ROBERTSON RESEARCH INTERNATIONAL LIMITED

OILFIELDS REPORT NO. 737

# THE CHALK IN A SCHLUMBERGER CORE SLICE IN THE AMOCO NORWAY 2/9-1 NORTH SEA WELL

by

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# CONTENTS



# ENCLOSURES

I

# INTRODUCTION

The results of a detailed study of the lithology of a Schlumberger core slice from the Amoco Norway 2/9-1 well drilled in the Norwegian offshore sector of the North Sea are contained in this report.

The interval 11,481' to 11,484' was investigated. The core was initially photographed to provide a record of sedimentary structures, lithological characteristics and the distribution of fractures and stylolites. The photographs are included, at 1:1 scale as Enclosure 1, together with a lithological log.

A detailed examination of the core was made in hand specimen, then four samples, each approximately three inches long, were selected (11,481', 11,482', 11,483' and 11,484') for further studies involving the measurement of porosities and permeabilities, petrographic analysis by optical and scanning electron microscopy, and X-ray diffraction analysis of insoluble residues to identify and quantify non-carbonate minerals.

The results of the various studies are summarised on Enclosure 2, and relevant photomicrographs and scanning electron micrographs are included as Plates 1 to 13.

II

## DESCRIPTION OF THE CORE SLICE

The interval 11,481' to 11,484' was recovered in its entirety. It consists of variable white, pale pink or buff chalk with a hardness of 3 to 3½. Between 11,481' and 11,482'3" areas of irregular mottling suggest that bioturbation has occurred. Dark grey to black 'argillaceous' streaks are present throughout the core; these occasionally form continuous thicker shaley bands, notably at 11,482'6" and 11,483'9". Elsewhere, several streaks may be closely associated and show complex bifurcations. They are often discontinuous, and while usually subhorizontal, may be inclined up to 45°. Three dark grey shaley bands at 11,481'6", two of which intersect, are inclined at about 40° and show slickensides.

Hairline fractures occur at several horizons, varying in inclination from 30° to vertical. They are often stylolitised and sometimes filled with black material. Between 11,481'6" and 11,482' several stylolitised fractures are developed parallel to an inclined slickensided horizon.

Stylolites occur throughout the core, but are usually developed on a microscopic scale. They have a very small amplitude, and are generally filled with black material. The stylolites occasionally grade into 'argillaceous' streaks, or may be developed along fractures, and their development appears to depend to some extent on pre-existing weaknesses in the chalk.

The chalk grades from a pale pink colour at 11,482'6" to buff at 11,483'4" where a sharp, stylolitic discontinuity occurs. It is inclined at about 35° and is filled with dark grey shaley material. Beneath the discontinuity the chalk is a pale greyish pink.

III

## PETROGRAPHY

Petrographic examination of the chalk in the core slice has been confined to samples at approximately 1 foot intervals; a total of four thin sections have been studied (11,481'; 11,482'; 11,483'4"; 11,483'10").

### a. Lithology

The samples consist mostly of greyish and buff, slightly argillaceous chalk with occasional thin black laminae. Petrographical analysis shows the chalk to be a very fine to fine grained, mud supported to locally grain supported biomicrite (Plate 1). It is rather uniform in appearance and composition in all of the four thin sections, but at 11,483'10" frequent thin, irregular argillaceous laminae are present (plate 3). Thin veins of calcite, showing anomalous interference colours, cut the chalk at 11,483'4" (plate 2).

#### i. Original Particle Type

The biomicrites contain appreciable quantities of microfossils with rare macrofossil debris scattered through a dominant micritic matrix. The micritic matrix has a distinctive pale brown tinge under the microscopic , a feature normally seen in Danian chalks.

#### ii. Replacement Diagenesis

There is no apparent diagenetic alteration of the chalk matrix, although many of the microfossil tests have been recrystallised.

#### iii. Sorting

The chalk is poorly sorted.

#### iv. Roundness

Skeletal debris is angular.

#### v. Porosity

The only porosity visible in thin section occurs within some of

the microfossil chambers. Generally, however, the microfossils are completely infilled with very finely crystalline spar or with micrite.

b. Palaeontology

i. Macrofauna

The macrofauna is extremely sparse, and is restricted to isolated, small fragments of echinoid and Inoceramus sp. debris, with sponge spicules.

ii. Microfauna

The chalk has a moderately rich microfauna consisting principally of planktonic foraminifera with rare small calcareous benthics and Oligostegina sp. Radiolaria are seen very rarely at 11,481' and possibly at 11,482'.

## Depositional Environment

The lithology and fauna of the chalk points to a very low energy marine, outer sublittoral environment, and the relative abundance of planktonic foraminifera indicate good connections with the open sea. Influxes of argillaceous material probably accounted for the thin, irregular laminae seen in the sample at 11,483'10".

IV

## SCANNING ELECTRON MICROSCOPY

Four samples, selected from the same areas of the core as the thin sectioned material, were examined under the scanning electron microscope to determine the nature and texture of the matrix of the chalk, to assess the amount of diagenetic alteration which has occured and to establish the presence of submicroscopic porosity and possible permeability.

Freshly broken surfaces of chalk were examined by the methods described in detail in our Oilfields Report No. 659. The features recognised are described in detail below and summarised on the data summary chart (Enclosure 2). The electron micrographs are included as Plates 4 to 13.

### Skeletal Material

The only identifiable skeletal material in the micritic matrix of the chalk consists of whole and fragmented coccolith plates (plates 8, 9, 11-13). The coccolith plates average 4 microns in diamter and are made up of aggregates of calcite crystals most of which are between 1 and 2 microns in size.

### Rhombohedral Calcite

Most of the samples contain significant amounts of rhombohedral calcite crystals ranging in size from 1 to 2 microns (plates 9, 10 and 13). These crystals are interpreted as being derived from the disaggregation of coccoliths.

### Welding

Welding has only been recognised in the upper two samples studied (at depths of 11,481'2" and 11,481'11"). Welding is particularly conspicuous in the lower of these two samples which was taken from an area where stylolites cut the chalk, and the extent of the welding in this sample

is thought to be related to pressure solution associated with the stylolitisation.

Secondary Calcite

Secondary calcite, as generally scattered crystals of cement, is present in all four samples examined, but is only common in the sample at 11,481'11". Calcite cement is clearly seen on plate 6 (where it is probably genetically associated with severe welding due to stylolitisation) and plate 8.

Clay Minerals

Clay minerals are particularly noticeable in the lower two samples studied (at depths of 11,483'2" and 11,483'10"), and are clearly visible on plates 8 to 13. It is significant that argillaceous partings have been recorded in the core (chapter II), and montmorillorite has been detected in the samples showing clay minerals under the scanning electron microscope (see chapter V).

Porosity

Recognisable porosity is present in all four samples studied, and is of primary interparticulate type. In general the amount of porosity seen correlates reasonably with the measured porosity (chapter VI). One exception to this generalisation is afforded by the sample at 11,481'11" which shows low porosity due to welding; the actual material subjected to core analysis was taken 1 inch away at 11,482' and gave a moderate porosity of 16.5%. This suggests that the welding in the sample at 11,481'11" is of strictly localised extent, as would be expected if it was caused by stylolitisation.

The measured permeability of all the four samples is low, a reflection of the small size of the pores in the chalks.

V

## X-RAY DIFFRACTION ANALYSIS

Four samples were analysed by X-ray diffraction to establish the amounts and identities of the components making up the insoluble fraction of the chalk. The core was sampled immediately adjacent to the chalk which was thin sectioned. Each sample was leached for 24 hours in 20% acetic acid and the insoluble fraction quantitatively determined. The residues were then X-rayed, the amounts of the various minerals present being shown in Table 1, overleaf.

Although apparently argillaceous laminae occur throughout the core (see chapter II) and clay minerals have been recognised in the scanning electron micrographs, quartz is the major non-carbonate phase in all samples. Montmorillorite is the only clay mineral identified in the samples, and it is possible that the dark colouration of the 'argillaceous' bands is due to amorphous organic material present in insufficient amounts to markedly modify the background of the X-ray diffraction trace. The diffraction trace of one sample (11,484') has two peaks which are tentatively assigned to haematite; this would accord with the slight pink colouration noted in particular in the lower part of the core. The quartz is probably present as fine grained detrital material in the dark laminae, and may also be concentrated along stylolites.

TABLE 1

X-RAY DIFFRACTION ANALYSES OF FOUR CORE SAMPLES

FROM THE 2/9-1 WELL

| Sample Depth | Calcium Carbonate % | Quartz % | Montmorillorite % | ? Haematite % |
|---|---|---|---|---|
| 11,481'3" | 88.7 | 9.6 | 1.7 | - |
| 11,482'2" | 86.4 | 11.7 | 1.9 | - |
| 11,483'2" | 86.5 | 10.1 | 3.4 | - |
| 11,484' | 84.6 | 11.8 | 2.8 | 0.8 |

VI

## POROSITY AND PERMEABILITY

Four samples were selected for core analysis (porosity, permeability and density), using the same techniques as described in our Oilfields Report No. 696. The material analysed was taken as close as possible to the core studied by mineralogical and X-ray diffraction techniques.

The results of the core analysis are given in Table 2. The porosity is seen to range from 12% to 18%, and the permeability is consistently low (less than 0.11 mD).

TABLE 2

CORE ANALYSIS OF FOUR SAMPLES FROM THE 2/9-1 WELL

| Sample Depth | Porosity (Percent) | Permeability (Millidarcies) | Density |
|---|---|---|---|
| 11,481' | 12.0 | 0.06 | 2.69 |
| 11,482' | 16.5 | 0.01 | 2.70 |
| 11,483' | 18.0 | 0.02 | 2.70 |
| 11,483'10" | 13.6 | 0.11 | 2.68 |

VII

## CONCLUSIONS

Analysis of the chalk is a Schlumberger core slice over the interval 11,481' to 11,484' in the Amoco Norway 2/9-1 well has lead to the following conclusions :

a. the core consists of chalk showing argillaceous partings, stylolites and fractures. The inclination of the argillaceous partings varies, and at least some of the partings are affected by stylolitisation. Almost all the stylolites are closed with black amorphous material. The fractures occur at varying inclinations, and are frequently stylolitised;

b. the chalks are fine-grained sparsely fossiliferous biomicrites in which planktonic foraminifera are the principal microfossil. Deposition in a low energy, open marine, outer sublittoral environment is likely. The appearance of the micritic matrix of the chalk under the petrographic microscope resembles that seen in Danian chalks;

c. scanning electron microscopy has shown that the micritic matrix of the chalks is largely made up of coccolith material. Secondary calcite cement is present in some samples, and clay minerals are also seen. Localised welding, probably associated with stylolitisation is conspicuous in one sample;

d. X-ray diffraction work has shown the presence of quartz and clay minerals (montmorillonite) in all the four samples examined;

e. core analysis has shown the chalk to have only a moderate porosity and a very low permeability.

VIII

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PLATES 1 TO 3

PHOTOMICROGRAPHS

## PLATE 1

SAMPLE DEPTH: 11,482'

LITHOLOGY: Fine-grained, mud supported biomicrite with numerous planktonic foraminifera in a micritic matrix.

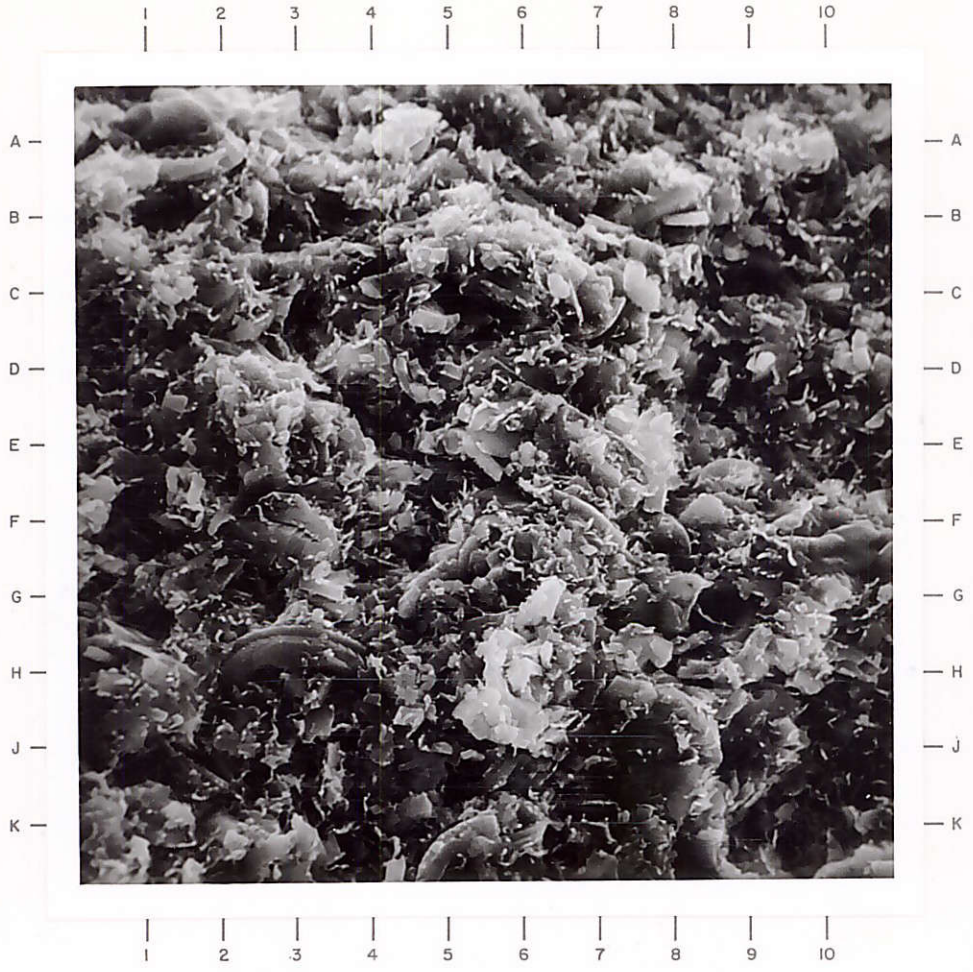
Photomicrograph x 40; plane polarised light.

## PLATE 2

SAMPLE DEPTH: 11,483'4"

LITHOLOGY: Fine-grained, mud supported biomicrite cut by a thin calcite vein (J1-J15). This vein is oblique to the bedding which is picked out by argillaceous laminae (A11-D15).

Photomicrograph x 40; plane polarised light.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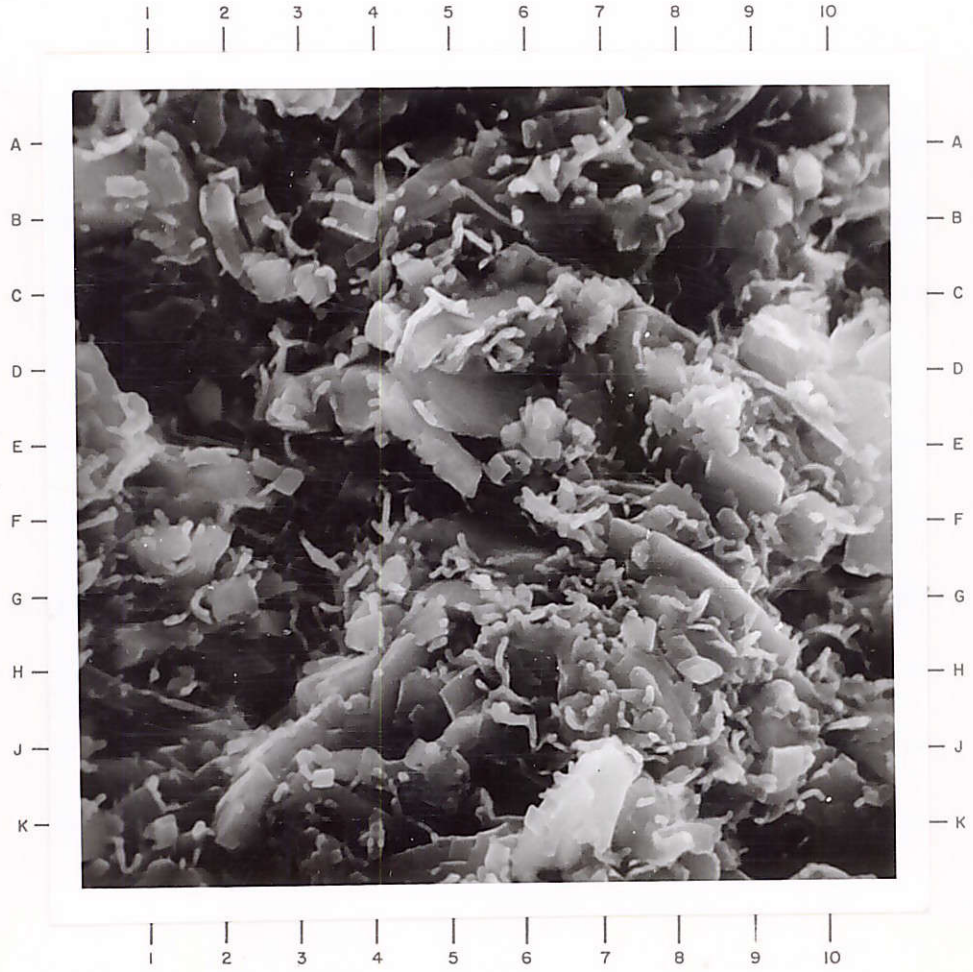
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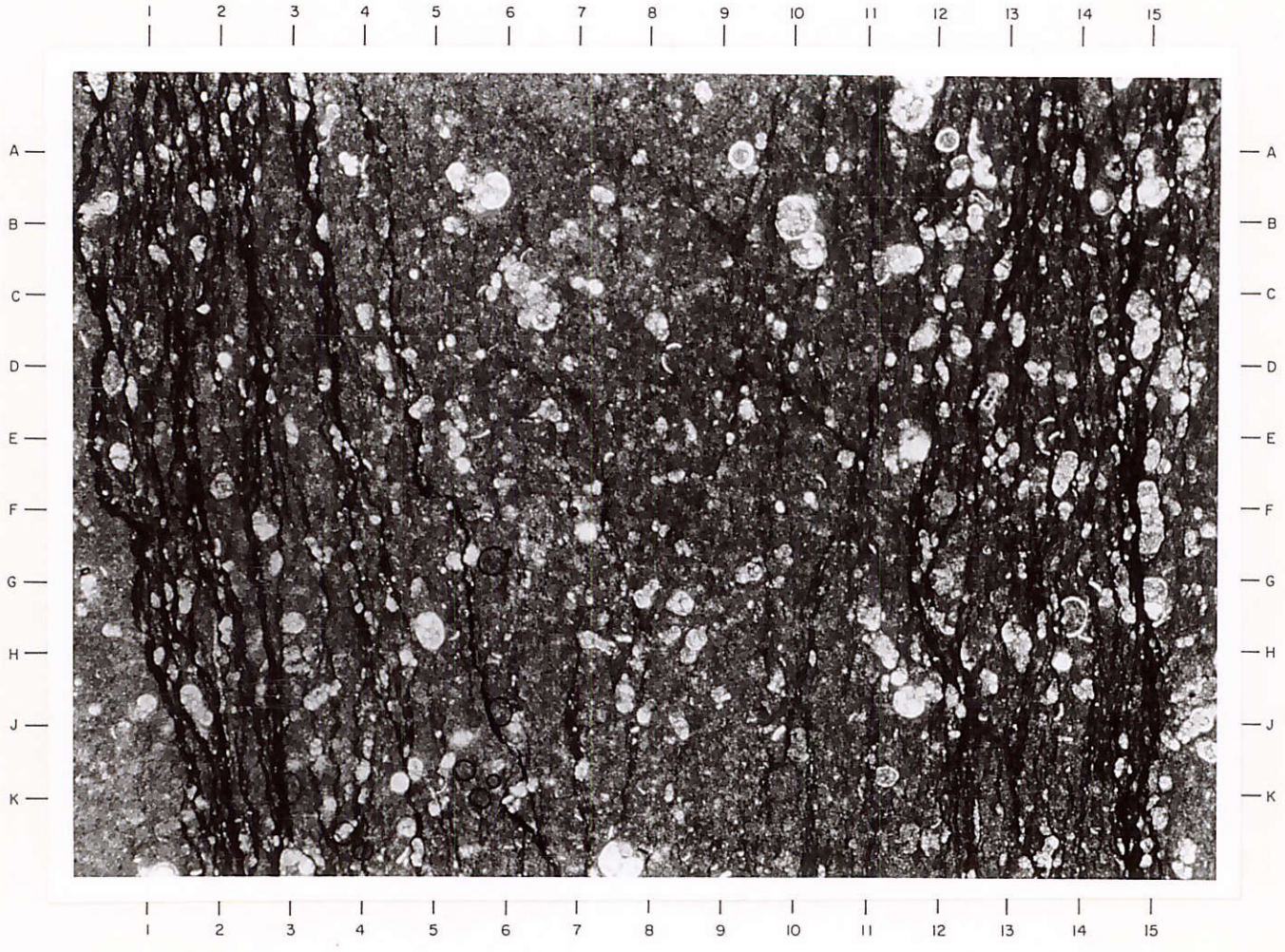
A B C D E F G H J K

## PLATE 3

SAMPLE DEPTH: 11,483'10"

LITHOLOGY: Fine-grained, mud supported biomicrite with scattered planktonic foraminifera and numerous 'argillaceous' partings, at least some of which are microstylolitic.

Photomicrograph x 40; plane polarised light.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A B C D E F G H J K
A B C D E F G H J K
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

PLATES 4 TO 13

SCANNING ELECTRON MICROGRAPHS

## PLATE 4

SAMPLE DEPTH: 11,481'2"

LITHOLOGY: Rare coccolith plates (C8) and common rhombohedral calcite crystals of coccolith derivation (C9). Secondary calcite is present as isolated crystals (A8, D3).

POROSITY: A moderate interparticulate porosity is seen.

Scanning electron micrographs, x 2200.

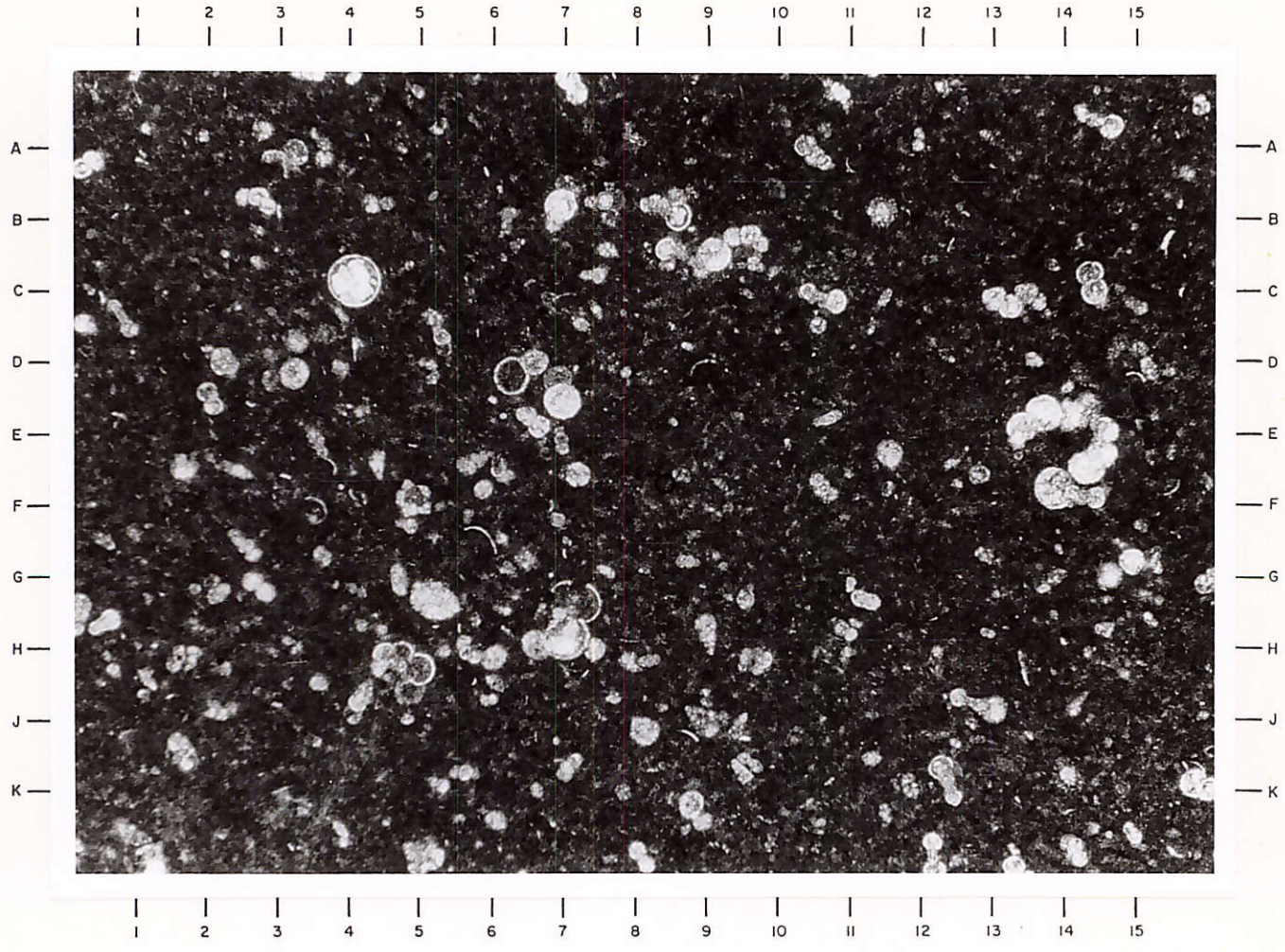
## PLATE 5

SAMPLE DEPTH: 11,481'2"

LITHOLOGY: Plentiful rhombohedral calcite crystals of coccolith derivation (H8, C9) and some secondary calcite cement (H4). Slight welding is visible (F6).

POROSITY: A moderate interparticulate porosity occurs.

Scanning electron micrograph, x 5500.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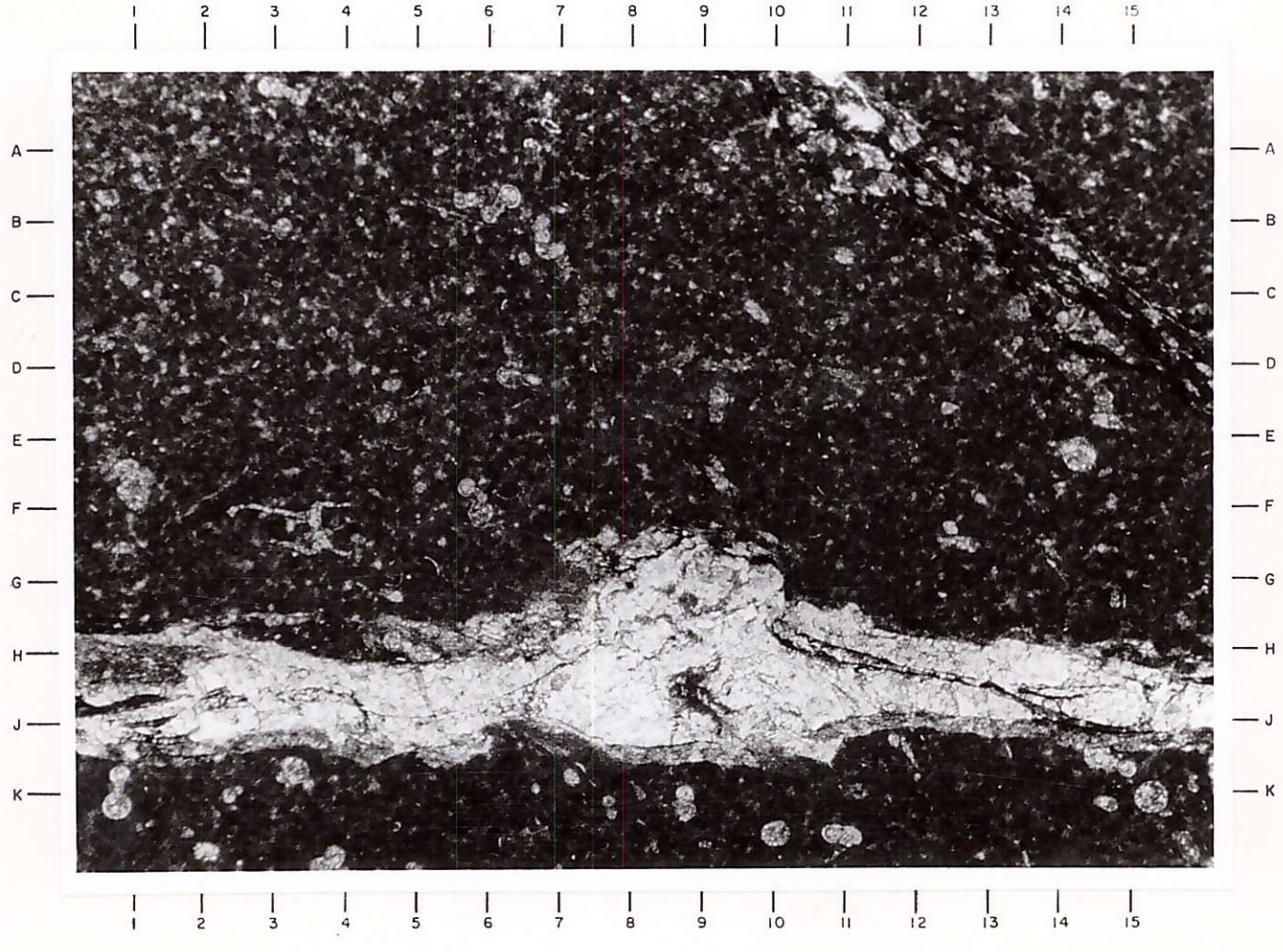
A B C D E F G H J K


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
A B C D E F G H J K

## PLATE 6

DEPTH: 11,481'11"

LITHOLOGY: Rather severely welded chalk matrix showing only diagenetic textures.

POROSITY: Only a poor porosity is seen.

Scanning electron micrograph, x 2300.

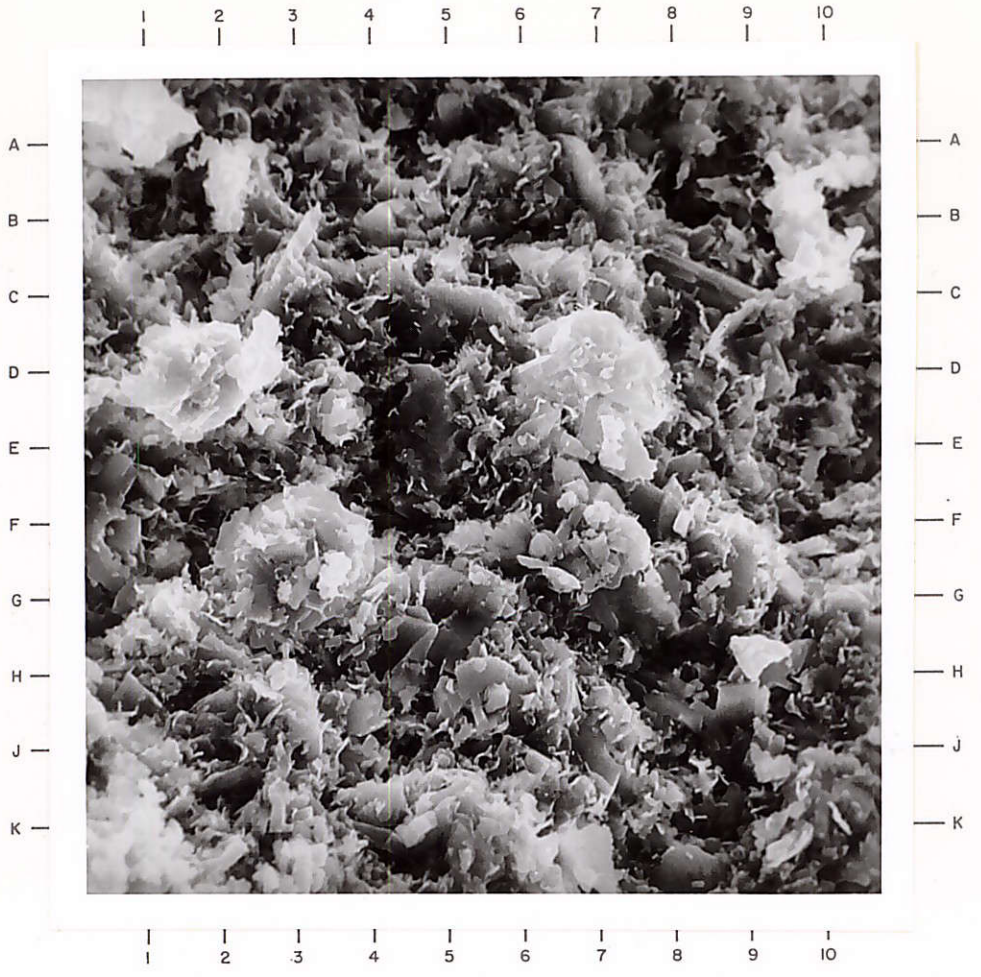
## PLATE 7

DEPTH: 11,481'11"

LITHOLOGY: Rather severely welded chalk matrix probably due to pressure solution in proximity to a stylolite.

POROSITY: Only poor visible porosity.

Scanning electron micrograph, x 2200.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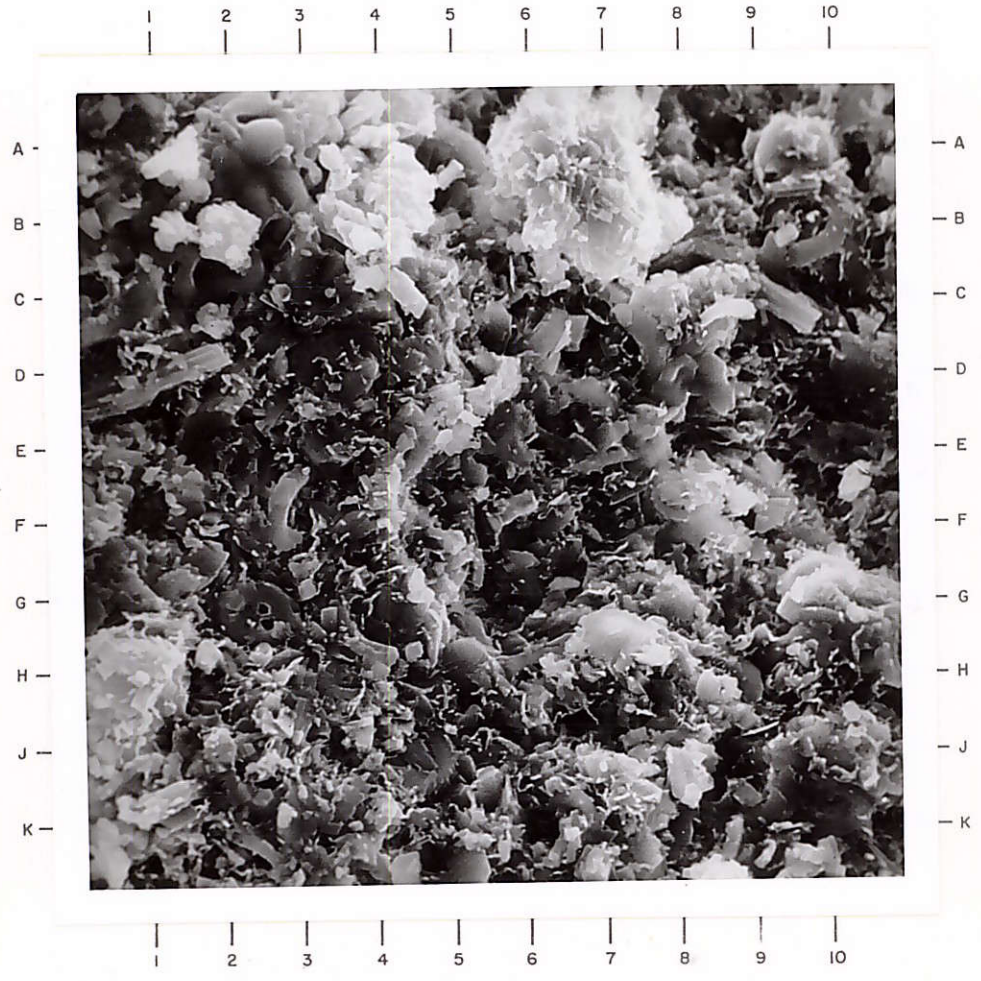

1 2 3 4 5 6 7 8 9 10
A B C D E F G H J K

## PLATE 12

SAMPLE DEPTH: 11,483'10"

LITHOLOGY: Plentiful coccolith plates (H3, F7) and coccolith derived calcite crystals, together with scattered clay minerals. Slight welding locally apparent (F10).

POROSITY: A slight to moderate visible interparticulate porosity.

Scanning electron micrograph, x 2200.

## PLATE 13

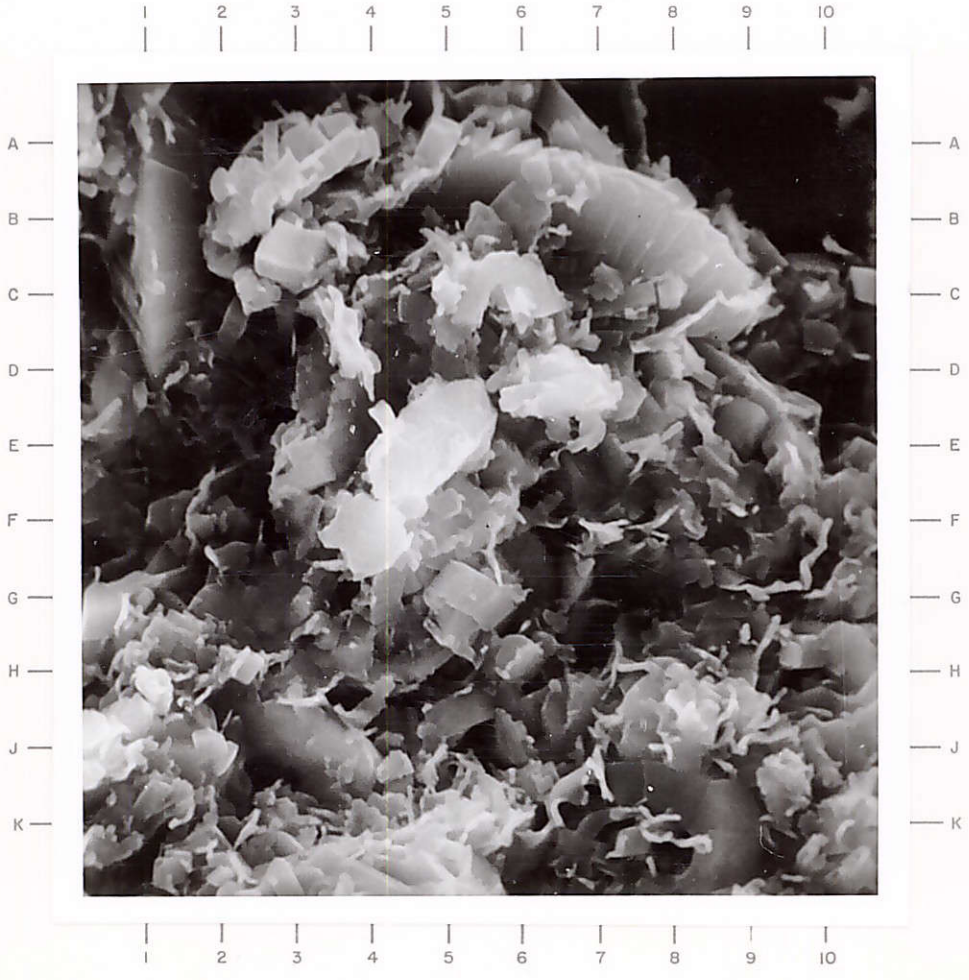
SAMPLE DEPTH: 11,483'10". Enlargement of area F6 on Plate 12.

LITHOLOGY: Coccolith plates (G8), rhombohedral calcite crystals derived from coccoliths (H5), and clay minerals (B5) forming the micritic matrix of a chalk.

POROSITY: A slight to moderate interparticulate porosity.

Scanning electron micrograph, x 5500.


1 2 3 4 5 6 7 8 9 10
A B C D E F G H J K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A B C D E F G H J K

## PLATE 10

SAMPLE DEPTH: 11,483'2"

LITHOLOGY: Coccolith debris (plates and isolated crystals), clay minerals (F6) and secondary calcite cement (C9) forming the matrix of a chalk.

POROSITY: A moderate visible interparticulate porosity.

Scanning electron micrograph, x 2160.

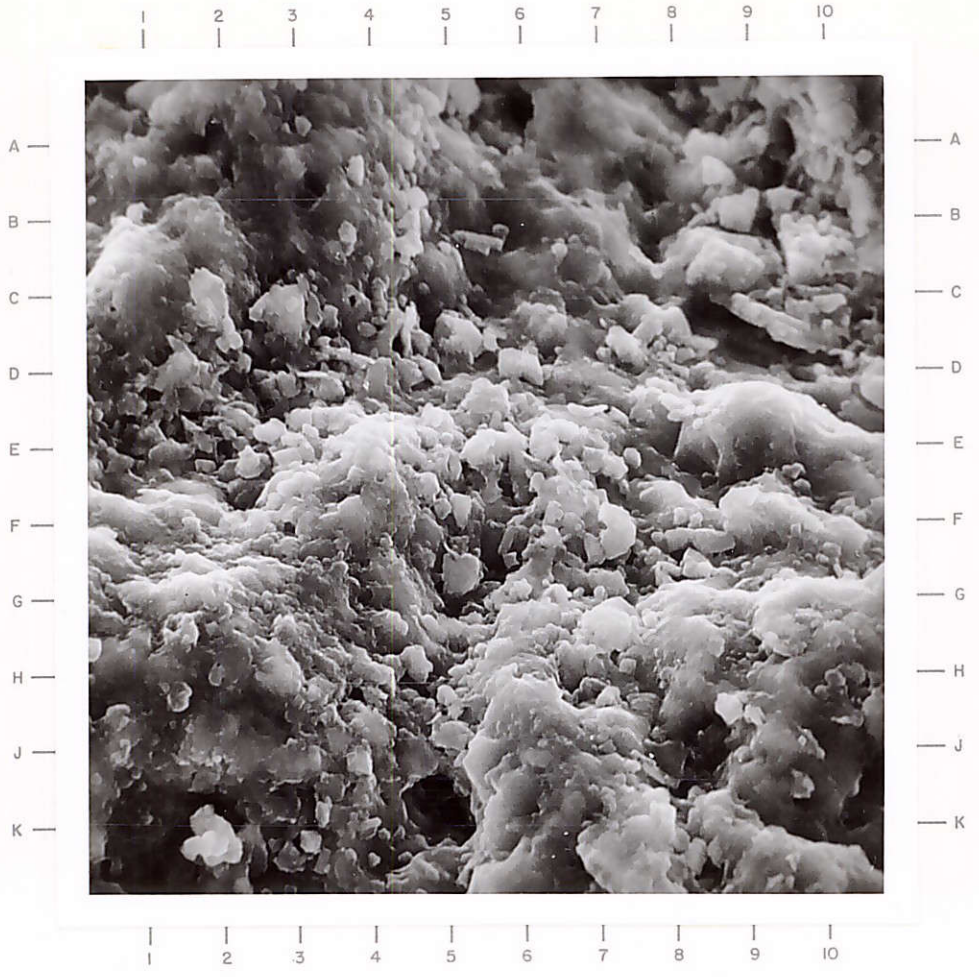
## PLATE 11

SAMPLE DEPTH: 11,483'10"

LITHOLOGY: Coccolith plates (J5), crystals derived from coccoliths (E1), clay minerals (H-J9) and secondary calcite cement (D1). Slight welding is visible locally (A3).

POROSITY: A slight to moderate interparticulate porosity is visible.

Scanning electron micrograph, x 2200.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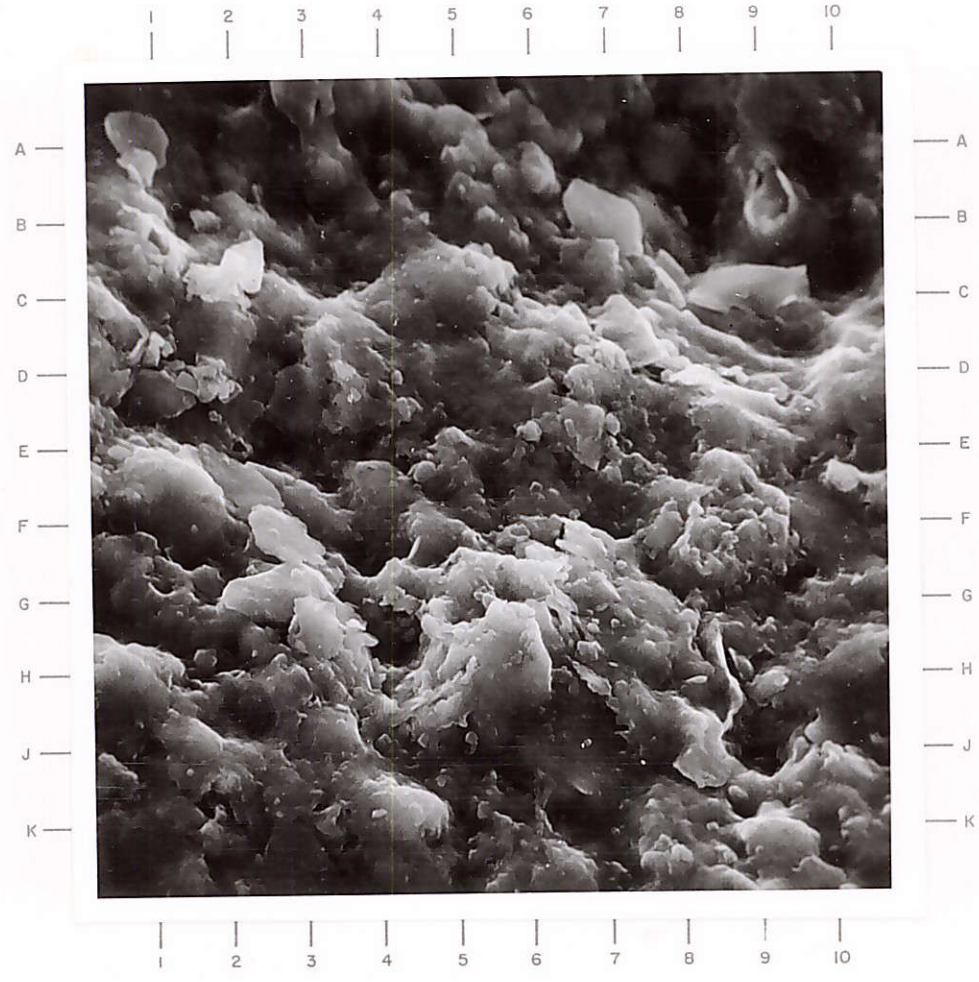
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A B C D E F G H J K

## PLATE 8

SAMPLE DEPTH: 11,483'2"

LITHOLOGY: Chalk matrix showing coccolith plates (D4, H2) and isolated crystals derived from coccoliths (E3). Clay minerals are conspicuous (F6-7), and a localised occurrence of calcite cement occurs (C8).

POROSITY: Moderate interparticulate porosity.

Scanning electron micrograph, x 2100.

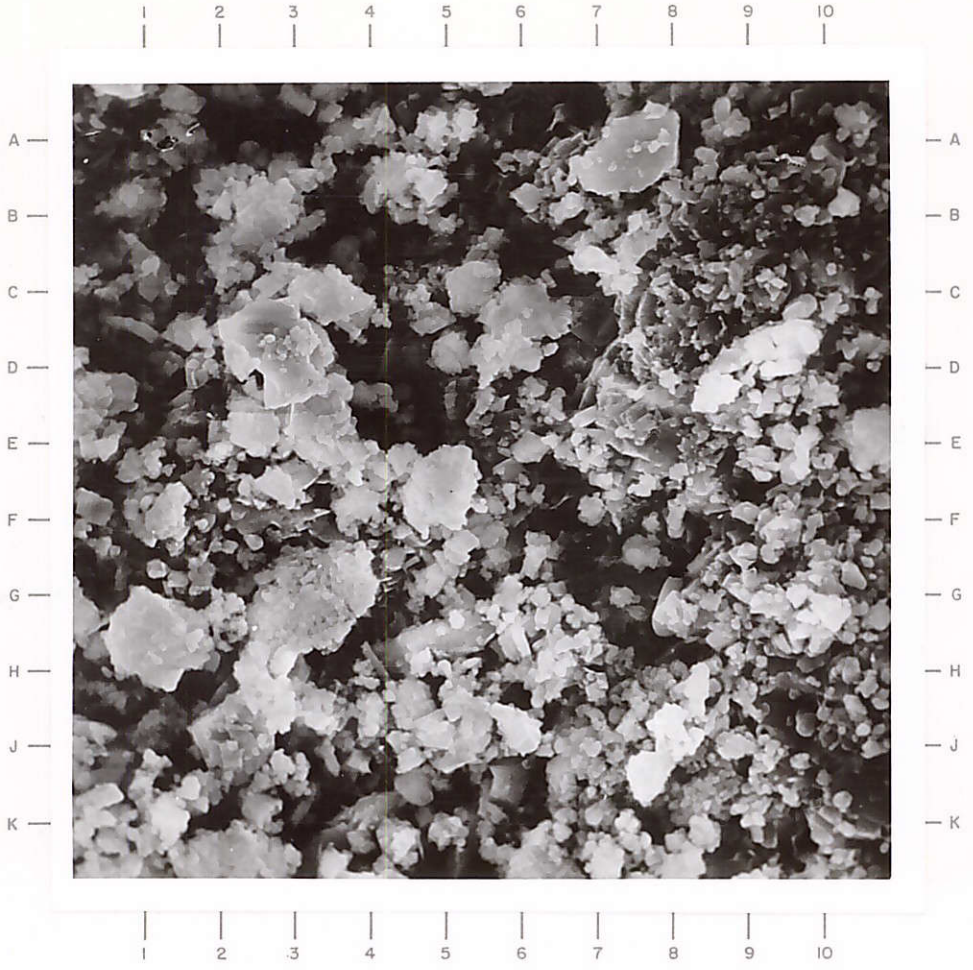
## PLATE 9

SAMPLE DEPTH: 11,483'2". Enlargement of area F6 on Plate 8.

LITHOLOGY: Coccolith plates (B8, J3), rhombohedral calcite plates derived from coccoliths (G6) and clay minerals (F7-8, J7).

POROSITY: A moderate visible interparticulate porosity.

Scanning electron micrograph, x 5400.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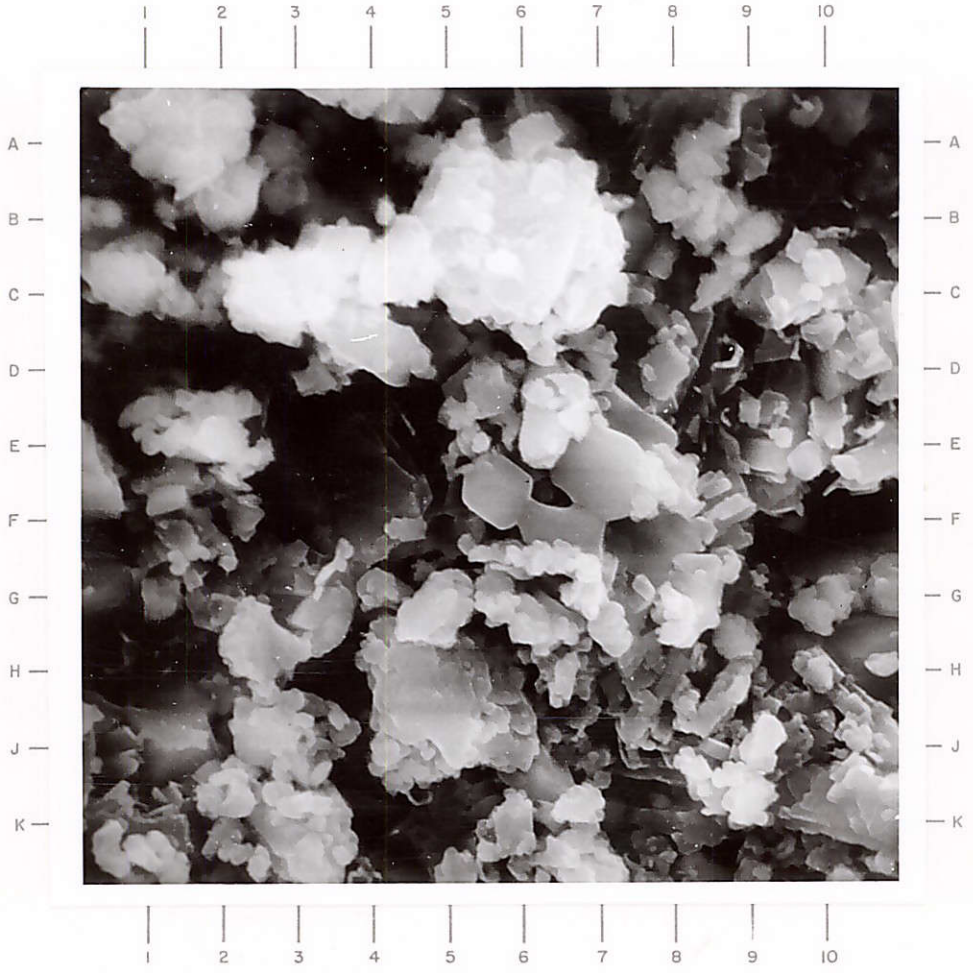
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# STRIP LOG OF A SIDEWALL CORE SLICE FROM THE AMOCO NORWAY 2/9-1 WELL

Plan prepared by ROBERTSON RESEARCH LABORATORIES "Pyn-y-Coed" Llanrhos, Llandudno.

Plan prepared for AMOCO NORWAY OIL COMPANY Storgaten 32, Oslo 1, Norway.

ENCLOSURE 1

Drawing No. 2006

Date 29 - 1 - 73


Greyish white chalk with buff lenses and discontinuous 'argillaceous' laminae.

Indistinct stylolite.

Common 'argillaceous' laminae with frequent bifurcations.

Microstylolites inclined at 40°.

Indistinct discontinuous 'argillaceous' laminae.

Steeply inclined 'argillaceous' laminae.

Slickensided dark grey shale laminae with parallel microstylolites.

Slickensided dark grey shale laminae with parallel microstylolites.

Slickensided dark grey shale laminae cutting stylolites.

Microstylolites.

Intersecting microstylolitised dark grey argillaceous' laminae.

Steeply inclined microstylolites, up to 80°.

Chalk much as above greyish white with less pronounced buff lenses.

Parallel microstylolitised fractures at 45°.

Fractures discontinuous across dark grey 'argillaceous' laminae.

Dark grey shale laminae.

White and cream chalk with discontinuous dark grey 'argillaceous' laminae. Possible bioturbation features.

Intersecting microstylolites inclined at 45° and horizontal dark grey 'argillaceous' laminae.

Grey to black shale laminae in pale pink chalk.

Discontinuous dark grey 'argillaceous' laminae in pale pink chalk with rare buff lenses.

Stylolitised fractures.

Irregular inclined grey to black 'argillaceous' laminae.

Buff chalk, rather uniform.

Steeply inclined fractures.

Discontinuity, grey to pink chalk in sharp contact with overlying buff chalk. Probably stylolitic.

Many dark grey to black 'argillaceous' laminae in pale pink chalk. Occasional steeply inclined fractures and rare stylolites.

# DATA SUMMARY CHART

PREPARED BY
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UNITED KINGDOM

Ref. :- ARP 723/III B/142
Drg. No. :- 2004
Date :- 25.1.73.

| COMPANY | COUNTRY | CONCESSION | FIELD | WELL |
|---|---|---|---|---|
| AMOCO NORWAY OIL COMPANY | OFFSHORE NORWAY | 2/9 | — | 2/9-1 |

Lithology: Chalk (Hardness 1-2); Chalk (Hardness 2 ½-4); Argillaceous laminae; Fractures; Stylolites; Flint; Reworked grains

Induration: 1 2 3 4

Original particle type: Microfossils; Macrofossils; Micrite; Clay minerals; 25 50 75

Macrofossils: Less than 2% of rock X; 2%-5% of rock XX; 6%-10% of rock XXX; More than 10% of rock A

Microfossils: Less than 2% of rock X; 2%-5% of rock XX; 6%-10% of rock XXX; More than 10% of rock A

Allochem and detrital grain size: Average; Range

Scanning electron microscopy: RARE •; OCCASIONAL ••; COMMON •••

| DEPTH IN FEET | CORES | LITHOLOGY | PHOTO REFERENCE: Photomicrographs | PHOTO REFERENCE: Scanning Electron Photomicrographs | MACROFOSSILS: SPONGE SPICULES | ECHINODERMS | INOCERAMUS | OTHER RIVALVES | BRYOZOANS | MICROFOSSILS: PLANKTONIC FORAMINIFERA | SMALL CALCAREOUS BENTHICS | AGGLUTINATING FORAMINIFERA | OSTRACODS | OLIGOSTEGINA | RADIOLARIA | ALLOCHEM AND DETRITAL GRAIN SIZE | POROSITY VISIBLE IN THIN SECTION | SORTING | ROUNDNESS | ENERGY INDEX | ENVIRONMENT | SCANNING ELECTRON MICROSCOPY: COCCOLITH PLATES | RHOMBIC CALCITE | FORAMINIFERA | SECONDARY CEMENT | CLAY MINERALS | WELDING | POROSITY | CORE ANALYSIS: MEASURED POROSITY % | MEASURED PERMEABILITY (m.d.) | X-RAY DIFFRACTION OF ACID INSOLUBLES: % ACID INSOLUBLES | % COMPOSITION OF RESIDUE TO TOTAL ROCK: QUARTZ | ILLITE | SMECTITE GROUP / MONTMORILLONITE | PLAGIOCLASE | KAOLINITE | HAEMATITE | AMORPHOUS MATERIAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11481' | | | | 4,5 | X | X | | | | A | X | | | | X | | • | | | | | • | • | | • | | S-M | • | | | | | 9·6 | | 1·7 | | | | |
| 11482' | | | 1 | 6,7 | | | X | | | A | X | | X | XX | X | | | | | | | | | | ••• | | M | • | | | | | 11·7 | | 1·3 | | | | |
| 11483' 4" | | Very fine to fine grained, mud supported to locally grain supported biomicrites. Rare shale laminae | 2 | 8-10 | | X | | | | A | X | | | X | | | | | | | Outer sublittoral with good open marine influence | • • | • | • | • | • • | | • • | | | | | | 10·1 | | 3·4 | | | | |
| 11483' 10" | | | 3 | 11-13 | | X | | | | A | XX | | | X | | | | | | | | ••• | • • | | • | • • | S | • • | | | | | 11·8 | | 2·8 | | | 0·8 | |

ENCLOSURE 2