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Ichron

Sedimentological & Biostratigraphical Consultants

16 Dalby Court,
Gadbrook Business Centre,
Hud Heath, Northwich,
Cheshire, CW9 7TN
Telephone: 01606 46113
Facsimile: 01606 46114

Attention: Gier Larssen

Re: Ichnofabric study, Barents Sea for the N.P.D.

16th October 1996

Dear Gier

Here is the much overdue report on the trace fossils in the barent sea core material. I also inclose an invoice for the work. Please note that I have enclosed two extra plates as small compensation for the late arrival of the report. I was in Pau last month when the AAPG conference on carbonates took place and looked out for you, but I gather you did not go. It was a good week by all accounts.

If you have any problems with the report to not hesitate to call

Regards



Dr. Andrew Taylor



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Sedimentological & Biostratigraphical Consultants

Trace Fossil Appraisal of Seven Cored Wells From the Nørdflaket Area, Barents Sea

prepared for

Norwegian Petroleum Directorate

by

Andrew M. Taylor

Ichron Limited

October 1996

Ref: 96/075/S



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FROM THE NØRDFLAKET AREA, BARENTS SEA**

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1. INTRODUCTION

This study was commissioned by Norwegian Petroleum Directorate (NPD) to examine 383.70 metres of core taken from the Early Cretaceous (Valanginian - Early Hauterivian) and Late Palaeocene, Early Eocene to Middle Eocene successions cored as part of a shallow drilling program in the Nørdflaket area of the Barent Sea. A total of seven wells (Figure 1.1) were analysed for their trace fossil content (Table 1.1). Standard NPD Sedimentological core logs were made available for four wells in the study and three wells were logged for both sedimentology and ichnology adopting the NPD profoma (7616/11-u-02, 7616/11-u-02 & 7616/11-u-02). A further well, 7517/12-u-01 was made available for viewing but was not logged due to lack of time.

The aim of this study was to examine the cored interval for trace fossils, annotate the NPD sedimentary logs and comment on the range of depositional environments present. The format for this report has been chosen by the NPD and deals with the trace fossil occurrences by well and by depth. Seven plates illustrate the trace fossils observed in core. The original 1:200 scale core logging sheets with trace fossil identifications, facies interpretation and comments on candidate key stratal surfaces are included (Enclosures 1-7) along with an Ichron trace fossil legend sheet (Appendix 1).

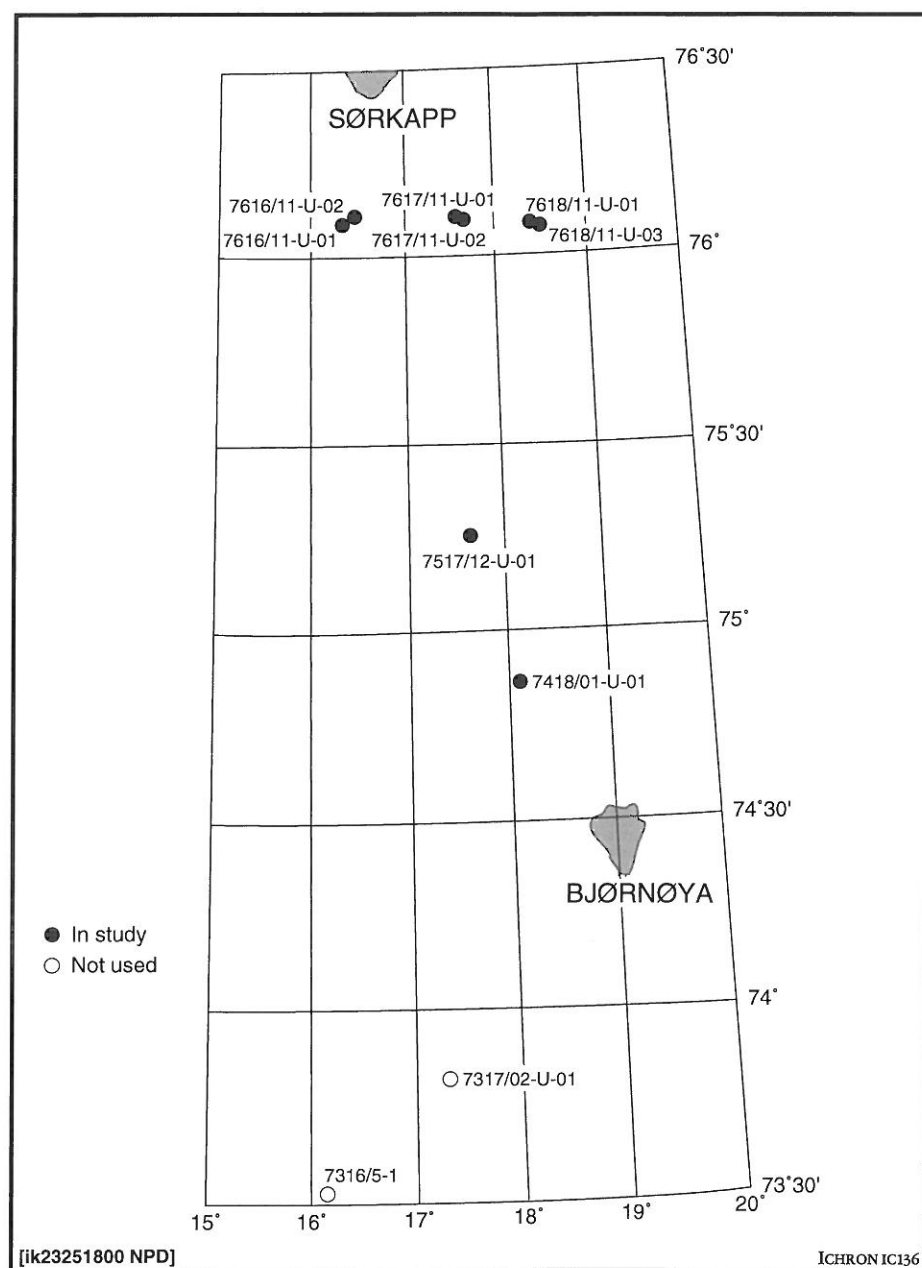


Figure 1.1 Location map of wells used in this study, Nordflaket Area, Barents Sea.

WELL	AGE	CORES	TOP (m)	BASE (m)	TOTAL (m)
7418/01-u-01	Late Palaeocene - Middle Eocene	1-51	8.40	126.15	117.75
7616/11-u-01	Early Cretaceous	1-12	2.00	69.25	67.25
7616/11-u-02	Late Palaeocene	6-12	35.45	47.80	12.35
7617/11-u-01	not dated	3-10	11.05	30.25	19.20
7617/11-u-02	Late Palaeocene	1-54	10.55	154.05	143.50
7618/10-u-01	Early Cretaceous	4-13	13.05	28.75	15.70
7618/10-u-03	not dated	1-3	14.30	22.25	7.95
				TOTAL	383.70

Table 1.1. Core data base

2. TRACE FOSSIL & DEPOSITIONAL FACIES

2.1. Introduction

In this study, the degree of bioturbation has been plotted. The method adopted here (*cf.* Taylor & Goldring 1993) is descriptive with an assessment of the amount of 'burrowed' to 'unburrowed' sediment. It is important to record trends in bioturbation to help establish the relative rates of sedimentation and erosion to indicate changes in oxygen levels. Individual ichnotaxa are listed for the purposes of ichnofacies analysis (*cf.* Bromley 1990) which has also been plotted. As trace fossils record an *in situ* response to prevailing environmental conditions, they are an excellent indicator of environmental change, which is reflected by a change in the benthic colonisation of the substrate (Frey & Goldring 1992). This may relate to differences in salinity, cementation (substrate lithification), sedimentation rates and facies shifts (Taylor & Gawthorpe 1993). It is by understanding the community changes recorded in the trace fossils that hiatal colonisation and subaerial exposure can be deduced and used to define key stratal surfaces (Enclosures 1-7). These candidate surfaces are also recorded.

In the following section the trends in bioturbation, ichnotaxa listings and environmental interpretation are presented on a well by well basis.

2.2. Well 7418/01-u-01

This Late Palaeocene and Early to Middle Eocene cored section exhibits a range of depositional facies with dark grey, moderately bioturbated, silty claystones (muddy shelf), brown grey, moderately bioturbated, claystones (basin floor) and grey, intensely bioturbated, silty very fine to fine grained sandstones (distal lower shoreface/transition zone). The trace fossils present occur in the *Cruziana*, *Nereites* and *Zoophycos* ichnofacies (Enclosure 1). Although the ranges of the micropalaeontological zones suggest that the change from Late Palaeocene to Early and Middle Eocene is uncertain; the core observations do suggest that there were a series of major breaks in sedimentation at 121.5m, 89.2m, 70.7m and 36.2m, respectively.

8.40 (top) - 70.70m: Dark grey to brown, laminated to moderately bioturbated (BI=3-4) claystones and silty claystones with *Chondrites*, *Phycosiphon* (2 sizes), *Schaubcylindrichnus*, *Scolicia* and *Thalassinoides* (Plates 1A-C). This is cross cut by a zone of large *Zoophycos* burrows which are infilled by lithic and volcanic clasts (34.0 - 37.0m: Plate 1B). This colonisation may indicate a condensed section. The presence of a low diversity (2-3) tiered, deposit-feeding community could reflect either soupground conditions (compacted and sheared bioturbate texture: Plate 1C) or that low to variable oxygen levels controlled colonisation on a muddy basin floor.

70.70 - 89.20m: This interval consists of an overall fining upward and silting upward cycle, with grey, weakly laminated to intensely bioturbated (BI=5-6) silty, very fine grained sandstones with *Planolites*, *Chondrites*, *Rosselia*, *Teichichnus*, *Schaubcylindrichnus*, *Phycosiphon*, faecal pellets, bivalve burrows, *Palaeophycus* and *Skolithos* (Plate 1D, 2A, 2B). The high diversity (5-7) and the nature of colonisation with both deposit-feeding (fairweather) and suspension-feeding (storm) communities plus lack of sedimentary structures define an overall deepening upward trend of distal lower shoreface to proximal transition zone facies (cf. Vossler & Pemberton, 1988, Frey 1990). The upper surface (Plate 1D) and lower surface (Plate 2B) of this sandbody are defined by abundant lithic clasts (non-bored pebbles) and volcanic fragments casting a firmground colonisation by *Thalassinoides*. The lower surface records a major shallowing event and could also be an angular unconformity (?Late Palaeocene to Early Eocene). The top surface is a major transgressive surface, marked by clasts and a firmground colonisation by *Teichichnus* and also could be an erosive unconformity (?Late Palaeocene to Early Eocene).

89.20 - 126.15m (base): Dark grey, laminated to moderately bioturbated (BI=3-4) silty claystones with *Phycosiphon* (two sizes), *Scolicia*, *Skolithos*, *Chondrites*, *Planolites* and *Schaubcylichnus* (Plate 2C). A zone of large ?*Teichichnus* burrows with sandstone infill marks a firmground colonisation (Plate 2D) and is associated with scattered lithic and volcanic clasts (119.0 - 121.5m). This colonisation marks a depositional hiatus. The presence of a low diversity (2-3) deposit-feeding community reflects possible low to variable oxygen levels (periodic anoxia) on a muddy shelf.

2.3. Well 7616/11-u-01

Part of this well (2.0 - 47.5m) is dated as Early Cretaceous and exhibits three depositional facies with buff, non-bioturbated, laminated fine grained sandstones (high density sandy turbidites); grey, bioturbated, silty, very fine grained sandstones (transition zone) and black, sparsely bioturbated claystones (muddy shelf). The trace fossils present occur within the *Cruziana* ichnofacies (Enclosure 2). The undated section (47.5 - 69.25m) consists of two depositional facies with buff, bioturbated to rippled, very fine to fine grained sandstones (lower shoreface) and grey, bioturbated, silty, very fine grained sandstones (transition zone). The trace fossils present occur within the mixed *Skolithos/Cruziana* ichnofacies.

2.00 (top) - 8.80m: Pale grey, laminated to low-angle cross-stratified very fine to fine grained sandstones with centimetre-scale mudstone clasts and shell debris. These sandstones are not colonised and are considered to have been deposited by gravity flow rather than by storm processes.

8.80 - 43.80m: This interval consists of a coarsening upwards and cleaning upward unit with, at the base black, laminated to sparsely bioturbated (BI=2-3) claystones with *Phycosiphon*, *Chondrites*, excavation burrows, *Scolicia* and *Planolites* (Plate 3A). This low to moderate diversity (2-4) deposit-feeding community reflects low to variable oxygen levels (periodic anoxia) on a muddy shelf. These claystones pass upwards into grey, moderate to intensely bioturbated (BI=3-5) silty claystones and thinly bedded, wave rippled, very fine grained sandstones with *Planolites*, *Scolicia*, *Skolithos*, J-shaped burrows, *Gyrochorte*, *Chondrites*, *Palaeophycus heberti*, escape burrows, faecal pellets, *Schaubcylichnus* and *Teichichnus*. This diverse community (6-9) which consists of deposit-feeding structures with a few suspension-feeding burrows present, suggests tiered colonisation of distal event beds within the transition zone on a muddy shelf. A large *Skolithos* burrow cross-cutting the other traces may reflect a period of depositional hiatus (e.g. 38.2m: Plate 3B).

43.80 - 51.18m: This interval consists of an overall fining upward and silting upward trend with grey, moderate to intensely bioturbated (BI=4-5), shell-rich, silty, very fine grained sandstones with *Asterosoma*, *Planolites*, *Teichichnus*, *Phycosiphon*, *Schaubcylichnus*, *Scolicia*, *Chondrites*, faecal pellets, bivalve burrows, *Palaeophycus* and *Thalassinoides* (Plate 3C). The high diversity (5-7) and the nature of colonisation with a distinctive alternation of deposit-feeding,

escape and suspension-feeding communities defines an overall deepening upwards cycle of proximal to distal transition zone.

51.18 - 69.25m (base): This interval consists of an overall coarsening upward and cleaning upward trend with grey, intensely bioturbated (BI=5), shelly, silty, very fine to fine grained sandstones (Plate 4A, 4B) which pass upwards into grey, moderately bioturbated (BI=3), decimetre-scale, rippled to cross-stratified fine grained sandstones (Plate 3D). These sandstones are burrowed by *Asterosoma*, *Planolites*, *Teichichnus*, *Phycosiphon*, *Schaubcylichnus*, *Taenidium*, *Rosselia*, *Scolicia*, *Chondrites*, ?*Ophiomorpha*, escape burrows, faecal pellets, *Palaeophycus* and *Skolithos*. The presence of *Diplocraterion* burrows cross-cutting the other traces present (e.g. 61.7m: Plate 4B) may reflect a period of depositional hiatus. The high diversity (5-8) and the nature of colonisation (tiered) with deposit-feeding, escape and suspension-feeding communities help define an overall shallowing upward cycle of proximal transition zone to proximal lower shoreface facies.

2.4. Well 7616/11-u-02

This Late Palaeocene cored section exhibits two depositional facies with black, laminated to sparsely bioturbated claystones (muddy shelf) and dark grey, moderately bioturbated, centimetre-scale claystones, siltstones and buff, very fine grained sandstones (distal transition zone). The trace fossils present occur in the *Cruziana* ichnofacies (Enclosure 3).

35.45 (top) - 38.4m: Black, laminated to sparsely bioturbated (BI=2) claystones with *Phycosiphon* and *Planolites* (pyritic infill) (Plate 4C). The presence of a low diversity (2) deposit-feeding community could reflect low to variable oxygen levels (periodic anoxia) on a muddy shelf.

38.4 - 41.6m: Dark grey, moderately bioturbated (BI=3-4) claystones, siltstones and thinly bedded, very fine grained sandstone event beds with *Phycosiphon*, *Chondrites*, *Planolites*, *Schaubcylichnus*, small *Skolithos* and small *Teichichnus* (Plate 4D). This diverse community consists of dominantly deposit-feeding structures with a tiered colonisation of distal event beds within the distal transition zone on a muddy shelf.

41.6 - 47.8m (base): Black, laminated to sparsely bioturbated (BI=2) claystones with *Phycosiphon*, *Chondrites* and *Planolites* (pyritic infill). The presence of a low diversity (2) deposit-feeding community could reflect low to variable oxygen levels (periodic anoxia) on a muddy shelf.

2.5. Well 7617/11-u-01

This section is not dated (no recovery) but is similar to the upper part of the cored section in well 7617/11-u-02 which is dated as Late Palaeocene in age. The cored section exhibits repeated cycles of three depositional facies with dark grey, laminated to moderately bioturbated, silty claystones (muddy shelf), dark grey, moderately bioturbated, centimetre-scale interbedded siltstones and very fine grained sandstones (distal transition zone) and light grey, interbedded, decimetre-scale rippled, very fine grained sandstones and bioturbated siltstones. There is an overall deepening upward trend. The trace fossils present occur in the *Cruziana* ichnofacies (Enclosure 4). It should be noted that this cored section is directly correlatable to the core taken in 7617/11-u-02.

11.05 (top) - 24.8m: Black, laminated to moderately bioturbated (BI=2-3) silty claystones and claystones with sediment starved ripples of very fine grained sandstone colonised by *Phycosiphon* (two sizes), *Chondrites*, J-shaped burrows and *Planolites* (Plate 6C). This low diversity (2-4) deposit-feeding community reflects possible low to variable oxygen levels (periodic anoxia) on a muddy shelf. It can be cross-cut by large *Skolithos* burrows, often with a pyrite infill, which mark potential hiatal colonisations (e.g. 23.5m: Plate 6C). In this interval there are two horizons with more pronounced siltier event beds colonised by additional burrows such as *Scolicia*, *Teichichnus* and *Schaubcylichnus*. These horizons relate to minor shallowing episodes into distal transition zone facies (see below).

24.8 - 30.25m (base): Dark grey, moderate to intensely bioturbated (BI=3-5) siltstones and buff, thinly bedded, ripple cross-laminated, very fine grained sandstones with *Phycosiphon*, *Chondrites*, *Planolites*, *Schaubcylichnus*, *Trichichnus*, *Palaeophycus heberti*, *Teichichnus*, *Scolicia*, excavation burrows, faecal pellets and J-shaped burrows (Plate 6D). This diverse community consists of dominantly deposit-feeding structures indicating a tiered colonisation of distal event beds within the transition zone on a muddy shelf. The differentiation of proximal to distal transition zone reflects the thickness and preservation of the sand-prone event beds and the relative abundance of the *Trichichnus* burrows (more abundant in the proximal transition zone).

2.6. Well 7617/11-u-02

This Late Palaeocene cored section exhibits repeated cycles of five depositional facies with dark grey, laminated to moderately bioturbated, silty claystones (muddy shelf), dark grey, moderately bioturbated, centimetre-scale interbedded siltstones and very fine grained sandstones (proximal and distal transition zone) and buff, interbedded decimetre-scale, bioturbated, rippled, laminated and hummocky cross-stratified, very fine to fine grained sandstones (proximal and distal lower shoreface). The trace fossils present occur in the *Cruziana* and mixed *Cruziana-Skolithos* ichnofacies (Enclosure 5). It should be noted that the top of this cored section is directly correlatable to the core taken in 7617/11-u-01. A brecciated zone between 36.0 - 39.0m in claystones above a thick sandstone interval corresponds to a major deepening event but is likely to be a faulted contact.

10.55 (top) - 39.3m: In this interval a number of coarsening upward and cleaning upward cycles with, at the base black, laminated to moderately bioturbated (BI=2-3) silty claystones with J-shaped burrows, *Scolicia* and *Planolites*. This low diversity (2-3) deposit-feeding community reflects low to variable oxygen levels (periodic anoxia) on a muddy shelf. These claystones pass upwards into dark grey, moderately bioturbated (BI=3-4), silty claystones and thinly bedded, rippled, very fine grained sandstones with *Planolites*, *Scolicia*, *Trichichnus*, *Skolithos*, J-shaped burrows, escape burrows, *Gyrochorte*, *Schaubcylichnus* and *Teichichnus*. This diverse community (5-7) consists of dominantly deposit-feeding structures which indicates a tiered colonisation of distal event beds within the transition zone. Also present are siderite cemented large *Skolithos* burrows cross-cutting the other traces present (e.g. 25.2m) which may reflect a period of depositional hiatus.

39.3 - 55.0m: This interval consists of an overall coarsening upward and cleaning upward cycle, with at the base, dark grey, intensely bioturbated (BI=5) and rippled, silty very fine grained sandstones which pass upwards into distinct, decimetre-scale fining upward bed sets of wave rippled to bioturbated couplets (Plate 5B). These event beds can become amalgamated and interbed with sparsely bioturbated (BI=0-3), hummocky cross-stratified very fine grained sandstones (Plate 5A). In the more bioturbated argillaceous intervals, *Planolites*, *Teichichnus*, *Phycosiphon*, *Schaubcylichnus*, J-shaped burrows, escape burrows, faecal pellets, *Palaeophycus* and *Skolithos* are recorded. In the sand-prone event beds colonisation is more restricted, with *Skolithos*, *Planolites*, escape burrows and *Phycosiphon* (Plates 5A, 5B). The high diversity (5-9) and

the nature of colonisation with a distinctive alternation of a deposit-feeding (fairweather) and escape plus suspension-feeding (storm) communities defines an overall shallowing upward trend of proximal transition zone to proximal lower shoreface facies.

55.0 - 154.05m (base): This interval consists of at least nine coarsening upward and cleaning upward cycles, which exhibit an overall shallowing upward trend. Bioturbation levels are high throughout (BI=3-5) with distinct decimetre-scale wave rippled to bioturbated couplets and scattered shell debris. In the siltstones and silty very fine grained sandstones *Planolites*, *Teichichnus*, *Phycosiphon* (two sizes), *Scolicia*, *Chondrites*, *Schaubcylindrichnus*, J-shaped burrows, excavation burrows, faecal pellets, *Taenidium*, *Palaeophycus* and *P. heberti* are widespread (Plates 5C, 5D, 6B). Black, laminated claystone intervals have a lower diversity ichnofauna of *Chondrites* and *Phycosiphon* (Plate 6A). Hiatal colonisations are marked by cross-cutting burrows of large *Teichichnus* (Plate 5C), *Rosselia* (Plate 5D), *Skolithos* (Plate 6A) and *Chondrites* (Plate 6B). The high diversity (5-8) and dominance of the deposit-feeding community (fairweather) defines an overall shallowing upward trend of muddy shelf to distal lower shoreface facies dominated by transition zone facies.

2.7. Well 7618/10-u-01

This Early Cretaceous cored section exhibits three depositional facies with buff, non-bioturbated, laminated fine grained sandstones (high density sandy turbidites); grey, bioturbated fine grained sandstones (high density sandy turbidites and hiatal colonisation) and black, sparsely bioturbated claystones (muddy shelf). The trace fossils present occur within the *Cruziana* ichnofacies (Enclosure 6). It should be noted that the upper part of this cored section is directly correlatable to the core taken in 7618/10-u-03.

13.05 (top) - 19.9m: Pale grey, laminated to low-angle cross-stratified very fine to fine grained sandstones with centimetre-scale coarser grained horizons. These sandstones are not colonised and are considered to be deposited by gravity flow rather than by storm processes.

19.9 - 24.6m: Black, laminated to sparsely bioturbated (BI=2-3) claystones with *Phycosiphon* (two sizes), *Schaubcylindrichnus*, small *Skolithos* and *Planolites* (pyritic infill) which interbed with pale grey, centimetre-scale, ripple cross laminated fine grained sandstones (see Plate 7C). The presence of a low to moderate diversity (2-4) deposit-feeding community could reflect low to variable oxygen levels (periodic anoxia) on a muddy shelf with minor event (?turbidite) bed deposition.

24.6 - 25.5m: Dark grey, intensely bioturbated (BI=5), silty fine grained sandstones with *Phycosiphon*, *Palaeophycus*, escape burrows and *Chondrites* burrows, cross-cut by large sand-filled *Arenicolites* (Plate 7A, 7B). The *Arenicolites* burrows are reburrowed by *Phycosiphon* and *Chondrites*. The multiple *Arenicolites* colonisations reflect a change from deposit-feeding to suspension-feeding that may relate to a major depositional hiatus (bypass or non-deposition). It is a candidate for a correlatable transgressive surface within the muddy shelf.

25.5 - 28.75m (base): Return to the interbedded black claystones and rippled to planar laminated sandstones colonised by *Phycosiphon*, *Chondrites*, *Schaubcylindrichnus*, small *Skolithos* and *Planolites*.

2.8. Well 7618/10-u-03

This core is not dated (poor recovery) but it is likely to be of Early Cretaceous age as it is similar to the core recovered from 7618/10-u-01. This section exhibits two depositional facies with buff, non-bioturbated, laminated fine grained sandstones (high density sandy turbidites) and black, sparsely bioturbated to laminated claystones (muddy shelf). The trace fossils present occur within the *Cruziana* ichnofacies (Enclosure 7).

14.15 (top) - 15.15m: Pale grey, laminated to low-angle cross-stratified very fine to fine grained sandstones with centimetre-scale coarse grained sandstone horizons. These sandstones are not colonised and are considered to be deposited by gravity flow rather than by storm processes.

15.15 - 19.3m: Interbedded black, laminated to sparsely bioturbated (BI=2-3) claystones with *Phycosiphon*, *Schaubcylichnus*, *Chondrites* and *Planolites* and decimetre-scale pale grey, laminated, fine grained sandstones with coarser grained layers (Plate 7C). The sandstones are colonised post-depositionally (top surface downwards) by aspects of the overlying ichnofauna. This low to moderate diversity (2-4) deposit-feeding community colonises a muddy shelf subjected to periodic anoxia with minor high density sandy turbidite deposition.

19.3 - 22.25m (base): Black, laminated to sparsely bioturbated (BI=2-3) claystones with scattered shell debris and *Phycosiphon*, *Schaubcylichnus*, small *Skolithos*, *Chondrites*, J-shaped burrows and *Planolites* (Plate 7D). A low to moderate diversity (2-4) deposit-feeding community colonised a muddy shelf subjected to periodic anoxia.

3. SUMMARY

1. **Early to Middle Eocene section:** Interbedded dark grey brown claystones and silty claystones moderately bioturbated by *Chondrites*, *Schaubcylindrichnus*, *Phycosiphon* (2 sizes), *Scolicia*, *Thalassinoides* and *Zoophycos*. This is placed in the *Nereites* and *Zoophycos* ichnofacies and interpreted as basin floor muds (?slope).
2. **Late Palaeocene sections:** Interbedded buff, wave rippled and hummocky cross-stratified, very fine grained sandstones with grey, intensely bioturbated silty sandstones, siltstones and black, laminated sparsely bioturbated claystones which are colonised by *Chondrites*, *Cylindrichnus*, bivalve burrows, escape burrows, excavation burrows, J-shaped burrows, faecal pellets, *Gyrochorte*, *Palaeophycus*, *P. heberti*, *Phycosiphon*, *Planolites*, *Rosselia*, *Schaubcylindrichnus*, *Scolicia*, *Skolithos*, *Teichichnus* (two sizes), *Thalassinoides* and *Trichichnus*. This is placed within the mixed *Skolithos/Cruziana* and *Cruziana* ichnofacies and interpreted as proximal lower shoreface, transition zone and muddy shelf subject to periodic anoxia.
3. **Early Cretaceous sections:** Interbedded buff, non bioturbated, planar to low angle cross-laminated, very fine to fine grained sandstones, black, laminated sparsely bioturbated claystones and grey intensely bioturbated, fine grained sandstones are colonised by *Arenicolites*, *Chondrites*, excavation burrows, J-shaped burrows, faecal pellets, *Gyrochorte*, *Palaeophycus*, *P. heberti*, *Phycosiphon* (two sizes), *Planolites*, *Schaubcylindrichnus*, *Scolicia*, *Skolithos* (two sizes) and *Thalassinoides*. This is placed within the *Cruziana* ichnofacies and interpreted as high density sandy turbidites and muddy shelf subject to periodic anoxia.
4. **Undated section in 7616/11-u-01:** Interbedded buff, sparsely bioturbated, ripple cross-laminated fine grained sandstone and grey, intensely bioturbated silty very fine sandstones are colonised by *Asterosoma*, bivalve burrows, *Chondrites*, *Diplocraterion*, escape burrows, ?*Ophiomorpha*, *Palaeophycus*, *P. heberti*, *Phycosiphon*, *Planolites*, *Rosselia*, *Schaubcylindrichnus*, *Scolicia*, *Skolithos*, *Taenidium* and *Teichichnus*. This is placed within the mixed *Skolithos/Cruziana* ichnofacies and interpreted as proximal lower shoreface to proximal transition zone facies.

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PLATE 1

A. Dark grey laminated. silty claystones are moderately bioturbated (BI=4) by *Scolicia* (SC), *Chondrites* (CH), and *Phycosiphon* (PH).

Well: 7418/01-u-01 Depth: 33.80m
Age: Early to Middle Eocene
Facies: Basin floor (?slope)

B. Dark grey laminated claystones are moderately bioturbated (BI=4) by *Chondrites* (CH), and *Thalassinoides* (TH). This is cross-cut by large *Zoophycos* (ZO) burrows which relate to a hiatal colonisation event. The *Zoophycos* burrows are preferentially infilled with lithic and volcanic clasts.

Well: 7418/01-u-01 Depth: 36.2m
Age: Early to Middle Eocene
Facies: Depositional hiatus (cMFS) within basin floor (?slope)

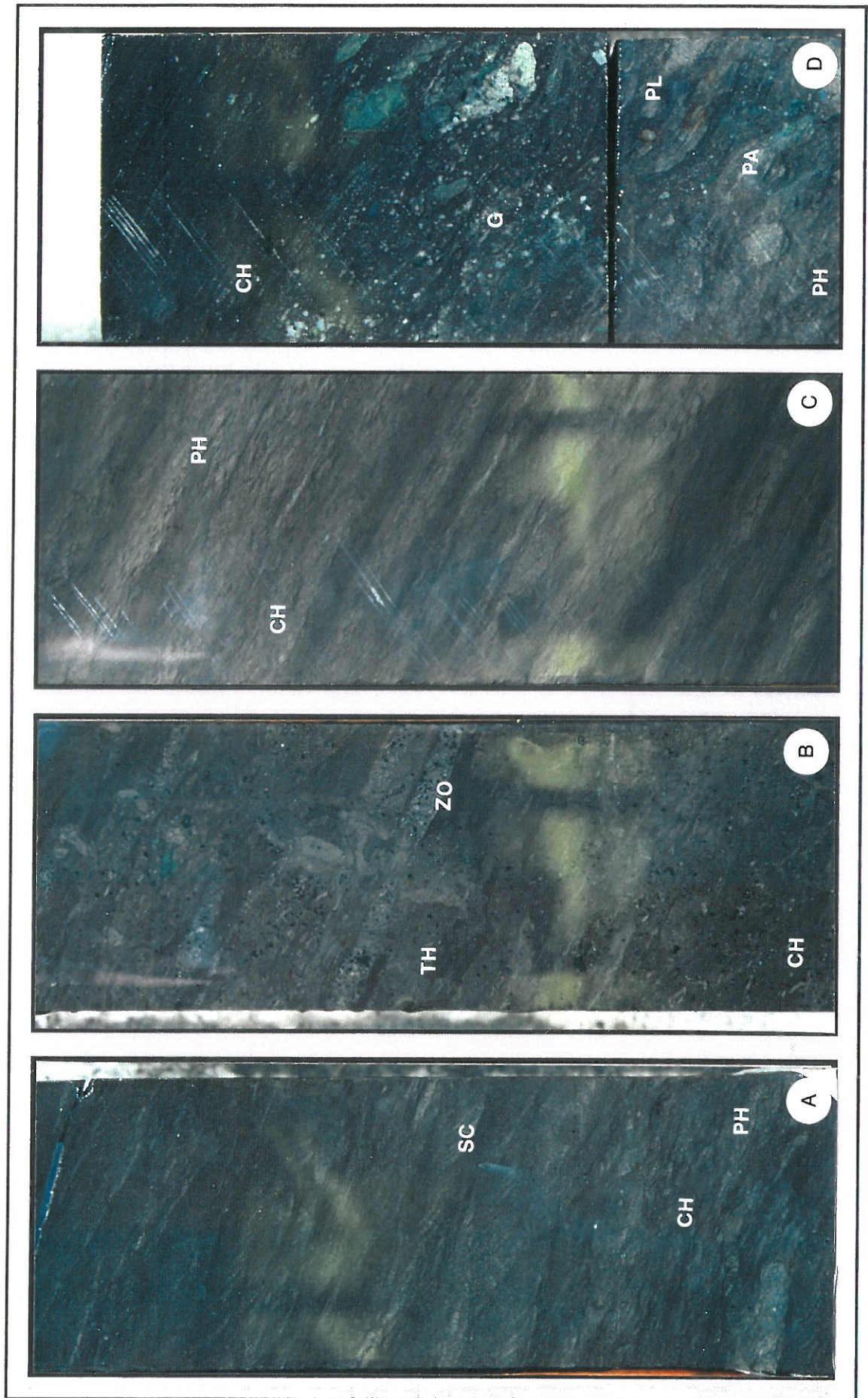
C. Dark grey brown laminated claystones are moderately bioturbated (BI=4) by *Chondrites* (CH) and compacted *Phycosiphon* (PH).

Well: 7418/01-u-01 Depth: 57.40m
Age: Late Palaeocene -Early Eocene
Facies: Basin floor (?slope)

D. Black laminated claystones are sparsely bioturbated (BI=2) by *Chondrites* (CH). These claystones overlie intensely bioturbated (BI=5) silty, very fine grained sandstones burrowed by *Palaeophycus* (PA) and *Planolites* (PL). The contact surface is burrowed and marked by scattered granules (G) and volcanic clasts

Well: 7418/01-u-01 Depth: 70.7m
Age: Late Palaeocene -Early Eocene
Facies: Major transgressive unconformity; shoreface transition zone to basin floor.

PLATE 1



PHOTOGRAPHIC SCALE 1:1

PLATE 2

A. Dark grey, silty very fine grained sandstones with scattered shell moulds (S) are intensely bioturbated (BI=5) by *Palaeophycus* (PA) and *Planolites* (PL).

Well: 7418/01-u-01 Depth: 87.5m
Age: Late Palaeocene -Early Eocene
Facies: Lower Shoreface

B. Dark grey, silty very fine grained sandstones are intensely bioturbated (BI=5) by *Palaeophycus* (PA). These sandstones overlie black laminated to sparsely bioturbated (BI=2) claystones with *Chondrites* (CH). The contact surface is burrowed by an open network of *Thalassinoides* (TH) burrows and marked by a concentration of granules, lithic and volcanic clasts.

Well: 7418/01-u-01 Depth: 89.2m
Age: Late Palaeocene -Early Eocene
Facies: Regressive unconformity; muddy shelf (periodically anoxic) to shoreface.

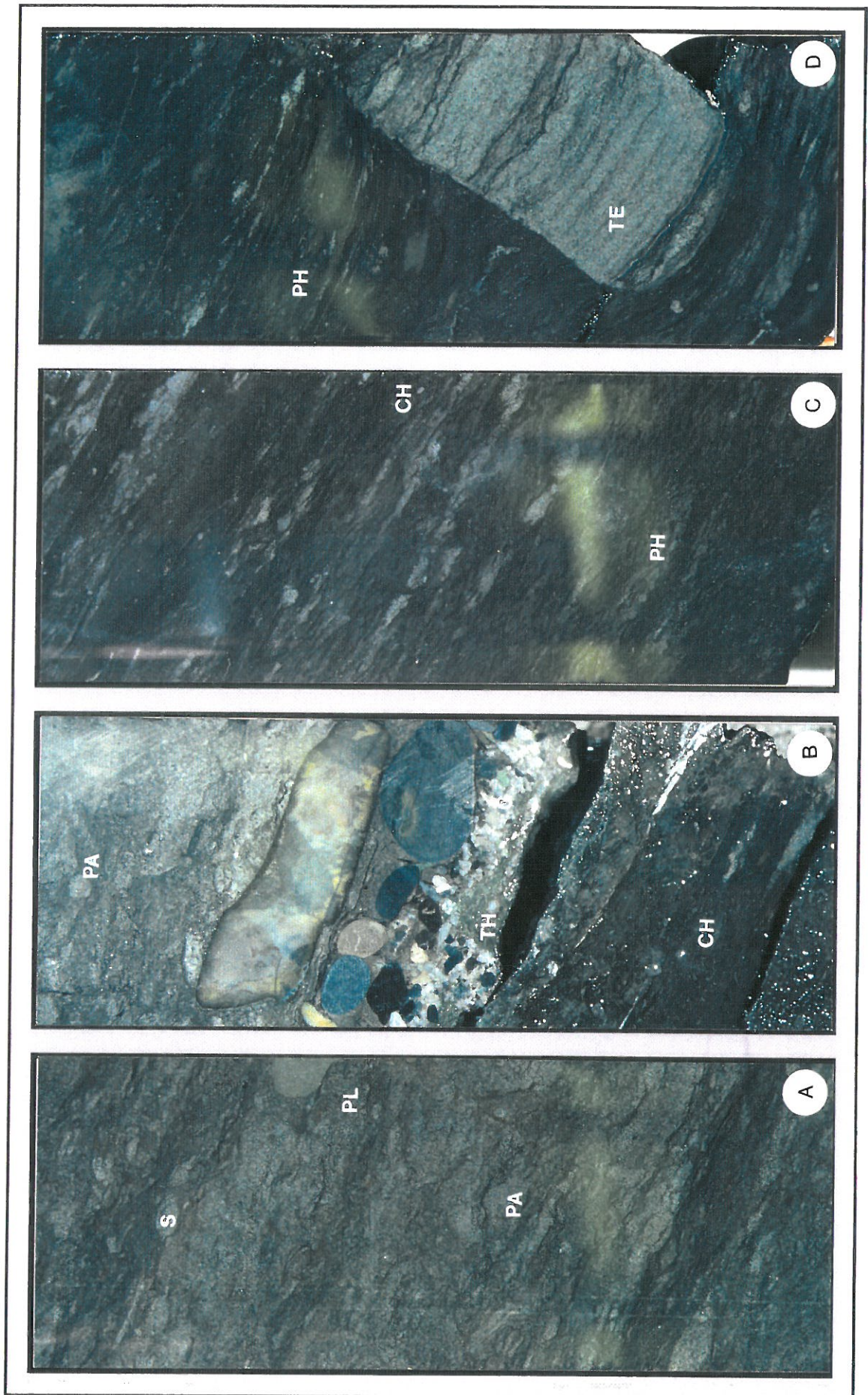
C. Black laminated, silty claystones with sediment starved ripples of mid grey, very fine sandstone are highly bioturbated (BI=4) by *Chondrites* (CH) and *Phycosiphon* (PH).

Well: 7418/01-u-01 Depth: 110.3m
Age: Late Palaeocene
Facies: Muddy shelf

D. Black laminated, silty claystones are moderately bioturbated (BI=4) by *Phycosiphon* (PH). This is cross-cut by large, sharp-walled *Teichichnus* (TE) burrows which are infilled by sandstone and reflect a period of depositional hiatus.

Well: 7418/01-u-01 Depth: 120.9m
Age: Late Palaeocene
Facies: Muddy shelf with depositional hiatus (cMFS)

PLATE 2



PHOTOGRAPHIC SCALE 1:1

PLATE 3

A. Thinly-bedded, dark grey, siltstones and buff, rippled, very fine grained sandstones are highly bioturbated (BI=4) with escape burrows (ES), *Gyrochorte* (GR), *Schaubcylindrichnus* (SB), faecal pellets (F), *Palaeophycus* (PA) and *Planolites* (PL).

Well: 7616/11-u-01 Depth: 13.3m
Age: Valanginian-Early Hauterivian
Facies: Proximal transition zone

B. Black laminated claystones with sediment starved ripples of mid grey, very fine sandstone are sparsely bioturbated (BI=2) by *Chondrites* (CH) cross-cut by a siderite cemented large *Skolithos* (SK) burrow. This colonisation may reflect a depositional hiatus.

Well: 7616/11-u-01 Depth: 38.6m
Age: Valanginian-Early Hauterivian
Facies: Muddy shelf, periodically anoxic with a hiatal colonisation (cMFS)

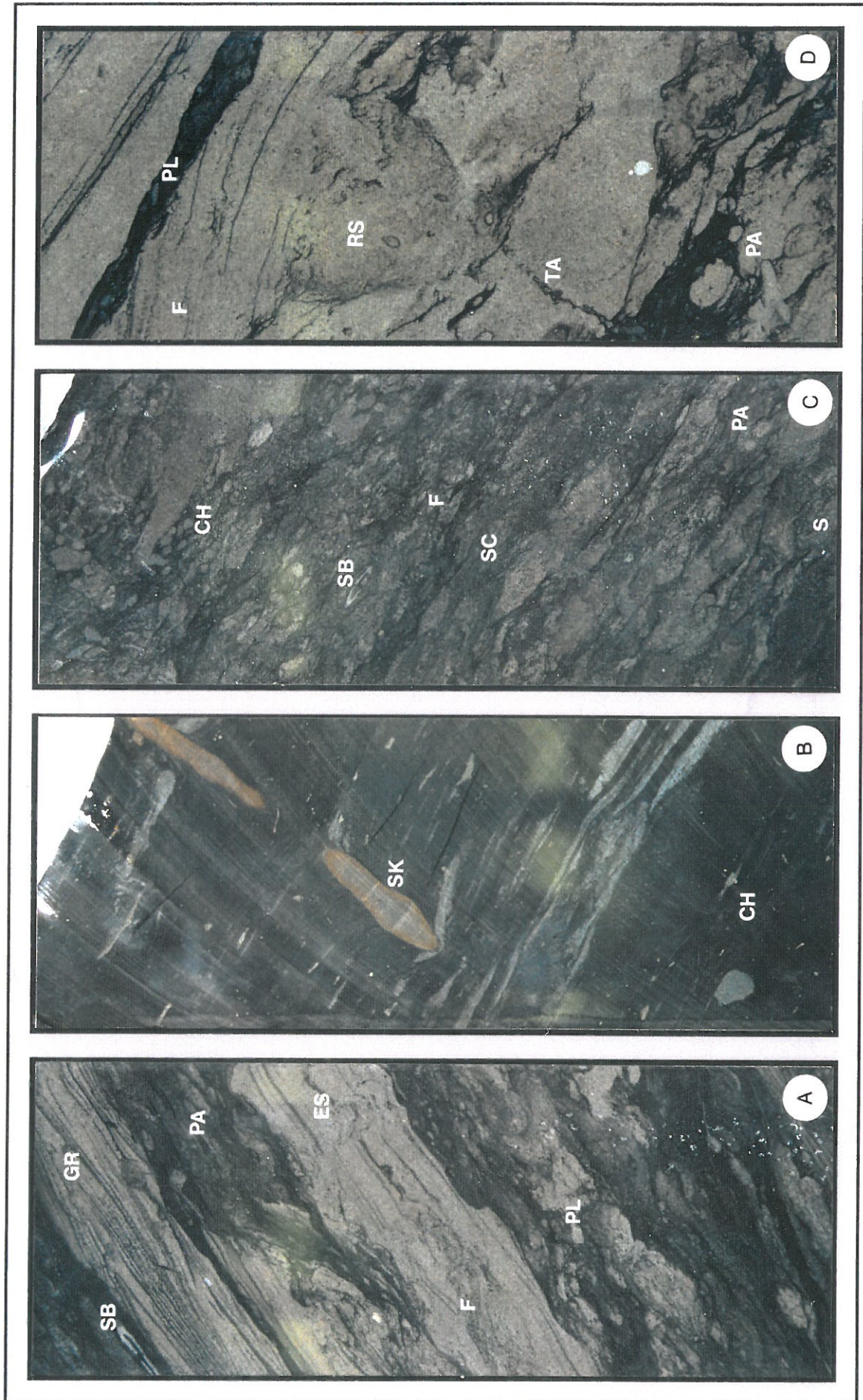
C. Thinly-bedded, dark grey, siltstones and buff, rippled, very fine grained sandstones are intensely bioturbated (BI=5) with *Scolicia* (SC), *Schaubcylindrichnus* (SB), faecal pellets (F), *Palaeophycus* (PA) and large *Chondrites* (CH). Shell moulds (S) are also seen.

Well: 7616/11-u-01 Depth: 48.5m
Age: not dated
Facies: Proximal transition zone

D. Buff, very fine to fine grained sandstones which exhibit planar to ripple cross-lamination and claystone ripple drapes. These sandstones are moderately bioturbated (BI=3) with *Planolites* (PL), *Rosselia* (RS), *Palaeophycus* (PA), *Taenidium* (TA) and faecal pellets (F).

Well: 7616/11-u-01 Depth: 58.4m
Age: not dated
Facies: Proximal lower shoreface

PLATE 3



PHOTOGRAPHIC SCALE 1:1

PLATE 4

A. Thinly-bedded, dark grey siltstones and buff, very fine grained sandstones are intensely bioturbated (BI=5) with *Scolicia* (SC), *Palaeophycus* (PA), *Teichichnus* (TE), *Asterosoma* (AS), *Planolites* (PL) and faecal pellets (F).

Well: 7616/11-u-01 Depth: 60.6m
Age: not dated
Facies: Distal lower shoreface

B. Thinly-bedded, dark grey siltstones and buff, very fine grained sandstones are intensely bioturbated (BI=5) with *Palaeophycus* (PA), *Asterosoma* (AS), *Teichichnus* (TE), *Planolites* (PL), *Skolithos* (SK) and faecal pellets (F). This suite of trace fossils is cross-cut by a large *Diplocraterion* (DP) burrow and could reflect a hiatal colonisation event.

Well: 7616/11-u-01 Depth: 61.7m
Age: not dated
Facies: Distal lower shoreface

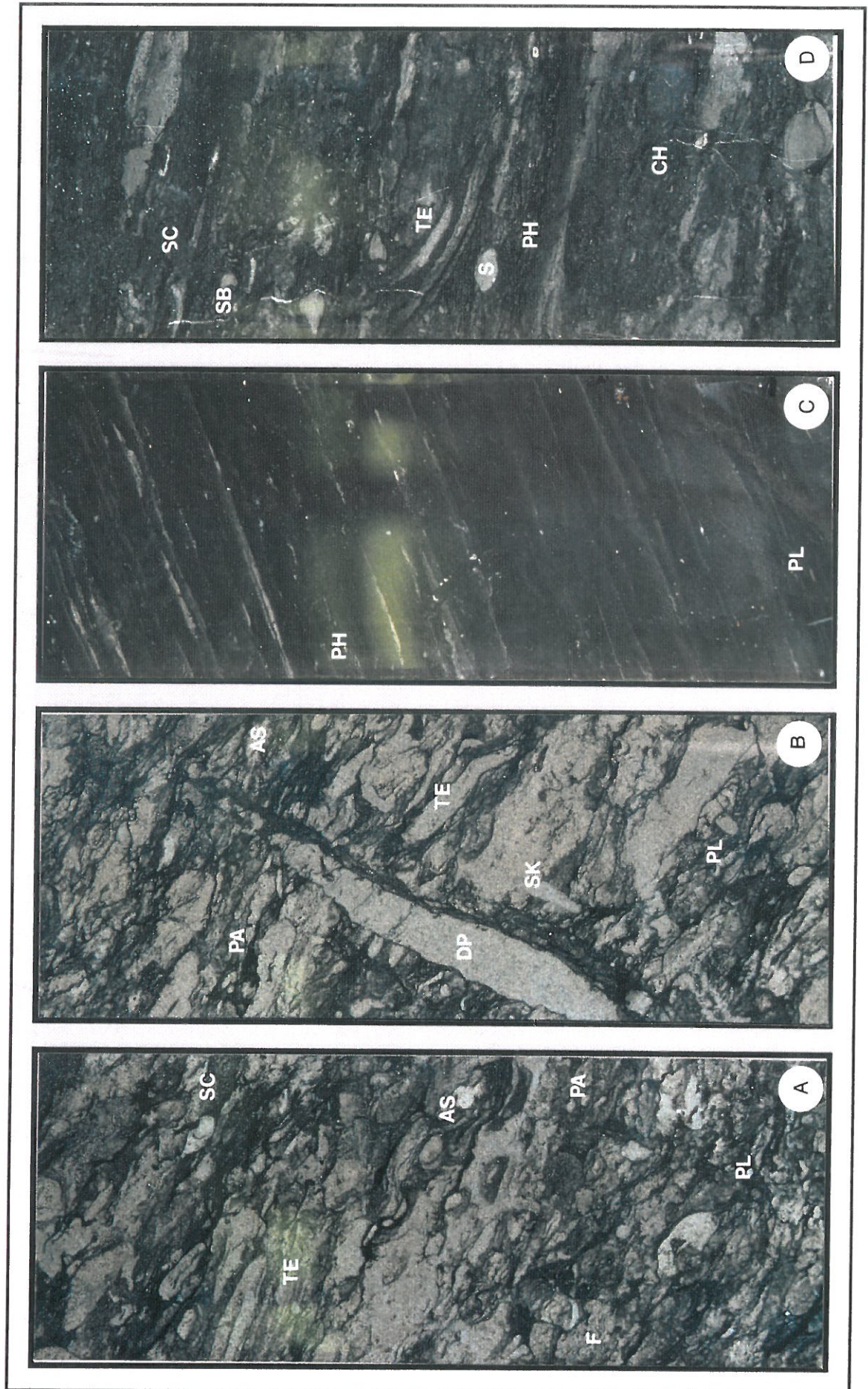
C. Black laminated claystones are sparsely bioturbated (BI=1) by *Phycosiphon* (PH) and *Planolites* (PL).

Well: 7616/11-u-02 Depth: 36.7m
Age: Late Palaeocene
Facies: Muddy shelf, periodically anoxic

D. Dark grey siltstones, silty claystones with sediment starved ripples of mid grey, very fine sandstone are highly bioturbated (BI=4) by *Schaubcylindrichnus* (SB), *Chondrites* (CH), *Phycosiphon* (PH) and *Teichichnus* (TE). Bivalve moulds (S) are also seen.

Well: 7616/11-u-02 Depth: 38.4m
Age: Late Palaeocene
Facies: Distal transition zone

PLATE 4



PHOTOGRAPHIC SCALE 1:1

PLATE 5

A. Buff, laminated to hummocky cross-stratified, very fine grained sandstones with minor interbedded siltstones are moderately bioturbated (BI=3) by *Skolithos* (SK), *Phycosiphon* (PH), J-shaped burrows (JB), *Palaeophycus* (PA) and *Planolites* (PL). The *Planolites* burrows colonise the sandstones and the other ichnotaxa are related to colonisations following the main phase of sand deposition.

Well: 7617/11-u-02 Depth: 48.4m
Age: Late Palaeocene
Facies: Proximal lower shoreface

B. Medium-bedded, black laminated silty claystones and buff, ripple cross-laminated very fine sandstone are moderately bioturbated (BI=3) by *Planolites* (PL), *Gyrochorte* (GR), *Phycosiphon* (PH), J-shaped burrows (JB) and *Palaeophycus* (PA).

Well: 7617/11-u-02 Depth: 50.7m
Age: Late Palaeocene
Facies: Distal lower shoreface

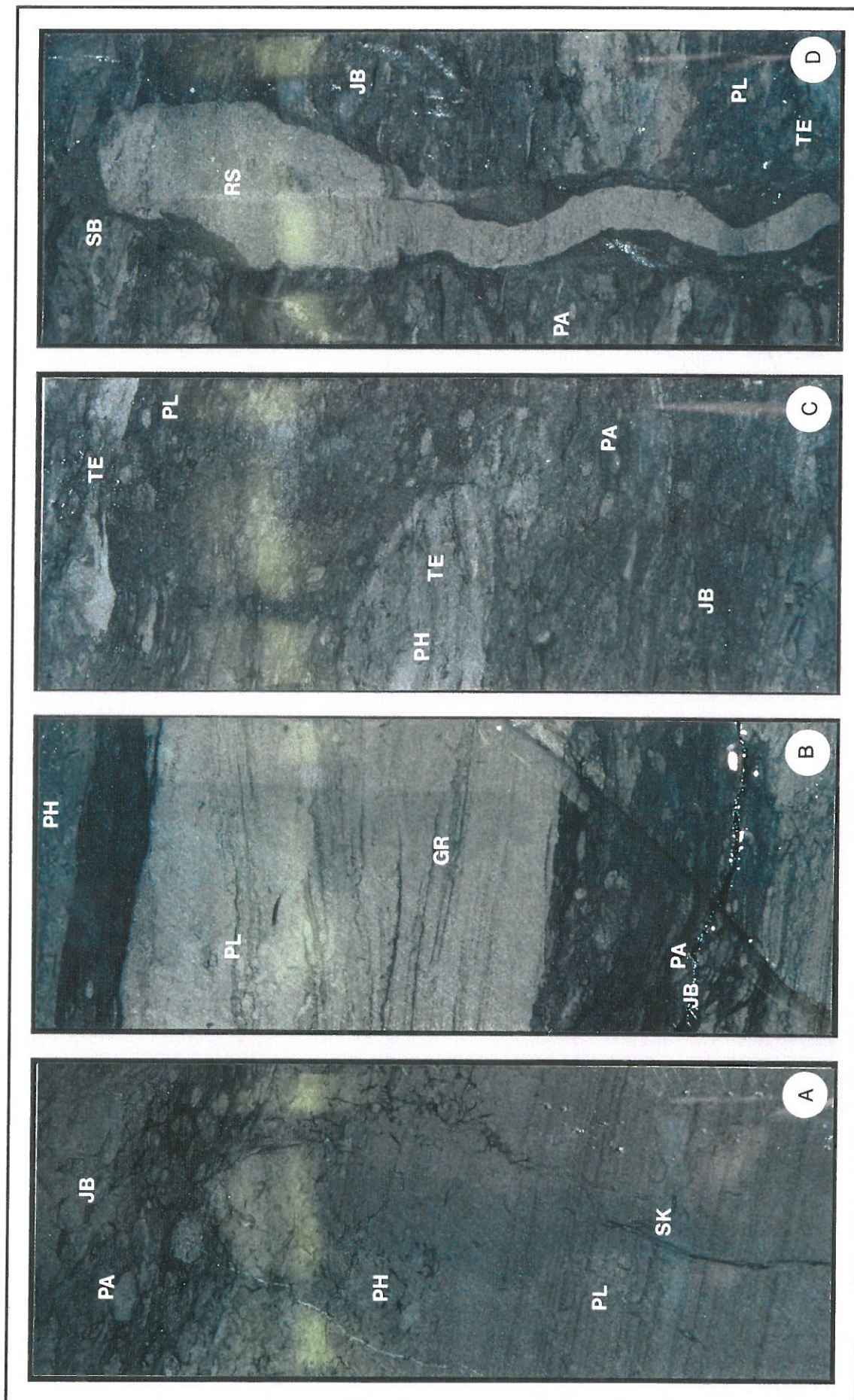
C. Thinly-bedded, dark grey siltstones and mid grey, very fine grained sandstones are intensely bioturbated (BI=5) by *Palaeophycus* (PA), J-shaped burrows (JB), *Teichichnus* (TE), *Phycosiphon* (PH) and *Planolites* (PL). This is cross-cut by large sand-filled *Teichichnus* (TE) which may reflect a hiatal colonisation.

Well: 7617/11-u-02 Depth: 84.0m
Age: Late Palaeocene
Facies: Distal transition zone with a hiatal colonisation (cTS)

D. Thinly-bedded, dark grey siltstones and mid grey, very fine grained sandstones are intensely bioturbated (BI=5) by *Palaeophycus* (PA), J-shaped burrows (JB), *Schaubcylindrichnus* (SB), *Teichichnus* (TE) and *Planolites* (PL). This is cross-cut by large sand-filled *Rosselia* (RS) which may reflect a hiatal colonisation.

Well: 7617/11-u-02 Depth: 92.5m
Age: Late Palaeocene
Facies: Proximal transition zone with a hiatal colonisation (cTS)

PLATE 5



PHOTOGRAPHIC SCALE 1:1

PLATE 6

A. Black, laminated silty claystones with sediment starved ripples of mid grey, very fine sandstone are moderately bioturbated (BI=3) by *Chondrites* (CH), two sizes of *Phycosiphon* (PH) and *Skolithos* (SK). The *Skolithos* burrows cross-cut the *Phycosiphon* colonisations and, in turn, are reburrowed by *Chondrites*. This may reflect a period of non-deposition.

Well: 7617/11-u-02 Depth: 104.9m
Age: Late Palaeocene
Facies: Muddy shelf with a hiatal colonisation event (cMFS)

B. Dark grey silty claystones are intensely bioturbated (BI=5) by *Chondrites* (CH), two sizes of *Phycosiphon* (PH), *Planolites* (PL), *Schaubcylichnus* (SB) and *Scolicia* (SC). These burrows are cross-cut by *Skolithos* (SK), which is reburrowed by *Chondrites*. This may reflect a period of non-deposition.

Well: 7617/11-u-02 Depth: 106.6m
Age: Late Palaeocene
Facies: Distal transition zone with a hiatal colonisation event (cMFS)

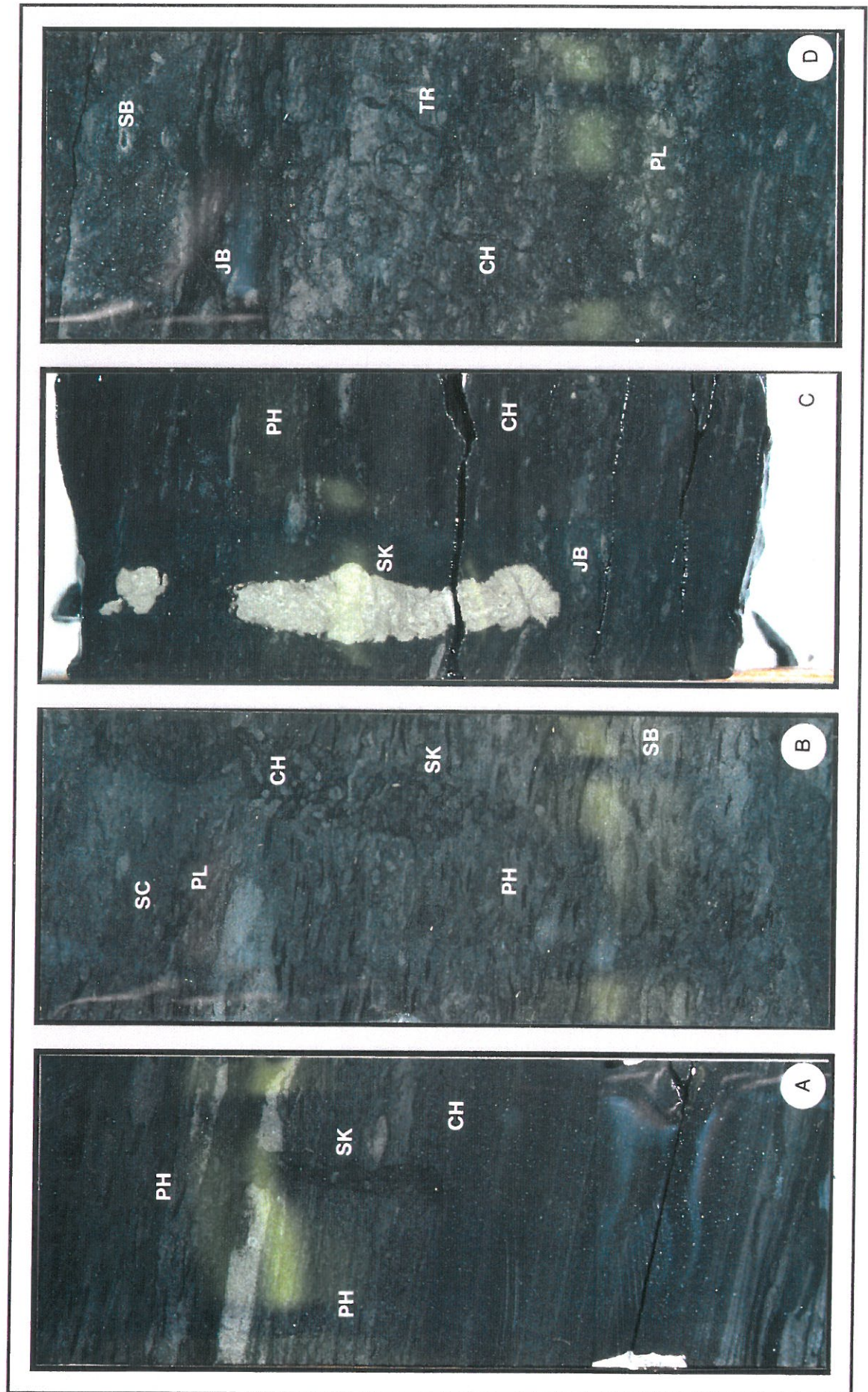
C. Black laminated claystones with sediment starved ripples of mid grey, very fine sandstone are sparsely bioturbated (BI=2) by *Chondrites* (CH), *Phycosiphon* (PH) and J-shaped burrows (JB), cross-cut by a large pyrite cemented *Skolithos* (SK) burrow. This colonisation may reflect a depositional hiatus.

Well: 7617/11-u-01 Depth: 23.5m
Age: not dated
Facies: Muddy shelf with a hiatal colonisation event (cMFS)

D. Thinly-bedded, dark grey siltstones, silty claystones and mid grey, very fine grained sandstones are intensely bioturbated (BI=5) by *Trichichnus* (TR), J-shaped burrows (JB), *Chondrites* (CH), *Schaubcylichnus* (SB) and *Planolites* (PL).

Well: 7617/11-u-01 Depth: 29.3m
Age: not dated
Facies: Proximal transition zone

PLATE 6



PHOTOGRAPHIC SCALE 1:1

PLATE 7

A. Dark grey, silty fine grained sandstones intensely bioturbated (BI=5) by *Palaeophycus* (PA), *Planolites* (PL) and *Arenicolites* (AR). This interbeds with black laminated claystones sparsely bioturbated (BI=2) by *Chondrites* (CH). *Arenicolites* clearly cross-cuts the other taxa present and originates from a higher hiatal colonisation surface.

Well: 7618/10-u-01 Depth: 24.6m
Age: Valanginian-Early Hauterivian
Facies: High density sandy turbidite with a hiatal colonisation (cTS)

B. Dark grey, silty fine grained sandstones intensely bioturbated (BI=5) by *Palaeophycus* (PA), *Phycosiphon* (PH), *Chondrites* (CH) and *Planolites* (PL). This suite of traces is cross-cut by a sharp-walled, sand-filled burrow system of *Arenicolites* (AR) which is reburrowed by *Phycosiphon*. This colonisation may reflect a depositional hiatus.

Well: 7618/10-u-01 Depth: 24.8m
Age: Valanginian-Early Hauterivian
Facies: High density sandy turbidite with a hiatal colonisation (cTS)

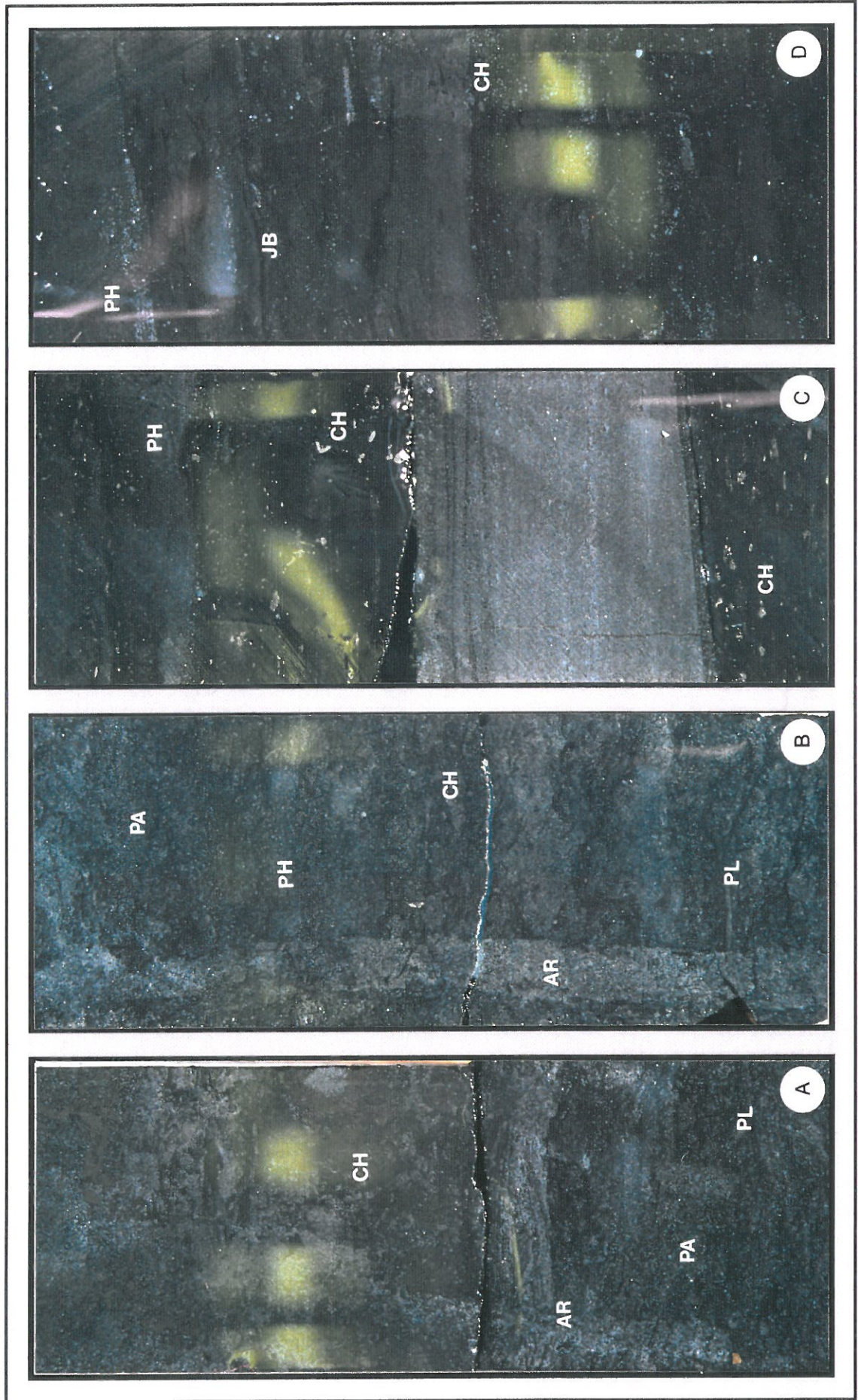
C. Medium-bedded, black laminated claystones and mid grey, fine grained sandstones are sparsely bioturbated (BI=2) by *Chondrites* (CH) and *Phycosiphon* (PH). The sandstones are not colonised.

Well: 7618/10-u-03 Depth: 15.8m
Age: not dated
Facies: Muddy shelf, periodically anoxic with minor high density turbidites

D. Black laminated, normally graded silty claystones and millimetre-scale medium grained sandstone layers are moderately bioturbated (BI=3) by *Chondrites* (CH), J-shaped burrows (JB) and *Phycosiphon* (PH).

Well: 7618/10-u-03 Depth: 20.7m
Age: not dated
Facies: Muddy shelf, periodically anoxic

PLATE 7



PHOTOGRAPHIC SCALE 1:1

APPENDIX 1: LEGEND

Ichron

TRACE FOSSILS

	<i>Arenicolites</i>
	<i>Asterosoma</i>
	Bivalve burrows
	<i>Chondrites</i>
	<i>Cylindrichnus</i>
	<i>Diplocraterion</i>
	<i>Gyrochorte</i>
	Escape
	<i>Helminthopsis</i>
	J-shaped burrows
	<i>Ophiomorpha</i>
	<i>Palaeophycus</i>
	<i>Palaeophycus heberti</i>
	<i>Phycosiphon</i>
	<i>Planolites</i>
	<i>Rhizocorallium</i>
	<i>Rosselia</i>

	<i>Scolicia</i>
	<i>Schaubcylindrichnus</i>
	Bivalve burrows
	<i>Skolithos</i>
	<i>Taenidium</i>
	<i>Teichichnus</i>
	<i>Thalassinoides</i>
	<i>Trichichnus</i>
	<i>Zoophycos</i>
	Bioturbation
	Faecal pellets

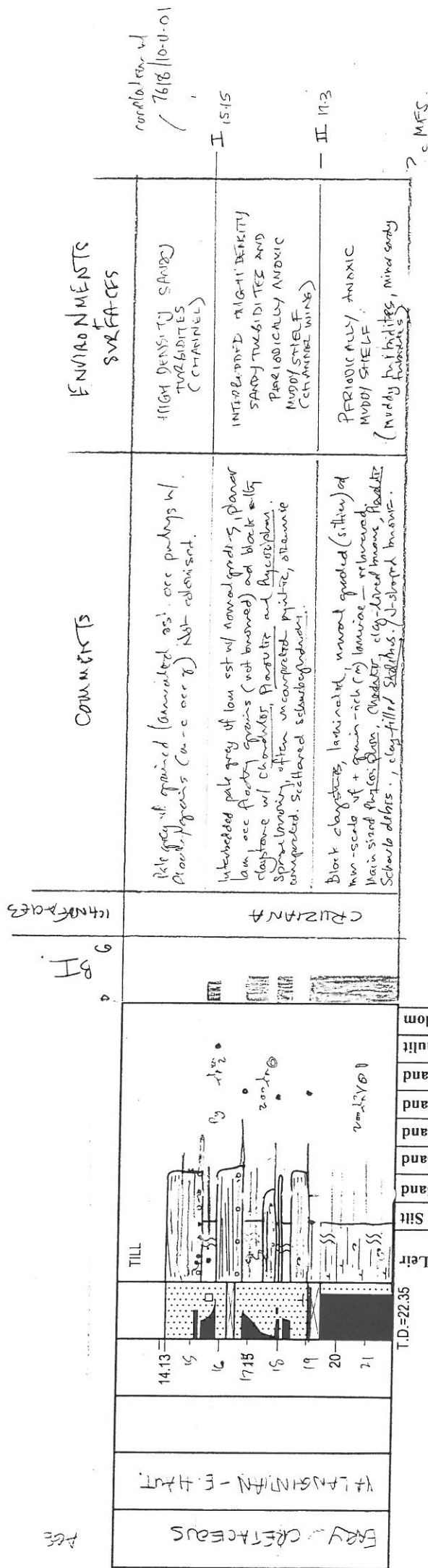
BODY FOSSILS

	Fine plant debris
	Coarse plant debris
	Bivalve shells
	Articulated valves

ICHRON IC003a

WELL 7618/10-4-3

1:200



Enclosure 7: 1:200 Scale Sedimentary core log of well 7618/10-4-3

WELL 7618 10-u-01

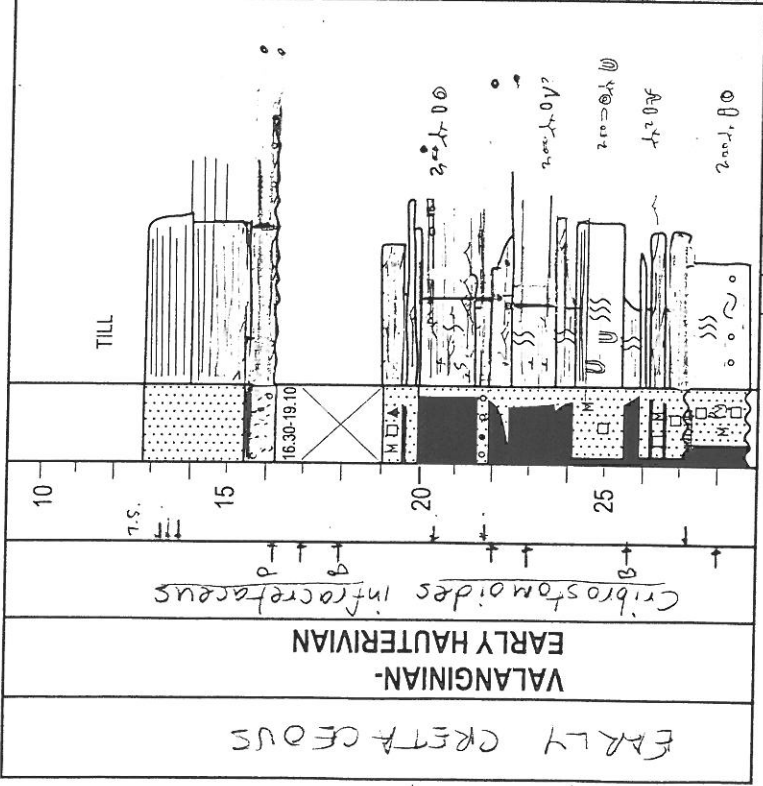
BIOTURBATION INDEX

BIOTURBATION

AGE

COMMENTS

ENVIRONMENTS + SURFACES

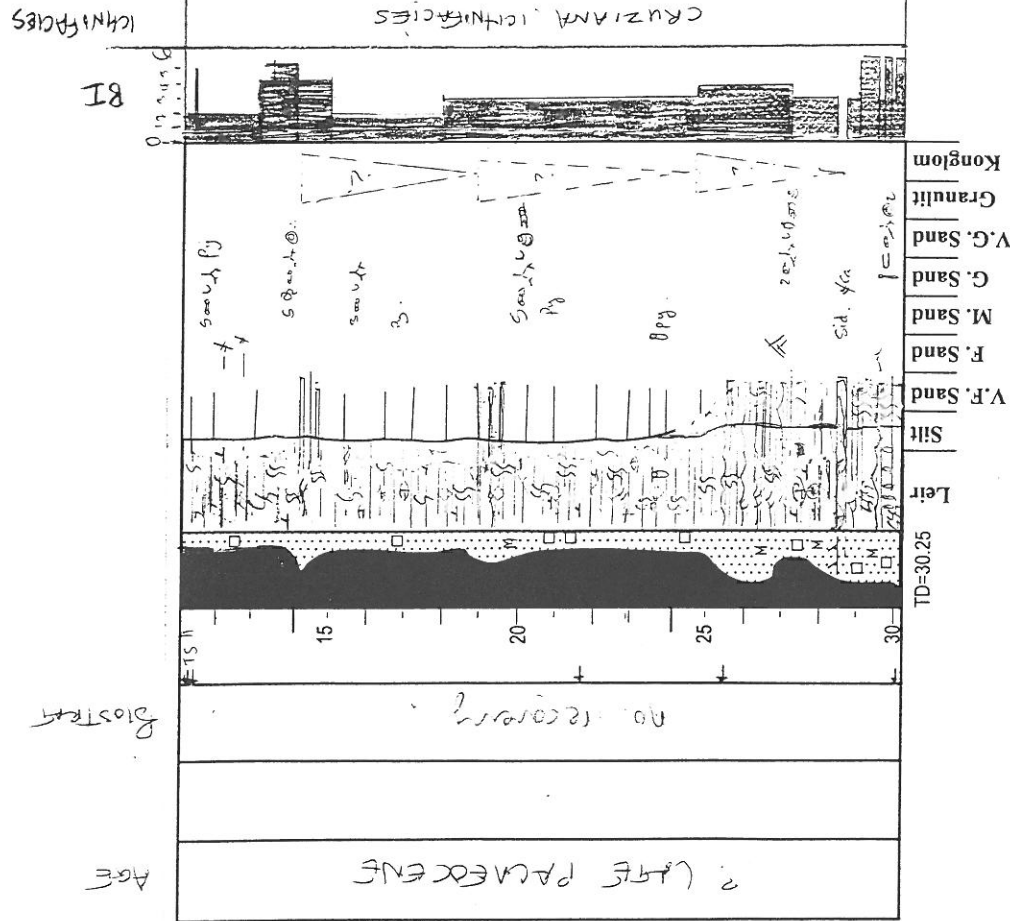


Leir
Silt
V.F. Sand
F. Sand
M. Sand
G. Sand
V.G. Sand
Granulite
Konglom

10-16.3 19.9 19.9 19.9	10-16.3 19.9 19.9 19.9	10-16.3 19.9 19.9 19.9	10-16.3 19.9 19.9 19.9
10-16.3 19.9 19.9 19.9	10-16.3 19.9 19.9 19.9	10-16.3 19.9 19.9 19.9	10-16.3 19.9 19.9 19.9

Enclosure 6: 1:200 scale Sedimentary core log of well 7618 10-u-01

WELL 7617/11-u-01



COMMENTS

SECTIONS
+
ENDNOTES

Monday Staff

DISCOUNT

Muddy Start
(PERIODICALLY/ANOXIC)

DISTAL TRANSITION

Muddy Street

Styl, has omission error, then
could make CMS.

dfs	deeping cost	15.0
-----	--------------	------

2. DISTAL TRANSITION

over 1st deeping

POXIMAL TRANSITION

761711-4-02
continued previous

Enclosure 4. 1:200 Scale sedimentary core log of well 7617 (11-4-01)

SKALA: 1:200.

[illegible]

Enclosure 3 1200 Scale Sedimentary corelog of well 7616/11-4-02

7616 (11-U-01



AV

FELT/OMRÅDE: NORDFLAKET

INTERVALL: 0-69.25m

GEOLOG: A. TAYLOR (GIER LARSEN LOG)

BRØNN NR: 7616/11-u-01

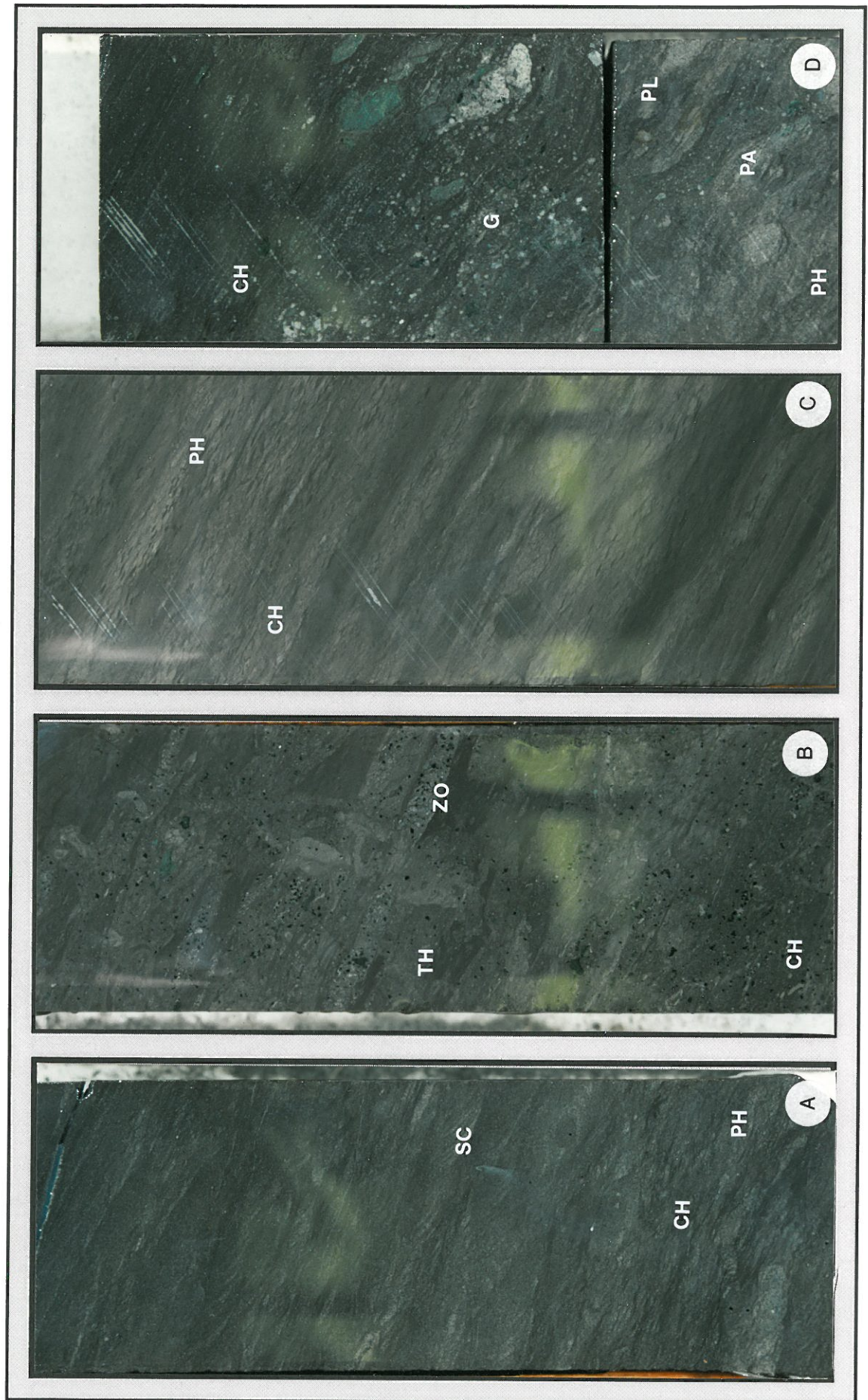
SKALA: 1:200.

Note: 25-30° structural dip on core.

LITOSTRAT. ENHET	RESERVOAR ENHET	LOGG DYP	KJERNE DYP	LITOLOGI	KORNSTØRRELSE - SEDIM. STRUKTURER	KJERNE NR.	BESKRIVELSE	AVSETNINGSMILJØ
					Leir Silt V.F. Sand F. Sand M. Sand G. Sand V.G. Sand Granulit Konglom			
QUAT							Pale grey upper to lower v.f. sst, w.d. sorted, laminated to massive with scattered shell debris (Inoceramus-type). Not colonised. Thin-scale bedsets, base more laminated (carb-rich) and basal surface shows non-casting.	(alt: FORCED REGRESSIVE SHOREFACE) w/ MIDDLE/UPPER SHOREFACE HIGH DENSITY SANDY TURBIDITES (CHANNEL)
		15					no trace fossils	CSB Erosive truncation
							Interbedded dm- to cm-scale pale gray w/ graded sandstones which exhibit planar to low angle lamination, ripple cross lamination, trough bedding (loading?) - carb/micro-reclam. The sst are rarely laminated w/ Scolithus, Phycosiphon fecal pellets and escape structures. The interbedded silty claystones are moderately to intensely bioturbated by Phycosiphon, Palaeophyges heberti (two sizes), Chondrites Schwabeyindivites, Planolites, Stalithes, horizontal excavation structures (cf. Scolicia) and Gyrogonites. Nodules, nod + shell debris present. Diverse benthic community established, tiering exhibited and coexisting by sst events - which are also colonized. Sst sharp based-sharp topped.	PROXIMAL TRANSITION
							Predominately intensely bioturbated silty claystones w/ cm-scale silty of tan sst (rippled w/ casts often well preserved). The ichnofauna is as above w/in Phycosiphon, Palaeophyges, excavations (cf. Scolicia) dominant. Abundant siderite nodules, shell moulds (coarse related).	(could be a number of poorly defined sequences with CMFS above each CU profile)
							Black laminated claystones, carb rich w/ minor tan (cm-) scale siltstone (if not, graded bedding shallow seam. Sparingly colonized by Phycosiphon, Planolites Gyrogonites + excavation burrows (cf. Scolicia). Scattered small sideritic nodules occurrence of Stalithes (cm) xat. On cm-scale claystone may not be colonized - patchy compacted distribution of Phycosiphon. Planolites can be punctate.	MUDDY SHELF (PERIODICALLY ANOxic)
							Scolithus differentially cemented x cuts other fauna. pyritic lam, abundant nodules. change in trace fossil fauna.	CMFS Scolithus omission colonisation and sparingly bioturbated claystones (carb-rich).
							Dark grey, intensely bioturbated silty claystones and silty sh of sst (lam i/p). Burrows dominated by by Teichichnus rectus, Phycosiphon, Palaeophyges Schwabeyindivites, Chondrites, Scolicia, J-shaped burrows Planolites. Size variations seen.	DISTAL TRANSITION
							In situ bit bioherms, log, brown till (Pachyspirifer type) w/ shell and debris removed. Above chondrite colonisation. Sst exhibit small debris, moulds, Palaeophyges rare dominant. Buried out large Teichichnus know appear as auto sst-filled elements	Proximal Transition Bioclastic lag, cemented zone
							top surface show rare event, no omission colonisation w/ but argillaceous material buried into sst (Teichichnus Phycosiphon)	Proximal Lower Shoreface
							Buff very fine grained silty sst with bioturbated to laminated (low angle cross-bedded) intervals (dm-scale) burrows dominated by Palaeophyges (cf. Probolus + Diploporis) as a recessed trace (cf. Asterionoma) also Taenidium, Scolicia Rosetta, Stalithes, ? Ophiomorpha abundant shell moulds + debris. Chondrites in more argillaceous intervals. Fecal pellets abundant. Diverse ichnofauna of deposit + suspension feeders - tiered community. Horizon of Diplocraterium xat (large).	DISTAL LOWER SHOREFACE
							large Teichichnus (? primary lam).	Proximal Transition

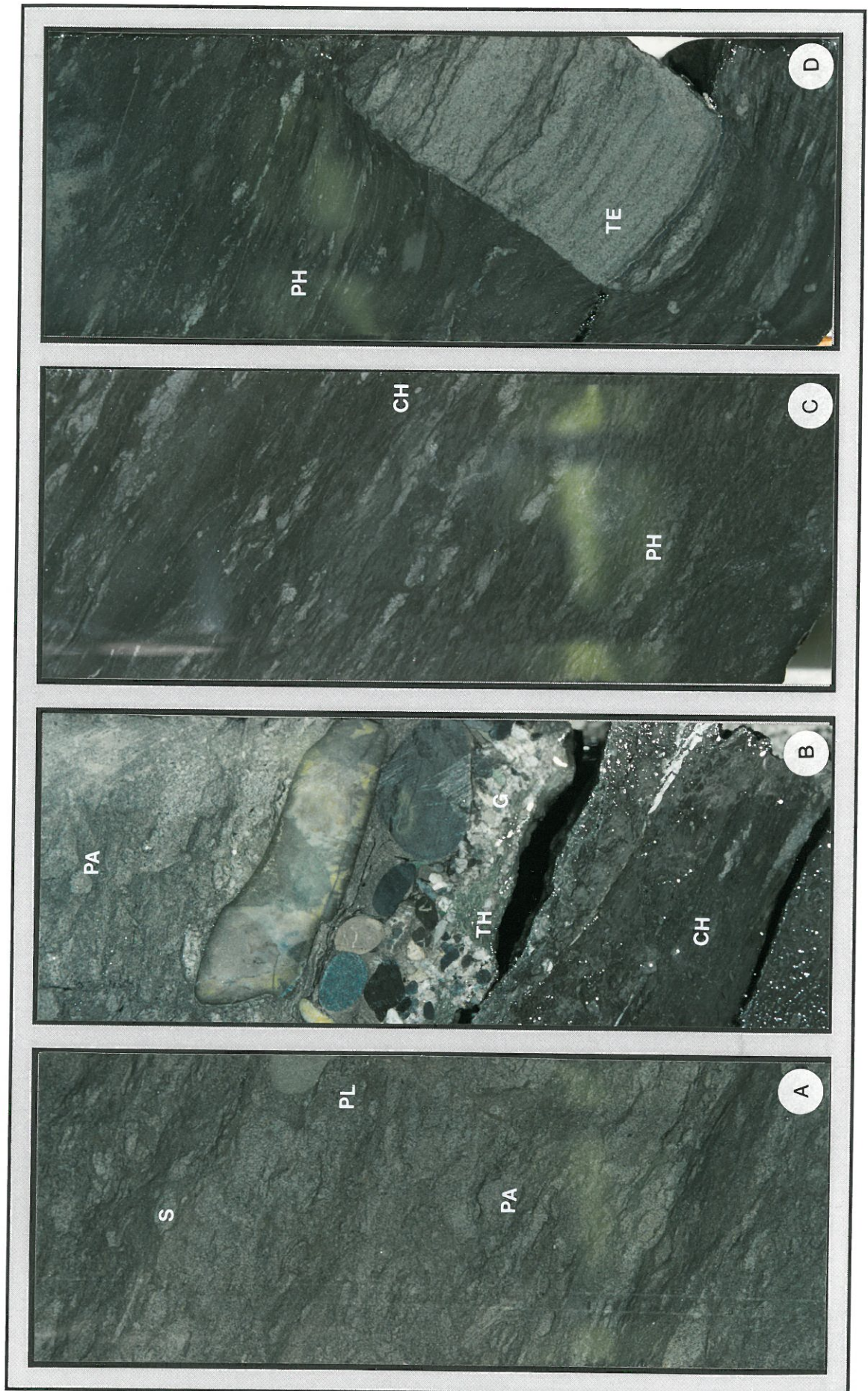
Enclosure 2 :- 1:200 scale sedimentary core log of well 7616/11-U-01

PLATE 1



PHOTOGRAPHIC SCALE 1:1

PLATE 2



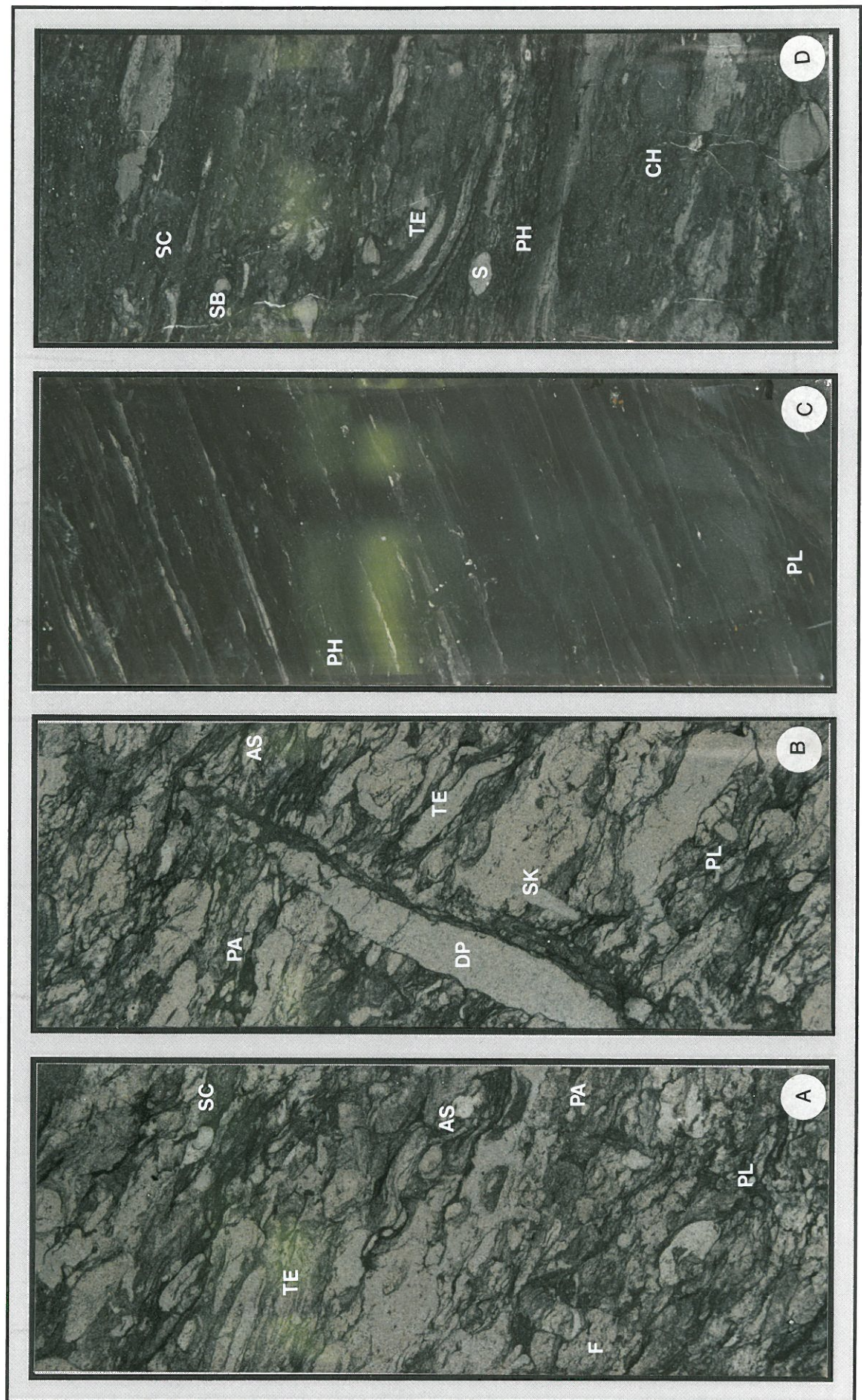
PHOTOGRAPHIC SCALE 1:1

PLATE 3



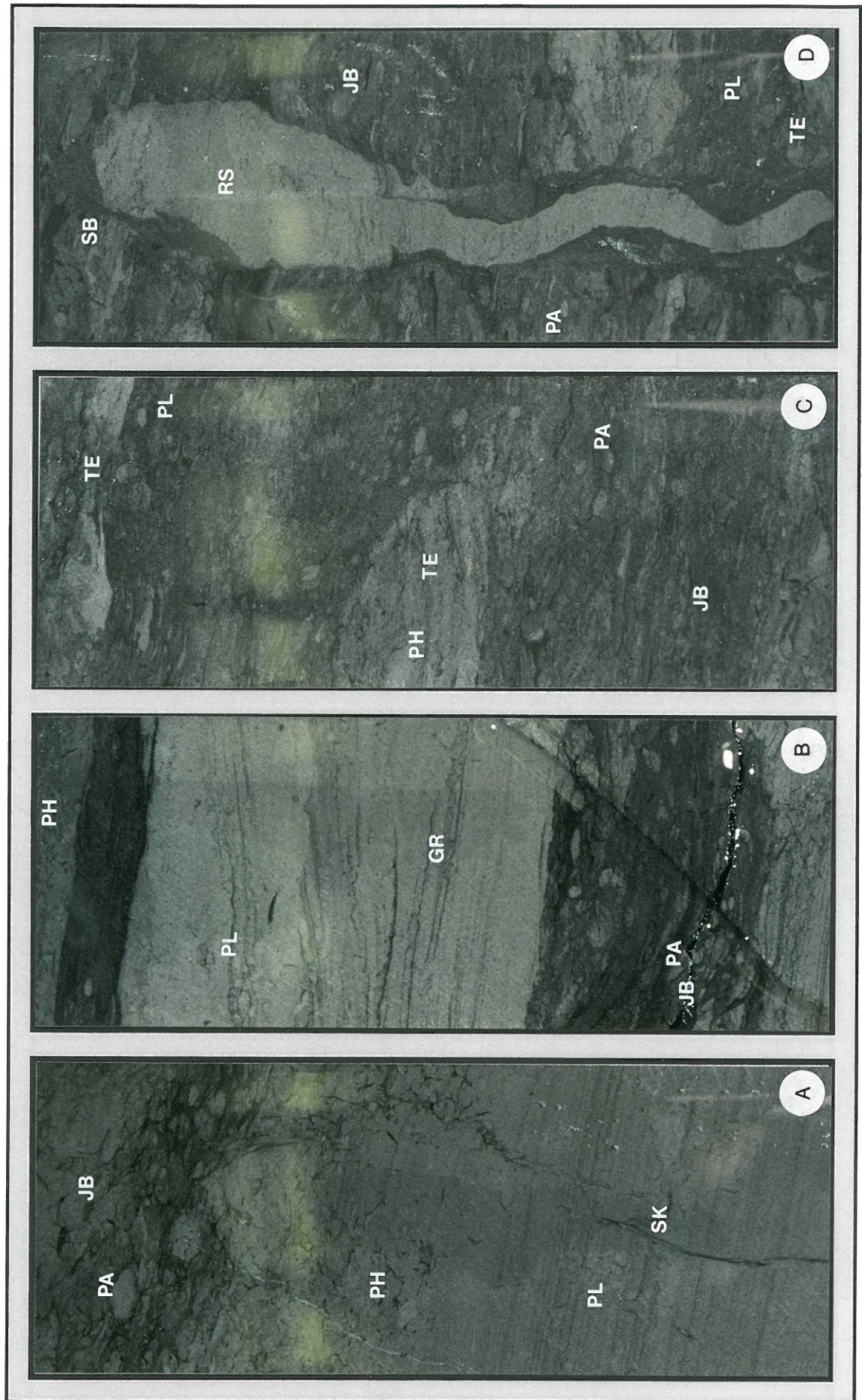
PHOTOGRAPHIC SCALE 1:1

PLATE 4



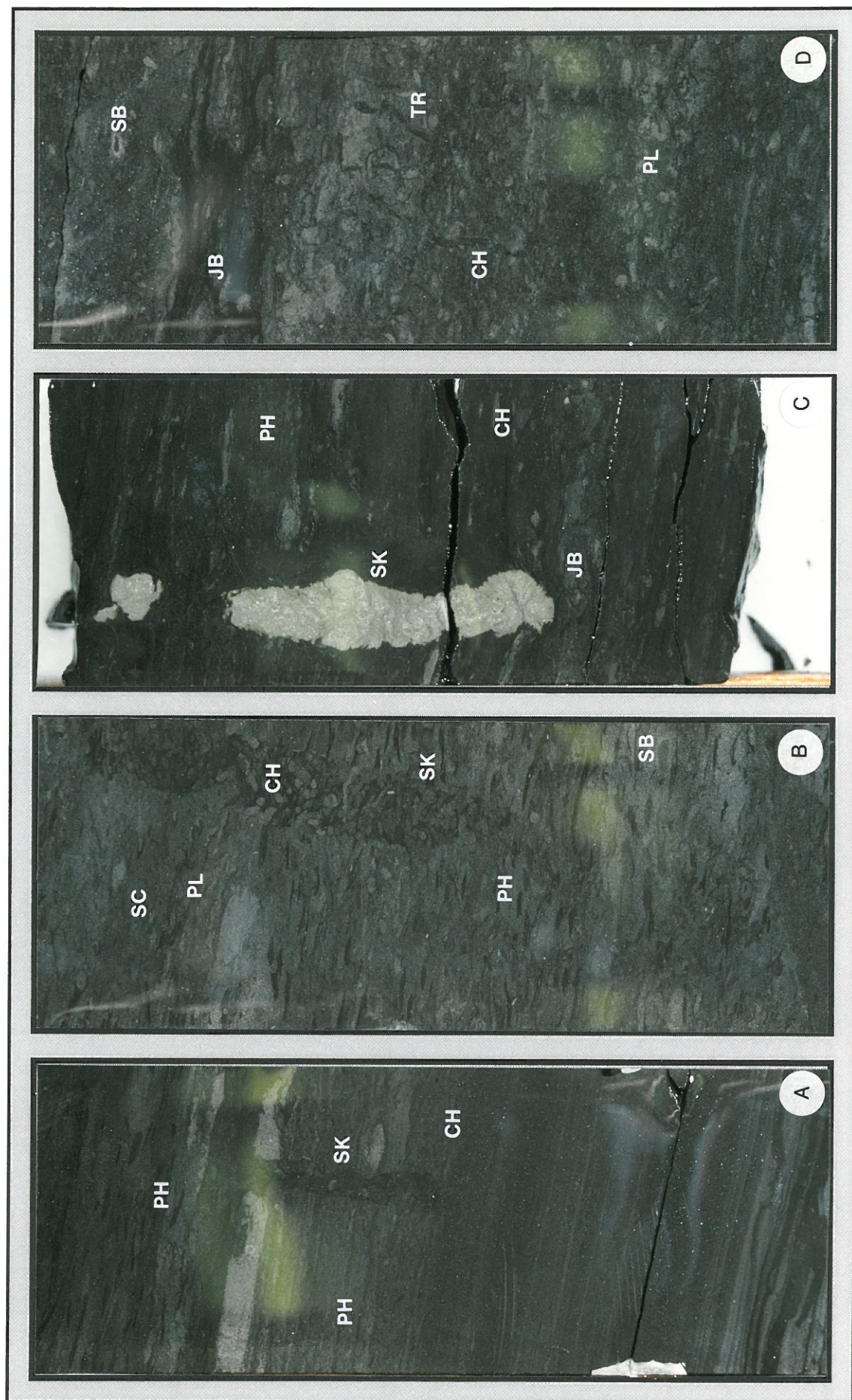
PHOTOGRAPHIC SCALE 1:1

PLATE 5



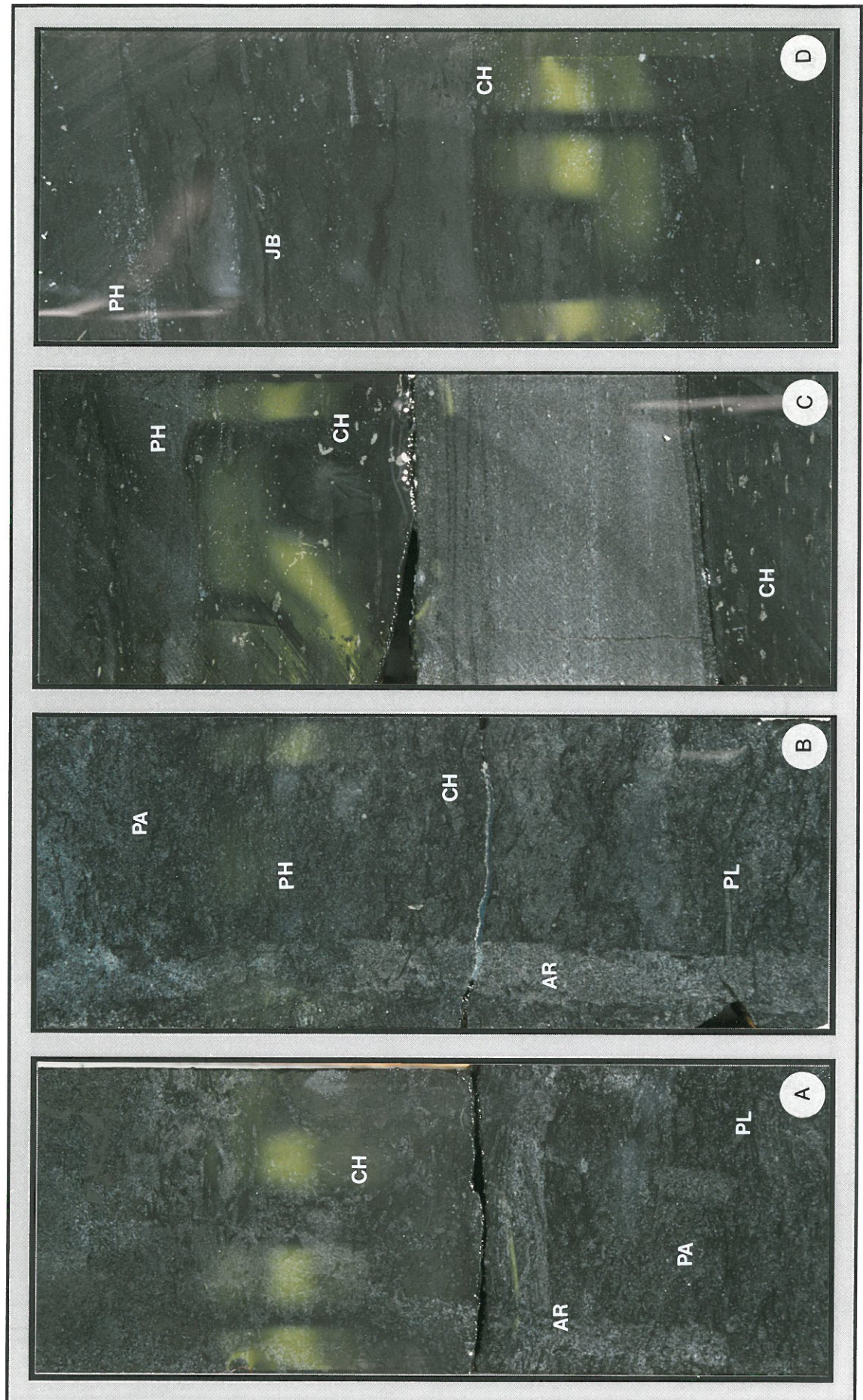
PHOTOGRAPHIC SCALE 1:1

PLATE 6



PHOTOGRAPHIC SCALE 1:1

PLATE 7



PHOTOGRAPHIC SCALE 1:1