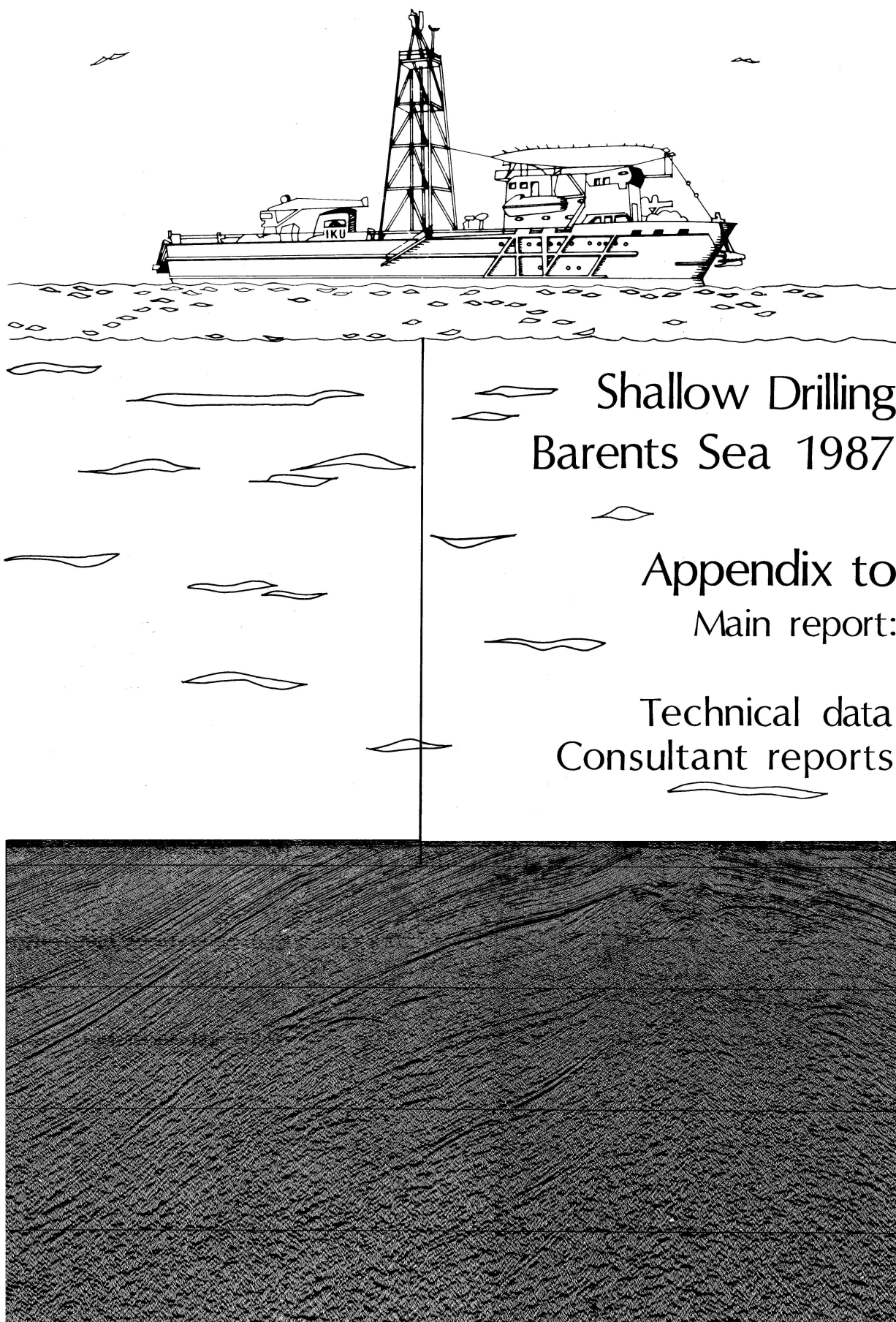




# REPORT

|           |                |
|-----------|----------------|
| REG. NO.: | ACCESSIBILITY: |
| 88.039    | Confidential   |

**REPORT TITLE:**
**SHALLOW DRILLING BARENTS SEA 1987**
**Appendix to main report:  
 Technical data & consultant reports.**
**REPORT NO.: 21.3427.00/04/88**
**AUTHORS:**
**A. Mørk & T. Bugge (eds)**

|                                                                                                                                                                                                                                                                                                                                                                   |                             |                                |                                      |                                   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|--------------------------------|--------------------------------------|-----------------------------------|
| <b>DATE:</b><br>15-MAR-88                                                                                                                                                                                                                                                                                                                                         | <b>NO. OF PAGES:</b><br>151 | <b>NO. OF APPENDICES:</b><br>9 | <b>PROJECT MANAGER:</b><br>Tom Bugge | <b>SIGN.:</b><br><i>Tom Bugge</i> |
| <b>CLIENT:</b><br>Amoco Norway Oil Co., A/S Norske Shell, BP Petroleum Development (Norway) Ltd., Conoco Norway Inc., Deminex (Norge) A/S, Elf Aquitaine Norge A/S, Esso Norge a.s, Fina Exploration Norway, Mobil Exploration Norway Inc., Norsk Agip A/S, Norsk Hydro a.s, Norwegian Petroleum Directorate, Saga Petroleum a.s, Statoil, Total Marine Norsk A/S |                             |                                |                                      |                                   |
| <b>SUMMARY:</b><br><br>This is an appendix volume of the main report in the project "Shallow drilling Barents Sea 1987". The volume contains technical data of the field work and analytical methods, consultant reports on paleontological topics, rock mechanical analysis and thermal conductivity measurements.                                               |                             |                                |                                      |                                   |

|                   |                      |
|-------------------|----------------------|
| <b>KEY WORDS:</b> |                      |
| Barents Sea       | Macrofossils         |
| Finnmark East     | Rock mechanics       |
| Nordkapp Basin    | Thermal conductivity |

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Appendix A.10 Summary sheets and A.11 Core logs are enclosed in the main volume. All organic geochemical analysis data are found in another appendix volume.

## **APPENDIX A.1**

### **FIELD OPERATION**

### A.1.1 General

Main contractor for the drilling operations was Offshore Support Services A/S in Oslo, using the drill ship M/S "Bucentaur" (Figure A.1.1). As bedrock coring machine the DB 1500S from Diamant Boart, Belgium/Norway was used, and Dia-Team, Norway provided diamond drilling staff.



Figure A.1.1. The drill ship M/S "Bucentaur".

A.1.2 Technical data

Drill ship M/S "Bucentaur"

|                                       |              |
|---------------------------------------|--------------|
| Length over all                       | 78.07 m      |
| Breadth moulded                       | 16.00 m      |
| Draft fully loaded                    | 5.55 m       |
| Displacement                          | 4.470 tonnes |
| Gross register tonnage, international | 2.768 tonnes |

|                             |                                                                                                                                                                                      |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main engine:                | Four Wärtsilä diesels, type Vasa 8R22HE, each driving a van Kaick generator of 1200 kW at 1200 RPM, 600V/60 periods AC.                                                              |
| Propulsion units:           | Two azimuthing thrusters with CP propeller in nozzle, make Liaaen.                                                                                                                   |
| Bow thrusters:              | Two tunnel thrusters with CP propeller, make KaMeWa.                                                                                                                                 |
| Dynamic positioning system: | One GEC simplex system with GEC-Elliott 2050 computer, video display and joystick. Positioning reference by deep water tautwire system and by Simrad HPR T209 hydro-acoustic system. |
| Hard-tie winch:             | One Ingersoll Rand, max pull 10,000 lbs, with auto. Failsafe brake.                                                                                                                  |
| Elevator:                   | Wirth, type special pipe pick-up chuck, suitable for 5 1/2" F.H. joints.                                                                                                             |
| Slips:                      | Wirth power slips type B12, with inserts for 5" pipe.                                                                                                                                |
| Heavy lift winch:           | One winch make Pusnes, capacity on single drum 2 lengths each 1200 m wire 36 mm dia. Braking force 90 tonn.                                                                          |

Mud system: Complete dry mud system with mud mixing equipment mud storage, and mud pumps (three X: WIRTH TPK 51/2" x 51/2", 84 HP hydraulic motor, capacity 1600 l/min at 20 bar).

Main drill string

Drill pipe: 2000 m of API-5" Grade E, range II, 19.5lbs/ft with 51/2" tool joints, 4" I.D.

Drill collars: Sixteen, each 5 m long, 7" O.D. and 4" I.D. with 51/2" tool joints.

Diamond core drill system Drilling machine: DBH 1500S electro/hydraulic drill.

Spindle opening: 127 mm

Rotating speed: max 900 rpm.

Drill string: Wireline HR Heavy duty rods O.D. 88.9 mm, I.D. 70 mm, length 10 ft, weight 38 kg. Back-up NR Heavy duty wire line drill rods, O.D. 69.9 mm, I.D. 60.3 mm.

Core barrels: Triple tube, 10 ft with split tube.

Core diameters: HR triple tube 54.2 mm, NR triple tube 38.1 mm.

Drilling capacities: HR - 1000 m, NR 1500 m.

Sea bed template: Fugro SEACLAM with hydraulic pipe clamping system, inclinometers and underwater TV camera.

A.1.3 Standard drilling operation (Figure A.1.2)

- (a) M/S "Bucentaur" moves onto position and sets the dynamic positioning system (D.P.) in operation.
- (b) Seabed re-entry template is lowered to the seabed, and constant tension is applied to the template cables via the template heave compensation system.
- (c) The 5" drill pipe with open centre bit is lowered on a guided template cable rider to the seabed.
- (d) The Quaternary overburden is penetrated until the drillbit is drilled into rockhead. Hammer samples of main Quaternary units are recovered during drilling.
- (e) The powerswivel heave compensator is then set to give the chosen main bit weight (often slightly in excess of the maximum weight that may be required by the diamond core bit used for the coring), and the 5" drill string is clamped to the seabed template.
- (f) The coring pipe and wireline core barrel is then run into the hole.
- (g) Core drilling commences, with length of each run being determined by the length of the inner tube (3.05 m), or by the drilling conditions. Coring continues for 1-2 days. Typical production rates are 1.5 - 3.0 m/h.
- (h) The coring pipe and subsequently the 5" drill pipe are pulled and stored on the deck. The seabed template is hoisted into the moonpool, D.P. is disengaged and the vessel proceeds to the next location.

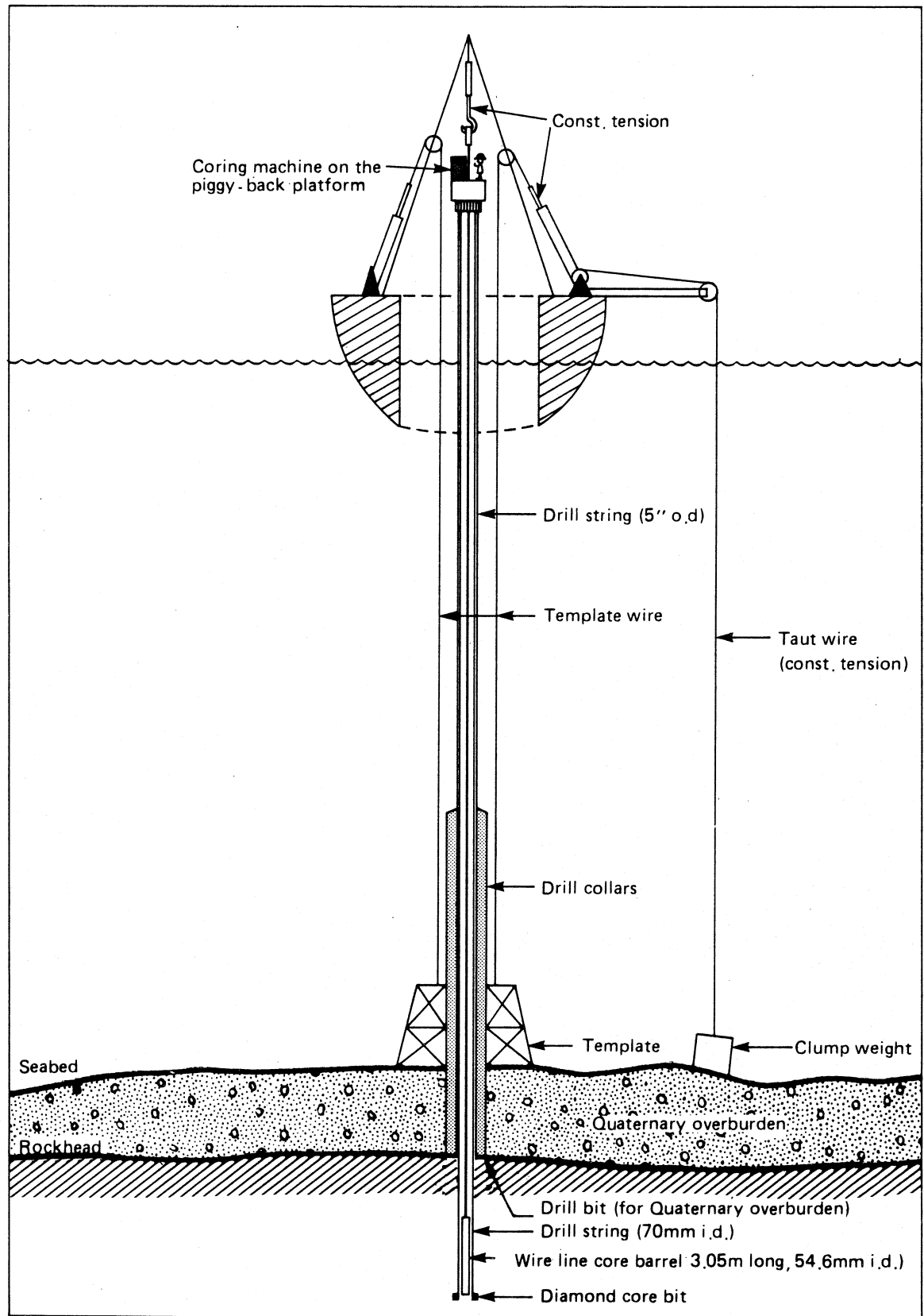


Figure A.1.2 Sketch showing the drilling operation for M/S "Bucentaur".

#### A.1.4 Seismic survey

The collection of seismic data was subcontracted to Master Surveys A/S in Oslo and the processing of seismic data to Geophysical Service International (GSI) in Stavanger.

The vessel M/S "Master Surveyor" was used for the field work, and mobilization started 1 May in Hammerfest. After the acceptance test the survey started 4 May and lasted until 18 May with demobilization in Hammerfest. The last day was used to shoot a seismic line at the Dia-Structure for another IKU drilling project. The time consumption for the total survey was as shown in Figure A.1.3.

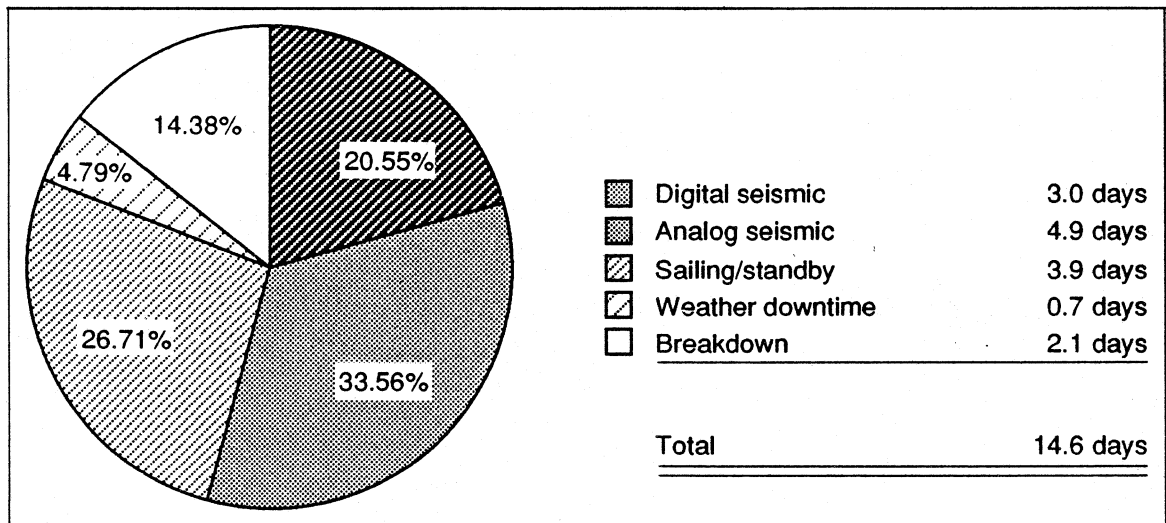


Figure A.1.3 Duration of field work activities for the seismic survey.

The navigation chains in the Barents Sea were operated by Bentech A/S in Tromsø. They were also subcontracted by Master Surveys to have an operator on board the vessel. In the coastal area three extra Syledis stations were put up, and navigation was here partly based on integration of Syledis and Hyperfix, while Hyperfix alone was used in the more offshore areas. Navstar GPS was used as back-up and for lane control. The navigation chains performed well during the seismic survey and no particular problems occurred.

Either digital multichannel data or analog seismic data were collected on all seismic lines. In addition side-scan sonar and deep towed boomer data were collected on all lines, except for in most of the coastal area, where

intensive fisheries made use of the deep towed fish impossible. The following data was collected:

|                                         |        |
|-----------------------------------------|--------|
| -Digital seismic data                   | 533 km |
| -Analog seismic data                    | 742 km |
| -Deep towed boomer/side-scan sonar data | 643 km |

Total length of seismic lines is 1275 km.

### **Main technical specifications**

#### **Analog data**

Sparker (used only on two lines):

- 9-electrode array
- 3 kJ output energy
- Filtering 100-900 Hz

Sleeve air-gun:

- Single air-gun, 20 cu in
- Shot interval 1 sec
- Recording time 1 sec
- Streamer length 15 m
- Filtering 80-900 Hz

Deep towed boomer:

- 240 J output energy
- Shot interval 0.5 sec
- Recording time 0.25 sec
- Filtering internal hydrophone 700-6000 Hz
- Filtering external hydrophone 750-2500 Hz

Side-scan sonar:

- Shot interval 0.5 sec
- Frequency 50 kHz
- Scale corrected (1:10 000)

### Digital data

- Single air-gun 463 cu in
- 15 m shot point interval
- 720 m streamer
- 96 channels
- 7.5 m group length
- 2.5-4.0 sec recording time
- 2 msec sampling rate
- Filter 8-125 Hz

### A.1.5 Drilling operation

The field operations started with mobilization of the ship and a technical test drilling off Kristiansund 17-18 July 1987. This season IKU performed heat flow measurements at three sites in the Nordkapp Basin and shallow drilling at five sites in separate projects in addition to the eight drillings in the present project. The field work started off in Honningsvåg 22 July and lasted for 49 days until demobilization in Honningsvåg 9 September.

In order to save sailing time and money the field work of the different projects was mixed. For the present project drilling was performed in the periods 26 July-22 August and 5-9 September. The mobilization cost, technical breakdown time and time for sailing to and from Honningsvåg were split between the three projects, depending on the duration of the field operation. The time spent in this project was as shown in Figure A.1.4.

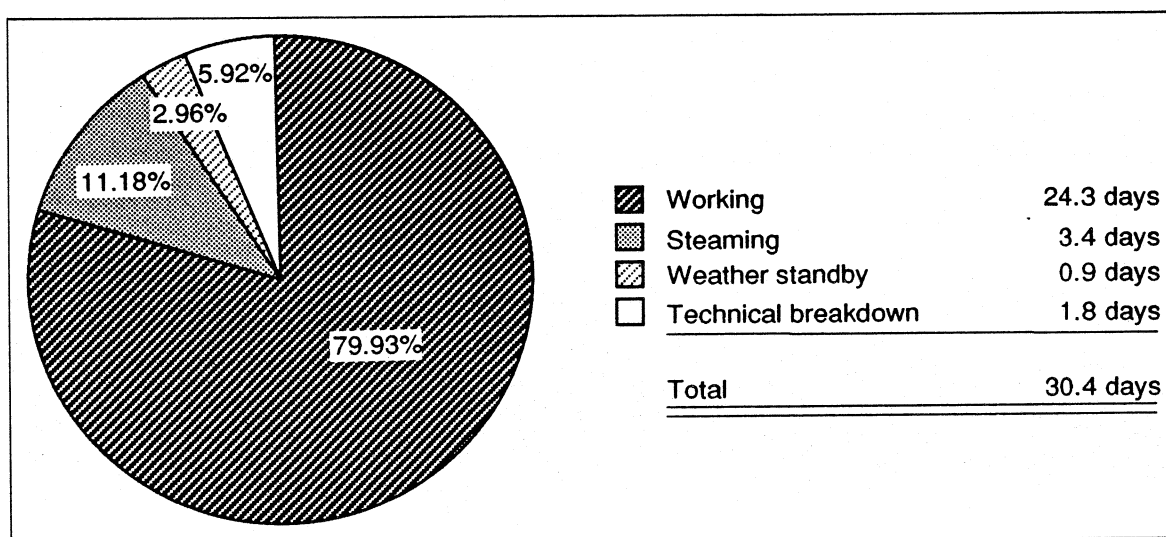


Figure A.1.4 Duration of field work activities for the present project.

At site 7230/05-U-02 the drillstring broke downhole and the drillbit, a Bottom Hole Assembly and some drill collars were lost.

After a short period of weather standby by the end of July, navigation was lost when the Hyperfix chain was reconfigured. The drilling vessel had therefore to go from the Nordkapp Basin to the coastal area in order to

reset the navigation. Although drilling was then started in this area, some valuable time was lost. Another problem occurred when the drill pipe was pulled at this first coastal site. The drill bit got stuck when it was being pulled and because of swell, the grip on the pipe in the drill floor retaining device loosened and the pipe was lost. Except for these incidents no other unusual incidents occurred with major loss of equipment. Drilling problems was, however, at a few occasions encountered when we drilled through the Quaternary overburden, and at site 7128/09-U-01 the glacial till was so hard and rich in boulders, stones and gravel that we did not succeed in getting through with the bedrock coring pipe. We may mention that with a few equipment modifications such problems will probably not occur in the future.

These problems may seem serious for the result of the survey, but because the operation was generally more effective than ever, the total result was nearly twice as good as planned, measured in drilled metres. Compared with the planned 30-50 m of drilling at each site, the average appeared to be appr. 77 m. Core recovery was 95.1 %, as normal (see Table A.1.1).

We would like to add that the very good result is due to various factors:

- Good weather conditions most of the time and minimal weather downtime
- Most of the rocks were easy to drill
- Several minor, but important technical improvements were made since last year.
- We had the same crew as in previous years

Table A.1.1 Key data of the boreholes.

| Core no.     | Seismic line  | Shotp. | Water depth (m) | Quat. over-burden (m) | Penetration in bedrock | Core length (m) | Core recovery | Tot. penetr. below seabed (m) |
|--------------|---------------|--------|-----------------|-----------------------|------------------------|-----------------|---------------|-------------------------------|
| 7230/05-U-02 | IKU-302230-87 | 760.0  | 286.0           | 28.7                  | 97.3                   | 95.05           | 97.7%         | 126.0                         |
| 7230/05-U-03 | IKU-302230-87 | 721.2  | 288.0           | 27.0                  | 88.5                   | 78.1            | 88.2%         | 115.5                         |
| 7230/05-U-04 | IKU-302230-87 | 660.9  | 282.7           | 23.6                  | 55.2                   | 54.5            | 98.8%         | 78.8                          |
| 7230/05-U-05 | IKU-302230-87 | 606.4  | 286.0           | 23.3                  | 26.4                   | 24.2            | 91.4%         | 49.7                          |
| 7230/05-U-06 | IKU-302230-87 | 575.1  | 285.5           | 24.6                  | 71.7                   | 68              | 94.9%         | 96.3                          |
| 7129/10-U-01 | IKU-3-87      | 358.5  | 382.0           | 55.4                  | 37.9                   | 34.9            | 92.3%         | 93.3                          |
| 7129/10-U-02 | IKU-3-87      | 466.0  | 336.0           | 30.3                  | 89.6                   | 85.7            | 95.6%         | 119.9                         |
| 7030/03-U-01 | IKU-10-87     | 164.1  | 308.0           | 26.3                  | 147.4                  | 143.6           | 97.4%         | 173.7                         |
| Sum/average  |               |        |                 | 239.2                 | 614.0                  | 584.1           | 95.1%         |                               |

## **APPENDIX A.2**

### **NAVIGATION DATA**

### A.2.1 General

Bentech A/S in Tromsø was operator of the navigation chains in the Barents Sea, and they provided equipment and personnel for positioning of the drilling vessel.

Hyperfix was used as the main system, with Navstar GPS as a backup system during the about 8 hours a day this system provided navigation coverage. The Hyperfix was calibrated using a Syledis navigation chain. This chain has a range of about 100 km, and calibration was done every time the vessel approached the coastal area.

### A.2.2 Chain performance and final positions

The general survey activity in the area was moderate this year, and the Hyperfix chain was therefore available in range-range mode all the time. We also had access to the same station combination as during the seismic survey. The best possible navigation accuracy was therefore achieved during the whole survey.

The final positions are listed in Table A.2.1.

Table A.2.1 Final positions (ED 50).

|              |                                                         |         |  |
|--------------|---------------------------------------------------------|---------|--|
| LOCATION     | Latitude 72° 40' 51.10" N<br>Longitude 30° 22' 29.51" E |         |  |
| 7230/05-U-02 | Northing 8 068 253.5 m<br>Easting 612 090.4 m           | UTM 27° |  |
| LOCATION     | Latitude 72° 41' 10.05" N<br>Longitude 30° 22' 26.70" E |         |  |
| 7230/05-U-03 | Northing 8 068 838.5 m<br>Easting 612 031.5 m           | UTM 27° |  |
| LOCATION     | Latitude 72° 41' 39.74" N<br>Longitude 30° 22' 26.63" E |         |  |
| 7230/05-U-04 | Northing 8 069 757.0 m<br>Easting 611 979.1 m           | UTM 27° |  |
| LOCATION     | Latitude 72° 42' 06.00" N<br>Longitude 30° 22' 31.64" E |         |  |
| 7230/05-U-05 | Northing 8 070 571.8 m<br>Easting 611 979.5 m           | UTM 27° |  |
| LOCATION     | Latitude 72° 42' 21.21" N<br>Longitude 30° 22' 28.86" E |         |  |
| 7230/05-U-06 | Northing 8 071 041.5 m<br>Easting 611 927.4 m           | UTM 27° |  |

|              |                                                         |         |  |
|--------------|---------------------------------------------------------|---------|--|
| LOCATION     | Latitude 71° 09' 35.45" N<br>Longitude 29° 16' 42.77" E |         |  |
| 7129/10-U-01 | Northing 7 896 983.0 m<br>Easting 582 110.9 m           | UTM 27° |  |
| LOCATION     | Latitude 71° 07' 13.47" N<br>Longitude 29° 13' 23.12" E |         |  |
| 7129/10-U-02 | Northing 7 892 512.6 m<br>Easting 580 274.6 m           | UTM 27° |  |
| LOCATION     | Latitude 70° 49' 36.18" N<br>Longitude 30° 44' 31.07" E |         |  |
| 7030/03-U-01 | Northing 7 862 512.1 m<br>Easting 637 093.3 m           | UTM 27° |  |

## **APPENDIX A.3**

### **ANALYTICAL METHODS**

### A.3.1 Core description and sampling

Detailed core description was undertaken on board the ship (as time permitted) as well as all subsampling. Both core description and sampling were completed in the laboratory. The legend of the sedimentological columns is given in Figure A.3.1. Samples for organic geochemistry, dating and X-ray diffraction were taken at 1-3 m intervals.

### A.3.2 X-ray diffraction analysis

Samples for X-ray diffraction analysis were prepared according to the following procedure. Analyses of the  $<4\ \mu\text{m}$  fraction is only undertaken on samples from core 7230/05-U-02.

1. The samples were gently crushed in a mortar with ethanol.
2. The whole rock sample were ground in ethanol to a fine powder and sucked onto millipore filters for whole rock analyses.
3. Samples for fine fraction analyses were disaggregated by use of an ultrasonic sound dispergator instead of grinding in order to avoid the production of fine powder from the silt and sand grains. The  $<4\ \mu\text{m}$  fraction was separated by use of settling tubes and sucked onto millipore filters for analysis.

|            |                                                                |
|------------|----------------------------------------------------------------|
| Radiation: | monochromatic $\text{CuK}\alpha$                               |
| Voltage:   | 40 kV                                                          |
| Current:   | 30 mA                                                          |
| Speed:     | $2^\circ/\text{minute}$ , $2\theta = 2^\circ\text{--}35^\circ$ |

# LITHOLOGY , SEDIMENTARY STRUCTURES & FOSSILS

|  |                               |  |                            |
|--|-------------------------------|--|----------------------------|
|  | Claystone / shale             |  | Increasing bioturbation    |
|  | Siltstone                     |  | Fecal pellets              |
|  | Sand                          |  | Sparse                     |
|  | Limestone                     |  | Abundant                   |
|  | Dolomitic limestone           |  | Mudstone clast             |
|  | Dolomite                      |  | Pyrite                     |
|  | Calcareous dolomite           |  | Glauconite                 |
|  | Siderite                      |  | Palaeoaplysina             |
|  | Sandy carbonate               |  | Bryozoa                    |
|  | Anhydrite                     |  | Corals                     |
|  | Calcite cement                |  | Fossils in general         |
|  | Dolomite cement               |  | Unspecif. fossil fragments |
|  | Siderite cement               |  | Bivalve                    |
|  | Phosphorite                   |  | Inoceramus                 |
|  | Chert, chert nodule           |  | Brachiopod                 |
|  | Concretion                    |  | Coquina                    |
|  | Breccia clasts                |  | Gastropod                  |
|  | Intra clasts                  |  | Ammonite                   |
|  | Erosion                       |  | Belemnite                  |
|  | Horizontal lamination         |  | Echinoderms                |
|  | Ripple lamination             |  | Foraminifera               |
|  | Wave ripples                  |  | Fusulinides                |
|  | Hummocky cross stratification |  | Ostracoda                  |
|  | Trough cross stratification   |  | Trilolite                  |
|  | Coal                          |  | Fish remains               |
|  | Loading                       |  | Cephalopod hook            |
|  | Stylolites                    |  | Cephalopod fragment        |
|  |                               |  | Spicule                    |
|  |                               |  | Calcsphere                 |
|  |                               |  | Plant fragments            |
|  |                               |  | Algae                      |
|  |                               |  | Taenidae                   |
|  |                               |  | Borings                    |
|  |                               |  | Wood debris                |
|  |                               |  | Roots                      |
|  |                               |  | Ooide                      |
|  |                               |  | Pellets                    |

Figure A.3.1 Legend to the sedimentological columns.

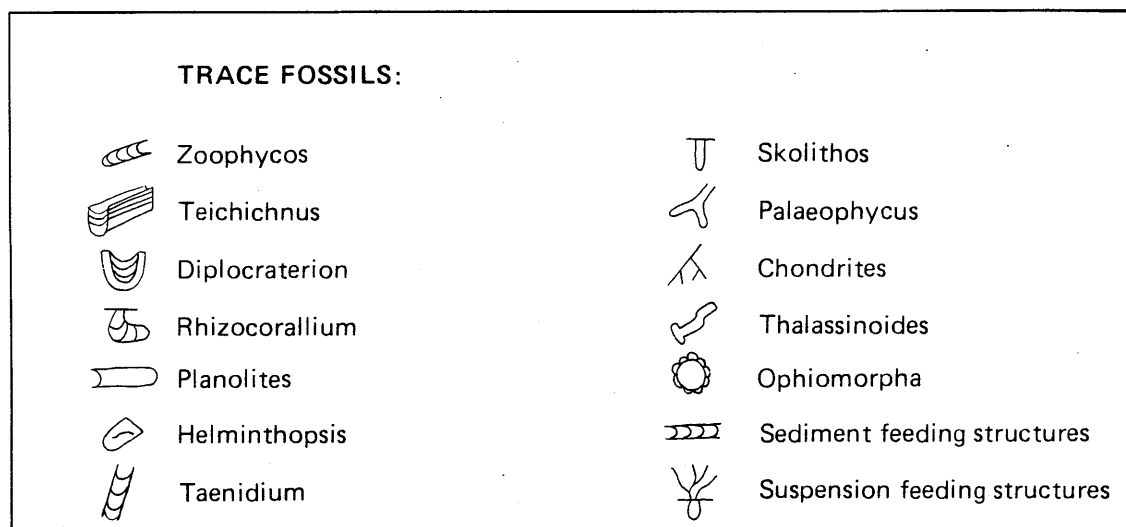


Figure A.3.1 Continued

The quantification is based on the peak height multiplied by the width of the peak at half maximum and by a weighted factor relative to quartz of the following reflections (Legend in Figure A.3.2):

|                      |         |                                 |
|----------------------|---------|---------------------------------|
| Smectite             | (Smec): | (14Å - 4.7Å) x 0.35             |
| Mixed layer minerals | (Mix) : | 10 to 14Å x 0.55                |
| Muscovite/Illite     | (Mica): | 10Å x 1.0 or 10Å x 1.4 (illite) |
| Chlorite             | (Chl) : | 4.74Å x 3 x 0.7                 |
| Kaolinite            | (Kaol): | 7Å x 0.7 - Chl                  |
| Quartz               | (Qtz) : | 4.26Å x 1                       |
| Cristobalite         | (Cris): | 4.05Å x 1                       |
| Goethite             | (Goet): | 4.18Å x 1                       |
| K-feldspar           | (KFsp): | 3.24Å x 0.5                     |
| Plagioclase          | (Plag): | 3.19Å x 0.5                     |
| Calcite              | (Calc): | 3.04Å x 0.25                    |
| Dolomite             | (Dolo): | 2.89Å x 0.20                    |
| Siderite             | (Sidr): | 2.79Å x 0.25                    |
| Anhydrite            | (Anhy): | 3.49Å x 1                       |
| Gypsum               | (Gyp) : | 7.56Å x 1                       |
| Pyrite               | (Pyr) : | 2.71Å x 0.7                     |

|                                                                                   |                  |                                                                                   |              |
|-----------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------------------|--------------|
|  | SMECTITE         |  | DOLOMITE     |
|  | MIXED LAYER CLAY |  | SIDERITE     |
|  | ILLITIC CLAY     |  | PHOSPHATE    |
|  | CHLORITE         |  | PYRITE       |
|  | KAOLINITE        |  | GYPSUM       |
|  | QUARTZ           |  | ANHYDRITE    |
|  | K FELDSPAR       |  | CRISTOBALITE |
|  | PLAGIOCLASE      |  | GOETHITE     |
|  | CALCITE          |                                                                                   |              |

Figure A.3.2 Legend to the semiquantitative mineralogy plots.

### A.3.3. Sound velocity measurements

Sound velocity measurements, horizontal and vertical, were carried out on board on wet, consolidated core pieces, using a portable ultrasonic (100 kHz) non destructive digital indicating tester (PUNDIT).

The pulse velocity ( $v$ ) was calculated using  $v = \frac{L}{T}$

where  $L$  is the path length and  $T$  is the transit time.

### A.3.4 Natural $\gamma$ -radiation

The measurements were carried out on board using a 5" x 5" NaI-detector connected to a 4048 channel analyser of the Canberra 40 series. The core was placed below the detector with its long axis parallel to the detector window. In that position a spectrum was accumulated for 600 sec (10 minutes). To reduce the background radiation, the detector and the samples were shielded by lead. The method requires a minimum sample length which is equal to the detector diameter if the collimation is 100% effective. To avoid this problem, only core pieces longer than twice the detector diameter (= 26 cm) were analysed.

The measured peaks are:

- 1) K-40: 1.460 MeV
- 2) U-238 via Bi-214: 1.764 MeV
- 3) Th-232 via Tl-208: 2.615 MeV

The results are presented as counts per 10 minutes. The logs show the relative amount of radiation and not the absolute abundance of K, Th and U.

In order to make the  $\gamma$ -logs more applicable, effort has been made to try to convert the core natural  $\gamma$ -readings from our laboratory measurements to a calibrated API value.

Five core samples taken from slim-hole wire-line logged boreholes taken elsewhere were chosen for calibration at IKU. The samples, which are in the API range 30 to 150, were measured for 10 minutes and compared to values obtained on core samples from the Barents Sea. The function established for converting total counts per 10 minutes to API units is:

$$\text{API} = -1615 + 169 \ln (\text{counts})$$

Problems with the calibration may arise when the  $\gamma$ -activity is higher than 200 API, as for the phosphate layer at 65 m in core 7129/10-U-01 and the black shales of Unit C in core 7230/05-U-02. Since we have no standards with that high activity, we had to extrapolate the calibration curve.

According to the function above, the lowest  $\gamma$ -activity, which is found in the anhydrite of core 7030/03-U-01, is about 4 API while the activity of the phosphate layer in core 7129/10-U-01 is about 240 API.

Recalculation of the  $\gamma$ -radiation for each core to API-units gives:

Core 7030/03-U-01: 4 API (anhydrite) - 118 API.

Most measurements are within 4-50 API.

Core 7129/10-U-02: 7 API (limestone) - 89 API (shale).

Core 7129/10-U-01: 7 API (limestone) - 242 API (phosphate). Most measurements are within 7-83 API.

Core 7230/05-U-06: 43 API - 90 API, averaging about 60 API.

Core 7230/05-U-05: 36 API - 78 API.

Core 7230/05-U-04: 64 - 128 API, averaging about 75 API.

Core 7230/05-U-03: 35 API (sandstone at 34 m) - 114 API (shale at 105 m). The average value is about 58 API (20 000 counts).

Core 7230/05-U-02: 21 API (clean sandstone at base) - 196 API (black shale above 50 m). The average value for Unit A is about 50 API. In Unit B the radiation increases upward from 50 API to 133 API. The average for Unit C is about 175 API.

#### A.3.5 Thermal conductivity

Thermal conductivity has been measured on core samples from sites 7129/10-U-01, 7129/10-U-02, 7030/03-U-01, 7230/05-U-02, 7230/05-U-04, 7230/05-U-05 and 7230/05-U-06. A total of 62 samples has been measured. The measurements are carried out at the University of Aarhus under supervision of Niels Balling. A complete report by Balling is included in Appendix A.9.

The conductivity is measured by the needle probe method. The measurements are undertaken with the probe vertically in the cores (yielding horizontal thermal conductivity,  $k_h$ ) and with the probe horizontally in the cores (yielding a weighted mean of vertical and horizontal thermal conductivity,  $k_m$ ). The vertical thermal conductivity,  $k_v$ , is calculated from the relation  $k_v = k_m^2 / k_h$  (Penner 1963; Balling et al. 1981).

Thermal conductivity values from Table 1 in Appendix A.9 have been plotted together with sound velocity measurements and simplified core logs of the cores where measurements have been carried out. The plots are found in subchapters "Sedimentology" under "Petrophysics" in Chapter 3.1-3.8.

The conductivity logs are then subdivided in lithological sections with approximately uniform vertical thermal conductivity within each section. The vertical thermal conductivity is calculated as the arithmetic mean of the measurements within each section and these values are shown as diagrams and numbers (mean values and standard deviations) in the above mentioned figures.

### A.3.6 Palynology

The standard processing for palynology included hot hydrochloric and hydrofluoric acids with continuous stirring. In most cases the organic residues were oxidized by the use of nitric acid (app. 3 minutes) followed by KOH. If necessary this process was repeated.

Samples from the cores were prepared at approximately 3 m intervals, leaving reference material at all levels. In lithologies with poor recovery an extra set of samples was later processed.

Slides were prepared of: the total residues, unoxidized sieved residues, and oxidized residues at various stages.

### A.3.7 Microfauna

Samples were prepared at approximately 3 m intervals, adjusted for lithological units. The samples were soaked in water for some days after being dried. The fraction  $>125\mu\text{m}$  was analysed with respect to foraminifera, ostracods and macrofossil debris. The fraction  $125-63\mu\text{m}$  was additionally analysed in the pre-Jurassic beds.

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## **APPENDIX A.4**

### **FUSULINIDS**

by

Inger Nilsson (7030/03-U-01)

Bjørn Tore Simonsen (7129/10-U-02 & 01)

In this appendix short description of the fusulinid taxa including biostratigraphical comments and fauna lists are given. Important taxa are illustrated.

## CORE 7030/03-U-01

20 fusulinid species are identified on the basis of 100 thin-sections from 25 samples. The contents of the individual samples are listed below, and the range chart is given in Figure A.4.1. Three fusulinid assemblages zones are defined, which show great similarity to assemblages in Svalbard and USSR. The uppermost assemblage in this core resembles the fauna in the lower part of core 7029/10-U-02. A discussion of the assemblages zones is given below.

### Fusulinid assemblages

#### Assemblage zone I (Gzelian)

This assemblage occurs in the lower part of the core (166.3–151.6 m) and is characterized by the distribution of *Pseudofusulinella usvae* (Dutkevich). In this assemblage *P. usvae* occurs together with *Triticites* cf. *rossicus* (Schellwien) and *Schwagerina* (*Daixina*) sp. Similar fauna is described from the Gzhelian stage on the Russian Platform (Grozdilova & Lebedeva 1960, 1961 and Mikhailova 1974).

#### Assemblage zone II (Lower Asselian)

No fusulinid fauna was observed in the interval between 151.6 to 95.9 m. The base of this assemblage is defined by the first appearance of *Schwagerina anderssoni* (Schellwien) (level 95.9 m). In addition to *S. anderssoni*, the following fusulinaceans are included in the zone:

*Schwagerina* cf. *furnishi* (Ross)

*Quasifusulina compacta* (Lee)

(?) *Schwagerina arctica* (Schellwien)

*Schwagerina* (*Daixina*) *sokensis* (Rauser-Chernousova)

*Pseudofusulina* cf. *alpina* (Schellwien)

*Schubertella*

In USSR this fauna is similar to those of uppermost Gzelian and lowermost Asselian age (e.g. Rozovskaya 1952, 1958, Semina 1961, Isakova 1986 and Davydov 1986). Close relationships to assemblages in lower part of the Kapp Dunér Fm. on Bjørnøya (Simonsen unpubl. data) and lower Tyrrellfjellet Mb. on Spitsbergen (Nilsson unpubl. data) correlate this assemblage zone to lower Asselian age.

### Assemblage zone III (Middle-Upper Asselian)

This assemblage occurs in the upper part of the core (55.1-26.8m).  
Following fusulinaceaens are included in the zone:

*Sphaeroschwagerina* cf. *vulgaris* (Scherbovich)  
*Sphaeroschwagerina sphaerica* var. *gigas* Rauser-Chernousova & Scherbovich  
*Schwagerina princeps* (Ehrenberg)  
*Schwagerina* cf. *emaciata* (Beede)  
*Schwagerina* cf. *rhomboides* (Shamov & Scherbovich)  
*Schwagerina parafecunda* (Shamov & Scherbovich)  
*Pseudofusulina* sp. A  
*Pseudofusulinella templensis* Ross

This fauna is closely allied with those in the upper part of the Kapp Dunér Fm. on Bjørnøya (Simonsen unpubl. data) and the middle part of the Tyrrellfjellet Mb. on Spitsbergen (Nilsson, unpubl. data). *Sphaeroschwagerina sphaerica* var. *gigas*, "*Schwagerina princeps*-group" and *Pseudofusulinella templensis* are also present in the lower part of core 7129/10-U-02. *Sphaeroschwagerina sphaerica* var. *gigas*, "*Schwagerina princeps* group" and *Pseudofusulinella templensis* are also present in the lower part of core 7129/10-U-02 (Simonsen, pers. com.). A similar assemblage is correlated to middle-upper Asselian in USSR (Shamov & Scherbovich 1949 and Scherbovich 1969).

### Biostratigraphical comments on the taxa

Short comments will be given on the biostratigraphic distribution of the fusulinid taxa found in core 7030/03-U-01. Unpublished data from Bjørnøya and Spitsbergen will in the future be available in theses written by Simonsen and Nilsson. These theses are included in IKU's Arctic Geoprogram, and the reports are planned to be finished during this spring, and will then be available for the Arctic Geoprogram participants (ed. comments).

Genus *Pseudofusulina* Dunbar & Skinner 1931 =  
*Rugosofusulina* Rauser-Chernousova 1937 in USSR

*Pseudofusulina* cf. *alpina* (Schellwien 1898)  
Asselian in USSR (Scherbovich 1969 and Isakova 1986)

*Pseudofusulina* sp. A

Has some similarities with *P. stabilis longa* (Rauser-Chernoussova 1938), but the secondary deposits in the axial area is not as heavy as in this species. *P. stabilis longa* is common in Asselian stage in USSR.

*Pseudofusulinella templensis* Ross 1965

Sakmarian in Spitsbergen (Ross 1965); Asselian (Nilsson unpubl.data).

*Pseudofusulinella usvae* (Dutkevich 1932)

Upper Carboniferous-lowermost Permian in Ural-Timan-area (Grozdilova & Lebedeva 1960); Nordenskiöldbreen Fm. (Spitsbergen) (Ross 1965, Nilsson unpubl. data); Lower Asselian in the lower part of the Kapp Dunér Fm. (Bjørnøya) (Simonsen unpubl. data); Asselian (ex. gr. *Usvae*) in Ellesmere Island (Wilde in Nassichuk & Wilde 1977).

*Quasifusulina compacta* (Lee 1927)

Upper Carboniferous in North-China (Lee 1927); Upper Carboniferous-Lower Permian in Carnic Alps (Kahler 1972); Lower Asselian in the lower part of the Tyrrellfjellet Mb. Spitsbergen) (Nilsson unpubl. data).

*Schubertella* Staff & Wedekind 1910

Long range genus (Carboniferous-Permian).

Genus *Schwagerina* Müller 1877, sensu Dunbar & Skinner 1936 =

*Pseudofusulina* Dunbar & Skinner 1931 in USSR

*Schwagerina anderssoni* (Shellwien 1908)

Asselian on the Russian platform (Semina 1961); Ellesmere Island (Wilde in Nassichuk & Wilde); middle-upper Asselian in upper part of the Kapp Dunér Fm. (Bjørnøya) (Simonsen unpubl. data); lower Asselian in the lower part of the Tyrrellfjell Mb. (Spitsbergen) (Nilsson unpubl.data).

*Schwagerina* cf. *emaciata* (Beede 1916)

Lower part of Wolfcampian in USA (Forbes & McGuan 1959); late Asselian-middle Sakmarian in East-Central Alaska Range (Petocz 1970); middle-upper Asselian in upper part of the Kapp Dunér Fm. (Bjørnøya) (Simonsen unpubl. data); middle-upper Asselin in middle part of the Tyrrellfjell Mb. (Spitsbergen) (Nilsson unpubl. data).

*Schwagerina* cf. *furnishi* (Ross 1965)

Sakmarian in Spitsbergen (Ross 1965); Asselian (Nilsson unpubl. data).

*Schwagerina parafecunda* (Schamow & Scherbovich 1949)

Middle-Upper Asselian in USSR (Schamow & Scherbovich 1949).

*Schwagerina princeps* (Ehrenberg 1842)

This species was redescribed by Dunbar and Skinner (1936) and *Schwagerina krotowi* (Schellwien 1908) was cited as a junior synonym of *S. princeps*. Most Russian workers still prefer *S. krotowi* for this group of inflated specimens. Several subspecies have been identified, and some of them such as *S. krotowi nux* (Schellwien 1908) and *S. krotowi sphaeroidea* (Rauser-Chernousova 1938) are very similar to *S. princeps*.

"The group of *S. princeps*" (species complex) is correlated to Asselian in USSR (Davydov 1986); middle-upper Asselian in upper part of the Kapp Dunér Fm. (Bjørnøya) (Simonsen unpubl. data) and middle part of the Tyrrellfjellet Mb. (Spitsbergen) (Nilsson unpubl. data).

*Schwagerina rhomboides* (Schamow & Scherbovich 1949)

Middle-upper Asselian in USSR (Schamow & Scherbovich 1949).

*Schwagerina* sp. B

Similar species have not been found (it may be a new species?).

*Schwagerina* (?) *arctica* (Schellwien 1908)

Upper Carboniferous-lowermost Permian in USSR (Rozovskaya 1958 and Davydov 1986); lower Asselian in lower part of the Kapp Dunér Fm. (Bjørnøya) (Simonsen unpubl. data); Lower Asselian in the lower part of the Tyrrellfjellet Mb. (Spitsbergen) (Nilsson unpubl. data).

*Schwagerina* (*Daixina*) *sokensis* (Rauser-Chernousova 1938)

Uppermost Carboniferous-lowermost Permian in USSR (Rauser-Chernousova 1938, Isakova 1986 and Davydov 1986); Asselian in the Kapp Dunér Fm. (Bjørnøya) (Simonsen unpubl. data); Lower Asselian in the lower part of the Tyrrellfjellet Mb. (Spitsbergen) (Nilsson unpubl. data).

*Schwagerina* (*Daixina*) sp. A

Similar to large forms of *Daixina* Rozovskaya 1958, which are common in uppermost Carboniferous-lowermost Permian in USSR.

*Sphaeroschwagerina* cf. *vulgaris* (Scherbovich 1949). Asselian in USSR (Scherbovich 1949)

*Sphaeroschwagerina shpaerica* var. *gigas* Rauser-Chernousova & Scherbovich 1949  
Middle-Upper Asselian in USSR; Upper part of the Kapp Dunér Fm. (Bjørnøya)  
(Simonsen unpubl. data).

*Triticites* cf. *rossicus* (Schellwien 1898)  
Gzhelian in USSR (Rozovskaya 1958, Grozdilova 1966); ?uppermost Gzhelian-  
lowermost Asselian in the Nordenskiöldbreen Fm. (Nilsson unpubl. data).

*Triticites* sp.A

Incomplete preserved specimen, showing slight rugosity but not enough to be  
assigned to *Pseudofusulina*.

#### Fauna list

Depth: 166.3 m, D-2080, three thin-sections.  
*Pseudofusulinella usvae* (Dutkevich 1932)

Depth: 160.3 m, D-2076, three thin-sections.  
*Pseudofusulinella usvae*  
*Triticites* sp. A

Depth: 153.9 m, D-2075, two thin-sections.  
*Schwagerina* (*Daixina*) sp. A

Depth: 151.6 m, D-2074, four thin-sections.  
*Triticites* cf. *rossicus* (Schellwien 1898)  
*Pseudofusulinella usvae*

Depth: 95.9 m, D-2068, five thin-sections.  
*Schwagerina anderssoni* (Schellwien 1908)  
*Schwagerina* cf. *furnishi* (Ross 1965)  
*Quasifusulina compacta* (Lee 1927)

Depth: 95.7 m, D2067, three thin-sections.  
*Quasifusulina compacta*  
*Schwagerina anderssoni*

Depth: 94.9 m, D-2065, three thin-sections.  
*Schwagerina* (?) *arctica* (Schellwien 1908)  
*Triticites* cf. *T. rossicus*

Depth: 87.6 m, D-2062, two thin-sections.  
*Schwagerina* (?) *arctica*

Depth: 86.1 m, D-2061, five thin-sections.  
*Schwagerina* (?) *arctica*

Depth: 76.6 m, D-2057, five thin-sections.  
*Schwagerina* (?) *arctica*  
? *Triticites rossicus*

- Depth: 74.6 m, D-2055, five thin-sections.  
Bad preservation of fusulinid shells.  
*?Schwagerina* sp.
- Depth: 71.3 m, D-2054, two thin-sections.  
*Schwagerina* (*Daixina*) cf. *sokensis* (Rauser-Chernousova 1936)
- Depth: 70.7 m, D-2053, seven thin-sections.  
*Schwagerina* (?) *arctica*  
*Schwagerina* (*Daixina*) *sokensis*  
*Schubertella*
- Depth: 69.6 m, D-2051, four thin-sections.  
*Schwagerina* (?) *arctica*  
*Schwagerina* (*Daixina*) *sokensis*
- Depth: 69.3 m, D-2049, seven thin-sections.  
*Schwagerina* (*Daixina*) *sokensis*  
*Pseudofusulina* cf. *alpina* (Shellwien 1898)  
*?Schwagerina princeps* (Ehrenberg 1942)
- Depth: 65.0 m, D-2046, two thin-sections.  
*Schwagerina* (*Daixina*) *sokensis*
- Depth: 55.1 m, D-2045, five thin-sections.  
*Sphaeroschwagerina* cf. *vulgaris* (Sherbovich 1949)  
*?Schwagerina princeps*  
*Pseudofusulina* sp. B
- Depth: 52.0 m, D-2042, four thin-sections.  
*Schwagerina princeps*
- Depth: 50.3 m, D-2039, two thin-sections.  
*Pseudofusulinella templensis* Ross 1965  
*Schwagerina* cf. *emacata* (Beede 1927)
- Depth: 49.7 m, D-2038, seven thin-sections.  
*Schwagerina princeps*  
*Schwagerina parafecunda* (Shamov & Scherbovich 1949)  
*Schwagerina rhomboides* (Shamov & Scherbovich 1949)
- Depth: 39.2 m, D-2034, seven thin-sections.  
*Schwagerina princeps*  
*Pseudofusulinella templensis*
- Depth: 29.7 m, D-2031, three thin-sections.  
*Schwagerina princeps*  
*Schwagerina* cf. *emaciata*  
*?Schwagerina rhomboides*  
*Schubertella*  
*Schwagerina* sp. B
- Depth: 28.4 m, D-2029, three thin-sections.  
*Sphaeroschwagerina sphaerica* var. *gigas* Rauser-Chernousova & Scherbovich 1949
- Depth: 27.8 m, D-2028, three thin-sections.  
*Schwagerina princeps*  
*Schwagerina parafecunda*

Depth: 26.8 m, D-2027, four thin-sections.

*Schwagerina princeps*

*Sphaeroschwagerina sphaerica* var. *gigas*

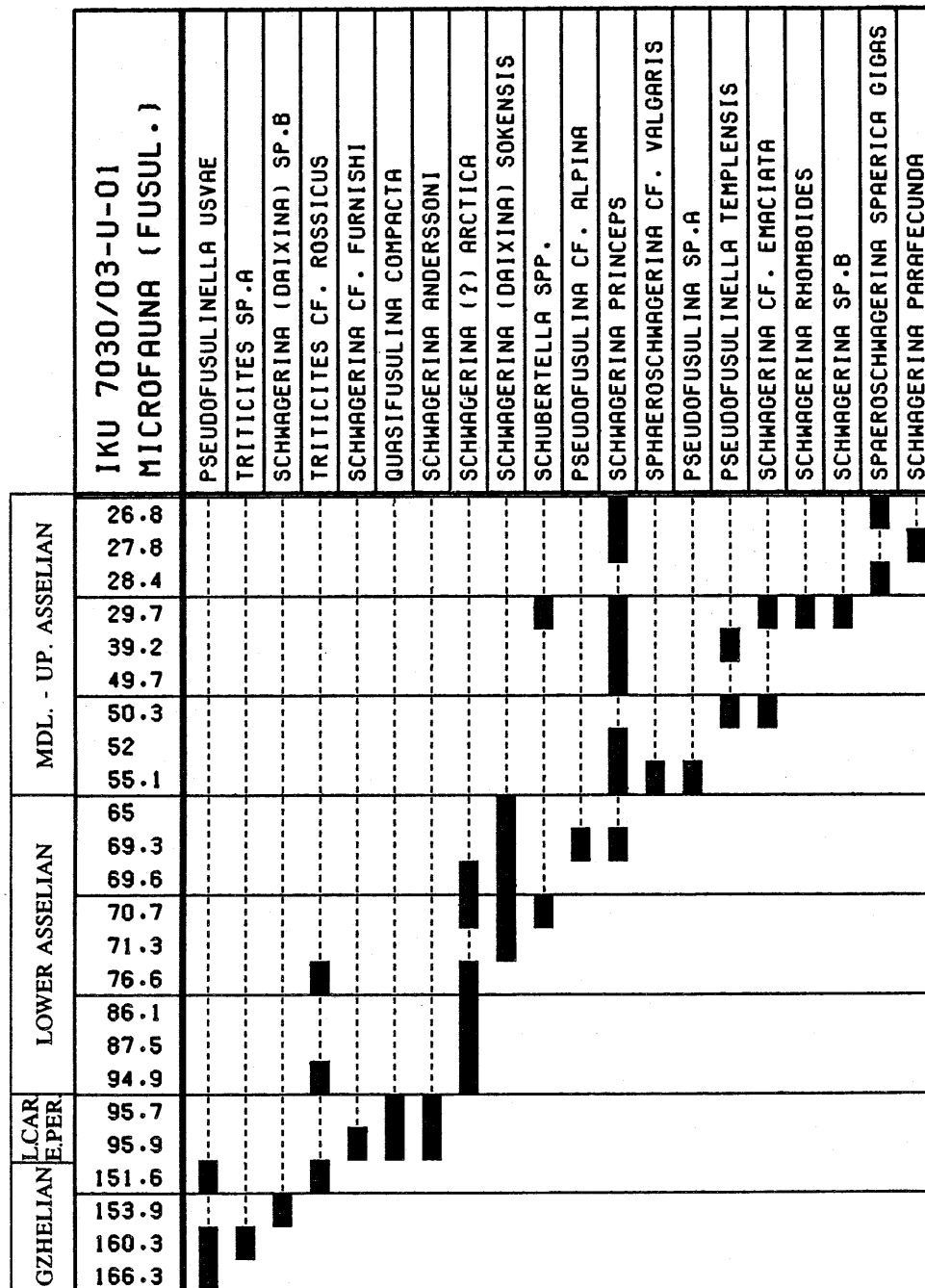


Figure A.4.1 Fusulinid range chart for core 7030/03-U-01.

## CORE 7129/10-U-02

20 species of fusulinids included in 9 genera have been identified from 29 samples in this core.

Special attention in dating this core has been given to correlation with similar sections from Timan and Ural (Grozdilova 1938 and Grozdilova & Lebedeva 1961); both faunazones and lithology seems to correlate to this core.

Zone: *Schwagerina* (108.9 - 105.7 m)

Taxa: *Schwagerina* cf. *declinata* (Korzenevsky)  
*Schwagerina* sp.  
*Pseudofusulinella* cf. *parvula* (Skinner & Wilde)  
*Pseudofusulinella templensis* (Ross)  
*Biwaella omiensis* (Morikawa & Isomi)  
*Pseudoendothyra* sp.  
*Schubertella* sp.

The interval 108.90-105.70 m is dominated by fusulinids identified as *Schwagerina* sp. Three well oriented sections of *S.* cf. *declinata* (Korzenevsky) make a correlation with middle to upper Asselian assemblages of USSR. *Biwaella* could be an important genus which occurs worldwide around upper Asselian time (Skinner & Wilde 1965).

Zone: *Sphaeroschwagerina moelleri* (104.7 - 101.15 m)

Taxa: *Sphaeroschwagerina moelleri* (Rauser-Chernousova)  
*Sphaeroschwagerina* sp.  
*Schwagerina* cf. *sphaeroidea* (Rauser-Chernousova)  
*Schwagerina* cf. *furnishi* (Ross)  
*Schubertella sphaerica* (Suleimanov)  
*Boultonia* sp.

This assemblage is critical for a correlation to middle and upper Asselian in USSR. *S. moelleri* defines a middle Asselian zone in USSR, but ranges throughout upper Asselian (Rauser-Chernousova & Scherbovich 1949,

Scherbovich 1969 and Isakova & Nazarov 1986). *S. sphaerica* is common in middle Asselian to lower Sakmarian (Suleimanov 1949). *Boultonia* is also a worldwide important genus which appears late in Asselian and ranges to the Artinskian Stage (upper Wolfcampian to Leonardian) (Grozdilova & Lebedeva 1961 and Leven & Scherbovich 1978). This assemblage correlates with fauna from the upper part of the Kapp Dunér Fm., Bjørnøya (Simonsen unpubl. data) and the middle part of the Tyrellfjellet Mb. in Spitsbergen (Nilsson unpubl. data).

Zone: *Sphaeroschwagerina sphaerica* (94.65 - 89.15 m)

Taxa: *Sphaeroschwagerina sphaerica* var. *gigas* (Rauser-Chernousova & Scherbovich)  
*Pseudofusulinella templensis* (Ross)  
*Schwagerina* sp. 1  
*Schwagerina* sp. 2  
? *Schwagerina moelleri* (Schellwien)  
*Boultonia* sp.

This assemblage correlates to the late Asselian on the Russian Platform (Rauser-Chernousova & Scherbovich 1949, Scherbovich 1969 and Grozdilova 1938). *S. sphaerica* var. *gigas* occurs in core 7030/03-U-01 and is also found in top of the Kapp Dunér Fm. at Bjørnøya (Simonsen unpubl. data). *P. templensis* is found in Asselian equivalents in Spitsbergen (Nilsson unpubl. data) and Sakmarian by Ross (1965). *Schwagerina moelleri* define the lowermost zone in Sakmarian in USSR, but the presence is not well documented in this part of the core.

Zone: *Eoparafusulina* (83.6 - 66.8)

Taxa: *Eoparafusulina* spp.  
*Pseudofusulinella* cf. *minima* (Grozdilova & Lebedeva)  
*Pseudofusulinella* cf. *infrequenta* (Grozdilova & Lebedeva)  
*Pseudofusulinella* sp.  
*Pseudofusulina plana* (Skinner & Wilde)  
*Schwagerina globosa* (Schellwien & Dyhrenfurth)  
*Schwagerina* sp.

Grozdilova & Lebedeva (1961) describes a fauna with *Triticites* and *Pseudofusulinella*-like fusulinids of lower Sakmarian in age. These *Triticites*

resembles closely the genus *Eoparafusulina* which is common in Sakmarian equivalents elsewhere.

Zone: *Schwagerina uralica* (61.5 - 36.2 m)

Taxa: *Schwagerina uralica* (Krotow)  
*Schwagerina indigaensis* (Grozdilova & Lebedeva)  
? *Schwagerina tastubensis* (Vissarionova)  
*Eoparafusulina perplexa* (Grozdilova & Lebedeva)  
*Pseudofusulinella sulanensis* (Grozdilova & Lebedeva)

This assemblage correlates to the Sakmarian zone of *S. uralica* in USSR (Grozdilova 1938, Beljaev & Rauser-Chernousova 1938 and Grozdilova & Lebedeva 1961).

Zone: *Schwagerina jenkinsi* (30.70 m)

Taxa: *Schwagerina jenkinsi* (Thorsteinsson)

*S. jenkinsi* correlates to Artinskian assemblages in other arctic regions. Identical faunas has been described by Thorsteinson (1960) and Ross (1967, 1978). This zone also shows great similarities to the Artinskian ?*Parafusulina lutugini* zone in USSR. *S. jenkinsi* is found in upper part of the Hambergfjellet Fm., Bjørnøya (Simonsen unpubl. data) and is present in lowermost part of core 7129/10-U-01.

#### Biostratigraphic comments on the taxa

*Schubertella sphaerica* Suleimanov, 1949

Middle Asselian to lower Sakmarian on the Russian Platform (Suleimanov 1949). Middle to upper Asselian in upper part of the Kapp Dunér Fm., Bjørnøya (Simonsen unpubl. data).

*Schubertella* sp.

Long ranging genus (upper Carboniferous-lower Permian)

*Pseudoendothyra* sp.

Long ranging genus (Carboniferous-Permian)

*Biwaella omiensis* Morikawa & Isomi, 1960

Lower Permian in Japan (Morikawa & Isomi 1960); Wolfcampian in New Mexico, North America (Skinner & Wilde 1965); middle Asselian (Leven & Scherbovich 1978). Similar forms are also noted from middle Asselian in Yugoslavia (Kochansky-Devide 1959).

*Boultonia* sp.

This seems to be a important genus which occurs in middle to upper Asselian sediments.

*Pseudofusulinella templensis* Ross, 1965

Sakmarian in Spitsbergen (Ross 1965). Asselian (Nilsson unpubl. data). Also present in core 7030/03-U-01.

*Pseudofusulinella* cf. *parvula* Skinner & Wilde, 1965

Wolfcampian in North America (Skinner & Wilde 1965); Asselian in Alaska (Petocz, 1970). Middle to upper Asselian in upper part of the Kapp Dunér Fm. on Bjørnøya (Simonsen unpubl. data).

*Pseudofusulinella* cf. *minima* Grozdilova & Lebedeva, 1961

Sakmarian (Tastubian) on the Russian Platform (Timan/Ural) (Grozdeleva & Lebedeva 1961).

*Pseudofusulinella sulaensis* Grozdilova & Lebedeva, 1961

Sakmarian (Tastubian) on the Russian Platform (Timan/Ural) (Grozdeleva & Lebedeva 1961).

*Pseudofusulinella* cf. *infrequenta* Grozdilova & Lebedeva, 1961

Sakmarian (Tastubian) on the Russian platform (Timan/Ural) (Grozdeleva & Lebedeva 1961).

*Pseudofusulina plana* Skinner & Wilde, 1965

Wolfcampian in North America (Skinner & Wilde 1965); Asselian in Arctic Canada (Nassichuck & Wilde 1977)

*Schwagerina* cf. *declinata* Korzenevsky, 1940 Middle to upper Asselian on the Russian Platform (Korzenevsky 1940 and Grozdilova & Lebedeva 1961).

*Shwagerina* cf. *princeps* Ehernberg, 1854

Synonymous with (part) *S. krotowi* Schellwien, 1908, which occurs in Asselian sediments from the USSR.

*Shwagerina* cf. *sphaeroidea* Rauser-Chernousova, 1938

Asselian in USSR (Rauser-Chernousova 1938 and Davydov 1986); Similar forms which all belong to the group *princeps* Ehernberg, 1854 are also found in upper part of the Kapp Dunér Fm., Bjørnøya, and in the middle part of the Tyrrellfjellet Mb., Spitsbergen (Nilsson unpubl. data).

*Schwagerina* cf. *furnishi* Ross, 1965

Lower Leonardian on Spitsbergen (Ross 1965); Asselian (Nilsson unpubl. data). A similar but larger form is present in core 7030/03-U-01.

*Schwagerina globosa* Schellwien & Dyhrenfurth, 1909

Lower Permian in USSR (Schellwien & Dyhrenfurth 1909). Middle to upper Asselian in upper part of the Kapp Dunér Fm., Bjørnøya (Simonsen unpubl. data).

*Schwagerina uralica* Krotow, 1888

Described from horizons in USSR now correlated to Sakmarian (Tastubian) (Krotow 1888, Grozdilova 1938, Grozdilova & Lebedeva 1961 and Beljaev & Rauser-Chernousova 1938).

*Schwagerina jenkinsi* Thorsteinsson, 1960

Lower to middle Artinskian (early to middle Leonardian) Arctic Canada (Thorsteinsson 1960 and Ross 1967, 1978). Lower to middle Artinskian in upper part of the Hambergfjellet Fm., Bjørnøya (Simonsen unpubl. data). Note: Nearly identical to the Artinskian ? *Parafusulina lutugini* Schellwien, 1908 which is found on the Russian Platform.

*Schwagerina mankomenensis* Petocz, 1970

Lower to middle Artinskian in Alaska (Petocz 1970). Present in the upper part of the Hambergfjellet Fm., Bjørnøya.

*Schwagerina indigaensis* Grozdilova & Lebedeva, 1961

Sakmarian on the Russian platform (Timan/Ural) (Grozdilova & Lebedeva 1961).

*Schwagerina* sp. 1

No references. Advanced form of a *Schwagerina*. Such forms are common in upper Asselian and Sakmarian.

*Schwagerina* sp. 2

No references. Correlative forms present in Sakmarian assemblages.

*Schwagerina* sp.

Lower Permian forms of *Schwagerina*.

*Sphaeroschwagerina moelleri* Rauser-Chernousova, 1936

Middle to upper Asselian in USSR (Rauser-Chernousova 1936, Rauser-Chernousova & Scherbovich 1949 and Leven & Scherbovich 1978). Middle to upper Asselian in upper part of the Kapp Dunér Fm., Bjørnøya (Simonsen unpubl. data).

*Sphaeroschwagerina sphaerica* var. *gigas* Rauser-Chernousova & Scherbovich, 1949

Middle to upper Asselian in USSR (Rauser-Chernousova & Scherbovich 1949, Scherbovich 1969, Isakova & Nazarov 1986). Middle to upper Asselian in upper part of the Kapp Dunér Fm., Bjørnøya. Also present in core 7030/03-U-01.

*Eoparafusulina perplexa* Grozdilova & Lebedeva, 1961

Sakmarian on the Russian Platform (Timan/Ural) (Grozdilova & Lebedeva 1961).

?*Eoparafusulina* sp.

This genus has a range from upper Asselian to Artinskian, but occurs most commonly in the Sakmarian stage. Grozdilova & Lebedeva has described an identical 'Triticites' fauna from the Sakmarian of the Russian Platform. These fusulinid types are usually described as *Eoparafusulina* (ex. Skinner & Wilde 1965).

**Fauna list**

ZONE: *Schwagerina*

Depth: 108.90 m, D-2025

*Schwagerina* cf. *declinata* Korzenevsky, 1940

*Biwaella omiensis* Morikawa & Isomi, 1960

- Depth: 108.50 m, D-2024  
*Schwagerina* cf. *declinata* Korzenevsky, 1940  
*Pseudofusulinella* cf. *parvula* Skinner & Wilde, 1965  
*Pseudofusulinella templensis* Ross, 1965  
*Pseudoendothyra* sp.
- Depth: 105.70 m, D-2022  
? *Schwagerina* sp.  
*Schubertella* sp.
- ZONE: *Sphaeroschwagerina moelleri*
- Depth: 104.70 m, D-2021  
*Sphaeroschwagerina moelleri* Rauser-Chernousova, 1936  
*Schwagerina* cf. *sphaeriodea* Rauser-Chernousova, 1938  
*Schubertella sphaerica* Suleimanov, 1949
- Depth: 104.50 m, D-2019  
*Schwagerina* cf. *sphaeriodea* Rauser-Chernousova, 1938  
*Schubertella* sp.
- Depth: 103.95 m, D-2017  
*Sphaeroschwagerina moelleri* Rauser-Chernousova, 1936
- Depth: 101.40 m, D-2015  
*Schwagerina* cf. *princeps* Ehrenberg, 1842  
*Schwagerina* cf. *furnishi* Ross, 1965
- Depth: 101.15 m, D-2014  
*Schwagerina* cf. *furnishi* Ross, 1965  
*Boultonia* sp.
- ZONE: *Sphaeroschwagerina sphaerica*
- Depth: 94.65 m, D-2011  
*Sphaeroschwagerina sphaerica* var. *gigas* Rauser-Chernousova & Scherbovich  
1949
- Depth: 93.70 m, D-2010  
*Pseudofusulinella templensis* Ross, 1965
- Depth: 89.15 m, D-2006  
*Schwagerina moelleri* Schellwien, 1908  
*Sphaeroschwagerina sphaerica* var. *gigas* Rauser-Chernousova & Scherbovich,  
1949  
*Schwagerina* sp. 1  
*Schwagerina* sp. 2  
*Boultonia* sp.
- ZONE: *Eoparafusulina*
- Depth: 83.60 m, D-2004  
? *Eoparafusulina* spp.  
*Pseudofusulinella* cf. *minima* Grozdilova & Lebedeva, 1961
- Depth: 80.70 m, D-2003  
? *Eoparafusulina* spp.  
? *Schwagerina* sp.

- Depth: 80.00 m, D-2002  
*Schwagerina globosa* Schellwien & Dyhrenfurth, 1909
- Depth: 76.30 m, D-2001  
? *Eoparafusulina* sp.  
*Pseudofusulinella* cf. *infrequenta* Grozdilova & Lebedeva, 1961
- Depth: 76.00 m, D-2000  
? *Eoparafusulina* sp.  
*Pseudofusulinella* sp.
- Depth: 75.00 m, D-1999  
*Pseudofusulina plana* Skinner & Wilde, 1965
- Depth: 66.80 m, D-1996  
? *Eoparafusulina* spp.  
*Pseudofusulinella* cf. *infrequenta* Grozdilova & Lebedeva, 1961
- ZONE: *Schwagerina uralica*
- Depth: 61.50 m, D-1994  
*Schwagerina uralica* Krotow, 1888
- Depth: 58.20 m, D-1992  
*Pseudofusulinella sulaensis* Grozdilova & Lebedeva, 1961  
*Eoparafusulina?* sp.
- Depth: 57.80 m, D-1991  
*Eoparafusulina perplexa* Grozdilova & Lebedeva, 1961  
*Pseudofusulinella sulaensis* Grozdilova & Lebedeva, 1961
- Depth: 54.90 m, D-1990  
*Schwagerina uralica* Krotow, 1888
- Depth: 52.30 m, D-1989  
*Schwagerina uralica* Krotow, 1888
- Depth: 51,7 m, D-693  
*Schwagerina uralica* Krotow, 1888
- Depth: 47.30 m, D-709  
*Schwagerina indigaensis* Grozdilova & Lebedeva, 1961
- Depth: 47.00 m, D-1988  
*Schwagerina tastubensis* Vissarionova, 1937
- Depth: 46.30 m, D-1987  
*Schwagerina uralica* Krotow, 1888
- Depth: 36.20 m, D-1982  
*Schwagerina uralica* Krotow, 1888
- ZONE: *Schwagerina jenkinsi*
- Depth: 30.70 m, D-1981  
*Schwagerina jenkinsi* Thorsteinsson, 1960



## CORE 7129/10-U-01

2 species of the genus *Schwagerina* have been identified from 3 samples in the lower part of this core. The different taxa are listed in each zone.

Zone: *Schwagerina jenkinsi*

Taxa: *Schwagerina jenkinsi* (Thorsteinsson)  
*Schwagerina mankomenensis* (Petocz)

This assemblage occurs in the lowermost part of the core (85.60 to 87.9 m.) and is a continuation of the same zone noted in the top of core 7129/10-U-02. One specimen, *S. jenkinsi*, dominates this assemblage which is recognized throughout the arctic regime from British Columbia to the Russian Platform. The zone of *S. jenkinsi* could be correlated to the zone of ?*Parafusulina lutugini* on the Russian Platform, both lower to middle Artinskian in age. This zone is also present in the upper part of the Hambergfjellet Fm. on Bjørnøya (Simonsen unpubl. data). A nearly identical fauna with *S. mankomenensis* (Petocz) is described by Petocz (1970) from Alaska. Description of identical fauna from Arctic Canada is given by Ross (1967, 1978) and Thorsteinsson (1960).

### Fauna list

ZONE: *Schwagerina jenkinsi*

Depth: 87.90 m, D-1933  
*Schwagerina jenkinsi* Thorsteinsson, 1960

Depth: 87.70 m, D-1932  
*Schwagerina jenkinsi* Thorsteinsson, 1960  
*Schwagerina mankomenensis* Petocz, 1970

Depth: 85.60 m, D-1923  
*Schwagerina jenkinsi* Thorsteinsson, 1960

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PLATE 1

Core 7030/03-U-01

All figures X10 except as noted

Figures

- 1,4. *Pseudofusulinella usvae* (Dutkevich); 1, D-2076 (depth 160.6 m);  
4 D -2080 (depth 166.3 m); axial sections.
- 2,3,5. *Pseudofusulinella templensis* Ross; D-2034 (39.2 m); axial sections.
- 6. *Schubertella* Staff & Wedekind; X40, D-2053 (70.7 m).
- 7,10,12. *Quasifusulina compacta* (Lee); D-2067 (95.7 m); axial sections.
- 8,9. *Triticites* cf. *rossicus* (Schellwien); 8, D-2074 (151.6 m); 9, D-2065  
(94.9 m); 8, axial section; 9, tangential section.
- 11,13,15. ? *Schwagerina arctica* (Schellwien); D-2065 (94.9 m); axial sections.
- 14. *Schwagerina* (*Daixina*) sp. A; D-2075 (153.9 m); tangential section.

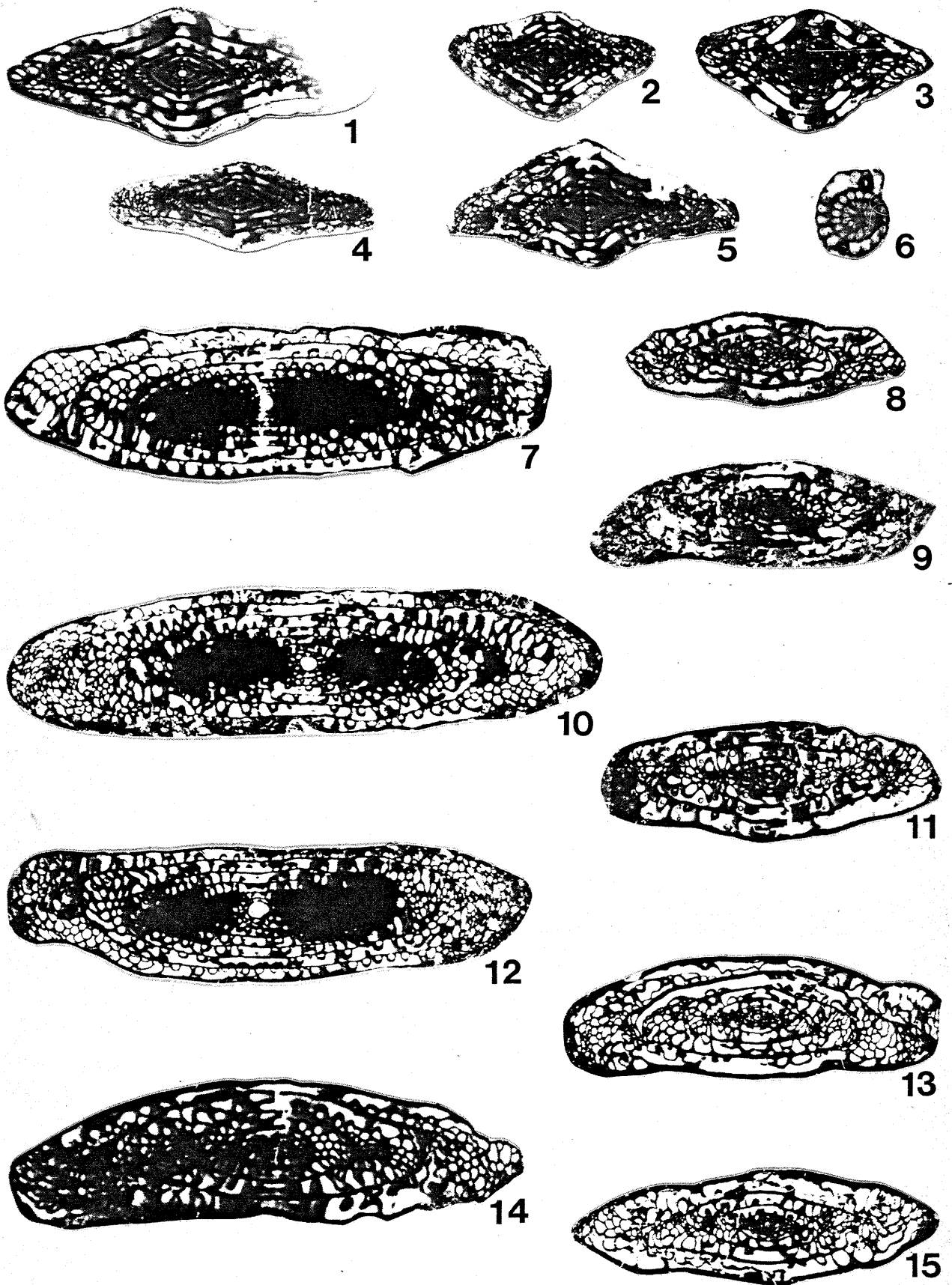


PLATE 2

Core 7030/03-U-01

All figures X10

Figures

- 1,2. *Schwagerina (Daixina) sokensis* (Rauser-Chernousova); D-2046 (65.0 m); axial sections.
3. *Schwagerina anderssoni* (Schellwien); D-2068 (95.9 m); axial section.
4. *Schwagerina* cf. *furnishi* (Ross); D-2068 (95.9 m); slightly oblique section.
5. *Pseudofusulina* sp. A; D-2045 (55.1 m); axial section.
- 6,7. *Pseudofusulina* cf. *alpina* (Schellwien); D-2049 (69.3 m); axial sections.
- 8,9,10. *Schwagerina rhomboiedes* (Shamov & Scherbovich); D-2038 (49.7 m); 8, slightly tangential, 9,10, axial sections.
- 11,12. *Schwagerina* cf. *emaciata* (Beede); D-2031 (29.7 m); axial sections.
- 13,15. *Schwagerina parafecunda* (Shamov & Scherbowich); 13, D-2038 (49.7 m); 15, D-2028 (27.8 m); axial sections.
14. *Schwagerina* sp. B; D-2031 (29.7 m); axial section.

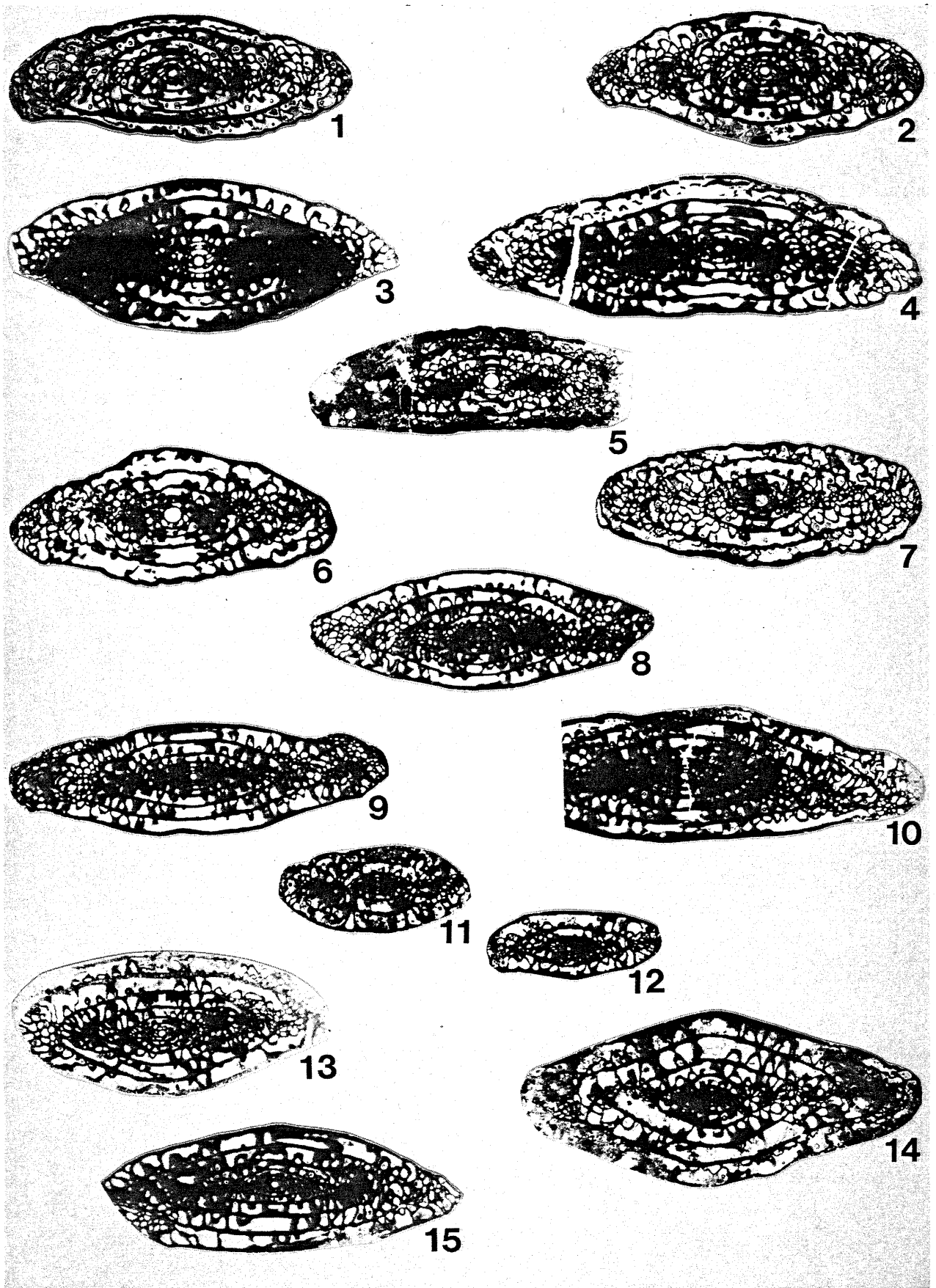


PLATE 3

Core 7030/03-U-01

All figures X10

Figures

- 1-4. *Schwagerina princeps* (Ehrenberg); 1, D-2028 (27.8 m); 2, D-2031 (29.7 m); 3, D-2042 (52.0 m); 4, D-2027 (26.8 m); 1,4, oblique sections; 2,3, axial sections.
- 5,7 *Sphaeroschwagerina cf. vulgaris* (Scherbovich); D-2045 (55.1 m); 5, oblique section; 7, tangential section.
- 6,8,9. *Sphaeroschwagerina sphaerica* var. *gigas* (Rauser-Chernousova & Scherbovich); 6, D-2027 (26.8 m); 8,9 D-2029 (28.4 m); 6,9 tangential sections; 8, saggital section.

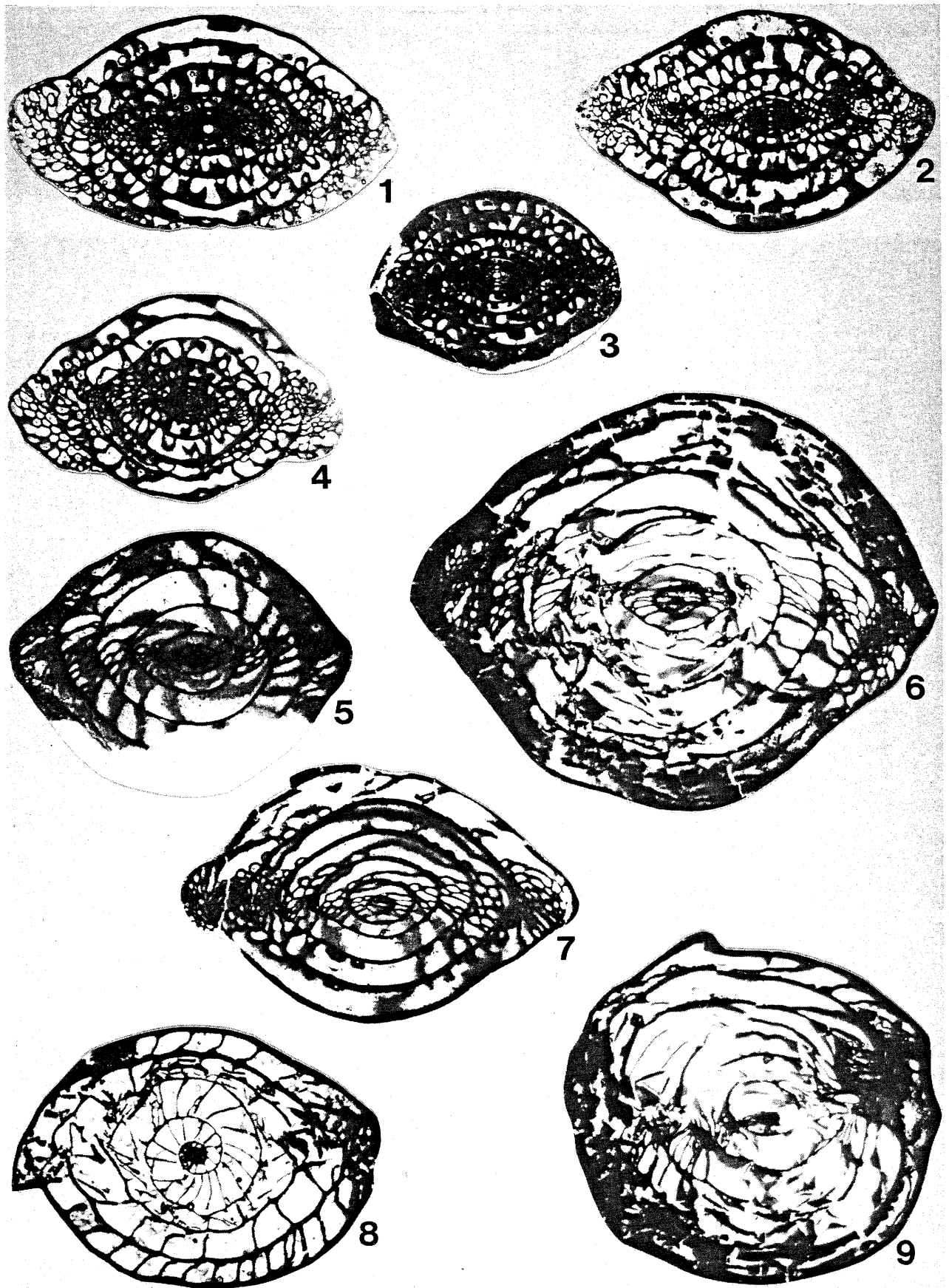


PLATE 4

Core 7129/10-U-02

Figures

- 1,2      *Pseudofusulinella* cf. *parvula* Skinner & Wilde X 10 (D-2024)
- 3,4,7,8      *Pseudofusulinella sulaensis* Grozdilova & Lebedeva, 3 (D-1992), 7 (D-1991)  
X 10
- 4,8      same specimens X 20.
- 5      *Pseudofusulinella* cf. *infrequenta* Grozdilova & Lebedeva X 10, (D-2001).
- 6,9      *Pseudofusulinella templensis* Ross X 10, 6 (D -2010), 9 (D-2024).
- 10,11      *Pseudofusulinella minima* Grozdilova & Lebedeva, 10 (D-2004) X 10, 11  
same specimen X 20.
- 12      *Biwaella omiensis* Morikawa & Isomi X 20, (D-2024).
- 13,14      *Schubertella sphaerica* Suleimanov X 40, (D-2021).
- 15      *Schubertella* sp. X 40, (D-2019).
- 16      *Boultonia* sp. X 40, (D-2014).
- 17      *Pseudoendothyra* sp. X 40, (D-2024).
- 18-20      *Schwagerina* cf. *furnishi* Ross X 10, 19,20 (D-2015), 18 (D-2014).
- 21      *Schwagerina* sp. 1 X 10, (D-2006).
- 22-24      *Schwagerina* cf. *declinata* Korzenevsky X10, 22 (D-2025), 23,24 (D-2024).
- 25      *Schwagerina* cf. *princeps* Eherenberg X 10, (D-2015).
- 26      *Schwagerina* sp. X 10, (D-2019).

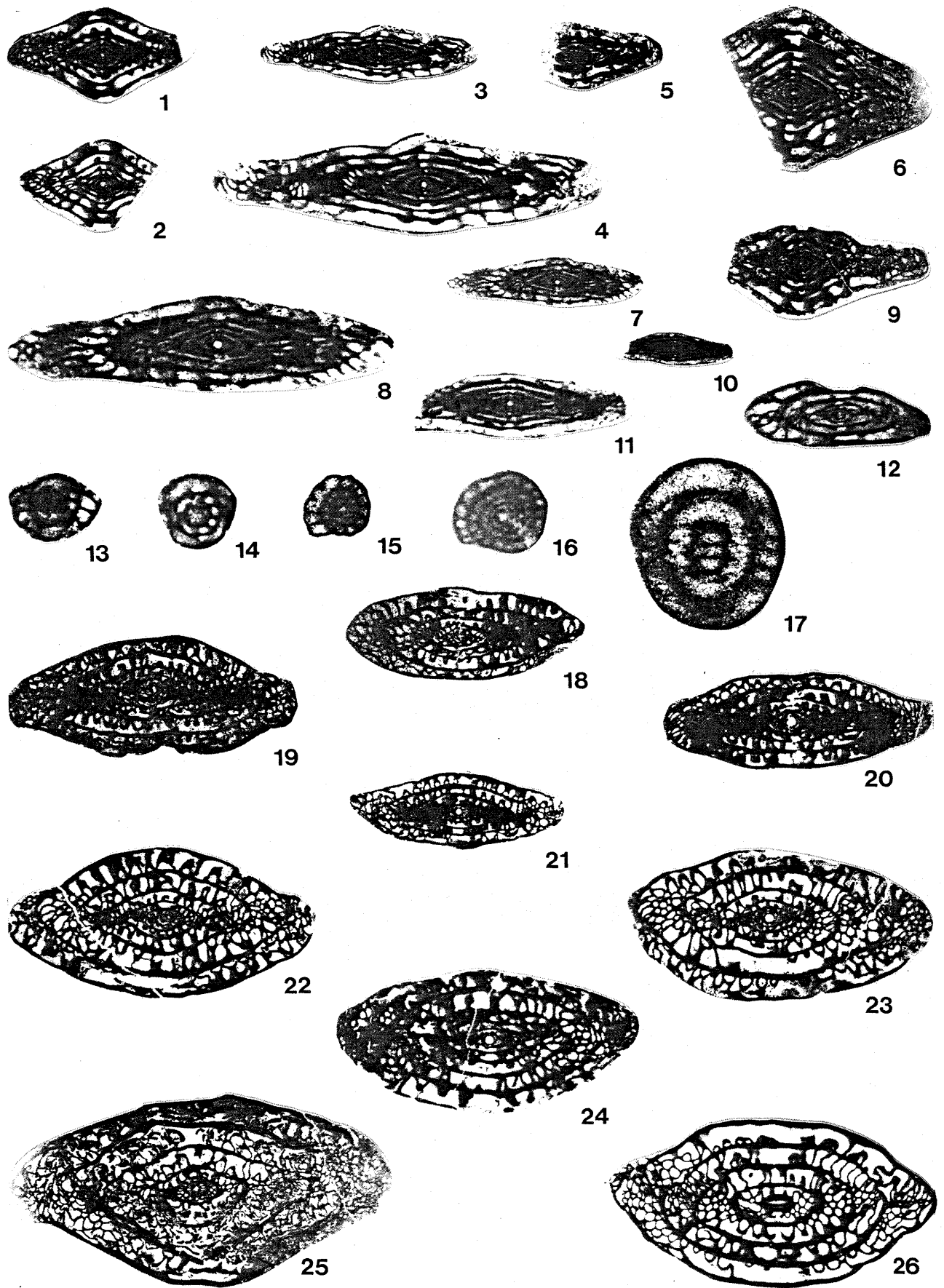


PLATE 5

Core 7129/10-U-02

Figures

- 1,4      *Schwagerina* cf. *sphaeroidea* Rauser-Chernousova X 10, (D-2021).
- 2,5      *Schwagerina globosa* Schellwien & Dyhrenfurth X 10, (D-2002).
- 3,6      *Pseudofusulina plana* Skinner & Wilde X 10, (D-1999).
- 7        ? *Schwagerina* sp. X 10, (D-2022).
- 8,10-12 ? *Eoparafusulina* sp. X 20, 8,12 (D-2000), 10 (D-1996), 11 (D-2001).
- 9        *Eoparafusulina perplexa* Grozdilova & Lebedeva X 10, (D-1991).
- 13       *Sphaeroschwagerina moelleri* Rauser-Chernousova X 10, (D-2017).
- 14       *Sphaeroschwagerina sphaerica* var. *gigas* Rauser-Chernousova & Scherbovich  
X 10, (D-2011).

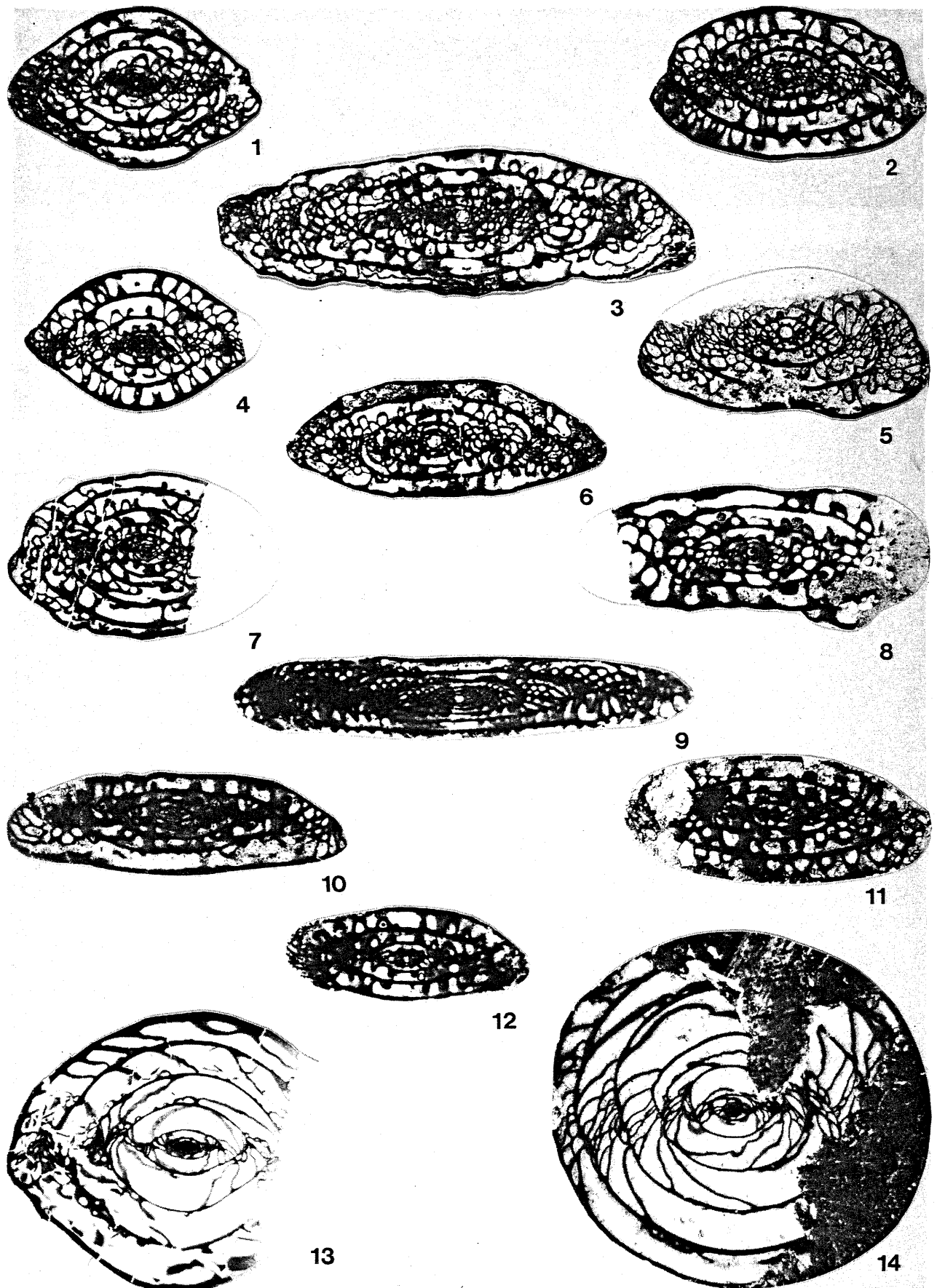


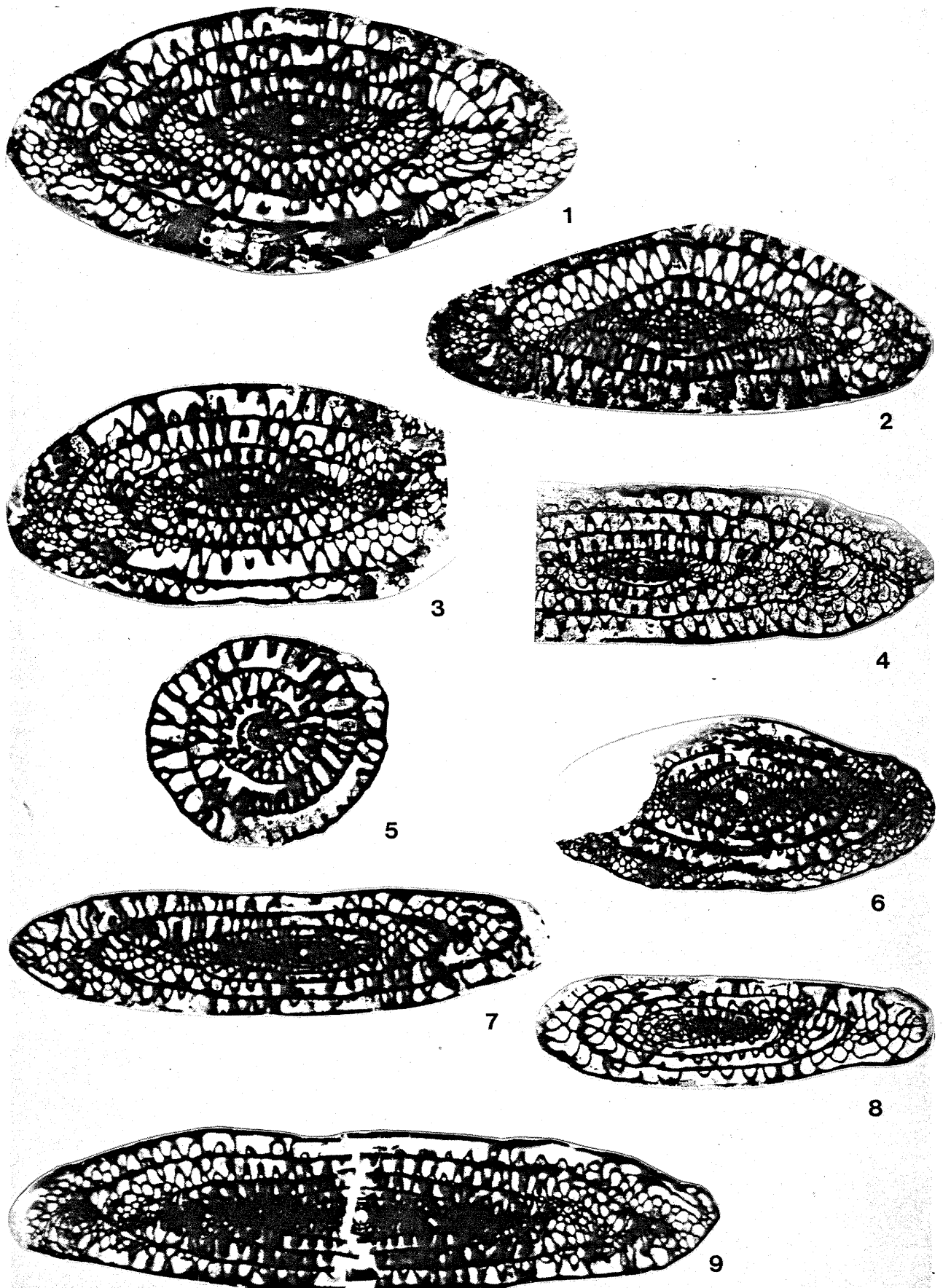
PLATE 6

Core 7129/10-U-02

- 1,2,3     *Schwagerina uralica* Krotow X 10, 1 (D-1989), 2 (D - 1982),  
3,5 (D - 693).
- 4         *Schwagerina indigaensis* Grozdilova & Lebedeva X 10, (D-709).
- 6         *Schwagerina* sp. 2 X 10, (D-2006).
- 9         *Schwagerina jenkinsi* Thorsteinsson X 10, (D-1981).

Core 7129/10-U-01

- 7         *Schwagerina jenkinsi* Thorsteinsson X 10, (D-1933).
- 8         *Schwagerina mankomenensis* Petocz X 10, (D-1933).



## **APPENDIX A.5**

### **BRYOZOANS**

by

**Hans Arne Nakrem**

Core 7129/10-U-2 & 1 have been investigated for presence of bryozoans. A description of the fauna in each core is given followed by a systematic list of all taxa present and comments on the biostratigraphical distribution of the individual taxa.

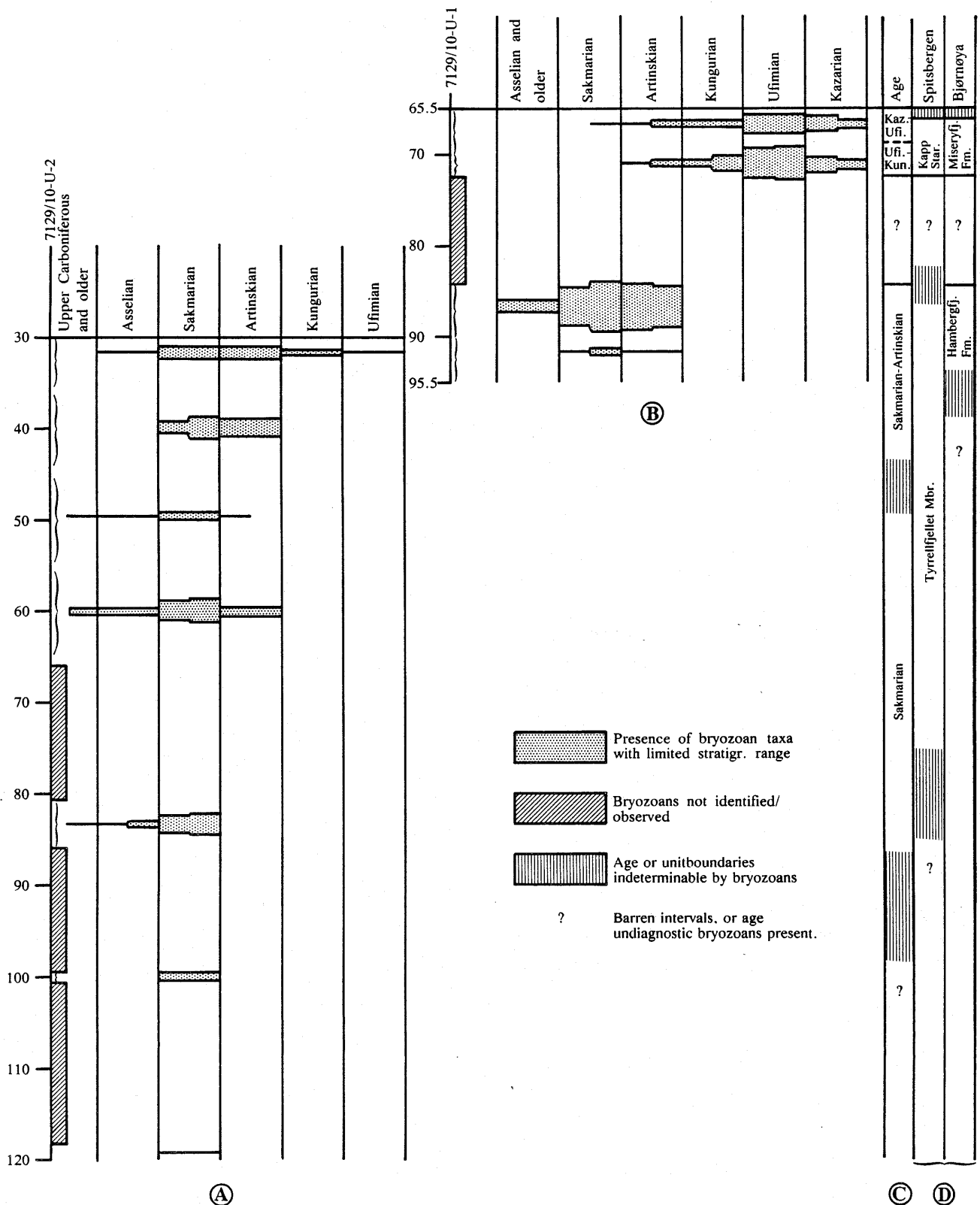


Figure A.5.1 Presence of bryozoan taxa within grouped core deep intervals. Size of shaded boxes indicates number of taxa within each grouped interval. The larger the box, the better the assignation of the interval to a specific stratigraphical series.

A: Core 7129/10-U-2

B: Core 7129/10-U-1

C: Possible ages of the cores

D: Tentative correlation with Svalbard lithological units.

## 7129/10-U-2

A total of 31 samples were specifically extracted from this core for bryozoan investigations. 50 acetate peels and 19 thin sections were prepared to identify the bryozoans in these samples. 39 taxa were identified; 19 of these to specific level (9 more to 'sp. cf.' species level).

### Biostratigraphy

Apart from the interval 119.50 to 67.91, the samples are grouped in 10 m intervals, and the presence of taxa from each interval correlated with standard Permian stratigraphy is presented in Figure A.5.1. This gives a graphical outline of a possible age of each grouped interval, and completes the range chart (Figure A.5.2).

The lowermost part (below deep 67.91m) has a very sparse bryozoan fauna, and both identifications and biostratigraphical implications are tentative. The stratigraphical range of the bryozoans within this interval is mostly Sakmarian, although some have an older distribution as well; it is not possible to assign any conclusive age.

In interval 67.91 to 56.12 m the diversity is richer, and faunal elements ranging through Asselian to Artinskian are present. *Polypora ellesmerensis*, *P. reciderata* and *Coscinium cyclops* are the most useful taxa in this interval proposing an (upper) Sakmarian age.

During the interval above 41.35 m the faunas shift towards relatively more Artinskian forms, and the youngest samples, with *Timanodictya dichotoma*, can be correlated with the Artinskian "Unnamed Formation" at Ellesmere Island; with Hambergfjellet Fm. at Bjørnøya; and core 7129/10-U-1 (see Figure A.6.1).

### Sample description

Depth: 119.50 m, D-1979, one acetate peel.

*Ascopora* sp. A.

*Fenestella* sp.

Depth: 119.15 m, D-1978, four acetate peels.

*Polypora* sp.

*Rectifenestella* sp. cf. *robusta* (Shul'ga-Nesterenko 1936)

*Ascopora* sp. A.

*Polypora* sp. A.

Depth: 100.42 m, D-1977, two acetate peels.

*Alternifenestella tenuiseptata* (Shul'ga-Nesterenko 1941).

Depth: 100.20 m, D-1976, one acetate peel.

*Cyclotrypa* sp.

*Rectifenestella* sp. cf. *robusta* (Shul'ga-Nesterenko 1936)

*Polypora* sp.

Depth: 87.75 m, D-1975, four thin sections.

*Ramiporidra minuta* Shul'ga-Nesterenko 1933

*Goniocladia* sp.

*Fenestella* (s.s.) sp.

*Rectifenestella robusta* (Shul'ga-Nesterenko 1936)

*Penniretepora subtila* (Shul'ga-Nesterenko 1941)

*Polypora reciderata* Trizna 1950

*Polypora* sp.

*Ascopora* sp. cf. *attenuata* Trizna 1950

Depth: 83.55 m, D-1974, two acetate peels, two thin sections.

*Ramiporidra minuta* Shul'ga-Nesterenko 1933

*Fabifenestella rhomboidea* (Nikiforova 1938)

*Polypora ellesmerensis* Morozova 1986.

Depth: 81.54 m, D-1972, one acetate peel.

Soft shale sample with pyritic/dolomitized fossils.

*Polypora* sp.

Depth: 67.91 m, D-1971, two acetate peels, three thin sections.

*Polypora extenta* Trizna 1939

Depth: 65.36 m, D-1969, one acetate peel.

*Fabifenestella rhomboidea* (Nikiforova 1938)

*Polypora extenta* Trizna 1939.

Depth: 62.69 m, D-1968, one acetate peel.

*Coscicium* sp. cf. *cyclops* (Keyserling 1846)

Depth: 62.02 m, D-1967, one acetate peel.

*Archimedes stuckenbergi* Nikiforova 1938

*Fistulipora* sp.

Depth: 61.69 m, D-1966, one acetate peel.

*Fistulipora* sp.

Depth: 60.55 m, D-1965, one acetate peel.

*Archimedes* sp.

Depth: 59.87 m, D-1964, one acetate peel.

*Archimedes* sp.

Depth: 59.55 m, D-1963, three acetate peels.

*Coscinium cyclops* (Keyserling 1846)

Depth: 58.69 m, D-1962, one acetate peel.

*Ascoporella* sp. cf. *grandis* (Kruchinina 1973)

*Polypora* sp. cf. *brevicellata* Baranova 1960

Depth: 56.12 m, D-1961, two acetate peels.

*Ascopora* sp.

*Reteporidra* (*Kingopora*) *tuberculata* Shul'ga-Nesterenko 1941

Depth: 53.93 m, D-1960, two acetate peels.

*Polypora* sp. cf. *martis* Fisher 1866

*Goniocladia* sp.

Depth: 48.09 m, D-1959, three acetate peels.

*Ascoporella* sp. cf. *grandis* (Kruchinina 1973)

*Pennirepora* sp.

*Rectifenestella* sp.

*Polypora* sp.

Depth: 41.35 m, D-1957, three acetate peels.

*Ascoporella grandis* (Kruchinina 1973).

Depth: 41.05 m, D-1956, four thin sections.

*Cyclotrypa* sp.

*Ramiporidra* sp.

Depth: 40.95 m, D-1955, one acetate peel.

*Flexifenestella* sp.

Depth: 39.49 m, D-1954, one acetate peel.

*Ascopora* sp.

Depth: 36.30 m, D-1953, six thin sections.

*Goniocladia* sp. cf. *tenuis* Shul'ga-Nesterenko 1941

*Coscinium cyclops* (Keyserling 1846)

*Alternifenestella bifida* (Eichwald 1860)

*Flexifenestella petschorica* (Shul'ga-Nesterenko 1941)

*Laxifenestella lahuseni* (Stuckenberg 1895)

*Penniretepora belajensis* (Trizna 1939)

*Polypora* sp. cf. *reciderata* Trizna 1950

*Polypora brevicellata* Baranova 1960

Depth: 35.30 m, D-1951, three acetate peels.

*Rectifenestella retiformis* (Schlotheim 1816)

*Archimedes* sp.

*Rhombotrypella invulgata* Trizna 1948

Depth: 34.87 m, D-1950, one acetate peel.

*Rectifenestella minutula* (Gorjunova 1975)

Depth: 33.77 m, D-1948, one acetate peel.

*Penniretepora* sp.

*Rectifenestella retiformis* (Schlotheim 1816)

Depth: 33.15 m, D-1947, one acetate peel.

*Timanodictya dichotoma* (Stuckenberg 1895)

Depth: 31.50 m, D-1945, one acetate peel.

*Coscinium cyclops* (Keyserling 1846)

Depth: 30.76 m, D-1944, two acetate peels.

*Coscinium cyclops* (Keyserling 1846)

*Timanodictya dichotoma* (Stuckenberg 1895)

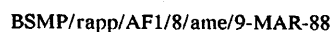
Depth: 30.50 m, D-1943, five acetate peels.

*Coscinium cyclops* (Keyserling 1846)

*Ascopora* sp. cf. *attenuata* Trizna 1950

*Rectifenestella pseudoveneris* (Shul'ga-Nesterenko 1941)

*Timanodictya* sp. cf. *dichotoma* (Stuckenberg (1895)



## 7129/10-U-1

A total of 38 samples were specifically extracted from this core for bryozoan investigations. 75 acetate peels and 33 thin sections were prepared to identify the bryozoans in these samples. Additionally, 17 thin sections prepared for general purpose (marked \* in the core description section) were briefly investigated. 68 taxa were identified; 30 of these to specific level (21 more to 'sp. cf.' species level).

### Biostratigraphy

Apart from the barren interval (84.50 to 74.00), the samples are grouped in appr. 5 m intervals, and the presence of taxa from each interval correlated with standard Permian stratigraphy is presented in Figure A.5.1. This gives a graphical outline of a possible age of each grouped interval, and completes the range chart (Figure A.5.3).

The lower part (below deep 84.50 m) has a cryptostomatous/fenestrate bryozoan fauna of typical Sakmarian through Artinskian age. Cystoporates are less abundant, and trepostomes play a minor role. The richest interval (90 to 85 m) contains important taxa (*Coscinium cyclops*, several species of *Rectifenstella* and *Ascopora*) that can be correlated to the Sakmarian of the Ural and the Russian Platform. *Coscinium cyclops* and *Ascoporella grandis* are common taxa of the mid-upper Tyrrellfjellet Mb. at Spitsbergen. Of significant importance is *Timanodictya dichotoma*, a species that correlates the deep 89- to 88 m to upper Hambergfjellet Fm. at Bjørnøya; to the Artinskian "Unnamed Formation" of Ellesmere Island (see Morozova & Kruchinina 1986) as well as to deep 30 m of core 7129/10-U-2.

The clastic interval 84- to 74.00 m is barren regarding identifiable bryozoans. Only in the upper part of this interval indet. trepostomatous bryozoans are sparsely occurring.

Bryozoans are common in the interval 73.70 m to 64.45 m; above this level no further bryozoans are observed. The faunal shift is abruptly from the lower association to this younger association dominated by large trepostomes (*Dyscritella*, *Rhombotrypella* and *Tabulipora*); abundant cystoporates (almost monospecific represented by *Ramipora hochstetteri*); cryptostomes (*Permoheloclema* and *Primorella*) and fenestrates being dramatically reduced in diversity. Although some of these species range from ?Artinskian-Kungurian

(Lower Permian) this association is regarded to be of Ufimian age as correlated with the Ural region and Novaya Zemlya. The fauna is almost identical to the fauna developed in the Kapp Starostin Fm. of Spitsbergen, and less similar to the Miseryfjellet Fm. fauna from Bjørnøya. Of special stratigraphic importance is the occurrence of *Hinganella improvisa* and ?*Neoeridotrypella* sp. cf. *magna* (samples 67.86 m and 67.32 m). These two species are important elements in the Kazanian succession in Novaya Zemlya (Morozova & Kruchinina 1986), and other species are described from Kazanian strata in Mongolia (Gorjunova & Morozova 1979), and other Soviet localities (Morozova 1970). *Hinganella*, as well as other typical Kazanian taxa are absent from the Permian succession of Svalbard (Nakrem unpubl. data) (see also note under *H. improvisa* in the following faunal list). The age of this deep interval may thus have no correlative equivalent to the Permian of Svalbard.

The correlation of this core, with core 7129/10-U-2 and with Spitsbergen and Bjørnøya is shown on Fig. A.5.1.

#### Sample description

Depth: 95.50m, \*

*Goniocladia* sp.

*Fenestella* sp.

Depth: 93.12m, \*

*Fenestella* sp.

? *Rhabdomeson* sp.

Depth: 92.10m, \*

*Polypora* sp.

*Fenestella* sp.

*Goniocladia* sp. cf. *tenuis* Shul'ga-Nesterenko 1941

Depth: 90.32-.44 m, D-1941, two acetate peels.

*Alternifenestella* sp. cf. *crassiseptata* (Shul'ga-Nesterenko 1941)

*Fistulipora* sp.

Depth: 89.71 m, D-1940, one acetate peel.

*Rectifenestella* sp. cf. *retiformis* (Schlotheim 1816)

Depth: 89.53 m, D-1939, one thin section.

*Polypora voluminosa* Trizna & Klautsan 1961

*Polypora martis* Fischer 1866

*Goniocladia* sp.

Depth: 89.14 m, D-1937, three thin section; one acetate peel.

*Fistulipora/Cyclotrypa* sp.

*Coscinium cyclops* (Keyserling 1846)

*Rectifenestella ornata* (Shul'ga-Nesterenko 1939)

*Rectifenestella* sp. cf. *pseudoveneris* (Shul'ga-Nesterenko 1941)

*Archimedes* sp.

*Penniretepora* sp. cf. *subtila* (Shul'ga-Nesterenko 1941)

*Timanodictya* sp. cf. *dichotoma* (Stuckenberg 1895)

Depth: 88.80 m, D-1936, one acetate peel.

*Coscinium* sp.

*Ascopora* sp.

Depth: 88.70 m, \*

*Fenestella* sp.

*Polypora* sp.

Depth: 88.07 m, D-1934, three acetate peels; three thin sections.

*Coscinium* sp. cf. *cyclops* (Keyserling 1846)

? *Paralioclema* sp.

*Ascopora sterlitamakensis* Nikiforova 1939

*Ascopora* sp. cf. *attenuata* Trizna 1950

*Rectifenestella retiformis* (Schlotheim 1816)

*Timanodictya dichotoma* (Stuckenberg 1895)

Depth: 87.67 m, D-1931, two thin sections.

*Fistulipora* sp.

*Coscinium cyclops* (Keyserling 1846)

? *Rhombopora* sp.

*Archimedes* sp. cf. *stuckenbergi* Nikiforova 1939

*Penniretepora* sp.

? *Reteporidra* sp.

Depth: 87.65 m, \*

*Archimedes stuckenbergi* Nikiforova 1939

*Streblascopora* sp.

Depth: 87.37 m, D-1930, four thin sections; two acetate peel.

? *Rhombotrypella* sp.

*Ascoporella* sp. cf. *grandis* (Kruchinina 1973)

*Polypora* sp. cf. *voluminosa* Trizna & Klautsan 1961

*Polypora confirmata* Kruchinina 1986

Depth: 87.00 - .15 m, D-1929, two thin sections; two acetate peels.

*Ascopora* sp.

*Primorella* sp.

*Permofenestella pentagonalis* (Shul'ga-Nesterenko 1941)

*Rectifenestella nikiforovae* (Shul'ga-Nesterenko 1936)

*Reteporidra* sp. cf. *eichwaldi* Nikiforova 1938

Depth: 86.70 m, D-1928, two acetate peels.

*Rectifenestella nikiforovae* (Shul'ga-Nesterenko 1936)

*Polypora voluminosa* Trizna & Klautsan 1961

*Polypora* sp. cf. *martis* Fischer 1866

Depth: 86.57 m, D-1927, two thin sections; two acetate peels.

*Primorella* sp.

*Flexifenestella eichwaldi* (Stuckenberg 1895)

*Fabifenestella rhomboidea* (Nikiforova 1938)

*Laxifenestella lahuseni* (Stuckenberg 1895)

*Rectifenestella biarmica* (Shul'ga-Nesterenko 1941)

*Rectifenestella nikiforovae* (Shul'ga-Nesterenko 1936)

*Archimedes* sp. cf. *stuckenbergi* Nikiforova 1938

*Penniretepora* sp.

*Polypora confirmata* Kruchinina 1986

*Polypora* sp.

? *Reteporidra* sp.

Depth: 86.55 m, \*

*Goniocladia* sp. cf. *tenuis* Shul'ga-Nesterenko 1941

*Rectifenestella* sp. cf. *permicus* (Shul'ga-Nesterenko 1941)

*Rectifenestella retiformis* (Schlotheim 1816)

Depth: 86.20 m, \*

*Archimedes* sp.

*Goniocladia* sp.

*Fenestella* sp.

Depth: 85.92 m, D-1925, one acetate peel.

*Fenestella* sp.

Depth: 85.70 m, D-1924, one acetate peel.

*Rectifenestella* sp. cf. *nikiforovae* (Shul'ga-Nesterenko 1936).

Depth: 84.90 m, \*

*Goniocladia* sp.

*Rectifenestella* sp. cf. *nikiforovae* (Shul'ga-Nesterenko 1936)

*Penniretepora* sp. cf. *praetenuis* (Trizna 1950)

Depth: 84.87 m, D-1922, one thin section.

*Fistulipora* sp.

*Ascopora* sp.

*Polypora confirmata* Kruchinina 1986

Depth: 84.66 m, D-1921, one acetate peel.

*Polypora* sp. cf. *martis* Fischer 1866

Depth: 84.57 m, D-1920, one acetate peel.

? *Rhombotrypella/Ascopora* sp.

Depth: 73.70 - .90 m, D-1916, three acetate peels.

*Cyclotrypa distincta* Morozova 1986  
*Ramipora hochstetteri* Toula 1875  
*Dyscritella speciosa* Morozova 1986  
*Permoheloclema merum* Ozhgibesov 1983  
*Reteporidra* sp. cf. *grandis* Morozova 1970

Depth: 73.50 m, \*

*Ramipora hochstetteri* Toula 1875  
*Dyscritella* sp. cf. *parallela* Morozova 1970  
*Dyscritella speciosa* Morozova 1986  
*Primorella* sp.  
*Streblotrypa* sp. cf. *suvodiensis* Shishova 1965  
*Permoheloclema merum* Ozhgibesov 1983  
*Reteporidra grandis* Morozova

Depth: 73.45 m, \*

*Rhombotrypella alfredensis* Morozova 1986.

Depth: 73.29 m, D-1913, four acetate peels.

*Cyclotrypa distincta* Morozova 1986  
*Ramipora hochstetteri* Toula 1875  
*Tabulipora arcticensis* Ross & Ross 1963  
*Dyscritella speciosa* Morozova 1986  
*Permoheloclema merum* Ozhgibesov 1983

Depth: 72.99 m, D-1912, three acetate peels.

*Ramipora hochstetteri* Toula 1875  
*Dyscritella speciosa* Morozova 1986  
*Streblotrypa suvodiensis* Shishova 1965  
*Permoheloclema merum* Ozhgibesov 1983

Depth: 72.07 - .17 m, D-1910, three acetate peels.

*Ramipora hochstetteri* Toula 1875  
*Dyscritella* sp.  
*Polypora* sp.

Depth: 71.30 m, \*

*Ramipora hochstetteri* Toula 1875  
*Permoheloclema merum* Ozhgibesov 1983  
*Rhombotrypella alfredensis* Morozova 1986.

Depth: 71.25 m, \*

*Ramipora hochstetteri* Toulou 1875  
*Dyscritella* sp.  
*Permoheloclema merum* Ozhgibesov 1983  
*Primorella* sp.

Depth: 71.00 m, D-1907, two acetate peels.

*Cyclotrypa distincta* Morozova 1986  
*Ramipora hochstetteri* Toulou 1875  
*Alternifenestella spitzbergenensis* (Nikiforova 1936)  
*Alternifenestella greenharbourensis* (Nikiforova 1936)  
*Polypora mariae* Ravikovich 1948

Depth: 70.83 - .96 m, D-1906, two thin sections; two acetate peels.

*Cyclotrypa distincta* Morozova 1986  
*Ramipora hochstetteri* Toulou 1875  
*Tabulipora arcticensis* Ross & Ross 1962  
*Dyscritella* sp.  
*Permoheloclema merum* Ozhgibesov 1983  
*Primorella* sp. cf. *tundrica* Kruchinina 1986  
*Rectifenestella savodovskiyi* (Nekhoroshev 1959)

Depth: 70.76 m, D-1903, two acetate peels.

*Ramipora hochstetteri* Toulou 1875  
*Rhombotrypella insolita* Morozova 1986  
*Permoheloclema merum* Ozhgibesov 1983  
*Streblotrypa* sp. cf. *suvodiensis* Shishova 1965  
*Penniretepora* sp. cf. *lineata* Nikiforova 1933  
*Polypora mariae* Ravikovich 1948

Depth: 70.10 m, D-1904, two acetate peels.

*Ramipora hochstetteri* Toulou 1875  
*Dyscritella speciosa* Morozova 1986  
*Permoheloclema merum* Ozhgibesov 1983

Depth: 69.78 m, \*

? *Tabulipora/Rhombotrypella* sp. (encrusting).

Depth: 69.30 m, D-1902, two thin sections; two acetate peels.

*Fistulipora* sp.

*Ramipora hochstetteri* Toulou 1875

*Rhombotrypella insolita* Morozova 1986

*Tabulipora arcticensis* Ross & Ross 1962

*Dyscritella speciosa* Morozova 1986

*Streblotrypa suvodiensis* Shishova 1965

*Permoheloclema merum* Ozhgibesov 1983

*Penniretepora* sp.

*Polypora* sp. cf. *brevicellata* Baranova 1960

*Polypora* sp. cf. *reteporidraeformis* Nikiforova 1936

Depth: 69.23 m, \*

*Ramipora hochstetteri* Toulou 1875

*Dyscritella speciosa* Morozova 1986

*Permoheloclema merum* Ozhgibesov 1983

*Primorella* sp.

*Fenestella* sp.

*Polypora* sp.

Depth: 69.02 m, D-1901, two acetate peels.

*Tabulipora arcticensis* Ross & Ross 1962

*Streblotrypa suvodiensis* Shishova 1965

*Polypora* sp. cf. *brevicellata* Baranova 1960

Depth: 68.05 m, D-1900, one acetate peel.

*Ramipora hochstetteri* Toulou 1875

*Tabulipora* sp. cf. *arcticensis* Ross & Ross 1963

*Permoheloclema merum* Ozhgibesov 1983

*Fenestella* sp.

*Polypora* sp.

Depth: 68.00 m, D-1899, two acetate peels; two thin sections.

*Ramipora hochstetteri* Toulou 1875

*Tabulipora arcticensis* Ross & Ross 1963

*Dyscritella speciosa* Morozova 1986

*Permoheloclema merum* Ozhgibesov 1983

*Primorella* sp. cf. *tundrica* Kruchinina 1986

Depth: 67.86 m, D-1898, six thin sections; four acetate peels.

*Ramipora hochstetteri* Toula 1875  
*Hinganella improvisa* Morozova 1986  
? *Neoeridotrypella* sp. cf. *magna* Morozova 1986  
? *Rhombotrypella alfredensis* Morozova 1986  
*Tabulipora* sp. cf. *arcticensis* Ross & Ross 1963  
*Dyscritella* sp. cf. *speciosa* Morozova 1986  
*Permoheloclema merum* Ozhgibesov 1983  
*Primorella* sp.  
*Sireblotrypa suvodiensis* Shishova 1965  
*Alternifenestella* sp. cf. *spitzbergensis* (Nikiforova 1936).

Depth: 67.60 m, D-1896, two acetate peels.

*Polypora mariae* Ravikovich 1948

Depth: 67.52 m, \*

*Ramipora hochstetteri* Toula 1875  
*Tabulipora* sp.  
*Permoheloclema merum* Ozhgibesov 1983  
*Sireblotrypa suvodiensis* Shishova 1965

Depth: 67.35 - .45 m, D-1894, two thin sections; two acetate peels.

*Ramipora hochstetteri* Toula 1875  
*Hinganella improvisa* Morozova 1986  
*Dyscritella* sp. cf. *speciosa* Morozova 1986  
*Permoheloclema merum* Ozhgibesov 1983  
*Fenestella* sp.  
*Polypora* sp.

Depth: 67.32 m, D-1893, four acetate peels.

*Ramipora hochstetteri* Toula 1875  
*Hinganella improvisa* Morozova 1986  
*Dyscritella speciosa* Morozova 1986  
*Rectifenestella savodovskiyi* (Nekhoroshev 1959)  
*Polypora mariae* Ravikovich 1948  
*Timanodictya nikiforovae* Morozova 1966.

Depth: 67.20 m, D-1891, two acetate peels.

*Ramipora hochstetteri* Toula 1875

*Dyscritella speciosa* Morozova 1986

*Permoheloclema merum* Ozhgibesov 1983

Depth: 67.05 m, D-1890, two acetate peels.

*Ramipora hochstetteri* Toula 1875

*Tabulipora* sp. cf. *arcticensis* Ross & Ross 1963

*Dyscritella* sp.

*Permoheloclema merum* Ozhgibesov 1983

*Primorella* sp.

*Fenestella* sp.

*Polypora* sp.

Depth: 66.81 m, D-1889, two acetate peels.

*Tabulipora arcticensis* Ross & Ross 1962

*Polypora* sp. cf. *russiensis* Shul'ga-Nesterenko 1941

Depth: 66.69 m, \*

*Ramipora hochstetteri* Toula 1875

*Dyscritella* sp. cf. *speciosa* Morozova 1986

*Permoheloclema merum* Ozhgibesov 1983

*Fenestella* sp.

*Polypora* sp.

Depth: 66.64 m, D-1888, two acetate peels.

*Ramipora hochstetteri* Toula 1875

*Tabulipora* sp. cf. *arcticensis* Ross & Ross 1963

*Dyscritella* sp.

*Permoheloclema merum* Ozhgibesov 1983

Depth: 66.55 m, D-1887, three acetate peels.

*Ramipora hochstetteri* Toula 1875

*Tabulipora* sp. cf. *arcticensis* Ross & Ross 1963

*Permoheloclema merum* Ozhgibesov 1983

*Streblotrypa* sp.

Depth: 65.81 m, \*

*Fenestella* sp.

*Polypora* sp.

Depth: 64.45 m, D-7129, eight acetate peels.

*Tabulipora arcticensis* Ross & Ross 1963

*Streblotrypa suvodiensis* Shishova 1965

*Permoheloclema merum* Ozhgibesov 1983

*Primorella* sp. cf. *tundrica* Kruchinina 1986

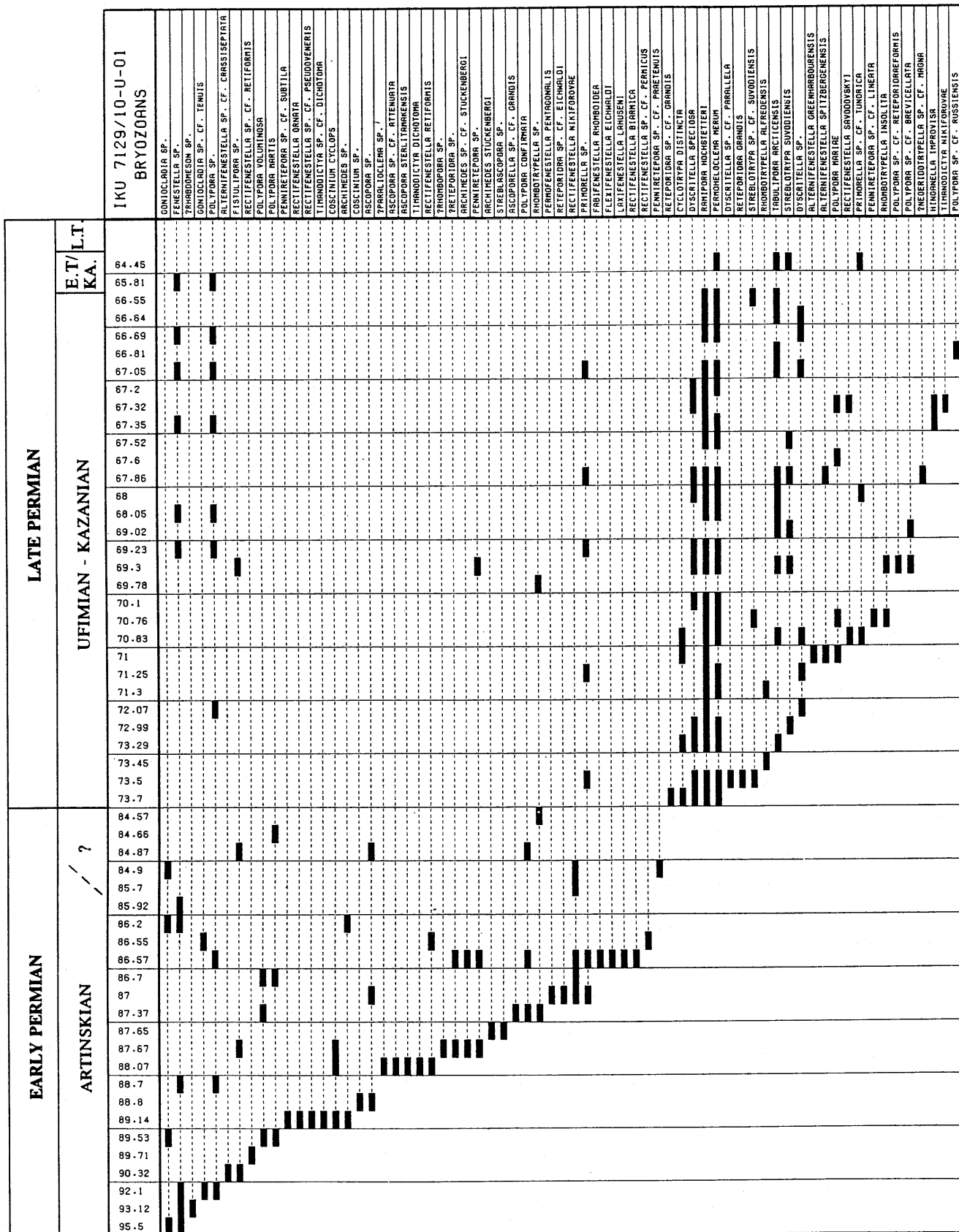


Figure A.5.3 Range chart, core 7129/10-U-1.

## Systematic faunal list

### Order Cystoporata

Genus *Fistulipora*

*Fistulipora* sp.

Genus *Cyclotrypa*

*C. distincta* Morozova 1986 (in Morozova & Kruchinina 1986)

Genus *Coscinium*

*C. cyclops* (Keyserling 1846)

Genus *Goniocladia*

*G. tenuis* Shul'ga-Nesterenko 1941

Genus *Ramiporidra*

*R. minuta* Shul'ga-Nesterenko 1933

Genus *Ramipora*

*R. hochstetteri* Toulou 1875

### Order Trepotomata

Genus *Hinganella*

*H. improvisa* Morozova 1986 (in Morozova & Kruchinina 1986)

Genus *Neoridotrypella*

*N. magna* Morozova 1986 (in Morozova & Kruchinina 1986)

Genus *Tabulipora*

*T. arcticensis* Ross & Ross 1963

Genus *Rhombotrypella*

*R. alfredensis* Morozova 1986 (in Morozova & Kruchinina 1986)

*R. insolita* Morozova 1986 (in Morozova & Kruchinina 1986)

*R. invulgata* Trizna 1948

Genus *Dyscritella*

*D. parallela* Morozova 1970

*D. speciosa* Morozova 1986 (in Morozova & Kruchinina 1986)

## Order Cryptostomata

- Genus *Primorella*  
*P. tundrica* Kruchinina 1986 (in Morozova & Kruchinina 1986)
- Genus *Ascopora*  
*A. attenuata* Trizna 1950  
*A. sterlitamakensis* Nikiforova 1939  
*A. sp. A.*
- Genus *Ascoporella*  
*A. grandis* (Kruchinina 1973)
- Genus *Streblotrypa*  
*S. suvodiensis* Shishova 1965
- Genus *Permoheloclema*  
*P. merum* Ozhgibesov 1983
- Genus *Timanodictya*  
*T. nikiforovae* Morozova 1966

## Order Fenestrata

- Genus *Fenestella*  
*F. spp.*
- Genus *Flexifenestella*  
*F. eichwaldi* (Stuckenberg 1895)  
*F. petschorica* (Shul'ga-Nesterenko 1941)
- Genus *Laxifenestella*  
*L. lahuseni* (Stuckenberg 1895)
- Genus *Fabifenestella*  
*F. rhomboidea* (Nikiforova 1938)
- Genus *Rectifenestella*  
*R. biarmica* (Shul'ga-Nesterenko 1941)  
*R. minutula* (Gorjunova 1975)  
*R. nikiforovae* (Shul'ga-Nesterenko 1936)  
*R. ornata* (Shul'ga-Nesterenko 1939)  
*R. permicus* (Shul'ga-Nesterenko 1941)  
*R. pseudoveneris* (Shul'ga-Nesterenko 1941)  
*R. retiformis* (Schlotheim 1816)  
*R. robusta* (Shul'ga-Nesterenko 1936)  
*R. savodovskyi* (Nekhoroshev 1959)

Genus *Alternifenestella*

- A. bifida* (Eichwald 1860)
- A. crassiseptata* (Shul'ga-Nesterenko 1941)
- A. greenharbourensis* (Nikiforova 1936)
- A. spitzbergenensis* (Nikiforova 1936)
- A. tenuiseptata* (Shul'ga-Nesterenko 1941)

Genus *Permofenestella*

- P. pentagonalis* (Shul'ga-Nesterenko 1941)

Genus *Archimedes*

- A. stuckenbergi* Nikiforova 1938

Genus *Penniretepora*

- P. belajensis* (Trizna 1939)
- P. sp. cf. lineata* (Nikiforova 1933)
- P. subtila* (Shul'ga-Nesterenko 1941)

Genus *Polypora*

- P. brevicellata* Baranova 1960
- P. confirmata* Kruchinina 1986 (in Morozova & Kruchinina 1986)
- P. ellesmerensis* Morozova 1986 (in Morozova & Kruchinina 1986)
- P. extenta* Trizna 1939
- P. mariae* Ravikovich 1948
- P. martis* Fischer 1866
- P. reciderata* Trizna 1950
- P. reteporidraeformis* Nikiforova 1936
- P. sp. cf. russiensis* Shul'ga-Nesterenko 1941.
- P. voluminosa* Trizna & Klautsan 1961
- P. sp. A.*

Genus *Reteporidra*

- R. sp. cf. eichwaldi* Nikiforova 1938
- R. grandis* Morozova 1970
- R. (Kingopora) tuberculata* Shul'ga-Nesterenko 1941

## Biostratigraphical distribution of referred taxa

Short comments on the biostratigraphic distribution of the bryozoan taxa found in cores 7129/10-U-1 and 7129/10-U-2. Unpublished data from Svalbard will be available for Arctic Geoprogram participants in Nakrem (in prep.) IKU-rep. 23.1252.05/01/88.

*Alternifenestella bifida* (Eichwald 1860)

Sakmarian and Artinskian (Ural); Ufimian (Novaya Zemlya (Morozova & Kruchinina 1986)); Tyrrellfjellet Mb. (Spitsbergen) and Miseryfjellet Fm. (Bjørnøya) (Nakrem unpubl. data)

*Alternifenestella crassiseptata* (Shul'ga-Nesterenko 1941) Sakmarian (Ural).

*Alternifenestella greenharboureensis* (Nikiforova 1936)

Ufimian (Novaya Zemlya (Morozova & Kruchinina 1986)); Upper Tempelfjorden Group (Svalbard) (Nakrem unpubl. data).

*Alternifenestella spitzbergenensis* (Nikiforova 1936)

Ufimian (Ellesmere Island (Morozova & Kruchinina 1986)); Upper Tempelfjorden Group (Svalbard).

*Alternifenestella tenuiseptata* (Shul'ga-Nesterenko 1941) Sakmarian (Ural).

*Archimedes stuckenbergi* Nikiforova 1938

Upper Carboniferous - Sakmarian.

*Ascopora attenuata* Trizna 1950.

Sakmarian (Ural).

*Ascopora sterlitamakensis* Nikiforova 1939.

Upper Sakmarian (Ural, Timan); Tyrrellfjellet Mb. (Spitsbergen) (Nakrem unpubl. data).

*Ascopora* sp. A.

Thin-branched incomplete preserved colonies. Closest species is *A. attenuata* Trizna, which is only reported from Sakmarian (Ural).

*Ascoporella grandis* (Kruchinina 1973)

Sakmarian (Timan (Morozova & Kruchinina 1986)); Tyrrellfjellet Mb. (Spitsbergen) (Nakrem unpubl. data)

*Coscinium cyclops* (Keyserling 1846).

Frequently occurring in Sakmarian to Artinskian strata (especially Lower Artinskian in Timan - Pechora area) (Russian Platform) (Morozova & Kruchinina 1986); Tyrrellfjellet Mb. (Spitsbergen) (Nakrem unpubl. data)

*Cyclotrypa distincta* Morozova 1986.

Miseryfjellet Fm. (Bjørnøya; (Morozova & Kruchinina 1986)); Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data)

*Dyscritella parallela* Morozova 1970.

Ufimian - Kazanian (USSR); Upper Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data).

*Dyscritella speciosa* Morozova 1986.

Ufimian - Kazanian (Novaya Zemlya (Morozova & Kruchinina 1986)); common above Vøringem Mb. (lower) Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data)

*Fabifenestella rhomboidea* (Nikiforova 1938).

Upper Carboniferous - Sakmar (Russian Platform and Japan).

*Flexifenestella eichwaldi* (Stuckenberg 1895).

(Upper Carboniferous) - Artinskian (Ural)

*Flexifenestella petschorica* (Shul'ga-Nesterenko 1941)

(?Sakmarian -) Artinskian (Ural); L. Artinsk (Timan - Pechora Region (Morozova & Kruchinina 1986)).

*Goniocladia tenuis* Shul'ga-Nesterenko 1941

(?Sakmarian -) Artinskian (Ural); lower Tyrrellfjellet Mb. (Spitsbergen) (Nakrem unpubl. data).

*Hinganella improvisa* Morozova 1986.

Kazanian (Novaya Zemlya (Morozova & Kruchinina 1986)).

"*Hinganella*" *heintzi* Malecki 1977 is reported from Miseryfjellet Fm. (Bjørnøya) by Malecki 1977, and Nakrem (1986:24, fig. 13B). This taxa is revised in Nakrem (1987), reassigned as the timanodictyine *Gilmoropora heintzi* (Malecki 1977). Thus, the Kazanian genus *Hinganella* is still not found within the upper Permian succession of Svalbard.

*Laxifenestella lahuseni* (Stuckenberg 1895).

Artinskian (Ural); Lower Permian (Arctic Canada (Morozova & Kruchinina 1986)).

*Neoeridotrypella magna* Morozova 1986

Kazanian (Novaya Zemlya (Morozova & Kruchinina 1986)); Lower Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data).

*Penniretepora belajensis* (Trizna 1939).

Sakmarian - Artinskian (Russian Platform).

*Penniretepora* sp. cf. *lineata* (Nikiforova 1933).

Originally described from Middle Carboniferous strata (Nikiforova 1933); later reassigned to Upper Permian (cf. Morozova & Kruchinina 1986: 11 (Russian text))

*Penniretepora praetenuis* Trizna 1950.

Artinskian (Ural).

*Penniretepora subtila* (Shul'ga-Nesterenko 1941).

Sakmarian (Ural).

*Permoheloclema merum* Ozhgibesov 1983.

Ufimian - Kazanian (Novaya Zemlya (Morozova & Kruchinina 1986)); very common in Kapp Starostin Fm. (Spitsbergen) and less frequently in Miseryfjellet Fm. (Bjørnøya) (Nakrem unpubl. data).

*Permofenestella pentagonalis* (Shul'ga-Nesterenko 1941).

U. Sakmarian - Artinskian (Ural).

*Polypora brevicellata* Baranova 1960.

Sakmarian to Artinskian distribution (cf. Gorjunova 1975).

*Polypora confirmata* Kruchinina 1986.

Artinskian (Timan - Pechora, Arctic Canada (Morozova & Kruchinina 1986))

*Polypora ellesmerensis* Morozova 1986.

Sakmar (Hare Fiord Fm., Ellesmere Island (Morozova & Kruchinina 1986)).

*Polypora extenta* Trizna 1939.

Sakmarian (cf. Gorjunova & Morozova 1979).

*Polypora mariae* Ravikovich 1948.

Artinskian - Kungurian (Russian Platform (Morozova & Kruchinina 1986)).

*Polypora martis* Fisher 1866.

Most common in Upper Carboniferous, but is also reported from the Lower Artinskian of the Ural Region (Trizna 1950); Hambergfjellet Fm. (Bjørnøya) (Nakrem unpubl. data).

*Polypora reciderata* Trizna 1950.

Upper Sakmarian (Sterlitamak) to Artinskian of the Ural Region (cf. Morozova 1981).

*Polypora reteporidraeformis* Nikiforova 1936

Kapp Starostin Fm. (Spitsbergen; cf. Nikiforova 1936)

*Polypora* sp. cf. *russiensis* Shul'ga-Nesterenko 1941.

?Artinskian (Greenland); Miseryfjellet Fm. (Malecki 1977; Nakrem 1987)

*Polypora voluminosa* Trizna & Klautsan 1961.

Artinskian (Ural, Timan - Pechora (Morozova & Kruchinina 1986))

*Polypora* sp. A.

Micrometer formula: 4-5/4/14/6. Not known from available literature.

*Primorella tundrica* Kruchinina 1986

Kungurian (Timan - Pechora region (Morozova & Kruchinina 1986)); Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data).

*Ramipora hochstetteri* Toulou 1875.

(Upper) Kapp Starostin- and Miseryfjellet Fms. (Svalbard) (Nakrem 1987; Nakrem unpubl. data).

*Ramiporidra minuta* Shul'ga-Nesterenko 1933.

?Asselian - Sakmarian (USSR); Lower Tyrrellfjellet Mb. (Spitsbergen) (Nakrem unpubl. data).

*Rectifenestella biarmica* (Shul'ga-Nesterenko 1941).

Sakmarian (Ural); Artinskian (China)

*Rectifenestella minutula* (Gorjunova 1975).

Lower Perm (Pamir).

*Rectifenestella nikiforovae* (Shul'ga-Nesterenko 1936).

Sakmarian - Artinskian (Southern Ural, China); Artinskian (Northern Ural) (Morozova & Kruchinina 1986).

*Rectifenestella ornata* (Shul'ga-Nesterenko 1939).

Artinskian (- ?U. Sakmarian) (Ural) (Morozova & Kruchinina 1986).

*Rectifenestella permicus* (Shul'ga-Nesterenko 1941)

Sakmarian - Artinskian (Ural); Kapp Dunér Fm. (Bjørnøya) (Nakrem unpubl. data).

*Rectifenestella pseudoveneris* (Shul'ga-Nesterenko 1941).

U. Sakmarian - Artinskian (Ural)

*Rectifenestella retiformis* (Schlotheim 1816).

Artinskian (Ural, China, Japan); Upper Permian (European and Baltic Zechstein, Ellesmere Island, Russian Platform) (Morozova & Kruchinina 1986); Miseryfjellet Fm. (Bjørnøya) (Nakrem unpubl. data).

*Rectifenestella robusta* (Shul'ga-Nesterenko 1936)

Sakmarian (Ural).

*Rectifenestella* sp. cf. *robusta* (Shul'ga-Nesterenko 1936).

Partly silicified/dolomitized specimens from within the palaeoaplysiniid bioherms.

*Rectifenestella savodovskyi* (Nekhoroshev 1959).

Kazanian (Novaya Zemlya and Soviet Far East (Morozova & Kruchinina 1986)); Upper Miseryfjellet Fm. (Bjørnøya) (Nakrem unpubl. data).

*Reteporidra* sp. cf. *eichwaldi* Nikiforova 1938

Incomplete preserved specimen. Reported range from U. Carboniferous - L. Permian (Ural).

*Reteporidra grandis* Morozova 1970.

Kazanian (USSR); Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data).

*Reteporidra* (*Kingopora*) *tuberculata* Shul'ga-Nesterenko 1941.

(?Upper Sakmarian -) Artinskian (Ural).

*Rhombotrypella alfredensis* Morozova 1986.

Upper Permian (Ufimian - Kazanian) (Arctic Canada and Svalbard (Morozova & Kruchinina 1986))

*Rhombotrypella insolita* Morozova 1986.

Ufimian (Novaya Zemlya (Morozova & Kruchinina 1986)); Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data).

*Rhombotrypella invulgata* Trizna 1948

Artinskian Reef (Ural); ?Upper Permian (Ellesmere Island) (Morozova & Kruchinina 1986); Tyrrellfjellet Mb. (Spitsbergen) (Nakrem unpubl. data).

*Streblotrypa suvodiensis* Shishova 1965

Lower Kazanian (USSR); Kapp Starostin Fm. (Spitsbergen) (Nakrem unpubl. data). (In the initial data report (IKU-rep. 21.3427.00/02/87) this taxa was referred to as *Streblascopora* sp. cf. *vera* Morozova 1986. Due to incomplete colonies, there is still doubt which genus/species the present taxa should be referred to.

*Tabulipora arcticensis* Ross & Ross 1963.

?Artinskian (Greenland); L. Permian (Ellesmere Island (Morozova & Kruchinina 1986)); Kapp Starostin Fm (Spitsbergen); Miseryfjellet Fm. (Bjørnøya) (Nakrem unpubl. data).

*Timanodictya dichotoma* (Stuckenberg 1895).

Sakmarian (Timan, Ural); Artinskian (Arctic Canada, Greenland (Morozova & Kruchinina 1986)); Hambergfjellet Fm. (Bjørnøya) (Nakrem unpubl. data).

*Timanodictya nikiforovae* Morozova 1966.

Lower Kazanian (Northern Russian Platform); Ufimian (Novaya Zemlya (Morozova & Kruchinina 1986)); frequently occurring in Miseryfjellet Fm. (Bjørnøya); less common in Upper Kapp Starostin Fm. (Spitsbergen).

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## **APPENDIX A.6**

### **BIVALVES FROM 7230/05-U-02**

by

**Simon R.A. Kelly**

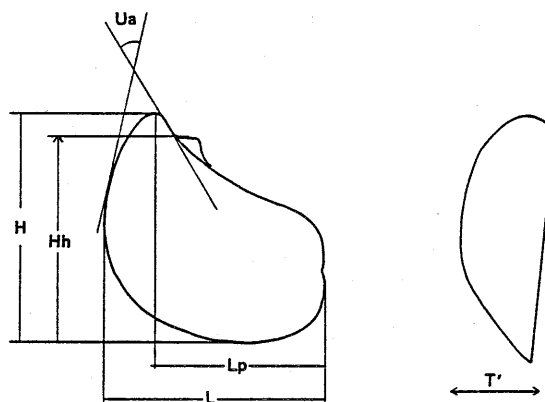
## Preservation

All specimens of bivalves from this core are isolated valves except for an articulated pair of valves from 48.90 m. They are all with commissure parallel to bedding and usually crushed flat. The matrix is always black shale, sometimes slightly silty and with fine mica. *Buchia* and *Oxytoma* are both fairly well preserved as calcitic shell. However, the heterodonts are preserved as composite moulds with only a thin film of white chalky material remaining of the original shell. Thus aragonite appears to have been severely affected during diagenesis.

The following abbreviations or symbols have been used:

LV = Left Valve  
 RV = Right Valve  
 P\* = Specimen to be photographed  
 L\* = Latex cast prepared

L = Length  
 Pl = Posterior length  
 Ol = Oblique length  
 H = Total height  
 Hh = Height of hinge  
 T' = Thickness (single valve)  
 Ua = Umbonal angle



All values are given in millimetres.

## Fauna list

- 48.90 m *Buchia* sp. Articulated LV and RV, shell interior with mould, fine radial and commarginal ornament.  
Fish scale.
- 46.85 m *Buchia* sp. 5 valves, very distorted, very fine radial and commarginal ornament.  
Fish scale.
- 46.77 m *Buchia* sp. 4 poorly preserved valves, very fine radial and very fine commarginal ornament.  
Heterodonts, 6 poorly preserved valves.
- 45.20 m *Buchia* sp. fragments Cyprinid, 3 specimens (as at 40.93) RV L 16, Lp 11, H 12.  
Fish remains.
- 43.37 m *Buchia* sp. shell hash.  
Cyprinid? valves.
- 40.93 m *Buchia concentrica* RV, internal mould, radial and concentric ornament, L 29, Lp 22, H 25  
Cyprinids, poor external moulds, shell dissolved, fine growth lines and spaced out stronger commarginal ornament, strongly prosogyrate, with deeper posterior than anterior, posterior area differentiated by curvature of commarginal ornament.  
LV L 16.5, Lp 10, H 12
- 40.76 m *Buchia* sp. LV, incomplete, < 10 mm, radial and commarginal ornament  
Astartids?, very poorly preserved, decalcified, c23 specimens, marginal denticulations on one specimen.
- 39.39 m *Buchia concentrica* RV, very large, incomplete *Oxytoma* sp. 2 LVs <10mm
- 38.60 m *Buchia concentrica*, RV, radial and commarginal ornament L 42.5, LP 34, H 37, Hh 35
- 38.05 m *Buchia concentrica* LV, radial and commarginal ornament L 29, Lp 23, H 27.5, Hh 24

- 37.95-97 m *Buchia concentrica*. 2 large LVs, RV, radial and concentric ornament throughout, posterodorsal margin weakly indented, damaged at posterior and venter RV L 38+, LP 25+, H 40+ 2nd LV exterior of large incomplete individual.  
Fish scales.
- 37.90 m *Buchia* sp. RV, mainly internal mould, coarse commarginal and fine radial ornament. L 26.5 Pl 19.5, H 24.5  
LV mainly external mould, umbo damaged, L 32, H c31.  
Fish scales  
*Oxytoma* sp.  
Astartid bivalve? fragment showing coarse crenulate margin.
- 37.46 m *Buchia* sp. LV large, incomplete, radial ribs on interior and exterior. RV, internal mould, umbo broken, L 13, H 12.5  
Fish scales.
- 36.80 m *Buchia* sp. Horizon rich in LV and RVs showing radial ribs and coarse commarginal folds.
- 36.60 m *Buchia* sp. 6 incomplete valves with radial ribs.  
*Oxytoma inequivalve*. LV shell exterior. Strong primary ribs up to 15 mm from umbo, thereafter secondary ribs intercalated, anterior missing.
- 34.95 m *Buchia* sp. 6 RVs with radial and coarse commarginal folds.
- 34.91 m *Buchia concentrica* LV, large and incomplete with coarse commarginal ornament, L >30.
- 34.52 m *Buchia* cf. *concentrica*. 2 RVs complete internal moulds; LV fragments and external moulds. Radial ornament strong on all specimens, both internally and externally  
RV1 L 20, Pl 14, H 15.5  
RV2 L c13, Pl 8.5, H 9.5
- 34.48 m *Buchia* sp. ?*tenuistriata*. RV, missing umbo, inflated mould, radial ornament on interior at c2-25 mm from approximate position of umbo. Other fragments of *Buchia* sp. with radial ornament.  
Fish scales.

-A.6.5-

- 34.43 m *Buchia tenuistriata*. LV with broad trigonal shell, slightly crushed with radial and commarginal ribbing.
- 33.89 m *Buchia* sp. ?*rugosa/mosquensis* group. LV missing umbo; shell exterior with coarse commarginal ornament, no radial ribs, therefore not *B. tenuistriata*.

## **APPENDIX A.7**

### **TRACE FOSSILS**

by

Richard G. Bromley (Ichnos)

#### **Editorial remark:**

The present report contains key-word, summaries and drawings made during Bromley's one week stay at IKU. The interpretations presented in the main report are compiled by the sedimentologists based on this report and our joint study of the cores.

## General conclusions

It is difficult to draw general conclusions for the eight wells treated in this report, because of their stratigraphically heterogeneous nature. The environments in general have a strong marine bias, excepting the well 7230/05-U-03 and the bottom of 7230/05-U-02. Even where plant roots characterize the rock, as in the top of 7230/05-U-04, they commonly cut through a marine ichnofabric.

Trace fossils are notoriously difficult tools in evaluating marginal marine sequences. On beaches, physical reworking obliterates much evidence; and in protected locations, fluctuation in physical parameters under the ecotonic conditions where the sea meets the land allows only immature communities of opportunist organisms to become temporarily established. By definition, opportunists are generalists, and their presence does not narrowly define environmental settings. Quite different are the mature, diverse, tier-structured communities of the open marine shoreface and shelf. The characteristic ichnofabrics these communities produce are less ambiguous. Excellent examples are offered by the present material, e.g., at 7129/10-U-01, 80 m and 7230/05-U-02, 70 m.

I have seen no trace fossils that are characteristic of the nonmarine realm in this material.

7030/03-U-01

The ichnofabrics displayed by this core are well developed and varied. (Figures for this well are found in the main report, Figures 3.1.4-8).

#### Unit A

Fabric 1. A three-tiered fabric having a diversity of 4-5 and a density 50-80%, locally reaching 100%.

Tier 1: Faint, compacted *Planolites* 5-10 mm Ø.

Tier 2: Pale, sharply outlined burrows that are not identifiable, but could be referred to as "*Thalassinoides*".

Tier 3: Tiny, dark-centred *Helminthopsis* 0.1 mm Ø. This tier is only locally present.

Fabric 2. A four-tiered fabric having a diversity of 2-4 and a density 20-80%, rarely 100%.

Tier 1: Faint, compacted *Planolites*.

Tier 2: Pale, distinct "*Thalassinoides*".

Tier 3: Large, very pale, sharply outlined *Thalassinoides*.

Tier 4: Grey *Zoophycos* 2-3 mm thick, having poorly visible spreite.

Fabrics 1 and 2 alternate somewhat (their distribution is shown on (Figure 3.1.4). Intervals of fine, homogeneous material occur in which no distinct bioturbation is visible; but these have been bioturbated nevertheless.

Where coarse bioclasts are dominant (echinoderm debris), the shallowest tiers disappear, and *Zoophycos* may occur alone.

Fabric 3. A two-tiered assemblage:

Tier 1: Compacted *Planolites* 10 mm Ø forming a background mottling.

Tier 2: Large, rounded structures that may be *Thalassinoides*, initiating concretion development. There are some shafts that contain the same pale fill and sharp outline, 2-3 mm Ø, which may be connected to the *Thalassinoides*.

Diversity of fabric 3 is 2-3, density 0-50%, locally reaching 80%.

Fabric 4. The mud that begins at ca 160.0 m contains abundant *Zoophycos*. Nothing else is visible, not even *Helminthopsis*. However, its base is piped down 25-30 cm into the wackestone below by 1 cm Ø shafts.

Fabric 5. Diversity gradually increases up through the mudstone. *Planolites* and *Thalassinoides*-like structures are cut by ever-present *Zoophycos*. Possibly *Helminthopsis* is present, but seeing is very poor.

Very similar to fabric 2, but density here is consistently higher: 100%.  
Diversity 3-4.

Bioturbation is interrupted by the siltstone at ca 158 m. *Taenidium*, 1 cm Ø, descends from the base of this. Above the siltstone, *Zoophycos* reappears in force again, but only briefly. All bioturbation fails as grainsize, and maybe depositional rate, increase upwards.

Interpretation

The presence of *Zoophycos* in this core must not be taken to represent "Zoophycos ichnofacies - outer shelf to abyssal". Certainly, this would be a reasonable starting point for the interpretation of a Mesozoic or later occurrence. Throughout the Palaeozoic, however, *Zoophycos* is a common shallow-water trace fossil.

Similar statements may be made for *Helminthopsis*. Both these forms are low-resource, deep-tier opportunists, however, and their significance is not merely as deepwater forms.

In the present core, both forms occur in high-diversity assemblages. As such, they represent the work of the deepest tier of mature endobenthic communities. Presence of such communities indicates fully marine conditions, relatively slow depositional rates, and a reduction potential discontinuity within reach of burrowing depth within the substrate.

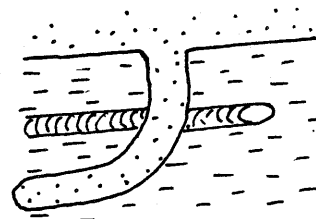
The presence of large burrowers (creators of sizable *Thalassinoides*) and of large-burrower vertical activity to several decimetres depth suggests shallow to very shallow marine conditions of deposition.

Presence of *Zoophycos* alone in the basal part of the mud above 160 m indicates that RPD (reduction Potential Discontinuity) in the sediment has moved up to nearer the seafloor, and oxygen-demanding shallower tiers have been excluded by dysaerobic seafloor conditions. Gradual reappearance of these tiers upwards, and the increase in grain size, correlate with increasing circulation of bottom waters.

## Unit B

Bioturbation reappears at ca 150 cm. At first, a *Planolites* - "*Thalassinoides*" association appears, in fine sand for a thickness of 40 cm: see Fabric 6.

The thin mud contains Fabric 4:  
its thinness creates ichnological  
condensation in that *Thalassinoides* from  
above cuts down through *Zoophycos* that  
belongs to the shale.



The following sand-shale couplet shows the same story. Here, *Zoophycos* descends down into the underlying sand's top from the overlying shale, some 10 cm. It also continues to be present in the base, at least, of the overlying sand.

Fabric 7.

Tier 1: Faint *Planolites*.

Tier 2: Faint "*Thalassinoides*".

Tier 3: *Zoophycos* forms the lowest tier.

Density is low, diversity 3-4. Details are of considerable academic interest. The depositional variation in rate and grain size (controlling RPD level within the sediment) have caused variation of endobenthic activity. Shallow marine environment.

**Unit C**

An alternation is seen between Fabrics 5 and 6, in that *Zoophycos* comes and goes in correlation with the muddiness of the substrate. Less muddy substrates contain poor-visibility *Planolites*/*"Thalassinoides"* bioturbation.

Minute *Helminthopsis* has reworked fills of some other burrows locally. Thus, a mature endobenthic community of fully marine aspect is indicated. On the basis of trace fossils alone, a quiet open lagoon or inner shelf environment would be likely. (At ca 137 m, a *Zoophycos* descends 40 cm from a mud bed, displaying 15 spiral whorls, 2 cm apart. In the uncompacted deeper whorls the spreite is 5 mm thick).

Between ca 137 and ca 132 m, bioturbation seems to be 100% but homogeneous. Deep tiers are lacking, but Fabric 6 seems to be present. The rate of sedimentation has probably increased. This is interrupted by the coarse sand at 132 m. When fine grained sand returns, this again contains Fabric 6, but very indistinct.

Overprinted onto this a superb grey *Zoophycos*, cutting down 40 cm from the overlying muddy siltstone. This grey *Zoophycos* is reworked by a black *Zoophycos* in its upper part, descending from a still higher level. Black and grey mudlined shafts and galleries 1 cm Ø occur down to 60 cm below the top of the sand unit, but may yet belong to the overlying muds. The alternative is that the black mud lining derives from material caught during suspension feeding activity, i.e., biodeposited material. Slow deposition of the muddy

top is indicated by the *Zoophycos*, and the large, deep shafts suggest shallow water. Visibility dies out with *Zoophycos* a metre above this shale. Between 129-128 m the homogeneous rock seems to have been bioturbated, perhaps by the *Planolites* assemblage of Fabric 6.

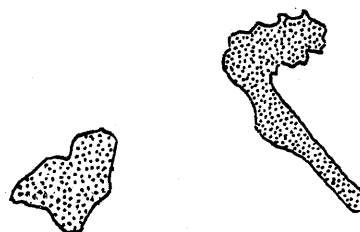
The evaporite-bearing beds between 128 and 126 m is not obviously bioturbated. However, *Zoophycos* returns with fine grain approximately at 166 m and continues up in the overlying fine sandstone. A fine sandstone (above 126 m), has a remarkable ichnofabric. Visibility is poor, but a very faint background *Planolites* fabric (100%) is cut by two sizes of *Helminthopsis*, a large one and a small (both bigger than that in Fabric 1). Cutting this in the lower part is *Zoophycos*, but this fails upwards. Crossing all this are 2 cm Ø shafts containing pink sand. The nature and origin of these shafts is mysterious. There is no obvious source for the pink filling material, unless a sand horizon or several have been completely removed by penecontemporaneous erosion.

Visibility dies out upwards. At ca 123 m, lamination appears, indicating that bioturbation is absent.

The only trace fossils in this sequence that might suggest nonmarine conditions of deposition are the mysterious pink sand-filled shafts above 123 m, but these cut a fully marine suite of trace fossils that indicate quiet, slow deposition, in apparently subtidal environments.

#### Unit E & Unit F

Bioturbation returns above the bioherm. Above ca 96 m, a distinctive ichnofabric is composed of at least two tiers. The fine-grained rock is totally bioturbated. A deep, lower tier consists of irregularly shaped, dark fills 1 cm Ø, showing no branching or internal structure. These cut tiny *Helminthopsis*, seen only in the darker levels, at the limits of visibility.



Lack of the open marine trace fossils that were seen in the lower part of this core might favour a lagoonal setting: there are neither large *Helminthopsis* nor *Zoophycos* for a change, and diversity is low. Only at two levels in 27 is bioturbation complete. Then lamination and 0% bioturbation return. At 92 m bioturbation dies out, but muddy intervals within the overlying evaporites seem to be bioturbated. Dark, 1 cm Ø fills are visible in the brown homogeneous matrix, a diversity of 2.

There are foraminifera in millions around 78-79 m, but no bioturbation. This is unexpected, unless the forams are reworked, and they show no signs of this.

Between 72 and 69 m, the fusulinids reveal a bioturbational fabric, being distributed in a swirled fashion around 1 - 2 cm Ø burrows. Distinct trace fossils are not visible. Probably this indicates deposit feeding activity by a low-diversity community. Reduced diversity might suggest a closed, lagoonal environment.

Fabric 11, at 69 m, is almost perfectly homogeneous. At approximately 65 m, a clayey bed contains *Zoophycos* and *Planolites* in Fabric 2. It is not visible above or below this.

Above 65 m, bioturbation levels seem to be very low to 0%. *Planolites* - "*Thalassinoides*" fabric (6) is present, possibly at 100%, in the long stick around 59 m. Homogeneous rock returns above this.

At ca 56-55 m, dark, sandy bodies 2 cm high might be half-preserved, partially collapsed burrows, but this is uncertain.

#### Interval 40-30 m

After a long period without any visible bioturbation, the rock becomes paler, and above 40 m, total *Planolites* (1 cm Ø) bioturbation is seen. Visibility is poor and diversity probably also is low.

From ca 36 to 33 m diversity appears to increase, but maybe only because visibility does. No particularly distinctive trace fossils occur, but *Planolites* is recognizable.

Between 33 and 30 m, coarse-grained units interrupt bioturbation, which reaches 0%, but picks up again at the top of the run. Very pale bioturbation, possibly of centimetre size.

### Conclusions

The presence of well developed, tier-structured ichnocoenoses in the lower part of the core (Unit A), represented by a range of distinctive, recurring ichnofabrics, implies a high level of predictability and stability of the ecological environment. A fully marine setting is indicated, open and unrestricted.

Above this, bioturbation fluctuates extremely in both quality and quantity. Few ichnocoenoses are diverse and the constant change indicates instability of the environment. Nevertheless, no distinctively nonmarine trace fossils are present, and *Zoophycos* is characteristically marine and present at many horizons. Restricted nearshore environments may be a reasonable setting for these assemblages, as is supported by the presence of evaporites, bioherms and low-diversity fusulinid cultures.

7129/10-U-02

The following summary is compiled from notes and sketches made by Bromley (ed. remark):

Trace fossils are only present in Unit B in this core, and their occurrence is shown in Figure 3.2.4. The whole unit is well bioturbated, and the diversity varies and seems to be highest in the marls. The unit contains two ichnocoenosis, in the lower and middle part (up to ca 72 m) a *Planolites-Zoophycos* ichnocoenosis and in the upper part a *Zoophycos-Helmintopsis* ichnocoenoses.

The *Planolites-Zoophycos* ichnocoenosis show that deposition has been slow enough to permit the development of a 6-tier (minimum) system. This development suggest an ecological climax endobenthic community of high diversity favouring open marine shelf environments. The presence of *Zoophycos* (see the Figure) against a 100 % bioturbated background show slow, steady deposition under fully marine aerobic conditions.

The *Zoophycos-Helmintopsis* ichnocoenoses occur uppermost in the unit and large taxa increase diversity towards the top. *Helmintopsis* occurs the whole way but patchily towards the top, and *Zoophycos* is also most abundant in the lower part of this ichnocoenosis. The ichnocoenosis is a clear indicator of open marine, aerobic conditions.

7129/10-U-01

#### Unit A

Pack-grainstone looks totally bioturbated, but no individual trace fossils or structures are visible at all. Stylolites emphasize bed contacts in places, but do not pick out burrow fills. It is difficult to decide how much bioturbation is represented.

#### Unit B

Fabric 1, diversity at least 11, which is exceptionally high. Bioturbational density 100%. The ichnofabric is unusually clear: common forms are *Planolites*, *Lophoctenium*, *Teichichnus*, *Helminthopsis* (two size classes) and *Zoophycos*. Cross-cutting relations are not all displayed.

The topmost 80 cm are more clayey and *Zoophycos* becomes excessively common, largely obliterating other forms. Dark rock colour reduces visibility. Glauconite at the top.

An open marine, inner or outer shelf setting is suggested by this highly diverse assemblage.

#### Unit C

79.00-76.10 m

Darker and more clayey; this unit is completely dominated by *Zoophycos*. The visible diversity is much lower than before, but actual visibility is not a limiting factor. 0.5 mm Ø, 1 cm long, pale shafts are present; the largest shafts appear to be *Zoophycos* shafts.

A more restricted setting is indicated. Benthic foraminifera and ostracodes pack some burrow fills.

*Zoophycos spreiten* are much thinner than those below. Possibly oxygen is a limiting factor on diversity and *Zoophycos* size. The dark colour of the mud supports this.

76.10 m

Base of a weathering profile, but *Zoophycos* continues up to the top (though not visible at the very end) of the soil profile at 74.80 m.

#### Unit D

74.80 - 74.30 m

A transgression bed seems likely; no bioturbation is visible. Considerable erosion and a long hiatus may be represented by this horizon.

74.30 - 72.70 m

Clumsey bioturbation of these coarse sediments; *Planolites*, 5 mm Ø, having a dark fill is the only trace fossil visible. There are many undisturbed horizons. Density is highly variable from bed to bed.

72.70 - 66.50 m

Similar. At 70.00 m, a mud-lined shaft resembling *Ophiomorpha nodosa* indicates a loose sand substrate occupied by a suspension feeder in a turbulent setting. Probably marine.

#### Unit E

66.00 - 64.50 m

There is 100% bioturbation of this interval, but trace fossils are not visible clearly. Apparently *Planolites* of three sizes.

64.50 - 63.50 m

Red mudstone, laminated and apparently unbioturbated. Above this, grey and red mudstones. I get the impression of a very minimal bioturbation at a few horizons, but generally zero. "Restricted lagoon" is a good guess, the limiting factor for endobenthic activity remaining unknown: oxygen supply, turbidity or salinity fluctuations, or indeed, a combination of these factors.

### **Conclusions**

The limestones at the base of the core are apparently well bioturbated, but yield no environmentally diagnostic ichnological information. The succeeding fine sands and muds, on the contrary, have very high ichnodiversity and indicate an open marine shelf setting. The soil profile truncates this sequence and presumably represents a considerable hiatus.

Above this break, conditions probably returned to marine, but unstable and fluctuating environment restricted benthic activity. The mudstone at the top of the core is largely unbioturbated and may represent extremely restricted, lagoonal conditions.

7230/05-U-06

Unit A

96.22 - 94.87 m

Diverse bioturbation, at least 5 forms. Density low.

*Planolites* - 1, 2-3 mm diameter ( $\emptyset$ ).

*Planolites* - 2, 10 mm  $\emptyset$ .

*Helminthopsis horizontalis*, very small.

Escape structures.

*Skolithos*.

*Palaeophycus heberti*.

The diversity and especially the presence of *P. heberti* give the impression of a subtidal environment.

94.47 - 91.48 m

*Diplocraterion parallelum*, rather high angle.

*Rhizocorallium irregulare* at 0° - 20° to the horizontal.

Small plus large *Planolites*.

Density low to medium; probably just subtidal.

94.47 - 88.42 m

The ichnoassemblage here lacks spreite structures. Cubichnia are present; one larger burrow fill; and small and large *Planolites*. Diversity thus is 3 - 4; density is low on average, with a few beds of high density bioturbation.

87.00 - 85.34 m

*Rhizocorallium irregulare*; possible *Diplocraterion* and two sizes of *Planolites*. Suggests just subtidal.

88.37 - 87.00 m

Small brown *Planolites* and white ones in certain beds of this sand 10 - 30 cm thick. Diversity down to one; density 0 to medium.

85 - 82 m

*Planolites* - 2, large, plus cubichnia. No *Diplocraterion* or *Rhizocorallium*.

82 - 79

There is a good diversity here, from 6 to 7.

Many types of *Planolites*: 1 mm, 2 mm, 5 mm and 10 mm.

Unquestionable *Diplocraterion parallelum* and *Rhizocorallium irregulare*.

Full marine, just subtidal.

79 - 73 m

Extremely low density. Diversity not so low, but it is so far between the traces that it is difficult to evaluate "assemblages". Salinity or oxygen problems in a coastal lagoon could inhibit bioturbation.

At 74.30 m a possible, deformed *Diplocraterion parallelum*.

#### Unit B

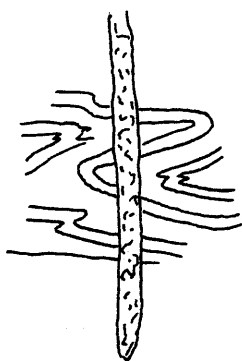
69 - 60 m

Just-visible 1 mm *Planolites* in sand.

Tidal channel sand, breccia layers; nearly no bioturbation in channel fills.

60.50 - 54.80 m

Density and diversity increase suddenly as mud returns.

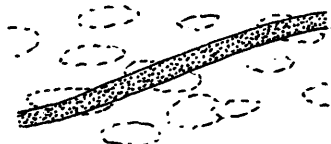


*Skolithos* may be 20 cm deep, cutting slump or sheared beds.

Many deposit feeder traces show minor lateral, spreite-like shift and upward adjustment.

No *Diplocraterion parallelum* seen, but possibly some crushed *Rhizocorallium irregulare*.

No desiccation cracks, but this may be a tidal flat, and is certainly marine.



Dark, tubular structures containing no internal structures are nevertheless probably *Rhizocorallium irregulare*; they cut the *Planolites* - 2 fabric.

54.80 - 53.50 m

Abrupt change to monotonous laminated mud, revealing nothing but a few *Planolites* - 1 (i.e., small). Very low diversity and density. High, protected tidal flat, but no desiccation.

53.90 m: a bed of high density bioturbation.

53.50 m: the same.

#### Unit C

53.25 - 52.60 m

Sand containing a few vertical structures; well-formed, not escape structures. Good *Skolithos* ichnofacies. Marginal marine/ backshore.

52.60 - 50.60 m

Weathered soil profile. Totally bioturbated, some vertical burrows. Plant roots near the top, beneath a coal-shale.

50.60 - 50.00 m

Sand with roots but cutting totally bioturbated to 50% fabric. Larger animals were involved, in centimetre size; the sediment has a highly disturbed appearance. The final event was the emplacement of the roots.

Suggests that temporary flooding by the sea built up a new level that was colonized by plant. A coal-shale at the top.

50.00 - 46.00 m

The mud above this is *Planolites* - 1 bioturbated, but sparsely. Sand above that shows no bioturbation.

46.00 - 45.00 m

Sands interrupted by muddy horizons, in which deposit feeder activity is apparent. Very shallow-tier, 2 cm maximum diameter borrows (most are 1 cm Ø) show lateral spreite-like shift. Diversity 2. The community consisted of two opportunists, one of them minute. Probably marine, but a stressful environment.

45.00 - 43.00 m

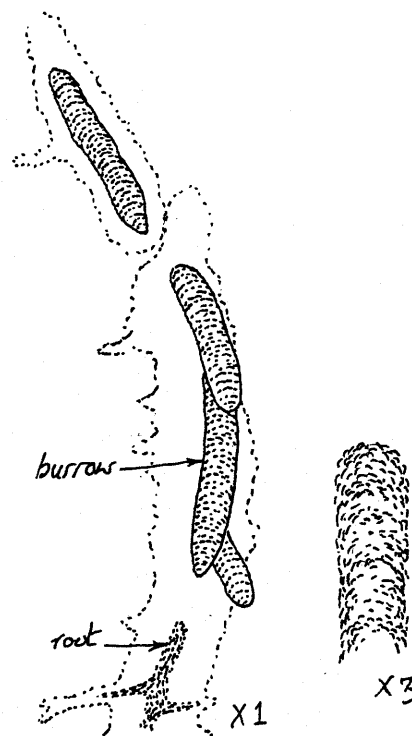
Weathered.

43.00 - 42.70 m

Clay; a grey clay bed containing a little bioturbation, 1 mm Ø animals. Diversity low but density up to 50%.

42.70 - 41.42 m

Brown soil with purple rhizoliths. At the core of the structure, a plant root gives off very fine lateral branches, crossing the zone of diagenesis. At ca. 42.00 m, there is a very interesting piece: a *Taenidium* occurs both within and outside the root structures. This is probably the work of a terrestrial animal that has eaten the rotten plant material of the root, but always progressing in a downward direction. I have seen similar borrows on a larger scale within Pleistocene plant roots. The menisci are minutely crumpled; it is not clear whether this is due to recent distortion, owing to frequent wetting of the sample, or to the presence of pellets within the fill.



41.24 - 39.95 m

A complicated muddy sand at 40.00 m reveals the following sequence of events:

- 1 - total to 50% bioturbation;
- 2 - deformation by maybe plant growth: - soupground diagenesis;
- 3 - plant roots emplaced to 20 - 30 cm depth;
- 4 - rare burrows emplaced in the now consolidated sediment: these show no compaction, cut the plant roots, and may be referred to *Planolites*, 2 - 3 mm Ø.

At 40.50 m: a fully marine diversity of trace fossils, 4 - 5 ichnotaxa.

39.95 - 39.00 m

Sandier. Bioturbation drops to zero.

39.00 - 36.30 m

Bioturbation 0 - 20%, diversity 2 - 3.

*Planolites* of 2 mm Ø. Deposit feeder traces showing lateral shift and a Ø of 5 - 10 mm.

There is some inhibiting factor here, perhaps low salinity, but not necessarily nonmarine.

36.30 - 36.20 m

A green mud 80% bioturbated by 1 mm all-directions *Planolites*: diversity = 1.

36.20 - 35.10 m

The diversity of 1 continues, being the same small *Planolites*, but in a heterolithic lithotope. Salinity problems?

35.10 - 32.00 m

High diversity. 1 cm Ø U-burrows are common, small, with a retrusive spreite; these are probably poorly developed *Diplocraterion parallelum*. They cross *Planolites* 2 mm Ø, small *Teichichnus* (or are these *D. parallelum*?) and a minute deposit feeder structure. Diversity is 5 - 6; density 80 - 100%.

Terrestrial roots cut deeply through all this fabric, which otherwise has a purely marine appearance.

32.00 - 29.00 m

A much lower density.

29.00 - 27.50 m

*Diplocraterion parallelum* is common but small, all retrusive. Sedimentation rate was high enough to constitute a stress factor. Plant roots cut down from the top.

27.50 m to top

Weathered.

7230/05-U-05

**Unit A**

49.92 - 49.10 m

Green mudstone, brecciated, full of *Planolites* - 1 (0.5 - 1 mm Ø). Nonmarine is likely.

49.10 - 48.10 m

Visibility drops to zero, but probable plant roots are seen. Clay.

48.10 - 47.87 m

Sand. Zero bioturbation.

47.87 - 47.10 m

Mudstone. A clear but gradual increase in diversity and density. Several obscure deposit feeder trace fossil types. Diversity up to 3 - 4.

47.10 - 46.50 m

A higher diversity, perhaps up to 6; density 100%. Oblique structures penetrate to perhaps 5 cm or more down.

44.88 - 43.93 m

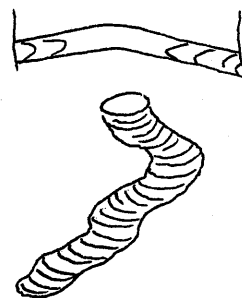
100% bioturbation at the bottom of this interval rapidly falls off upwards. Becomes clayey, visibility is lost as weathering degree increases. Soil, capped by a coal-shale at the top.

43.93 - 42.15 m

Fully marine bioturbation fabric, 100% in most places. A high to medium diversity, dominated by *Planolites* 1 cm Ø, but there are occasional deposit feeder structures showing some degree of lateral shift. A few large spreiten, interpretable either as *Diplocraterion parallelum* or, more likely, large *Teichichnus rectus*.

42.15 - 40.75 m

The same, but the density is down to 70% or so. Oblique *Palaeophycus* indicate tiers to 10 cm or more, cutting *Skolithos*. 42.00 m: a *Rhizocorallium irregulare* and a large, fine *Teichichnus rectus*. Fall-off of the larger structures towards the top of the interval. There is a dominance of dark-walled burrows with pale fill: *Palaeophycus*.



40.75 - 39.60 m

Sideritic and nonsideritic laminae have been little disturbed. Individual beds are 20% bioturbated, containing *Planolites*. There are some large (10 mm Ø) oblique burrow fills. It is remarkable that whereas siderite is taken to indicate slow deposition, the bioturbation nearly ceased. What was the inhibiting factor? Salinity problems?

## Unit B

39.60 - 30.80 m

Sand. Cross-bedded sets show no bioturbation. Several flat bedded horizons, however, are well bioturbated. The combined diversity of all the bioturbated beds is high. Many vertical structures are present, as well as plugs. Well-bioturbated horizons indicated deposit feeder activity, although individual structures are not identifiable.

Many of the clay layers 1 mm thick may owe their presence to biodepositon by suspension feeding activity.

There is a possible protrusive *Diplocraterion parallelum* in the top of the sand body.

These sands were not deposited particularly rapidly, and their ichnology indicates a marine environment.

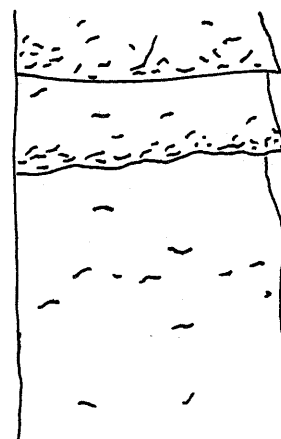
Everything above this level is dominated by very low density and low diversity bioturbation in muds. Tiny *Planolites* occur; occasional cubichnia, and larger deposit feeder traces are rare. A protected, turbid lagoon may be indicated. The endobenthos was depressed by some factor: maybe turbid, rapid deposition, or brackish salinity fluctuation.

7230/05-U-04

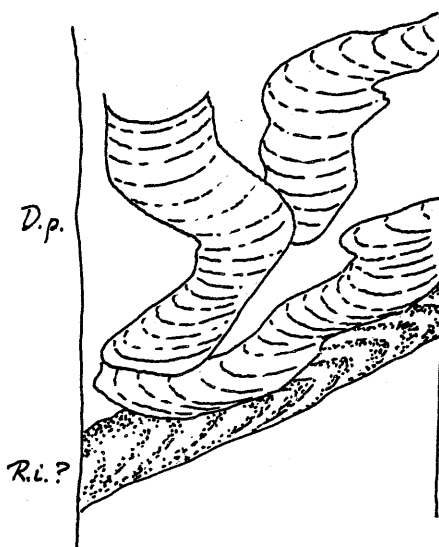
# Unit A

78.82 - 70.00 m

Monotonous unit, coarsening slightly upwards, but composed of 2 - 5 cm beds of fining-up silt-mud. Very dark. In some of the beds, 1 mm Ø *Helminthopsis horizontalis* alone, up to 5% bioturbation maximum, in the bases of beds. Density fades upwards away from beds' bases. Possibly the burrows indicate the most aerated part of the micro-sequence, which was dysaerobic in general. The "turbidite" erosion and deposition broke the stagnation and introduced temporary water circulation. The mud above represents the stagnant normal situation, turbid, very low O<sub>2</sub> tension.



Rising through the unit, there is an increase in sand content, accompanied by a slight increase in diversity. At ca 70.40 m and 72.30 m, *Helminthopsis* is joined by small, dark *Planolites*, and dark-walled *Palaeophycus*, 2 mm Ø.



At the very top of the cycle at 70.00 m, two or three intersection *Diplocraterion parallelum* and a possible *Rhizocorallium irregulare* are seen, very deformed by compaction. These taxa are definitely absent below. This succession might be read to indicate very shallow sub-tidal at the base, rising to possible intertidal at the top of the cycle.

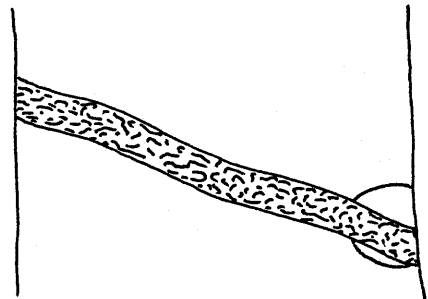
70.00 - 64.10 m

The next cycle is somewhat similar to the last; but *Helminthopsis* is extremely small and rare. The lower part of the cycle is almost uniformly unbioturbated, and was probably anoxic. *Planolites* comes in half way up, and a large burrow fill is seen at the top. At 64.50, a *Rhizocorallium irregulare*.

64.10 - 62.80 m

Top part of the cycle.

At 64.00 m, a *R. irregulare* cuts primary lamination and a large, pale *Planolites*. The fill of the *Rhizocorallium*, however, shows no spreite structure; it has been meticulously reworked by very small *Helminthopsis*.



Above this, two or three *Planolites*, rare *Rhizocorallium* and patchy, fill-reworking *Helminthopsis* provide a diversity of 6-7. A fully marine, high subtidal or lower foreshore environment is indicated.

62.80 - 57.50 m

The third cycle starts dark and muddy, but is bioturbated at 10-15%. Much compactional distortion. Rare *R. irregulare*, and many *Planolites* of different size-groups.

A *Diplocraterion parallelum* at ca 59.60, above which a high diversity includes *D. parallelum* as the deepest tier crossing *Planolites* of 10 mm Ø, *R. irregulare*, and a tiny black deepest-tier structure (possibly *Helminthopsis*). Diversity 5-6, density 100%.

57.50 - 54.48 m

There is poor visibility in this dark rock. Pale, sparse burrows occur throughout. The facies probably resembles that of the base of the previous cycle.

54.50 - 51.50 m

100% bioturbated, high diversity (about 7). *Diplocraterion parallelum* and *Rhizocorallium irregulare* are common, with *Helminthopsis horizontalis* within the fills of *R. irregulare*. Oblique burrows may be small *Teichichnus*. There are two size classes of *Planolites*.

57.48 - 47.90 m

The first shell bed marks an abrupt change in the ichnology. Density drops to 0-30%. But diversity remains high, about 5. *Teichichnus* and *Helminthopsis* are both absent. There is *R. irregulare*; *Diplocraterion parallelum* (three similarly orientated examples at 50.10); and *Planolites*, two size-groups, large and small. Low intertidal is likely.

47.90 - 45.60 m

Weathering has destroyed visibility, leading up to a soil profile.

#### Unit B

45.20 - 42.00 m

Immediately above the soil, a laminated sand has been well bioturbated with *R. irregulare*. This passes up into a heterolithite, also containing *R. irregulare*.

At 41.65 m, several *Rhizocorallium* are seen cutting other burrow fills. The tiering structure of the community is well developed. Small *Planolites*; large *Planolites*; *Thalassinoides*; *R. irregulare* and *Helminthopsis*. A complex ichnofabric is developed by this activity. Either upper shoreface, open marine or large, deep, protected lagoon. *Teichichnus rectus* at 42.00 m indicates that, if a lagoon, then the circulation was good; these are large, retrusive spreiten that wander laterally somewhat.

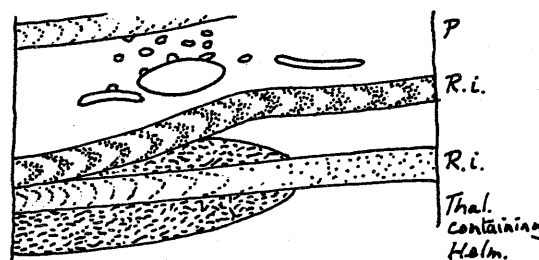
42.00 - 30.00 m

Gradual reduction of the amount of bioturbation. *R. irregulare* remains present and *Teichichnus rectus* becomes noticeably smaller. Real *Diplocraterion parallelum* is not seen - at least, no vertical spreiten have mud walls: all resemble deposit feeder activity. Lack of complete bioturbation here might indicate increasing restriction of circulation in the lagoon as we approach the overlying plant-root level.

30.00 m - top

Sideritic breccia, at 30.00 m.

High diversity continues to 28.50 m. At this level is the last *R. irregulare*. Above this, larger structures disappear. At 26.60 m the first plant root is seen. Tiny *Teichichnus* and possible small *Thalassinoides* occur. Restricted circulation may be the cause of the ichnofaunal poverty, but the assemblage remains marine to top, with 100% bioturbation and still a moderate diversity. A marine ichnofabric cut by plant roots.



*P.* = Planolites

*R.i.* = Rhizocorallium irregular

*T. c. H.* = Teichichnus contain  
Helminthopsis

7230/05-U-03

#### Unit A

No bioturbation until ca 109 m. Here, several 5-10 mm Ø structures disturb bedding, cutting upwards. These are presumed to be biogenic, but nothing ichnologically diagnostic was seen.

108.90 m

Grey clay, apparently laminated with structureless layers, but at one level 10 cm or so thick, there are pale burrow fills 1 mm Ø that resemble *Chondrites*. This ichnotaxon alone, in an otherwise unbioturbated sediment, is provocative. As an opportunist trace fossil, it often occurs in alien settings. Commonly, dysaerobia is indicated, but it has also been reported in brackish water. In this case, the proximity of roots may indicate salinity stress as the limiting factor.

106.35 m

Dark-filled plant root in situ. That makes those *Chondrites* the most shallow-water occurrence I have seen!

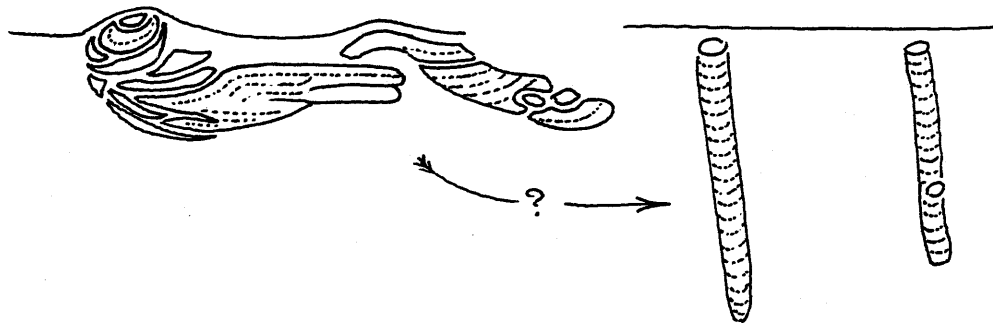
Clay below this (at 103 m) is "weathered" by post-drilling drying out. No structures are visible.

#### Unit B

93.00 m

Around here, heterolithites contain numerous signs of sediment flow, as registered by sand bodies floating in the clay. The largest of these bodies do not seem to be biogenic in origin. In places the rock is cracked and brecciated. Smaller, 1 mm Ø *Planolites* and a few 3 mm Ø *Planolites* seem to be present, but have not been confirmed on horizontal fracture surfaces.

Throughout this core, the purer muds show great post-depositional mobility and early deformation by loading. This renders interpretation of sand structures difficult. In the sketch below, a twisted structure might be "de-deformed" as a *Diplocraterion parallelum*, or as a starved ripple.

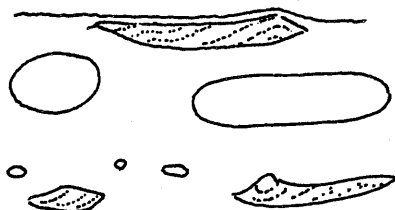


If they are interpreted as *D. parallelum*, then there is undoubted marine influence here at 93.00 m.

The following sand unit contains no recognizable bioturbational structures. Neither does the first laminated sand unit at 79.90 - 79.40 m. The laminae are leaf debris.

79.40 - 79.30 m

As soon as mud lamellae reappear, however, deposit feeders also returned. Small (1 mm Ø) *Planolites* is soon joined, upwards, by larger *Planolites* and a 20 mm Ø, sand-filled system that is temptingly like *Thalassinoides* (unconfirmed by horizontal fractures).



Serious deformation by mud flow under the weight of compactional load, again renders laminated bodies difficult to evaluate.

79.30 - 78.50 m

The pure mud above this contains no recognizable biogenics, except at thin sand laminae, where *Planolites* is seen. Deformation at 78.50 is extreme. The laminated "ball and pillow" bodies here probably have inorganic origin.

Diversity and density are both low. The inhibiting factors responsible could be any of several: turbidity, excessive wateriness of the substrate, or salinity fluctuation. No marine indicators were identified, but this does not exclude the possibility of marine influence.

78.50 - 78.20 m

More mud containing minimal information ends upwards in 20 cm of mud/sand that has been disturbed in similar fashion. The micro-ball and pillow fabric may have originated chiefly in isolated sand ripples, as the lamination within them indicates. (Resemblance to cross sectioned *Fuersichnus communis* is only superficial).

78.20 - 72.50 m

These sands are generally unbioturbated. There are no distinct biogenic structures.

72.50 - 71.80 m

These muds contain small *Planolites* extremely sparsely. Larger structures around 72.00 m look temptingly like sand burrow-fills. However, they all contain plant fragments orientated parallel with the sand body; this looks like physical rather than biogenic deposition.

Evidence for deposit feeding is very thin; yet the microscope reveals an abundance of red-brown sideritized grains that may be pellets, at 72.00 m.

71.80 - 69.20 m

Sand. No biogenics except small *Planolites* sparsely in mud laminae.

69.20 m

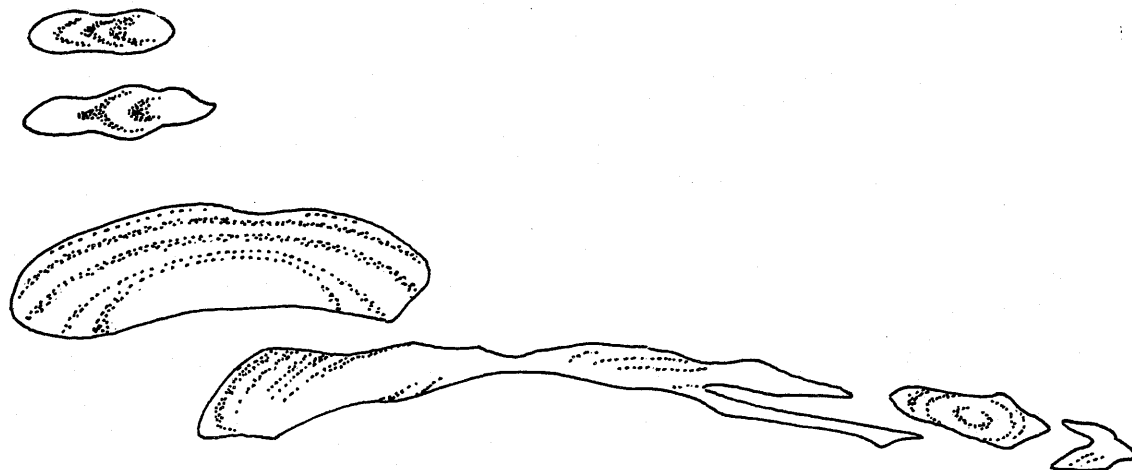
In much brecciated mud laminae, two or three sizes of *Planolites* can be detected: 1 mm, 3 mm and 10 mm Ø. I hesitate to use this meagre evidence as a basis for an environmental interpretation.

61.75 - 61.62 m

A muddy horizon containing the same deformed sand bodies. Many are unquestionably *Planolites*, but excessive compactional flow has obliterated all details.

60.25 - 58.75 m

This muddy interval contains highly distorted sand bodies, rolled and twisted.



It is not possible to estimate diversity on this basis! No individual ichnotaxa can confidently be recognized, except of course for *Planolites*. Certainly no *Fuersichnus* is present in this material.

58.75 - 58.00 m

Small, genuine *Planolites* occur sparsely. Above this, no recognizable biogenic structures were seen.

#### Unit C

Except for a few undiagnostic, small *Planolites* at the top of the core no recognizable biogenic structures were seen.

#### Conclusions

The sediment of this core has been very little bioturbated and structures in mud are unusually highly distorted by compaction. I suggest that the lack of biogenics in sands and the watery consistency of the mud may have been caused by rapid rates of deposition.

No trace fossils of unquestionable marine or nonmarine origin have been identified, and ichnological data are too meagre to allow environmental evaluation beyond the few hints made above.

Well 7230/05-U-02

The general transgressive trend represented by this core is clearly reflected in the trace fossils. In the following, I mention horizons and units that have ichnological interest only.

Unit A

125.00 m

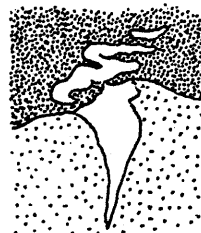
Lumpy bioturbation in a muddy bed.

124.20 m

Disturbance by rather large animals, around 1 cm Ø.

123.00 - 123.25 m

Thin mud beds in this interval are cut by strange vertical structures: mud cracks, perhaps sineresis phenomena. They continue down into the sand beneath.



Diversity here is rather high for nonmarine communities, but there are no diagnostic ichnotaxa. Density reaches 80% maximum.

118.50 m

A possible *Planolites* and a short retrusive *Diplocraterion parallelum*. A marine influence is indicated by the latter.

118.00 m

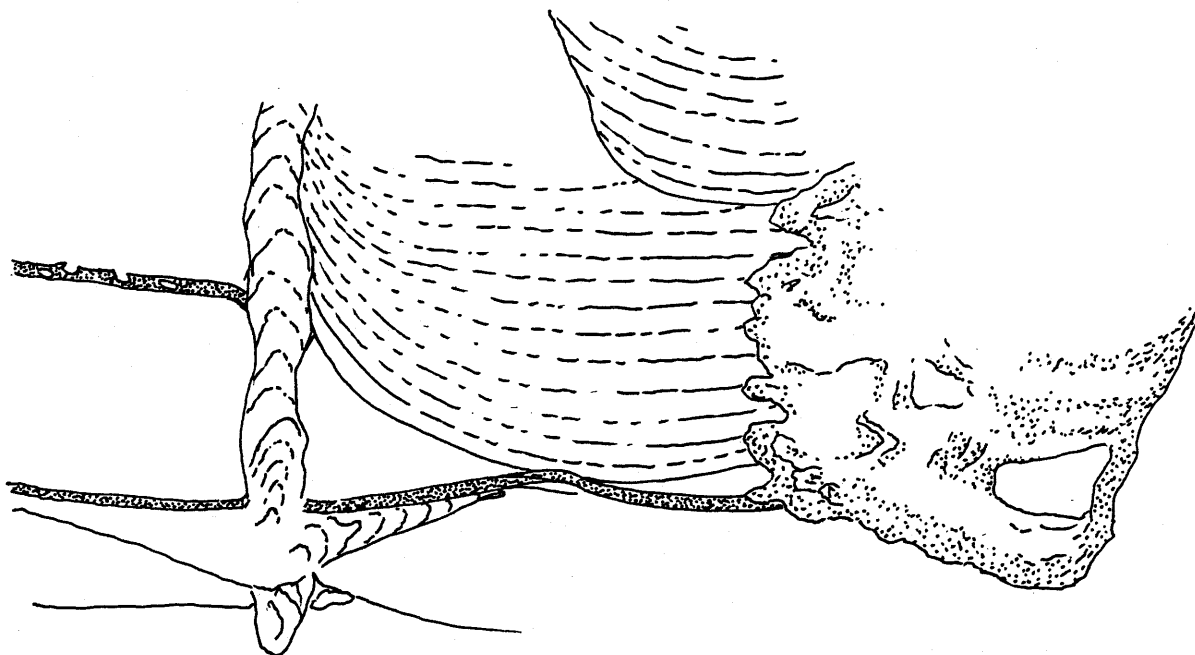
Sineresis cracks and 50% bioturbation by small *Planolites*.

116.75 m

100% bioturbation by large *Planolites*.

116.15 m

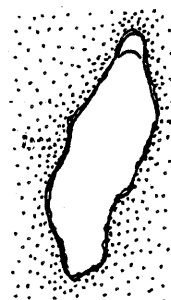
Spreiten, distorted by compaction. These are probably *Diplocraterion parallelum*. Thin mud beds crossed by the spreiten contain small *Planolites*.



116.15 - 113.00 m

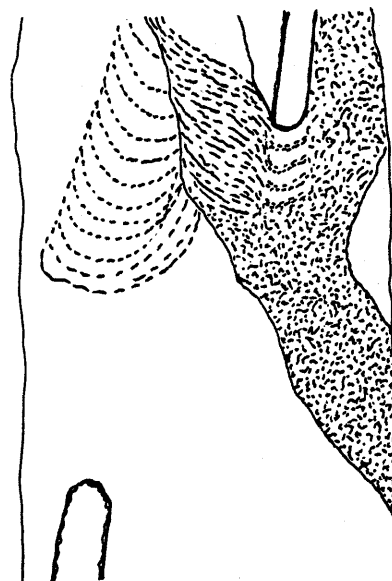
Wherever there is a muddy input in this interval, there is substantial bioturbation, up to 80% in many places.

Quite large animals are at work as well as small. The figure shows a structure resembling *Ophiomorpha nodosa* (but the wall is too thin and weakly organized for that ichnotaxon); otherwise, assemblages are dominated by deposit feeder structures. There is a strong marine aspect to all this.



111.70 m

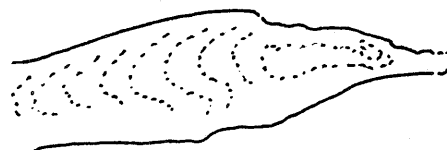
A thick-walled structure that resembles structures I have seen in connection *D. parallelum* in Jurassic backshore/foreshore environments. This mud structure cuts a faint meniscus or spreite.



106.70 - 88.00 m

There is much bioturbation at several levels in this interval. Although little is diagnostic, *Planolites* is large and dominant, producing mottled fabrics of 60-80%, perhaps up to 100%. There are two or three size classes of *Planolites*, and a reasonable diversity. The fabric meniscus backfill is markedly horizontal, indicating the lack of deep burrowing. Marginal marine conditions; plant roots cut the fabric at several levels.

102.50 m: probable  
meniscus backfill



88.00 - 86.00 m

The high density bioturbation continues; it would be remarkable in a non-marine environment. Diversity and density both are high. But no *D. parallelum* or true *O. nodosa* occur, so direct evidence for marine is missing.

86.00 - 82.00 m

A further slight increase in diversity and corresponding subtle changes in the ichnofabric. Large burrow fills, probably *Thalassinoides*, disrupt the fabric as the lowest tier. This is certainly marine.

## Unit B

82.00 - 81.70 m

This bed probably represents a hardground, containing omission-suite *Thalassinoides*.

81.70 - 74.00 m

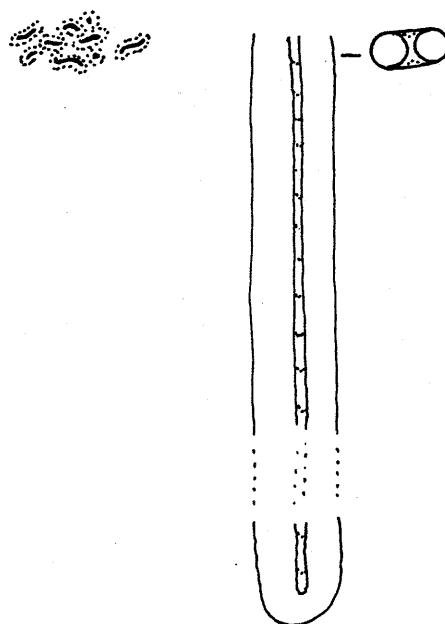
High diversity, 100% bioturbation. Large *Teichichnus rectus* are common, all retrusive, as much as 15 cm high. Horizontal sections of these *Teichichnus* at several places give a false impression of primary lamination. Visibility is greatly reduced in this greensand. Lower shoreface?

74.00 - 71.00 m

The same ichnofabric as below, but loss of glauconite improves visibility. Shallow-tier *Planolites*, 1-2 mm Ø, are seen everywhere where they have not been obliterated by deeper burrowing. Rare *Thalassinoides* are cut by common *Teichichnus rectus*. Towards the top, a deeper tier of minute burrows appears, reworking the *T. rectus*, at 72.00 m.

71.00 - 63.00 m

Two deep-tier trace fossils dominate the fabric here. Tiny *Helminthopsis horizontalis*, 0.5 mm Ø, is patchy, restricted to reworking certain fills of earlier burrows; and large, long *Diplocraterion habichi*. This looks like *Skolithos*, but has two closely spaced arms. A cross section visible at 68.00 m shows its nature clearly. *D. habichi* is characteristic of slowly deposited relict sediment-settings, shallow shelf. *Teichichnus* and *Planolites* occur as below.



63.00 - 51.00 m

Visibility becomes seriously reduced. The sediment is apparently 100% bioturbated, but details are missing. Individual structures can be detected but not identified, except *Helminthopsis*, which may account for much of the bioturbation. Above 51.00 m, there is no bioturbation, owing probably to anoxia.

## **APPENDIX A.8**

### **ROCK MECHANICAL ANALYSIS**

by

**Rune M. Holt and Berit Horvei, IKU**

## 1. INTRODUCTION

Knowledge of rock mechanical behaviour is of importance in many aspects of petroleum exploration and production. For instance, knowing the stress (i.e. burial) history of a formation, one can better judge its potential as a source rock. Knowing the present stress field and its orientation, one can design drilling programs to avoid hole instabilities. The in situ elastic/non-elastic behaviour plus rock strength parameters also play an important role here, as well as in stabilizing the wellbore against sanding during petroleum production.

Formation damage prevention or hydraulic fracturing/stimulation treatments are other tasks where rock mechanical input parameters from the near-wellbore region are necessary. Reservoir compaction/surface subsidence prediction requires information of mechanical behaviour of the entire structure, composed of the reservoir itself, the overburden and also the strata beneath. Rock mechanical parameters are also important for evaluation of flexuring of the crust due to for instance glacial isostatic depression.

Obtaining reliable rock mechanical data is not straightforward. Acoustic and density logs give elastic moduli, but the measurements are dynamic - and in general give different results from static measurements. Further, strength evaluation from logs is currently based on empirical correlations with static elastic properties - and may give erroneous results, in particular in weak formations.

In situ stress measurements are normally performed by integrating the density log (vertical stress), by fracturing the formations or performing leakoff tests (minimum horizontal stress), and by RFT (Repeat Formation Tester) measurements in the reservoir (pore pressure). Methods based on expected trendlines for sonic or other measurements may reveal abnormally pressured zones.

Measurements on cores in the laboratory on the other side offer a possibility of direct determination of static elastic properties and strength parameters. Core alteration due to unloading, changes due to sample treatment or due to rock-fluid interactions represent uncertainties in tests besides direct experimental uncertainty, rock heterogeneity and size effects.

Laboratory experiments serve not only as a possibility of getting data for current operations. As important, in particular in this context, is to

collect information and establish correlations and experience for future use in the Barents Sea. This includes:

- Establish data base of mechanical properties for key formations
- Explore elastic/non-elastic and strength behaviour vs. stress to obtain a picture of the stress-field and eventually stress history.
- Relate static and dynamic properties with rock strength for future log evaluation.

In the following, we present results and discussion of a series of experiments performed with samples from the 1987 shallow drilling program in the Barents Sea.

## 2. LABORATORY EXPERIMENTS

### 2.1 Samples

The following 54 mm diameter core plugs, see Table 1, were selected for rock mechanical testing:

Table 1 Overview of the samples.

| Sample # | Core         | Depth [m] | Age         | Lithology        |
|----------|--------------|-----------|-------------|------------------|
| D5189    | 7230/05-U-06 | 93.0      | M. Triassic | Clayey siltstone |
| D5190    | 7230/05-U-05 | 43.0      | M. Triassic | Clayey siltstone |
| D5193    | 7230/05-U-03 | 64.5      | U. Triassic | Sandstone        |
| D5191    | 7230/05-U-03 | 105.4     | U. Triassic | Shale            |
| D5192    | 7230/05-U-03 | 111.1     | U. Triassic | Shale            |

The samples, which had been stored in plastic bags with remaining formation water, were in the process of drying out when received in the laboratory. This is expected to have a large influence on the results, in particular for rocks with high clay content. We should therefore use the results more as guidelines rather than relying too much on the quantitative results. To perform mechanical testing in the triaxial cell, 1½" diameter x 3"

length samples had to be drilled out from the cores. This drilling process turned out to be very difficult, particularly in the clay rich rocks. In the case of sample D5191 (7230/05-U-03, 111.1 m), it was not possible to obtain a suitable core plug.

## 2.2 Unconfined acoustic measurement

Prior to preparation for failure testing, acoustic velocities were measured with the core plugs at atmospheric conditions. Both P- and S-wave velocities were measured axially, while in the radially direction only the P-wave velocity was recorded. The measuring frequency is in the range of 250-500 kHz. The results are summarized in the Table 2.

All velocities are given in km/sec.

Table 2 P- and S-wave velocities measured at atmospheric conditions.

| Plug No | Lithology        | Density<br>[g/cm <sup>3</sup> ] | $v_{pz}$ | $v_{pr}$ | $v_{sz}$ | $v_{pz}/v_{sz}$ | $v_{pr}/v_{pz}$ |
|---------|------------------|---------------------------------|----------|----------|----------|-----------------|-----------------|
| D5189   | Clayey Siltstone | 2.28                            | 2.73     | 3.22     | 1.72     | 1.59            | 1.18            |
| D5190   | Clayey Siltstone | 2.11                            | 2.19     | 2.62     | 1.63     | 1.34            | 1.20            |
| D5193   | Sandstone        | 1.85                            | 1.80     | 1.95     | 1.20     | 1.50            | 1.08            |
| D5191   | Shale            | 2.25                            | 2.39     | 3.05     | 1.72     | 1.39            | 1.28            |
| D5192   | Shale            | 2.17                            | 2.21     | 2.64     | 1.55     | 1.43            | 1.19            |

## 2.3 Instrumentation for rock mechanical tests

The present work has been carried out in IKU's Formation Mechanics laboratory. Fig. 1 shows a sketch of the experimental set-up. The sample is confined in a plastic sleeve inside a triaxial cell. Steel pistons are pressed against its end surfaces. The load frame (Robcon OY, Finland) gives force to the lower piston which may be moved by displacement control (constant strain rate) or force control. In the present experiments, the displacement control was used. A hydraulic system is pumping oil into the cell around the plastic sleeve to give the required confining pressure. This may be regulated to follow the axial stress (hydrostatic testing) or to be maintained at a constant value during loading/unloading (triaxial testing).

During the tests, axial force and confining pressure are measured together with axial and radial displacements. The latter are measured with 3 LVDT's (linear variable displacement transducers) which are placed in a horizontal plane near the middle of the sample, and with 120° angle between each other. - Broadband acoustic transducers (~ 0.1 - 1 MHz) are placed inside the steel pistons as well as in the confining oil, where they are pressed with spring forces against the wall of the sleeve (see Fig. 2). This gives the possibility of measuring ultrasonic velocities in two directions during

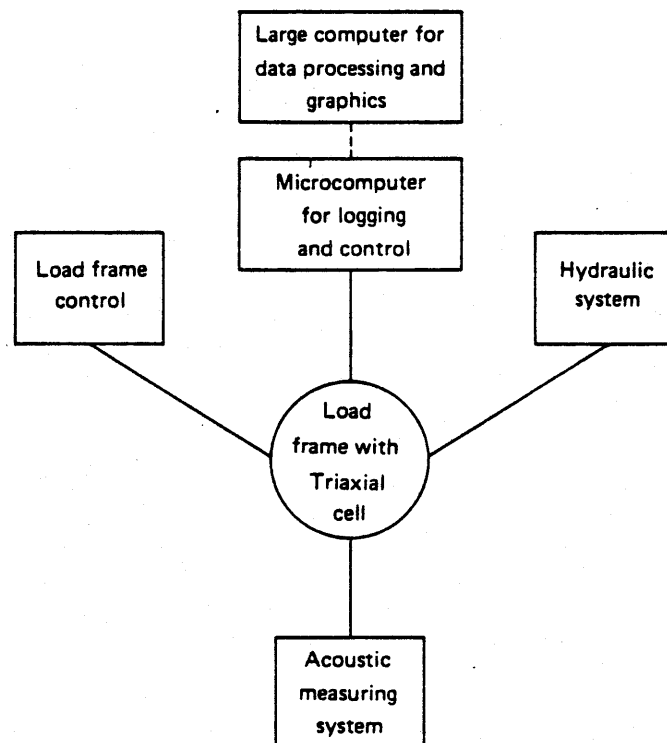


Figure 1 Sketch of the experimental set-up.

a laboratory test. - In the present experiments, Panametrics P-wave transducers were placed inside the steel pistons in order to be able to record the vertical wave velocity. A thin layer of glue (Panametrics Shear Wave Couplant) is used to ensure a good acoustic coupling between the transducers and the pistons as well as between pistons and sample. At low pressures (< 3 MPa), the coupling may be too poor to allow reliable measurements of the axial wave velocities. Panametrics S-wave transducers were placed in the confining oil.

-A.8.6-

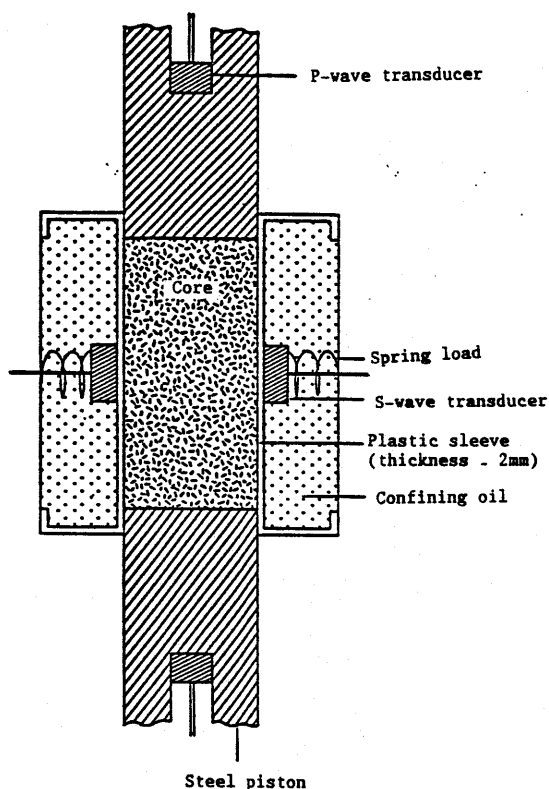


Figure 2 Inside look in the triaxial cell showing acoustic transducer configuration.

## 2.4 Uniaxial Compression Tests

A total of three uniaxial tests were performed, in one of them acoustic measurements were included. The stress path is shown in Fig. 3. The E-modulus has been defined as the slope at a stress level corresponding to 50% of the ultimate strength. Table 3 gives a list of measured E-modulus, uniaxial compressive strength, shear modulus and Poisson's ratio. The stress-strain response obtained during the tests are shown in Fig. 4.a, 4.b and 4.c.

Table 3 Measured uniaxial compressive strength, E-modulus, Poisson's ratio and shear modulus for cores from Block 7230.

| Plug  | Uniaxial compressive strength [MPa] | E-modulus [GPa] | Poisson's ratio | Shear modulus [GPa] |
|-------|-------------------------------------|-----------------|-----------------|---------------------|
| D5189 | 30.6                                | 2.8             | 0.00            | 1.4                 |
| D5192 | 25.5                                | 2.6             | -0.01           | 1.3                 |
| D5193 | 11.3                                | 1.2             | 0.07            | 0.6                 |

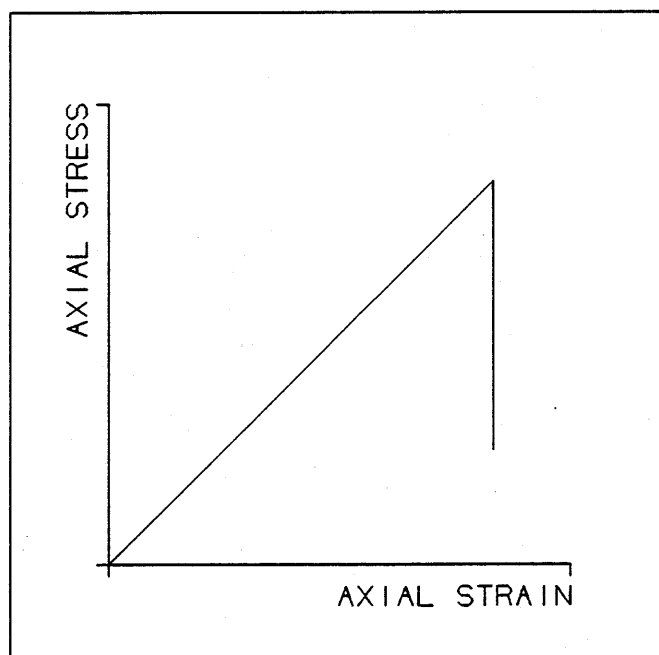


Figure 3 Stress path in uniaxial test.

In an uniaxial test without a confining oilbath, it is difficult to get a good acoustic coupling between the transducer, the rubber sleeve and the sample. The acoustic measurements in the radial direction were not reliable during this test. The P-wave velocity measured on plug 5193 (7230/05-U-03, 64.4 m) was 2930 m/s with an axial load of 11.3 MPa.

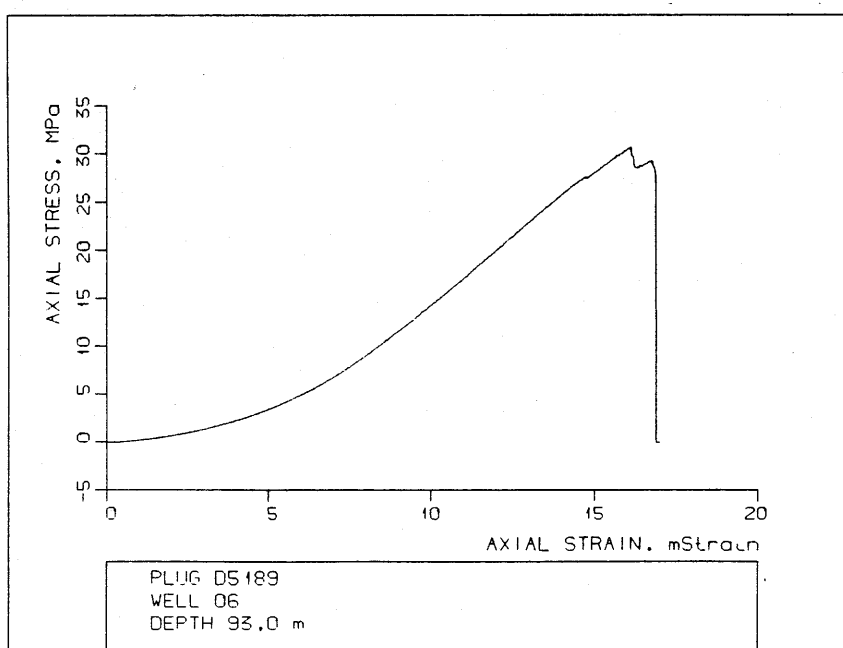


Figure 4.a Axial stress vs. axial strain for plug D5189 (7230/05-U-06, 93.0 m).

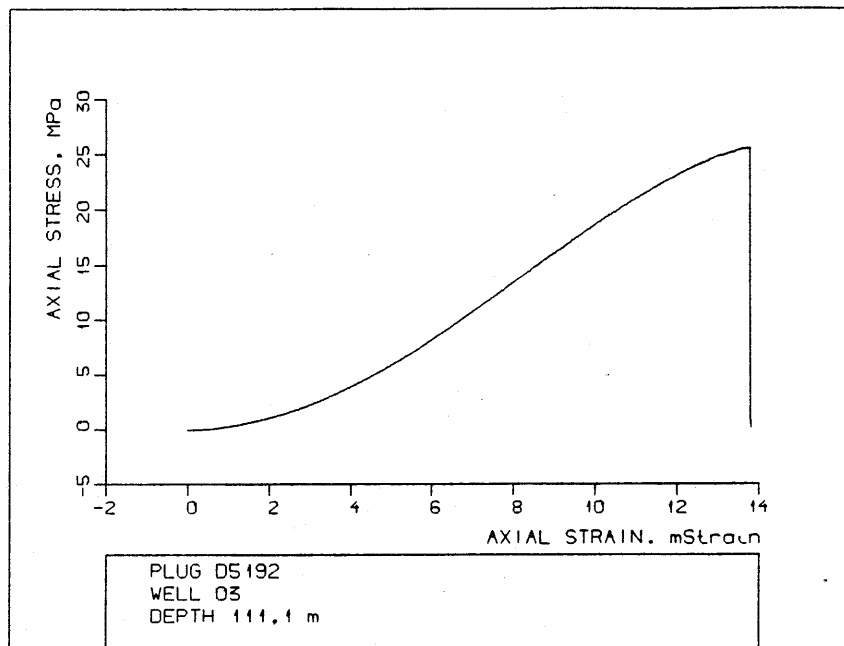


Figure 4.b Axial stress vs. axial strain for plug D5192 (7230/05-U-03, 111.1 m)

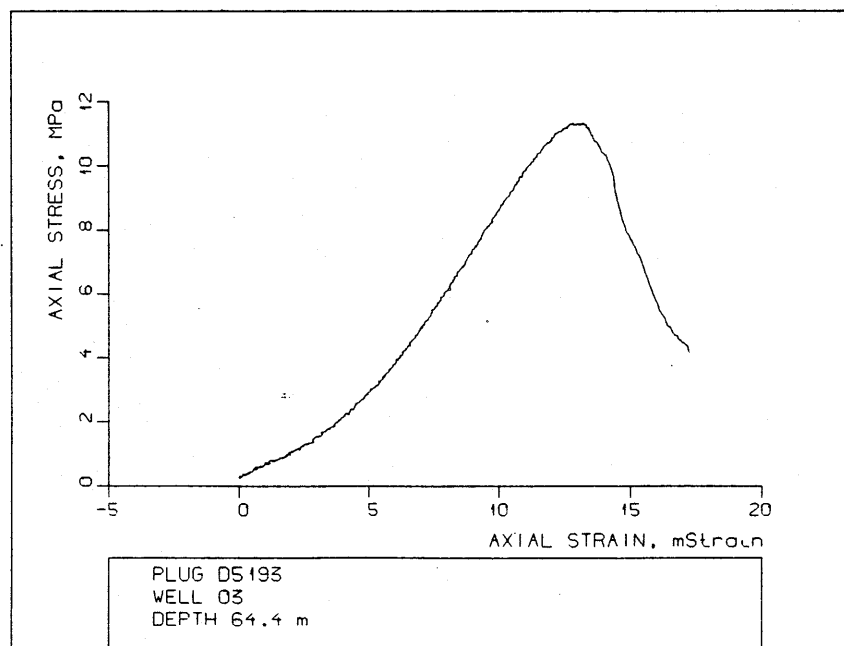


Figure 4c Axial stress vs. axial strain for plug D5193 (7230/05-U-03, 64.4 m).

## 2.5 Hydrostatic and Triaxial Compression Test

The stress path is shown in Fig. 5. One core (plug D5190, 7230/05-U-05, 43.0 m) was undertaken a triaxial test. The sample is brought hydrostatically to the confining pressure. From here the confining pressure is held constant and the axial load is increased until failure. The stress-strain response is shown in Fig. 6. The readings from all three LVDT's are shown in the left part of the plot. Below we summarize, (Table 4), the measured peak strength and elastic moduli.

Table 4 Measured peak stress, E-modulus, Poisson's ratio, shear strength and shear modulus for plug D5190 (7230/05-U-05, 43.0 m).

| Confining Pressure [MPa] | Peak Stress [MPa] | E-modulus | Poisson's ratio | Shear Strength [MPa] | Shear modulus [GPa] |
|--------------------------|-------------------|-----------|-----------------|----------------------|---------------------|
| 5                        | 53.9              | 3.6       | -0.0            | 24.4                 | 1.8                 |

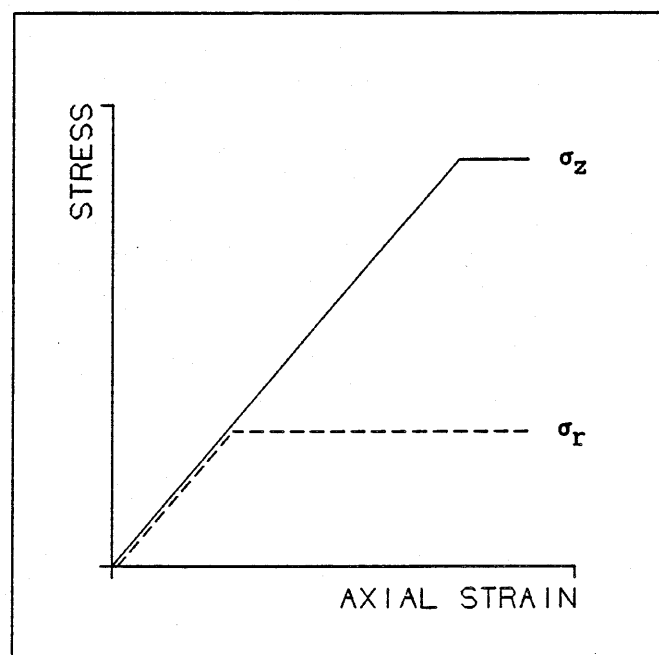


Figure 5 Stress path in triaxial test.

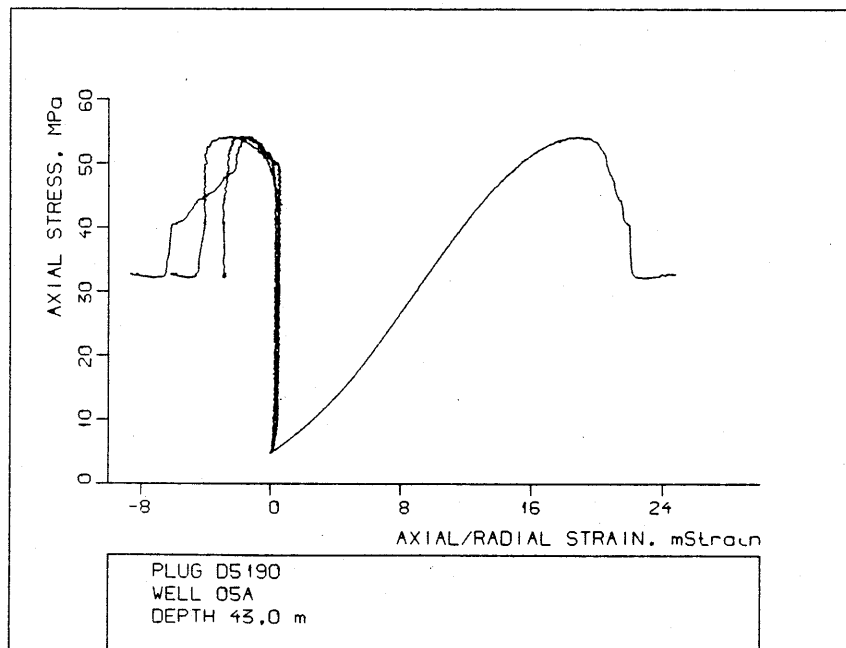


Figure 6 Stress-strain response for plug D5190 (7230/05-U-05, 43.0 m). Radial strains are the three curves in the left part of the plot

During the test the radial P- and S-wave and axial P-wave velocities were measured. In Fig. 7 the velocity is plotted against axial strain. Fig. 7.a shows the results from the hydrostatic loading and Fig. 7.b shows the results from the triaxial part. The velocity at hydrostatic conditions, 5 MPa, at failure and the maximum reading is tabulated in Table 5.

Table 5 Measured velocities at hydrostatic conditions, at failure and the maximum reading (plug D5190, 7230/05-U-05, 43.0 m).

|          | $\sigma_H = 5 \text{ MPa}$ | $\sigma_z = 53.9 \text{ MPa}$ | Maximum reading |
|----------|----------------------------|-------------------------------|-----------------|
| $v_{pz}$ | 2210                       | 2870                          | 2890            |
| $v_{pr}$ | 2810                       | 2740                          | 2970            |
| $v_{sr}$ | 1350                       | 1310                          | 1410            |

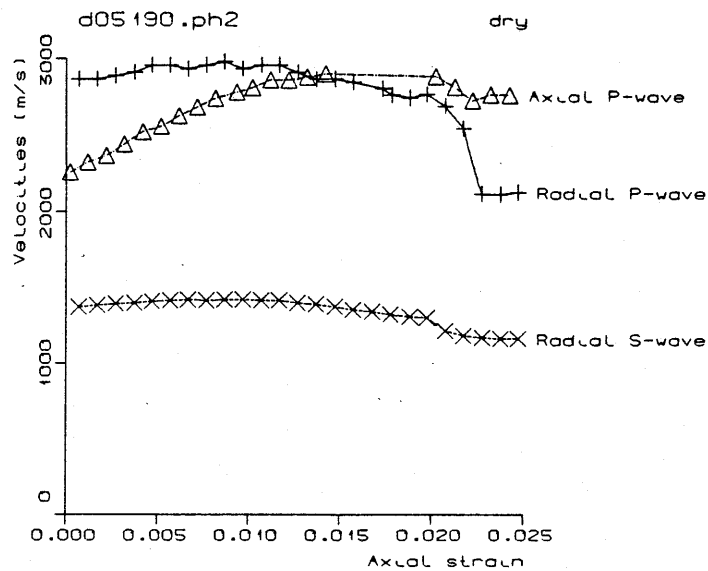
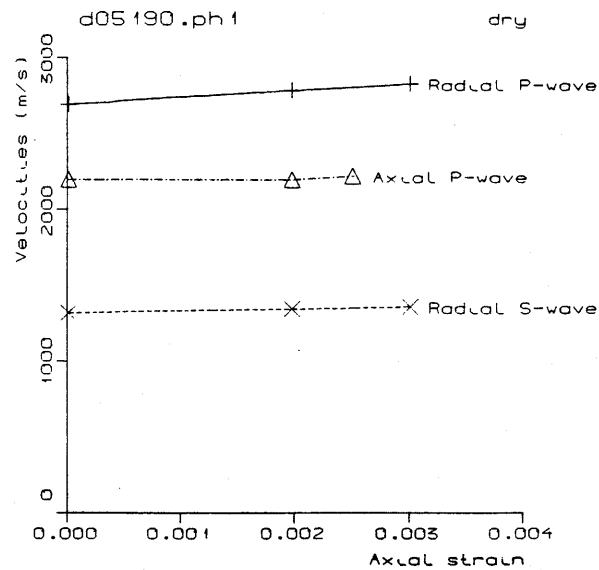


Figure 7 P- and S-wave velocity vs. axial strain, measured on plug D5190.

a) Hydrostatic loading  
b) Triaxial part

### 3. DISCUSSION

The amount of data collected during this study is not sufficient to draw any firm conclusions regarding mechanical behaviour and stress history. We feel, however, that it represents a starting point, and as such, it is of value to inspect closer the data recorded and the information that can be drawn for them.

#### 3.1 Acoustic measurements

The acoustic measurements performed at unconfined conditions (Section 2.2), show a significant acoustic anisotropy, which is largest in the shales. This is expected, since these rocks are strongly bedded by flat clay minerals oriented parallel to each other. The sound velocity is as expected higher in the direction parallel to the bedding than perpendicular to it.

Also in the sandstone there is a significant anisotropy. In previous work (Holt et. al., 1987), we have proposed that acoustic anisotropy can be related also to cracks opened during unloading. This is particularly valid in sandstones, and can be used to aid evaluation of in situ stress directions, and hopefully, at a later stage, also magnitudes. Sedimentological studies, including thin sections, show a massive sandstone without any lithological microlamination. We may therefore conclude that the measured anisotropy of the sandstone is due to stress release.

It is, anyway, important to be aware of the acoustic anisotropy when analyzing logs and seismic data, since logs will read mainly the vertical and seismics the horizontal velocity. Not taking the anisotropy into account may lead to erroneous depth estimates (Banik, 1984).

During loading, the sound velocities change. In the case of uniaxial compression, the P-wave velocity in the sandstone sample was found to increase from 1850 to 2930 m/s when  $\sigma_z$  increased from 0 to 11.3 MPa. This shows the potential of using the acoustic log as a stress indicator. In the triaxial test with sample D5190 (clayey siltstone at 43 m in core 7230/05-U-05), one can see not only a velocity increase during loading, but also the development of a strong acoustic anisotropy due to the anisotropic loading of the rock. Beyond failure this causes the vertical velocity to exceed the horizontal. This effect has been discussed in more detail elsewhere (Holt and Fjær, 1987), and is related to the development of an oriented microcrack pattern prior to rock failure. This is yet another documentation

that acoustic velocity anisotropy can be used to monitor stress field anisotropy. The main, fundamental problem lies in distinguishing between lithological and stress-induced anisotropy.

### 3.2 Rock mechanical measurements

Dynamic elastic moduli for the unconfined situation can be derived from the acoustic data in Section 2.2. The dynamic Young's modulus, defined as:

$$E_{\text{dyn}} = \rho v_{\text{sz}}^2 \cdot \frac{3v_{\text{pz}}^2 - 4v_{\text{sz}}^2}{v_{\text{pz}}^2 - v_{\text{s}}^2} \quad (\text{x.1})$$

can be tabulated as follows (Table 8):

**Table 8: Dynamic Young's modulus.**

| Sample |                  | Unconfined<br>$E_{\text{dyn}}$ [GPa] |
|--------|------------------|--------------------------------------|
| D5189  | Clayey Siltstone | 16.0                                 |
| D5190  | Clayey Siltstone | 9.9                                  |
| D5193  | Sandstone        | 5.9                                  |
| D5191  | Shale            | 12.8                                 |
| D5192  | Shale            | 10.6                                 |

During failure tests,  $E_{\text{dyn}}$  increases slightly, in accordance with the increase in sound velocities. It is therefore clear that  $E_{\text{dyn}}$  exceeds its statically measured counterpart by a factor of at least 4-6 in the uniaxial tests, regardless of lithology.

The uniaxial strength ( $\sigma_c$ ) increases with the static E-modulus:

$$\sigma_c \text{ [MPa]} \sim 10 E_{\text{stat}} \text{ [GPa]}$$

The factor 10 must not be taken to lithology, since the relation is based on just 3 experiments, but the relation is not off scale from what has been found from rock testing elsewhere (Holt et. al., 1987; and references cited therein). Notice, however, the correction that needs to be made due to the static-dynamic disagreement when logs are to be interpreted for strength parameters. More data is required to establish reliable conversion schemes

between  $E_{\text{stat}}$ ,  $E_{\text{dyn}}$  and  $\sigma_c$ .

It is seen from all the tests performed that the stress-strain curves are nonlinear. The rock stiffness increases with increased loading. This is due to closing of preexisting microcracks in the samples. If we believe that all the microcracks were opened during unloading while coring, the transition between nonlinear and linear behaviour can be used as a guideline (together with acoustic measurements) to establish previous stress levels experienced by the rock. Again, the amount of data here is too scarce to allow such an investigation.

#### 4. CONCLUDING REMARKS

A mechanical property analysis has been carried out with selected samples of sandstone, siltstone and shale from the 1987 shallow drilling program in the Barents Sea. The rocks were not properly preserved prior to testing, and the amount of data obtained is modest. We have, however, found:

- i) Static are exceeded by dynamic elastic moduli by a factor of at least 4-6 regardless of formation.
- ii) Correlations between static and dynamic modulus and peak strength can be found. These findings (i and ii) have importance for future mechanical property logging.
- iii) Acoustic velocities, velocity anisotropy and elastic nonlinear behaviour may be tracked back to the in situ stress state.

Acoustic anisotropy is also due to lithological bedding. This is important for correlations between seismic and log readings.

- iv) The failure criterion is - as expected - seen to be nonlinear.

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## **APPENDIX A.9**

### **THERMAL CONDUCTIVITY MEASUREMENTS**

by

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## INTRODUCTION

Thermal conductivity has been measured on 67 rock core samples from the IKU-1987 Barents Sea core units. Five of those samples are from a core not drilled within the present project and the data from those are omitted here.

The measurements were taken by the needle probe method. The probes used have a length of 50 mm and an outer diameter of 1.5 mm. Thermal conductivity anisotropy was measured on all samples.

Measurements were carried out on water saturated samples at room temperature ( $\sim 20^{\circ}\text{C}$ ) and for the data set as a whole at a pressure of 1 bar. (Full water saturation was ensured by keeping samples in water under vacuum for at least 24 hours before measurements). Some samples were measured also under the original near water saturated condition. Generally only minor conductivity differences ( $< 5\text{-}10\%$ ) were observed between the two conditions).

On 6 samples conductivity was measured as a function of pressure within the pressure range 1 to 50 bar. From the original total set of 71 samples, 4 samples were not measured due to too bad sample quality.

The needle probe technique used shows a conductivity repeatability generally within 1-3%.

During measurements all probes used were currently tested in standard materials of known conductivity.

## THERMAL CONDUCTIVITY AND CONDUCTIVITY ANISOTROPY

In general we aimed at taking 4 single measurements in each sample, 2 measurements in two mutually perpendicular directions in the "top part" of the sample and 2 measurements in the bottom part of the sample, to measure any local variation in conductivity.

The samples are lithified and small drill holes were drilled with high speed drills for the insertion of the needle probes. Due to the variable core quality (the risk of destroying samples during preparation) and to the existence of some very hard materials, "double sets" of measurements were taken in slightly less than half the samples.

Measuring results are summarized in Table 1. Generally, for each sample horizontal conductivity ( $k_h$ ), vertical conductivity ( $k_v$ ) and coefficient of conductivity anisotropy ( $A=k_h/k_v$ ) are given. If both "top" and "bottom" sets of measuring results are available, the sample result (first column) is the average of "top" and "bottom" sets. Also a sample quality code is given. Quality code 2 and 3 are assigned to samples where minor cracks may affect the measuring results.

Apparent conductivity anisotropy lower than 1 is observed in 8 sample data sets (Table 1). Such values may result from local conductivity variations not associated with well defined conductivity anisotropy or, for values close to 1 ( $\sim 0.95$  to  $1.00$ ), also from experimental uncertainty. Here we prefer to use the average value of the original measuring results ( $k_1$  and  $k_2$ , Table 3) and assign the average value as the sample  $k$ -value (Table 2).

In Table 2 also station average conductivity values are calculated. These average values are given only for statistical reasons and not to indicate lithological representative station averages.

For 5 samples as indicated in Tables 1 and 2, we observed minor deviations from horizontal lamination. Consequently, for those samples,  $k_h$ ,  $k_v$  and  $A$  are approximate values. An analysis of the detailed orientation of lamination was not performed, and corrections for deviations from horizontal lamination are not included.

#### TEST FOR CONDUCTIVITY - PRESSURE DEPENDENCE

From the above set of cores 6 samples were selected for conductivity - pressure measurements to test any minor effects resulting from sample unloading, transportation, preparation etc. Measurements were taken with the needle placed as usual in the two mutually perpendicular directions at 8 pressure levels between 1 and 50 bar (1, 5, 10, 20, 30, 40, 50, 1). The last "1 bar measurements" were taken to test for conductivity hysteresis.

The measurements were carried out with the core samples placed in cylinders with an inner diameter of 60 mm and variable height. The needle probe used was inserted into the sample from bottom to yield  $k_h$  and from side to yield  $k_v$ . (We recall that  $k_v = k_h^2/k$ ). The samples were embedded in water saturated quartz sand which fills up the space between the cylinder and the rock sample. The pressure was supplied hydraulically to a cylindrical disk

on top of the quartz sand, thus resulting in, at sample location, a dominating vertical pressure component and significant horizontal components. The single pressure values are read from a stressmeter placed above the sample cylinder. Inaccuracy of pressure is less than 5%.

Measuring results are summarized in Table 4. Conductivity values are normalized to conductivity at 1 bar (first set of measurements) to emphasize relative variations. Average values, standard deviation, and standard error of average values are calculated for the normalized conductivities and for the (non-normalized) conductivity anisotropy. (Anisotropy values less than 1, values in brackets, are not included in the averaging).

Two samples with a conductivity anisotropy less than 1 were especially selected to be tested for pressure dependence.

The measuring results generally show a high degree of accuracy and internal consistency. For most samples and for the data set as a whole we observe no or only a very small increase of conductivity with pressure. Any effect is on an average not higher than 2%.

Sample 5177 shows clear indications of an increase of  $k_m$  and  $k_v$  of the order of 5-10% over the pressure range 1 to 30 bar. Here the last measuring value at 1 bar indicates the existence of hysteresis effect (e.g. closing of minor cracks). Conductivity anisotropy is generally not affected by the increase of pressure, and the two samples with  $A < 1$  (5152 and 5172) do not differ from the general trend of  $A$  being unaffected. For sample 5177 a minor (5-10%) decrease in  $A$  seems resolved.

Normally, sedimentary rocks (also under water saturated conditions as here) show some conductivity increase for increasing pressure at the pressure levels in question. The general lack of pressure dependence for the present measured samples is probably due to a high degree of lithification/low porosities.

Table 1 Summary of thermal conductivity data. Abbreviations are explained in the text. a: For alternative, more likely interpretation see Table 2 and 3. b: Indications of non-horizontal lamination. c: Sample quality code, 1: good, 2: fair, 3: poor.

| Samplenummer | Conductivity (W/m K) |           |         |      |        |      |      |           |      | Sample quality(c) |
|--------------|----------------------|-----------|---------|------|--------|------|------|-----------|------|-------------------|
|              | kh                   | Sample kv | A       | kh   | Top kv | A    | kh   | Bottom kv | A    |                   |
| 7230/5-U-4   |                      |           |         |      |        |      |      |           |      |                   |
| 5001- 25.60  | 2.11                 | 2.06      | 1.02    | 2.23 | 2.13   | 1.05 | 1.98 | 1.99      | 1.00 | 2                 |
| 5002- 30.90  | 2.00                 | 2.07      | 0.97(a) | 2.06 | 1.96   | 1.05 | 1.95 | 2.18      | 0.89 | 2                 |
| 5003- 40.27  | 1.86                 | 1.56      | 1.20    | 1.69 | 1.63   | 1.03 | 2.03 | 1.48      | 1.37 | 2                 |
| 5004- 47.90  | 1.83                 | 1.61      | 1.14    | 1.83 | 1.61   | 1.14 |      |           |      | 3                 |
| 5005- 54.85  | 1.66                 | 1.12      | 1.49    | 1.66 | 1.10   | 1.51 | 1.65 | 1.13      | 1.47 | 3                 |
| 5006- 64.05  | 2.21                 | 1.83      | 1.21    | 2.12 | 1.68   | 1.26 | 2.29 | 1.97      | 1.16 | 2                 |
| 5007- 72.15  | 2.14                 | 1.64      | 1.32    | 2.00 | 1.43   | 1.40 | 2.28 | 1.85      | 1.23 | 2                 |
| 5008- 75.60  | 2.19                 | 1.59      | 1.38    | 2.23 | 1.62   | 1.37 | 2.15 | 1.56      | 1.38 | 2                 |
| 7230/5-U-5   |                      |           |         |      |        |      |      |           |      |                   |
| 5009- 49.30  | 3.78                 | 3.16      | 1.19    | 3.78 | 3.16   | 1.19 |      |           |      | 1                 |
| 5010- 42.15  | 2.18                 | 1.85      | 1.18    | 2.18 | 1.81   | 1.21 | 2.17 | 1.89      | 1.15 | 2                 |
| 5011- 36.10  | 2.44                 | 2.11      | 1.15    | 2.42 | 2.03   | 1.19 | 2.46 | 2.19      | 1.12 | 1                 |
| 5012- 32.85  | 2.51                 | 2.15      | 1.17    | 2.48 | 2.05   | 1.21 | 2.55 | 2.25      | 1.13 | 1                 |
| 5013- 39.10  | 1.98                 | 1.12      | 1.78    | 1.94 | 1.03   | 1.89 | 2.02 | 1.21      | 1.67 | 3                 |
| 7230/5-U-2   |                      |           |         |      |        |      |      |           |      |                   |
| 5014- 40.10  | 1.36                 | 0.99      | 1.37    | 1.36 | 0.99   | 1.37 |      |           |      | 3                 |
| 5015- 43.40  | 1.24                 | 0.78      | 1.59(b) | 1.22 | 0.78   | 1.57 | 1.26 | 0.78      | 1.61 | 2                 |
| 5016- 52.05  | 1.82                 | 1.63      | 1.20    | 2.02 | 1.27   | 1.60 | 1.61 | 2.00      | 0.81 | 3                 |
| 5017- 63.50  | 2.03                 | 1.65      | 1.23    | 2.03 | 1.65   | 1.23 |      |           |      | 3                 |
| 5018- 71.10  | 2.15                 | 1.72      | 1.25    | 2.36 | 1.75   | 1.35 | 1.93 | 1.68      | 1.15 | 3                 |
| 5019- 78.80  | 2.14                 | 1.99      | 1.08    | 2.14 | 1.99   | 1.08 |      |           |      | 3                 |
| 5020- 87.30  | 2.63                 | 2.07      | 1.27    | 2.63 | 2.07   | 1.27 |      |           |      | 2                 |
| 5021- 95.30  | 2.83                 | 1.81      | 1.56(b) | 2.83 | 1.81   | 1.56 |      |           |      | 2                 |
| 5022-106.90  | 3.49                 | 2.49      | 1.40(b) | 3.57 | 2.65   | 1.34 | 3.42 | 2.33      | 1.47 | 1                 |
| 5023-115.70  | 2.72                 | 1.90      | 1.43(b) | 2.72 | 1.90   | 1.43 |      |           |      | 3                 |
| 5024-120.40  | 3.56                 | 2.85      | 1.25    | 3.56 | 2.85   | 1.25 |      |           |      | 3                 |
| 7230/5-U-6   |                      |           |         |      |        |      |      |           |      |                   |
| 5025- 28.75  | 2.38                 | 2.73      | 0.87(a) | 2.21 | 2.50   | 0.88 | 2.55 | 2.96      | 0.86 | 2                 |
| 5026- 36.40  | 1.96                 | 1.58      | 1.24    | 1.90 | 1.59   | 1.20 | 2.02 | 1.57      | 1.20 | 2                 |
| 5027- 42.90  | 2.19                 | 1.54      | 1.43    | 2.23 | 1.46   | 1.52 | 2.16 | 1.62      | 1.34 | 2                 |
| 5028- 48.75  | 2.51                 | 2.09      | 1.20    | 2.46 | 2.19   | 1.13 | 2.55 | 1.99      | 1.28 | 1                 |
| 5030- 60.10  | 2.28                 | 1.71      | 1.34    | 2.29 | 1.58   | 1.45 | 2.27 | 1.83      | 1.24 | 1                 |
| 5031- 69.30  | 2.32                 | 1.62      | 1.47    | 2.29 | 1.38   | 1.66 | 2.35 | 1.85      | 1.27 | 1                 |
| 5032- 75.35  | 2.26                 | 1.48      | 1.53    | 2.24 | 1.49   | 1.51 | 2.27 | 1.47      | 1.55 | 1                 |
| 5033- 81.40  | 2.15                 | 1.68      | 1.28    | 2.21 | 1.69   | 1.30 | 2.09 | 1.66      | 1.26 | 2                 |
| 5034- 88.85  | 2.14                 | 1.38      | 1.56(b) | 2.16 | 1.40   | 1.54 | 2.13 | 1.35      | 1.57 | 1                 |
| 5035- 94.00  | 2.28                 | 1.79      | 1.28    | 2.27 | 1.68   | 1.36 | 2.28 | 1.90      | 1.20 | 1                 |
| 7129/10-1    |                      |           |         |      |        |      |      |           |      |                   |
| 5151- 60.04  | 2.76                 | 3.14      | 0.88(a) | 2.76 | 3.14   | 0.88 |      |           |      | 3                 |
| 5152- 72.20  | 2.21                 | 2.55      | 0.87(a) | 2.21 | 2.55   | 0.87 |      |           |      | 1                 |
| 5153- 79.65  | 2.01                 | 1.95      | 1.03    | 2.01 | 1.95   | 1.03 |      |           |      | 2                 |
| 7129/10-2    |                      |           |         |      |        |      |      |           |      |                   |
| 5178- 31.84  | 3.14                 | 2.98      | 1.05    | 3.14 | 2.98   | 1.05 |      |           |      | 2                 |
| 5179- 40.71  | 3.04                 | 2.78      | 1.09    | 3.04 | 2.78   | 1.09 |      |           |      | 1                 |
| 5180- 49.96  | 2.99                 | 2.96      | 1.01    | 2.99 | 2.96   | 1.01 |      |           |      | 1                 |
| 5181- 59.70  | 2.79                 | 2.77      | 1.01    |      |        |      | 2.79 | 2.77      | 1.01 | 1                 |
| 5182- 67.93  | 1.69                 | 1.19      | 1.42    | 1.69 | 1.19   | 1.42 |      |           |      | 3                 |
| 5183- 74.33  | 2.34                 | 2.24      | 1.04    | 2.34 | 2.24   | 1.04 |      |           |      | 1                 |
| 5184- 83.65  | 2.19                 | 1.74      | 1.26    | 2.19 | 1.74   | 1.26 |      |           |      | 1                 |
| 5185- 93.05  | 2.62                 | 2.45      | 1.07    | 2.62 | 2.45   | 1.07 |      |           |      | 1                 |
| 5186-102.24  | 2.52                 | 2.30      | 1.09    | 2.52 | 2.30   | 1.09 |      |           |      | 1                 |
| 5187-111.78  | 3.02                 | 2.60      | 1.17    | 3.02 | 2.60   | 1.17 |      |           |      | 1                 |
| 5188-119.26  | 3.24                 | 3.16      | 1.02    | 3.24 | 3.16   | 1.02 |      |           |      | 2                 |
| 7030/03-01   |                      |           |         |      |        |      |      |           |      |                   |
| 5162- 27.40  | 2.60                 | 2.35      | 1.11    | 2.60 | 2.35   | 1.11 |      |           |      | 1                 |
| 5163- 37.20  | 2.14                 | 2.13      | 1.01    | 2.14 |        |      | 2.15 | 2.13      | 1.01 | 1                 |
| 5164- 50.42  | 1.87                 | 1.84      | 1.02    | 1.87 | 1.84   | 1.02 |      |           |      | 1                 |
| 5165- 59.22  | 2.31                 | 2.15      | 1.08    | 2.31 |        |      | 2.31 | 2.15      | 1.08 | 1                 |
| 5167- 78.83  | 2.30                 | 2.31      | 0.99(a) |      |        |      | 2.30 | 2.31      | 0.99 | 1                 |
| 5168- 86.02  | 2.20                 | 2.38      | 0.93(a) | 2.20 | 2.38   | 0.93 |      |           |      | 2                 |
| 5170-106.37  | 3.09                 | 3.12      | 0.99(a) | 3.09 | 3.12   | 0.99 |      |           |      | 1                 |
| 5171-116.70  | 3.75                 | 2.37      | 1.58    | 3.75 | 2.37   | 1.58 |      |           |      | 1                 |
| 5172-126.97  | 3.52                 | 3.48      | 1.01    | 3.52 | 3.48   | 1.01 |      |           |      | 1                 |
| 5173-133.77  | 2.63                 | 2.70      | 0.97(a) | 2.63 | 2.70   | 0.97 |      |           |      | 2                 |
| 5174-142.48  | 3.15                 | 3.03      | 1.04    | 3.15 | 3.03   | 1.04 |      |           |      | 2                 |
| 5175-154.22  | 3.23                 | 3.18      | 1.02    | 3.23 | 3.18   | 1.02 |      |           |      | 2                 |
| 5176-164.63  | 2.69                 | 2.56      | 1.05    | 2.69 | 2.56   | 1.05 |      |           |      | 1                 |
| 5177-171.22  | 3.05                 | 2.87      | 1.06    | 3.05 | 2.87   | 1.06 |      |           |      | 1                 |

Table 2 Average thermal conductivity (W/m K) for each site. Variations in the lithological columns are not accounted for.

| Samplenumber                               | kh(k) | kv(k) | A        | Sample quality | Samplenumber                                  | kh(k) | kv(k) | A        | Sample quality |
|--------------------------------------------|-------|-------|----------|----------------|-----------------------------------------------|-------|-------|----------|----------------|
| 7230/5-U-4                                 |       |       |          |                | 7129/10-1                                     |       |       |          |                |
| 5001- 25.60                                | 2.11  | 2.06  | 1.02     | 2              | 5151- 60.04                                   | 2.85  | 2.85  | 1.00 (a) | 3              |
| 5002- 30.90                                | 2.02  | 2.02  | 1.00 (a) | 2              | 5152- 72.20                                   | 2.29  | 2.29  | 1.00 (a) | 1              |
| 5003- 40.27                                | 1.86  | 1.56  | 1.20     | 2              | 5153- 79.65                                   | 2.01  | 1.95  | 1.03     | 2              |
| 5004- 47.90                                | 1.83  | 1.61  | 1.14     | 3              |                                               |       |       |          |                |
| 5005- 54.85                                | 1.66  | 1.12  | 1.49     | 3              | kav :                                         | 2.38  | 2.36  | 1.01     |                |
| 5006- 64.05                                | 2.21  | 1.83  | 1.21     | 2              | s :                                           | 0.28  | 0.30  | 0.01     |                |
| 5007- 72.15                                | 2.14  | 1.64  | 1.32     | 2              | s.err. :                                      | 0.12  | 0.12  | 0.00     |                |
| 5008- 75.60                                | 2.19  | 1.59  | 1.38     | 2              | Samples with quality code 3 not included :    |       |       |          |                |
|                                            |       |       |          |                | kav :                                         | 2.15  | 2.12  | 1.02     |                |
| kav :                                      | 2.00  | 1.68  | 1.22     |                | s :                                           | 0.10  | 0.12  | 0.01     |                |
| s :                                        | 0.17  | 0.26  | 0.15     |                | s.err. :                                      | 0.05  | 0.06  | 0.01     |                |
| s.err. :                                   | 0.05  | 0.07  | 0.04     |                |                                               |       |       |          |                |
| Samples with quality code 3 not included : |       |       |          |                | 7323/12-1                                     |       |       |          |                |
| kav :                                      | 2.09  | 1.78  | 1.19     |                | 5155- 71.17                                   | 1.95  | 1.93  | 1.01     | 1              |
| s :                                        | 0.11  | 0.18  | 0.13     |                | 5156- 81.40                                   | 2.04  | 1.99  | 1.02     | 1              |
| s.err. :                                   | 0.03  | 0.05  | 0.04     |                | 5157- 93.33                                   | 1.46  | 1.17  | 1.24     | 2              |
|                                            |       |       |          |                | 5159-109.05                                   | 2.16  | 2.17  | 1.00     | 1              |
| 7230/5-U-5                                 |       |       |          |                | 5160-118.10                                   | 1.79  | 1.59  | 1.12     | 1              |
| 5009- 49.30                                | 3.78  | 3.16  | 1.19     | 1              |                                               |       |       |          |                |
| 5010- 42.15                                | 2.18  | 1.85  | 1.18     | 2              | kav :                                         | 1.88  | 1.77  | 1.08     |                |
| 5011- 36.10                                | 2.44  | 2.11  | 1.15     | 1              | s :                                           | 0.22  | 0.32  | 0.08     |                |
| 5012- 32.85                                | 2.51  | 2.15  | 1.17     | 1              | s.err. :                                      | 0.07  | 0.10  | 0.03     |                |
| 5013- 39.10                                | 1.98  | 1.12  | 1.78     | 3              |                                               |       |       |          |                |
|                                            |       |       |          |                | 7129/10-2                                     |       |       |          |                |
| kav :                                      | 2.58  | 2.08  | 1.29     |                | 5178- 31.84                                   | 3.14  | 2.98  | 1.05     | 2              |
| s :                                        | 0.56  | 0.59  | 0.22     |                | 5179- 40.71                                   | 3.04  | 2.78  | 1.09     | 1              |
| s.err. :                                   | 0.18  | 0.19  | 0.07     |                | 5180- 49.96                                   | 2.99  | 2.96  | 1.01     | 1              |
| Samples with quality code 3 not included : |       |       |          |                | 5181- 59.70                                   | 2.79  | 2.77  | 1.01     | 1              |
| kav :                                      | 2.73  | 2.32  | 1.17     |                | 5182- 67.93                                   | 1.69  | 1.19  | 1.42     | 3              |
| s :                                        | 0.54  | 0.43  | 0.01     |                | 5183- 74.33                                   | 2.34  | 2.24  | 1.04     | 1              |
| s.err. :                                   | 0.19  | 0.15  | 0.00     |                | 5184- 83.65                                   | 2.19  | 1.74  | 1.26     | 1              |
|                                            |       |       |          |                | 5185- 93.05                                   | 2.62  | 2.45  | 1.07     | 1              |
| 7230/5-U-2                                 |       |       |          |                | 5186-102.24                                   | 2.52  | 2.30  | 1.09     | 1              |
| 5014- 40.10                                | 1.36  | 0.99  | 1.37     | 3              | 5187-111.78                                   | 3.02  | 2.60  | 1.17     | 1              |
| 5015- 43.40                                | 1.24  | 0.78  | 1.59     | 2              | 5188-119.26                                   | 3.24  | 3.16  | 1.02     | 2              |
| 5016- 52.05                                | 1.82  | 1.63  | 1.20     | 3              |                                               |       |       |          |                |
| 5017- 63.50                                | 2.03  | 1.65  | 1.23     | 3              | kav :                                         | 2.69  | 2.47  | 1.11     |                |
| 5018- 71.10                                | 2.15  | 1.72  | 1.25     | 3              | s :                                           | 0.43  | 0.53  | 0.12     |                |
| 5019- 78.80                                | 2.14  | 1.99  | 1.08     | 3              | s.err. :                                      | 0.09  | 0.11  | 0.02     |                |
| 5020- 87.30                                | 2.63  | 2.07  | 1.27     | 2              | Samples with quality code 3 not included :    |       |       |          |                |
| 5021- 95.30                                | 2.83  | 1.81  | 1.56     | 2              | kav :                                         | 2.79  | 2.60  | 1.08     |                |
| 5022-106.90                                | 3.49  | 2.49  | 1.40     | 1              | s :                                           | 0.32  | 0.38  | 0.07     |                |
| 5023-115.70                                | 2.72  | 1.90  | 1.43     | 3              | s.err. :                                      | 0.07  | 0.09  | 0.02     |                |
| 5024-120.40                                | 3.56  | 2.85  | 1.25     | 3              |                                               |       |       |          |                |
|                                            |       |       |          |                | 7030/03-01                                    |       |       |          |                |
| kav :                                      | 2.36  | 1.81  | 1.33     |                | 5162- 27.40                                   | 2.60  | 2.35  | 1.11     | 1              |
| s :                                        | 0.64  | 0.47  | 0.15     |                | 5163- 37.20                                   | 2.14  | 2.13  | 1.01     | 1              |
| s.err. :                                   | 0.14  | 0.10  | 0.03     |                | 5164- 50.42                                   | 1.87  | 1.84  | 1.02     | 1              |
| Samples with quality code 3 not included : |       |       |          |                | 5165- 59.22                                   | 2.31  | 2.15  | 1.08     | 1              |
| kav :                                      | 2.55  | 1.79  | 1.46     |                | 5167- 70.83                                   | 2.30  | 2.30  | 1.00 (a) | 1              |
| s :                                        | 0.71  | 0.55  | 0.11     |                | 5168- 86.02                                   | 2.24  | 2.24  | 1.00 (a) | 2              |
| s.err. :                                   | 0.25  | 0.19  | 0.04     |                | 5170-106.37                                   | 3.10  | 3.10  | 1.00 (a) | 1              |
|                                            |       |       |          |                | 5171-116.70                                   | 3.75  | 2.37  | 1.58     | 1              |
| 7230/5-U-6                                 |       |       |          |                | 5172-126.97                                   | 3.52  | 3.48  | 1.01     | 1              |
| 5025- 28.75                                | 2.46  | 2.46  | 1.00(a)  | 2              | 5173-133.77                                   | 2.55  | 2.55  | 1.00 (a) | 2              |
| 5026- 36.40                                | 1.96  | 1.58  | 1.24     | 2              | 5174-142.49                                   | 3.15  | 3.03  | 1.04     | 2              |
| 5027- 42.90                                | 2.19  | 1.54  | 1.43     | 2              | 5175-154.22                                   | 3.23  | 3.18  | 1.02     | 2              |
| 5028- 48.75                                | 2.51  | 2.09  | 1.20     | 1              | 5176-164.63                                   | 2.69  | 2.56  | 1.05     | 1              |
| 5030- 60.10                                | 2.28  | 1.71  | 1.34     | 1              | 5177-171.22                                   | 3.05  | 2.87  | 1.06     | 1              |
| 5031- 69.30                                | 2.32  | 1.62  | 1.47     | 1              |                                               |       |       |          |                |
| 5032- 75.35                                | 2.26  | 1.48  | 1.53     | 1              | kav :                                         | 2.75  | 2.58  | 1.07     |                |
| 5033- 81.40                                | 2.15  | 1.68  | 1.28     | 2              | s :                                           | 0.52  | 0.44  | 0.14     |                |
| 5034- 88.85                                | 2.14  | 1.38  | 1.56     | 1              | s.err. :                                      | 0.10  | 0.08  | 0.03     |                |
| 5035- 94.00                                | 2.28  | 1.79  | 1.28     | 1              |                                               |       |       |          |                |
|                                            |       |       |          |                | a : No or more complex anisotropy.            |       |       |          |                |
| kav :                                      | 2.26  | 1.73  | 1.23     |                | b : Indications of non-horizontal lamination. |       |       |          |                |
| s :                                        | 0.14  | 0.29  | 0.41     |                |                                               |       |       |          |                |
| s.err. :                                   | 0.03  | 0.06  | 0.09     |                |                                               |       |       |          |                |

Table 3 Average thermal conductivity,  $k_{av}$  (W/m K9), for samples yielding apparent anisotropy ( $A = k_1/k_2$ ) less than 1.  $k_{av} = 1/2 (k_1 + k_2)$ .

| Samplenummer | Sample conductivity<br>k1 | k2   | kav  | Sample quality |
|--------------|---------------------------|------|------|----------------|
| 5002- 30.90  | 2.00                      | 2.04 | 2.02 | 2              |
| 5025- 28.75  | 2.38                      | 2.55 | 2.46 | 2              |
| 5151- 60.04  | 2.76                      | 2.94 | 2.85 | 3              |
| 5152- 72.20  | 2.21                      | 2.37 | 2.29 | 1              |
| 5167- 78.83  | 2.30                      | 2.30 | 2.30 | 1              |
| 5168- 86.02  | 2.20                      | 2.29 | 2.24 | 2              |
| 5170-106.37  | 3.09                      | 3.11 | 3.10 | 1              |
| 5173-133.77  | 2.63                      | 2.46 | 2.55 | 2              |

Table 4 Thermal conductivity as a function of pressure normalized to conductivity at 1 bar.

|                                            |      |        |      |      |      |      |      |       |
|--------------------------------------------|------|--------|------|------|------|------|------|-------|
| <b>kh - normalized data</b>                |      |        |      |      |      |      |      |       |
| Pressure (bar):                            | 1    | 5      | 10   | 20   | 30   | 40   | 50   | 1     |
| Sample                                     | 5152 | 1.00   | 1.00 | 1.01 | 0.99 | 1.00 | 1.01 | 1.01  |
|                                            | 5162 | 1.00   | 1.01 | 1.02 | 1.02 | 1.01 | 1.00 | 1.01  |
|                                            | 5170 | 1.00   | 1.02 | 1.01 | 1.02 | 1.03 | 1.03 | 1.01  |
|                                            | 5172 | 1.00   | 0.97 | 0.99 | 0.99 | 0.99 | 0.99 | 1.00  |
|                                            | 5177 | 1.00   | 1.01 | 1.02 | 1.01 | 1.02 | 1.00 | 1.01  |
| kav:                                       | 1.00 | 1.00   | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01  |
| s:                                         | 0.00 | 0.02   | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01  |
| s.err:                                     | 0.00 | 0.00   | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00  |
| <b>kv - normalized data</b>                |      |        |      |      |      |      |      |       |
| Pressure (bar):                            | 1    | 5      | 10   | 20   | 30   | 40   | 50   | 1     |
| Sample                                     | 5152 | 1.00   | 0.99 | 0.97 | 0.97 | 0.96 | 0.96 | 0.94  |
|                                            | 5162 | 1.00   | 0.99 | 0.98 | 1.00 | 1.01 | 1.01 | 1.01  |
|                                            | 5170 | 1.00   | 0.97 | 1.00 | 0.99 | 0.98 | 0.96 | 0.99  |
|                                            | 5172 | 1.00   | 1.09 | 1.03 | 1.06 | 1.01 | 1.02 | 1.02  |
|                                            | 5177 | 1.00   | 1.04 | 1.07 | 1.09 | 1.11 | 1.13 | 1.09  |
| kav:                                       | 1.00 | 1.02   | 1.01 | 1.02 | 1.01 | 1.02 | 0.99 | 1.01  |
| s:                                         | 0.00 | 0.05   | 0.04 | 0.05 | 0.06 | 0.07 | 0.04 | 0.05  |
| s.err:                                     | 0.00 | 0.02   | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.02  |
| <b>km - normalized data</b>                |      |        |      |      |      |      |      |       |
| Pressure (bar):                            | 1    | 5      | 10   | 20   | 30   | 40   | 50   | 1     |
| Sample                                     | 5152 | 1.00   | 0.99 | 0.99 | 0.98 | 0.98 | 0.98 | 0.98  |
|                                            | 5162 | 1.00   | 1.00 | 1.00 | 1.01 | 1.01 | 1.00 | 1.01  |
|                                            | 5170 | 1.00   | 0.99 | 1.01 | 1.00 | 1.00 | 1.00 | 1.00  |
|                                            | 5172 | 1.00   | 1.03 | 1.02 | 1.02 | 1.00 | 1.01 | 1.01  |
|                                            | 5177 | 1.00   | 1.02 | 1.04 | 1.05 | 1.06 | 1.06 | 1.05  |
| kav:                                       | 1.00 | 1.01   | 1.01 | 1.01 | 1.01 | 1.01 | 1.00 | 1.01  |
| s:                                         | 0.00 | 0.02   | 0.02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03  |
| s.err:                                     | 0.00 | 0.01   | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01  |
| <b>A = kh/kv (non-normalized A)</b>        |      |        |      |      |      |      |      |       |
| Pressure (bar):                            | 1    | 5      | 10   | 20   | 30   | 40   | 50   | 1     |
| Sample                                     | 5152 | ( 0.71 | 0.72 | 0.73 | 0.72 | 0.73 | 0.75 | 0.76) |
|                                            | 5162 | 1.03   | 1.05 | 1.08 | 1.05 | 1.04 | 1.03 | 1.03  |
|                                            | 5170 | 1.01   | 1.07 | 1.02 | 1.04 | 1.06 | 1.08 | 1.03  |
|                                            | 5172 | ( 0.94 | 0.84 | 0.88 | 0.88 | 0.93 | 0.91 | 0.92) |
|                                            | 5177 | 1.10   | 1.07 | 1.05 | 1.02 | 1.02 | 0.97 | 1.02  |
| A <sub>av</sub> <sup>1)</sup> :            | 1.05 | 1.06   | 1.05 | 1.04 | 1.04 | 1.03 | 1.05 | 1.03  |
| s <sup>1)</sup> :                          | 0.05 | 0.01   | 0.03 | 0.02 | 0.02 | 0.06 | 0.01 | 0.01  |
| s.err <sup>1)</sup> :                      | 0.03 | 0.01   | 0.02 | 0.01 | 0.01 | 0.03 | 0.01 | 0.00  |
| 1) Samples 5152 and 5172 are not included. |      |        |      |      |      |      |      |       |

# Shallow Drilling Barents Sea 1987

Appendix  
to

Main  
report:

Technical  
data  
Consultant  
reports



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