BRITISH GEOLOGICAL SURVEY

MARINE REPORT SERIES
TECHNICAL REPORT WB/95/11C
VOLUME 3: APPENDIX 2
COMMERCIAL-IN-CONFIDENCE

ROCKALL CONTINENTAL MARGIN PROJECT
FINAL GEOLOGICAL REPORT

TECHNICAL REPORT WB/95/11C
VOLUME 3: APPENDIX 2
SHALLOW SAMPLING PROGRAMME 1994
STRATIGRAPHICAL SITES

M S Stoker

Geographical index:
Rockall Trough, Rockall and George Bligh banks, Rosemary Bank and Anton Dohrn seamounts

Subject index:
Lower Proterozoic, Cenozoic, Rockall Continental Margin

Production of report was funded by:
BGS and a consortium of Oil Companies

Bibliographic reference:
Stoker, M S. 1995. Shallow Sampling Programme 1994 - Stratigraphical Sites. Volume 3, Appendix 2 of Stoker, M S, and Hitchen, K. 1995. Rockall Continental Margin Project: Final Geological Report. *British Geological Survey Technical Report* WB/95/11C, (5 Volumes).

British Geological Survey
Marine Geology and Operations Group
Murchison House
West Mains Road
Edinburgh
EH9 3LA

Tel: 0131 667 1000
Fax: 0131 668 4140
Tlx: 727343 SEISED G

CONTENTS

Cover Photograph: Two sections of core from an interbedded sequence of upper Paleocene-lower Eocene clastic sediments and fine-grained, basaltic, pillow lavas recovered in borehole 94/3. Three separate pillow lavas were penetrated by this borehole; see Volume 2, Appendix 1, Fig. 10 for stratigraphical details.

The left-hand section (207.87-207.99m) illustrates the contact between the uppermost pillow lava and overlying, shelly, marine sandstones, whilst the right-hand section (208.48-208.62m) shows the contact between the middle pillow lava and overlying, shelly, marine mudstones. In both sections, the outer part of the pillow lavas is cracked, locally fragmented, and partially altered to paler coloured smectite or chlorite. The infiltration of sediment into the cracks suggests that they may represent cooling cracks. The mottled texture of the mudstone (right-hand section) may be due, in part, to the decomposition of the pale coloured, altered, lava fragments enclosed within the sediment.

INTRODUCTION

Background

This report presents a description of the shallow 'stratigraphical' cores collected between April and June 1994 by the British Geological Survey (BGS) as part of the Rockall Continental Margin Project. The shallow sampling programme was funded by members of the Rockall Continental Margin Consortium, consisting:

British Gas Exploration and Production
British Geological Survey
BP Exploration Operating Co Ltd
Conoco (UK) Ltd
E E Caledonia Ltd
Elf UK plc
Enterprise Oil plc
Esso Exploration and Production UK Ltd
Mobil North Sea Ltd

Shallow sampling programme

The shallow sampling programme had two main objectives:

1. To collect sediment cores for organic geochemical analysis.
2. To collect sediment and rock cores for stratigraphical analysis.

The cores collected for organic geochemistry form the subject of a separate study (see Volume 4: Appendix 3). This report concentrates on the sediment and rock cores recovered from the stratigraphical sites.

Forty-eight stratigraphical sites ('S' sites) were occupied during the survey. These were originally numbered S1-S31 and S40-S56. The sampling equipment used was largely dependent upon the geological objective, sea-bed conditions and the anticipated depth to bedrock. The BGS rockdrill was deployed in all situations where bedrock (Palaeogene and older) occurred within 5m of the sea bed. Where the target prognosis indicated a softer (Neogene and Quaternary) lithology the vibrocorer or gravity corer was utilised; both of these systems had the capability of a 6m core barrel. The operational details of the shallow sampling survey have been presented by Skinner *et al.* (1994).

The location of the 'S' sites is shown in Figure 1. The recovered cores have subsequently been allocated a formal BGS sample number (Table 1). The latter are registered by BGS in chronological order according to degree rectangles. Each degree rectangle covers 1° latitude by 1° longitude. Where more than one attempt was made at a single site, to improve or increase recovery of material, each attempt was assigned a different number. In total, 75 cores were taken from the 48 'S' sites; these are detailed in Table 2, together with their location, water depth and sample summary.

Report

All of the cores (including those from the geochemistry sites) were provisionally described on-board the ship. However, the stratigraphical cores were re-examined in the laboratory and logged in greater detail in terms of their lithology and sedimentary structures. These core descriptions form the bulk of this report. They are complimented by the seismic-stratigraphical setting for each site; for profile locations, refer to Figure 1.2 in Volume 1. For ease of reference, the shallow-core descriptions are ordered by their original site numbers - S1-S31 and S40-S56 - as some sites with multiple core recovery have very different BGS numbers, eg. S7 (2 cores: 59-14/8 and 59-14/42).

Specialist palaeontological information, supplied by the BGS and the University of Sheffield, was provided for most of the sites. The subsampled intervals are indicated on

the core logs. The details of these studies are presented as separate sections describing the dinoflagellate cyst, calcareous microfauna, calcareous nannofossil and macrofaunal assemblages within the cores. These descriptions have been partly reformatted by the author from the original biostratigraphical manuscripts of Hine (1994a,b), Riding (1994), Wilkinson (1994) and Woods (1994). A summary of the palaeontological ages is presented in Table 3.

Several cores were analysed for igneous and metamorphic petrology, geochemistry and isotopic age dating, the results of which are detailed in Volume 1 and Volume 5, Appendix 4. Additionally, one core (58-14/54: S42) was tested for organic geochemistry due to its effervescent nature upon recovery; this is reported in Volume 4, Appendix 3.

References cited in this report are listed at the back of the respective chapters. This report compliments the geological summary presented in Volume 1.

Explanatory notes for shallow-core logs

- All depths referred to on the logs are in metres below sea bed

- Where recovery was poor, the drill-log (cf. Skinner *et al.,* 1994) was used to more-accurately locate the sampled intervals

- The percentage of core recovery is indicated on the logs.

- The lithological descriptions are based on estimates of grain-size, texture and composition from hand specimens and microscopic analyses.

- The sediments fall into three main lithological groups: siliciclastic, mixed siliciclastic/carbonate and carbonate. These have been further subdivided into textural groups on the basis of the relative proportions of three grain-size components: gravel,

sand and mud. The size limits are those defined by Folk (1954). For the consolidated carbonate rocks, the textural classification is that of Folk (1962) which is based largely on the ratio of lime mud to spar forming the matrix.

- The hardness of muds is based on a field test code ranging from very soft (material exudes between fingers when squeezed in the fist) to firm (moderate finger pressure is required to mould) to very stiff (the material cannot be moulded). The suffix 'stone' is used to indicate hard or consolidated equivalents of the unconsolidated sediments.

- The descriptions of the igneous and metamorphic rocks has been greatly enhanced by specialist petrographical study. This is detailed in Volume 5, Appendix 4 which should be read in conjunction with this report.

- Symbols used to represent the various lithologies are shown in Figure 2. This is located in a plastic wallet at the back of this volume; the pull-out format will enable easy reference with the core logs.

- Bed thicknesses are defined according to Ingram (1954): laminae, less than 1cm; very thin beds, 1-3cm; thin beds, 3-10cm; medium beds, 10-30cm; thick beds, 30-100cm, and very thick beds, greater than 100cm.

- Sediment colour is most conveniently measured by comparison with a colour chart. The colour chart used in this study is the Munsell (1973 edition) soil colour chart. This is an international correlation tool based on common terms so defined as to obtain descriptive uniformity.

- Subsamples are indicated on the logs at their appropriate depth. The abbreviations are explained in Figure 2 (plastic wallet at back of volume). The palaeontological subsamples are referenced by a CSC number, eg. CSC8882, which is an internal Marine Geology and Operations Group reference number. This allows for easy cross-

reference between the borehole logs and the specialist palaeontological reports which retain this number.

- The most-common abbreviations used in the lithological descriptions are explained in Figure 2 (plastic wallet at back of volume).

Acknowledgements

The author would like to acknowledge the contributions made by all concerned in the shallow sampling programme. The following people deserve special mention for their contributions to this report:

BGS

J B Riding, I P Wilkinson and M A Woods, micropalaeontology; A C Morton, petrography and igneous geochemistry (Volume 5, Appendix 4); E J Gillespie, draughting and IT skills; D Evans for constructive comment.

External contributor

N M Hine (Industrial Palynology Unit, University of Sheffield), micropalaeontology.

REFERENCES

FOLK, R L. 1954. Sedimentary rock nomenclature. *Journal of Geology*, Vol. 62, 345-351.

-----. 1962. Spectral subdivision of limestone types. 62-84 in *Classification of carbonate rocks - a symposium,* Ham, W E (editor). American Association of Petroleum Geology, Memoir 1.

HINE, N M. 1994a. Calcareous nannofossil analysis of samples from the Rockall area, North East Atlantic. *Confidential Report to British Geological Survey.*

-----. 1994b. Additional calcareous nannofossil analysis of samples from the Rockall area, North East Atlantic. *Confidential Report to British Geological Survey.*

INGRAM, R L. 1954. Terminology for the thickness of stratification and parting units in sedimentary rocks. *Bulletin of the Geological Society of America*, Vol. 65, 937-938.

RIDING, J B. 1994. A palynological investigation of a suite of seabed samples from the Rockall area. *British Geological Survey Technical Report,* WH/94/227C.

SKINNER, A C, ALEXANDER, S A, and GILLESPIE, E J. 1994. Rockall Continental Margin Project. Sampling Survey - Operational Report. *British Geological Survey Technical Report* WB/94/20C.

WILKINSON, I P. 1994. Foraminiferida and Bolboforma from a suite of samples from the Rockall area. *British Geological Survey Technical Report*, WH/94/236C.

WOODS, M A. 1994. Macrofaunas from boreholes around Rockall. *British Geological Survey Technical Report* WH/94/40C.

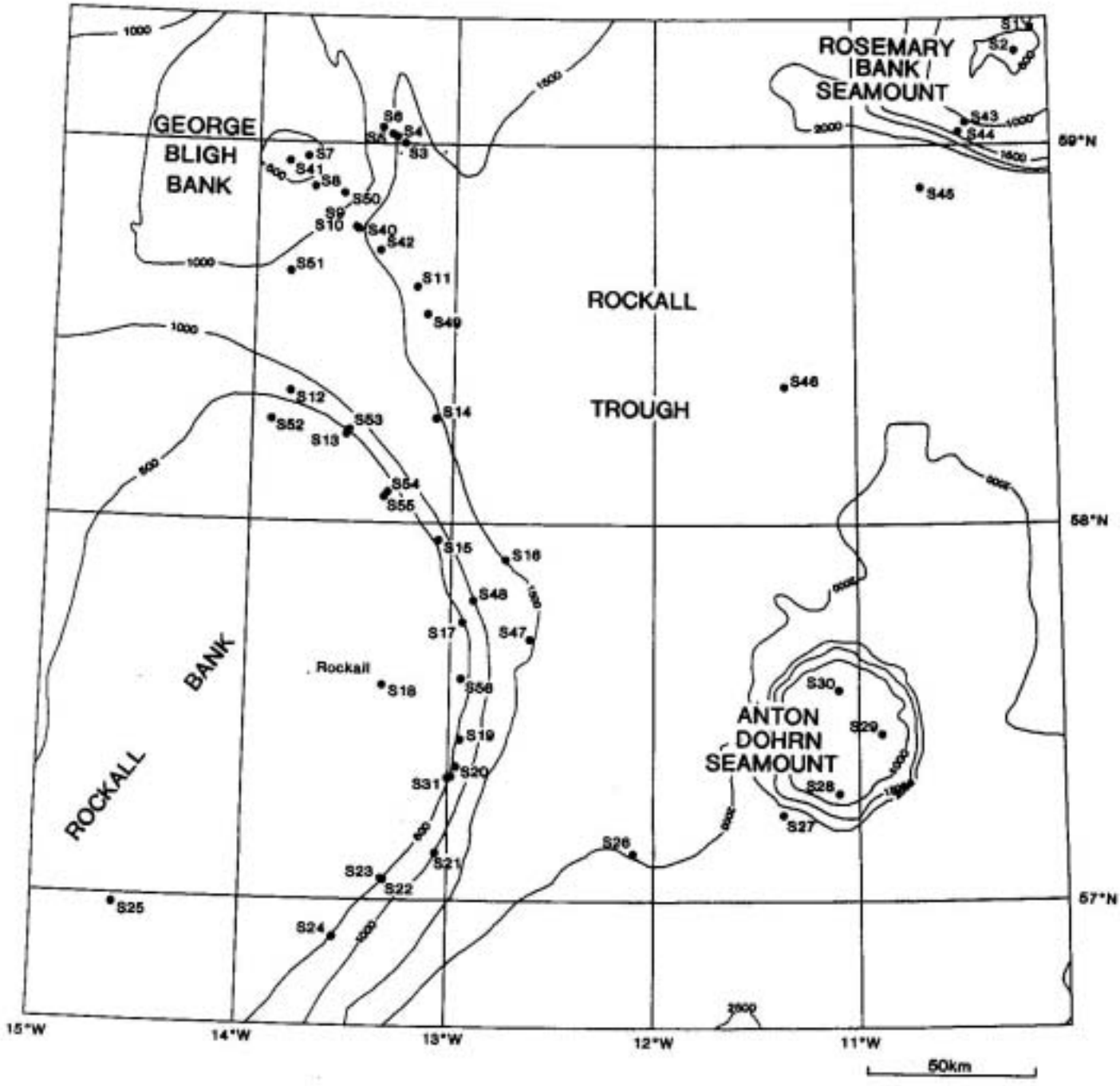


Fig. 1. Location of stratigraphical 'S' sites cored during 1994 Rockall Continental Margin Project shallow-coring programme.See Table 1 for correlation with BGS-listed, shallow-core reference number. Bathymetric contours in metres.

TABLE 1

STRATIGRAPHICAL SITES - ORIGINAL SITE NUMBERS AND NEW BGS NUMBERS

ORIGINAL SITE NO:	BGS CORE NO:	ORIGINAL SITE NO:	BGS CORE NO:
S1	59-11/12	S25	56-15/11, 12
S2	59-11/13	S26	57-13/26
S3	59-14/8	S27	57-12/33
S4	59-14/7	S28	57-12/19
S5	59-14/4, 5, 6	S29	57-11/67
S6	59-14/2, 3, 9, 10	S30	57-12/18
S7	59-14/8, 42	S31	57-13/57
S8	58-14/9	S40	58-14/55
S9	58-14/10, 43	S41	57-14/57, 58
S10	58-14/11	S42	58-14/54
S11	58-14/53	S43	59-11/16
S12	58-14/31, 32	S44	59-11/17
S13	58-14/29, 30	S45	58-11/2
S14	58-14/34	S46	58-12/5
S15	57-14/49, 51, 52	S47	57-13/75
S16	57-13/53	S48	57-13/76
S17	57-13/54	S49	58-14/44, 45
S18	57-14/53	S50	58-14/56
S19	57-13/63, 64, 65	S51	58-14/60
S20	57-13/66, 67, 68	S52	58-14/61
S21	57-14/47, 48	S53	58-14/62, 63
S22	57-14/42, 43	S54	58-14/52, 64
S23	57-14/37, 44, 45, 54	S55	58-14/50, 51
S24	56-14/10, 13	S56	57-13/77

TABLE 2

STRATIGRAPHICAL SITES - LOCATIONS, WATER DEPTHS AND SAMPLE SUMMARIES

BGS NO:	ORIGINAL SITE NO:	GENERAL LOCATION	LAT/LONG	WATER DEPTH (m)	SAMPLE SUMMARY (T.D. metres)
56-14/10	S24	Eastern flank of Rockall Bank	56°54.11'N 13°32.63'W	568	Gravel (5.1)
56-14/13	S24	Eastern flank of Rockall Bank	56°54.13'N 13°32.63'W	570	Muddy and gravelly sands (2.1)
56-15/11	S25	Top of Rockall Bank	56°58.52'N 14°36.38'W	158	Gneiss (1.0)
56-15/12	S25	Top of Rockall Bank	56°58.52'N 14°36.38'W	158	Gneiss (0.85)
57-11/67	S29	Top of Anton Dohrn	57°26.61'N 10°53.36'W	727	Interbedded sands and muds (5.1)
57-12/18	S30	Top of Anton Dohrn	57°33.62'N 11°05.87'W	705	Conglomerate - volcanic clasts in carbonate matrix (3.8)
57-12/19	S28	Southern flank of Anton Dohrn	57°17.12'N 11°05.79'W	869	Interbedded sands and muds (5.6)
57-12/33	S27	Rockall Trough, SW of Anton Dohrn	57°13.79'N 11°22.15'W	2035	Interbedded sands and muds on chalk (3.06)
57-13/26	S26	Rockall Trough, SW of Anton Dohrn	57°07.55'N 12°05.96'W	1961	Massive, bioturbated muds (3.08)
57-13/53	S16	North-west Rockall Trough	57°54.22'N 12°43.95'W	1480	Interbedded sands and muds (2.84)
57-13/54	S17	North-east flank of Rockall Bank	57°44.20'N 12°56.39'W	634	Basaltic agglomerate (1.1)
57-13/57	S31	Eastern flank of Rockall Bank	57°19.66'N 12°59.34'W	658	Interbedded sands and muds (5.1)
57-13/63	S19	Eastern flank of Rockall Bank	57°25.68'N 12°56.82'W	610	Gravel (3.5)
57-13/64	S19	Eastern flank of Rockall Bank	57°25.69'N 12°56.89'W	575	Gravel (1.0)
57-13/65	S19	Eastern flank of Rockall Bank	57°25.59'N 12°56.69'W	634	Interbedded sand, gravel and mud on mudstone (3.1)
57-13/66	S20	Eastern flank of Rockall Bank	57°21.28'N 12°57.81'W	750	Basaltic boulder (0.9)
57-13/67	S20	Eastern flank of Rockall Bank	57°21.27'N 12°57.82'W	750	No recovery
57-13/68	S20	Eastern flank of Rockall Bank	57°21.29'N 12°57.81'W	750	Muddy sand (0.16)
57-13/75	S47	Rockall Trough, NE of Rockall Bank	57°41.68'N 12°36.62'W	1523	Interbedded sands and muds (4.1)
57-13/76	S48	Western margin of Rockall Trough	57°47.73'N 12°53.35'W	970	Interbedded sands and muds (4.48)
57-13/77	S56	Eastern flank of Rockall Bank	57°35.25'N 12°56.71'W	617	Gravel on muddy sandstone (5.1)
57-14/37	S23	Eastern flank of Rockall Bank	57°03.43'N 13°19.10'W	429	Sandy gravel (0.4)
57-14/42	S22	Eastern flank of Rockall Bank	57°03.24'N 13°18.55'W	578	Gravel (1.05)
57-14/43	S22	Eastern flank of Rockall Bank	57°03.25'N 13°18.56'W	578	Sandstone (0.95)
57-14/44	S23	Eastern flank of Rockall Bank	57°03.43'N 13°19.10'W	438	Gravel (3.77)
57-14/45	S23	Eastern flank of Rockall Bank	57°03.43'N 13°19.10'W	438	Gravelly sand (2.1)
57-14/47	S21	Western margin of Rockall Trough	57°07.56'N 13°03.55'W	1078	Sand on massive, bioturbated muds (1.1)
57-14/48	S21	Western margin of Rockall Trough	57°07.54'N 13°03.54'W	1081	Interbedded mud, sand and gravel on sandstone (2.3)
57-14/49	S15	North-east flank of Rockall Bank	57°57.19'N 13°04.33'W	505	Basaltic pebble (0.05)

TABLE 2 (...continued)

STRATIGRAPHICAL SITES - LOCATIONS, WATER DEPTHS AND SAMPLE SUMMARIES

BGS NO:	ORIGINAL SITE NO:	GENERAL LOCATION	LAT/LONG	WATER DEPTH (m)	SAMPLE SUMMARY (T.D. metres)
57-14/51	S15	North-east flank of Rockall Bank	57°57.18'N 13°04.34'W	536	Basaltic gravel (2.35)
57-14/52	S15	North-east flank of Rockall Bank	57°57.19'N 13°04.34'W	531	Weathered and fractured basalt - ?boulder or *in situ* (3.05)
57-14/53	S18	Top of Rockall Bank	57°34.14'N 13°19.80'W	177	Trachyte (3.2)
57-14/54	S23	Eastern flank of Rockall Bank	57°03.43'N 13°19.09'W	423	Interbedded sands and muds on gravel (2.0)
58-11/2	S45	Rockall Trough, SW of Rosemary Bank	58°53.23'N 10°39.65'W	1863	Massive, bioturbated muds (3.54)
58-12/5	S46	Rockall Trough, SW of Rosemary Bank	58°21.80'N 11°21.18'W	1809	Massive, bioturbated muds (3.26)
58-14/8	S7	Top of George Bligh Bank	58°57.73'N 13°45.46'W	442	Conglomerate - volcanic clasts in carbonate matrix (5.1)
58-14/9	S8	Top of George Bligh Bank	58°53.11'N 13°43.04'W	484	Interbedded sands (5.97)
58-14/10	S9	Eastern flank of George Bligh Bank	58°46.76'N 13°13.30'W	1014	Calcareous sandy mudstones (2.6)
58-14/11	S10	Eastern flank of George Bligh Bank	58°46.62'N 13°30.05'W	1033	Gravel on bioclastic sandstone (5.1)
58-14/29	S13	North-east flank of Rockall Bank	58°13.92'N 13°32.02'W	705	Gravel on sandstone and siltstone (5.12)
58-14/30	S13	North-east flank of Rockall Bank	58°13.92'N 13°32.01'W	705	Sandstone and siltstone (4.6)
58-14/31	S12	North-east flank of Rockall Bank	58°20.52'N 13°48.81'W	705	Conglomerate - volcanic clasts in carbonate matrix (3.96)
58-14/32	S12	North-east flank of Rockall Bank	58°20.52'N 13°48.80'W	705	Limestone on conglomerate - a/a (4.0)
58-14/34	S14	North-west Rockall Trough	58°16.51'N 13°05.11'W	1486	Interbedded sands and muds on mudstone (5.25)
58-14/42	S7	Top of George Bligh Bank	58°57.72'N 13°45.45'W	438	Conglomerate - volcanic clasts in carbonate matrix - on basalt (5.12)
58-14/43	S9	Eastern flank of George Bligh Bank	58°46.75'N 13°30.24'W	1028	Gravel on calcareous sandy mudstone (5.1)
58-14/44	S49	North-west Rockall Trough	58°33.00'N 13°08.33'W	1621	Gravel on claystone (5.1)
58-14/45	S49	North-west Rockall Trough	58°33.01'N 13°08.31'W	1622	Gravel on claystone (5.1)
58-14/50	S55	Top of Rockall Bank	58°04.13'N 13°20.45'W	244	Gravel (2.75)
58-14/51	S55	Top of Rockall Bank	58°04.12'N 13°20.48'W	244	Gravel (0.25)
58-14/52	S54	Top of Rockall Bank	58°04.78'N 13°19.57'W	263	Gravel (3.9)
58-14/53	S11	North-west Rockall Trough	58°37.36'N 13°11.62'W	1595	Mud and gravel on calcareous claystone (5.1)
58-14/54	S42	North-west Rockall Trough	58°43.08'N 13°22.86'W	1433	Sands on sandstone and conglomerate (3.4)
58-14/55	S40	Eastern flank of George Bligh Bank	58°46.47'N 13°29.72'W	1062	Gravel on sandstone on mudstone (5.1)
58-14/56	S50	Eastern flank of George Bligh Bank	58°52.11'N 13°34.12'W	685	Limestone (2.7)
58-14/57	S41	Top of George Bligh Bank	58°56.98'N 13°50.85'W	444	Sand on conglomerate - volcanic clasts in carbonate matrix (4.1)
58-14/58	S41	Top of George Bligh Bank	58°56.96'N 13°50.85'W	444	Sand on conglomerate - a/a (4.05)
58-14/60	S51	North-west Rockall Trough	58°39.48'N 13°49.72'W	1270	Sands and gravels (1.07)

TABLE 2 (...continued)

STRATIGRAPHICAL SITES - LOCATIONS, WATER DEPTHS AND SAMPLE SUMMARIES

BGS NO:	ORIGINAL SITE NO:	GENERAL LOCATION	LAT/LONG	WATER DEPTH (m)	SAMPLE SUMMARY (T.D. metres)
58-14/61	S52	Top of Rockall Bank	58°15.98'N 13°54.43'W	377	Gravel (5.1)
58-14/62	S53	North-east flank of Rockall Bank	58°14.47'N 13°31.34'W	916	Gravel (5.1)
58-14/63	S53	North-east flank of Rockall Bank	58°14.48'N 13°31.32'W	916	Gravel (3.9)
58-14/64	S54	Top of Rockall Bank	58°04.78'N 13°19.55'W	262	Sandy gravel (3.9)
59-11/12	S1	Top of Rosemary Bank	59°18.41'N 10°04.99'W	477	Interbedded ultarpotassic lavas and thin limestones (5.1)
59-11/13	S2	Top of Rosemary Bank	59°14.87'N 10°09.98'W	473	Interbedded sands (4.67)
59-11/16	S43	South-west flank of Rosemary Bank	59°03.57'N 10°25.55'W	1013	Interbedded sands and muds (4.35)
59-11/17	S44	South-west flank of Rosemary Bank	59°02.09'N 10°27.60'W	1209	Interbedded muds and thin sands and gravels (5.25)
59-14/2	S6	Western margin of Rockall Trough	59°02.60'N 13°22.82'W	1342	Gravel (0.05)
59-14/3	S6	Western margin of Rockall Trough	59°02.56'N 13°22.78'W	1343	Sands and gravel (1.17)
59-14/4	S5	Western margin of Rockall Trough	59°01.52'N 13°19.72'W	1445	Gravel (0.75)
59-14/5	S5	Western margin of Rockall Trough	59°01.52'N 13°19.74'W	1445	Claystone (3.7)
59-14/6	S5	Western margin of Rockall Trough	59°01.52'N 13°19.75'W	1445	Claystone on siltstone (5.12)
59-14/7	S4	Western margin of Rockall Trough	59°01.04'N 13°18.40'W	1453	Sandstone on claystone (5.12)
59-14/8	S3	Western margin of Rockall Trough	59°00.14'N 13°16.04'W	1585	Gravel on mudstone and slitstone (4.0)
59-14/9	S6	Western margin of Rockall Trough	59°02.58'N 13°22.76'W	1341	Gravel on claystone (5.12)
59-14/10	S6	Western margin of Rockall Trough	59°02.57'N 13°22.77'W	1341	Gravel on interbedded mudstones and thin sandstones (5.12)

TABLE 3. STRATIGRAPHICAL SITES - BIOSTRATIGRAPHICAL DATA

BGS NO:	ORIGINAL SITE NO:	CSC NO:	DEPTH IN CORE (m)	AGE *DINOFLAGELLATES*	*FORAMINIFERA*	*CALCAREOUS NANNOFOSSILS*
56-14/13	S24	8813	0.05-0.07	Mid-Pleistocene to Holocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8814	0.28-0.30	a/a	a/a	Mid- to late Pleistocene (NN21)
		8815	0.90-0.93	–	a/a	Late Pleistocene (NN21)
57-11/67	S29	8816	0.00-0.01	Mid- to late Pleistocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8817	0.2	a/a	a/a	Late Pleistocene (NN21)
		8818	1.5	a/a	a/a	a/a
		8819	3.5	a/a	a/a	a/a
		8820	4.9	a/a	a/a	Mid-Pleistocene (NN20)
57-12/18	S30	8900	2.87-2.90		Mid- to late Eocene (NP17-19)	
		8821	3.70-3.73	–		–
57-12/19	S28	8822	0.00-0.03	Mid- to late Pleistocene	Mid- to late Pleistocene	Late Pleistocene (NN21)
		8823	5.3	–	a/a	Late Pliocene (NN18)
57-12/33	S27	8824	0.05-0.10	Holocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8825	1.25-1.30	Pleistocene	a/a	? Early / mid-Pleistocene (NN19)
		8826	2.5	–	(Mid- to late Miocene - ? reworked)	Mid- to late Pliocene (NN15)
57-13/26	S26	8827	0.00-0.01	Late Pleistocene to Holocene	Pleistocene to Holocene	Holocene (NN21)
		8828	0.5	a/a	a/a	Late Pleistocene (NN21)
		8829	1.0	a/a	a/a	a/a
		8830	1.5	a/a	a/a	a/a
		8831	2.0	Late Pleistocene	a/a	a/a
		8832	2.5	a/a	a/a	a/a
		8833	3.0	a/a	a/a	a/a
57-13/53	S16	8834	0.00-0.03	Late Pleistocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8835	0.50-0.53	a/a	a/a	Late Pleistocene (NN21)
		8836	2.80-2.83	–	a/a	Early / mid-Pleistocene (NN19)
57-13/57	S31	8837	0.00-0.05	Late Pleistocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8838	5.00-5.02	a/a		Mid- / late Pleistocene (NN21)
57-13/65	S19	8839	3.05-3.10	–	–	–
57-13/75	S47	8840	0.00-0.04	Mid- / late Pleistocene to Holocene		Holocene (NN21)
		8841	4.05-4.10	–		Early / mid-Pleistocene (NN19)
57-13/76	S48	8842	0.00-0.07	Mid- / late Pleistocene		Holocene (NN21)
		8843	4.13-4.18	–		Late Pliocene (NN16-18)
57-13/77	S56	8844	5.04-5.08	–		Mid-Eocene (NP15-16)
57-14/43	S22	8845	0.72	–	–	–
		8846	0.90	–	(Mid- to late Miocene - ? reworked)	–
57-14/44	S23	8847	Sea-bed boulder	–	–	–

TABLE 3 (...continued). STRATIGRAPHICAL SITES - BIOSTRATIGRAPHICAL DATA

BGS NO:	ORIGINAL SITE NO:	CSC NO:	DEPTH IN CORE (m)	AGE *DINOFLAGELLATES*	AGE *FORAMINIFERA*	AGE *CALCAREOUS NANNOFOSSILS*
57-14/48	S21	8848	0.00-0.03	Quaternary		Mid- / late Pleistocene (NN21)
		8849	0.90-0.93	a/a	Mid-Pleistocene to Holocene	Early / mid-Pleistocene (NN19)
		8850	2.00-2.01	(Early Miocene to Quaternary)		Pliocene (NN13-15)
57-14/54	S23	8851	0.65-0.68	Late Pleistocene to Holocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8852	1.80-1.90	Quaternary	–	Mid-Pleistocene (NN20)
		8853	1.90-2.00	Quaternary	Mid-Pleistocene to Holocene	–
58-11/2	S45	8854	0.00-0.03	Late Pleistocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8855	3.50-3.54	a/a	a/a	Late Pleistocene (NN21)
58-12/5	S46	8856	0.00-0.03	Late Pleistocene to Holocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8857	3.17-3.20	Late Pleistocene	a/a	Late Pleistocene (NN21)
58-14/8	S7	8901	4.45-4.47			
		8858	4.47-4.49	–		–
58-14/9	S8	8859	0.00-0.03	Mid- / late Pleistocene	Mid- / late Pleistocene	Late Pleistocene (NN21)
		8860	0.35-0.38	a/a	a/a	Mid- / late Pleistocene (NN20-21)
		8861	5.50-5.53	a/a	a/a	Mid-Pleistocene (NN20)
58-14/10	S9	8862	1.80-1.84	(Mid-Pleistocene - ? contaminated)	Early Eocene (NP12-13)	Late Paleocene (NP7-9)
58-14/11	S10	8863	4.72-4.77	–	–	Late Paleocene (NP6-9)
58-14/29	S13	8905	0.40-0.46		(Eocene - ? reworked)	
		8899	0.46-0.50	–		–
		8864	4.95-5.00	Early to mid-Eocene (NP10/11-15)	Earliest mid-Eocene	–
58-14/31	S12	8865	3.51-3.55	–	(Pliocene to Pleistocene - ? contaminated)	(Pliocene to Pleistocene - ? contaminated)
58-14/32*	S12	8866	3.11-3.14			? Pliocene (NN12-15)
		8902	3.45-3.48		Pleistocene (? reworked Eocene)	
		8867	3.85-3.90		Pliocene to Pleistocene	? Pliocene (NN12-15)
58-14/34	S14	8868	0.00-0.03	Late Pleistocene	Mid- / late Pleistocene	Late Pleistocene (NN21)
		8869	0.50-0.53	Quaternary	a/a	Mid- / late Pleistocene (NN20-21)
		8870	4.79-4.82	–	Early mid-Eocene	Mid-Eocene (NP14-17)
58-14/42	S7	8903	4.43-4.45		–	
		8871	4.5	(Early Miocene to Holocene - ? contaminated)		Paleocene
58-14/43	S9	8904	4.65-4.70			
		8872	5.07-5.12	–		Late Paleocene (NP6-9)
58-14/44	S49	8873	5.04-5.08	–	–	Mid-Eocene (NP16)
58-14/53	S11	8874	3.43-3.47	–	Eocene	Mid-Eocene (NP16)
58-14/54	S42	8875	1.90-1.92	–	Mid- to late Eocene (NP17-19)	Eocene to Pliocene range
		8876	2.52-2.54	–	a/a	a/a
58-14/55	S40	8877	5.05-5.10	–	–	Late Paleocene to Pliocene range (NP4-NN16)
58-14/56	S50	8878	1.01-1.06	–	–	–

* Macrofaunal analysis (sample no: CSC 8986) supports a Pliocene to Pleistocene age

TABLE 3 (...continued). STRATIGRAPHICAL SITES - BIOSTRATIGRAPHICAL DATA

BGS NO:	ORIGINAL SITE NO:	CSC NO:	DEPTH IN CORE (m)	AGE *DINOFLAGELLATES*	AGE *FORAMINIFERA*	AGE *CALCAREOUS NANNOFOSSILS*
58-14/57	S41	8879	3.83-3.89	(Miocene to Holocene - ? partly reworked)	Mid-Pleistocene to Holocene	Mid-Pleistocene (NN21)
		8880	4.10	–	–	Paleocene
58-14/60	S51	8881	0.00-0.02	Holocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8882	1.02-1.07	Quaternary	a/a	Early / mid-Pleistocene (NN19)
58-14/63	S53	8883	0.81-0.83 *	–		Mid-Eocene (NP15-16) *
59-11/12	S1	8884	1.40-1.43	–	–	–
59-11/13	S2	8885	0.00-0.05	Holocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8886	0.60-0.65	Late Pleistocene	a/a	Late Pleistocene (NN21)
		8887	0.80-0.85	a/a	a/a	a/a
		8888	4.60-4.67	–	a/a	Mid- / late Pleistocene (NN21)
59-11/16	S43	8889	4.30-4.35	(Early to mid-Eocene (NP12-15) - ?reworked)	–	Mid- / late Pleistocene (NN21)
59-11/17	S44	8890	0.00-0.05	Holocene	Mid-Pleistocene to Holocene	Holocene (NN21)
		8891	4.60-4.63	Late Pleistocene	a/a	Mid- / late Pleistocene (NN21)
59-14/6	S5	8892	5.00-5.03	Early to mid-Eocene	–	–
		8893	5.05-5.06	Early to mid Eocene (NP12-14)	Latest early Eocene to earliest mid-Eocene (NP13-14)	–
59-14/7	S4	8894	4.00-4.03	–	–	–
		8895	5.07-5.12	Early to mid-Eocene (NP13-15)	–	–
59-14/8	S3	8906	0.95-0.98		–	
		8896	0.98-1.00	–		Early Eocene (NP13)
		8897	3.80-3.83	Palaeogene	–	a/a
59-14/9	S6	8898	5.07-5.12	–		Mid-Eocene (NP15-16)
		8907	5.09-5.12		–	

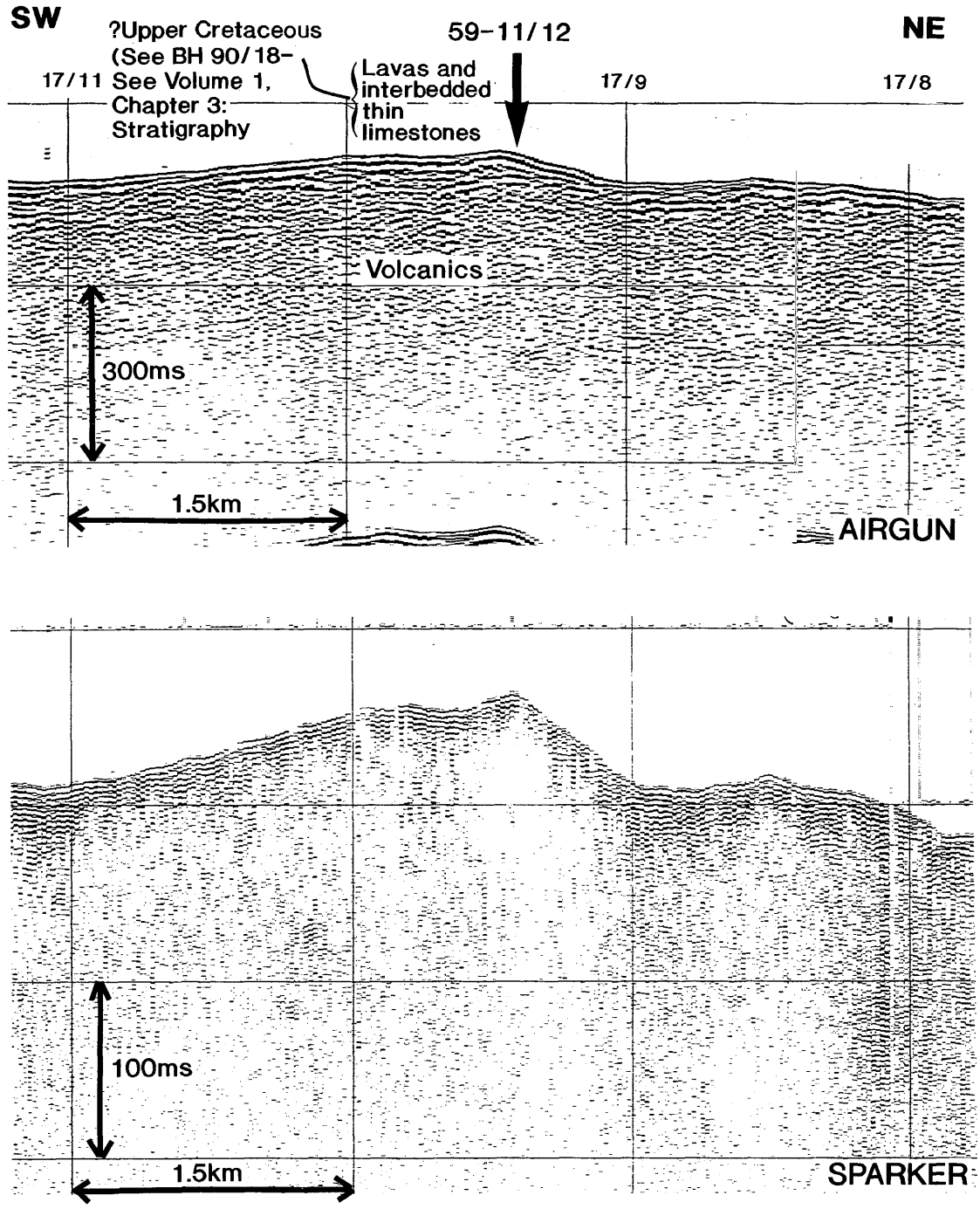
* Clast in sea-bed gravel

NB. Barren samples indicated by short dashed line. Lack of entry relates to samples not analysed for that specific microfauna or flora.

SHALLOW–CORE DESCRIPTIONS AND SEISMIC–STRATIGRAPHICAL SETTING OF SAMPLE SITES

59-11/12
(S1)

ROSEMARY BANK



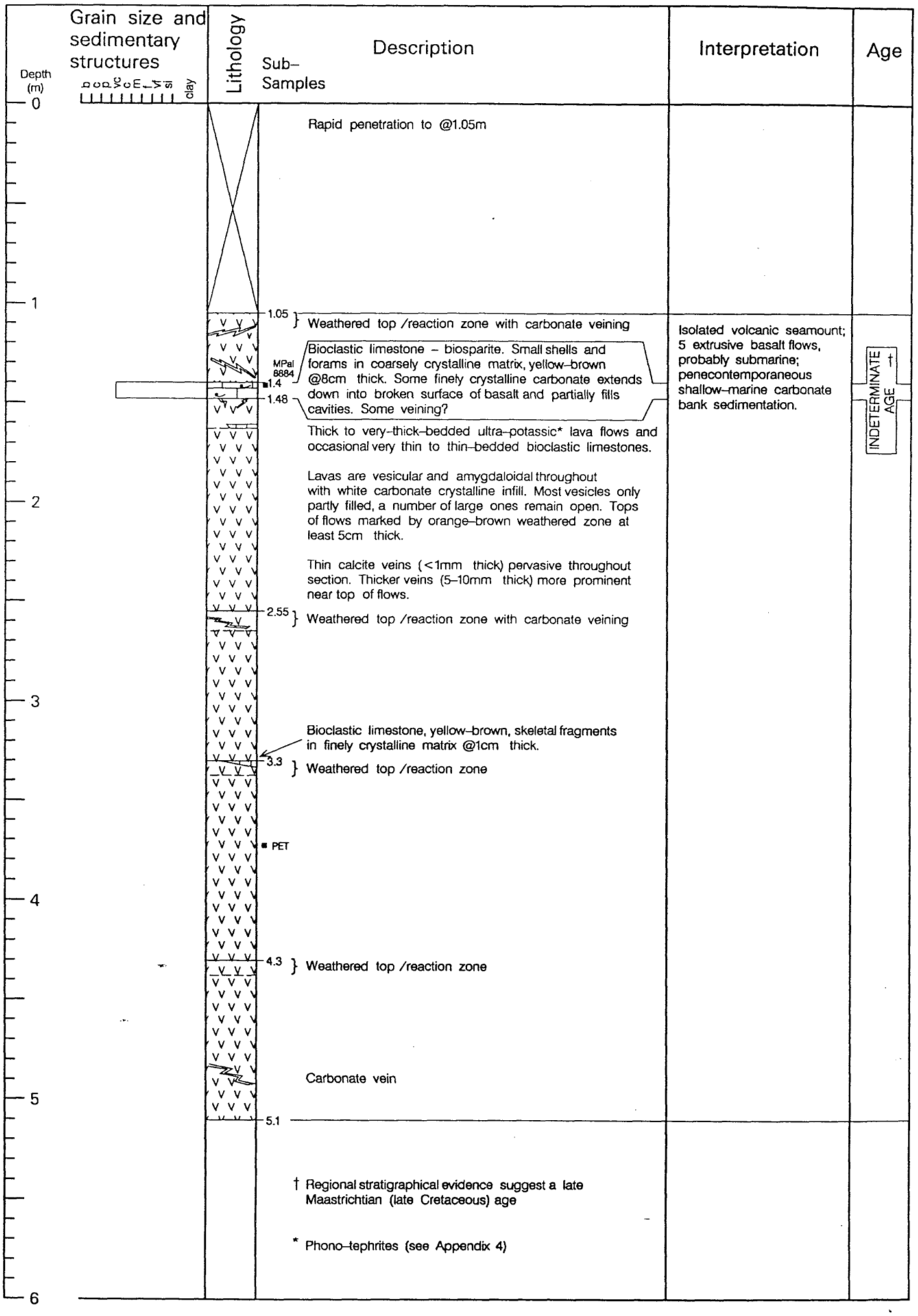
BGS no: 59-11/12
Original site no: S1
Location: Top of Rosemary Bank
Latitude: 59° 18.41' N
Longitude: 10° 04.99' W
Water depth: 477m

BGS core no: 59–11/12

Original site no: S1

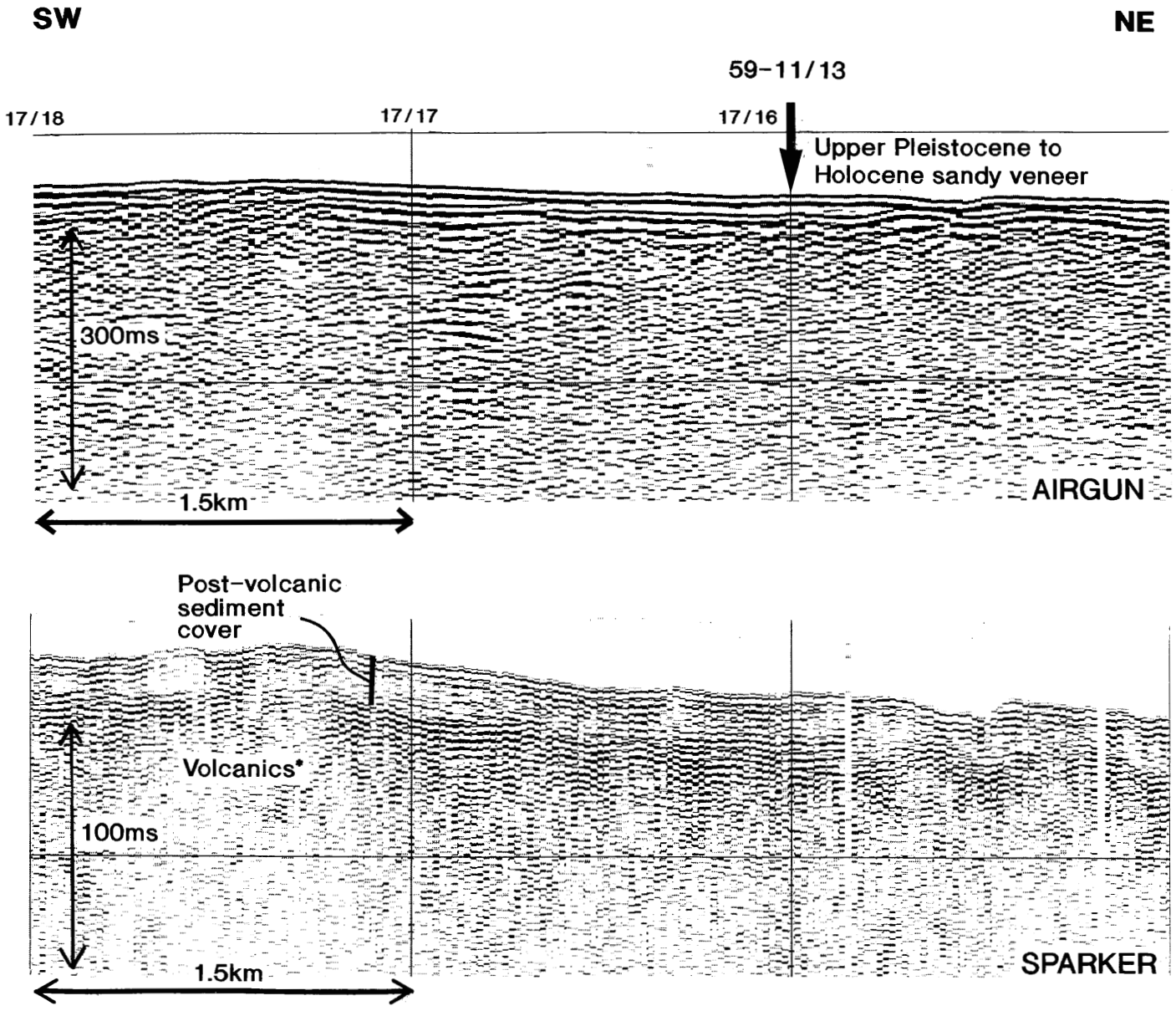
T.D. metres: 5.1

Recovery %: 80



59-11/13
(S2)

ROSEMARY BANK



* ?Upper Cretaceous
(see BH 90/18-main text)

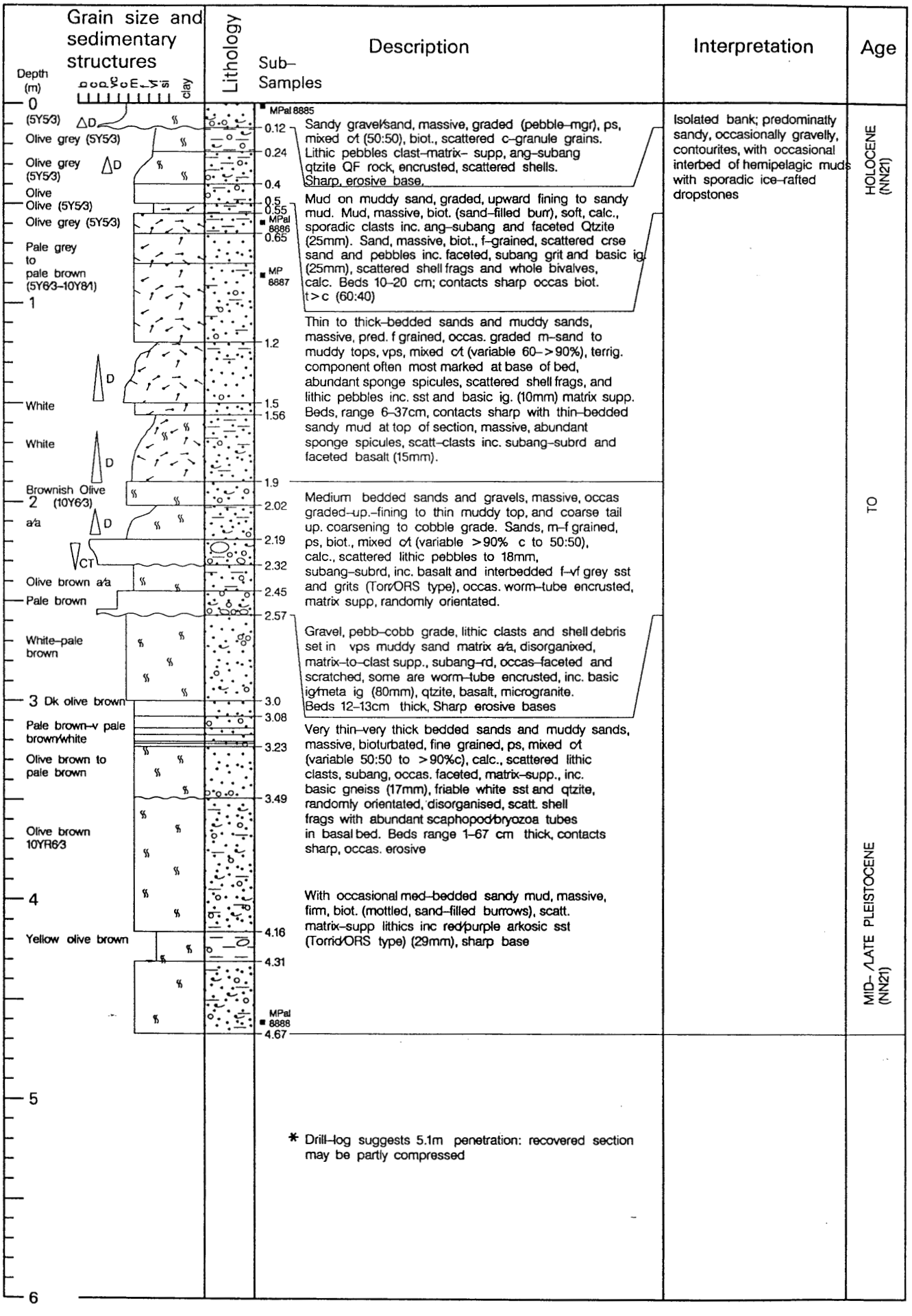
BGS no: 59-11/13
Original site no: S2
Location: Top of Rosemary Bank
Latitude: 59° 14.87' N
Longitude: 10° 09.98' W
Water depth: 472m

BGS core no: 59–11/13

Original site no: S2

T.D. metres: 4.67*

Recovery %: 100



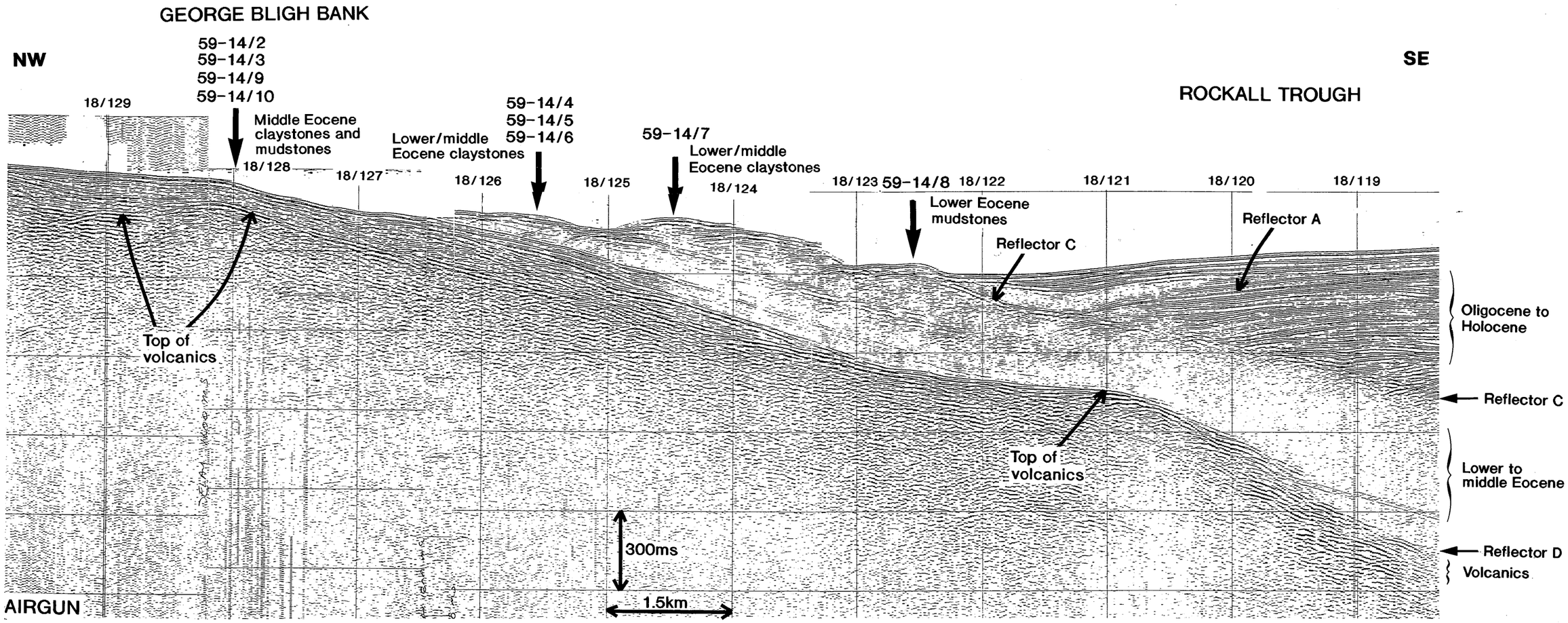
* Drill–log suggests 5.1m penetration: recovered section may be partly compressed

59-14/2,3,9,10
(S6)

59-14/4,5,6
(S5)

59-14/7
(S4)

59-14/8
(S3)



BGS no: 59-14/2*
59-14/3
59-14/9
59-14/10
Original site no: S6
Latitude: 59° 02.58' N
Longitude: 13° 22.76' W } 59-14/9
Water depth: 1341m

* Poor Recovery

BGS no: 59-14/4*
59-14/5
59-14/6
Original site no: S5
Latitude: 59° 01.52' N
Longitude: 13° 19.75' W } 59-14/6
Water depth: 1445m

* Poor Recovery

BGS no: 59-14/7
Original site no: S4
Latitude: 59° 01.04' N
Longitude: 13° 18.40' W
Water depth: 1453m

BGS no: 59-14/8
Original site no: S3
Latitude: 59° 00.14' N
Longitude: 13° 16.04' W
Water depth: 1585m

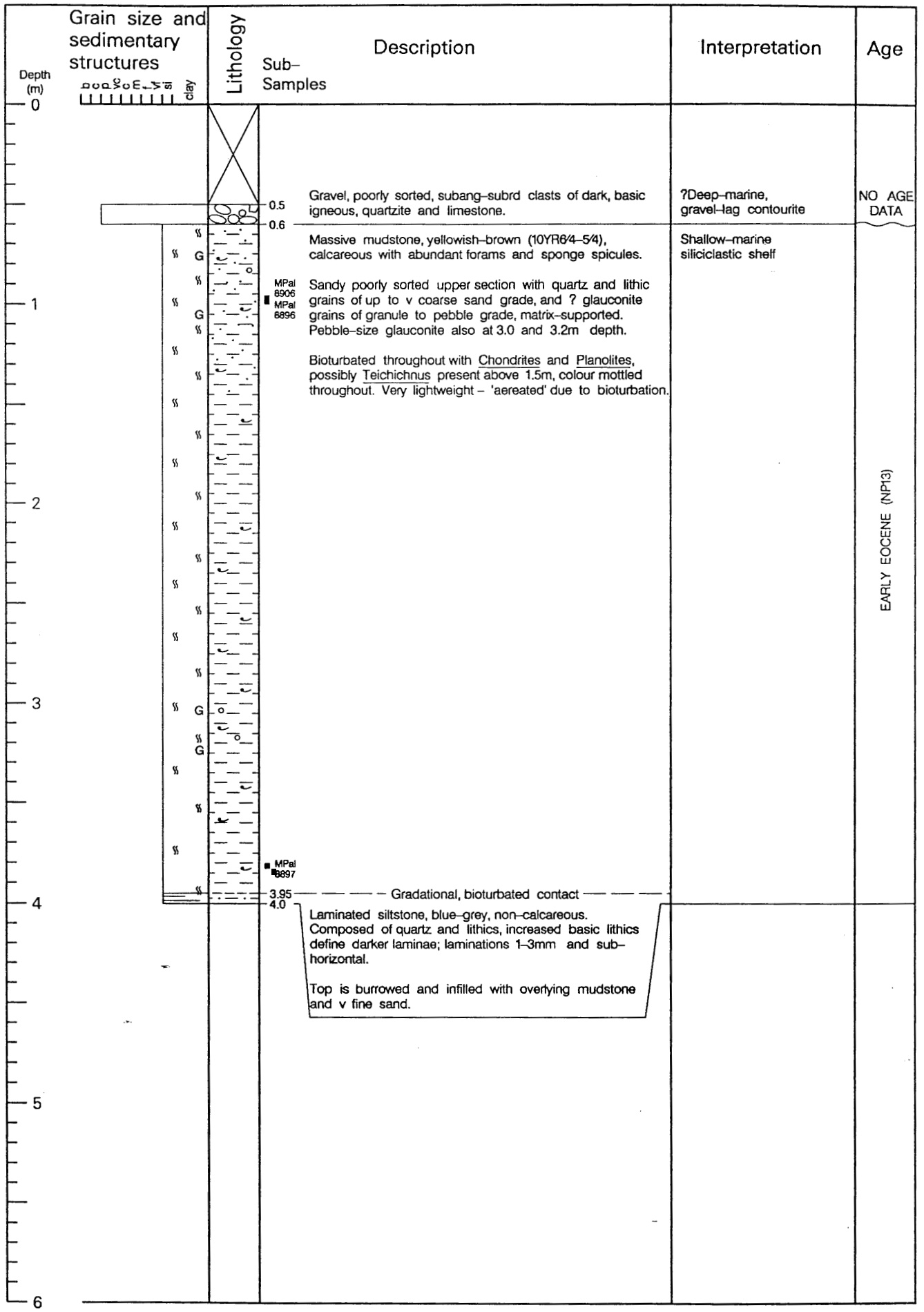
Location: Eastern flank of George Bligh Bank

BGS core no: 59–14 /8

Original site no: S3

T.D. metres: 4.0

Recovery %: 88

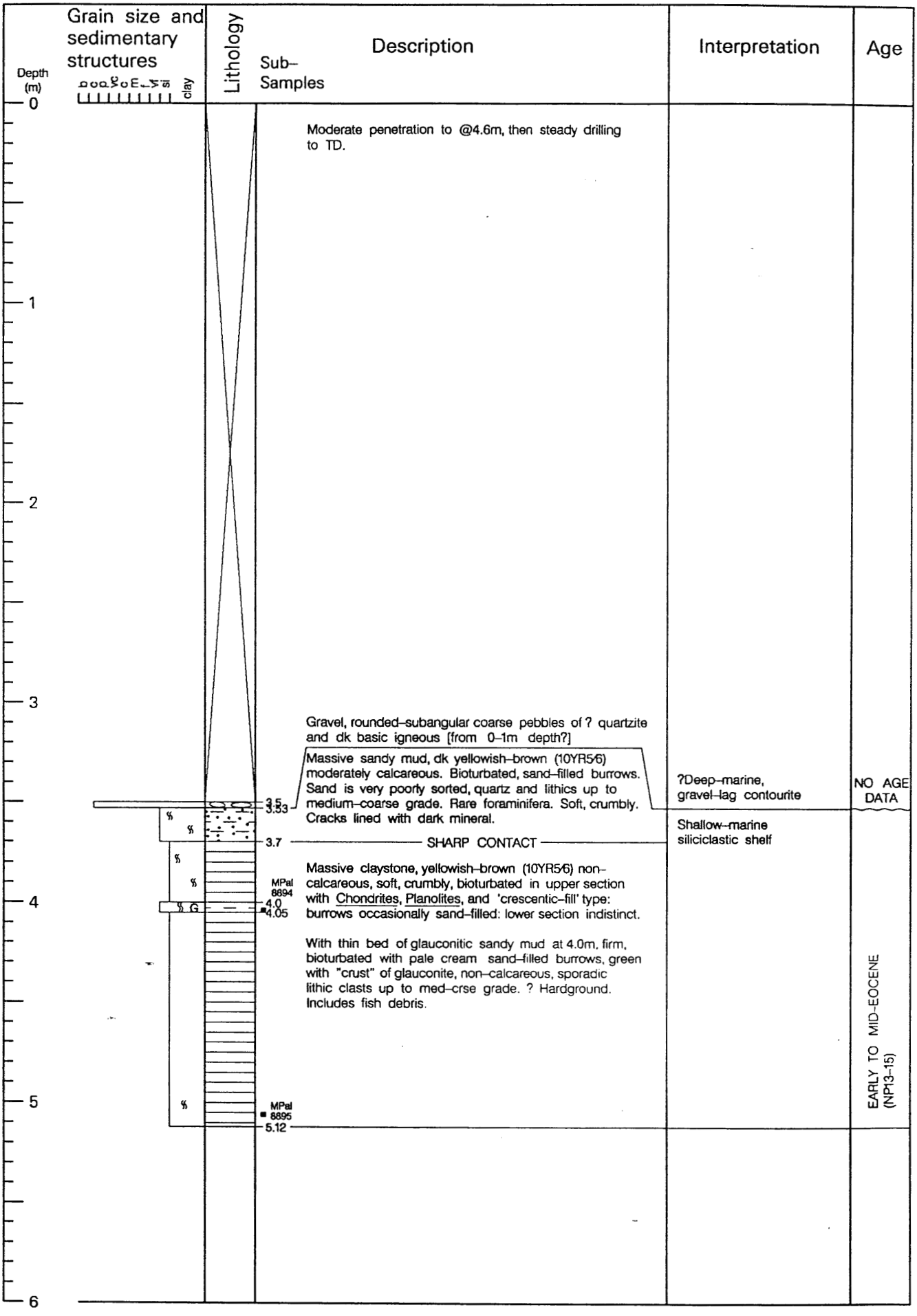


BGS core no: 59–14 /7

Original site no: S4

T.D. metres: 5.12

Recovery %: 32

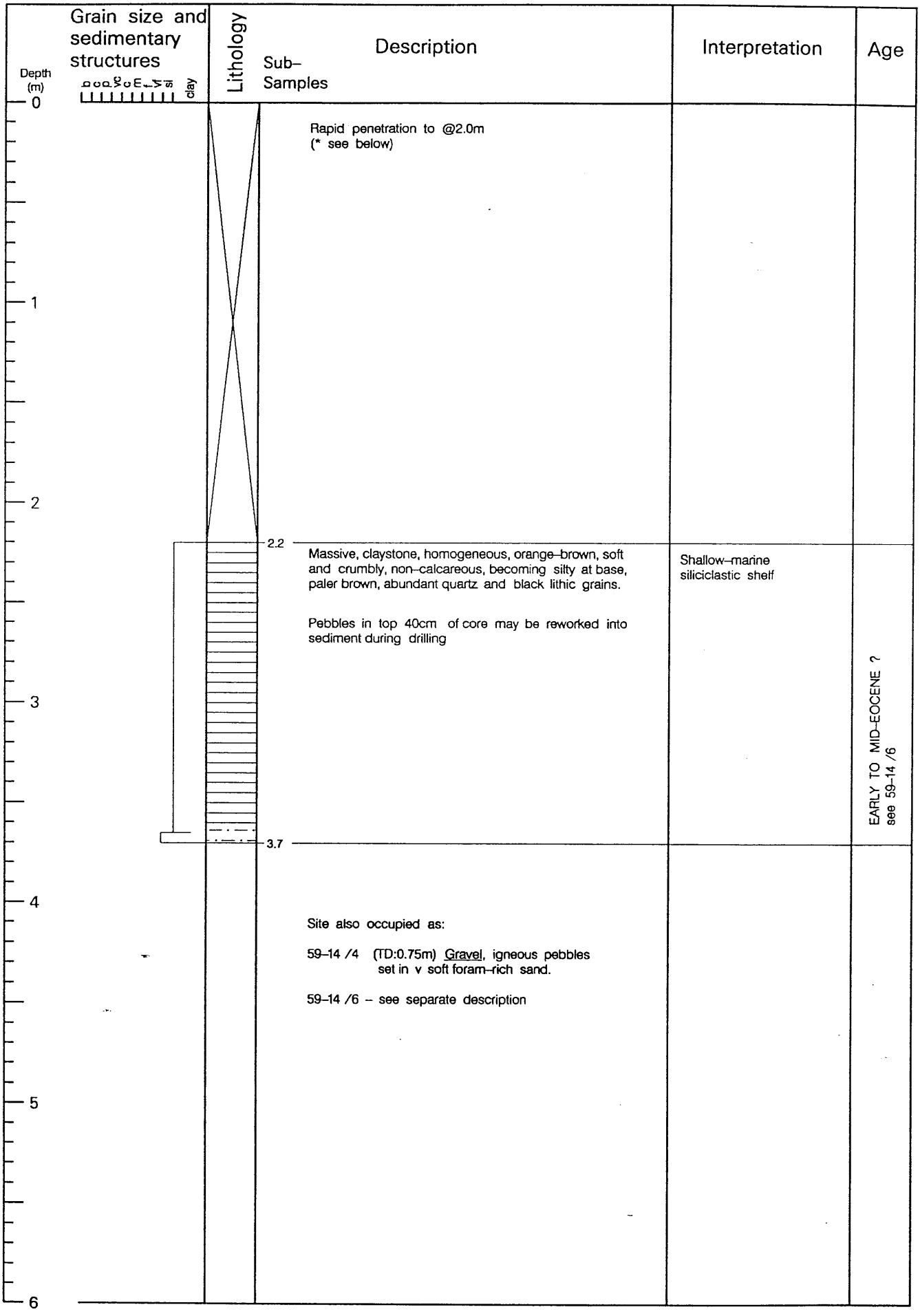


BGS core no: 59–14 /5*

Original site no: S5

T.D. metres: 3.7

Recovery %: 41

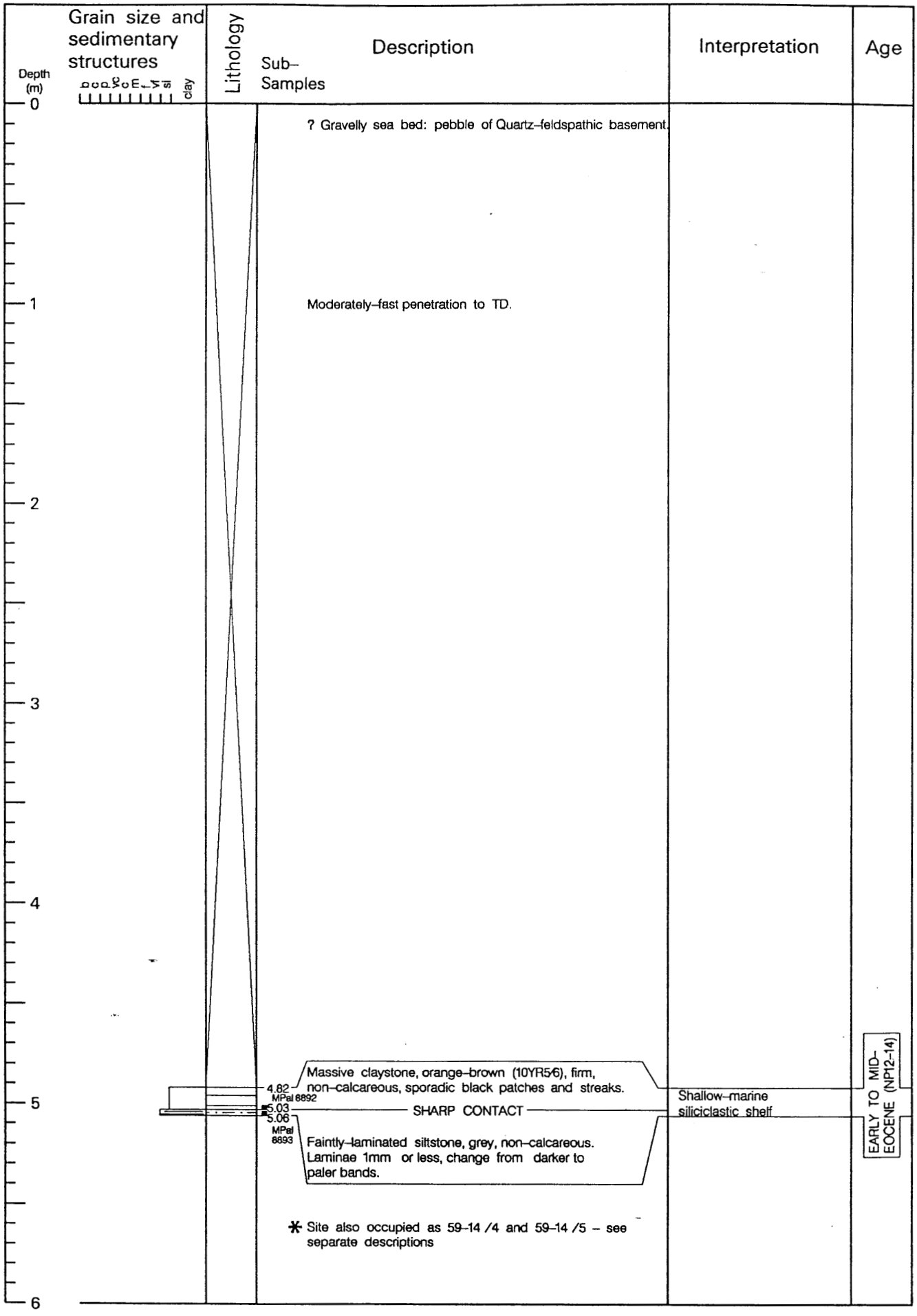


BGS core no: 59–14 /6*

Original site no: S5

T.D. metres: 5.06

Recovery %: 5

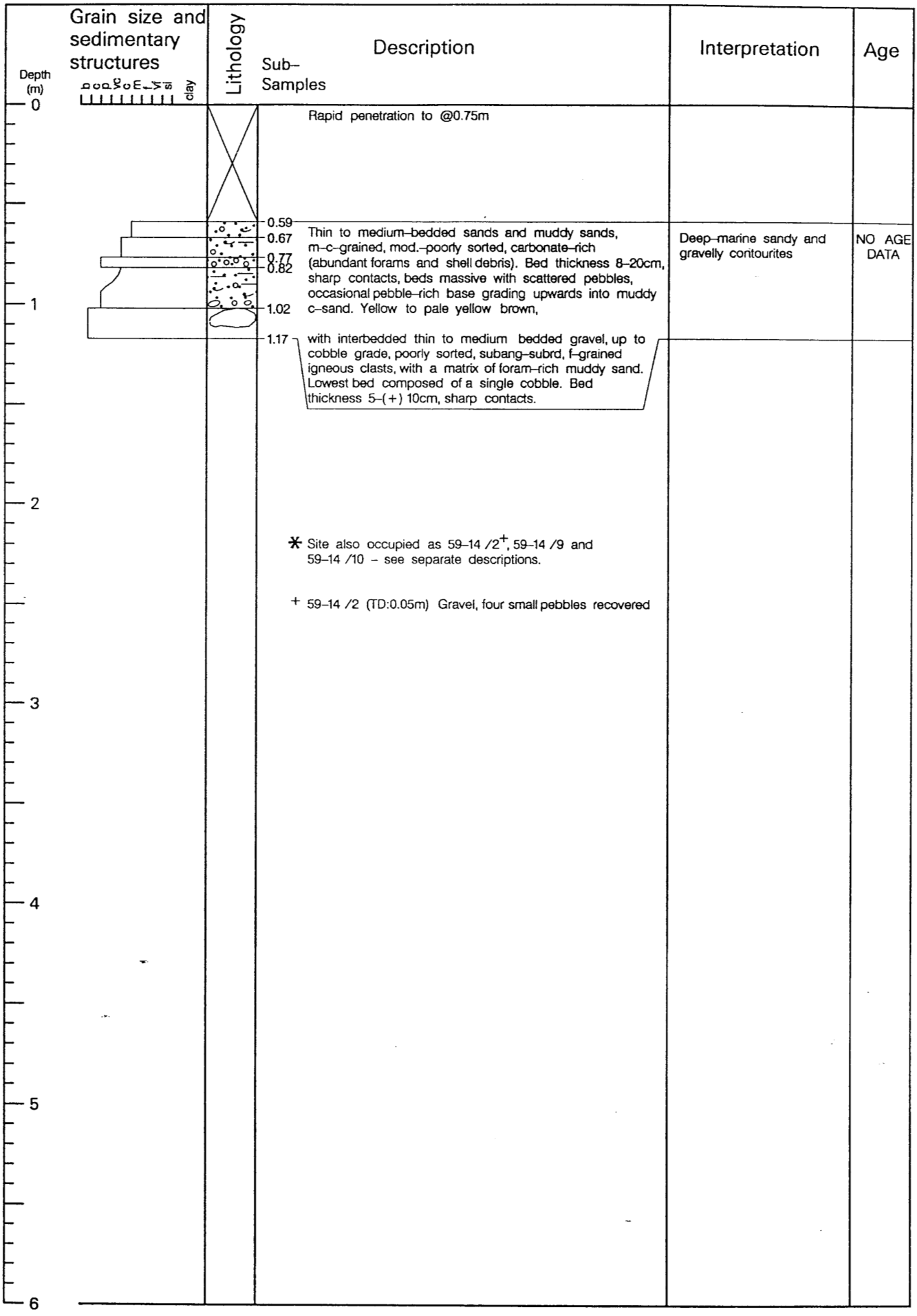


BGS core no: 59–14 /3*

Original site no: S6

T.D. metres: 1.17

Recovery %: 47

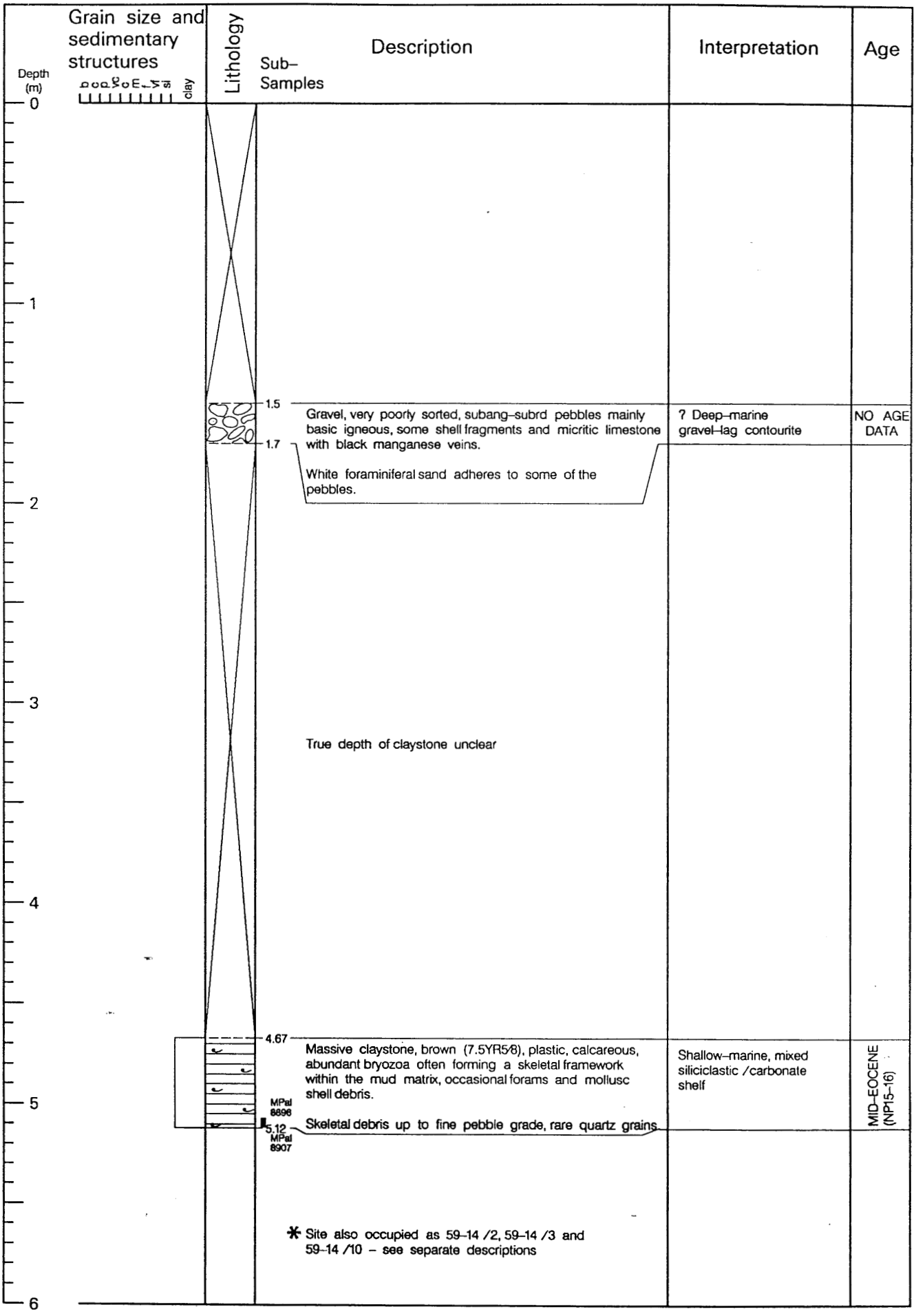


BGS core no: 59–14 /9*

Original site no: S6

T.D. metres: 5.12

Recovery %: 13



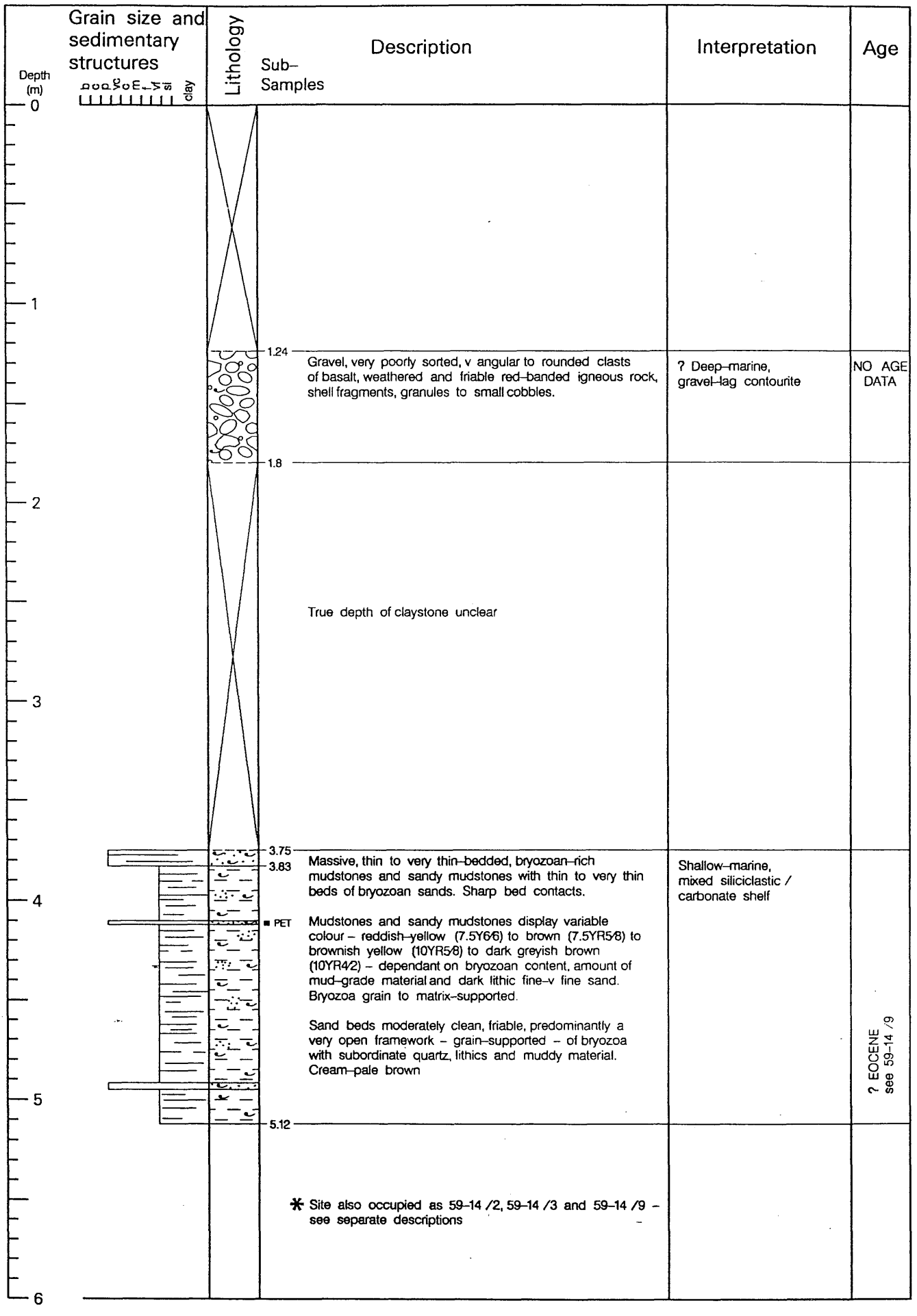
* Site also occupied as 59–14 /2, 59–14 /3 and 59–14 /10 – see separate descriptions

BGS core no: 59–14 /10*

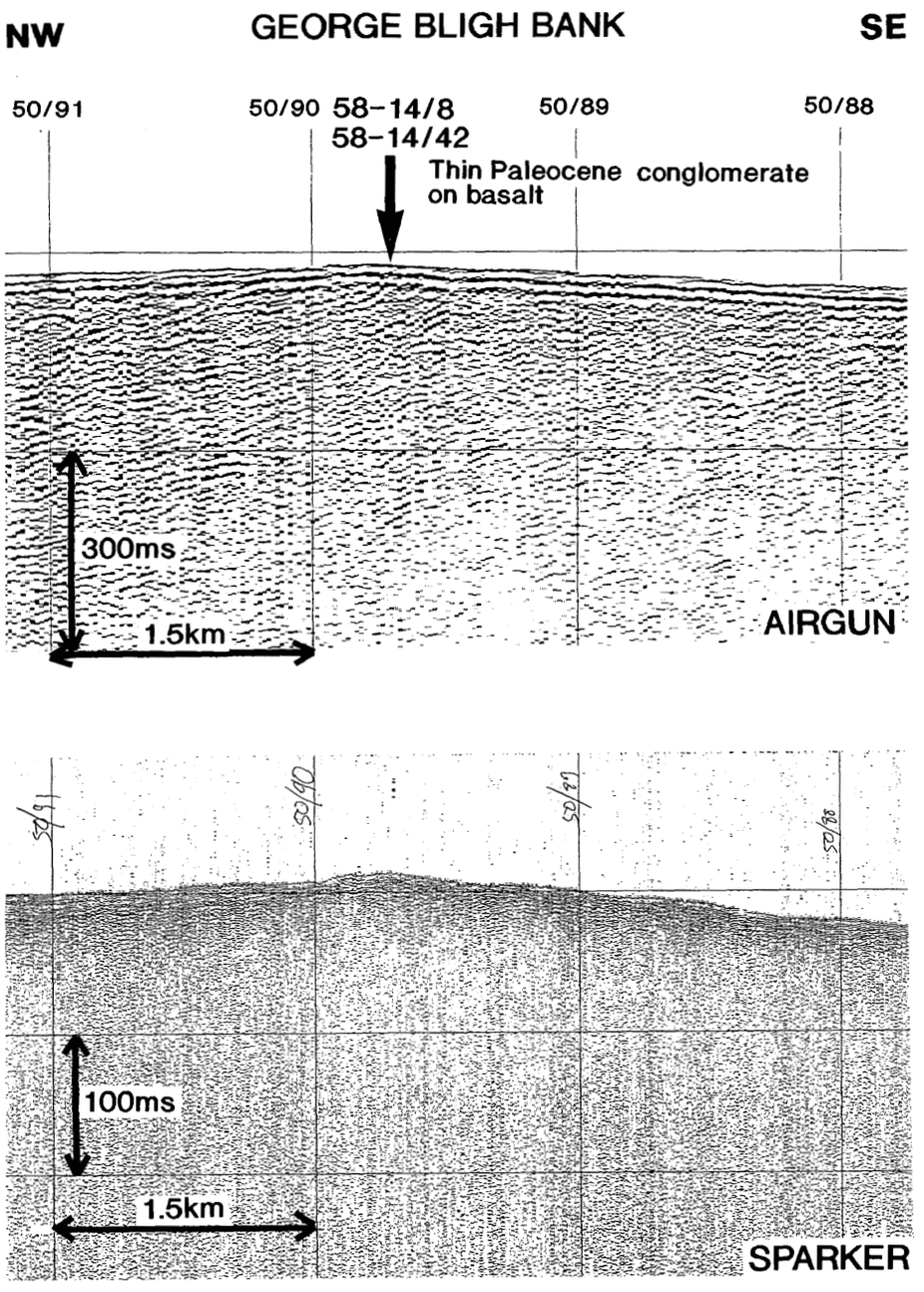
Original site no: S6

T.D. metres: 5.12

Recovery %: 38



58-14/8
58-14/42
(S7)



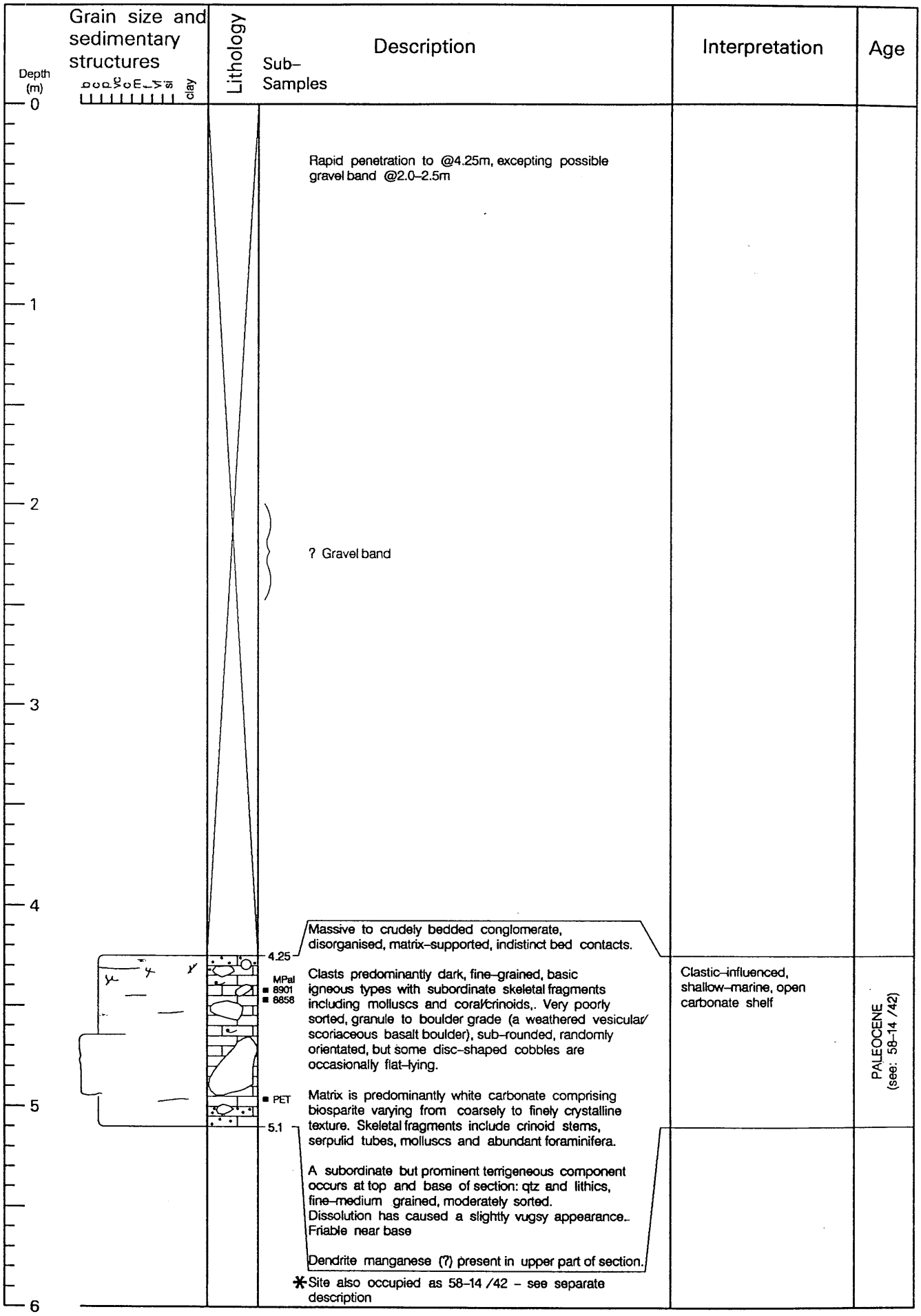
BGS no: 58-14/8
58-14/42
Original site no: S7
Location: Top of George Bligh Bank
Latitude: 58° 57.74' N
Longitude: 13° 45.51' W } 58-14/42
Water depth: 438m

BGS core no: 58–14 /8*

Original site no: S7

T.D. metres: 5.1

Recovery %: 17

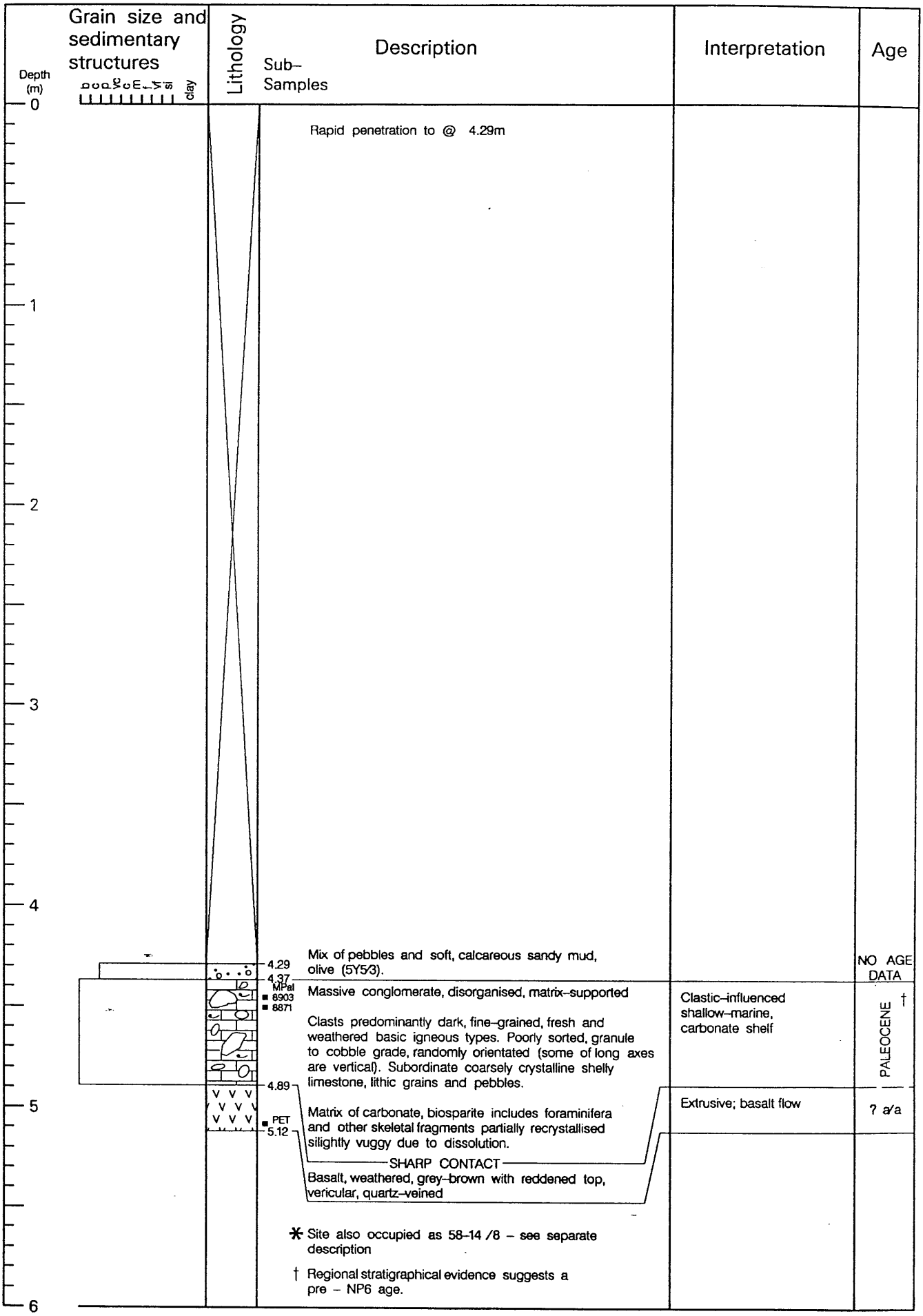


BGS core no: 58–14 /42*

Original site no: S7

T.D. metres: 5.12

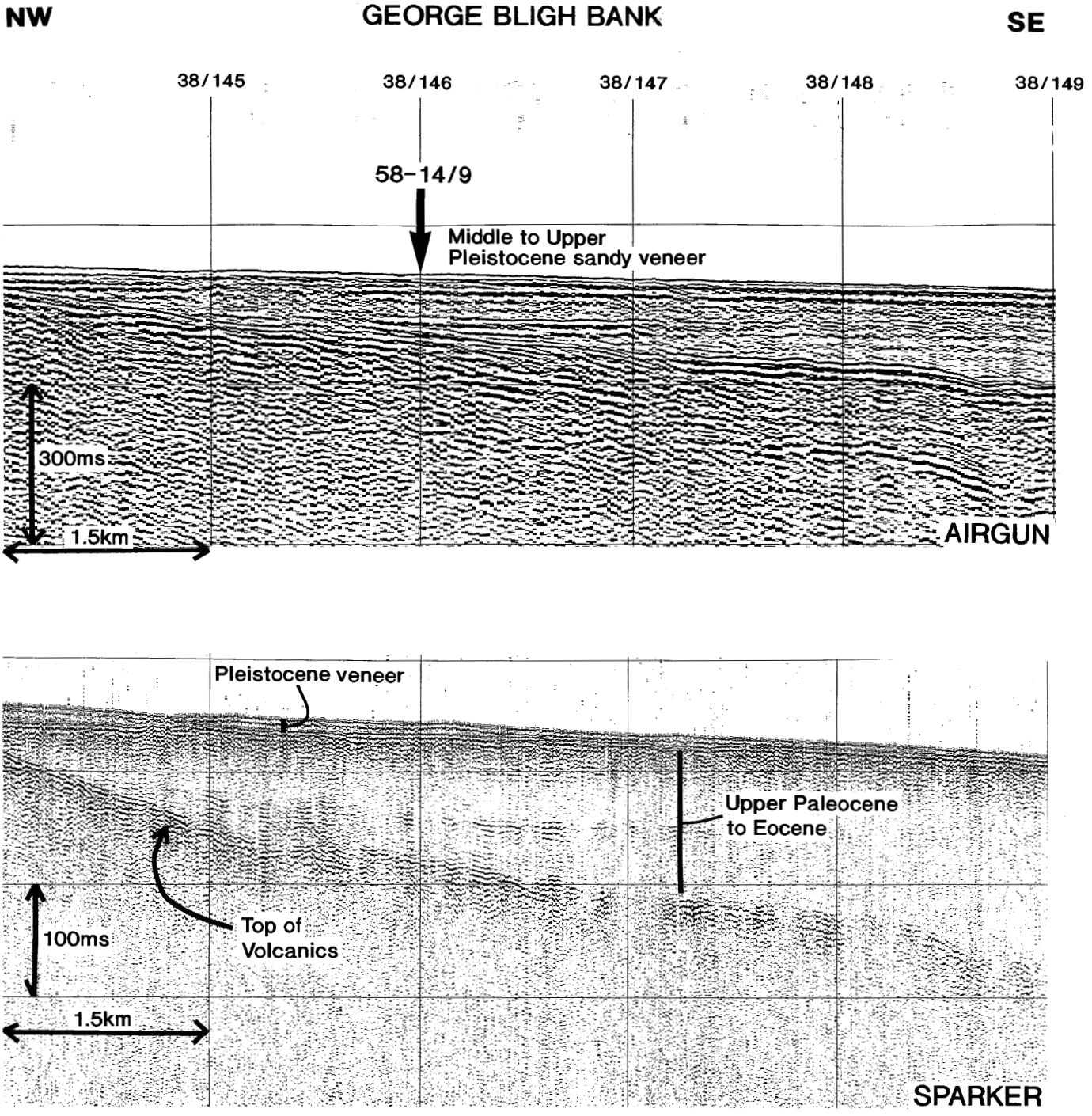
Recovery %: 83



* Site also occupied as 58–14 /8 – see separate description

† Regional stratigraphical evidence suggests a pre – NP6 age.

59-14/9
(S8)



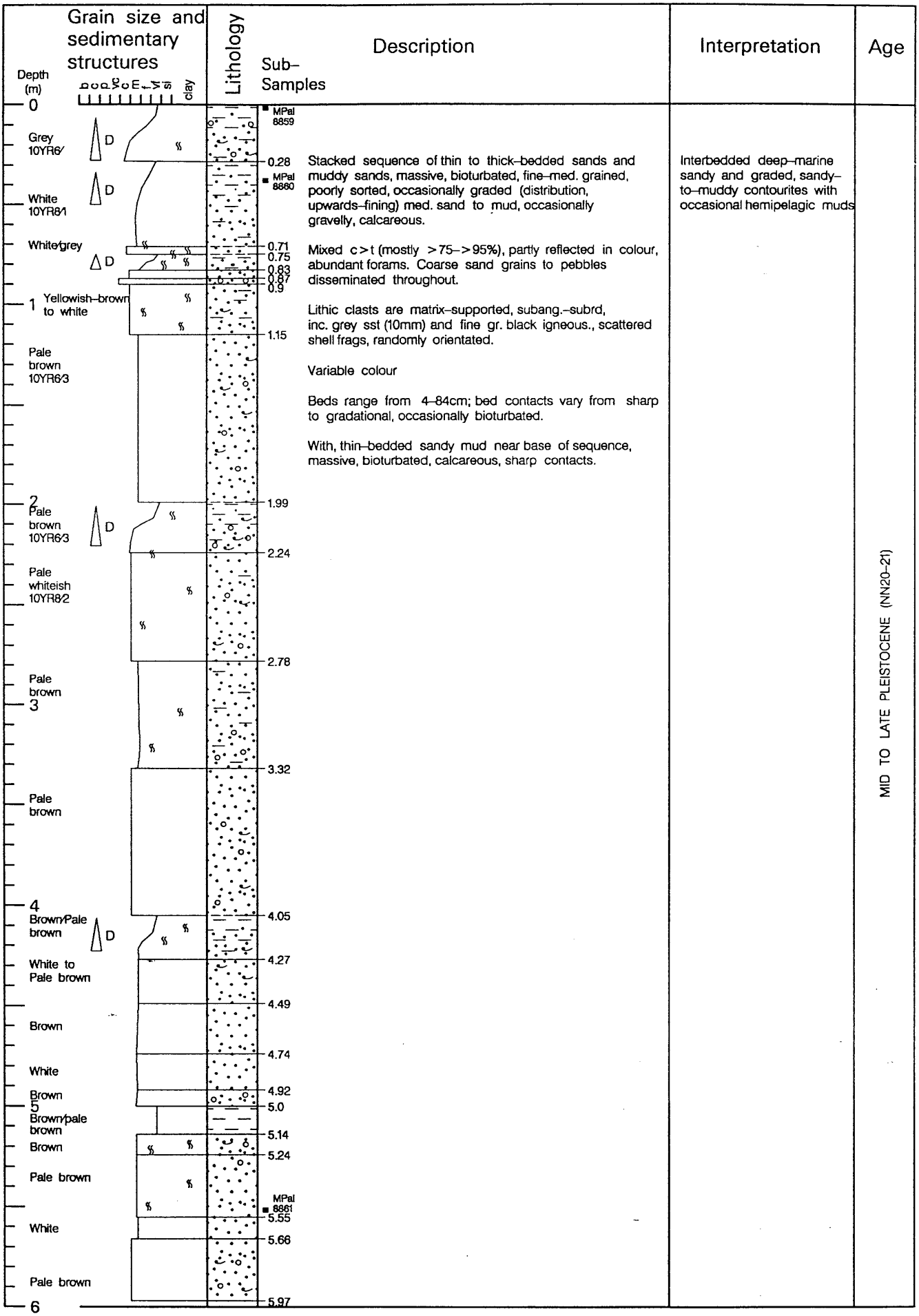
BGS no: 58-14/9
Original site no: S8
Location: Top of George Bligh Bank
Latitude: 58° 53.11' N
Longitude: 13° 43.04 W
Water depth: 484m

BGS core no: 58–14 /9

Original site no: S8

T.D. metres: 5.97

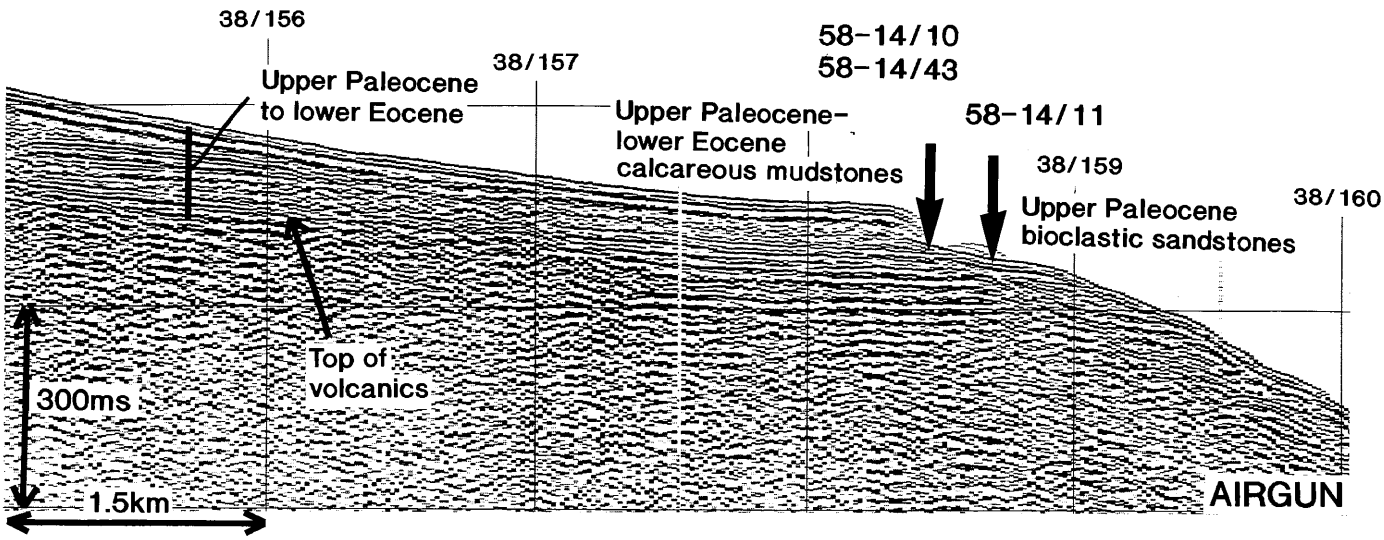
Recovery %: 100

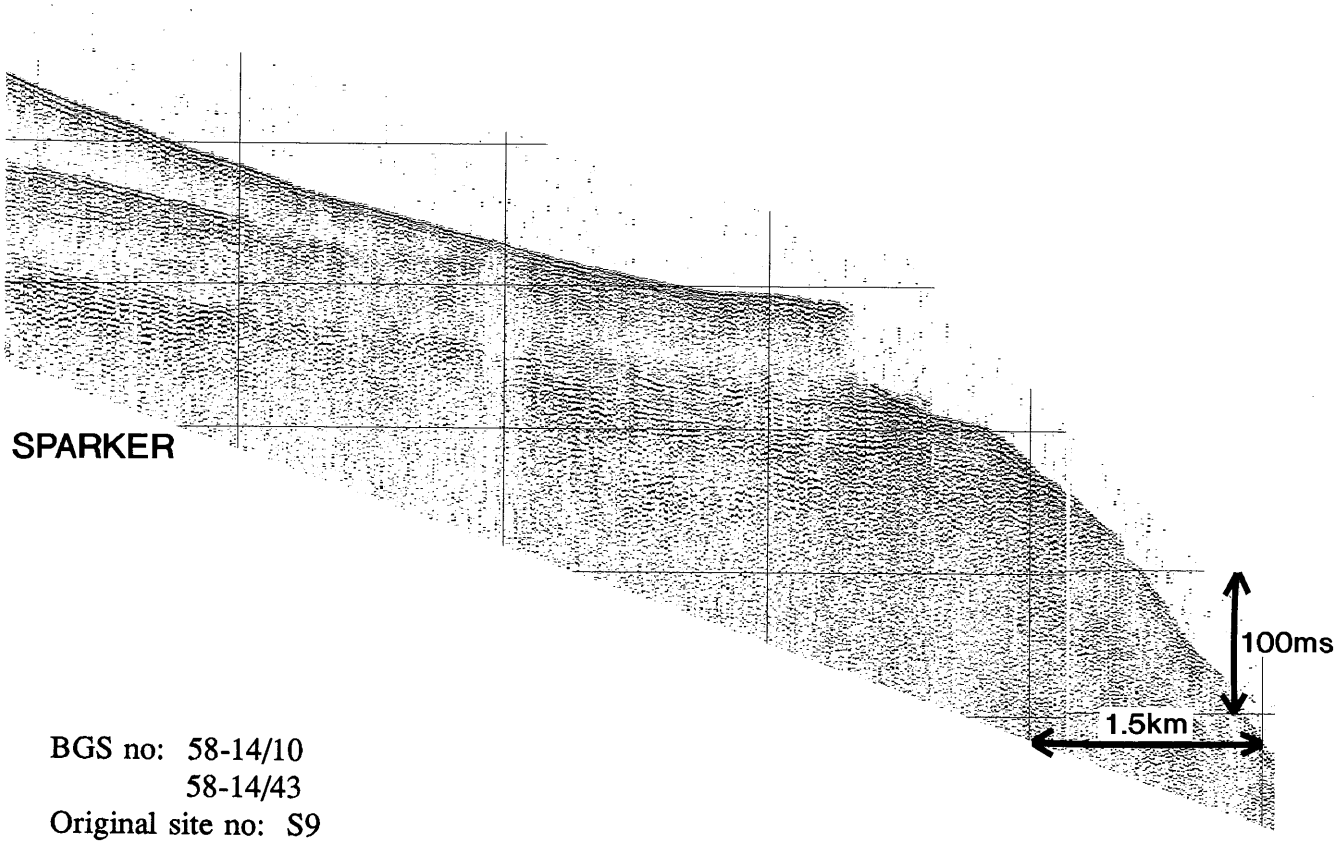


58-14/10 & 43
(S9)

58-14/11
(S10)

NW GEORGE BLIGH BANK SE





BGS no: 58-14/10
58-14/43
Original site no: S9

Latitude: 58° 46.76' N
Longitude: 13° 13.30' W } 58-14/10
Water depth: 1014m

Latitude: 58° 46.75' N
Longitude: 13° 30.24' W } 58-14/43
Water depth: 1028m

BGS no: 58-14/11
Original site no: S10
Latitude: 58° 46.62' N
Longitude: 13° 30.05' W
Water depth: 1033m

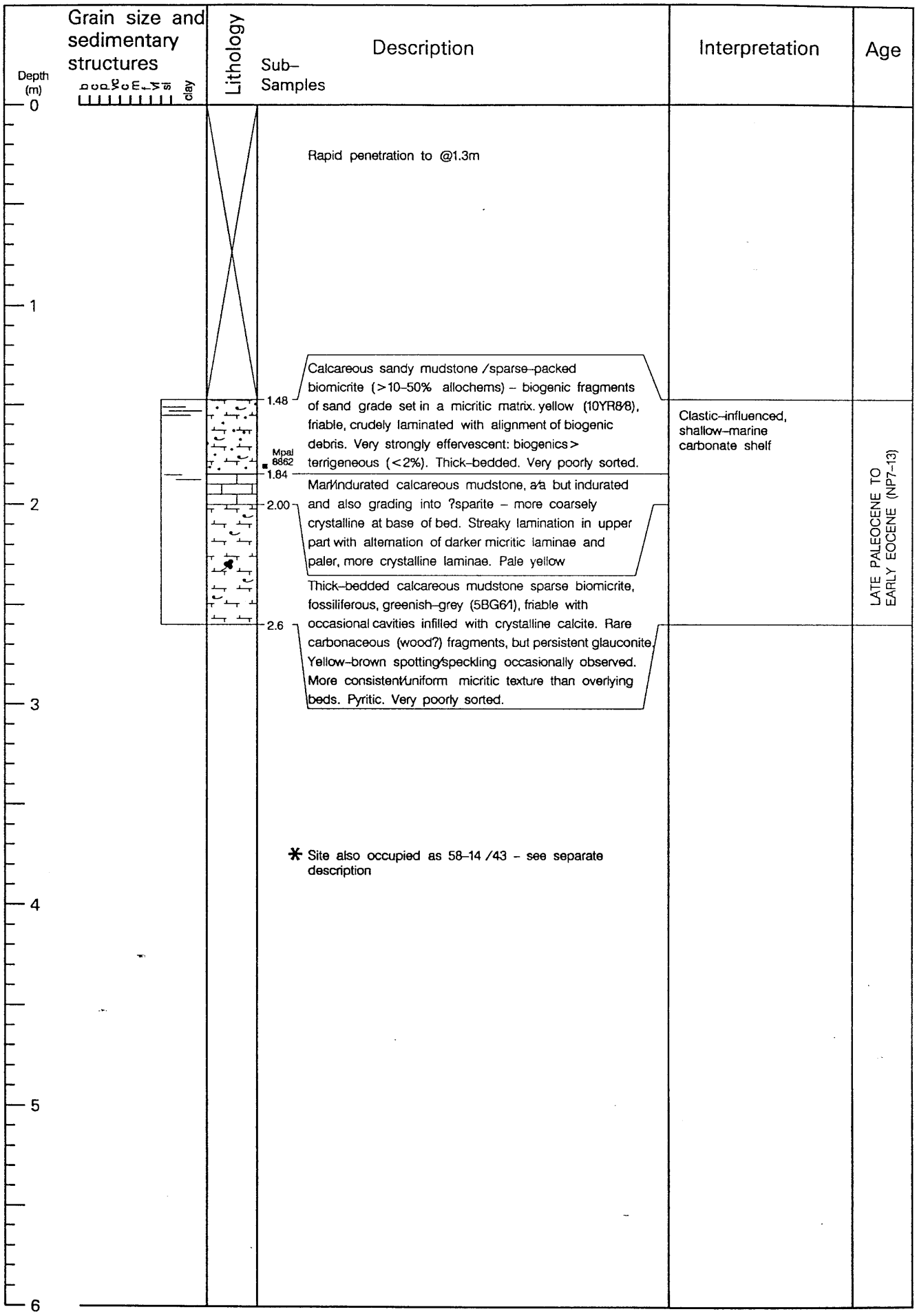
Location: Eastern flank of George Bligh Bank

BGS core no: 58–14 /10*

Original site no: S9

T.D. metres: @2.6

Recovery %: 43



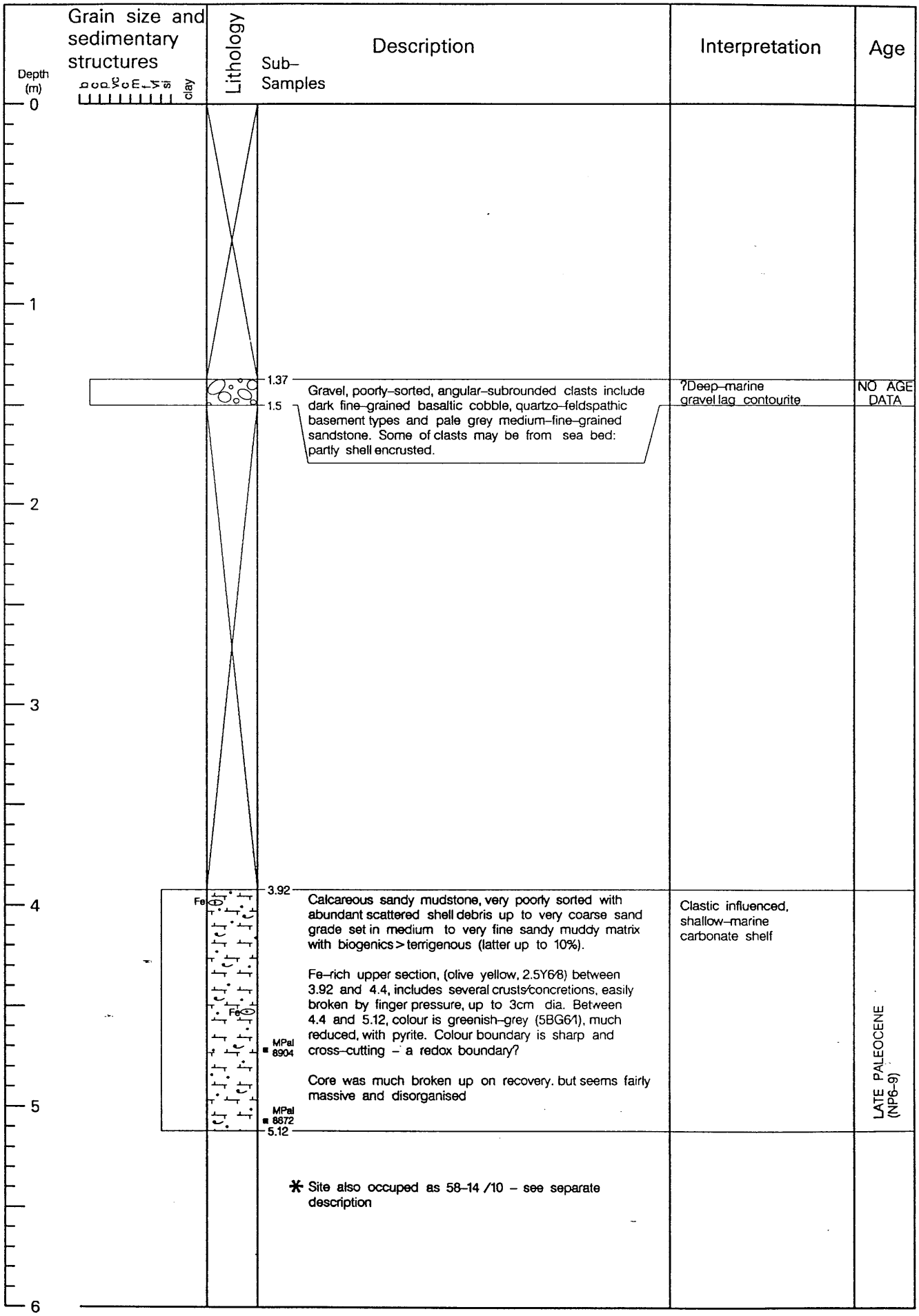
* Site also occupied as 58–14 /43 – see separate description

BGS core no: 58–14 /43*

Original site no: S9

T.D. metres: 5.12

Recovery %: 26

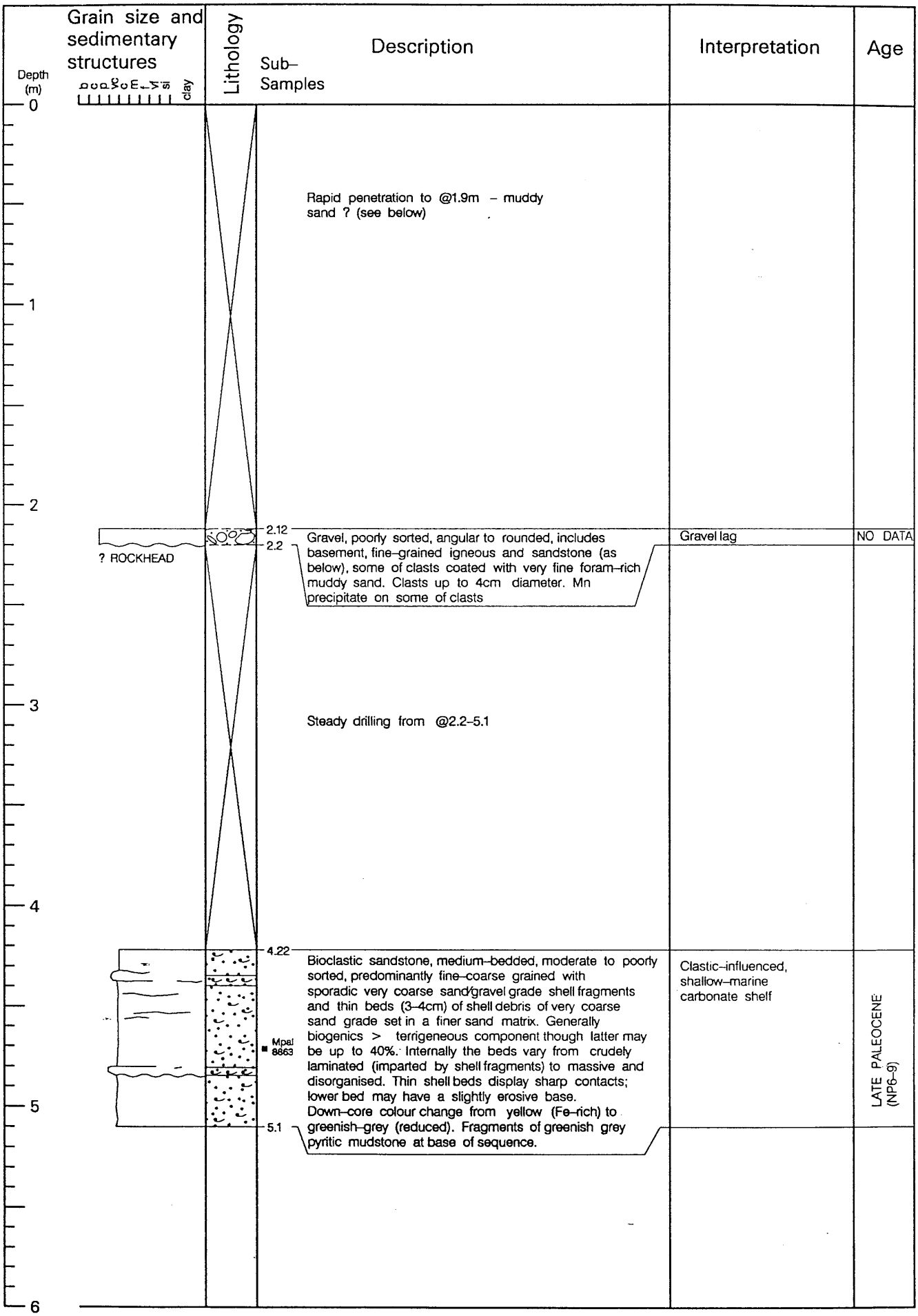


BGS core no: 58–14 /11

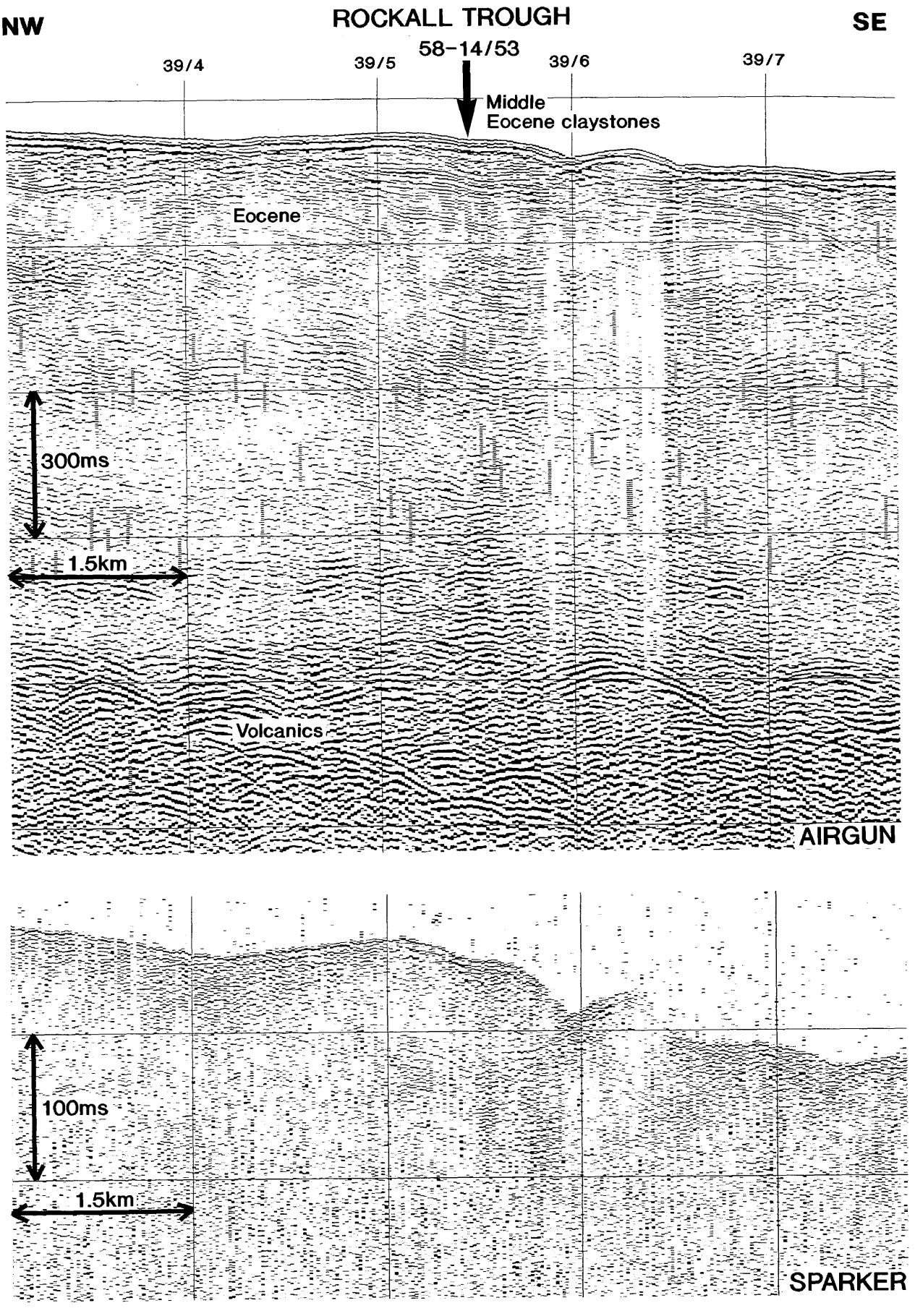
Original site no: S10

T.D. metres: @5.1

Recovery %: 19



58-14/53
(S11)



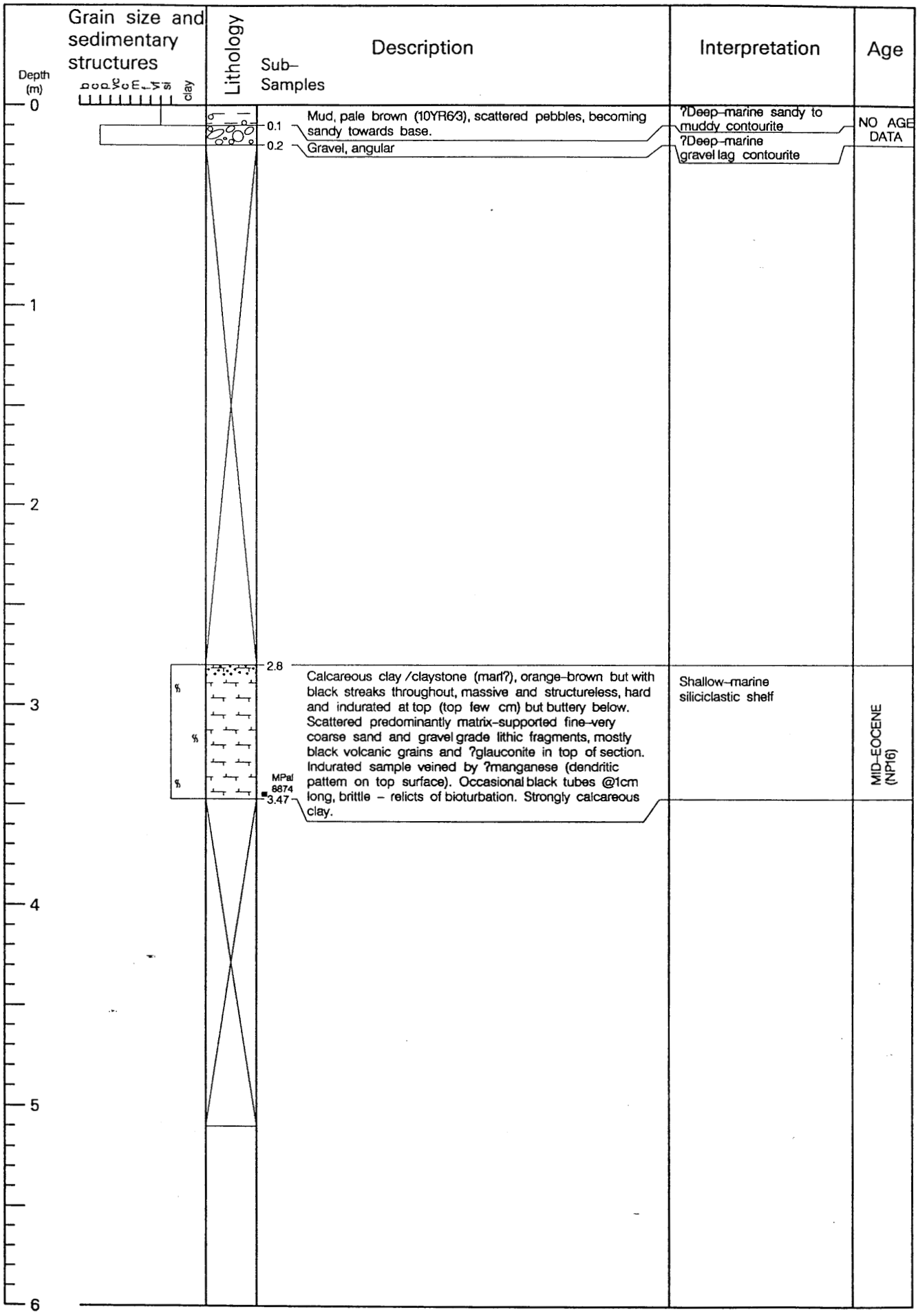
BGS no: 58-14/53
Original site no: S11
Location: North-west Rockall Trough
Latitude: 58° 37.36' N
Longitude: 13° 11.62' W
Water depth: 1595m

BGS core no: 58–14 /53

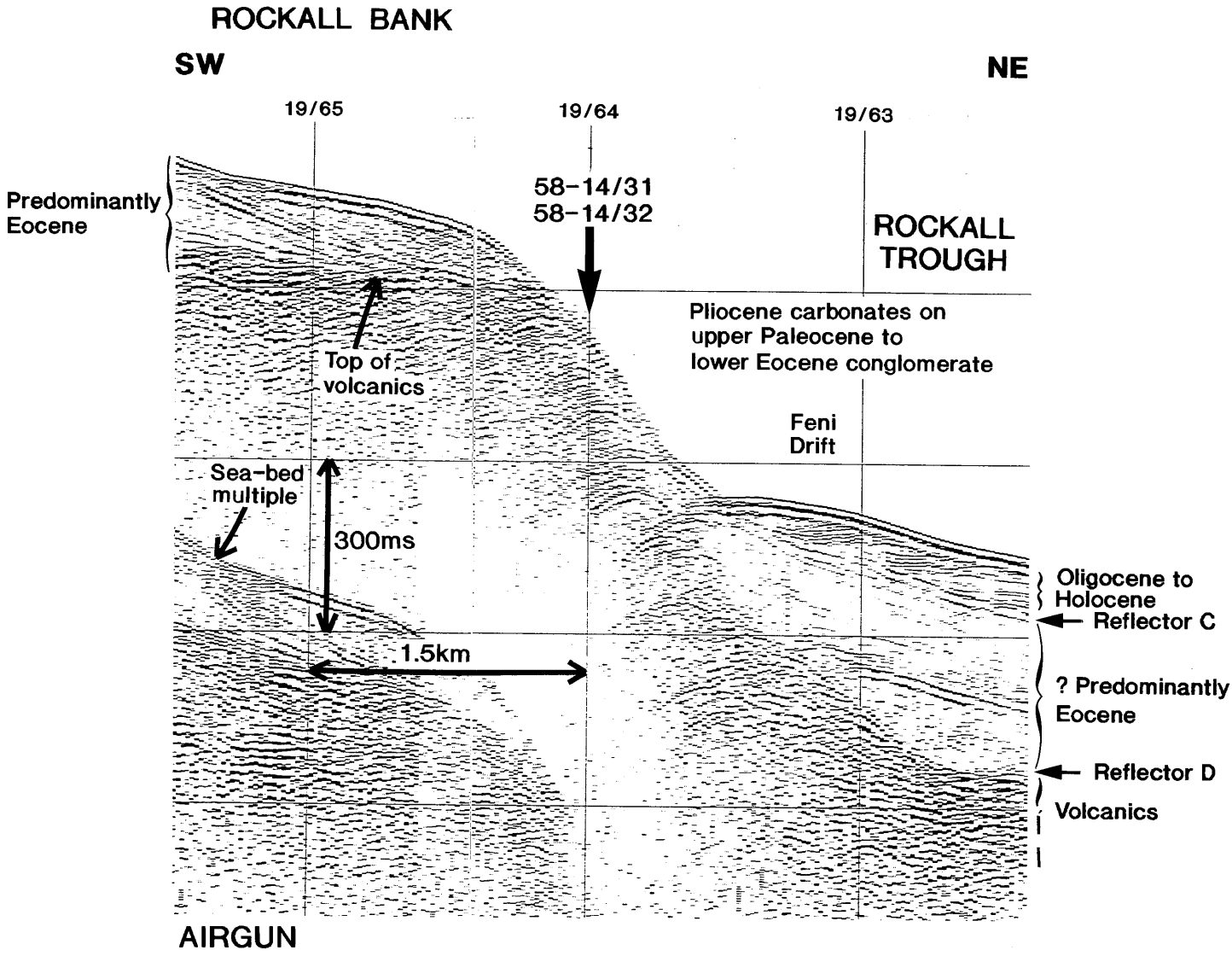
Original site no: S11

T.D. metres: 5.1

Recovery %: 17



58-14/31 & 32
(S12)



BGS no: 58-14/31
58-14/32
Original site no: S12
Location: North-east slope of Rockall Bank

Latitude: 58° 20.52' N	58-14/31	Latitude: 58° 20.52' N	58-14/32
Longitude: 13° 48.81' W		Longitude: 13° 48.80' W	

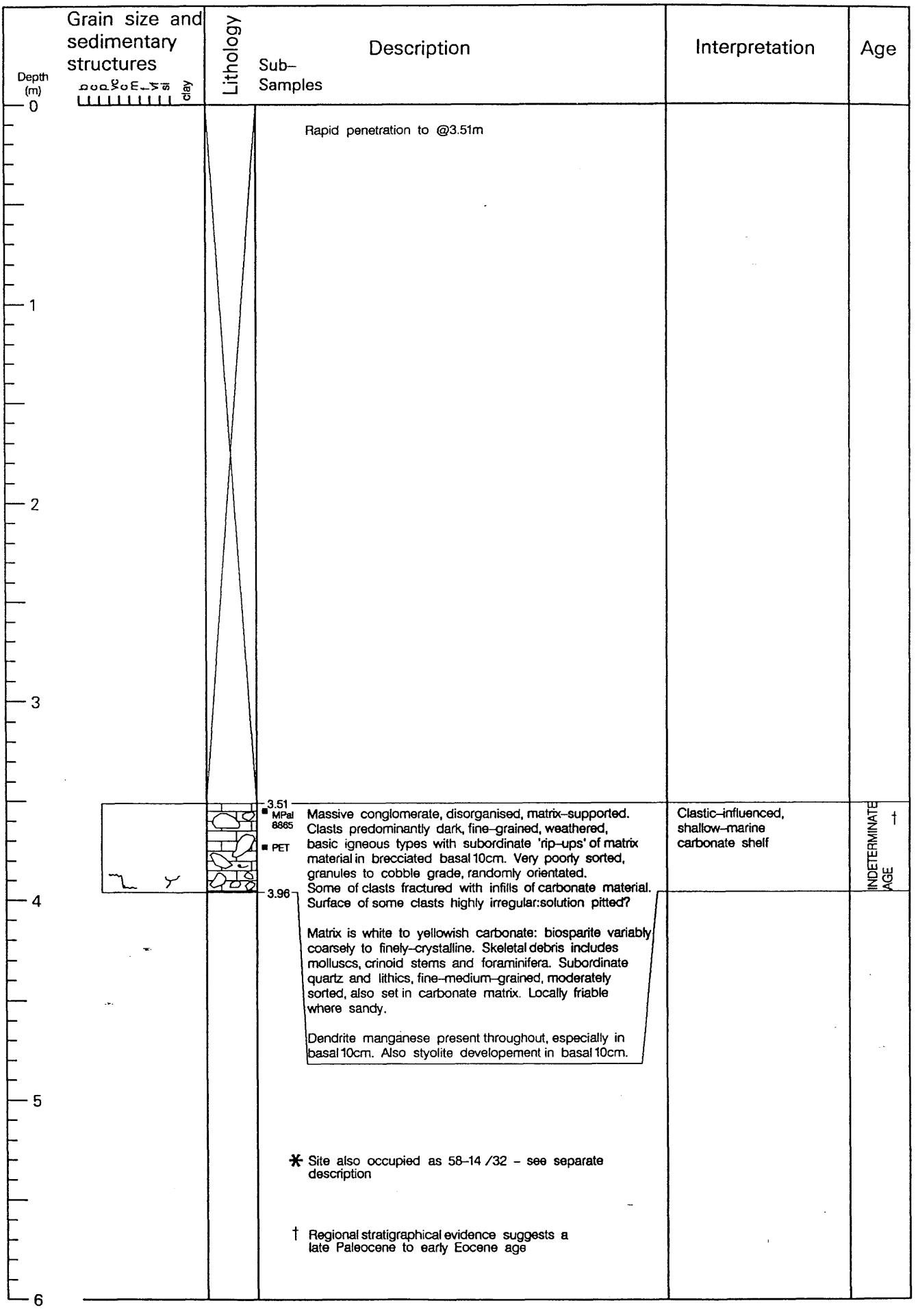
Water depth: 705m

BGS core no: 58–14 /31*

Original site no: S12

T.D. metres: 3.96

Recovery %: 12

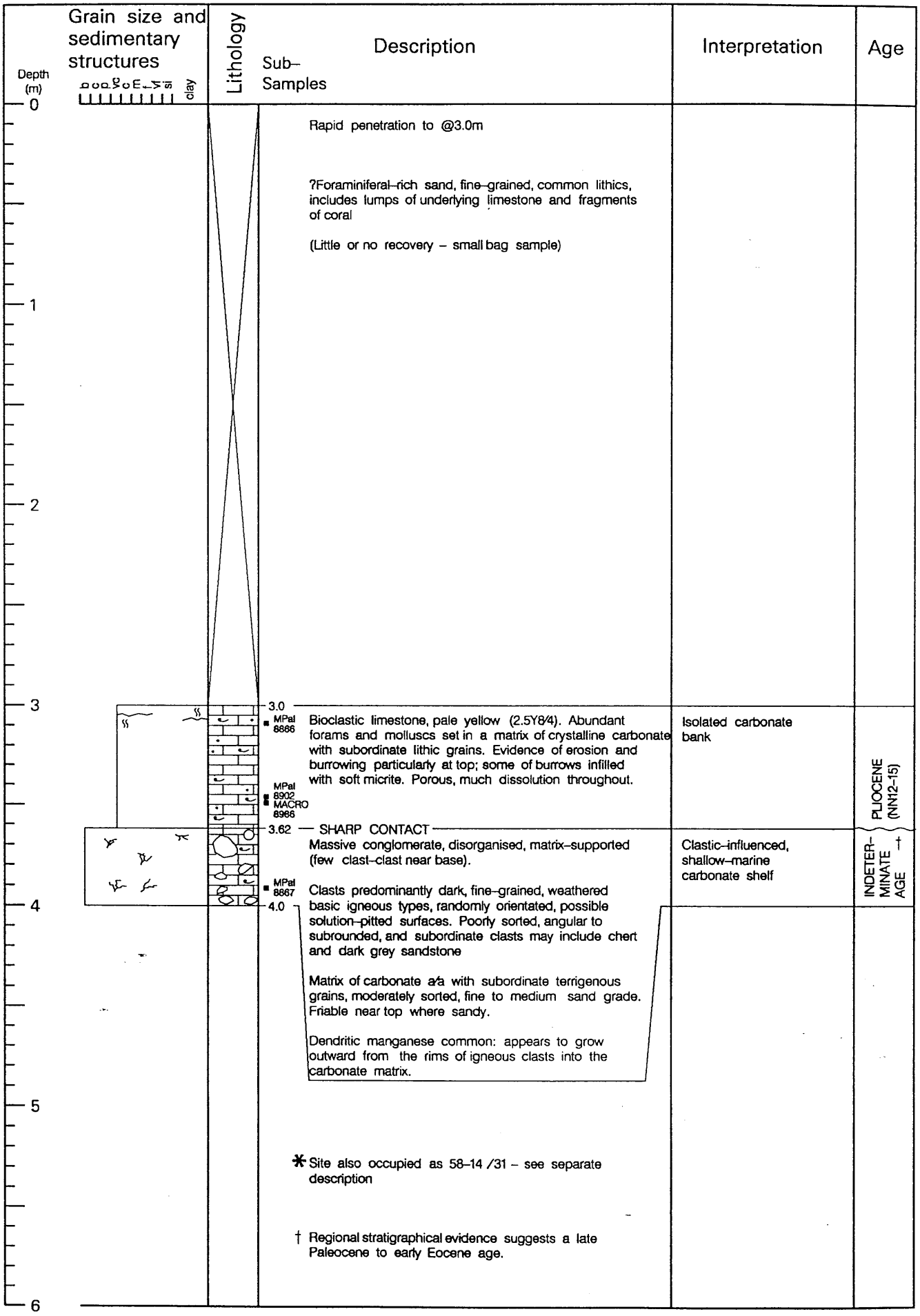


BGS core no: 58–14 /32*

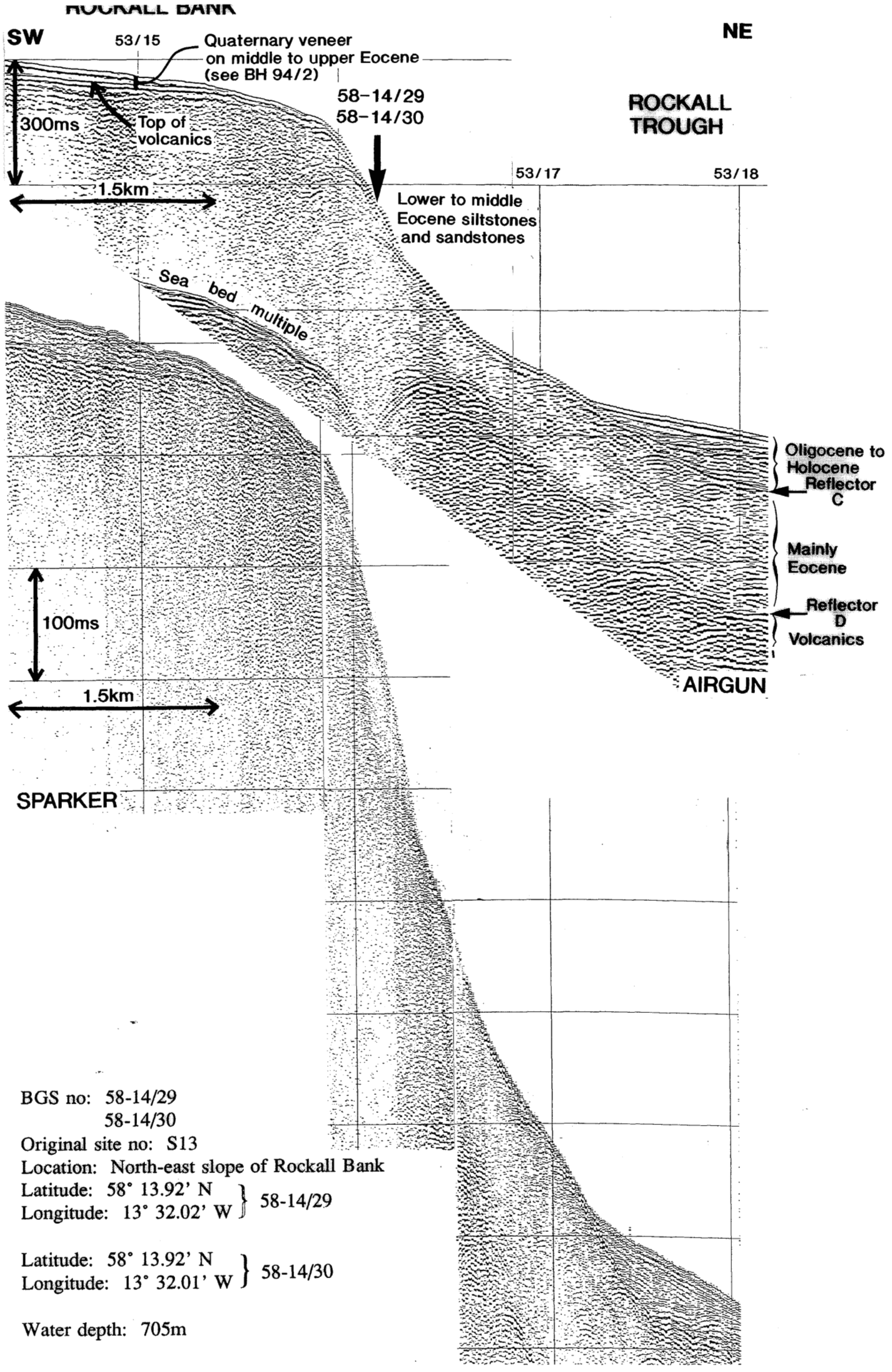
Original site no: S12

T.D. metres: 4.0

Recovery %: 25



58-14/29 & 30
(S13)



BGS no: 58-14/29
58-14/30
Original site no: S13
Location: North-east slope of Rockall Bank
Latitude: 58° 13.92' N } 58-14/29
Longitude: 13° 32.02' W }

Latitude: 58° 13.92' N } 58-14/30
Longitude: 13° 32.01' W }

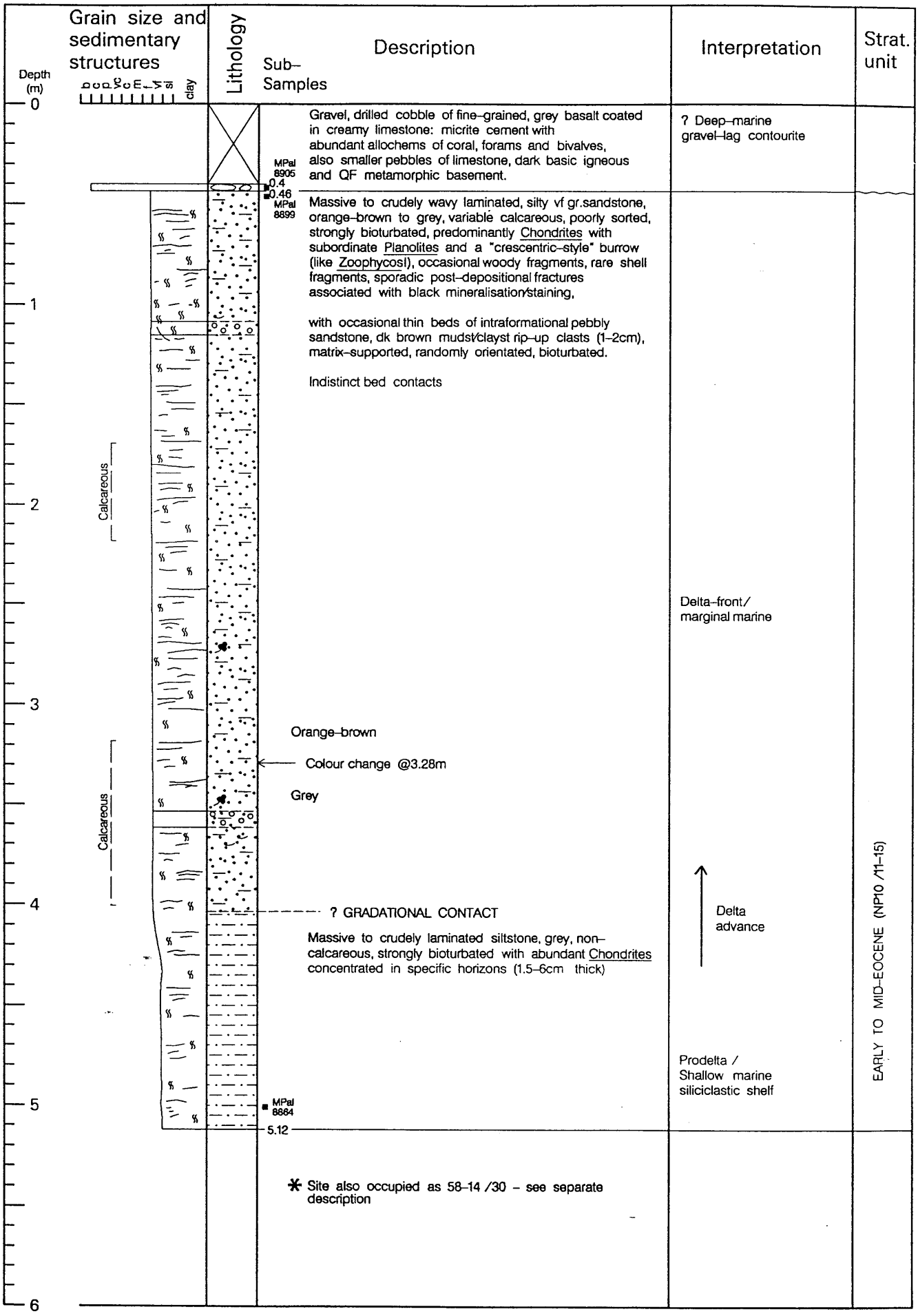
Water depth: 705m

BGS core no: 58–14 /29*

Original site no: S13

T.D. metres: 5.12

Recovery %: 93



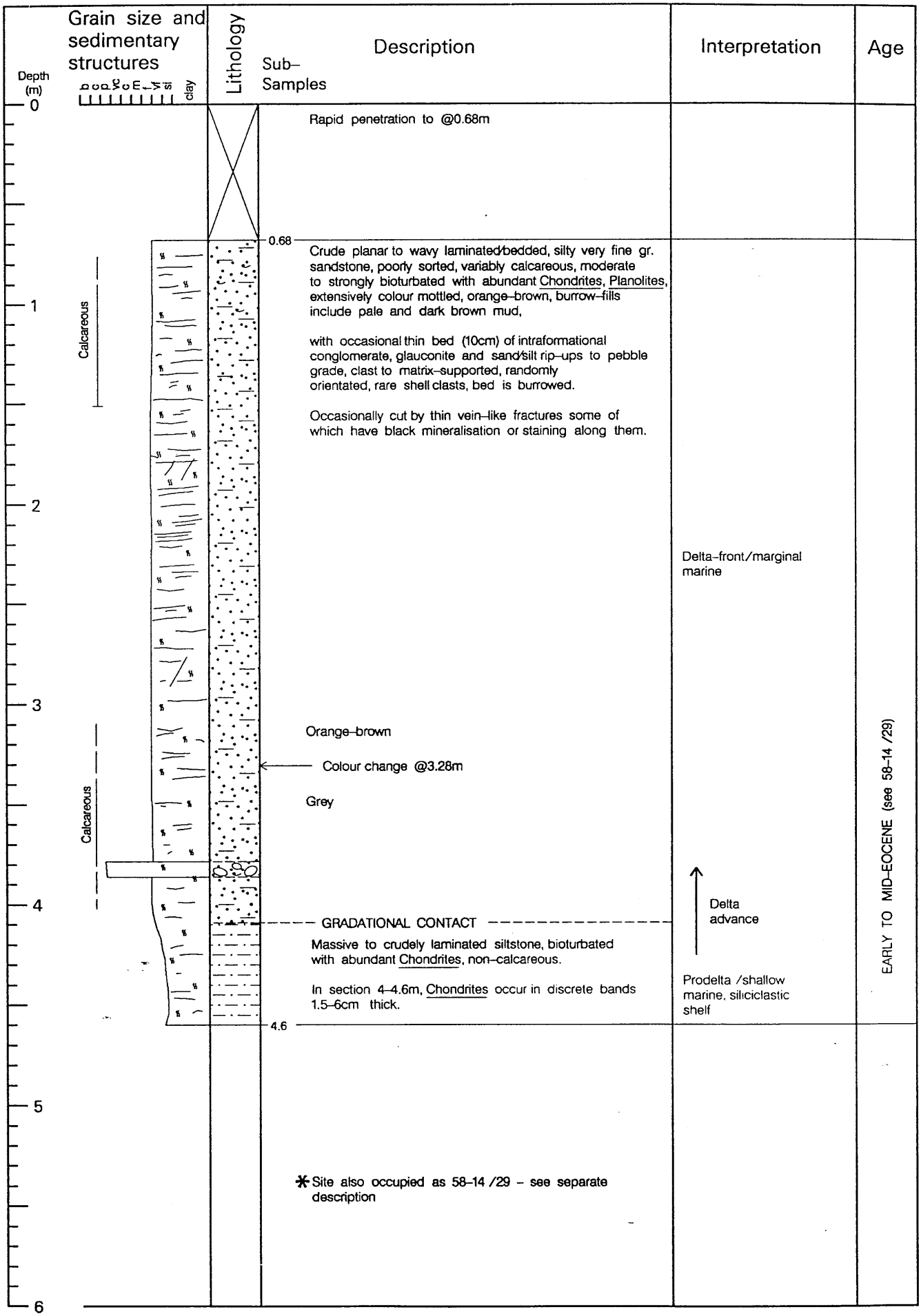
* Site also occupied as 58–14 /30 – see separate description

BGS core no: 58–14 /30*

Original site no: S13

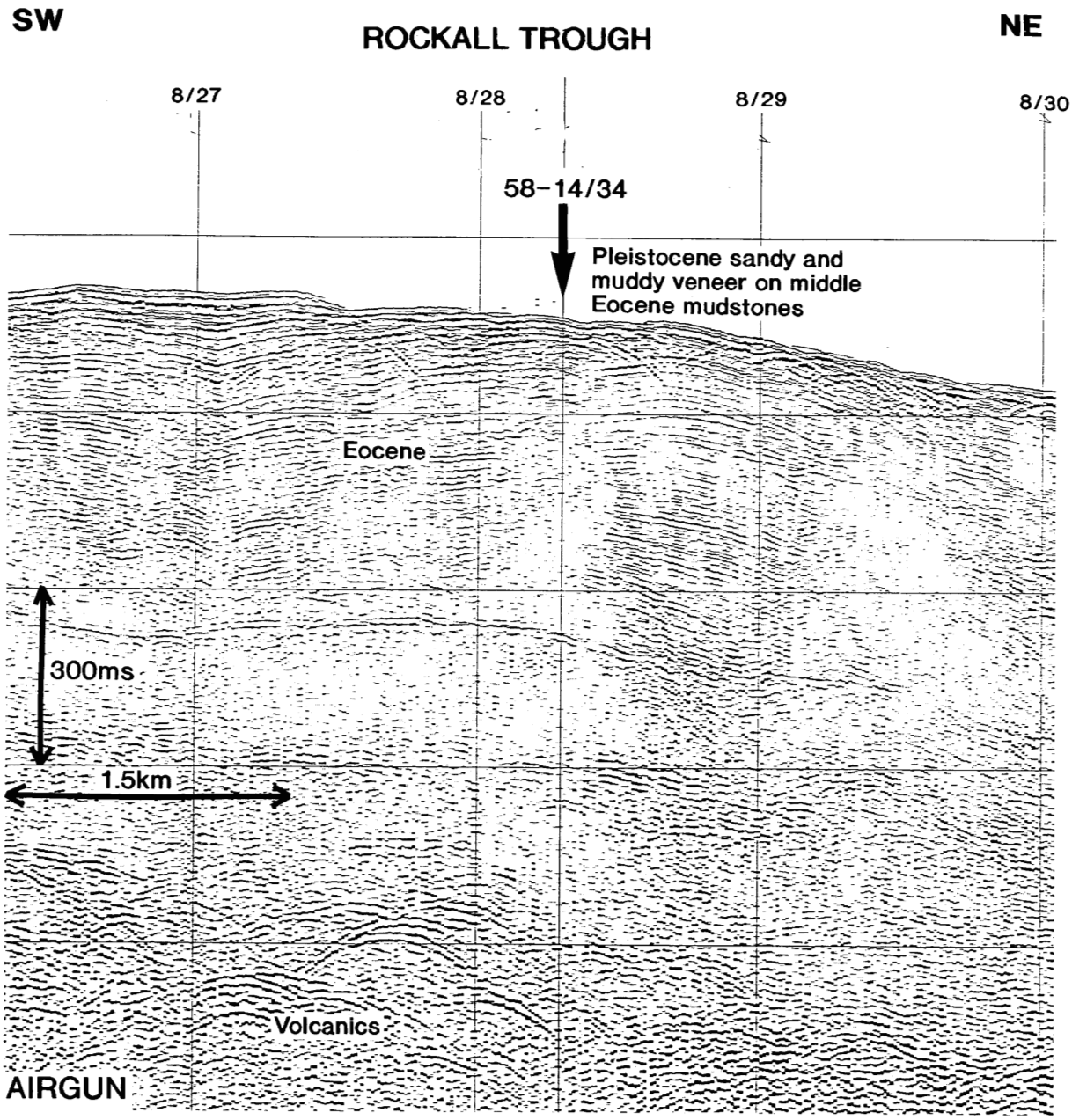
T.D. metres: 4.6

Recovery %: 85



*Site also occupied as 58–14 /29 – see separate description

58-14/34
(S14)



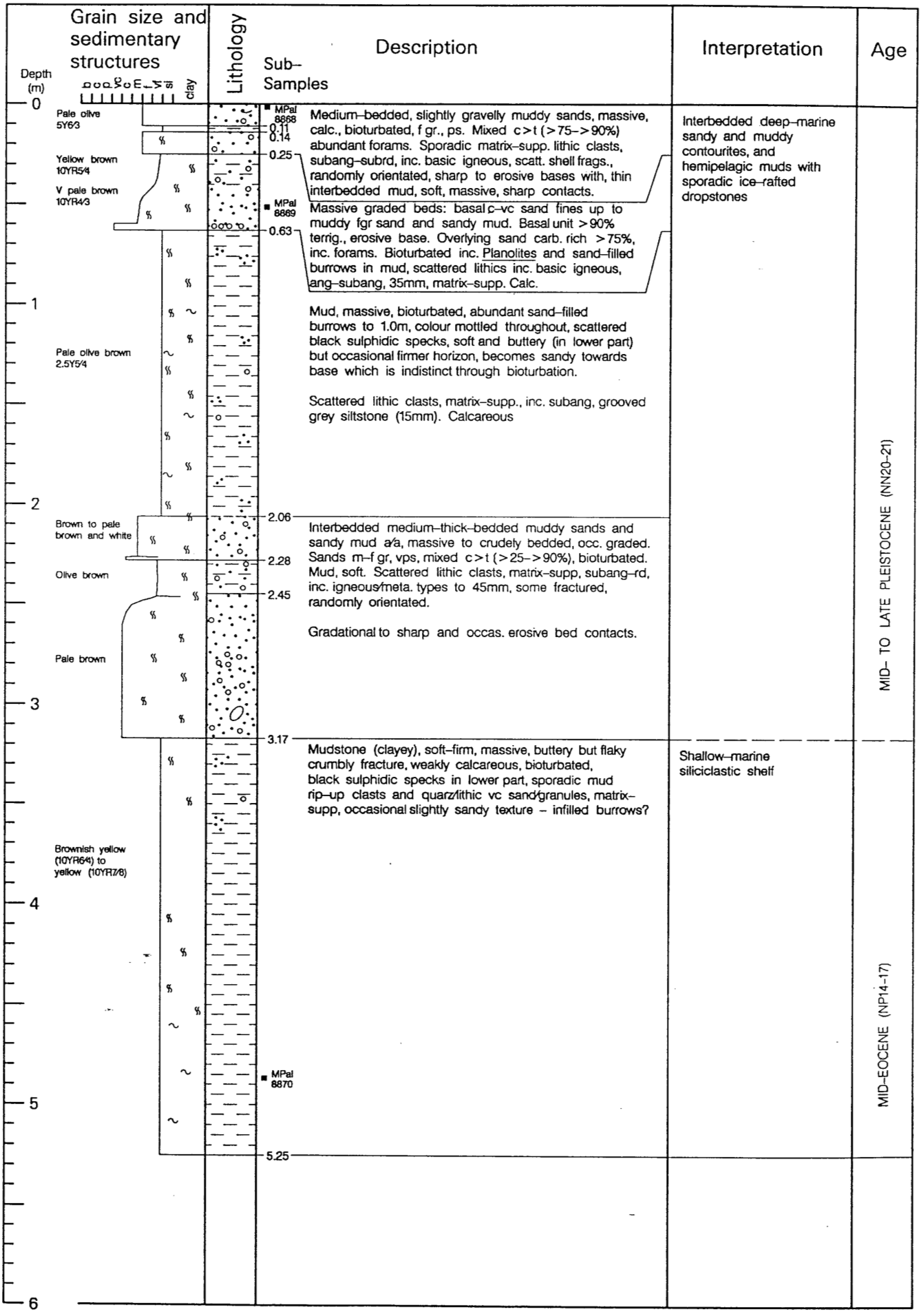
BGS no: 58-14/34
Original site no: S14
Location: North-west Rockall Trough
Latitude: 58° 16.51' N
Longitude: 13° 05.11' W
Water depth: 1486m

BGS core no: 58–14 /34

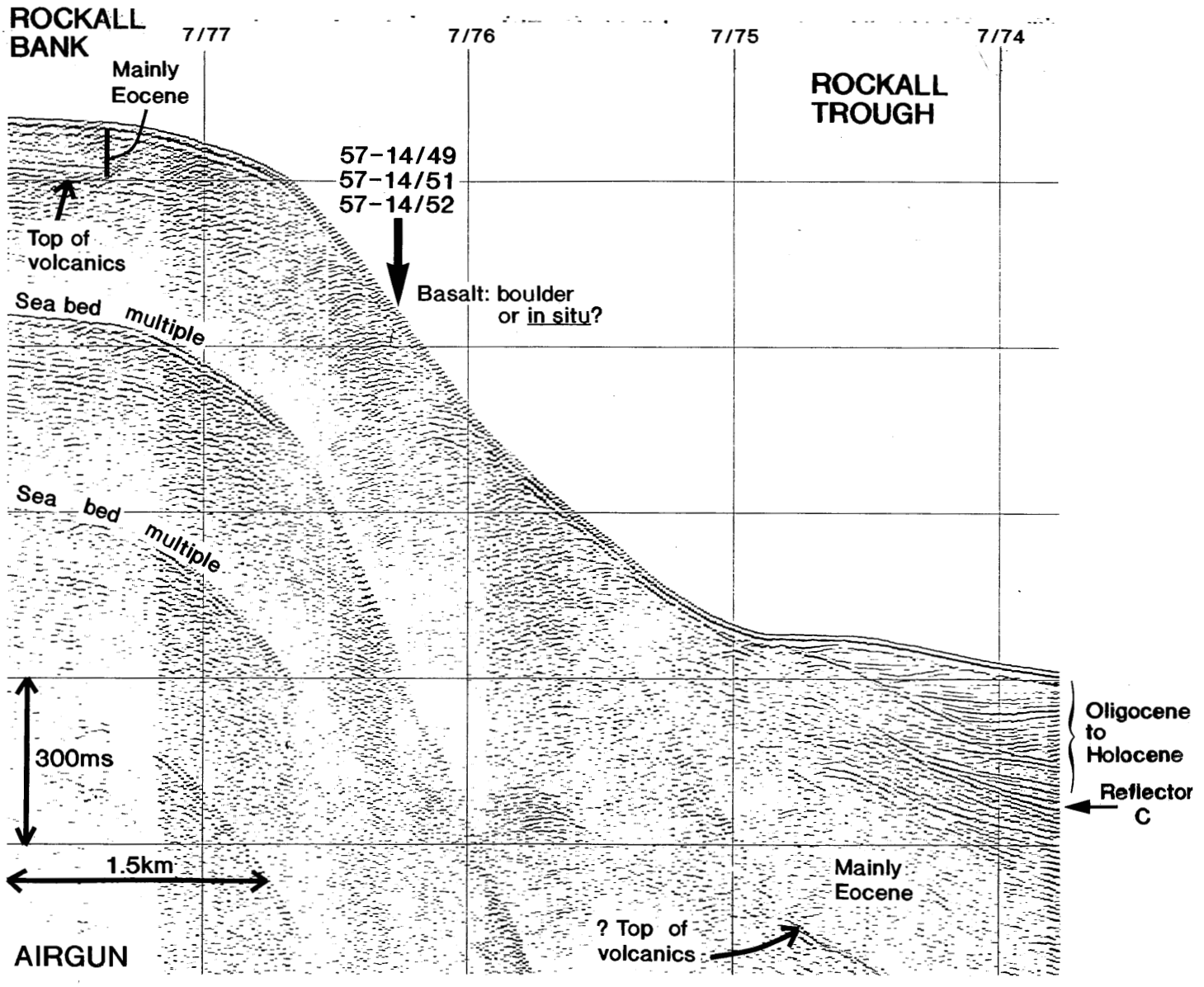
Original site no: S14

T.D. metres: 5.25

Recovery %: 100



57-14/49,51,52
(S15)



BGS no: 57-14/29*
57-14/51*
57-14/52
Original site no: S15
Location: North-east slope of Rockall Bank
Latitude: 57° 57.19' N
Longitude: 13° 04.34' W } 57-14/52
Water depth: 531m

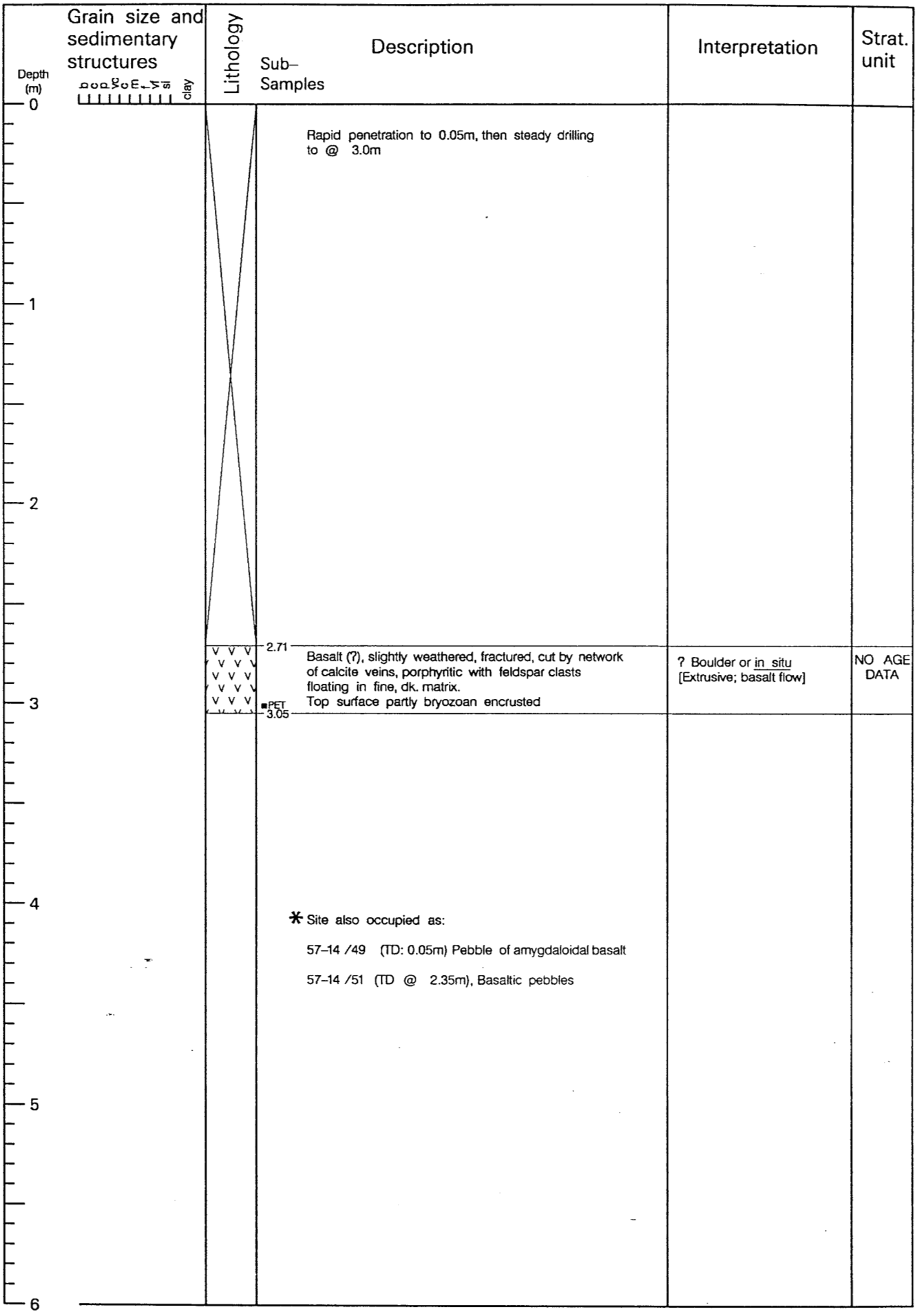
* Poor Recovery

BGS core no: 57–14 /52*

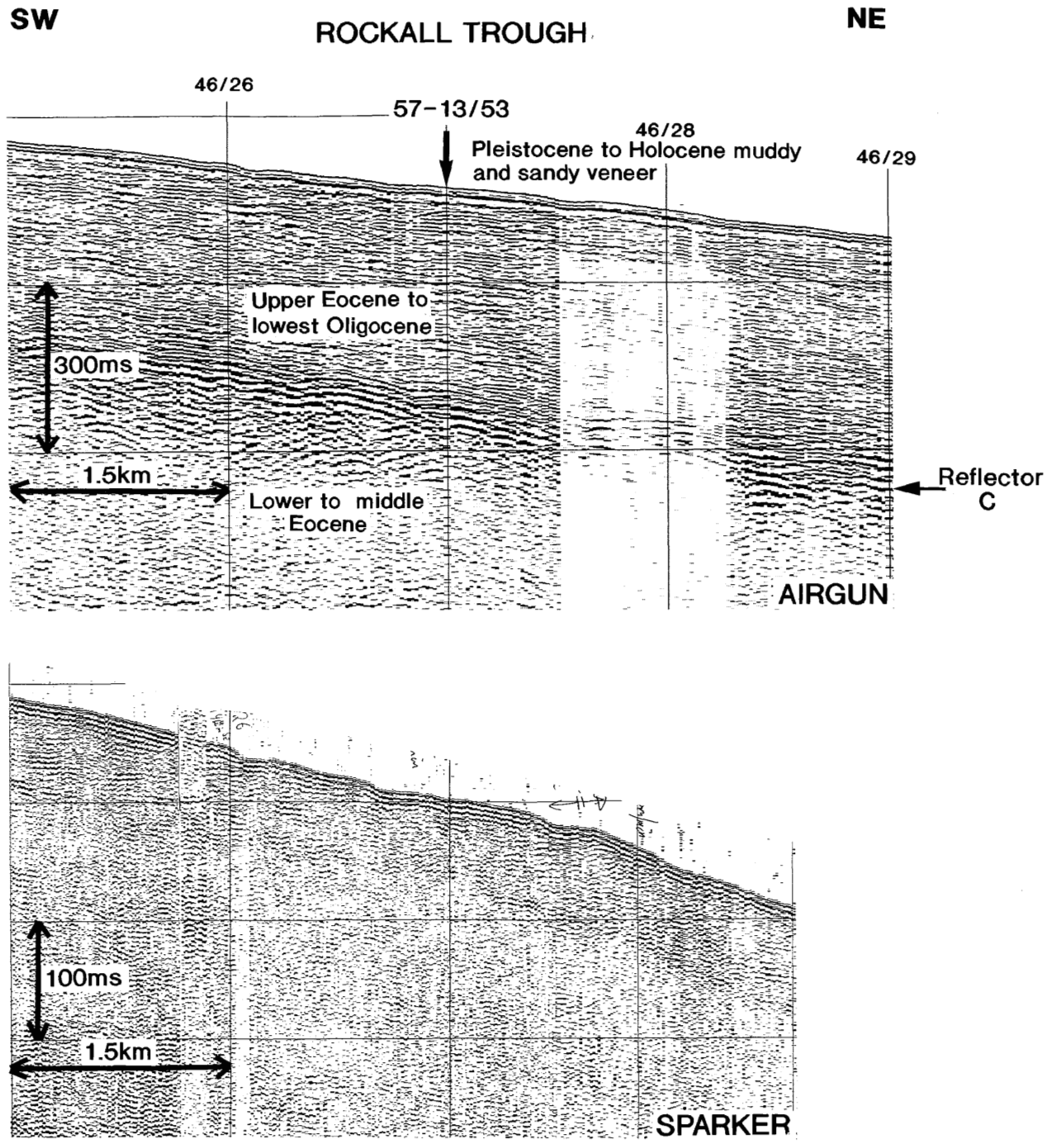
Original site no: S15

T.D. metres: 3.05

Recovery %: 12



57-13/53
(S16)



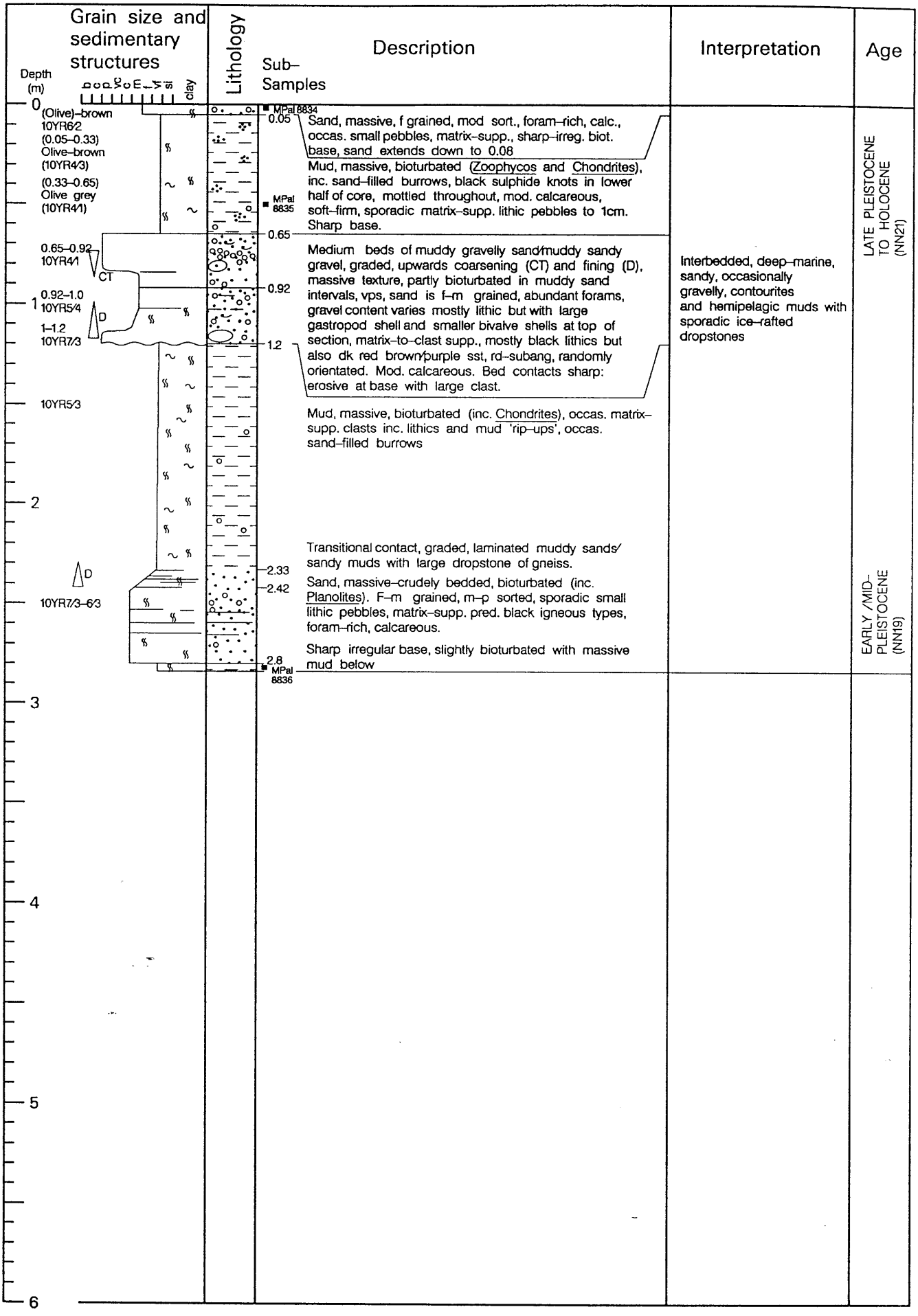
BGS no: 57-13/53
Original site no: S16
Location: North-west Rockall Trough
Latitude: 57° 54.22' N
Longitude: 12° 43.95' W
Water depth: 1480m

BGS core no: 57–13 /53

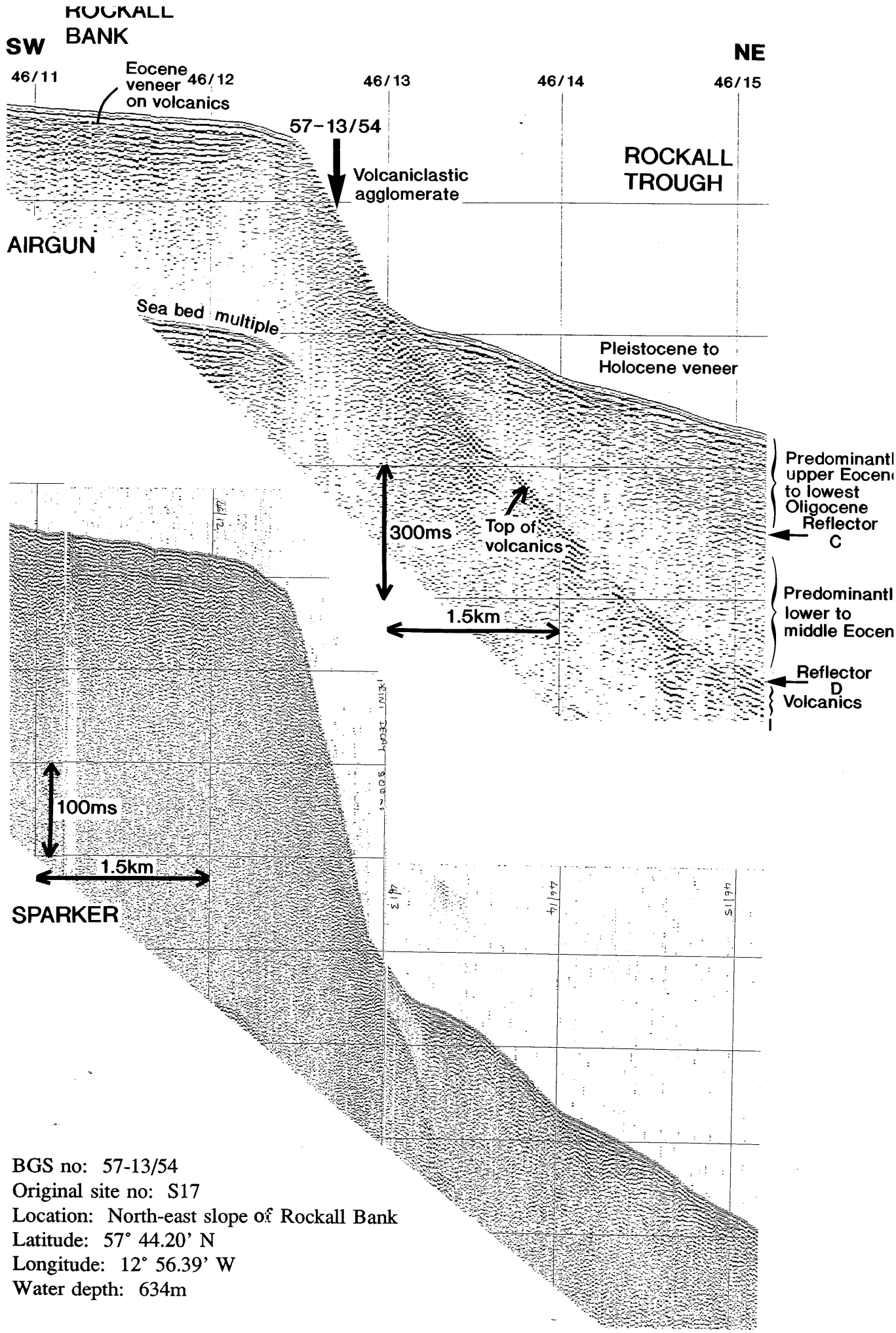
Original site no: S16

T.D. metres: 2.84

Recovery %: 100



57-13/54
(S17)



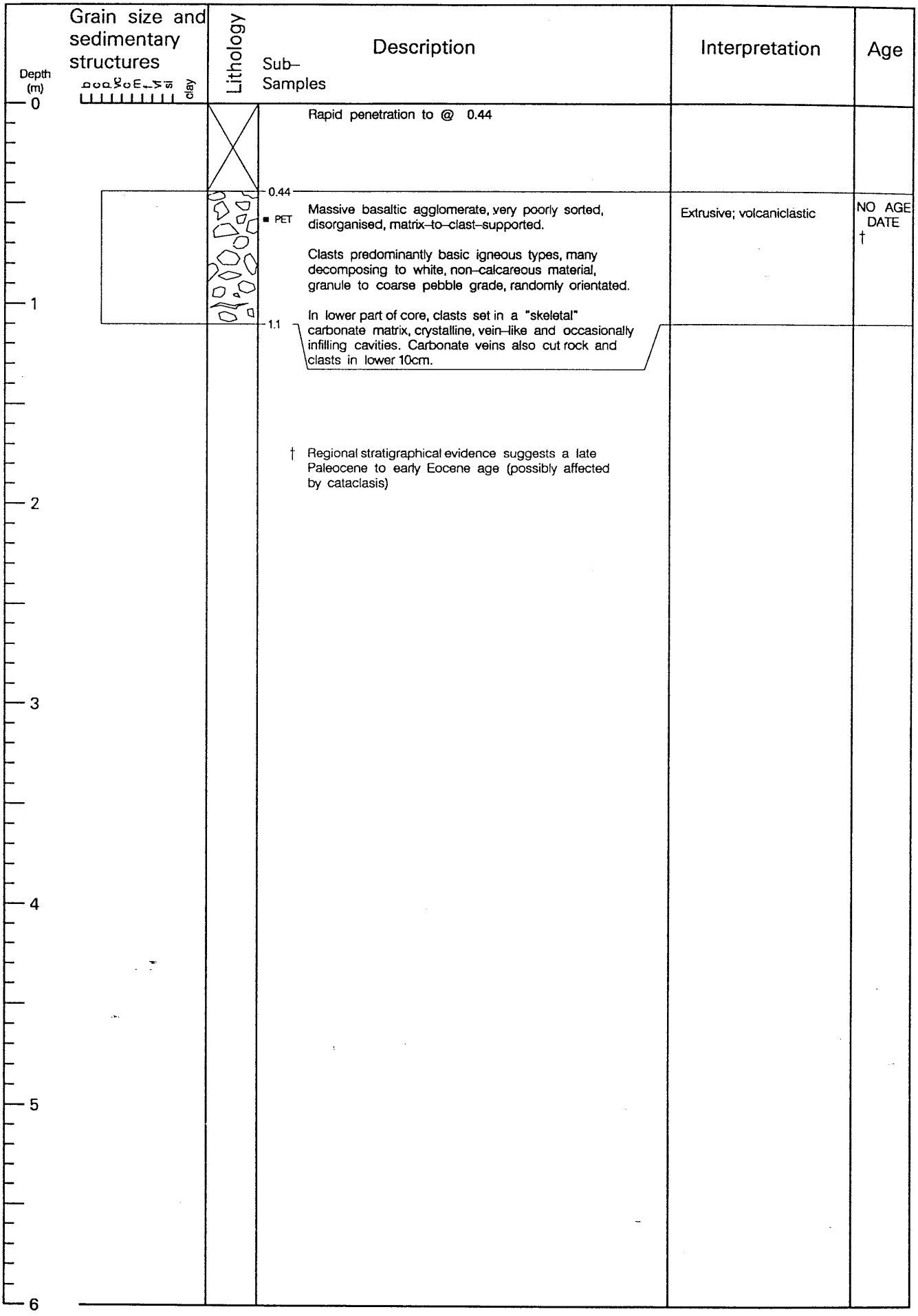
BGS no: 57-13/54
Original site no: S17
Location: North-east slope of Rockall Bank
Latitude: 57° 44.20' N
Longitude: 12° 56.39' W
Water depth: 634m

BGS core no: 57–13 /54

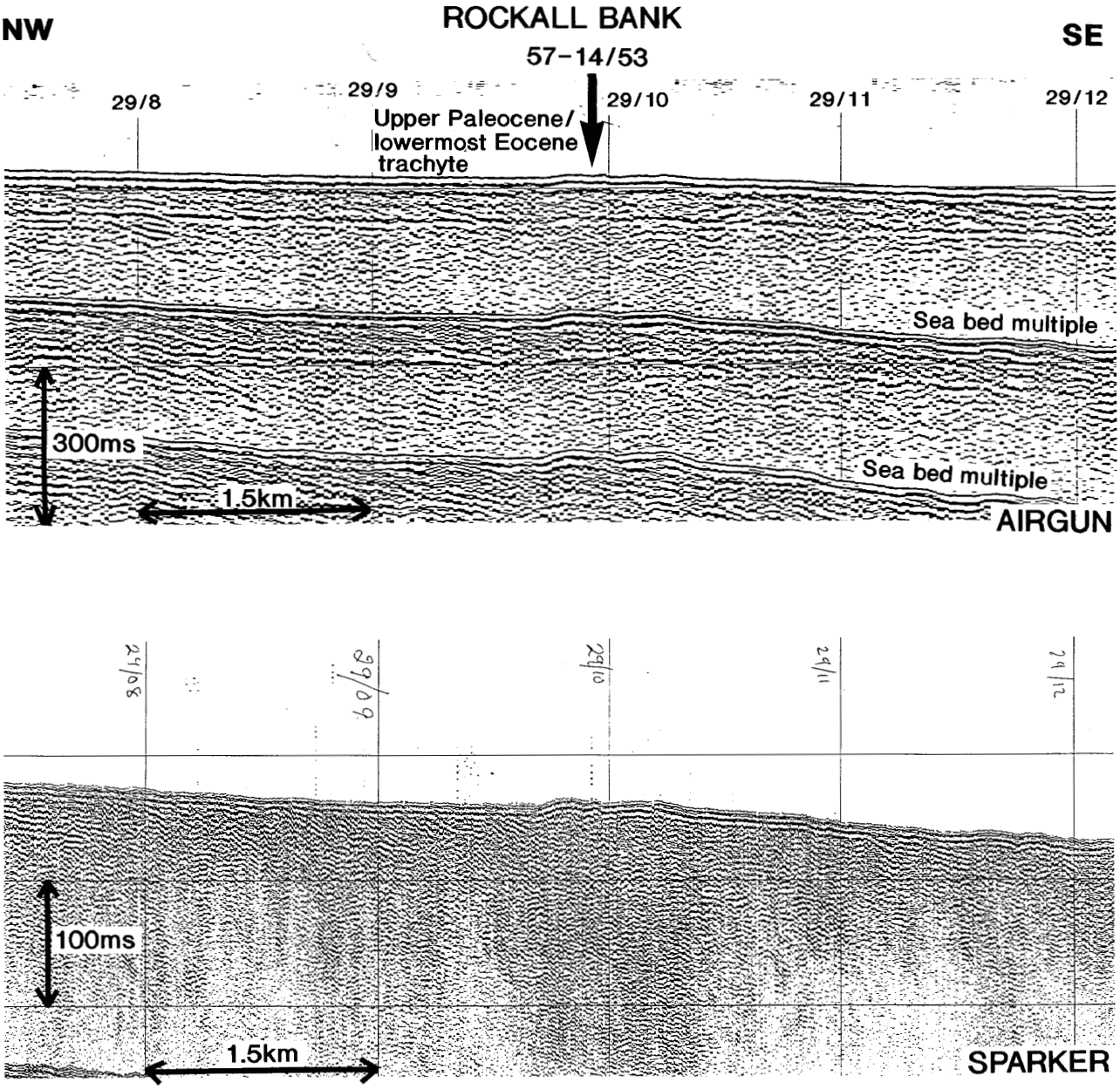
Original site no: S17

T.D. metres: 1.1

Recovery %: 60



57-14/53
(S18)



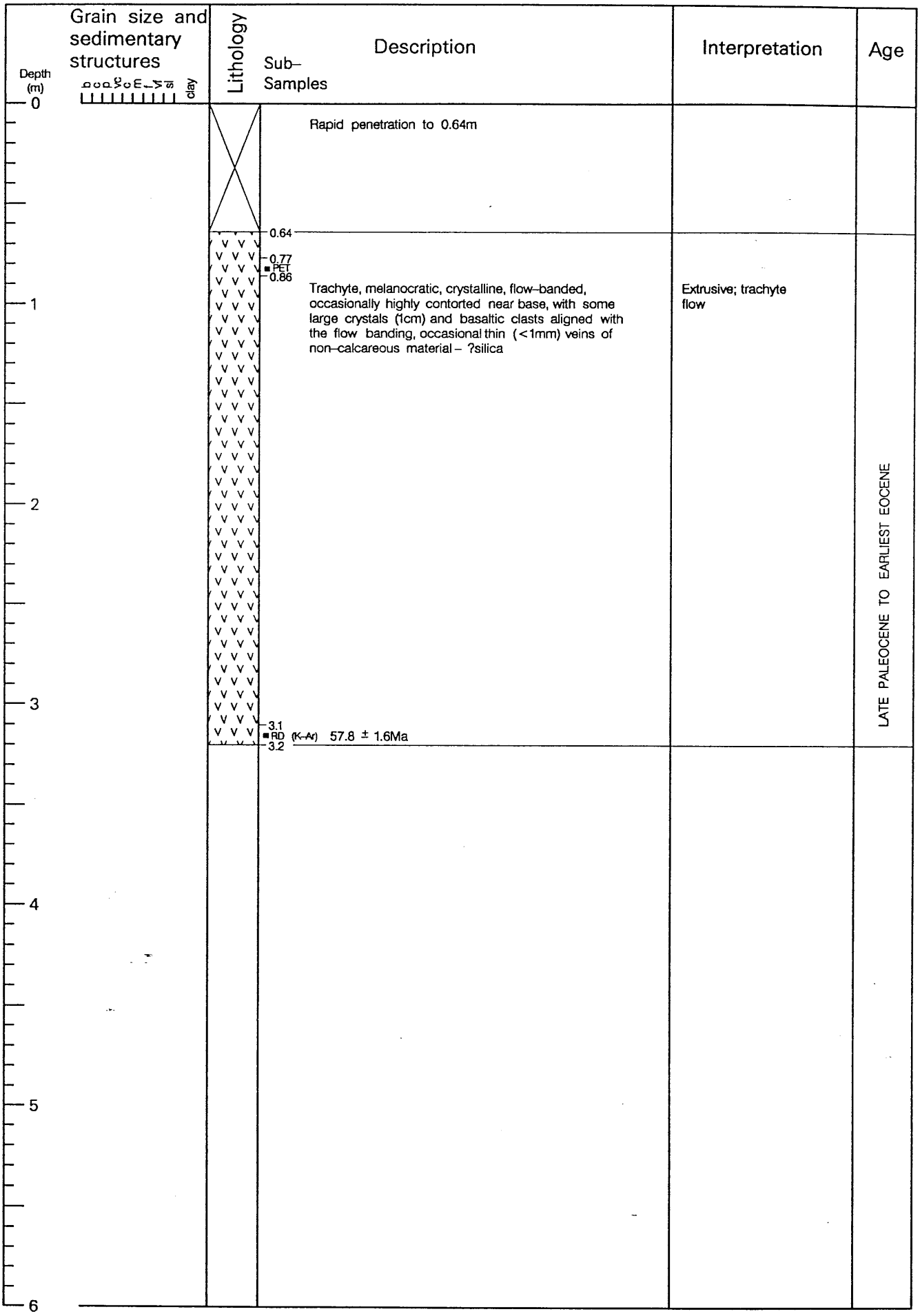
BGS no: 57-14/53
Original site no: S18
Location: Top of Rockall Bank
Latitude: 57° 34.14' N
Longitude: 13° 19.80' W
Water depth: 177m

BGS core no: 57–14 /53

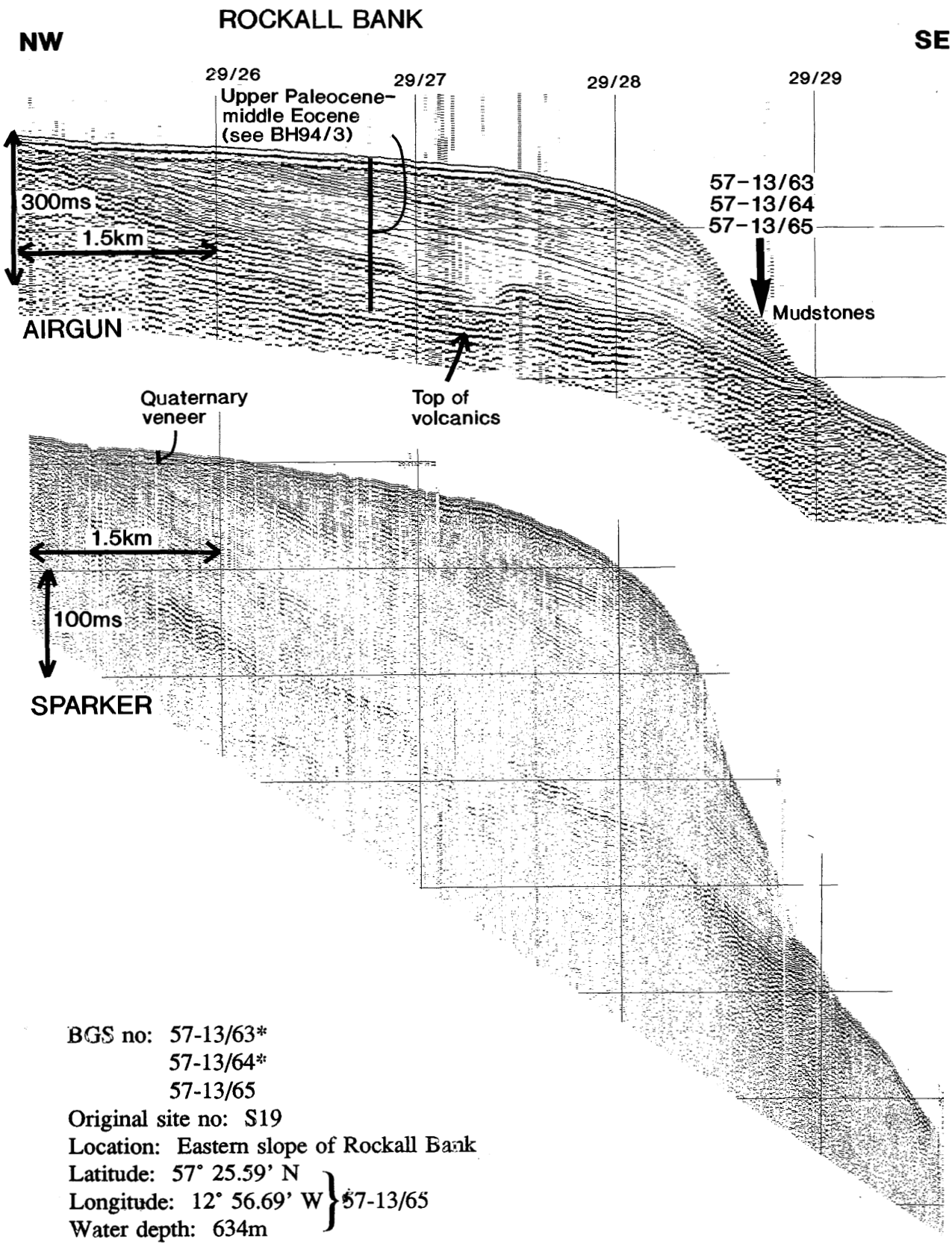
Original site no: S18

T.D. metres: 3.2

Recovery %: 80



57-13/63,64,65
(S19)



BGS no: 57-13/63*
57-13/64*
57-13/65

Original site no: S19

Location: Eastern slope of Rockall Bank

Latitude: 57° 25.59' N
Longitude: 12° 56.69' W } 57-13/65

Water depth: 634m

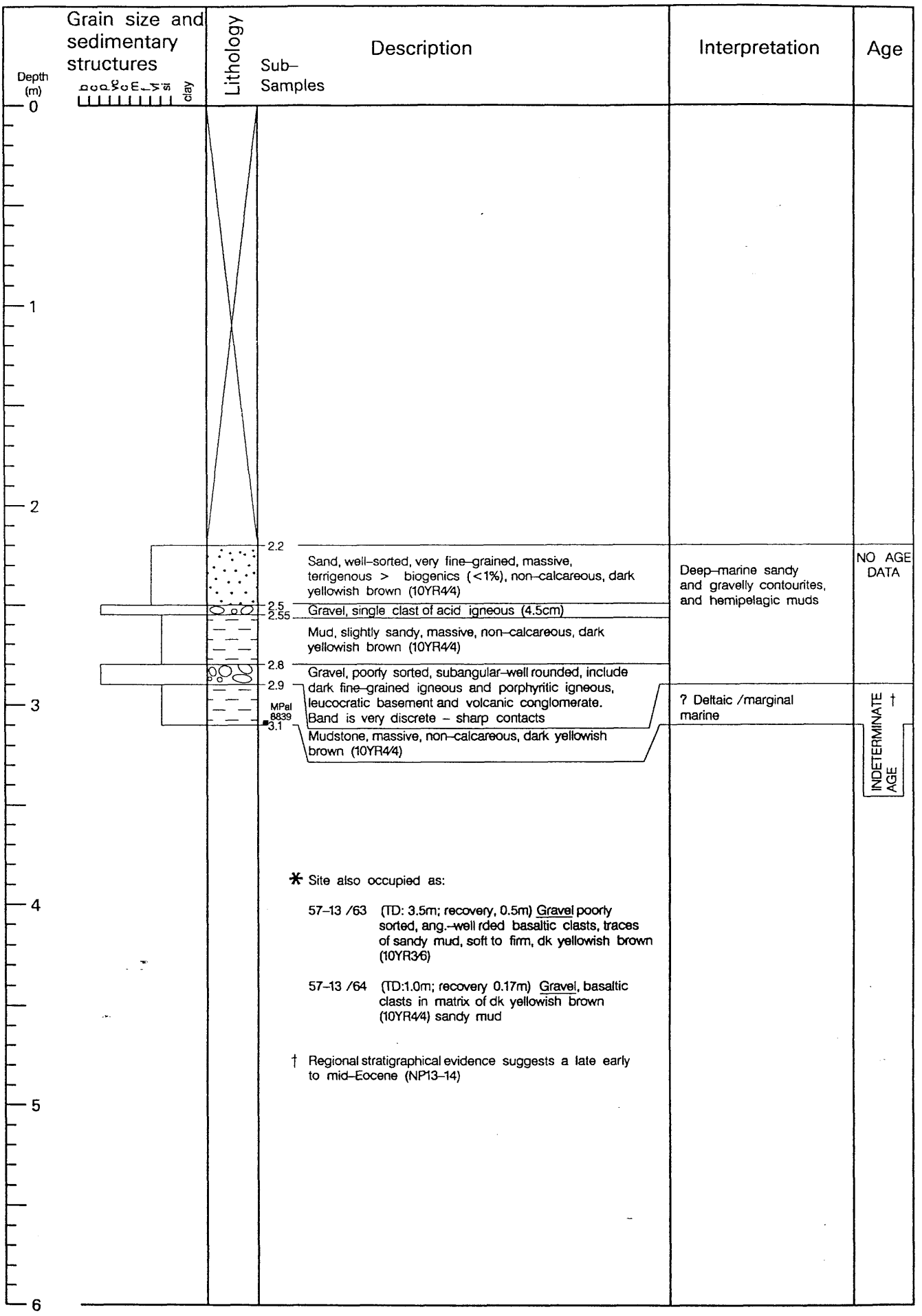
*Poor Recovery

BGS core no: 57–13 /65*

Original site no: S19

T.D. metres: 3.1

Recovery %: 29



* Site also occupied as:

57–13 /63 (TD: 3.5m; recovery, 0.5m) Gravel poorly sorted, ang.–well rded basaltic clasts, traces of sandy mud, soft to firm, dk yellowish brown (10YR3/6)

57–13 /64 (TD:1.0m; recovery 0.17m) Gravel, basaltic clasts in matrix of dk yellowish brown (10YR4/4) sandy mud

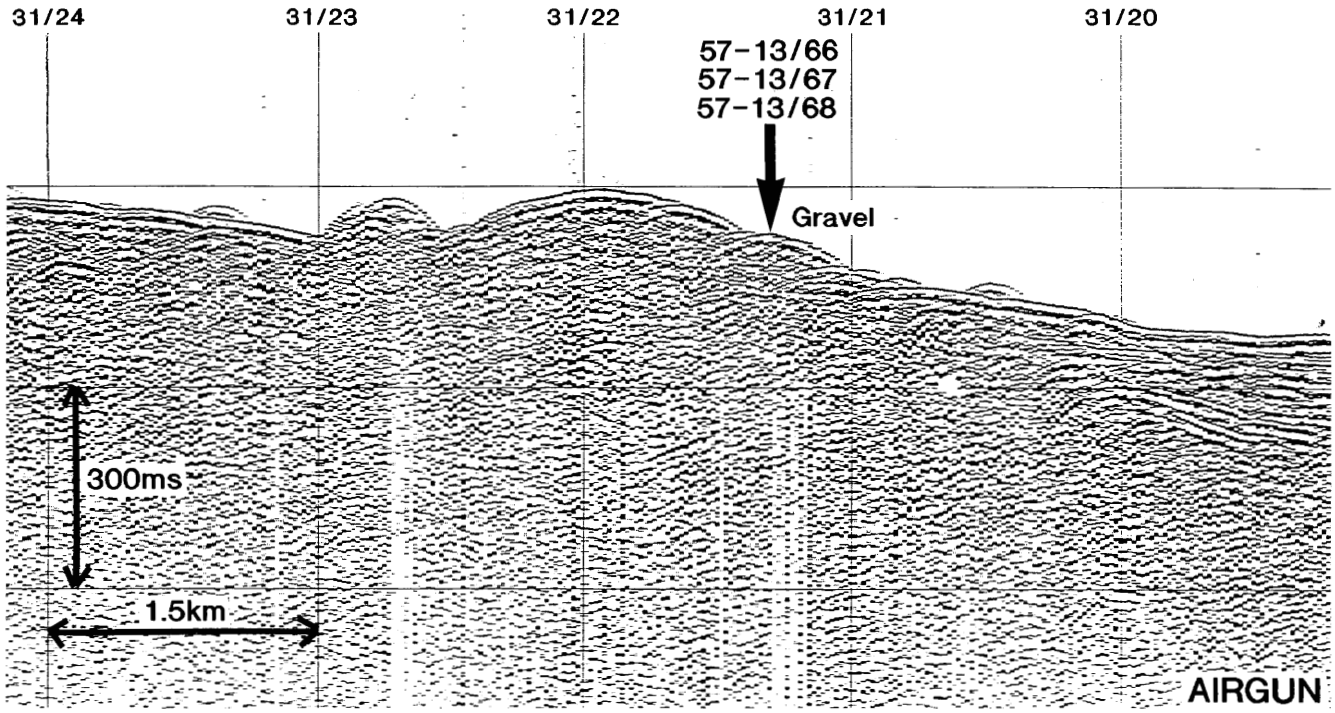
† Regional stratigraphical evidence suggests a late early to mid–Eocene (NP13–14)

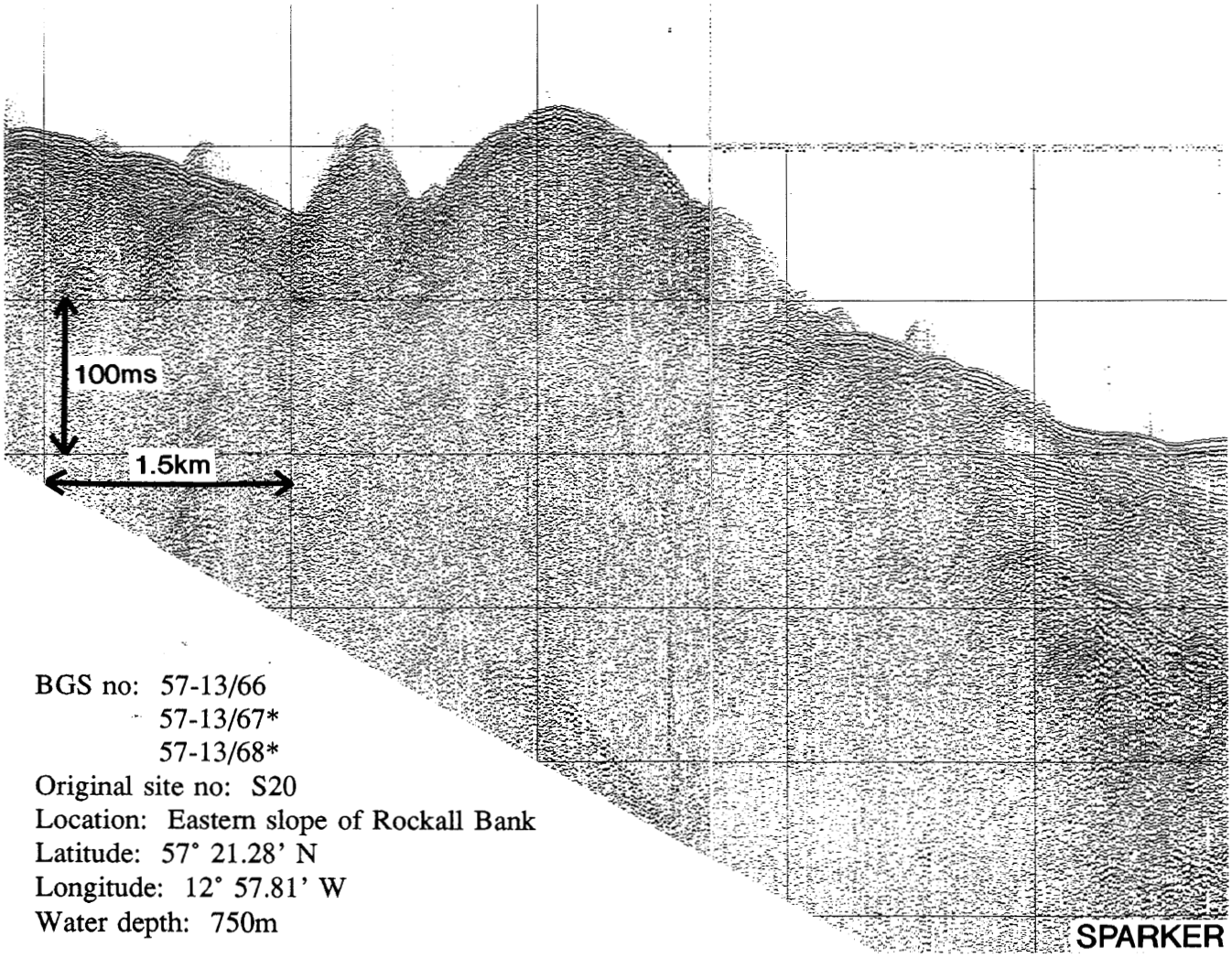
57-13/66,67,68
(S20)

SW

EASTERN SLOPE OF ROCKALL BANK

NE





BGS no: 57-13/66
57-13/67*
57-13/68*
Original site no: S20
Location: Eastern slope of Rockall Bank
Latitude: 57° 21.28' N
Longitude: 12° 57.81' W
Water depth: 750m

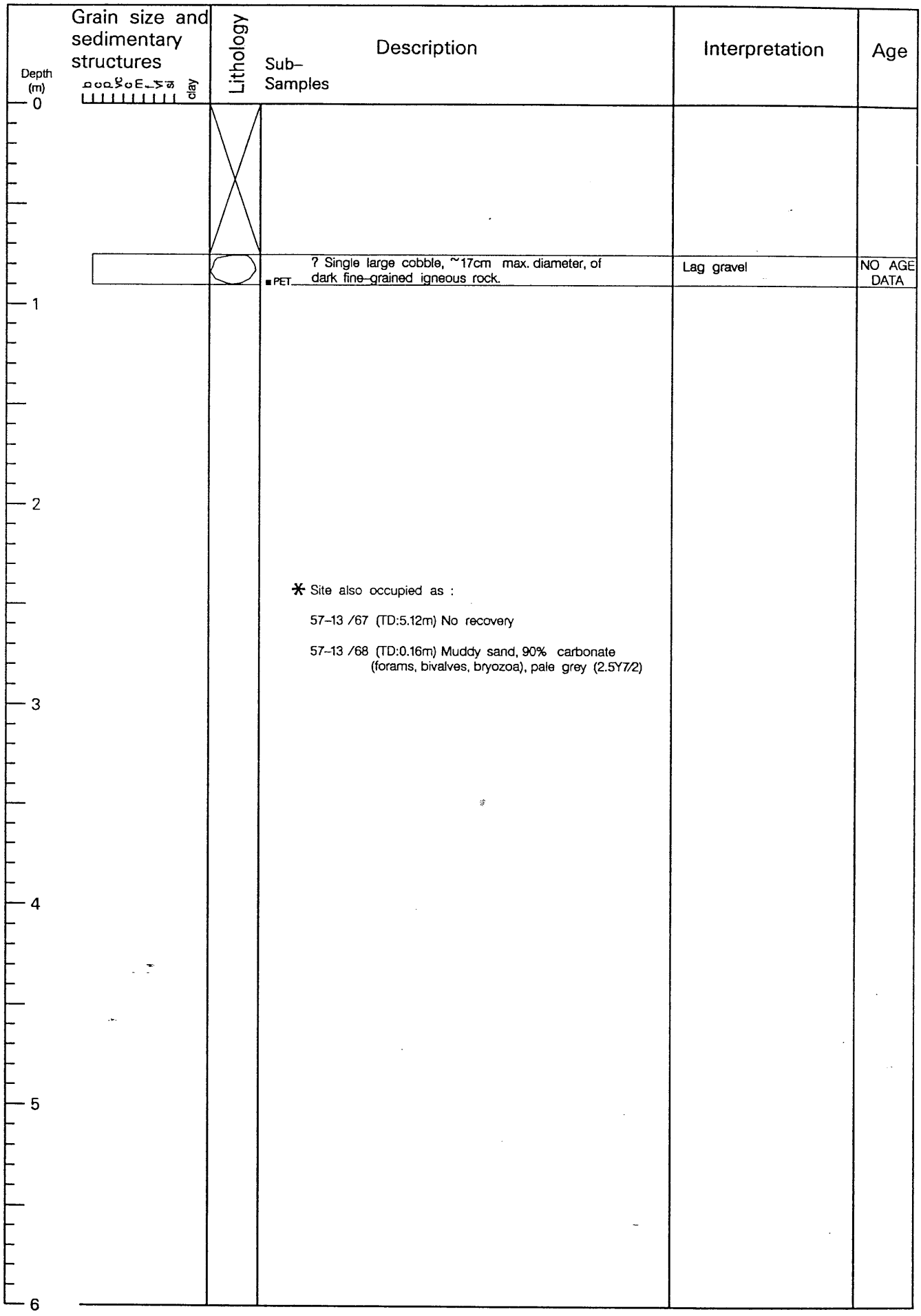
* Very Poor Recovery

BGS core no: 57–13 /66*

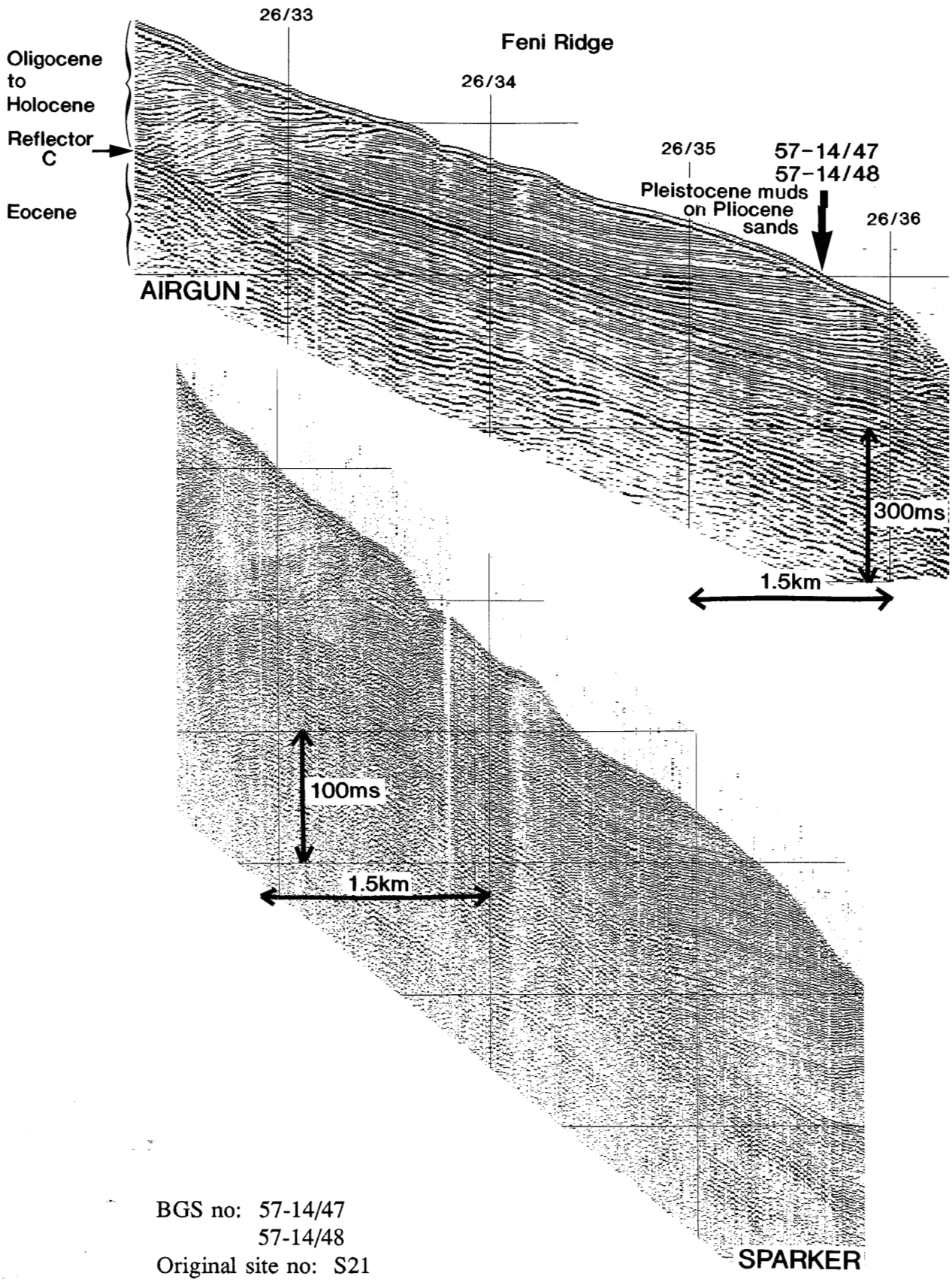
Original site no: S20

T.D. metres: 0.9

Recovery %: 21



57-14/47 & 48
(S21)



BGS no: 57-14/47
57-14/48
Original site no: S21
Location: Western margin of Rockall Trough

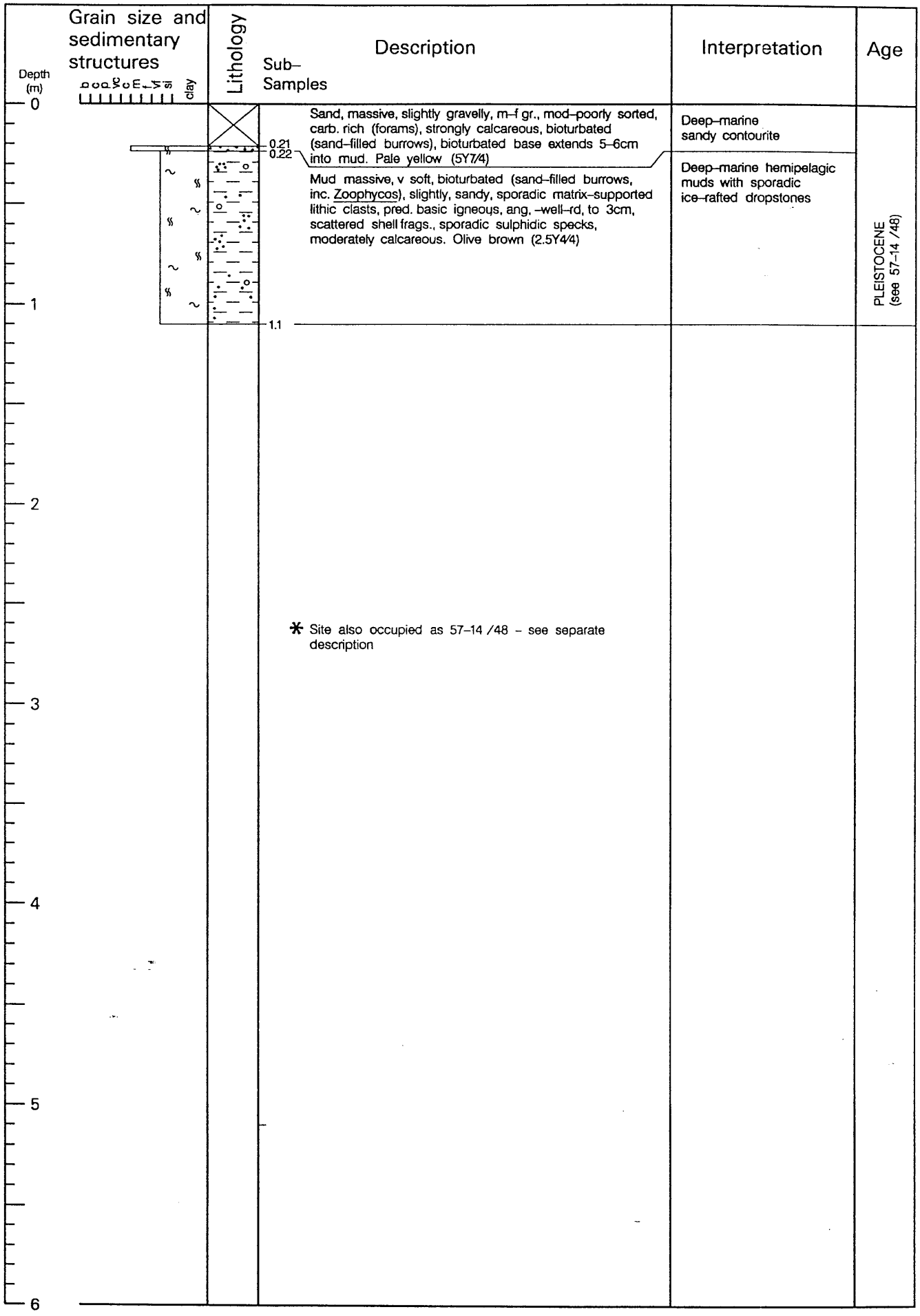
Latitude: 57° 07.56' N	57-14/47	Latitude: 57° 07.54' N	57-14/48
Longitude: 13° 03.55' W		Longitude: 13° 03.54' W	
Water depth: 1078m		Water depth: 1078m	

BGS core no: 57–14 /47*

Original site no: S21

T.D. metres: 1.1

Recovery %: 82

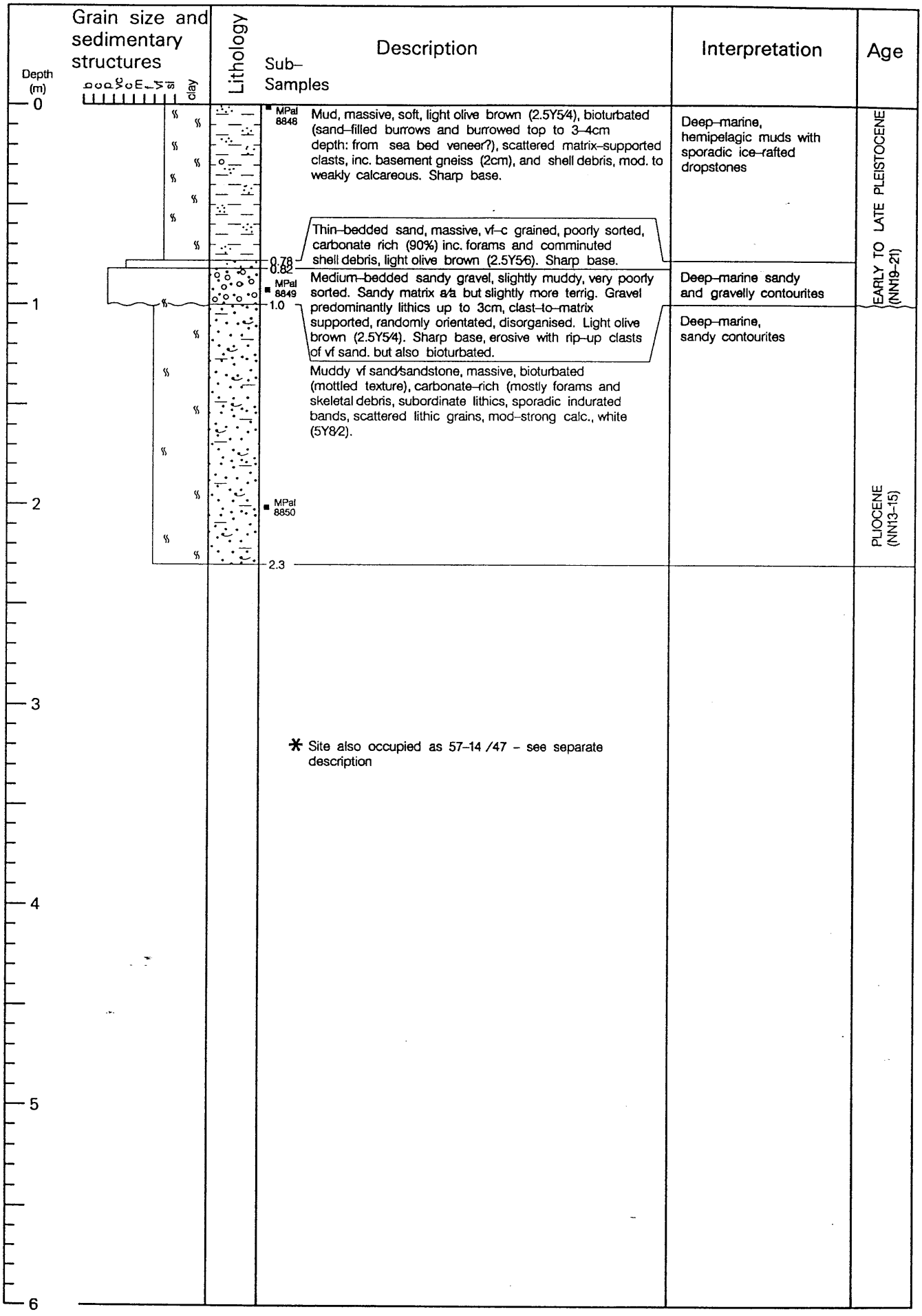


BGS core no: 57–14 /48*

Original site no: S21

T.D. metres: 2.3

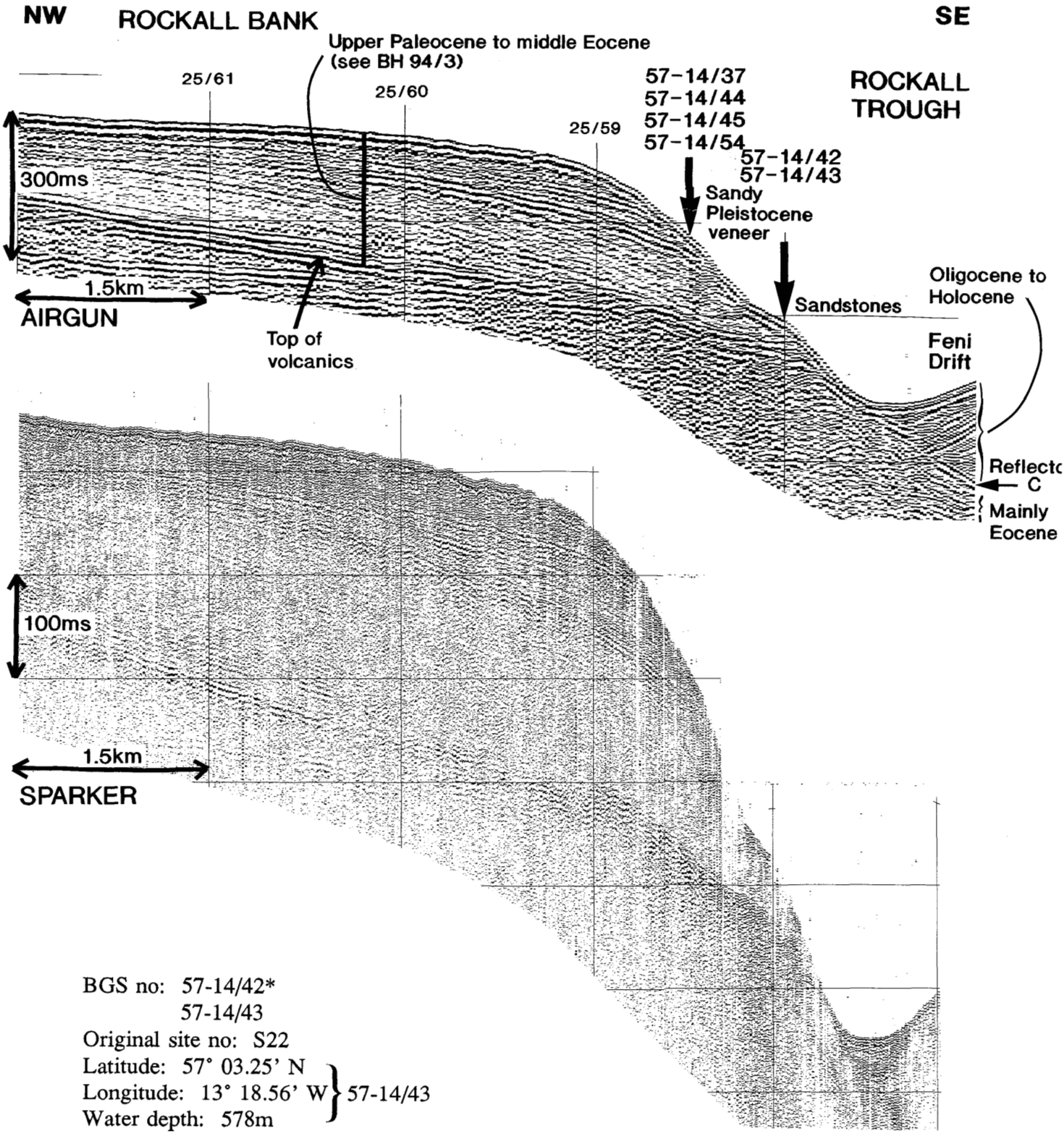
Recovery %: 100



* Site also occupied as 57–14 /47 – see separate description

57-14/42 & 43
(S22)

57-14/37,44,45,54
(S23)



BGS no: 57-14/42*
57-14/43
Original site no: S22
Latitude: 57° 03.25' N
Longitude: 13° 18.56' W } 57-14/43
Water depth: 578m

Location: Eastern slope of Rockall Bank

BGS no: 57-14/37*
57-14/44*
57-14/45*
57-14/54
Original site no: S23
Latitude: 57° 03.43' N
Longitude: 13° 19.09' W } 57-14/54
Water depth: 423m

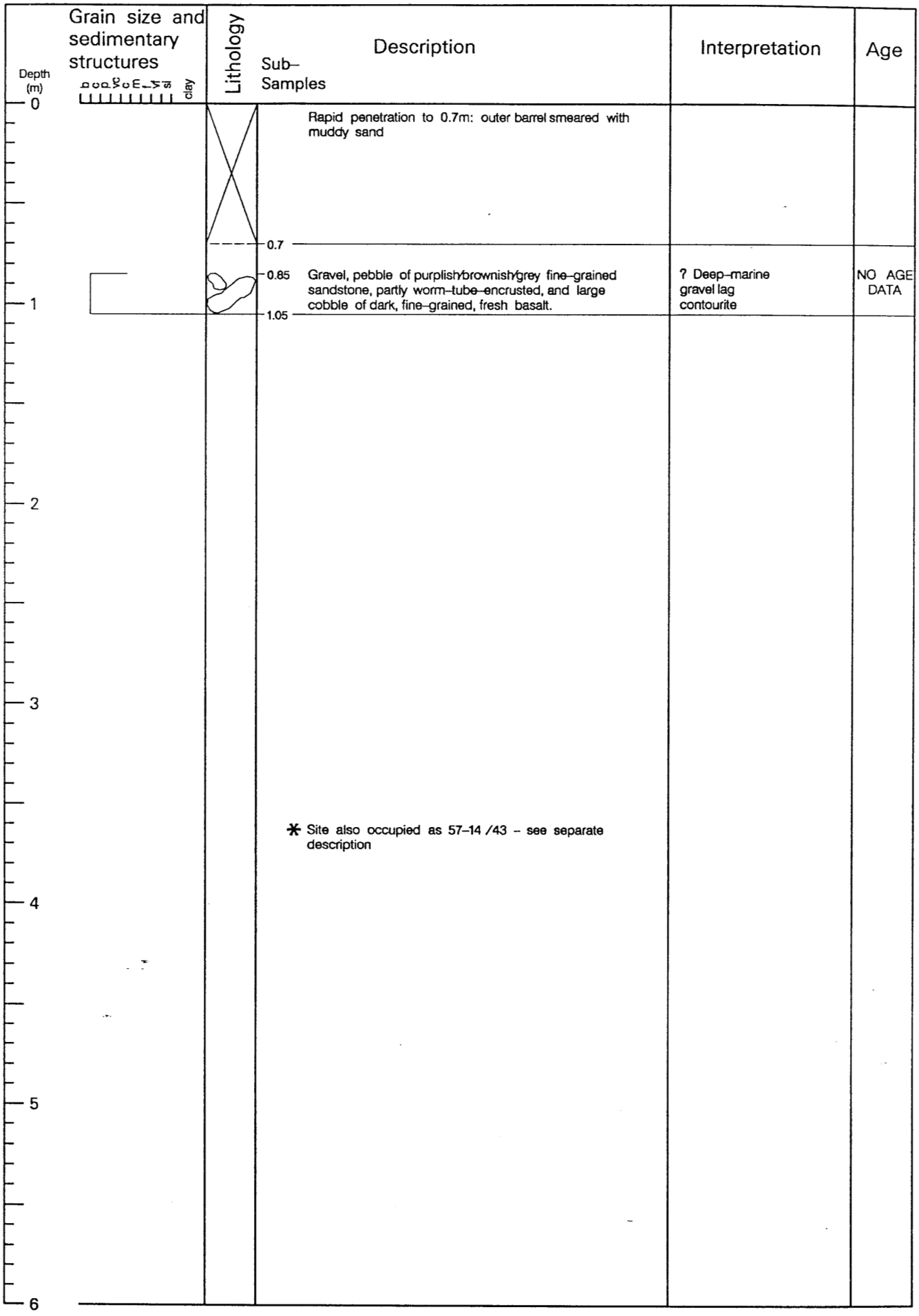
* Poor Recovery

BGS core no: 57–14 /42*

Original site no: S22

T.D. metres: 1.05

Recovery %: 33

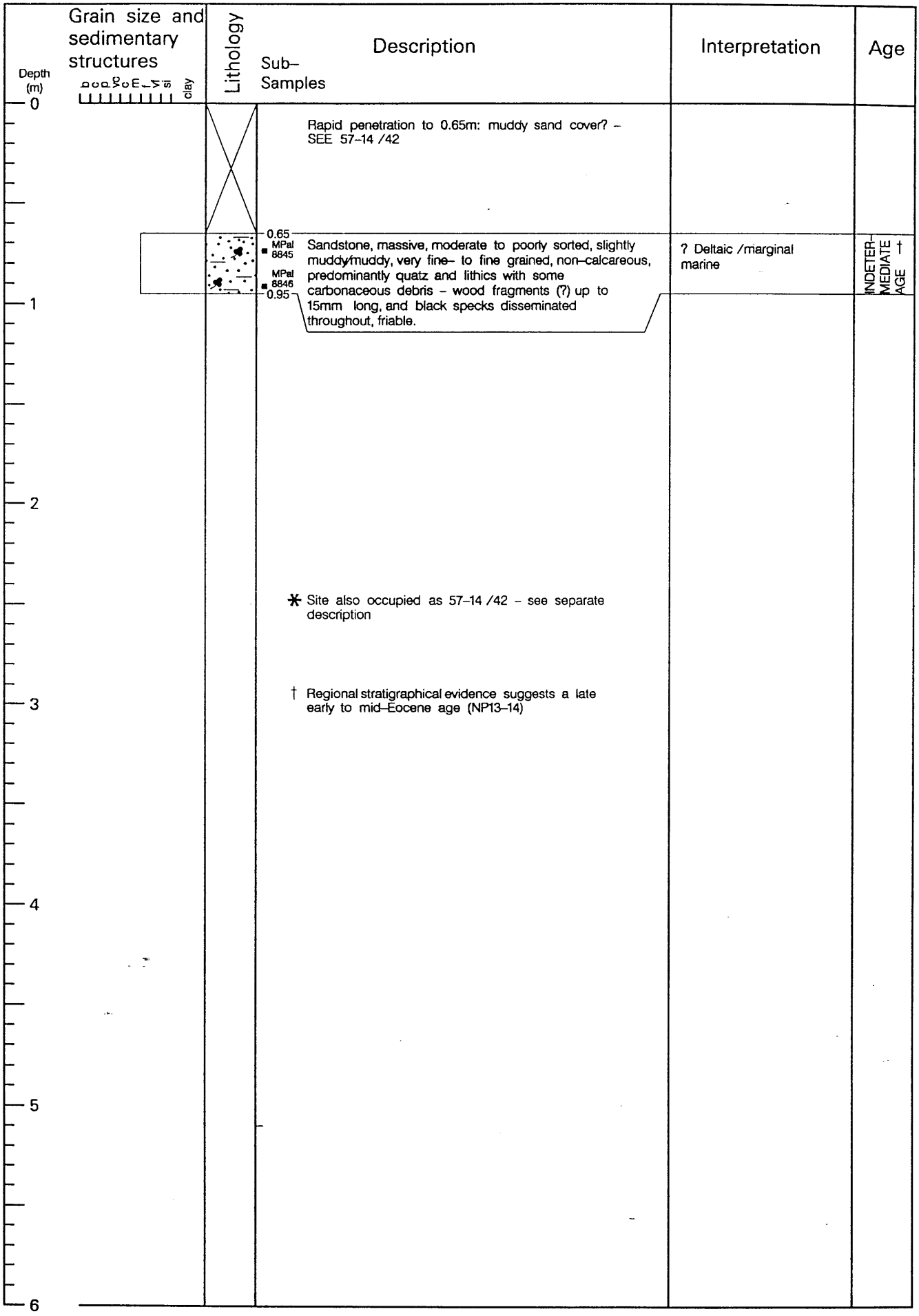


BGS core no: 57–14 /43*

Original site no: S22

T.D. metres: 0.95

Recovery %: 32

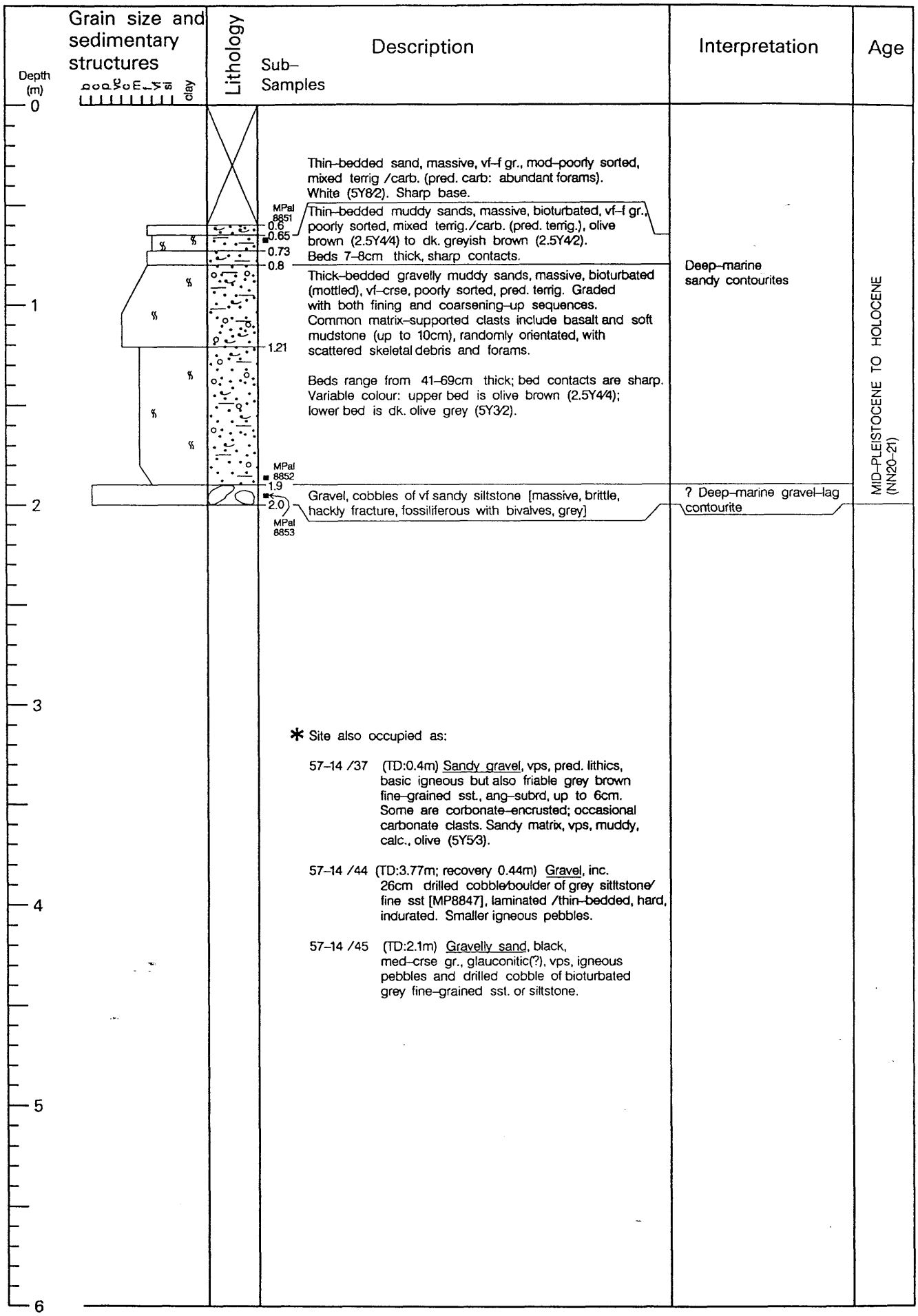


BGS core no: 57–14 /54*

Original site no: S23

T.D. metres: 2.0

Recovery %: 70



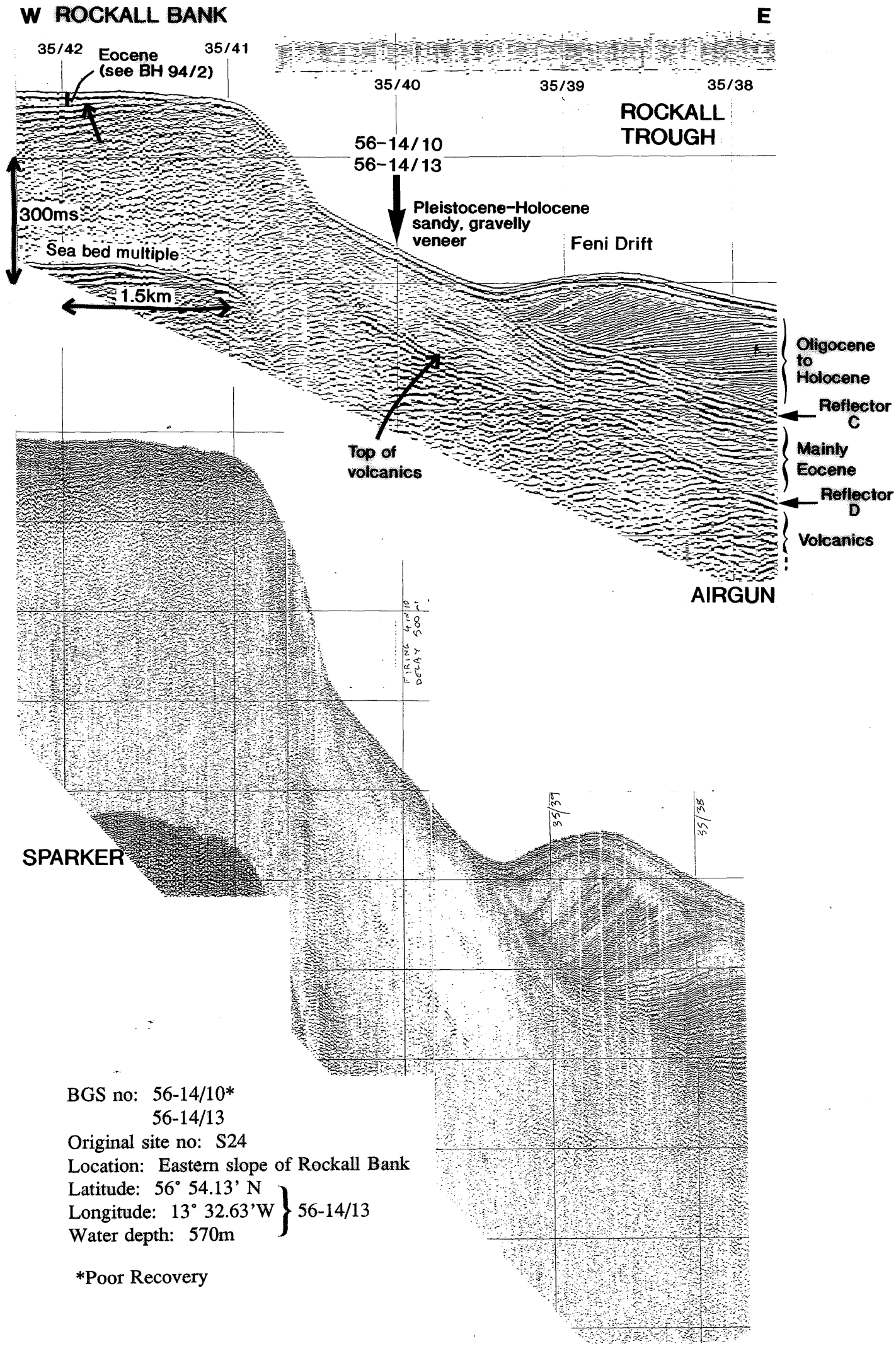
* Site also occupied as:

57–14 /37 (TD:0.4m) Sandy gravel, vps, pred. lithics, basic igneous but also friable grey brown fine–grained sst., ang–subrd, up to 6cm. Some are corbonate–encrusted; occasional carbonate clasts. Sandy matrix, vps, muddy, calc., olive (5Y5/3).

57–14 /44 (TD:3.77m; recovery 0.44m) Gravel, inc. 26cm drilled cobble/boulder of grey siltstone/ fine sst [MP8847], laminated /thin–bedded, hard, indurated. Smaller igneous pebbles.

57–14 /45 (TD:2.1m) Gravelly sand, black, med–crse gr., glauconitic(?), vps, igneous pebbles and drilled cobble of bioturbated grey fine–grained sst. or siltstone.

56-14/10 & 13
(S24)



BGS no: 56-14/10*
56-14/13
Original site no: S24
Location: Eastern slope of Rockall Bank
Latitude: 56° 54.13' N
Longitude: 13° 32.63'W } 56-14/13
Water depth: 570m

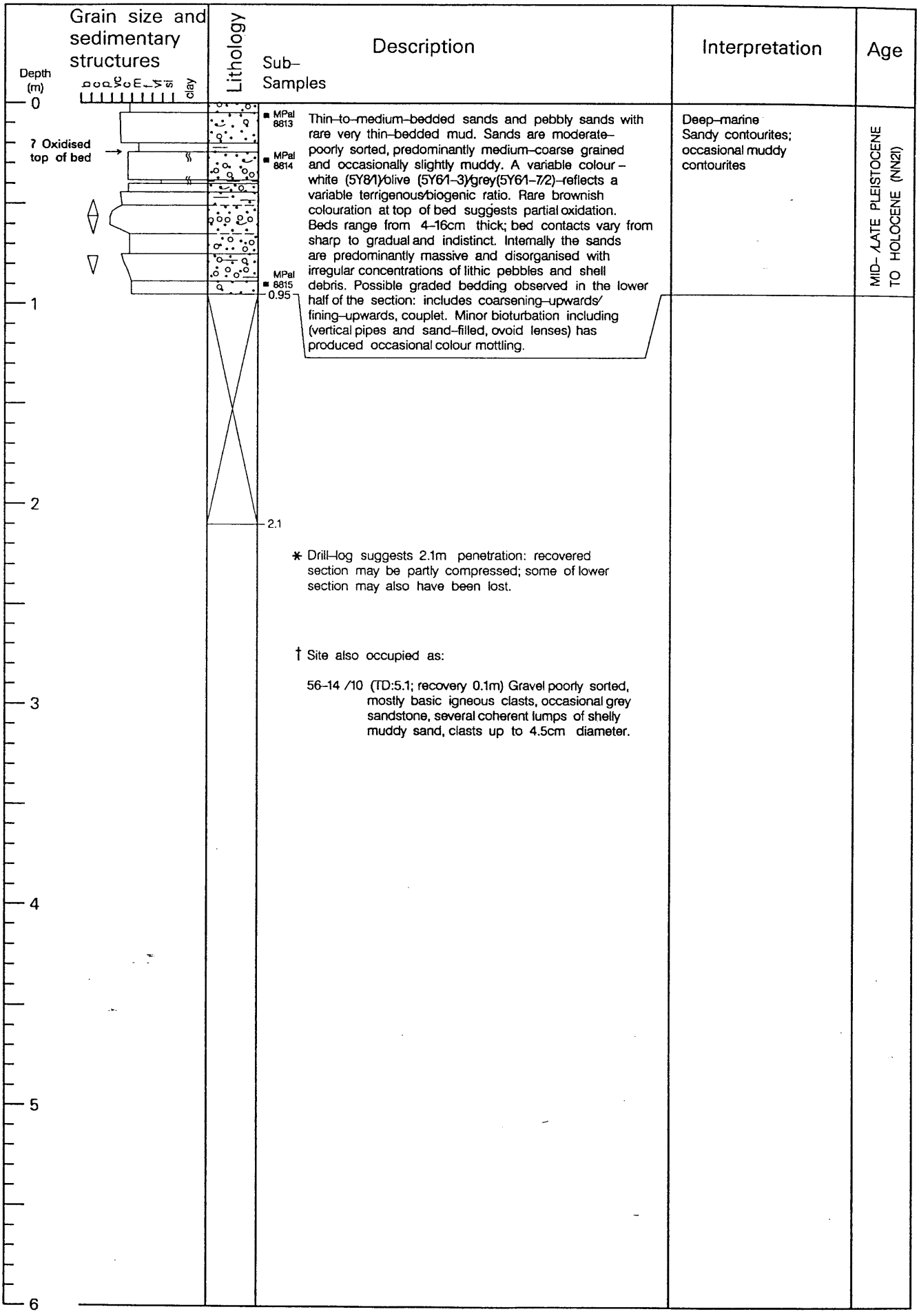
*Poor Recovery

BGS core no: 56–14 /13 †

Original site no: S24

T.D. metres: 2.1 *

Recovery %: 45

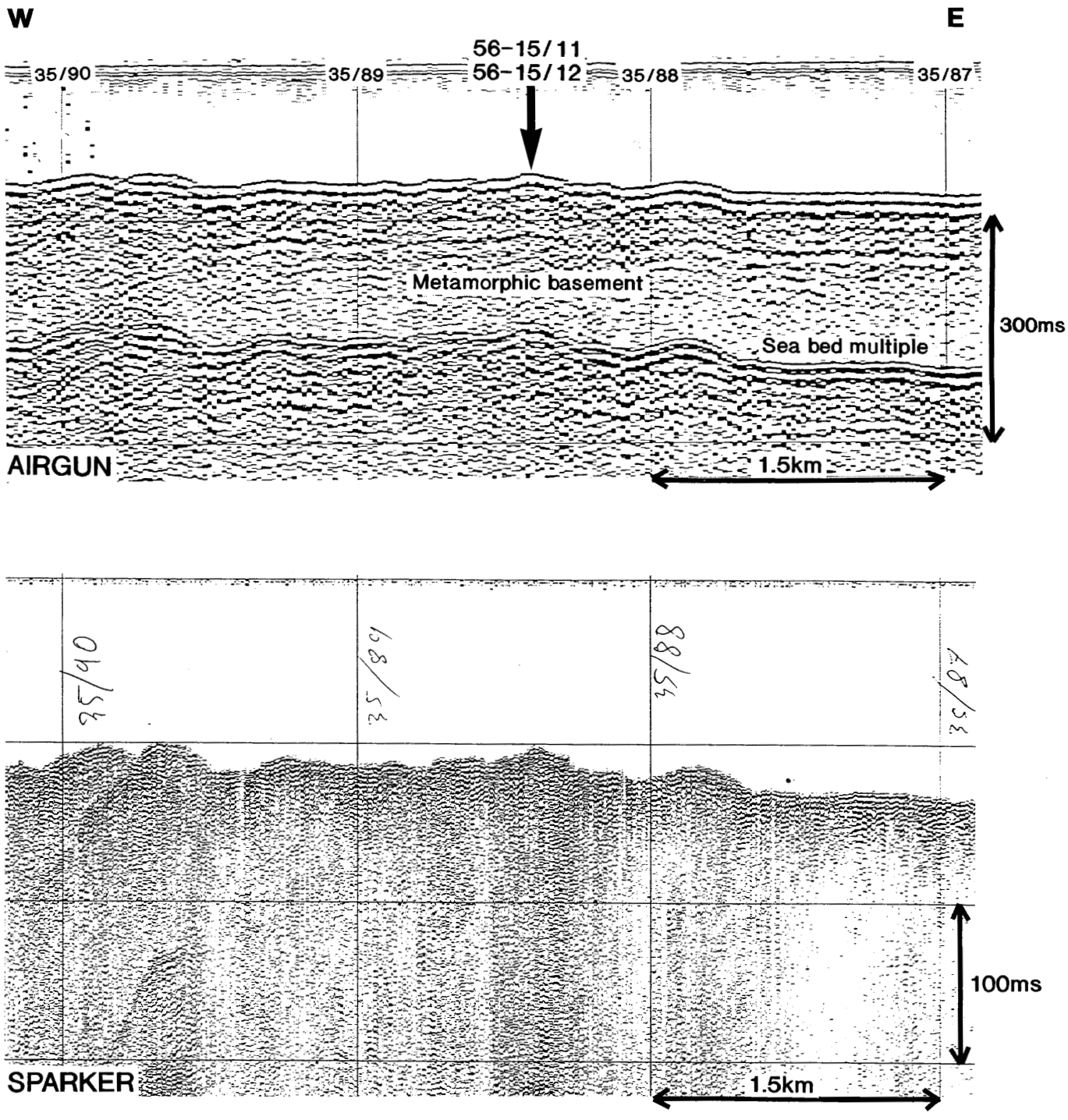


* Drill–log suggests 2.1m penetration: recovered section may be partly compressed; some of lower section may also have been lost.

† Site also occupied as:

56–14 /10 (TD:5.1; recovery 0.1m) Gravel poorly sorted, mostly basic igneous clasts, occasional grey sandstone, several coherent lumps of shelly muddy sand, clasts up to 4.5cm diameter.

56-15/11 & 12
(S25)



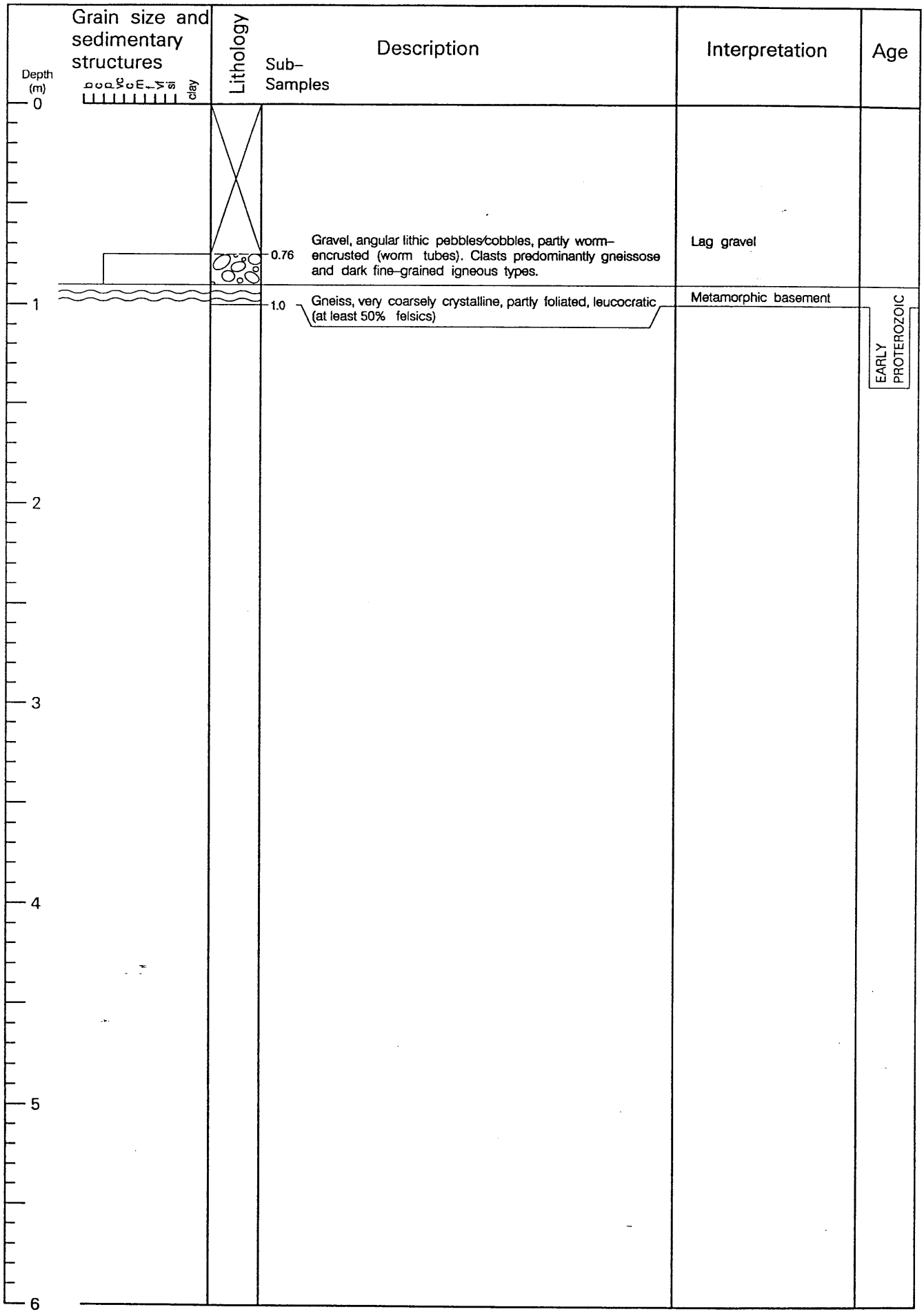
BGS no: 56-15/11
56-15/12
Original site no: S25
Location: Top of Rockall Bank
Latitude: 56° 58.52' N
Longitude: 14° 36.38' W
Water depth: 158m

BGS core no: 56–15 /11

Original site no: S25

T.D. metres: @1.0

Recovery %: 24

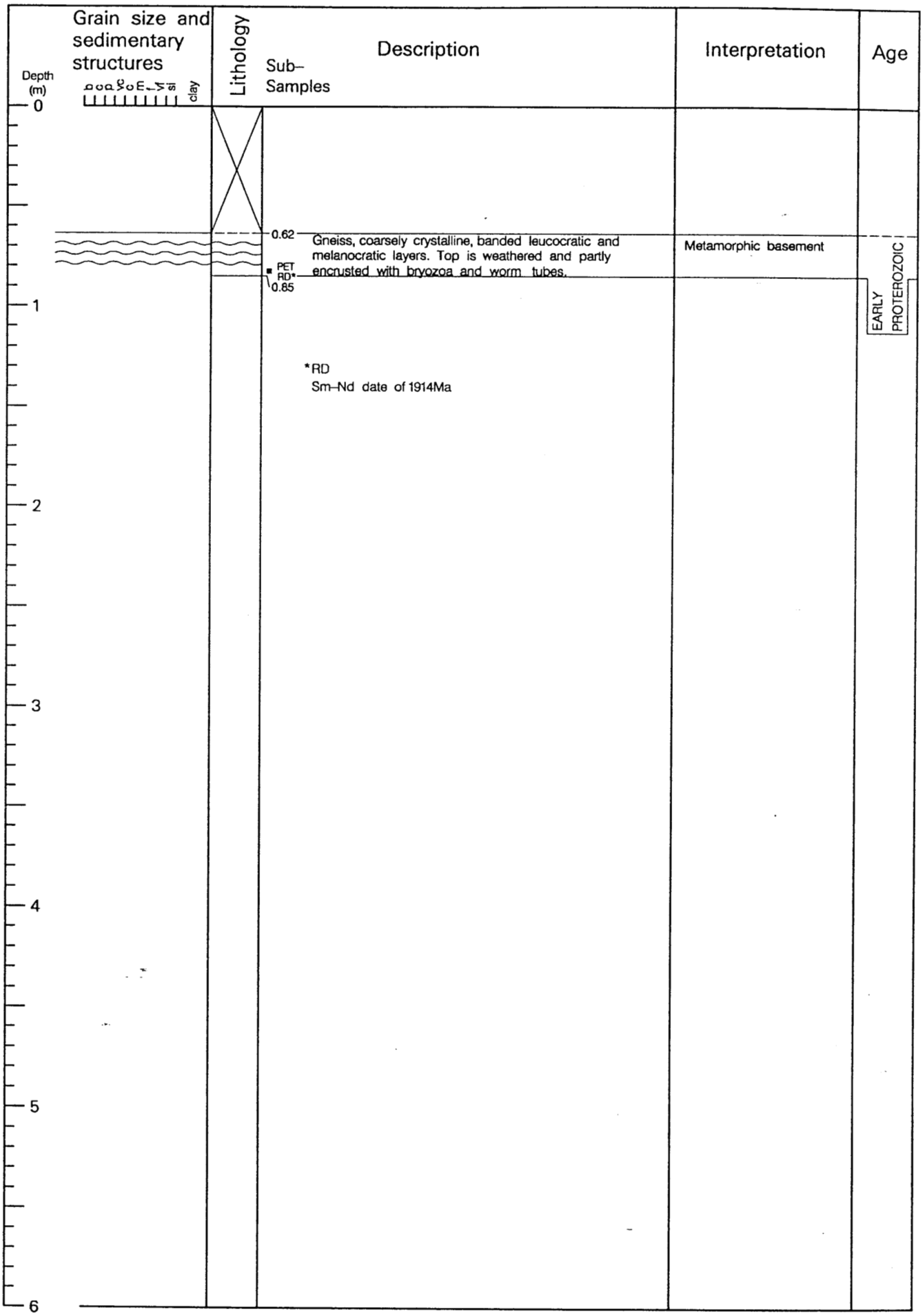


BGS core no: 56–15 /12

Original site no: S25

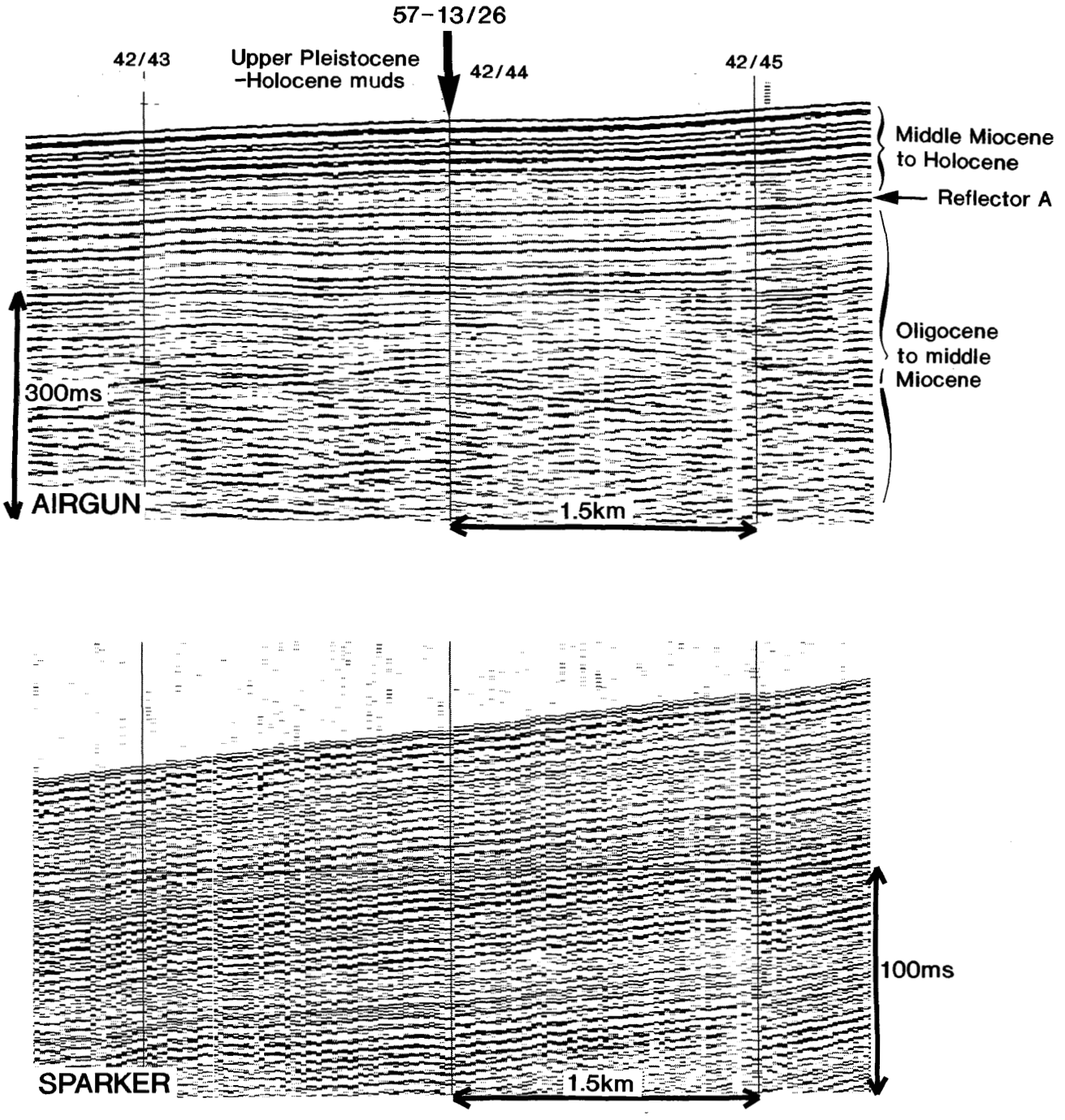
T.D. metres: 0.85

Recovery %: 27



57-13/26
(S26)

ROCKALL TROUGH



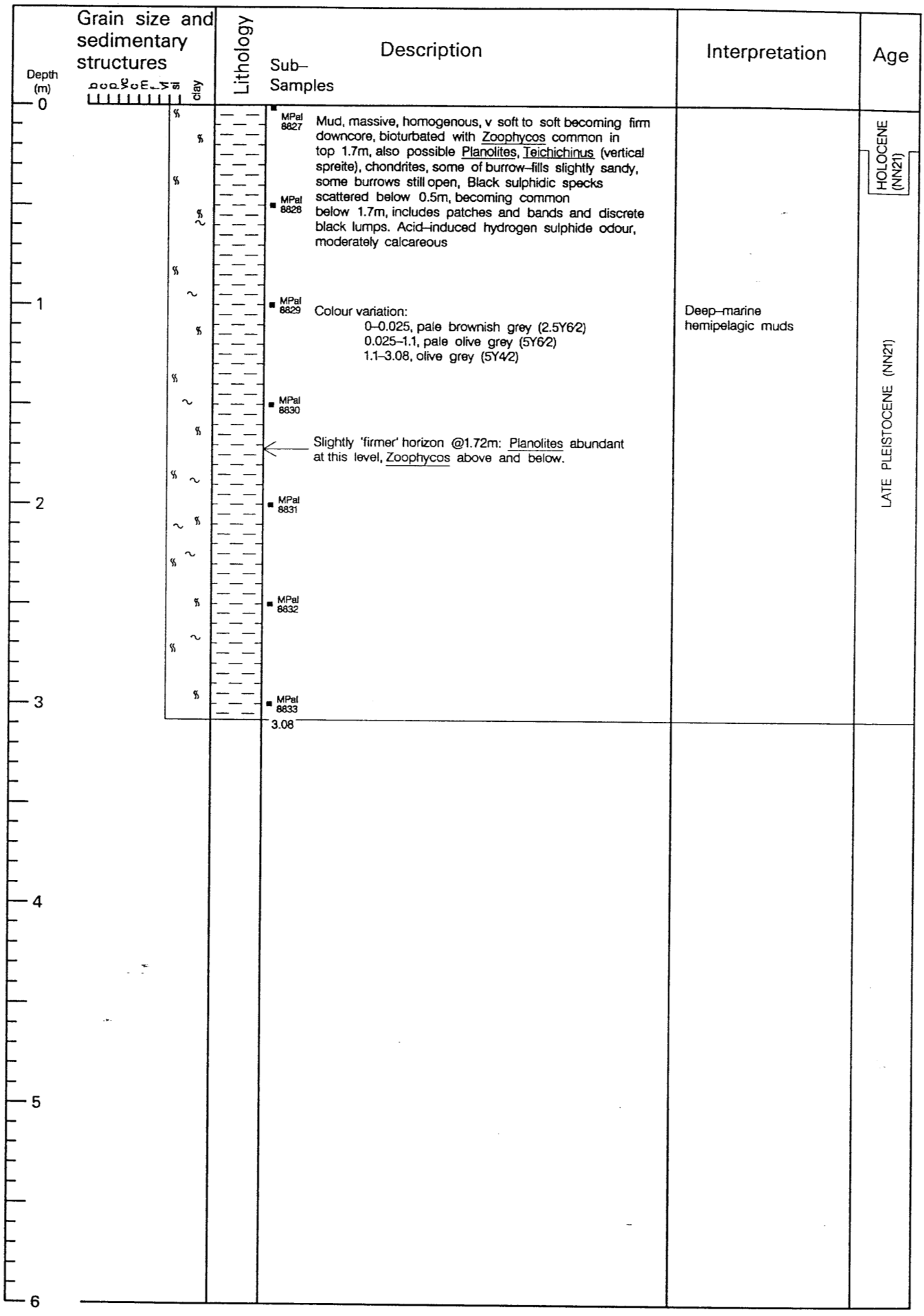
BGS no: 57-13/26
Original site no: S26
Location: Rockall Trough, south-west of Anton Dohrn
Latitude: 57° 07.55' N
Longitude: 12° 05.96' W
Water depth: 1961m

BGS core no: 57–13 /26

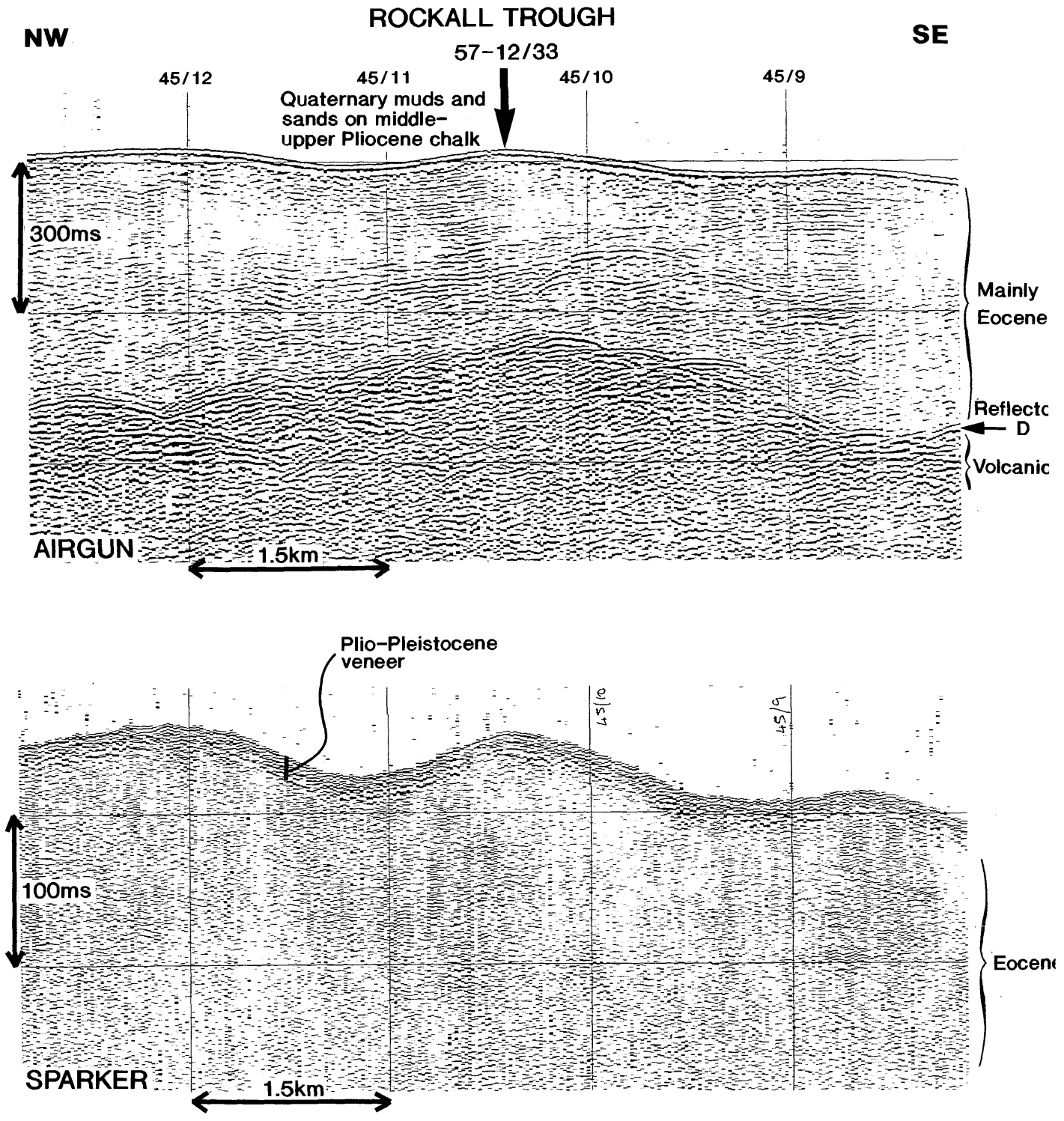
Original site no: S26

T.D. metres: 3.08

Recovery %: 100



57-12/33
(S27)



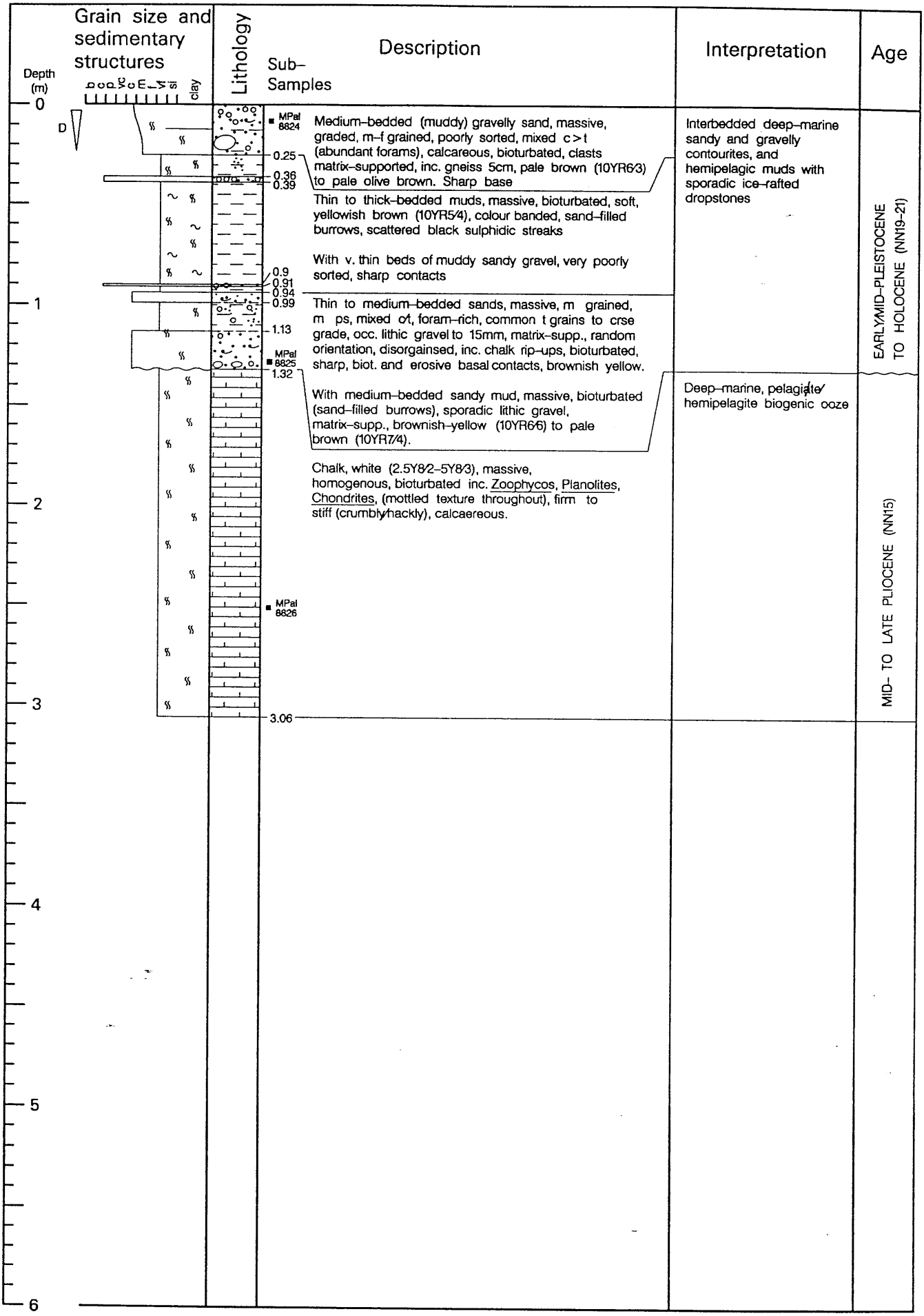
BGS no: 57-12/33
Original site no: S27
Location: Rockall Trough, south-west of Anton Dohrn
Latitude: 57° 13.79' N
Longitude: 11° 22.15' W
Water depth: 2035m

BGS core no: 57–12 /33

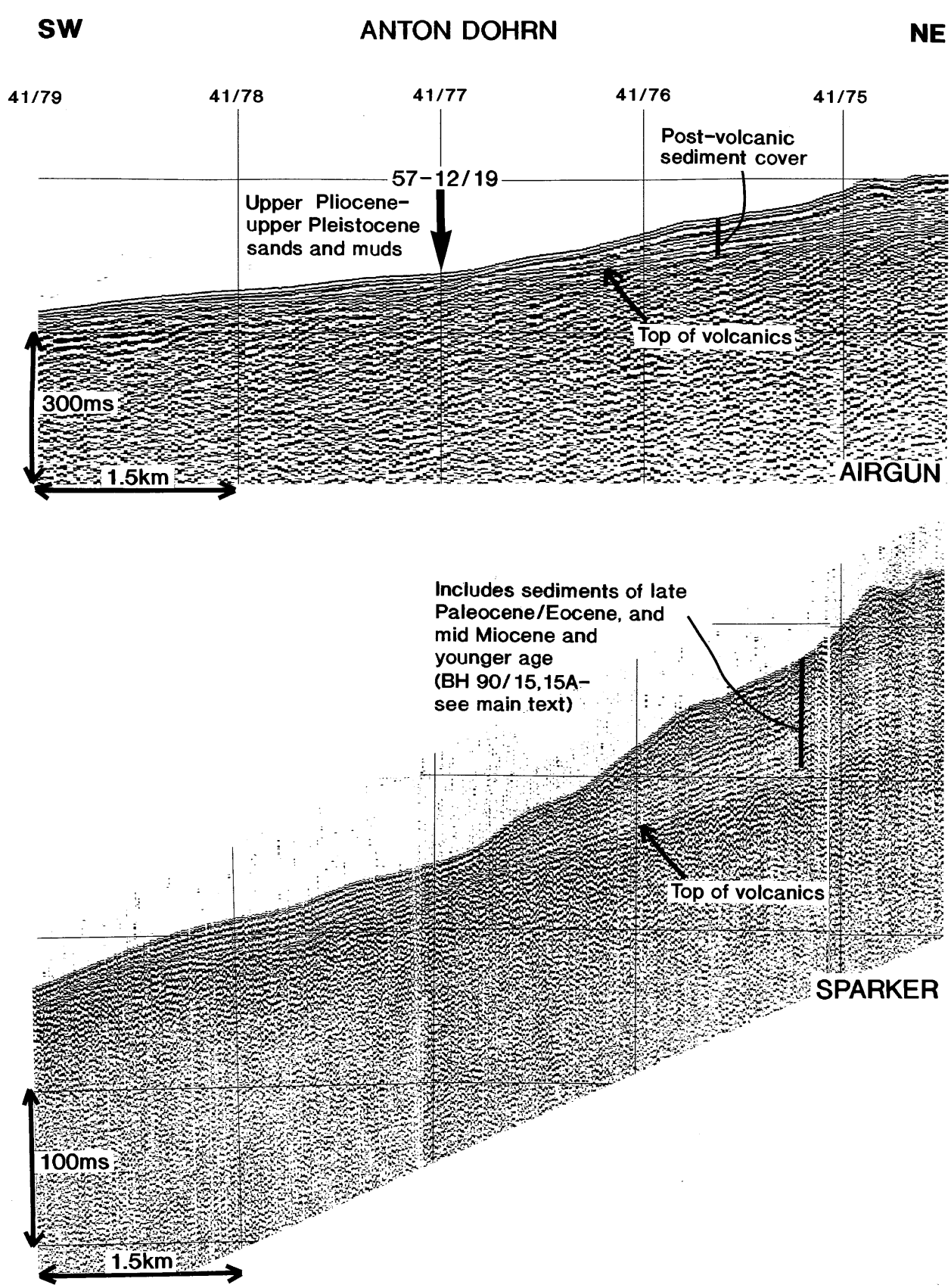
Original site no: S27

T.D. metres: 3.06

Recovery %: 100



57-12/19
(S28)



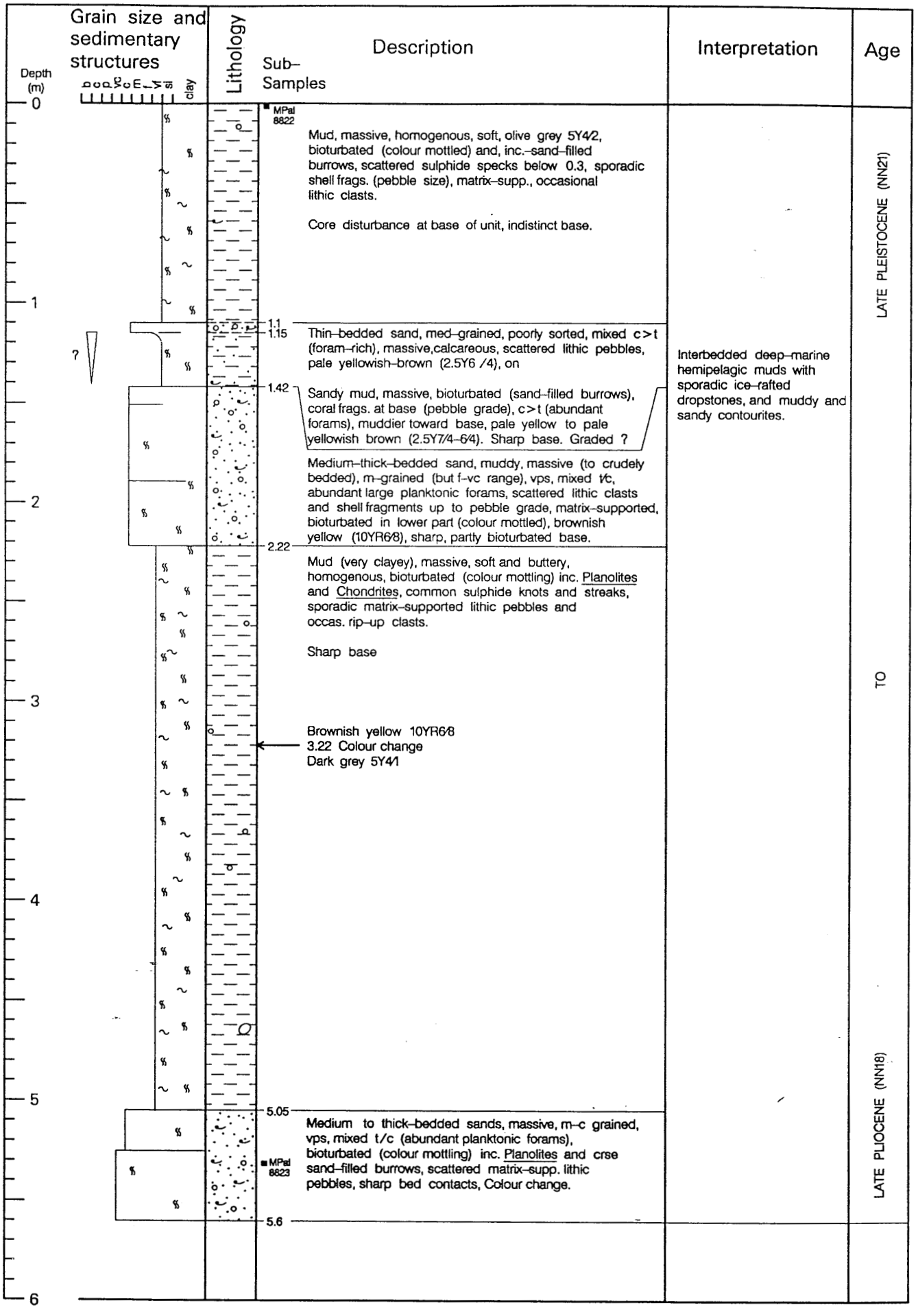
BGS no: 57-12/19
Original site no: S28
Location: Southern flank of Anton Dohrn
Latitude: 57° 17.12' N
Longitude: 11° 05.79' W
Water depth: 869m

BGS core no: 57–12 /19

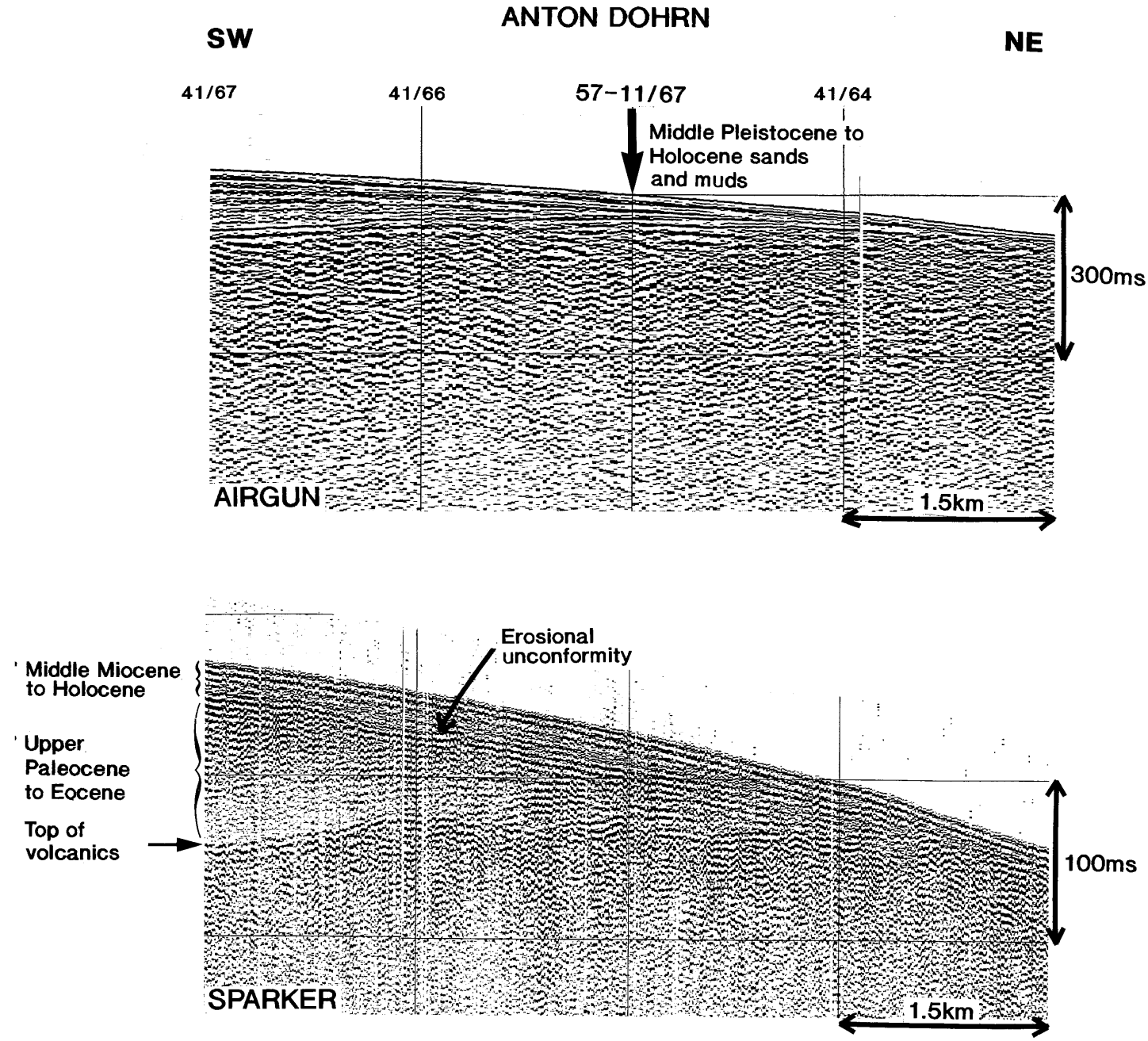
Original site no: S28

T.D. metres: 5.6

Recovery %: 100



57-11/67
(S29)



* Based on borehole 90/15,15A - see main text

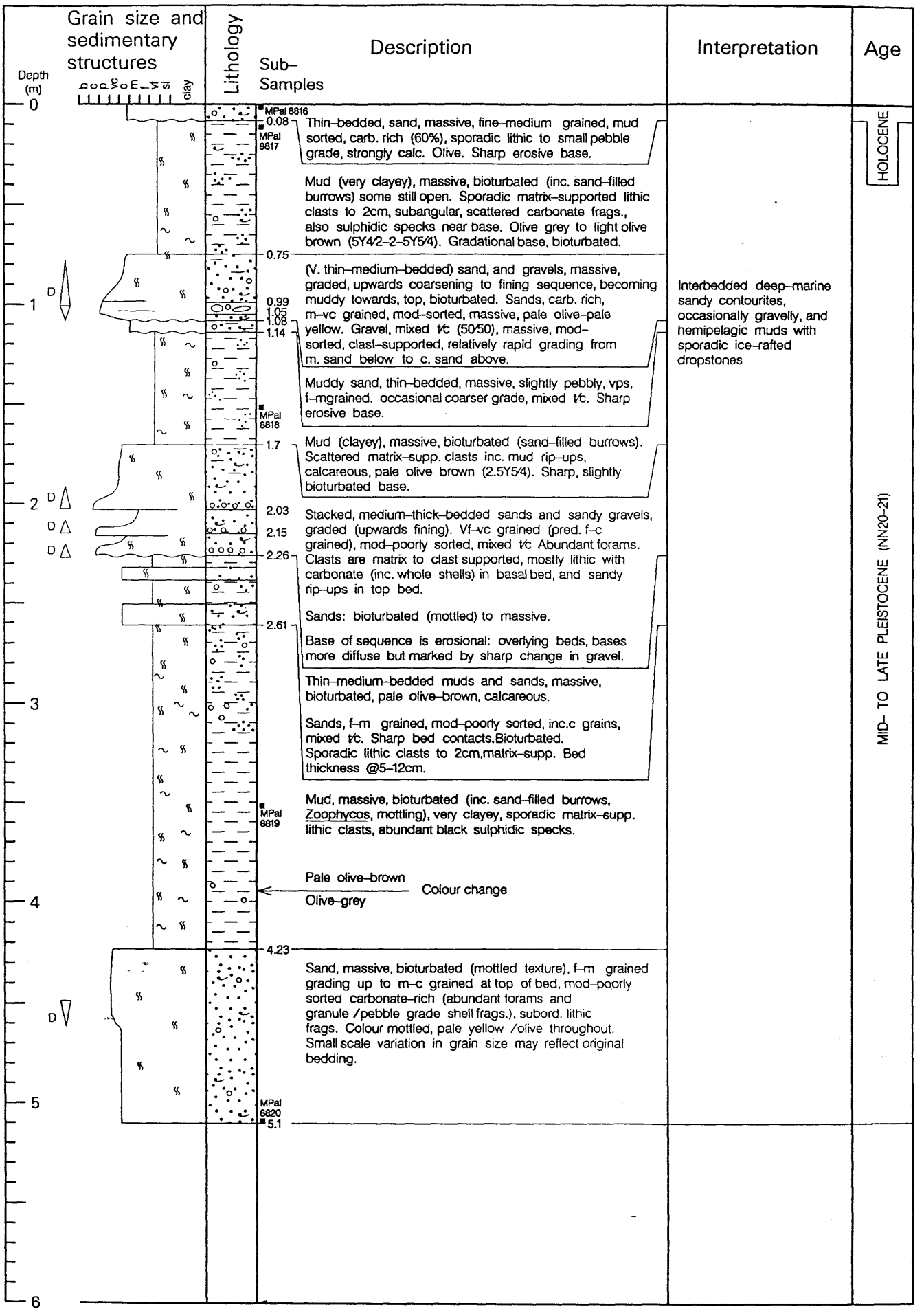
BGS no: 57-11/67
Original site no: S29
Location: Top of Anton Dohrn
Latitude: 57° 26.61' N
Longitude: 10° 53.36' W
Water depth: 727m

BGS core no: 57–11/67

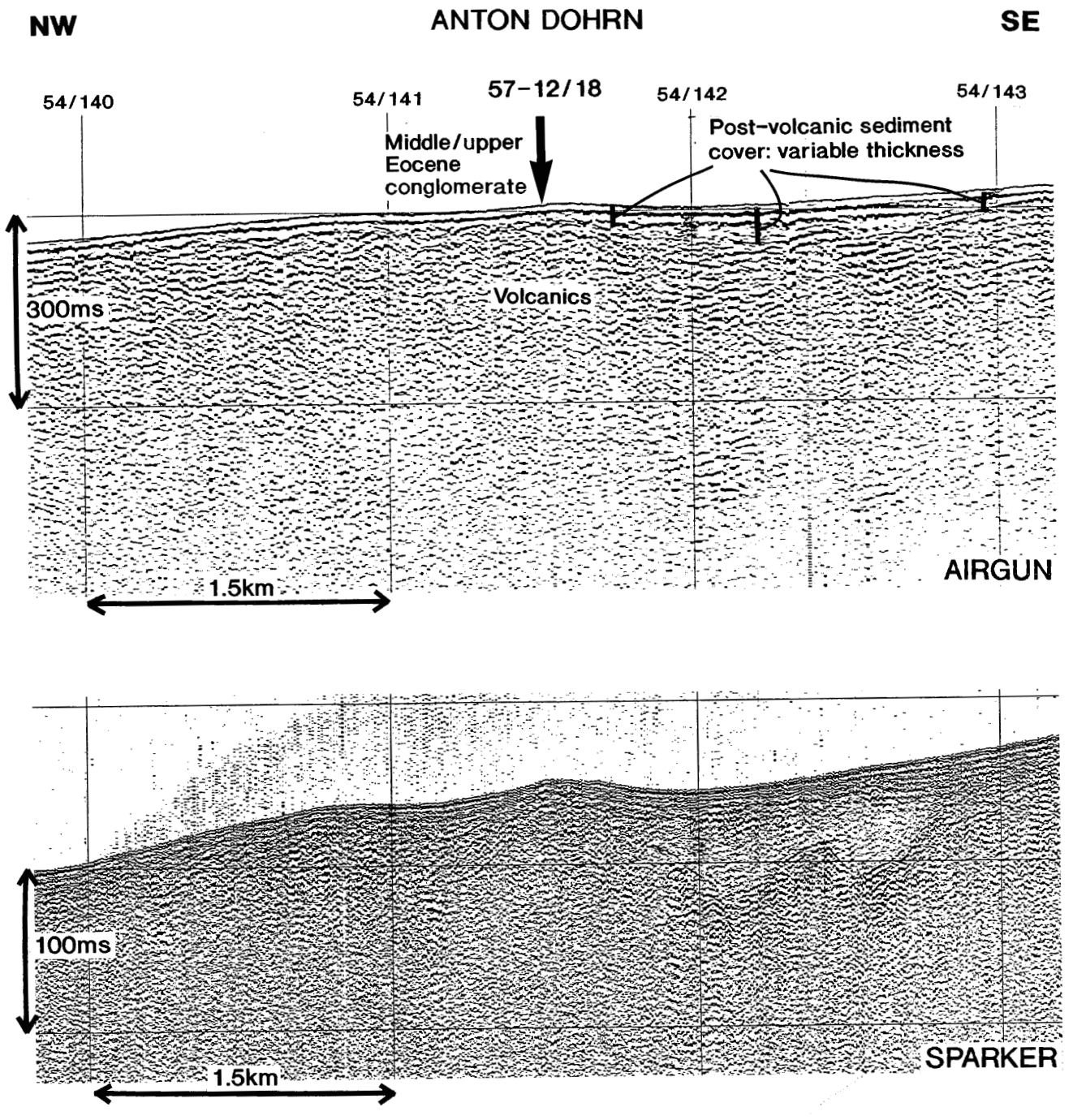
Original site no: S29

T.D. metres: 5.1

Recovery %: 100



57-12/18
(S30)



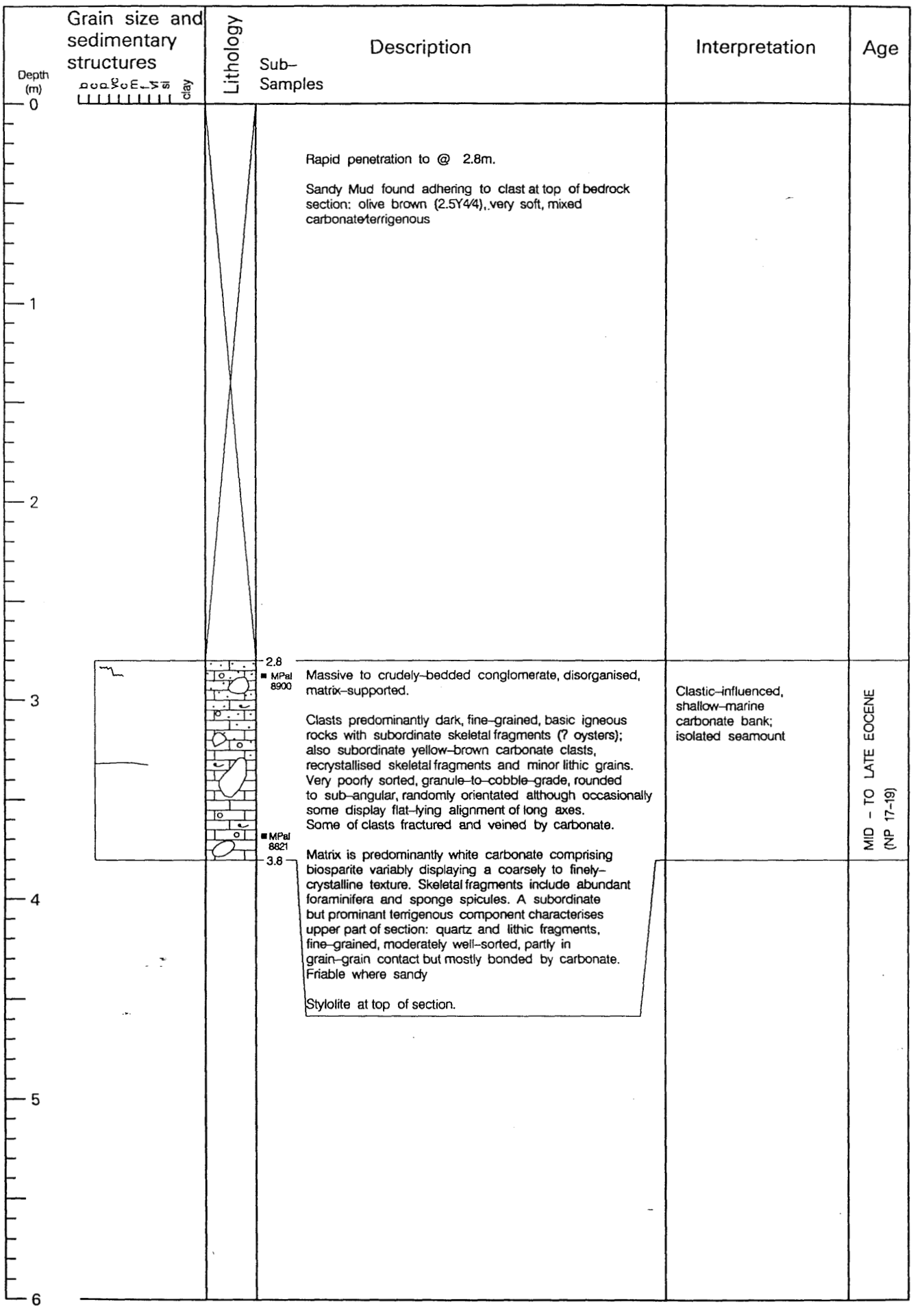
BGS no: 57-12/18
Original site no: S30
Location: Top of Anton Dohrn
Latitude: 57° 33.62' N
Longitude: 11° 05.87' W
Water depth: 705m

BGS core no: 57–12 /18

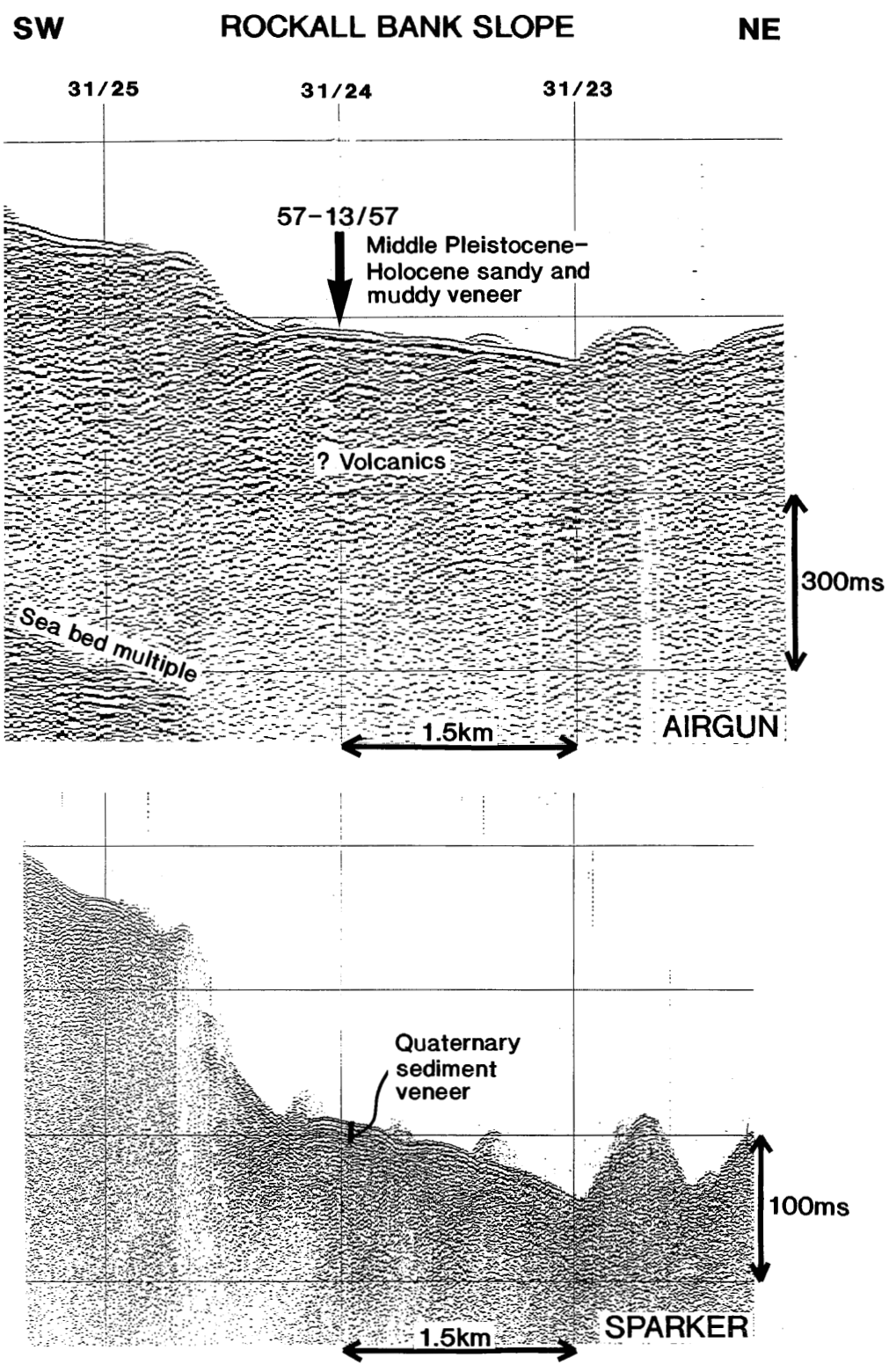
Original site no: S30

T.D. metres: 3.8

Recovery %: 27



57-13/57
(S31)



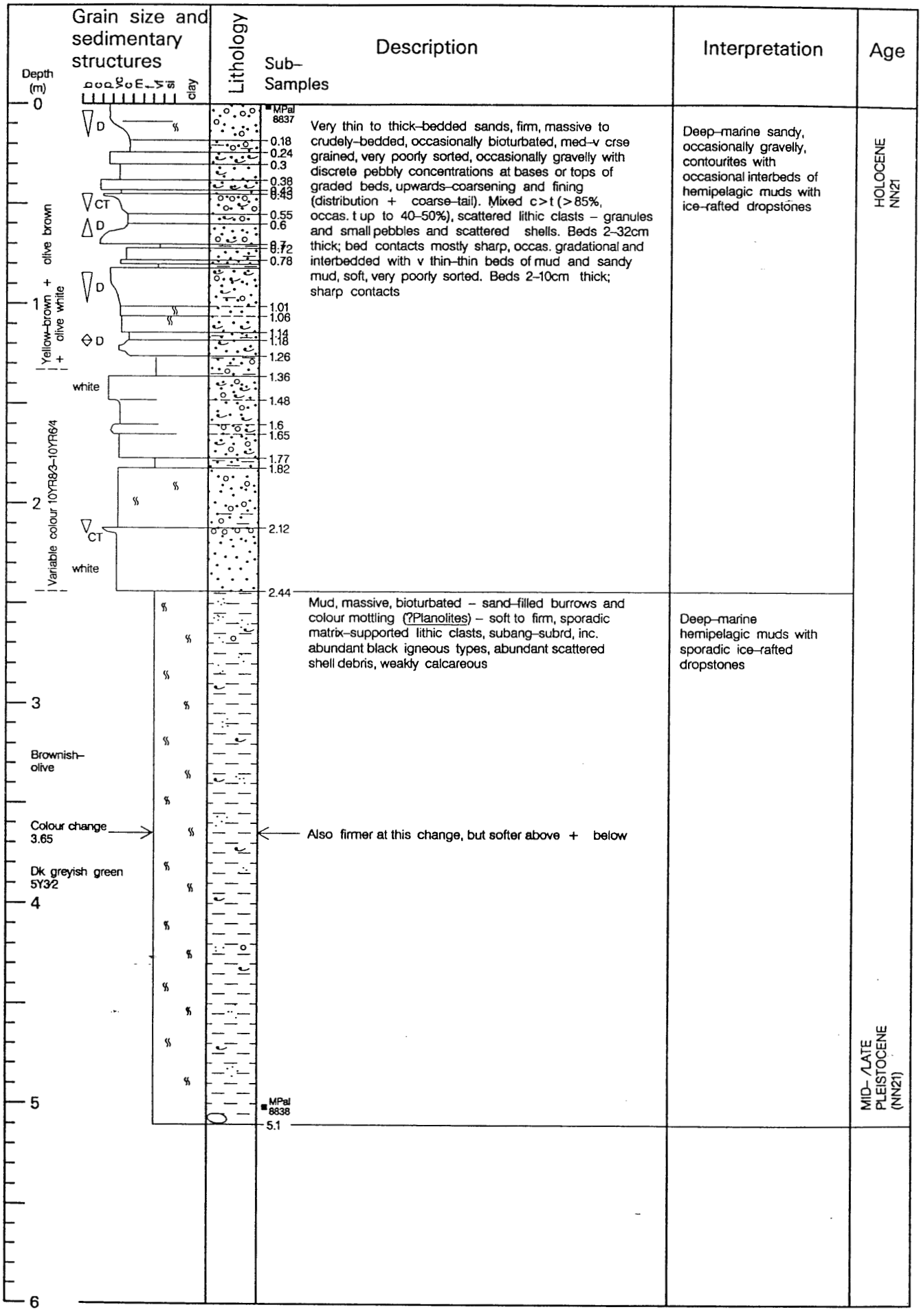
BGS no: 57-13/57
Original site no: S31
Location: Eastern slope of Rockall Bank
Latitude: 57° 19.66' N
Longitude: 12° 59.34' W
Water depth: 658m

BGS core no: 57–13 /57

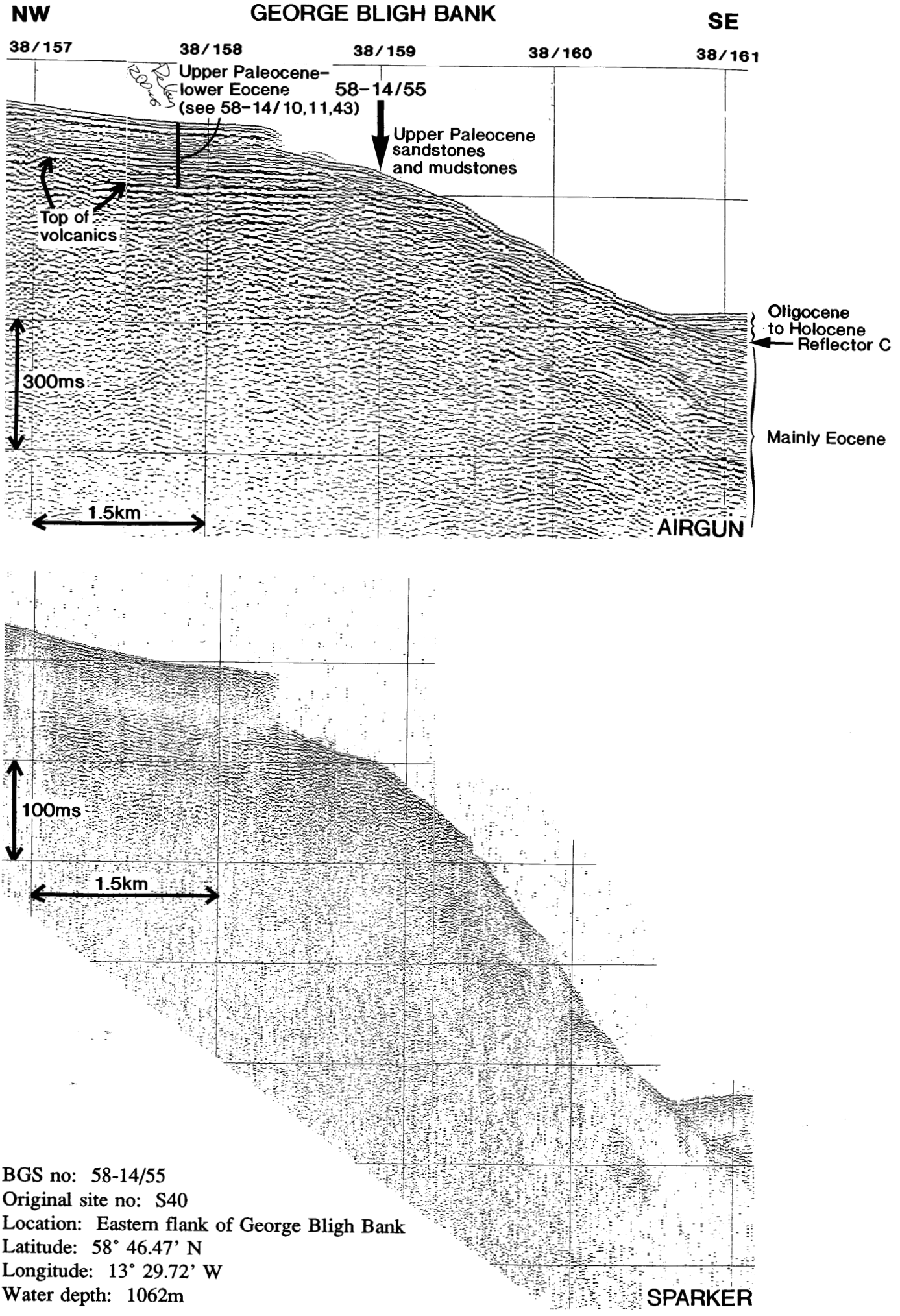
Original site no: S31

T.D. metres: 5.1

Recovery %: 100



58-14/55
(S40)



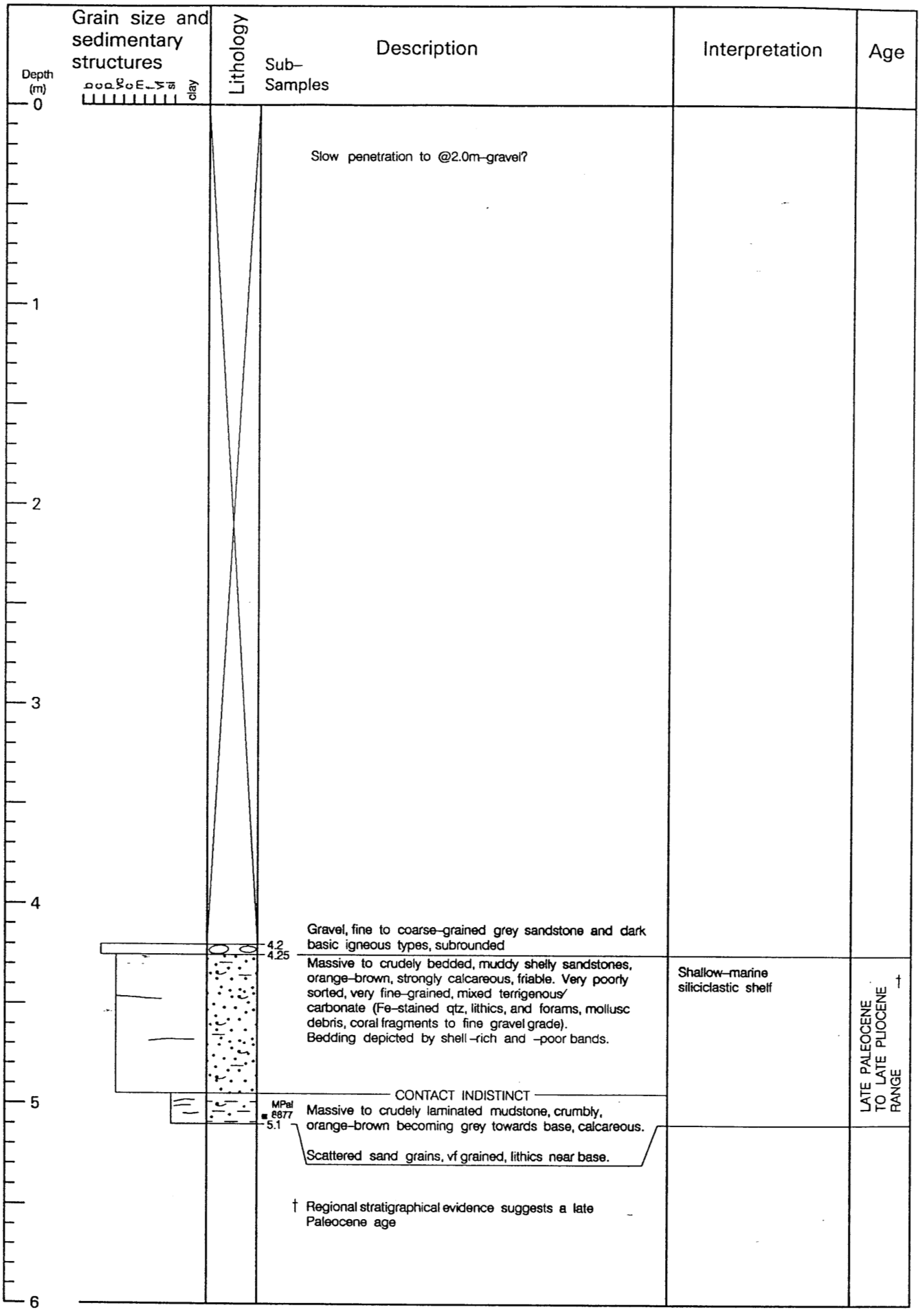
BGS no: 58-14/55
Original site no: S40
Location: Eastern flank of George Bligh Bank
Latitude: 58° 46.47' N
Longitude: 13° 29.72' W
Water depth: 1062m

BGS core no: 58–14 /55

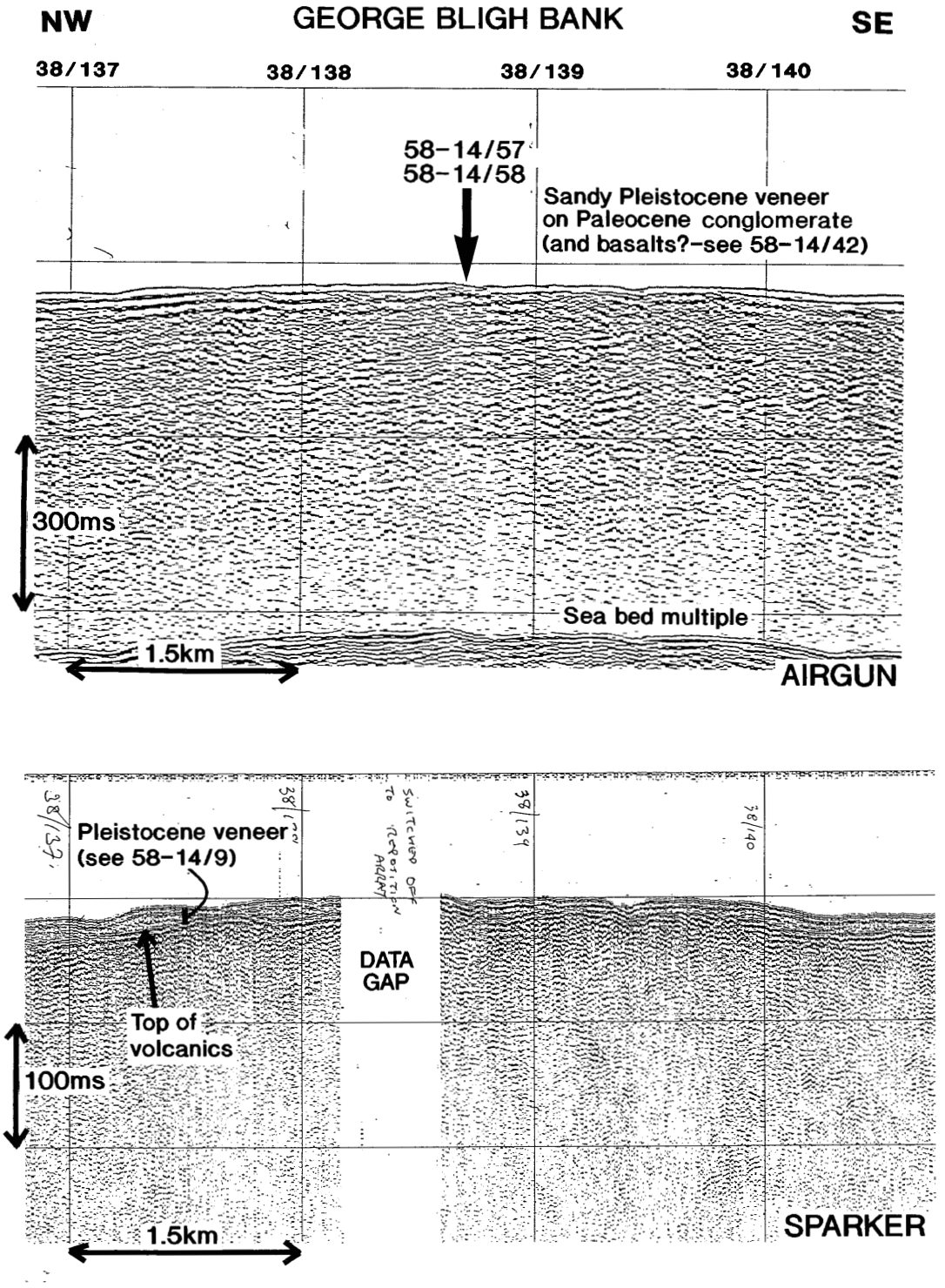
Original site no: S40

T.D. metres: 5.1

Recovery %: 18



57-14/57 & 58
(S41)



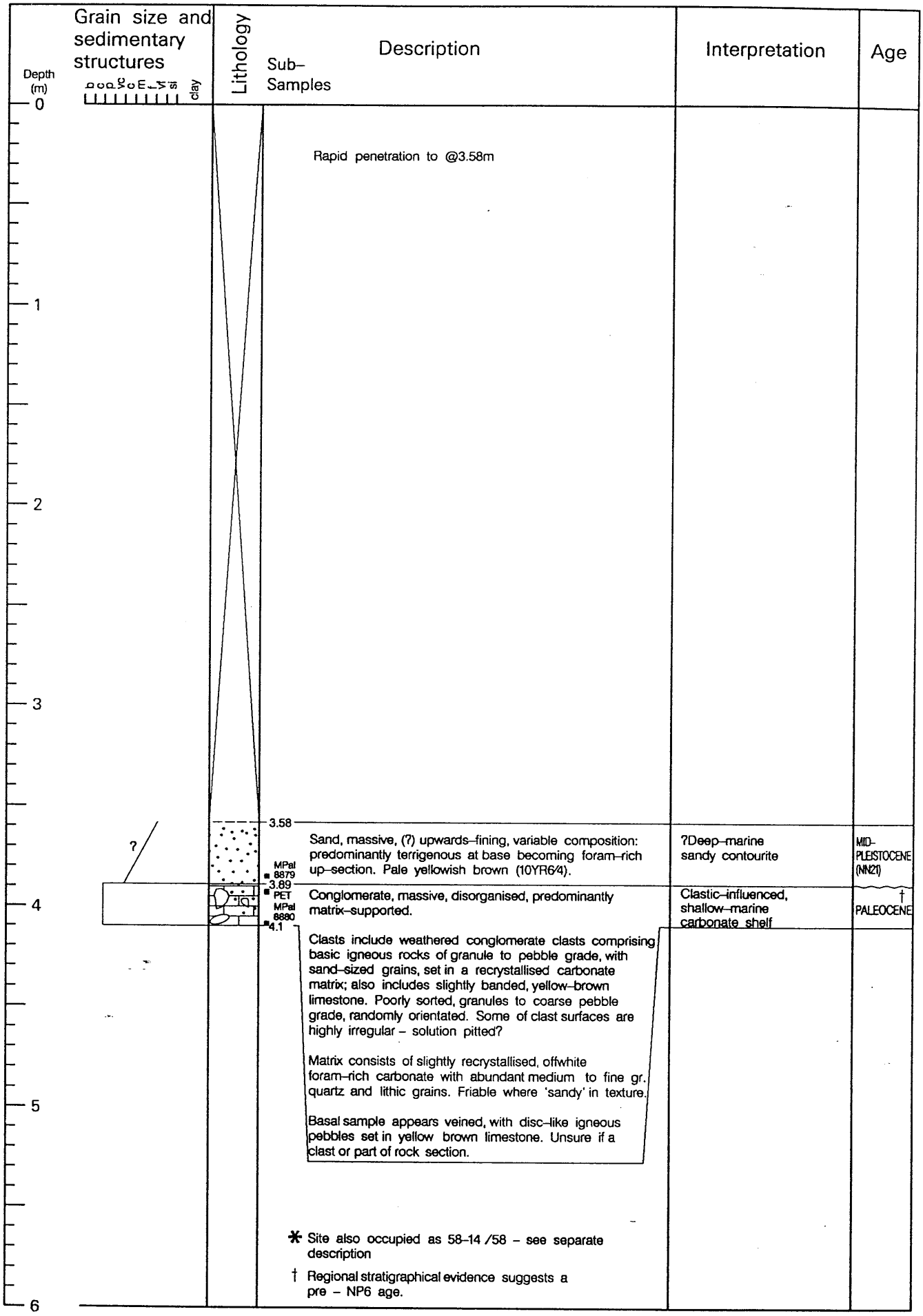
BGS no: 58-14/57
58-14/58
Original site no: S41
Location: Top of George Bligh Bank
Latitude: 58° 56.98' N
Longitude: 13° 50.85' W
Water depth: 444m

BGS core no: 58–14 /57*

Original site no: S41

T.D. metres: 4.1

Recovery %: 13

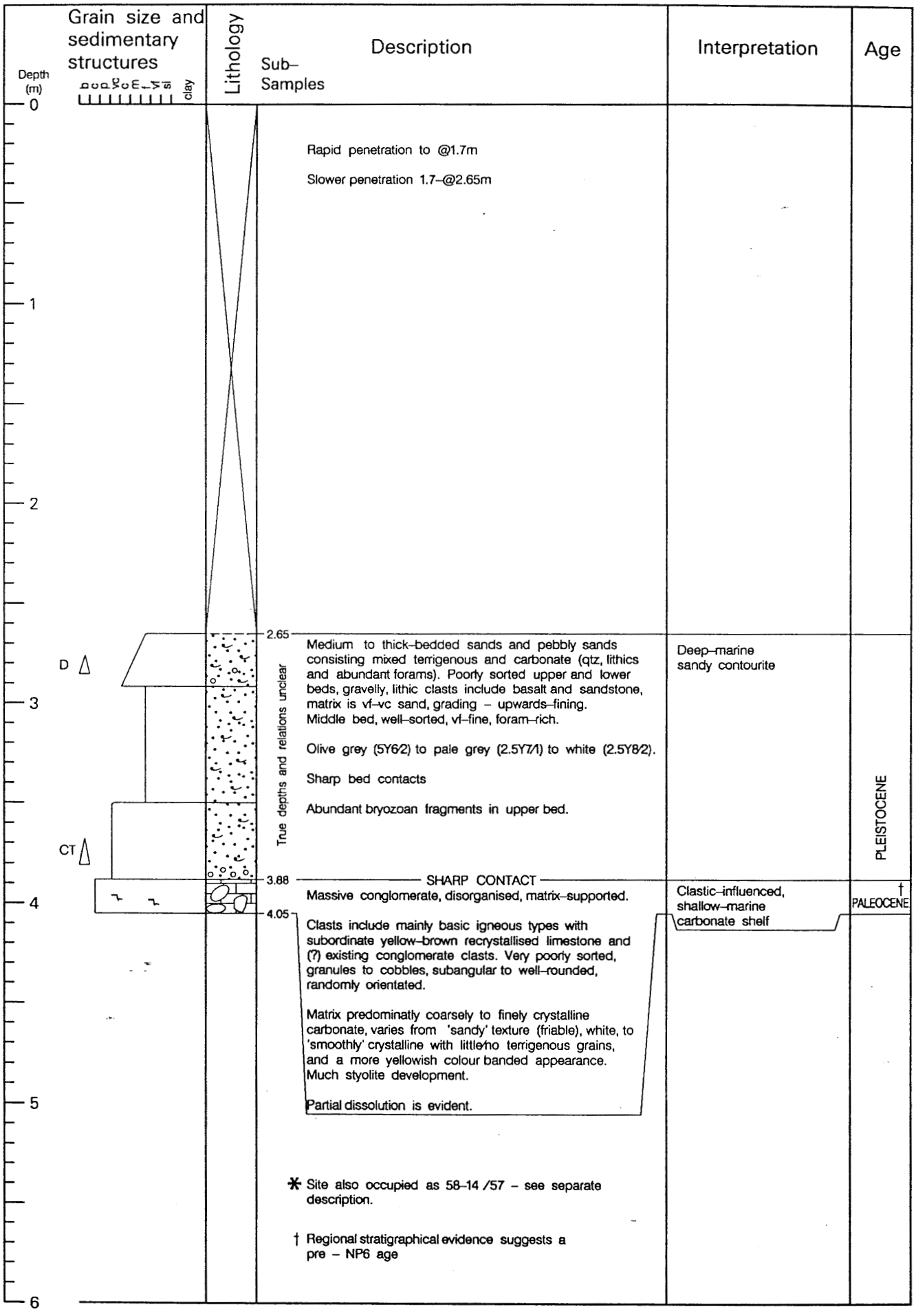


BGS core no: 58–14 /58*

Original site no: S41

T.D. metres: 4.05

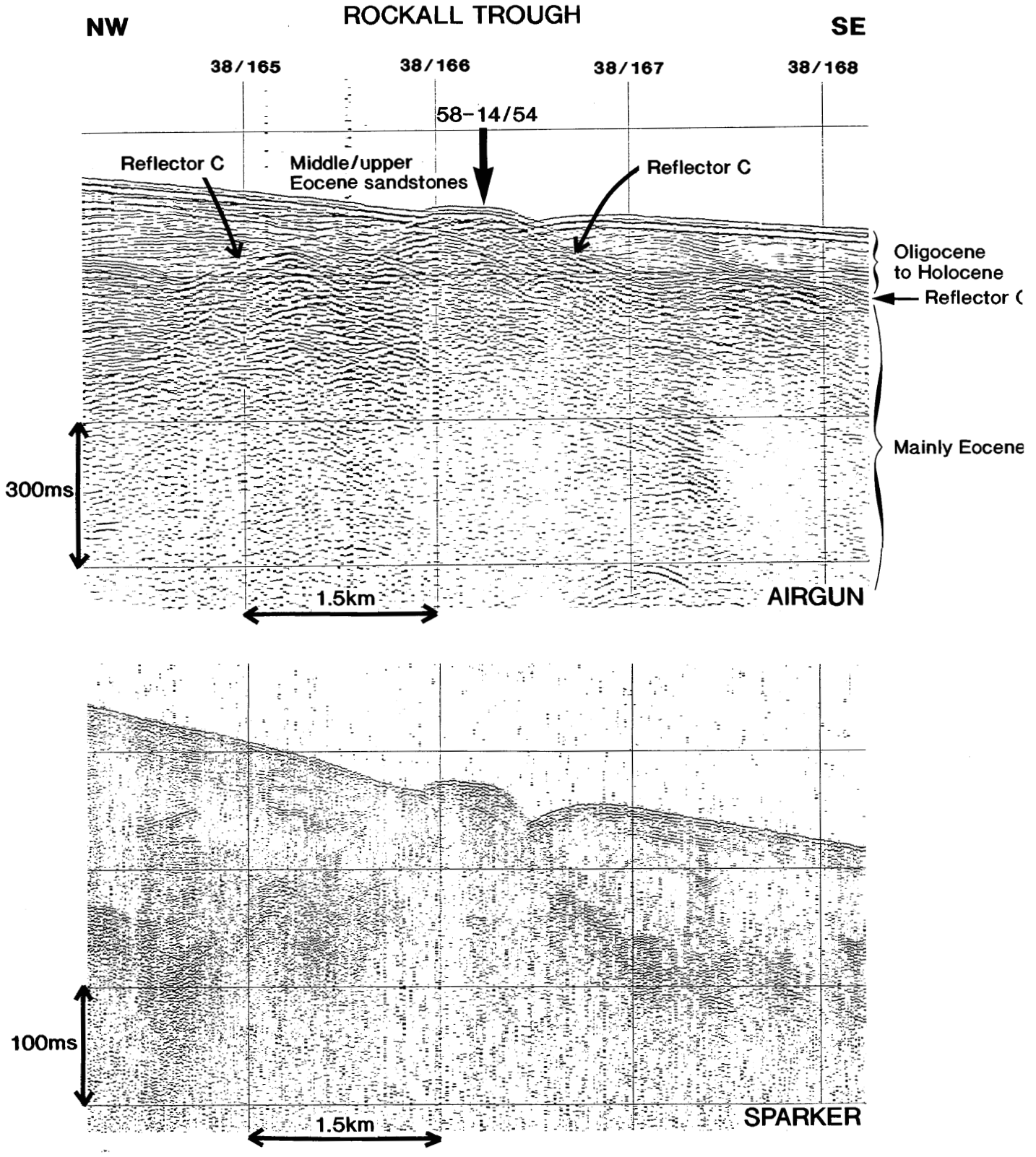
Recovery %: 35



* Site also occupied as 58–14 /57 – see separate description.

† Regional stratigraphical evidence suggests a pre – NP6 age

58-14/54
(S42)



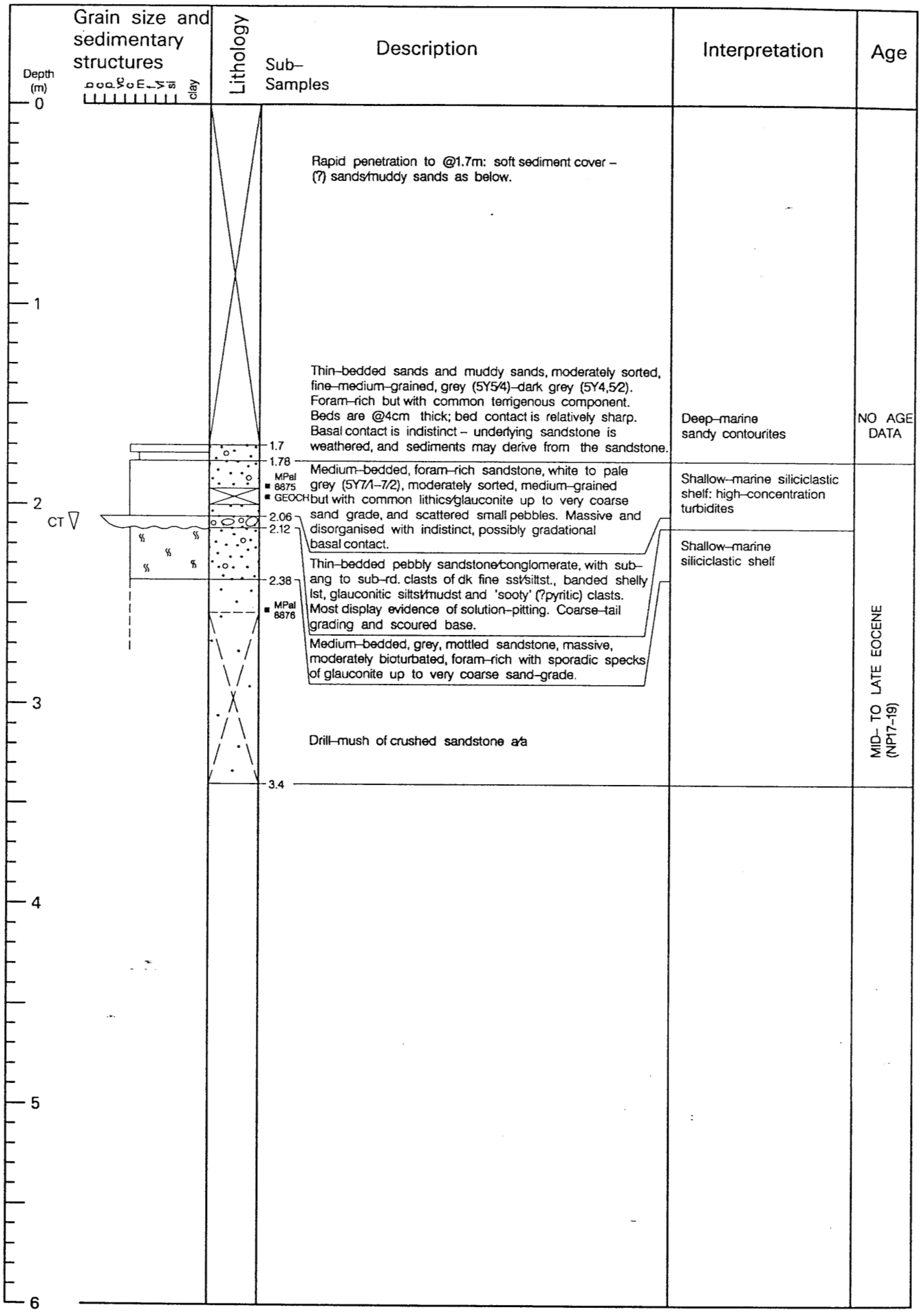
BGS no: 58-14/54
Original site no: S42
Location: North-west Rockall Trough
Latitude: 58° 43.08' N
Longitude: 13° 22.86' W
Water depth: 1433m

BGS core no: 58–14 /54

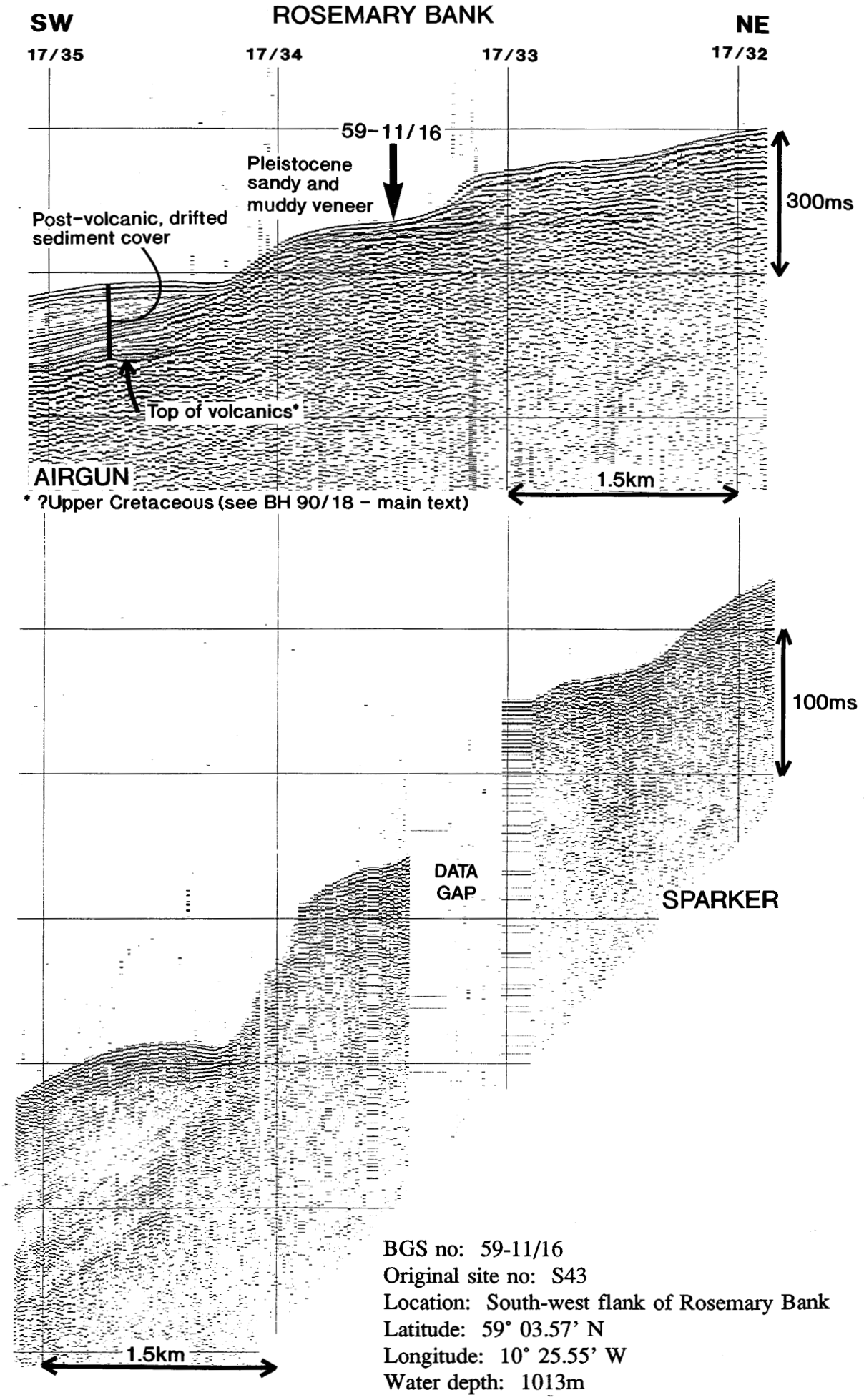
Original site no: S42

T.D. metres: 3.4

Recovery %: 25



59-11/16
(S43)



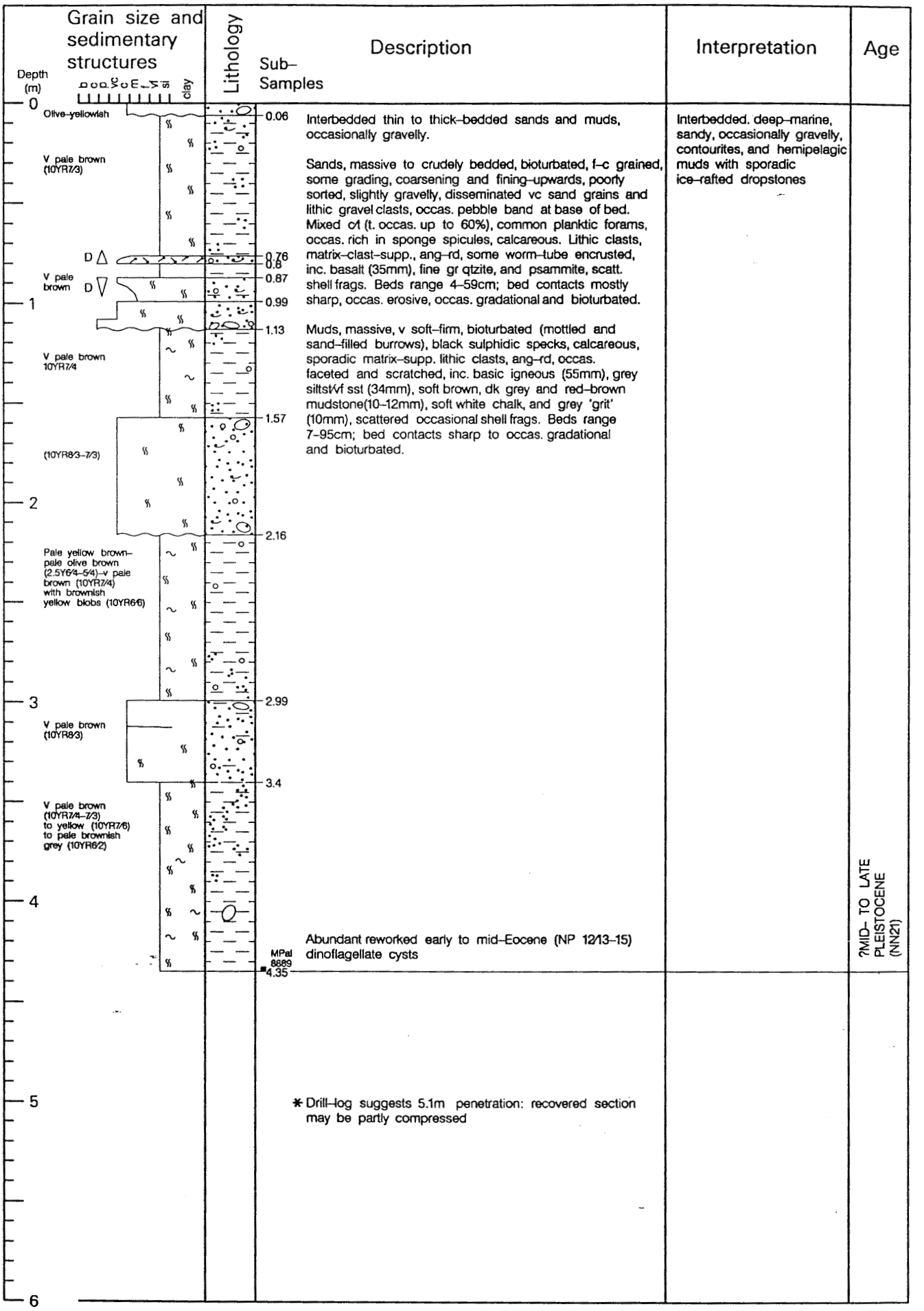
BGS no: 59-11/16
Original site no: S43
Location: South-west flank of Rosemary Bank
Latitude: 59° 03.57' N
Longitude: 10° 25.55' W
Water depth: 1013m

BGS core no: 59–11/16

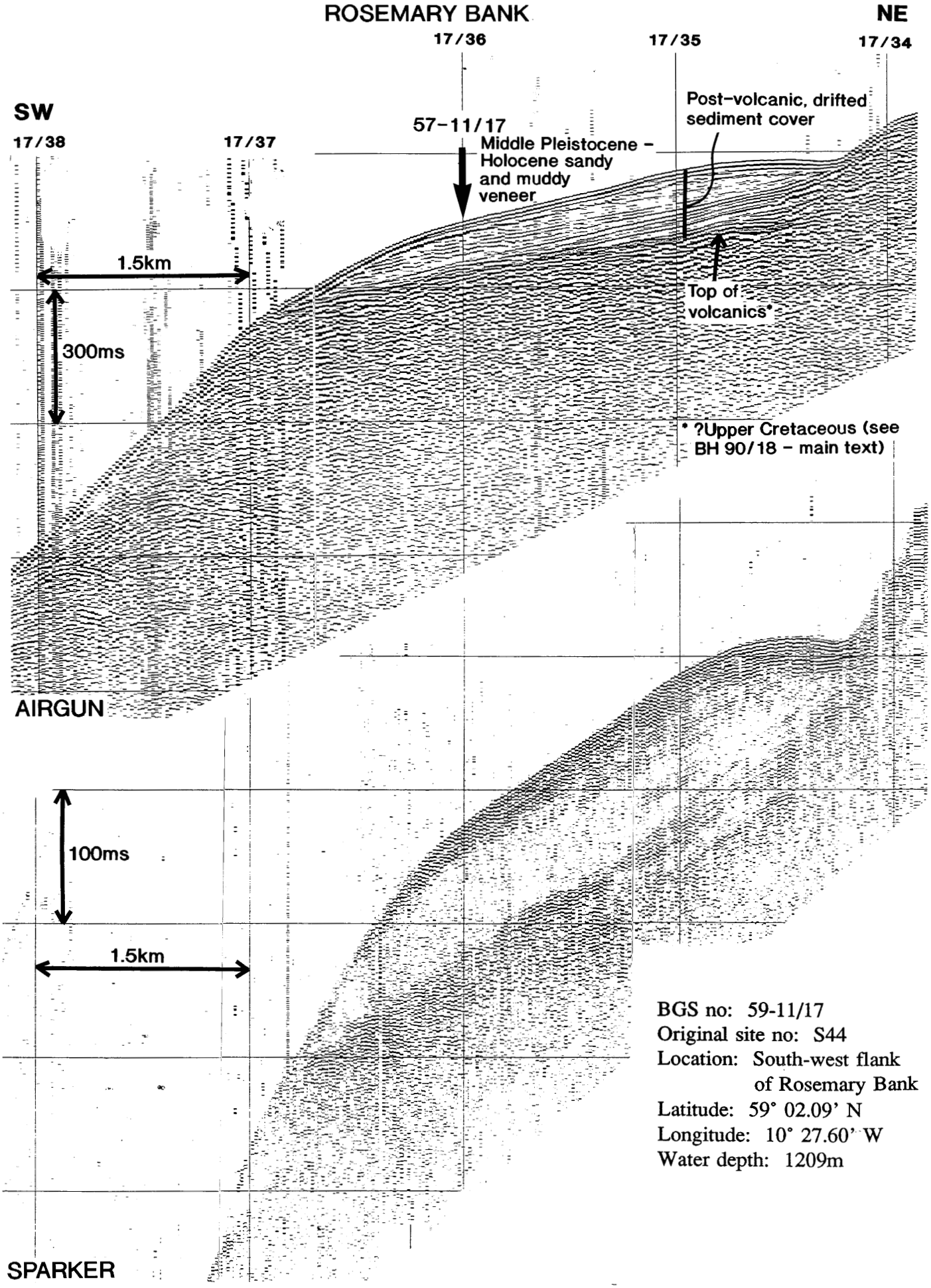
Original site no: S43

T.D. metres: 4.35*

Recovery %: 100



59-11/17
(S44)



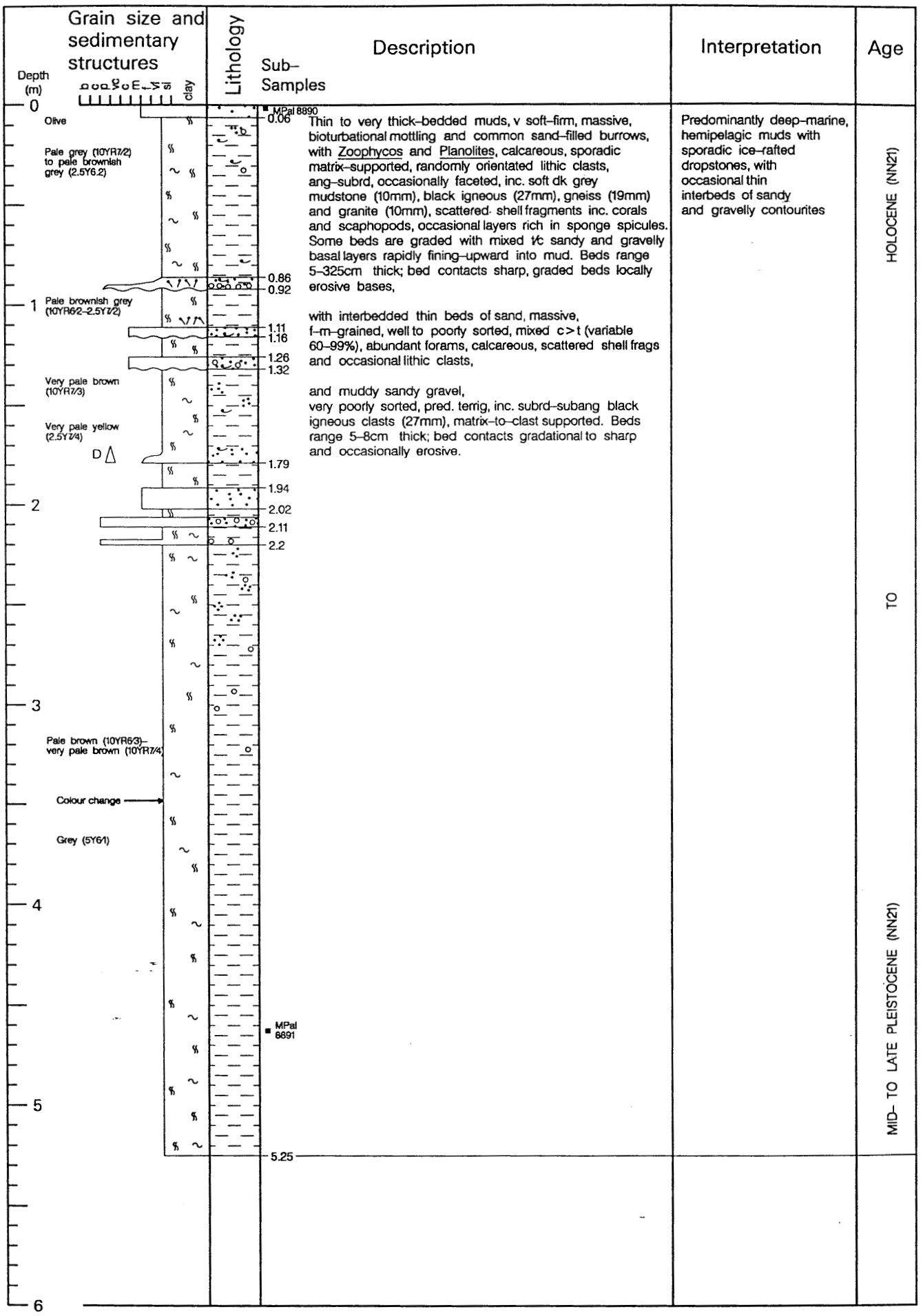
BGS no: 59-11/17
Original site no: S44
Location: South-west flank of Rosemary Bank
Latitude: 59° 02.09' N
Longitude: 10° 27.60' W
Water depth: 1209m

BGS core no: 59–11/17

Original site no: S44

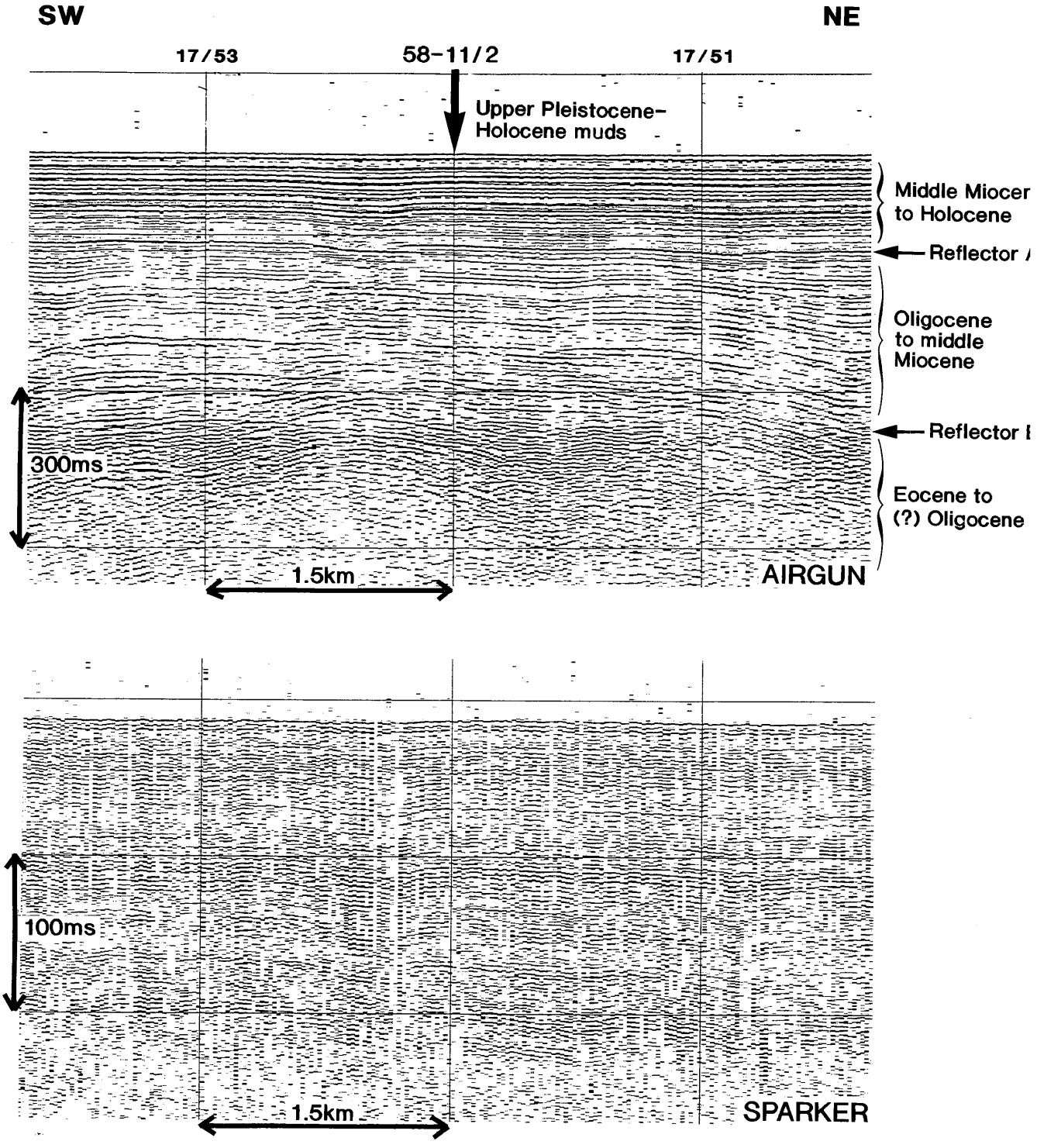
T.D. metres: 5.25

Recovery %: 100



58-11/2
(S45)

ROCKALL TROUGH



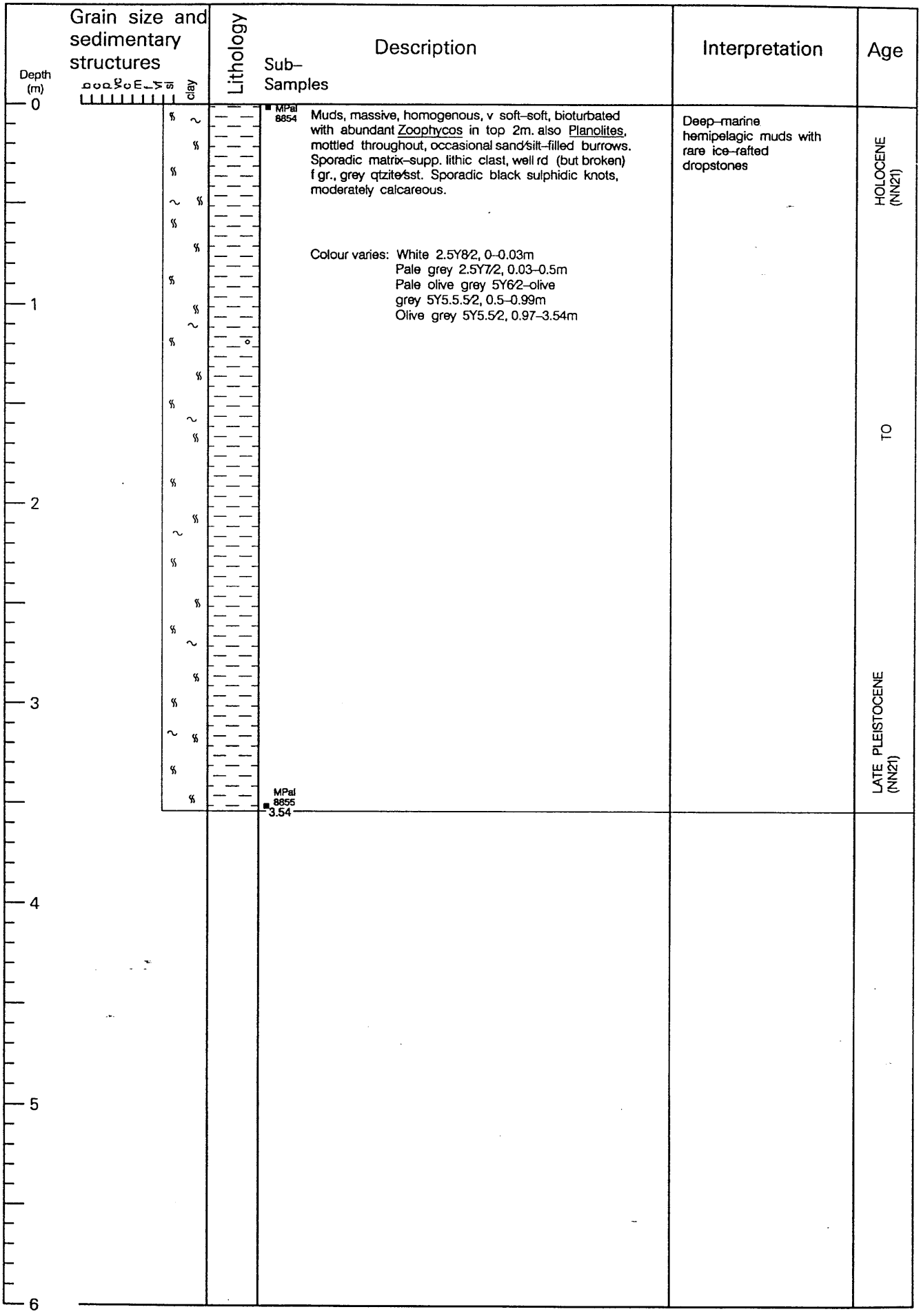
BGS no: 58-11/2
Original site no: S45
Location: Rockall Trough, south-west of Rosemary Bank
Latitude: 58° 53.23' N
Longitude: 10° 39.65' W
Water depth: 1863m

BGS core no: 58–11/2

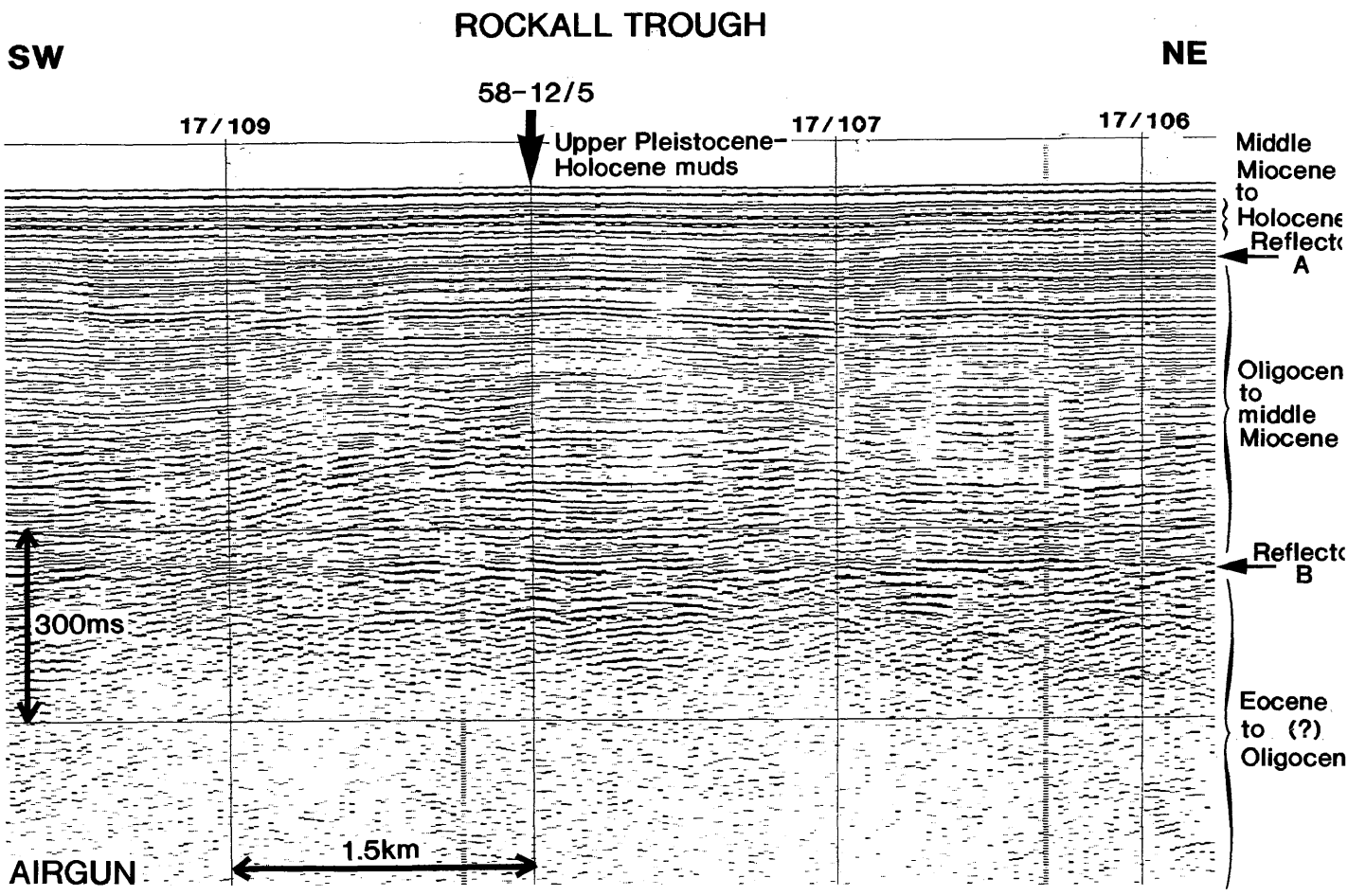
Original site no: S45

T.D. metres: 3.54

Recovery %: 100



58-12/5
(S46)



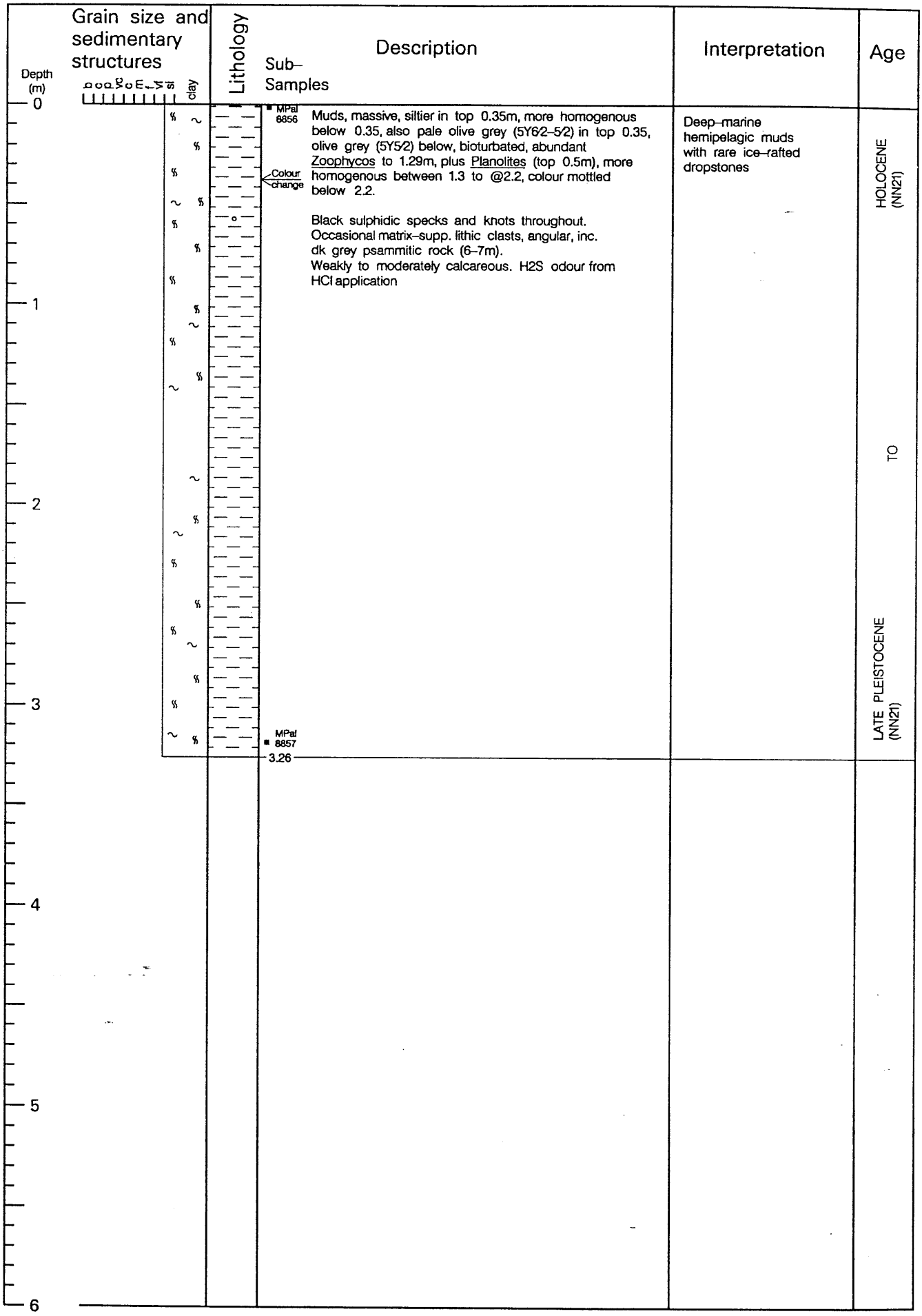
BGS no: 58-12/5
Original site no: S46
Location: Rockall Trough, south-west of Rosemary Bank
Latitude: 58° 21.80' N
Longitude: 11° 21.18' W
Water depth: 1809m

BGS core no: 58–12 /5

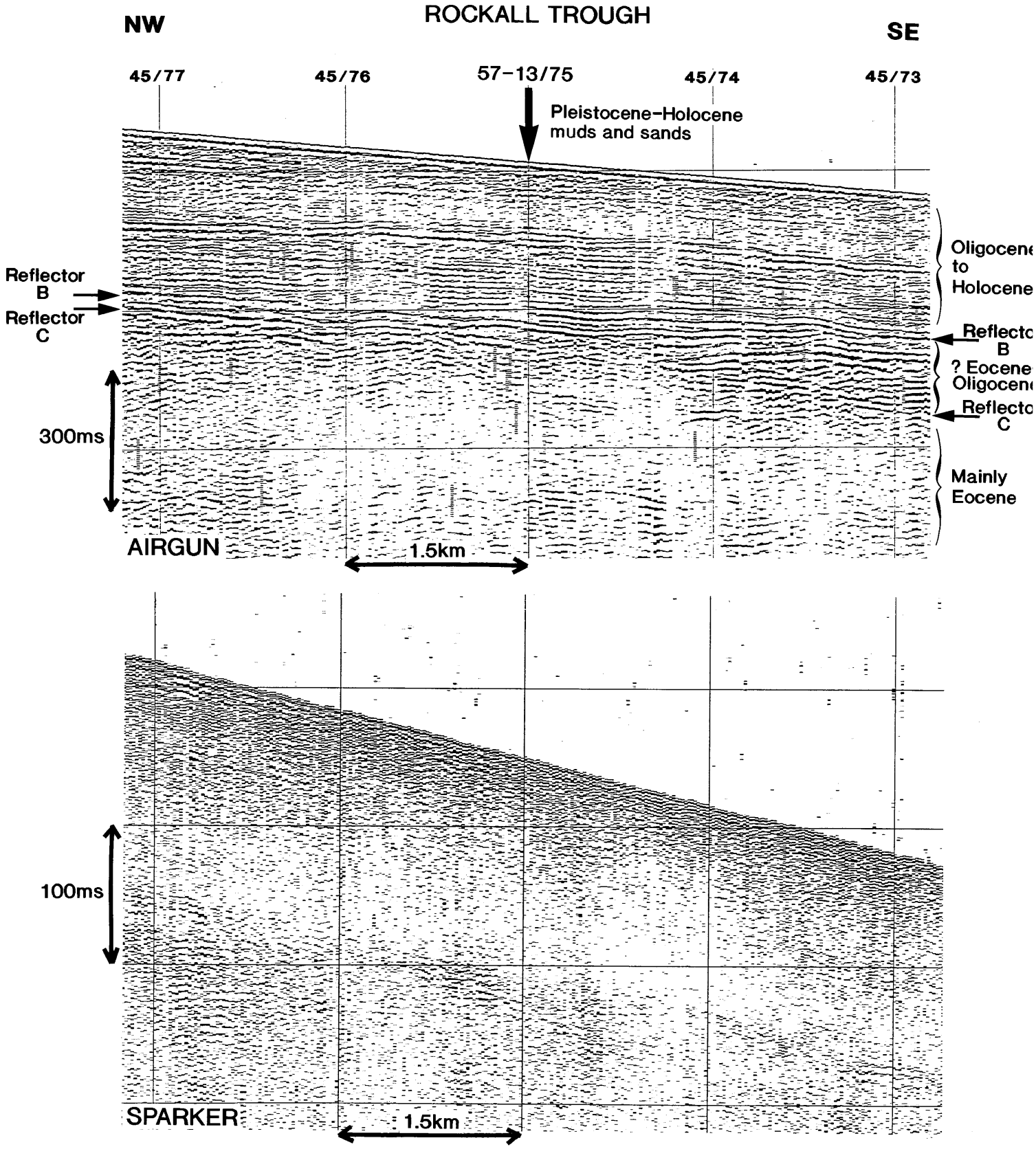
Original site no: S46

T.D. metres: 3.26

Recovery %: 100



57-13/75
(S47)



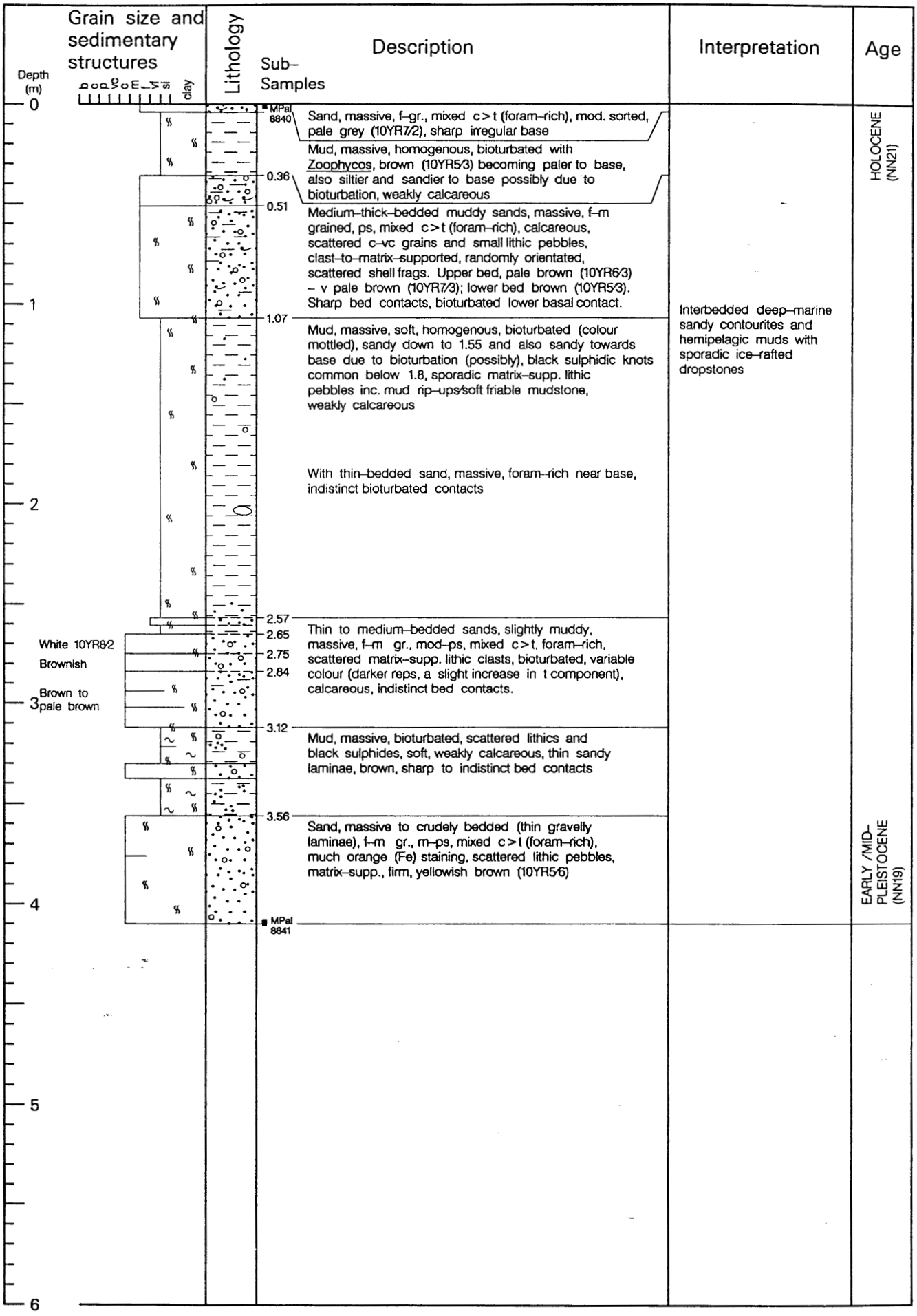
BGS no: 57-13/75
Original site no: S47
Location: Rockall Trough, north-east of Rockall Bank
Latitude: 57° 41.68' N
Longitude: 12° 36.62' W
Water depth: 1523m

BGS core no: 57–13 /75

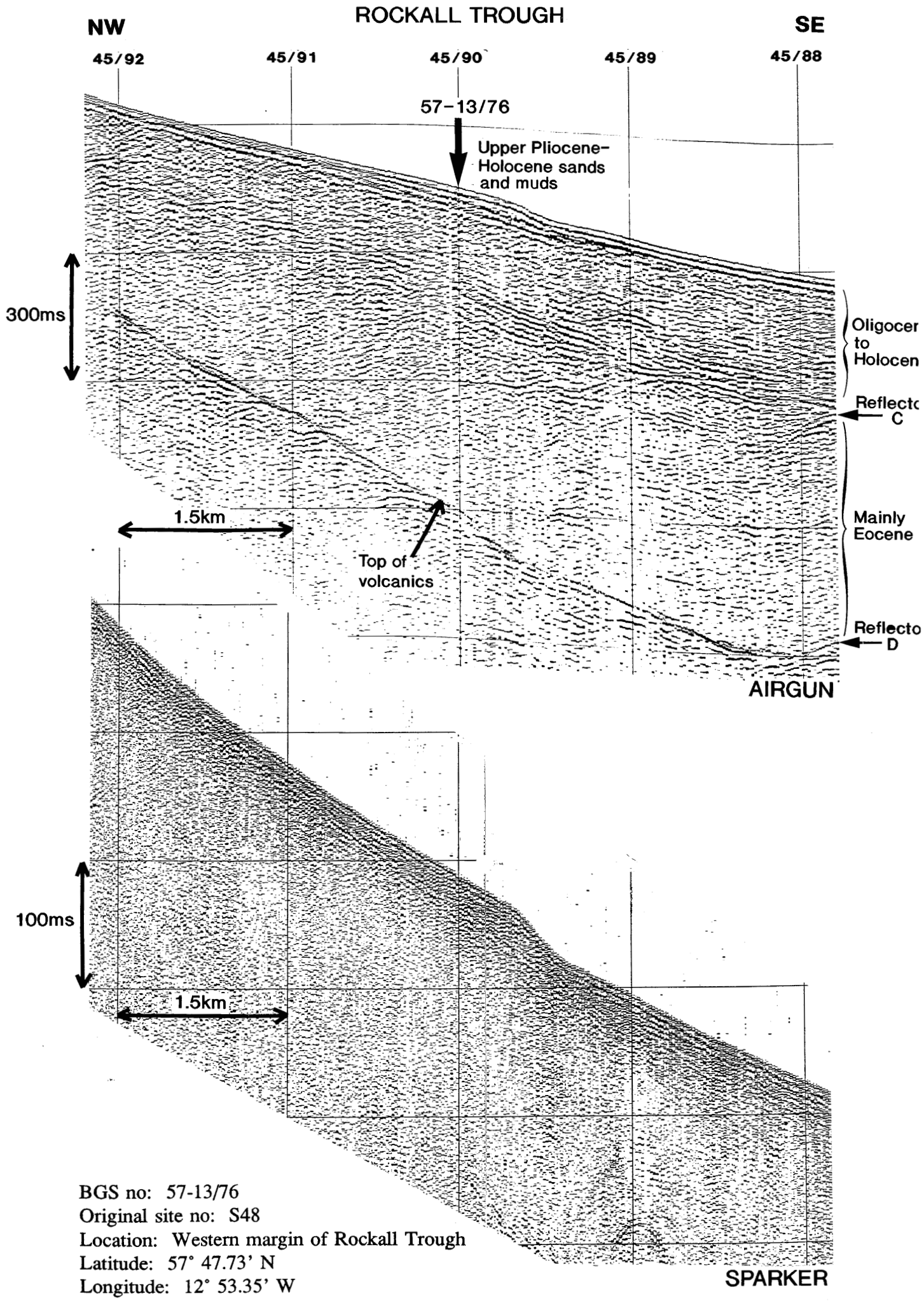
Original site no: S47

T.D. metres: 4.1

Recovery %: 100



57-13/76
(S48)



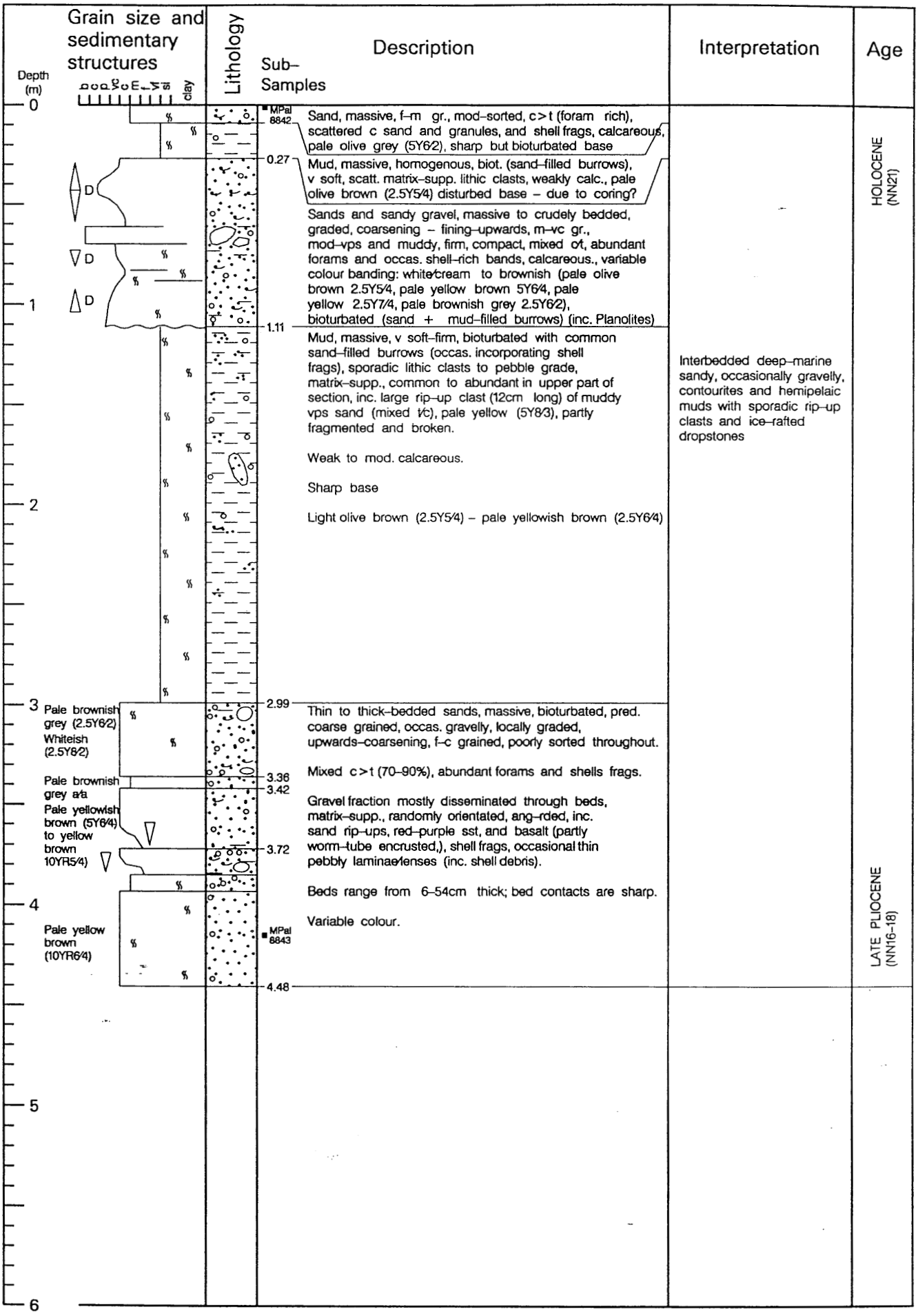
BGS no: 57-13/76
Original site no: S48
Location: Western margin of Rockall Trough
Latitude: 57° 47.73' N
Longitude: 12° 53.35' W
Water depth: 970m

BGS core no: 57–13 /76

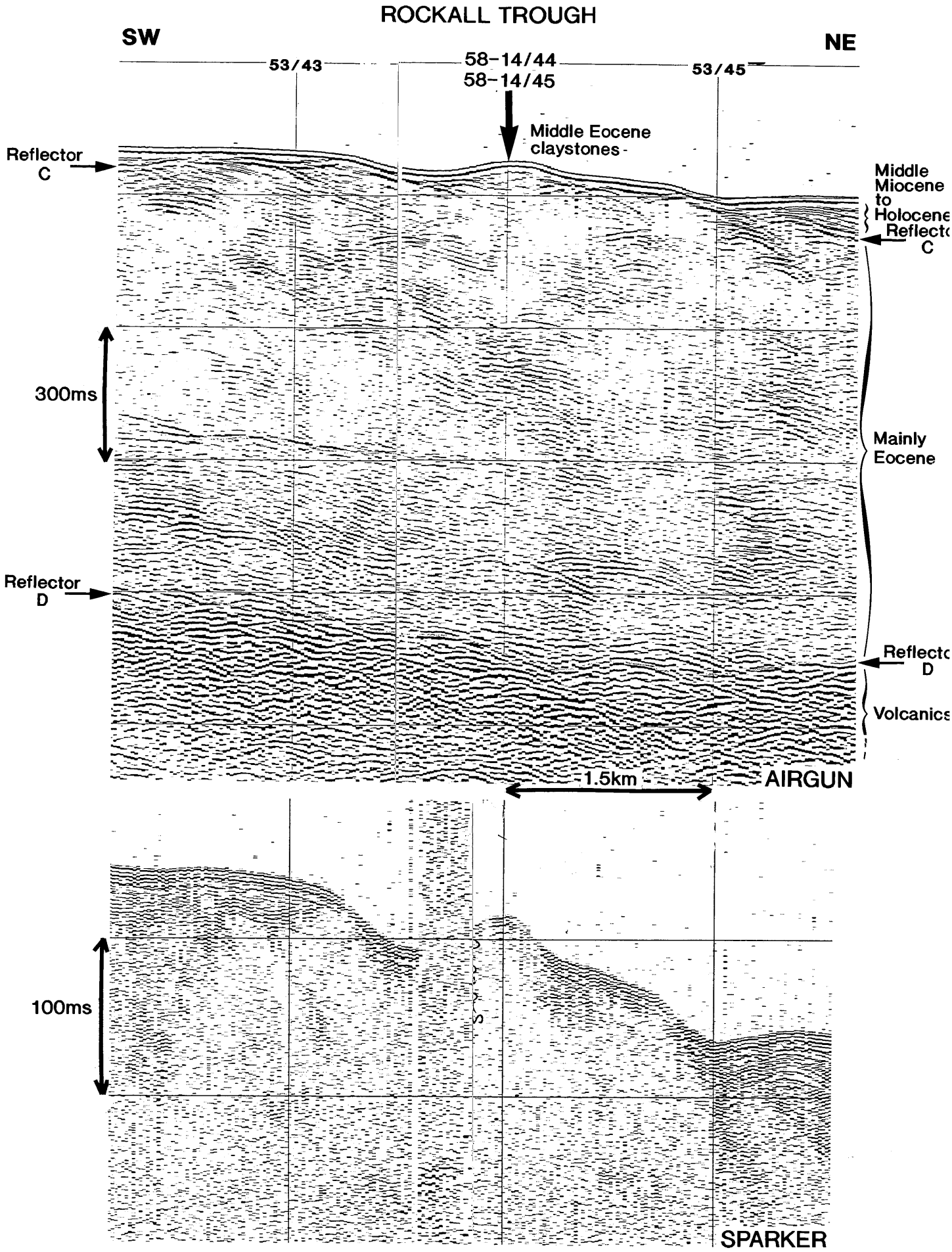
Original site no: S48

T.D. metres: 4.48

Recovery %: 100



58-14/44 & 45
(S49)



BGS no: 58-14/44
58-14/45
Original site no: S49
Location: North-west Rockall Trough

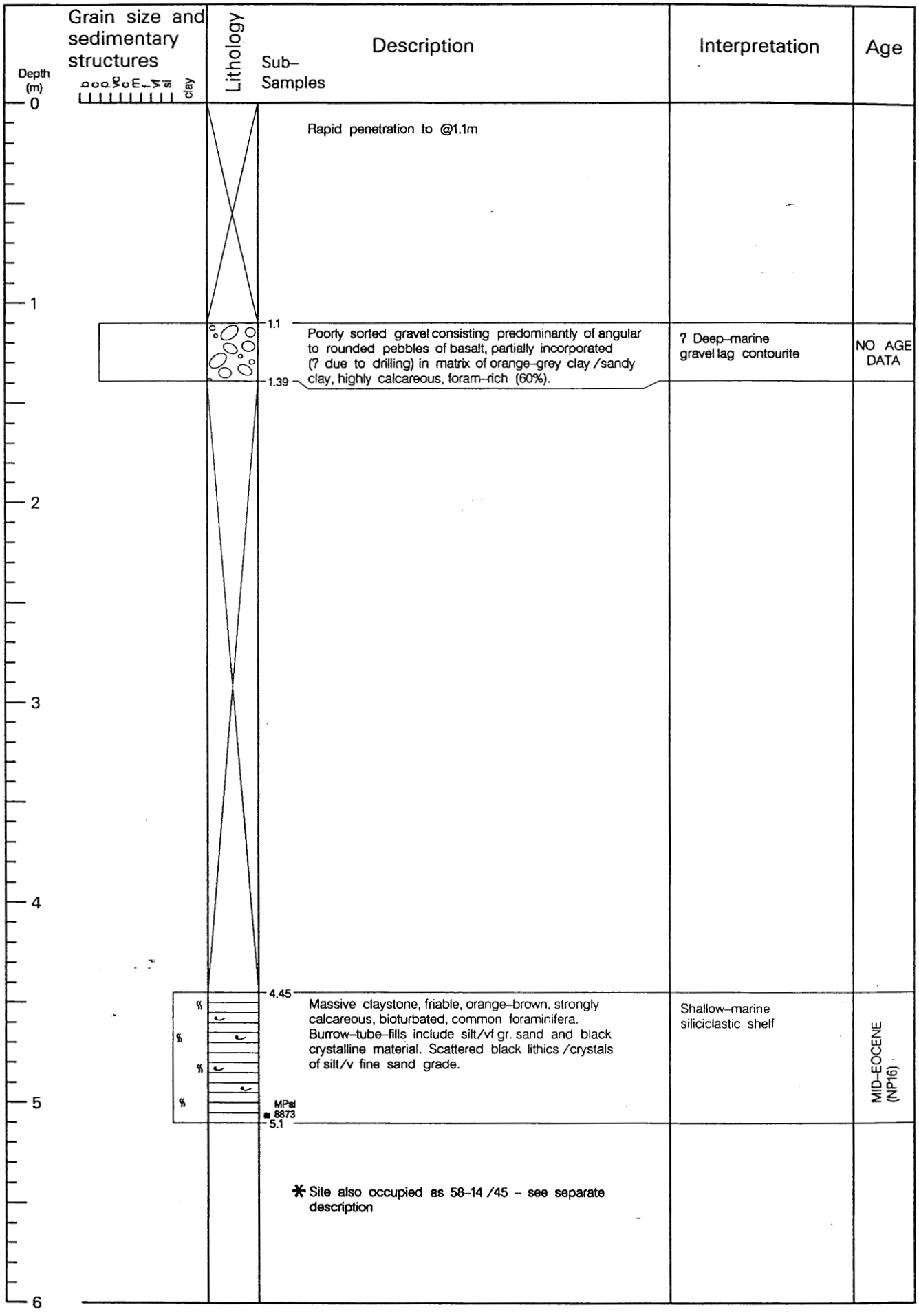
58-14/44		58-14/45	
Latitude:	58° 33.00' N	Latitude:	58° 33.01' N
Longitude:	13° 08.33' W	Longitude:	13° 08.31' W
Water depth:	1621m	Water depth:	1622m

BGS core no: 58–14 /44*

Original site no: S49

T.D. metres: 5.1

Recovery %: 18

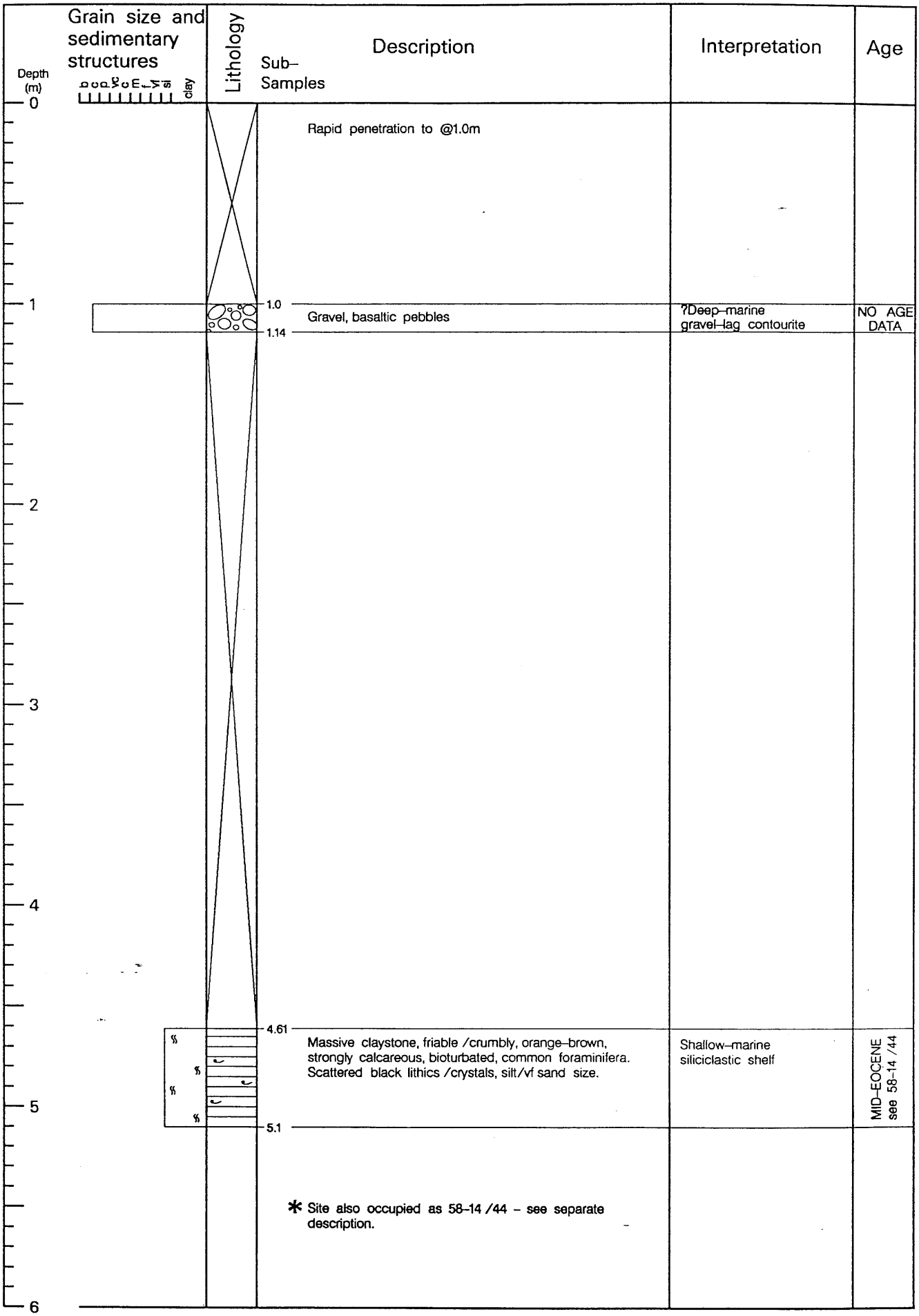


BGS core no: 58–14 /45*

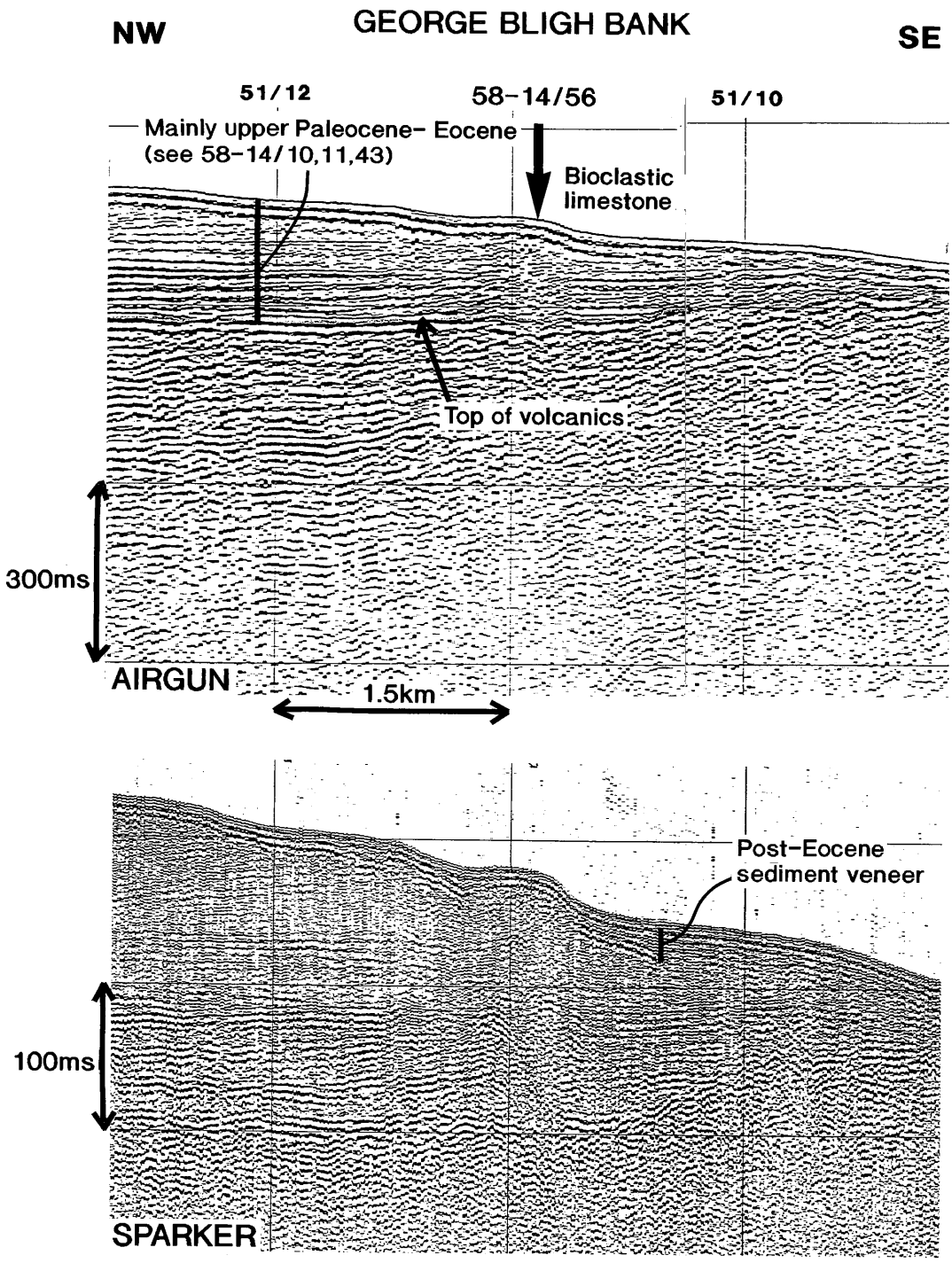
Original site no: S49

T.D. metres: 5.1

Recovery %: 13



58-14/56
(S50)



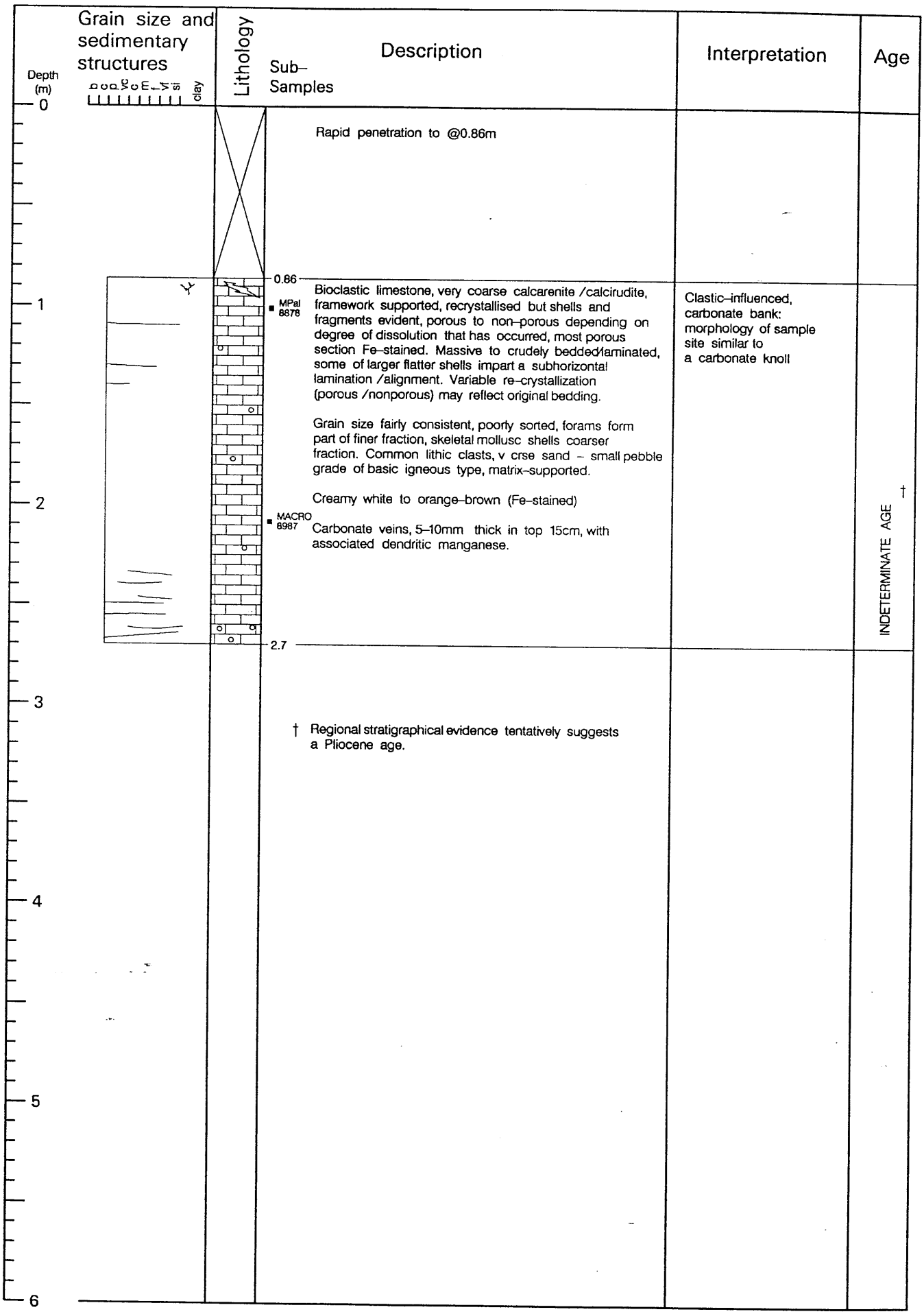
BGS no: 58-14/56
Original site no: S50
Location: Eastern flank of George Bligh Bank
Latitude: 58° 52.11' N
Longitude: 13° 34.12' W
Water depth: 685m

BGS core no: 58–14 /56

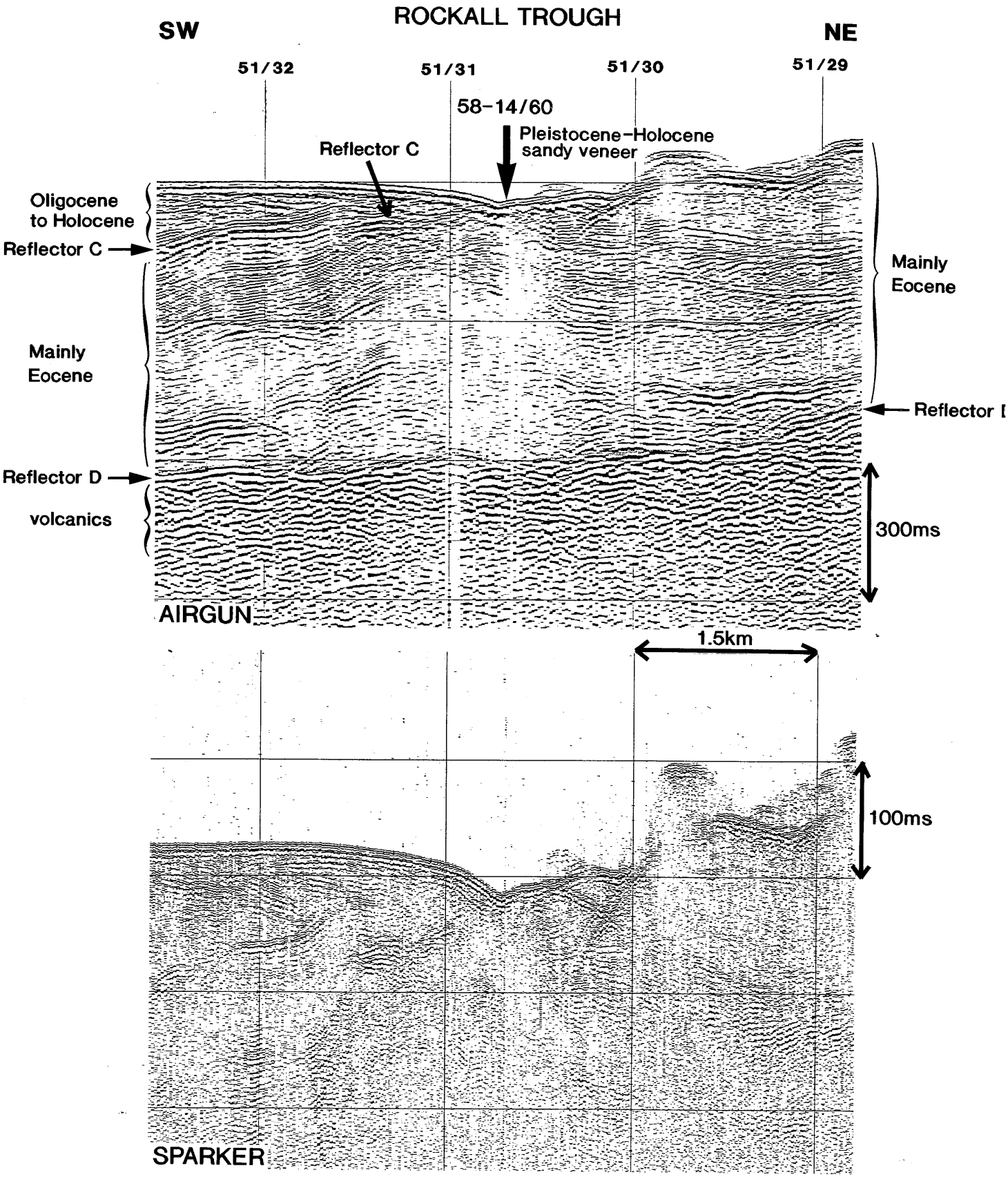
Original site no: S50

T.D. metres: 2.7

Recovery %: 68



58-14/60
(S51)



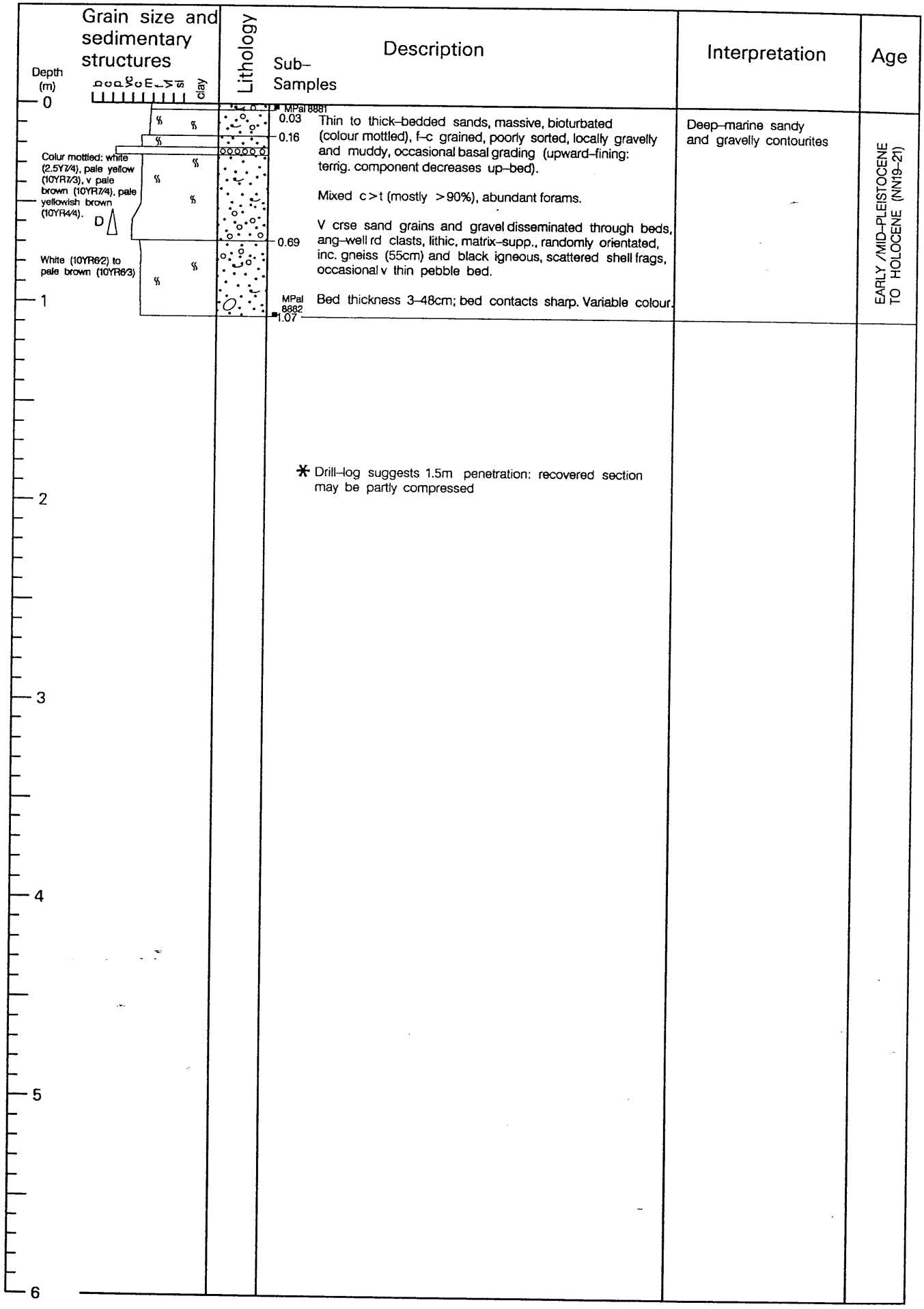
BGS no: 58-14/60
Original site no: S51
Location: North-west Rockall Trough, adjacent to George Bligh Bank
Latitude: 58° 39.48' N
Longitude: 13° 49.72' W
Water depth: 1270m

BGS core no: 58–14 /60

Original site no: S51

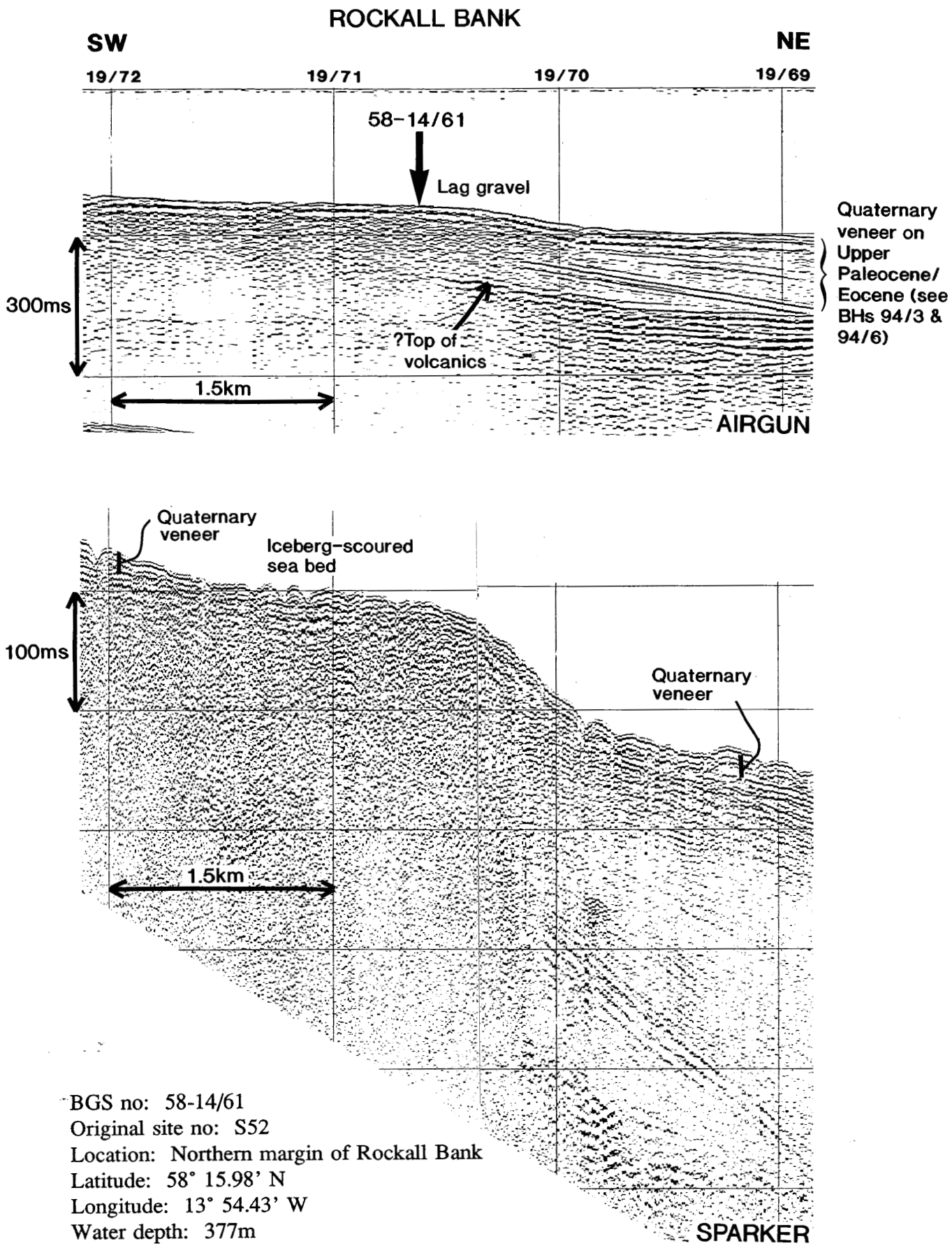
T.D. metres: 1.07*

Recovery %: 100



* Drill–log suggests 1.5m penetration: recovered section may be partly compressed

58-14/61
(S52)



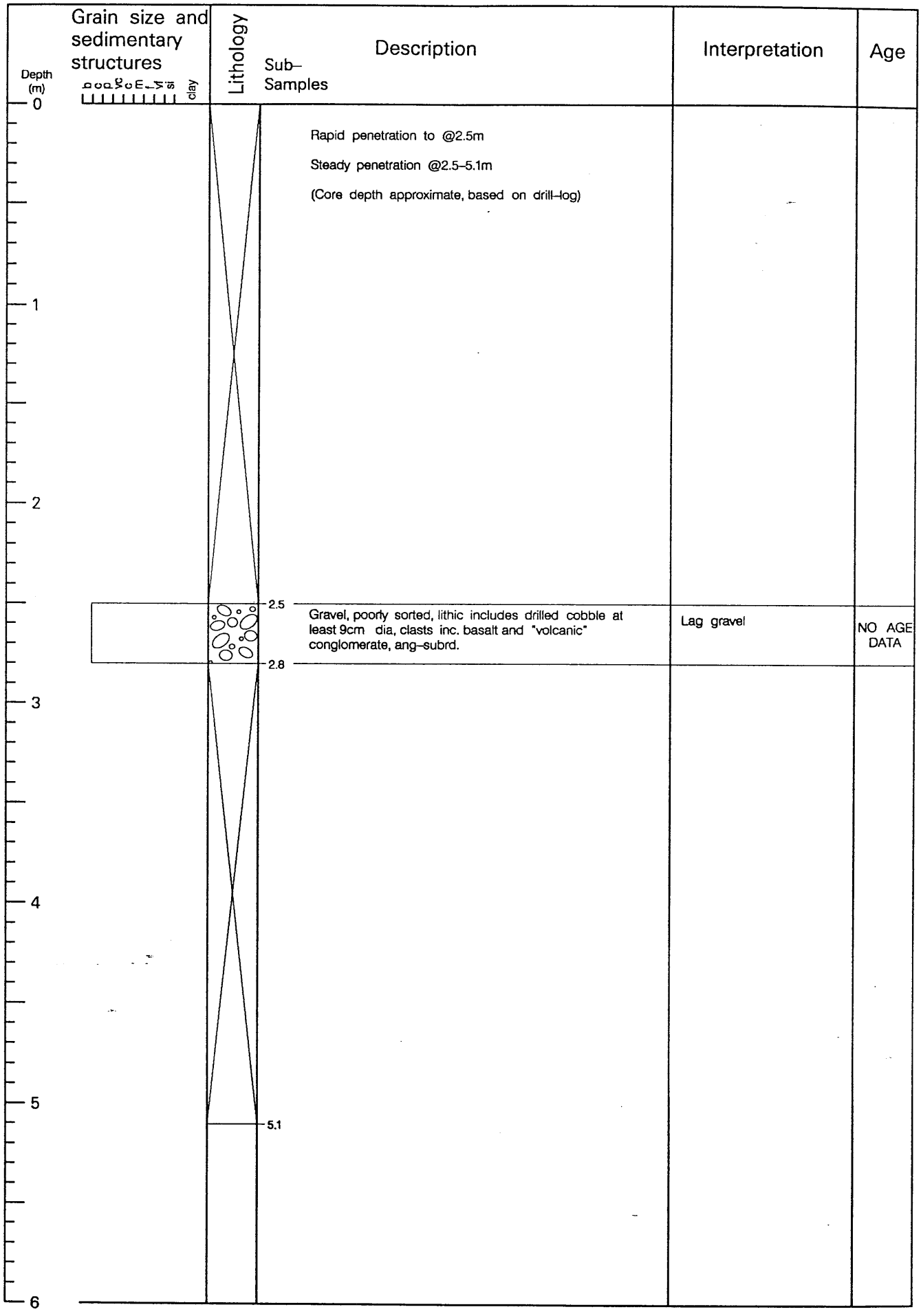
BGS no: 58-14/61
Original site no: S52
Location: Northern margin of Rockall Bank
Latitude: 58° 15.98' N
Longitude: 13° 54.43' W
Water depth: 377m

BGS core no: 58–14 /61

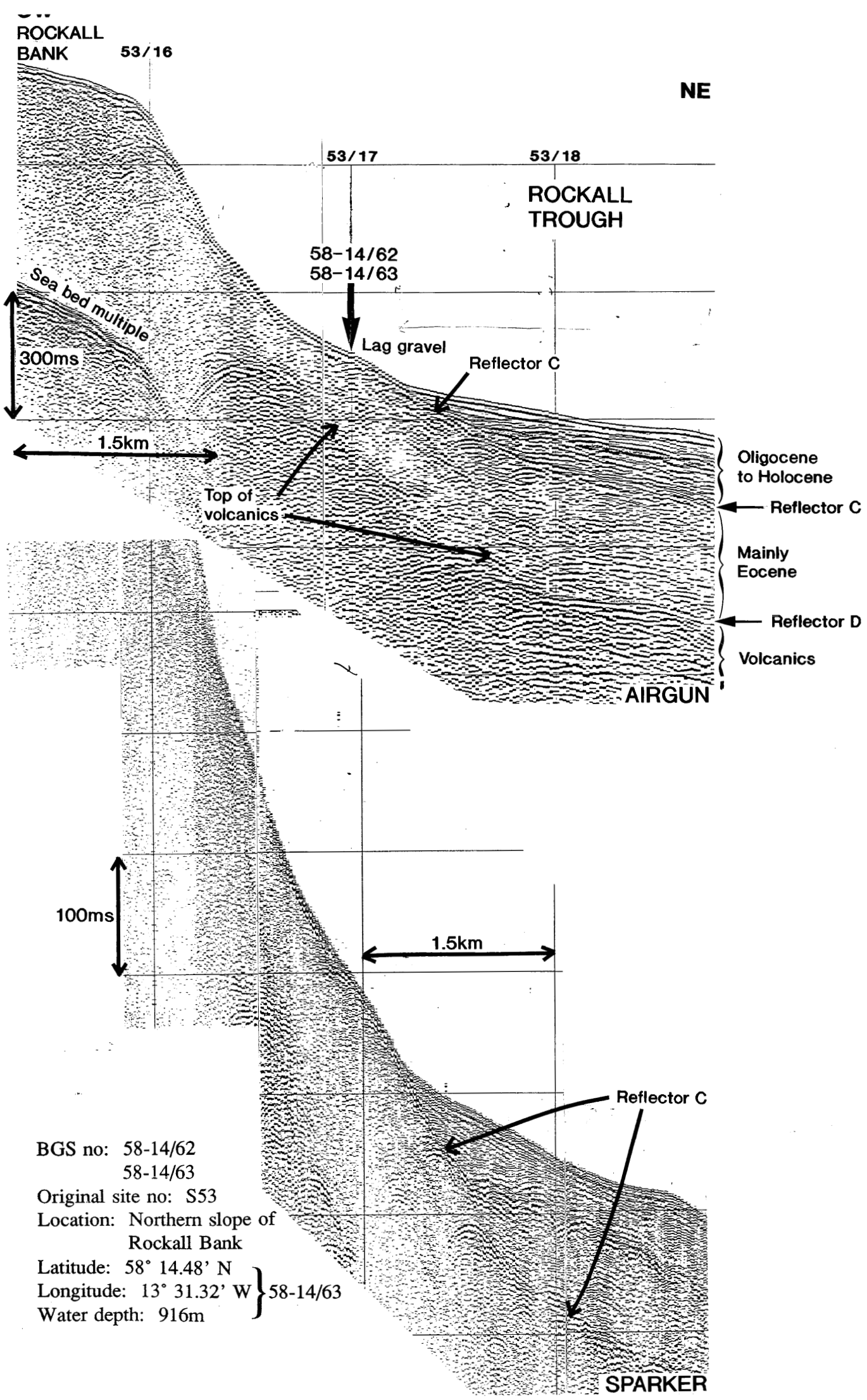
Original site no: S52

T.D. metres: 5.1

Recovery %: 6



58-14/62 & 63
(S53)



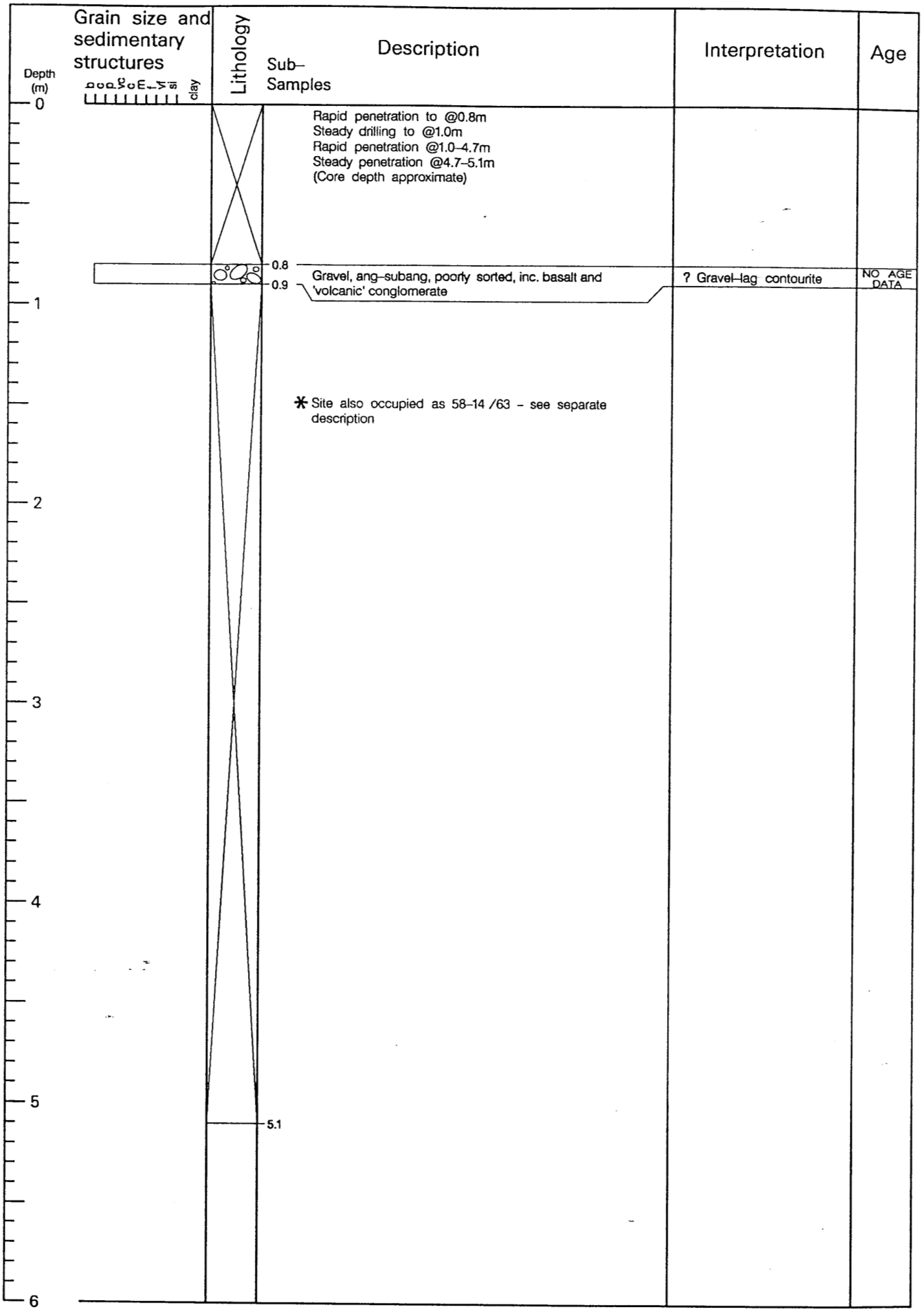
BGS no: 58-14/62
58-14/63
Original site no: S53
Location: Northern slope of Rockall Bank
Latitude: 58° 14.48' N
Longitude: 13° 31.32' W } 58-14/63
Water depth: 916m

BGS core no: 58–14 /62*

Original site no: S53

T.D. metres: 5.1

Recovery %: 2

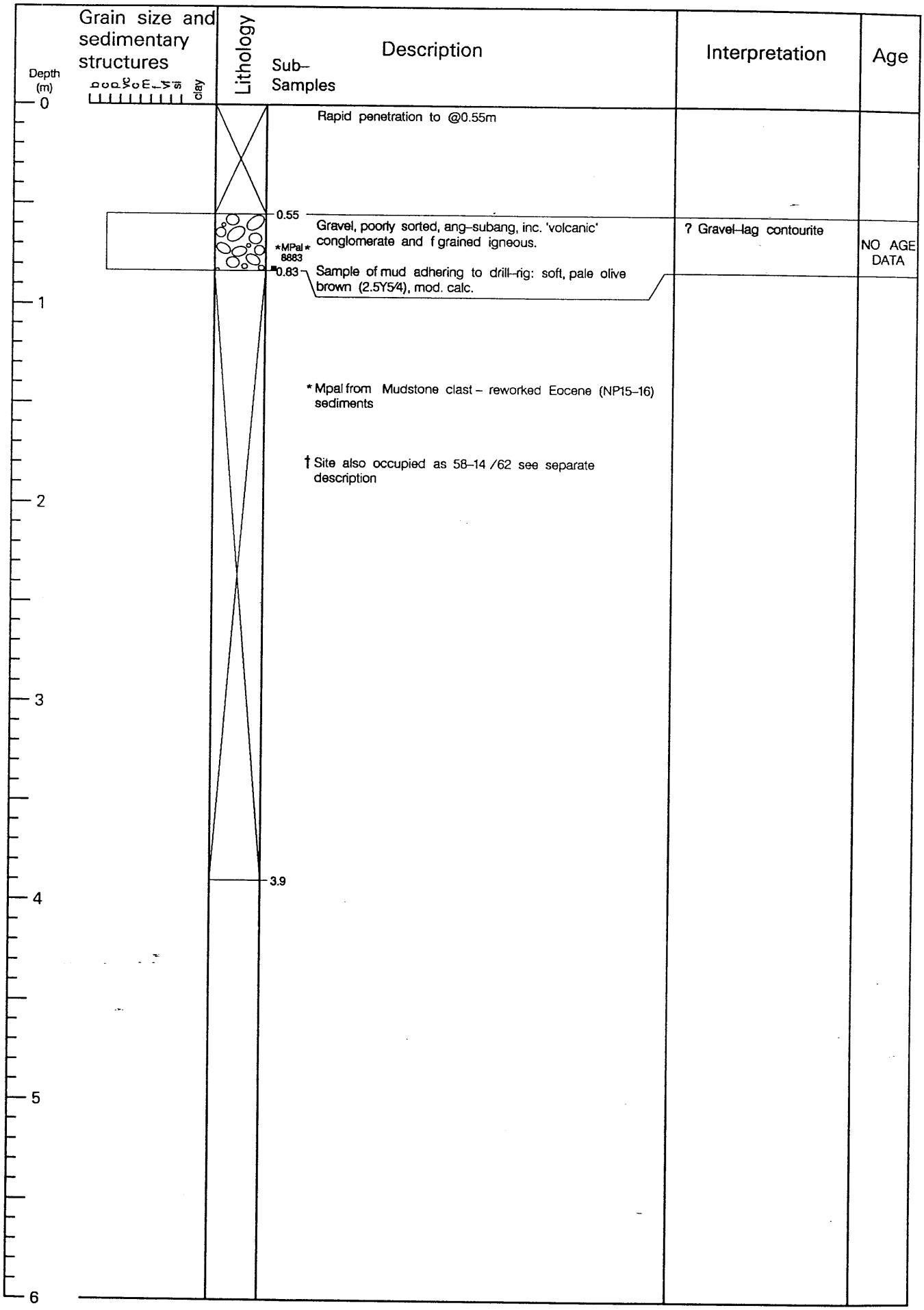


BGS core no: 58–14 /63†

Original site no: S53

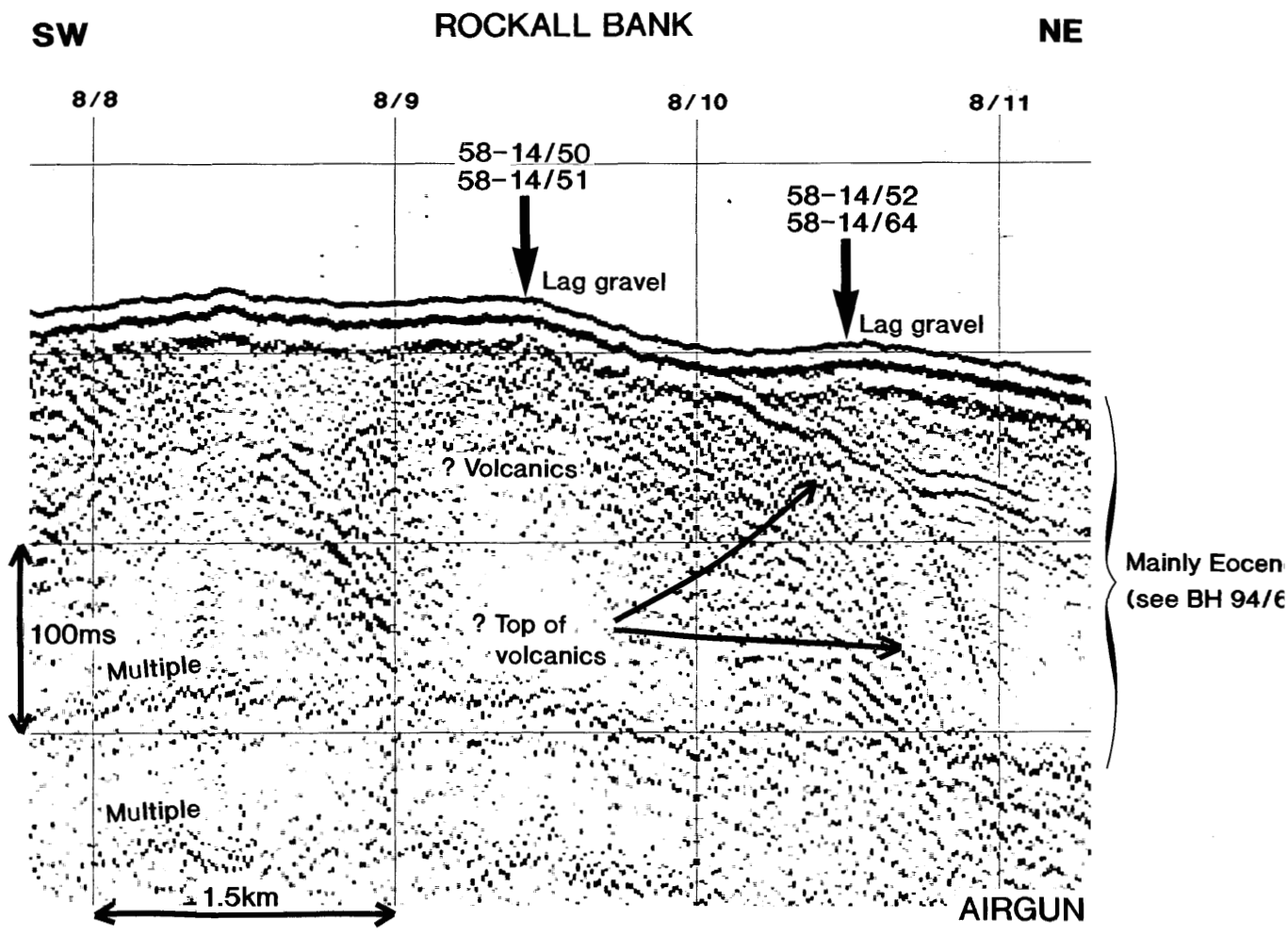
T.D. metres: 3.9

Recovery %: 7



58-14/50 & 51
(S55)

58-14/52 & 64
(S54)



BGS no: 58-14/50
58-14/51
Original site no: S55
Latitude: 58° 04.13' N
Longitude: 13° 20.45' W } 58-14/50
Water depth: 244m

BGS no: 58-14/52
58-14/64
Original site no: S54
Latitude: 58° 04.78' N
Longitude: 13° 19.55' W } 58-14/64
Water depth: 262m

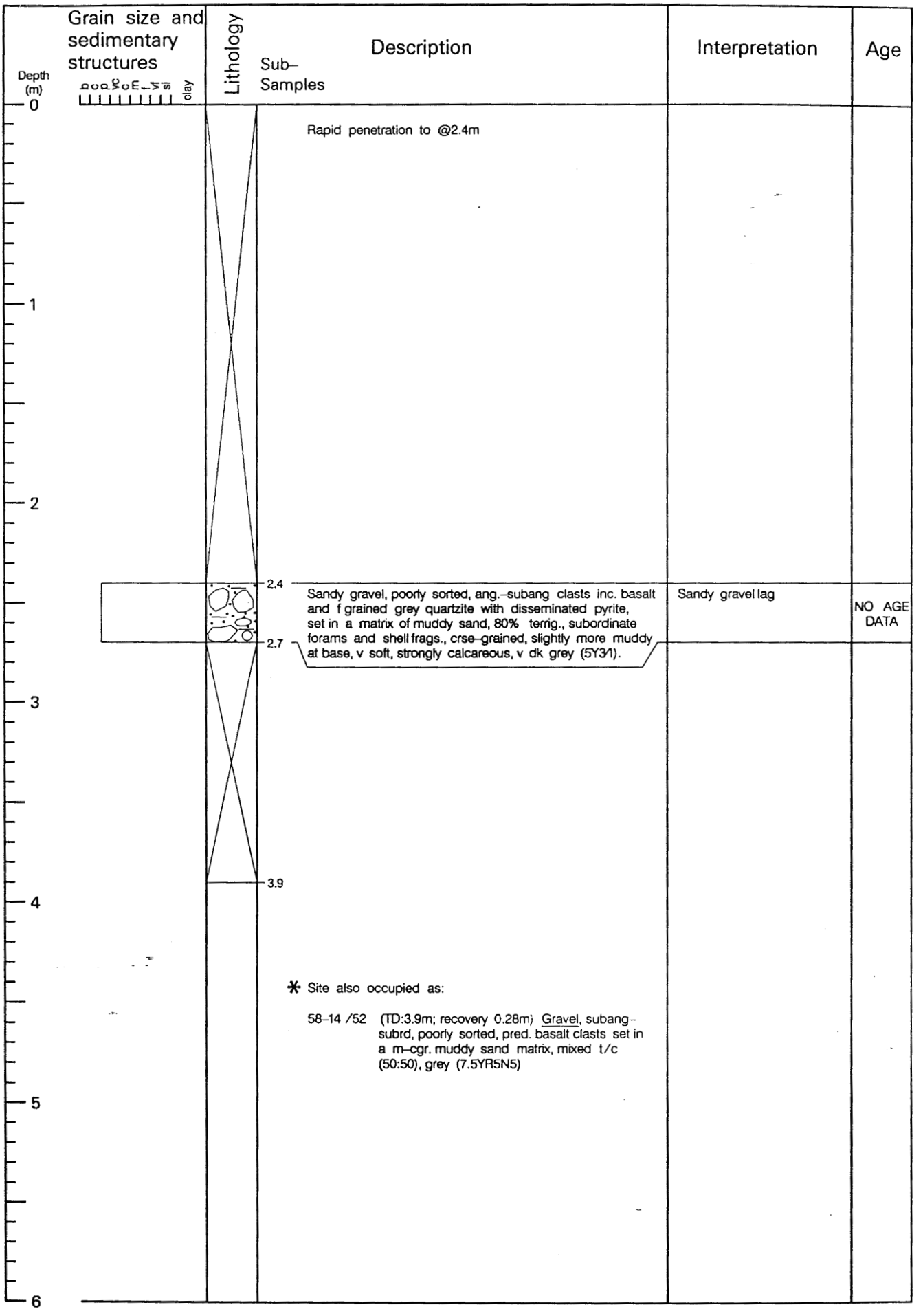
Location: Northern margin of Rockall Bank

BGS core no: 58–14 /64*

Original site no: S54

T.D. metres: 3.9

Recovery %: 8



* Site also occupied as:

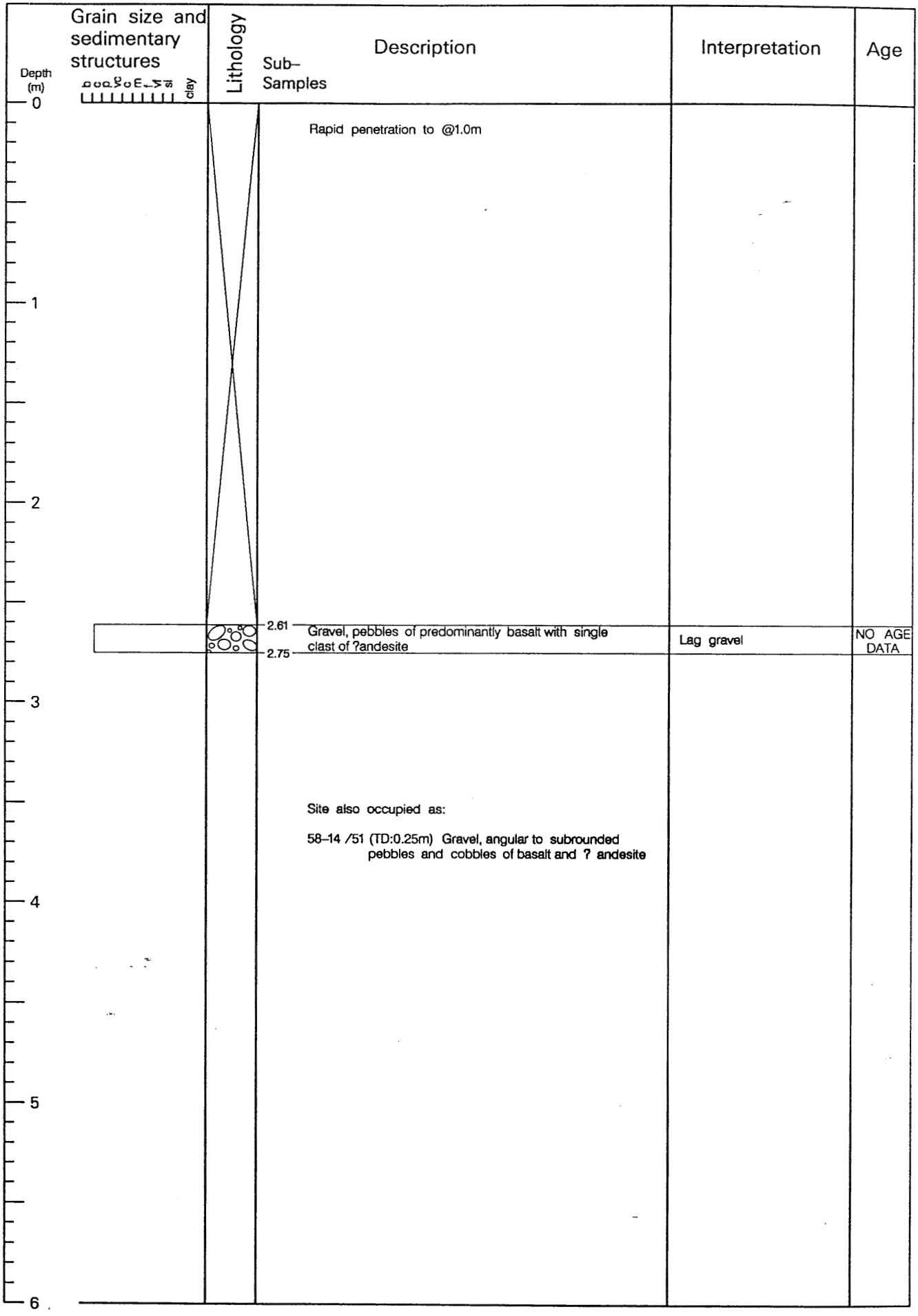
58–14 /52 (TD:3.9m; recovery 0.28m) Gravel, subang–subrd, poorly sorted, pred. basalt clasts set in a m–cgr. muddy sand matrix, mixed t/c (50:50), grey (7.5YR5N5)

BGS core no: 58–14 /50*

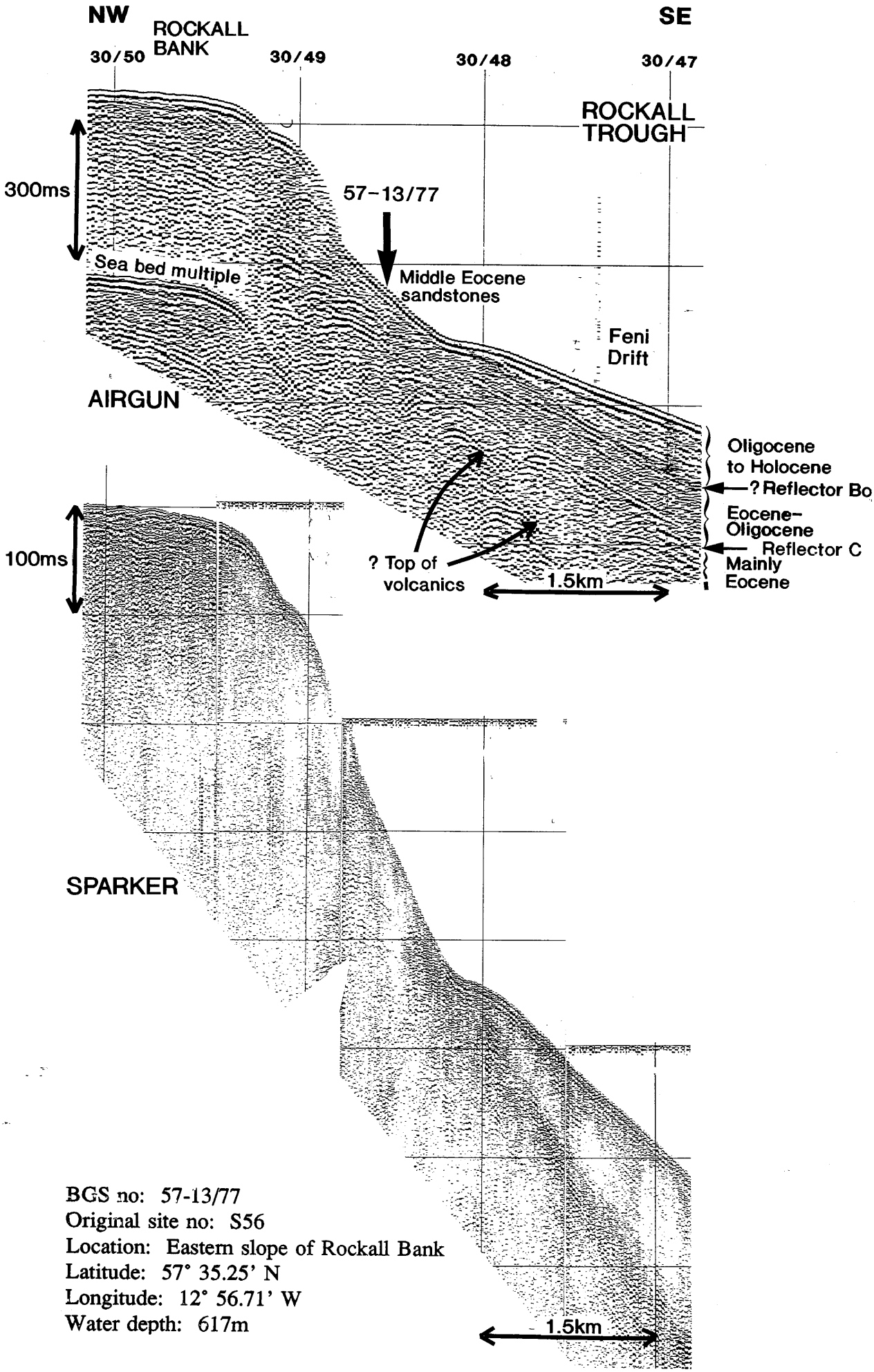
Original site no: S55

T.D. metres: 2.75

Recovery %: 5



57-13/77
(S56)



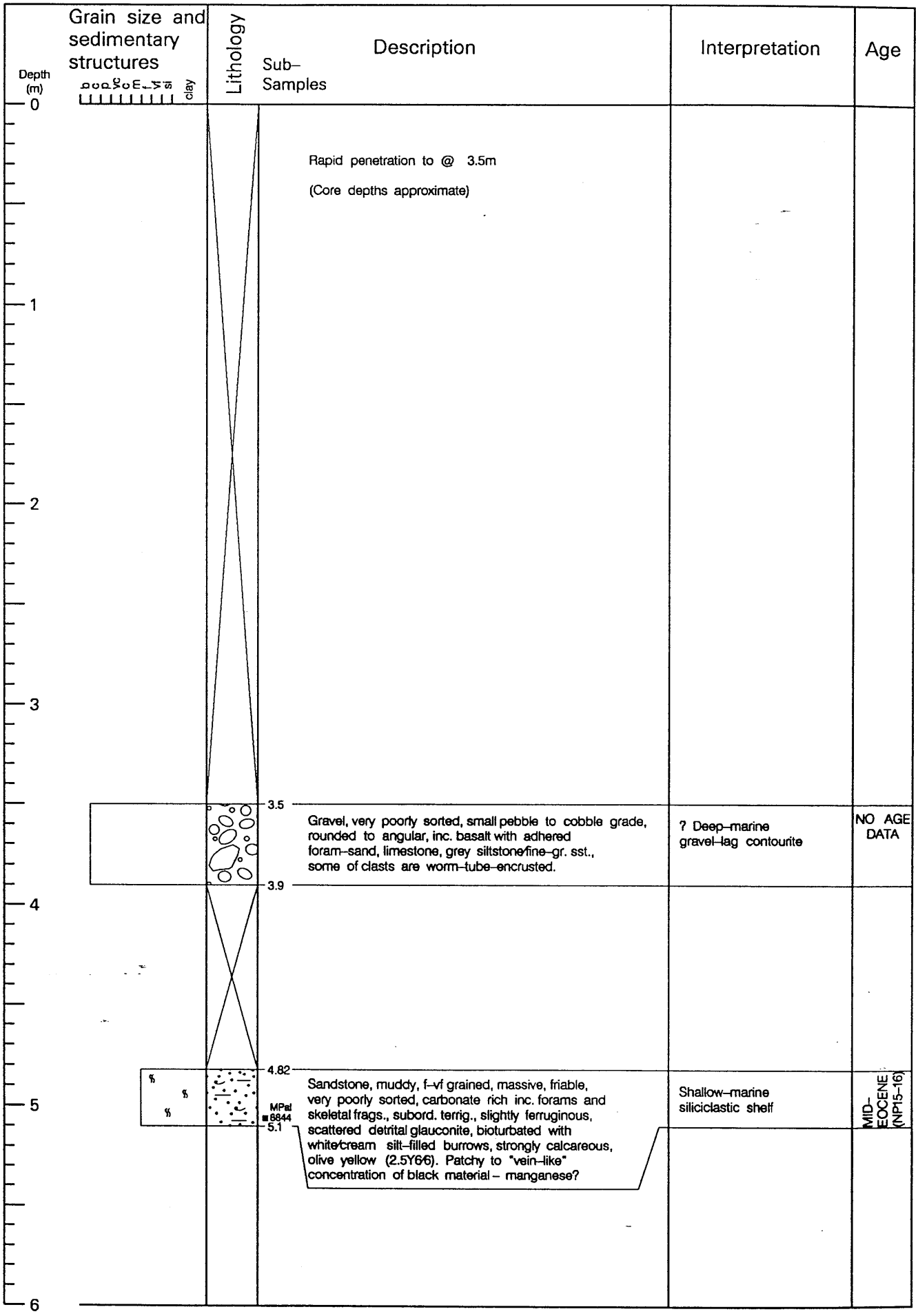
BGS no: 57-13/77
Original site no: S56
Location: Eastern slope of Rockall Bank
Latitude: 57° 35.25' N
Longitude: 12° 56.71' W
Water depth: 617m

BGS core no: 57–13 /77

Original site no: S56

T.D. metres: 5.1

Recovery %: 13



DINOFLAGELLATE CYST ANALYSIS OF SHALLOW CORES FROM THE ROCKALL AREA

DINOFLAGELLATE CYST ANALYSIS OF SHALLOW CORES FROM THE ROCKALL AREA

J.B. Riding

Introduction

Eighty-seven shallow core samples (CSC8813 to 8899) from 44 sites on the Rockall Continental Margin were submitted for palynological analyses in order to attempt detailed age and/or palaeoecological determinations. The samples yielded variably abundant residues and palynofloras. Palynomorph preservation varied from fair to good. The majority of the productive samples produced dinoflagellate cyst assemblages characteristic of the Quaternary System, although several samples yielded dinoflagellates indicative of the Eocene. Preparation techniques employed avoided the use of aggressive oxidising reagents in order to prevent the possible damage to, and loss of, relatively fragile and chemically susceptible dinoflagellate cysts (Dale, 1976). The biologically-based nomenclatural scheme of Harland (1982) is utilised for the Quaternary dinoflagellate genus *Protoperidinium.*

Palynology

The palynofloras extracted from the 44 sites are described below, listed in BGS sample order.

56-14/13 - S24 (CSC8813 to 8815)

This locality, originally site number 24, yielded muddy and gravelly sands on a cobble layer to 0.90-0.95m. Samples CSC8813 (0.05-0.08m) and CSC8814 (0.28-0.30m) produced abundant, well-preserved dinoflagellate cyst floras of Quaternary aspect and dominated by *Operculodinium centrocarpum.* By contrast, sample CSC8815 (0.90-

0.93m) yielded an extremely sparse organic residue, virtually barren of palynomorphs. No evidence of reworking was observed.

The presence of *Protoperidinium conicoides* (CSC8813), *Protoperidinium conicum* (CSC8813 and 8814), *Protoperidinium leonis* (CSC8813) and *Protoperidinium pentagonum* (CSC8813 1) indicates that this succession to 0.3m is probably no older than mid-Pleistocene (de Vernal *et al.,* 1992; Harland, 1992). The nature of the sediments are consistent with this assessment. The remaining species, e.g. *Achomosphaera andalousiensis, Bitectatodinium tepikiense, Nematosphaeropsis labyrinthea, Operculodinium centrocarpum,* round brown cysts *sensu lato, Polykrikos schwartzii* and *Spiniferites* spp. are extremely characteristic of North Atlantic Quaternary sediments (Harland, 1983; 1992). No evidence of the lower Pleistocene or the Pliocene/Miocene (Neogene) was encountered.

The richness of samples CSC8813 and 8814, with an average of 745 specimens per slide, together with the abundance of *Operculodinium centrocarpum* and presence of *Protoperidinium* spp. is indicative of an interglacial, ameliorative climatic episode, under the influence of relatively warm, North Atlantic water. The lack of *Impagidinium* spp. (and the presence of common *Protoperidinium* spp.) indicates probable shelfal sedimentation. Because the section studied is relatively thin, it is not possible to state unequivocally whether the assemblages are referable to the Windermere Interstade and/or latest Pleistocene-Holocene or an intra mid-/late Pleistocene episode. However, due to the high productivity, it seems most likely that both these samples are Holocene, as opposed to late Pleistocene or older (see Harland, 1988).

57-11/67 - S29 (CSC8816-8820)

Five samples were prepared from site S29. This succession comprises interbedded sands and muds to 4.9m. The samples, especially CSC8818 (1.5m) to CSC8820 (4.9m), produced sparse organic residues. Reworking of Jurassic-Lower Cretaceous miospores

was noted in samples CSC8816 (0.00-0.01m) and CSC8817 (0.2m). *Lycospora* sp., a Carboniferous spore was noted in sample CSC8817.

Sample CSC8816, however, did yield a relatively common (87 specimens per slide) dinoflagellate cyst assemblage. The flora is dominated by *Operculodinium centrocarpum* and round, brown cysts *(Protoperidinium* spp.). The association is of Quaternary aspect and also includes *Bitectatodinium tepikiense, Impagidinium patulum, Nematosphaeropsis labyrinthea* and *Spiniferites* spp. The occurrences of *Protoperidinium conicum* and *Protoperidinium pentagonum* indicate that this sample is probably no older than mid-Pleistocene. No Tertiary elements were encountered.

The low dinoflagellate cyst recovery and dominance of *Operculodinium centrocarpum* and round, brown *Protoperidinium* species points to a cold, arctic-like glacial climate of deposition (Harland, 1992). The relatively large proportions (35.6%) of round brown cysts is indicative of seasonal or permanent sea ice. The dinoflagellate cyst spectrum is entirely consistent with those from the Late Devensian (Harland, 1988), but this age cannot be unequivocally invoked without independent evidence.

Samples CSC8817 to 8820 yielded extremely sparse palynofloras. Rare dinoflagellate cysts of Quaternary aspect were noted, but none of these have significant biostratigraphical value. Furthermore, the sparseness of the associations precludes meaningful climatostratigraphical analyses.

57-12/18 - S30 (CSC8821)

A single sample from site S30 was analysed. This was a calcareous conglomerate from the top of the Anton Dohrn Seamount. The sample, CSC8821 (3.30-3.73m) produced an extremely sparse organic residue, virtually barren of palynomorphs. Occasional woody fragments and a single, poorly-preserved dinoflagellate cyst was recovered. Due to the

indeterminate nature of this single specimen, assessments of age and palaeoenvironment are precluded.

57-12/19 - S28 (CSC8822 to 8823)

Two samples were taken from site S28, where interbedded sands and muds to 5.3m from the southern flank of the Anton Dohrn Seamount were recovered. Sample CSC8822 (0.00-0.03m) produced a sparse organic residue comprising woody material, dinoflagellate cysts of Quaternary aspect and Carboniferous and Jurassic reworked grains. The presumably indigenous Quaternary dinoflagellate cyst flora comprises rare *Operculodinium centrocarpum* and *Protoperidinium conicoides,* together with relatively persistent round brown *Protoperidinium* species. The occurrence of *Protoperidinium conicoides* indicates that the sample is probably no older than mid-Pleistocene (Harland, 1992). Because of the relatively sparse palynoflora, assessment of the palaeoclimate is more speculative. The preponderance of round, brown dinoflagellate cysts points to a cold, glacial palaeoclimate; the low numbers of specimens, however, make this a tentative conclusion.

Sample CSC8823 (5.30m) produced a residue virtually barren of organic remains; rare fungal spores were encountered. Therefore age/palaeoenvironmental assessments are not possible.

57-12/33 - S27 (CSC8824 to 8826)

Three samples were analysed from site S27 in the Rockall Trough, south-west of the Anton Dohrn Seamount. The lithologies recovered here were interbedded muds and sands resting on Chalk. Sample CSC8824 (0.05-0.10m) proved the only palynologically productive sample from this site. The sample yielded abundant dinoflagellate cysts of Quaternary aspect. The assemblage was dominated by *Operculodinium centrocarpum* (78.7%), with subordinate *Bitectatodinium tepikiense, Impagidinium* spp.,

Nematosphaeropsis labyrinthea, Protoperidinium spp. and *Spiniferites* spp. The occurrence of *Protoperidinium conicum, Protoperidinium pentagonum* and *Spiniferites elongatus* indicates that the sample is probably no older than mid-Pleistocene (de Vernal et al., 1992; Harland, 1992). The dinoflagellate cyst richness (606 specimens per slide) and the spectrum of species points to an interglacial ameliorative interval, under the influence of relatively warm North Atlantic waters and in a shelfal setting. It is difficult to speculate on the precise positioning of this interglacial interval within the Quaternary due to the isolated nature of the sample. However, the high recovery means that a Holocene age is most likely (Harland, 1988). Rare possibly reworked Mesozoic pollen was recovered from sample CSC8824.

Samples CSC8825 and CSC8826 (1.25-1.30m and 2.5m respectively) produced extremely sparse organic residues, virtually barren of palynomorphs. Sample CSC8825 yielded a single questionable round brown *Protoperidinium* dinoflagellate cyst and both levels produced rare indeterminate miospores. Therefore, age and palaeoenvironmental assessments are precluded. However, the limited dinoflagellate cyst evidence from sample CSC8825 tentatively suggests a Quaternary age.

57-13/26 - S26 (CSC8827 to 8833)

Seven samples were taken from site S26 in the Rockall Trough, south-west of Anton Dohrn Seamount, where 3m of massive, bioturbated muds were proved. The samples proved variably palynologically productive, with dinoflagellate cysts of Quaternary aspect dominating the associations.

The dinoflagellate cyst floras are variously dominated by *Operculodinium centrocarpum* and *Protoperidinium* spp. (largely round, brown morphotypes). *Bitectatodinium tepikiense, Nematosphaeropsis labyrinthea* and *Spiniferites* spp. are also sporadically common. The succession is probably no older than late Pleistocene due to the presence of *Protoperidinium avellana* in samples CSC8829 (1.0m) to CSC8833 (3.0m) (Harland,

1992). This contention is supported by the presence of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium leonis, Protoperidinium pentagonum* and *Spiniferites elongatus* (all probably no older than mid-Pleistocene).

The dinoflagellate cyst spectrum divides into two distinct climatostratigraphical units. Samples CSC8827 to 8830 (0.00-0.01m to 1.50m) are dominated by *Operculodinium centrocarpum;* the interval represents an interglacial ameliorative episode, under the influence of relatively warm North Atlantic waters and in a shelfal setting. The dinoflagellate cyst productivity is variable (274 to 1446 specimens per slide); late Pleistocene and Holocene ages are possible (see Harland, 1988). Samples CSC8831 to 8833 (2.00m to 3.00m) are, by contrast, dominated by *Protoperidinium* spp (principally round, brown cysts), pointing to a cold, arctic-like palaeoclimate. Seasonal sea-ice conditions are invoked due to the relatively large proportions of round brown cysts. However, the presence of relatively common *Bitectatodinium tepikiense* in sample CSC8833 indicates some influence of meltwater (Harland, 1992). The probable no-younger-than late Pleistocene dating of this interval means that a Late Devensian age is possible for this unit (compare Harland, 1988).

Samples CSC8830 to 8833 exhibit evidence of reworking; typically Jurassic and Lower Cretaceous miospores *(Callialasporites* spp., *Cyathidites* spp. and *Vitreosporites pallidus)* were encountered in samples CSC 8832 and 8833. Samples CSC8830, 8832 and 8833 yielded the recycled Carboniferous spores *Densosporites* spp. and *Lycospora* spp.

57-13/53 - S16 (CSC8834 to 8836)

Three samples were prepared from site S16 in the western Rockall Trough, which proved a succession of muds and sands to 2.44m. Samples CSC8834 and 8835 yielded relatively abundant, fairly well preserved palynofloras; dinoflagellate cyst diversity proved relatively low and concentrations were also rather small (average of 152 specimens per slide).

Sample CSC8836 proved barren of dinoflagellate cysts. The dinoflagellate cyst assemblages in samples CSC8834 and 8835 were dominated by *Bitectatodinium tepikiense* and round, brown forms *(Protoperidinium* spp.). Other, less common, taxa comprise *Impagidinium* spp., *Operculodinium centrocarpum* and *Spiniferites elongatus.*

The presence of *Protoperidinium avellana* in sample CSC8835 indicates a probable no-older-than late Pleistocene age for both productive samples (Harland, 1992). This conclusion is supported by the occurrences of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium leonis* and *Spiniferites elongatus.*

The productive assemblages are indicative of a cold, arctic glacial palaeoenvironment. Any sea ice was likely to have been seasonal as the relatively high proportions of *Bitectatodinium tepikiense* (average 40.6%) point to less than fully marine meltwater regime (Harland, 1992). By comparison with the Witch Ground Formation of the North Sea (Harland, 1988), it is difficult to invoke deposition during the Younger Dryas or an older (?Devensian) glacial stage with precision. The dinoflagellate cyst concentrations and levels of reworking in samples CSC8834 and 8835 are such that such a distinction cannot be made. Rare reworked Mesozoic grains were encountered in all three samples and occasional Carboniferous spores were recovered from samples CSC8834 and 8835.

57-13/57 - S31 (CSC8837 and 8838)

Two samples were taken from site S31, which proved 5.83m of interbedded sands and muds. The samples yielded sparse organic residues comprising low diversity, low concentration dinoflagellate cyst floras. Preservation was fair throughout. The associations are dominated by round, brown cysts *(Protoperidinium* spp). Other taxa recovered were *Bitectatodinium tepikiense, Operculodinium centrocarpum, Protoperidinium conicum, Protoperidinium pentagonum* and *Spiniferites* sp.

The occurrence of *Protoperidinium avellana* in both samples strongly suggests that the succession is no older than late Pleistocene (Harland, 1992). This contention is supported by the presence of *Protoperidinium conicoides, Protoperidinium conicum and Protoperidinium pentagonum.*

Both assemblages are indicative of a cold, arctic-like glacial palaeoenvironment. The overwhelming dominance of round, brown cysts, together with the rareity of *Bitectatodinium tepikiense,* points to the presence of sea ice, possible permanent (i.e. non-seasonal) (Harland, 1992). The relatively low dinoflagellate cyst concentrations are not unequivocally biostratigraphically useful. However, coupled with significant reworking they may indicate a correlation with the Late Devensian (Harland, 1992). This is somewhat speculative and due to the relatively wide sample spacing, the two samples may even represent separate glacial events.

Undifferentiated skolochorate dinoflagellate cysts, reworked from the Mesozoic/Tertiary were relatively common in both samples and rare Carboniferous spores *(Densosporites* spp.) were encountered in sample CSC8838.

57-13/65 - S19 (CSC8839)

The single sample from the site S19 produced a palynologically barren residue. The mudstone sample (CSC8839 at 3.05-3.10m) yielded resistant mineral grains and rare woody tissue. Therefore an age and palaeoecological assessment is not possible.

57-13/75 - S47 (CSC8840 and 8841)

Two samples from were prepared from site S47, which proved 4.10m of interbedded sands and muds. Sample CSC8840 (0.00-0.04m) produced an abundant (492 dinoflagellate cyst specimens per slide) and well-preserved palynoflora. The association is dominated by *Operculodinium centrocarpum* (75%), with subordinate *Bitectatodinium*

tepikiense, Impagidinium sphaericum, Nematosphaeropsis labyrinthea, Protoperidinium spp. and *Spiniferites* spp.. No reworking was discerned. Sample CSC8841 (4.05-4.10m), by contrast, proved virtually barren of palynomorphs.

The presence of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium pentagonum* and *Spiniferites elongatus* is indicative of a probable age no older than mid-Pleistocene (de Vernal *et al.*, 1992; Harland, 1992). The *Operculodinium centrocarpum*-dominated dinoflagellate spectrum is indicative of an interglacial episode, under the influence of relatively warm North Atlantic waters and in a shelfal setting. An age/palaeoenvironmental analysis of sample CSC8841 is not possible.

57-13/76 - S48 (CSC8842 and 8843)

Site S48 proved 4.48m of interbedded sands and muds. Two samples were prepared, CSC8842 and CSC8843, (0.00-0.07m and 4.13-4.18m respectively). Sample CSC8842 produced a relatively abundant palynoflora, dominated by *Bitactatodinium tepikiense* (43.21%) and round brown *Protoperidinium* spp. (30.86%). Also present are *Operculodinium centrocarpum, Nematosphaeropsis labyrinthea, Protoperidinium conicum, Protoperidinium pentagonum* and *Spiniferites* spp.. Sample CSC8843 yielded a virtually palynologically barren residue.

The presence of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium leonis* and *Protoperidinium pentagonum* is indicative of a probable no older than mid-Pleistocene age. It is not possible to state uneqivocally whether the sample is referable to the Younger Dryas or an older glacial interval. The dominance of *Bitectatodinium tepikiense* and round, brown cysts points to a cold, glacial palaeoenvironment. The presence of a less than fully marine meltwater regime is postulated due to the abundance of *Bitectatodinium tepikiense.* Reworked grains from sample CSC8842 were not encountered. An age/palaeoenvironmental analysis of sample CSC8843 is not possible.

57-13/77 - S56 (CSC8844)

The single sample from siteS56 proved virtually barren of palynomorphs. The muddy sandstone at 5.04-5.08m (CSC8844) only yielded rare, indeterminate fungal spores, sporadic woody fragments and resistant mineral grains. An age/palaeoenvironmental assessment is therefore precluded.

57-14/43 - S22 (CSC8845 and 8846)

Two samples were taken from site S22; nearly one metre of sandstones and silty mudstones were proven. Both samples, at 0.72m and 0.90m (CSC8845 and CSC8846 respectively) produced extremely sparse residues and palynofloras. Both horizons yielded undifferentiated angiosperm and bisaccate (gymnosperm) pollen and sample CSC8845 produced questionable specimens of *Protoperidinium* and *Spiniferites*. Residual mineral grains and woody fragments were also present at both levels. Due to the sparse associations age and/or environmental conclusions are not possible.

57-14/44 - S23 (CSC8847)

A possible sea-bed boulder from site S23 was sampled. This sample, CSC8847 produced an extremely sparse palynoflora. Undifferentiated angiosperm pollen and fungal spores were recovered, together with rare *?Spiniferites* spp. and indeterminate skolochorate dinoflagellate cysts. The principal constituents of the residue, however, are wood fragments and resistant minerals. The paucity of the palynoflora means that an age dating and palaeoenvironmental assessment are not feasible.

57-14/48 - S21 (CSCCSC8848 to 8850)

Three samples were taken from site S21. Lithologies encountered were interbedded muds and gravelly sands on white chalky mudstone. All samples proved paliniferous, but the

diversities and concentrations of palynomorphs proved low. No age diagnostic species were recovered, but the taxa are of Quaternary aspect. Sample CSC8848 (0.00-0.03m) only produced 13 dinoflagellate cysts per slide. These were dominated by *Operculodinium centrocarpum* (61.5%), with subordinate round, brown cysts *(Protoperidinium* spp.) and *Spiniferites* spp. Ordinarily, a flora of this type, dominated by *Operculodinium centrocarpum,* would be interpreted as representing an interglacial episode in a shelfal setting. However, the low number of specimens means that this contention has to be tentative.

A relatively sparse association dominated by *Bitectatodinium tepikiensis* ((87.7%) was recovered from sample CSC8849 (0.90-0.95m). Round, brown cysts *(Protoperidinium* spp.) and indeterminate forms (presumably reworked) were also observed. This assemblage type is interpreted as representing cold glacial conditions with significant meltwater influence (Harland, 1992). The basal sample, CSC8850 (2.00-2.01m) yielded an extremely sparse palynoflora. *Bitectatodinium tepikiense* and round, brown cysts *(Protoperidinium* spp.) were recorded rarely (2 and 1 specimens respectively). This association, if in significant numbers, would signify cold glacial conditions, with meltwater influence. However, due to the sparsity of the flora, this conclusion must be regarded as tentative.

57-14/54 - S23 (CSC8851 to 8853)

Three samples were taken from the site S23; interbedded sands and muds on ?gravel/boulders were observed to 2.0m. Sample CSC8851 (0.05-0.08m) produced an abundant palynoflora, wheras samples CSC8852 and 8853 (1.20-1.30m and 1.30-1.40m respectively) yielded relatively sparse assemblages

The occurrence of *Protoperidinium avellana* in sample CSC8851 indicates that this horizon is probably no older than late Pleistocene (Harland, 1992). The additional presence of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium*

leonis and *Protoperidinium pentagonum* is supportive of this contention. Samples CSC8852 and 8853 are devoid of age-diagnostic Quaternary taxa.

Sample CSC8851 is dominated by *Operculodinium centrocarpum* (73.3%), with subordinate *Bitectatodinium tepikiense, Nematosphaeropsis labyrinthea, Polykrikos schwartzii, Protoperidinium* spp. and *Spiniferites* spp. This configuration is characteristic of interglacial ameliorative episodes, under the influence of warm North Atlantic waters. The absence of *Impagidinium* spp. and presence of significant *Protoperidinium* spp and *Spiniferites* spp. suggests acccumulation in a shelfal setting (Harland, 1992). No evidence of reworking was observed.

Samples CSC8852 and 8853 produced relatively sparse palynofloras; the dinoflagellate cyst concentration is 39 and 17 specimens per slide respectively. Therefore, any palaeoenvironmental conclusions are relatively speculative; a fact borne out by the somewhat ambiguous results from the two, adjacent samples. The proportions of *Operculodinium centrocarpum* and round, brown cysts are similar in sample CSC8852. This situation makes the assemblage difficult to interpret, but the presence of round, brown cysts may indicate at least seasonal ice cover. Significant levels of presumably reworked Eocene/Oligocene dinoflagellate cysts were observed in this sample. *Operculodinium centrocarpum* dominates sample CSC8853 (58.8%); this may indicate interglacial conditions.

58-11/2 - S45 (CSC8854 and 8855)

Two samples of massive, bioturbated muds were taken from site S45. Both proved palynologically productive, yielding well preserved dinoflagellate cyst associations. Both floras are dominated by round, brown cysts *(Protoperidinium* spp.). Other forms recognised include *Bitectatodinium tepikiense, Impagidinium* spp., *Operculodinium centrocarpum* and *Polykrikos schwartzii.*

The occurrence of *Protoperidinium avellana* in sample CSC8855 (3.50-3.54m) means that the succession is probably no older than late Pleistocene in age (Harland, 1992). The presence of *Protoperidinium conicoides* and *Protoperidinium conicum* in sample CSC8854 (0.00-0.03m) support this contention. The overwhelming dominance of round, brown forms is indicative of a cold, glacial, arctic-like episode (or episodes as the samples are some 3m apart). The lack of significant proportions of *Bitectatodinium tepikiense* suggests permanent (i.e. non-seasonal) sea ice conditions. It is not feasible to correlate these floras to the Younger Dryas or older, late Pleistocene glacial episodes. Reworked Carboniferous spores were observed in both samples and sample CSC8855 produced rare reworked Mesozoic miospores. Sample CSC8854 proved rich in silicoflagellates and diatoms.

58-12/5 - S46 (CSC8856 and 8857)

Two samples were taken from site S46. A succession of massive, bioturbated muds was proved to 3.20m. Both samples, CSC8856 and 8857 (0.00-0.03m and 3.17-3.20m respectively) yielded abundant, well-preserved palynofloras. The presence of *Protoperidinium avellana* in sample CSC8857 indicates that the succession is probably no older than late Pleistocene in age (Harland, 1992).

Sample CSC8856 proved extremely productive, with a dinoflagellate cyst concentration of 1962 specimens per slide. The assemblage is dominated by *Operculodinium centrocarpum* (52.6%), with subordinate *Bitectatodinium tepikiense, Impagidinium* spp., *Nematosphaeropsis labyrinthea, Polykrikos schwartzii, Protoperidinium* spp. and *Spiniferites* spp. Round, brown cysts, however, are relatively common (16.5%). The productivity and dominance of *Operculodinium centrocarpum* indicate an interglacial ameliorative episode. The relative abundance of *Protoperidinium* spp. and *Spiniferites* spp., together with the paucity of *Impagidinium* spp, is indicative of a shelfal setting.

Sample CSC8857, however, is interpreted as representing cold, glacial conditions. The evidence is the relatively low productivity (228 dinoflagellate cyst specimens per slide), low diversity and dominance of round, brown cysts. The relatively small proportions (1.8%) of *Bitectatodinium tepikiense* strongly suggests the existence of permanent (i.e. non-seasonal) sea ice conditions. Reworking of Carboniferous and Jurassic/Cretaceous miospores was observed in this sample.

58-14/8 - S7 (CSC8858)

A single sample, CSC8858 (4.47-4.49m), was taken from site S7. The lithology proved to 5.10m was conglomerate (limestone with basalt clasts). The single sample proved to be extremely sparse and virtually palynologically barren. Palynomorphs identified comprised rare bisaccate pollen undifferentiated pollen and fungal spores. Woody tissue and resistant mineral grains were relatively common. The sparsity of the palynoflora means that an age/palaeoenvironmental assessment is impossible.

58-14/9 - S8 (CSC8859 to 8861)

Three samples from site S8 were taken. At this locality, 5.53m of sands were proved. All the samples proved variably sparse, the maximum productivity being 68 dinoflagellate cysts per slide in sample CSC8859 (0.00-0.03m). Sample CSC8860 (0.35-0.38m) proved extremely sparse, the only determinable dinoflagellate cyst being *Bitectatodinium tepikiense.* Sample CSC8861 (5.50-5.53m) produced a similar assemblage to sample CSC8859, i.e. dominated by *Operculodinium centrocarpum.* The presence of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium pentagonum* and *Spiniferites elongatus* in samples CSC8859 and 8861 indicates that the probable age of the succession is no older than mid-Pleistocene (Harland, 1992). The *Operculodinium centrocarpum*-dominated dinoflagellate cyst spectrum of samples CSC8859 and 8861 is indicative of interglacial, ameliorative conditions in a shelfal setting. The relatively low numbers of specimens in sample CSC8861, however, makes this contention somewhat

speculative. The Carboniferous spore *Densosporites* sp was observed rarely from sample CSC8859. Low levels of Upper Cretacous/Paleogene reworking was noted in sample CSC8861.

58-14/10 - S9 (CSC8862)

The single sample, CSC8862 (1.80-1.84m) taken from site S9 yielded an extremely sparse palynoflora. The mudstone sample produced a residue dominated by resistant mineral grains. The only palynomorphs recognised were undifferentiated fungal spores, and two questionable dinoflagellate cyst specimens *(?Protoperidinium pentagonum* and *?Protoperidinium* sp.). This sparse association means that an unequivocal age dating and a precise palaeoenvironmental assessment are not feasible. However, the presence of questionable *Protoperidinium pentagonum* indicates that the most likely age is no older than mid-Pleistocene (Harland, 1992).

58-14/11 - S10 (CSC8863)

A sandstone sample, CSC8863 (4.72-4.77m), from site S10 proved palynologically barren. The residue was dominated by light amorphous material and resistant mineral grains. Rare, undifferentiated fungal spores were encountered. Thus age/palaeoenvironmental analyses are not possible.

58-14/29 - S13 (CSC8899 and 8864)

Two samples were taken from the 5m of sandstone on siltstone recovered from site S13. Sample CSC8899 (0.46-0.50m) proved to be virtually palynologically barren. The residue was dominated by residual mineral grains and woody tissue. Only rare, poorly-preserved miospores and fungal spores were recognised, indicating that a detailed age/palaeoenvironmental synthesis is precluded.

Sample CSC8864 (4.95-5.00m), however, yielded an abundant residue which is totally dominated by light plant tissue. The palynoflora, which is not abundant, is dominated by dinoflagellate cysts of Eocene aspect. Prominent species include *Areoligera* spp., *Cordosphaeridium gracile, Thalassiphora pelagica* and *Spiniferites* spp. The occurrence of *Deflandrea phosphoritica* means that the sample is no older than earliest Eocene (earliest Ypresian) (Powell, 1992; Stover *et al.,* 1994). Furthermore, the presence of *Areoligera senoniensis* and *Glaphyrocysta ordinata* is indicative that the sample is no younger than mid-Eocene (Lutetian) (Powell, 1992). The overlapping ranges of these three taxa therefore indicate an early mid-Eocene (Ypresian to Lutetian) age for this sample, spanning Calcareous Nannoplankton Zones NP10/11 to intra NP15 (Powell, 1992). The presence of *?Cerodinium depressum, Cleistosphaeridium? insolitum, Cordosphaeridium gracile, Phthanoperidinium* cf. *stockmansii* and *Thalassiphora pelagica* are consistent with this determination. Moreover, the presence of relatively common marine microplankton is indicative of an open marine setting. The low proportions of peridinacean dinoflagellate cysts may point to an offshore shelfal depositional regime. Reworked grains were not observed.

58-14/31 - S12 (CSC8865)

Sample CSC8865 (3.51-3.55m) from a conglomerate at site S12 proved virtually palynologically barren. Resistant mineral grains and wood fragments dominate the sparse residue. Occasional pollen grains and fungal spores were, however, present. This means that an age and/or palaeoenvironmental assessment is not possible.

58-14/32 - S12 (CSC8866 and 8867)

Two samples from site S12 were prepared for analyses. This site proved 3.90m of limestone on a conglomerate. . The samples, CSC8866 and 8867 (3.11-3.14m and 3.85-3.90m respectively), yielded extremely sparse palynofloras. Rare pollen and fungal spores

were recovered; the residues proved rich in resistant mineral grains and plant tissue. This means that an age/palaeoenvironment assessment is not possible.

58-14/34 - S14 (CSC8868 to 8870)

Three samples from site S14 were analysed, taken from 5m-thick section of interbedded sands and muds on yellow claystone. Only sample CSC8868 (0.00-0.03m) proved rich in palynomorphs. This sample yielded a fairly abundant palynoflora dominated by dinoflagellate cysts. *Operculodinium centrocarpum* is the dominant species, comprising 74.6%) of the association. Other forms present include subordinate *Bitectatodinium tepikiense, Nematosphaeropsis labyrinthea,* round, brown cysts *(Protoperidinium* spp) and *Spiniferites* spp. The presence of *Spiniferites elongatus* and *Spiniferites frigidus* means that the probable age of this sample is no older than mid-Pleistocene (Harland, 1992). From modern analogs, this assemblage is interpreted as repersenting an interglacial, ameliorative phase, under the influence of North Atlantic waters. The relative abundances of *Spiniferites* spp. and *Protoperidinium* spp. (6.8% and 1.1% respectively), together with the absence of *Impagidinium* spp., points to shelfal deposition. Reworking was not observed in this sample.

Samples CSC8869and CSC8870 (0.50-0.53m and 4.79-4.82m respectively) yielded extremely sparse residues, dominated by resistant mineral grains. Sample CSC8869 produced rare dinoflagellate cysts of Quaternary aspect *(Bitectatodinium tepikiense* and *Operculodinium centrocarpum).* These taxa are not deemed to be age- or palaeoenvironmentally diagnostic, especially given their sparsity in this sample. If they are *in situ* and representative of the actual dinoflagellate cyst flux, a similar, interglacial, palaeoenvironment to that of sample CSC8868 is suggested. Rare miospores were also recovered. The deepest sample, CSC8870, proved barren of dinoflagellate cysts, only occasional indeterminate miospores and fungal spores were recognised. Hence an age/palaeoenvironmental analysis is impossible.

58-14/42 - S7 (CSC8871)

Sample CSC8871 (4.50m) from a conglomerate from site S7 yielded a sparse palynoflora. The residue was dominated by mineral grains and wood fragments, however, indeterminate moispores, fungal spores and a single specimen of the dinoflagellate cyst *Bitectatodinium tepikiense* were recovered. The range of *Bitectatodinium tepikiense* is early Miocene to Holocene (Powell, 1992; Harland, 1992). However, a single palynomorph specimen should not be viewed as an unequivocal age index. Similarly, a palaeoenvironmental assessment is not possible on such a sparse flora. Mionor levels of both Carboniferous and Jurassic/Lower Cretaceous reworking was discerned.

58-14/43 - S9 (CSC8872)

Sample CSC8872 (5.07-5.12m) yielded an extremely sparse palynoflora. This sample of mudstone from site S9 produced a residue composed largely of resistant mineral grains. Rare, undifferentiated miospores were present. This association is not age-diagnostic and a palaeoenvironmental assessment is similarly precluded.

58-14/44 - S49 (CSC8873)

A claystone sample, CSC8873 (5.04-5.08m) from site S49 was analysed. The residue proved virtually palynologically barren, with rare, undifferentiated angiospermous pollen and fungal spores only present. The residue is dominated by resistant mineral grains and woody tissue. Hence an age/palaeoecological determination is precluded.

58-14/53 - S11 (CSC8874)

Sample CSC8874 (3.43-3.47m), an orange-brown claystone, yielded a palynologically sparse sample.The residue is dominated by residual mineral grains and plant material. The only palynomorphs recovered were rare foraminiferal test linings, fungal spores and

undifferentiated pollen grains. A single reworked *Lycospora* sp., a reworked Carboniferous spore, was recognised. Hence, an age and/or palaeoenvironmental asssessment is not possible.

58-14/54 - S42 (CSC8875 and 8876)

Two samples, CSC8875 and 8876 (0.20-0.22m and 0.82-0.84m respectively), were prepared from sandstone recovered from site S42. Both yielded residues rich in mineral grains and sparse in palynomorphs including undifferentiated pollen grains and fungal spores. Sample CSC8876 produced single specimens of *Operculodinium centrocarpum* and *Spiniferites mirabilis.* This assemblage is characteristic of the Quaternary, but this cannot be regarded as a definitive age dating (Harland, 1992). The paucity of the flora precludes a palaeoecological interpretation. Rare indeterminate skolochorate dinoflagellate cysts were also observed from sample CSC8876; these are interpreted as being reworked from the Mesozoic/Tertiary.

58-14/55 - S40 (CSC8877)

A single sample, CSC8877 (0.85-0.90m), was prepared from mudstone from site S40. The sample yielded an extremely sparse palynoflora comprising rare angiospern pollen and fungal spores. Mineral grains and wood dominated the residue. An age/palaeoenvironmental analysis is, therefore, not possible.

58-14/56 - S50 (CSC8878)

A limestone sample at 1.01-1.06m was taken from the site S50. Sample CSC8878 proved to be essentially palynologically barren, the only palynomorphs recovered being rare bisaccate pollen grains and fungal spores. The residue was, however, rich in mineral grains and wood. This virtually barren nature of this sample precludes an age/palaeoenvironmental determination.

58-14/57 - S41 (CSC8879 and 8880)

Site S41 proved to be a sand succession resting on conglomerate. Two samples, CSC8879 and 8880 were taken at 3.83-3.89m and 4.10m respectively. The residues proved extremely sparse palynologically and are dominated by mineral grains and woody tissue. Palynomorphs recognised in sample CSC8879 include *?Bitectatodinium tepikiense,* skolochorate (spine-bearing) dinoflagellate cysts and *Senoniasphaera* sp.. *Bitectatodinium tepikiense* ranges from the Miocene to the Holocene (Powell, 1992; Harland, 1992), suggesting that the other dinoflagellate cysts may be reworked. The Jurassic/Lower Crertaceous pollen *Perinopollenites elatoides* was also observed; this form is probably reworked. However, the paucity of the flora dictates that no firm conclusions are tenable.

Sample CSC8880 proved virtually barren, with a single indeterminate dinoflagellate cyst, undifferentiated pollen grains and fungal spores present.

58-14/60 - S51 (CSC8881 and 8882)

Two samples from the site S51 were prepared for analyses. This locality proved a succession of interbedded sands to 1.07m. Sample CSC 8881 (0.00-0.02m) yielded a rich dinoflagellate cyst assemblage (2394 specimens per slide) dominated by *Operculodinium centrocarpum* (55.6%). Also present in lower proportions were *Achomosphaera andalousiensis, Bitectatodinium tepikiense, Impagidinium* spp., *Nematosphaeropsis labyrinthea, Polykrikos schwartzii, Protoperidinium conicum, Protoperidinium pentagonum,* round, brown forms *(Protoperidinium* spp.) and *Spiniferites* spp. The occurrence of *Protoperididinium avellana* indicates that the probable age of the sample is no older than late Pleistocene (Harland, 1992). This conclusion is supported by the presence of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium leonis Protoperidinium pentagonum* and *Spiniferites elongatus.* This rich association is compatible with the Holocene associations (compare Harland, 1988). The flora is

indicative of interglacial ameliorative conditions, under the influence of North Atlantic waters. The dominance of *Protoperidinium* spp. and Spiniferites spp. over *Impagidinium* spp. is indicative of a shelfal setting. Reworking was negligible.

Sample CSC8882 (1.02-1.07m) proved much less productive, with 46 dinoflagellate cysts per slide. No age-diagnostic elements were present. However, the dominance of *Operculodinium centrocarpum* (56.5%) over *Bitectatodinium tepikiense* (39.1%) is again suggestive of a Quaternary age and indicative of interglacial conditions. Relatively low, yet significant levels of reworked Jurassic/Lower Cretaceous pollen were noted.

58-14/63 - S53 (CSC8883)..

A single mudstone sample at 0.81-0.83m was taken from site S53. Sample CSC8883 yielded an extremely sparse palynoflora, the residue being dominated by mineral grains and wood. Dinoflagellate cysts recognised include *Operculodinium centrocarpum* and rare round, brown *Protoperidinium* species. This assemblage is reminiscent of Quaternary successions but the paucity does not allow a palaeoclimatological determination to be made. No evidence of reworking was noted.

59-11/12 - S1 (CSC8884)

A single sample from site S1 was taken at 1.40-1.43m. This locality proved limestone interbedded with basalt flows. Sample CSC8884 produced a virtually palynologically barren residue, being dominated by mineral grains and woody tissue. No microplankton was recognised, the only palynomorphs being rare *Botryococcus* and undifferentiated pollen. Therefore, an age/palaeoecological analysis is not feasible.

59-11/13 - S2 (CSC8885 to 8888)

Four samples were prepared from site S2, which proved a suuccession of interbedded sands to 4.67m. The youngest three samples (CSC8885-8887) yielded abundant palynofloras all dominated by the dinoflagellate cyst *Operculodinium centrocarpum*. Other species present include *Achomosphaera andalousiense, Bitectatodinium tepikiense, Impagidinium* spp., *Nematosphaeropsis labyrinthea, Protoperidinium conicum, Protoperidinium pentagonum,* round, brown forms *(Protoperidinium* spp.) and *Spiniferites* spp. Productivity was especially great in sample CSC8885 (0.00-0.05m), where there are 1170 dinoflagellate cysts per slide. The presence of *Protoperidinium avellana* is indicative of a probable no-older-than late Pleistocene age for this sample. The occurrences of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium pentagonum* and *Protoperidinium leonis* supports this contention. These *Operculodinium centrocarpum*-dominated floras in samples CSC8885 to 8887 are indicative of interglacial, ameliorative conditions, influenced by relatively warm, North Atlantic waters. The predominance of *Protoperidinium* spp. and *Spiniferites* spp. over *Impagidinium* spp. signals deposition in a shelfal environment. The relatively high productivity in sample CSC8875 indicates a possible Holocene age for this horizon (Harland, 1988). This sample also produced a single grain of *Lycospora* sp., a reworked Carboniferous spore. Rare reworked Carboniferous and Mesozoic/Tertiary grains were also observed in sample CSC8886 (0.60-0.65m). Sample CSC8888 (4.60-4.67m) proved virtually barren of dinoflagellate cysts.

59-11/16 - S43 (CSC8889)

A single sample, CSC8889 (4.30-4.35m), from site S43 was taken from a succession of interbedded sands. This sample yielded an abundant palynoflora, dominated by dinoflagellate cysts of Eocene aspect. The assemblage is abundant, diverse and well-preserved. Prominent forms include *Areoligera* spp., *Glaphyrocysta* spp. and *Spiniferites* spp. The assemblage is rich in species which characterise the early to mid-Eocene

(Ypresian-Lutetian), for example *?Dracodinium condylos, Glaphyrocysta? vicina, Lejeunecysta hyalina, Wetzeliella lunaris* and *Wetzeliella* cf. *meckelfeldensis*. The presence of *Areoligera lauloma,* however, suggests that the sample is mid-Eocene in age (Lutetian, Calcareous Nannoplankton Zones NP14-NP16) (Powell, 1992). *Areoligera tauloma* is relatively rare and an age dating based on this small population is deemed to be somewhat speculative. The sample is therefore considered to be early to mid-Eocene (Ypresian-Lutetian) on the evidence of *Glaphyrocysta? vicina* and *Wetzeliella lunaris.* The presence of these key taxa indicate a Ypresian to early Lutetian age (Calcareous Nannoplankton Zones NP12/13 to early NP15) (Powell, 1992). The occurrence of abundant marine microplankton is indicative of an open marine depositional setting. The presence of significant proportions of peridiniacean dinoflagellate cysts suggests a nearshore marine regime. Rare reworked spores of Carboniferous *(Densosporites* spp., *Lycospora* spp.) and Early Cretaceous age *(Cicatricosisporites* sp.) were observed.

59-11/17 - S44 (CSC8890 and 8891)

Two samples from site S44 were prepared from a mud-rich succession to 4.63m. The samples produced rich, well-preserved palynofloras. Productivity was high with dinoflagellate cyst concentrations of 996 and 480 specimens per slide for samples CSC8890 (0.00-0.05m) and CSC 8891 (4.60-4.63m) respectively.

Sample CSC8890 yielded an assemblage rich in *Operculodinium centrocarpum* (56.6%). Other, relatively minor, elements include *Achomosphaera andalousiensis, Bitectatodinium tepikiense, Nematosphaeropsis labyrinthea, Polykrikos schwartzii, Protoperidinium conicum, Protoperidinium pentagonum,* round, brown cysts *(Protoperidinium* spp.) and *Spiniferites* spp. This flora is indicative of an interglacial, ameliorative episode, with deposition in a shelfal setting. No unequivocal reworked palynomorphs were observed.

Sample CSC8891, by contrast, is dominated by round, brown cysts *(Protoperidinium* spp.) (55.8%). The remainder of the indigenous dinoflagellate cyst association comprises

Polykrikos schwartzii and *Spiniferites* spp. The presence of *Protoperidinium avellana* at this horizon indicates that the entire succession is probably no older than late Pleistocene (Harland, 1992). This is supported by the occurrences of *Protoperidinium conicoides, Protoperidinium conicum, Protoperidinium leonis* and *Protoperidinium pentagonum.* The preponderance of round, brown forms is indicative of a cold, arctic-like, glacial episode, with permanent (i.e. non-seasonal) ice-cover. This sample also contains relatively high levels of reworked palynomorphs. The reworking is multiphase, with Carboniferous *(Densosporites* spp., *Lycospora* spp.), Jurassic *(Callialasporites dampieri, Callialasporites turbatus, Cyathidites australis, Nannoceratopsis gracilis)* and Paleogene (e.g. *Eatonicysta ursulae, Lejeunecysta hyalina, Homotriblium* spp.) elements present.

59-14/6 - S5 (CSC8892 and 8893)

Two virtually stratigraphically adjacent samples were prepared from site S5, which proved 5.06m of claystone. Sample CSC8892 (5.00-5.03m) produced a sparse residue and palynoflora, largely comprising dinoflagellate cysts of Eocene aspect. The presence of *Areoligera* cf. *senoniensis, Hystrichodinium* cf. *salacium* and *Thalassiphora pelagica* are strongly suggestive of an early/mid-Eocene age (Powell, 1992).

The underlying sample 81 (CSC 8893, 5.05-5.06m) yielded an extremely rich, well-preserved palynofloral association, again dominated by typically Eocene dinoflagellate cysts. The association is totally dominated by *Thalassiphora pelagica* see also Appendix 2). The most stratigraphically significant species present is *Dracodinium politum,* which typifies the early Eocene. Powell (1992) stated that the full range of this distinctive species is intra-Ypresian (Calcareous Nannoplankton Zone NP12) to earliest Lutetian (Calcareous Nannoplankton Zone NP14). However, as *Dracodinium politum* was present in significant proportions, a correlation with the Ypresian Ccl dinoflagellate cyst zone of Powell (1992) is considered most likely. The presence of *Achilleodinium biformoides, Adnatosphaeridium multispinosum,* the *Charlesdownia coleothrypta* group, *Cordosphaeridium gracile, Deflandrea phosphoritica, Homotryblium tenuispinosum,*

Hystrichokolpoma cinctum, Rottnestia borussica, Wetzeliella lunaris and *Wetzeliella meckelfeldensis* supports this Ypresian-?Lutetian age determination. The presence of abundant marine microplankton is indicative of an open marine depositional setting. Due to the presence of significant proportions of peridiniacean forms, an inshore marine regime is suggested. Rare Carboniferous spores *(Lycospora* sp.) were observed.

59-14/7 - S4 (CSC8894 and 8895)

Site S4 proved a succession of 5.12m of sandstone on mudstone. Two samples were taken, CSC 8894 and 8895 (4.00-4.03m and 5.07-5.12m respectively). Sample CSC8894 proved virtually palynologically barren, with only rare fungal spores present. However, sample CSC8895 yielded a relatively abundant, well-preserved dinoflagellate cyst flora. The presence of *Areoligera senoniensis Areosphaeridium* cf. *diktyoplokos.* and cf. *Eatonicysta ursulae* means that the sample is of early mid-Eocene age (Ypresian to Lutetian, Calcareous Nannoplankton Zone NP13 to NP15) (Powell, 1992). This contention is supported by the occurrences of *Achilleodinium biformoides, Cordosphaeridium gracile, Homotryblium abbreviatum, Homotryblium tenuispinosum, Hystrichokolpoma cinctum* and *Thalassiphora pelagica.* The presence of marine microplankton is indicative of an open marine setting. Furthermore, the dominance of gonyaulacacean species suggests deposition in an offshore shelfal regime. No evidence of reworking was observed.

59-14/8 - S3 (CSC8896 and 8897)

Two samples were taken from site S3 which proved a mudstone succession. Sample CSC8896 (0.98-1.00m) produced an extremely sparse, non age-diagnostic palynoflora comprising fungal debris, and indeterminate pollen grains. The underlying sample CSC8897 (3.80-3.83m) also yielded a sparse association, dominated by woody tissue. The (rare) presence of the dinoflagellate cyst *Thalassiphora pelagica* indicates a probable Paleogene age. This species has its range base in the Maastrichtian (Stover *et al.,* 1994),

but a Late Cretaceous age is precluded on lithological grounds. The range top is in the earliest Miocene (Powell, 1992), however, at this level the species is rare, hence a Paleogene age is most likely. Reworking of the Carboniferous spore *Lycospora* sp. was noted.

59-14/9 - S6 (CSC8898)

A single sample was taken from site S6, a mudstone succession proved to 5.09m. Sample CSC8898 (5.07-5.09m) proved to be virtually palynologically barren, with only fungal debris and indeterminate pollen grains present. The residue is dominated by mineral grains; some of these grains appear to have structure. It is possible that some are mineralised microfossils, however, if so, they are not identifiable due to the intense mineral induration. An age/palaeoenvironmental assessment is therefore impossible.

SUMMARY

This suite of samples yielded variably productive palynomorph assemblages. Of the paliniferous samples, the majority proved to be of probable Mid-Late Pleistocene age based on dinoflagellate cyst associations. Of these, both interglacial and glacial episodes were represented. Samples CSC 8864, 8889, 8892, 8893, 8895 and ?8897 are Eocene (Ypresian/Lutetian) based on dinoflagellate cyst floras. Carboniferous, Jurassic/Lower Cretaceous and Paleogene reworking was frequently observed.

References

DALE, B. 1976. Cyst formation, sedimentation and preservation: factors affecting dinoflagellate assemblages in Recent sediments from Trondheimsfjord, Norway. *Review of Palaeobotany and Palynology* Vol. 22, 39-60.

de VERNAL, A, LONDEIX, L, MUDIE, P J, HARLAND, R, MORZADEC-KERFOURN, M-T, TURON, J-L, and WRENN, J H. 1992. Quaternary organic-walled dinoflagellate cysts of the north Atlantic Ocean and adjacent seas: ecostratigraphy and biostratigraphy. 289-328 in *Neogene and Quaternary dinoflagellate cysts and acritarchs,* Head, M J, and Wrenn, J H, (editors). American Association of Stratigraphic Palynologists Foundation, Dallas.

HARLAND, R. 1982. A review of Recent and Quaternary organic-walled dinoflagellate cysts of the genus *Protoperidinium. Palaeontology* Vol. 25, 369-397.

-----. 1983. Distribution maps of recent Dinoflagellate Cysts in bottom sediments from the North Atlantic and adjacent seas. *Palaeontology* Vol. 26, 321-387.

-----. 1988. Dinoflagellates, their cysts and Quaternary stratigraphy. *New Phytologist* Vol. 108, 111-120.

-----. 1992. Dinoflagellate cysts of the Quaternary System. 253-272 in *A stratigraphic index of dinoflagellate cysts,* Powell, A J, (editor). British Micropalaeontological Society Publications Series. (London: Chapman and Hall).

LENTIN, J K, and WILLIAMS, G L. 1993. Fossil dinoflagellates: index to genera and species 1993 edition. *American Association of Stratigraphic Palynologists Contributions Series* No. 28, viii + 856p.

POWELL, A J. 1992. Dinoflagellate cysts of the Tertiary System. 155-251 in *A stratigraphic index of dinoflagellate cysts,* Powell, A J, (editor). British Micropalaeontological Society Publications Series. (London: Chapman and Hall).

STOVER, L E, BRINKHUIS, H, DAMASSA, S P, de VERTEUIL, L, HELBY, R J, MONTEIL, E, PARTRIDGE, A D, POWELL, A J, RIDING, J B, SMELROR,

M, and WILLIAMS, G L. 1994. Mesozoic-Tertiary dinoflagellates, acritarchs and prasinophytes. In press in *Palynology: principles and applications,* Jansonius, J, and McGregor, D C, (editors). American Association of Stratigraphic Palynologists Foundation, Dallas, Vol. 2.

FORAMINIFERAL ANALYSIS OF SHALLOW CORES FROM THE ROCKALL AREA

FORAMINIFERAL ANALYSIS OF SHALLOW CORES FROM THE ROCKALL AREA

I.P. Wilkinson

Introduction

A suite of samples from the Rockall Area were submitted for micropalaeontologoical analysis. They were examined for foraminifera and although other groups were also noted, e.g. ostracods, Bolboformids and radiolaria, there was insufficient time to utilise them in any meaningful way. The full list of species for each sample is located within the biostratigraphy records of the BGS and selected species are discussed in this report. All samples are considered to be of no older than the mid-Pleistocene (and several are probably Holocene in age) unless otherwise stated. The planktonic assemblages are related to the faunal provinces defined by Bé (1977). Due to time constraints, not all of the samples in the batch CSC8813 to 8899 were examined, whilst several additional samples - CSC8900 to 8907 - were submitted from key cores. The microfauna extracted from the samples are described below, listed in BGS sample order.

Results

56-14/13 - S24 (CSC8913-8915)

CSC8913

Paromalina crassa and *Cibicides lobatulus* are abundant and *Planulina ariminensis* and *Cibicides refulgens* are frequent. Amongst the rare species are *Pullenia quinqueloba, Lagena williamsoni, Trifarina angulosa, Pyrgo williamsoni, Uvigerina peregrina* and *Textularia agglutinans*. Conditions are considered to be as of those for the upper continental slope, and the high proportions of attached species is comparable with the assemblage dicussed under CSC8814. The planktonic association is dominated by

common *G. inflata* and frequent *N. pachyderma* (both sinistral and dextral forms are present) but *G. bulloides, G.bradyi* and small *O. universa* were rare. This assemblage is indicative of the warmer part of the Subarctic Province.

CSC8814

The fauna is dominated by abundant benthonic *Cibicides lobatulus* and *Paromalina crassa*, together with planktonic *Globorotalia inflata* and (mainly sinistral) *Neogloboquadrina pachyderma. Hoeglundina elegans, Uvgerina peregrina, Rupertia stabilis, Cibicides refulgens* and *Trifarina angulosa* are also present in small numbers within the benthos and frequent *Globigerina bulloides* and rare *Globigerina glutinata* and *Globorotalia truncatulinoides* occur in the plankton.

Of the benthos, taxa that have an attached mode of life, such as *Paromalina crassa,* species of *Cibicides,* such as *C. lobatulus and C. refulgens,* and *Planulina ariminensis* are characteristic elements between about 700 and 1500m depth and Pujos (1970) suggested that the distribution of these species is related to the presence of the core of Mediterranean water. Weston (1985) suggested that this attached association was able to colonise parts of the continental slope that were unfavourable to other species due to instability in the environment. Perhaps low oxygen or salinity levels are indicated. In the Western Approaches and Porcupine Seabight they are characteristic of continental slope in 700-1400m water depths, but are often found in the outer shelf/upper slope environments to depths of 500m (Murray, 1971;Weston, 1985). The substrates used may be pebbled, plants,bryozoa, shell debris, bundles of sponge spicules etc.

Rupertia stabilis, another attached form, is characteristic of the lower slope/lower bathyal, in water depths of between1750-4000m, but it occurs in depths as shallow as 1156m in the cold waters of the Faeroe-Shetland Channel. Its rarity in the present sample may indicate that it is at the limit of its endurance. *Hoeglundina elegans* is characteristic of the 2500-3800m interval of the North Atlantic Seaboard of the USA on silty clay and temperatures of 2-3°C, but it occurs higher on the slope off northwestern Europe. Finally *Uvigerina pergrina* is found on fine-grained sediment with over 1% organic carbon and reach high percentages where oxygen content of the water is at a minimum. It is known

from the outer shelf on, for example the Gulf of Mexico and on the outer shelf and slope off Europe in waters of 200 to 3000m and at depths of between 1000 and 2660m off the Atlantic Seaboard of North America.

The planktonic element is dominated by taxa characteristic of the Subarctic faunal province (sensu Bé, 1977) and the high proportion of sinsitrally coiled *N. pachyderma* implies the colder part of this province where the April isotherm is less that 7.2°C.

CSC8815

The fauna in this sample is similar to that of CSC8814. There are minor differences such as the inceased numbers of *Trifarina angulosa* and the occurrence of rare *Cassidulina laevigata* and *Planulina ariminensis*, in the benthos, and a larger proportion of dextrally coiled *N. pachyderma* together with very rare *Globorotalia crassaformis* and *Globorotalia truncatulinoides* in the planktonic element. The surface waters are probably slightly warmer than CSC8814 as *G. crassaformis* is not found in waters colder than the transitional zone according to Bé (1977).

Planulina ariminensis is an important element in the *Paromalina crassa/Cibicides lobatulus* assemblage described from 442-1095m water depth in the Porcupine Seabight and Western Approaches (Weston, 1985). This species are often attached to sponges that extend to about 150mm from the sea floor where it can take advantage of water movement. *Trifarina angulosa* is apparently controlled by temperature as it is found in waters of less than about 8°C in the Atlantic Seaboard of USA and is present on the shelf as well as the slope. Hence, whereas the surface waters appear to be slightly warmer, the bottom conditions remain relatively cold.

57-11/67 - S29 (CSC8916-8920)

CSC8816

Benthonic foraminifera are rare and of poor preservation so that their provenance must be in doubt. Shallow water species *Ammonia batavus* is present indicating contamination from near shore areas. The planktonics include small morphs of *Orbulina universa*, a

species that is widespread in tropical and subtropical areas Where the larger morph is present, but rare in the transitional province, becoming small in dimension when close to their northern limit. This, together with the presence of rare specimens of *N. pachyderma* in an essentially sinistrally coiled population, may indicate a position close to the transitional/Subarctic boundary.

CSC8817

The benthos is in a poor state of preservation, however, rare specimens of *Cibicides lobatulus, Paromalina crassa Cibicides pseudungerianus, Rupertia stabilis, Uvigerina peregrina* and *Hoeglundina elegans* indicates a similar environment to that of CSC8814. The planktonic element is dominated by flood proportions of cold water, sinistrally coiled *N. pachyderma* and the Arctic Province is indicated.

CSC8818

The benthos is very rare and comprises mainly of species of *Cibicides* and *Paromalina crassa,* and the planktonic element comprises mainly of the cold water, sinistral *N. pachyderma* (see comments for CSC8814).

CSC8819

Microfossils are very rare. *N. pachyderma* is mainly sinistral and the benthos comprises mainly of the attached forms described for CSC8814.

CSC8820

The benthos is dominated by abundant *Paromalina crassa,* together with subordinate *Hoeglundina elegans, Cibicides refulgens, C. lobatulus, C. pseudoungerianus* and *Planulina ariminensis.* It is similar to that of CSC8814. However, the absence of *Rupertia stabilis,* which is particularly characteristic of the lower slope/lower bathyal (1750-4000m), implies somewhat shallower water depths. Species such as *P. crassa, C. lobatulus* and *Planulina ariminensis* are characteristic elements between about 700 and 1500m. A reworked specimen of *Elphidium* cf *albiumbilicatum* indicates off-shelf

contamination. Of the planktonic specimens, abundant sinistral *N. pachyderma* and *Globigerina bulloides* also indicates cold surface waters, although very rare specimens of the small morph of *Orbulina universa* indicates the influence of waters from the transitional province.

57-12/18 - S30 (CSC8821 and 8900)

CSC8821

The microfauna is identical to that of CSC8820.

CSC8900

As for CSC8875

57-12/19 - S28 (CSC8822 and 8823)

CSC8822

Hoeglundina elegans was not found in the sample, but otherwise the fauna (both benthonic and planktonic) is identical to that of CSC8820.

CSC8823

Although slightly more diverse than CSC8820, the fauna is essentially similar.

57-12/33 - S27 (CSC8824 to 8826)

CSC8824

The benthonic part of the assemblage is dominated by *Cibicides lobatulus* and *Planulina wuellerstorfi.* The latter species is characteristic of the assemblages off Norway between c.1000m and c.3000m where it is found with *Epistominella exigua* (a species that has not been recognised in CSC8824) and is often found associated with the North Atlantic Deep

Water and the Norwegian Sea Bottom Water. It is better developed in the latter compared to the former, presumably due to the low temperatures (-2°C compared to 2.5-4.0°C)

Rare *Pullenia bulloides* occurs in the present sample, together with *Sigmoilina schlumbergeri* and as these species range down to depths of about 1500m off Norway and Bay of Biscay, it may be that the present sample was deposited shallower water depth than that in which *E. exigua* shows preference. An alternative is that the absence of this species is a result of sample failure, because other species of deeper water origin, such as very rare *Rupertia stabilis*, are present. The occurrence of very rare Ammonia batavus indicates reworking from near shore conditions.

The planktonic association comprises common *N. pachyderma* (mainly sinistrally coiled, but including a dextral element) and *G. bulloides*, with frequent *G. inflata, Globorotalia sciula* and larger specimens of *Orbulina universa.* The presence of the last named implies that the the area came under the influence of waters from the transitional province.

CSC8825

The presence of frequent *Cibicides lobatulus, P. wuellerstorfi* and *Hoeglundina elegans* together with rare *Sigmoilina Schlumbergeri* and *Paromalina crassa* is similar to the assemblage of CSC8824. Although *R stabilis* and *P. bulloides* were not recorded, the environment of deposition appears to be similar. The high proportion of dextrally coiled *N. pachyderma* together with the rare. large, *O. universa* and the frequent *Globorotalia truncatulinoides*, indicates the influence of the Transitional province.

CSC8826

Foraminifera are rare and poorly preserved. Specimens tentatively assigned to *Bolboforma reticulata* and *B. badensis* point to a mid- to late Miocene age.

57-13/26 - S26 (CSC8827 to 8833)

CSC8827

The occurrence of *Globigerinapsis index* and *Globigerina* cf *triangularis* with a sparse Pleistocene to Recent assemblage indicates either Eocene reworked with a younger assemblage or and Eocene sample with younger contamination caused during sampling.

CSC8828

The benthonic association is sparse, but include frequent *Planulina wuellerstorfi.* The planktonic element comprises abundant *Globigerina bulloides,* common *Orbulina universa* (large morph) and *G. inflata* as well as frequent dextral *N. pachyderma* and rare *G. truncatulinoides.* It is considered to be indicative of the Transitional province sensu Bé (1977).

CSC8829

The plankton comprises abundant *Globigerina bulloides*, common *Globorotalia scitulus* and *Globorotalia inflata*, frequent dextrally coiled *Neogloboquadrina pachyderma*, rare *Globorotalia hirsuta* and very rare *Orbulina universa* (large morph). This implies a position well within the Transitional Province. Although the benthos is sparse, *Pullenia bulloides* is present, a species characteristic of the slope down to about 1500m. Very rare specimens tentatively assigned to *Bulimina mexicana* were also found, but the significance of this is unclear due to taxonomic problems and lack of data.

CSC8830

Although rare, the foraminifera have a moderately high diversity, including *Planulina wuellerstorfi, Planulina ariminensis, Sigmoilina schlumbergeri, Hoeglundina elegans, Pullinia* cf *bulloides, Triloculina trigonula, Pyrgo williamsoni* and *Hansenisca soldanii*, but all are rare or very rare. Species of the attached taxa *Cibicides spp.,Paromalina crassa* and *Rupertia stabilis* are notably absent, presumably due to the lack of a suitable substrate. *Planulina wuellerstorfi* is found off Norway between c.1000m and c.3000m and

Pullenia bulloides together with *Sigmoilina schlumbergeri* range down to depths of about 1500m off Norway and Bay of Biscay. *Hoeglundina elegans* is characteristic of the 2500-3800m interval of the North Atlantic Seaboard of the USA on silty clay and temperatures of 2-3°C, but it occurs higher on the slope off northwestern Europe (between 725 and 950m in the Porcupine Seabight and Western Approaches) and between 180-275m off Tristan d'Acunha in the South Atlantic. The plankton include abundant sinistrally coiled *N. pachyderma* and *G. bulloides,* frequent *G. inflata,* rare *G. scitulus* and very rare *O. universa* (small morph) indicating cold surface waters of the Subarctic Province.

CSC8831

With the exception of very rare *Cassidulina laevigata* and *Pullenia bulloides*, benthonic foraminifera are absent. The reason for this absence is unknown, but perhaps low oxygen is the answer. However, it should be pointed out that species tolerent of low oxygen levels are also absent. The planktonic population is larger, although relatively rare compared to many other samples from the area, with abundant sinistral *N. pachyderma*, rare *Globigerinita bradyi* and *Globirotalia inflata* and very rare *Globigerinella glutinata* and *Globigerina bulloides.* Cold surface waters of the Arctic province is indicated with water temperatures of less than about 5 °C.

CSC8832

Again, the benthonic element is lacking, being confined to very rare *P. ariminensis* and *Trifarina angulosa.* The planktonic element is similar to that in CSC8831 and similar environmental conditions are indicated.

CSC8833

Although the benthos is a little richer compared to the above two samples, it is very sparse. *Cassidulina laevigata, P. ariminensis, Pullenia bulloides* and *Lenticulina peregrina* were recovered. Little can be concluded, except that, if the fauna is in situ, water depths were probably less than1500m if comparison is made with the assemblages off Norway. The planktonic element is similar tto that of CSC8831, but *Globorotalia*

scitulus is also present suggesting that temperatures are not quite as cold. This species is not present in the Arctic Province and it implies the colder part of the Subarctic Province where surface water temperatures are below the 7.2°C Spring isotherm.

57-13/53 - S16 (CSC8834 to 8836)

CSC8834

The benthos is sparse, but there is a return to the *Planulina wuellerstorfi, Cibicides lobatulus, Hoeglundina elegans, Sigmoilina schlumbergeri* assemblage seen above. *Melonis barleeanum i*s also present in very small numbers and although present on the outer shelf, it is a typical slope species which prefers temperatures of between-0.5 and 10°C, active bottom currents and muddy or silty substrates. It is found living between 370 and 1900m off nothwestern Europe, for example. The planktonic association is identical to that of CSC8833.

CSC8835

Floods of sinistral *N. pachyderma* together with rare *G. bulloides* is typical of the Arctic Province. However, the presence of rare *G. inflata* may indicate that the sample is from a position low within the province as that species is not normally found north of the Subarctic Province. The benthos is again sparse, but includes rare or very rare *Cibicides lobatulus, Sigmoilina schlumbergeri, Trifarina angulosa* and *Hoeglundina elegans.*

CSC8836

A diverse benthonic population was recovered, although individual species are rare or very rare. *Hoeglundina elegans, Sigmoilina sclumbergeri, Rupertia stabilis, Pyrgo murrhhana, Cibicides refulgens, Planulina wuellerstorfi,, Rectoglandulina* cf *rotundata, Quinqueloculina agglutinans, Cibicides pseudoungerianus, Cibicides lobatulus, Bulimina marginata* and *Bulimina* cf *mexicana.* Many of these were discussed for CSC8814, however, *Bulimina marginata* is normally associated with the shelf and upper slope, and is found living down to depths of about 510m on the upper slope. Considering *Rupertia*

stabilis is a deep water form, The specimens of *B. marginata* probably represent off-shelf reworking. Of the planktonics, sinistral *N. pachyderma* is abundant, *G. inflata* is common, *G. bulloides* is frequent and *G. truncatulioides* and *O. universa* (small) are very rare. The colder part of the Subarctic Province is indicated, although the influence of Transitional Province is implied by the occurrence of O. universa.

57-13/57 - S31 (CSC8837 and 8838)

CSC8837

This sample yielded a diverse benthonic assemblage dominated by abundant *Paromalina crassa*, but with frequent *Cibicides lobatulus, Textularia agglutinans, Cibicides refulgens, Mississipina concentrica, Uvigerina peregrina* and *Trifarina angulosa. Rupertia stabilis* and *Globocassidulina subglobosa* are very rare. The fauna is essentially similar to CSC8814, although there are several additional taxa. *Mississippi concentrica*, for example, was recorded off the Shetland in depths of 70-90 (128-164m) fathoms during the "Challenger" Cruise and it is also recorded living off Norway in water depths of between 205 and 293m in temperatures of 8.71°C and salinities of 35.25 mille. *Trifarina angulosa* is particularly characteristic of the shelf and uppermost slope, down to a depth of about 800m off northwestern Europe in water temperatures of about 5-9 C and salinities in excess of 35 mille and often associated with coarser sediment. The significance of the attached forms was outlined for CSC8814. *Rupertia stabilis* is characteristic of the lower slope/lower bathyal, in water depths of between1750-4000m, but it occurs in depths as shallow as 1156m in the cold waters of the Faroes Channel. There appears then to be two distinct assemblages represented here, one characteristic of the upper slope and one more indicative of the lower slope. It can only be assumed that down-slope reworking has taken place.

The planktonic association comprises abundant, mainly (but not entirely) sinistrally coiled *N. pachyderma* and *G. bulloides* together with frequent *G. inflata, G. scitulus* and *O universa* and very rare *G. truncatulinoides* implying that the fauna is from the Subarctic Province with influence from the Transitional Province in the form of O. universa. The

sample also contained rare specimens tentatively indentified as *Calcarina stellata.* This unusual species is totally out of place in that it is recorded from the Eocene of France. It must be considered to be reworked.

CSC8838

Not examined.

57-13/65 - S19 (CSC8839)

CSC8839

Foraminifera very rare and poorly preserved (a specimen of *N. pachyderma* and an indeterminate fragment). Provenance is questionable. No conclusions can be drawn.

57-13/75 - S47 (CSC8840 and 8841)

Not examined.

57-13/76 - S48 (CSC8842 and 8843)

Not examined

57-13/77 - S56 (CSC8844)

Not examined

57-14/43 - S22 (CSC8845 and 8846)

CSC8845

Very rare *N. pachyderma, G. bulloides* and *G. inflata.* The provenance of these specimens is questinable and no conclusions are drawn.

CSC8846

Barren of foraminifera, but very rare specimens of *Bolboforma* were seen. *Bolboforma metzmacheri*, if correctly identified, is indicative of the mid- to late Miocene.

57-14/44 - S23 (CSC8847)

CSC8847

Barren

57-14/48 - S21 (CSC8848 to 8850)

CSC8848

Foraminifera are not common. *Paromalina crassa, Cibicides pseudoungerianus, Sigmoilina schlumbergeri, Melonis barleeanum, Lenticulina peregrina, Cibicides lobatulus, Rupertia stabilis, Bulimina* sp, *Cassidulina teretis, Elphidium clavatum* are recorded. The last two named are assumed to be reworked from the shelf, but the remainder are for the most part similar to those described for CSC8834 although attached forms are more common. Both sinistrally and dextrally coiled specimens of *N. pachyderma* were common and found together with frequent *Globigerina bulloides* and rare *Globorotalia inflata, Globigerina quinqeloba* and *Orbulina universa (*small). A position low in the Subarctic Province is inferred.

CSC8849

Paromalina crassa and *Cibicides refulgens* are frequent and *Cibicides pseudoungerianus, Sigmoilina schlumbergeri, Pyrgo murrhyna, Melonis pompilioides, Hansenisca soldanii* and *Rupertia stabilis* are rare. Attached species form a significant part of the assemblage (see above for a discussion). The fauna is similar in many respects to that of CSC8848, but part of the fauna is abraided implying reworking. The planktonic species are also similar, although *N. pachyderma* is manily sinistrally coiled indicating slightly colder conditions within the Subarctic Province.

CSC8850

The benthos is sparse though diverse. It is esentially similar to CSC8849. The planktonic element is less rich than in many other sample and comprises frequent *G. bulloides*, rare *G. inflata* and *N. pachyderma.* The Subarctic province is likely

57-14/54 - S23 (CSC8851 to 8853)

CSC8851

As for CSC8813.

CSC8852

Very sparse microfauna comprising very rare *Cibicides refulgens, Trifarina angulosa* and *N. pachyderma* (dextral and sinistral). No conclusions are drawn. The benthonic element is probably derived from the shelf.

CSC8853

A rare fauna comprising *Trifarina angulosa, Cibicides refulgens, C. lobatulus, Globocassidulina subglobosa*, sinistral *N. pachyderma* and fragments of other very rare foraminifera. This is possibly reworked *T. angulosa/C. lobatulus* Species Assemblage (*sensu* Mackensen et al., 1985) from the outer shelf to upper slope off Norway. Very rare specimens of (?)*Bolboforma* are also present implying possible Miocene reworking.

58-11/2 - S45 (CSC8854 to 8855)

CSC8854

Foraminifera are rare, particularly the benthonic element. Frequent *G. inflata* and *G. bulloides* and rare *O. universa* (small) and sinistral *N. pachyderma* form the planktonic association indicative of the colder part of the Subarctic Province.

CSC8855

Foraminifera are very rare; only a single benthonic specimen was seen. Of the planktonics, sinistrally coiled *N. pachyderma* is frequent and *G. bulloides* and *G. inflata* are rare. A position high in the Subarctic Province or low in the Arctic Province seems most likely.

58-12/5 - S46 (CSC8856 to 8857)

CSC8856

Benthonic specimens are exceedingly rare. Abundant *G. bulloides* and *G. inflata* together with rare dextral *N. pachyderma*, small *O. universa* and *G. quinqueloba* as well as very rare *G. bradyi* and *G. scitulus* places the fauna into the high transitionl or low Subarctic provinces.

CSC8857

A flood of *N. pachyderma* (sinistrally coiled) and only very rare *G. inflata* places the fauna into the Arctic Province. Benthonics are again very rare, the total fauna comprising *P. ariminensis* and *P. wuellerstorfi* and *Lenticulina* sp all being represented by only one or two specimens.

58-14/8 - S7 (CSC8858 and 8901)

Not examined

58-14/9 - S8 (CSC8859 to 8861)

CSC8859

The diverse benthonic fauna is dominated by common *Uvigerina peregrina*, frequent *Quinqueloculina seminulum, Cibicides lobatulus, Paromalina crassa* and rare *Bigenerina nodosaria, Hoeglundina elegans, Cibicides refulgens, Planispirinoides* sp and *Oridorsalis umbonatus*. Reworked speciens from the outer shelf such as *Bulimina*

marginata and *Melonis barleeanum* are very rare. The large numbers of *U. peregrina* is indicative of low oxygen level according to some authors, whereas Miller & Lohmann (1982) show it to be related to maximum values of organic carbon and silt in the substrate and hence the low oxygen content of the substrate and not the overlying water. The species is the dominant taxon in Variomax Factor 10 (of Weston, 1985) which is present at a depth of about 2000m (ie. lower slope-upper rise) in the Porcupine Seabight although it occurs on the outer shelf, slope as well as in bathyal regions off Europe and America. The species shows a preference for cold water (3-4°C). Sinistral *N. pachyderma* occurs in flood proportions and *G, bulloides* is common (*G. inflata, G. bradyi* and small *O. universa* are very rare). Surface waters of the Arctic Province is inferred.

CSC8860

Flood of sponge spicules and radiolaria. Of the benthonic foraminifera, abundant *Paromalina crassa* and frequent *Uvigerina peregrina* and *Trifarina angulosa* dominate the assemblage. Rarer attached species are aso present such as *Cibicideslobatulus* and *C. pseudoungerianus*. Cold water, upper slope conditions are indicated with maximum values of organic carbon and silt in the substrate and the low oxygen content of the substrate. Abundant *G. bulloides* and rare *G. quinqueloba* and sinistral *N. pachyderma* comprise the planktonic association and a high Subarctic or low Arctic Province is implied.

CSC8861

The planktonic element of the fauna is dominated by abundant *Globorotalia inflata*, common , mainly sinistral, *N. pachyderma*, frequent *Globigerina bulloides* and very rare, small *Orbulina universa.* The abundance of *G. inflata* is indicative of theTransitional Province, although the sinistrally coiled *N. pachyderma* implies colder waters(Subarctic Province). The reason for this mixing may be due to reworking, but this is not clear.

The benthonic fauna is dominated by abundant *Paromalina crassa* and other species are rare or very rare, but include *Pyrgo murrhyana, Trifarina angulosa, Cibicides lobatulus, C. pseudoungerianus, C. refulgens, Sigmoilina schlumbergeri, Melonis barleeanum, Cassidulina laevigata, Bolivina spathula, Bulimina marginata* and *Oolina*

melo. This fauna appears to be from the upper slope, perhaps fitting within the *angulosa/lobatulus* assemblage from offshore Norway (Mackensen et al., 1985).

58-14/10 - S9 (CSC8862)

CSC8862

The fauna is sparse and poorly preserved. *Planulina wuellerstorfi, Cibicides lobatulus, Gyroidina neosoldanii* and *Pullenia quinqueloba* are present with abundant bryozoa and echinoid spines. The preservation and sparse nature of the fauna precludes conclusions. Several specimens from this sample appear to be poorly preserved Eocene taxa (*Alabamina* cf *wilcoxensis, Globorotalia* cf *esnaensis, Globigerina* cf *linaperta, Globigerrina* cf *boweri*). *Globigerina linaperta* is a fairly long-ranging species, with its inception in the Palaeocene but ranging up to the basal part of foram zone P16 (i.e. earliest late Eocene). *Globorotalia pentacamerata* ranges through P8 and P9 (i.e. early Eocene). If the specimens of *Globorotalia cf esnaensis* are indeed that species, this is also a Palaeocene to early Eocene indicator. It would seem that an early Eocene age is likely.

58-14/11 - S10 (CSC8863)

CSC8863

Calcareous microfossils are rare and poorly preserved. No conclusions are possible.

58-14/29 - S13 (CSC8864, 8899 and 8905)

CSC8864

Foraminifera are rare. Although the planktonic taxa (sinistral *N. pachyderma* and *G. quinqueloba*) are very rare and undoubtedly Pleistocene in age, the benthonic specimens are not. They are similar to those from the deep water, dysaerobic conditions characteristic of the Eocene in the North Sea. *Rabdammina* cf *discreta* fragments, *Reticulophragmium amplectens* (of King, 1989),crushed *Trochammina* sp. and

Haplophragmoides sp. cf *walteri, Karrerulina conversa* and other agglutinatined forms. *Rectophragmium amplectens* suggests an age no younger than the earliest part of the mid-Eocene at which level it has its First Down-hole Occurrence. Perhaps significant is the fact that *Cenosphaera* sp which has its FDO approximately at the mid-/early Eocene boundary was not observed, but *Karrerulina conversa* is present, the inception of which is near the base of the Mid Eocene. Age: mid-Eocene.

CSC8899

Not examined

CSC8905

A very sparse fauna of very poor preservation. Very rare *Cibicides lobatulus* and *Paromlina crassa* were recognised together with a poor specimen tentatively identified as *Reticulophragmium amplectens*. It is not clear whether this is reworked from the Eocene or whether the specimen is in situ.

58-14/31 - S12 (CSC8865)

CSC8865

Paranomalina crassa, Textulariella agglutinans, Gyroidina neosoldanii, Planulina ariminensis, Uvigerina peregrina, Cassidulina laevigata, Planulina wuellerstorfi, Cibicides pseudoungerianus and *Trifarina angulosa* are present . The benthonic fauna is similar to that in CSC8860. Dextral *N. pachyderma* is also present indicating the low Subarctic Province. The indurated rock chips of the sample have a fauna which is difficult to deal with due to the encrusting material, but many look to be Pleistocene to Pliocene forms. Further work on this material may be beneficial.

58-14/32 - S12 (CSC8866, 8867 and 8902)

CSC8866

Not examined

CSC8867

As for CSC8865, although diversity is lower.

CSC8902

Pleistocene faunas are common in this sample, however Eocene planktonic foraminifera are also common including *Globigerina* cf *boweri, Globigerinita* cf *unicava primitiva, Globigerina* cf *boweri* together with what appears to be a broken *Nummulites*.

58-14/34 - S14 (CSC8868 to 8870)

CSC8868

A flood of sinistrally coiled *N. pachyderma* with rare *G. inflata, G. bulloides* and very rare *G. truncatulinoides* is indicative of the high Subarctic and low Arctic provinces. The benthonic element is sparse, but includes the deep, cold water species *Rupertia stabilis* together with *Planulina wuellerstorfi, Cibicides lobatulus, Sigmoilina schlumbergeri* and *Pullenia bulloides.* Deposition at 1000-1500m seems likely. Rare specimens more characteristic of the shelf (eg. *Fissurina lucida*) are present and probably reworked.

CSC8869

Although the benthonic association is similar to that of CSC8868, the planktonic taxa show distinct differences. Sinistral *N. pachyderma* is frequent, though not abundant, and dextrally coiled forms are also present, although very rare *Globorotalia inflata* and *Globigerina bulloides* are common and *Globigerina quinqueloba, Globorotalia truncatulinoides* and small *Orbulina universa* are very rare. However, this fauna is

probably indicative of the more temporate part of the Subarctic Province, where waters temperatures exceed 7.2°C in Spring.

CSC8870

As for 8864, but *Ammoglobigerina* cf *globigerinaeformis*, *Glomospira charoides* and *Spiroplectammina spectabilis* are present. The last named has been used as a biomarker in the North Sea as it has a first Down-hole Occurrence in the mid-Eocene. *Rectophragmium amplectens* is also present suggesting the age is no younger than the earliest part of the mid-Eocene at which level it has its FDO. The occurrence of *Karrerulina conversa* precludes an early Eocene age. Age: mid-Eocene

58-14/42 - S7 (CSC8871 and 8903)

CSC8871

Not examined

CSC8903

Very rare *Globigerinita bradyi, Cibicides* sp, indet frags. No conclusions are possible. Foraminifera occur in rock chips, but could not be identified or liberated. Thin section work is required.

58-14/43 - S9 (CSC8872 and 8904)

CSC8872

Not examined

CSC8904

Bryozoa occurs in floods, together with shell fragments. Microfossils are not common, but are moderately diverse. *Hoeglundina elegans, Oridorsalis umbonata, Cibicides peudoungerianus, Trifarina angulosa, Cibicides lobatulus, Cornuspira carinata* and

Eponides repandus. This association can probably be placed within the *Trifarina angulosa/Cibicides lobatulus* association of Mackesen et al. (1985).

58-14/44 - S49 (CSC8873)

CSC8873

This sample yielded a very sparse fauna comprising only specimens of very small dimensions. It seems likely that this is the product of the accumulation of winnowed material. No conclusions are made.

58-14/53 - S11 (CSC8874)

CSC8874

The Pleistocene to Recent planktonic taxa *Neogloboquadrina pachyderma* (sinistral) is frequent and *Globigerina bulloides* and *Globorotalia cf inflata* are rare. This assemblage structure may indicate the Arctic Province, but the sparsity of the fauna means that this conclusion is very tentatively suggested. The benthos includes frequent "*Rhizammina*" sp., but all other species are very rare and not well preserved. These include *Hyperammina subnodosum, Pullenia bulloides, Planorbulina mediterranensis, Cassidulina reniforme, Trifarina angulosa, Glomospira charoides* and *Alveophragmium* sp cf *scitulum*. Some of these taxa, for example *Glomospira charoides*, are probably reworked. This is supported by the fact that rare specimens of *Bolboforma* are present (?Miocene) together with *Globigerina* cf *yeguaensis* and *Pseudohastigerina* cf *wilcoxensis* (Eocene). No further conclusions are possible.

58-14/54 - S42 (CSC8875 and 8876)

CSC8875

The poorly preserved fauna is difficult to identify so that conclusions here should be treated with caution. The rock chips within the sample are composed of more than 90%

foraminifera, although these are very difficut to extract from the indurated sediment. *Globorotalia* cf *esnaensis*, *Globigerina* cf *linaperta*, *Truncrotalites* cf *rohri*, *Globigerinita* cf *unicava primitiva* and *Globigerina* cf *eocaena* were noted. *Globigerinita unicava primitiva* is a mid-Eocene (foram zone P14) to Oligocene species. Its presence, together with *G. linaperta* (see CSC8862) and large spherical radiolaria (present in the Eocene of the North Sea - particularly the early Eocene), suggests an Eocene age.

CSC8876

The deposit is similar to CSC8875. Common specimens of *Globigerina* cf *eocaena* were noted together with rare *Globigerina* cf *venezuelana*. These are Eocene forms. The Pleistocene element in the assemblage comprises rare *Stilostomella bradyi, Hoeglundina elegans, Sigmoilina schlumergeri, Globigerina* cf *bulloides* and *Orbulina* sp, but little can be drawn from the sparse fauna which is most probably the result of down-core contamination.

58-14/55 - S40 (CSC8877)

Barren

58-14/56 - S50 (CSC8878)

Barren

58-14/57 - S41 (CSC8879 and 8880)

CSC8879

Attached forms including abundant *Paromalin crassa*, frequent *Cibicides lobatulus, C pseudoungerianus* and *C. refulgens* dominate the assemblage, other species (including *Gyroidina neosoldanii, Uvigerina peregrina, Pyrgo murrhyna, Planulina ariminensis, Sigmoilina schlumbergeri, Hoeglunina elegans* and *Trifarina angulosa*) are rare or very

rare. The fauna is similar to that described for CSC8820. Of the planktonic specimens, abundant sinistral *N. pachyderma* and common *Globorotalia inflata* and *Globigerina bulloides* also indicates cold surface waters of the Subarctic Province, although very rare specimens of the small morph of *Orbulina universa* may indicate the influence of waters from the transitional province if reworking is not ruled out.

CSC8880

This sample contains indurated rock chips containing foraminifera. Identication is not possible, although thin section work may prove useful. No specimens could be released fronm this matrix for identification. No conclusions are possible.

58-14/60 - S51 (CSC8881 and 8882)

CSC8881

The planktonic element is composed of a flood of sinistrally coiled *N. pachyderma* together with rare *G. inflata, G. bulloides* and *G. truncatulinoides.* The structure of this association implies the Arctic Province, but the occurrence of rare *G. inflata* and *G. truncatulinoides* implies that the assemblage must be close to the Arctic/Subarctic province boundary, as both species not normally found further north than the Subarctic Province. The benthos is very sparse, but includes frequent *Rupertia stabilis* together with rare *Sigmoilina schlumbergeri* and *Cibicides pseudoungerianus.* The frequent *R. stabilis* is indicative of cold, deep water. It is characteristic of the lower slope/lower bathyal, in water depths of between1750-4000m, but it occurs in depths as shallow as 1156m in the cold waters of the Faeroe-Shetland Channel. Its frequent occurrence in the present sample is interesting as it is unlike other assemblage described from the European slope.

CSC8882

This sample contained a diverse benthonic assemblage, but individual species were rare or very rare, with the exception of frequent *Sigmoilina schlumergeri*, the environmental requirements of which are inadequately known. It occurs on the slope in at least bathyal

depths. Of the remainder, *Cibicides lobatulus, C. pseudoungerianus, C. refulgens* and *Bigenerina nodosaria* are rare and *Pyrgo williamsoni, Hoeglundina elegans, Eggerella bradyi, Uvigerina peregrina, Gyroidina neosoldanii, Paromalina crassa* and *Melonis barleeanum*. Despite the smaller numbers, the assemblage is not unlike those described previously (eg. CSC8814)

58-14/63 - S53 (CSC8883)

Not examined

59-11/12 - S1 (CSC8884)

CSC8884

A very sparse fauna comprising rare *Hoeglundina elegans, Pullenia bulloides,, N. pachyderma, G. bulloides* and very rare *Gyroidina* sp. Indeterminate specimens were noted in the indurate grains and only thin section work would solve problems here. No conclusions are drawn from this sparse fauna.

59-11/13 - S2 (CSC8885 to 8888)

CSC8885

Cibicides lobatulus is common and *C. refulgens* and *Uvigerina peregrina* are frequent. With these are rare *Trifarina angulosa, Melonis barleeanum* and *Hoeglundina elegans.* The upper slope is indicated, the fauna apparently being a mixture of the *Trifarina angulosa* Assemblage and *Trifarina angulosa/Cibicides lobatulus* Assemblage of Mackensen et al. (1985) which are characteristic of the outer shelf and upper slope, down to about 700m, off the coast of Norway. The planktonic association comprises common , mainly dextral *N. pachyderma, G. bulloides* and *G. inflata*, while moderately large specimens of O. universa are frequent. This assemblage structure is indicative of the warmer part of the Subarctic Province and, perhaps, the colder parts of the Transitional

Province, although the characteristic species that define the Transitional Province, such as *Globigerinoides ruber, Hastigerina pelagica* and *Globigerinella aequilateralis*, were not observed.

CSC8886

Sponge spicules are abundant in this sample and (?)diatoms are also common. Foraminifera are similar to those of CSC8885, although less diverse and sinistrally coiled *N. pachyderma* are more common indicating colder surface waters, colder than the 7.2°C Spring isotherm, and a position in the colder part of the Subarctic Province is inferred.

CSC8887

Sponge spicules abundant. Frequent *Cibicides lobatulus, C. refulgens* and *Quinqueloculina seminulum* dominate the assemblage, while *Trifarina angulosa, Textularia aspera, Uvigerina peregrina* and *Cibicides peudoungerianus* are rare. This is an outer shelf to upper slope association and would not be out of place off northwestern Europe today. *Globigerina bulloides* and mainly sinistral *Neogloboquadrina pachyderma* are common, *Globorotalia inflata* is frequent and *Globigerina quinqeloba* and *Globigerinita bradyi* are rare. The colder part of the Subarctic Province is implied rather than the Arctic Province.

CSC8888

Paromalina crassa and *Cibicides lobatulus* are abundant here with rare *Cibicides pseudoungerianus, Textularia agglutinans, Trifarina angulosa* and very rare *Rectoglandulina rotundata, Hoeglundina elegans, Cassidulina laevigata* and *Planulina wuellerstorfi*. Shelf species such as *Elphidium subarcticum*, are reworked. Although slightly more diverse, this assemblage, as well as the planktonic association, is essentially similar to CSC8887

59-11/16 - S43 (CSC8889)

CSC8889

Foaraminifera are very rare, dominated by frequent specimens of the cold water ,sinistrally coiled *N. pachderma.* Rare *Rupertia stabilis* is also present, indicating cold deep water. The assemblage is so sparse, however, that no further conclusions are possible.

59-11/17 - S44 (CSC8890 and 8891)

CSC8890

The benthos is sparse, comprising rare *Rupertia stabilis, Cibicides lobatulus, C. pseudoungerianus, Sigmoilina schlumbergeri* and *Trifarina angulata,* together with very rare *Uvigerina peregrina, Pullenia bulloides, Spiroloculina depressa* and *Melonis barleeanum.* This is an outer shelf to upper slope fauna. The planktonic association is dominated by common *G. inflata* and *G. bulloides*, frequent *Globorotalia scitulus*, moderately large *O. universa* and frequent sinistral *N. pachyderma* and rare *G, bradyi,* dextral *N. pachyderma* and *G. truncatulinoides.* The Subarctic province is indicated, and although there are a number of sinistrally coiled specimens of *N. pachyderma*, the presence of the dextral form and the large *O. universa* and the common *G. inflata,* a position in the warmer part of the province seems most likely.

CSC8891

The benthonic fauna is dominated by frequent *Bulimina marginata*, the remaining species being rare or very rare (*Bulimina elongata, Elphidium incertum, Elphidium excavatum, Triloculina trifera* and *Cassidulina laevigata*). This is a shelf or upper slope fauna, although it includes reworked near shore taxa, such as species of *Elphidium.* It shows some similarities with the *Bulimina marginata* association of Murray (1991) of the European Atlantic Seaboard. This association is found in muddy sands, salinities of about 35 mille and temperatures of 5.5°C and 13°C.

Sinistral *N. pachyderma* is abundant and *G. inflata* is frequent, but the only other planktonic species, *G. bulloides* and *G. glutinata* are rare. A position high within the Subarctic or low within the Arctic Province seems most likely.

59-14/6 - S5 (CSC8892 and 8893)

CSC8892

Foraminifera very rare comprising only rare sinistral and very rare dextral *N. pachyderma*, rare *G. bulloides* and *G. infata* and very rare *G scitulus*. No benthonics were seen. No conclusions can be made on this sparse assemblage.

CSC8893

The Pleistocene to Recent fauna is represented by rare *N. pachyderma, G. inflata* and *G. quinqueloba.* However, *Caenosphaera* sp together with *'Cenodiscus'* sp (probably crushed *Cenosphaera*) are abundant. These radiolaria are characteristic of the earliest mid-Eocene and latest early Eocene (i.e. immediately above and immediately below the Ypresian/Lutetian boundary. In the North Sea this is an important biomarker and King (1989) places it in the NSP6 planktonic Zone. The absence of calcareous benthonics and planktonic foraminifera is another characteristic of the zone.

59-14/7 - S4 (CSC8894 and 8895)

CSC8894

Foraminifera extremely rare comprising very rare *Uvigerina peregrina* and *Cassidulina laevigata* and planktonic *G. inflata,* and *N. pachyderma* (both dextral and sinistral). Fish debris is also present. Little can be drawn from the this sparse assemblage.

CSC8895

Sponge spicules are common, but the foraminifera comprise very rare *N. pachyderma, G. inflata* and ?*G.bulloides*. No conclusions are possible.

59-14/8 - S3 (CSC8896, 8897 and 8906)

CSC8896

Not examined

CSC8897

Sponge spicules and radiolaria abundant but the foraminiferal fauna is composed of very rare sinistral *N. pachyderma* and *O. universa.* No conclusions are possible.

CSC8906

Fish teeth are present. The foraminiferal assemblage is very sparse, comprising frequent sinistral *N. pachyderma* and very rare *G. inflata, G. bradyi, Cibicides lobatulus, Pullenia bulloidea* and *?Planulina wuellerstorfi.* Apart from pointing out that the sinistral *N. pachyderma* suggests cold conditions (high Subarctic or Actic Province), little can be inferred from the sample.

59-14/9 - S6 (CSC 8898 and 8907)

CSC8898

Not examined

CSC8907

Bryozoan flood. The foraminiferal assemblage is moderately diverse, although individual species are rare or very rare, the exception being *Cibicides lobatulus*, which is frequent. Species include *Hoeglundina elegans, Bulimina* sp., *Valvulineria laevigata, Cornuspira* sp., *Lagena costata, Patellina corrugata, Stilostomella bradyi Orbulina universa* and sinistral *N. pachyderma.* This is a shelf assemblage of the Subarctic Province.

References

BE, A.W.H. 1977. An ecological, zoogeographic and taxonomic review of Recent planktonic foraminifera. 1-100 in Ramsay, (editor) *Oceanic Micropalaeontology,* (London: Academic Press).

MACKENSEN, A, SEJRUP, H P, JANSEN, E. 1985. The distribution of living foraminifera on the continental slope and rise southwest Norway. *Marine Micropaleontology,* Vol. 9, 275-306.

MILLER, K G, and LOHMANN, G P. 1982. Environmental distribution of Recent benthic foraminifera on the northeast United States continental slope. *Bulletin of the Geological Society of America,* Vol. 93, 200-206.

MURRAY, J.W. 1971. *An Atlas of British Recent Foraminiferids.* 245pp (London: Heinemann).

PUJOS, M. 1970. Influence des eaux de type mediterranean sur la repartitions de certains foraminiferes benthiques dans le Golfe de Gascogne. *Cahiers de oceanographie,* Vol. 22, 827-831.

WESTON, J F. 1985. Comparison between Recent benthic foraminiferal faunas of the Porcuopine Seabight and Wetern Approaches Continental Slope. *Journal of Micropalaeontology*, Vol. 4, 165-183.

CALCAREOUS NANNOFOSSIL ANALYSIS OF SHALLOW CORES FROM THE ROCKALL AREA

CALCAREOUS NANNOFOSSIL ANALYSIS OF SHALLOW CORES FROM THE ROCKALL AREA

N.M. Hine

Introduction

The aim of this investigation was to provide biostratigraphical information by way of calcareous nannofossil analysis of eighty-seven samples (CSC8813 to 8899) collected from the Rockall Area. Calcareous nannofossils provide a tool with which to date marine calcareous sediments from the Late Triassic to Holocene. Of particular relevance to this study is their application to late Quaternary sedimentary sequences. Following the work of Weaver (1983), Gard (1988, 1989), Pujos (1988), Hine (1990) and Baumann & Matthiessen (1992), amongst others, a sequence of calcareous nannofossil events have been identified which occur throughout the north-east Atlantic and adjacent areas. Figure 3 presents a summary of these events for the Quaternary and Figure 4 depicts the standard calcareous nannofossil zonation scheme of Martini (1971) for the entire Cenozoic.

Quaternary calcareous nannofossil biostratigraphy

The Quaternary of the north-east Atlantic has been subdivided into a number of intervals based on a combination of datum events and taxa acme zones. A summary of those zones recorded in this investigation are presented below and are depicted in Figure 3. The abbreviations LAD and FAD, used throughout this report, refer, respectively, to last appearance datum and first appearance datum.

Small *Gephyrocapsa* acme zone (Hine, 1990): A zone in which small *Gephyrocapsa* dominate the assemblage. This zone spans 600 to 860 ky BP, which is equivalent to lower oxygen isotope Stage 15 to Stage 25. The principal species which constitute the Small *Gephyrocapsa* zone include *G. aperta* and the small *G. caribbeanica.* This zone

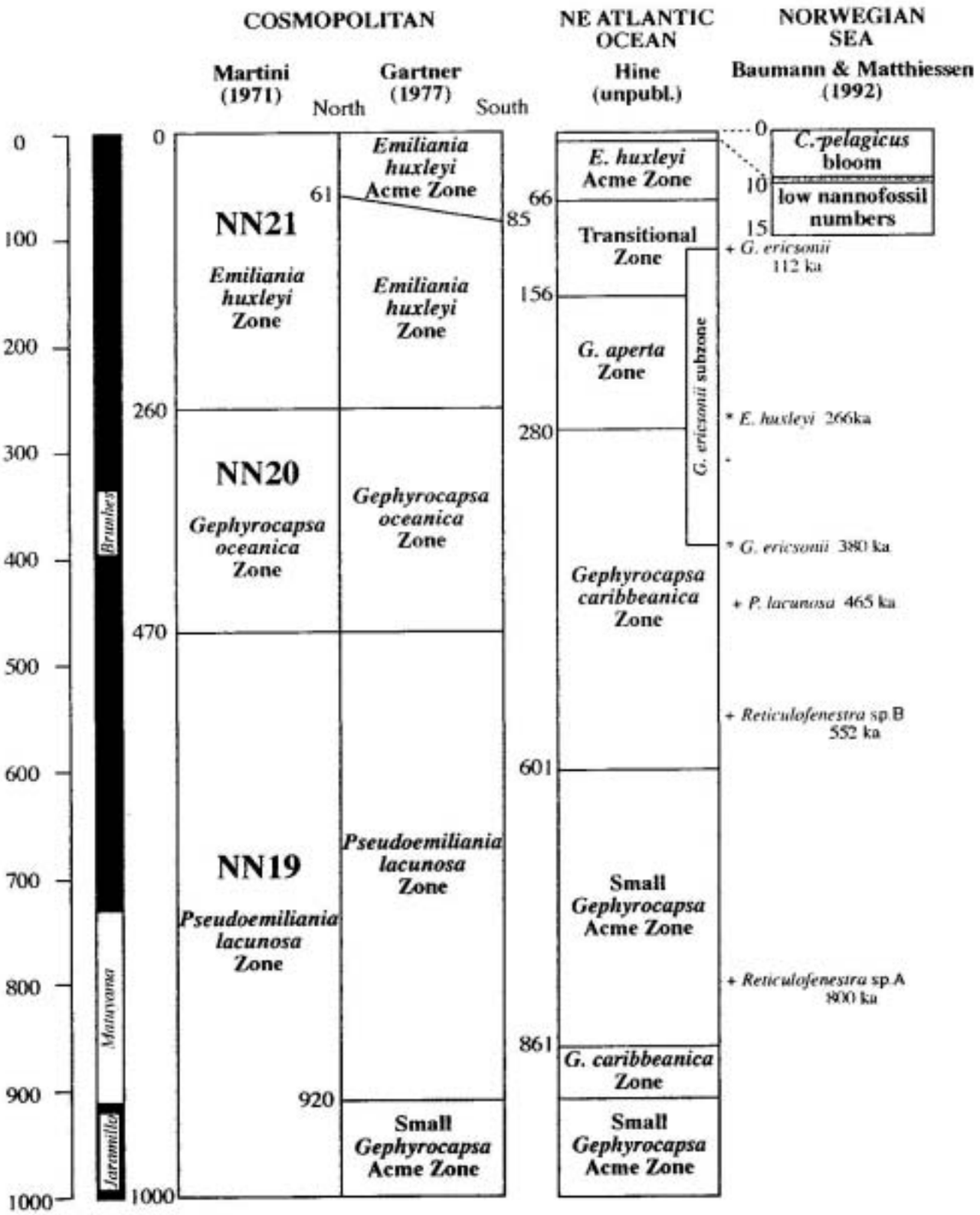


Fig. 3. Summary of calcareous nannofossil events and zones occurring over the last 1 million years. Symbols: *, first appearance datum (FAD); +, last appearance datum (LAD).

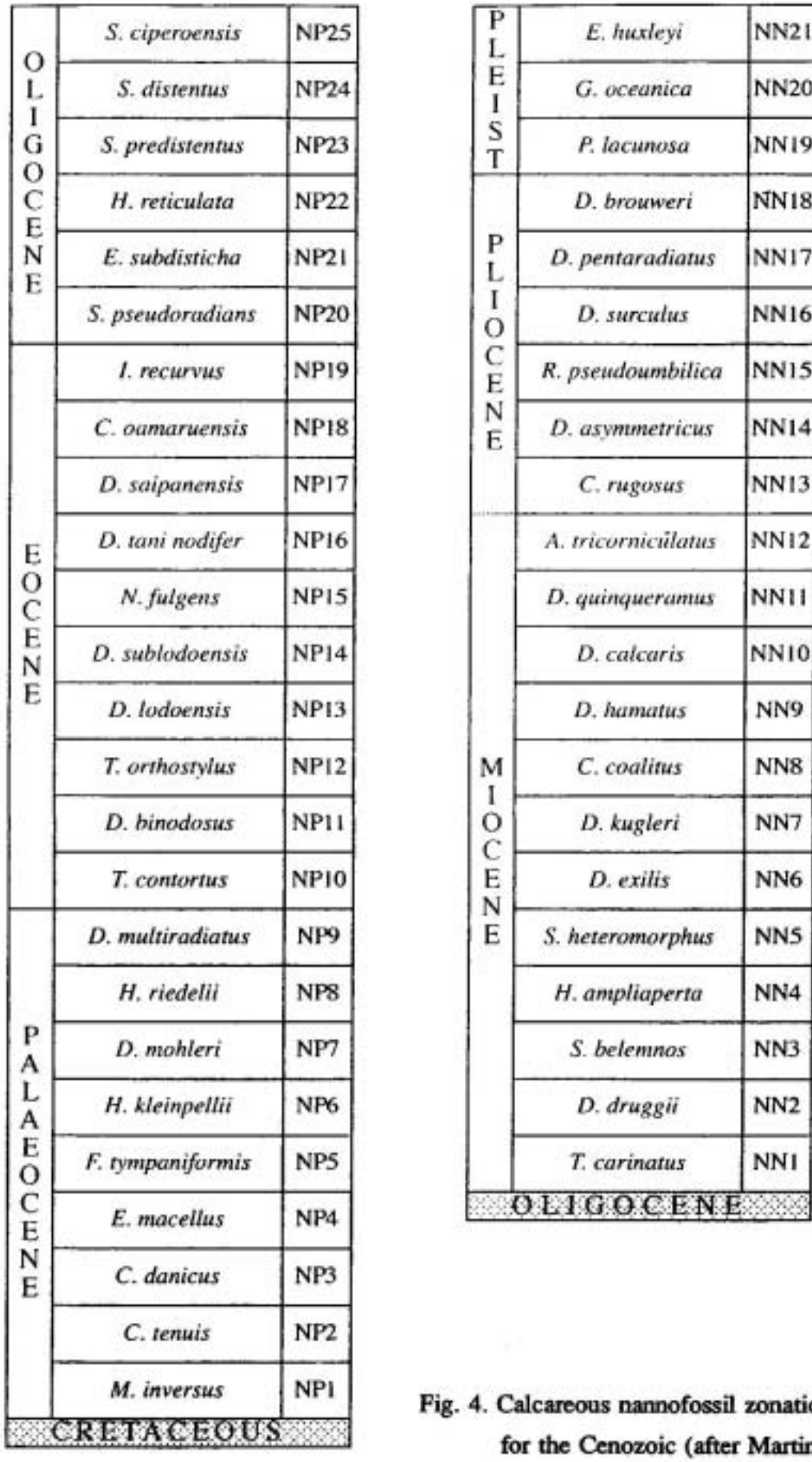


Fig. 4. Calcareous nannofossil zonation scheme for the Cenozoic (after Martini, 1971).

can be distinguished from the Small Gephyrocapsa Zone of Gartner & Emiliani (1976) by the lower frequency of both *P. lacunosa* and *Reticulofenestra.*

Gephyrocapsa caribbeanica Acme Zone (Hine, 1990): A zone in which *Gephyrocapsa caribbeanica* dominates the assemblage. This zone spans 280-600 ky BP, that is, oxy gen isotope stages lower 8 to lower Stage 15.

Gephyrocapsa aperta Acme Zone (Hine, 1990): A zone in which *Gephyrocapsa aperta* dominates the assemblage. This zone range from 156-280 ky BP, which is equivalent of oxygen isotope Stages lower 6, 7 and upper Stage 8. The first evolutionary appearance of *E. huxleyi* is a globally synchronous event occurring at 270 ky BP and was used by Martini (1971), to define the base of the *Emiliania huxleyi* Zone (NN21) which continues to the present day. All samples containing *E. huxleyi* have, therefore, been deposited less than 270 ky BP.

Transitional Zone (Hine, 1990): A zone in which no one species predominates, although *G. muellerae* is often abundant. This zone spans oxygen isotope stages 4,5 and upper Stage 6 (66-156 ky BP). The LAD of *G. ericsonii* occurs within this zone. Although the LAD of this species is a globally diachronous event (Pujos 1988) being recorded between 20 and 150 ky BP, it has a mean LAD of 122 ky BP in the high latitude northeast Atlantic Ocean (Pujos 1988; Hine 1990). The LAD of *G. ericsonii*, for the purpose of this investigation, is considered to occur within oxygen isotope Stage 5 (112 ky BP). In consequence, all samples containing *G. ericsonii* can be considered as older than oxygen isotope Stage 5.

Emiliania huxleyi Acme Zone (Gartner, 1977): A zone in which *E. huxleyi* dominates the assemblage. The base of this zone is defined by a reversal from assemblages dominated by species of *Gephyrocapsa*, to assemblages dominated by *E. huxleyi*. The base of this zone is slightly time transgressive in the north-east Atlantic, occurring first in low latitudes (85 ky BP; isotope stage 5b) and at progressively younger ages in higher

latitudes (Thierstein et al., 1977; Gard 1988). For the purpose of this investigation this event is taken at the oxygen isotope Stage 3/4 boundary. All samples in which *E. huxleyi* is dominant are, therefore, considered to have been deposited between 65 and 0 ky BP.

Coccolithus pelagicus bloom: A bloom of *C. pelagicus* is characteristic of Holocene high-latitude assemblages in the North East Atlantic. The base of this bloom occurs near to the the base of the Holocene (Gard, 1988, 1989; Baumann & Matthiessen, 1992).

Neogene calcareous nannofossil biostratigraphy

Recognition of Miocene sediments at high latitudes by way of calcareous nannofossils is often problematic due to the absence of warm water discoasters which are used extensively in standard zonation schemes. High-latitude Miocene and Pliocene calcareous nannofossil assemblages tend to be dominated by a single *Reticulofenestra* species. Backman (1980) used the mean size of these to differentiate Miocene from Pliocene sediments in high latitudes of the north-east Atlantic, assigning the larger sizes to the Miocene and the smaller to the Pliocene. Although this is not a very satisfactory methodology, at times it is the only one available to enable Miocene assemblages to be distinguished from Pliocene assemblages.

Methods

Standard smear slides were prepared for light microscope analysis from raw sediment strews. Scanning electron microscopy (SEM) analysis was beyond the remit of this investigation. Abundance counts were made either of a minimum of 300 specimens, or a maximum of 25 fields of view, following the technique of Backman & Shackleton (1983). The results of the calcareous nannofossil analysis are presented below in order of their official CSC number.

Results

56-14/13 - S24 (CSC8813 to 8815)

CSC8813

Depth: 0.05-0.07m: This is a rich assemblage composed of high numbers of both *C. pelagicus* and *E. huxleyi*. Accessory taxa include *G. aperta, C leptoporus, S. histrica* and *Helicosphaera carteri.* The occurrence of such high numbers of coccoliths suggests the sediment was deposited under interglacial conditions, with surface-water mixing making nutrients available, resulting in this burst of high productivity.

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); *Coccolithus pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8814

Depth: 0.28-0.30m: The assemblage is composed of *Emiliania huxleyi, Gephyrocapsa aperta, Gephyrocapsa caribbeanica, Gephyrocapsa muellerae, Coccolithus pelagicus, Calcidiscus leptoporus, Syracosphaera histrica* and *Pontosphaera* sp.. SEM analysis is necessary to determine the ratio of *Gephyrocapsa* to *Emiliania* although light microscope analysis suggests the ratio is positive (ie. more *Gephyrocapsa* than *Emiliania*). The occurrence of *E. huxleyi* (FAD, 266 ka; oxygen isotope stage 8) and the absence of *Pseudoemiliania lacunosa* (LAD, 465 ka) restricts this sample to the late Quaternary *Emiliania huxleyi* Zone, NN21, of Martini (1971). There is no evidence of the *Coccolithus pelagicus* bloom which occurs at the base of the Holocene. Assuming the ratio of *Gephyrocapsa:Emiliania* is positive, the sample can be assigned to the Transitional Zone of Hine (1990). The absence of *Gephyrocapsa ericsonii* (LAD 112 ka), further supports the assignment of this sample to the upper part of the Transitional Zone.

The absence of a significant terrigenous input combined with the high numbers of coccoliths suggests the sediment was deposited under interglacial conditions, with surface water mixing making nutrients available, resulting in this burst of high productivity.

Zonation: Mid-/late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); ?Transitional Zone (Hine, 1990).

CSC8815

Depth: 0.90-0.93m: A rich and diverse assemblage composed of *G. caribbeanica, G. aperta, C. pelagicus, G. oceanica, C. leptoporus, S. histrica,* and *H. kamptneri. E. huxleyi* is recorded in the light microscope counts but SEM analysis is necesssary to confirm this. The occurrence of *E. huxleyi* restricts the sample to Zone NN21 of Martini (1971), however, the dominance of *Gephyrocapsa* spp. suggests the sample should be assigned to the Transitional Zone of Hine (1990).

Specimens of *Reticulofenestra* cf. *doronicoides* are recorded in the counts. This species has its last appearance datum in the Early Pleistocene (c.800 ky BP). These recordings are considered to be evidence of reworking, supported by the absence of *Pseudoemiliania lacunosa.*

Zonation: Mid-/late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); (*Emiliania huxleyi* Acme Zone, Gartner, 1977/Transitional Zone, Hine 1990)

57-11/67 - S29 (CSC8816 to 8820)

CSC 8816

Depth: 0.00-0.01m: This is a rich assemblage composed of high numbers of both *C. pelagicus* and *E. huxleyi.* Accessory taxa include *G. aperta, C leptoporus, S. histrica* and *Helicosphaera carteri.* The occurrence of such high numbers of coccoliths suggests the sediment was deposited under intergalcial conditions, with surface water mixing making nutrients available, resulting in this burst of high productivity.

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); *Coccolithus pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC 8817, 8818 & 8819

Depth: 0.2m, 1.5m & 3.5m: All three assemblages are characterised by the occurrence of rare *E. huxleyi*. Accessory taxa include*G. aperta, G. caribbeanica, G. muellerae* and*S. histrica*. The proportion of terrigenous material and reworked nannofossils increases with depth. There is no evidence of the *C. pelagicus* bloom.

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

CSC 8820

Depth: 4.9m: The assemblage is dominated by *G. caribbeanica* with little in the way of accessory taxa. SEM analysis is necessary to determine if *E. huxleyi* is present, but this species is not recorded in the light microscope counts. There is no evidence of *P. lacunosa*.

Zonation: Mid-/late Pleistocene - Gephyrocapsa oceanica Zone, NN20 (Martini, 1971); upper part of the *G. caribbeanica* Zone of Hine (1990).

NB. If *E.huxleyi* was identified the sample would be assigned to NN21 of Martini (1971) and the Transitional Zone of Hine (1990).

57-12/18 - S30 (CSC8821)

CSC8821

Depth: 3.70-3.73m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view). After extensive scanning of the slide two small specimens of badly preserved placolith were recorded. These are tentatively attributed to ?*Cyclagelosphaera*, a genus which ranges from the mid-Jurassic to the Palaeocene.

Zonation: None.

57-12/19 - S28 (CSC8822 to 8823)

CSC 8822

Depth: 0.00-0.03m: This sample yields only rare specimens of *E. huxleyi* and is characterised by reworked nannofossils and a high terrigenous component. There is no evidence of the *C. pelagicus* bloom.

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

CSC8823

Depth: 5.3m: The assemblage is dominated by small *Reticulofenestra* and *Dictyococcites* spp. (such as *R. productella D. antarcticus, R. minutula* and *R. minuta*). Additional taxa include *Coccolithus pliopelagicus, Calcidiscus macintyrei, Calcidiscus fuscus* and *Helicosphaera kamptneri.* No whole specimens of *Discoaster* are recovered, although individual arms of *D.* cf. *broweri* are recorded. Reworked Cretaceous calcareous nannofossils are common in this sample. In addition to this a number of small prinseaceans which can be assigned to *Gephyrocapsa caribbeanica* are recorded. The assemblage, in general, has a late Pliocene character, however, in view of the absence of whole discoasters, and the recording of only individual arms (which may be reworked), a slightly later NN19 age (lowermost Pleistocene age) cannot be excluded for this sample.

Zonation: Late Pliocene (NN18).

57-12/33 - S27 (CSC8824 to 8826)

CSC 8824

Depth: 0.05-0.10 m: The assemblage consists of abundant *E. huxleyi* together with *C. leptoporus, C. pelagicus, S. histrica* and *G. muellerae.*

Zonation: ?Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); (?*C. pelagicus* bloom).

CSC 8825

Depth: 1.25-.30 m: The assemblage contains rare specimens of *Pseudoemiliania lacunosa*, the NN19 zonal marker of Martini (1971). SEM analysis is required to determine whether or not *E. huxleyi* occurs. Based on the assumption that *P. lacunosa* is not reworked, the sample, which has a diverse and abundant nannofossil assemblage, is assigned to the Small *Gephyrocapsa* Acme Zone of Hine (1990) .

Zonation: ?Early/mid-Pleistocene - *P. lacunosa* Zone, NN19 (Martini, 1971); Small *Gephyrocapsa* Acme Zone (Hine, 1990).

CSC8826

Depth: 2.5m: Nannofossil assemblages are dominated by *Reticulofenestra* spp. and *Discoaster* spp.. Marker species include *Helicosphaera sellii, Sphenolithus abies, Discoaster brouweri, D.scoaster tristellifer, P. lacunosa* and *Calcidiscus macintyrei.*

Zonation: NN15, *Reticulofenestra pseudoumbilica* Zone of Martini (1971).

57-13/26 - S26 (CSC8827 to 8833)

CSC 8827

Depth: 0.00-0.01 m: The assemblage is composed of abundant specimens of *E. huxleyi* together with *C. leptoporus, C. pelagicus, S. histrica* and *G. aperta. C. pelagicus* counts are relatively high and may indicate the base of the *C. pelagicus* bloom.

Zonation: ?Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); (?*C. pelagicus* bloom).

CSC 8828, 8829, 8830, 8831, 8832, 8833

Depth: 0.5m, 1.0m, 1.5m, 2.0m, 2.5m and 3.0m: The uppermost assemblage is composed of abundant specimens of *E. huxleyi* together with *C. leptoporus, C. pelagicus, S. histrica, G. caribbeanica* and *G. aperta.* Both the terrigenous component and reworked nannofossils increase in number down core and the number of in-situ Quaternary nannofossils correspondingly decrease. In all samples the ratio of *Gephyrocapsa*

:*Emiliania* is negative, so the samples can be assigned to the Emiliania huxleyi Acme zone of Gartner (1977). There is no evidence of the *Coccolithus pelagicus* bloom which occurs at the base of the Holocene.

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

57-13/53 - S16 (CSC8834 to 8836)

CSC 8834

Depth: 0.00-0.03m: The assemblage is composed of abundant specimens of *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica* and *G. aperta*

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner 1977); *C. pelagicus* bloom (Baumann & Matthiessen 1992).

CSC 8835

Depth: 0.50-.53m: This sample yields specimens of *E. huxleyi* together with *C. leptoporus, C. pelagicus, S. histrica* and *G. aperta* although the amount of reworked and other terrigenous material has increased by comparison with sample CSC8834. The numbers of Quaternary nannofossils decrease and reworked material (of Cretaceous and Tertiary age) increases with depth.

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

CSC 8836

Depth: 2.80-2.84m: The assemblage is dominated by small *Gephyrocapsa* (*G. aperta, G. caribbeanica* and *G. "protohuxleyi"*); *P. lacunosa* is also present.

Zonation: Early/mid-Pleistocene - *P. lacunosa* Zone, NN19 (Martini, 1971); Small *Gephyrocapsa* Acme Zone (Hine, 1990).

57-13/57 - S31 (CSC8837 to 8838)

CSC8837

Depth: 0.00-0.05m: This is a rich assemblage composed of high numbers of both *C. pelagicus* and *E. huxleyi*. Accessory taxa include *G. aperta, C leptoporus, S. histrica* and *Helicosphaera carteri* (see also CSC 8813).

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); *Coccolithus pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC 8838

Depth:5.00-5.02m: This sample contains rare in situ nannofossils together with high proportions of terrigenous material and reworked nannofossils (Cretaceous and Tertiary). The *in situ* forms include *G. caribbeanica, G. aperta, G. muellerae, E. huxleyi, S. histrica* and *C. pelagicus*. The ratio of *Gephyrocapsa* to *Emiliania* is positive (ie. more *Gephyrocapsa* than *Emiliania*), and on this basis the sample is asssigned to the Transitional Zone of Hine (1990). The occurrence of *E. huxleyi* should, however, be confimed by SEM analysis.

Zonation: Mid-/late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); Transitional Zone (Hine, 1990).

57-13/65 - S19 (CSC8839)

CSC8839

Depth: 3.05-3.10m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view).

Zonation: None.

57-13/75 - S47 (CSC8840 and 8841)

CSC 8840

Depth: 0.00-0.04m: This sample yielded abundant specimens of *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica, G. aperta, G. caribbeanica, G. muellerae* and *H. carteri.*

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); *Coccolithus pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8841

Depth: 4.05-4.10m: A rich and diverse assemblage including abundant specimens of *G. caribbeanica* together with *G. oceanica* and *G. aperta.* The assemblage also contains *Pseudoemiliania lacunosa*, the NN19 zonal marker of Martini (1971); and *Calcidiscus macintyrei* which has its last occurrence at 1.45 Ma (Backman & Shackleton, 1983). Based on the co-occurrence of *P. lacunosa, G. caribbeanica, G. oceanica* and *C. macintyrei*, the sample is assigned to mid NN19 (=CN13b of Okada & Bukry 1980).

Zonation: Early/mid-Pleistocene - *P. lacunosa* Zone, NN19 (Martini, 1971).

57-13/76 - S48 (CSC8842 and 8843)

CSC8842

Depth: 0.00-0.07m: This is a rich assemblage composed of high numbers of both *C. pelagicus* and *E. huxleyi.* Accessory taxa include *G. aperta, C leptoporus*, *S. histrica* and *Helicosphaera carteri* (see also CSC8813 & CSC8837).

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); *Coccolithus pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8843

Depth: 4.13-4.18m: This is a low diversity, poorly preserved assemblage dominated by small *Reticulofenestra* and *Dictyococcites* spp. (such as *R. productella, D. antarcticus, R. minutula* and *R. minuta*). Additional taxa include *Calcidiscus macintyrei, Sphenolithus* spp and *Calcidiscus fuscus.* This assemblage suggests a Late Pliocene age, however the occurrence of small prinseaceans which can be assigned to *Gephyrocapsa caribbeanica* and the absence of whole discoasters may indicate a slightly younger age. This assemblage is similar to that recovered from CSC8823 although has a much lower diversity assemblage and is more poorly preserved.

Zonation: Late Pliocene (?NN16-18). The absence of discoasters prevents designation to a more precise stratigraphic age.

57-13/77 - S56 (CSC8844)

CSC8844

Depth: 5.04-5.08m: A rich and diverse assemblage composed of high numbers of *Reticulofenestra* spp. (including *R. callidus, R. hillae, R. dictyoda, R. minuta* and *R. minutula*), together with *R. bisecta, Chiasmolithus oamaruensis, Zygrhablithus bijugatus, Sphenolithus moriformis, R. scissura* and *Nannoturbida* sp. *Pontosphaera* and *Transversopontis* spp. are also common. The co-occurrence of these species suggest an Eocene age assignment. Reworking of older Palaeocene material is common throughout the assemblage.

Zonation: Mid-Eocene - NP15-16 *Nannotetrina fulgens-Discoaster tanii nodifer* Zone, (Martini, 1971)

57-14/43 - S22 (CSC8845 and 8846)

CSC8845, 8846

Depth: 0.72 & 0.90m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view).

Zonation: None.

57-14/44 - S23 (CSC8847)

CSC8847

Depth: Sea-bed boulder: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view). After extensive scanning of the slide a single specimen of the long ranging Cenozoic species *Ericsonia ovalis* was identified.

Zonation: None.

57-14/48 - S21 (CSC8848 to 8850)

CSC 8848

Depth: 0.00-0.03 m: This sample yielded specimens of *E. huxleyi* together with *C. leptoporus, C. pelagicus, S. histrica, G. aperta* and *G. caribbeanica.* Reworked nannofossils and other terrigenous material are high. The sample is assigned to Martini's NN21 Zone due to the occurrence of *E. huxleyi*, and to the Transitional Zone of Hine (1990) due to the ratio of *Gephyrocapsa*:*Emiliania* being positive.

Zonation: Mid-/late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); Transitional Zone (Hine, 1990).

CSC 8849

Depth: 0.90-.93m: The assemblage is dominated by *G. caribbeanica* together with *G. aperta, S. histrica, C. leptoporus* and *P. lacunosa.*with little in the way of accessory taxa. SEM analysis is necessary to determine if *E. huxleyi* is present, but this species is not recorded in light microscope counts. Due to the occurrence of *P. lacunosa* the sample can be assigned to Zone NN19 of Martini (1971) and based on the predominance of small *Gephyrocapsa*, to the Small *Gephyrocapsa* Zone of Hine (1990).

Zonation: Early/mid-Pleistocene - *P. lacunosa* Zone, NN19 (Martini, 1971); Small *Gephyrocapsa* Zone of Hine (1990).

CSC8850

Depth: 2.00-2.01m: The assemblage is dominated by *Reticulofenestra* spp. and *Discoaster* spp.. *D. tristellifer, D. surculus, D. antarcticus, Coccolithus pliopelagicus, Gephyrocapsa* spp. (large) *H. sellii, Sphenolithus abies, S. verensis* and *Calcidiscus macintyrei*.

Zonation: Pliocene (NN13-15) (Martini, 1971), although the mean size of placoliths (esp. *D. antarcticus*) which are medium-sized suggests that a latest Miocene to earliest Pliocene age cannot be discounted.

57-14/54 -S23 (CSC8851 to 8853)

CSC8851

Depth: 0.65-0.68m: This sample yields abundant specimens of *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica, G. aperta, G. caribbeanica, G. muellerae* and *H. carteri*.

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977); *C. pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8852

Depth: 1.80-1.90m: This sample yields very few nannofossils, only 5 specimens of *G. caribbeanica* being recorded in 25 fields of view. Although no positive zonal assignment is made due to the paucity of data, a *G. caribbeanica* (NN20) zonal assignment seems the most probable.

Zonation: ?Mid-Pleistocene - *G. caribbeanica* Zone (Hine, 1990).

CSC8853

Depth: 1.90-2.00m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view).

Zonation: None.

58-11/2 - S45 (CSC8854 and 8855)

CSC 8854

Depth: 0.00-0.03m: This sample yielded abundant specimens of *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica, G. aperta, G. caribbeanica, G. muellerae* and *H. carteri.*

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977);*C. pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8855

Depth: 3.50-3.54m: This sample yielded specimens of *E. huxleyi* together with *G. aperta* and *G. caribbeanica.* The amount of reworked specimens and other terrigenous material has greatly increased relative to sample CSC8854. There is no evidence of the *C. pelagicus* bloom.

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

58-12/5 - S46 (CSC8856 and 8857)

CSC 8856

Depth: 0.00-0.03m: The assemblage is composed of abundant specimens of *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica, G. aperta, G. caribbeanica, G. muellerae* and *H. carteri.*

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977);*C. pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8857

Depth: 3.17-3.20m: This sample yielded specimens of *E. huxleyi* together with *G. aperta* and *G. caribbeanica* although the amount of reworked and other terrigenous material has greatly increased by comparison with sample CSC 8856.

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

58-14/8 - S7 (CSC8858)

CSC8858

Depth: 4.47-4.49m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view).

Zonation: None.

58-14/9 - S8 (CSC8859 to 8861)

CSC 8859

Depth: 0.00-0.03m: This sample yielded abundant specimens of *E. huxleyi* together with *Gephyrocapsa* spp., *C. pelagicus, C. leptoporus, S. histrica, H. carteri,* and *Pontosphaera.*

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977)

CSC8860

Depth: 0.35-0.38m: The assemblage is dominated by *G. caribbeanica* together with *G. aperta, G. muellerae, C. pelagicus, C. leptoporus* and *S. histrica.* SEM analysis is necessary to determine if *E. huxleyi* is present, but this species is not recorded in light microscope counts. There is no evidence of *P. lacunosa.*

Zonation: Mid-/late Pleistocene - *G. oceanica* Zone, NN20 of Martini (1971); upper part of *G. caribbeanica* Zone of Hine (1990). If *E.huxleyi* was identified in SEM analysis the sample would be assigned to the Transitional Zone (NN21) of Hine (1990).

CSC8861

Depth: 5.50-5.53m: The assemblage is dominated by *G. caribbeanica* together with *G. aperta, G. ericsonii, G. muellerae, G. oceanica, C. pelagicus, C. leptoporus* and *S. histrica*. Very rare specimens of a form resembling *P. lacunosa* are recorded, but there are no positive identifications, and they may be reworked.

Zonation: Mid-Pleistocene - *G. oceanica* Zone, NN20 of Martini (1971); upper part of *G. caribbeanica* Zone of Hine (1990).

58-14/10 - S9 (CSC8862)

CSC8862

Depth: 1.80-1.84m: This is a low diversity poorly preserved nannofossil assemblage consisting of lower Tertiary forms with Cretaceous reworking. The assemblage is dominated by the genus *Toweius* (*T. eminens, T. pertusus*). Additional species include *Braarudosphaera bigelowii, Markalius inversus, Coccolithus pelagicus Sphenolithus primus* and *Prinsius bisulcus*. Further specimens can be assigned to *Chiasmolithus* a genus which has its last occurrence in the Oligocene.

Zonation: Late Palaeocene, NP7-NP9, Martini (1971).

58-14/11 - S10 (CSC8863)

CSC8863

Depth: 4.72-4.77m: The assemblage is composed of extremely rare, badly preserved nannofossils dominated by the genus *Toweius* (*T. martinii, T.* cf. *pertusus*). Additional species include *Braarudosphaera bigelowii, Markalius inversus, Coccolithus pelagicus* and *Hornibrookina* cf. *australis*. Further specimens can be assigned to the genera *Syracosphaera* and *Pontosphaera* both of which have their first occurrence in the late Palaeocene.

Zonation: Late Palaeocene, NP6-NP9, Martini (1971).

58-14/29 - S13 (CSC8899 and 8864)

CSC8899

Depth: 0.46-0.50m: Barren of nannofossils.

Zonation: None.

CSC 8864

Depth: 4.95-5.00m: No nannofossils recorded.

Zonation: None.

58-14/31 - S12 (CSC8865)

CSC 8865

Depth: 3.51-3.55m: The assemblage is dominated by *Gephyrocapsa caribbeanica* and a bloom of small-sized *Reticulofenestra productella* (NN10-21). Accessory taxa include abundant *C. pelagicus*, *C. leptoporus* (Miocene to Recent) and *S. histrica*. There are no records of any sphenoliths (last occurrence NN15), discoasters or *P. lacunosa*, and there is no evidence of Cretaceous or Eocene material.

Zonation: Plio-Pleistocene; NN16-19, Martini (1971).

58-14/32 - S12 (CSC8866 and 8867)

CSC8866, CSC 8867

Depth: 3.11-3.14m and 3.85-3.90m: Both these assemblages are dominated by small *Dictyococcites* and *Reticulofenestra* spp. (such as *R. productella, D. antarcticus, R. minutula, R. haqii* and *R. minuta*). Additional taxa include *Coccolithus pliopelagicus, Calcidiscus macintyrei, Calcidiscus leptoporus, Sphenolithus neoabies, S. abies* and *Helicosphaera* spp. No discoasters were recorded from the sample. In their absence, the sample is assigned to the Pliocene based on the predominance of small *Dictyococcites* and

Sphenolithus spp. *Cyclicargolithus floridanus* is, however, recorded in the counts. This species has its last occurrence in the Miocene (NP6/7). It is here attributed to reworking.
Zonation: Pliocene (NN12-15). The absence of discoasters prevents designation to a more precise biostratigraphic zone.

58-14/34 - S14 (CSC8868 to 8870)

CSC 8868

Depth: 0.00-0.03m: This sample yields abundant in situ nannofossils together with reworked Cretaceous forms. Specimens of *E. huxleyi* dominate the assemblage together with *Gephyrocapsa* spp., *C. pelagicus, C. leptoporus, S. histrica, H. carteri,* and *Pontosphaera.* sp.
Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

CSC8869

Depth: 0.50-.53m: The assemblage is dominated by *Gephyrocapsa caribbeanica.* Other accessory taxa include *G. ericsonii, G. aperta* and *C. pelagicus.* SEM analysis is necessary to determine if *E. huxleyi* is present, but this species is not recorded in light microscope counts. There is no record of *P. lacunosa.*
Zonation: Mid-/late Pleistocene - *G. oceanica* Zone, NN20 of Martini (1971): upper part of *G.caribbeanica* Zone of Hine (1990). If *E.huxleyi* was recorded the sample would be assigned to the Transitional Zone (NN21) of Hine (1990).

CSC8870

Depth: 4.79-4.82m: The sample is dominated by large *Reticulofenestra* spp. (*R. hillae, R. umbilicus, R. scissura, R. reticulata, R. minuta*); *Chiastozygus* spp. (*C. solitus, C. grandis, C. expansus*), and *Neococcolithes* spp. (*N. minutus, N. dubius*). No discoasters were recorded. There is no evidence of any younger material in this assemblage and it is considered to be *in situ.*

Zonation: Mid-Eocene, NP14-17 of Martini (1971).

58-14/42 - S7 (CSC8871)

CSC8871

Depth: 4.5m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view). After extensive scanning of the slide three specimens were recorded; *Sphenolithus* sp. , *Cyclagelosphaera sp.* (last occurrence in the Palaeocene) and ?*Toweius* sp. (genus ranges from the Palaeocene to the Eocene).

Zonation: Tertiary (?Palaeocene).

58-14/43 - S9 (CSC8872)

CSC8872

Depth: 5.07-5.12m: The assemblage is composed of rare nannofossils including *Prinsius bisulcus*, *Toweius pertusus* , *Sphenolithus* spp. and *Hornibrookina australis*. There is no evidence of any younger material in this assemblage and, in consequence, this is considered to be *in situ*, despite the poor state of preservation.

Zonation: Late Palaeocene, NP6-NP9, Martini (1971).

58-14/44 - S49 (CSC8873)

CSC8873

Depth: 5.04-5.08m: This is a rich and diverse assemblage composed of high numbers of *Reticulofenestra* spp. (including *R. callidus, R. hillae, R. umbilicus, R. reticulatum, R. minuta* and *R. minutula*), together with *Chiasmolithus solitus, C. grandis, N. dubius* and *Discoaster deflandrei*. The co-occurrence of these species suggest an Eocene age assignment.

Zonation: Mid-Eocene - *Discoaster tanii nodifer* Zone, NP16 (Martini, 1971)

58-14/53 - S11 (CSC8874)

CSC8874

Depth: 3.43-3.47m: This is a rich and diverse assemblage composed of high numbers of *Reticulofenestra* spp. (including *R. callidus, R. hillae, R. umbilicus,, R. minuta* and *R. minutula*), together with *Chiasmolithus solitus, Ch. grandis,* and *Discoaster barbadiensis. Transversopontis* spp. are also common. The co-occurrence of these species suggest an Eocene age assignment. Reworking of older Palaeocene material is common throughout the assemblage.

Zonation: Mid-Eocene - *Discoaster tanii nodifer* Zone, NP16 (Martini, 1971)

58-14/54 - S42 (CSC8875 and 8876)

CSC8875

Depth: 1.90-1.92m: The assemblage is dominated by small *Reticulofenestra* and *Dictyococcites* spp. including *D. productus, D. antarcticus, R. minutula* and *R. minuta.* Additional taxa include *Sphenolithus* spp and *Coccolithus pliopelagicus.*

Zonation: Pliocene (?NN16). The absence of discoasters precludes designation to a more precise stratigraphic age.

CSC8876

Depth: 2.52-2.54m: This sample is similar to CSC8875 but contains an increased terrigenous component and a nannofossil assemblage that is very poorly preserved, suffering from extensive secondary calcite overgrowth.

The assemblage is dominated by *Coccolithus pelagicus* (*C.* cf. *pliopelagicus).* Additional taxa include small *Reticulofenestra* and *Dictyococcites* spp.such as *R. productella* (NN10-21), *D. antarcticus, D. productus, R. minutula* (NN1-18) and *R. minuta* (NP13-18). *Helicosphaera* and *Calcidiscus* spp. are recorded but are rare. The small size of the *Reticulofenestra* and *Dictyococcites* spp. suggests a Pliocene age. However, due to the poor state of preservation, few species have been identified to

species level and so confidence is low. Despite this, the assemblage is not considered to be older than Neogene. Further to this there are a number of reworked forms recorded. These include *Chiasmolithus* spp. with no central areas (last occurrence of genus coincides with the Oligocene/Miocene boundary), *Reticulofenestra* cf. *scrippsae* (NP16-25) and *Toweius* spp. (last occurrence of genus coincides with the NP15/16 boundary). These suggest assignment to the Upper Eocene NP16 nannofossil zone.

As with previous analyses, the younger Pliocene material is considered to be *in situ,* however, due to the low degree of confidence in this analyses, an older Eocene age is possible.

Zonation: None (Eocene to Pliocene range).

58-14/55 - S40 (CSC8877)

CSC8877

Depth: 5.05-5.10m: Nannofossils are extremely rare and when recorded are poorly preserved. Only three specimens were recorded in fifty fields of view (*Sphenolithus* sp. and *Reticulofenestra* sp.).

Zonation: Tertiary. The occurrence of *Sphenolithus* provides a maximum age of NP4 to NN16, and the occurrence of large *Reticulofenetra* further restricts the sample to an Eocene-Pliocene age range.

57-14/56 - S50 (CSC8878)

CSC8878

Depth: 1.01-1.06m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view).

Zonation: None.

58-14/57 - S41 (CSC8879 and 8880)

CSC 8879

Depth: 3.83-3.89m: The assemblage is dominated by small *Gephyrocapsa* including *G. aperta, G. ericsonii* and *G. caribbeanica.* Accessory taxa include *E. huxleyi, H. carteri, Thoracosphaera* sp., *S. histrica, C. leptoporus* and holococcoliths. A form resembling *Reticulofenestra* with slits in its outer shield was occasionally encountered. This sample can be assigned to Zone NN21 of Martini (1971) based on the occurrence of *E huxleyi*, to the *Gephyrocapsa aperta* Zone of Hine (1990).

Zonation: Mid-Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Gephyrocapsa aperta* Zone of Hine (1990).

CSC8880

Depth: 4.10m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view). After extensive scanning of the slide three specimens were recorded, two of *Cyclagelosphaera alta* (last occurrence in the Palaeocene) and a single specimen of the Tertiary genus *Ericsonia ovalis.* Based on this evidence the sample is tentatively assigned to the Palaeocene.

Zonation: Palaeocene.

58-14/60 - S51 (CSC8881 and 8882)

CSC 8881

Depth: 0.00-0.02 m: The assemblage consists of abundant *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica* and *G. caribbeanica.*

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977);*C. pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC 8882

Depth: 1.02-.07m: The assemblage is dominated by *G. caribbeanica* and *G. aperta* together with *S. histrica, C. leptoporus* and *P. lacunosa.* Based on the occurrence of *P. lacunosa* the sample can be assigned to Zone NN19 of Martini (1971) and based on the predominance of small *Gephyrocapsa*, to the Small *Gephyrocapsa* Zone of Hine (1990).
Zonation: Early/mid-Pleistocene - *P. lacunosa* Zone, NN19 (Martini, 1971); Small *Gephyrocapsa* Zone of Hine (1990).

58-14/63 - S53 (CSC8883)

CSC 8883

Depth: 0.81-0.83m (clast in sea-bed gravel): The assemblage is dominated by large *Reticulofenestra* spp. (*R. callidus, R. umbilicus, R. dictyoda, R. minuta*) and*Chiastozygus* spp. Accessory taxa include *N. dubius* and discoasters (*D. gemmeus, D. siapensis*). As there is no evidence of any younger material, this assemblage is considered to be *in situ.*
Zonation: Mid-Eocene, NP15-16 of Martini (1971).

59-11/12 - S1 (CSC8884)

CSC 8884

Depth: 1.40-1.43m: Barren of nannofossils (no specimens recorded in 25 fields of view). After extensive scanning of the slide two badly preserved calcareous nannofossils were located, however, due to the poor state of preservation no specific identification was possible. Both specimens were of small, circular placoliths, probably belonging to the long ranging genus *Cyclagelosphaera.*
Zonation: None.

59-11/13 - S2 (CSC8885 to 8888)

CSC8885

Depth: 0.00-0.05m: The assemblage consists of abundant *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica* and *G. caribbeanica.* The high numbers of *C. pelagicus* indicate the base of the *C. pelagicus* bloom.

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977);*C. pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8886 and 8887

Depth: 0.60-0.65 and 0.80-0.85m: Both assemblages are dominated by *E. huxleyi* together with *C. pelagicus, C. leptoporus,, S. histrica* and *G. caribbeanica, H. carteri* and *G. muellerae.* Sample CSC8886 records a huge increase in both the terrigenous component and reworked nannofossils and a drop in the *in situ* nannofossil numbers. The sample at 0.80m records a return to high numbers of *in-situ* nannofossils.

Zonation: Late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977).

CSC8888

Depth: 4.60-4.67m: The assemblage consists of rare specimens of *E. huxleyi* together with*G. caribbeanica.*The terrigenous component has increased relative to sample CSC8887, as have the number of reworked nannofossils. The sample is assigned to Martini's Zone NN21 due to the occurrence of *E. huxleyi*, and to the Transitional Zone (of Hine 1990) due to the ratio of *Gephyrocapsa*:*Emiliania* being positive.

Zonation: Mid-/late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); Transitional Zone (Hine, 1990).

59-11/16 - S43 (CSC8889)

CSC 8889

Depth: 4.30-4.35m: In situ nannofossils are very rare and the terrigenous component and reworked nannofossils are high. The assemblage consists of *G. caribbeanica, G. aperta, E. huxleyi* and *C. pelagicus.* The occurrence of *E. huxleyi* restricts the sample to Zone NN21 of Martini (1971). As data is so scarce and positive identification of *E. huxleyi* requires SEM analysis, it is not possible to assign the sample to the *E. huxleyi* Acme Zone with any degree of certainty, although based on the limited data available, this seems likely.

The sample also contains much reworked material including pulses of Upper Cretaceous, Palaeocene and Eocene reworking. The Eocene assemblage includes species such as *Toweius callosus* (NP12-15), *Campylosphaera dela* (NP10-16) and *Cruciplacolithus cribellum* (NP9-11).

Zonation: Mid-/latePleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); (*Emiliania huxleyi* Acme Zone, Gartner, 1977/Transitional Zone, Hine 1990)

59-11/17 - S44 (CSC8890 and 8891)

CSC8890

Depth: 0.00-0.05m: This sample yielded abundant specimens of *E. huxleyi* and *C. pelagicus* together with *C. leptoporus,, S. histrica, G. aperta, G. muellerae* and *G. caribbeanica.*

Zonation: Holocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); *Emiliania huxleyi* Acme Zone (Gartner, 1977);*C. pelagicus* bloom (Baumann & Matthiessen, 1992).

CSC8891

Depth: 4.60-4.63m: *In situ* nannofossils are very rare and the terrigenous component and reworked nannofossils high. The assemblage consists of *G. caribbeanica, G. aperta, E. huxleyi* and *C. pelagicus.* The occurrence of *E. huxleyi* restricts the sample to Zone NN21

of Martini (1971). Positive identification of *E. huxleyi* requires SEM analysis. Based on the limited data available the sample may belong to the Transitional Zone as the ratio of *Gephyrocapsa* to *Emiliania* is positive..

Zonation: Mid-/late Pleistocene - *Emiliania huxleyi* Zone, NN21 (Martini, 1971); ?Transitional Zone (Hine, 1990).

59-14/6 - SS5 (CSC8892 and 8893)

CSC8892

Depth: 5.00-5.03m: Barren of calcareous nannofossils (no specimens in over 25 fields).

Zonation: None.

CSC 8893

Depth: 5.05-5.06m: Barren of nannofossils.

Zonation: No zonation.

59-14/7 - S4 (CSC8894 and 8895)

CSC8894, 8895

Depth: 4.00-4.03 and 5.07-5.12m: Barren of calcareous nannofossils (no specimens recorded in 25 fields of view).

Zonation: None.

59-14/8 - S3 (CSC8896 and8897)

CSC8896, 8897

Depth: 0.98-1.00 and 3.80-3.83m: These samples yielded rich and diverse assemblages. Preservation is only moderate and in many instances the central area structures of placoliths have been lost. The assemblages are dominated by *Reticulofenestra dictyoda* and *Transversopontis* spp. Other common floral elements include *Chiasmolithus solitus,*

Sphenolithus radians and *C. pelagicus.* Discoasters include *Discoaster keupperi, D. lodoensis, D. bronnemason* and *D. distinctus.* The sample also contains species of *Nannoturbida* sp. (*N. spinosa* and *N. robusta*).

The co-occurrence of these species suggest an Eocene (NP13) age assignment. There is no evidence of older reworking; however, the sample does contain a high percentage of siliceous material in the form of diatoms and silicoflagellates.

Zonation: Early Eocene - *Discoaster lodoensis* Zone, NP13 (Martini, 1971).

59-14/9 - S6

CSC 8898

Depth: 5.07-5.12m: The assemblage is formed of calcareous nannofossils of three different ages: Late Cretaceous, early Eocene and mid-Eocene. The youngest, mid- Eocene assemblage is considered to be *in situ.* It is dominated by large *Chiasmolithus* spp. (*C. solitus, C. grandis, C. gigas, C. expansus*), *Neococcolithes* spp. (*N. minutus, N. dubius*) and small noelaerhabdaceans including species of *Toweius* , *Dictyococcites, Cribrocentrum* and *Reticulofenestra.* Additional taxa include *Discoaster* sp. and *Zygrhablithus bijugatus.* This assemblage provides an NP15-16 age assignment.

In addition to this, the assemblage also includes some Upper Cretaceous and lower Eocene material. The latter nannoflora is characterised by taxa such as *Toweius pertusus, T. eminens, Neochiastozygus distensus, N. rosenkrantzii* and *Discoaster elegans* derived from lower Eocene (NP10-11) strata.

Zonation: Mid-Eocene, NP15-16 of Martini (1971).

Summary

Eighty-seven samples were analysed for their calcareous nannofossil component to aid in the chronostratigraphical interpretations of the Rockall area. Seventy-two samples yielded calcareous nannofossils which represented a biostratigraphical range from the late

Palaeocene to the Holocene. There is no evidence of any *in-situ* Cretaceous material. All recordings of Cretaceous calcareous nannofossils are attributed to reworking.

References

BACKMAN, J. 1980. Miocene-Pliocene nannofossils and sedimentation rates in the Hatton-Rockall Basin, NE Atlantic Ocean. *Acta University Stockholm Contributions to Geology,* Vol. 32, 115-137.

-----. and SHACKLETON, N J. 1983. Quantitative Biochronology of Pliocene and Early Pleistocene calcareous nannofossils from the Atlantic, Indian and Pacific Oceans. *Marine Micropalaeontology*, Vol. 8, 141-170.

BAUMANN, K -H. and MATTHIESSEN, J. 1992. Variations in surface water mass conditions in the Norwegian Sea: Evidence from Holocene coccolith and dinoflagellate cyst assemblages. *Marine Micropaleontology*, Vol. 20, 129-146.

GARD, G. 1988. Late Quaternary calcareous nannofossil biozonation, chronology and palaeo-oceanography in areas north of the Faeroe-Iceland ridge. *Quaternary Science Review*, Vol. 7, 65-78.

-----. 1989. Variations in coccolith assemblages during the last glacial cycle in the high and mid-latitude Atlantic and Indian Oceans. 108-121 in *Nannofossils and their applications,* Crux, J A, and van Heck, S E (editors). (Ellis Horwood).

GARTNER, S. 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. *Marine Micropaleontology*, Vol. 2, 1-25.

HINE, N. 1990. Late Cenozoic calcareous nannofossils from the Northeast Atlantic. Ph.D. Thesis, University of East Anglia, 356 pp.

KIDD R.B., *et al.* 1983. Kings Trough Flank: Geological and Geophysical investigations of its suitability for high level radioactive waste disposal. *Institute of Oceanographic Sciences, Report No. 166*, Vol. 12, 99 pp.

MARTINI, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proceedings II Planktonic Conference, Roma, 1970*, Vol. 2, 739-785

OKADA, H, and BUKRY, D. 1980. Supplimentary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). *Marine Micropalaeontology*, Vol. 5, 321-325.

PUJOS, A. 1988. Spatio-temporal distribution of some Quaternary coccoliths. *Oceanologica Acta*, Vol. **11,** 65-77.

THIERSTEIN, H R, GEITZENAUER, K R, *et al.* 1977. Global Synchroneity of Late Quaternary coccolith datum levels: validation by oxygen isotopes. *Geology*, Vol. 5, 400-404.

WEAVER, P P E. 1983. An integrated stratigraphy of the Upper Quaternary of the King's Trough flank area NE Atlantic. *Oceanologica Acta*, Vol. 6, 451-456

MACROFAUNAL ANALYSIS OF SHALLOW CORE 58-14/32 FROM THE ROCKALL AREA

M A Woods

Introduction

One sample of bioclastic limestone was submitted for macrofaunal analysis from shallow core 58-14/32; sample details and a summary of the palaeontological age are as follows:

CSC No:	Depth (m)	Palaeontological Age
8986	3.45-3.50	Pliocene to Holocene

Results

The fauna is as follows:

Anthozoa:	solitary corals?
Brachiopoda:	cf. *Fallax dalliniformis*
	Terebratulina abyssicola?
	T. caputserpentis?
	rhynchonellid of unknown affinity
Gastropoda:	indeterminate internal mould
Bivalvia:	*Capulus* aff. *unguis*?
	Lima aff. *subauriculata*
	pectinacean (juv.)
Echinoidea:	spine

Lack of comparative material inhibits precise deyermination of species. The current status of some of the above taxa is uncertain in the absence of comprehensive modern literature.

Interpretation

Fallax dalliniformis is an extant brachiopod species, recorded at @1300m in the Bay of Biscay by Cooper (1981). *Terebratulina caputserpentis*, the type species of the genus *Terebratulina* (Moore, 1965), is similarly Holocene, known from around Norway, the Faeroe Islands, the Hebrides, and west of Ireland, in water depths from @160m to @1400m (Davidson, 1874; Moore, 1965). Fossil examples of the latter occur in the Coralline Crag (Pliocene) of East Anglia (Davidson, 1852). *Terebratulina abyssicola* is a Holocene species recorded by Cooper (1973) from around South Africa, at depths between @80m and @160m. The remainder of the fauna is difficult to interpret, but some elements (eg. *Capulus unguis*, *Lima subauriculata*) occur in the Pliocene and Pleistocene faunas detailed by Harmer (1914-1924) and Wood (1848-1882).

Conclusion: Pliocene to Holocene

References

COOPER, G A. 1973. Vema's Brachiopoda (Recent). *Smithsonian Contributions to Palaeobiology,* Vol. 17.

-----. 1981. Brachiopoda from the Gulf of Gascogne, France (Recent). *Smithsonian Contributions to Palaeobiology*, Vol. 44.

DAVIDSON, T. 1852. British Tertiary Brachiopoda. *Palaeontological Society* [Monograph].

-----. 1874. Supplement to the Recent, Tertiary and Cretaceous species. *Palaeontological Society* [Monograph].

HARMER, F W. 1914-1924. The Pliocene Mollusca of Great Britain. *Palaeontologcal Society* [Monograph].

MOORE, R C (editor). 1965. *Treatise on Invertebrate Palaeontology, Part H, Brachiopoda.* (Lawrence, Kansas: The Geological Society of America and University of Kansas Press).

WOOD, S V. 1848-1882. A Monograph of the Crag Mollusca. *Palaeontological Society* [Monograph].

Fig. 2 Key to symbols and common abbreviations used on the shallow-core logs.

LITHOLOGY AND SEDIMENTARY STRUCTURES


Clay/Claystone


Mud/Mudstone


Calcareous mudstone


Silt/Siltstone


Sand/Sandstone


Gravel/Conglomerate


Chalk


Limestone


Basic igneous


Agglomerate


Gneiss


No recovery


Sporadic clast


Shell/shell fragment


Organic debris

Sponge spicules

Iron concretions

Glauconite


Dendritic manganese


Mineral vein


Stylolite

Fracture (post-depositional)

Monosulphidic knots and streaks

Bioturbation

Parallel lamination

Wavy lamination


Upward fining


Upward coarsening


Distribution grading


Coarse-tail grading

Sharp, planar contact

Gradational contact

Erosive, scoured contact

COMMON ABBREVIATIONS

Sub-samples

Mpal	Micropalaeontology
MACRO	Macrofauna
PET	Petrology
GEOCH	Geochemistry
RD	Radiometric age date
8826	BGS palaeontological sub-sample reference number

Grain size

si	silt	Mud
vf	very fine	Sand
f	fine	Sand
m	medium	Sand
c	coarse	Sand
vc	very coarse	Sand
p	pebble	Gravel
c	cobble	Gravel
b	boulder	Gravel

Other

gr.	grained
mps.	moderately poorly sorted
vps.	very poorly sorted
matrix-supp.	matrix-supported
inc.	including
biot.	bioturbated
calc.	calcareous
rd.	rounded
subang.	subangular
a/a	as above

t terrigenous
c carbonate
} t/c, t>c relative proportions of....