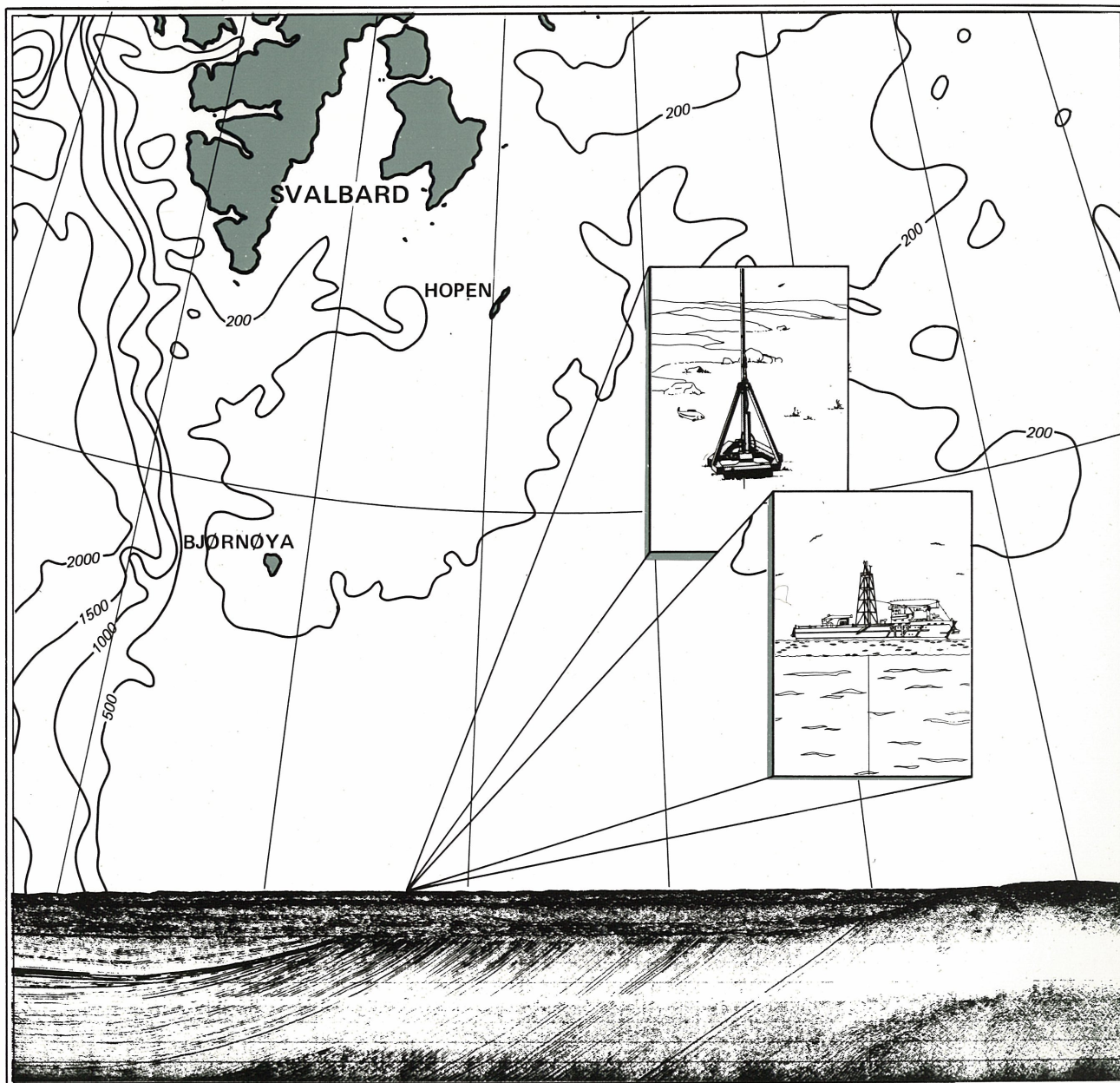


BARENTS SEA MAPPING PROGRAM 1984/85

COMPARISONS and CORRELATIONS



IKU

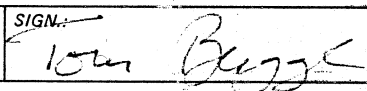
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INSTITUTT FOR KONTINENTALSOKKELUNDERSØKELSER OG PETROLEUMSTEKNOLOGI AS
CONTINENTAL SHELF AND PETROLEUM TECHNOLOGY RESEARCH INSTITUTE LTD.

REPORT

REG. NO.: 86.095	ACCESSIBILITY: Restricted
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REPORT TITLE: BARENTS SEA MAPPING PROGRAM 1984/85. COMPARISONS AND CORRELATIONS.
REPORT NO.: 21.3405.00/04/86
AUTHORS: Atle Mørk, Tom Bugge, Robert M. Goll & Joar Sættem

DATE: 86.08.08	NO. OF PAGES: 50	NO. OF APPENDICES: -	PROJECT MANAGER: Tom Bugge	SIGN.: 
CLIENT: Oil companies				

SUMMARY:

As part of the "IKU Barents Sea Mapping Program" the following three projects were carried out in 1984 and 1985:

- "Shallow sampling Barents Sea 1984"
- "Shallow seismic and shallow drilling Barents Sea 1984"
- "Shallow seismic, shallow drilling and heat flow
- Barents Sea 1985"

The projects were organized as multi-client projects and a total of 9 oil companies participated. Valuable data comprising 7260 km of shallow seismic, 39 short bedrock cores (<3 m), 10 shallow drilling cores (1-34 m), and 6 heat flow measurements were obtained.

In the present report, geological maps of the Stappen High, the so-called Dia-Structure and a regional map of the southwestern part of the Barents Sea are presented. The bedrock samples are summed up and internally correlated and compared with the geology on Bjørnøya and Spitsbergen. In the northern part of the area, we apply the Svalbard terminology of lithostratigraphical groups to the Carboniferous-Triassic sequence. A brief consideration of organic geochemistry and source potential data is given. Final values of heat flow measurements are also presented.

KEY WORDS:	
Barents Sea	Shallow seismic
Bedrock geology	Shallow sampling
Heat flow measurements	Shallow drilling

IKU Reports

21.3405.00/01/85: "Shallow Drilling Barents Sea 1985"

21.3405.00/02/85: "Heat Flow Measurements Barents Sea 1985"

21.3405.00/03/86: "Shallow drilling and heat flow measurements Barents Sea 1985. Data report 3."

21.3405.00/04/86: "Barents Sea mapping program 1984/85. Comparisons and correlations."

21.3405.00/05/86: "Shallow drilling Barents Sea 1985. Macrofossil dating of core D85-K."

ADDENDUM

The coreholes drilled in the Barents Sea in 1984 and 1985 were given preliminary names by IKU, and these were used in all reports. The table shows these names along with the later assigned official NPD names and the final coordinates and water depths.

IKU name	NPD name	Latitude	Longitude	Water depth (m)
Dia84-1 ¹⁾	7323/07-U-14	73° 15' 41.33" N	23° 16' 7.01" E	366
Dia84-11 ¹⁾	7323/07-U-14	73° 15' 41.33" N	23° 16' 7.01" E	366
Dia84-2	7323/07-U-11	73° 16' 45.65" N	23° 9' 29.57" E	418
Dia84-3	7323/11-U-02	73° 13' 59.95" N	23° 27' 0.04" E	380
Dia84-31	7323/11-U-01	73° 13' 59.67" N	23° 26' 59.32" E	380
Dia84-5	7323/07-U-12	73° 19' 5.58" N	23° 16' 21.46" E	421
C85-A	7126/06-U-01	71° 38' 49.795" N	26° 52' 43.295" E	369
D85-H	7220/02-U-01	72° 45' 3.095" N	20° 34' 45.644" E	429
C85-E	7222/09-U-01	72° 24' 19.739" N	22° 47' 39.787" E	322.5
D85-V	7317/02-U-01	73° 49' 10.924" N	17° 22' 4.526" E	296
D85-I	7317/02-U-02	73° 47' 8.062" N	17° 23' 35.505" E	324
D85-J	7320/03-U-01	73° 51' 15.18" N	20° 55' 0.802" E	419
D85-K	7323/07-U-10	73° 16' 51.539" N	23° 1' 25.834" E	420
D85-W	7323/10-U-01	73° 13' 15.87" N	23° 18' 42.716" E	380
D85-N	7425/09-U-01	74° 29' 25.296" N	25° 46' 19.261" E	334
D85-O	7524/12-U-01	75° 12' 20.536" N	24° 43' 21.607" E	108

¹⁾ Dia84-1 and Dia84-11 were given the common NPD name 7323/07-U-14 as these cores were taken at the same location and do not vertically overlap.

1. SUMMARY

As part of the IKU Barents Sea Mapping Program the following three research projects were carried out in 1984 and 1985:

- "Shallow sampling Barents Sea 1984"
- "Shallow seismic and shallow drilling Barents Sea 1984"
- "Shallow seismic, shallow drilling and heat flow
- Barents Sea 1985"

The projects were financed by a total of 9 oil companies. Valuable data comprising 7260 km of shallow seismic, 39 short bedrock cores (<3 m), 10 shallow drilling cores (1-34 m), and 6 heat flow measurements were obtained (Fig. 2.1).

From these data and partly by use of deep seismic data obtained in an IKU/Esso project, a geological map of the southwestern Barents Sea has been compiled (Fig. 1.1). More detailed maps from the Dia-Structure and the Stappen High are shown in Figures 3.2 and 3.3. Maps of the Loppa High and the shelf off Sørøya were previously presented in IKU report 01.0219.00/01/85. We have now reinterpreted the position of the Jurassic/Triassic boundary, and this decision effects the geologic maps accordingly. For example, on the Loppa High the Triassic section extends higher than originally proposed, with concomitant reduction of the Jurassic section. The revised interpretation is shown in Figure 1.1.

In situ cores from more than 40 sites on the Dia-Structure and the Stappen High and from one site on the Loppa High were obtained. In the first two areas the oldest sediments seem to be of Carboniferous/Lower Permian age. Together with a zone off the coast of mainland Norway, these are the oldest sedimentary rocks subcropping below the Quaternary overburden in the area. In the basins between the structural highs (see Fig. 3.1), Cretaceous sediments dominate and are overlain in some places by Tertiary sediments.

The Dia-Structure is remarkable in that sediments ranging in age from Carboniferous to Cretaceous crop out or subcrop within a very small area. Because most of these sediments were deposited in a basinal

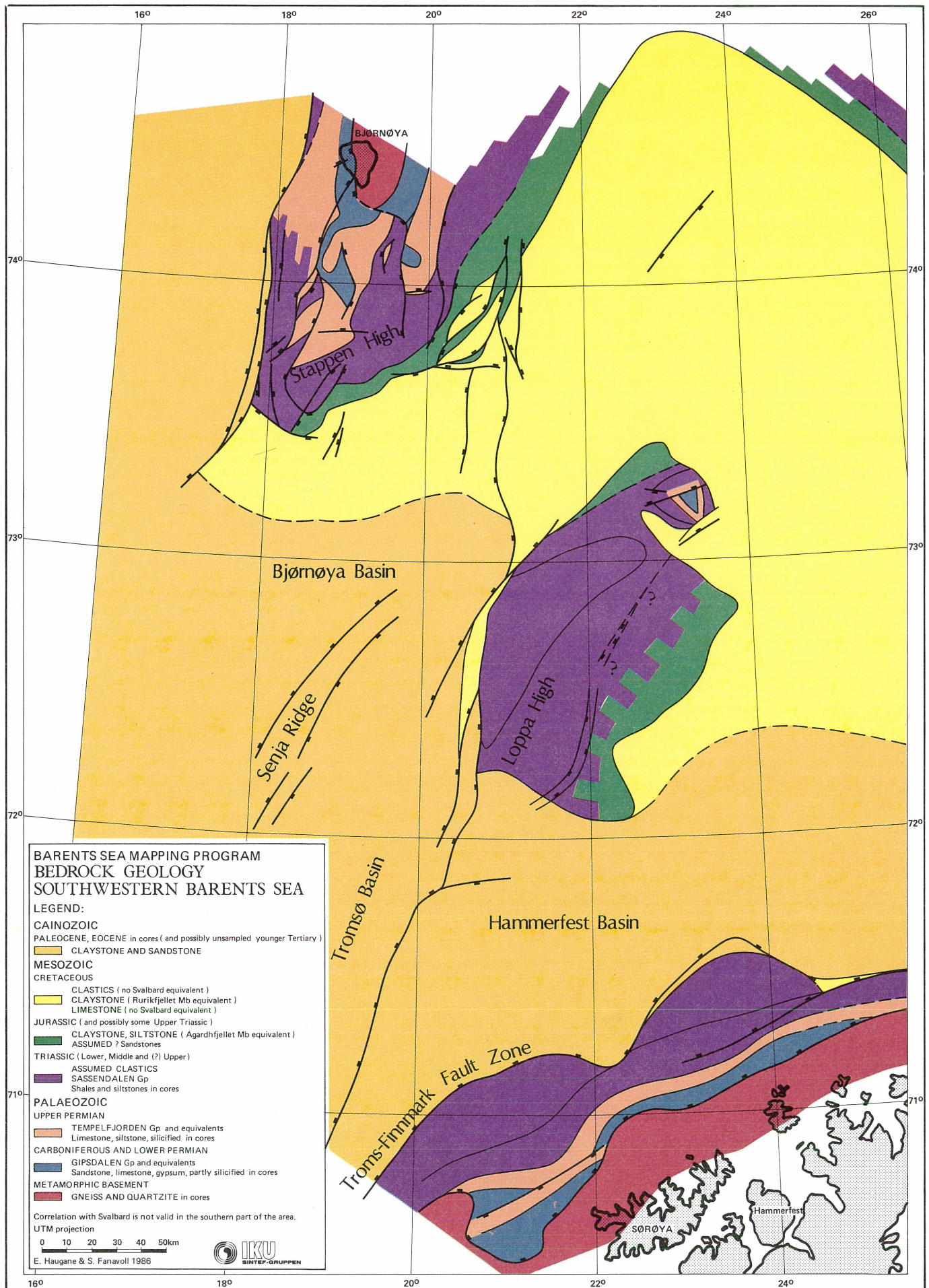


Fig. 1.1 Geological map of the southwestern Barents Sea, mainly based on seismic data and bedrock cores obtained in the IKU Barents Sea Mapping Program.

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situation and therefore are representative of much of the southwestern Barents Sea, major parts of the projects have been concentrated on the Dia-Structure.

In the 1985 shallow drilling project two regional seismic reflectors have been penetrated, one on the eastern side of the Stappen High (D85-J) and one to the northeast of the Dia-Structure (D85-N). Both were originally thought to represent the Late Kimmerian unconformity. Thorough investigations of the cores now show that core D85-N did not penetrate the Late Kimmerian unconformity, but instead penetrated a Lower Cretaceous, probably Valanginian/Hauterivian unconformity. Core D85-J probably penetrated both unconformities (Fig. 3.7). Careful studies of seismic data seem to indicate that the sequence between the two unconformities may be traced in seismic data, particularly in the area around site D85-N. In core D85-J the sequence is represented by a condensed dolomite unit of only 3.3 m thickness. The D85-N core penetrated approximately 11 m of the sequence. About 4.5 m was a thick limestone of Valanginian age overlying a 5.5 m red brown claystone unit of Ryazanian age and 0.7 m of a homogeneous wackestone. The latter two are not present in core D85-J.

All in situ sea bed cores and shallow drilling cores have been assigned to "map units", which are sections of sediments primarily defined by seismic data and secondarily by the samples. The samples have been grouped mainly based on lithology, palaeontology, mineralogy and facies. In Table 4.1, all samples are listed numerically, classified, and assigned to map units. In Table 4.2 we have ranked the samples according to age and correlation to map units. The oldest samples, from Carboniferous to Upper Triassic, have been correlated with lithostratigraphical groups on Bjørnøya/Spitsbergen. We have grouped the samples on the Stappen High on the left side of the table and the samples from further east on the right side.

Because of a relatively good sample coverage from Carboniferous to Upper Triassic we feel it is now time to introduce group names for this sequence, and for the Stappen High, the Dia-Structure and the areas further east and north we propose to use Svalbard terminology. This is reflected in the geological maps in Figures 1.1, 3.2 and 3.3 and in Table

4.2. Figures 1.2 and 1.3 show a simplified correlation with the Bjørnøya and Spitsbergen geology, respectively.

AGE	LITHOLOGY	m	FORMATION/Mb.	SHALLOW DRILLING 1984-1985	SEA BED CORING (BIO DRILL) 1984
recent	erosion			0	
TRIASSIC	Upper CARNIAN	140	SKULD	2	31 29 28 25
	Middle		Verdande Bed		27
	Lower	65	URD	31	24 23 22
PERMIAN	UPPER PERMIAN	115	MISERYFJELLET		35 34 33 32
	KUNGURIAN				
	SAKMARIAN	50	HAMBERG-FJELLET		
	ASSELIAN	50	KAPP DUNER		
CARBONIFEROUS	ORENBURGIAN				
	GZHELIAN	100	KAPP HANNA		
		45	Kobbabukta		
	MOSKOVIAN	80	Efuglvika		
		90	Bogevika		
		145	LANDNØRDINGSVIKA		
	VISÉAN	230	NORDKAPP		
	TOURNAISIAN	80	Tunheim		
DEVONIAN		80	Kapp Levin		
	FAMENNIAN	200	Vesalstranda		
		~ 1200	HECLA HOEK		

Fig. 1.2 Tentative correlation of the cores from the Stappen High and the Dia-Structure with the stratigraphical units on Bjørnøya.

Organic geochemical data, although based on limited sampling, suggest that the most promising hydrocarbon source intervals lie in the Mesozoic rocks, although the rocks sampled were generally of insufficient thermal maturity. Of particular interest in this sense, are the samples from units equivalent to the Triassic Sassendalen and Kapp Toscana Groups and the Jurassic/Cretaceous Adventdalen Group of Svalbard (Table 4.3).

As a special part of the 1985 project, heat flow was measured as an integrated part of the drilling operation. Temperatures were measured with an absolute accuracy of 0.02°C (relative accuracy 0.008°C) in the Quaternary overburden down to a maximum of 65 m below sea floor. Soil samples were obtained at the same intervals and the thermal conductivities of these samples were measured on board. Heat flow values were calculated on the basis of temperatures and thermal conductivity. The final values are presented in Figure 1.4. They have been adjusted according to an expansion effect due to gas in the soil samples and according to a suggested palaeoclimatic model of the last glaciation.

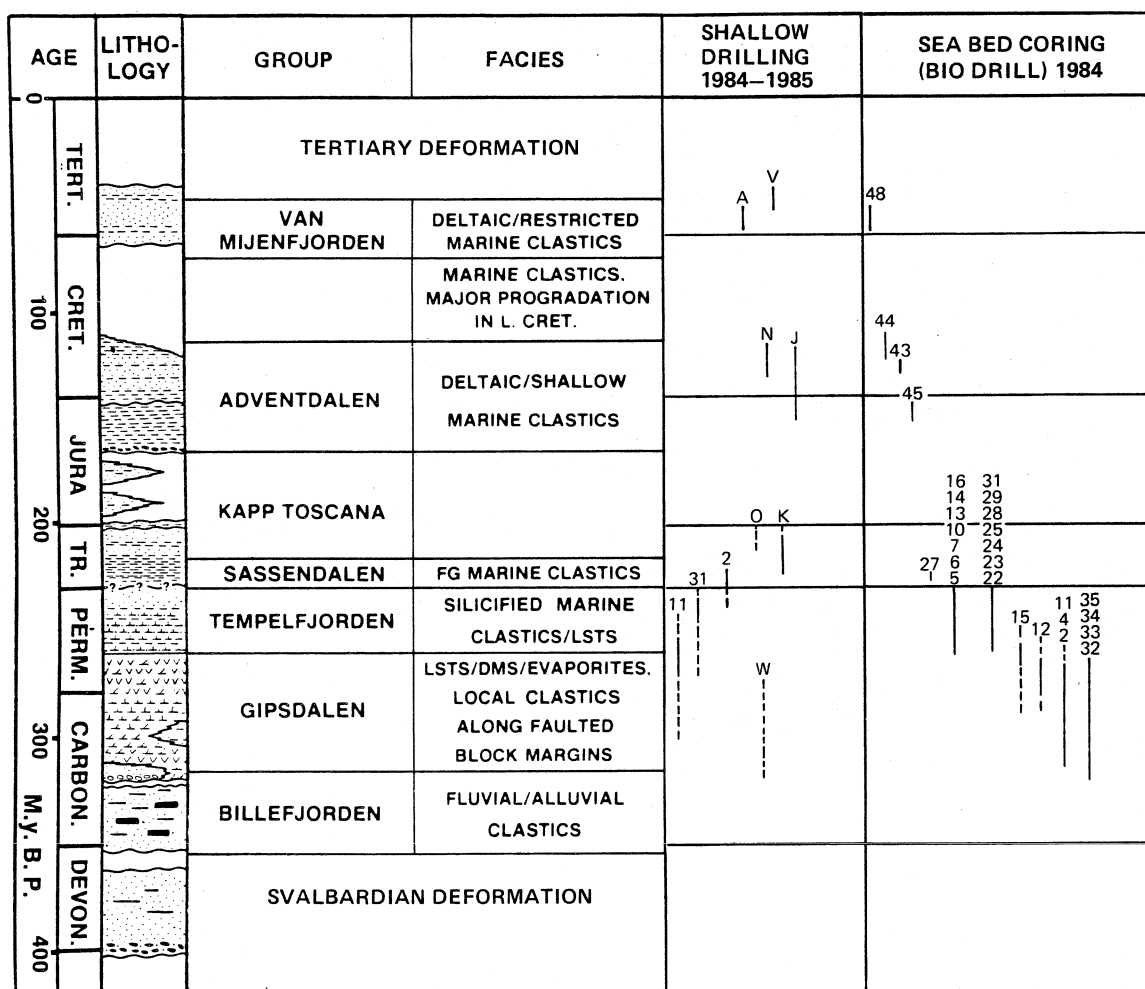


Fig. 1.3 Tentative correlation of the cores from the Stappen High and the Dia-Structure with the sedimentary succession on Svalbard. (Sedimentary column is modified from Steel & Worsley 1984).

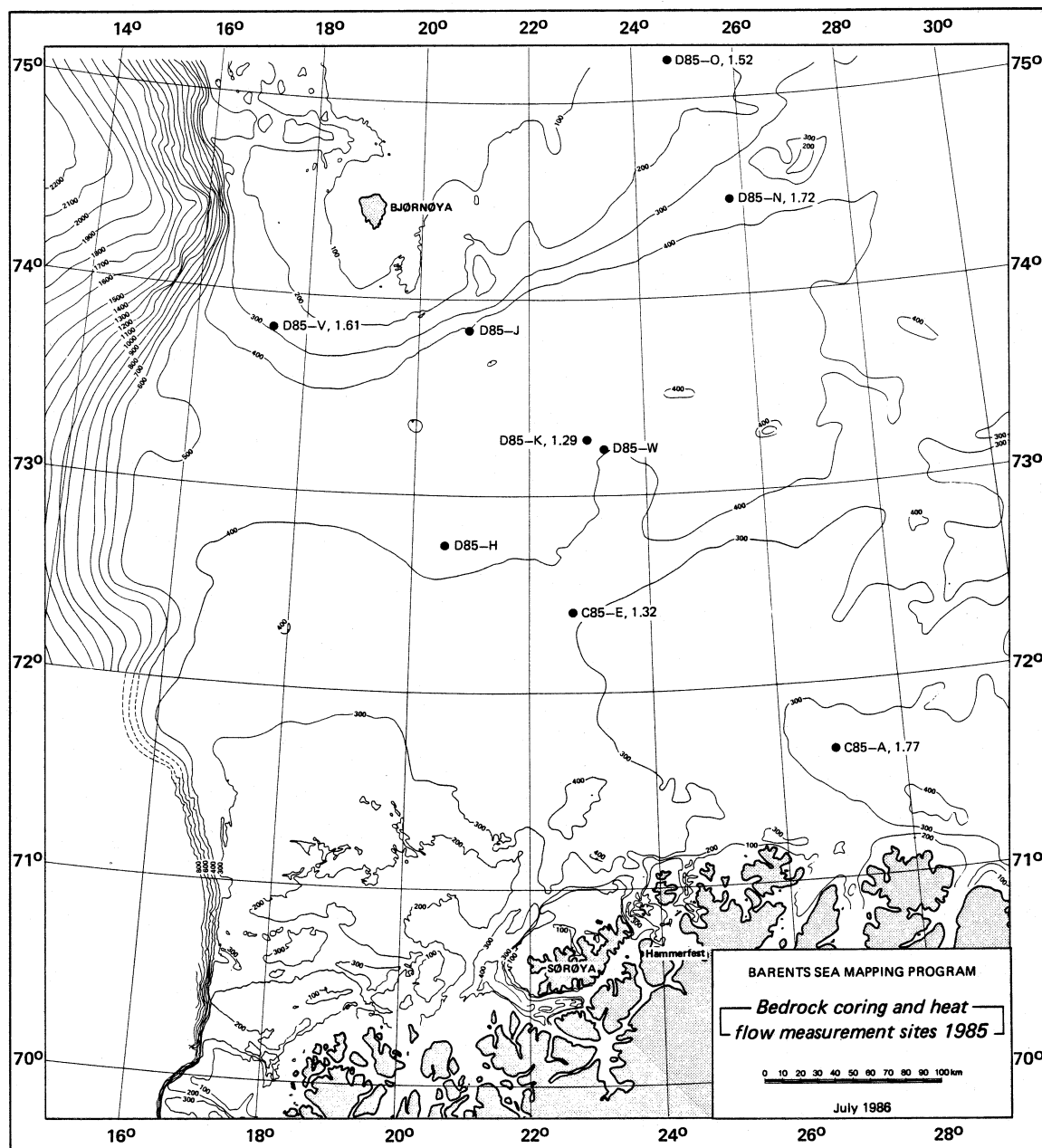


Fig. 1.4 Final heat flow values expressed in HFU (HFU = Heat Flow Units. $1 \text{ HFU} = 1 \text{ mcal cm}^{-2} \text{ s}^{-1}$).

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PREFACE

In 1984, IKU started the "IKU Barents Sea Mapping Program", which consists of separate projects organized on an annual basis with variable sponsors for each project. The basis for this report is the three projects:

- "Shallow sampling Barents Sea 1984"
- "Shallow seismic and shallow drilling Barents Sea 1984"
- "Shallow seismic, shallow drilling and heat flow - Barents Sea 1985"

The following companies participated as "early" or "late" participants, both in the 1984 and 1985 projects:

BP Petroleum Development Ltd., Norway
Conoco Norway Inc.
Den norske stats oljeselskap a.s (Statoil)
Esso Norge a.s, Exploration and Production
Fina Exploration Norway
Norsk Agip A/S
A/S Norske Shell

In addition, Norsk Hydro a.s and Mobil Exploration Norway Inc. participated in the 1984 projects.

Their participation is gratefully acknowledged.

The following reports have been issued in these projects:

- "Shallow sampling Barents Sea 1984"
(IKU report 01.0219.00/01/85)
- "Shallow drilling Barents Sea 1984"
(IKU report 01.0217.00/01/85)
- "Shallow drilling Barents Sea 1985"
(IKU report 21.3405.00/01/85)

- "Heat flow measurements Barents Sea 1985"
(IKU report 21.3405.00/02/85)
- "Shallow drilling and heat flow measurements Barents Sea 1985. Data report III"
(IKU report 21.3405.00/03/86)

All documentation of samples, cores and analyses are given in these reports and the reader is referred to these reports for details not presented in the present report.

This report is a synthesis based on the above-mentioned reports with valuable contributions from many IKU scientists. We will particularly mention the following:

Erik Haugane: Seismic interpretation Bjørnøya East, compilation of regional map

Stein Fanavoll: Seismic interpretation Stappen High and Dia-Structure, compilation of regional map

Nils Aarhus: Palynological correlation

Jorunn Os Vigran: Palynological correlation

Geir Elvebakk: Lithology/sedimentology

Thomas L. Leith: Organic geochemistry

Joar Sættem was responsible for the heat flow part of the project.

The valuable cooperation of others who have contributed to the various reports is greatly appreciated.

2. INTRODUCTION

The present report is intended as a synthesis and summary of the results of the "IKU Barents Sea Mapping Program" during 1984 and 1985 (see preface). Regional geology of the southwestern Barents Sea is given in the subcrop map (Fig. 1.1) supported by separate maps of the Dia-Structure, the Stappen High and an area east of Bjørnøya. The stratigraphic relationship of two Upper Jurassic/Lower Cretaceous cores (D85-J and D85-N) is given special attention.

In Chapter 4, we correlate and group the bedrock samples and cores and discuss their relationship with the geology on Bjørnøya and Spitsbergen. Finally, we summarize the results of the heat flow measurements carried out in the shallow boreholes, mainly 0-50 m below sea bed.

The offshore data treated in this study was collected during the three projects mentioned in the preface. This includes the following data (Fig. 2.1):

- 5900 km analog shallow seismic, 1984 and 1985
- 1360 km digital shallow seismic, 1984 and 1985
- 39 short bedrock cores (<3 m), 1984
- 3 shallow drillings (14-25 m), 1984
- 7 shallow drillings (1-34 m), 1985
- 6 heat flow measurements, 1985

The onshore data is obtained from the literature as well as from IKU's work on Bjørnøya and Spitsbergen over the past several years and more than 10 years involvement in this area by some IKU scientists. We feel that this report benefits from our extensive experience in the Arctic and consequently tentative correlations and conclusions are proposed rather than restricting our discussion to firmly based and fully objective local correlations.

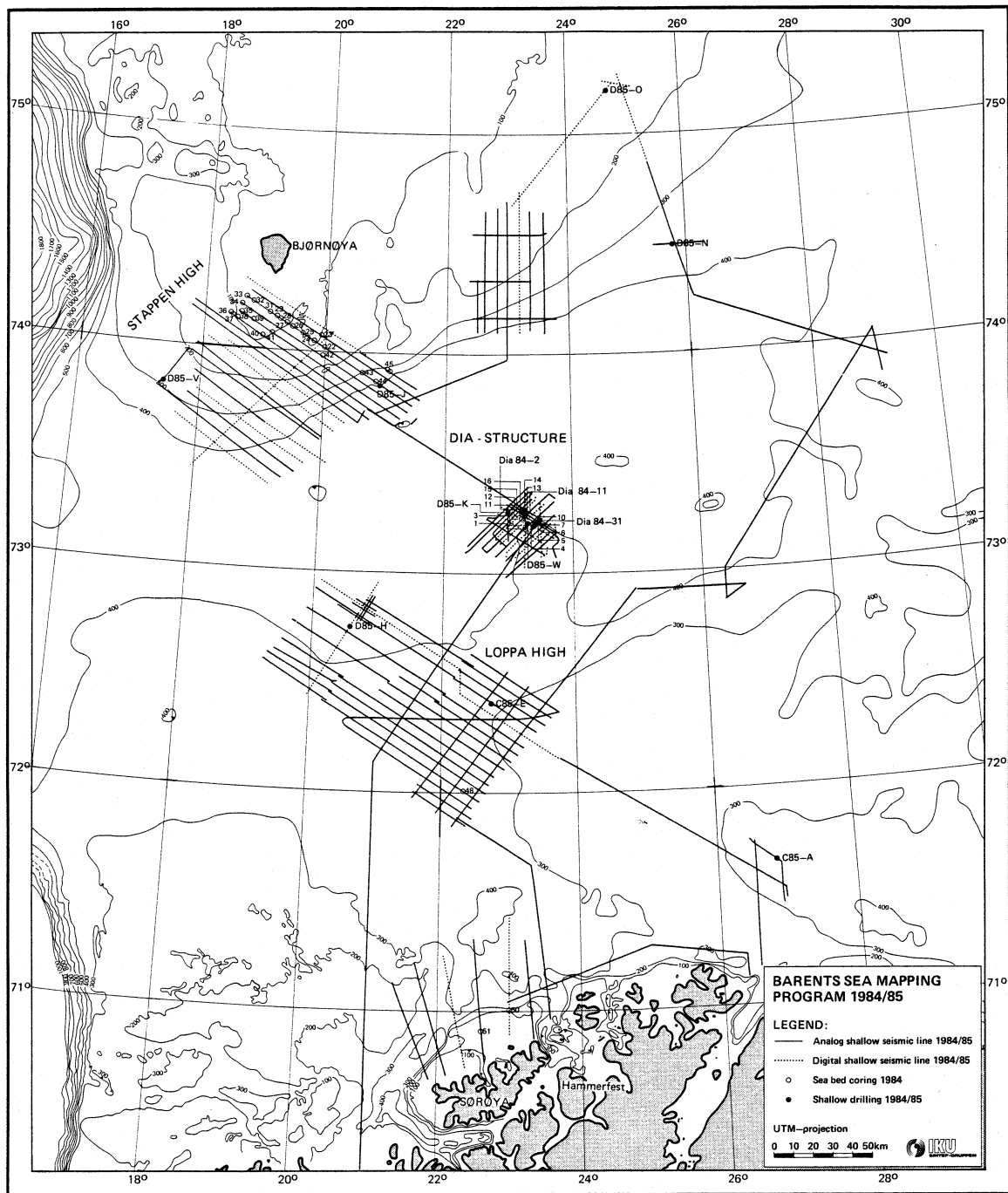


Fig. 2.1 Data collected in the Barents Sea Mapping Program 1984 and 1985.

3. SEISMIC INTERPRETATION

The bedrock map covering the whole study area (Fig. 1.1) is mainly based on the shallow geological data collected in the IKU Barents Sea Mapping Program in 1984 and 1985 (Fig. 2.1). Interpretation of the 1984 data was presented in geological maps of the four areas: Sørøya, Loppa High, Dia-Structure and Stappen High to the south of Bjørnøya (for location see Fig. 3.1). In 1985 additional seismic data was collected on the

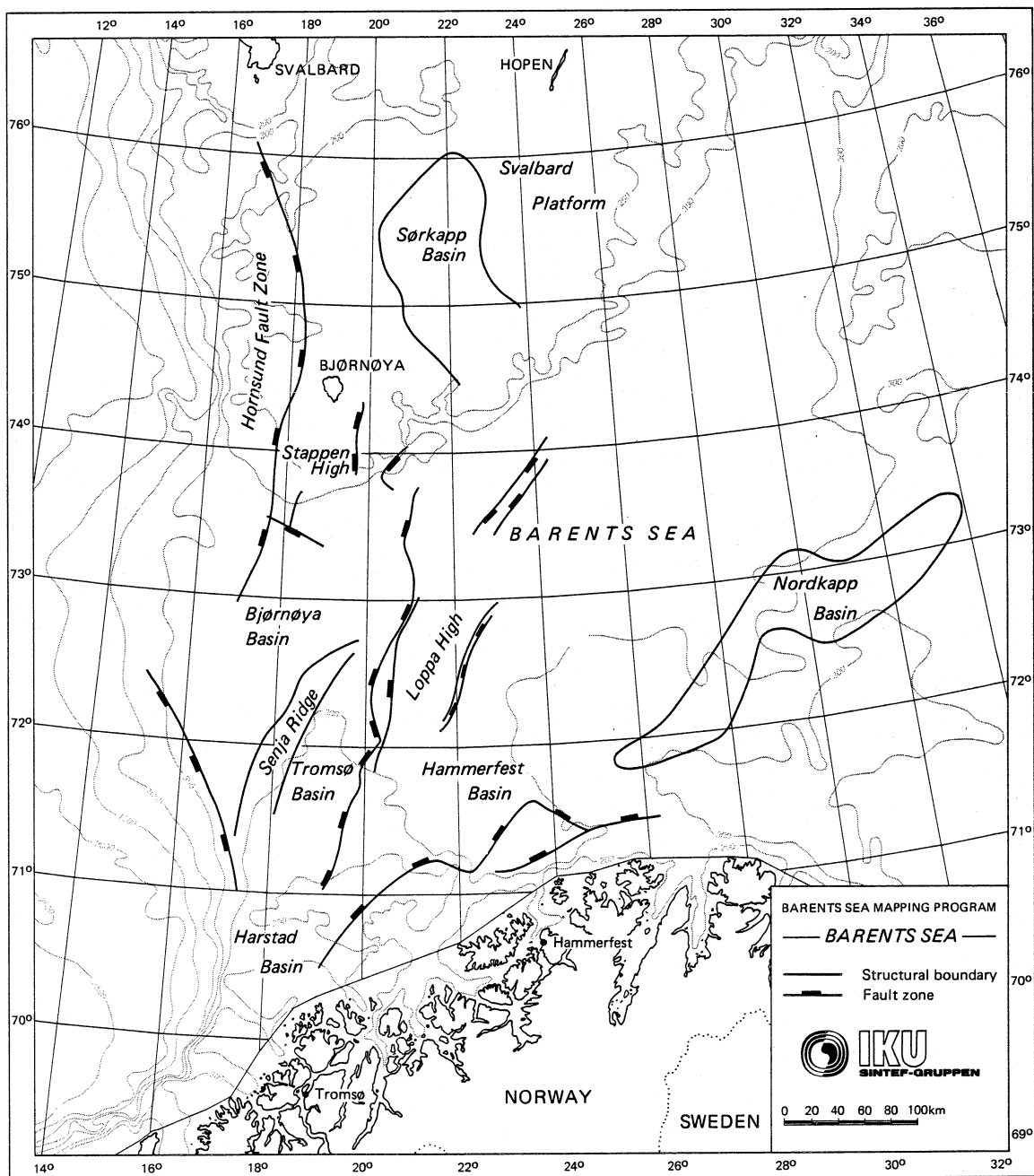


Fig. 3.1 Simplified structural map.

Loppa High, the Stappen High, an area east of Bjørnøya and along tie-lines between the areas. Updated interpretations are therefore presented in local maps of the Stappen High and the Bjørnøya East area, while revised interpretation of the other areas is shown in the summary map (Fig. 1.1). For tie and interpolation between the areas we have used NPD's analog sparker data and published results.

The bedrock sections throughout the region consist predominantly of Tertiary and Cretaceous strata. Tertiary basin subsidence was more pronounced in the south and west. The underlying Mesozoic and Palaeozoic sediments have been studied in seismic profiles and by sea bed coring and shallow drilling.

Based on the new data and a better understanding of the geology of the area we now believe that the thickness of subcropping Jurassic sediments is less than presented in the 1984 maps. On the Loppa High this implies that the area of subcropping Triassic sediments has been extended at the expense of the Jurassic subcrop. We should further mention that the Tertiary sediments on the southern flank of the Loppa High are relatively thin (locally some few tens of metres) and may be hard to recognize in some places on conventional seismic data. For more information on the Loppa High and the shelf off Sørøya, we advise the reader to the shallow sampling report (IKU report 01.0219.00/01/85).

The Dia-Structure is unique for the Barents Sea in that sediments of Cretaceous to Lower Permian/Carboniferous age are all accessible by shallow sampling within a small area (Fig. 3.2). This has enabled us to investigate these sediments in detail by high resolution seismic and shallow coring and drilling. The evolution of the Dia-Structure is not clear. The triangular shape of the structure, which coincides with the regional structural trends comprising major wrench faults, indicates a mainly tectonic origin as opposed to simple salt intrusion. However, the occurrence of a local gravity low (Riis et al. 1985) and the possible presence of rim synclinals indicate that salt may be present and therefore may have contributed in the formation of the Dia-Structure.

The Stappen High south of Bjørnøya is difficult to interpret because of its complex tectonic pattern and difficulties in obtaining good quality seismic data. The latter is mainly due to shallow water and an enormous

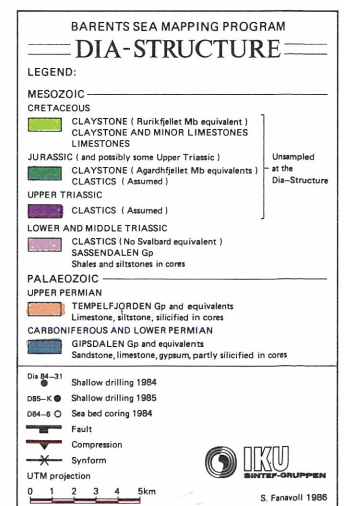
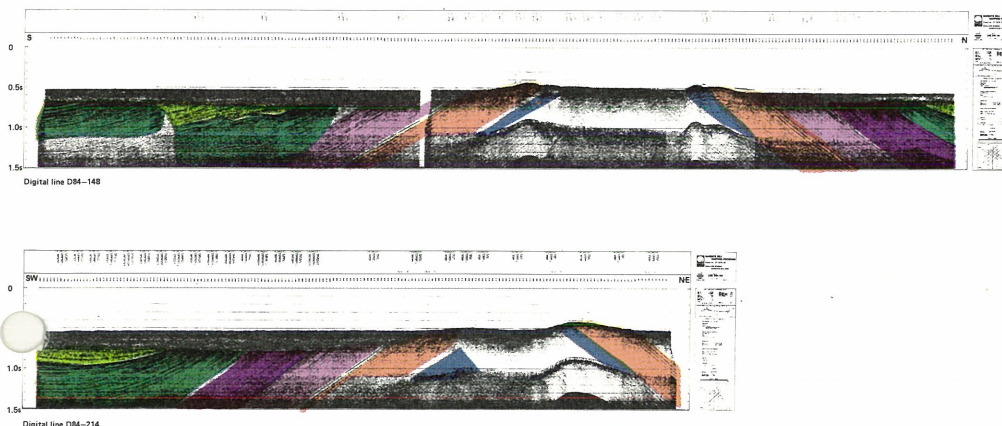
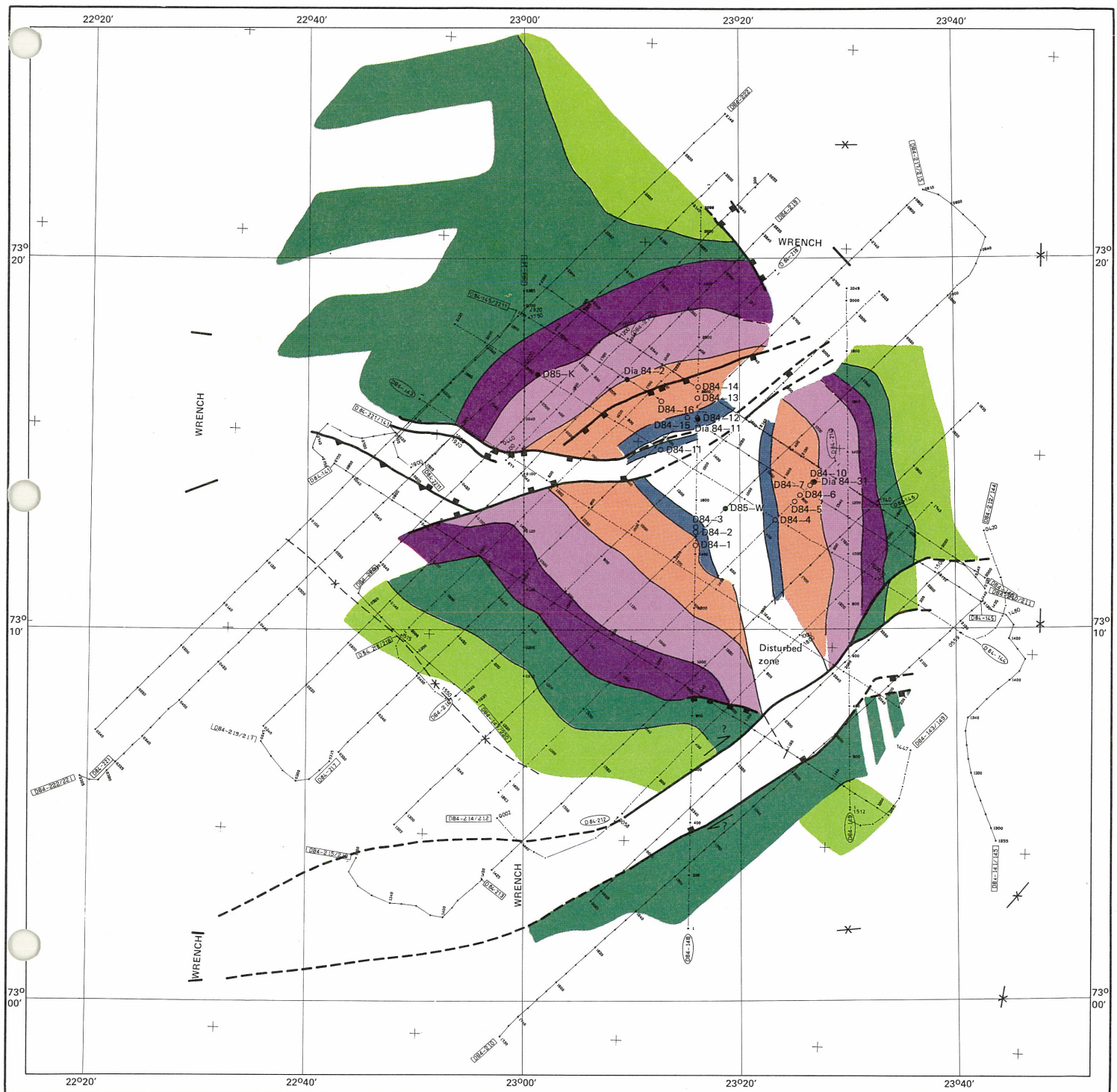


Fig. 3.2 Geological map of the Dia-Structure.

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velocity contrast at the sea floor (1500 m/s versus 5000-6000 m/s). Because of good coverage with sea bed cores in the northern part we have nevertheless been able to compile a map of the area (Fig. 3.3). Cretaceous sediments subcrop in the Bjørnøya Basin to the east, and gradually older rocks occur from here and northwestwards on the Stappen High. Lower Permian/Carboniferous rocks crop out in the shallowest part, directly south of Bjørnøya. From here and southwards, Upper Permian and Triassic sediments occur. The southern boundary of the high is also apparently of a rather complicated nature. A strange fault can be traced just south of the main area covered by shallow seismic. Reversed dip on one of the seismic lines can be related to this fault, but the real nature of the southern boundary of the Stappen High is not yet fully understood. On the western side of the Stappen High we observe a main fault zone related to the early Tertiary sea floor spreading. This zone represents an abrupt transition from Palaeozoic and Mesozoic sediments on the eastern side to Tertiary on the western side.

As mentioned above the quality of the seismic data in this area is not the best. As no real seismic reflection can be observed below the first sea bed multiple, it is sometimes hard to define the correct displacement of the faults. The geologic interpretation presented in Figure 3.3 should be regarded as tentative until more bedrock samples are available.

For convenience, we call the area east of Bjørnøya covered by a shallow seismic grid the "Bjørnøya East" area (Fig. 3.4). In this discussion we partly include the area further east and northeast with the two shallow drill sites D85-N and D85-O. In support of this the interpretation, we have also used some of the deep seismic lines (16 and 18 sec. records) collected by IKU/Esso in 1984/85.

The thickness of the Quaternary overburden varies from 0-20 m in much of the area to a maximum of about 60 m. Maximum thickness is found along a band following the 240-320 m depth contours in a SW-NE direction which partly also coincides with a depression in the bedrock (Fig. 3.4).

The outcropping bedrock in this area is Mesozoic, probably Cretaceous. The structural trend in the upper bedrock is mainly parallelling the

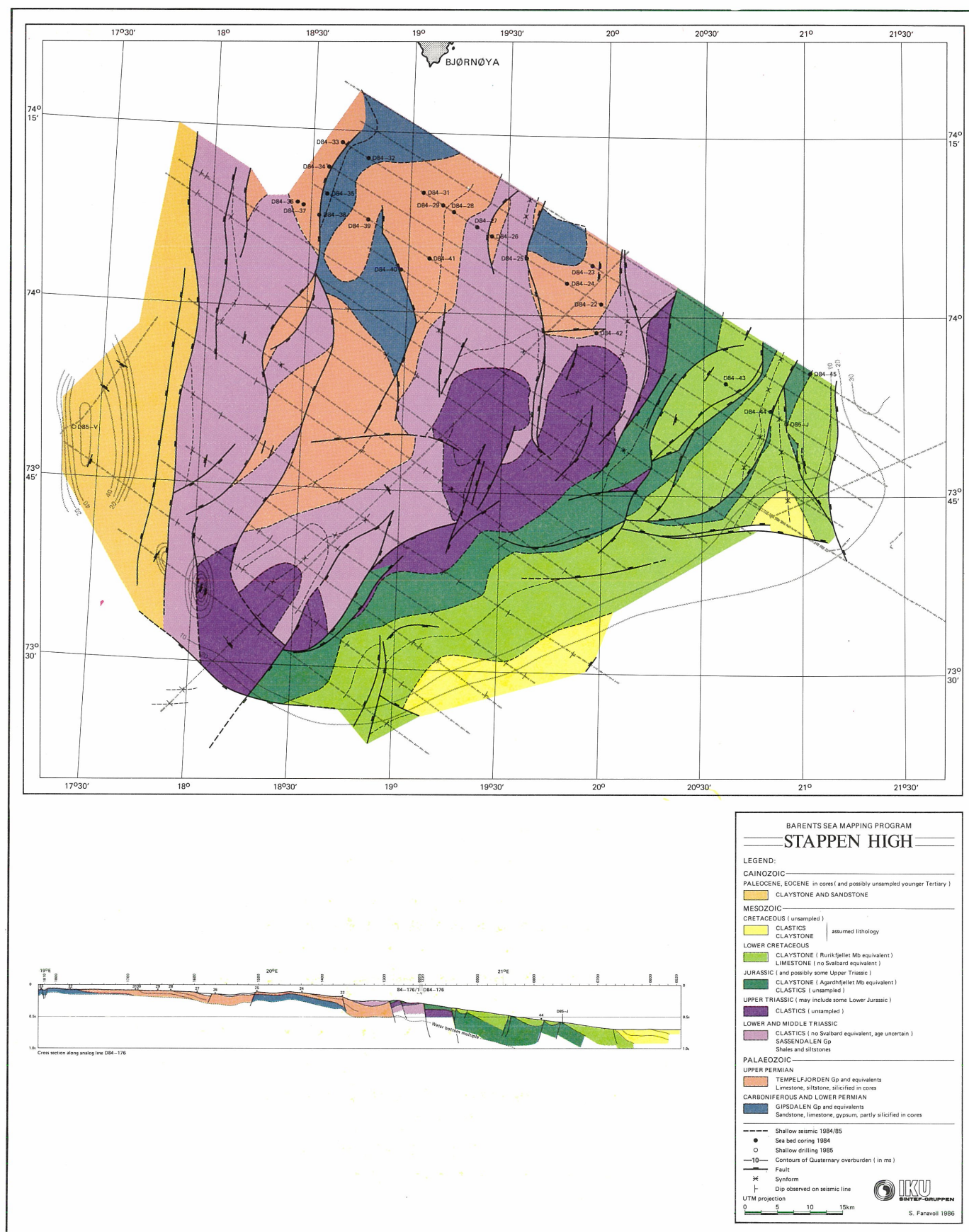


Fig. 3.3 Geological map of the Stappen High.

prominent northeast trending fault indicated in Figure 3.4. Both graben patterns and compressional folds occur. The seismic interpretation is illustrated in fence diagrams in Figures 3.5 and 3.6. Based on data from the Stappen High and core D85-N we relate the reflector δ to the Late Kimmerian unconformity. Consequently there is a significant succession of Cretaceous sediments in this area. We believe they are mainly of Lower Cretaceous age and trace them past the Dia-Structure and on to the eastern flank of the Stappen High. The top reflector, β , of these sediments is often truncational and the package rarely exceeds 200 m.

The correlation between core D85-J on the eastern flank of the Stappen High and core D85-N is indicated in Figure 3.7. The relation between seismic reflectors and the cores has been discussed in the previous reports. We now believe that the reflector representing the Late Kimmerian unconformity, δ , correlates between units A and B in core D85-J and that it was not penetrated by core D85-N (Fig. 3.7). The regional seismic reflector γ , penetrated by core D85-N probably correlates with the top of the limestone in unit C. We correlate the same limestone with unit B in core D85-J. The sequence between reflector δ and γ is therefore represented by units A, B and C in core D85-N and only unit B in core D85-J. Due to the resolution in seismic data the unit can not be seen in seismic data at site D85-J.

For further discussion of the relationship between cores D85-J and D85-N we advise the reader to Chapter 4 below.

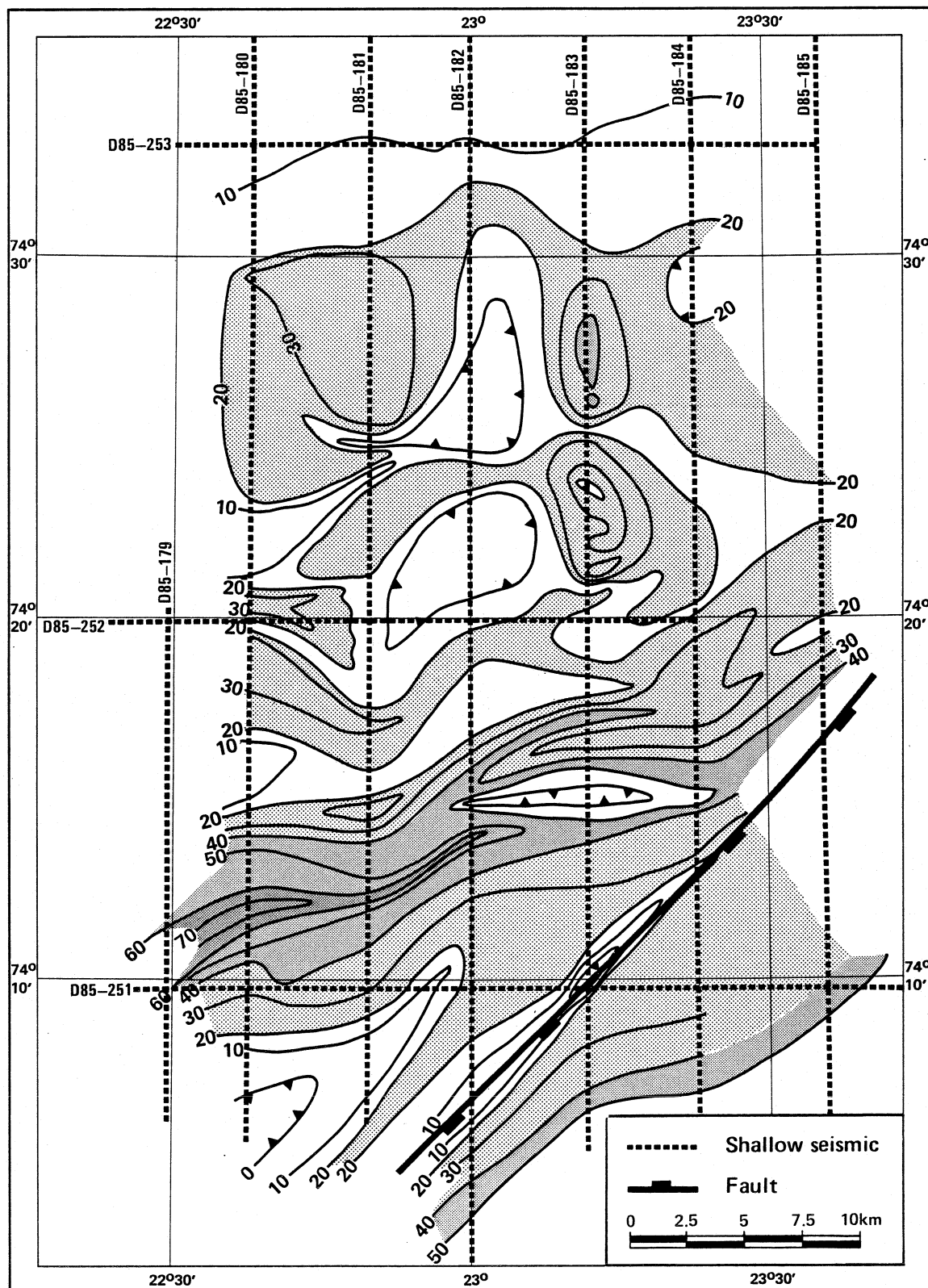
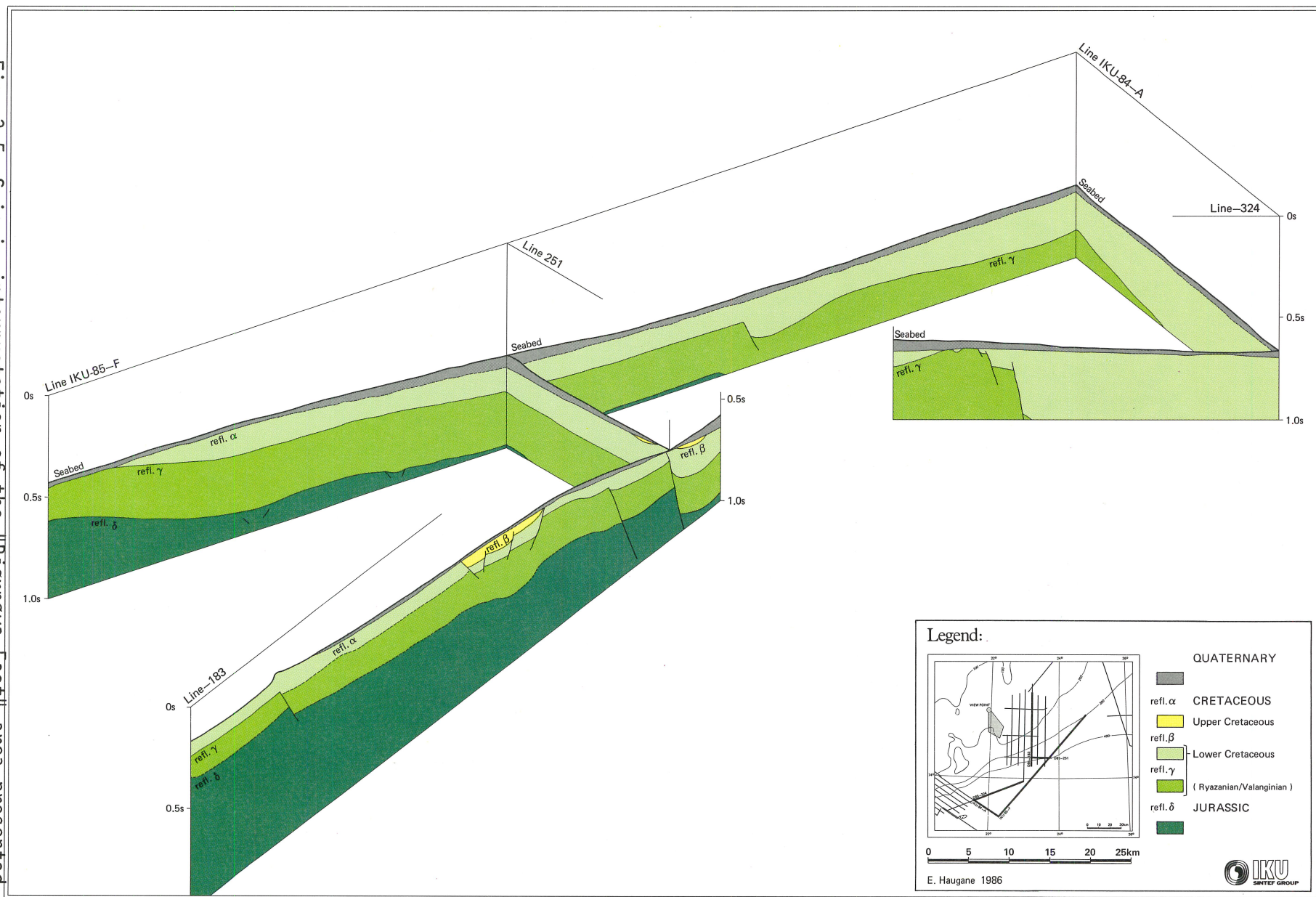


Fig. 3.4 Isopach map of Quaternary overburden in the "Bjørnøya East" area. Contours are in msec. two-way travel time (equals metres if sound velocity is 2000 m/sec.).

Fig. 3.5 Seismic interpretation of the "Bjørnøya East" area presented as fence diagram.



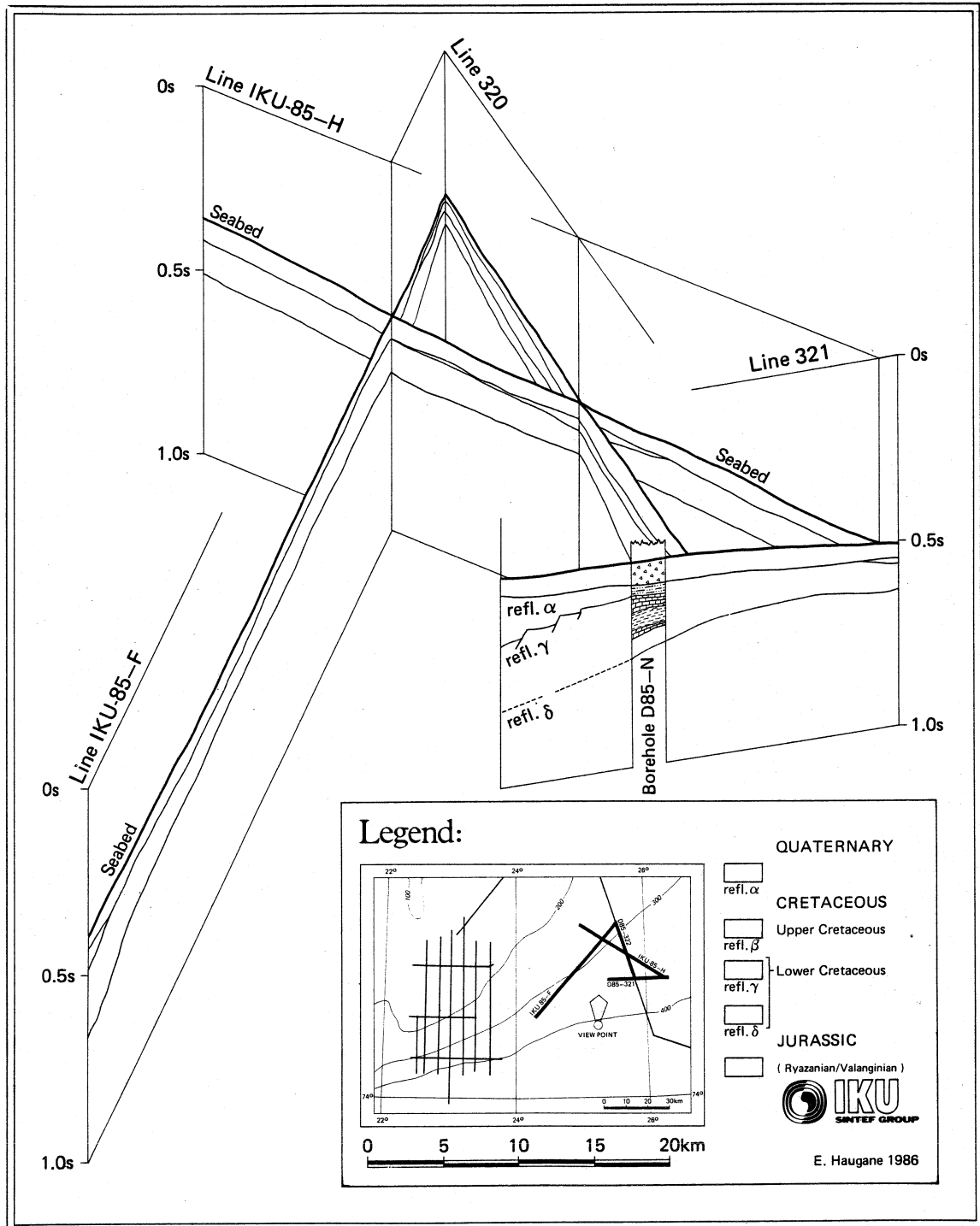


Fig. 3.6 Seismic interpretation near the shallow drilling site D85-N, 200 km to the east of Bjørnøya, cf. Figures 3.3 and 3.7.

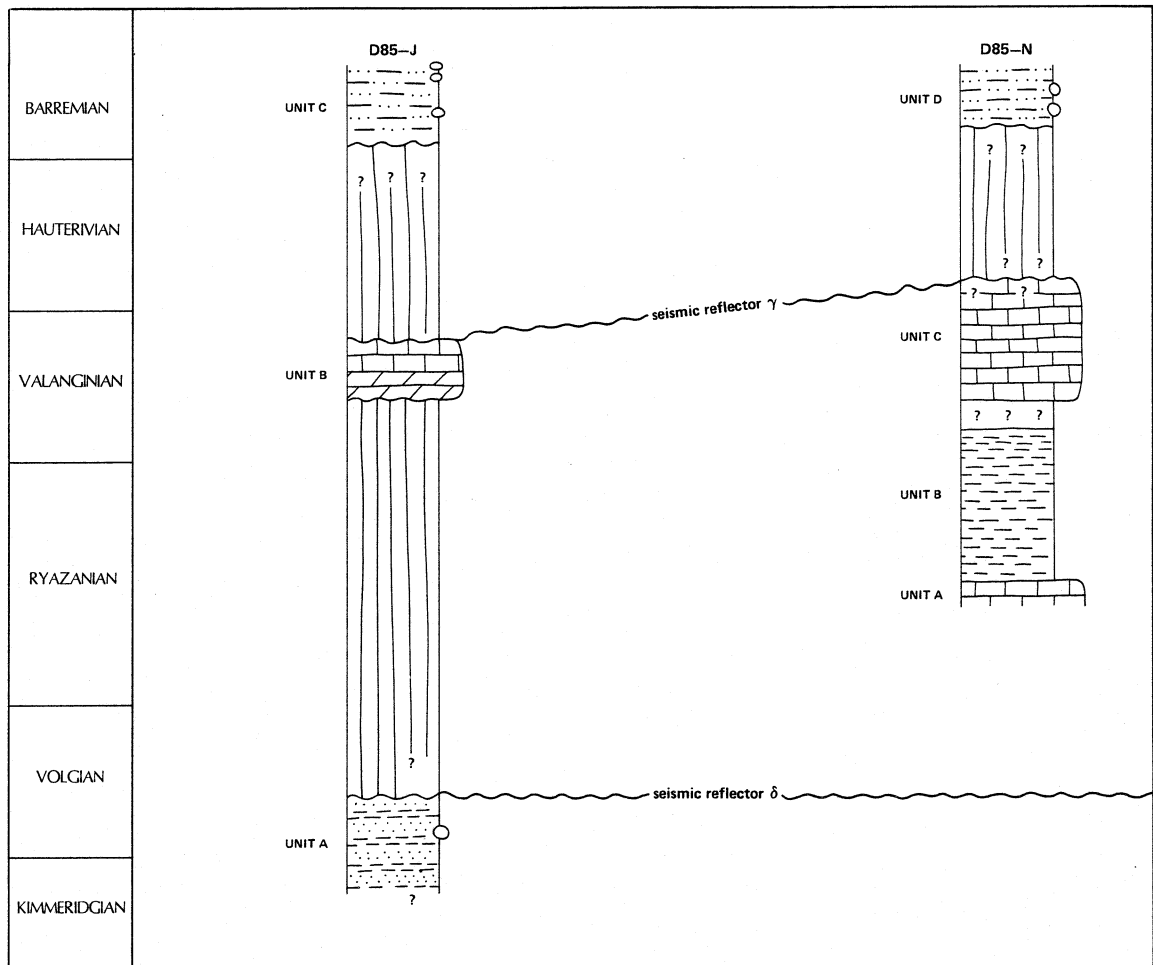


Fig. 3.7 Tentative correlation between the shallow drilling cores D85-J and D85-N. Seismic reflectors refer to Figures 3.5 and 3.6.

4. CORRELATION

4.1 Correlation criteria

A summary of sample criteria and major correlations is given in Tables 4.1 and 4.2. Table 4.1 presents technical information and a short description of the individual samples, while Table 4.2 represents an interpreted compilation and comparison of conclusions based on the analytical results.

The sample quality varies greatly, and while the cores from the drillships both years mostly gave sample material in abundance for analytical purposes, several of the thinner cores from the sea bed rock core drill usually gave more sparse information. Comparing and grouping of such cores from neighbouring localities, however, often permit us to indicate the relationships between these cores and the map units also when palaeontological information is sparse or lacking.

The criteria used for correlations vary between the samples depending on the age, the lithology, the fossil content, and the size of the core. The accuracy level for the palaeontological datings is strongly dependent on which fossil groups are present and quality of preservation.

In the present study, palynology has given good results and accuracy level for the Tertiary and Mesozoic succession. In the Palaeozoic sequence, palynology has given evidences for grouping of samples and also for rough correlation with sections from the surrounding land areas, although the age information is more sparse.

Microfossils have also been studied when possible, dependent on the sample quality. Foraminifera have been hand picked and gave valuable information in the Lower Cretaceous cores. Foraminifera have also been recorded from the thin section studies; these have, however, not been involved in the dating and correlation attempts. Several of the Palaeozoic cores contain fusulinid foraminifera. A large number of thin sections has been made from these units. At IKU two projects (in the Arctic Geoprogram) are in progress studying the fusulinid fauna of the Carboniferous and Permian strata on Bjørnøya and Spitsbergen. As these

projects are still in progress, and due to sparse published information of the fauna from this region, our accounts of this fauna are preliminary. Nevertheless, important information for correlation with the land areas are given. In one core (Lower Cretaceous) nannofossil study also gave results.

Macrofossils are important constituents of the lithology in many of the cores. Correlations based on macrofossils have been carried out at two levels. In one core, ammonites were found, and although they could not be identified to the species level, generic identification was sufficient to indicate the appropriate ammonite zone. Such ammonite datings represent the highest accuracy level which may be reached by palaeontological methods. Evolutionary lineages may also give excellent age information. In our material the bivalve genus Buchia, which has one of the better documented evolutionary lineages, has supported valuable age information in the Lower Cretaceous. Other fossils as bryozoan and brachiopods have also been studied, however, at the present stage of investigations they are more useful as lithologic indication for correlation between cores and land areas rather than as age indicators. Other macrofossils present (e.g. sponge spicules) provide no age information, but they are very typical for certain lithostratigraphical units.

Lithology is the most characteristic criterion of any rock unit and forms the main basis for most correlations that are not based on age information. In the present study, the lithological information may be used for major correlation of similar rock units as well as in a more direct way when special rock types occur. In the geological record, certain rock types are easily recognized, and several such criteria occur in the core material, although the direct facts for correlation may be sparse. It should, however, be remembered that use of such criteria may result in slightly wrong age correlation as the features often result from special environment control of the depositional basin. Such factors may be time transgressive in a large depositional basin, and in the present study they include thin-shelled bivalves as well as phosphate nodules typical of the upper part of Middle Triassic. Sponge spicules and resulting early silicification are elsewhere often seen in the upper part of the Permian sequence. Evaporitic minerals are

fairly time restricted in the neighbouring areas, to Carboniferous and early Permian sediments.

Macrofossils may often be an important element of the lithology, and fossiliferous rocks may often give good indicators for correlation also when the involved fauna has not been the subject of a systematic palaeontological study.

In the present study the mineral composition have been used to a limited extent, a few typical trends may, however, be mentioned: dolomites are much more abundant in the Carboniferous and Lower Permian strata than elsewhere, and very immature sandstones occur in the Upper Triassic of Spitsbergen.

Together with the above mentioned parameters, ichnofacies (trace fossil facies) have been utilized. In the upper Permian of most arctic areas a very typical development of the basinal environment contain abundant Zoophycus. Although this trace fossil also occurs both lower and higher in the succession the association with spiculitic chert and interbedded biosparites is clearly indicative of upper Permian units.

No.	EQUIPMENT	AREA	LAT. (N)	LONG. (E)	DEPTH (m)	LENGTH (m)	LITHOLOGY	FOSSILS	AGE AND CRITERIA	MAP UNIT
D84-1/1	BIO	Dia-Struc.	73°12'17.379"	23°15'54.087"	329	2.6	Packstone/Wackestone Silicified	Bryozoa, Brachiopods, Echinoderms, Sponge spicules, Forams	Indeterminant	Upper Permian
D84-2/1	"	"	73°12'36.966"	23°15'54.917"	345	0.07	Packstone/Wackestone Silicified	Bryozoa, Echinoderms, Brachiopods, Sponge spicules, Palynomorphs	Permian (Paly)	Lower Permian/Carboniferous
D84-3/2	"	"	73°12'15.185"	23°15'55.226"	344	5 frag.	Carbonate, silicified Claystone, brown. Sandstone, fine	None recorded	Indeterminant	Lower Permian/Carboniferous
D84-4/1	"	"	73°12'57.111"	23°13'19.576"	352	0.09	Sandstone/Mudstone alternating, laminated w. Gypsum	Wood fragments, Palynomorphs (poorly preserved)	Indeterminant	Lower Permian/Carboniferous
D84-5/1	"	"	73°13'25.578"	23°25'08.689"	324	0.09	Siltstone, (silicified), carbonaceous	Echinoderms, Brachiopods, Forams, Ostracods, Bryozoa, Palynomorphs	Permian (Paly)	Upper Permian
D84-6/1	"	"	73°13'36.252"	23°25'35.673"	336	0.3	Spiculitic Chert and Wackestone	Brachiopods, Bryozoa, Sponge spicules	Indeterminant	Upper Permian
D84-7/1	"	"	73°13'52.489"	23°26'31.944"	364	0.27	Wackestone, cherty	Bryozoa, Brachiopods, Echinoderms	Indeterminant	Upper Permian
D84-10/3	"	"	73°13'57.370"	23°26'49.721"	374	0.45	Wackestone, silicified	Bryozoa, Brachiopods, Echinoderms, Forams, Sponge spicules	Indeterminant	Upper Permian
D84-11/1	"	"	73°14'51.292"	23°12'42.519"	380	1.1	Packstone/Wackestone fractured, w. Barite in fractures	Bryozoa, Brachiopods, Forams, Echinoderms	Indeterminant	Lower Permian/Carboniferous
D84-12/3	"	"	73°15'42.670"	23°16'04.614"	355	1.12	Grainstone/Packstone, partly silicified	Bryozoa, Brachiopods, Forams, Echinoderms and Fusulinids	Carboniferous/Late Gzelian (Fusul)	Lower Permian/Carboniferous
D84-13/1	"	"	73°16'14.377"	23°16'08.676"	354	1.30	Siltstone, partly silicified. Bioturbated	Sponge spicules, Palynomorphs	Permian (Mid-Late) (Paly)	Upper Permian
D84-14/1	"	"	73°16'33.952"	23°16'00.208"	371	0.35	Wackestone and Mudstone, silicified	Echinoderms, Forams, Bryozoa, Palynomorphs	Permian (Mid-Late) (Paly)	Upper Permian
D84-15/1	"	"	73°15'43.583"	23°15'11.287"	343	1.93	Interbedded Wackestone, very fine Sandstone and Siltstone, both silicified	Brachiopods, Sponge spicules, Echinoderms, Bryozoa, Fusulinids, Forams, Palynomorphs, Ostracods	?Permian - Carboniferous Boundary (Fusulinids)	Lower Permian/Carboniferous
D84-16/1	"	"	73°16'09.902"	23°12'48.108"	373	0.05	Siltstone, silicified	Brachiopods, Sponge spicules, Palynomorphs	Permian (Mid-Late) (Paly)	Upper Permian
D84-22/1	"	Stappen High	74°00'58.932"	19°58'31.033"	148	0.36	Packstone, partly silicified	Brachiopods, Bryozoa, Echinoderms, Ostracods, Forams, Palynomorphs	Permian	Upper Permian
D84-22/2	"	"	74°00'58.867"	19°58'30.815"	148	0.67	Packstone, partly silicified	Brachiopods, Bryozoa, Echinoderms, Ostracods, Forams, Ostracods	?Permian	Upper Permian
D84-23/2	"	"	74°04'12.199"	19°55'36.588"	108	0.45	Packstone, moderate silicified	Bryozoa, Echinoderms, Brachiopods, Forams, Gastropods	?Permian	Upper Permian
D84-24/2	"	"	74°02'43.944"	19°48'05.074"	104	3.30	Wackestone/Packstone and spiculitic Chert	Bryozoa, Echinoderms, Brachiopods, Sponge spicules, Forams	Permian	Upper Permian
D84-25/1	"	"	74°04'42.908"	19°36'08.303"	99	1.03	Wackestone, silicified	Bryozoa, Echinoderms, Brachiopods, Sponge spicules, Forams	Indeterminant	Upper Permian
D84-26/1	"	"	74°06'29.895"	19°25'16.211"	110	0.03	Spiculitic Chert	Sponge spicules	?Permian	Upper Permian
D84-27/1	"	"	74°07'13.918"	19°20'44.403"	104	0.93	Sandstone, medium	Brachiopods, Palynomorphs	Triassic/Early (Paly)	Lower Permian
D84-28/3	"	"	74°08'25.970"	19°13'29.152"	83	1.03	Packstone, variable silicification	Brachiopods, Bryozoa, Sponge spicules, Forams, Echinoderms	Indeterminant	Upper Permian
D84-29/2	"	"	74°08'58.510"	19°10'03.331"	79	2.29	Packstone	Bryozoa, Brachiopods, Forams, Sponge spicules, Trilobite	Indeterminant	Upper Permian
D84-31/1	"	"	74°09'57.371"	19°04'01.962"	72	0.18	Wackestone, heavily silicified	Brachiopods, Bryozoa, Forams, Sponge spicules	Indeterminant,	Upper Permian
D84-32/1	"	"	74°12'43.060"	19°46'46.967"	52	0.69	Wackestone, dolomitic, local cherty	Bryozoa, Echinoderms, Brachiopods	Indeterminant, ?Carboniferous	Lower Permian/Carboniferous
D84-33/2	"	"	74°13'59.484"	18°38'49.952"	44	0.40	Dolomite, strongly fractured	None recorded	Indeterminant	Lower Permian/Carboniferous
D84-34/1	"	"	74°11'53.355"	18°35'11.370"	51	0.15	Dolomitic Breccia in sandy matrix	None recorded	Indeterminant	Lower Permian/Carboniferous
D84-35/1	"	"	74°09'34.923"	18°34'54.400"	68	0.57	Siltstone with Dolomite and Limestone beds	None recorded, ?Acrirarchs	Indeterminant	Lower Permian/Carboniferous
D84-36/1	"	"	74°08'49.833"	18°27'26.596"	117	0.22	Packstone	Bryozoa, Brachiopods, Echinoderms, Acrirarchs	Indeterminant	Upper Permian
D84-37/1	"	"	74°08'35.631"	18°27'26.596"	110	0.42	Wackestone/Packstone, moderate silicification	Bryozoa, Brachiopods, Echinoderms, Forams, Sponge spicules	Indeterminant	Upper Permian
D84-38/2	"	"	74°07'44.773"	18°32'34.403"	66	0.22	Wackestone/Packstone, silicified	Bryozoa, Brachiopods, Echinoderms, Sponge spicules	Indeterminant	Upper Permian
D84-39/2	"	"	74°07'33.958"	18°47'34.531"	66	0.47	Packstone/Grainstone partially silicified	Bryozoa, Brachiopods, Echinoderms, Sponge spicules	Indeterminant	Upper Permian
D84-40/1	"	"	74°03'29.848"	18°58'01.857"	94	0.21	Wackestone, strongly silicified	Bryozoa, Echinoderms, Brachiopods, Forams, Sponge spicules	Indeterminant	Upper Permian
D84-41/2	"	"	74°04'28.803"	19°06'23.504"	100	0.29	Wackestone/Packstone, partly silicified	Bryozoa, Brachiopods, Forams, Echinoderms, Sponge spicules	Indeterminant	Upper Permian
D84-42/2	"	"	73°58'35.932"	19°57'09.932"	175	0.16	Packstone, partly silicified	Bryozoa, Brachiopods, Forams, Sponge spicules	Indeterminant	Upper Permian
D84-43/1	"	"	73°54'25.507"	20°36'46.871"	330	0.12	Claystone, dark grey	Palynomorphs	Barremian (Paly)	Lower Cretaceous
D84-44/1	"	"	73°52'03.717"	20°50'23.339"	402	0.17	Claystone, dark grey	Palynomorphs	Aptian - Middle Albian (Paly)	Lower Cretaceous
D84-45/1	"	"	73°55'19.949"	21°01'49.081"	364	0.22	Claystone, dark grey	Palynomorphs	Kimmeridgian - Ryazanian (Paly)	Jurassic
D84-48/2	"	Loppa High	72°00'28.887"	22°20'09.088"	380	0.40	Claystone, dark grey	Palynomorphs	Paleocene (Paly)	Tertiary
D84-50/1	"	Seruya	71°00'16.934"	22°59'58.773"	207	0.75	Gneiss	None	Metamorphic	Crystalline basement
D84-51/1	"	"	70°54'36.803	22°06'36.063"	59	0.25	Quartzite and Gneiss	None	Metamorphic	Crystalline basement
Dia84-11	M/V "Pholas"	Dia-Struc.	73°15'41.33"	23°16'07.11"	367	16.11	Breccia divides core into 2 units. Upper = LS, grey, strongly fractured with some Silt and Chert, Lower = LS, grey	Echinoderms, Bryozoa, Brachiopods, Forams, Gastropods, Ostracods, Fusulinids	Permian/Early Sakmarian (Fusul)	Lower Permian/Carboniferous
Dia84-2	"	"	73°16'45.65"	23°09'29.57"	418	25.26	26cm Wackestone/Packstone overlain by 25m silty Shale laminated with carbonate lenses	Ammonites, Bivalves, Palynomorphs in shale, Bryozoa, Brachiopods, Echinoderm in limestone.	Triassic, Early above (Ammo, Paly) Permian below,	Upper Permian/Lower Triassic
Dia84-31	"	"	73°13'59.67"	23°26'59.032"	379	21.53	Siltstone, dark grey, chert cemented, bioturbated, spiculitic	Palynomorphs, Sponges	Permian/Mid - Late (Paly)	Upper Permian
D85-A	M/V "Bucentaur"	off Nordkapp	71°38'49.795"	26°52'43.295"	369	1.5	Claystone, dark olive grey	Palynomorphs	Paleocene (Paly)	Tertiary
D85-J	"	Stappen High	73°51'15.180"	20°55'00.802"	419	34.1	3 units, grey silty claystone, separated by dolomitized limestone	Bivalves, Palynomorphs, Forams	Kimmeridgian - Barremian (Paly, Bivalves, Forams)	Lower Cretaceous/Jurassic
D85-K	"	Dia-Struc.	73°16'51.539"	23°01'25.834"	420	27.2	Shale, dark grey silty, calcareous, laminated	Bivalves, Gastropods, Leaf, Wood fragments, Palynomorphs	Triassic: Ladinian - ?Anisian (Paly)	Lower Triassic
D85-N	"	Bjørnøya East	74°29'25.246"	25°46'19.261"	334	14.5	Wackestones and Shale, interbeds	Bivalves, Forams, Brachiopods, Barnacles, Palynomorphs	Ryazanian - Barremian	Lower Cretaceous
D85-O	"	"	75°12'20.536"	24°43'21.607"	108	2.07	Sandstone, dark brown	Palynomorphs	Triassic (?Late) (Paly)	Upper Triassic
D85-V	"	Stappen High	73°49'10.924"	17°22'04.526"	296	10	Sand, very fine laminated w. clay and silt	Rare poor Forams, Palynomorphs	Eocene (Paly)	Tertiary
D85-W	"	Dia-Struc.	73°13'15.870"	23°18'42.716"	380	0.20	Wackestone with Gypsum	Fusulinids (poorly preserved)	Carbon - Early Permian	Lower Permian/Carboniferous

Table 4.1 In situ sea bed cores and shallow drilling cores obtained in 1984 and 1985. Map units refer to the geological maps in Figures 1.1, 3.2 and 3.3.

No.	EQUIPMENT	AREA	LAT. (N)	LONG. (E)	DEPTH (m)	LENGTH (m)	LITHOLOGY	FOSSILS	AGE AND CRITERIA	MAP UNIT
D84-1/1	B10	Dia-Struc.	73°12'17.379"	23°15'54.087"	329	2.6	Packstone/Wackestone Silicified	Bryozoa, Brachiopods, Echinoderms, Sponge spicules, Forams	Indeterminant	Upper Permian
D84-2/1	"	"	73°12'36.966"	23°15'54.917"	345	0.07	Packstone/Wackestone Silicified	Bryozoa, Echinoderms, Brachiopods, Sponge spicules, Palynomorphs	Permian (Paly)	Lower Permian/Carboniferous
D84-3/2	"	"	73°12'15.185"	23°15'55.226"	344	5 frag.	Carbonate, silicified Claystone, brown. Sandstone, fine	None recorded	Indeterminant	Lower Permian/Carboniferous
D84-4/1	"	"	73°12'57.111"	23°23'19.576"	352	0.09	Sandstone/Mudstone alternating, laminated w. Gypsum	Wood fragments, Palynomorphs (poorly preserved)	Indeterminant	Lower Permian/Carboniferous
D84-5/1	"	"	73°13'25.578"	23°25'08.689"	324	0.09	Siltstone, (silicified), carbonaceous	Echinoderms, Brachiopods, Forams, Ostracods, Bryozoa, Palynomorphs	Permian (Paly)	Upper Permian
D84-6/1	"	"	73°13'36.252"	23°25'35.673"	336	0.3	Spiculitic Chert and Wackestone	Brachiopods, Bryozoa, Sponge spicules	Indeterminant	Upper Permian
D84-7/1	"	"	73°13'52.489"	23°26'31.944"	364	0.27	Wackestone, cherty	Bryozoa, Brachiopods, Echinoderms	Indeterminant	Upper Permian
D84-10/3	"	"	73°13'57.370"	23°26'49.721"	374	0.45	Wackestone, silicified	Bryozoa, Brachiopods, Echinoderms Forams, Sponge spicules	Indeterminant	Upper Permian
D84-11/1	"	"	73°14'51.292"	23°12'42.519"	380	1.1	Packstone/Wackestone fractured, w. Barite in fractures	Bryozoa, Brachiopods, Forams, Echinoderms	Indeterminant	Lower Permian/Carboniferous
D84-12/3	"	"	73°15'42.670"	23°16'04.614"	355	1.12	Grainstone/Packstone, partly silicified	Bryozoa, Brachiopods, Forams, Echinoderms and Fusulinids	Carboniferous/Late Gzelian (Fusul)	Lower Permian/Carboniferous
D84-13/1	"	"	73°16'14.377"	23°16'08.676"	354	1.30	Siltstone, partly silicified. Bioturbated	Sponge spicules, Palynomorphs	Permian (Mid-Late) (Paly)	Upper Permian
D84-14/1	"	"	73°16'33.952"	23°16'00.208"	371	0.35	Wackestone and Mudstone, silicified	Echinoderms, Forams, Bryozoa, Palynomorphs	Permian (Mid-Late) (Paly)	Upper Permian
D84-15/1	"	"	73°15'43.583"	23°15'11.287"	343	1.93	Interbedded Wackestone, very fine Sandstone and Siltstone, both silicified	Brachiopods, Sponge spicules, Echinoderms, Bryozoa, Fusulinids Forams, Palynomorphs, Ostracods	?Permian - Carboniferous Boundary (Fusulinids)	Lower Permian/Carboniferous
D84-16/1	"	"	73°16'09.902"	23°12'48.108"	373	0.05	Siltstone, silicified	Brachiopods, Sponge spicules, Palynomorphs	Permian (Mid-Late) (Paly)	Upper Permian
D84-22/1	"	Stappen High	74°00'58.932"	19°58'31.033"	148	0.36	Packstone, partly silicified	Brachiopods, Bryozoa, Echinoderms, Ostracods, Forams, Palynomorphs	Permian	Upper Permian
D84-22/2	"	"	74°00'58.867"	19°58'30.815"	148	0.67	Packstone, partly silicified	Brachiopods, Bryozoa, Echinoderms, Ostracods, Forams, Ostracods	?Permian	Upper Permian
D84-23/2	"	"	74°04'12.199"	19°55'36.588"	108	0.45	Packstone, moderate silicified	Bryozoa, Echinoderms, Brachiopods Forams, Gastropods	?Permian	Upper Permian
D84-24/2	"	"	74°02'43.944"	19°48'05.074"	104	3.30	Wackestone/Packstone and spiculitic Chert	Bryozoa, Echinoderms, Brachiopods, Sponge spicules, Forams	Permian	Upper Permian
D84-25/1	"	"	74°04'42.908"	19°36'08.303"	99	1.03	Wackestone, silicified	Bryozoa, Echinoderms, Brachiopods, Sponge spicules, Forams	Indeterminant	Upper Permian
D84-26/1	"	"	74°06'29.895"	19°25'16.211"	110	0.03	Spiculitic Chert	Sponge spicules	?Permian	Upper Permian
D84-27/1	"	"	74°07'13.918"	19°20'44.403"	104	0.93	Sandstone, medium	Brachiopods, Palynomorphs	Triassic/Early (Paly)	Lower Triassic
D84-28/3	"	"	74°08'25.970"	19°13'29.152"	83	1.03	Packstone, variable silicification	Brachiopods, Bryozoa, Sponge spicules, Forams, Echinoderms	Indeterminant	Upper Permian
D84-29/2	"	"	74°08'58.510"	19°10'03.331"	79	2.29	Packstone	Bryozoa, Brachiopods, Forams, Sponge spicules, Trilobite	Indeterminant	Upper Permian
D84-31/1	"	"	74°09'57.371"	19°04'01.962"	72	0.18	Wackestone, heavily silicified	Brachiopods, Bryozoa, Forams, Sponge spicules	Indeterminant,	Upper Permian
D84-32/1	"	"	74°12'43.060"	19°46'46.967"	52	0.69	Wackestone, dolomitic, local cherty	Bryozoa, Echinoderms, Brachiopods	Indeterminant, ?Carboniferous	Lower Permian/Carboniferous
D84-33/2	"	"	74°13'59.484"	18°38'49.952"	44	0.40	Dolomite, strongly fractured	None recorded	Indeterminant	Lower Permian/Carboniferous
D84-34/1	"	"	74°11'53.355"	18°35'11.370"	51	0.15	Dolomitic Breccia in sandy matrix	None recorded	Indeterminant	Lower Permian/Carboniferous
D84-35/1	"	"	74°09'34.923"	18°34'54.400"	68	0.57	Siltstone with Dolomite and Limestone beds	None recorded, ?Acritarchs	Indeterminant	Lower Permian/Carboniferous
D84-36/1	"	"	74°08'49.833"	18°27'26.596"	117	0.22	Packstone	Bryozoa, Brachiopods, Echinoderms Acritarchs	Indeterminant	Upper Permian
D84-37/1	"	"	74°08'35.631"	18°27'26.596"	110	0.42	Wackestone/Packstone, moderate silicification	Bryozoa, Brachiopods, Echinoderms Forams, Sponge spicules	Indeterminant	Upper Permian
D84-38/2	"	"	74°07'44.773"	18°32'34.403"	66	0.22	Wackestone/Packstone, silicified	Bryozoa, Brachiopods, Echinoderms, Sponge spicules	Indeterminant	Upper Permian
D84-39/2	"	"	74°07'33.958"	18°47'34.531"	66	0.47	Packstone/Grainstone partially silicified	Bryozoa, Brachiopods, Echinoderms, Sponge spicules	Indeterminant	Upper Permian
D84-40/1	"	"	74°03'29.848"	18°58'01.857"	94	0.21	Wackestone, strongly silicified	Bryozoa, Echinoderms, Brachiopods Forams, Sponge spicules	Indeterminant	Upper Permian
D84-41/2	"	"	74°04'28.803"	19°06'23.504"	100	0.29	Wackestone/Packstone, partly silicified	Bryozoa, Brachiopods, Forams, Echinoderms, Sponge spicules	Indeterminant	Upper Permian
D84-42/2	"	"	73°58'35.932"	19°57'09.932"	175	0.16	Packstone, partly silicified	Bryozoa, Brachiopods, Forams, Sponge spicules	Indeterminant	Upper Permian
D84-43/1	"	"	73°54'25.507"	20°36'46.871"	330	0.12	Claystone, dark grey	Palynomorphs	Barremian (Paly)	Lower Cretaceous
D84-44/1	"	"	73°52'03.717"	20°50'23.339"	402	0.17	Claystone, dark grey	Palynomorphs	Aptian - Middle Albian (Paly)	Lower Cretaceous
D84-45/1	"	"	73°55'19.949"	21°01'49.081"	364	0.22	Claystone, dark grey	Palynomorphs	Kimmeridgian - Ryazanian (Paly)	Jurassic
C84-48/2	"	Loppa High	72°00'28.887"	22°20'09.088"	380	0.40	Claystone, dark grey	Palynomorphs	Paleocene (Paly)	Tertiary
C84-50/1	"	Sørøya	71°00'16.934"	22°59'58.773"	207	0.75	Gneiss	None	Metamorphic	Crystalline basement
C84-51/1	"	"	70°54'36.803"	22°06'36.063"	59	0.25	Quartzite and Gneiss	None	Metamorphic	Crystalline basement
Dia84-11	M/V "Pholas"	Dia-Struc.	73°15'41.33"	23°16'07.11"	367	16.11	Breccia divides core into 2 units. Upper = LS, grey, strongly fractured with some Silt and Chert, Lower = LS, grey	Echinoderms, Bryozoa, Brachiopods, Forams, Gastropods, Ostracods, Fusulinids	Permian/Early Sakmarian (Fusul)	Lower Permian/Carboniferous
Dia84-2	"	"	73°16'45.65"	23°09'29.57"	418	25.26	26cm Wackestone/Packstone overlain by 25m silty Shale laminated with carbonate lenses	Ammonites, Bivalves, Palynomorphs in shale Bryozoa, Brachiopods, Echinoderm in limestone.	Triassic, Early above (Ammono, Paly) Permian below,	Upper Permian/Lower Triassic
Dia84-31	"	"	73°13'59.67"	23°26'59.032"	379	21.53	Siltstone, dark grey, chert cemented, bioturbated, spiculitic	Palynomorphs, Sponges	Permian/Mid - Late (Paly)	Upper Permian
C85-A	M/V "Bucentaur"	off Nordkapp	71°38'49.795"	26°52'43.295"	369	1.5	Claystone, dark olive grey	Palynomorphs	Paleocene (Paly)	Tertiary
D85-J	"	Stappen High	73°51'15.180"	20°55'00.802"	419	34.1	3 units, grey silty claystone, separated by dolomitized limestone	Bivalves, Palynomorphs Forams	Kimmeridgian - Barremian (Paly, Bivalves, Forams)	Lower Cretaceous/Jurassic
D85-K	"	Dia-Struc.	73°16'51.539"	23°01'25.834"	420	27.2	Shale, dark grey silty, calcareous, laminated	Bivalves, Gastropods, Leafs, Wood fragments, Palynomorphs	Triassic: Ladinian - ?Anisian (Paly)	Lower Triassic
D85-N	"	Bjørnøya East	74°29'25.246"	25°46'19.261"	334	14.5	Wackestones and Shale, interbeds	Bivalves, Forams, Brachiopods, Barnacles, Palynomorphs	Ryazanian - Barremian	Lower Cretaceous
D85-O	"	"	75°12'20.536"	24°43'21.607"	108	2.07	Sandstone, dark brown	Palynomorphs	Triassic (?Late) (Paly)	Upper Triassic
D85-V	"	Stappen High	73°49'10.924"	17°22'04.526"	296	10	Sand, very fine laminated w. clay and silt	Rare poor Forams, Palynomorphs	Eocene (Paly)	Tertiary
D85-W	"	Dia-Struc.	73°13'15.870"	23°18'42.716"	380	0.20	Wackestone with Gypsum	Fusulinids (poorly preserved)	Carbon - Early Permian	Lower Permian/Carboniferous

Table 4.1 In situ sea bed cores and shallow drilling cores obtained in 1984 and 1985. Map units refer to the geological maps in Figures 1.1, 3.2 and 3.3.

STAPPEN HIGH AND PROXIMITY							DIA-STRUCTURE AND EASTERN AREA					
SAMPLE	LITHOLOGY	FOSSILS	AGE AND CRITERIA	FACIES	CORRELATIONS	MAP UNIT	CORRELATIONS	FACIES	AGE AND CRITERIA	FOSSILS	LITHOLOGY	SAMPLE
D85-V	Sandstone, very fine. Laminated w. Clay and Silt	Palynomorphs	Eocene (paly)	?Deltaic		"Tertiary"						
								Open marine	Paleocene (paly)	Palynomorphs	Claystone, dark olive grey, laminated, bioturbated	D85-A
								Open shelf	Paleocene (paly)	Palynomorphs	Claystone, dark grey	C84-48
D84-44	Claystone, dark grey	Palynomorphs	Aptian - Middle Albian (paly)	Open Shelf	Carolinefjellet Fm (age) (litho)	"Lower Cretaceous"	Upper part of Rurikfjellet Mb of the Janusfjellet Fm	Open shelf	Barremian (paly)	Palynomorphs	Claystone, dark grey	D85-N
D84-43	Claystone, dark grey	Palynomorphs	Barremian (paly)	Open Shelf	?Uppermost Rurikfjellet Mb Janusfjellet Fm			Shallow shelf	Valanginian or Valanginian-Barremian (bivalves, forams)	Bivalves Foraminifera Palynomorphs	Wackestone, light to dark grey	
D85-J	Claystone, silty dark grey	Palynomorphs	Upper Hauterivian - Barremian (paly)	Open Shelf	?Uppermost Rurikfjellet Mb Janusfjellet Fm			Open shelf	Lower Ryazanian - Valanginian (bivalves-forams)	Foraminifera Palynomorphs Bivalves Belemnites	Claystone, silty, reddish brown	
	Wacke, Pack - grainstone, light grey, dolomitic	Nannofossils Bivalves Foraminifera	Valanginian - Lower Hauterivian (nanno, bivalves)	Shallow Shelf (condensed)				Shallow shelf	Uppermost Volgian - Lower Ryazanian (bivalves, forams)	Bivalves Foraminifera Palynomorphs	Wackestone, grey-green	
	Claystone/siltstone, dark grey	Palynomorphs	Kimmeridgian - Volgian (paly)	Open Shelf	Agardhfjellet Mb, Janusfjellet Fm	"Upper Jurassic"						
D84-45	Claystone, dark grey	Palynomorphs	Kimmeridgian - Volgian (paly). Ryazanian (less problem)	Open Shelf	Agardhfjellet Mb, Janusfjellet Fm							
						"Upper Triassic" Kapp Toscana Gp.	De Geerdalen Fm (lith, age)	Shallow marine	Late Triassic (paly)	Palynomorphs	Sandstone, (immature)	D85-0
D84-27/1	Sandstone	Palynomorphs	Early Triassic (Paly)		Sassendalen Gp Urd Fm	"Lower Triassic", Sassendalen Gp.	Sassendalen Gp Botneheia Mb (lith, age, paly)	Open Marine	Ladinian or ?Anisian (paly)	Bivalves Palynomorphs	Shale, silty, carbonaceous, grey	D85-K
							Sassendalen Gp Urd Fm (lith, age, paly)	Shallow marine	Griesbachian (ammonite, paly)	Ammonites Bivalves fish palynomorphs	Siltstone, grey	Dia84-2
D84-22/1	Packstone, part. silicified	Brachiopods Bryozoa, Forams Sponge spicules Ostracods Echinoderms Palynomorphs		Moderate to high energy marine	Tempelfjorden Gp	"Upper Permian" Tempelfjorden Gp.		Marine High energy	Permian (lith)	Bryozoans Brachiopods Echinoderms	Packstone	
D84-23/2	Packstone, mod. silicified	Bryozoa Echinoderms Brachiopods Forams		Moderate to high energy marine	Most similar to the Miseryfjellet Fm on Bjørnøya		Tempelfjorden Gp	Neritic	Permian/Mid-Upper (paly)	Palynomorphs Sponges	Siltstone, dark grey, chert cemented, bioturbated, spiculitic	Dia84-31
D84-24/2	Wackestone/Packstone, spiculitic Chert	Bryozoa, Forams Echinoderms Brachiopods Sponge spicules		Open marine			Most similar to the Kapp Starostin Fm on Spitsbergen	Marine	Indeterminant	Bryozoa Brachiopods Echinoderms Forams Sponge spicules	Wackestone, silicified	D84-10/3
D84-25/1	Wackestone, silicified	Bryozoa, Sponge spicules, Echinoderms Brachiopods Forams		Marine				?Shallow marine	Indeterminant	Bryozoa, Brachiopods Echinoderms	Wackestone, Cherty	D84-7/1
D84-28/3	Packstone, variable silicification	Brachiopods Bryozoa Sponge spicules Forams Echinoderms	Indeterminate	Shallow marine	Based on lithology macrofossils e.g. unspecified brachiopods & bryozoa and palynology		Based on lithology macrofossils, e.g. unspecified brachiopods and bryozoans. Palynology and ichnology	Neritic marine low energy		Echinoderms Forams, Bryozoa Palynomorph	Wackestone/Mudstone silicified	D84-14/1
D84-29/2	Packstone	Bryozoa Brachiopods Forams Trilobite Sponge spicules	Indeterminate	Marine				Neritic	Indeterminant	Brachiopods Bryozoa Sponge spicules	Spiculitic Chert and Wackestone	D84-6/1
D84-31/1	Wackestone, heavily silicified	Brachiopods Bryozoa Forams, Sponge spicules	Indeterminate	Quiet marine				Marine Low energy	?Upper Permian (paly)	Echinoderms Brachiopods Forams Ostracods Bryozoa, Sponge spicules Palynomorphs	Siltstone, silicified carbonaceous	D84-5/1
D84-36/1	Packstone	Bryozoa Brachiopods Echinoderms Acritarchs	Indeterminate	Marine				Neritic Zoophycus	Permian: Mid-Upper (paly)	Sponge spicules Palynomorphs	Siltstone, part. silicified, bioturbated	D84-13/1
D84-37/1	Wackestone/Packstone, moderate silicification	Bryozoa Brachiopods Forams, Sponge spicules	Indeterminate	Marine				Neritic	Permian: Mid-Upper (paly.)	Brachiopods, Sponge spicules Palynomorphs	Siltstone, silicified	D84-16/1
D84-38/2	Wackestone/Packstone, silicified	Bryozoa Brachiopods Echinoderms Sponge spicules	Indeterminate	Shallow marine		"Lower Permian/Carboniferous"	Gipsdalen Gp (litho)	Evaporitic	Indeterminate	Wood fragments poorly Pres'd Palynomorphs	Sandstone/Mudstone alternating laminae and Gypsum	D84-4/1
D84-32/1	Wackestone, Dolomitic	Bryozoa Echinoderms Brachiopods	Indeterminate		?Gipsdalen (litho)	Gipsdalen Gp.		Marine	Permian (Paly)	Bryozoa Echinoderms Brachiopods Acritarchs Palynomorphs	Packstone/Wackestone Silicified	D84-2/1
D84-35/1	Siltstone w. Dolomite and Limestone beds	None recorded ?Acritarchs	Indeterminate		?Gipsdalen (litho)				Indeterminate	None recorded	Carbonate, silicified Claystone, brown, Sandstone, fine	D84-3/2
D84-33/2	Dolomite, strongly fractured	None recorded	Indeterminate		?Gipsdalen (litho)		Gipsdalen (fusul) (litho)	?Open marine	Permian - Carboniferous Boundary (fusul)	Brachiopods Sponge spicules Ostracods Echinoderms Bryozoa, Forams	Interbedded Wackestone veryfine Sandstone and Siltstone, both silicified	D84-15/1

Table 4.2 Tentative correlation of core Svalbard. Stappen High cores Dia-Structure and other cores

Table 4.2 Tentative correlation of cores with stratigraphical units on Svalbard. Stappen High cores are on the left hand side and Dia-Structure and other cores on the right hand side.

	grey		(paly)		Rurikfjellet Mb Janusfjellet Fm				Valanginian-Barremian (bivalves, forams)	Foraminifera Palynomorphs	dark grey	
D85-J	Claystone, silty dark grey	Palynomorphs	Upper Hauterivian - Barremian (paly)	Open Shelf	?Uppermost Rurikfjellet Mb Janusfjellet Fm			Open shelf	Lower Ryazanian - Valanginian (bivalves- forams)	Foraminifera Palynomorphs Bivalves Belemnites	Claystone, silty, reddish brown	
	Wacke, Pack - grainstone, light grey, dolomitic	Nannofossils Bivalves Foraminifera	Valanginian - Lower Hauterivian (nanno, bivalves)	Shallow Shelf (condensed)				Shallow shelf	Uppermost Volgian - Lower Ryazanian (bivalves, forams)	Bivalves Foraminifera Palynomorphs	Wackestone, grey-green	
	Claystone/silt- stone, dark grey	Palynomorphs	Kimmeridgian - Volgian (paly)	Open Shelf	Agardhfjellet Mb, Janusfjellet Fm	"Upper Jurassic"						
D84-45	Claystone, dark grey	Palynomorphs	Kimmeridgian - Volgian (paly). Ryazanian (less problem)	Open Shelf	Agardhfjellet Mb, Janusfjellet Fm							
						"Upper Triassic" Kapp Toscana Gp.	De Geerdalen Fm (lith, age)	Shallow marine	Late Triassic (paly)	Palynomorphs	Sandstone, (immature)	D85-0
D84-27/1	Sandstone	Palynomorphs	Early Triassic (Paly)		Sassendalen Gp Urd Fm	"Lower Triassic", Sassendalen Gp.	Sassendalen Gp Botneheia Mb (lith, age, paly)	Open Marine	Ladinian or ?Anisian (paly)	Bivalves Palynomorphs	Shale, silty, carbonaceous, grey	D85-K
							Sassendalen Gp Urd Fm (lith, age, paly)	Shallow marine	Griesbachian (ammonite, paly)	Ammonites Bivalves fish palynomorphs	Siltstone, grey	Dia84-2
D84-22/1 D84-22/2	Packstone, part. silicified	Brachiopods Bryozoa, Forams Sponge spicules Ostracods Echinoderms Palynomorphs		Moderate to high energy marine	Tempelfjorden Gp Most similar to the Miseryfjellet Fm on Bjørnøya Based on lithology macrofossils e.g unspecified brachiopods & bryozoa and palynology	"Upper Permian" Tempel- fjorden Gp.		Marine High energy	Permian (lith)	Bryozoans Brachiopods Echinoderms	Packstone	
D84-23/2	Packstone, mod. silicified	Bryozoa Echinoderms Brachiopods Forams		Moderate to high energy marine			Tempelfjorden Gp Most similar to the Kapp Starostin Fm on Spitsbergen	Neritic	Permian/Mid-Upper (paly)	Palynomorphs Sponges	Siltstone, dark grey, chert cemented, bio- turbated, spiculitic	Dia84-31
D84-24/2	Wackestone/ Packstone, spiculitic Chert	Bryozoa, Forams Echinoderms Brachiopods Sponge spicules		Open marine				Marine	Indeterminant	Bryozoa Brachiopods Echinoderms Forams Sponge spicules	Wackestone, silicified	D84-10/3
D84-25/1	Wackestone, silicified	Bryozoa, Sponge spicules, Echinoderms Brachiopods Forams		Marine				?Shallow marine	Indeterminant	Bryozoa, Brachiopods Echinoderms	Wackestone, Cherty	D84-7/1
D84-28/3	Packstone, variable silicification	Brachiopods Bryozoa Sponge spicules Forams Echinoderms	Indeterminate	Shallow marine			Based on lithology macrofossils, e.g. unspecified brachiopods and bryozoans. Palynology and ichnology	Neritic marine low energy		Echinoderms Forams, Bryozoa Palynomorph	Wackestone/Mudstone silicified	D84-14/1
D84-29/2	Packstone	Bryozoa Brachiopods Forams Trilobite Sponge spicules	Indeterminate	Marine				Neritic	Indeterminant	Brachiopods Bryozoa Sponge spicules	Spiculitic Chert and Wackestone	D84-6/1
D84-31/1	Wackestone, heavily silicified	Brachiopods Bryozoa Forams, Sponge spicules	Indeterminate	Quiet marine				Marine Low energy	?Upper Permian (paly)	Echinoderms Brachiopods Forams Ostracods Bryozoa, Sponge spicules Palynomorphs	Siltstone, silicified carbonaceous	D84-5/1
D84-36/1	Packstone	Bryozoa Brachiopods Echinoderms Acritarchs	Indeterminate	Marine				Neritic Zoophycus	Permian: Mid-Upper (paly)	Sponge spicules Palynomorphs	Siltstone, part. silicified, bioturbated	D84-13/1
D84-37/1	Wackestone/ Packstone, moderate silicification	Bryozoa Brachiopods Forams, Sponge spicules	Indeterminate	Marine				Neritic	Permian: Mid-Upper (paly.)	Brachiopods, Sponge spicules Palynomorphs	Siltstone, silicified	D84-16/1
D84-38/2	Wackestone/ Packstone, silicified	Bryozoa Brachiopods Echinoderms Sponge spicules	Indeterminate	Shallow marine		"Lower Permian/ Carboniferous	Gipsdalen Gp (litho)	Evaporitic	Indeterminate	Wood fragments poorly Pres'd Palynomorphs	Sandstone/Mudstone alternating laminae and Gypsum	D84-4/1
D84-32/1	Wackestone, Dolomitic	Bryozoa Echinoderms Brachiopods	Indeterminate		?Gipsdalen (litho)	Gipsdalen Gp.		Marine	Permian (Paly)	Bryozoa Echinoderms Brachiopods Acritarchs Palynomorphs	Packstone/Wackestone Silicified	D84-2/1
D84-35/1	Siltstone w. Dolomite and Limestone beds	None recorded ?Acritarchs	Indeterminate		?Gipsdalen (litho)				Indeterminate	None recorded	Carbonate, silicified Claystone, brown, Sandstone, fine	D84-3/2
D84-33/2	Dolomite, strongly frac- tured	None recorded	Indeterminate		?Gipsdalen (litho)		Gipsdalen (fusul) (litho)	?Open marine	Permian - Carboniferous Boundary (fusul)	Brachiopods Sponge spicules Ostracods Echinoderms Bryozoa, Forams Fusulinids Palynomorphs	Interbedded Wackestone veryfine Sandstone and Siltstone, both silicified	D84-15/1
D84-34/1	Dolomitic Breccia in sandy matrix	None recorded	Indeterminate		?Gipsdalen (litho)		Gipsdalen Gp (fusul) (litho)	Marine Shelf	Carboniferous/Late Gzelian (fusul)	Bryozoa Brachiopods Forams Echinoderms Fusulinids	Grainstone/Packstone partly silicified	D84-12/1
							Gipsdalen Gp (?Hambergfjellet Fm) (fusul, litho)	Shallow open marine	Permian: ?Lower (?Sakmarian) (fusul)	Echinoderms Bryozoa Brachiopods Forams Gastropods Ostracods Fusulinids	Breccia divides core into 2 units upper = LS, grey, strongly fractured with Silt and Chert, Lower = LS, grey	Dia84-11
								Open marine	Indeterminate	Bryozoa Brachiopods Forams Echinoderms	Packstone/Wackestone fractured. Barite filled fractures	D84-11/1
							Gipsdalen Gp (litho)	Evaporitic	Carbon - Lower Permian	Fusulinids	Wackestone with Gypsum	D85-W

4.2 Lithostratigraphical and biostratigraphical correlations Carboniferous - Triassic

The samples have been grouped in map units combining all available information. The geographical relationships between individual samples as well as the sub- or superposition of individual samples as seen on the seismic records are one of the main criteria for referring the samples to individual units. The characterization of the map units as representing different rock types, age units and also the differences between the units depend, however, on the sampled material. In this way a local stratigraphy has been made in the different areas. The superposition principle has thus worked well in the Dia-Structure area and for the younger rocks. On the Stappen High the quality of the seismic data and abundant faulting only permitted such grouping at a more tentative level for the Permian-Carboniferous rocks. The lithological and palaeontological information was thus of help in defining lithological units and in the construction of the geological map on the Stappen High.

Technical information for all the samples which are obtained from in situ bedrock is summarized in Table 4.1 while correlations between the samples, map units and lithostratigraphical units on Svalbard are given in Table 4.2.

The samples may easily be correlated with the depositional units at group level on Bjørnøya and Spitsbergen. More detailed correlation is also possible for several of the cores, and in a few occasions such a more precise correlation has been done.

All except for the oldest of the post Caledonian stratigraphical groups on Svalbard (Billefjorden Group) are represented by samples from the drilling program in the Barents Sea (Table 4.2).

4.2.1 "Lower Permian/Carboniferous" map unit - Gipsdalen Group

The oldest samples obtained from the Dia-Structure and the Stappen High are referred to this map unit. The unit is dominated by carbonates, both limestones and dolomites, but sandstones and shales are also

present. In two samples gypsum has been located showing the presence of evaporites (Fig. 4.1).

Palaeontological dating of this unit has been problematic. Palynomorphs have only produced age information for one core which was of unspecified Permian age. Three cores contained fusulinids, and these clearly are of different age. The drillship core Dia84-11 contains a fauna resembling what has been found in the Hambergfjellet Formation on Bjørnøya, while the fusulinids of core D84-15/1 indicate a stratigraphic position near the Carboniferous boundary. In core D84-12/1 an unspecified Carboniferous - Lower Permian age is indicated.

Macrofossils are also common in most of the cores from this unit, but although they indicate similarities with the land geology, more thorough study is required before any positive conclusions can be made. The general macrofossil evidence may therefore be given by the lithology.

This map unit is correlated with the Gipsdalen Group on Svalbard which was deposited from the Bashkirian to Artinskian, and shows a great variety in lithologies. The group is dominated by carbonates, mainly dolomites, and the group also contains several intervals of evaporites, exposed as gypsum or anhydrites, as well as solution breccias. Part of the group is fossiliferous, and earlier correlations are mainly based on fusulinids (Cutbill & Challinor 1965) and brachiopods (Gobbett 1963), however other fossil groups have also been used.

At Bjørnøya, the Gipsdalen Group slightly exceeds 500 m in thickness, and it is subdivided into 4 formations: The Kapp Kåre Formation overlain by the Kapp Hanna, Kapp Duner and Hambergfjellet Formations (Fig. 1.2). The Kapp Kåre Formation is dominated by limestones and cherty carbonates, but also contains minor amounts of shale, while the overlying Kapp Hanna Formation consists of alternating beds of mudstone and sandstone. Of major interest is the Kapp Duner Formation with its reef structures consisting of carbonate buildups of Palaeoaplysina. Towards the top this formation also contains organic rich and very fusulinid rich limestones. Uppermost in the Gipsdalen Group is the Hambergfjellet Formation separated with erosional unconformities at base and top from the remaining part of the succession.

The duration of these breaks is at present not well understood, and time equivalent beds may have been deposited in nearby areas during these periods. Fusulinids have previously not been reported from the Hambergfjellet Formation, but were collected on the IKU expeditions in 1984 and 1985.

Lithologies which may be correlated with the Gipsdalen Group have been found both in the Dia-Structure and Stappen High areas, and except for the samples containing fusulinids the correlations have mainly been based on lithological evidences. Neither fusulinids nor evaporites have been recorded in the literature from rocks overlying the Gipsdalen Group, and presence of either of these is a very strong indicator that the sample may be correlated with this group. The Gipsdalen Group was deposited over a long geological period and contains a variety of units, and problems are encountered in correlating the samples with either chronostratigraphical units or more directly with the formations on land.

Clear relationships between the individual cores are problematic, however, several comments may be given to individual cores. A grey, very fossiliferous limestone, (Dia84-11) contains abundant fusulinids, which show similarities with specimens from the Hambergfjellet Formation, although this correlation is at present not verified. Core D84-15/1, also contains fusulinids, these resemble what has been recovered from the Brucebyen Beds at Spitsbergen, i.e. at the extreme basal part of the Permian, or close to the Carboniferous/Permian boundary. These indications are slightly contradictory to what we would expect from the seismic data, and we would therefore like to comment that at present all fusulinid ages indicate unspecified Middle Carboniferous to Lower Permian ages. The presently suggested correlations are therefore tentative.

Other correlations have to be mainly based on lithologies as the fossil content is not age diagnostic. Lithologies dominated by dolomite and containing evaporites are reported from the surrounding land areas to be represented throughout the period from Bashkirian to Artinskian, and without further evidences we may only suggest a general correlation with the Gipsdalen Group.

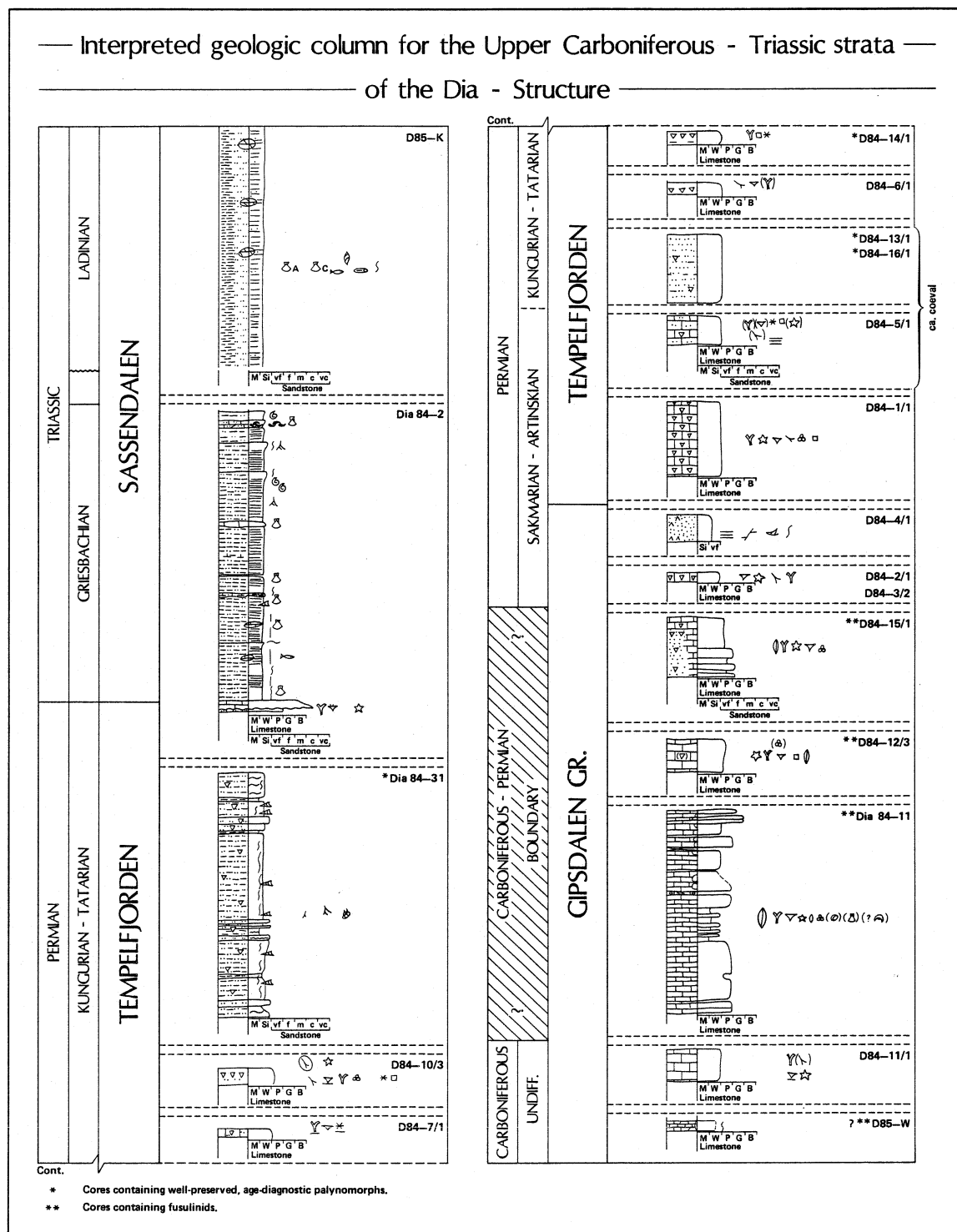


Fig. 4.1 Tentative internal correlation of the Dia-Structure cores.

All the analysed samples from this map unit have a low organic carbon content and contain little pyrolysable kerogen. This suggests that the unit has no hydrocarbon generation potential. This contrasts with the basal Permian both on Bjørnøya and Spitsbergen which contains abundant organic material of good hydrocarbon source material. A brief summary of the organic geochemical analyses is presented in Table 4.3.

4.2.2 "Upper Permian" map unit - Tempelfjorden Group

A thick sequence of rocks occurs between the Lower Permian/Carboniferous map unit and the marked seismic reflector found to represent the Palaeozoic/Mesozoic boundary. The unit is well defined in the Dia-Structure area, but in the Stappen High area the same problems as met in the underlying unit still apply.

The "Upper Permian" map unit is dominated by limestones, with varying degree of silicification. The limestones mostly are very fossiliferous. Parts of the unit also contain mudstones. From the collected samples there seems to be a tendency towards more bioclastic, coarse-grained very fossil rich lithologies in the Stappen High area than in the Dia-Structure area. This corresponds well with the geology on Bjørnøya, where the Miseryfjellet Formation is dominated by such bioclastic limestones. More fine-grained, more strongly silicified wacke - and - or - mudstones on the other hand dominate in the Dia-Structure area, although also here interbedded with coarse bioclastic limestones. This facies resembles the development of the Kapp Starostin Formation as seen in central Spitsbergen where this unit has a basinal development.

Although lithological evidences for correlation of these units with the land areas are very strong, direct age information is sparse. Several of the samples from the Dia-Structure area do, however, contain palynoflora which is similar to palynoflora studied by IKU from the Spitsbergen Tempelfjorden Group, particularly the Kapp Starostin Formation. The correlative unit on Svalbard to this map unit, is the Tempelfjorden Group which will be commented on below.

Table 4.3 Summary of organic geochemistry of selected samples. Note that the data were obtained on the available samples and will not necessarily reflect the organic geochemistry of the whole group/map unit.

STAPPEN HIGH		MAP UNIT	DIA-STRUCTURE AND EASTERN AREA	
SAMPLE	ORGANIC GEOCHEMISTRY		ORGANIC GEOCHEMISTRY	SAMPLE
D85-V	Clst/Siltst: Poor TOC. (Catagenic gas in Quaternary overburden).	"TERTIARY	Clst: Fair TOC, Type III/IV kerogen, thermally immature (0.42%Ro; 417°C Tmax).	C85-A C84-48
D85-J	Clst: Good TOC, type III kerogen, thermally mature. Mature catagenic gas in 1st in unit B.	"Lower CRETACEOUS" (Adventdalen Gp)	Clst: Fair-good TOC, Type II/III or III kerogen, early thermal maturity. (units A-C have poor TOC).	D85-N
D85-J	Clst: Good TOC, type II/III kerogen, thermally mature.	"Upper JURASSIC" (Adventdalen Gp)		
D84-45	Clst: Good TOC, Type II/III kerogen, thermally immature to early mature.			
		"Upper TRIASSIC" (Kapp Toscana Gp)	Sst: Poor-fair TOC, type III kerogen, thermally mature. Traces of hydrocarbons. Clst: Fair TOC, type III (locally II/III) kerogen, early thermal maturity.	D85-0 D85-K
D84-27	Sst: Poor TOC, type IV-III or IV kerogen.	"Lower TRIASSIC" (Sassendalen Gp)	Clst: Fair-good TOC, Type III to II/III kerogen, immature to early mature. Catagenic gas.	Dia84-2
D84-29	Lst: Fair TOC, little pyrolyseable organic matter.	"Upper PERMIAN" (Tempelfjorden Gp)	Lst: Poor TOC, type III/IV kerogen, thermally immature. Siltst: Fair TOC, type III kerogen, moderate-thermal maturity. Lst/Siltst: Poor to fair TOC, type III or III/IV kerogen, moderate maturity to thermal maturity.	Dia84-2 Dia84-31 D84-1 D84-5 D84-13
D84-35	Sst/Lst: Poor TOC, little pyrolyseable organic matter.	"Lower PERMIAN?" (Gipsdalen Gp)	Sst/Lst: Poor TOC, little pyrolyseable organic matter Lst/Sst: Fair-poor TOC, type III kerogen, thermally mature. Lst: Poor TOC.	Dia84-11 D84-4 D84-15 D85-W

At Bjørnøya the Tempelfjorden Group is represented by the Miseryfjellet Formation which is dominated by fossiliferous rubbly limestone. A sand bar complex occurs in the middle part of the unit. At Spitsbergen a more basinal development of the equivalent Kapp Starostin Formation also contains fossiliferous limestones at the base and occasionally higher in the sequence. The major part of the unit is characterized by cherty shale and fine-grained carbonate, very often with characteristic trace fossil development (Zoophycus). The chert is mainly derived from sponge spicules, such spicules are often recognized in thin-sections.

Lithologies which may be correlated with the Tempelfjorden Group are abundant both in the samples from the Dia-Structure and the Stappen High.

As a result of our Permian palynology of Svalbard projects, palynoassemblages have been recognized that are characteristic referable to the Kapp Starostin Formation. Similar assemblages have been recorded in five of the drilled cores in the Dia-Structure area. Macrofossils are often only available as fragments in cores, but nevertheless they may be of value for correlation. A Tempelfjorden Group fauna (especially bryozoans) are common both in cores from the Dia-Structure and the Stappen High.

The abundant spiculites, presence of the trace fossil Zoophycus and the general fine-grained lithology show much stronger similarities for the Dia-Structure samples with the development of the Kapp Starostin Formation on Spitsbergen than the Miseryfjellet Formation on Bjørnøya. This indicates that going southwards from Bjørnøya and also southeastwards towards the Dia-Structure area basinal facies comparative to the central Spitsbergen are seen, and not the higher energy deposits as occur at Bjørnøya.

One typical sample from the Stappen High was analysed for organic matter content and type, although little pyrolysable material was found. This could correspond to the high maturation level as is found on Bjørnøya. In the Dia-Structure area, the carbonate lithologies contain little organic carbon. However, the silicified fine-grained clastic rocks in this area have a fair organic carbon content of around 1 wt%. This organic matter consists of type III kerogen of poor

hydrocarbon generation potential. The maturation level of the Dia-Structure samples varies from immature to mature. A more basinal setting, as seen in the equivalent Van Hauen Formation of the Sverdrup Basin, may provide more organic-rich lithologies elsewhere in this unit.

4.2.3 "Lower Triassic" map unit - Sassendalen Group

A relatively homogeneous unit above the Palaeozoic/Mesozoic seismic reflector is assigned to the "Lower Triassic" map unit. Preliminary datings and comparisons with neighbouring areas indicate that this map unit comprises both Lower and Middle Triassic rocks.

The unit consists of fine-grained clastic rocks, in the neighbouring land areas these occur as coarsening upwards sequences. This interval also contains good to excellent hydrocarbon source rocks on Svalbard and is therefore of major importance. Varying amounts of sand and siltstone occur depending on the palaeogeographical setting. Thin limestone beds and abundant calcite cementation also occur. In the Middle Triassic rocks phosphate nodules occur in equivalent units throughout the Arctic. Dating of these units may be more accurate than in the Palaeozoic succession, although the palynomorphs are often poorly preserved due to oxidation or sapropelization. Macrofossils may give supporting evidence for dating. In the Dia84-2 core ammonites were found, and these give good age control. The correlative unit on Svalbard is the Sassendalen Group which will be commented on below. The Sassendalen Group on Svalbard is of Lower and Middle Triassic age and is dominated by shales although sandstones occur in the area. The whole group contains good source rocks for hydrocarbons and the Middle Triassic shales provide the richest oil source rocks presently known in the arctic areas. The age of the group is well established by ammonites. Palynological studies are also useful, however, the reference framework is at present being improved.

Two cores are referred to this group. Core Dia84-2 penetrated the Triassic-Permian boundary, and ammonites were recovered in the shale giving a late Griesbachian (commune zone) age. The lithology of the core strongly resembles the Lower Triassic beds (although not the basal) as

seen on Bjørnøya (Urd Formation) and on Spitsbergen and Edgeøya (Deltadalen Member).

The sandstone in core D84-27 was the only sample obtained from this map unit on the Stappen High. It contained a sparse palynoflora of Early Triassic age which can be correlated to any of the sandy intervals in the Early Triassic. The sandstone contained little organic matter and further samples will be requested to evaluate the hydrocarbon generation potential of this unit in the Stappen High area.

The shale samples from the Dia-Structure area have a fair to good organic matter content comprised of a mixed type II/III to type III kerogen and may have a fair hydrocarbon generation potential. The maturation level of the samples varies from immature to early maturity. The Lower Triassic samples are very similar to samples analysed from equivalent beds on Bjørnøya. It should, however, be remembered that the lowermost part of the Triassic succession has a lower organic matter content than higher parts of the succession. Middle Triassic dark shales are regarded as the best source rock interval occurring on the Svalbard archipelago, despite the occurrence of local, more organic lean intervals.

4.2.4 "Upper Triassic" map unit - Kapp Toscana Group

The base of the "Upper Triassic" map unit is set at the top of a prograding sequence with several internal seismic reflectors. Core D85-K at the Dia-Structure was obtained from the extreme lower part of the "Upper Triassic" map unit. The boundary between the "Lower" and "Upper Triassic" map units probably is of Mid Triassic age. More data is required to distinguish the upper boundary of the map unit with the overlying "Jurassic" map unit.

The Kapp Toscana Group on Svalbard is dominated by sandstones, but shales are also important constituents of the group. The sediments were deposited in shallow marine and deltaic environments. In the lower part of the group the sandstones are highly immature while reworking has produced mature sandstones in the upper part of the group.

The D85-K core penetrated a dark grey shale with abundant small bivalve fragments of Daonella/?Halobia which indicate a Ladinian to Carnian age. If Halobia is present a Carnian age would be favoured. Bivalves similar to those seen in the core are very abundant on Svalbard in the beds of the Botneheia Member in the Sassendalen Group. Further analyses are expected to clarify this dating problem. As for the Sassendalen Group the reference framework in palynology is at present being improved, and seems to have some potential for dating.

The shales of core D85-K have a fair organic matter content of a mixed type II/III kerogen which may have a fair hydrocarbon generation potential. The maturation level varies from immature to mature. The abundant fauna in the core indicates oxidizing depositional conditions, suggesting that the depositional basin was open. The observations show that further study of this unit is needed also for a better evaluation of its source rock potential.

The fine-grained sandstone in core D85-0 contains a sparse palynoflora indicating a possible Late Triassic age. The sandstone is also very immature with a high content of feldspars. Both the age and the mineralogy suggest a correlation with the De Geerdalen Formation on Svalbard.

The core has a poor organic carbon content with negligible hydrocarbon generation potential. Traces of migrated hydrocarbons were observed in the sandstone.

4.3 Lithostratigraphical and biostratigraphical correlations Middle Jurassic - Tertiary

The Middle Jurassic - Cretaceous sequence is dominated by clastic, mainly fine-grained rocks in the northern part of the studied areas. Minor limestones also occur and may be of major stratigraphical importance. On Svalbard the equivalent rocks form the Adventdalen Group, and on this archipelago the Upper Cretaceous is missing. A major break in sedimentation is regionally thought to have happened close to the Jurassic - Cretaceous boundary. This break in sedimentation subdivides the dark claystones at the Janusfjellet Formation on

Spitsbergen into the lower Agardhfjellet Member of Jurassic age, and the Rurikfjellet Member of Cretaceous age. The source rock potential for the Agardhfjellet Formation is good for both oil and gas while the potential for the Rurikfjellet Formation is fair to good for gas (Mørk & Bjørøy 1984). The break in sedimentation observed on Spitsbergen is tentatively correlated with the Late Kimmerian unconformity as seen in seismic data and cores. This break defines the boundary between the "Jurassic" and "Cretaceous" map units in our investigation.

Below a more detailed discussion of the internal relationship of the IKU cores will be given, followed by further comments on their relationships with the land geology.

Bedrock of Jurassic and Cretaceous age has been recovered from an area to the east of Bjørnøya and from the eastern part of the Stappen High. These localities include: D84-43/1, D84-44/1, D84-45/1 and D85-J from Stappen High and D85-N from east of Bjørnøya. D84-43, -44, -45 are short sea bed cores ranging in length from 0.12 - 0.22 m. D85-J and D85-N are drill-ship cores of lengths 34.1 and 14.5 m, respectively.

Both D85-J and D85-N penetrated carbonate beds, but the dominant lithology of the Mid to Late Mesozoic appears to be claystones, shales and siltstones.

Our interpretation of the chronostratigraphic relationship of D85-J and D85-N is illustrated in Figure 3.5. The cores D84-43, -44, -45 are not shown in this figure, but they will be integrated into our description of D85-J and D85-N. The bedrock recovery of these two latter cores has been divided into 3 and 4 sedimentary units, respectively, designated A-D. In terms of both sediment and fossil characteristics, D84-45/1 closely resembles unit A of D85-J, which is 2.9 m long and consists of a coarsening upwards section of grey clayey sandy siltstone. Both this unit and the muscovite-rich claystone of D84-45/1 are barren of fossils, except for sparse palynofloras that can be dated only as Kimmeridgian to Ryazanian. The generally restricted species composition of palynofloras of this age and region (the Paragonyaulacysta borealis assemblage) results in reduced biostratigraphic resolution in high latitudes. The flora in D85-J, unit A, is somewhat more diverse than that of D84-45/1, but it is regrettably no more age diagnostic.

Missing from D85-J are sediments of Ryazanian age and possibly Late Volgian and Early Valanginian age as well. Abundant glauconite in the lower 0.5 m of unit B can be interpreted as additional evidence of an episode of slow or nondeposition. Abundant occurrences of bivalves (Buchia) in unit B firmly date this 3.3 m carbonate as Valanginian in age. The mutually exclusive distributions of Buchia keyserlingi and Buchia sublaevis is suggestive of a condensed section containing both Lower and Upper Valanginian sediments. The lower part of unit B has undergone successive phases of dolomitization and ankeritization. Palynomorphs are the only age diagnostic fossils preserved in the 27.9 m thick section of silty claystone and clayey sandy siltstones of unit C, D85-J. The palynoflora bears weak evidence of a Late Hauterivian age, but Barremian is the most probable age for these sediments. In terms of lithology, age and fossils, D84-43/1 and unit D of D85-N are very similar to unit C of D85-J. Below unit D of D85-N, there is no palynological age control. Buchia biostratigraphy indicates that the lower 2 m of unit C are essentially time correlative with unit B, of core D85-J. A confident age for the upper 2.5 m of unit C, D85-N, has not been obtained. Inoceramids and forams indicate a possible, aberrantly young age for these strata (Albian), which is inconsistent with the Barremian age for unit D.

With the exception of the presence of sparse forams and the absence of extensive diagenetic alteration, the wackestones of unit C, D85-N, are lithologically similar to those of unit B, D85-J.

There are no sediments in core D85-J equivalent to units A and B of core D85-N. The unit B/unit C contact appears to be highly deformed, but the variegated sediments of the transition zone probably resulted only from oxidation. Unit B consists of 5.7 m of reddish brown silty claystones containing abundant bivalves and sparse forams. Its age is Ryazanian to Early Valanginian. Unit A consists of 0.7 m of greyish green wackestone of Ryazanian age.

The youngest Cretaceous sample obtained is from the Stappen High (D84-44/1), where a 0.17 m grey claystone core was palynologically dated as Aptian-Middle Albian.

Paleocene cores were obtained on the Loppa High, close to the Hammerfest Basin (C84-48) and off Nordkapp, between the Hammerfest and Nordkapp Basins (C85-A). Both cores consisted of dark grey claystone rich in palynomorphs.

Core D85-V was obtained on the Stappen High to the west of the northerly striking Tertiary fault zone on the western part of the High. Palynomorph datings gave an Eocene age. The core contained mainly sand, deposited in a deltaic environment. A Quaternary sample from this site had a very high gas content of catagenic origin which may be associated with a mature source.

4.3.1 "Middle and Upper Jurassic" map unit

This unit has been penetrated by two cores (D84-45 and D85-J), both from the eastern margin of the Stappen High. As we have no reliable seismic or well control to define the base of the unit, this will have to be set tentatively.

The unit is upward terminated by the Late Kimmerian unconformity, which can be regionally correlated from the Hammerfest Basin. Both cores resemble the dark claystones occurring in the Agardhfjellet Member of the Janusfjellet Formation of Svalbard. The lithological similarities are supported by similarities in the palynoflora which also supply the evidences for the palaeontological dating.

The claystones in the cores have a good organic matter content consisting of relatively hydrogen-rich type II/III kerogen which is thermally immature to mature. This unit has a good hydrocarbon source potential.

4.3.2 "Cretaceous" map unit

In the summary map (Fig. 1.1) the "Cretaceous" map unit is defined to have its lower boundary at the Late Kimmerian unconformity and continue up to Paleocene sediments characterized by strong and continuous seismic reflectors. In the Dia-Structure area only rocks referable to

the lower part of this unit are thought to be present. Close to Bjørnøya the presence of a younger series of sediment have lead us to include an "Upper Cretaceous" map unit although no sample material from this unit exists. The division into an "Upper" and "Lower Cretaceous" map unit is carried through only in the Stappen High and Bjørnøya East areas.

"Lower Cretaceous" map unit

Good samples from this unit are given by the D85-J and -N cores south-east and east of Bjørnøya as well as by two short sea bed cores (D84-43 and -44) close to D85-J. The correlation between these samples has been discussed above, and only some regional comments will be given.

In both the long cores (D85-J and -N) limestones occur in the basal part of the unit. Such limestones are not known from the Svalbard area, however, in drilling further south (commercial drilling and IKU shallow drilling off Helgeland (Bugge et al. 1984)) equivalent limestones are present. Further information of this unit is needed to improve correlations and understand its development. The limestone unit of D85-J contained both catagenetic gas and heavier migrated hydrocarbons.

The thin unit B of core D85-N consists of reddish brown claystone of insignificant hydrocarbon source potential. The unit is assigned a Lower Ryazanian - Valanginian age from the Buchia and foram study. This subunit seems to belong to the partly condensed Lower Cretaceous period and further informations are needed also for this unit to help in correlations. It should be remarked that a similar setting with grey and red-brown Hauterivian-Lower Barremian claystone overlying a latest Ryazanian to Lower Valanginian limestone also occurred off Helgeland (Bugge et al. 1984; Aarhus et al. 1986).

The upper part of both core D85-N and D85-J as well as sample D84-43 consist of dark grey claystone dated by palynology to be of Hauterivian to Barremian age. Both the lithology and age suggest a correlation with the Rurikfjellet Member of the Janusfjellet Formation as it occurs on Spitsbergen. This member correlates with unit D of core D85-N, which contains claystone with a fair to good organic richness of type II/III

or type III kerogen of early maturity. On Spitsbergen, the Rurikfjellet Member is dominated by type III kerogen.

One sample from the eastern side of the Stappen High (D84-44) also consisting of dark grey claystone, has been dated by palynology to be of Aptian to Middle Albian age. Claystones of a similar age are known to be extensively developed further south on the Barents Shelf. The equivalent interval on Spitsbergen consists of fine-grained sandstone, siltstone and shales, referable to the Carolinefjellet Formation. On Spitsbergen this formation is dominated by type IV kerogen and has no hydrocarbon source potential.

The whole "Lower Cretaceous" map unit consists of heterogeneous lithologies. The dark shales seem to correlate well with the Rurikfjellet Member on Spitsbergen and have some hydrocarbon source potential. Correlations of the other parts of the "Lower Cretaceous" map unit require more samples for further analyses.

"Upper Cretaceous" map unit

No samples exist from this unit which is mapped in the Stappen High and Bjørnøya East areas. The mapping is based on the correlation of a subcropping reflector which is stratigraphically higher than the Aptian to Middle Albian sample D85-44 from the Stappen High. At Svalbard the entire Upper Cretaceous is missing, due to the upheaval of the archipelago accompanying the processes leading to the opening of the Norwegian Sea. Younger sediments on land are of Albian age and renewed sedimentation started in Paleocene as a direct result of the tectonic activity on Spitsbergen. Further information is needed to evaluate the presence and duration of a possible hiatus in the uppermost Cretaceous.

4.3.3 "Tertiary" map unit

The "Tertiary" map unit comprises all sediments overlying the relatively strong reflector correlated as the Tertiary/Cretaceous boundary. This unit is overlain by the usually more flatlying

Quaternary overburden. The base Quaternary is in most places defined by an angular unconformity, but there is reason to believe that Pliocene and may be some Miocene sediments occur in some areas as erosional remnants above the unconformity. At present no suggestions for correlating the Tertiary samples to onshore areas are presented.

5. HEAT FLOW MEASUREMENTS

5.1 Field methods

High resolution temperature measurements (estimated resolution 0.008°C and absolute accuracy of 0.02°C) performed in shallow boreholes (down to about 65 m below sea bed) have been combined with thermal conductivity measurements on Quaternary samples from the corresponding depth intervals in the same boreholes. This method has provided heat flow values from 6 sites in the Barents Sea (Sættem et al. 1985). The data in this field data report was, however, hampered by a computer input error resulting in all the values being reported too low by a factor of 1.799.

5.2 Corrections of the thermal conductivity

In the IKU report 21.3405.00/03/86 the above sited error is thoroughly checked and possible effects on the thermal conductivity from the difference in temperature and pressure between in situ and laboratory conditions have been quantified.

The following effects have been found significant:

1. The thermal conductivity measurements on the samples from sites D85-N, D85-O and D85-V gave values that on average were 16%, 8% and 4% too low, respectively. This is an effect of gas voids forming in the samples under laboratory conditions. 
2. The on board thermal conductivity measurements largely represent the horizontal thermal conductivity. However, 28 representative samples have later been subjected to measurement of both horizontal and vertical thermal conductivity, and those are found to differ by a factor of 1.13. For the purpose of calculating vertical heat flow we therefore suggest that all the measured thermal conductivities are 10% too high and should be multiplied by a correction factor of 0.91 ($0.91 = 1/1.1$).

5.3 Correction of temperature gradients due to climatic perturbations

The temperature history models presented by Sættem et al. (1985) have been refined and the resulting transient effect on the measured temperatures and temperature gradients are calculated (IKU report 21.3405.00/03/86). The probable maximum (model I) and minimum (model II) effects on measured temperature gradients are summarized in Table 5.1 below.

Table 5.1 Maximum and minimum disturbance based on temperature history models I and II.

Site	Depth (m)	Temperature gradient disturbance ($^{\circ}\text{C m}^{-1}$)	
		Temperature history model I Thermal diffusivity $0.4 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ ($10^{-3} \text{ }^{\circ}\text{C m}^{-1}$)	Temperature history model II Thermal diffusivity $0.6 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ ($10^{-3} \text{ }^{\circ}\text{C m}^{-1}$)
C85-A	0-50	-6.2	-3.6
C85-E	"	-5.9	-3.5
D85-H	"	-5.9	-3.6
D85-I	"	-3.2	-1.9
D85-K	"	-3.5	-1.9
D85-N	"	-3.2	-1.6
D85-O	"	-1.1	-0.1
D85-V	"	-3.2	-1.9
D85-W	"	-3.5	-1.9

5.4 Final heat flow values

For a more detailed discussion of the various alternative corrections to the measured heat flow reference is made to IKU report 21.3405.00/03/86. Table 5.2 below summarizes these corrections expressed as correction factors to be directly applied to the measured heat flow values, accompanied by our suggested final heat flow values.

Table 5.2 Field results, correction factors and final heat flow values.

k_g = correction of thermal conductivity due to gas expansion,

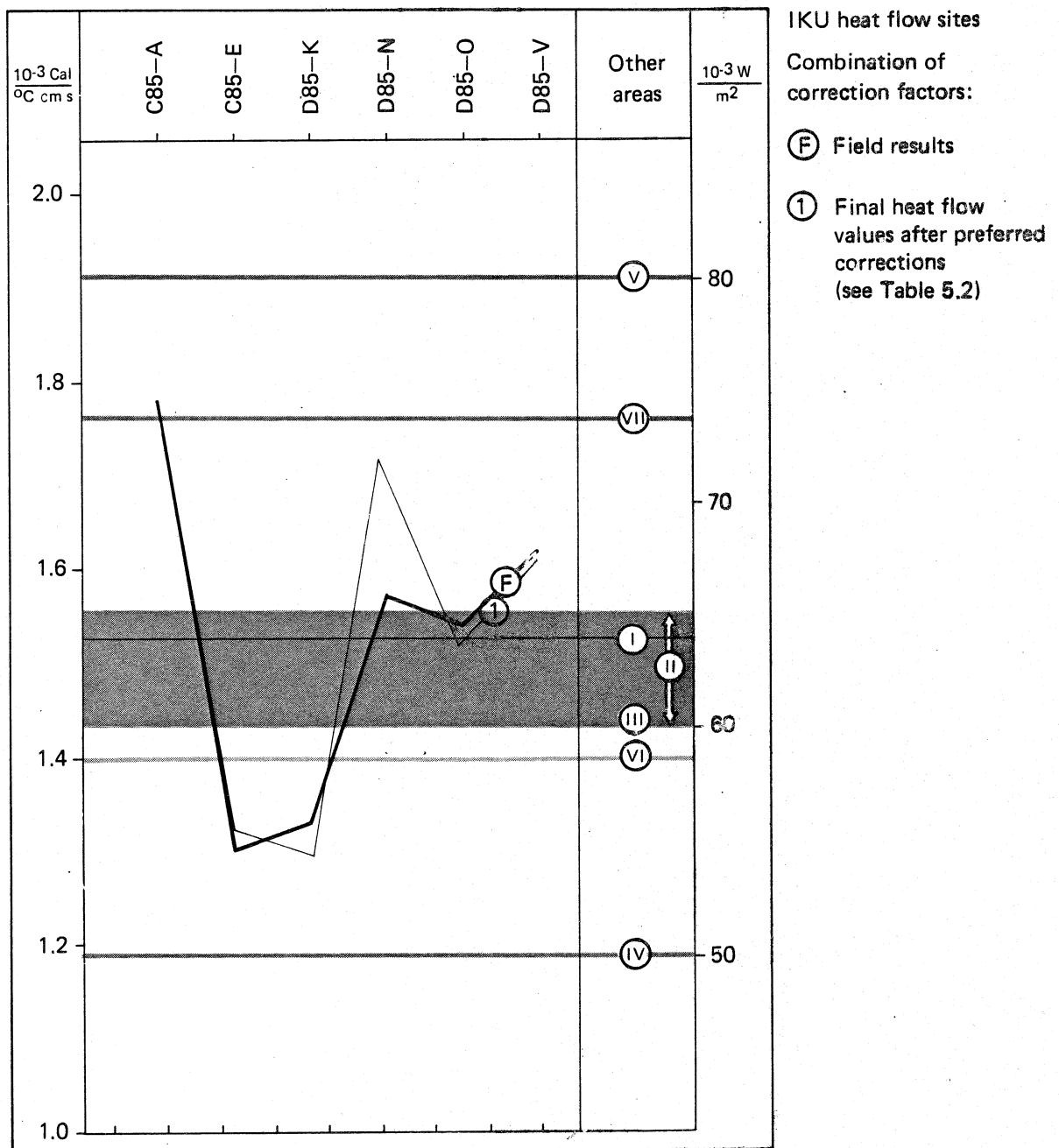
K_A = correction of thermal conductivity due to anisotropy

"Model I" and "Model II" are alternative temperature history corrections to the measured temperature gradients.

The correction factors k_g and K_A and temperature Model II are applied for the suggested final values.

Site	Field results		Correction of thermal conductivity		Correction for glacial history			
	(HFU)	(mW/m ²)	k_g	$k_A = \frac{1}{A_{mean}}$	Model I	Model II	Suggested final results (HFU)	(mW/m ²)
C85-A	1.78	74.5	1.00	0.91	1.15	1.08	1.77	74.1
C85-E	1.30	54.5	1.00	0.91	1.18	1.11	1.32	55.2
D85-K	1.33	55.7	1.00	0.91	1.10	1.06	1.29	54.0
D85-N	1.57	65.7	1.16	0.91	1.08	1.04	1.72	72.0
D85-O	1.54	64.5	1.08	0.91	1.04	1.00	1.52	63.6
D85-V	1.62	76.8	1.04	0.91	1.09	1.05	1.61	67.4

For comparison we present a range of heat flow values published from other areas in Figure 5.1.



- Ⓕ Europe (Čermak 1979)
- Ⓖ North Sea (52° – 56° N) (Andrews – Speed et al. 1984)
- Ⓖ Mainland UK (Richardson and Oxburg 1979 in Andrews – Speed et al. 1984)
- Ⓖ Central Graben and Anglo Dutch Basin (Andrews – Speed et al. 1984)
- Ⓖ Mid North Sea High and East Midland Shelf (Andrews – Speed et al. 1984)
- Ⓖ Continental crust (Lee 1963 in Gretner 1981)
- Ⓖ Mesozoic- Cenozoic orogenic areas (Lee 1969 in Zielinski 1986 a)

Fig. 5.1 Heat flow values from the Barents Sea. Published heat flow values from other areas are shown for comparison.

6. LITERATURE

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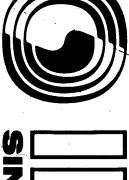
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COMPARISONS and CORRELATIONS



NPD
SINTEF-GRUPPEN