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THE INNER MORAY FIRTH:

A REVIEW FOLLOWING THE BEATRICE

FIELD DISCOVERY (BLOCK 11/30)

BY

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SHELL ONLY

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Attn: EP/11

Dear Sirs,

We have pleasure in forwarding our report "The Inner Moray Firth: a review following the Beatrice field discovery (block 11/30)" by M.J. Caswell, G.J. Knox and F.W. Vlierboom.

The report comprises a comprehensive interpretation of all the seismic data in the area; a review of facies and structural development in the basin and a comprehensive geochemical study. Since the report was written, a thorough PAQC prospect analysis has been undertaken and the results of this work are being reported upon separately.

The geological work incorporated in the report was completed by mid 1977, and the text was written and refereed by the end of 1977. The seismic mapping was delayed by teething troubles in implementing the SEIFI system in the U.K. and the maps were not completed before mid 1978. The delay in publication since that time was due to the volume of draughting involved and the higher priority assigned to the Reference and Programme Data Books. A modified version of this report has been prepared for Esso.

Yours truly,
For: SHELL U.K. EXPLORATION AND PRODUCTION

for G.W. VERSPYCK

CONTENTS

LIST OF FIGURES

LIST OF ENCLOSURES

LIST OF TABLES

SUMMARY

A reappraisal of the Inner Moray Firth area has been carried out in the light of the discovery of the Beatrice oilfield by the Mesa Petroleum Co. and their partners in Block 11/30.

A geological model has been developed which postulates the existence of palaeo-oil kitchens extending towards the western edge of the Inner Moray Firth basin. It is suggested that these palaeo-kitchens are now elevated towards the west as a result of regional tilt coincident with the downwarping of the Central Graben in Paleogene time. The model does not accord completely with actual VR/E measurements made in different parts of the area. These variations are thought to be caused by differences in thermal gradient as a result of changes of crustal heat flow or to differences caused by variation in lithology.

Lithological divisions are constructed to suggest broad distributions of reservoir and non-reservoir but since well data are limited these maps are approximations. The Upper Jurassic lithofacies is better predicted, because of the recognized fault control on sedimentation. Adjacent to faults the Upper Jurassic develops coarse clastic reservoir facies.

Source rocks are certainly recognized in the Upper, Middle and Lower Jurassic and possibly in the Zechstein. In view of this, structures developed at different stratigraphic levels can be considered potentially oil bearing, where they occur within or adjacent to these levels. Structures are downgraded locally by lack of sealing formations.

1. INTRODUCTION

1.1 General

This report is a reappraisal of the Inner Moray Firth (Fig. 1). The area has been the subject of licence application by competitors in the 1st, 2nd, 3rd and 4th rounds. A total of six wells had been drilled prior to the Beatrice discovery without commercial success although two wells produced oil shows. This caused a fall-off in interest in the area by oil companies.

The Inner Moray Firth area was reviewed in detail by Townson and MacFarlane (1976) as part of the Greater Moray Firth open acreage evaluation (UEE/12, 1976). In March 1976, Peninsular & Orient Co., approached Shell-Esso with a farm-in offer in block 11/30 (4th round licence P187). After a technical appraisal of this block the farm-in offer was not recommended (Shell-Esso Exploration Note 2).

The recommendations were based on the assumption that the only significant source rocks were Upper Jurassic. A small kitchen area was postulated. This would generate a limited amount of hydrocarbons, only part of which would reach the 11/30 structure. While recognizing structures, reservoirs and seal possibilities in pre-Upper Jurassic levels it was not thought that hydrocarbons could migrate into deeper levels. The structures were also postulated to have been smaller at the time of oil migration than at present, owing to a post-migration regional tilt.

Later in 1976 the first well in the block 11/30-1 was drilled and announced as the discovery well. Subsequently, seven wells have been drilled in the block proving the extent of the field which has been named the Beatrice field.

This discovery has reawakened interest in the Inner Moray Firth particularly as large amounts of open acreage are available for future application rounds.

In 1973 and 1974 G.S.I Ltd shot, processed and interpreted seismic reflection data from the Inner Moray Firth. Time contour maps made by G.S.I. were subsequently modified by UEE/12 and used in the Prospect Review of the Greater Moray Firth Area (Townson and MacFarlane, 1976).

As a result of the Breatrice field discovery a reinterpretation of the 1973/74 data and of data from a recent I.G.S commissioned survey (Chesher and Bacon, 1975) were used to make new time contour maps of the main horizons. The Base Cretaceous time map was included in the 1978 Data Book. In August 1977 new unmigrated and migrated seismic sections were obtained from surveys by GECO a/s and SEFEL. All data (Fig. 2) has been used to update the previous time maps and to make contour maps for the following horizons and intervals:-

. Top Chalk	Time (Encl 1a), Depth (Encl 1b).
. Base Chalk	Time (Encl 2a), Depth (Encl 2b).
. Base Cretaceous	Time (Encl 3a), Depth (Encl 3b).
. Intra Upper Jurassic	Time (Encl 4).
. Near Top Middle Jurassic	Time (Encl 5a), Depth (Encl 5b).

- Near Top Triassic Time (Encl. 6).
- Interval velocity: Top-Chalk - Base Chalk (Encl. 7)
- Interval velocity: Base Chalk - Base Cretaceous (Encl. 8)
- Interval velocity: Base Cretaceous - Near Top Middle Jurassic Encl. 9a)
- Isopach map: Base Cretaceous - Near Top Middle Jurassic (Encl 9b).
- Interval time difference map: Near Top Middle Jurassic - Near Top Triassic (Encl. 10).

The total seismic line coverage is shown in Fig. 2.

Interval velocity information was obtained from the stacking velocities used to process the 1977 seismic lines.

The time sections and velocity contour maps were digitised and the data stored using the SEIFI data base.

Subsequent calculations of isochrons, isopachs and depth values were made using the computer.

The following data has also been digitised and is stored in the Data Base but has not been used to make contour maps.

- Water Depths
- Lower Jurassic time
- Near Top Permian time
- Top Rotliegendes time

A geochemical evaluation has been carried out to confirm known source rocks and determine others. The Vitrinite (absolute) reflectance (VR/E) has been ascertained by various methods.

1.2 The Beatrice Field

The Beatrice field proves that oil has been generated and in significant quantities to be trapped in a commercial field in the Inner Moray Firth Area.

As several dry holes had been drilled before this discovery the problem is to assess whether or not the Beatrice field is a unique occurrence.

The Mesa consortium have not exchanged any of the 11/30 wells with Shell-Esso. Nevertheless, it has been possible to glean some information about the well from press and scouting reports. Therefore as a starting point the Beatrice field data can be compared with other dry wells in the area.

A preliminary well Summary Sheet has been constructed (Encl 11) and basic data are shown on Table 1.

Essential points to note are the following:

- The Structure is fault and dip closed at top Middle Jurassic
- Lower and Middle Jurassic reservoir section of sands and shales (811' gross thickness)
- Dominantly Upper Jurassic shale section provides a good vertical and juxtaposition seal
- Sand protected by Lower Cretaceous to Pleistocene shale but no structure at this level.
- Possible Triassic reservoir
- Field contains high wax paraffinic oil

The proven reservoirs of the Beatrice field are of Lower to Middle Jurassic age. Three tests in the area 12/21-1 (Encl. 12) 12/22-1 (Encl. 13) and 12/24-1 (Encl. 15) bottomed in the Upper Jurassic. In one test 13/24-1 (Encl. 19), the Lower and Middle Jurassic are missing, while others 12/23-1 (Encl. 14), 12/30-1 (Encl. 17), 13/17-1 (Encl. 18) contain a reduced interval due to non-deposition or erosion. Only 12/26-1 (Encl. 16) contains a Lower to Middle Jurassic section equivalent to the Beatrice field but even this section is reduced in the Middle Jurassic. However, no structural or fault closure occurs at this level in this well. In those wells with a reduced sequence the structure is ambiguous and/or an effective seal is missing.

The Beatrice field appears to be the only case where the Lower to Middle Jurassic sequence was tested in a closed structure with an effective seal formation - the Upper Jurassic Kimmeridge Clay Formation (See Encls. 3b, 4, 5b, 11 to 19 inclusive).

The Kimmeridge Clay is the recognized source rock for the Central and Viking Grabens, where it has generated oil of a mainly marine source rock origin with lesser influence from land-derived source rock material.

The Beatrice field contains a distinct paraffinic waxy oil with an API range 33.9°- 39.0°(Table I). It is low in sulphur (0.2%). The gas chromatogram of the saturated hydrocarbons (Fig. A1) and the C_7 alkane distribution (Fig. A2) indicate that the crude has not been subjected to bacterial transformation. The low phytane/n-C_{18} alkane ratio, the low sulphur content and the n.alkane distribution point to expulsion from a well matured source rock.

The C7-alkane/naphthene distribution (Fig. A2) indicate that the crude originates from source material mainly consisting of structureless organic matter possibly largely of algal origin and/or some land plant contribution (Fig. A3). The low pristane/n.C_{17} alkane ratio (Table 1, Fig. A1) points to a reducing environment of deposition of the source of rock.

Source rocks of a composition that could generate this kind of crude are known to occur in the Kimmeridgian and Callovian of the Brora section, the Oxfordian of well 12/23-1, the Lower Jurassic of well 12/26-1, and the Kimmeridgian of well 12/21-1.

Indications for the occurrence of mixed source rocks with a high sporomorph content have been found in the Zechstein of wells 12/30-1 and 12/23-1, but it is rather unlikely that they could have produced a crude of the composition of the Beatrice field.

2. INNER MORAY FIRTH

2.1 Facies Development

Considerable thickness and lithofacies variation occurs in the area. Owing to the limited amount of scattered data it is only possible to construct broad generalised lithofacies maps for different formations.

Upper Cretaceous: The Chalk forms a seafloor subcrop in the east of the Inner Moray Firth (Fig. 3) where it may act locally as a seal to underlying formations. To the west of the subcrop it has been eroded away.

Lower Cretaceous: This is known as an extensive sea floor subcrop in the Inner Moray Firth although it is not present on land. Well data, sea floor sampling and isolated glacial erratics indicate that this Lower Cretaceous consisted largely of a arenaceous or silty facies, although local argillaceous and marly deposition did occur. The environment of deposition varied from holomarine outer/middle/inner neritic to coastal. A lithofacies distribution map is shown in Fig. 4.

Lower Cretaceous sands have good porosity ranging from 25-30%. Formation water salinities are low which suggest fresh water flushing of the sands. Seal efficiency would therefore be extremely low within most of the Lower Cretaceous. In addition any oil, trapped would probably be bacterially altered.

Upper Jurassic

The Upper Jurassic has a very variable lithofacies which can be related to syn-sedimentary fault activity. Fault controlled troughs developed adjacent to structural highs. Submarine fault scarp debris mixed with shallow water sediments became intercalated (in tectonic basins) with deeper marine shales some of which form extensive source rocks.

A classic sequence is exposed north of Brora, Sutherland along the Helmsdale fault. Marine shales are intercalated with clastic boulder beds and calcarenites (Encl. 20). The sequence grades down into a sandstone-boulder breccia. The sequence was described by Bailey and Weir (1932) and later reinterpreted by Neves and Selley (1975). The upper part of the sequence contains Devonian boulders which are thought to have fallen from the active fault scarp (Fig. 5). Associated sand dykes led Sykes and Horsfield (1977) to suggest that seismic activity initiated sediment-laden debris pulses.

On the downthrown side of faults, within the basin, considerable thickening is visible towards faults active in Upper Jurassic time (Encl. 9b). Away from faults a dominantly shale facies is known for example in 12/26-1 and the Beatrice (Encl. 11) field. In contrast well 12/24-1 is directly adjacent to a fault active in Upper Jurassic and Lower Cretaceous times (Encl. 15). The sedimentary section in this well consists of largely continuous sands with a porosity range 20-25%.

Adjacent to this section (12/23-1, 12/22-1) the Upper Jurassic thickness is reduced where it has onlapped onto a high having a mixed shale/sand sequence (Encl. 9b). Well 12/21-1 is in a position intermediate between a high and basinal area and exhibits a (largely) sand sequence interpreted similarly to 12/24-1 as a coastal or barren environment with limited holomarine inner neritic influences. This suggests either that the active fault coincided with coastline along which coastal sediments were being concentrated or that the coastal sediments were being swept into a deeper water fault controlled basin. The latter interpretation is preferred as the "high" sequences suggest holomarine and inner/middle/outer neritic with fresh water influences. The downthrown sand sequence is expected to pinch-out updip away from the fault into continuous shale forming speculative stratigraphic traps southwest of 12/24-1 (see Encl. 21). The Upper Jurassic isopach map illustrates thickening against other faults (Encl. 9b).

A lithofacies distribution map of the Upper Jurassic (Fig. 6) and subsea paleotopographic sketch (Fig. 7) shows the suspected position of dominant shale as opposed to coarse clastic sequences (sand and/or boulder bed type) related to active faulting. Apart from documented cases it is difficult to predict clastic facies type. Nevertheless, sands and boulder beds are considered to develop reservoir facies. Shale facies distribution is important as a seal to Middle Jurassic reservoirs and any older reservoirs if part of the pre-Upper Jurassic section is missing. It has already been noted that the Upper Jurassic shales form an efficient seal in the Beatrice field. Conversely, a continuous Upper Jurassic sand sequence in combination with a similar Lower Cretaceous facies will downgrade Middle Jurassic and/or older prospects.

Middle Jurassic

The Middle Jurassic is encountered onshore in the Brora section and in wells 12/23-1, 12/26-1, 12/30-1 and 13/17-1 (Encls. 14, 16, 17 and 18) where extremely limited sections occur. The Beatrice field Middle Jurassic has the most extensive section with almost 1,000' of intercalated sands and shales (Encl. 11). The onshore section is not completely exposed but consists of sandstones, shales, thin argillaceous limestones and the Brora coal bed (Encl. 20) which has been interpreted to be part of a coastal plain sequence passing up into a regressive marine sequence.

From the limited well data it is not possible to produce a facies map. Nevertheless, a seismic time difference map* illustrates the broad variations in thickness (Encl. 10). The thickest Middle Jurassic occurs adjacent to the shore outcrops on the downthrown side of the Helmsdale Fault. Apart from local changes along the Great Glen Fault-trend the Middle Jurassic thins rapidly into the Inner Moray Firth. The pattern of thinning suggests that clastic sediments were being brought into the area from the northwest and deposited in a shallow marine basin with a shoreline not far inland of the Helmsdale fault. The extent of this basin is not known. A volcanic centre in the Outer Moray Firth probably acted as a barrier to the east while a possible marine connection existed along the trend of the Great Glen Fault from the southwest.

Lower Jurassic

The Lower Jurassic is present in the Beatrice field and is also oil bearing. It has been recognized elsewhere in wells 12/26-1, 13/17-1 (Encls 16 & 18) and in an IGS** borehole at Lossiemouth (Encl. 22), Morayshire. The sequences represent a change from continental conditions to open marine and contain sandstones, shales and rare coals. On seismic sections it is not possible to pick a continuous Lower to Middle Jurassic boundary - therefore the variation in thickness over the whole area cannot be shown.

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* also includes Lower Jurassic which does not have a significant thickness.

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Triassic

The Triassic consists of two dominant lithologies: sand or variegated shales and marls. Sandstones were laid down in an aeolian and/or fluvial environment. The shales and marls are variegated green/red and were probably deposited in transient lakes or inland seas. A lithofacies map (Fig. 8) suggests that the Inner Moray Firth basin was already existent in Triassic times and that fine clastic deposition predominated in the basin while the edges were dominated by aeolian and fluviatile sedimentation. Locally good porosities, 10-25% are present in Triassic sandstones.

Permian

The Permian consists of Zechstein and Rotliegendes lithofacies. Aeolian sandstones are known onshore. Offshore possible aeolian Lower Permian sandstone occur in 12/23-1, 12/26-1, 12/30-1 and 13/17-1 (Encls. 14, 16, 17 & 18). Porosity varies from 7-24%. The Zechstein occurs in 12/23-1, 12/26-1 and 12/30-1 and consists of dolomites and/or shales. Oil shows in the Rotliegend of 12/30-1 may have originated from a Zechstein source rock.

Carboniferous

The Carboniferous is unknown in the Inner Moray Firth.

Devonian

Devonian sediments are recognized in extensive areas on the Scottish mainland and include conglomerates, sandstones, siltstones and shales. Possible Devonian sediments are present in wells 12/23-1, 12/30-1 and 13/24-1 (Encls. 14, 17 and 19). Porosity varies from 0-5%. Although this is primary, secondary porosity may have developed along very active fault trends. Locally onshore, fish beds provide source rocks but their development in the Inner Moray Firth is an unknown quantity.

2.2 Geochemistry

All maturity measurements are related to a standard Vitrinite (absolute) reflectance scale (VR/E).

Temperature and Vitrinite (absolute) reflectance

Information on temperature in the wells of the 12 quadrant is rather scarce and not very accurate (Table 2). Notably absent in most wells is a reliable record of temperature build-up. When the few available uncorrected temperatures are plotted against depth the temperature-depth relation can be roughly established (Fig. 9). With the use of the temperature VR/E graph (Fig. 10) the estimated temperature VR/E can be estimated. (First column Table 3 gives the values at top-Jurassic (X), top Middle Jurassic and top Triassic).

Sporomorph Translucency and Vitrinite (absolute) reflectance

The Sporomorph Translucency in samples from wells 12/21-1, 12/23-1, 12/24-1, 12/26-1 and 12/30-1 has been measured. With the help of the Sporomorph Translucency VR/E graph (Fig. 11) the corresponding VR/E values can be ascertained. (Column 3 table 3).

When the measured VR/E and the temperature VR/E are compared it seems that only in the case of 12/21-1 are the two values compatible. In all the other cases (Fig. 12) the difference between the two values suggests removed overburden (or a higher palaeo-heat flow).

Source Rocks

Based on extrapolation of maturity date in wells the main source rocks in the Kimmeridgian locally become mature in the basin. Source rocks in the Lower Kimmeridgian and Oxfordian and the Middle Jurassic probably become mature.

The maceral composition of all these source rocks consists mainly of structureless organic matter. Land plant influence increases towards the shore with the possibility of the occurrence of plant waxes and resins.

Some intervals are rich in algal matter in the form of botryococcus. All these factors will influence the type of oil generated.

The analysis of the Beatrice crude indicates that the oil was expelled from a mature source rock of a calculated maturity of VR/E 1.04. The crude originated from source material mainly consisting of structureless organic matter, largely of algal origin with possibly some land plant contribution.

The character of the Beatrice crude therefore fits the types of source rocks found, in the Kimmeridgian, Oxfordian and Callovian source rocks.

There is a possibility of source rocks in the Zechstein but nothing is yet known about their distribution and source rock quality except for some indication of lipids in one of the macerals. The Zechstein should not be excluded as a potential source and, as the lipids are mostly formed by sporomorphs, will probably produce oil with some land plant character but expelled at a higher maturity level. The other source rocks hypothetically present in the basin are Carboniferous coal beds, oil shales, and Devonian lacustrine deposits. Nothing is known concerning their distribution (or lack of) in the basin although they occur elsewhere in Scottish outcrops.

2.3 Structure

The Inner Moray Firth forms a faulted basin between the Scottish mainland and the North and South Halibut areas to the east. (Encl. 23). The basin is terminated on the western side by two major faults: the Great Glen fault extension and the Helmsdale fault.

The Great Glen fault has been long recognzied as a wrench fault, but conflicting claims have been made for both the time and sense of movement (see Johnstone 1976). The Helmsdale fault is less equivocal as clear evidence of normal movement during the Upper Jurassic is available (Bailey & Weir, 1932; Neves & Selley 1975), which coincided with movement on the majority of the faults within the Inner Moray Firth. However, both pre- and post Upper Jurassic movements are recognisable on most of the faults in the area.

The Fault Pattern

The fault pattern is dominated by two major trends and two subsidiary trends (see Encls. 1b, 2b, 3b, 4, 5b, 6 and 23). The trends are as follows:

<u>Great Glen parallel</u> The Great Glen fault system strikes

approximately N40 E. Parallel to it are numerous small faults (25km length) throughout the Inner Moray Firth basin.

Smith Bank parallel* The Smith Bank fault system trends approximately N60 E. Faults paralleling this trend run across the basin and separate horsts and troughs. The Helmsdale fault may be considered part of this system.

Minor trends. Two subsidiary trends are recognised running approximately N(80° -90°)E and N(100° -110°)E.

Fault Activity

The time of origin of faults cannot be stated with any certainty. The Great Glen and Smith Bank parallel systems reflect old Caledonian directions which have also been recognised on the Scottish mainland (see Johnson and Frost, 1977-Encl. 2).

The Great Glen fault has a pre-Mesozoic origin (Flinn, 1969; Garson & Plant, 1972) but controversy exists as to its sense of movement. If fault trends within the Inner Moray Firth are related to it in origin then they suggest that the early movement was dextral. Inner Moray Firth faults would have acted as synthetic strike slip faults during the Palaeozoic.

During the Mesozoic these basement faults became reactivated as the Inner Moray Firth basin developed. Faults of the Great Glen trend were generally more active during Triassic to early Upper Jurassic time while some members of the Smith Bank trend were strongly active

* These faults are also sub-parallel to the Highland Boundary and Southern Upland faults which border the Midland Valley Graben in central Scotland.

throughout Upper Jurassic and Lower Cretaceous time and defined the position of uplifts (supply areas) and troughs (sedimentation areas). Coarse clastics were deposited adjacent to these faults during strong normal activity (see Fig. 6, 7).

During the Lower Cretaceous fault activity ceased on most faults although continued synsedimentary movements occurred locally in the north west corner of the area (Fig. 13).

It is also suspected that during the Lower Cretaceous or post-Lower Cretaceous that the Great Glen Fault (locally active during the Upper Jurassic) became reactivated with lateral movements.

This is shown by the base Cretaceous unconformity being distorted or disrupted about and reversed throws are also locally observed (Fig 14) in the base Upper Jurassic.

Several small faults exhibit flower structures and disrupt younger horizons while no displacement is seen at older horizon levels. These may be complementary dextral synthetic strike slip faults. The normal faults of the Upper Jurassic may have also have moved in the same sense.

The post Lower Cretaceous fault history is not known. Uplift of the area is suspected in late Paleocene or Eocene time. Some adjustment along faults may have taken place but no evidence is available.

Development of Structures

Structures have developed gradually during sedimentation. Different areas have been persistent highs or lows respectively throughout the Mesozoic. Fault closed structures have tended to develop in association with these highs. As structures are repeated with different closures at various stratigraphic levels normalisation and stripping off of younger stratigraphic levels reduces the closure on structures at deeper levels (Fig 15). It is apparent that the maximum development of any structure took place in post Lower Cretaceous time, probably in the Paleocene or Eocene when greatest burial took place. Since this maximum burial (which is probably the time of oil migration) the structures have been tilted by as much as $0.7° \sim 0.8°$. This would indicate that any structure filled to a spill point on its western side will have lost hydrocarbons, but be filled to spill point at the present day assuming no leakage through cap rocks. Conversely, structures with an eastern spill point would at present be full to a new western spill point or not full to spill point assuming that no migration has taken place since tilting and maximum burial.

Maximum Burial

Townson and MacFarlane (1976) have drawn attention to shale sonic travel times with depth (Fig. 16) which suggest that the Inner Moray Firth area has been uplifted + 2,500 ft compared to wells in the Outer Moray Firth where travel times are compatible with burial. Geochemical studies using various indicators of organic metamorphism also suggest that past burial has been of the following orders of magnitude greater than present overburden in different wells ± 4,000ft (12/26-1),± 2,000 (12/23-1), ± 1600 ft (12/30-1 and 12/21-1) at the base Cretaceous level. On the other hand the sections in wells 12/22-1, and 12/24-1 appear not to have been buried to these levels. Variations in temperature gradients caused by lithology differences are a possible explanation.

Shale sections dissipate heat solely by conduction. Permeable sand sections in connection with surface waters can also dissipate heat by convective flow of formation waters. The presence of low salinity formation water in Lower Cretaceous/Upper Jurassic sandy sections indicates that surface waters have flushed into deeper levels. Thus, such sandy sections as in 12/24-1 would depress the temperature compared to a shale section at the same depth and source rocks would reach a lower level of maturity.

Uplift History

Three types of uplift may be considered: (a) an equal vertical uplift of the whole area where palaeo-burial indications would have equal values parallel to the present surface; (b) differential uplift of various fault blocks where each block has palaeo-burial indicators in unique relationships and (c) a differential tilted uplift where palaeo-burial indicators are shallower in the east than in the west.

Case (b) is discounted because the structural evidence on seismic sections does not show any evidence of large differential movements in post - Lower Createcous history. Although case (a) cannot be discounted the balance of evidence suggests that case (c) is more correct. Support for the concept comes from the following:

1. Towards the Central Graben younger formations outcrop on the sea floor from Upper Cretaceous chalk through to Tertiary deposits. The Chalk and the top Paleocene plunge gently towards the Central Graben at an approximate angle of $0.7^\circ \sim 0.8^\circ$. In addition burial indicators are compatible with the present depth of burial in the Outer Moray Firth area.

2. The Scottish mainland shows geomorphological evidence of uplift during the Tertiary (George, 1965), with eastward flowing discordantly superimposed rivers which developed on a presumed uplifted tilted surface, during the early Neogene (Owen, 1976). The erosion which culminated in a Neogene planation surface may have begun in the Early Tertiary and supplied Paleocene and Eocene clastics to the Inner Moray Firth (since eroded) and the Central Graben.

3. VR/E values (0.36-0.44) of Middle Jurassic onshore samples suggest removal of overburden amounting to ± 5,000 ft compared to lesser amounts indicated in the Inner Moray Firth wells.

   Overall the best model in corporating the above geological, geomorphological and geochemical factors that can be adopted is one illustrated in fig. 17 which is broadly compatible with variations in VR/E measurments and tilted Upper Cretaceous and top Paleocene levels.

The whole area is postulated to have been tilted $0.7^\circ \sim 0.8^\circ$ about an axis centred on and parallel to the present outcrop of the base Eocene in the Outer Moray Firth. As the main Central Graben Tertiary basin developed, a progressive uplift took place of North Scotland and the Inner Moray Firth. If the area is tilted back a planar palaeo - maturity oil kitchen picture can be constructed which intersects with the various mapped levels: (Base Cretaceous, Encl. 24, Intra-Upper Jurassic Encl 25; Near Top Middle Jurassic Encl 26). This can also be illustrated on a cross-section to indicate the depth of section involved in the postulated kitchens. (Fig. 18).

On such a model part of the Upper Jurassic and all the Lower and Middle Jurassic are within the kitchen in the area of Block 11/30. In particular the Middle Jurassic section downdip to the west of the Beatrice field is well within a VR/E - 1.0 kitchen level which accords with the measured VR/E of expulsion for the oil. In fact, much of the Inner Moray Firth area would contain mature source rocks.

Sections with high percentages of sand would provide exceptions. Such areas would also be downgraded because of the chance of poor seal formations above any reservoirs.

3.0 CONCLUSIONS

Previous studies of the Inner Moray Firth area (Townson & MacFarlane, 1976) downgraded it because the volume of mature source rocks was considered insufficient to charge structures. The Upper Jurassic source rocks were not considered to be mature over a sufficient area even if account was taken of uplift and a palaeo-kitchen. The results of the present study suggest that a larger area of Upper Jurassic source rocks could have formed a kitchen. Middle and Lower Jurassic source rocks would almost certainly have been well mature (VR/E = 1.0) and therefore could have generated the Beatrice Field oil during the development of the palaeo-kitchen. Possible Permian and speculative Devonian and Carboniferous would certainly have reached maturity. Altogether, it appears probable that enough source rocks were matured - although their identity is suspect - to provide enough oil to charge structures. The Beatrice field appears to be filled to spill point. Middle and Lower Jurassic sands are capped by an extensive Upper Jurassic shale seal. While no other Lower to Middle Jurassic section was tested in a closed structure, other closures at different levels have been drilled.

Structures at Lower Cretaceous and Upper Jurassic level were drilled in sandy sections which at the present day contain low salinity formation water indicating freshwater invasion from the surface. Such sections would equally allow hydrocarbons to escape.

At deeper levels the Middle and Lower Jurassic, Triassic and Zechstein may provide good cap rocks.

Lower Cretaceous is suspect as a cap rock, therefore an internal cap rock is required for two structures (Encls 4 & 5b) which are dip and fault closed against the Great Glen Fault.

Upper Jurassic shale caps the Middle Jurassic reservoirs in the Beatrice Field. Structures in the south of the area are also probably capped by Upper Jurassic shale. A large fault and dip structure in the north west of the area has unknown caprock. Structures north east of 11/30-1 are probably not capped by shale.

Triassic reservoir rocks are probably restricted to the Inner Moray Firth basin edges in small structures which are probably not economic even if truncated and covered with a Jurassic shale cap rock.

Permian Rotliegend sandstones form some large structures capped by Zechstein or Triassic cap rocks, which could be charged by oil from Zechstein, Devonian or Carboniferous source rocks. Large throw on some faults also brings Lower and Middle Jurassic sections adjacent to the Permian sandstones.

Since completion of this study further work has been done on evaluation of various structures recognised during the remapping of the Inner Moray Firth. This work carried out by P. Suessli includes a PAQC rating of these structures which will be reported at a later date.

References

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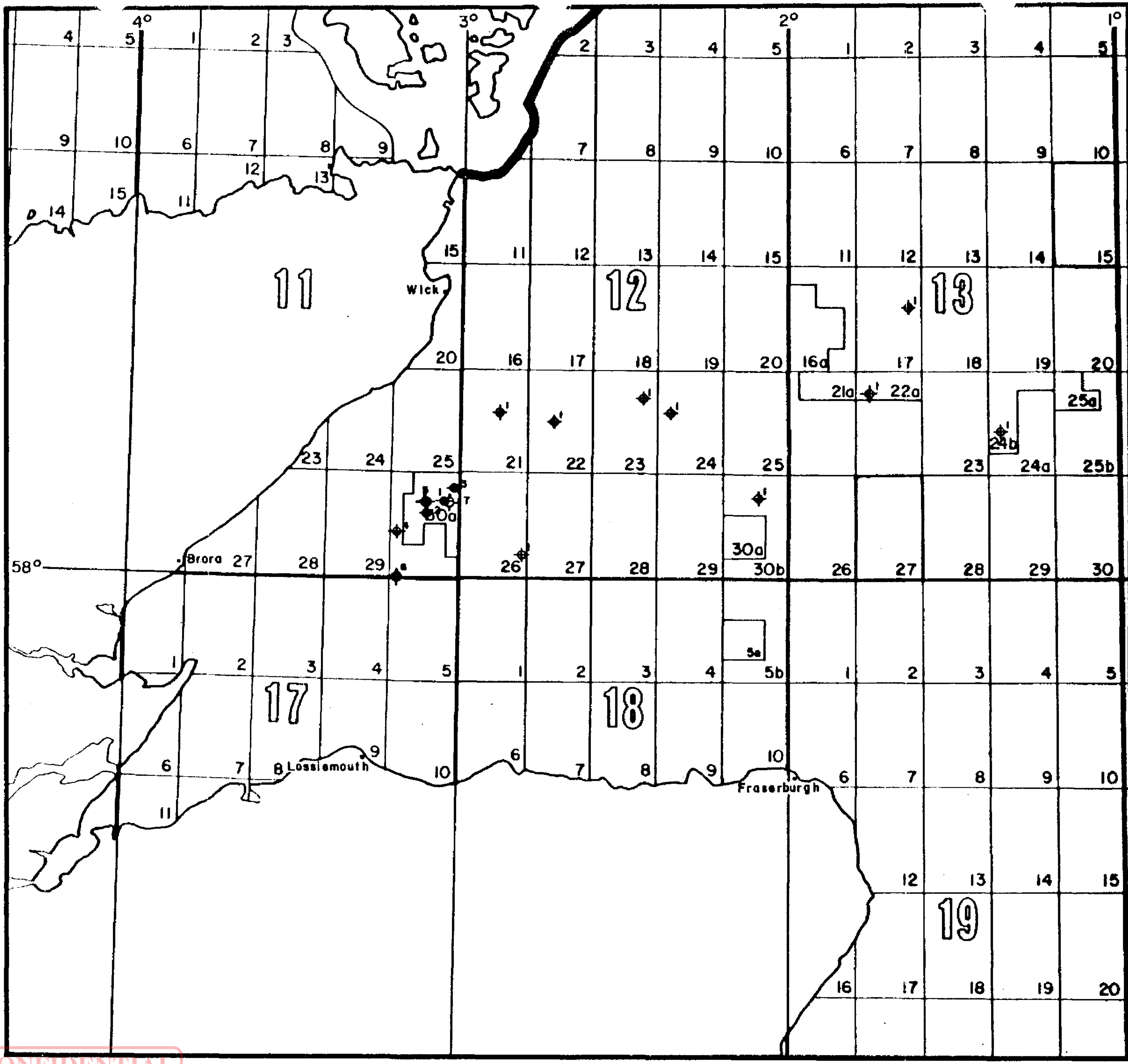
UEE/12, 1976. Shell/Esso North Sea Venture Appraisal of open acreage blocks in the Greater Moray Firth area. Shell UK Expro Report E78.064N.



1:1 000 000

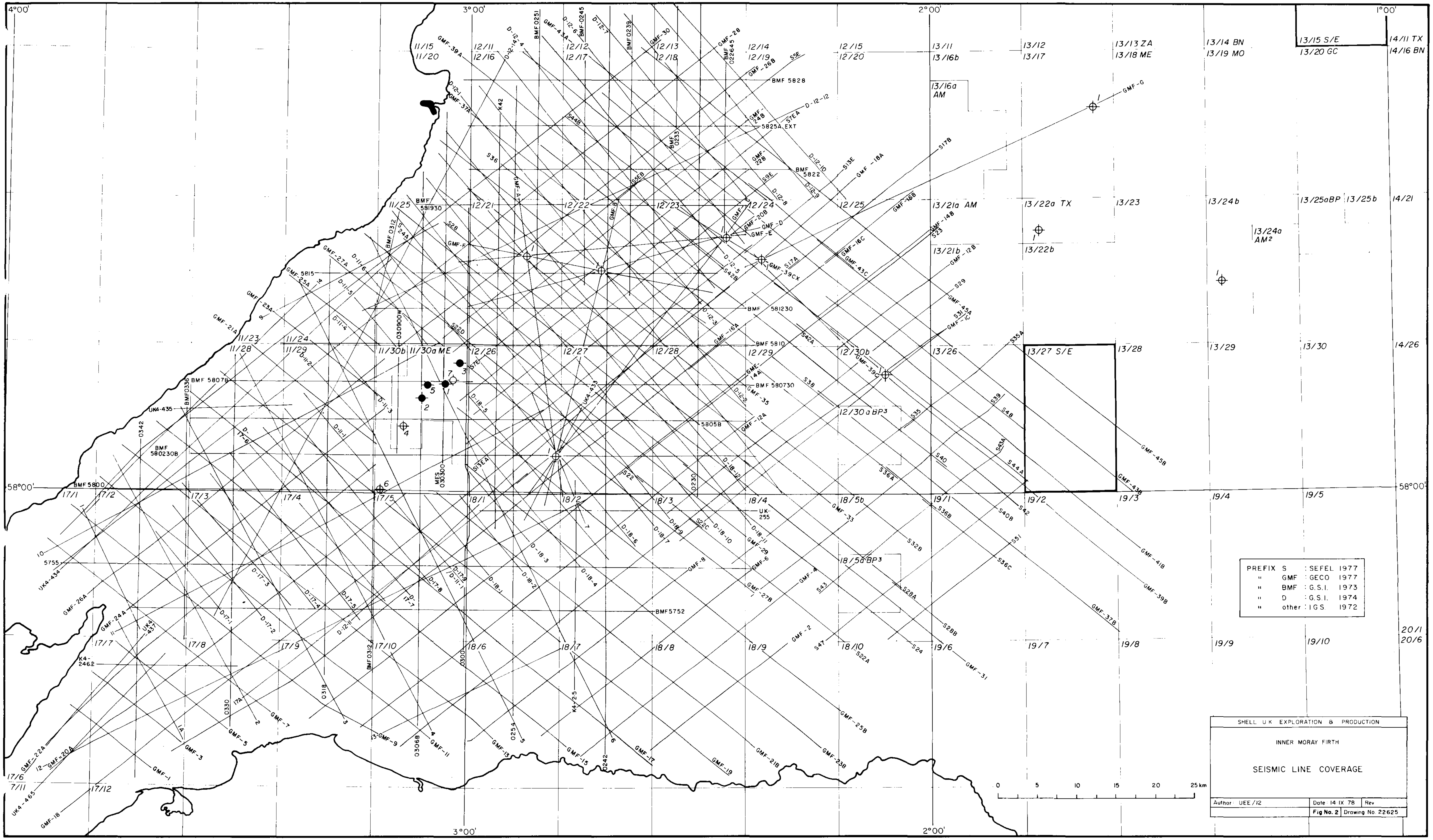
0 50km

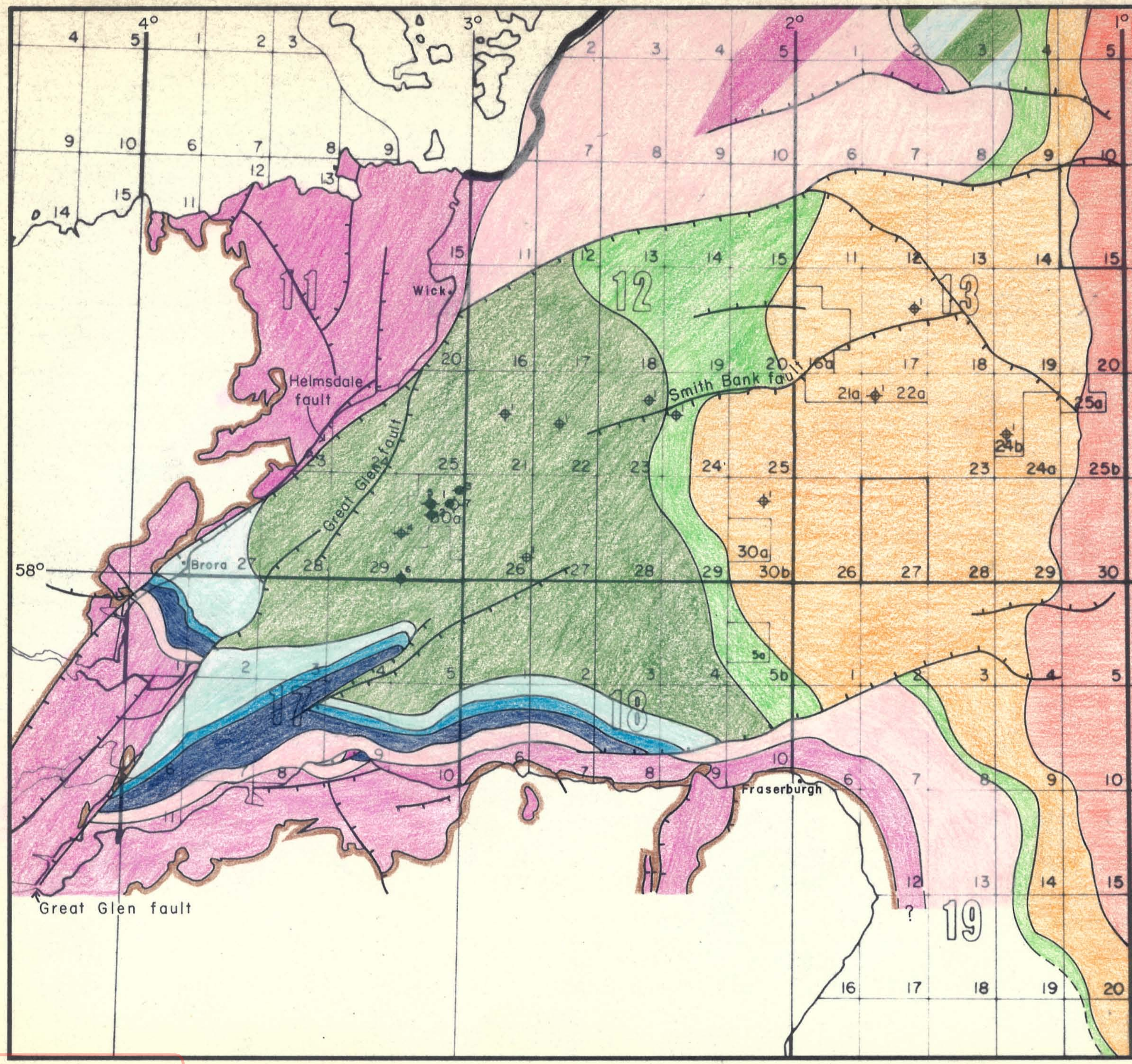
SHELL U.K. EXPLORATION & PRODUCTION

INNER MORAY FIRTH

LOCATION MAP

Author: UEE / 12	Date:	
	Fig. 1	Drg. No. 22624


SHELL U.K. EXPLORATION & PRODUCTION
INNER MORAY FIRTH
SEISMIC LINE COVERAGE
Author UEE/12
Date 14 IX 78
Rev
Fig No. 2
Drawing No. 22625
PREFIX S : SEFEL 1977
" GMF : GECO 1977
" BMF : G.S.I. 1973
" D : G.S.I. 1974
" other : IGS 1972
0 5 10 15 20 25 km
4°00'
3°00'
2°00'
1°00'
58°00'



POST SILURIAN SEDIMENTARY ROCKS

- Eocene
- Paleocene
- Upper Cretaceous
- Lower Cretaceous
- Upper Jurassic
- Middle Jurassic
- Lower Jurassic
- Permo-Trias
- Devonian

PRE DEVONIAN

- Undifferentiated sedimentary, metamorphic & igneous rocks

- Geological boundary
- Faults

1:1 000 000

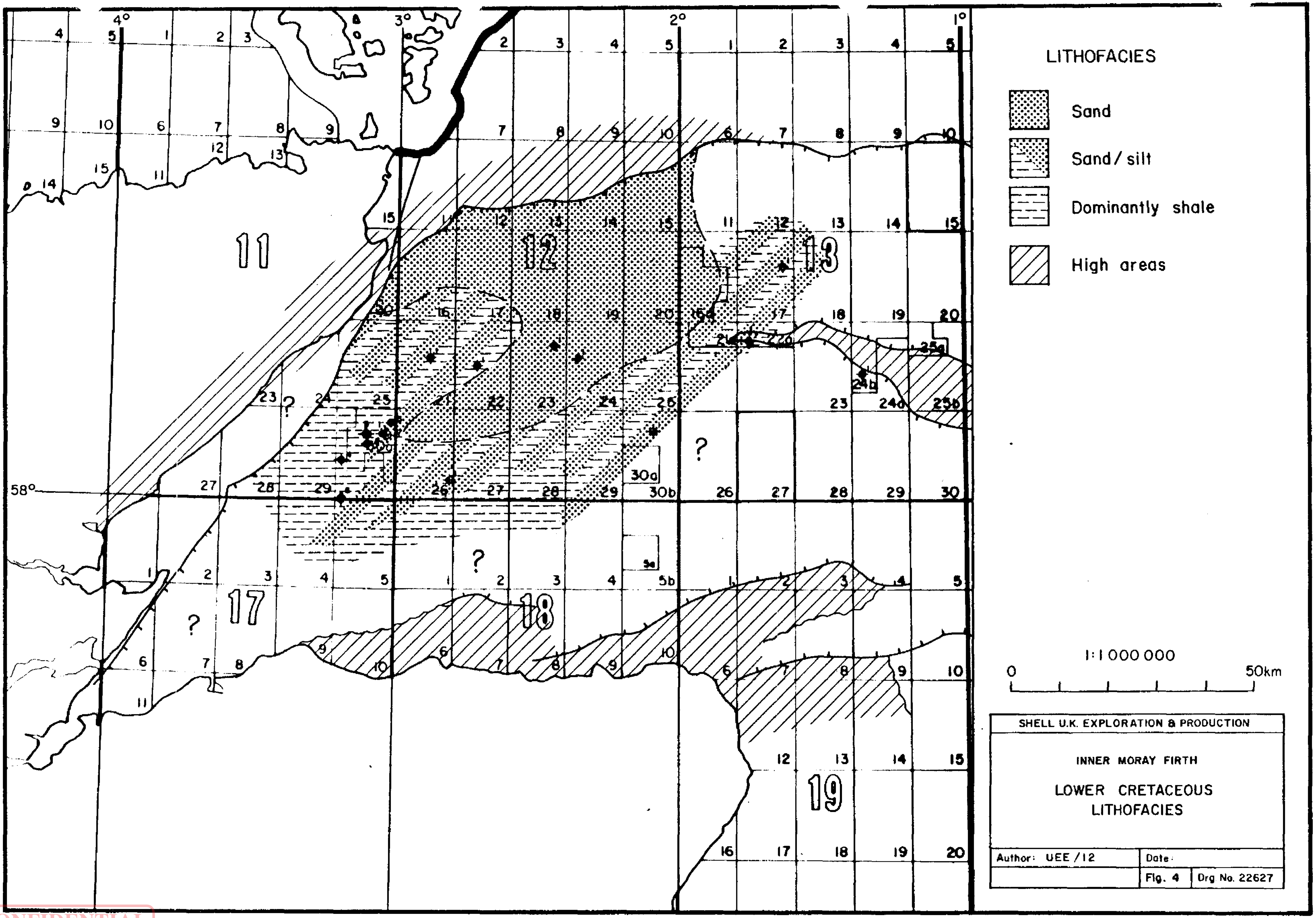
0 50km

SHELL U.K. EXPLORATION & PRODUCTION

INNER MORAY FIRTH

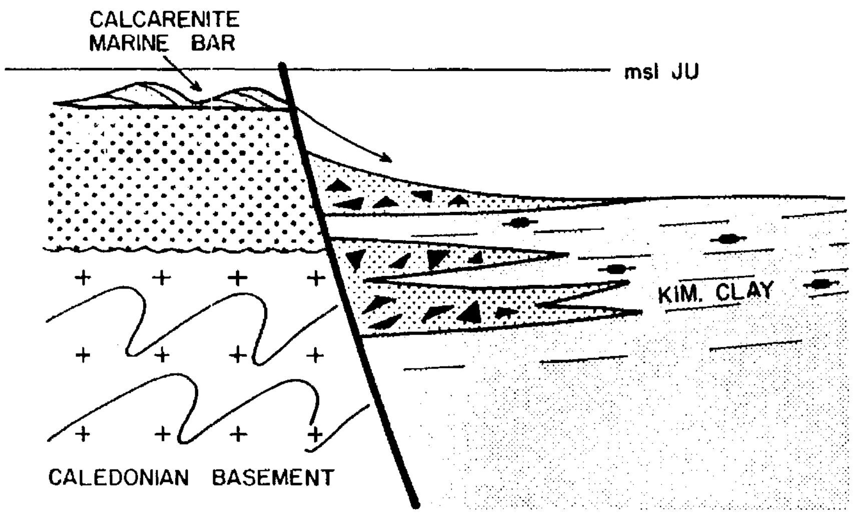
PRE-DRIFT GEOLOGICAL MAP

Author: UEE/12	Date:
	Fig. 3 Drg. No. 22626

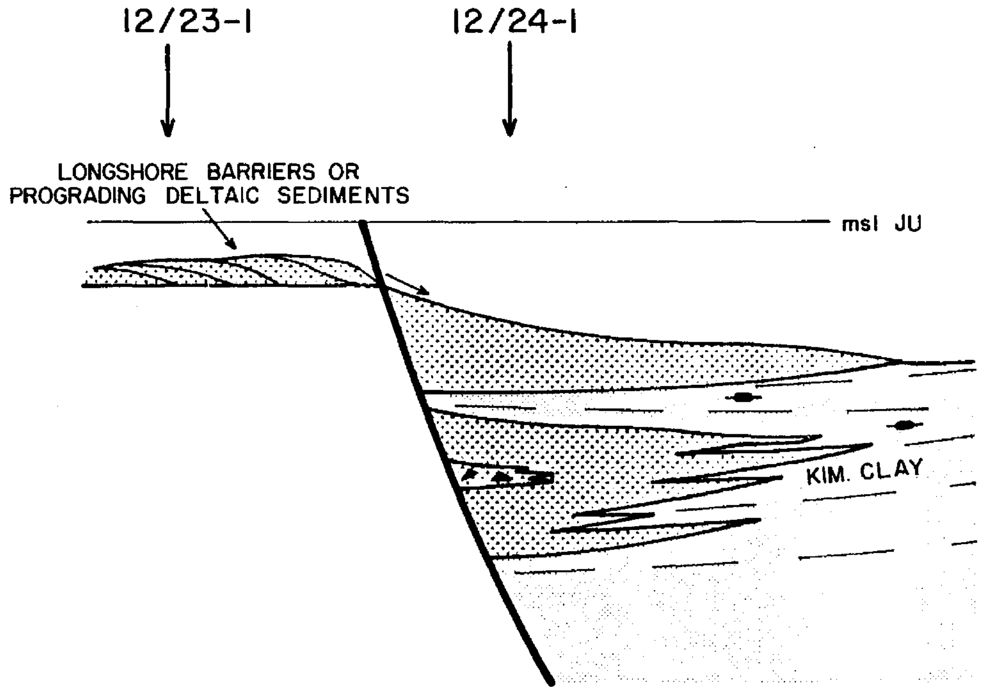


LITHOFACIES
Sand
Sand / silt
Dominantly shale
High areas
1:1 000 000
0
50km
SHELL U.K. EXPLORATION & PRODUCTION
INNER MORAY FIRTH
LOWER CRETACEOUS LITHOFACIES
Author: UEE / 12
Date:
Fig. 4
Drg No. 22627
4°
3°
2°
1°
58°
11
12
13
17
18
19

UPPER JURASSIC FAULT CONTROLLED SEDIMENTATION



HELMSDALE FAULT AFTER BAILEY & WEIR, 1932
NEVES & SELLEY, 1975

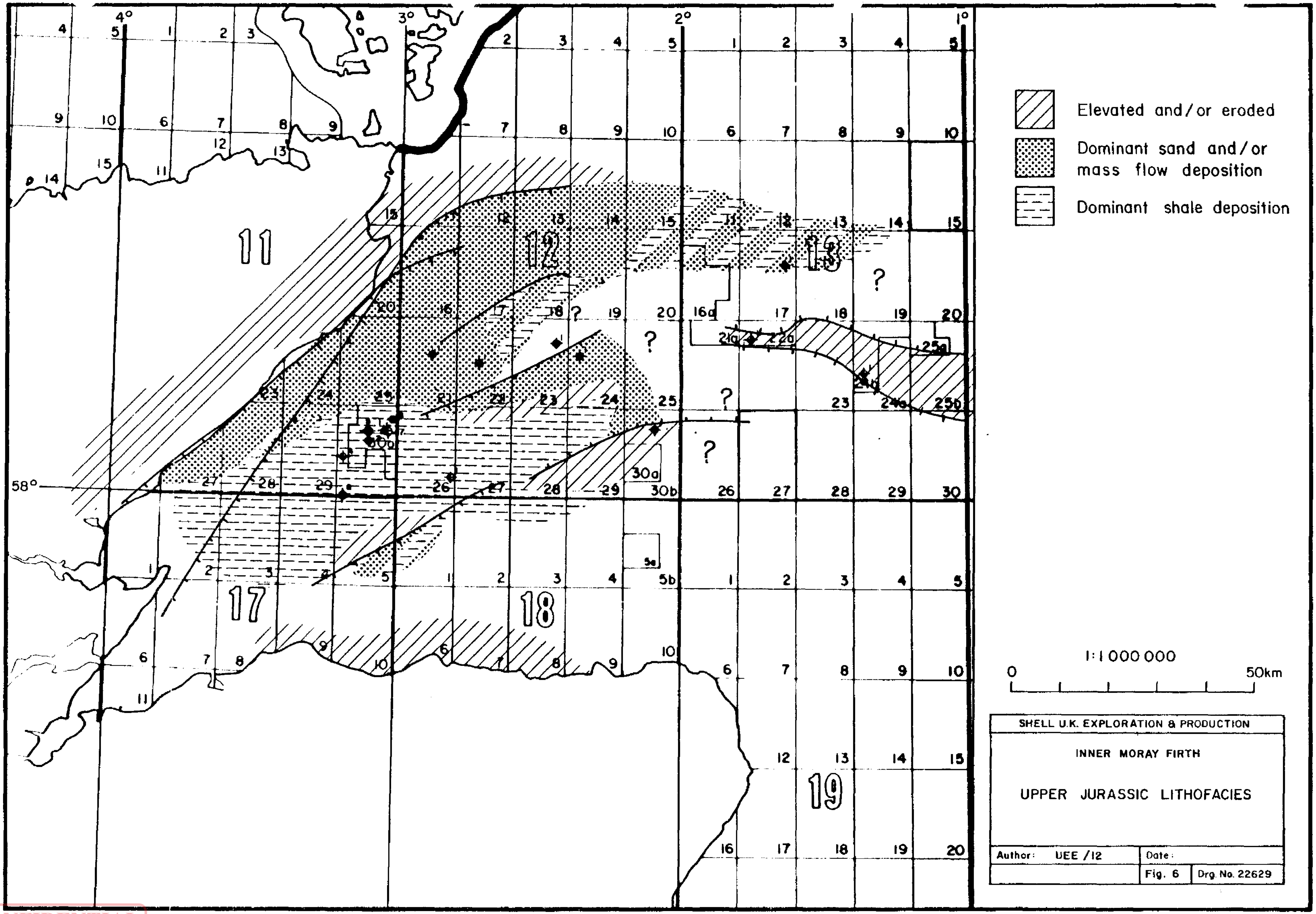


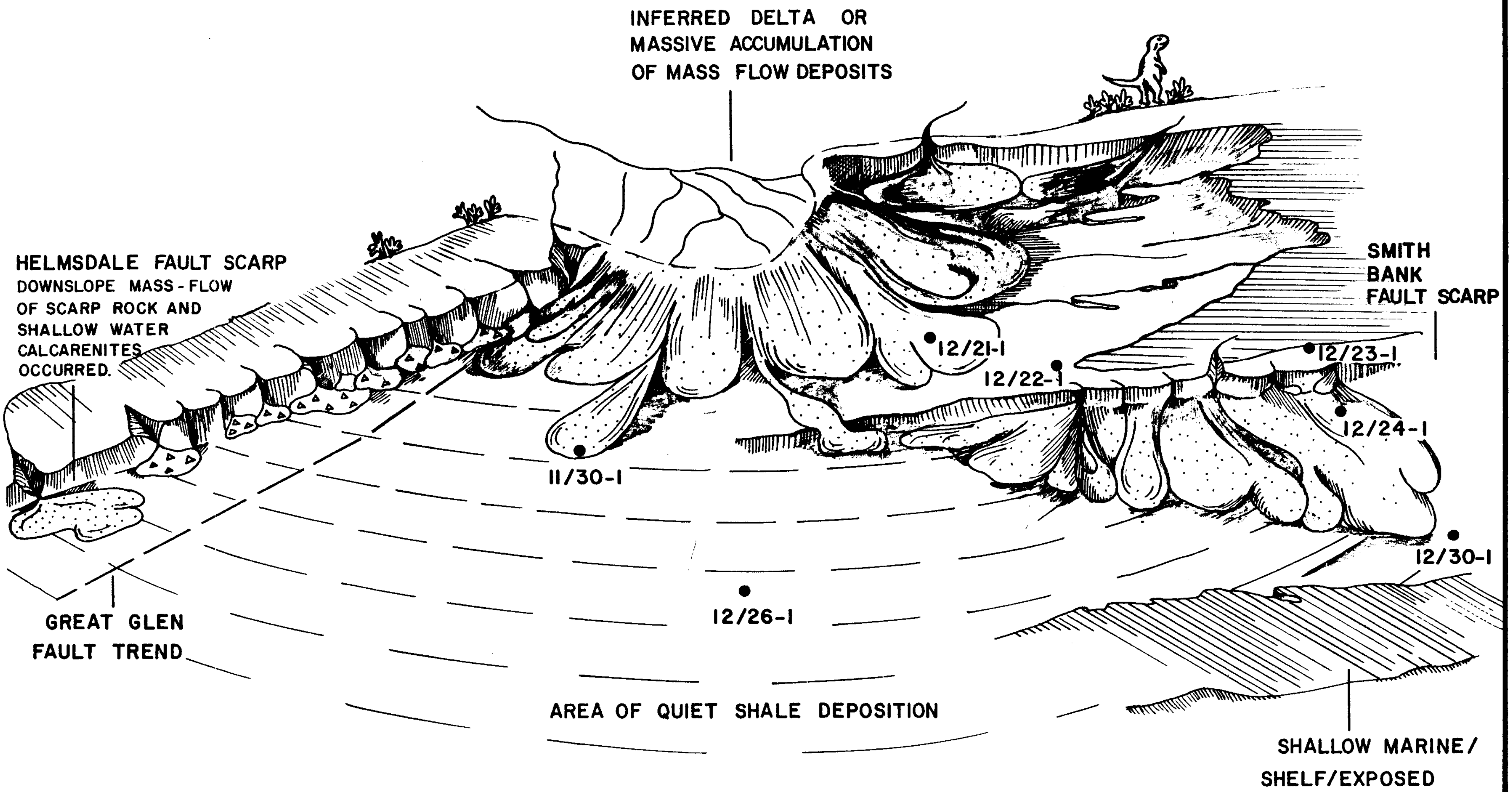
SMITH BANK FAULT THIS REPORT

SUBMARINE FAULT SCARP PROVIDED LARGE BLOCKS AND BOULDERS OF CONSOLIDATED DEVONIAN SEDIMENTS. CALCARENITE MATERIAL DEVELOPING ON A SHALLOW SHELF WAS ALSO SWEPT OVER THE FAULT EDGE INTO THE BASIN AND MIXED WITH THE DEVONIAN DEBRIS.

LONGSHORE BARRIER SAND OR FLUVIOMARINE SANDS WERE SWEPT OVER THE EDGE OF AN ACTIVE FAULT SCARP. IT IS NOT KNOWN IF THE SCARP ALSO CONTRIBUTED CLASTIC DEBRIS.

Figure No. 5

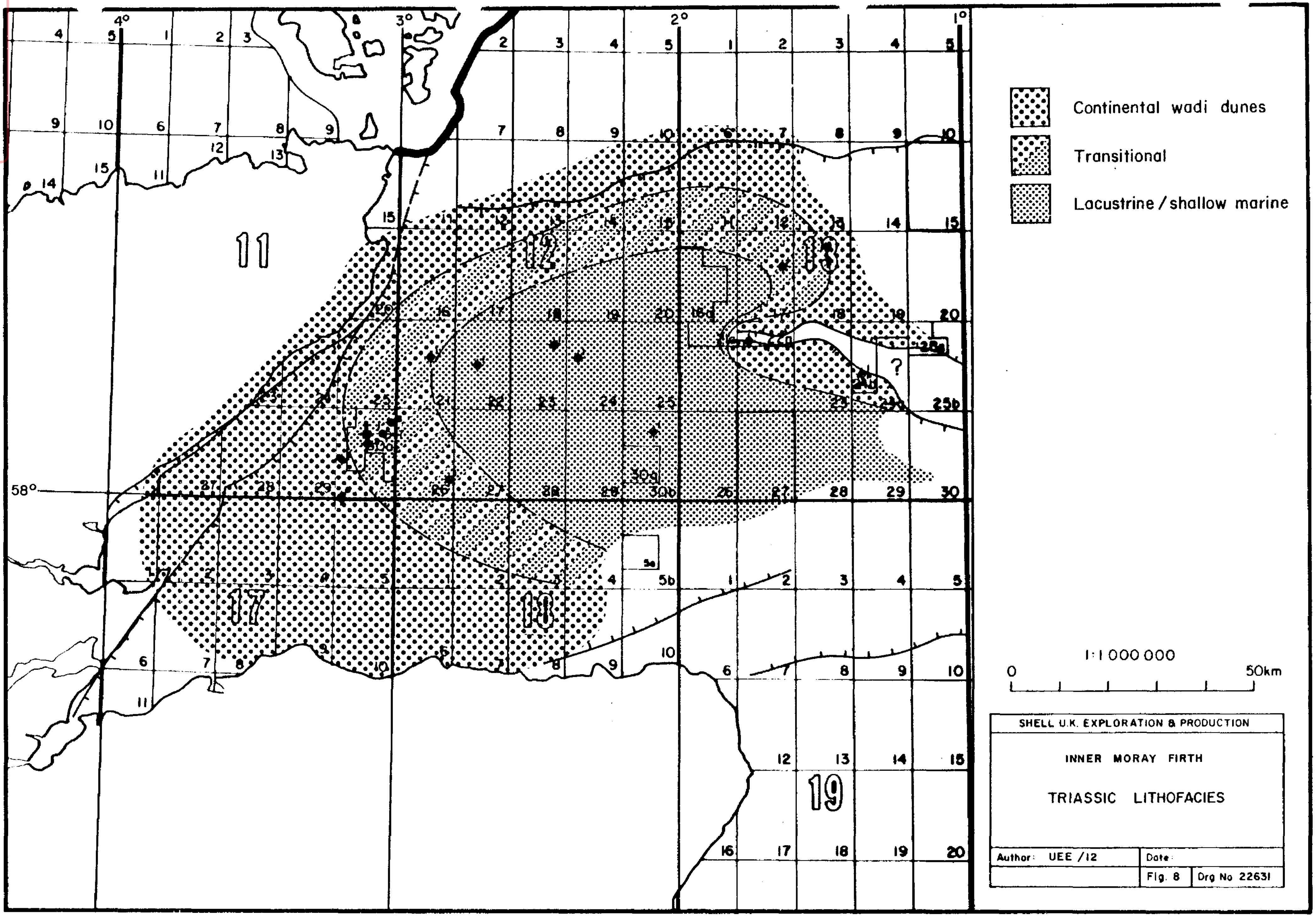

Elevated and/or eroded
Dominant sand and/or mass flow deposition
Dominant shale deposition
1:1 000 000
0
50km
SHELL U.K. EXPLORATION & PRODUCTION
INNER MORAY FIRTH
UPPER JURASSIC LITHOFACIES
Author: UEE /12
Date:
Fig. 6
Drg. No. 22629



INNER MORAY FIRTH - UPPER JURASSIC KIMMERIDGIAN
-SKETCH OF PALEO-TOPOGRAPHY

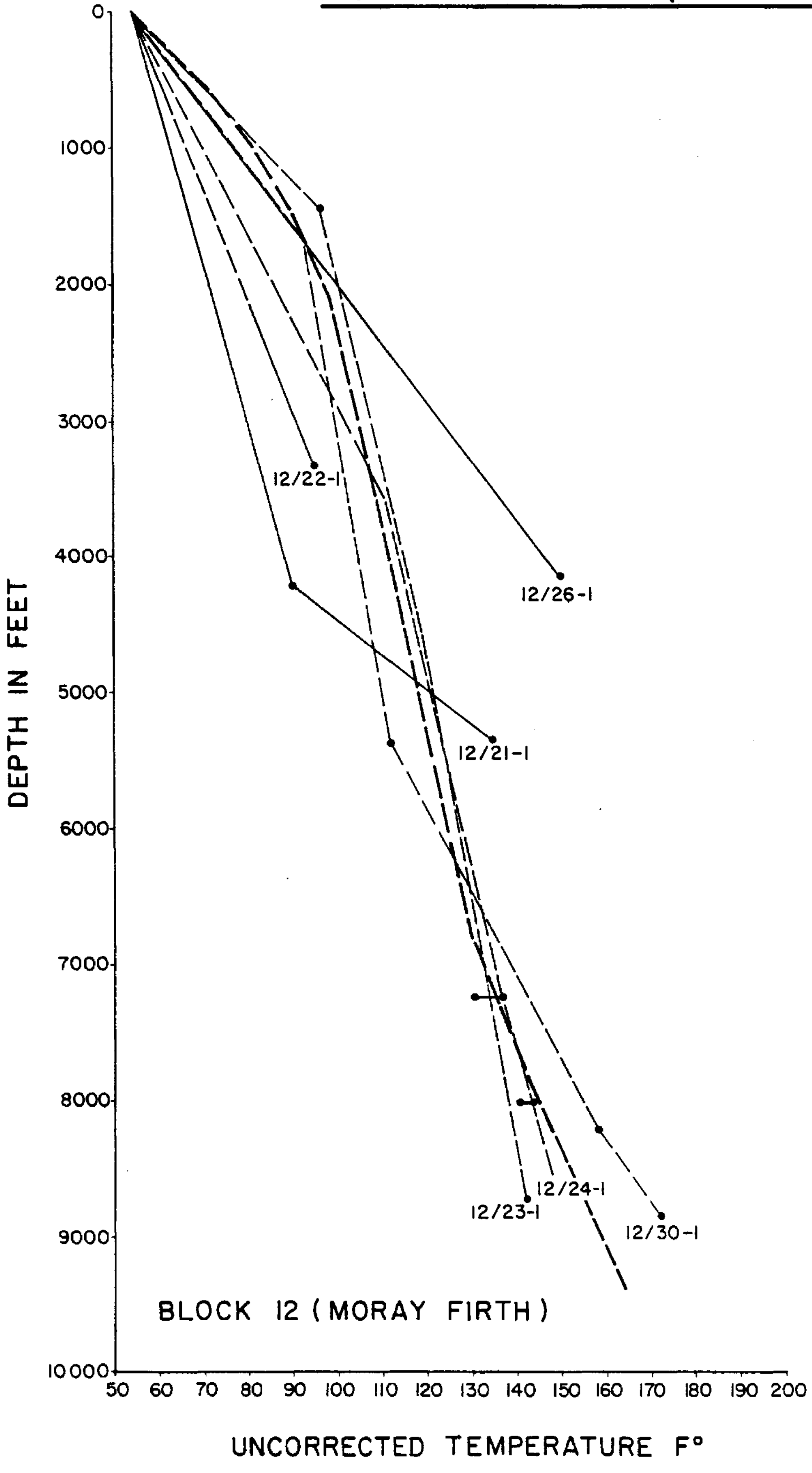
Drawing No. 22630

Figure No. 7



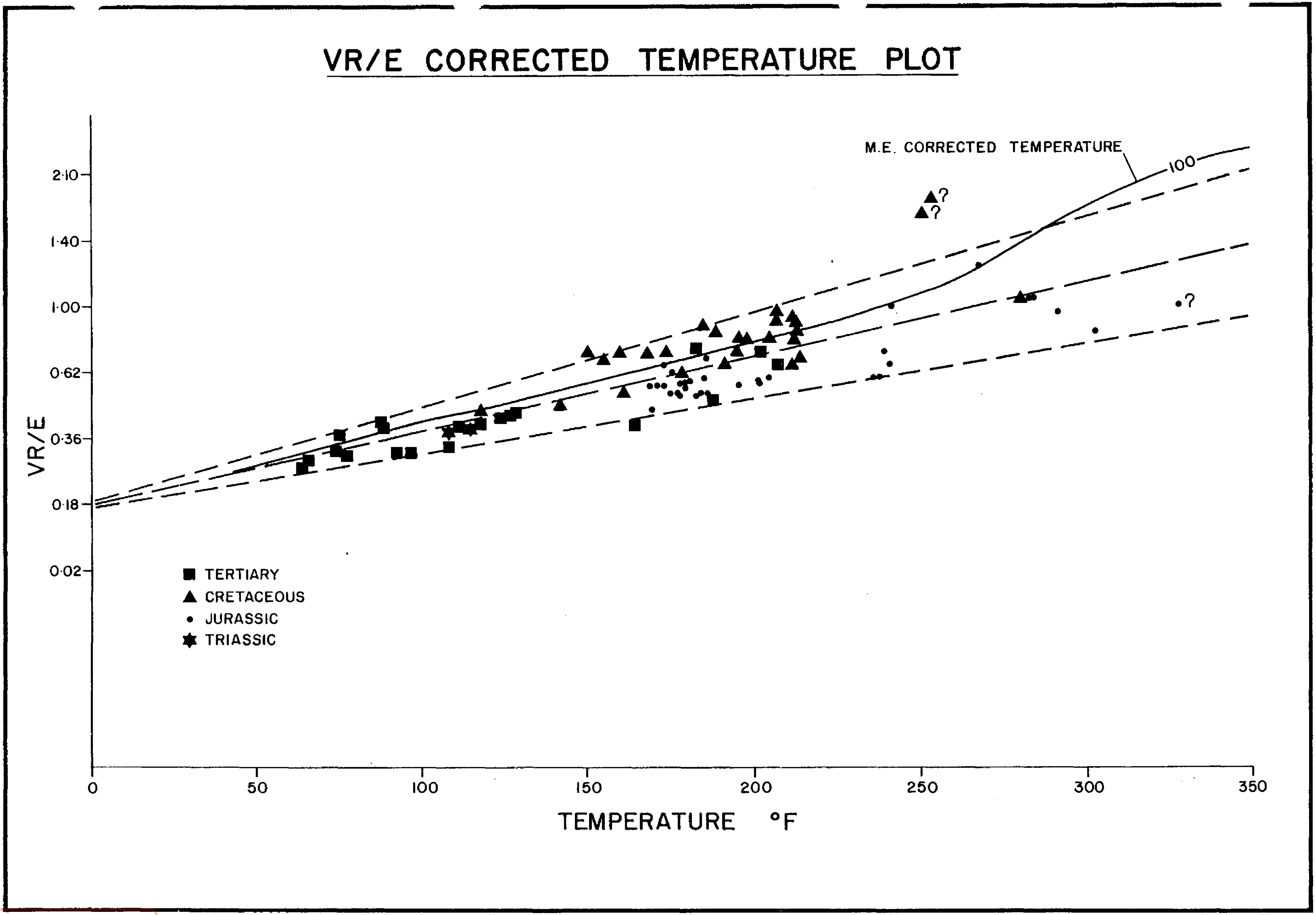
Continental wadi dunes
Transitional
Lacustrine / shallow marine
1:1 000 000
0
50km
SHELL U.K. EXPLORATION & PRODUCTION
INNER MORAY FIRTH
TRIASSIC LITHOFACIES
Author: UEE /12
Date:
Fig. 8
Drg No 22631
11
12
13
17
18
19
4°
3°
2°
1°
58°

TEMPERATURE/BHT DATA PLOT FOR BLOCK 12 (MORAY FIRTH)



Drawing No. 22632

Figure No. 9

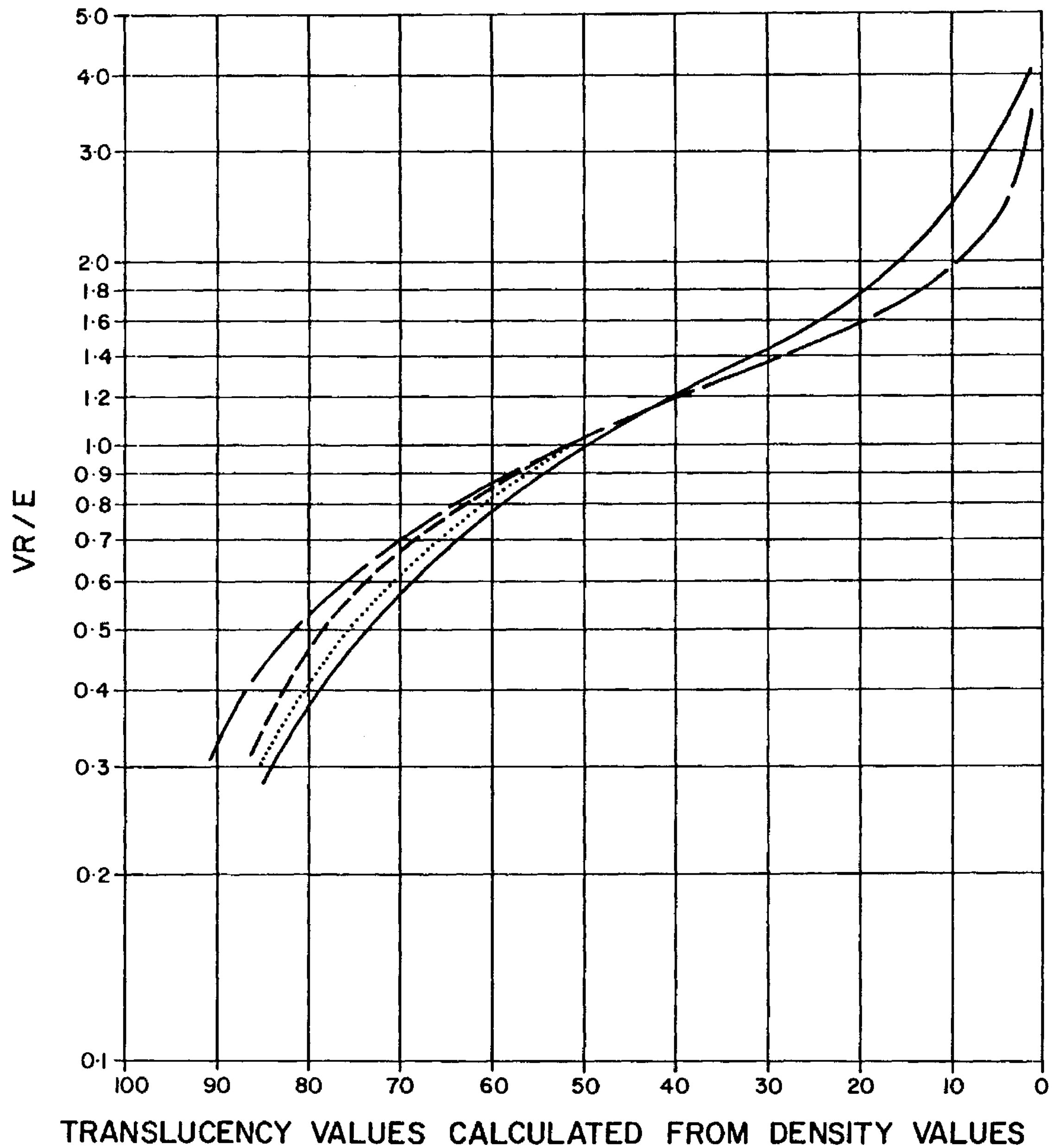


Drawing No. UK 7646

Figure No. 10

Drawing No. UK 7647

COLOUR DENSITY / VR/E PLOT



GREY FILTERS

COLOUR FILTERS

GREY / COLOUR	0	1	2	3	4	5	6	7
O	100	79	62	49	33	18	9.6	4.4
A	89	71	55	44	30	16	8.6	3.9
A_1	87	69	54	43	29	16	8.4	3.8
A_2	81	65	50	40	27	15	7.8	3.6
B	76	60	47	37	25	14	7.3	3.3
B_1	71	56	44	35	24	13	6.8	3.1
B_2	62	49	38	30	20	11	5.9	2.7
C	55	44	34	27	18	10	5.3	2.4
C_1	53	42	32	26	17	9.6	5.0	2.3
C_2	42	33	26	20	14	7.6	4.0	1.8
D	35	28	21	17	11	6.3	3.3	1.5
D_1	24	19	15	12	8.0	4.4	2.3	1.0
D_2	22	17	14	11	7.3	4.0	2.1	0.9
E	19	15	11	9.2	6.2	3.4	1.8	0.8
E_1	13	10	7.8	6.2	4.2	2.3	1.2	0.6
F	8.8	6.9	5.4	4.3	2.9	1.6	0.8	0.4
G	4.4	3.5	2.7	2.2	1.4	1.0	0.4	0.2

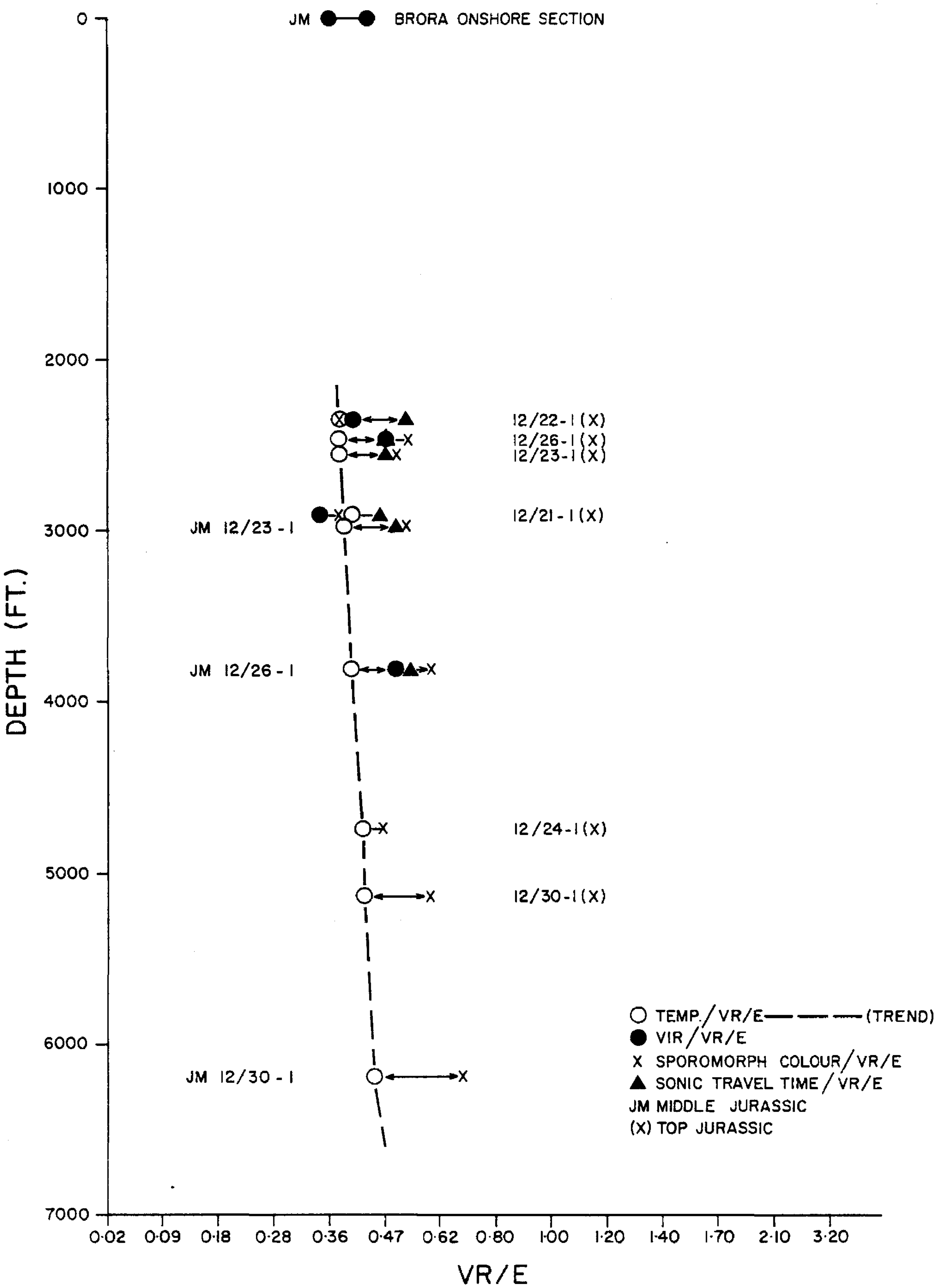
TRANSLUCENCY VALUES

SPOROMORPH GROUPS

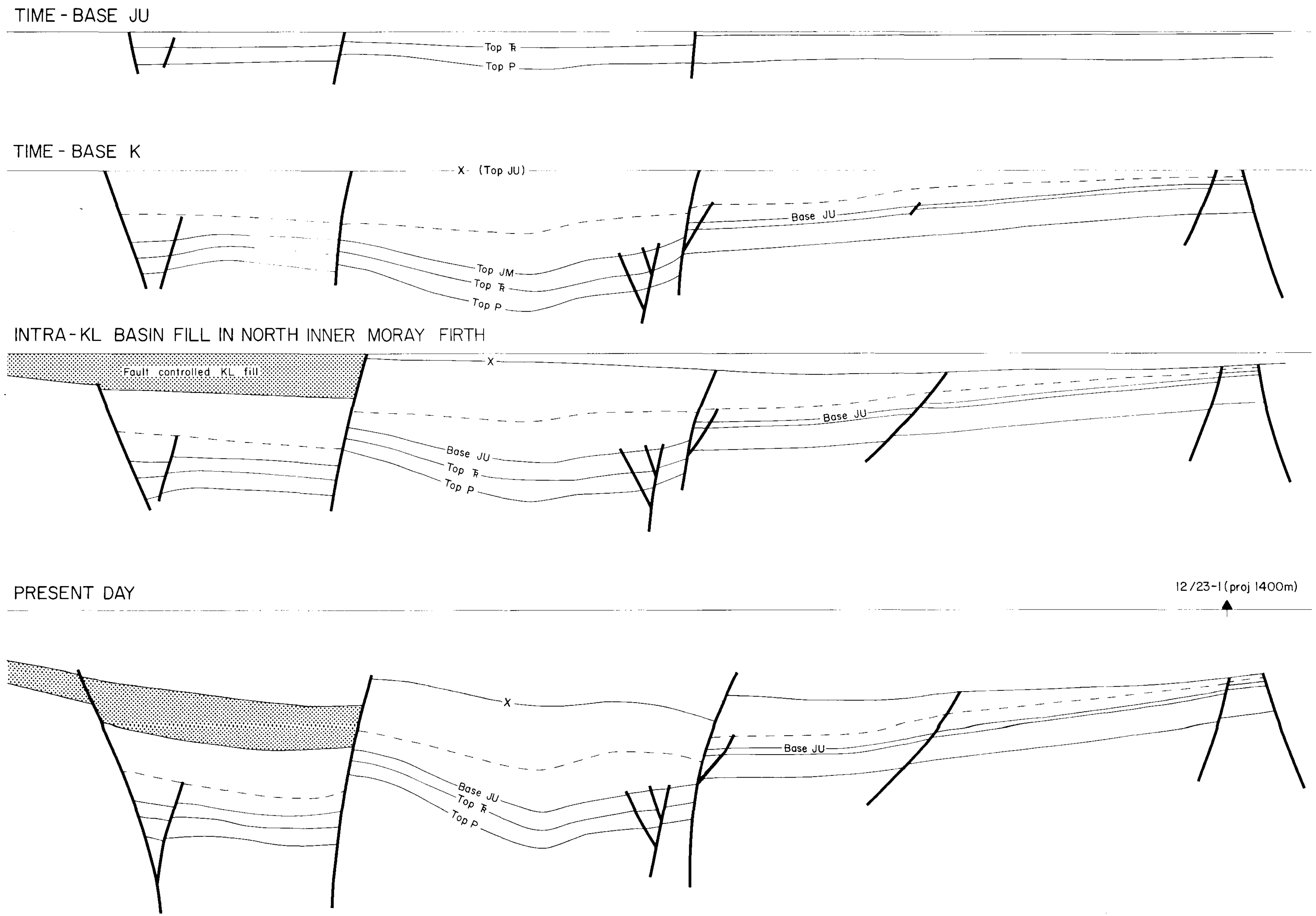
- – – – – – GROUP I
- ·············· GROUP II
- ———— GROUP III
- —— —— GROUP 506

Figure No. 11

TEMPERATURE VR/E / MEASURED VR/E PLOT



FAULT ACTIVITY AND SEDIMENTATION
INNER MORAY FIRTH AREA I (ADAPTED FROM GSI 12-6)

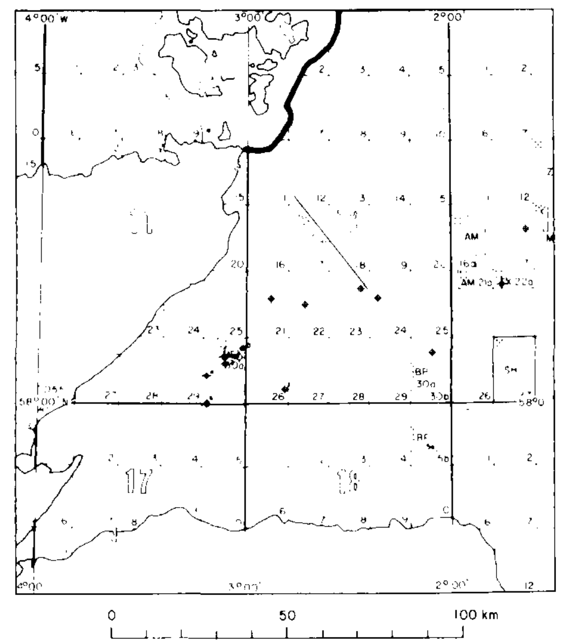


During Ŧr and JMJL faults exerted limited control on sedimentation.

Fault control during upper Jurassic sedimentation was strong - normal faulting may have been associated with some wrenching.

During early KL local fault control on sediments occurred in the north-east of the area. No well control exists ∴ lithology associated with faulting is not known.

Active faulting continued in KL or post-KL time. Faults may have been associated with small wrench faults.



LOCATION MAP

K	Cretaceous
KL	Lower Cretaceous
X	approximate Base Cretaceous
JU	Upper Jurassic
JM	Middle Jurassic
JL	Lower Jurassic
Ŧr	Triassic
P	Permian

0 1 2 3 4 5 6 7 8 9 10 km

Drawing No. 22636

Figure No 13

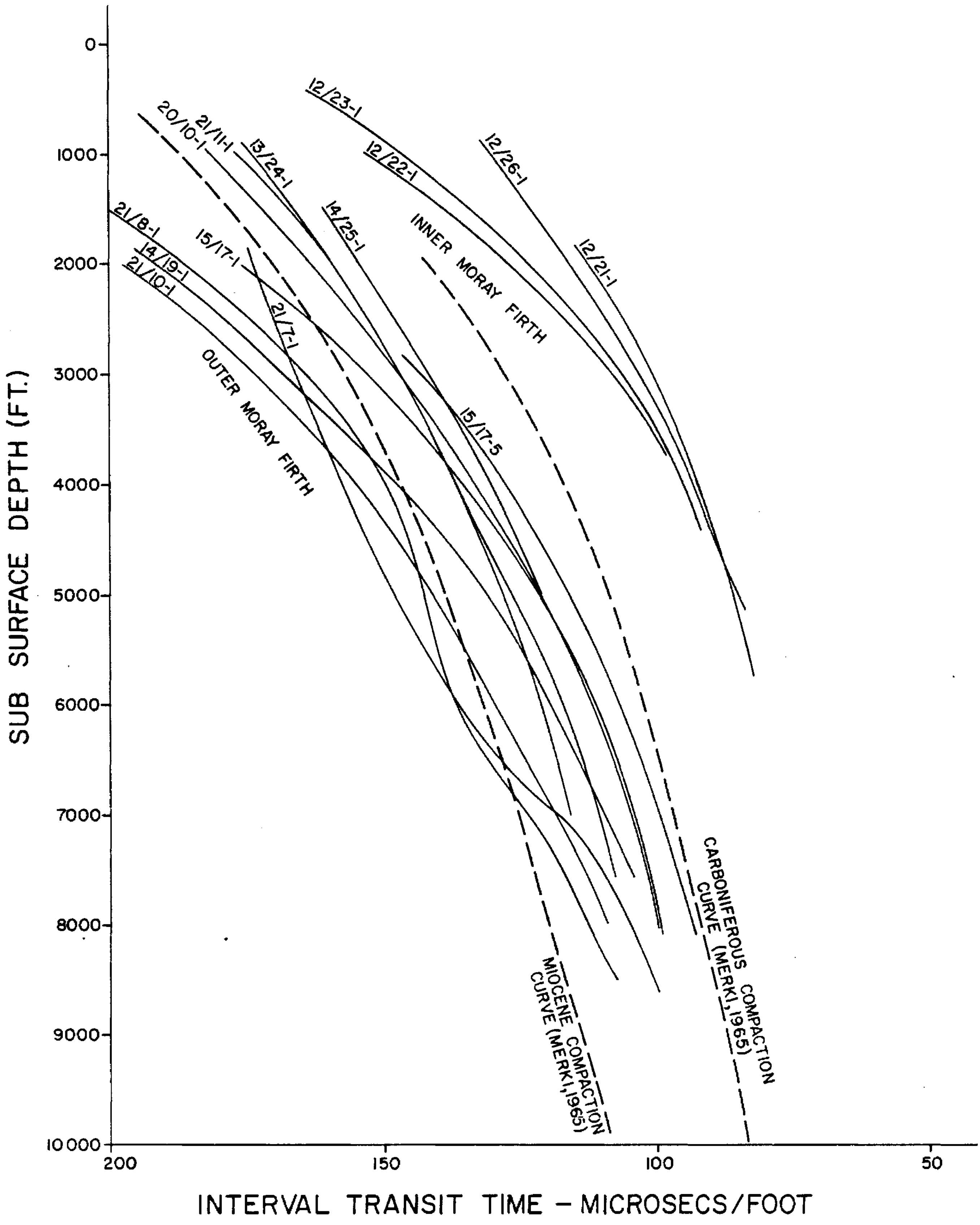
ep50728

See separate pdf or high resolution jpeg/tif with name:

ep50728 draw 001-002

SHALE COMPACTION TRENDS IN THE INNER AND OUTER MORAY FIRTH

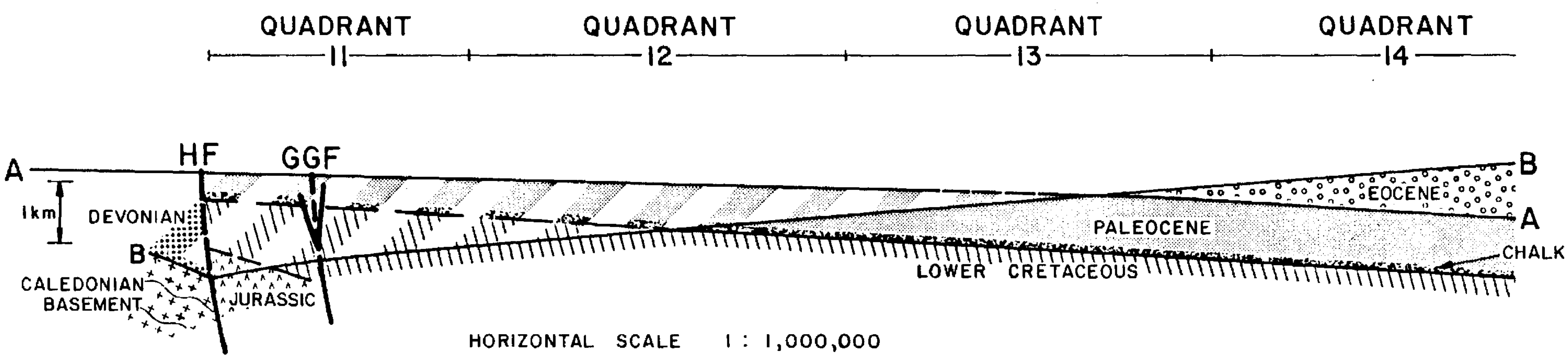
(FROM TOWNSON & MacFARLANE, 1976)



Drawing No. 22639

Figure No. 16

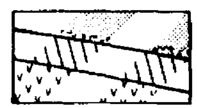
TILTED MODEL OF INNER MORAY FIRTH AREA



HORIZONTAL SCALE 1 : 1,000,000
VERTICAL SCALE 1 : 100,000

SCHEMATIC CROSS – SECTION ILLUSTRATING EFFECT OF TILT SINCE END PALEOCENE. SINCE THIS TIME LOWER AND UPPER CRETACEOUS PLUS SOME PALEOCENE HAS BEEN REMOVED FOLLOWING UPLIFT.

TILT — 0·7 – 0·8°
HF — HELMSDALE FAULT
GGF — GREAT GLEN FAULT
A-A — PALEOCENE SURFACE
B-B — PRESENT DAY SURFACE



SECTION ERODED AND REMOVED

Drawing No. 22640

Figure No.17

ep50728

See separate pdf or high resolution jpeg/tif with name:

ep50728 draw 003

Drawing No. UK 7655

BEATRICE FIELD OIL SAMPLE – NORMAL ALKANE DISTRIBUTION

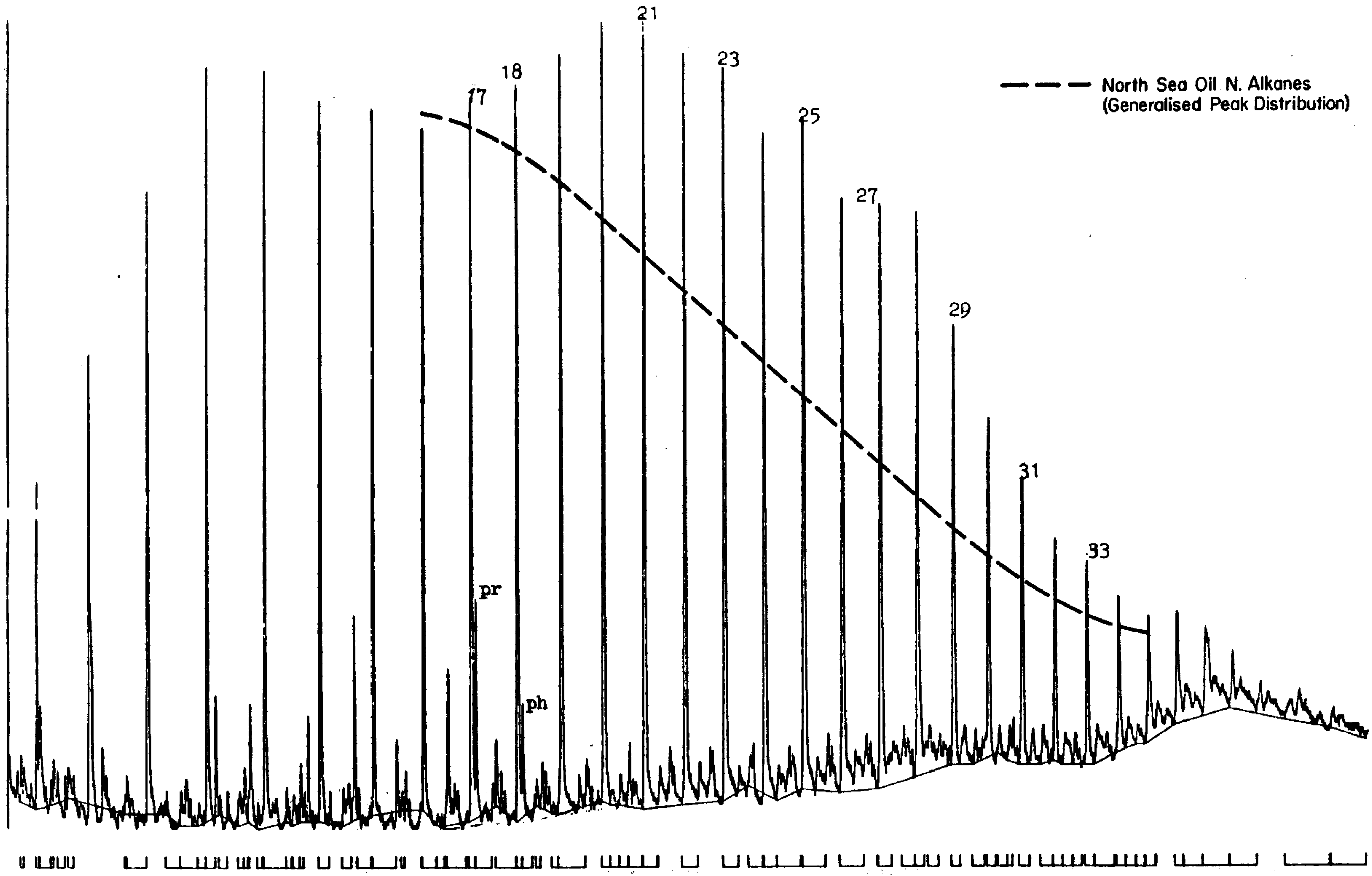
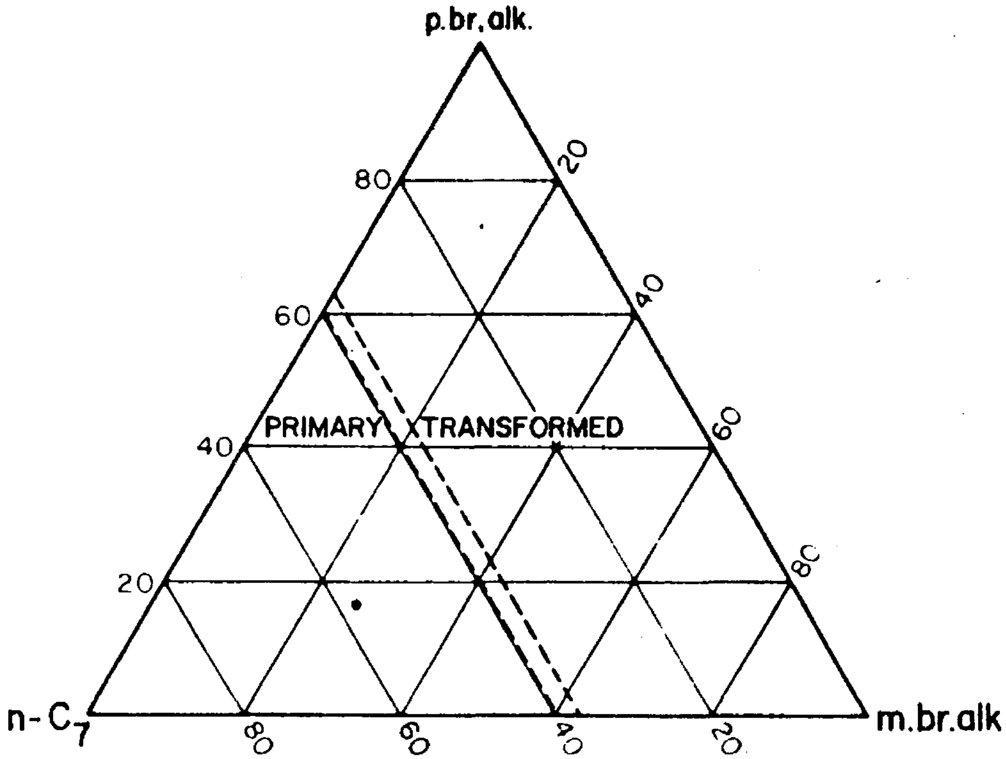


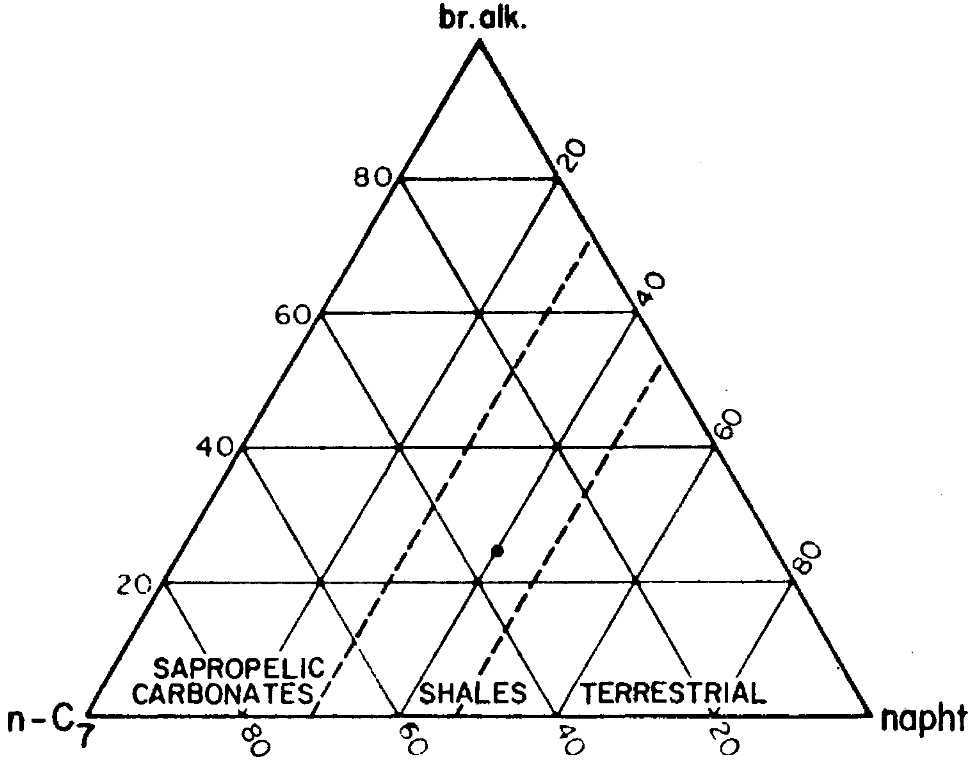
Figure No. A1

Drawing No. UK 7656

BEATRICE FIELD OIL SAMPLE – C_7 DISTRIBUTION



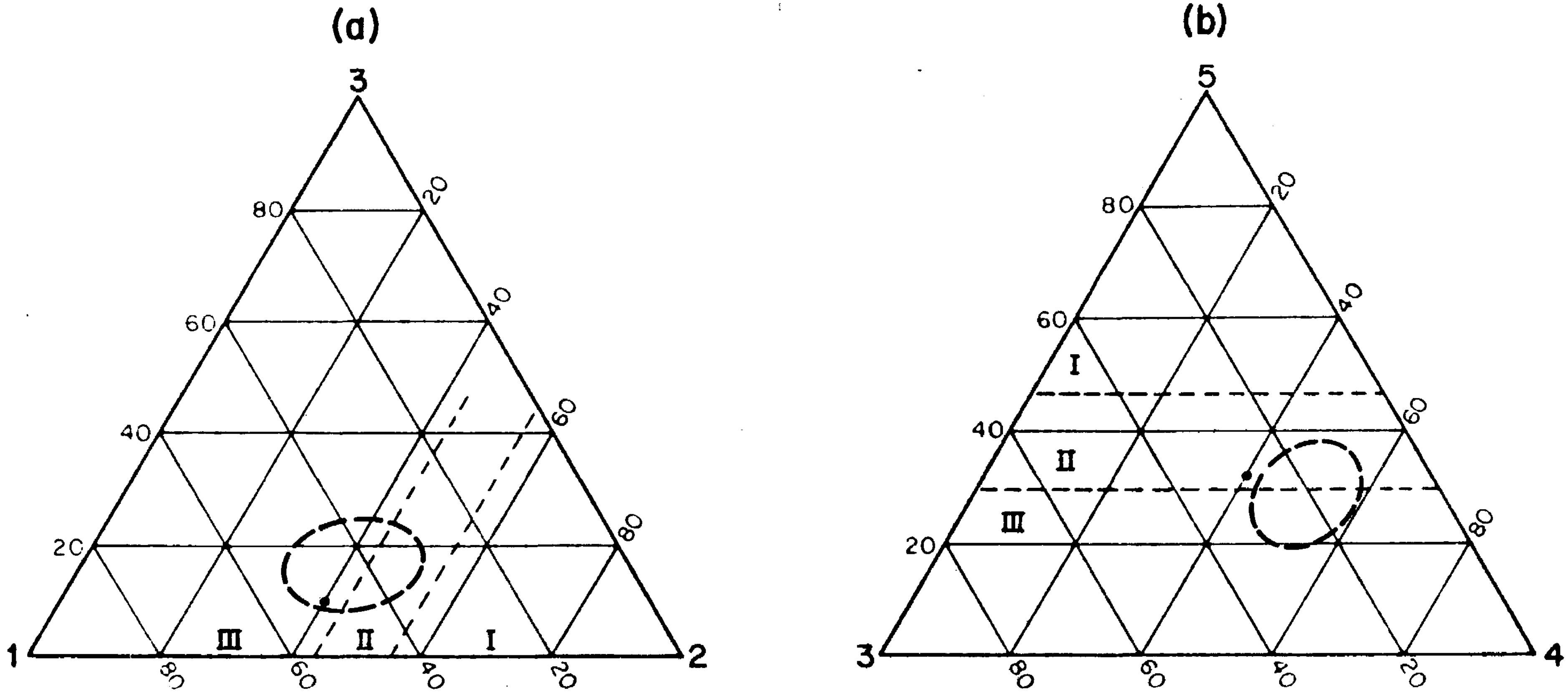
C_7 - ALKANE DISTRIBUTION



C_7 - ALKANE/NAPHTHENE DISTRIBUTION

Figure No. A2

BEATRICE FIELD OIL SAMPLE
(a) C_{15} RING DISTRIBUTION and (b) C_{30} RING DISTRIBUTION



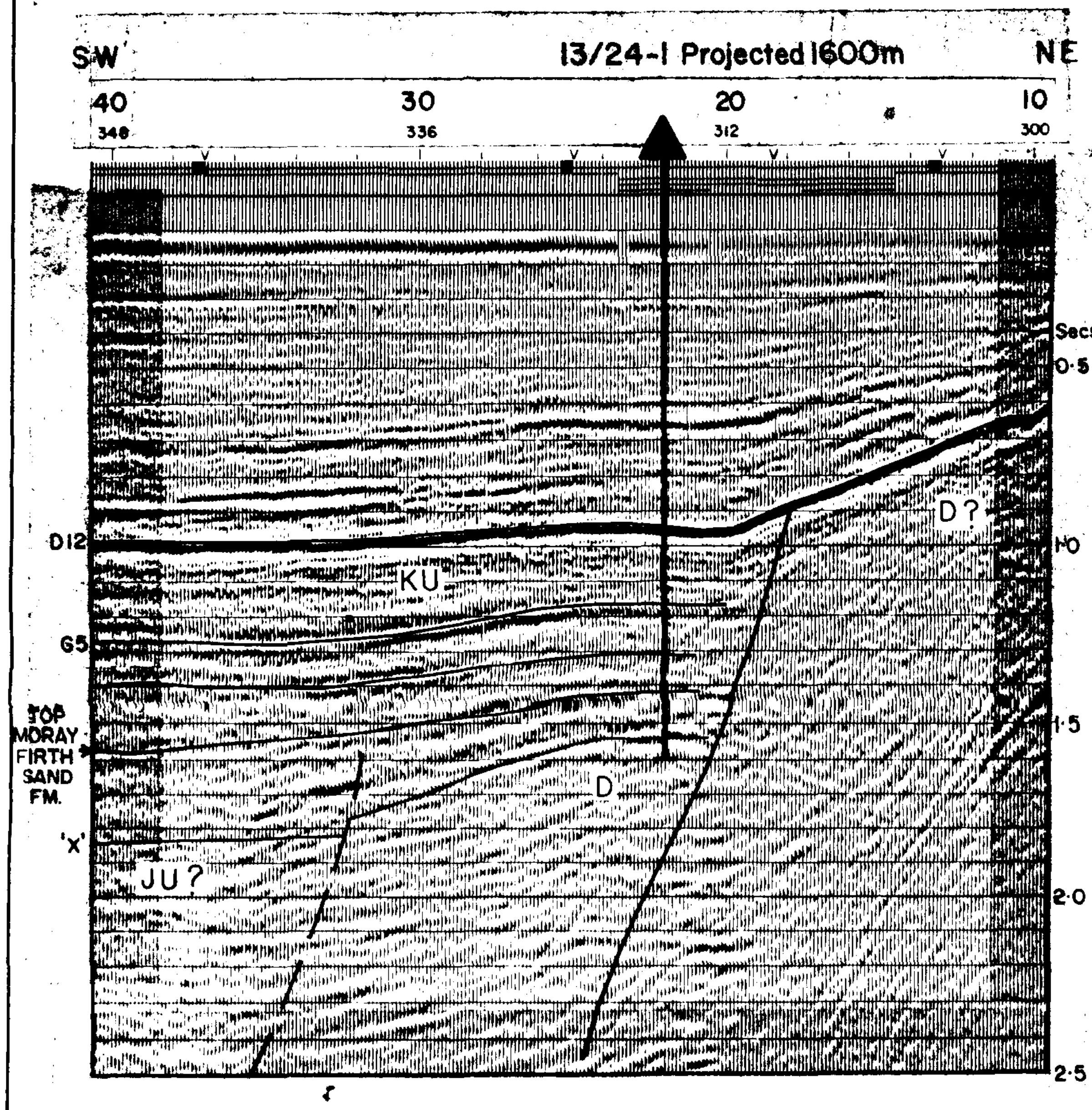
I LANDPLANT-DERIVED CRUDES WITH SUBSTANTIAL RESIN CONTRIBUTION TO SOURCE MATTER
II CRUDES OF MIXED ORIGIN
III CRUDES DERIVED FROM SOM AND/OR ALGAL MATTER
NORTH SEA OILS IN GENERAL

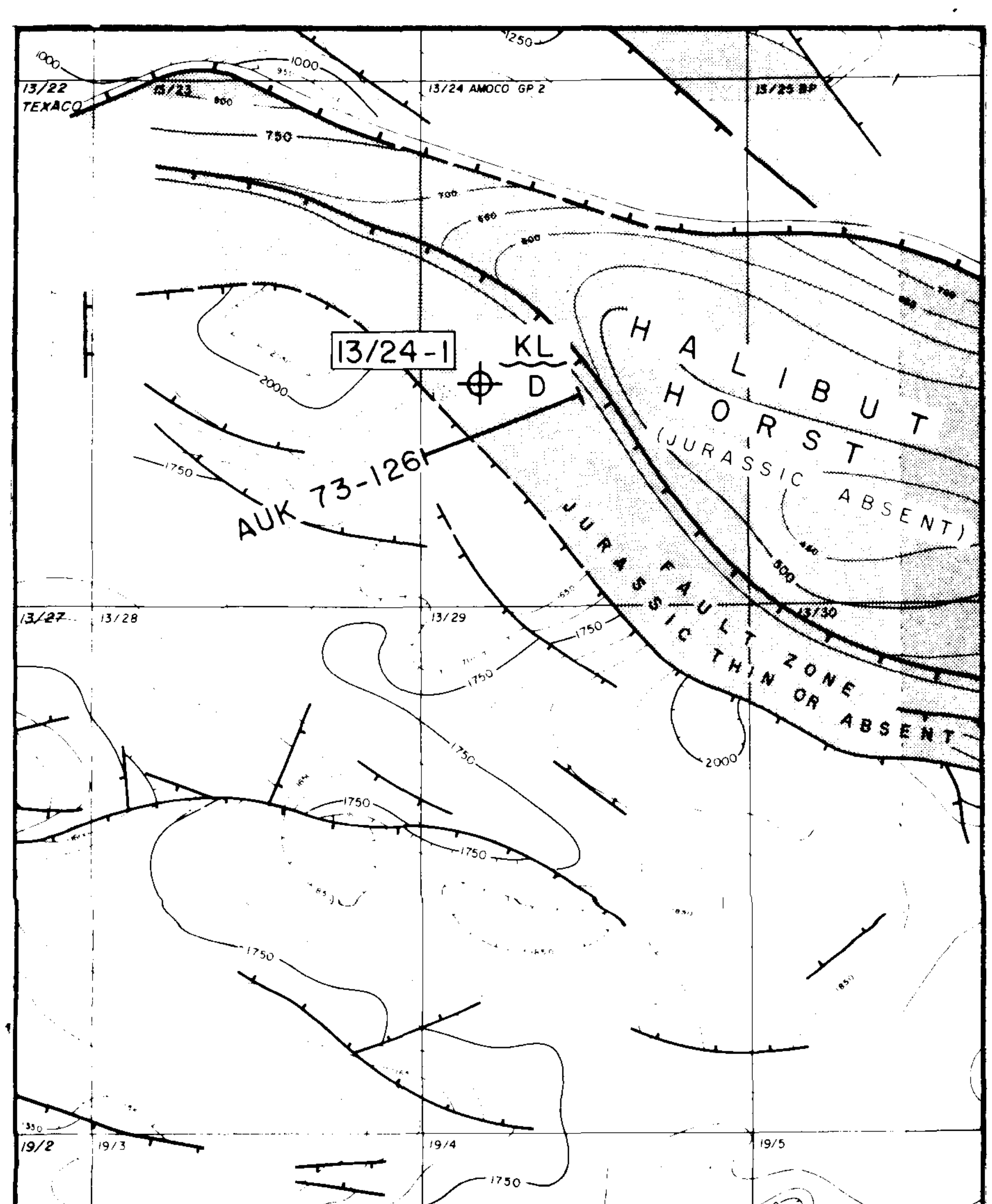
ep50728

See separate pdf or high resolution jpeg/tif with name:

ep50728 draw 004-018

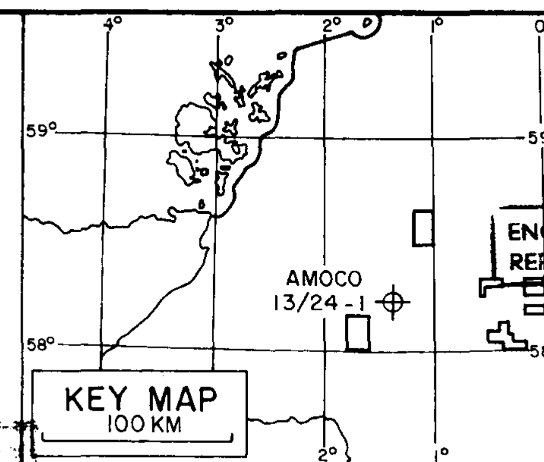
SEISMIC LINE AUK 73 - 126





REGIONAL BASE CRETACEOUS ISOCHRONE MAP

0 5 10 KMS



SHELL U.K. EXPLORATION & PRODUCTION

AMOCO 13/24-1

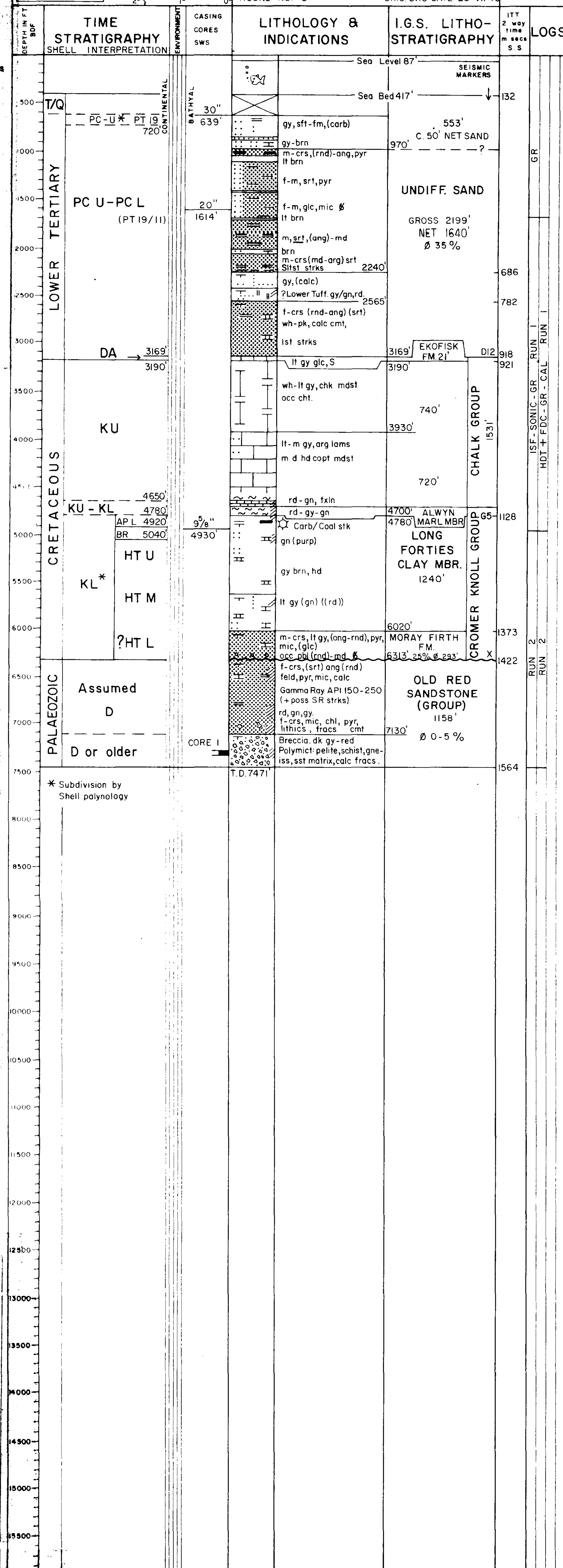
ENCLOSURE TO REPORT EP 30428

SCALE 1:10 000

COORDINATES LAT 58°14'16.49"N LONG 01°21'52.58"W
ELEVATION DF 87'
WATER DEPTH 330'
TOTAL DEPTH 7471'
LICENCE NO P.101
ROUND NO. 3

RIG WAAGE I
SPUDDED 3-11-74
COMPLETED 29-12-74
TYPE COMPL P&A
ORIG DRG DATE 28-VII-75

AUG. 1978



SUMMARY

LOCATION

130 km NNE of Aberdeen, midway between Inner Moray Firth and Piper Area. At present, an isolated well within a large area of open acreage. Located on fault flank, S. side Halibut Horst.

OBJECTIVES

Test of fault closure against horst at pre-Chalk level.

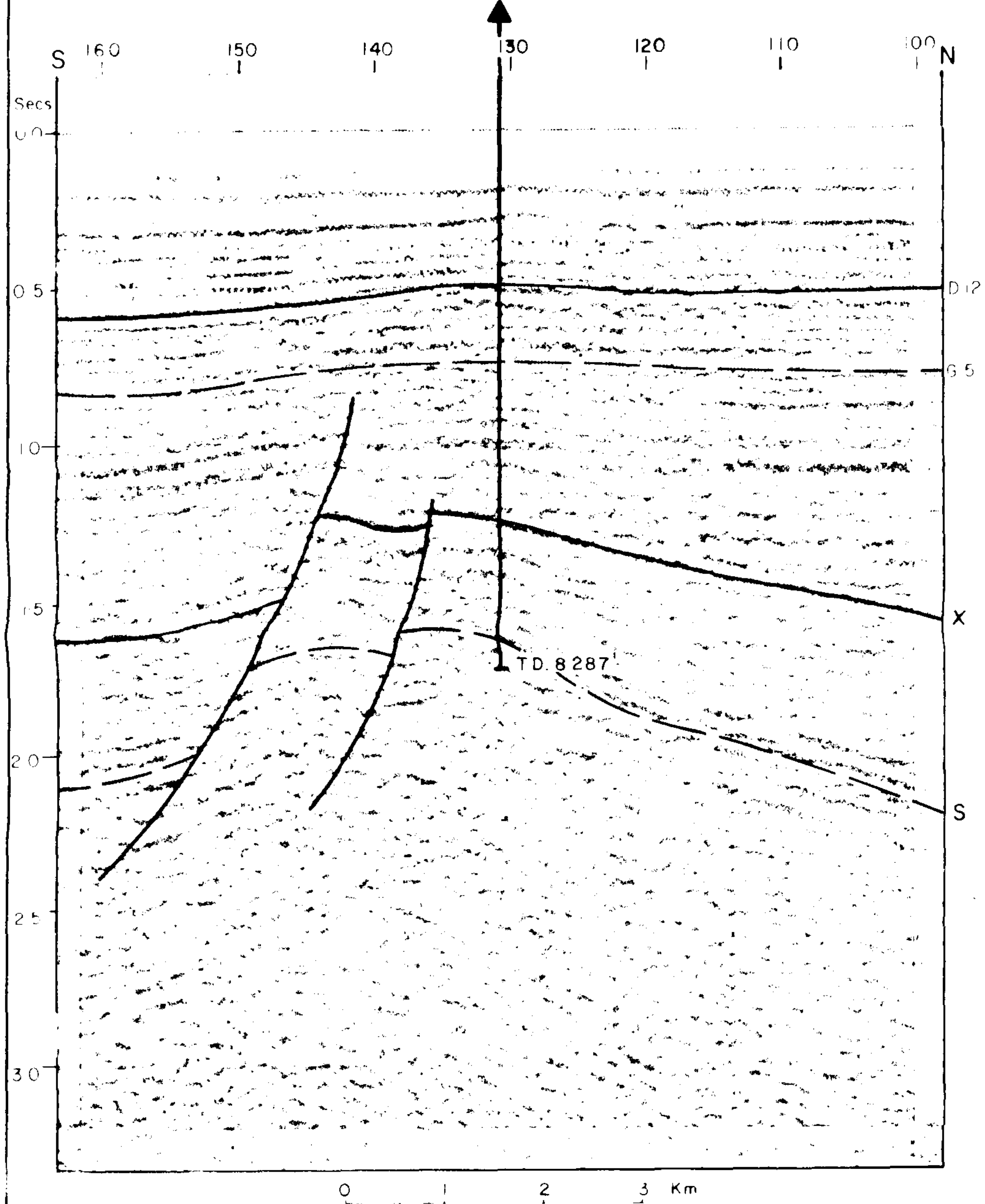
RESULTS

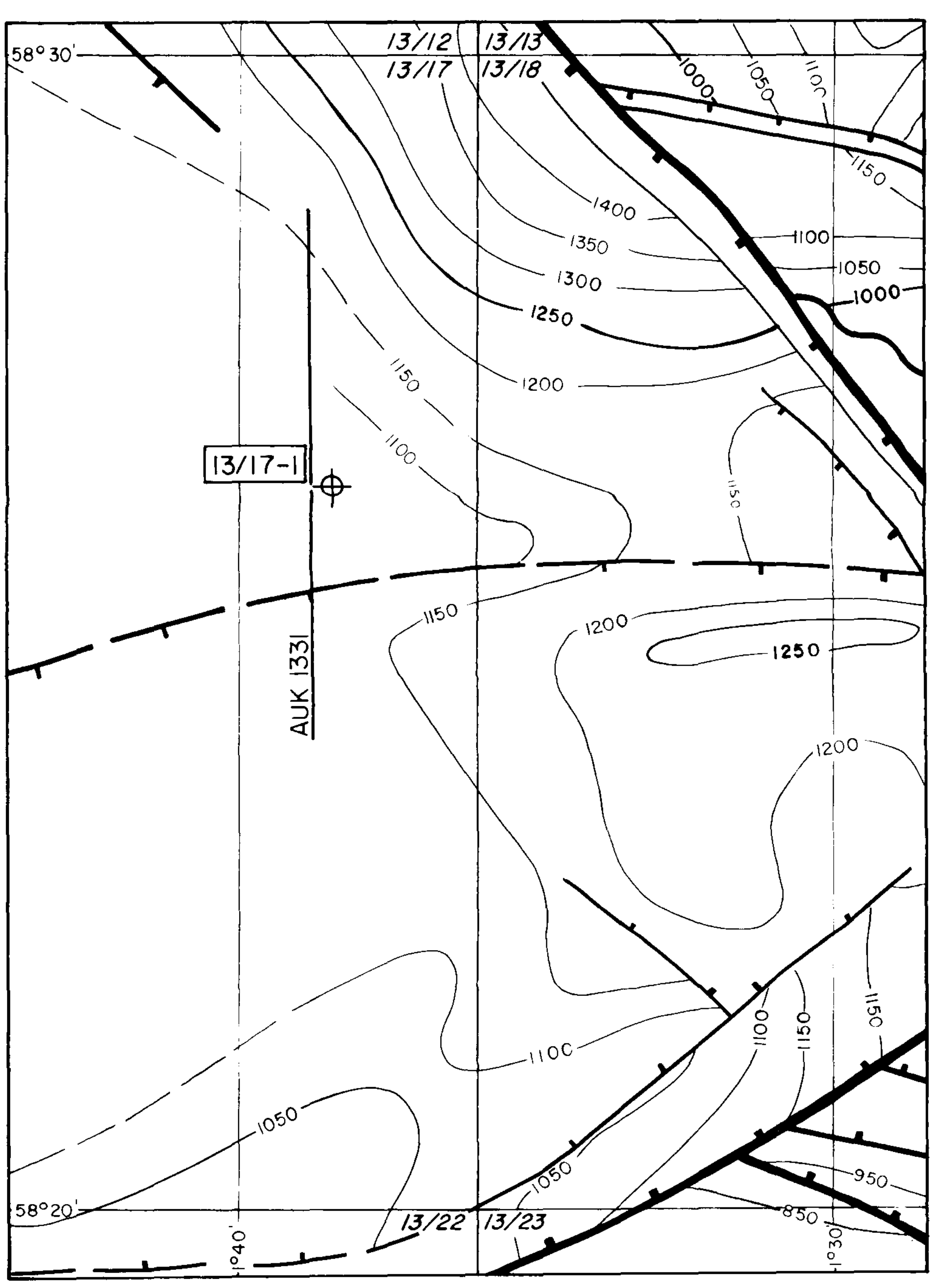
No hydrocarbons apart from gas show associated with KL coal streaks. Sandy Tertiary, thick Chalk, Shaley KL with basal sand on assumed non-reservoir quality Devonian ORS (incl. possible SR streaks).

CONCLUSIONS

Drilled too close to Horst to penetrate possible Jurassic to Carboniferous sequence.

SEISMIC LINE AUK 1331 W





REFLECTION TIME (M SEC) K.L. HORIZON?

0 1 2 3 4 5 Km

SUMMARY

LOCATION
Inner Moray Firth Basin, to west of North Halibut Shelf 140 km north of Aberdeen.

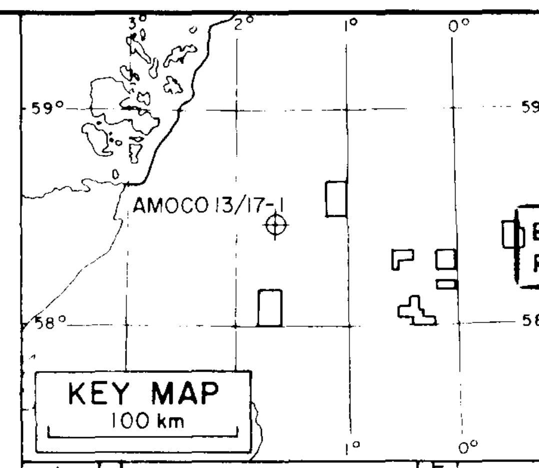
OBJECTIVE
First test in the area, probably principally for stratigraphic control.

RESULTS
Thick KL with well developed sands. Shaly JU overlying sandy Ʀ and Rotliegendes. No shows.

CONCLUSIONS
Good reservoirs present. Unable to assess structural validity of test because of lack of seismic data but absence of shows could be because of no mature Jurassic in the area.

TRADED, 210/20-1 DEC. 76.

Drawing No 22663



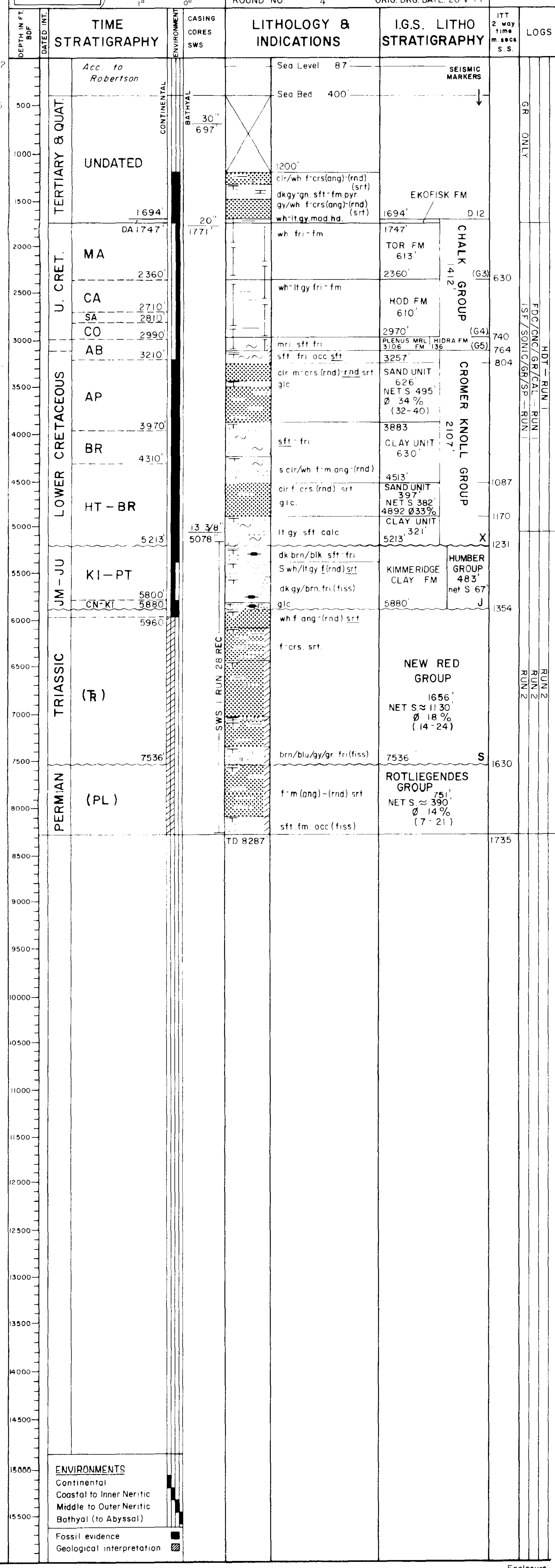
SHELL U.K. EXPLORATION & PRODUCTION

AMOCO 13/17-1

ENCLOSURE TO REPORT EP 50428

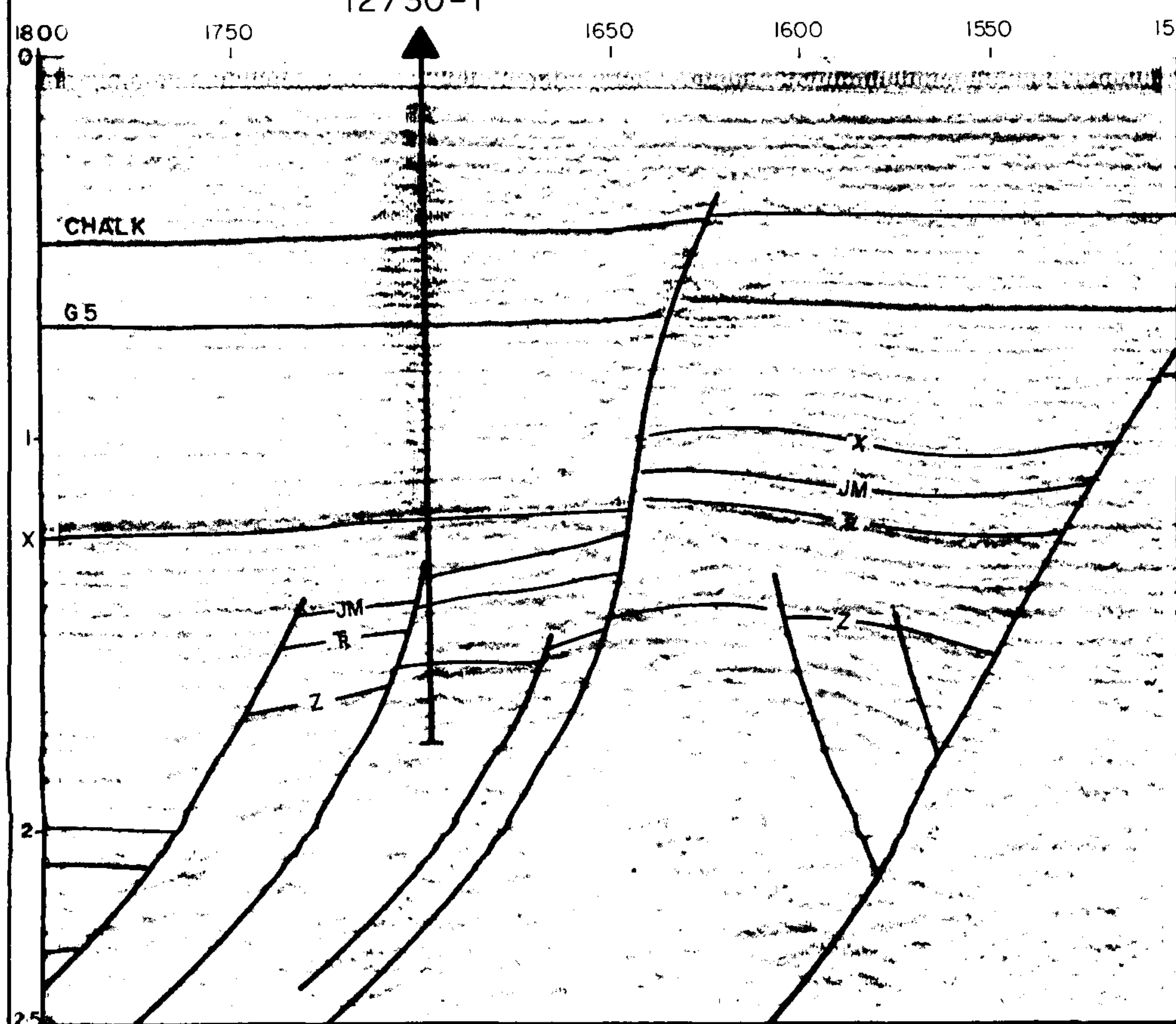
SCALE 1:10 000

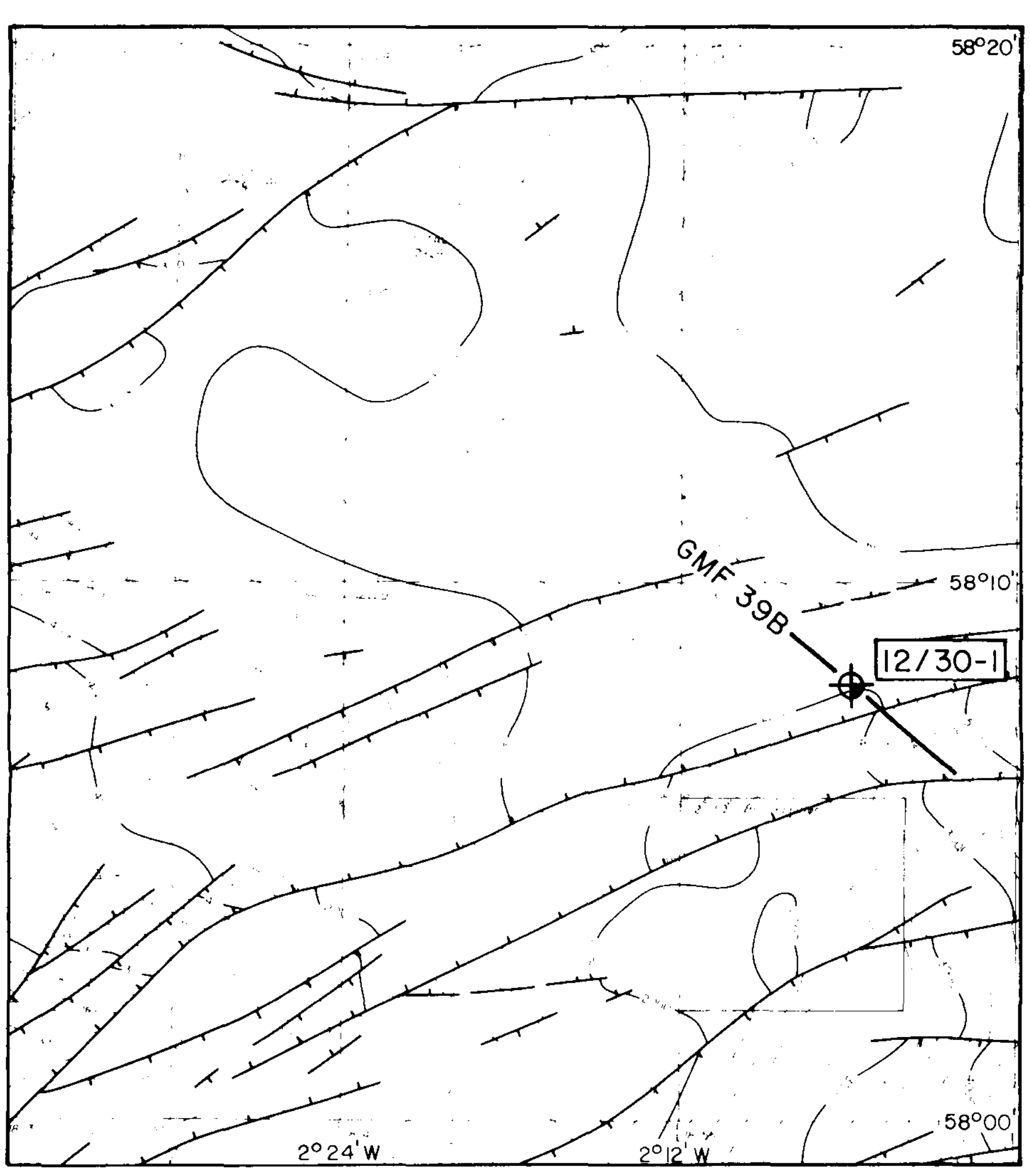
CO ORDS. LAT. 58°26'18.4" N	LONG. 01°38'26.1" W		UPDATED
ELEVATION DF 87'	RIG WAAGE 1		AUG
WATER DEPTH 313'	SPUDDED 10-10-75		1978
TOTAL DEPTH 8287'	COMPLETED 19-11-75		
LICENCE NO. P 185	TYPE COMPL. P & A		
ROUND NO. 4	ORIG. DRG. DATE 26-V-77		



Enclosure

SEISMIC LINE GMF 39 B (MIGRATED)

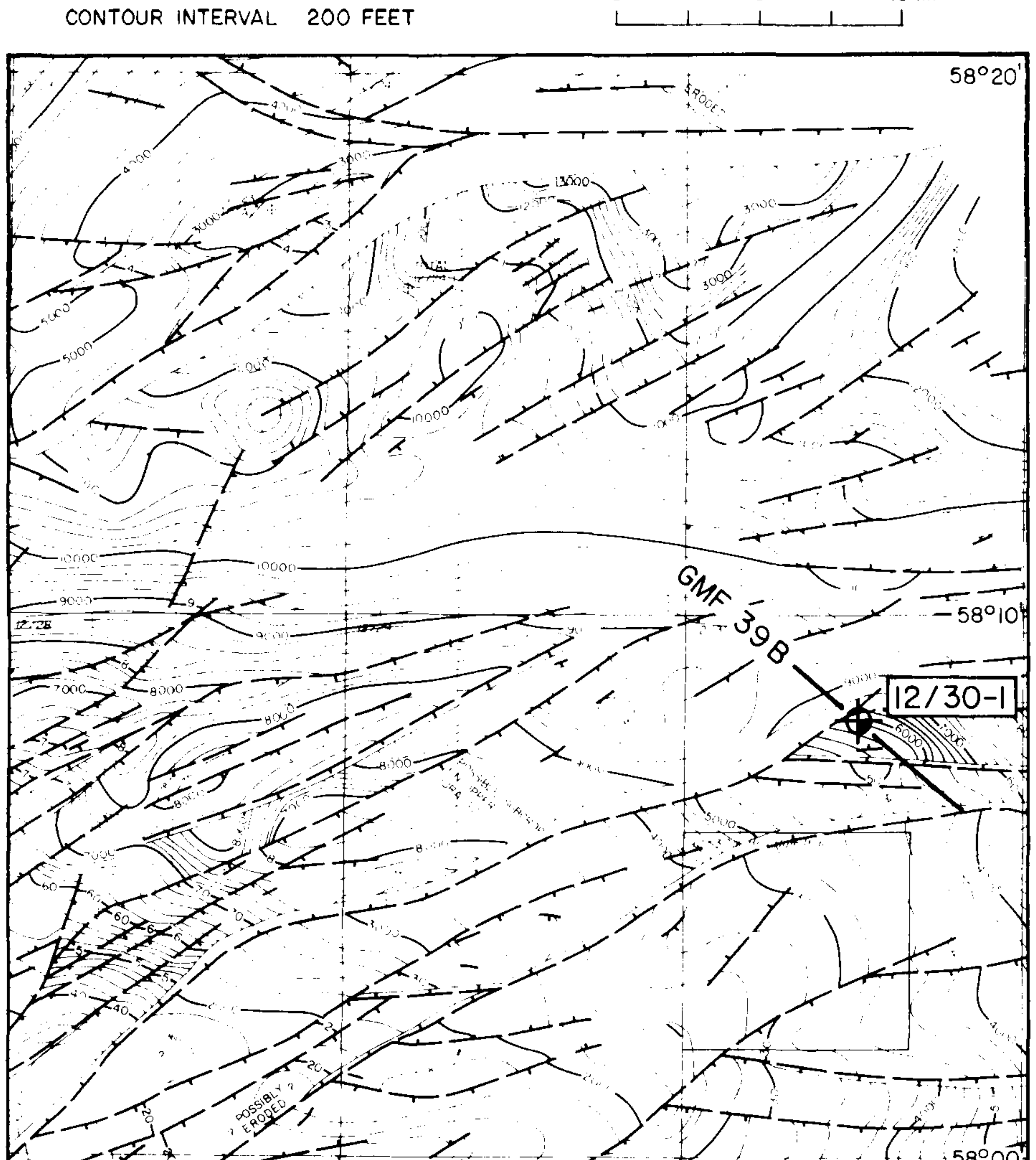




DEPTH MAP-BASE CRETACEOUS

CONTOUR INTERVAL 200 FEET

0 5 10 km



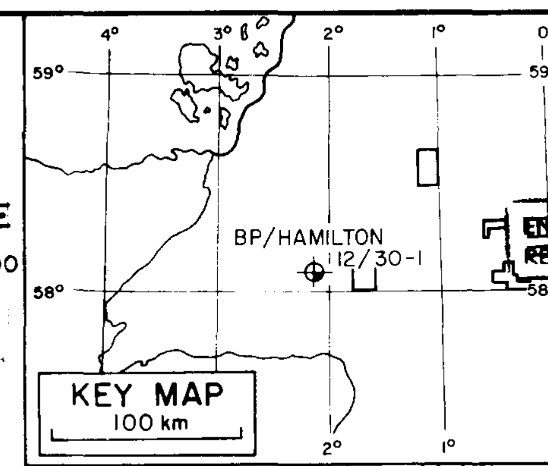
DEPTH MAP-NEAR TOP MIDDLE JURASSIC

CONTOUR INTERVAL 200 FEET

0 5 10 km

SHELL U.K. EXPLORATION & PRODUCTION

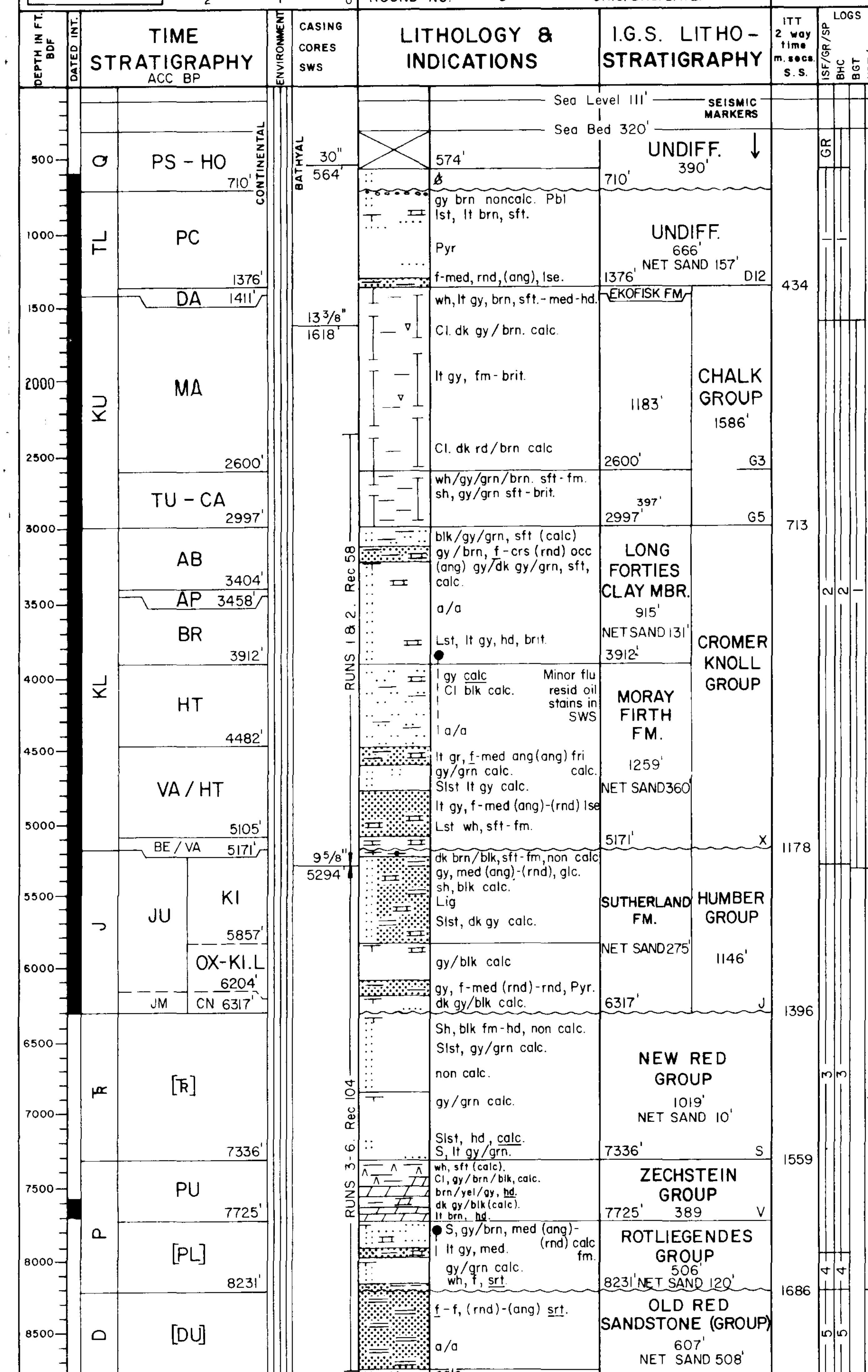
BP / HAMILTON 12/30-1



ENCLOSURE TO REPORT EP 50428

SCALE 1:10 000

CO-ORDS. LAT. 58° 08' 05·3" N	LONG. 02° 05' 51·8" W		(UPDATED)
ELEVATION DF 111'	RIG SEA QUEST		AUG 1978
WATER DEPTH 204'	SPUDDED 6-7-74		
TOTAL DEPTH 8838'	COMPLETED 15-8-74		
LICENCE NO. P 094	TYPE COMPL. P & A		
ROUND NO. 3	ORIG. DRG. DATE. MAR. 76		



SUMMARY

LOCATION. Inner Moray Firth 22 km. S.E. of 12/24-1

OBJECTIVES (acc BP). To obtain stratigraphical information from the Mesozoic, and to investigate possible hydrocarbon accumulations in Jurassic and Triassic sands.

RESULTS. Minor oil and gas shows in Lower Cretaceous and Lower Permian. T.D. in probable Upper Devonian. Jurassic reservoir water bearing, source rock present. Lower Cretaceous sands fresh water bearing.

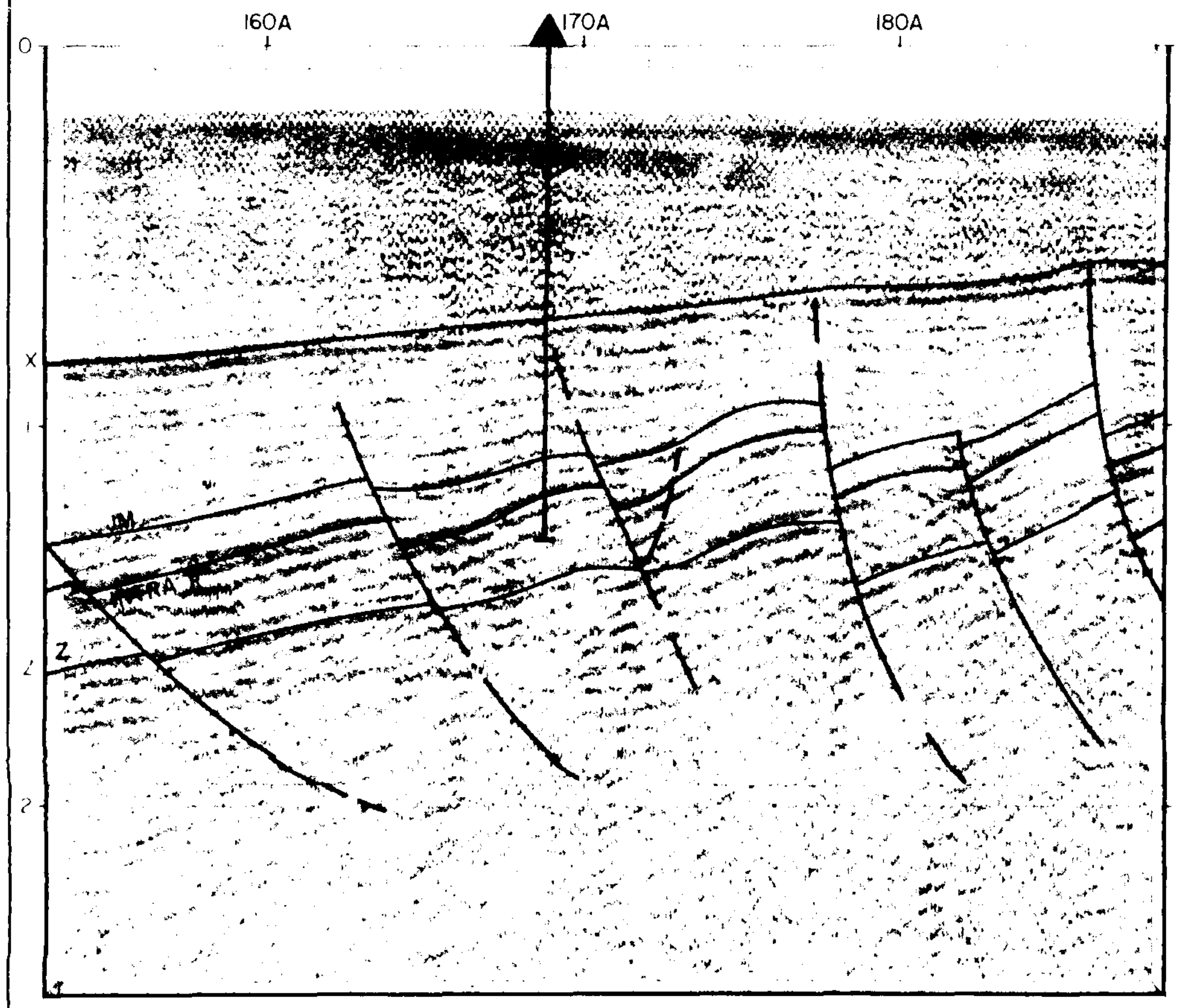
CONCLUSIONS. Valid test of dip and fault closed structures at top and base "JU" (X-J). Oil generated but probably a lack of seal between JU and KL (latter probably flushed by meteoric water during Tertiary). Shows in Rotliegend possibly generated from the Zechstein.

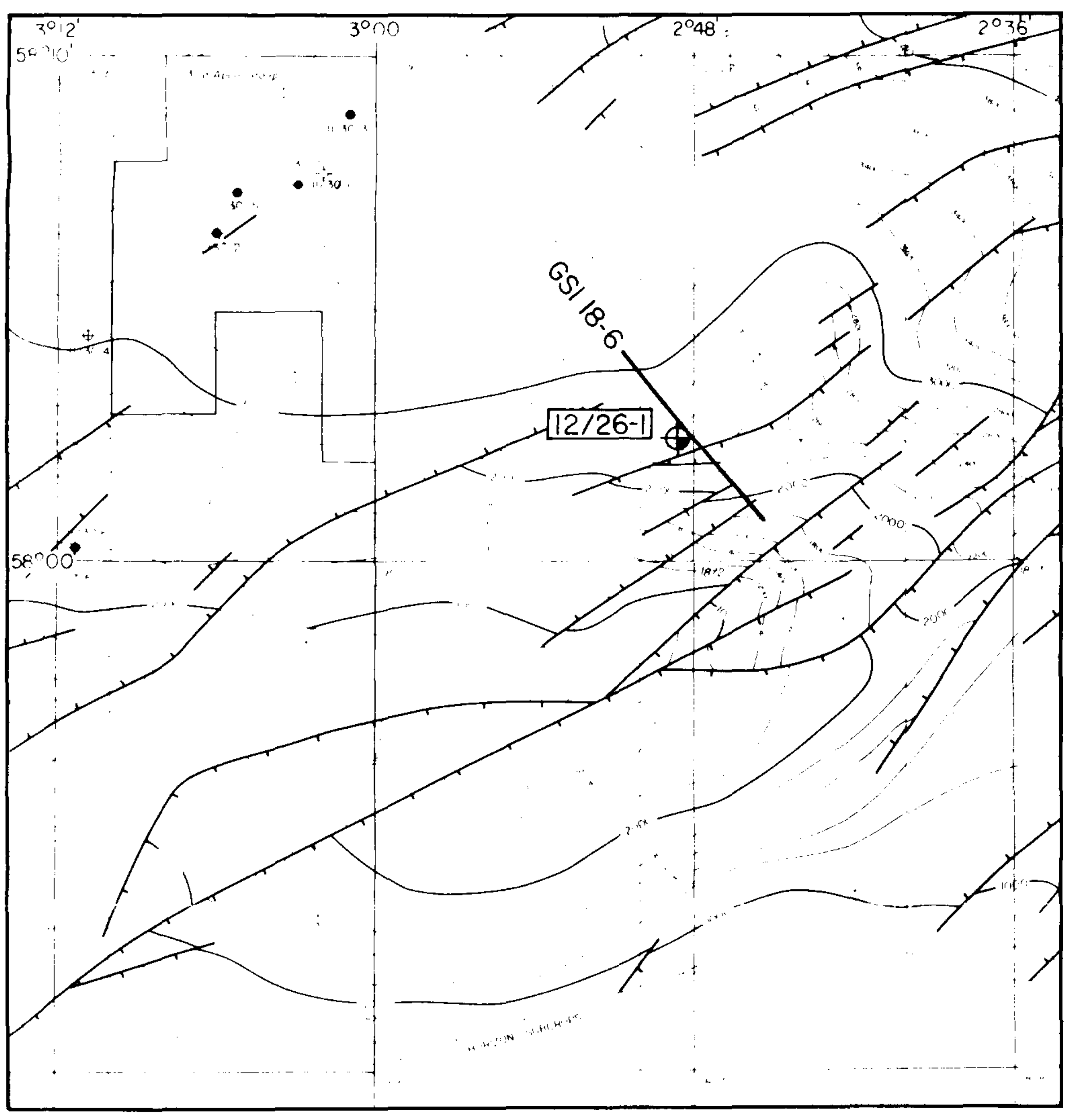
TRADED FOR. 8/27a-1 in January 1976

Drawing No 22662

Enclosure 17

SEISMIC LINE GSI 18-6

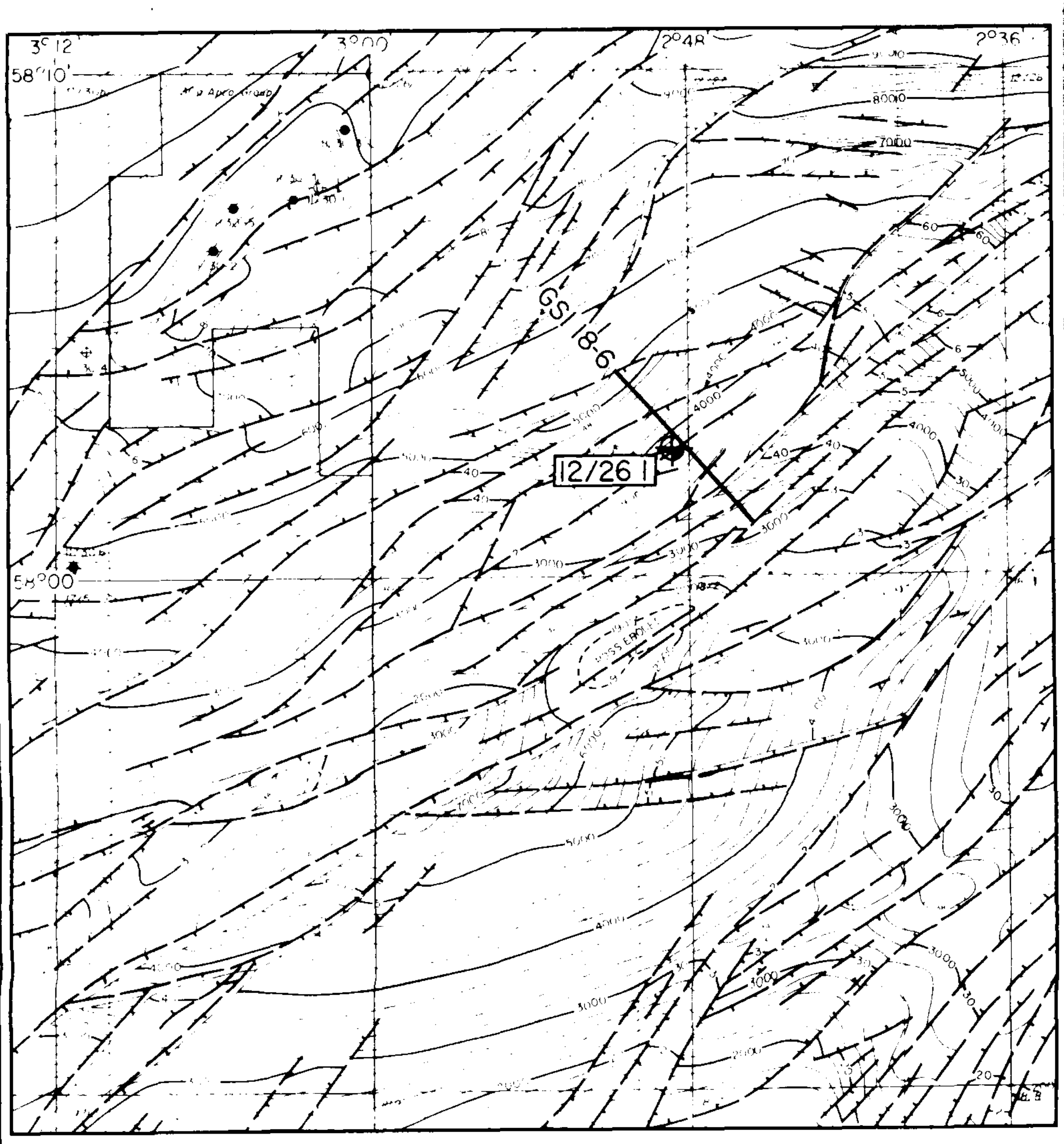




DEPTH MAP-BASE CRETACEOUS

CONTOUR INTERVAL 200 FEET

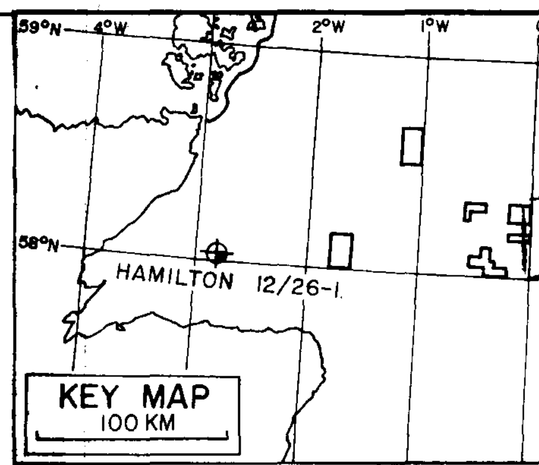
0 5 10 km



DEPTH MAP-NEAR TOP MIDDLE JURASSIC

CONTOUR INTERVAL 200 FEET

0 5 10 km



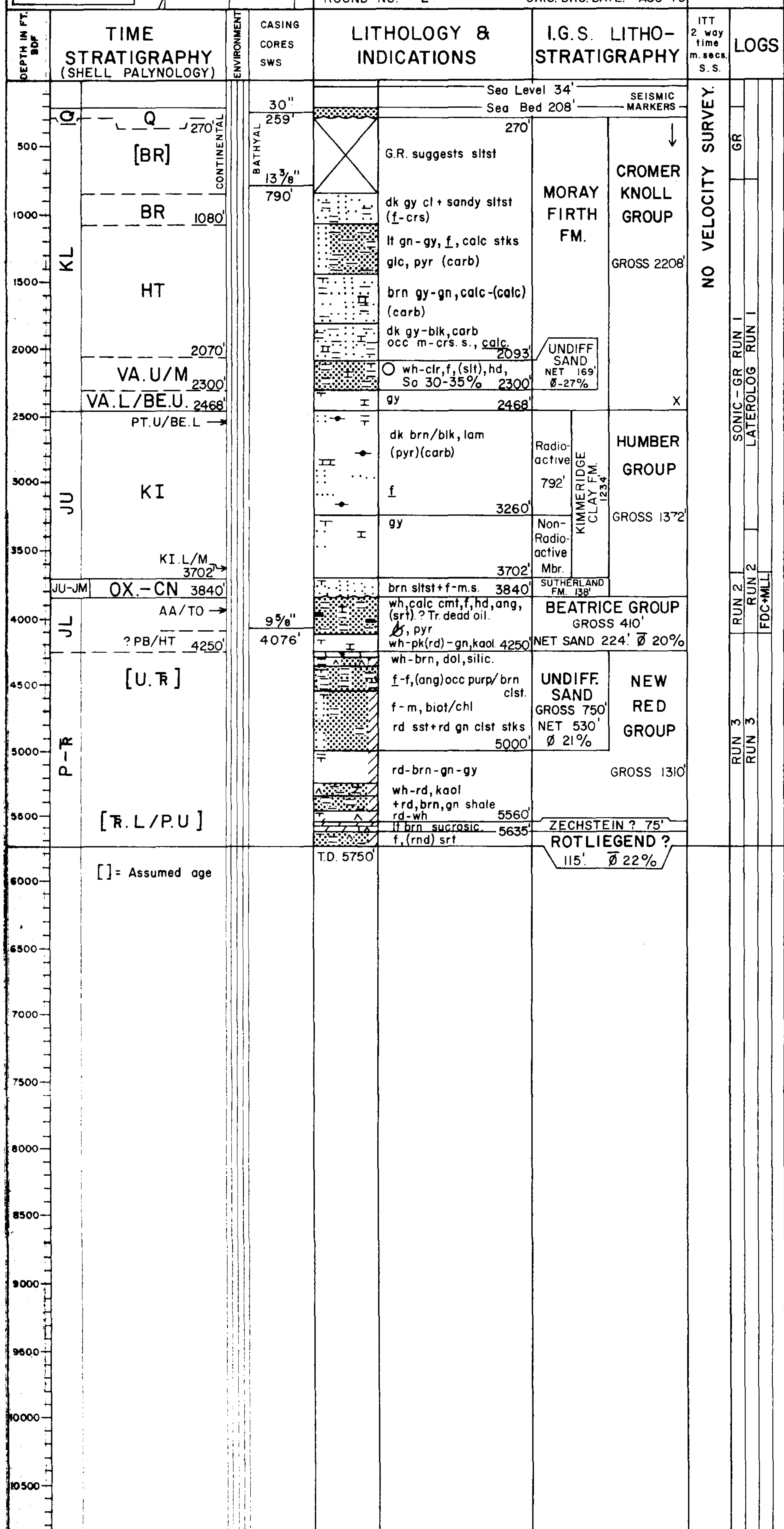
SHELL U.K. EXPLORATION & PRODUCTION

HAMILTON 12/26-1

ENCLOSURE TO
REPORT EP 50428

SCALE 1:10 000

COORDINATES LAT. 58°02'26.9N LONG. 02° 48' 37.4" W		AUG. 1978
ELEVATION DF 34'	RIG GLOMAR IV	
WATER DEPTH 174'	SPUDDED 28-7-67	
TOTAL DEPTH 5750'	COMPLETED 18-8-67	
LICENCE NO. P. 074	TYPE COMPL. P & A	
ROUND NO. 2	ORIG. DRG. DATE. AUG 73	



SUMMARY

LOCATION

Southern side of Moray Firth Basin, about 35 km offshore and 60 km due East of Jurassic outcrops near Brora.

OBJECTIVES

According to Hamilton prognosis, they expected to find basal Permian sands draping a Devonian high at a level which subsequently proved to be top Jurassic. No obvious closure at location.

RESULTS

Succession in 12/21-1, 12/22-1 & 12/23-1 confirmed and facies change in JU to thick SR interval discovered. Zechstein reduced and probably replaced by siliciclastic marginal facies. Poor oil shows in KL sands (7' net), salinity 13 g/l. No shows in pre-Cretaceous JL sands salinity 9 g/l. Triassic sands 6 g/l and sands at TD 13 g/l.

CONCLUSIONS

Structure doubtful. Probably not valid test of any trap. Low salinities may imply meteoric invasion after uplift of basin.

Drawing No. 22661

Enclosure 16

SHELL U.K. EXPLORATION & PRODUCTION

PETROSWEDE / TOTAL 12/24-1

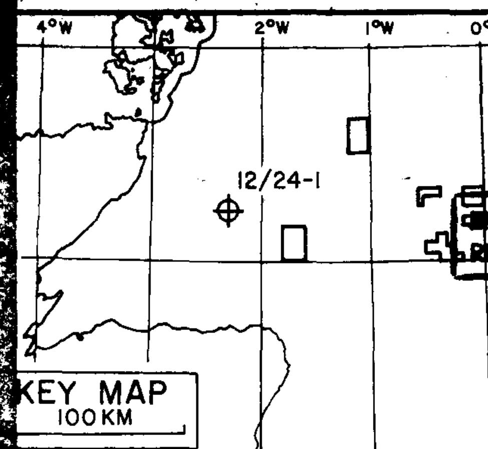
NFW

ENCLOSURE TO REPORT EP 30928

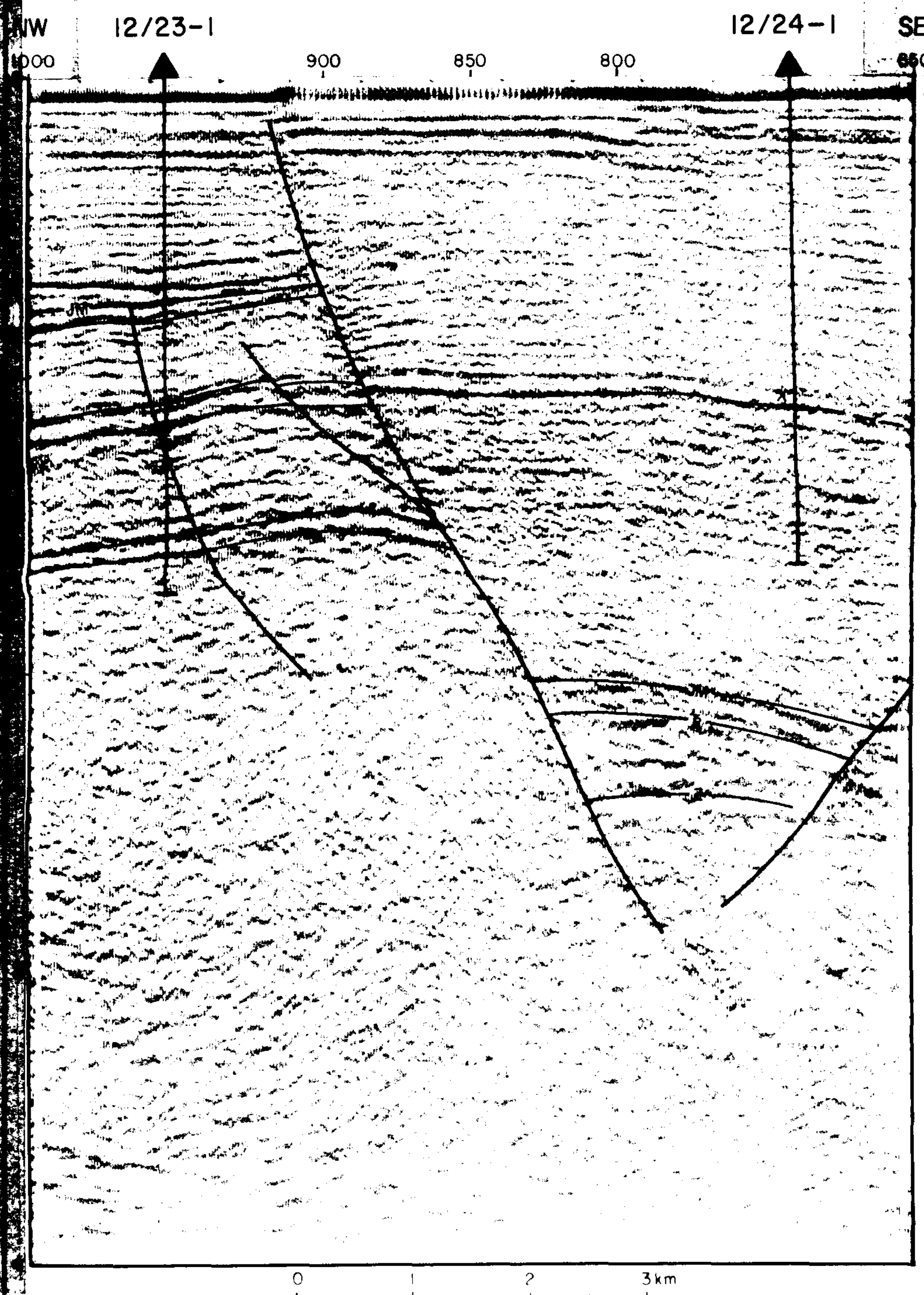
SCALE 1:10 000

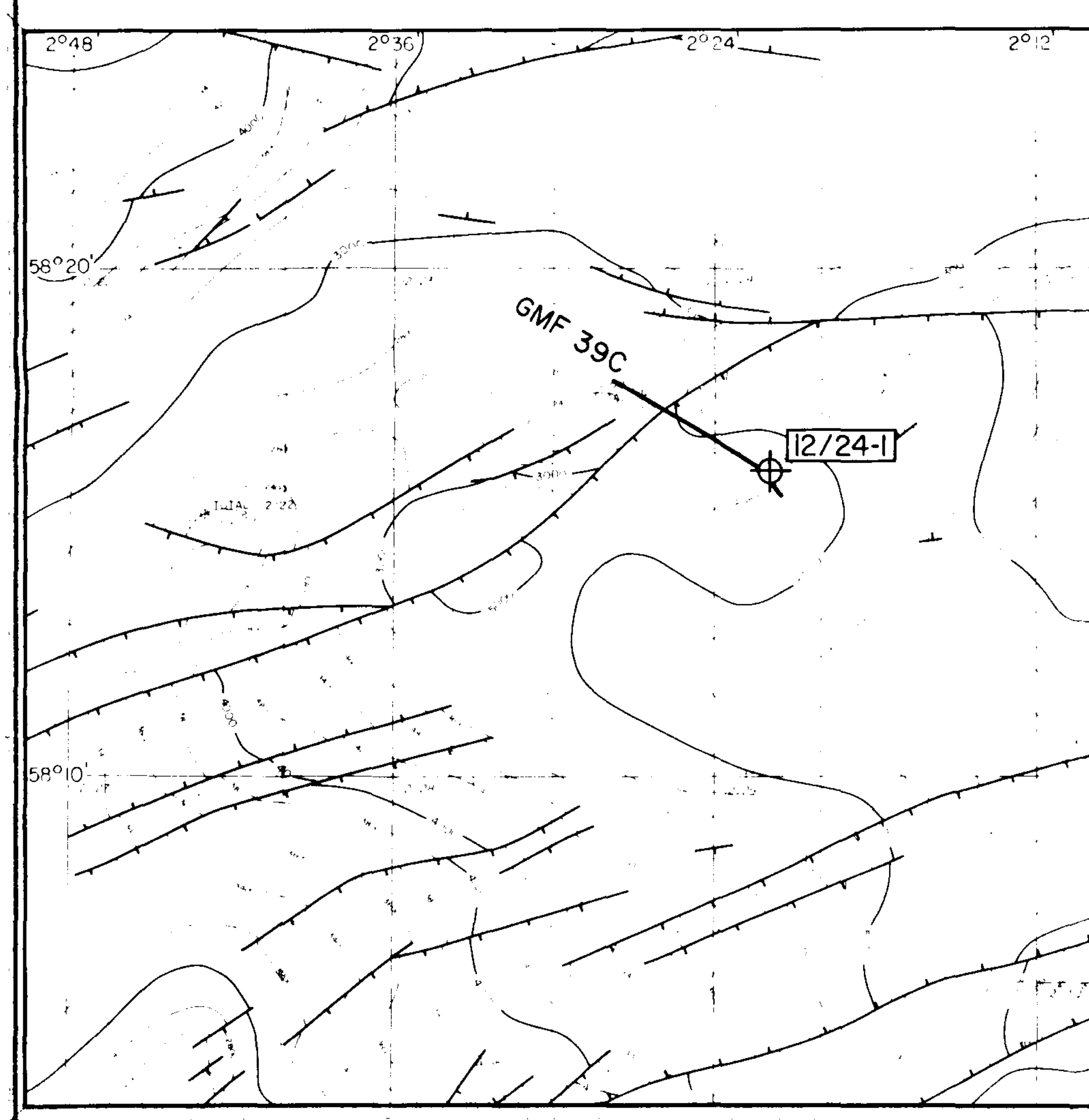
COORDINATES LAT. 58° 16' 05" N LONG. 02° 21' 59" W	RIG BLUEWATER III
ELEVATION DF 64'	SPUDDED 8-4-75
WATER DEPTH 178'	COMPLETED 12-5-75
TOTAL DEPTH 8014'	TYPE COMPL. P & A.
LICENCE NO. P. 089	ORIG. DRG. DATE. 9-IX-75
ROUND NO. 2	

AUG 1978



SEISMIC LINE GMF 39C
(MIGRATED)

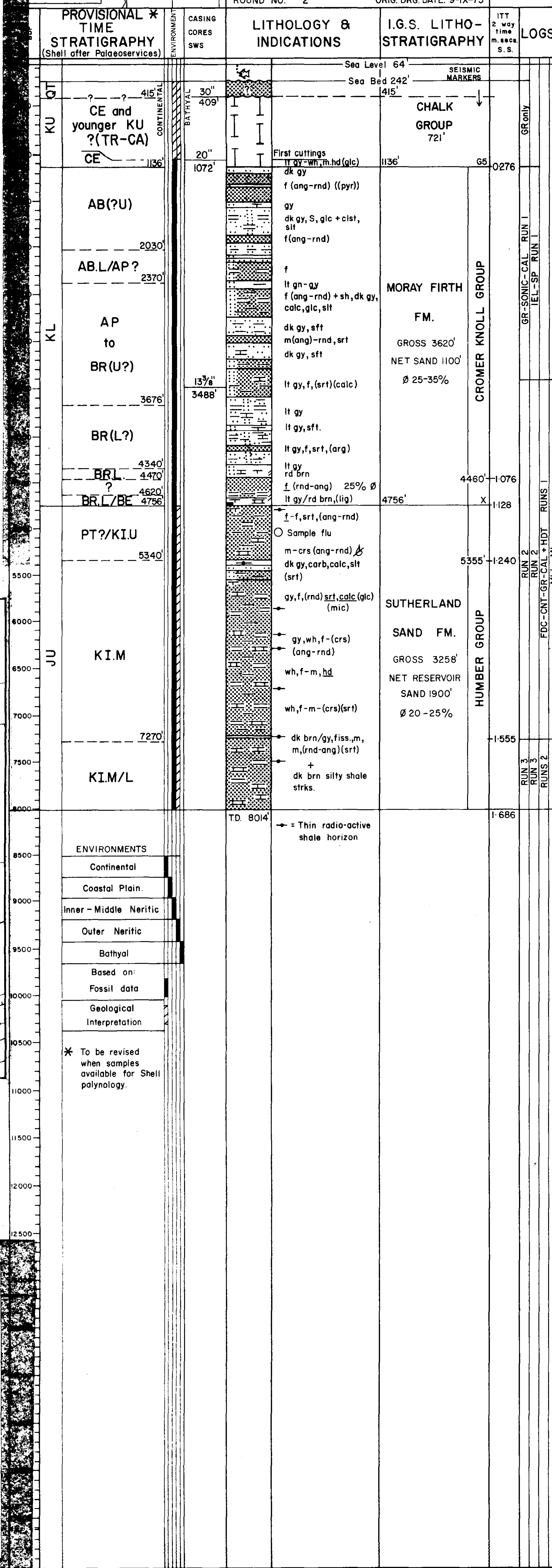




DEPTH MAP - BASE CRETACEOUS

CONTOUR INTERVAL: 200 FEET

0 5 10 km.



SUMMARY

LOCATION

Inner Moray Firth, 45 km ESE of Wick. Drilled on fault/dip closure on downthrownside of major fault, 8 km SE of 12/23-1.

OBJECTIVES

Assumed test of KL-J on downthrown side of fault (hydrocarbons found in 12/23-1).

RESULTS

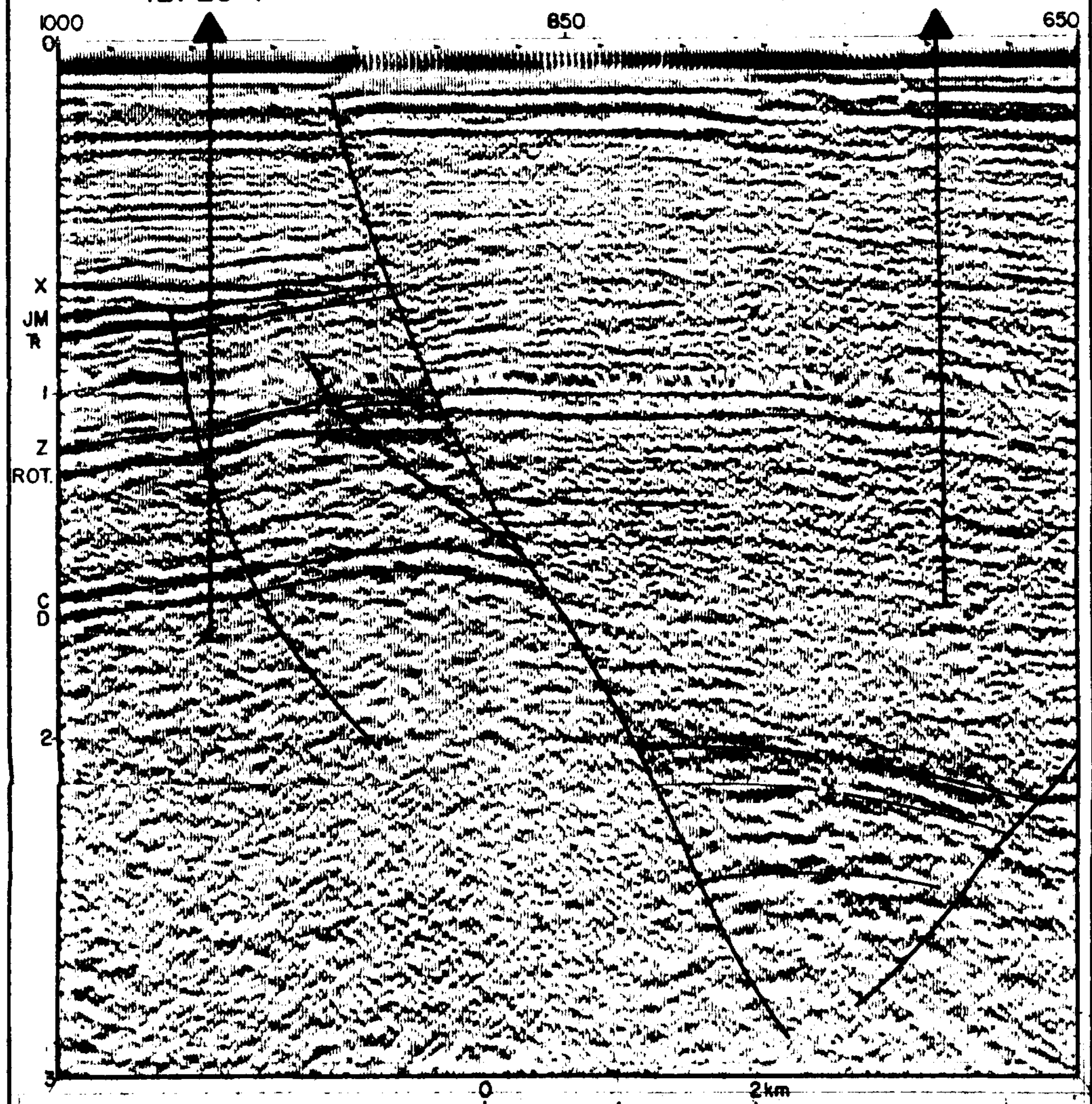
Well almost entirely sandy KL to Jurassic throughout with no shows. Thin beds of organic shale in Jurassic.

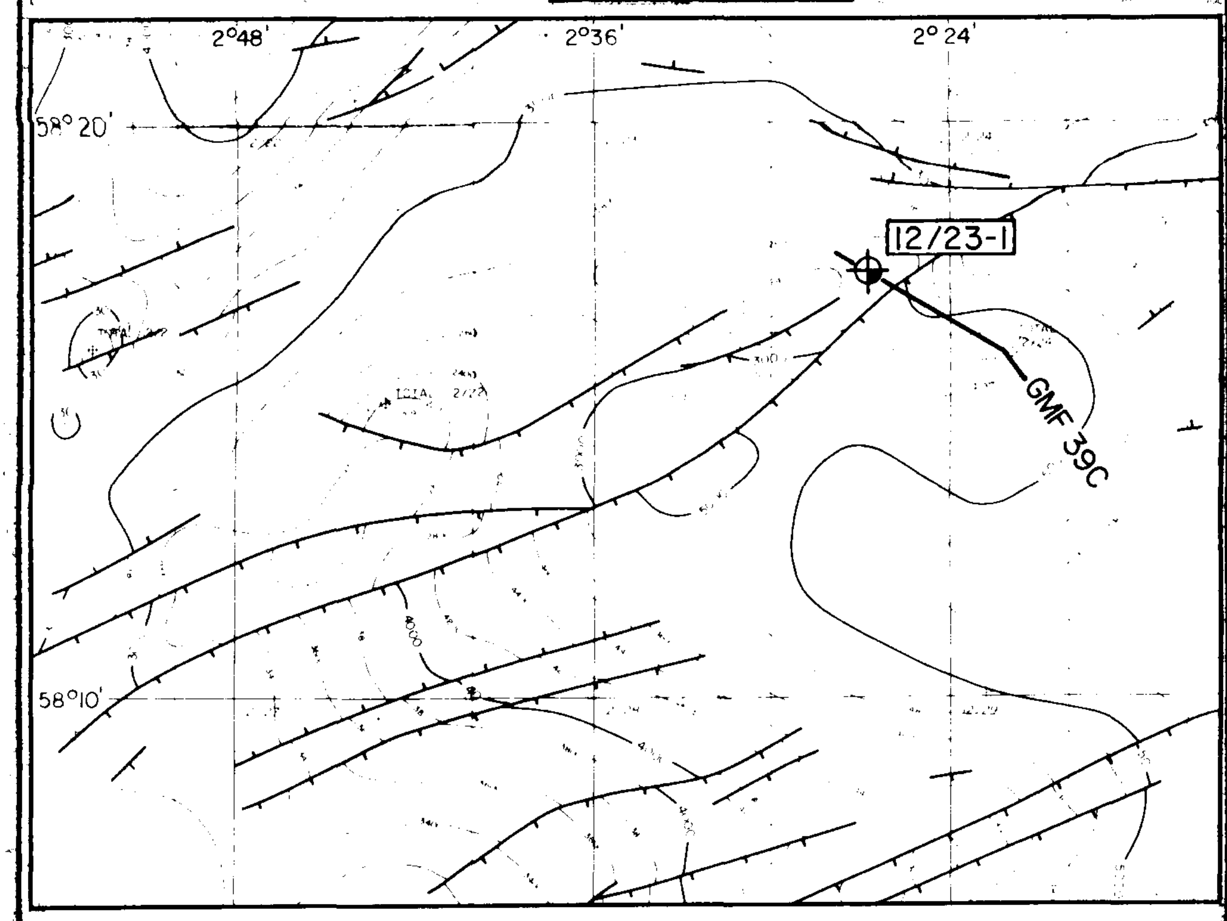
CONCLUSIONS

Pre Jurassic unknown. Jurassic should be mature but no shows and predominence of sands suggests no trap due to lack of seal.

Enclosure 15

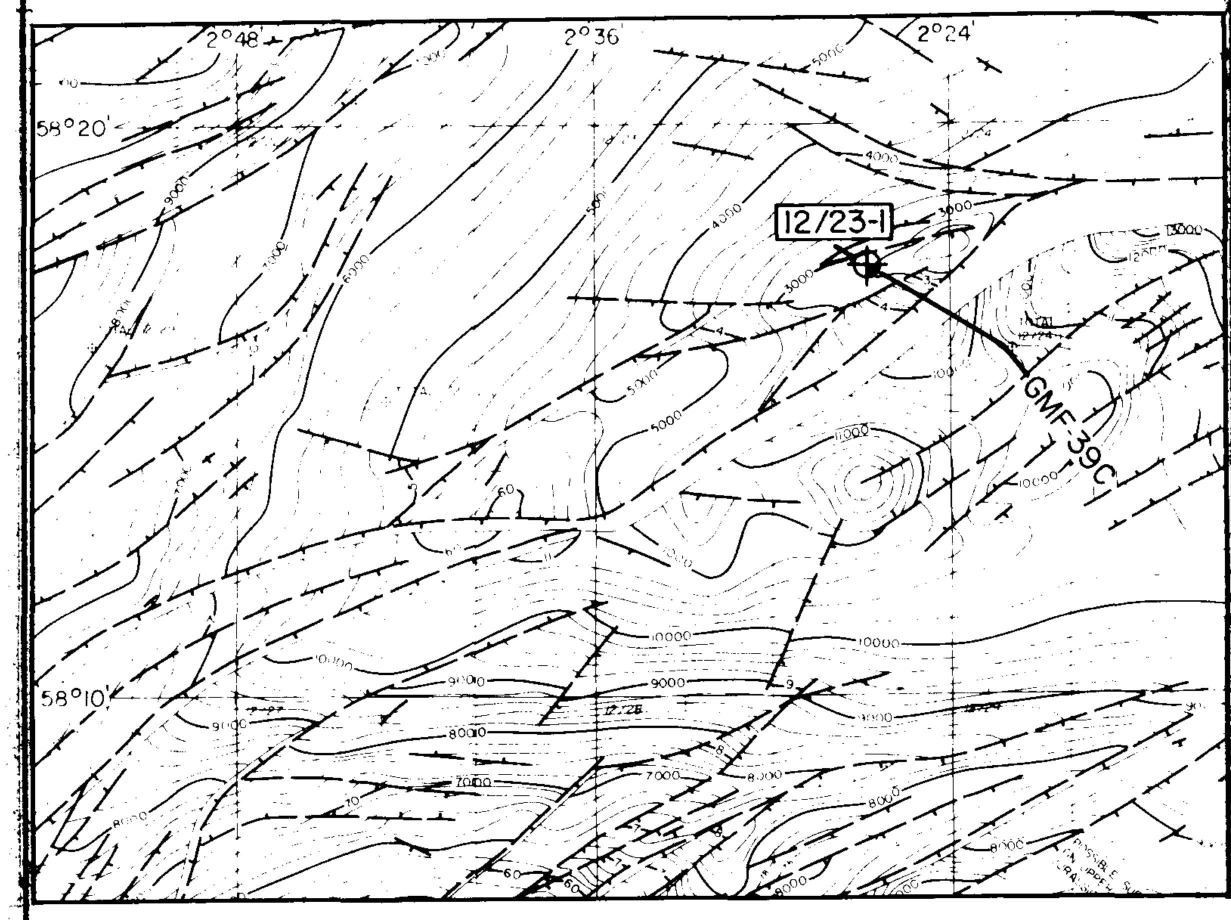
SEISMIC LINE GMF 39C (MIGRATED)





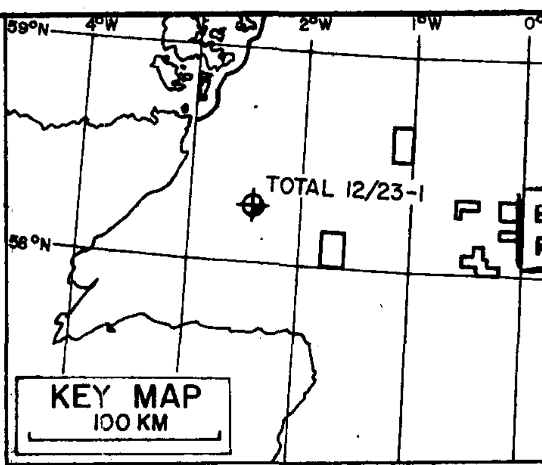
DEPTH MAP-BASE CRETACEOUS

CONTOUR INTERVAL 200 FEET 0 5 10 km



DEPTH MAP-NEAR TOP MIDDLE JURASSIC

CONTOUR INTERVAL 200 FEET 0 5 10 km



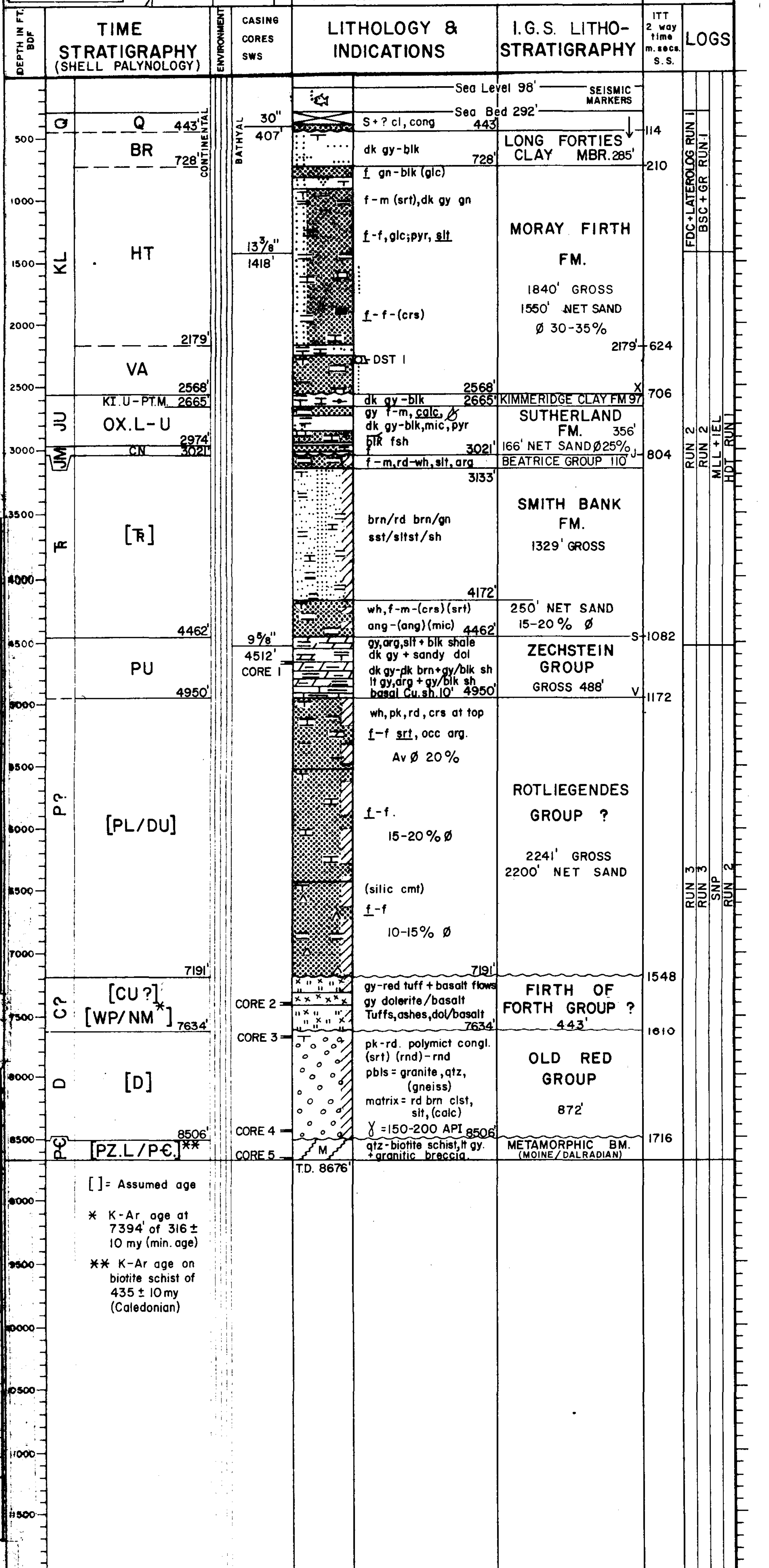
SHELL U.K. EXPLORATION & PRODUCTION

TOTAL 12/23-1

ENCLOSURE TO REPORT EP 50498

SCALE 1:10 000

COORDINATES LAT. 58° 17' 30" N	LONG. 02° 26' 45" W	AUG 1978
ELEVATION DF 98'	RIG. ENDEAVOUR	
WATER DEPTH 194'	SPUDDED 22-8-67	
TOTAL DEPTH 8676'	COMPLETED 29-9-67	
LICENCE NO. P. 089	TYPE COMPL. P & A	
ROUND NO. 2	ORIG. DRG. DATE. 7-X-70	



SUMMARY

LOCATION

50 km E of Scottish coast (Sutherlandshire). Inner Moray Firth Basin, Central North Sea. Previously undrilled (12/26-1 drilled at same time).

OBJECTIVES

Test of dip and fault closed structures at different levels.

RESULTS

Oil shows in KL sands. Tested water only. Thin Jurassic (incomplete). Thick Permo Trias. Carboniferous igneous. Devonian on basement.

CONCLUSIONS

Potential reservoirs at several levels. Oil generated in the basin. Best structure dry. Possible down dip JM truncation present.

TEST DATA

DST No. 1 (Cased hole)

Perforated 2242' - 2277'
2285' - 2305'

First opening time: 3 mins.
First shut-in time: 45 mins.
Second opening time: 19 mins. - good flow, decreasing slowly and stopping after 22 mins.

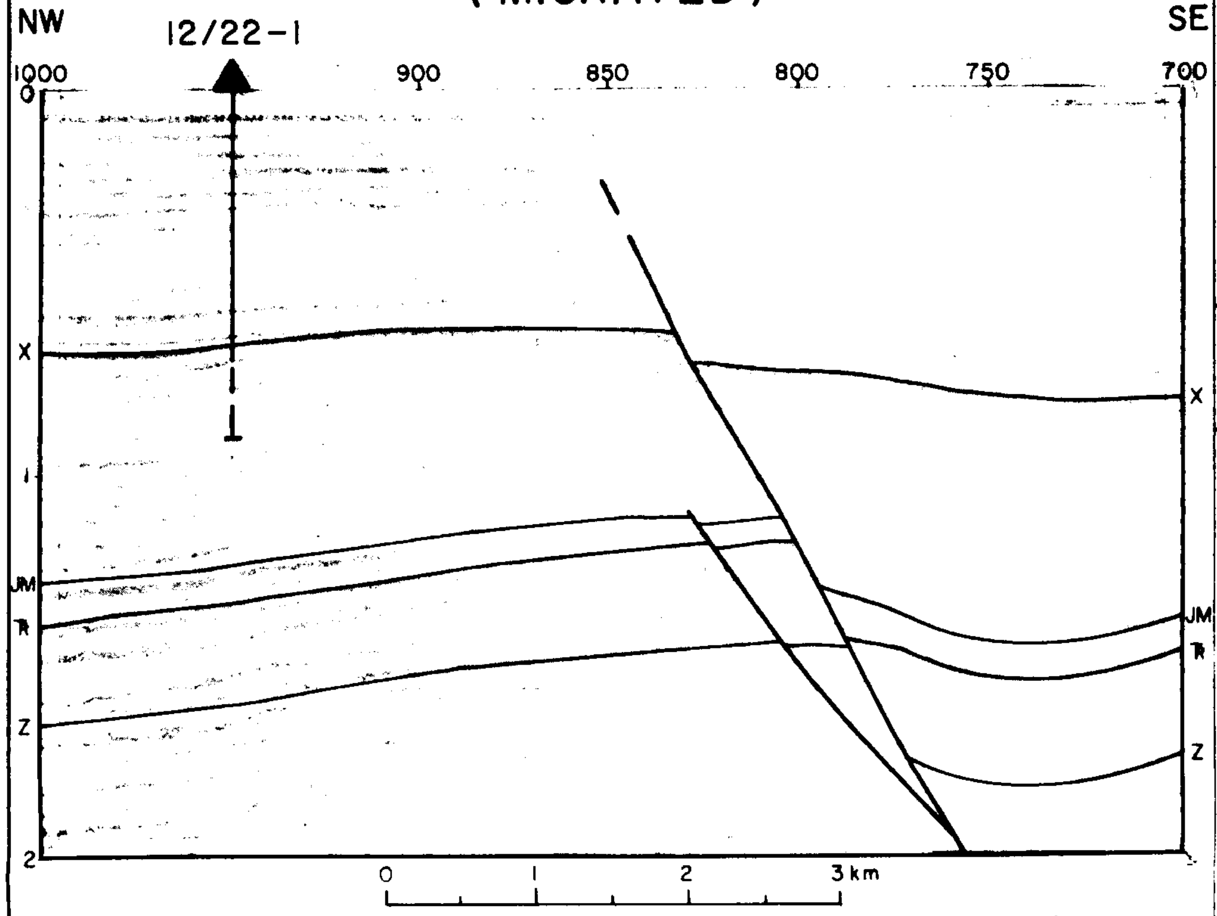
Final shut-in time: 120 mins.

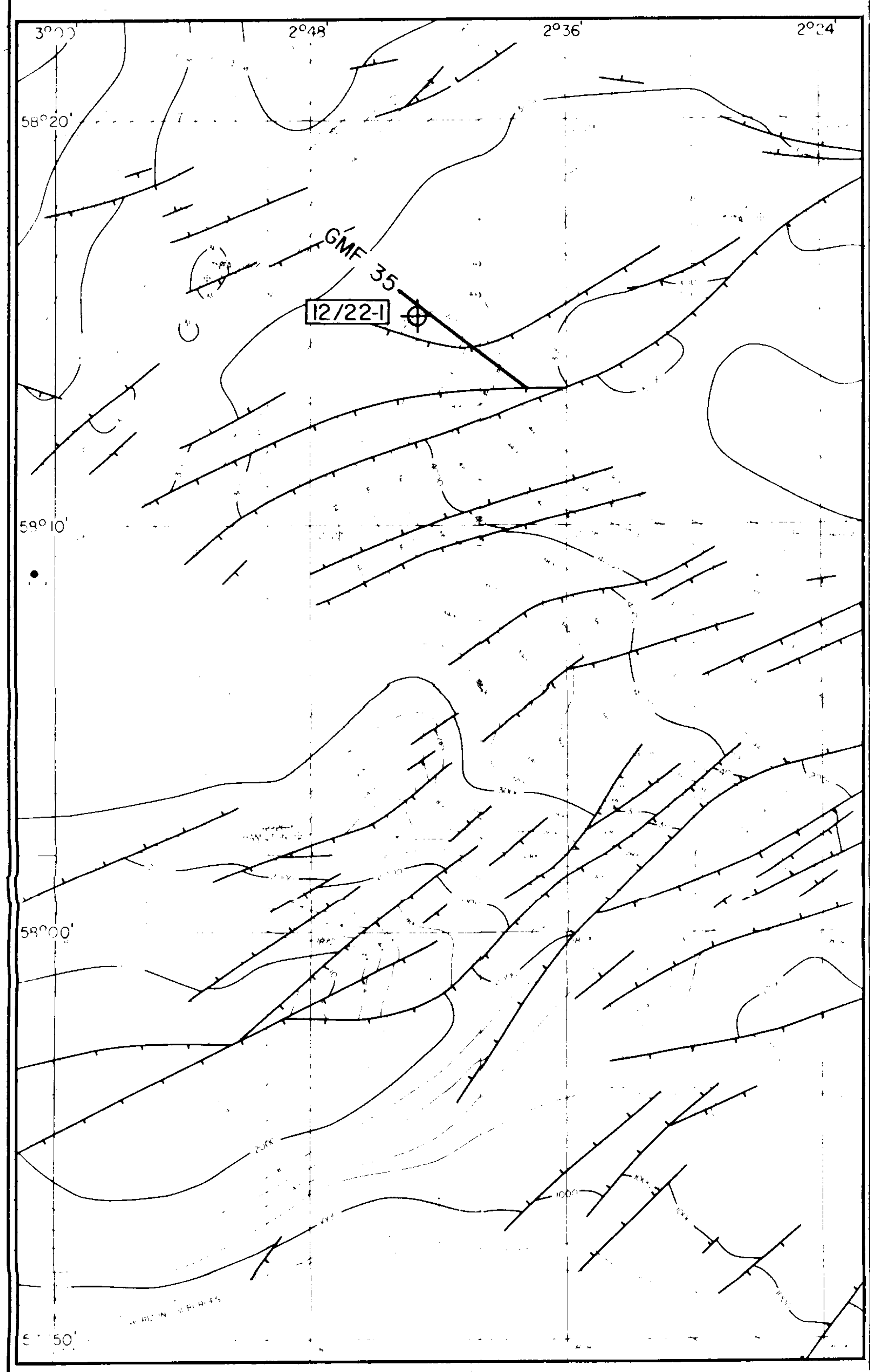
Recovered 22 bbl of water (10 g/l)

Pressures

	Upper Recorder (2173')	Lower Recorder (2316')
IHMP	1110, 2 psi	1184, 4 psi
ISIP	936, 2 psi	1002, 2 psi
IFP	819, 1 psi	951, 9 psi
FFP	936, 2 psi	1000, 0 psi
FSIP	938, 3 psi	1000, 0 psi
FHMP	1095, 3 psi	1169, 2 psi

SEISMIC LINE GMF 35 (MIGRATED)





DEPTH MAP-BASE CRETACEOUS

CONTOUR INTERVAL: 200 FEET

0 5 10 km

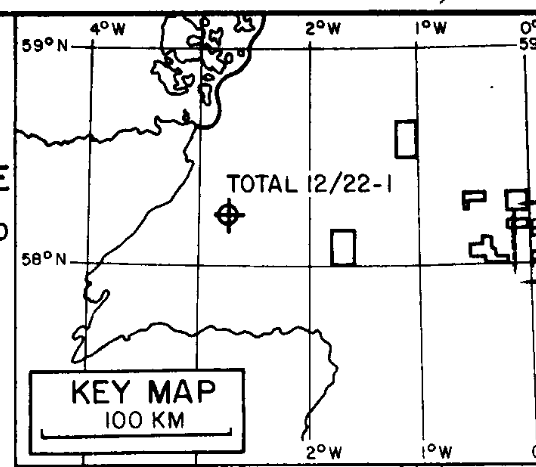
SUMMARY

LOCATION
Inner Moray Firth 50 km from E Sutherlandshire coast. Minor closure on major structure drilled by 12/23-1 updip in 1967.

OBJECTIVES
Test Lower Cretaceous and Jurassic sand sections after oil shows found in 12/23-1 KL.

RESULTS
Thick sandy KL-JU sections but no shows.

CONCLUSIONS
Confirms good reservoirs in Moray Firth but tested largest structure dry to JU level. The fault closure and sandy section have caused seal problems.



SHELL U.K. EXPLORATION & PRODUCTION

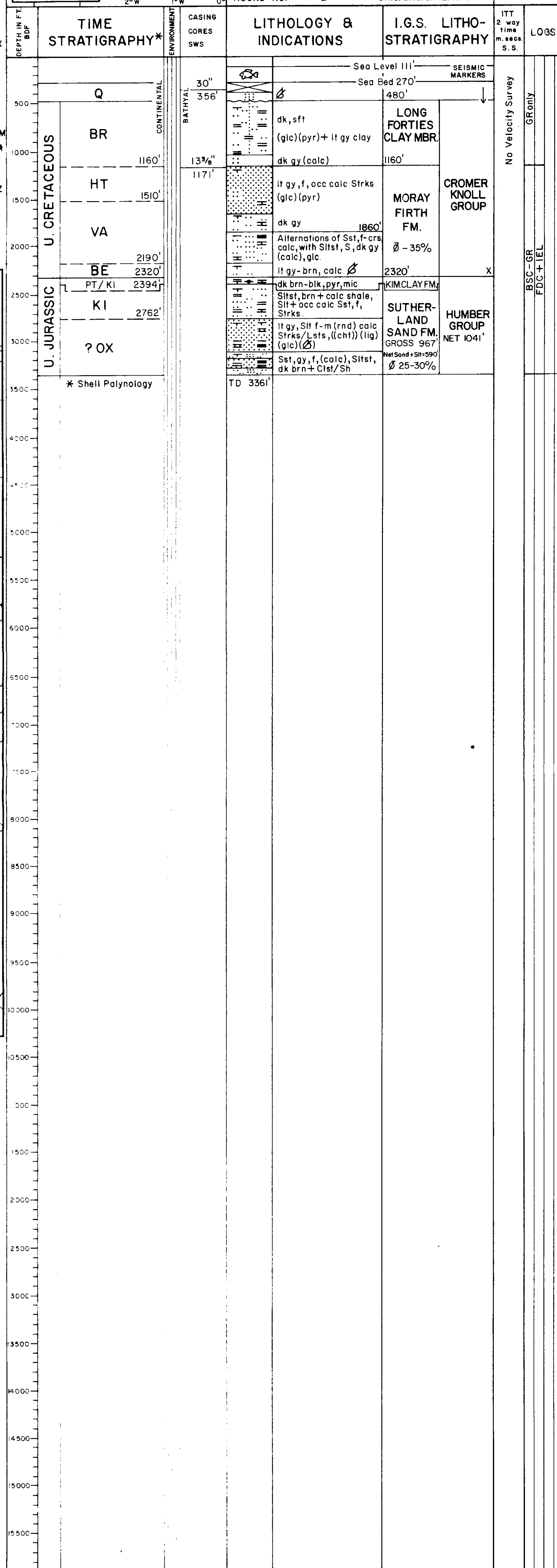
TOTAL 12/22-1

ENCLOSURE TO REPORT EP 50928.

SCALE 1:10 000

COORDS LAT	58°15'11"N	LONG.	02°42'58"W
ELEVATION DF	111'	RIG	MAERSKE EXPLORER
WATER DEPTH	159'	SPUDDED	3·7·69
TOTAL DEPTH	3361'	COMPLETED	11·7·69
LICENCE NO.	P089	TYPE COMPL.	P & A
ROUND NO.	2	ORIG. DRG. DATE.	XI·71

AUG 1978



CONFIDENTIAL

Drawing No. 22658

Enclosure 13

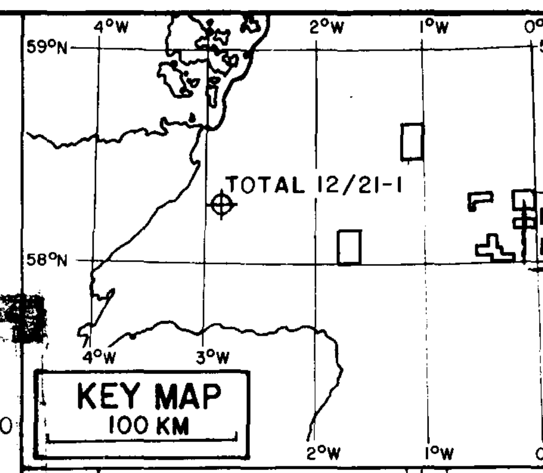
SHELL U.K. EXPLORATION & PRODUCTION

TOTAL 12/21-1

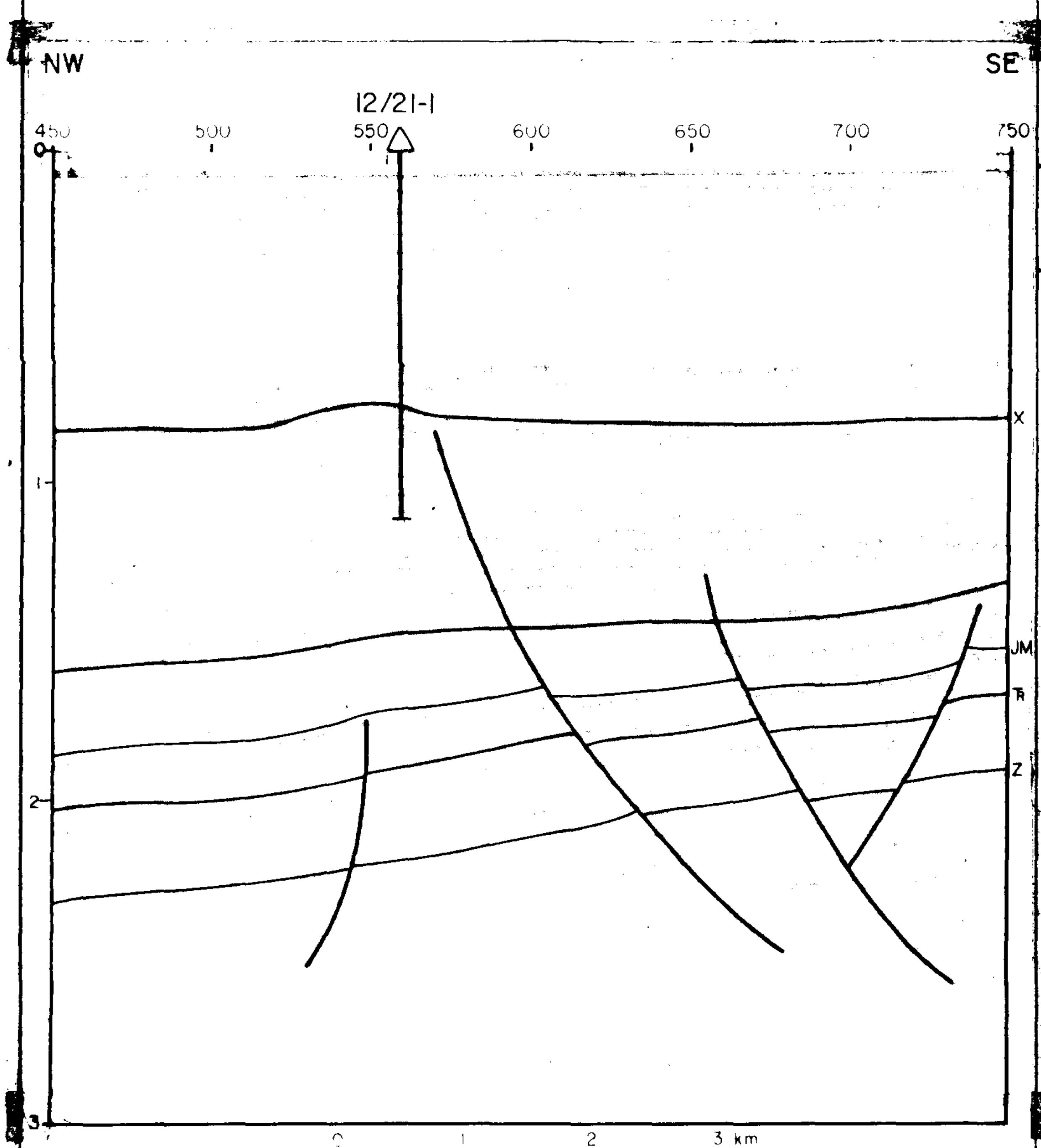
ENCLOSURE TO REPORT EP 50428

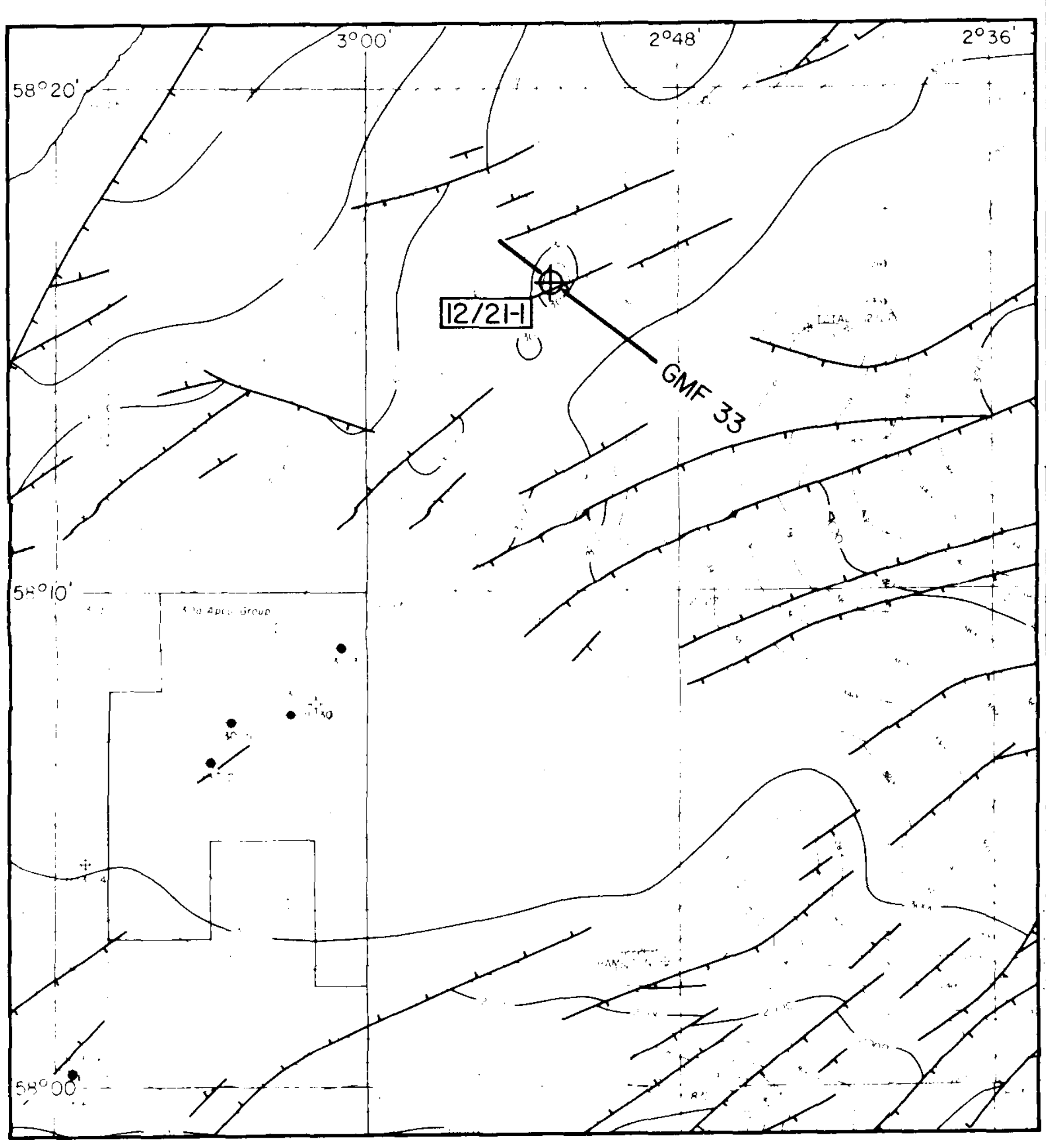
SCALE 1:10 000

COORDINATES LAT. 58°16'06"N	LONG. 02°52'53"W	AUG 1978
ELEVATION DF 118.5'	RIG MAERSK EXPLORER	
WATER DEPTH 170'	SPUDDED 19.6.69	
TOTAL DEPTH 5335'	COMPLETED 30.6.69	
LICENCE NO. P.089	TYPE COMPL. P&A	
ROUND NO. 2	ORIG. DRG. DATE. III.72	



SEISMIC LINE GMF 33 (MIGRATED)

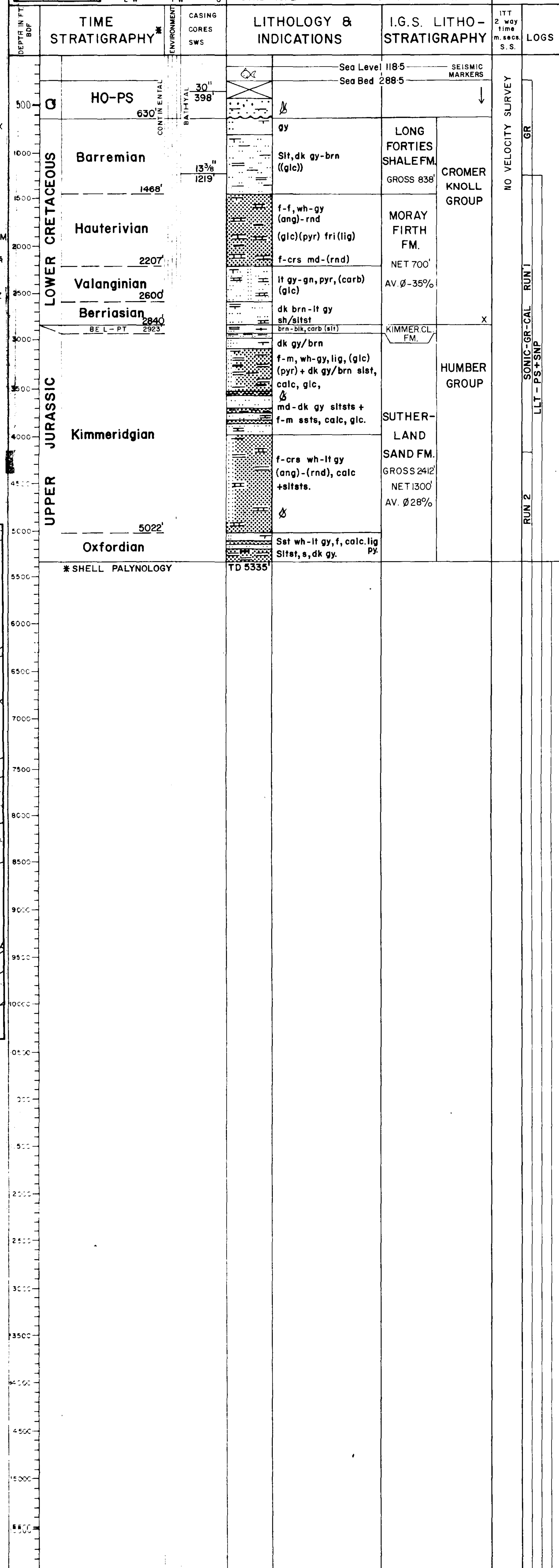




DEPTH MAP-BASE CRETACEOUS

CONTOUR INTERVAL 200 FEET

0 5 10 km



SUMMARY

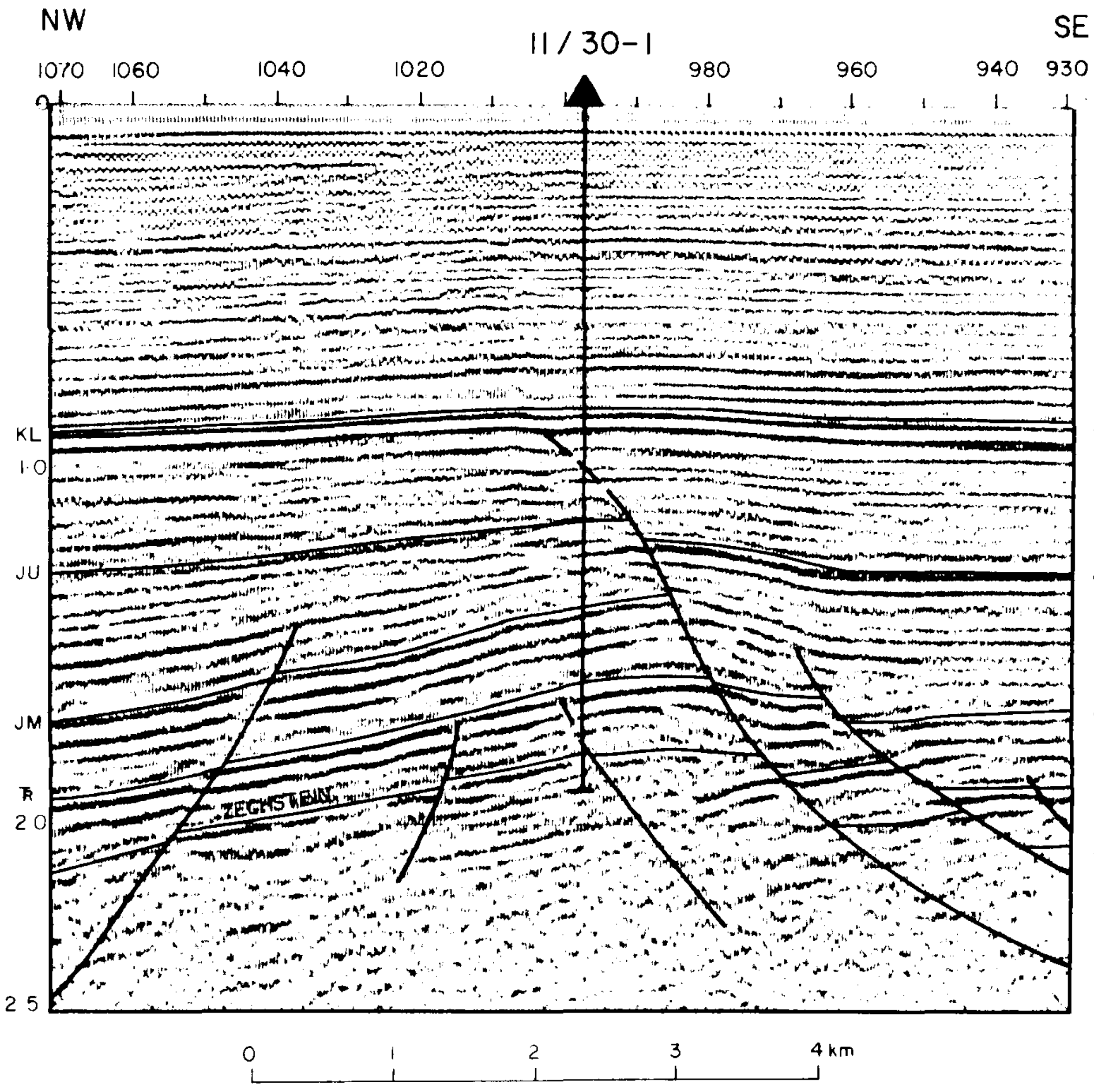
LOCATION
Inner Moray Firth, 20Km east of Scottish coast, (nearest well to land in N. North Sea). On small horst feature on flank of large fault block.

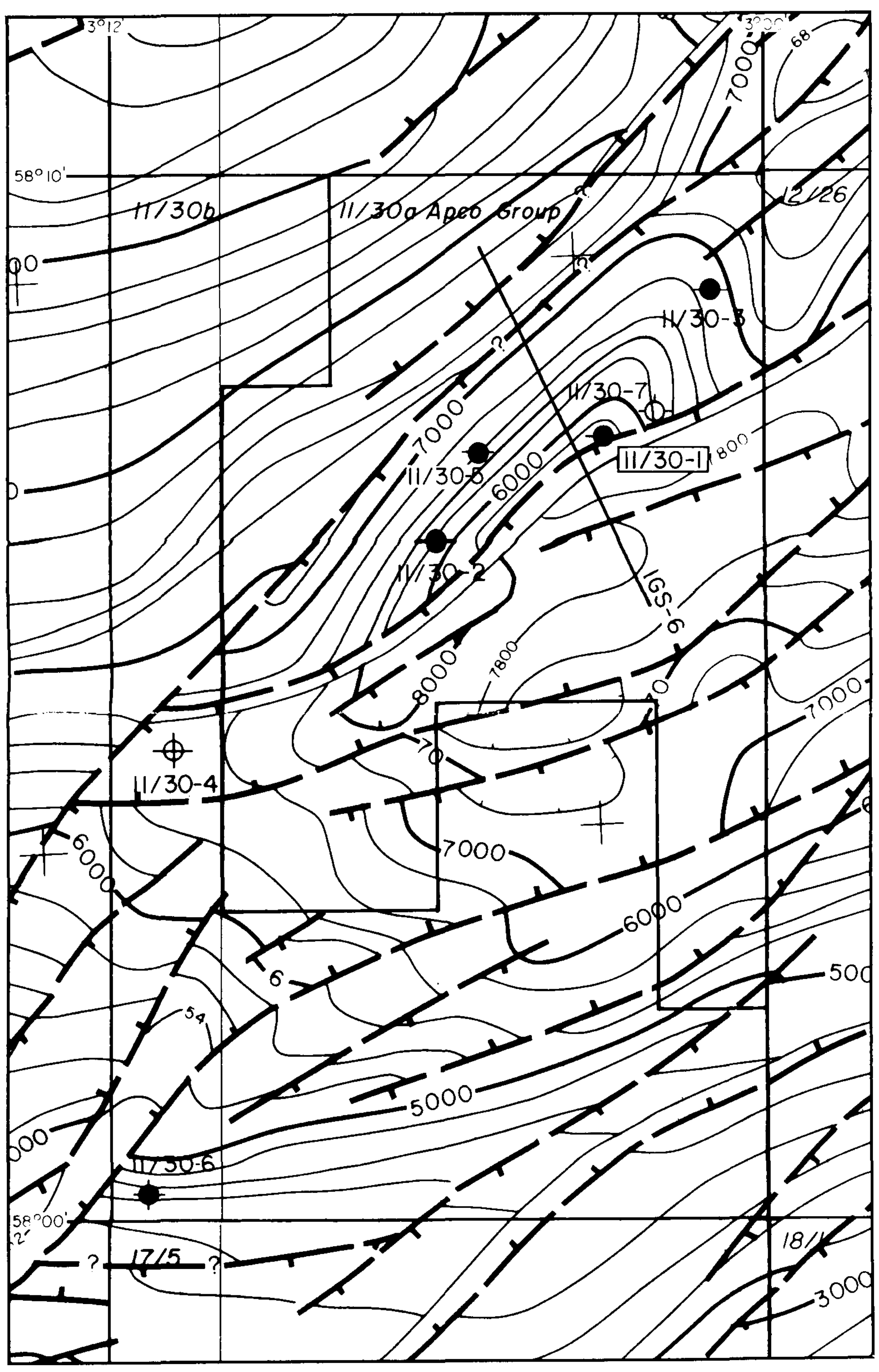
OBJECTIVE
Test for hydrocarbons in KL-JU after shows found in 12/23-1 KL.

RESULTS
Thick KL and JU sands/shales. No hydrocarbons. Valid test of small closure.

CONCLUSION
No trap as effective seal is not present

SEISMIC LINE IGS-6





DEPTH MAP - NEAR TOP MIDDLE JURASSIC

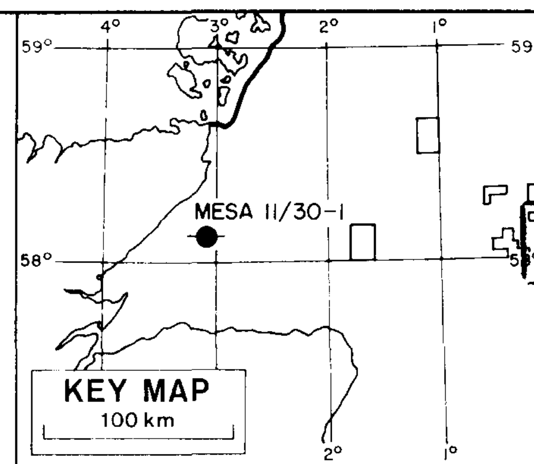
CONTOUR INTERVAL 200 FEET — 0 5 km

LOCATION:
In Inner Moray Firth 22.6 km to SW of nearest point on Highland coastline and about 47 km ENE of the Middle Jurassic outcrops at Brora.

OBJECTIVE:
Probably drilled to test structures at base Upper Jurassic/top Middle Jurassic level.

RESULTS:
Found 811' gross section of Lower and Middle Jurassic in which 297' NOS are present. Upper Jurassic and Lower Cretaceous are present largely as shales, therefore providing an effective seal.

CONCLUSIONS:
This well has found oil bearing Middle/Lower Jurassic sands in an area where the kitchen was previously considered small or suspect.



SHELL U.K. EXPLORATION & PRODUCTION

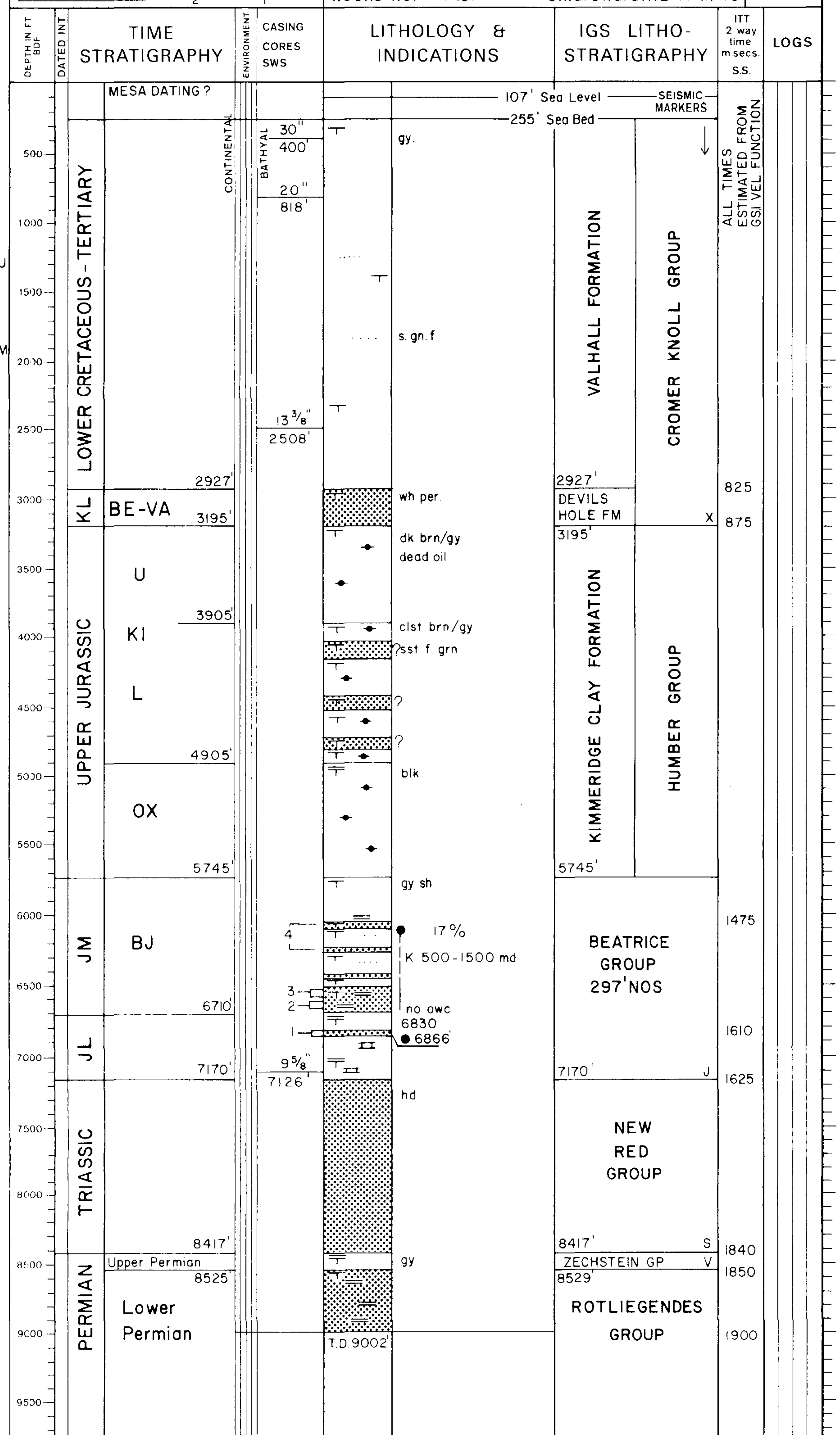
MESA 11/30-1

BEATRICE FIELD DISCOVERY

ENCLOSURE TO REPORT EP 50728.

SCALE 1:10000

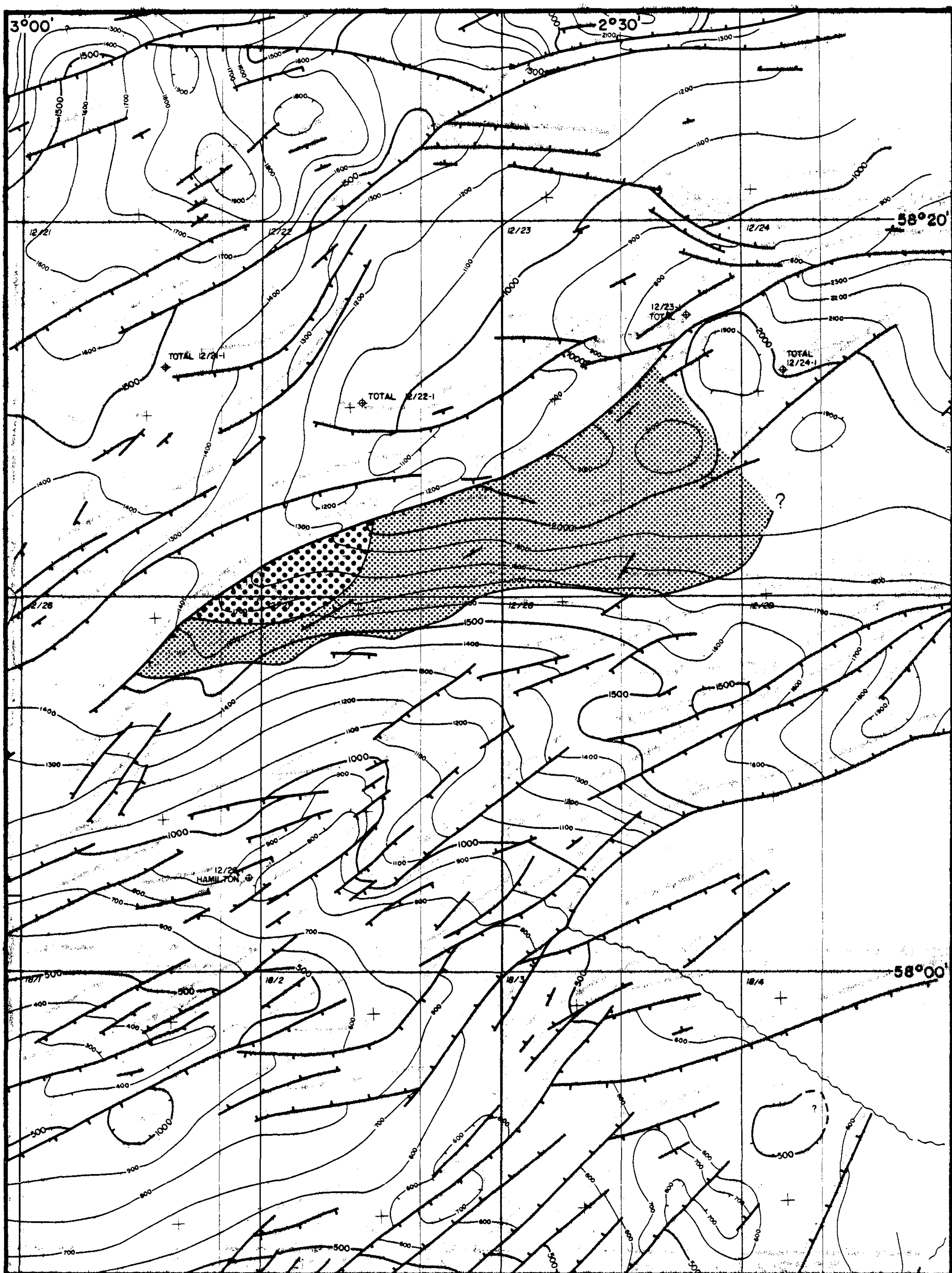
CO-ORDS. LAT.	58°07'31·3"N	LONG.	03°02'58·6"W	UPDATED
ELEVATION DF	107'	RIG.	PENROD 65	AUG
WATER DEPTH	148'	SPUDDED	15·7·76	1978
TOTAL DEPTH	9002'	COMPLETED	20·9·76	
LICENCE NO.	4	TYPE COMPL.	SUSPENDED	
ROUND NO.	P187	ORIG. DRG. DATE	14·IX·78	



DST'S	Interval	Flowrate	Gravity	Choke
1 & 1A	6830'-6864'	690-1080 BOPD	37.5° API	2" on max Flowrate
2 & 2A	6622' 6690'	368-1068 BOPD	33.9° API	2" on max Flowrate
3	6560'-6602'	2829 BOPD	38.1° API	2" on max Flowrate
4	6060' 6294'	2020 BOPD		2" on max Flowrate

NOTE: All information based on scouting data.

ENVIRONMENTS
Continental
Coastal to Inner Neritic
Middle to Outer Neritic
Bathyal (to Abyssal)
Fossil evidence
Geological interpretation



POSITION OF POSTULATED UPPER JURASSIC SAND WEDGES ADJACENT TO SMITH BANK FAULT

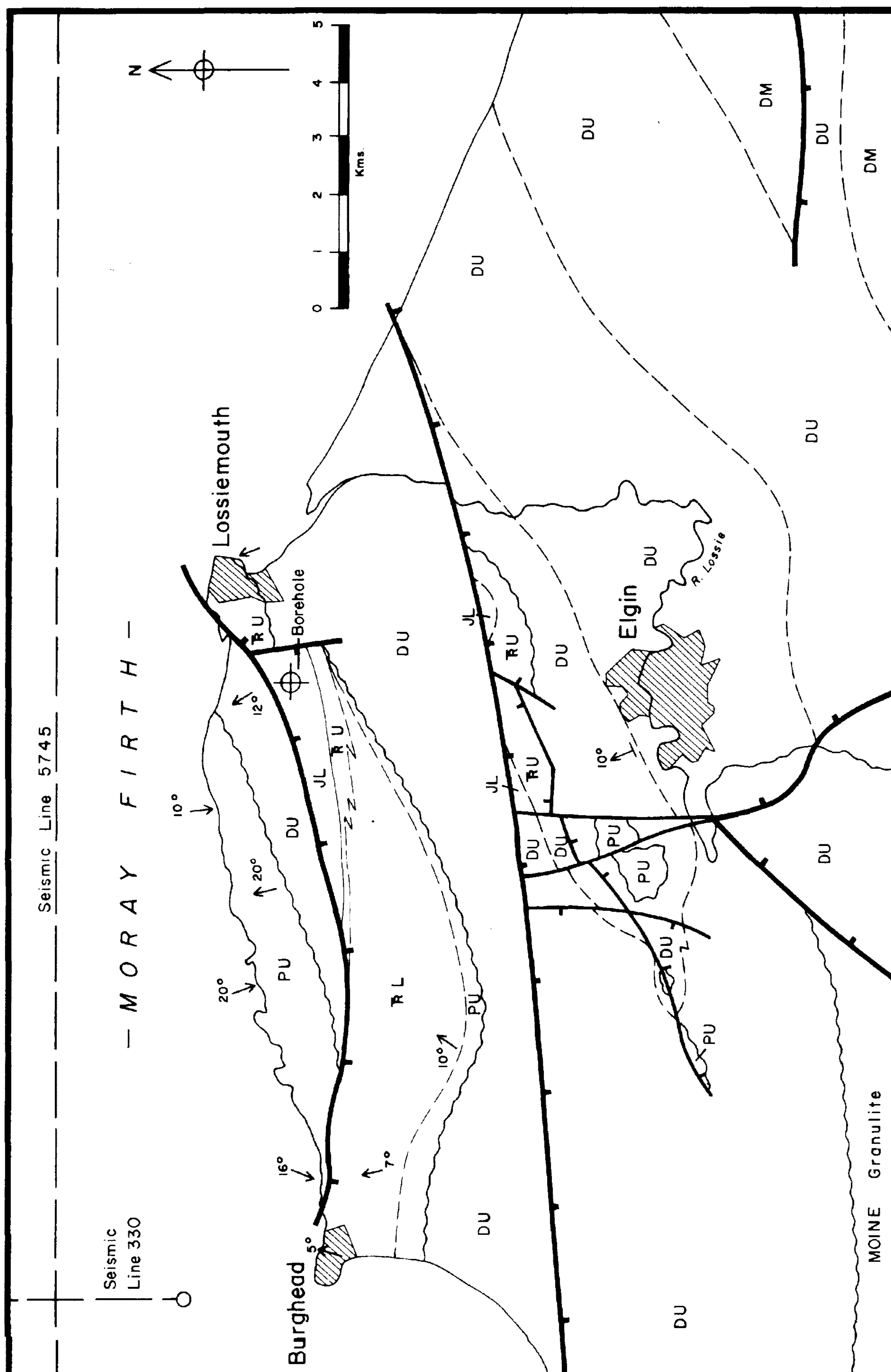
(BASED ON REFLECTION TIME CONTOUR MAP - INTRA-UPPER JURASSIC)

0 5 10 km

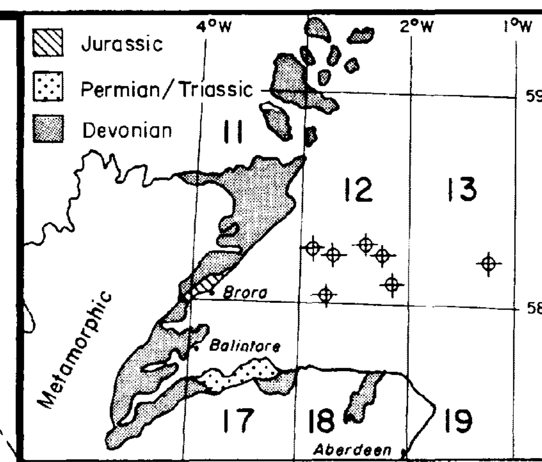
Drawing No. 22666

ENCLOSURE TO
REPORT EP 50728

Enclosure 21



LAND AREA shown under Petroleum Exploration Licence to Cambrian Exploration Ltd Licence XL.011.



SHELL U.K. EXPLORATION & PRODUCTION

NORTH GRAMPIAN COAST (Lossiemouth Area) Borehole and Outcrop

COORDINATES LAT. 57°42' N. LONG. 3°18' W.

VERTICAL SCALE 1:1000

AUG 1978

TIME STRATIGRAPHY	ENVIRONMENT	THICKNESS	LITHOLOGY & INDICATIONS	I.G.S. LITHO-STRATIGRAPHY Published+	I.G.S. LITHO-STRATIGRAPHY Shell	REGEO MARKERS
QT	CONTINENTAL	42'	Glacial pbly clay	"Drift"		
JL* (PB-SM-?HE)	BATHYAL	56'	pa yell-gy, kaol 100% sst	"Lias"	DUN-ROBIN FM GROSS 228' (equiv. of Statfjord Fm ?)	
		154'	60% Sltst, gy arg, kaol; 30% sst, gy, arg kaol; 10% Sh, gy, slt (cyclic, crs. up) gngy/olive gy			
		18'	gngy clst + lst beds			
JL		30'?	Gap of unknown, but not great, thickness.			BG 01
RH?		10-20'	ltgy, silic, lst replacement of sst (?silcrete)	"Cherty rock"	NEW RED GROUP ELGIN SST FM 100–230' at any one place? (?part equivalent to Zechstein)	
?Ꞧ U**	Aolian	c100'?	f, wh, md, slt, lam, Aolian. Large crossets. fri–hd (silic)	"Ssts of Spynie, Lossiemouth and Foudrassie"		
?Ꞧ L**	Waterlaid	0–80'	f–pbl. Wadi Deposits ? rnd. yellbrn–orange occ calc	"Burghead Beds"		
?PU**	Aolian	100–150'	yell-brn rnd, f-m sft-hd (silic) srt, occ pbl. large; reptiles	"Ssts of Cutlies' Hillock and Hopeman"		NR 01C
U–M Dev.*		?	yell-rd brn ssts, occ pbl	"Old Red Sst"	OLD RED GROUP	

* Based on ammonites &/or palynology

** Based on vertebrate remains.

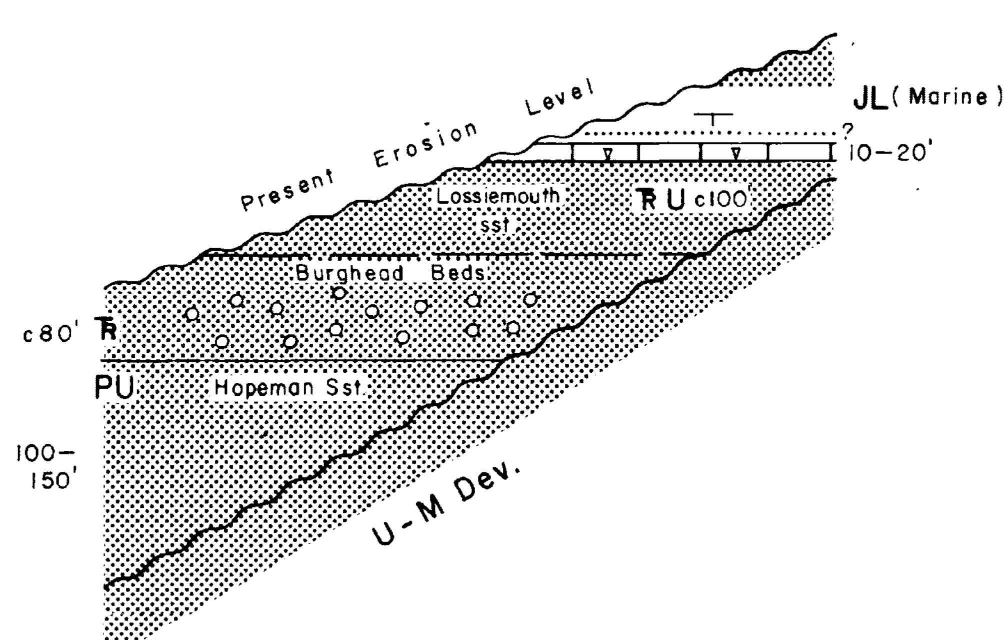
\+ Data from:

Peacock et. al. 1968 "The Geology of the Elgin District." Mem. Geol. Surv. Scot.

K.W. Glennie 1973 "Reconnaisance of Old Red Sandstone, Permo-Trias, Jurassic and Cretaceous Geology, Northern Scotland - 1972" Shell U.K. Exploration and Production Ltd. Internal Report No. 3 (RS 13).

Plus personal observation by W.G. Townson

Interpreted relationship of strata (excluding faulting)



ENCLOSURE TO REPORT EP 50798

Drawing No 22667

Enclosure 22

ep50728

See separate pdf or high resolution jpeg/tif with name:

ep50728 draw 019-023

TABLE 1

	Beatrice U.K.
Sulphur, %w	0.2
API gravity 60 F	39.0
Specific gravity 60/60 F	0.8299
Extract (Et. Ac),	-
Stripping volatiles	-
Fraction 120 C	10.7
Porphyrins	
ppm vanadyl complex	-
ppm nickel complex	-
n-Alkanes	
figure	A-1
gaschromatogram	
Rp	2.3
R29	-
Isoprenoids	
isoprenoid index	-
pristane/phytane	1.9
pristane/n-C17	0.2
phytane/n-C18	0.1
C7 distribution	
n-C7 alkane	58
monobranched alkane	25
polybranched alkane	17
figure	A-2
n-C7 alkane	35
C7 naphthenes	40
C7 branched alkanes	25
figure	A-2
C7 alkanes	59
C7 naphthenes	39
C7 aromatics	2

Physical and Chemical Data from Beatrice Field Oil Sample

FB7804

WELL	DEPTH	M/F	HRS	TEMP F
12/21-1	4200	F	2	90
	5335	F	3	135
	5335	F	5	135
	5335	F	8	135
12/22-1	1460	F	2	96
	3361	F	3.5	96
12/23-1	1460	F	2	96
	4531	F	-	119
	4531	F	3	119
	4529	F	3.5	119
	4533	F	14	119
	8676	F	-	142
	8672	F	4	142
12/24-1	3525	F	3	108
	8525	F	5	110
	7269	F	5	130
	7273	F	7	135
	7269	F	10	137
	8011	F	4	140
	8010	F	6	141
	8005	F	g	144
12/26-1	4116	F	2.5	150
	4117	F	6	150
12/30-1	495	M	7	92
	1620	M	-	112
	2480	M	-	188
	2680	M	-	172

(BHT) TEMPERATURE
BLOCK 12

TABLE 2

FB7805

(x) Top Jurassic	TEMP	VIR VR/E	COLOUR DENSITY	ESR	X-RAY	SONIC TRAVEL TIME	DEPTH IN FEET
12/21-1	0.39	0.34	0.38	0.44	0.33	0.53	2923
12/22-1	0.38	0.39		0.38	0.39	0.41	2320
12/23-1	0.38		0.50			0.47	2568
12/24-1	0.42		0.47				4756
12/26-1	0.38	0.47	0.53			0.47	2468
12/30-1	0.42		0.59				5171
Top Middle Jurassic							
12/21-1							
12/22-1							
12/23-1	0.39		0.53			0.50	2974
12/24-1							
12/26-1	0.39	0.50	0.58			0.53	3040
12/30-1	0.44		0.68				6204
Top Triassic							
12/21-1							
12/22-1							
12/23-1	0.39		0.53			0.50	3021
12/24-1							
12/26-1	0.42	0.55	0.59			0.58	4250
12/30-1	0.44		0.68				6317

LIST OF VR/E VALUES AT TOP JURASSIC, TOP MIDDLE JURASSIC, TOP TRIASSIC, OBTAINED BY VARIOUS METHODS.

TABLE 3

FB7807