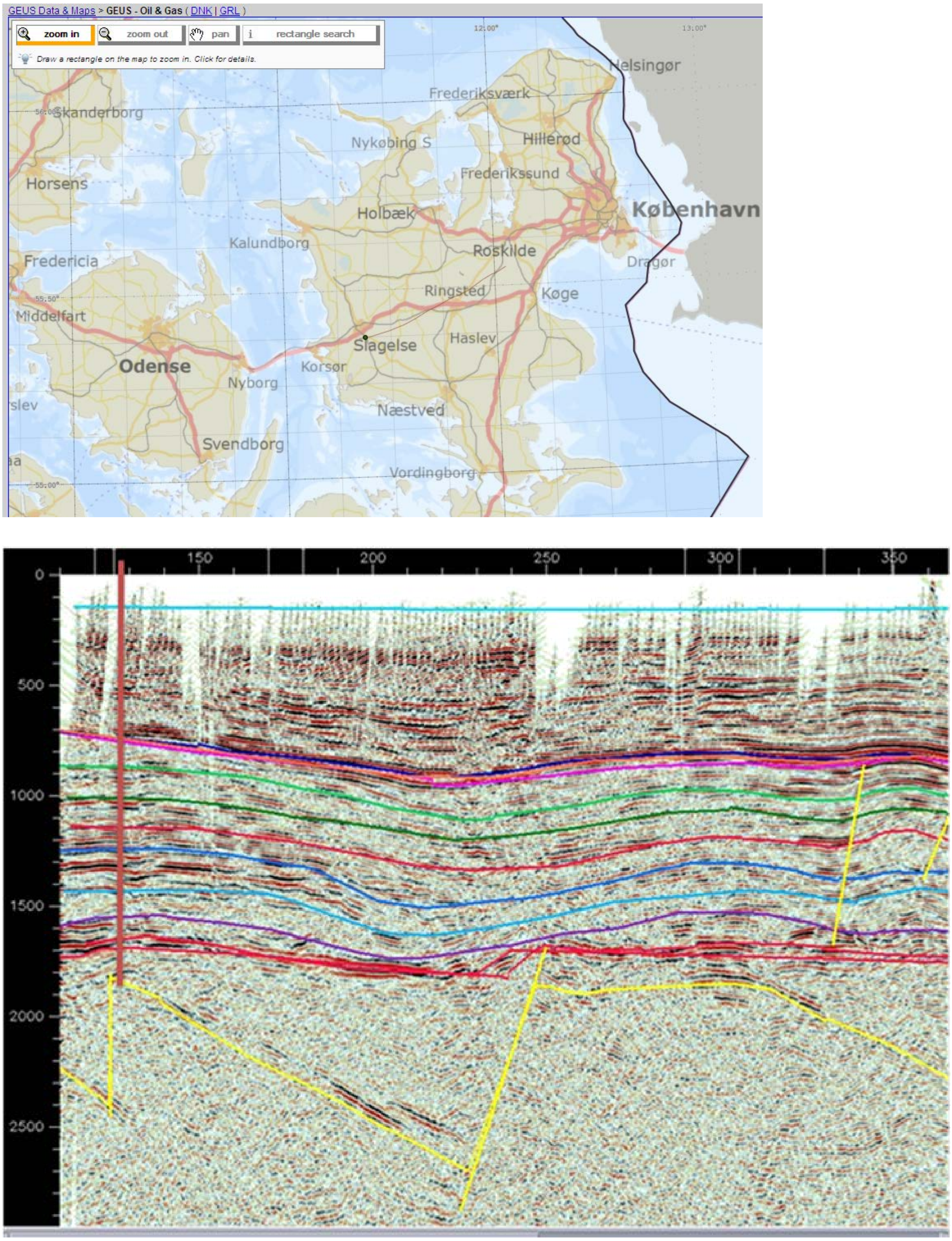


Figure 3. Location of the Slagelse-1 well and the seismic line SSl7276 72/001 (top) and interpretation of the seismic line 72/001 (below). The Slagelse-1 well is not positioned directly on the seismic line and a projected approximate position of the well onto the line is indicated with a red-brown vertical line. On the seismic line the top Pre-Zechstein surface is shown with a red line and the outline of the Palaeozoic fault blocks is shown with a yellow line. The seismic line is interpreted by Torben Bidstrup, GEUS.

3. Stratigraphical evaluation of the Lower Palaeozoic

3.1. Stratigraphical frame for the Lower Palaeozoic in Denmark

The Lower Palaeozoic litho- and biostratigraphical frame is presented in Figures 4, 5 and 6.

The Cambrian sand- and siltstones in Denmark comprise the Nexø, Hardeberga, Læså and Gislöv formations (Figure 4). For a recent review of these formations see Nielsen & Schovsbo (2006).

The Nexø Fm comprises a reddish coloured somewhat arkosic sandstone.
The Hardeberga Fm comprises well-sorted strongly cemented quartzite sandstone. The formation includes subordinate silt- and mudstone layers.
The Læså Fm is dominated by greenish grey siltstone with variable glauconite content. Phosphorite nodules occur at several levels and sandstone layer are common especially in the upper part of the formation. The top member, the Rispebjerg Member, is a regionally distributed sandstone bed (Figure 4).

The Cambrian to Lower Ordovician Alum Shale Fm consists of dark organic rich mudstone with abundant disseminated pyrite. In Denmark and southern Sweden (Scania) the formation has a low proportion of diagenetic carbonate beds (Figure 5). This lithology has been termed the 'outer shelf type' by Schovsbo (2002). Alum Shale with higher proportions of non shale beds including primary carbonates, conglomerates and diagenetic carbonate concretions are present in the south-central parts of Sweden and on Öland (Figure 5). This lithology has been termed 'inner shelf' type by Schovsbo (2002). The Exsulans and Andrarum limestones (both <1 m thick) occur in the lower part of the formation (Figure 5). These marker beds are primary bioclastic limestones. They represent important stratigraphical horizons that are particular easy to recognise on gamma ray logs due to low GR response.

Ordovician shales and limestone formations on Bornholm above the Alum Shale comprises the Komstad Limestone, Dicellograptus shale and the Lindegård Fm (previous the Jerrestad and Tommarp mudstones) (Figure 6).

The Komstad Limestone is a thin-bedded cold water bioclastic carbonate. The unit contains variable amounts of clay, phosphorite and glauconite. It is known from Bornholm and southern Sweden (Scania), but peters out westwards and is likely not present subsurface of Denmark.

The Dicellograptus Shale is a grey to dark mudstone. The lower part contains numerous bentonite beds including the up to one meter thick 'Kinnekulle' Bentonite. The top of the Formation, corresponding to the Fjäcka Shale of south central Sweden, is developed as a black mudstone that contain up to 4 % TOC in Scania and on Bornholm (Schovsbo 2003, Figure 12).

The Lindegård Fm is a bioturbated green-grey mudstone to siltstone. Thin sandstone beds with conglomeratic horizons may occur.

The Silurian shale is represented by the Rastrites and Cyrtograptus shales on Bornholm. Upper Silurian shales (Nøvling and Rønde Formations) are present in the Nøvling and Rønde wells (Michelsen & Nielsen 1991). The Rønde Fm consists of interbedded shale and sandstone and the Nøvling Formation consists of volcanics interbedded with shales and sandstone. Sørensen & Martinsen (1987) suggested that the Nøvling Formation was of Rotliegendes age.

The Rastrites shale comprises a black to dark-grey silty mudstones. Current generated sedimentary structures and calcite cemented sandy beds occur in some intervals. TOC rick intervals occur notably in the base of the Formation and in *convolute* graptolite Zone (Figure 12, Schovsbo 2003). The Cyrtograptus Shale comprises a grey silty mudstone.

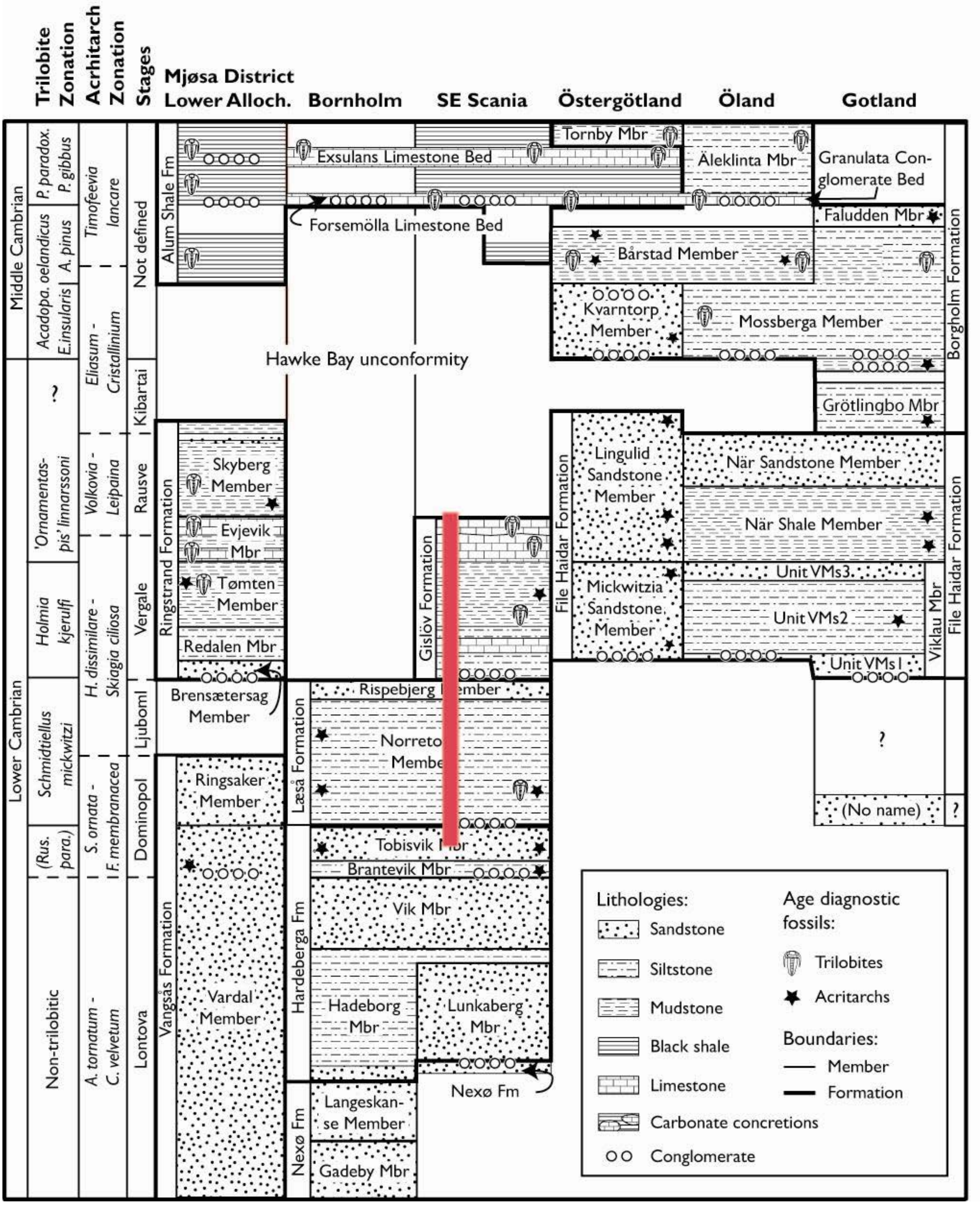


Figure 4. Lithostratigraphic scheme for the Lower and lower Middle Cambrian of southern Scandinavia. From Nielsen & Schovsbo (2006). Red line indicates the approximate stratigraphic range of the Slagelse-1 well (see also Fig 5).

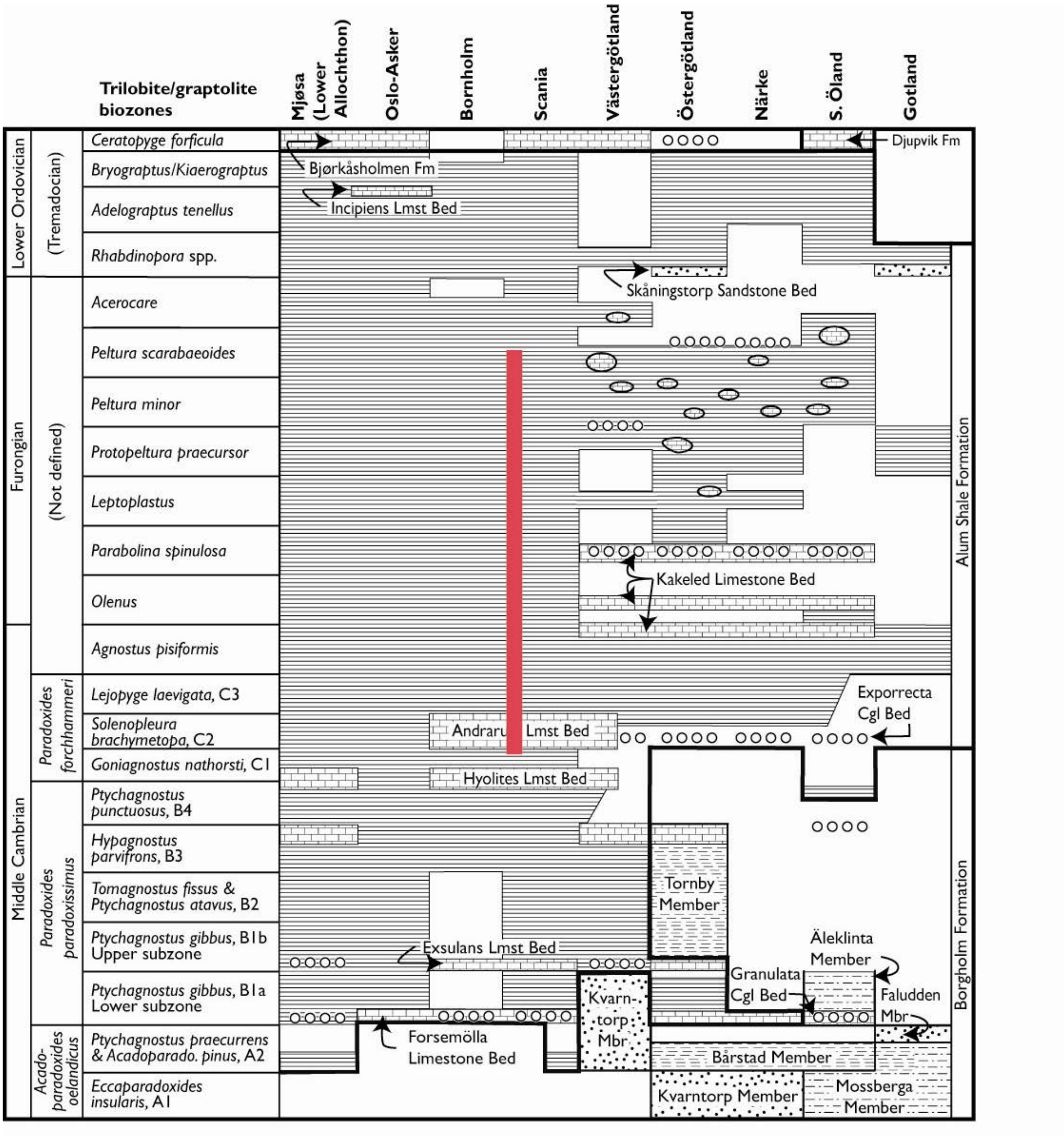


Figure 5. Lithostratigraphic scheme for the Middle Cambrian, Furongian and Lower Ordovician (Tremadocian) of southern Scandinavia. From Nielsen & Schovsbo (2006). Red line indicates the approximate stratigraphic range of the Slagelse-1 well (continued from Fig 4, but the Hawke Bay unconformity seems to be more extensively developed in the Slagelse area. See also Fig. 6).

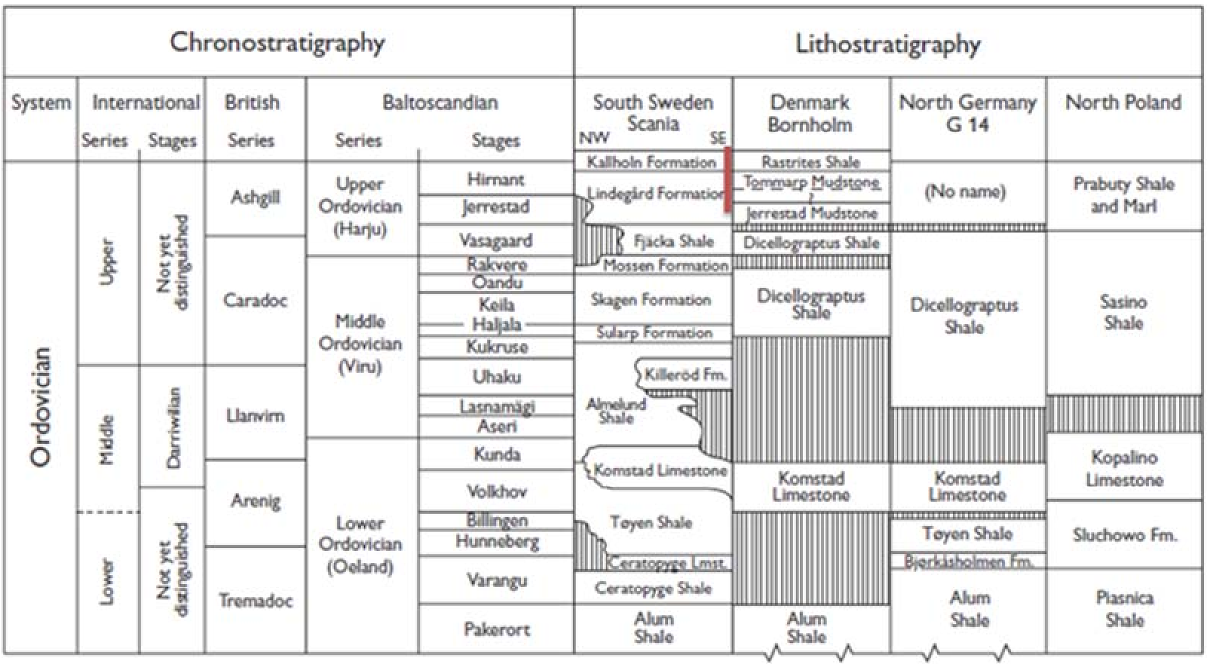


Figure 6. Stratigraphic scheme of Scania, Bornholm, northern Germany (G14) and northern Poland with indications of main lithologies. From Stouge & Nielsen (2003). Red line indicates the approximate stratigraphic range of the Slagelse-1 well.

3.2. Biostratigraphical results

Biostratigraphic dating of the Lower Palaeozoic interval in the Slagelse-1 well is based mainly on macrofossils found in the cored sections (Table 1). Studies of acritarchs have been published by Vecoli & Samuelsson (2001) for a few samples from the Silurian cores.

The macrofossil investigations were summarised by Poulsen (1974). The Lower Cambrian cores (core 14-16) did not yield any macrofossils and neither did the Alum Shale core (#13) contain any age diagnostic fossils (only fragments of indeterminable inarticulate brachiopod shells were observed). The association of brachiopods with spindle-shaped crystals indicate, however, a Furongian age although an Early Ordovician age cannot be ruled out (Poulsen 1974).

Core 11-12 did not contain any macrofossils either, but they are here assumed to be of Ordovician age. Core 7 to 10 contained graptolites that according to Poulsen (1974) indicated an Early Silurian (Llandovery) age. Poulsen (1974) assigned all samples to the *M. crispus* graptolite Zone.

Studies of acritarchs in cores and cutting samples were initiated by Claus Kock Clausen and a total of 38 slides prepared for palynology were made in the 1980'thies. The results of this study have, however, not been published. Nielsen (1995) cited a personal communication from Claus Kock Clausen that 3 m of Upper Ordovician (Caradoc) mudstone was present above the Alum Shale Formation. This suggests that part of the Dicellograptus Shale might be present in the Slagelse-1 well.

Vecoli & Samuelsson (2001) reported on the acritarchs from core 10. The recovered in-situ Llandovery flora contained reworked Cambrian and Ordovician species.

Table 1. Summary of the biostratigraphic results obtained on the cored intervals in the Slagelse-1 well. Modified from Poulsen (1974).

M, depth below RT	**Core #**	**Biostratigraphic index fossil**	**Age**
2640.0-2647.7	7 and 8	*Monograptus priodon*	?Lower Silurian, upper part of Llandovery, the *Monograptus crispus* Zone
2770.8-2777.6	9	*Monograptus crispus*	Lower Silurian, upper part of Llandovery, the *Monograptus crispus* Zone
2812.5-2814.7	10	*Monograptus crispus*	Lower Silurian, upper part of Llandovery, the *Monograptus crispus* Zone
2855.0-2856.1	11	Barren	
2905.0-2906.0	12	Barren	
2932.3-2933.8	13	inarticulate brachiopods, spindle shaped pyrite crystals	Furongian ?*Olenus-Parabolina* Zone
2957.0-2958.0	14	Barren	
2971.8-2973.3	15 and 16	Barren	

3.3. Rock types in Slagelse-1

The main Lower Palaeozoic rock types in the Slagelse-1 well have been defined based on the GR-NEUT log response (Figure 7). The following main rock types have been identified:

1) Black shale: GR >10 api,
2) Sandstone-siltstone: NEUT >250
3) Silty shale: GR <10 api and 225< NEUT <250
4) Green shale: GR <10 api and NEUT <225

The selections of cut-offs for the rock types have been made in order to match the lithological descriptions of the cores and cutting samples.

Based on the above criteria rock type curves have been constructed for the Lower Palaeozoic interval. The rock type curves are presented in Figure 8. Digital versions are included in LAS file format on the attached CD.

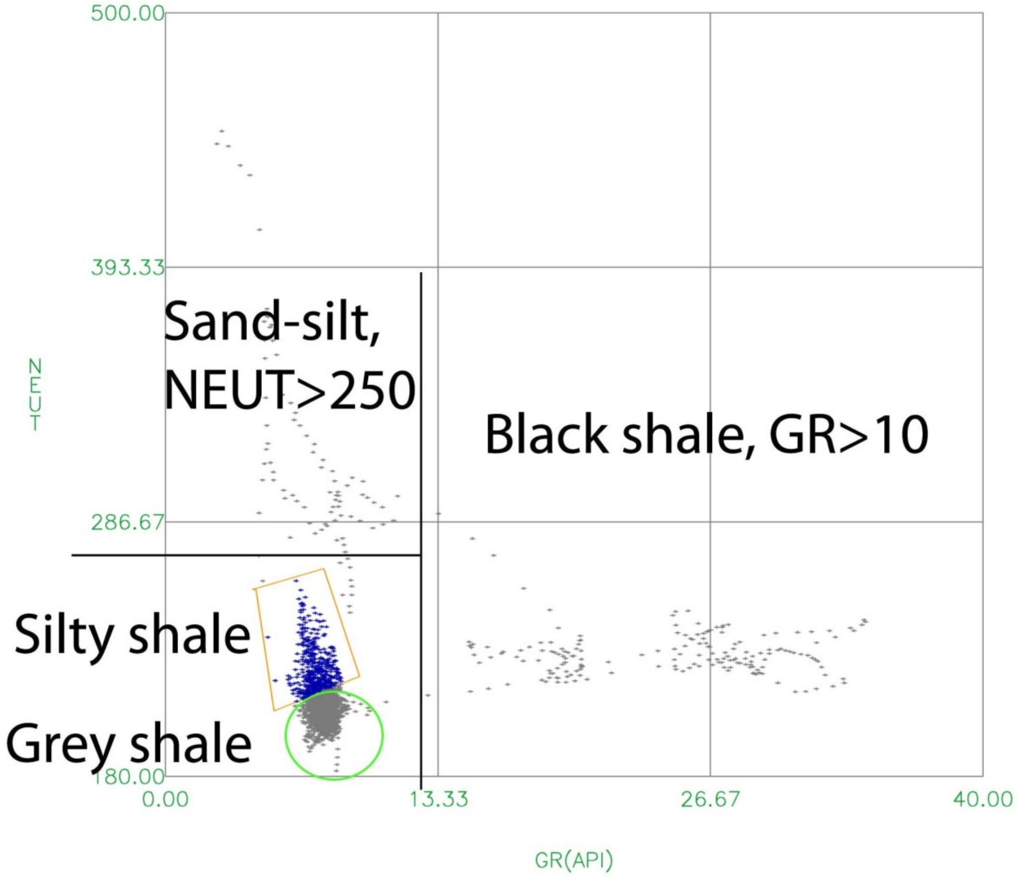


Figure 7. Discrimination of Lower Palaeozoic rock types in the Slagelse-1 well based on the GR-NEUT log response. The selection of the cut-offs are based on an evaluation of the lithological description of cores and cutting samples.

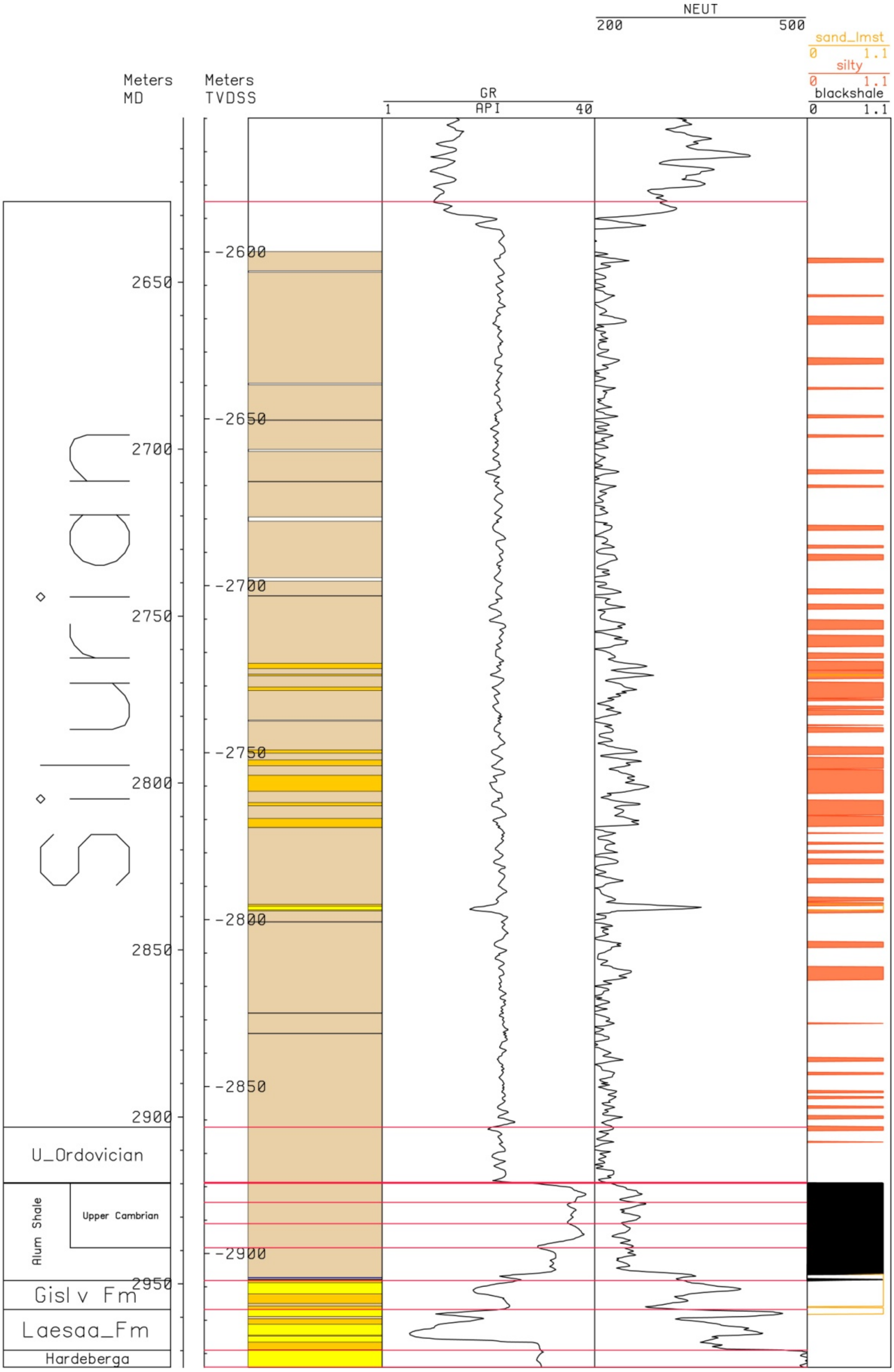


Figure 8. GR and NEUT log curves in the Slagelse-1 well together with the stratigraphical division and lithological analysis. The lithological column is based on the cutting and core descriptions. The right panel shows two of the lithological rock types. Black intervals indicate a black shale rock type (GR >10 api) and red intervals indicate a silty shale rock type (GR <10 api and NEUT between 225 and 250). Curves are also calculated for the sand-siltstone and green shale rock types.

3.4. Lithostratigraphical units

The following lithological units have been identified in the Slagelse-1 well:

<u>Hardeberga Formation 2969.8-2974.7 m (TD)</u>
Description: Quartzite, semi translucent and extremely hard.

Log response: Very high NEUT values (>225) and high GR values. The log response is interpreted to reflect strongly cemented sandstone, in part glauconitic. The top of the Hardeberga Fm is characterised by a very sharp decrease in NEUT values.

<u>Læså Formation 2957.7-2969.8 m</u>
Description: Dark-green to grey siltstone with trace of sandstone and carbonate seams.

Log response: High but variable NEUT values (>225) and low GR values (<10 api units). The base of the formation is characterised by low NEUT values. GR values are relatively high. The GR values decrease slightly above the base of the unit. This pattern may reflect the presence of glauconite in this part of the formation. The top of the formation is characterised by a sharp increase in NEUT values that become almost as high as those recorded in the Hardeberga Fm. The increase in NEUT values is interpreted to reflect the Rispebjerg Member that is a regionally distributed sandstone bed in the topmost part of the Læså Fm (Figure 4).

<u>Gislöv Formation 2949.4-2957.7 m</u>
Description: Silty mudstone with occasional sandstone and carbonate seams.

Log response: Variable to intermediate high NEUT values (>225) and low GR values. The base of the formation is characterised by low NEUT values and high GR values. This signature likely reflects the presence of glauconite in the unit. The top of the unit is characterised by a spike in the NEUT curve immediately below an interval where the GR increases to >10 api units. This level probably represents a sandstone or, more likely, limestone bed in the topmost part of the Gislöv Formation.

<u>Alum Shale Fm 2919.6-2949.4 m</u>
Description: Dark black and very carbonaceous mudstone with nodules and thin seams of pyrite.

Log response: Very high GR values (>10 api units) and low NEUT values. The base of the Alum Shale Fm is placed where the GR values increase to above 10 api units. An interval with high NEUT values and low GR in the basal part is interpreted to reflect limestone beds possibly the Andrarum Limestone. The top of the Alum Shale is indicated by a very marked decrease in GR values.

At 2932.2 m the GR curve shows a local minimum. This level is interpreted to reflect a diagenetic limestone bed that commonly occurs in the basal Furongian *Olenus* Zone (Figure 5). Above this level the GR curve records the highest GR values in the unit. The increase in GR values are taken to reflect the increase in uranium concentrations that is known to occur in the upper part of the *Olenus* Zone (Schovsbo 2002).

At 2925.6 m a marked peak in GR values occur. This level is interpreted to be within the Furongian *Peltura* Zone.

<u>Upper Ordovician ?Lindegård Fm 2949.4-2903.0 m</u>
Description: Green to dark green shale with trace of sandstone.

Log response: GR values <10 api and low NEUT (<225) values. The base of the formation is picked at a sharp decreased in GR values. The top of the unit is placed at a peak in GR values. At this level the NEUT log response increases slightly indicating a somewhat siltier interval in the upper part of the unit (Figure 8).

<u>Lower Silurian shale 2903.0-2625.0 m</u>
Description: Dark-grey siltstone to mudstone with a slight greenish tint. Thin beds of cross bedded sandstone occur in some parts of the formation.

Log response: GR values (<10 api) and intermediate to low NEUT values. Intervals with NEUT >225 are interpreted to reflect the presence of silty shale (Figures 7 and 8). The base of the unit is marked by a peak in GR values that is interpreted to reflect enhanced uranium concentrations associated with slightly elevated TOC content. This level corresponds to the TOC rich basal apart of the Rastrites shale known from Bornholm (Figure 12).

Table 2. Stratigraphical picks and units with indication of the TOC content.

Depth, m MD	Pick name	unit/interval	Thickness	main Lithology	TOC %
2625.0	Top Pre-Zechstein				
2903.0	Base Silurian	Silurian	278.0	Grey green silty mudstone	0.1-0.6
2919.6	Base Lindegård Fm?	Lindegård Fm?	16.6	Grey green mudstone	0.1-0.2
2919.6	Base Upper Ordovician	Upper Ordovician	16.6		0.1-0.2
2919.6	Top Alum Shale				
2925.6	Base *Peltura* Zone	*Peltura* Zones	6.0	Dark mudstone	
2932.0	Base *Parabolina* Zone	*Parabolina + Leptoplastus* zones	6.3	Dark mudstone	
2939.2	Base *Olenus* Zone	*Olenus* Zone	7.3	Dark mudstone	7.2-8.6 (core)
2939.2	Base Furongian / Top Middle Cambrian	Furongian Alum Shale	19.6	Dark mudstone	
		Middle Cambrian Alum Shale	10.2	Dark mudstone	
2949.4	Base Alum Shale / Top Gislöv Fm	Alum Shale Fm	29.8	Dark mudstone	
2957.7	Base Gislöv Fm / Top Læså Fm	Gislöv Fm	8.3	Siltstone-sandstone	0.6
2969.8	Top Hardeberga	Læså Fm	12.1	Sandstone	0.5

3.5. Correlation with Scania and Bornholm

Cambrian

In the Slagelse-1 well the Alum Shale Fm rests directly on the Lower Cambrian Gislöv Fm being separated by the widespread regional unconformity termed the Hawke Bay unconformity (Figure 4). The unconformity reflect the Hawke Bay Event that is a combined tectonic uplift of the plate margins and a sea level lowering that affected the sedimentation on a regional scale in Baltoscandia. In general terms the hiatus is more extensive towards the plate margins whereas the stratigraphic sections are more complete on the central part of the plate (Figure 4). This reflects differential subsidence in the aftermath of the uplift.

The basal parts of the Alum Shale Fm do not appear to be stratigraphically complete. Judging from the log pattern in Gislövshammar-2 and Billegrav-2 it appears reasonable to correlate the limestone bed in the basal part of the Alum Shale Fm in the Slagelse-1 well with the Andrarum Limestone bed (Figure 9). This indicates that the basal Middle Cambrian hiatus in Slagelse-1 is slightly more extensive than on Bornholm and which implies that the Slagelse area was uplifted for longer time associated with the Hawke Bay Event than the Bornholm area.

The log pattern in the Alum Shale Formation in the Slagelse-1 well is remarkably similar to the log pattern observed in the Gislövshammar-2 well (Figure 9). The correlation between these wells indicates that the thickness from the base of the Andrarum Limestone and to the *Peltura* Zone is approximately the same in these two areas (Figure 9). The log pattern in the Billegrav-2 well is also very similar to the Slagelse-1 well, but the sequence in the Billegrav-2 well is slightly more condensed (Figure 9). See also Michelsen & Nielsen (1991) for a correlation between Slagelse-1 and the Bornholm sections.

The youngest Alum Shale that can be inferred from the log correlation is the *Peltura* Zone. Substantial parts of the Furongian and the Lower Ordovician shales are thus missing in the well. The section that is not present in Slagelse-1 is approximately 30 m thick in the Gislövshammar-2 well (Figure 9) and it may be reasonable to suggest that the depositional thickness of the Alum Shale in the Slagelse area originally was about 60 m.

The reason for the incomplete section might either be related to erosion or to faulting out of the sequence. The position of the well near a major fault (Figure 3) corroborates that tectonic complications may be at play. However, erosion of the sequence related to the late Tremadocian Ceratopyge regressive Event (CRE) or due to Mid Ordovician uplift of plate margins is also likely. The uplift in Middle Ordovician affected the sedimentation on a regional scale (Figure 6, Stouge & Nielsen 2003).

Ordovician

The Alum Shale Fm in the Slagelse-1 well is directly overlain by TOC lean green-grey shale of assumed Late Ordovician age. The unit does not contain any organic rich intervals suggesting that the organic rich Dicellograptus Shale known from the Bornholm-Scania area is absent in the Slagelse-1 well and the thin Ordovician sequence is correlated with the Upper Ordovician Lindegård Fm. However, if the findings of Claus Kock Clausen (cited in Nielsen 1995 as pers. comm. 1988) are correct then the basal 3 m of the succession might belong to the lower TOC lean parts of the Dicellograptus Shale (Figure 12).

Silurian

In the Slagelse-1 well the graptolites in core 7 to 10 indicate a Lower Silurian (Llandovery) age and all samples appear to belong to the *Monograptus crispus* graptolite Zone (Poulsen 1974). Compared to Bornholm the Silurian sequence in Slagelse-1 appear to be expanded and thus that the depositional rates in the Slagelse area was significantly higher than on Bornholm.

On Bornholm several intervals in the Rastrites Shale are known to be TOC rich (Figure 12). In Slagelse-1 no TOC units have been identified in the Silurian. This probably reflects the high local depositional rates that diluted the TOC content.

Table 3. Picks depth in Slagelse-1 and Billegrav-2 used in the correlation in Figure 9.

Pick name	Slagelse depth, m MD	Billegrav-2, Depth, m
Base Silurian	2903.0	61.1
Base Lindegård Fm	2919.6	73.8
Base Dicellograptus Shale	2919.6	95.3
Top Alum Shale	2919.6	95.4
Base Peltura Zone	2925.6	106.7
Base Parabolina Zone	2932.0	109.2
Base Olenus Zone	2939.2	115.6
Base Furongian	2939.2	115.6
Base Alum Shale	2949.4	121.4

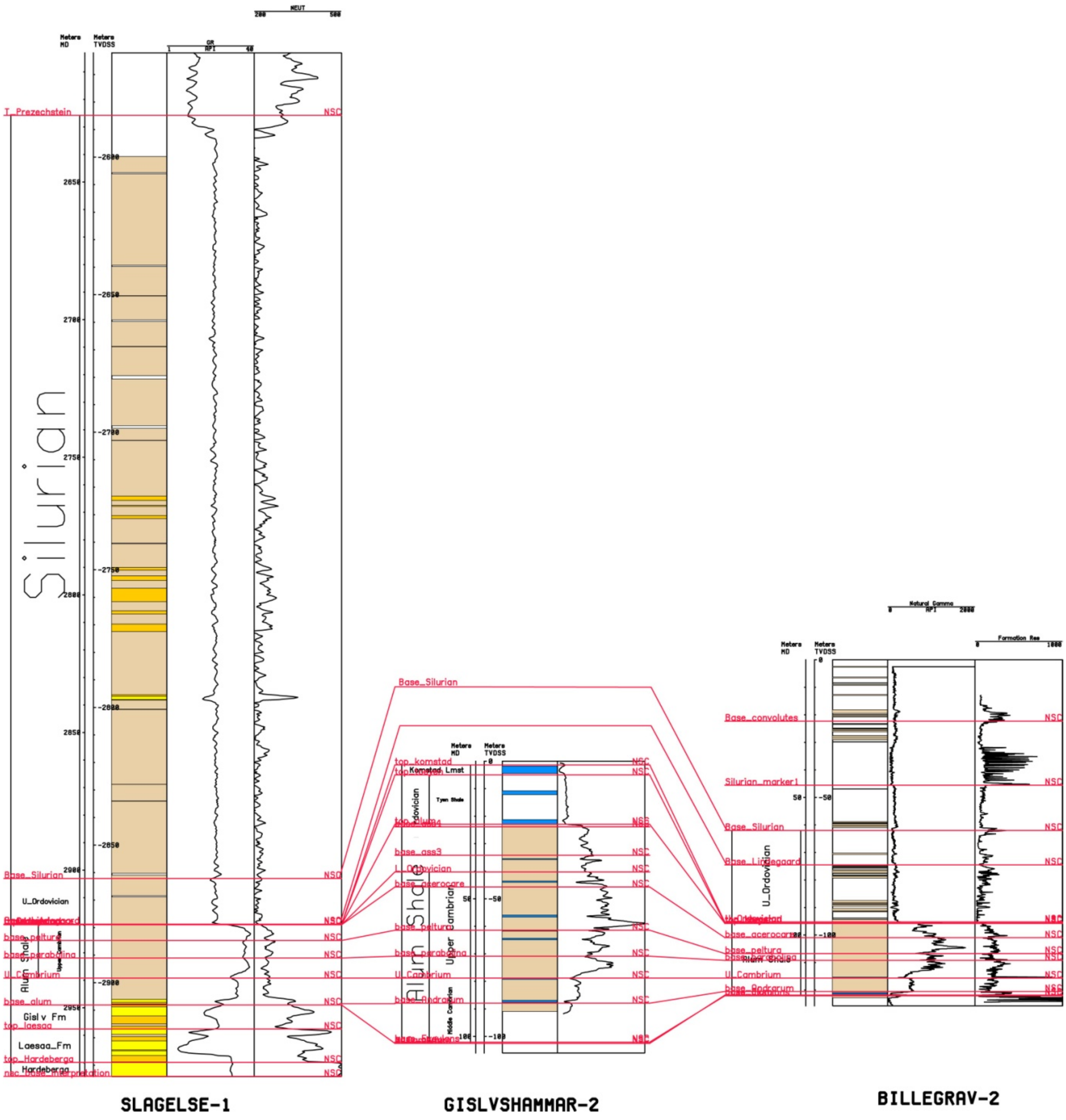


Figure 9. Correlation between Slagelse-1, Gislövshammar-2 (southern Scania, Sweden, Schovsbo 2002) and Billegrav-2 (Bornholm, Schovsbo et al. 2011). Vertical scale is the same for all wells. The profile is “flattened” on the base Furongian surface.

4. TOC content and mineralogical composition

4.1. Sample material

During preparation of this report cores and cutting samples from the Palaeozoic interval in the Slagelse-1 well were restudied. The mudstones showed clear evidence of mineral and salt precipitations on the surface and numerous cracks related to expansion and contraction of the shale due to changes in moisture during storage. Consequently it is not recommended to perform rock physical related measurements on the shales.

All cutting types (washed and unwashed) showed a mix of different lithologies. Caving of red sandstone (Triassic or Lower Permian) was present in almost all cutting samples. The red lithologies were removed from the samples prior to analysis.

In the Alum Shale interval the cuttings showed a mix between dark and green cuttings. The mix is attributed to caving of material from the Ordovician/Silurian sequence into the Alum Shale.

Only the darkest cuttings were selected for analysis in order to provide an estimate of the highest TOC content present in the sample.

Prior to analysis the cutting samples were washed with water. After drying approximately 2 g of material was picked from the 1-4 mm fraction. Any magnetic material was removed and the samples were crushed to a grain size below 250 my. No pre-treatment of the core samples was made.

4.2. TOC content

The TOC content was measured in 20 samples by combustion of acid treated carbonate-free samples in a LECO-type oven. Measurements were made at GEUS source rock laboratory. The data is presented in Table 4.

In the Alum Shale the TOC content measured on core samples ranges from 7.2-8.6%. The cutting samples from the Alum Shale interval contained <0.2 % TOC and is interpreted to reflect caved Ordovician and Silurian materiel despite that fact that only dark lithologies were picked and analysed.

The TOC content in the Slagelse-1 well is comparable with the concentrations measured in the Furongian part of the Alum Shale in Scania (Figure 10). Based on the TOC distribution of the core samples from wells in Scania it is expected that the Middle Cambrian Alum Shale in Slagelse-1 has on average of 4.9% TOC and that the Furongian Alum Shale contains on average 10.3±2.3% TOC.

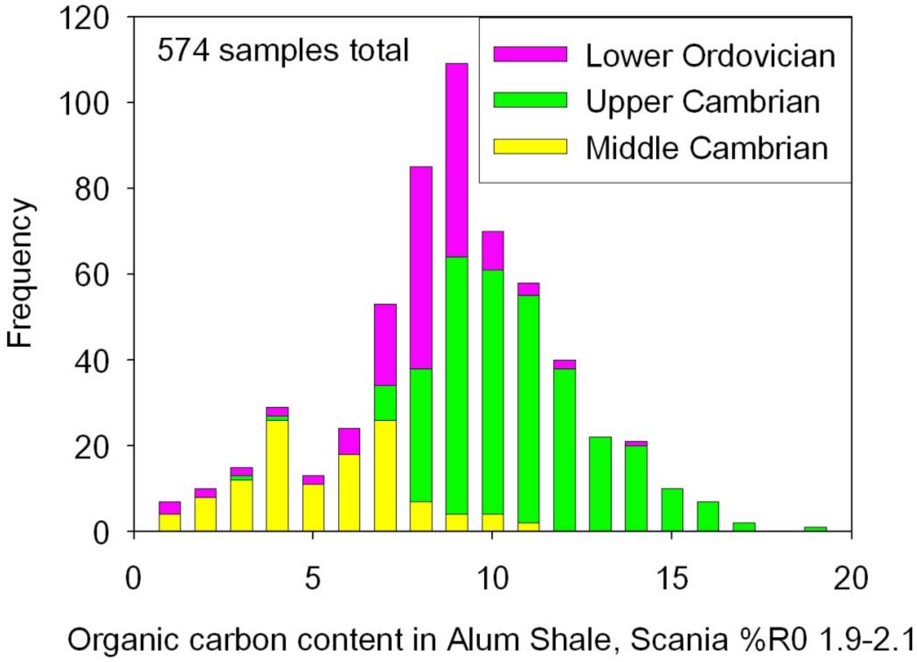


Figure 10. Distribution of TOC content in Alum Shale core sample from Scania divided into main stratigraphical units. Middle Cambrian Alum Shale has on average 4.9±2.2% TOC, Upper Cambrian Alum Shale has on average 10.3±2.3% TOC and Lower Ordovician Alum Shale has on average 7.5±1.9% TOC.

In the Ordovician and Silurian interval the highest TOC content was 0.6% (at 2770.8 m). In all other samples the TOC concentrations are below 0.5%. This indicates that no other Palaeozoic TOC rich units beside the Alum Shale occur in the Slagelse-1 well.

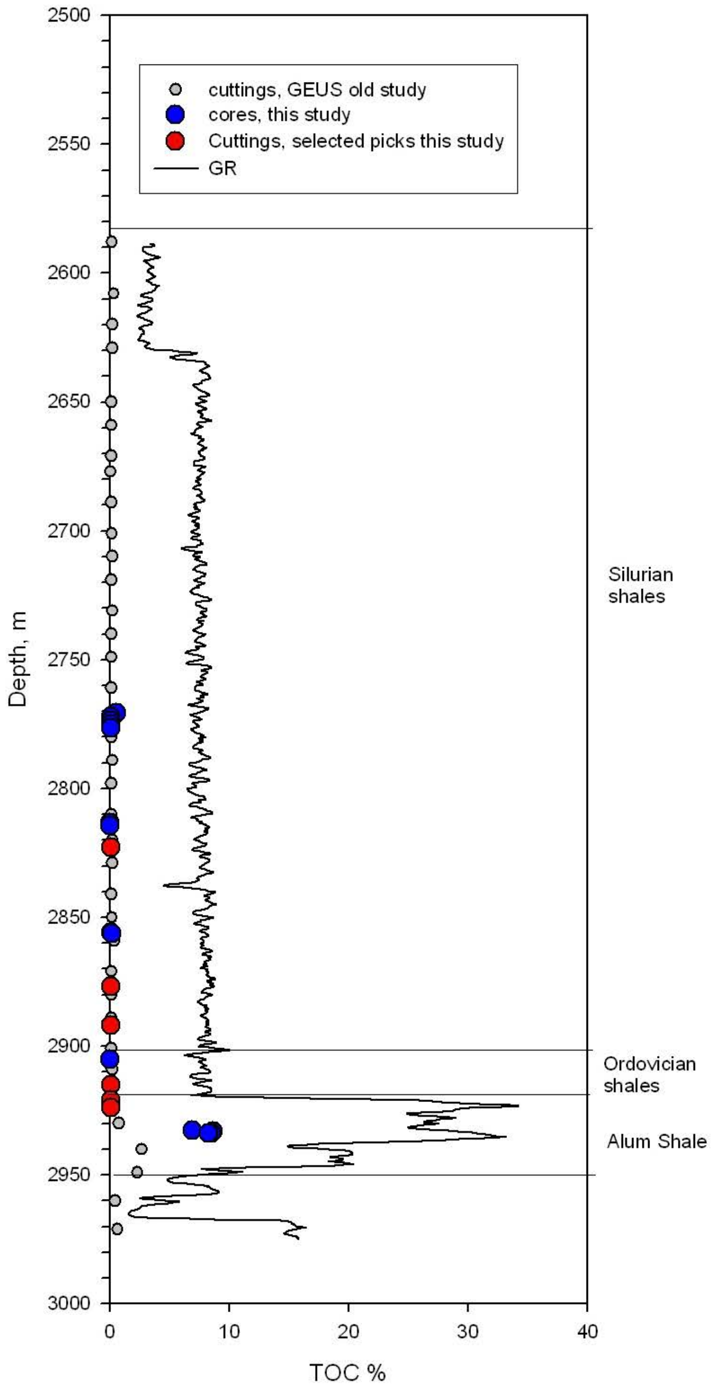


Figure 11. TOC analysis in the Slagelse-1 well. The Alum Shale is characterised by 6-8 % TOC content. In the Alum Shale interval only measurements on core material produced reasonable high TOC values. The cutting samples represent caved younger material. The GR curve is shown for reference.

Table 4. TOC, carbonate and pyrite content of the Slagelse-1 samples.

Material	Unit	Depth bottom (m)	TOC (%)	TC (%)	TS mg/g	Carbonate %	Pyrite %
Core	Silurian	2770.8	0.61	0.80	0.05	1.55	0.10
Core	Silurian	2772.0	0.12	0.26	0.32	1.13	0.60
Core	Silurian	2773.5	0.11	0.20	0.12	0.71	0.23
Core	Silurian	2775.0	0.10	0.25	0.19	1.20	0.35
Core	Silurian	2776.4	0.14	0.19	0.97	0.41	1.82
Core	Silurian	2813.3	0.05	0.10	0.47	0.44	0.89
Core	Silurian	2814.5	0.06	0.12	0.34	0.44	0.65
Picked Cuttings	Silurian	2823.0	0.09	0.42	0.38	2.74	0.72
Core	Silurian	2855.8	0.15	0.24	0.03	0.72	0.05
Core	Silurian	2856.1	0.19	0.29	0.04	0.79	0.08
Picked Cuttings	Silurian	2877	0.08	0.40	0.22	2.67	0.41
Picked Cuttings	Silurian	2892	0.08	0.40	0.55	2.68	1.02
Core	Ordovician	2905.3	0.07	0.27	0.05	1.67	0.09
Picked Cuttings	Ordovician	2915.0	0.08	0.37	0.33	2.48	0.61
Picked Cuttings	Ordovician/Alum Shale	2921.0	0.08	0.34	0.21	2.16	0.40
Picked Cuttings	Alum Shale (100% Caving)	2924.0	0.09	0.38	0.28	2.40	0.52
Core	Alum Shale	2932.6	6.93	7.18	5.40	2.04	10.10
Core	Alum Shale	2933.0	8.64	8.65	2.98	0.08	5.57
Core	Alum Shale	2933.7	8.49	8.44	3.28	0.00	6.14
Core	Alum Shale	2933.8	8.26	8.13	3.72	0.00	6.96

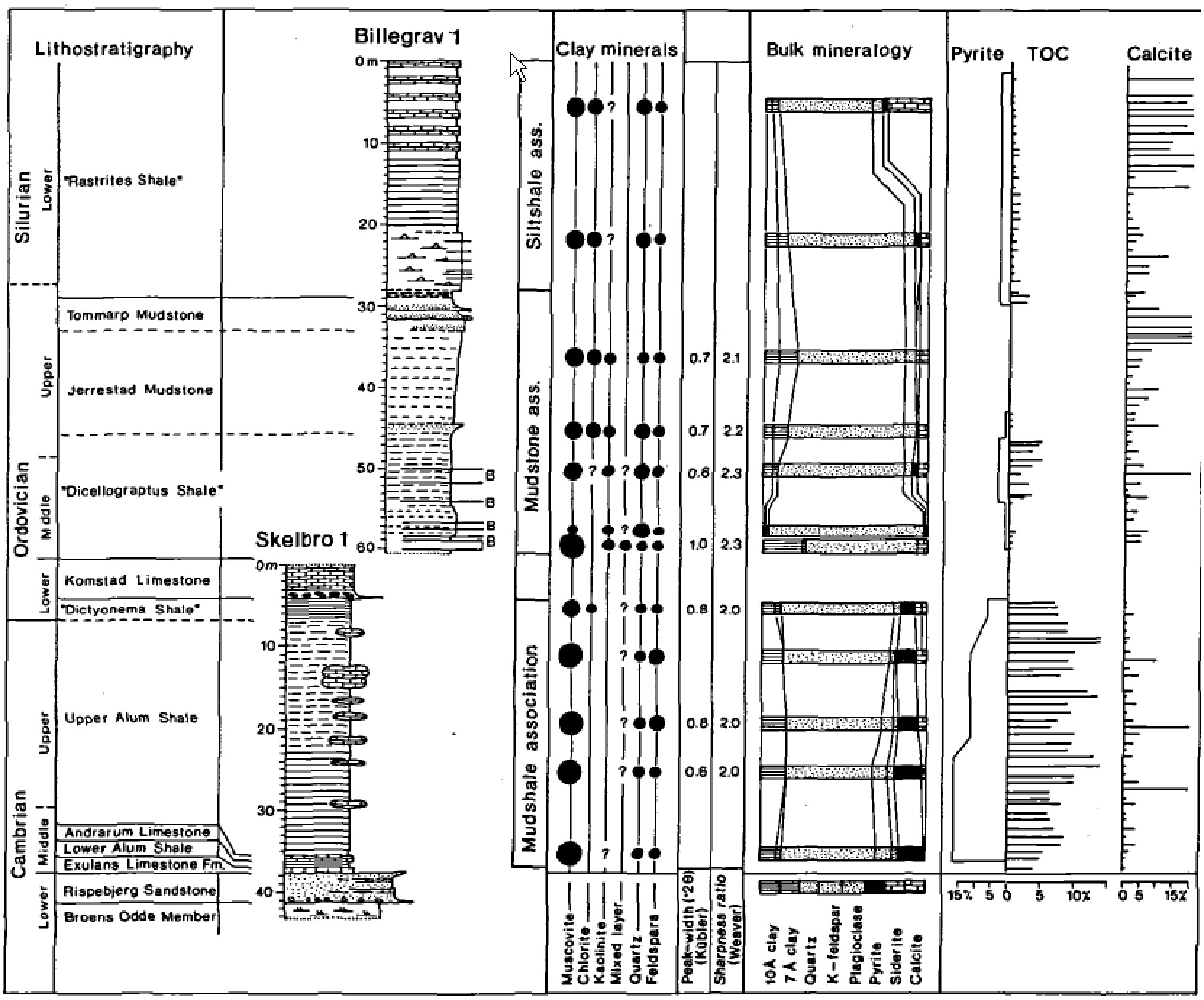


Figure 11. TOC, mineralogy and carbonate content of the Skelbro-1 and the Billegrav-1 wells on Bornholm (Pedersen 1989). The TOC rich parts of the Dicellograptus Shale and the Rastrites Shale cannot be documented in the Slagelse-1 well.

4.3. Bulk XRD analyses

The XRD powder diffraction patterns were obtained based on randomly oriented samples using CoKα-radiation. Merck quartz 1.07536 ground to <0.063 micron was used as standard. The analyses were made at the GEUS clay laboratory.

The XRD spectra were investigated for the main mineral groups present, which includes clay, quartz, alkalifeldspar, plagioclase, calcite and pyrite/marcasite. In the samples only clay and quartz have been identified on the XRD spectra suggesting that the feldspar content is below detection limit. The XRD spectra are included on the enclosed CD.

The clay type in the cored part of the Alum Shale was analysed by Lindgreen et al. (2000). The clay has a mixed illite-torbelite-smectite composition with more than 90% of the interlayer developed as mica interlayers of which 18% was composed of torbelite. No kaolinite was observed in the sample.

According to Lindgreen et al. (2000) the clays exhibited very low expandability reflecting a high degree of transformation of the original smectite layers. The transformation of smectite to torbelite was assumed to have occurred during oil generation.

Table 5. Identified minerals in the Slagelse-1 well. Number refers to peak height. A proxy of the quartz/clay ratio has been calculated based on the peak heights. The ratio is not calibrated (see Figure 15).

			Clay	**Quartz**	**Alkali-feldspars**	**Plagio-clase**	**Calcite**	**Pyrite / Marcasite**	**Peak height Q / (Peak height Q + clay)**
Material	**Unit**	**Depth (m)**	**4.48 Å**	**4.26 Å**	**4.2 Å**	**4.03 Å**	**3.03**	**1.63 Å**	
Core	Silurian	2770.8	17	185					0.92
Core	Silurian	2772.0	37	99					0.73
Core	Silurian	2773.5	33	56					0.63
Core	Silurian	2775.0	36	88					0.71
Core	Silurian	2776.4	35	113					0.76
Core	Silurian	2813.3	32	124					0.79
Core	Silurian	2814.5	35	87					0.71
Picked Cuttings	Silurian	2823	30	97					0.76
Core	Silurian	2855.8	23	150					0.87
Core	Silurian	2856.1	32	75					0.70
Picked Cuttings	Silurian	2877	29	103					0.78
Picked Cuttings	Silurian	2892	31	74					0.70
Core	Ordovician	2905.3	30	113					0.79
Picked Cuttings	Ordovician	2915	30	76					0.72
Picked Cuttings	Ordovician/Alum Shale	2921	31	100					0.76
Picked cuttings	Alum Shale (100% Caving)	2924	29	89					0.75
Core	Alum Shale	2932.6	24	58					0.71
Core	Alum Shale	2933.0	34	77					0.69
Core	Alum Shale	2933.7	35	92					0.72
Core	Alum Shale	2933.8	36	94					0.72

4.4. Quantitative mineralogy

In order to quantify the main mineralogical components in the samples the following components have been calculated:

Carbonate content: Calculated from the difference between total carbon (TC) and total organic carbon (TOC) content.

% pyrite (FeS_2): Calculated from total sulphur (TS) content assuming that all sulphur is present in pyrite.

Organic matter: Calculated directly from the TOC content.

% Quartz content: Measured by X-ray diffraction using a quartz standard as reference. The % quartz was calculated by comparing peak heights between the sample and the standard.

Clay content: Examination of the bulk XRD spectra indicates that only clay is present in the samples in addition to the above mentioned components. Accordingly the % clay content is estimated from the formula 100 – (%Quartz + %TOC + % Pyrite + % Carbonate).

Quartz / Clay ratio: Calculated as % relative quartz using the formula: % Quartz / (% Quartz+ % Clay).

The % relative quartz (Q/(Q+C) is compared with the XRD peak height Q / peak height C in Figure 15 and with the wt.% rock in the clay fraction (Figure 14).

Table 6. Quantitative mineralogical analysis of the Slagelse-1 samples.

Material	Unit	Depth (m)	% Clay size faction by weight	TOC (%)	Carbonate %	Pyrite %	% Q from XRD	% Clay	Q/(Q+Clay)
Core	Silurian	2770.8	10	0.61	1.55	0.10	45	53	0.46
Core	Silurian	2772.0	28	0.12	1.13	0.60	20	78	0.20
Core	Silurian	2773.5	25	0.11	0.71	0.23	19	80	0.19
Core	Silurian	2775.0	30	0.10	1.20	0.35	23	76	0.23
Core	Silurian	2776.4	10	0.14	0.41	1.82	31	67	0.31
Core	Silurian	2813.3	15	0.05	0.44	0.89	31	67	0.32
Core	Silurian	2814.5	26	0.06	0.44	0.65	24	75	0.24
Picked Cuttings	Silurian	2823		0.09	2.74	0.72	22	74	0.23
Core	Silurian	2855.8	11	0.15	0.72	0.05	52	47	0.52
Core	Silurian	2856.1	22	0.19	0.79	0.08	27	72	0.27
Picked Cuttings	Silurian	2877		0.08	2.67	0.41	24	73	0.25
Picked Cuttings	Silurian	2892		0.08	2.68	1.02	23	74	0.24
Core	Ordovician	2905.3	21	0.07	1.67	0.09	35	63	0.36
Picked Cuttings	Ordovician	2915		0.08	2.48	0.61	26	71	0.26
Picked Cuttings	Ordovician/ Alum Shale	2921		0.08	2.16	0.40	23	74	0.24
Picked cuttings	Alum Shale (100% Caving)	2924		0.09	2.40	0.52	28	69	0.29
Core	Alum Shale	2932.6	18	6.93	2.04	10.10	22	59	0.27
Core	Alum Shale	2933.0	17	8.64	0.08	5.57	29	57	0.34
Core	Alum Shale	2933.7	17	8.49	0.00	6.14	29	57	0.34
Core	Alum Shale	2933.8	16	8.26	0.00	6.96	25	59	0.30

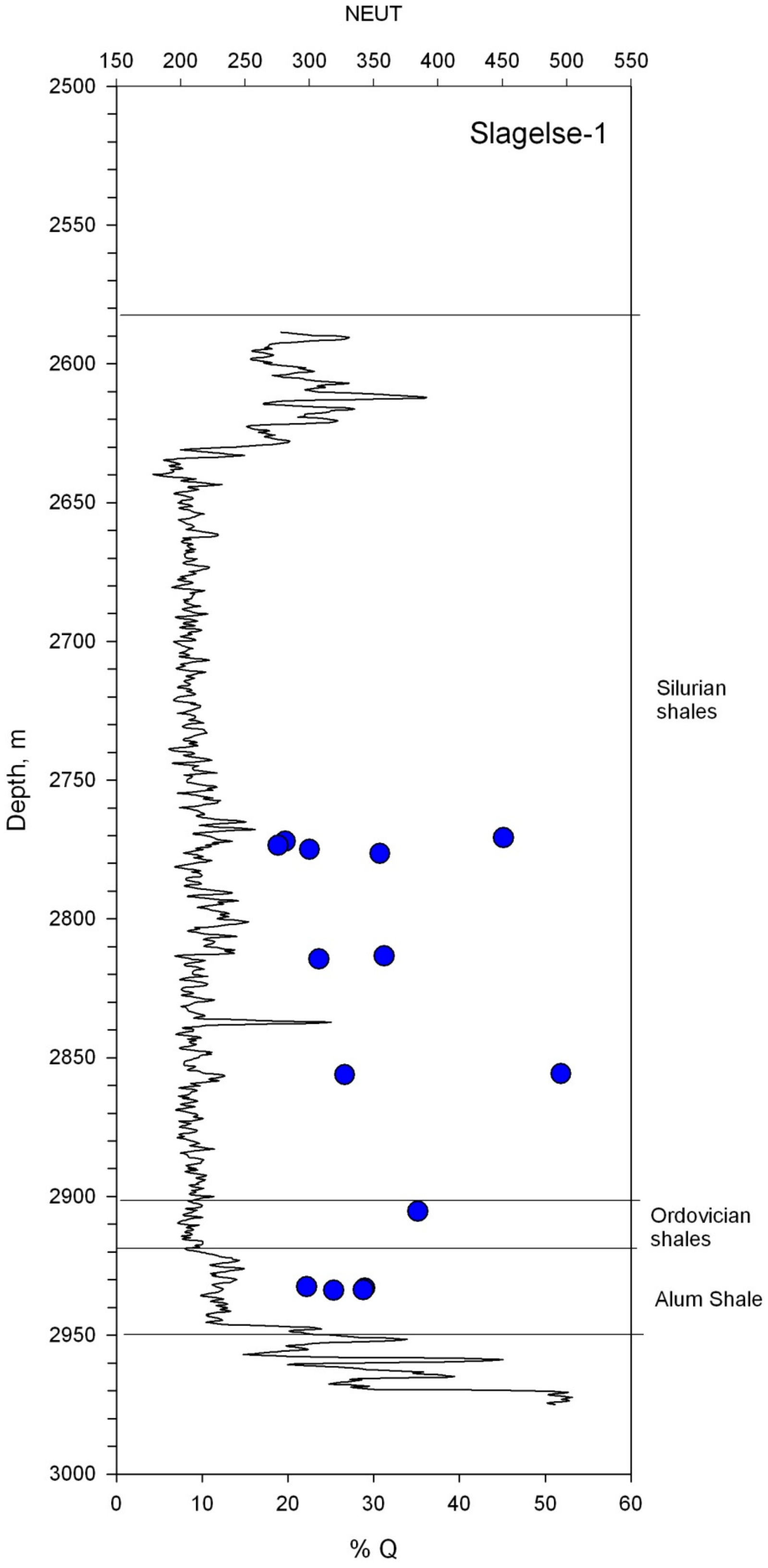


Figure 13. Stratigraphical variation of the quartz content calculated from XRD. The NEUT curve is shown for reference.

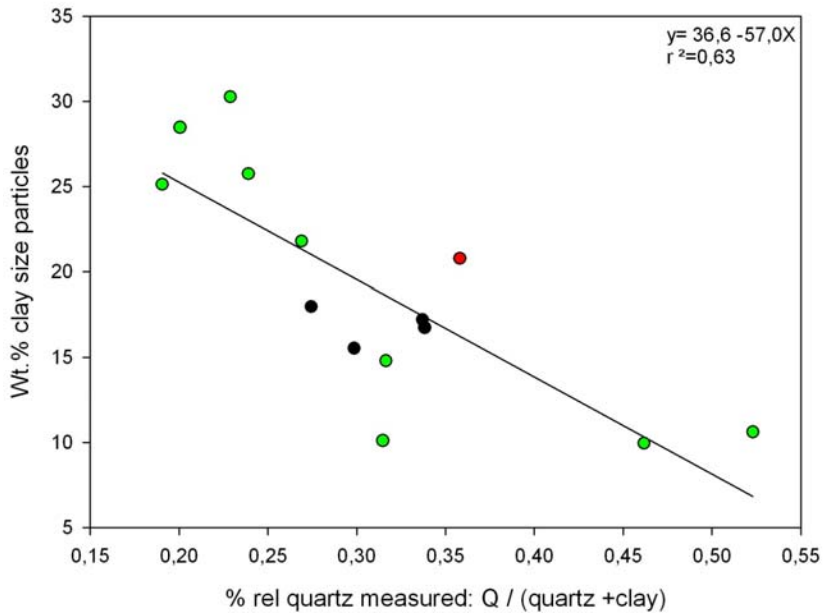


Figure 14. Comparison between wt % clay size particles and % quartz determined from XRD. Colours of circles indicate stratigraphic age. Black: Alum Shale. Red: Ordovician shale. Green: Silurian Shale. The two parameters are inversely correlated.

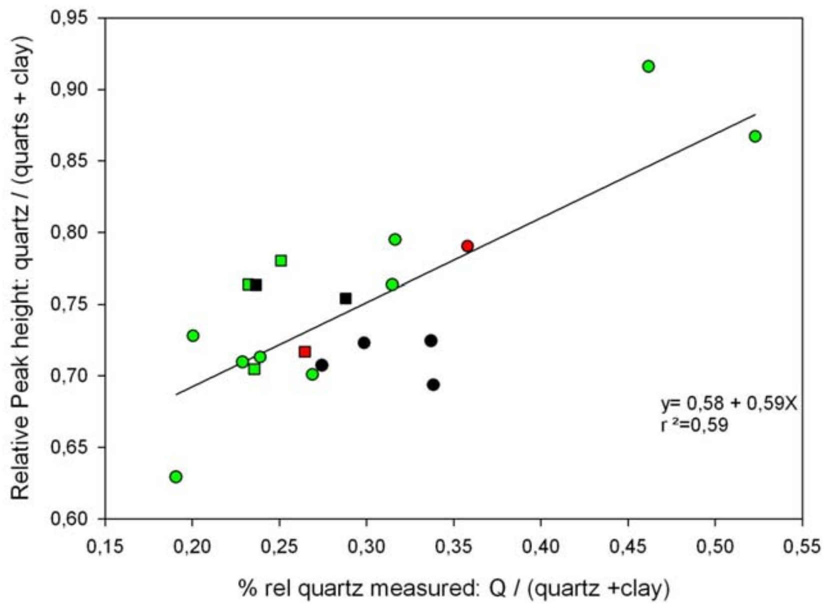


Figure 15. Comparison between the % relative quartz content (Q/(C+Q)) from Table 6 with the peak height intensity of quartz relative to clay calculated from Table 5. The two ratios are positive correlated. Circles indicate core samples and squares indicate cutting sample. Colours of circles and squares indicate stratigraphic age. Black: Alum Shale. Red: Ordovician shale. Green: Silurian Shale. The two parameters are inversely correlated.

4.5. Quantification of the clay size fraction

In order to quantify the grain size distribution the weight % of the sample that is in the clay size was calculated. Determination of the clay content (<2 µm) was done by dispersing the sample in distilled water by ultrasonic treatment. The fraction >30 µm was removed by sedimentation. From the suspension of particles < 30µm, the suspension of the clay fraction <2 µm was separated in a continuous flow centrifuge. The clay was flocculated by adding sodiumchloride and the liquid removed by centrifugation. The clay was washed free of sodiumchloride with water and air-dried. The amount of clay was then determined by weight. The data is presented in Table 6. The % clay size particles are as expected inversely correlated to the % Quartz content (Figure 14). Alum Shale samples plots with intermediate %Q and % clay size particles.

5. Maturity and Burial History

The Alum Shale was deposited prior to the evolution of vascular land plants and the shale does not contain terrestrial vitrinite particles. Nevertheless the unit contains vitrinite-like particles supposedly of marine origin. According to Buchardt & Lewan (1990) these particles behaves in a similar manner as true vitrinite. Consequently reflectance of vitrinite-like particles has been widely used as a thermal marker for the shale. For detailed discussion of the origin and geochemical similarities between Alum Shale vitrinite and true vitrinite, see Buchardt & Lewan (1990).

Buchardt et al. (1986) reported a value of 3.25 %Ro for the Alum Shale in Slagelse-1. The data point was subsequently used by Vejbæk et al. (1994) and Buchardt et al. (1997) on their Alum Shale maturity maps (Figure 19). Jensenius (1987) cited E. Thomsen (pers. comm.) for additional information on vitrinite measurements in the Slagelse-1 well. Lindgreen & Thomsen (1985) presented 8 vitrinite measurements for the well. According to these authors the atomic H/C ratio is 0.30 for the well and which is in accordance with the high thermal rank (Buchardt & Lewan 1990).

5.1. Vitrinite reflectance measurements

Samples for vitrinite measurement were picked in the cored intervals and measurements were conducted on polished slides of powdered whole rock (1-2 mm). Measurements were performed with non-polarized light at a wavelength of 546 nm through an immersion oil (n=1.52). The average of different vitrinite-like macerales in each slide is referred to as the mean reflectance and the abbreviation % Ro is used.

The vitrinite samples presented here (Table 7) were previously measured by Lindgreen & Thomsen (1985). However, in this report additional measurements have been added in order to improve measuring statistics. Moreover the frequency population has been reprocessed and for each sample a careful evaluation of the data quality has been undertaken based on the frequency distribution. The sample frequencies are presented in Appendix B and all measurements are included on the CD attached to this report. The raw data allows for a further selection of populations.

It is evident from Table 7 that for a given sample there is a relative high standard variation on the calculated %Ro. This variation reflects a strong anisotropy of the samples due to its high thermal maturation rank as well as the presence of other reflecting material besides vitrinite-like particles. These include especially bitumite and graptolite fragments. The effect of such particles has been minimized based on the evaluation of the frequency histograms.

For the Alum Shale in the Slagelse-1 well the average vitrinite reflectance is 3.0% Ro based on two samples (Table 7). The average vitrinite value for the Silurian shale samples is 2.7% Ro. The reflectance gradient established in the well for the Palaeozoic is 1.9% Ro/km (Figure 16). The gradient in vitrinite reflectance is very high and may reflect a steep geothermal gradient of about 35-45 ^{o}C for the area (Jensenius 1987).

Table 7. Summary of vitrinite reflectance measurements from the Slagelse-1 well. All samples are from core material.

			Total population			Selected population		
Sample	Stratigraphy	Depth	%Ro	Std	N	%Ro	std	N
258A	Silurian	2641.6	2.41	0.54	38	2.5	0.35	25
259A	Silurian	2773.1	2.65	0.32	41	2.58	0.23	34
260A	Silurian	2775.3	2.89	0.4	53	2.72	0.17	26
261A	Silurian	2812.6	2.67	0.29	57	2.72	0.17	42
262A	Silurian	2855.8	2.78	0.33	83	2.85	0.22	69
263A	Ordovician	2905	3.02	0.36	84	3.01	0.26	75
264A	Alum Shale	2932.7	3.18	0.43	219	3.07	0.23	140
265A	Alum Shale	2933.2	2.81	0.54	75	2.91	0.35	49

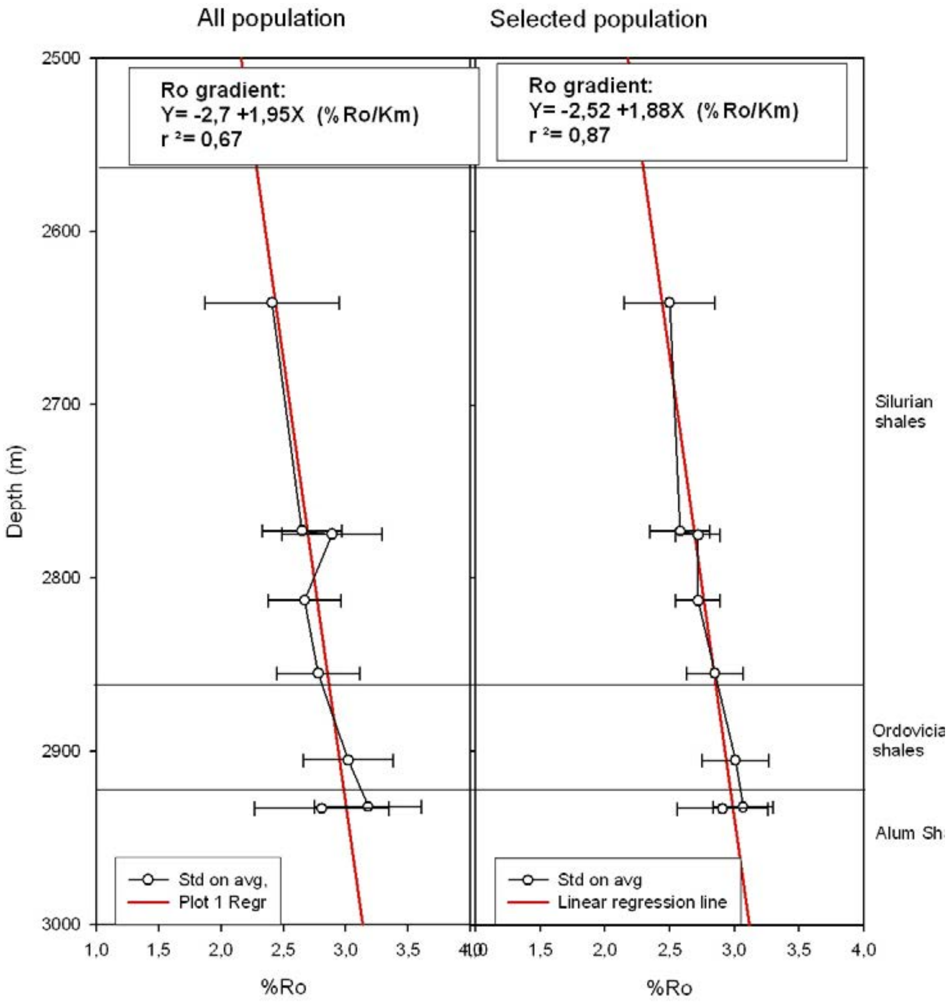


Figure 16. Vitrinite measurements versus depth in the Slagelse-1 well for the total population (left) and for the selected population (right). The arrow bars are standard derivation of the mean. The gradients are established as a linear correlation line.

5.2. Rock Eval analysis

20 samples were measured by the Rock Eval apparatus at GEUS. The analysis was made on whole rock powder samples using a Delsi Rock Eval instrument. Results include pyrolysis yield S1 and S2 and the temperature of maximal pyrolysis yields (Tmax). The Hydrogen Index (HI) was calculated as the pyrolysis yield S2 normalized to the TOC content.

The analytical results are presented in Table 8. Pdf of the pyrograms are included on the attached CD in the *Appendix* folder.

The pyrolysis yields of the S1, S2 are very low and thus the Rock Eval data all indicate a very high thermal alteration (Table 8). Due to low S2 yields no Tmax-value can be defined based on the S2 shape.

For comparison immature Alum Shale samples have S2 yield within the range of 30-80 mg HC /g rock and HI values of about 400-500 mg HC/ g TOC (Figure 17).

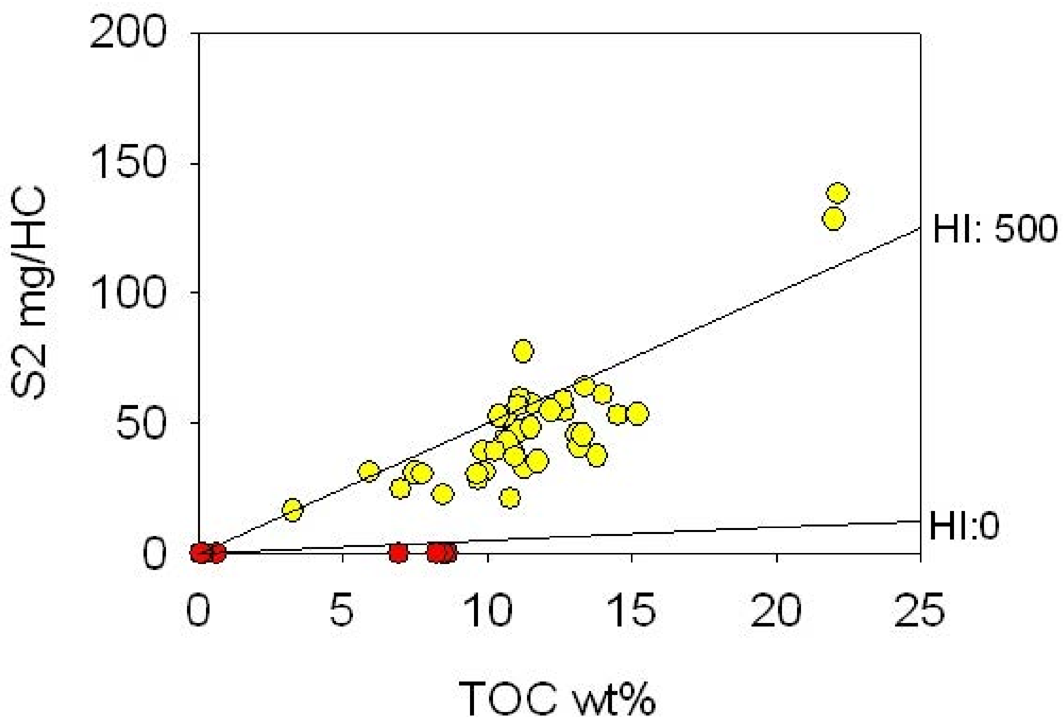


Figure 17. Comparison between Rock Eval S2 yields of immature samples (%Ro<0.5, shown with yellow circles) and samples from Slagelse-1 (%Ro 3.0, shown with red circles). Immature Alum Shale samples have HI values between 400-600 mg HC/g TOC. The Slagelse-1 samples all have a HI value of 0 mg HC/g TOC.

Table 8. Summary of Rock Eval data from the Slagelse-1 well. The Tmax was not defined (n.d.) due to low S2 yields.

Material	Unit	Depth bottom (m)	TOC (%)	Tmax (°C)	S1 (mg/g)	S2 (mg/g)	HI	PI	PC
Core	Silurian	2770.8	0.61	n.d.	0.07	0.00	0	0	0
Core	Silurian	2772.0	0.12	n.d.	0.00	0.00	0	0	0
Core	Silurian	2773.5	0.11	n.d.	0.00	0.00	0	0	0
Core	Silurian	2775.0	0.10	n.d.	0.00	0.00	0	0	0
Core	Silurian	2776.4	0.14	n.d.	0.00	0.00	0	0	0
Core	Silurian	2813.3	0.05	n.d.	0.00	0.00	0	0	0
Core	Silurian	2814.5	0.06	n.d.	0.00	0.00	0	0	0
Picked Cuttings	Silurian	2823	0.09	n.d.	0.00	0.00	0	0	0
Core	Silurian	2855.8	0.15	n.d.	0.00	0.00	0	0	0
Core	Silurian	2856.1	0.19	n.d.	0.00	0.00	0	0	0
Picked Cuttings	Silurian	2877	0.08	n.d.	0.00	0.00	0	0	0
Picked Cuttings	Silurian	2892	0.08	n.d.	0.00	0.00	0	0	0
Core	Ordovician	2905.3	0.07	n.d.	0.00	0.00	0	0	0
Picked Cuttings	Ordovician	2915	0.08	n.d.	0.00	0.00	0	0	0
Picked Cuttings	Ordovician/Alum Shale	2921	0.08	n.d.	0.00	0.00	0	0	0
Picked cuttings	Alum Shale (100% Caving)	2924	0.09	n.d.	0.00	0.00	0	0	0
Core	Alum Shale	2932.6	6.93	n.d.	0.01	0.00	0	0	0
Core	Alum Shale	2933.0	8.64	n.d.	0.02	0.00	0	0	0
Core	Alum Shale	2933.7	8.49	n.d.	0.03	0.00	0	0	0
Core	Alum Shale	2933.8	8.26	n.d.	0.02	0.00	0	0	0

5.3. Fluid inclusions

Jensenius (1987) analyzed 2 samples from the Slagelse-1 well for fluid inclusions. The samples were from core 7/1 in the Silurian siltstone and from core 16/1 in the Cambrian Hardeberga Fm.

Small amount of gases such as methane was inferred present in the inclusion from the Hardeberga sandstone. The homogenization temperatures in the fluid inclusions belonged to several distinctly different groups. Quartz overgrowth on sandgrains indicated a homogenisation temperature of 82 ^{o}C whereas calcite veins indicated a homogenisation temperature of about 136 ^{o}C.

5.4. Burial History

It is generally assumed that the present day maturation pattern (Figure 19) of the Alum Shale reflects deep burial in during the Caledonian Orogony (Buchardt et al. 1986, Thomsen et al. 1987, Jensenius 1987).

Buchardt et al. (1997) showed that the thermal maturation in the wells increases rapidly towards the Caledonian Front (Figure 20). According to Buchardt et al. (1997) the Caledonian burial commenced in late Silurian time where rapid subsidence led to deposition of several kilometres of sediments in Late Silurian and Early Devonian time. The increase in subsidence reflected the development of a foreland basin in front on the German-Polish Caledonides.

A detailed burial history of the Slagelse-1 well has not been established//reconstructed (see Japsen et al. 2007 for a recent review) but in general terms the geological history sketched in Figure 18 is also valid for the Slagelse area. Deep burial matured the Alum Shale to its present day maturity levels during the foreland basin development in the Late Silurian-Devonian time (cf. Buchardt et al. 1997).

Uplift in Palaeocene of the Slagelse area has been estimated to be about 500-750 m (Japsen & Bidstrup 1999).

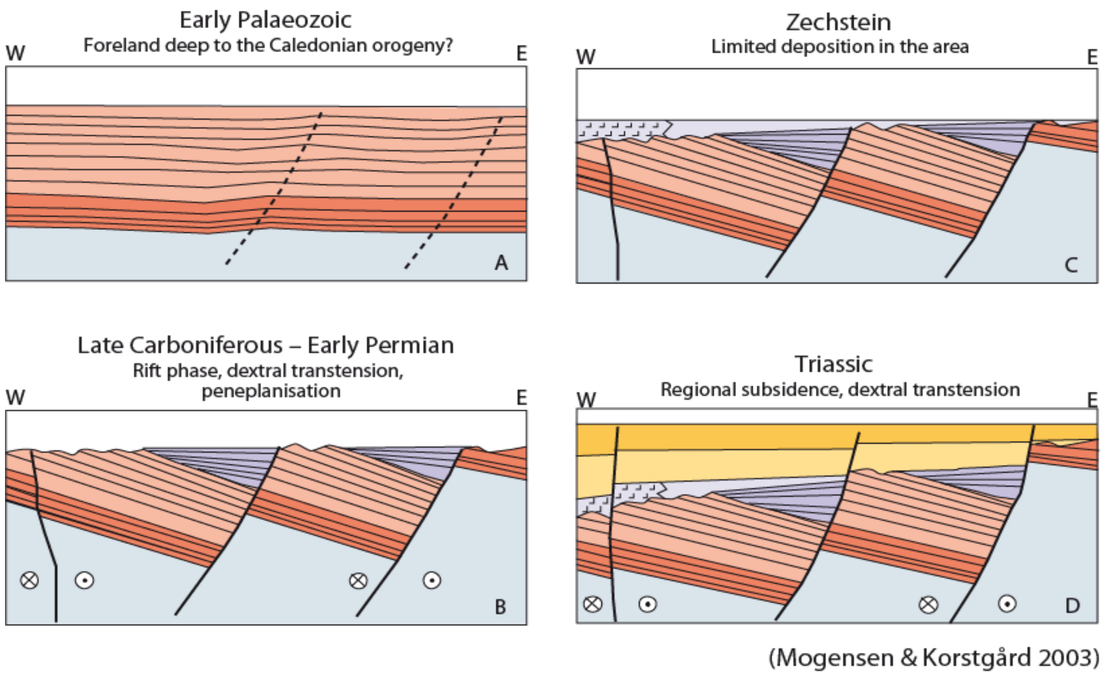


Figure 18. Geological development during the Palaeozoic in the Norwegian-Danish Basin. From Mogensen & Korstgård (2003)

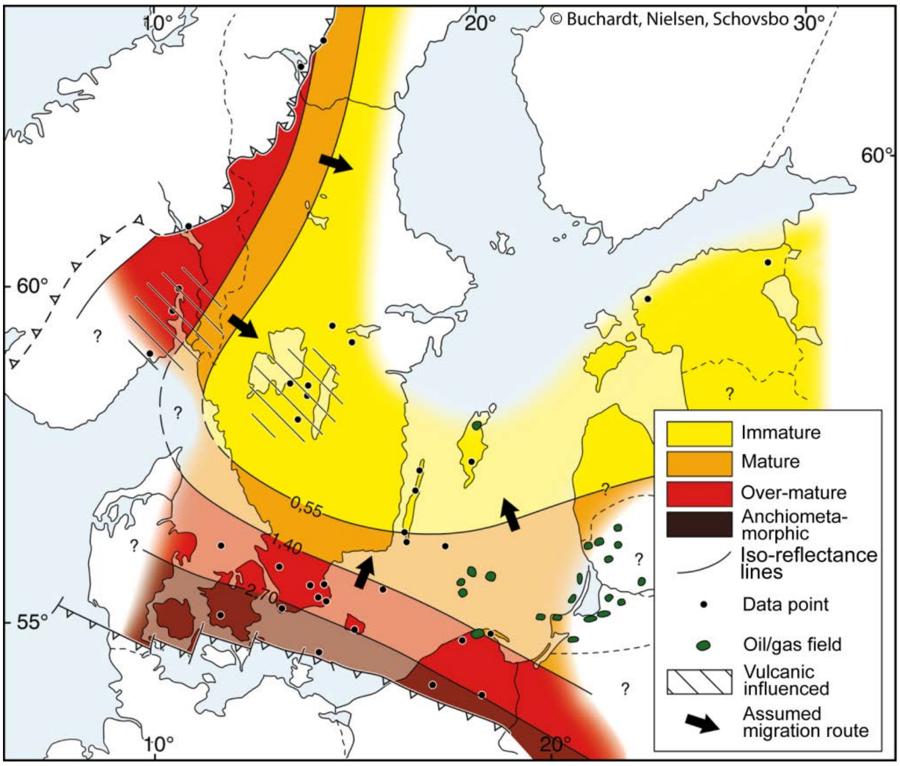


Figure 19. Maturity map of the Alum Shale formation based on vitrinite reflectance data. From Buchardt et al. (1997).

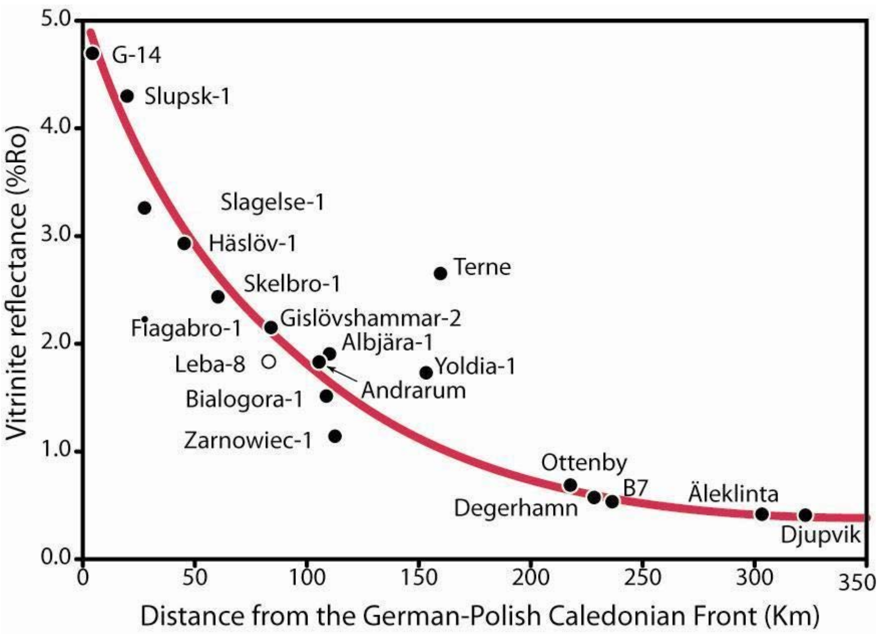


Figure 20. Relationship between vitrinite reflectance and distance from the German-Polish Caledonian Front. From Buchardt et al. (1997).

6. References

Bojesen-Koefoed, J., Petersen, H.I., 2001. Source rock evaluation of the Danish Basin and Fennoscandian Border Zone. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2001/128.

Buchardt, B., Lewan, M.D., 1990. Reflectance of vitrinite-like macerals as a thermal maturity index for Cambrian-Ordovician Alum Shale, southern Scandinavia. AAPG Bulletin 74, 394–406.

Buchardt, B., Clausen, J., Thomsen, E., 1986. Carbon isotope composition of Lower Palaeozoic kerogen: Effects of maturation. Organic geochemistry 10, 127–134.

Buchardt, B., Nielsen, A.T., Schovsbo, N.H., 1997. Alun Skiferen i Skandinavien. Geologisk Tidsskrift 3, 1–30.

Japsen, P., Bidstrup,T., 1999. Quantification of late Cenozoic erosion in Denmark based on sonic data and basin modelling. Bulletin of the Geological Society of Denmark 46, 79–99.

Japsen, P., Green, P.F., Nielsen, L.H., Rasmussen, E.S., Bidstrup, T., 2007. Mesozoic–Cenozoic exhumation events in the eastern North Sea Basin: a multi-disciplinary study based on palaeothermal, palaeoburial, stratigraphic and seismic data. Basin Research 19, 1365–2117.

Jensenius, J., 1987. Regional studies of fluid inclusions in Paleozoic sediments from southern Scandinavia. Bulletin of the Geological Society of Denmark 36, 221–235.

Lindgreen, H., Thomsen, E., 1985. Investigations on the source rock potential of the Danish onshore area. Reprint 8/8-85 (originally published 15/6-82). Geological Survey of Denmark Internal report 22.

Lindgreen, H., Drits, V.A., Sakharov, B.A., Salyn, A.L., Wrang, P., Dainyak, L.G., 2000. Illite-smectite structural changes during metamorphism in black Cambrian Alum shales from the Baltic area. American Mineralogist 85, 1223–1238.

Michelsen, O., Nielsen, L.H., 1991. Well records on the Phanerozoic stratigraphy in the Fennoscandian Border Zone, Denmark: : Sæby-1, Hans-1 and Terne-1 wells. Danmarks Geologiske Undersøgelse Serie A29, 1–37.

Mogensen, T.E., Korstgård, J.A., 2003. Triassic and Jurassic transtension along part of the Sorgenfrei-Tornquist Zone, in the Danish Kattegat. In Ineson, J.R, Surlyk, F. (eds): The Jurassic of Denmark and Greenland. Geological Survey of Denmark and Greenland Bulletin 1, 439–458.

Nielsen, A.T., 1995. Trilobite Systematics, Biostratigraphy and Palaeoecology of the Lower Ordovician Komstad Limestone and Huk Formations, Southern Scandinavia. Fossils and Strata 38, 1–374.

Nielsen, A.T., Schovsbo, N.H., 2006. Cambrian to basal Ordovician lithostratigraphy of southern Scandinavia. Bulletin of the Geological Society of Denmark 53, 39–85.

Pedersen, G.K., 1989. The sedimentology of Lower Palaeozoic black shales from the shallow wells Skelbro 1 and Billegrav 1, Bornholm, Denmark. Bulletin of the Geological Society of Denmark 37, 151–173.

Poulsen, C., 1974. Further contributions to the knowledge of the Palaeozoic of Slagelse no 1, Western Sealand. Danmarks Geologiske Undersøgelse II række nr 101, 1–42.

Schovsbo, N.H., 2002. Uranium enrichment shorewards in black shales: A case study from the

Scandinavian Alum Shale. GFF 124, 107–116.

Schovsbo, N.H., 2003. The geochemistry of Lower Palaeozoic sediments deposited at the margins of Baltica. Bulletin of the Geological Society of Denmark 50, 11–27.

Schovsbo, N.H., Nielsen, A.T., Klitten, K., Mathiesen, A., Rasmussen, P., 2011. Shale gas investigations in Denmark: Lower Palaeozoic shales on Bornholm. Geological Survey of Denmark and Greenland Bulletin 23, 9–14.

Stouge, S., Nielsen, A.T., 2003. An integrated biostratigraphical analysis of the Volkhov-Kunda (Lower Ordovician) succession at Fågelsång, Scania, Sweden. Bulletin of the Geological Society of Denmark 50, 75–94.

Sørensen, S., Martinsen, B.B., 1987. A paleogeographic reconstruction of the Rotliegendes Deposits in the Northeastern Permian Basin. In J. Brooks, K. Glennin (eds): Petroleum Geology of North West Europe. 497–508. Graham & Trotman.

Thomsen, E., Damtoft, K., Andersen, C., 1987. Hydrocarbon plays in Denmark outside the Central Trough. In J. Brooks, K. Glennin (eds): Petroleum Geology of North West Europe. 375–388. Graham & Trotman.

Vecoli, M., Samuelsson, J., 2001. Reworked acritarchs as provenance indicators in the Lower Palaeozoic of Denmark. Earth and Planetary Sciences 332, 465–471.

Vejbæk, O., Stouge, S., Poulsen, K.D., 1994. Palaeozoic tectonic and sedimentary evolution and hydrocarbon prospectivity in the Bornholm area. Geological Survey of Denmark A34, 1–23.

7. Files included on CD

Attached to this report is a CD that contains the following documentation:

1. In folder *Tables* are Excel files of Tables 1 to 8.
2. In folder *Appendices* are data presented in Appendix A and B in the printed version of this report and Appendix C to G only available on the attached CD.
    a. Appendix A: Results of GEUS source rock screening (Bojesen-Koefoed & Petersen 2001).
    b. Appendix B: Vitrinite reflectance raw data.
    c. Appendix C: pdf of the Rock Eval programs
    d. Appendix D: Bulk XRD spectra
    e. Appendix E: Excel file with combined data on the 20 samples analysed.
    f. Appendix F: Rock types in ‘las’ file format with rock type curves
    g. Appendix G: High resolution correlation profile between Slagelse-1, Gislövshammar-2 and Billegrav-2.
3. In folder *Literature* are pdf version of cited literature if it is an open access source
4. A pdf version of this report *Lower_Palaeozoic_in_Slagelse_1*.pdf

Appendix A: GEUS source rock screening data

meter	feet	TC	TOC	Tmax	S1	S2	S3	HI
125	410	1.18	0.09		0.03	0.05	0.51	59
185	607	5.42	0.83	434	0.40	1.44	1.13	174
215	705	6.54	0.52		0.12	0.16	1.14	31
245	804	5.53	0.56		0.20	0.18	1.10	32
805	2641	7.69	0.02		0.02	0.00	0.75	0
930	3051	10.06	0.06		0.00	0.00	0.27	0
940	3084	10.82	0.1		0.01	0.00	0.37	0
950	3117	10.35	0.23		0.04	0.05	0.86	23
960	3150	7.53	0.12		0.03	0.00	0.77	0
970	3182	3.54	0.28		0.06	0.08	1.28	27
980	3215	5.48	0.63		0.08	0.17	1.65	27
990	3248	3.12	0.88	415	0.15	0.33	1.50	38
1000	3281	2.38	0.82		0.05	0.18	1.27	22
1010	3314	3.2	0.8		0.06	0.16	1.46	20
1020	3346	3.02	0.9	415	0.04	0.22	1.23	25
1030	3379	1.84	0.67		0.05	0.20	1.20	30
1040	3412	2.07	1.01	427	0.04	0.36	2.93	36
1050	3445	2.43	0.82	429	0.03	0.24	1.86	29
1060	3478	2.25	0.94	424	0.05	0.36	2.60	39
1070	3510	2.56	0.83		0.03	0.17	1.96	21
1080	3543	2.13	0.92	429	0.06	0.29	1.65	31
1090	3576	2.14	0.79	424	0.05	0.25	2.13	31
1100	3609	2.67	0.62	423	0.08	0.24	1.58	38
1110	3642	2.28	0.92	413	0.13	0.36	2.74	39
1120	3675	2.36	0.84	425	0.03	0.27	2.26	32
1130	3707	2.17	0.72		0.03	0.18	1.51	25
1140	3740	2.31	0.71		0.08	0.20	1.61	29
1150	3773	2.08	0.9	421	0.06	0.33	1.36	37
1160	3806	2.88	0.66	419	0.04	0.21	0.91	32
1170	3839	2.03	0.87		0.02	0.19	0.99	22
1180	3871	2.45	0.75		0.02	0.19	1.24	26
1190	3904	2.26	0.96	423	0.03	0.32	1.12	33
1200	3937	1.68	0.88	425	0.04	0.24	1.82	27
1210	3970	2.28	1.29	429	0.09	1.67	1.27	129
1220	4003	3.15	0.83	425	0.05	0.35	2.09	42
1230	4035	1.82	0.98	425	0.04	0.25	1.31	25
1240	4068	1.47	0.91	425	0.04	0.25	1.43	27
1250	4101	2.63	0.85	419	0.04	0.21	1.55	25
1260	4134	1.58	1.09	421	0.04	0.30	1.65	27

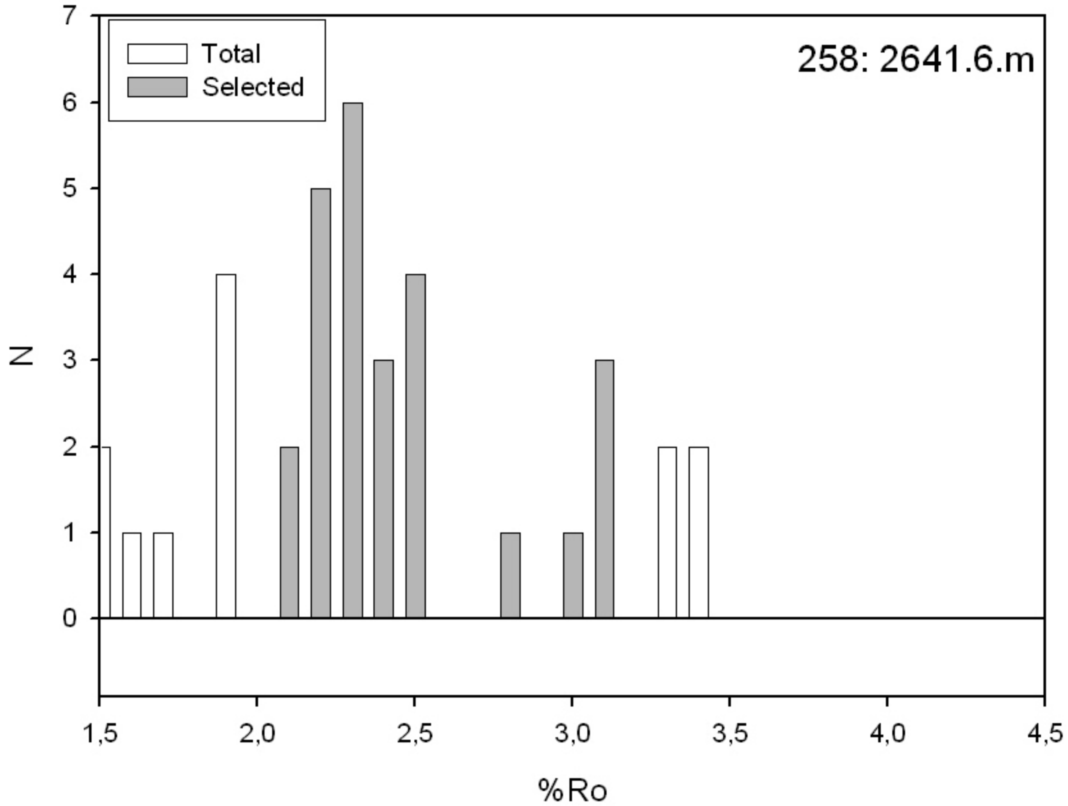
meter	feet	TC	TOC	Tmax	S1	S2	S3	HI
1270	4167	5.28	0.48		0.03	0.13	0.84	27
1280	4199	1.2	0.8		0.03	0.18	1.09	23
1290	4232	1.71	0.89	364	0.05	0.22	1.66	25
1300	4265	5.66	3.33	430	0.17	3.13	2.15	94
1310	4298	1.98	0.37		0.01	0.05	0.40	14
1320	4331	1.81	0.4		0.02	0.07	0.56	18
1330	4364	4.9	0.12		0.00	0.00	0.28	0
1340	4396	2.44	1.53	431	0.04	1.28	0.69	83
1350	4429	2.42	0.48		0.00	0.11	0.46	23
1360	4462	1.9	0.53		0.00	0.12	0.35	23
1370	4495	2.73	0.81	425	0.03	0.51	0.61	63
1380	4528	3.32	0.93	427	0.03	0.59	0.96	64
1390	4560	4.23	0.36		0.00	0.08	0.33	23
1400	4593	3.09	0.5	425	0.03	0.25	0.40	49
1410	4626	2.6	0.81	429	0.06	0.48	0.48	59
1420	4659	4.88	0.86	433	0.07	0.71	0.96	83
1430	4692	2.99	0.41		0.05	0.12	0.89	30
1440	4724	3.02	0.47	420	0.02	0.22	0.40	48
1450	4757	2.96	0.22		0.03	0.06	0.48	28
1460	4790	2.39	0.21		0.03	0.05	0.49	24
1470	4823	2.86	0.22		0.03	0.03	0.57	14
1480	4856	2.27	0.29		0.03	0.05	0.72	18
1490	4888	3.33	0.28		0.04	0.09	0.61	33
1500	4921	2.71	0.32		0.03	0.09	0.58	29
1510	4954	2.28	0.34		0.03	0.07	0.51	21
1520	4987	2.63	0.91	423	0.11	0.76	0.82	83
1530	5020	3.45	0.3		0.03	0.05	0.46	17
1540	5052	3.15	0.51		0.02	0.13	0.60	26
1550	5085	3.02	0.33		0.06	0.09	0.50	28
1560	5118	2.39	0.29		0.16	0.12	0.50	42
1570	5151	2.3	0.31		0.07	0.06	0.51	20
1580	5184	1.52	0.15		0.02	0.02	0.24	13
1590	5217	1.36	0.19		0.01	0.00	0.33	0
1600	5249	1.45	0.6		0.01	0.00	0.25	0
1610	5282	1.72	0.32		0.04	0.05	0.37	16
1620	5315	1.9	0.24		0.03	0.00	0.32	0
1630	5348	1.03	0.04		0.01	0.00	0.10	0
1640	5381	1.13	0		0.00	0.00	0.10	
1650	5413	0.85	0.08		0.03	0.00	0.21	0
1660	5446	2.35	0.37		0.02	0.15	0.82	41
1670	5479	4.56	0.29		0.02	0.08	1.01	28
1680	5512	2.53	0.39		0.02	0.05	1.01	13

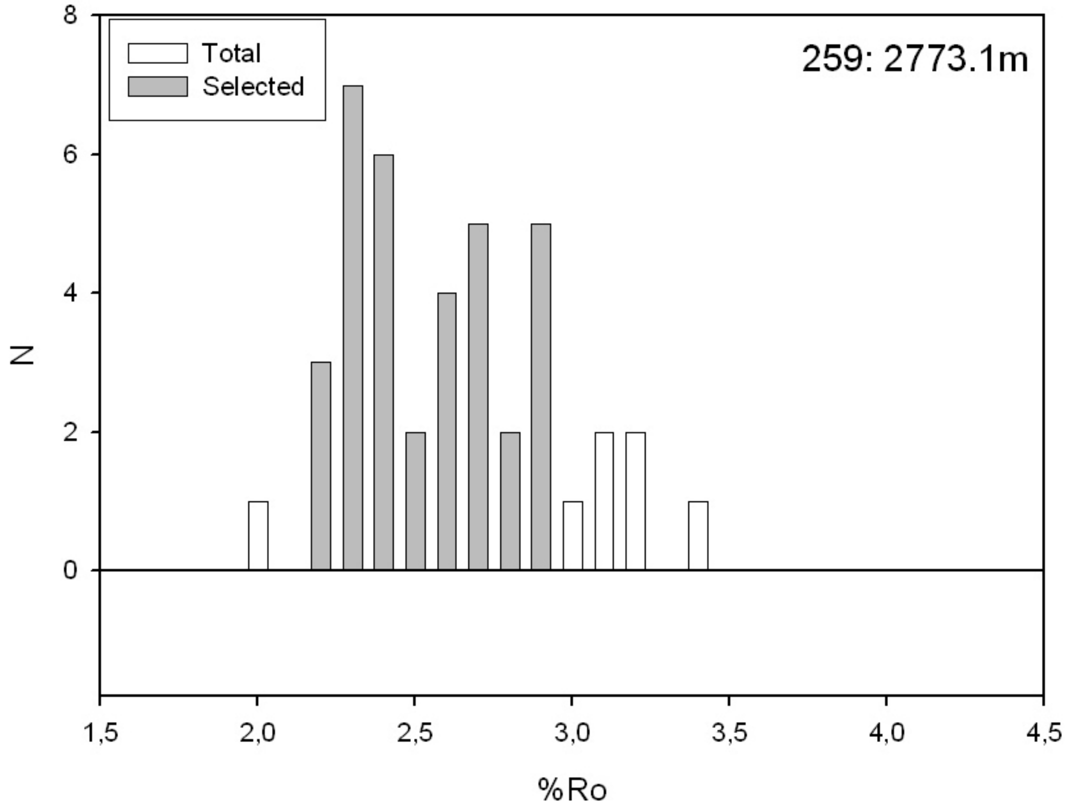
meter	feet	TC	TOC	Tmax	S1	S2	S3	HI
1690	5545	1.72	0.28		0.01	0.02	0.93	7
1700	5577	3.13	0.33		0.02	0.05	1.22	15
1710	5610	4.45	0.31		0.03	0.18	1.09	59
1720	5643	5	0.2		0.01	0.04	1.33	21
1730	5676	4.24	0.38		0.00	0.05	1.39	14
1740	5709	4.2	0.19		0.01	0.02	0.95	11
1750	5741	4.59	0.22		0.01	0.04	0.94	19
1760	5774	3.23	0.13		0.00	0.01	0.63	8
1770	5807	5.31	0.17		0.00	0.03	0.82	18
1780	5840	3.99	0.28		0.01	0.05	1.11	19
1790	5873	3.04	0.18		0.02	0.02	1.32	12
1800	5906	2.97	0.21		0.01	0.03	1.05	15
1810	5938	2.96	0.19		0.01	0.02	0.92	11
1820	5971	2.85	0.39		0.02	0.09	0.89	24
1830	6004	2.79	0.19		0.01	0.01	0.48	5
1840	6037	2.77	0.12		0.02	0.00	0.56	0
1850	6070	3.24	0.12		0.01	0.00	0.57	0
1860	6102	2.68	0.35		0.01	0.08	1.06	24
1870	6135	3.4	0.16		0.01	0.02	0.41	13
1880	6168	2.69	0.34		0.02	0.19	0.52	55
1890	6201	1.94	0.28		0.01	0.05	0.83	19
1900	6234	2.54	0.17		0.00	0.05	0.78	31
1910	6266	2.61	0.13		0.00	0.00	0.85	0
1920	6299	2.93	0.15		0.02	0.00	0.81	0
1930	6332	2.62	0.21		0.01	0.00	0.64	0
1940	6365	2.12	0.15		0.01	0.00	0.80	0
1950	6398	3.12	0.19		0.01	0.01	0.81	5
1960	6430	2.27	0.11		0.01	0.01	1.01	9
1970	6463	2.29	0.16		0.03	0.04	0.96	26
1980	6496	2.77	0.24		0.00	0.00	0.58	0
1990	6529	2.51	0.13		0.01	0.00	0.57	0
2000	6562	2.57	0.09		0.01	0.09	0.61	104
2010	6594	2.74	0.66	408	0.06	0.22	2.10	33
2020	6627	2.49	0.54	423	0.03	0.23	0.62	42
2030	6660	2.62	0.16		0.02	0.02	0.57	13
2040	6693	2.12	0.2		0.02	0.03	0.82	16
2050	6726	2.43	0.17		0.02	0.04	1.04	25
2060	6759	2.75	0.19		0.02	0.05	0.87	27
2070	6791	2.26	0.29		0.04	0.14	1.08	47

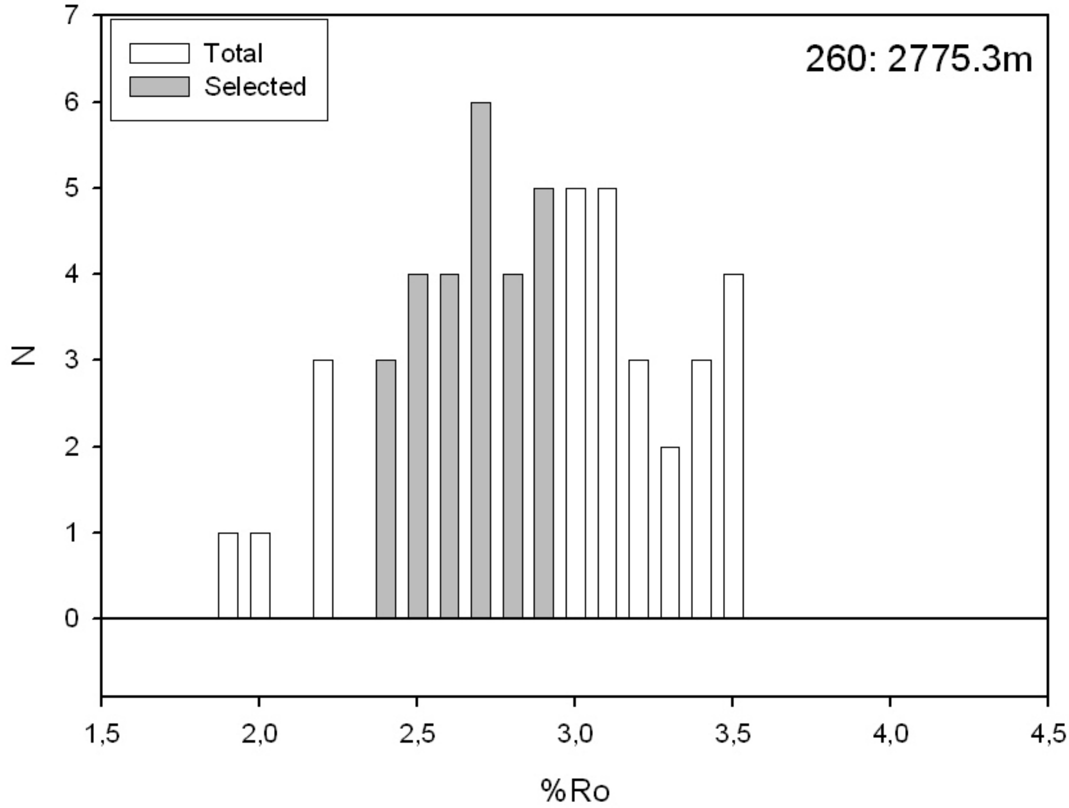
meter	feet	TC	TOC	Tmax	S1	S2	S3	HI
2080	6824	3.75	0.11		0.01	0.03	0.95	28
2090	6857	3.05	0.14		0.03	0.06	1.35	45
2100	6890	2.24	0.15		0.03	0.06	0.79	42
2110	6923	2.84	0.3		0.03	0.06	1.45	21
2120	6955	2.5	0.15		0.02	0.05	1.16	35
2130	6988	2.5	0.17		0.03	0.03	0.57	18
2140	7021	2.15	0.17		0.02	0.06	0.78	38
2150	7054	2.45	0.21		0.00	0.00	0.79	0
2160	7087	2.48	0.24		0.01	0.02	1.40	9
2170	7119	2.49	0.73	426	0.09	0.97	1.27	133
2180	7152	1.9	0.15		0.02	0.04	0.92	29
2190	7185	1.78	0.26		0.00	0.02	1.07	8
2200	7218	1.81	0.11		0.02	0.03	0.69	29
2210	7251	1.91	0.21		0.02	0.08	1.05	36
2220	7283	1.92	0.1		0.01	0.02	0.81	21
2230	7316	2.05	0.3		0.02	0.13	0.98	43
2240	7349	1.7	0.09		0.01	0.02	0.72	21
2250	7382	1.92	0.13		0.02	0.03	0.79	22
2260	7415	2.02	0.13		0.06	0.09	1.07	67
2270	7448	1.96	0.05		0.00	0.00	0.66	0
2280	7480	1.34	0.05		0.01	0.02	0.42	38
2290	7513	0.9	0.07		0.02	0.01	0.32	14
2300	7546	0.86	0.13		0.03	0.06	0.50	45
2319	7608	0.7	0.06		0.00	0.00	0.25	0
2322	7618	0.94	0.05		0.00	0.01	0.42	20
2328	7638	1.22	0.07		0.00	0.00	0.74	0
2340	7677	1.04	0.05		0.00	0.00	0.51	0
2349	7707	0.87	0.06		0.00	0.00	0.46	0
2361	7746	1.37	0.05		0.00	0.00	0.61	0
2370	7776	1.36	0.07		0.01	0.01	0.80	14
2381	7812	0.87	0.18		0.00	0.00	0.81	0
2390	7841	0.44	0.03		0.00	0.00	0.30	0
2400	7874	0.1	0.02		0.00	0.00	0.15	0
2409	7904	1.23	0.25		0.00	0.00	0.59	0
2421	7943	1.99	0.28		0.03	0.04	1.06	14
2453	8048	1.14	0.15		0.02	0.06	1.00	39
2462	8077	0.44	0.03		0.01	0.00	0.31	0
2588	8491	4.33	0.18		0.14	0.17	0.54	92
2608	8556	10.73	0.35	430	0.17	0.49	0.81	141
2620	8596	9.63	0.26	426	0.16	0.21	0.84	82
2629	8625	11.5	0.24	427	0.22	0.23	0.56	97
2650	8694	0.61	0.13		0.02	0.00	0.29	0

meter	feet	TC	TOC	Tmax	S1	S2	S3	HI
2659	8724	1.86	0.16		0.01	0.00	0.84	0
2671	8763	0.91	0.12		0.01	0.00	0.49	0
2677	8783	0.32	0.09		0.03	0.00	0.45	0
2689	8822	0.79	0.13		0.02	0.01	0.83	8
2701	8862	0.94	0.18		0.03	0.06	0.91	32
2710	8891	1.14	0.22		0.02	0.00	0.76	0
2719	8921	1.08	0.16		0.02	0.01	0.68	6
2731	8960	1.07	0.21		0.04	0.05	1.11	23
2740	8990	0.63	0.16		0.03	0.02	0.52	12
2749	9019	1.4	0.17		0.02	0.00	0.76	0
2761	9058	0.71	0.17		0.03	0.01	0.54	6
2770	9088	0.79	0.28		0.09	0.02	0.73	7
2780	9121	0.7	0.14		0.02	0.00	0.37	0
2789	9150	0.82	0.22		0.03	0.00	0.92	0
2798	9180	0.89	0.17		0.03	0.04	0.97	25
2810	9219	0.52	0.12		0.01	0.01	0.74	9
2820	9252	0.81	0.21		0.02	0.04	0.74	20
2829	9281	0.88	0.21		0.04	0.05	0.94	25
2841	9321	1.05	0.16		0.01	0.00	0.83	0
2850	9350	1.02	0.18		0.02	0.00	0.86	0
2859	9380	0.76	0.36		0.08	0.13	0.63	35
2871	9419	0.5	0.13		0.01	0.00	0.54	0
2880	9449	1.3	0.15		0.00	0.00	0.80	0
2889	9478	0.55	0.15		0.00	0.00	0.41	0
2901	9518	0.81	0.15		0.00	0.00	0.96	0
2909	9544	1.25	0.21		0.01	0.00	0.75	0
2921	9583	0.45	0.21		0.00	0.00	0.50	0
2930	9613	1.3	0.78		0.08	0.00	0.47	0
2940	9646	3.22	2.67		0.17	0.00	0.87	0
2949	9675	2.93	2.32		0.42	0.00	0.80	0
2960	9711	1.11	0.46		0.04	0.00	0.42	0
2971	9747	0.68	0.67		0.01	0.00	0.35	0

Appendix B: Vitrinite frequency histograms



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Selected
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N
%Ro
7
6
5
4
3
2
1
0
1,5
2,0
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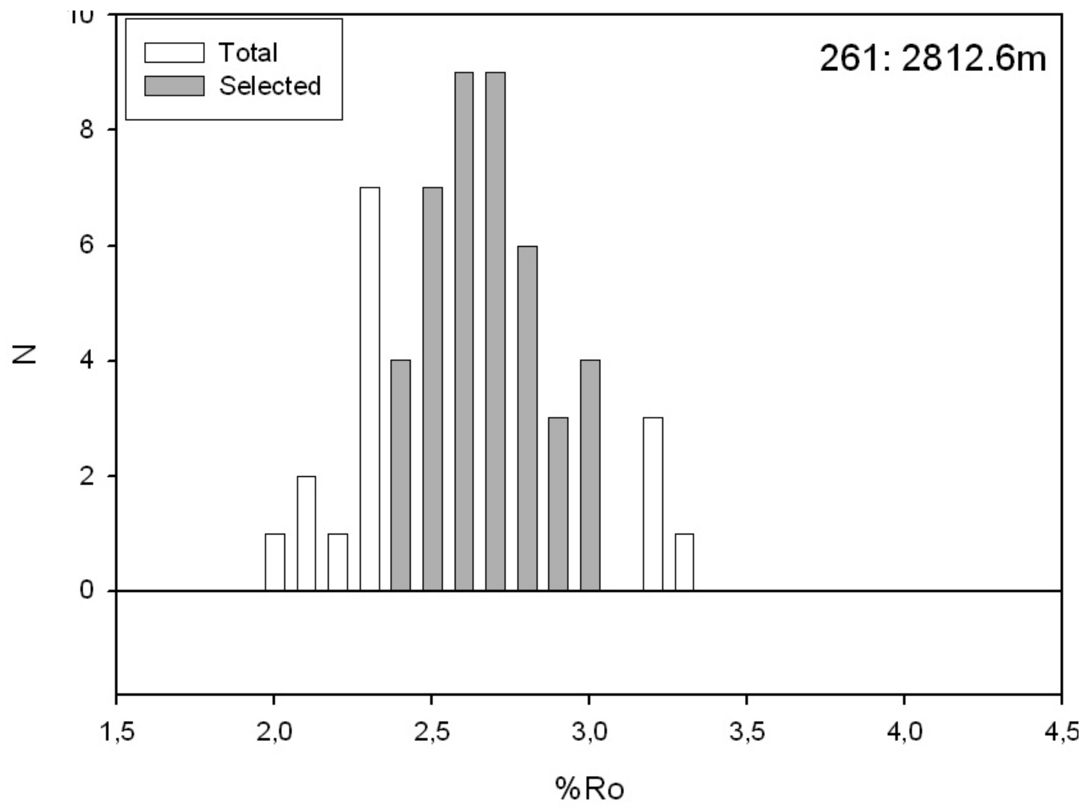
3,0
3,5
4,0
4,5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Selected
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N
%Ro
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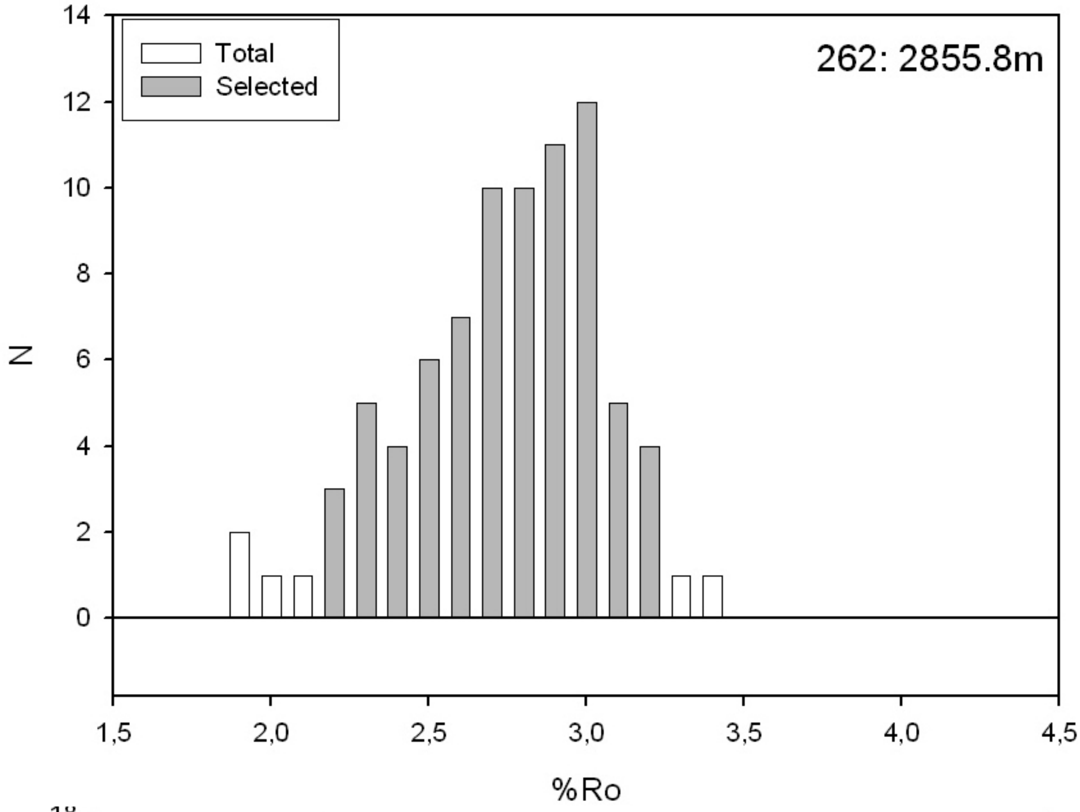
6
4
2
0
1,5
2,0
2,5
3,0
3,5
4,0
4,5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Selected
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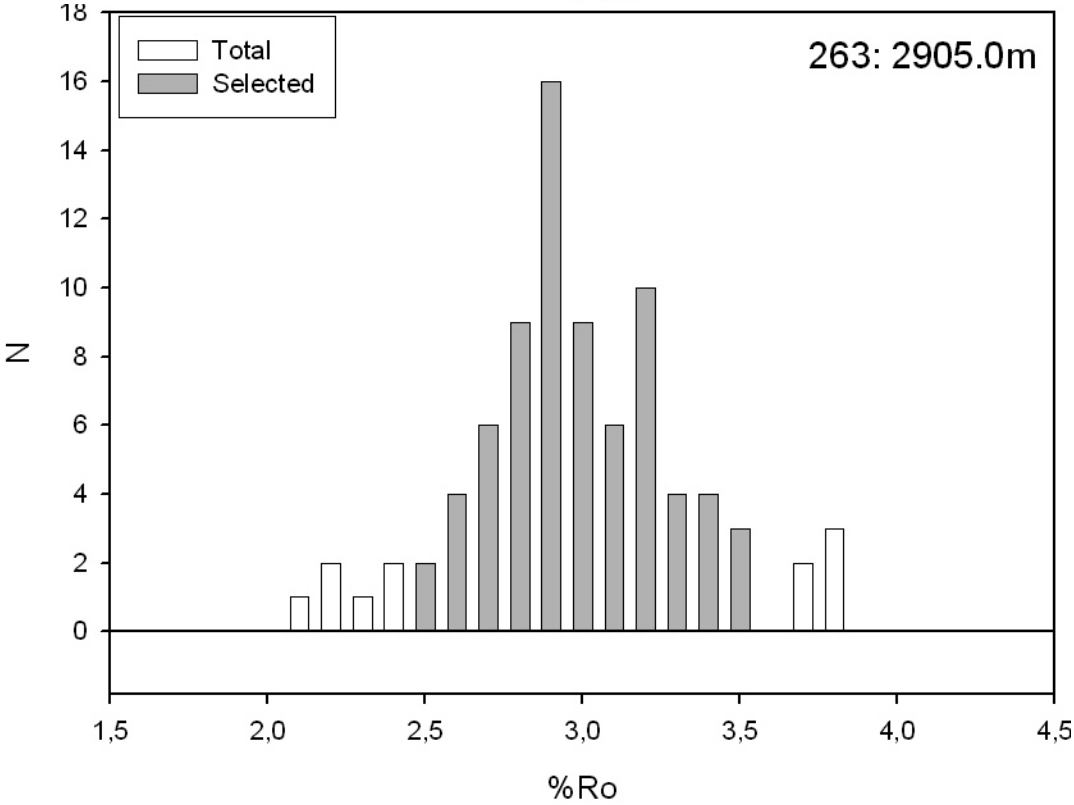
N
%Ro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Selected
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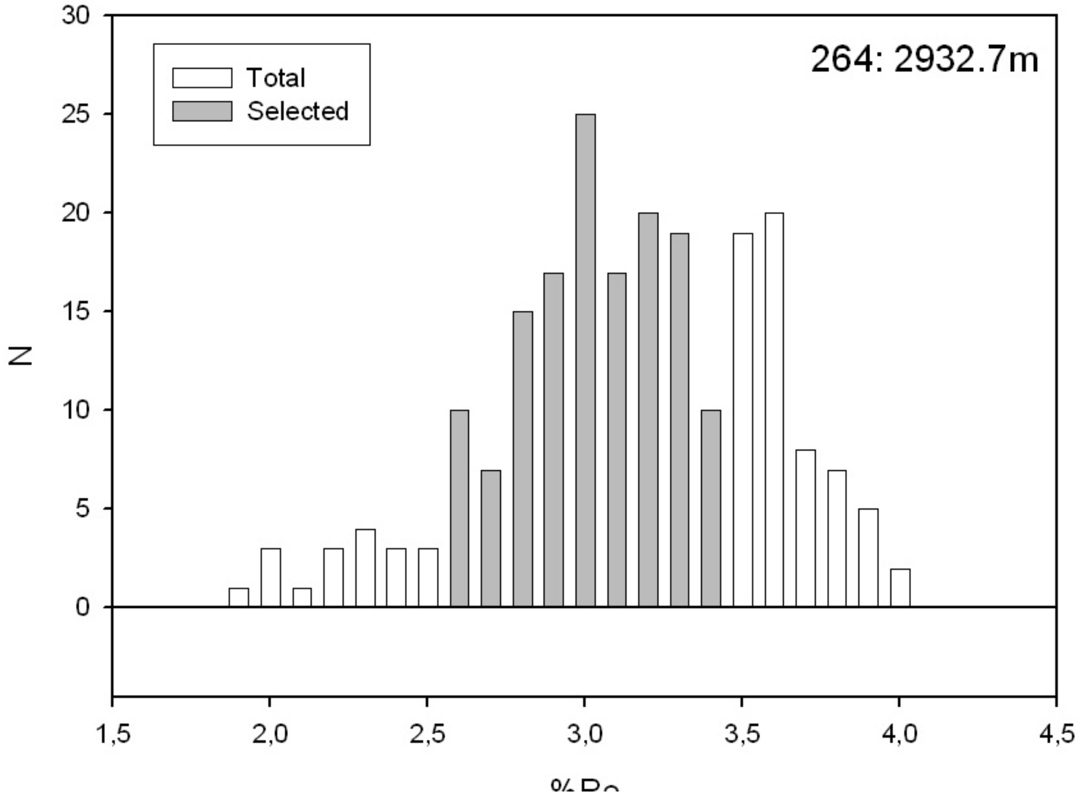
N
%Ro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Selected
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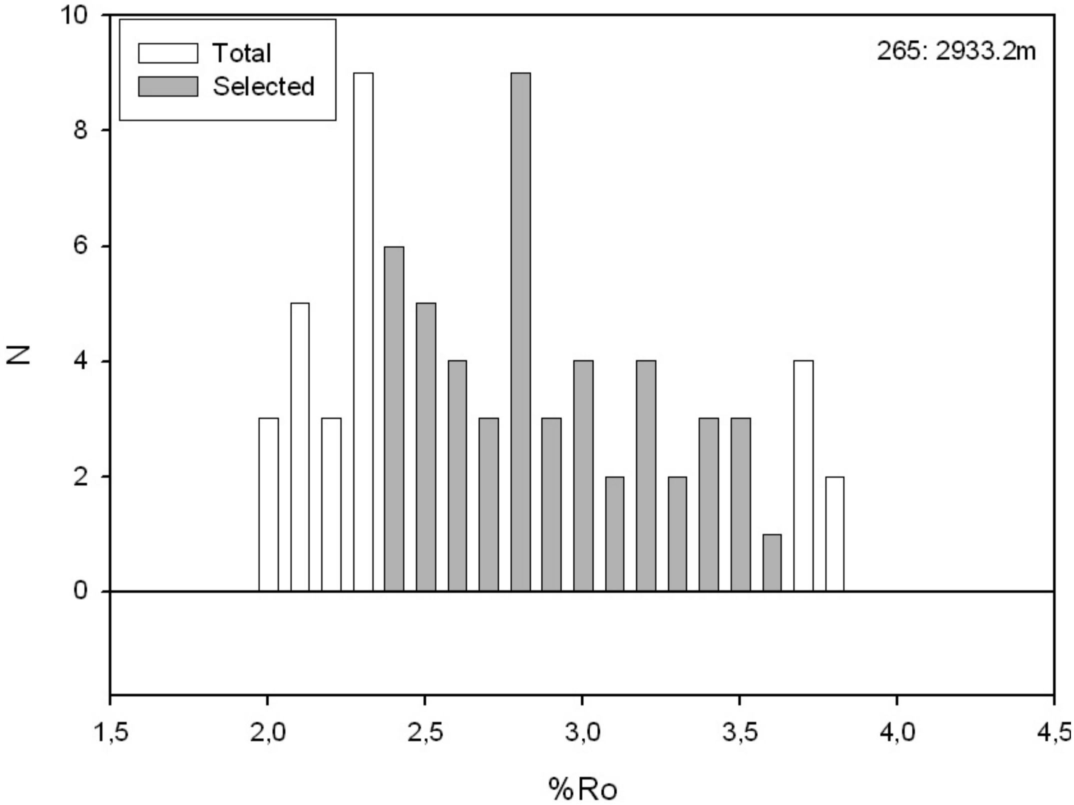
30
25
20
15
10
5
0
1,5
2,0
2,5
3,0
3,5
4,0
4,5


265: 2933.2m
Total
Selected
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8
6
4
2
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1,5
2,0
2,5
3,0
3,5
4,0
4,5
%Ro