BP

BP PETROLEUM DEVELOPMENT LTD. NORWAY

A GEOLOGICAL EVALUATION OF THE TRIASSIC OIL DISCOVERY IN NOCS 7/12-6

by

Bjarne Tveiten

BP Copy

BP PETROLEUM DEVELOPMENT LTD., NORWAY U/A

A GEOLOGICAL EVALUATION OF THE TRIASSIC OIL DISCOVERY IN NOCS 7/12-6

by

Bjarne Tveiten

Approved by: A.M. Spencer

Stavanger, October 1982.

Report No. GL/NO/562

BP Petroleum Development Ltd., Norway
(Utenlandsk aksjeselskap)

c.c. A.M. Spencer

SØRFLATVEIEN 11, P.O. BOX No.3077 MARIERO, 4001 STAVANGER

Conoco Norway Inc.
Attn: J.I. Horning

Statoil
Attn: H. Mork

A.S. Pelican & Co. K.S.
Attn: T. Braadlie

Our reference	Your reference	Telephone / Telex	Date
PED-213/596.06 TNDH/kok		(04) 589580 33339 BPEXPN	20th October 1982

Dear Sirs,

1. A Geological Evaluation of Triassic Oil Discovery in NOCS 7/12-6. B. Tveiten, October 1982.

2. Block 7/12 Triassic Reservoir and Economics Study. P.S. Buckley, October 1982.

Your copies of the above reports are enclosed.

The Triassic section in Well 7/12-6 was 179m thick and tested 1000 STBOPD. No certain oil water contact was penetrated.

The main conclusions of the reports are:-

i) Oil in place is uncertain; it is most likely to be approximately 60 MMSTB but could be as high as 230 MMSTB.

ii) Only approximately 10% of the oil in place is likely to be recovered at the economic limit.

iii) At best there is only likely to be a small economic benefit to the Ula project by Triassic development. This is regarded as speculative.

iv) No alterations to the current Ula development plans are warranted to allow for possible Triassic development.

v) Further appraisal of the Triassic is required but is best achieved by drilling one or more of the early Ula Jurassic development wells to the salt.

B.G. Williams
Exploration Manager

R. Summers
Operations Manager

c.t. Norwegian Petroleum Directorate - T. Pedersen

b.c.t. J.W.G. Sharp w.o. reports
L.P. Newman (DOS) 1 copy of each report
F.J. Frape/J. Sharpley (DOS) 1 copy of report no. 2
W. Digings (DOS) 1 copy of report no. 2
T.N.D. Hares w.o. reports
A. Wilson w.o. reports

7/12-6

NOCS NORTH SEA

SUMMARISED WELL LOG

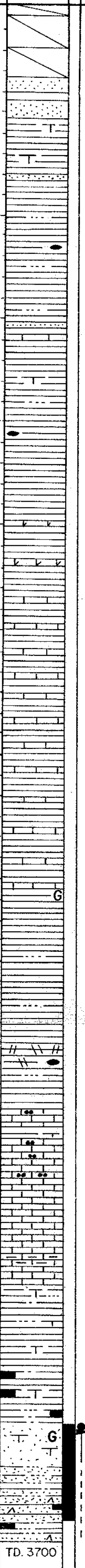
SCALE 1:10,000

LOCATION: 57° 07' 15,59"N 02° 50' 03,40"E

Stratigraphy	Depth Drilled ft. & m.	Description	Casing	Remarks
		Sea surface		
		Sea bed		NOTE: PALAEOREPORT GIVES TOPS WITH AN UNCERTAINTY OF 5 - 15M. AVERAGE HAS BEEN USED HERE. COMP. LOG HAS ACCURATE DATA.
QUAT. (to 335)	250 m / 1000 ft	No returns above 167 m. SAND, qtz, clear, white, c-vc, ang - subang, poorly srt, loose. CLAY, lt-m gy, v. soft, sticky, sl. calc, sl-silty	30" 167m; 18 5/8" 465m	
PLIO. (335–875)	500 m / 2000 ft; 750 m	SILT, wh-clear qtz, loos, subr. CLAY, as above, non-calc. SAND/SILT, clear qtz, rnd-subr. loose. LIMESTONE, cream, blocky, hd		
L. MIO (875–1485), NORDLAND GROUP	3000 ft; 1000 m; 4000 ft; 1250 m	CLAY, lt-mgy, v.soft, sticky. LIMESTONE, dolomitic, cream firm-hd. LIMESTONE, wh-cream, fm-hd		
? E. - M. MIO (1485–1795), NORDLAND GROUP to 1680	1500 m / 5000 ft; 1750 m	MUDSTONE, m-dk gy, brn, black, soft - firm, occ. hd, subfiss. MUDSTONE, brn-gy brn, fm micromic.	13 5/8" 1684m	
OLIGO. (1795–2342), HORDALAND GROUP	6000 ft; 2000 m; 7000 ft; 2250 m	LIMESTONE, crm-wh, fm-hd. MUDSTONE, gy, grn, brn, fm, argill		
EOC. (2342–2405)				
E. EOC. (2405–2565), BALD FM. 2538.5	8000 ft; 2500 m	MUDSTONE, red, purple, specled, tuffaceous, fiss, occ pyr.		BALDER FM. 2538.5m; SELE FM. 2563.5m
PALAEO. (2565–2805); ROGALAND GP: SELE FM., LISTA; MONT GP: MAUR FM.; EKOF FM.	9000 ft; 2750 m	LIMESTONE, wh, fm-hd, blocky, cherty. LIMESTONE, as above		LISTA FM. 2605.0m; MAUREEN FM. Eqv. 2617m; EKOFISK FM. 2661m
MAASTR. (2805–3007), CHALK GROUP, TOR FM.				TOR FM. 2730m
? CAMP (3007–3085), HOD FM., PLENUS MARL FM., HIDRA FM.	3000 m / 10000 ft	LIMESTONE, pink, sort-fm, occ hd, occ argill		HOD FM. 3002m; PLENUS MARL FM. 3071m; HIDRA FM. 3085m
H-VAL-APT (3085–3105)		MUDSTONE, red calc		
VALANG (3105–3292), CROMER KNOLL GROUP, VALHALL FM.	3250 m	MUDSTONE, med gy, fm-hd, subfiss. SILTSTONE, dk brn, carb, occ v-calc grading to silty LST.		VALHALL 3092m
BERR (3292–3355), U. JURA MUDST GP: UPPER PART, MIDDLE PART, LOWER PART	11000 ft	MUDSTONE, dk gy, v.carb silty occ calc, fm-hd	9 5/8" 3337m	U. JURA. MUDST. GP. UPPER PART 3292m; MIDDLE PART 3332m; LOWER PART 3388m; ULA FM. 3406m
E.KIMM. E.PORT. (3355–3521), ULA FM.	3500 m	SANDSTONE, cl. qtz, gy, hd, f-vf, med sort, subrnd, grst text, occ well calc cmt, tr mic, tr. glauc.		SHOWS: oil bleed, yel. fluor, good to fair white cut & crust-cut.
UNDATED TRIAS (?) (from 3521), SKAGERRAK FM.	12000 ft; 3750 m; TD. 3700	SILTSTONE, med gy, firm-hd. SANDSTONE, as above, occ well sil cmt, occ interb with SANDSTONE, as above, but v. mic and SANDSTONE, as ~~above, but v. carb.~~ MUDSTONE, dk gy, occ v. silty fm-h, v. carb. becoming red below 3650 m.	7" 3688m	• RFT Tests
	13000 ft; 4000 m; 4250 m / 14000 ft; 4500 m / 15000 ft; 4750 m			

Electric Logs: ISF/BHC/GR/SP (167–465 m); ISF/BHC/GR/SP/MSFL/CAL (465–1684 m); ISF/BHC/GR/SP/MSFL/CAL (1684–3337 m); ISF/BHC/GR/SP, FDC/CNL/GR/CAL, DLL/MSFL/GR, RFT/GR, HDT, CBL (3337–3700 m)

Tests: DST 2, DST 1



Note: Jurassic stratigraphic nomenclature is presently under revision. No existing nomenclature can be used in this well. The upper Jurassic mudstones are therefore grouped together and divided into three parts based on logs. The "Ula Fm." is used for the marine sandstones in this well. This is equivalent to "Fm. Z" in previous Ula Field Wells

BT81

GL/NO/562

Fig. 2

CONTENTS LIST

FIGURES

TABLES

ENCLOSURES

Summary

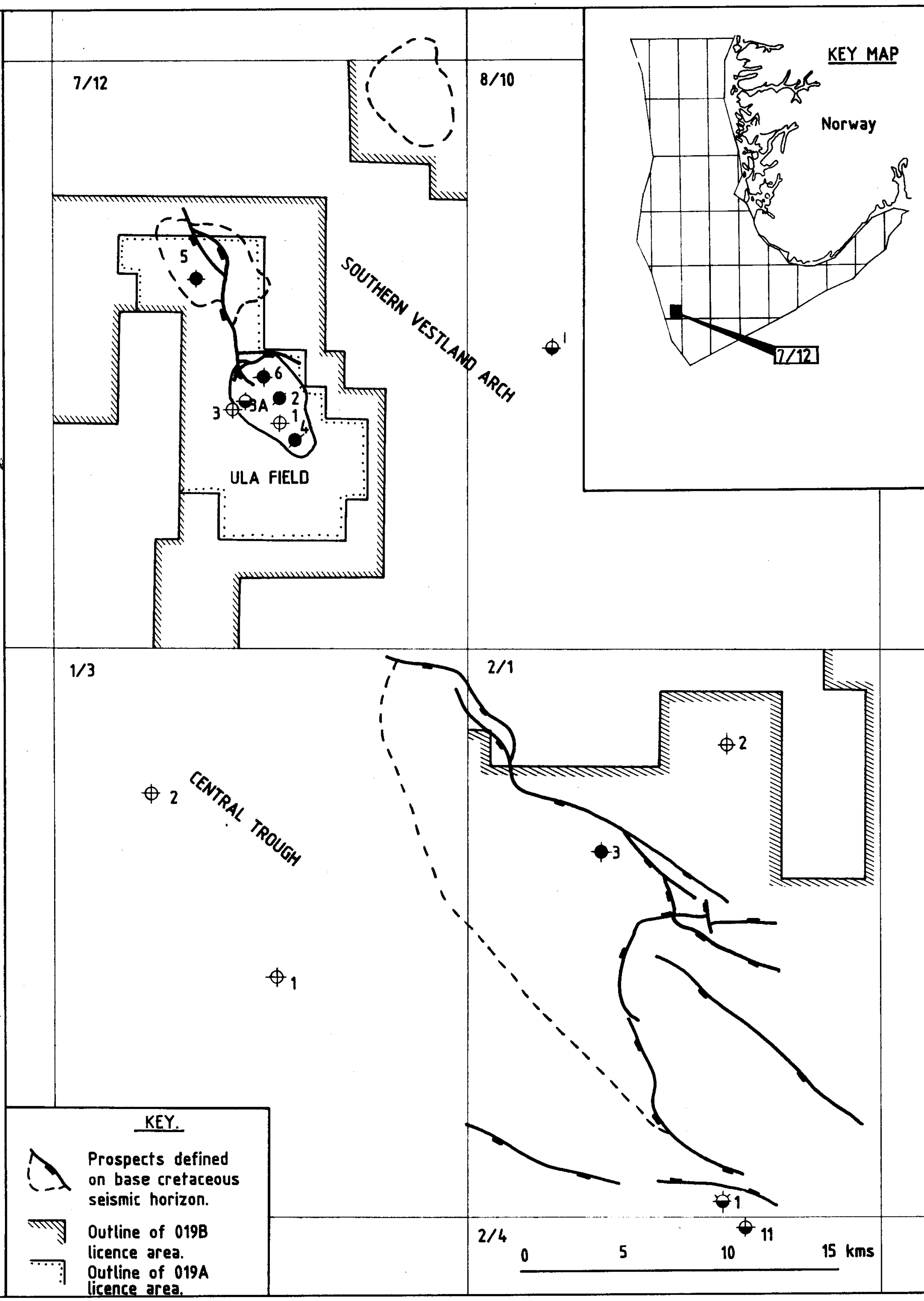
7/12-6 was drilled as an appraisal well on the Ula field and encountered a 115m thick Ula Fm. with oil down to the base of this formation. Unexpectedly the well then went into oil bearing Triassic rocks. A 179m thick Triassic section was penetrated with oil shows on logs down to 3661 mBRT. No porous rocks were present from this level down to TD at 3700 mBRT and hence no OWC has been proved. A total of 9 cores were cut, half of which were in the Triassic section.

The Triassic reservoir predominantly consist of sandstones with minor siltstones, mudstones and conglomerates. The sedimentary environment has been interpreted as braided streams.

One drill stem test was performed in the Triassic section and produced 1005 STBD of oil with 39.2^{o} API gravity and GOR of 487 SCF/STB.

The oil is slightly different from that in the overlying Ula Fm. but the two types are believed to come from the same source.

Reserves calculations have been difficult due to the lack of a top reservoir map. Most likely oil-in-place 'proven' by 7/12-6 are estimated to be 58 x 10^6 STB. Possible oil-in-place (yet-to-be-found) are estimated to be up to 136 x 10^6 STB.



LOCATION MAP 1:250000

Fig. 1

BP PETROLEUM DEVELOPMENT LTD, NORWAY

Ref: GL/NO/562	
Author: B. TVEITEN	
Date: Aug. 81'	Drg No: 5580

INTRODUCTION

1.1 Aims of report.

7/12-6 was drilled in 1981 as an appraisal well on the Ula field to test the North-Western flank of the structure. It encountered the top of the Ula reservoir higher than predicted and found it oil bearing throughout. The base of the Ula reservoir was also higher than predicted and was above the previously established OWC in the field.

Immediately below the Ula Fm. the well unexpectedly encountered an oil bearing Triassic section. A total of 9 cores were cut of which 4.5 were in the Triassic. The section predominantly consisted of sandstones with minor siltstones, mudstones and conglomerates.

Oil was indicated on electric logs down to 3661 m BRT but no porous zones below this depth could be proven water wet and thus prove the presence of an OWC. TD was at 3700 m BRT.

4 wells had been drilled in the Ula structure in 7/12 and one well on another ("B") structure in the block before drilling of 7/12-6.
The well results are summarized below:

7/12-1	TD in Cretaceous
7/12-2	Upper Jurassic oil discovery (Ula Fm). Also small amounts of oil in Triassic rocks, TD in Triassic.
7/12-3	Drilled downflank of 7/12-2, dry hole, TD in Upper Jurassic.
7/12-3A	Deviated from 7/12-3, penetrated Ula Fm. slightly below OWC, water wet Triassic, TD in salt.
7/12-4	Downflank of 7/12-2, oil found in Ula Fm., TD in L. Jurassic or Triassic, no shows at TD.
7/12-5	Drilled on the 7/12-B structure to the NW of Ula. Encountered tight, oil bearing Ula Fm. No shows in Triassic. TD in salt.

This means that a total of 5 wells now have penetrated rocks of presumably Triassic age in block 7/12. The purpose of this report is to present an evaluation of the oil discovery in 7/12-6. This can be split into four parts:

a) To evaluate the pre-Haldager Fm. rocks in 7/12-6, which will involve much basic geological work as

   i) the age of the rocks is uncertain,

   ii) the lithostratigraphy is uncertain and

   iii) the correlation to adjacent wells is uncertain.

   The overall aim is to understand and possibly predict the overall structure of the Triassic rocks.

b) To attempt a geophysical evaluation of the pre-Haldager Fm. section. This has proved very difficult since there are no mappable reflectors (hence part a) is even more important).

c) To evaluate the nature of the trap and hence attempt to predict the geographical and stratigraphical extent of the oil accumulation

d) To attempt to predict the range of possible oil-in-place present in the Triassic rocks in the Ula structure and also in the 7/12-B structure.

Due to the general lack of good diagnostic fossils in the formations older than Late Jurassic, this report will deal with all formations below the supposedly Middle Jurassic unconformity (pre-Haldager Fm. or pre-Sleipner Fm. according to new nomenclature) which is found in all wells in the block. (Haldager Fm. will be used in this report).

The evaluation of the rocks above the unconformity (Haldager Fm. and Ula Fm.) is presented in Price (1982).

Since the presence of Triassic rocks in the wells has not been proven by fossils, the term "?Triassic" should be used. For convenience, the questionmark is omitted in this report.

1.2 WELL RESULTS

WELL: 7/12-6 NOCS

LATITUDE: $57^{o}07'15.59"N$

RTE: 24.5 m.a.m.s.l.
94.3 m.a.s.b.

LONGITUDE: $02^{o}50'03.40"E$

WATER DEPTH: 69.3 m

TYPE OF RIG: Semisubmersible

NAME: Sedco 707

OBJECTIVE: To determine sand distribution in northern part of the Ula field, and production and injection properties of reservoir and aquifer.

DATE SPUDDED: 10th April 1981.

DATE COMPLETED: 25th July 1981.

DEPTH: 3700 m.b.k.b. (drill depth)

WELL STATUS: Plugged and abandoned oil well.

GEOLOGICAL DATA

Lithostratigraphy

	Tops		
	DD (m)	SS (m)	Thickness (m)
Nordland Group	94.3	69.3	1585.7
Hordaland Group	ca 1700.0	1655.0	858.5
Rogaland Group	2538.5	2513.5	66.5
Balder Fm.	2538.5	2513.5	25.0
Sele Fm.	2563.5	2538.5	41.5
Montrose Group	2605.0	2580.0	56.0
Lista Fm.	2605.0	2580.0	12.0
Maureen Fm. Eqv.	2617.0	2592.0	44.0
Chalk Group	2661.0	2636.0	431.0
Ekofisk Fm.	2661.0	2636.0	69.0
Tor Fm.	2730.0	3705.0	272.0
Hod Fm.	3002.0	2977.0	69.0
Plenus Marl Fm.	3071.0	3046.0	14.0
Hidra Fm.	3085.0	3060.0	7.0
Cromer Knoll Group	3092.0	3068.0	200.0
Valhall Fm.	3092.0	3068.0	200.0
U. Jur. Mudstone Group	3292.0	3268.0	114.0
Upper Part	3292.0	3268.0	46.0
Middle Part	3338.0	3313.0	50.0
Lower Part	3388.0	3363.0	18.0
Ula Fm.	3406.0	3381.0	115.0
Triassic Group	3521.0	3496.0	179.0+
?Skagerrak Fm.	3521.0	3496.0	179.0+
	TD. 3700.0		

Chronostratigraphy

(BP Sunbury) (Palaeotops are given with 5 to 15 m uncertainty in palaeoreport. Average has been used here. Composite log has accurate data.)

	DD (m)	SS (m)	Thickness (m)
Quaternary	94.3	69.8	240.7
Tertiary	335 ± 5	310.5	2470
Pliocene	335 ± 5	310.5	540
Late Miocene	875 ± 5	850.5	615
?E. -M. Miocene	1485 ± 5	1465.5	305

	DD (m)	SS (m)	Thickness
Oligocene	1795 ±5	1770.5	547.5
Eocene undiff.	2342.5 ±7.5	2318	62.5
E. Eocene	2405 ±5	2380.5	160
Palaeocene	2565 ±5	2540.5	95
Danian	2660	2635.5	145
Cretaceous	2805 ±5	2780.5	550
Maastrictian	2805 ±5	2780.5	202.5
?Campanian	3007.5 ±2.5	2983	82.5
E. Haut. - M. Apt.	3090	3065.5	10
M. Valang. - E. Haut	3100	3075.5	10
Valanginian	3110	3085.5	180
Berriasian	3290 ±10	3265.5	65
Jurassic	3355 +5	3330.5	163.3
L. Kimm. - E. Port.	3355 ±5	3330.5	56.5
Kimm.	3411.5 ±5	3387	104.5
Late Early Kimm.	3516	3491.5	1.5
Probably E. Kimm.	3517.5	3493	0.8
Indeterminate	3518.3	3493.8	

CORES

No.	Depth (drillers depths) (mBRT)	Recovery (m)
1	3406.70 - 3434.30	27.60 (100%)
2	3434.30 - 3461.66	27.34 (98%)
3	3461.66 - 3488.64	26.98 (100%)
4	3488.64 - 3515.48	26.84 (100%)
5	3515.48 - 3542.78	27.30 (100%)
6	3542.78 - 3569.78	27.00 (100%)
7	3569.78 - 3595.78	27.00 (100%)
8	3596.78 - 3624.27	27.49 (100%)
9	3624.27 - 3647.17	22.90 (100%)

SHOWS

Age	Depth (m BRT)	Shows	Lithology
E. Eocene	2450	Dull yel. fluor, slow stream cut	Siltstone
U. Cret.	3010 - 3060	Dull yel. fluor, slow milky wh crush cut	Limestone
U. Jur.	3404 - 3500	Brite yel. nat fluor blue cut	Sandstone
U. Jur	3500 - 3520	White/yell. nat fluor sl blue cut	Sandstone
Trias. ?	3520 - 3675	Dull yell fluor, weak milky white cut	Sandstone

TESTS

Type & No.	Point No.	Depth	FSIP (PSIG) (Temp. corr.)
RFT 1 Run No. 5A	1	3415.5	7027
	2	3427.5	7038
	3	3436.6	6944
	4	3417.0	7030
	5	3427.5	7039
	6	3436.5	7046
	7	3447.5	7055

Type & No.	Point No.	Depth	FSIP (PSIG)
RFT 1 Run No. 5A	8	3459.5	7070
	9	3468.5	7078
	10	3483.0	7094
	11	3499.0	7108
	12	3509.5	7121
	13	3533.0	7151
	14	3548.5	7201
	15	3589.0	7210
	16	3599.0	7225
	17	3610.5	7241
	18	3622.5	-
	19	3621.5	7283
	20	3659.5	-
	21	3660.5	-
	22	3670.0	-
	23	3670.0	7596
RFT 2 Run No. 5B	1	3416.5	7029
	2	3436.0	7043
	3	3459.0	7070
	4	3482.0	7094
	5	3506.0	7118
	6	3530.0	7152
	7	3532.5	7174
	8	3545	7174
	9	3523	7181
	10	3526	7175
	11	3588.5	7210
	12	3598.5	7228
	13	3610.5	7244
	14	3570.3	7203
	15	3570.3	

	Depth (mBRT)	Recovery
DST 1	3543 - 3612	1005 STBD 39.2° API, 12/64" choke GOR 487 SCF/STB
DST 2	3434 - 3511	7980 STBD 36.9°API, GOR 374 SCF/STB

COMMENTS: The well hit the Ula reservoir higher than expected. The OWC was not reached so injection properties in the aquifer could not be determined. An unexpected ?Triassic oil discovery was tested. The OWC in this reservoir was probably not reached.

REPORT REFERENCE: 7/12-6 W28

AUTHOR: B. Tveiten/I. Madland

DATE: 31st July 1981

2. RESERVOIR GEOLOGY.

2.1 Lithological and sedimentological description.

128.35 m of core were cut in the Triassic interval of 7/12-6 and described on the rig (Tveiten, 1981) and by a BP sedimentologist (Davies, 1981).

The cored section consists of interbedded sandstones, siltstones and mudstones and some intraformational conglomerates with sandstones as the dominant lithology. Oil bleed, dull yellow fluorescence and weak milky white cut fluorescence were present in all cores (although weaker in the last core) and electric logs confirmed that oil was present in the whole interval. Summaries of each lithotype follow:

SANDSTONE: grey brown to weak red brown, more red near the base predominantly fine but often medium grained, occ. silty and occ. coarse, predominantly moderately sorted, subangular to subrounded, hard to very hard, often very micaceous, well silica cemented, arkosic, grainstone texture, some wackestone texture, trace of pyrite. The sandstones are locally dolomite cemented except in the upper 15 m, where they are locally calcite cemented.

The rig-site description of high carbonaceous content is wrong. Dark mica was erronously described as carbonaceous matter.

SILTSTONE: grey green to dark green, often very argillaceous, moderately micromicaceous, arkosic. The siltstones often contain white dolomite nodules.

MUDSTONE: grey, green, dark grey to black, firm to hard, often very sandy near the bottom of the cored section. The black mudstones also have dolomite nodules.

CONGLOMERATE: Pebbles of green mudstone, dolomite cemented sandstone and dolomite in sandy matrix. The matrix is similar to the sandstone described above.

Structurally the sandstones are dominated by planar horizontal lamination, planar cross lamination and ripple cross lamination. Less commonly the rocks are structureless. Subvertical burrows can obliterate sedimentary structures. Gas escape structures and brecciation have been seen.

The siltstones are normally structureless but ripple cross lamination or planar horizontal lamination can be seen. The conglomerates often rest on a scoured surface and either grade upwards into finer sandstones or have a sharp erosional top. The mudstones show a good to moderate fissility.

Abundant small scale, high angle normal and reverse faulting can be seen throughout the cored interval. Also some few examples of anastomosing faults can be seen (see encl. 1 in Davies, 1981).

The basal 50 m of the well was not cored. Logs do not show hydrocarbon indications, but since an oil-water-contact has not been established, these rocks could be a part of the reservoir. The same sequence of rocks seem to continue with sandstone, although less micaceous, as the dominant lithology. Brick red colour is seen in the siltstone and light red-brown in the sandstone. The FDC-CNL overlay (Encl. 1) indicates more argillaceous or silty rocks than in the cored section.

2.2 Depositional model.

Davies (1981) concludes that the rocks were laid down in a braided stream environment as a product of ephemeral streams (streams lasting only a short time). This interpretation agrees well with that from the Triassic cores in 7/12-2 (Walls, 1978). It is also consistent with what is known of the Triassic regionally in the southern Norwegian North Sea.

Davies bases his interpretation on several facts, of which the most important are:

1) The abundance of mica in the sandstones precludes an eolian origin, the rocks must therefore have been lain down by water.

2) A high ratio of sand to fine clastics is more likely on a sandy fan or in braided channels than on an alluvial plain.

3) Dolomite nodules in siltstones and mudstones are interpreted

	TRIASSIC SANDSTONES			ULA FM.
	EARLY DIAGENESIS	UNCONFORMITY RELATED DIAGENESIS	LATE DIAGENESIS	EARLY DIAGENESIS
MICA DEFORMATION	—			
ILLITE	—			– –
CHLORITE	—			
FELDSPAR	—		—	—
QUARTZ	—		—	– – –
DOLOMITE	?—? —			
BITUMEN		?—?		
FELDSPAR DISSOLUTION		—		
PYRITE			—	—
CALCITE			—	—
BARITE			?—?	

SUMMARIZED DIAGENETIC HISTORY OF THE TRIASSIC SANDSTONES, 7/12-6.

Also included is the summarized early diagenetic history of the Ula Fm. sandstones, 7/12-6.

Data from Davies, (1981) and Bowman, (1981).

Fig.3

BP PETROLEUM DEVELOPMENT LTD. NORWAY	
Ref: GL/NO/562	
Author: B. TVEITEN	
Date: MARCH 1982	Drg No: 6171

as calcretes, indicative of a semi-arid environment.

4) Irregular interbedding of the various sedimentary structures in the sandstones found in cores have also been found in recent ephemeral streams in semi-arid terrains.

The three types of sedimentary structures found in the sandstones were interpreted as:

1) Planar lamination: Indicative of deposition in upper-flow regime in fine grained sediments. Interpreted as flood-stage sedimentation.

2) Planar cross lamination: Interpreted as linguoid or transverse bars or sand waves (typical of braided rivers).

3) Ripple cross lamination: Interpreted as a reworking of the sand waves during falling-water-stage.

2.3 Diagenesis.

Davies (op. cit.) recognized two events that enabled him to separate the diagenetic events in relative time.

1) The occurrence of dolomite cemented sandstone in intraformational conglomerates shows a very early dolomite diagenesis.

2) Leaching of feldspar was thought to be related to freshwater flushing at an unconformity.

On this basis the diagenetic events were grouped into a) Early burial diagenesis b) Unconformity-related diagenesis and c) Late burial diagenesis. Figure 3 summarizes the results.

It is difficult to compare the above diagenetic history with that from the Triassic core in 7/12-2 because the latter was not systematically described by Walls (1978).

The bitumen problem:

The presence of bitumen as a cement was also described by Walls (1978) from 7/12-2.

The bitumen in 7/12-6 is confined to the primary porosity and is not seen in the secondary porosity nor in any pores in the overlying Ula Fm. (Bowman, 1981). It must therefore have been emplaced before the development of the secondary porosity in the Triassic rocks.

To date the emplacement of the bitumen it is necessary to date the secondary porosity in the Triassic rocks.

The sequence of diagenetic events in the late burial diagenesis in 7/12-6 Triassic (feldspar and pyrite before calcite) is similar to the early diagenesis in the Ula Fm. of the same well (Fig. 3). It is thus possible that the late diagenesis in the Triassic is time-equivalent to the early diagenesis in the Ula Fm. The fact that pyrite and calcite are confined to the uppermost 15 metres of the Triassic and therefore may be derived from the Ula Fm. support this.

The above reasoning is based on few facts, but if it is correct, then the unconformity responsible for leaching the Triassic feldspars must occur between the deposition of the Triassic rocks and the Ula Fm. This could be the Pre-Haldager Fm. unconformity which separates rocks of ?Middle - Late Jurassic age from rocks of Triassic - Early Jurassic age or, as is suggested later in this report, a top Triassic unconformity.

To explain the presence of bitumen it would then be necessary to have a pre-Middle Jurassic source rock present. This source rock must have been mature and oil must have got into the Triassic rocks before Middle Jurassic time. The oil must then have been lost during the erosion in ?Middle Jurassic leaving the bitumen behind.

This would imply that a source rock other than the Upper Jurassic shales is present in the area. The most likely source rock is the Fjerritslev Fm. which Lowe (1979) described as having moderate to poor oil source potential.

2.4 Poroperm/Net-Gross.

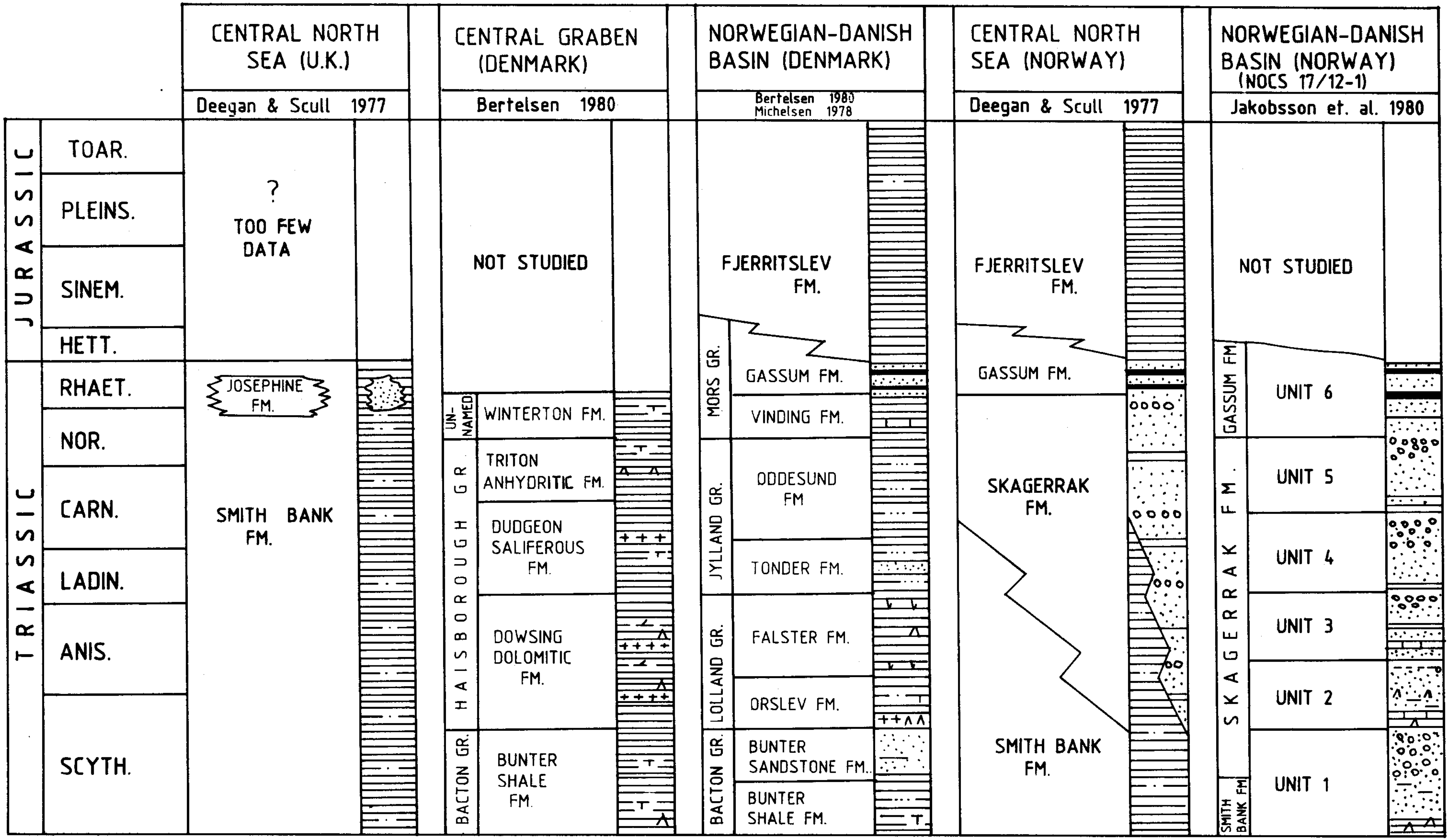
A plot of Helium porosity and horizontal permeability vs. depth can be found on the core sheets in the Geological Completion Report (Tveiten, 1981) and on enclosure 1 in Davies (1981). Both porosity and permeability are very variable throughout the cored interval. Porosity varies from 2% to 26% with an average of 16.0%. Permeability varies from less than 0.1 millidarcy to more than 200 millidarcies, average is 13.9 md. Net/Gross has been calculated to be 0.35 (data from Buckley, 1982).

The poroperm values are closely related to the grain size variations and the original mineralogy. Medium grained sandstones have highest poroperm values while finer grained sandstones with high mica content have low values. The vertical permeability is often lower than the horizontal because of high mica content. Diagenetic quartz and feldspar have to a certain extent reduced poroperm values, but this effect seems minor in relation to the grain size and primary mineralogy. The secondary porosity is present throughout the reservoir, but seems to have a minor influence on the porosity and permeability.

The permeabilities in the Triassic cores (average 13.9 md) are much lower then those in the overlying Ula Fm. (average 200 md). This is thought to reflect the much higher mica content in the Triassic rocks.

2.5 Hydrocarbons tested.

A drill stem test was performed between 3544 m bkb and 3612.5 m bkb in 7/12-6 (DST 1). A flowrate of 1005 STBD was achieved through a 12/64" choke. The oil had a 39.2^{o} API gravity and a GOR of 489 SCF/STB (cf 8000 STBD, $36{,}9^{o}$ API, GOR 374 SCF/STB for the Ula Fm).



TRIASSIC AND LOWER JURASSIC LITHOSTRATIGRAPHY IN CENTRAL NORTH SEA AND DENMARK.

Fig.4

BP PETROLEUM DEVELOPMENT LTD, NORWAY	
Ref: GL/NO/562	
Author: B. TVEITEN	
Date: JAN. 1982	Drg No: 6028

3. STRATIGRAPHIC POSITION.

3.1 Introduction.

To determine the stratigraphic position of the oil bearing strata in 7/12-6, the following steps have been performed:

a) The existing type - and reference wells from the Lower Jurassic and Triassic formations were reviewed to determine the characteristics of each formation (section 3.2).

b) The knowledge gained from a) was used to recognize the various formations in the 7/12-wells. This exercise was partly successful (Section 3.3) and 7/12-3A was chosen as a reference well for Lower Jurassic and Triassic formations within 7/12.

c) 7/12-3A was compared to the other 7/12 wells to obtain an intra-7/12 stratigraphy using all available log- and lithology data. (Section 3.4).

3.2 Existing stratigraphic terminology.

The first formal Lower Jurassic and Triassic lithostratigraphic nomenclature for the central North Sea was published in 1977 (Deegan & Scull). A review of the Danish Jurassic and Triassic deposits were published in 1978 and 1980 (Michelsen, 1978 and Bertelsen, 1980 resp.). A Triassic study in the Norwegian part of the Norwegian - Danish basin was published in 1980 by Statoil (Jakobson et. al.).

The various formation names and simplified lithological columns for each area are presented in Fig. 4.

From a quick look at the rocks present in the 7/12-wells (Encl. 1) it is obvious that the mudstone - and - evaporite environment described from Denmark is not present. These formations will therefore not be considered further here.
A short description of the remaining formations is presented below:

Fjerritslev Fm.

Rock types: MUDSTONE, dk. grey - black, grey, sl. calc, sl. silty. Occasionally minor SILTSTONE and SANDSTONE.

Age / Dating: Hettangian - Aalenian (occ. basal Bajocian). Normally some dateable fossils.

Ref. well used: NOCS 7/9-1 (2523 -2600 mBRT)

Remarks: No red colour. Marine, only small facies changes expected laterally.

Gassum Fm.

Rock types: SANDSTONE, clear, white, grey, occ. red, fine to medium, occ. coarse to gravelly, quartz and rock fragments, moderately sorted, rounded to angular, often red argillaceous matrix.
MUDSTONE, dark grey, black, red brown, brick red, occ. silty, occ. calc, occ. carbonaceous.
Locally COAL in thin seams.

Age / Dating: Rhaetian - Hettangian, often difficult to find fossils.

Ref. well used: NOCS 7/9-1, (2600-2608 mBRT), NOCS 17/10-1 (2682-2825 mBRT).

Remarks: Always faster sonic than above, very often also faster sonic than below. At least faster sonic than immediately below. Commonly high radioactivity peak at the base. Higher CNL-response and often higher FDC - response than below. Deltaic environment, rapid local facies changes can be expected. Coal not necessarily present.

Skagerrak Fm.

Rock types: CONGLOMERATE, grey, white, red brown, quartz, subrounded to angular, poorly to moderately sorted, occ. silica cemented, occ. anhydritic.
SANDSTONE, grey, red, pink, brown, fine to coarse, quartz, subrounded to angular, poorly to moderately sorted, occ. calcareous cement, occ. anhydritic.
MUDSTONE/SHALE, grey, red, brick red, occ. silty occ. calcareous.

Age / Dating: ?Early, Middle and Late Triassic. Very commonly barren of fossils.

Ref. well used: NOCS 10/8-1 (1516 - 2744 mBRT), NOCS 17/10-1 (2825 - 3405 mBRT), NOCS 17/12-1 (2490 - 3880 mBRT).

Remarks: NOCS 17/12-1 has been devided into several coarsening upwards cycles (Jakobson et. al. 1980). Commonly evaporites in the lower half of the formation. Environment is commonly interpreted as alluvial fans and fluvial braided streams, i.e small scale facies changes can be expected locally, but large scale facies changes are unlikely.
Some wells have high radioactive sandstones near the top (70^{o} API).

Smith Bank Fm.

Rock types: MUDSTONE, brick red, red brown, hard, silty, anhydritic, occ. calcareous.
SILTSTONE, grading to MUDSTONE, as above.
Minor red brown SANDSTONE, also minor CONGLOMERATE, dark grey MUDSTONE, LIMESTONE, ANHYDRITE, DOLOMITE.

Age / Dating: Early to ?Late Triassic. Commonly barren.

Ref. well used: NOCS 10/8-1 (2744 - 2825 mBRT), NOCS 17/10-1 (3405 m - TD).

Remarks: Generally higher radioactivity than above, higher CNL than above. The formation overlies salt.

Josephine Member in the Smith Bank Fm.

Rock type: SANDSTONE, brown, fine to medium, friable.
Age / Dating: ?Late Triassic

Ref. well used: UKCS 30/13-1 (3765 - 3835.5 mBRT)

Remarks: No good description of this member has been found.

3.3 Recognizable formations in block 7/12.

The formations described in section 3.2 has been recognized in some of the 7/12 -wells. The reasons for picking them are explained below:

The Fjerritslev Formation has been recognized in 7/12-3A from 3859 to 3930 m BRT (drilled depth) as a predominantly mudstone formation of ?Hettangian to Late Sinemurian age (Encl. 1). The FDC - CNL - overlay log does not give a good mudstone response in the top part of the interval. This is thought to be a function of an error on the FDC log caused by large caved hole.

The formation has also been picked in 7/12-4 from 3573 to 3593 mBRT with certainty. The lower section in 7/12-4 possibly includes some Fjerritslev Fm., this will be discussed later.

The Gassum Formation is picked in 7/12-3A from 3930 to 3962 mBRT on the basis of rock types, sonic log, radioactivity peak at the base and stratigraphic position underneath the Fjerritslev Fm. (There is not supposed to be an unconformity between the two formations). Three of the five samples investigated for biostratigraphy proved barren, the results from the upper two samples were not reported in the palaeontology report (Duxbury et. al, 1977).

The Skagerrak Fm. was fully penetrated in 7/12-3A (3962 - 4043 mBRT) and 7/12-5 (3900 - 4152 mBRT). The evidence for picking the formation is in both cases:

a) The rock types described (variable, but predominantly sandy).
b) The red colour in the mudstones and siltstones and the occasional red colour in the sandstones.
c) The presence of anhydrite in the lower half of the section.

d) The absence of fossils (although not very well investigated).

e) characteristic, but not diagnostic, GR and FDC - CNL - overlay patterns.

The Smith Bank Fm. was also recognized in 7/12-3A and 7/12-5. The evidence is:

a) Predominantly mudstone and siltstone lithology.

b) Slightly higher GR trend than above.

c) Clear mudstone response on the FDC - CNL - overlay plot.

d) Higher CNL - response than above.

e) Presence of anhydrite throughout.

There is no evidence of any equivalent to the Josephine Member in the Smith Bank Fm.

The Zechstein Group evaporites were penetrated in 7/12-3A and 7/12-5. Estimates of the depth to the salt are included in Encl. 1 for the other wells. The depth has been calculated from the check-shot surveys and the seismic sections.

As all formations recognized are present in 7/12-3A this well has been chosen as the reference well in block 7/12.

3.4 Comparison between 7/12-3A and the other 7/12 - wells.

To be able to correlate 7/12-3A with the other 7/12 - wells a diagram with all relevant log- and lithology data was constructed (Encl. 1). The following information was put on: (left to right on each log Encl. 1):

1) GR log
2) SONIC log
3) FDC-CNL-overlay log
4) CNL-log
5) Direction of structural dip
6) FDC-log
7) Presence of red colour in mudstones as this often is taken as indicative of Triassic rocks.
8) Presence of red colour in sandstones in an attempt to separate out specific intervals for correlation of reservoir rocks.
9) Presence of anhydrite as this is indicative of the lower part of the Skagerrak Fm. and the whole of the Smith Bank Fm.
10) Presence of calcite.
11) Presence of dolomite. 10) and 11) were incorporated to test wether dolomite replaced calcite with depth as in 7/12-6.

12) Presence of coarse mica in the sandstones.
This would serve as a means of correlating the sandstones as it will give information about source rock and/or transport mechanism and length.

13) Presence or absence of recognizable fossils is included because the Triassic rocks in the area are very commonly barren of fossils.

To help identification of the different formations a shading technique was used, i.e. the GR curve was filled in with dark grey colour below a certain ^{o}API number. The cut-off values used in the different logs are:

GR - 50 ^{o}API
SONIC - 70 msec/ft
CNL - 20 nphi
FDC - 2,5 g/cc

The shading was chosen in the reference well 7/12-3A to highlight the various formations there. It was then used on the other wells to help picking the formations.
To put on the lithology data it was necessary to go back to cuttings books and lithologs to get reliable data. To compare the mica content, some selected samples from each well were re-examined using a binocular microscope by R. Ree.

From the diagram produced it is possible to draw several conclusions about some sections in the various wells. The remaining sections, i.e. those which are not readily grouped into one of the formations seen in 7/12-3A, will be discussed later.

<u>7/12-2, 7/12-5 and 7/12-6 have no Fjerritslev Fm.</u>
No mudstone dominated interval is present below the pre-Haldager unconformity above a sand dominated interval.

<u>7/12-5 and 7/12-6 have not penetrated the Gassum Fm.</u>
The Gassum Fm. in 7/12-3A is best characterized by the sonic and CNL-logs and also on the FDC-logs. The rock types are very similar to the Skagerrak Fm. and if no coal is present, logs are the best guide to picking the formation. An upward increasing CNL, FDC and faster sonic is not seen in 7/12-5 and -6 just below the pre-Haldager Unconformity and the formation is thus not believed to be present in the two wells.

7/12-6 drilled rocks resembling the Skagerrak Fm. (3522 - 3700mBRT)

The predominantly sandy rocks with minor amounts of siltstone and mudstone, the shape of the GR - and FDC-CNL-overlay logs and the lack of fossils indicates that 7/12-6 drilled a formation that resembles the Skagerrak Fm. The fact that the sedimentary environment has been interpreted as braided streams supports this.

7/12-2 also drilled rocks resembling the Skagerrak Fm. (3620 - 3670 mBRT).

This interval is very sandy with minor siltstone and mudstone beds. The one core taken has been interpreted as being deposited in a braided stream environment (Walls, 1978) and correlated with the cores from 7/12-6 (Davies, 1981). The shape of the GR and the lack of fossils support this.

7/12-2, 4 and 6 have not reached the Smith Bank Fm.

None of these wells terminated in rocks with FDC-CNL-overlay responses which could fit the Smith Bank Fm. The lack of evaporites also supports this conclusion.

In the above paragraphs, the presence or absence of several formations has been indicated for most of the sections studied and thus a stratigraphy has been established. Two sections: 7/12-2 (3553 - 3620 mBRT) and 7/12-4 (3593 m - TD) have not been commented upon.

7/12-2, section from 3553 to 3620 mBRT.

This interval looks sandy on the GR and the FDC - CNL - overlay logs, but only silty mudstones and siltstones have been described. The interval is well covered with sidewall cores. Most of the rocks are very micaceous as are the rocks below 3620 m. No fossils have been found.

The log pattern (FDC-CNL-overlay and FDC in particular) look very much like the Skagerrak Fm. of 7/12-5 and the supposedly Skagerrak Fm. of 7/12-6. But it seems also possible to correlate the GR-curve of the Gassum Fm. of 7/12-3A with the GR-curve of 7/12-2 (section in 7/12-2 from about 3580 m to 3620 m). Two log correlations are therefore possible.

To try to solve this problem it is important to look at the relationship downwards with the underlying rocks. A major change in structural dip occurs at the base of the interval, at 3620 m. If this is an unconformity it implies a time gap and tilting of the underlying rocks before the deposition of the section in question. This could possibly indicate the presence of a Gassum Fm. However, the dip break has been studied by a dipmeter consultant who concluded that a SSE dipping reverse fault was the best explanation, but a N dipping normal fault could be an alternative explanation (E.R. Aston, letter to Dr. I. Price, 12th Oct. 1981). A fault is more likely than an unconformity because the surface defining the break dips 30 - 35^{o} SSE which is too steep for an unconformity, but acceptable for faulting. Also Aston feels that the occurrence of shales/siltstones immediately above an unconformity would be unusual. The present author agrees with Aston that the evidence in favour of a fault is stronger than that favouring an unconformity and the fault model is adopted here. However, the author does not agree with Aston that the fault has a reverse throw. The dipmeter pattern indicates, as Aston says, either a S dipping reverse fault or a N dipping normal fault. On the base Haldager map the well is situated very close to a N dipping normal fault.

Also, a reverse fault would appear in the well as repetition of strata. The logs clearly show that the preserved strata do not repeat anywhere. If the fault is reverse, the upthrown rocks must have been eroded. It is then possible to calculate the minimum throw on a reverse fault and this is shown in Appendix 1. The throw must be at least 230 m. That is very substantial to have been overlooked on the seismic maps which makes the author prefer a N-dipping normal fault.

However, to understand the rocks between 3553 m and 3620 m it is important to know that the boundary to the underlying rocks is a fault, not what kind of fault.

If the boundary at 3620 m is a fault there is not necessarily a large time gap between the rocks above and below and they can be interpreted as different facies of the same formation. Both rock types are characterized by very high mica content which could support this.

As a summary, the rocks between 3553 m and 3620 m in 7/12-2 can be assigned to a Skagerrak Fm. Eqv. or a Gassum Fm. Eqv. It has not been possible to prove or disprove either of these correlations, but the author feels that the evidence for assigning the rocks to the Skagerrak Fm. is stronger and this correlation will be used here.

7/12-4, section below 3593 mBRT.

The section in question is from 3593 m to 3623 m (TD) i.e. 30 m. Of this, the interval 3593 m to 3611 m contain Early Jurassic - Triassic fossils (Encl. 1). Normally (7/12-2, 3A Encl. 1) the fossils disapppear approximately when the mudstones get a red colouration. In 7/12-4 however, the red colour appears in the lower half of what would normally be assigned to the Fjerritslev Fm., above where the fossils disappear. The Fjerritslev Fm. is not, by definition, supposed to have red coloured rocks.

The mudstones of the 'certain' Fjerritslev Fm. (3573 m - 3593 m) grade downwards into more sandy rocks at about 3610 m. The last fossil has been found at 3610 m. Disregarding the red colour, the rocks from 3593 m to 3610 m are assigned to the Fjerritslev Fm. on the basis of rock type and fossils present.

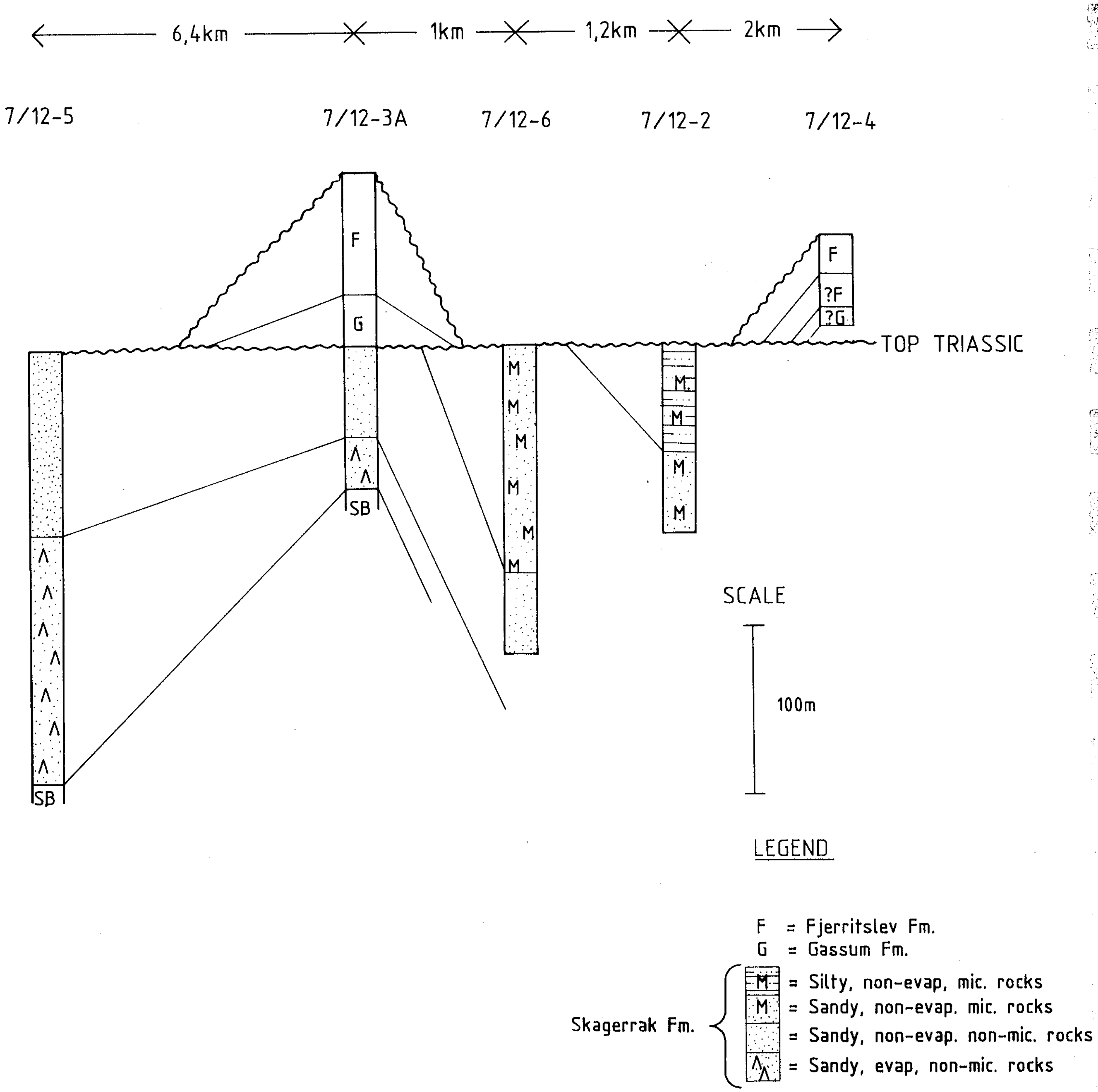
The rocks below 3610 m are more like the Skagerrak Fm./Gassum Fm. in appearance and no fossils are present. This interval is assigned to the Gassum Fm. mainly because it underlies the Fjerritslev Fm. and there is not normally an unconformity between the two.

The above choice of formations is a best guess based on somewhat contradictory facts and the fact that 7/12-4 did not drill deep enough into the ?Triassic to enable an identification of the formation at TD.

The Gassum Fm. spans the boundary between the Jurassic and the Triassic and the TD of the well may therefore still be in the Triassic even though it is proposed that the Skagerrak Fm. has not been penetrated.

3.5 Detailed stratigraphy and correlation within the Skagerrak Fm.

Formation names have now been assigned to all parts of the sections drilled in the 7/12-wells below the pre-Haldager unconformity.



POSSIBLE CORRELATION OF TRIASSIC FORMATIONS IN BLOCK 7/12

Fig.5

BP PETROLEUM DEVELOPMENT LTD. NORWAY
Ref GL/NO/562
Author B. TVEITEN
Date MARCH'82 Drg No. 6039

The oil bearing rocks in 7/12-2 and 7/12-6 have both been assigned to a Skagerrak Fm. Eqv. A detailed correlation of the rocks assigned to the Skagerrak Fm. or a Skagerrak Fm. Eqv. is now necessary to solve the problem of the shape of the oil reservoir.

A summary of the lithostratigraphic interval in the Skagerrak Fm. in the separate wells are given below:

7/12-2 has a very micaceous, non-evaporitic, silty interval on top of a very micaceous, non-evaporitic, sandy interval.

7/12-6 has a very micaceous, non evaporitic, sandy interval on top of an unmicaceous, non-evaporitic, sandy interval.

7/12-3A has an unmicaceous, non-evaporitic, sandy interval on top of an unmicaceous, anhydritic, sandy interval.

7/12-5 is similar to 7/12-3A.

7/12-4 did probably not reach this formation.

How are these intervals to be placed in their overall stratigraphic arrangement? The following sequence is proposed:

1) Top: silty, non-evaporitic, micaceous rocks (7/12-2)
sandy, non-evaporitic, micaceous rocks (7/12-2, -6)
sandy, non-evaporitic, non-micaceous rocks (7/12-6, -3A, -5)
Bottom: sandy, evaporitic, non-micaceous rocks (7/12-3A, -5) which is illustrated on Fig. 5.

The implication of this sequence is discussed in section 3.7.

3.6 Structure of the Triassic rocks.

In order to define how the oil is distributed in the Triassic rocks it is essential to understand the structure of these rocks.

There are three different methods of approaching this problem

a) Seismic
b) Lithological correlation
c) Dipmeter interpretation

		7/12-5	7/12-3A	7/12-6	7/12-2
Ula Fm. dip angle and azimuth	From seismic maps	2^{o}/SW	9^{o}/WSW	10^{o}/NNE	6^{o}/ENE
	From dipmeter	5^{o}/SW	15^{o}/WSW	7^{o}/NNE	6^{o}/E
Triassic dip angle and azimuth	From dipmeter	10-20^{o}/SE	15-25^{o}/N	6^{o}/SE	15^{o}/ESE 13^{o}/NNE

LEGEND

2^{o}/SW = DIP ANGLE/AZIMUTH

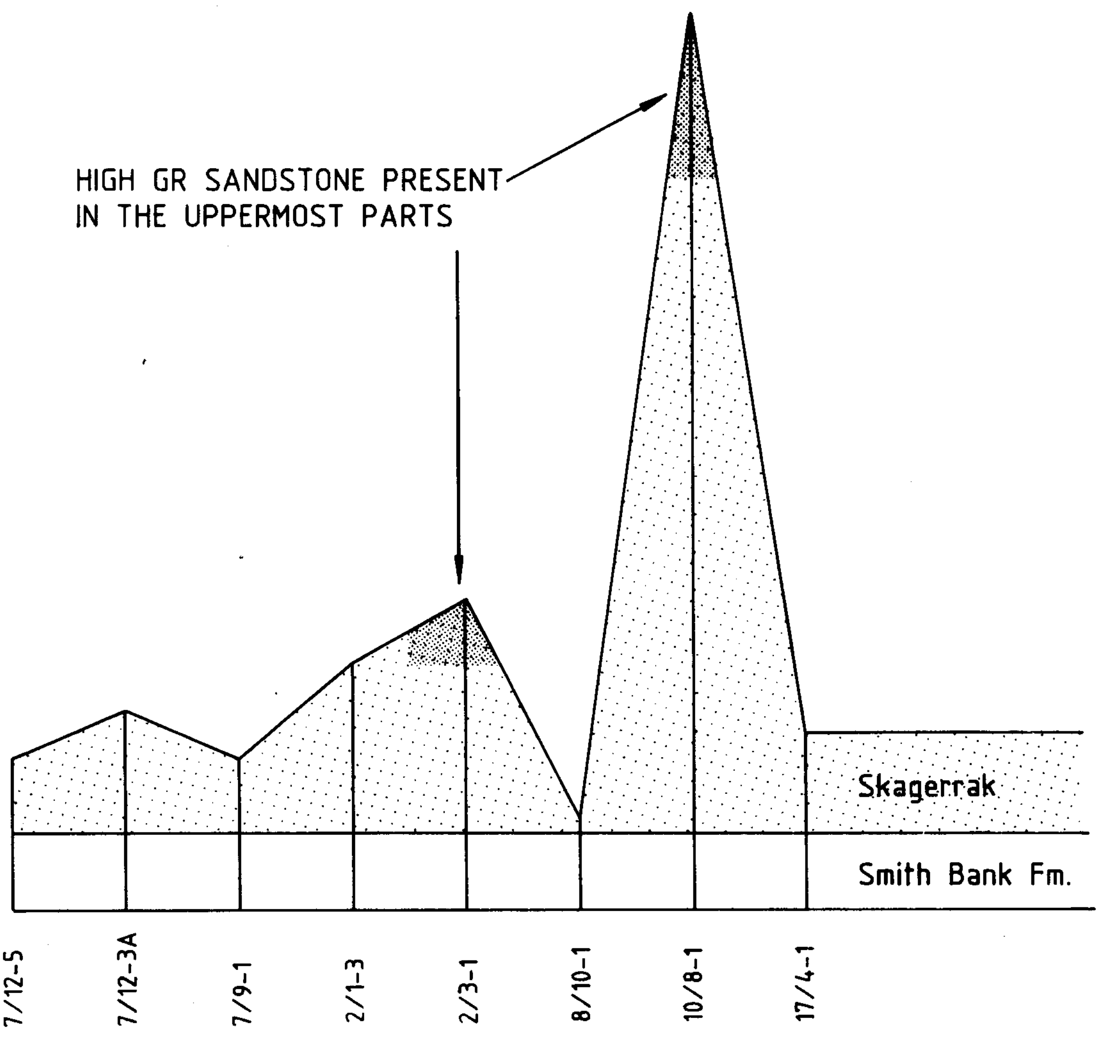
TABLE 1 STRUCTURAL DIP DATA FROM DIPMETER EVIDENCE.

Seismic mapping across the Ula structure shows a simple domal structure at top Ula Fm. level. Reflectors at base Haldager and top salt levels also show similar simple domal structures. Thus, although seismic reflectors are absent between base Haldager and top salt levels, the simplest assumption is that the strata between these levels also lie in a simple domal structure. The implication of such an assumption is that these strata ought to correlate from well to well. However, the lithological correlation (Sections 3.4 and 3.5) shows that this is not the case. One has to imply sudden facies changes to be able to correlate directly from well to well and this does not seem very likely in the implied sedimentary environment.

The third method to indicate the structure of the Triassic rocks is the dipmeter (Encl. 2; Table 1). The data quality is not very good due to frequently caved hole, but there are relatively strong indications that the dip of the beds are different above and below the base of the Haldager Fm. The author believes the dipmeter data indicate that the Triassic and Lower Jurassic rocks have a different structure to that of the Middle - Upper Jurassic rocks.

In summary, the three methods that give information on the structure of the Triassic rocks do not give the same answer to the problem. The author feels that the evidence for saying that the Triassic and Lower Jurassic rocks have a different structure to the Middle and Upper Jurassic rocks are the stronger.

The preferred correlation implies that units within the Skagerrak Fm. subcrop beneath the Haldager, Fjerritslev and Gassum Formations (i.e. Top Triassic) since the very micaceous units do not occur in 7/12-3A and -5. Because of the importance of mica and anhydrite with regard to mineralogical source and environment of deposition, it is not felt possible to correlate the micaceous rocks of 7/12-2 and -6 with the non-micaceous rocks in 7/12-3A and -5 directly. A top Triassic unconformity is therefore implied by the correlation.



COMPARISON OF THE RELATIVE THICKNESSES BETWEEN THE SMITH BANK FM. AND THE SKAGERRAK FM.

The thickness of the Smith Bank Fm. is one unit.
The shaded areas in 2/3-1 and 10/8-1 represents the presence of high GR sandstones.

Fig.6

BP PETROLEUM DEVELOPMENT LTD, NORWAY	
Ref: GL/NO/562	
Author: B. TVEITEN	
Date: JAN. 1982	Drg No: 6029

3.7 The post-Skagerrak, pre-Gassum unconformity.

As the correlation is uncertain and the top Triassic unconformity has not been suggested previously in block 7/12, it is important to seek other evidence or indications to support the existence of an unconformity.

a) Seismostratigraphy.

23 unmigrated lines in a 1 x 1 km grid covering the area were investigated to try to see events subcropping the green horizon (pre-Haldager Unconformity) recently mapped by Mills (1982).
Some very vague indications of possible subcrops were seen over the top of the salt pillow, but the quality of these were so poor that they may be more imaginary than real.
Along the side of the salt pillow, however, a clear trough was seen (Encl. 3) filled with younger sediments than present over the top of the pillow.

The study thus showed that subcrops were present, but failed to exactly show the stratigraphic level of the angularity. The trough mentioned could be filled with Lower Jurassic sediments thus not proving subcrop below the top of the Triassic.

b) Regional well information.

The fact that both the Smith Bank Fm. and the Skagerrak Fm. has been recognized in 7/12-3A allows a comparison between the relative thicknesses of the two formations.
If this proportion is smaller in 7/12-3A than in other wells in the area, it would be an indication to support the idea of an eroded top of the Skagerrak Fm. Fig. 6 is a plot of the relative thicknesses of the Skagerrak and Smith Bank Formations where the thickness of the Smith Bank Fm. is one unit. Three wells show a significantly thicker Skagerrak Fm., three wells show the same relative thickness and in one well the Skagerrak Fm. is much thinner than the Smith Bank Fm. The relative thicknesses in some wells thus indicates the possibility that sections are missing in others.

SKETCH TIME DIFFERENCE MAP OF BLUE-GREEN INTERVAL
(LOWER JURASSIC AND TRIASSIC ROCKS.)

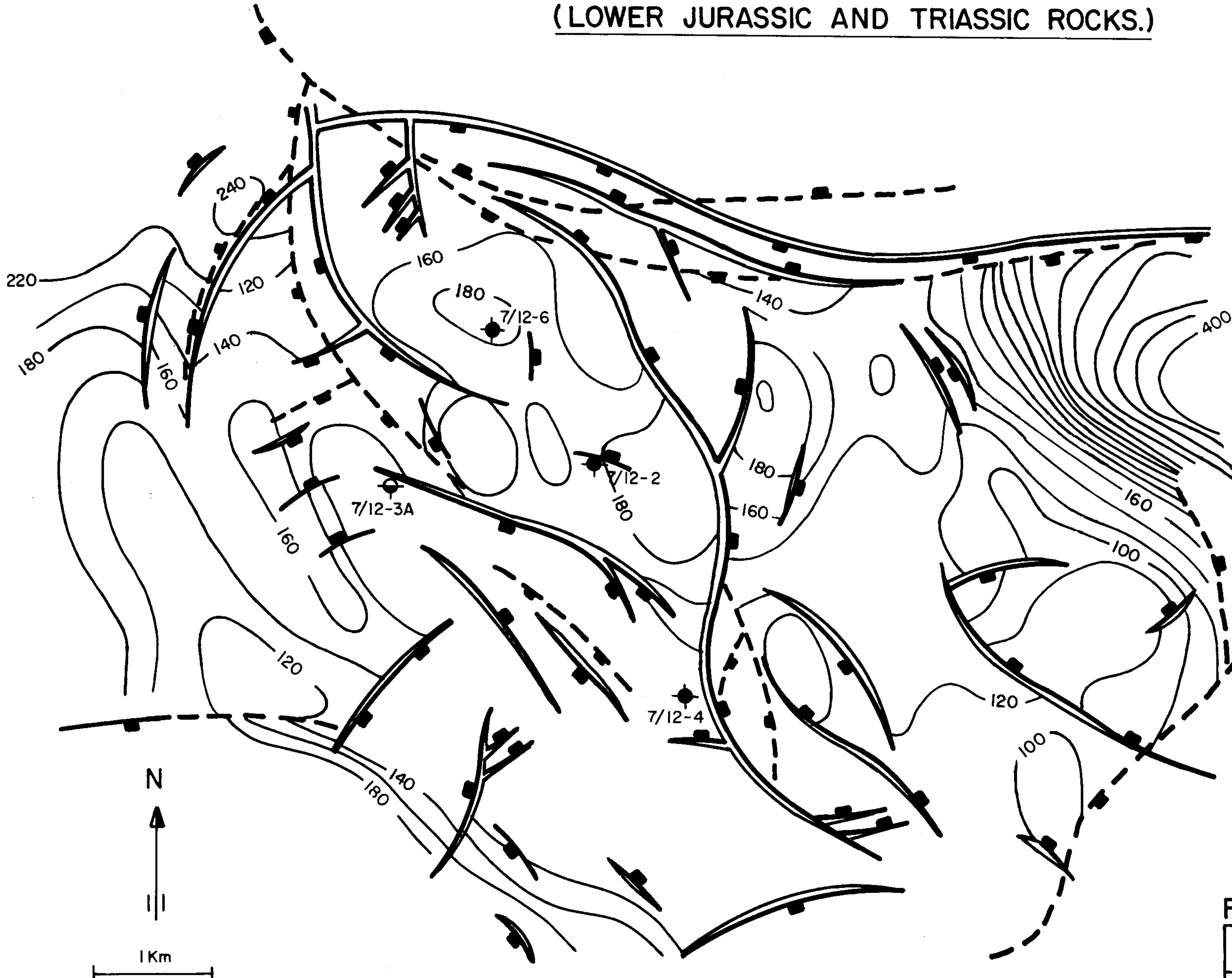


Fig. 7

BP PETROLEUM DEVELOPMENT LTD, NORWAY	
Ref: GL/NO/562	
Author: P.CARR / B.TVEITEN	
Date: JAN. 1982	Drg No: 6031

The two wells with the thickest relative Skagerrak Fm. have a zone of high GR sandstone (mica-rich) at the top. This top zone is also found in 9/12-1 which is not included in Fig. 6 because TD was in the Smith Bank Fm. This is an indication that the micaceous sandstone in 7/12-6 and 7/12-2 indeed is regional and situated on top of the non-micaceous sandstones found in 7/12-3A and is preserved only in some few wells.

3.8 Implications of the correlations with regard to the depositional history.

Several points are apparent from the preferred correlation which previously have not been known and discussed in block 7/12.

1) The top part of the Triassic succession in 7/12-3A have been eroded before the deposition of the Gassum Fm.

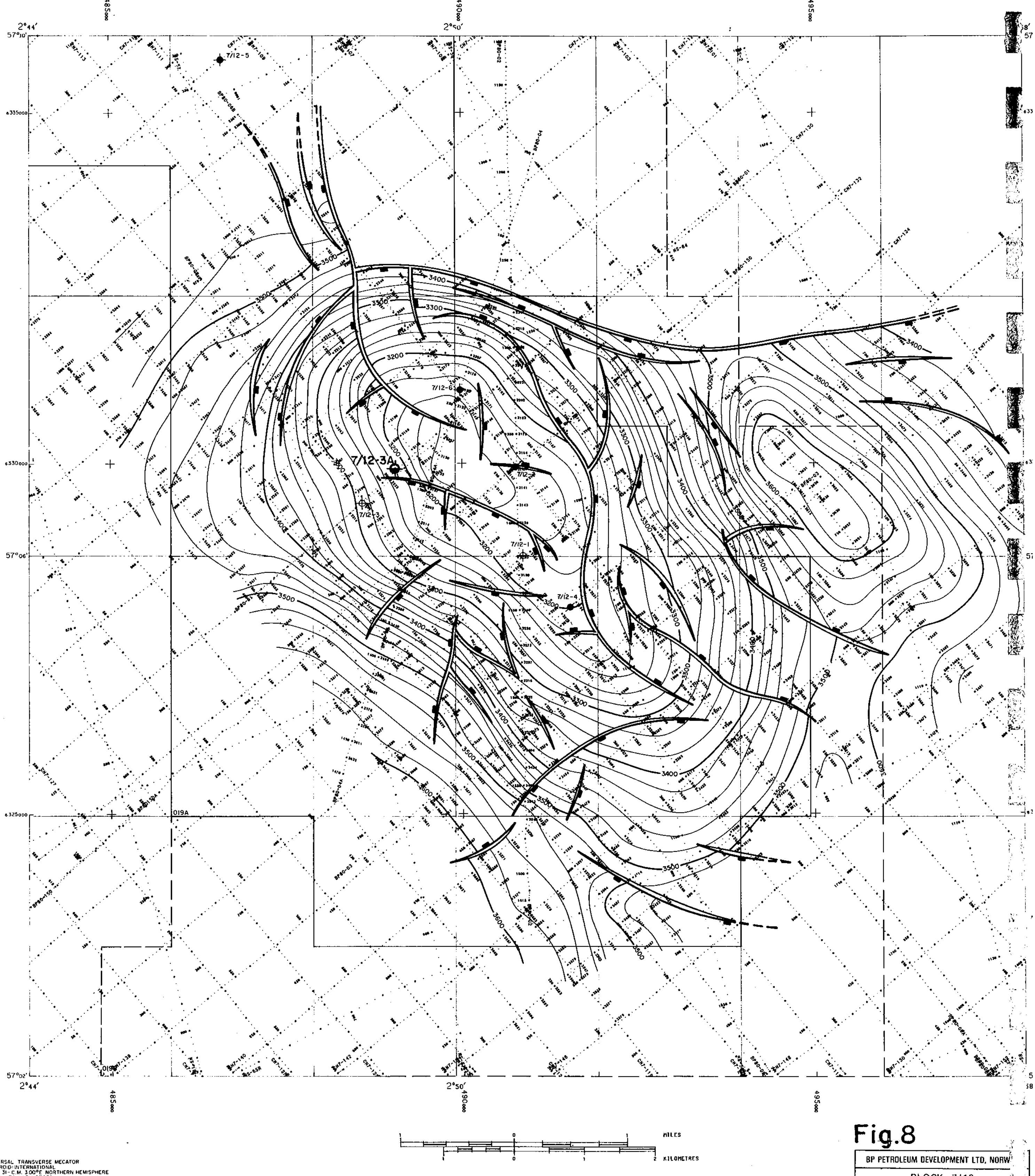
   Assuming that erosion flattens the topography, 7/12-3A must have been on a topographic high relative to 7/12-2 and -6 during the erosion.

2) Lower Jurassic sediments are preserved in 7/12-3A and -4, not in 7/12-2 and 6. Thus 7/12-3A apparently represent a relative Jurassic low on the pre Haldager erosion surface (cf. pre Gassum).

To explain these two points different uplift at different times must be assumed.

The salt pillow seems to have moved before mid-Jurassic. This is shown by a dramatic thickening of the Triassic to Lower Jurassic strata (green - blue interval) away from the pillow. (Encl.3 and Fig. 7). This thickening must be explained by salt movement during deposition of the strata or after deposition, before or during the erosion in Mid-Jurassic times.

7/12-3A is situated on top of the salt dome on the top salt map (encl. 10, Pape et. al., 1978). This indicates that this is the point of maximum updoming and could support the theory of a



UNIVERSAL TRANSVERSE MECATOR
SPHEROID: INTERNATIONAL
ZONE 31 - C.M. 3.00°E NORTHERN HEMISPHERE
GRID UNITS ARE METRES

Fig.8

BP PETROLEUM DEVELOPMENT LTD. NORW	
BLOCK 7/12	
ISOCHRONS ON GREEN HORIZON BASE HALDAGER	
CI - 20msec	
Ref. GL/NO/562	Datum: MSL
Author. K MILLS	Scale: 1 : 25000
Date: MARCH 1982	Drg No: 6117

topographic high near 7/12-3A. On the map of the green horizon (Mills, 1982) (Fig. 8) 7/12-3A and 7/12-4 seem to be within small grabens. If these grabens reflect not only mid-Jurassic events, but the continuation of earlier events the Lower Jurassic rocks could be preserved in them. The following geological history is then possible:-

1) Deposition of salt.
2) Deposition of not very micaceous Triassic rocks and possible simultaneously salt movement in certain areas triggered off by thick Triassic sediments (up to 900 m) (Fig. 7).
3) Deposition of very micaceous Triassic rocks.
4) Differential erosion of Triassic strata near end of Triassic time. Micaceous rocks eroded in 7/12-3A.
5) Deposition of thick Lower Jurassic rocks away from the salt swell, deposition of thin Lower Jurassic in downfaulted areas on the swell.
6) Erosion in ?Middle Jurassic.

With the present facts and the author's present ideas the history mentioned is a possible one, but not neccesarily the only possible one.

TAB1E 2: Comparison of Crude Oil Inspection Data Well 7/12-6

	Ula Crude Oil DST 2	Triassic Oil DST 1
GOR single stage flash (SCF/STB)	672	487
^{o}API	36.9	39.2
SP. Gr. at 60/60^{o}F	0.8405	0.829
Wax wt %	9.5	13.5
Melting Pt. wax ^{o}C	54	58
Pour Point ^{o}C	3	12
Asphaltenes % wt	0.25	0.6
Nitrogren ppm	683	316
Sulphur % wt	0.12	0.075

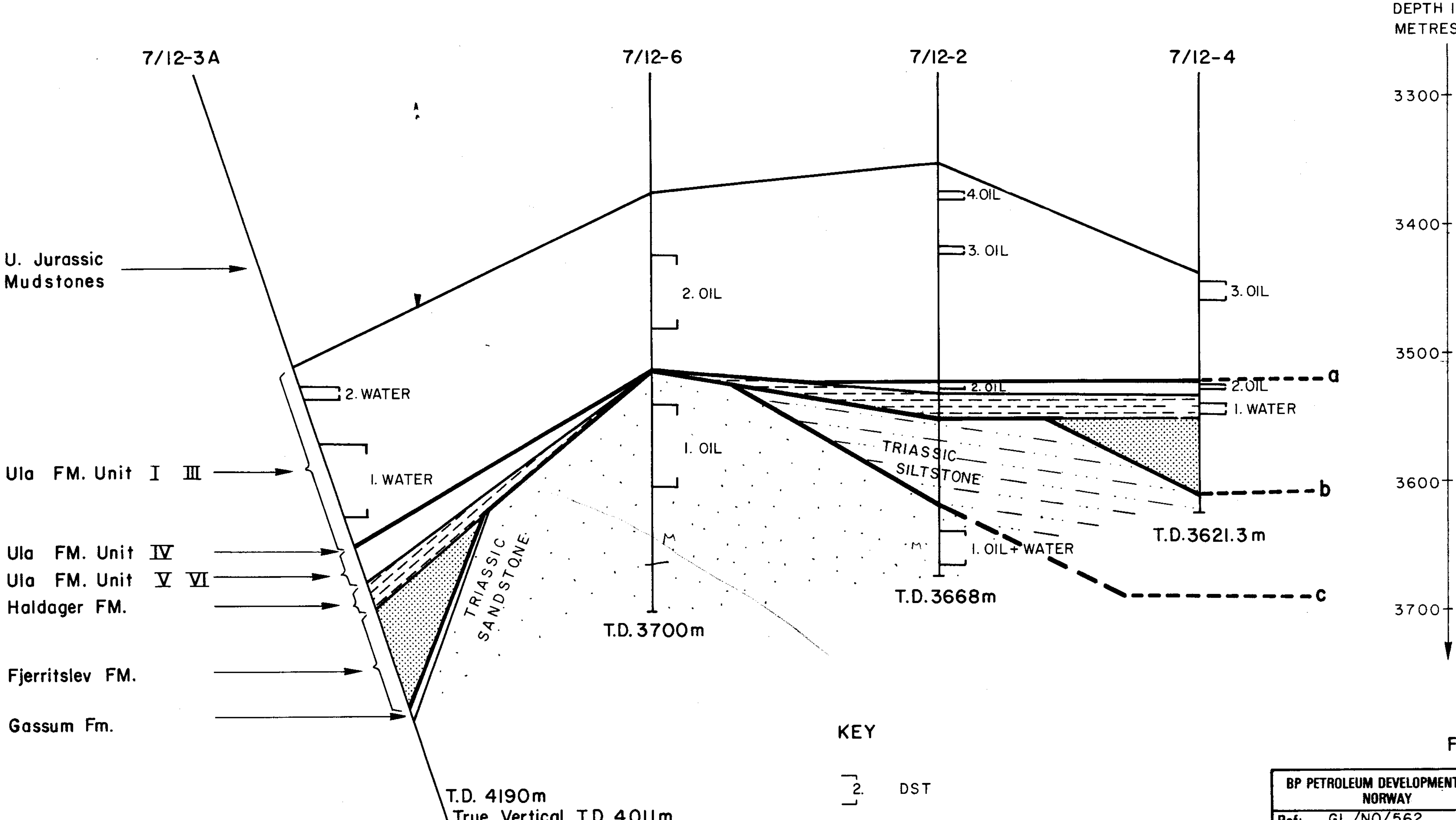


Fig.9

BP PETROLEUM DEVELOPMENT LTD, NORWAY	
Ref: GL/NO/562	
Author: I. Price	
Date: JULY '81	Drg No: 5818

4. TRAP.

4.1 Possible trap mechanisms.

After it was discovered that the two oils in 7/12-6 had different physical properties (Table 2) two studies were initiated to define the trap of the Triassic oil pool. These included geochemical oil correlation study and a re-look at the logs and tests in the 7/12 wells.

Three different seals could be envisaged at the time the studies were started (Fig. 9):

a) Ula Fm. unit IV. Implies that DST 2 in 7/12-2 and DST 2 in 7/12-4 belonged to the Triassic oil pool. The water producing DST 1 in 7/12-4 was a problem with this model.

b) Top Triassic, i.e. a combined seal consisting of
   - 7/12-6: Unit IV or top Triassic surface.
   - 7/12-2: Haldager Fm.
   - 7/12-4: Fjerritslev Fm.

c) Top sandy parts of Triassic i.e. a combined seal consisting of:
   - 7/12-6: Unit IV or top Triassic
   - 7/12-2: Triassic silty rocks above 3620 m.

4.2 Geochemical evidence.

An oil correlation study of oils from DST 1 and 2 in 7/12-6, DST 1 and 3 in 7/12-2, DST 2 in 7/12-4 and core extracts opposite DST 1 in 7/12-4 was made by Bockmeulen & Ward (1981). They concluded:

1) The two oils in 7/12-6 were derived from the same (?Upper Jurassic) source rock and were slightly different due to the Triassic oil being derived from a somewhat deeper, more mature level.

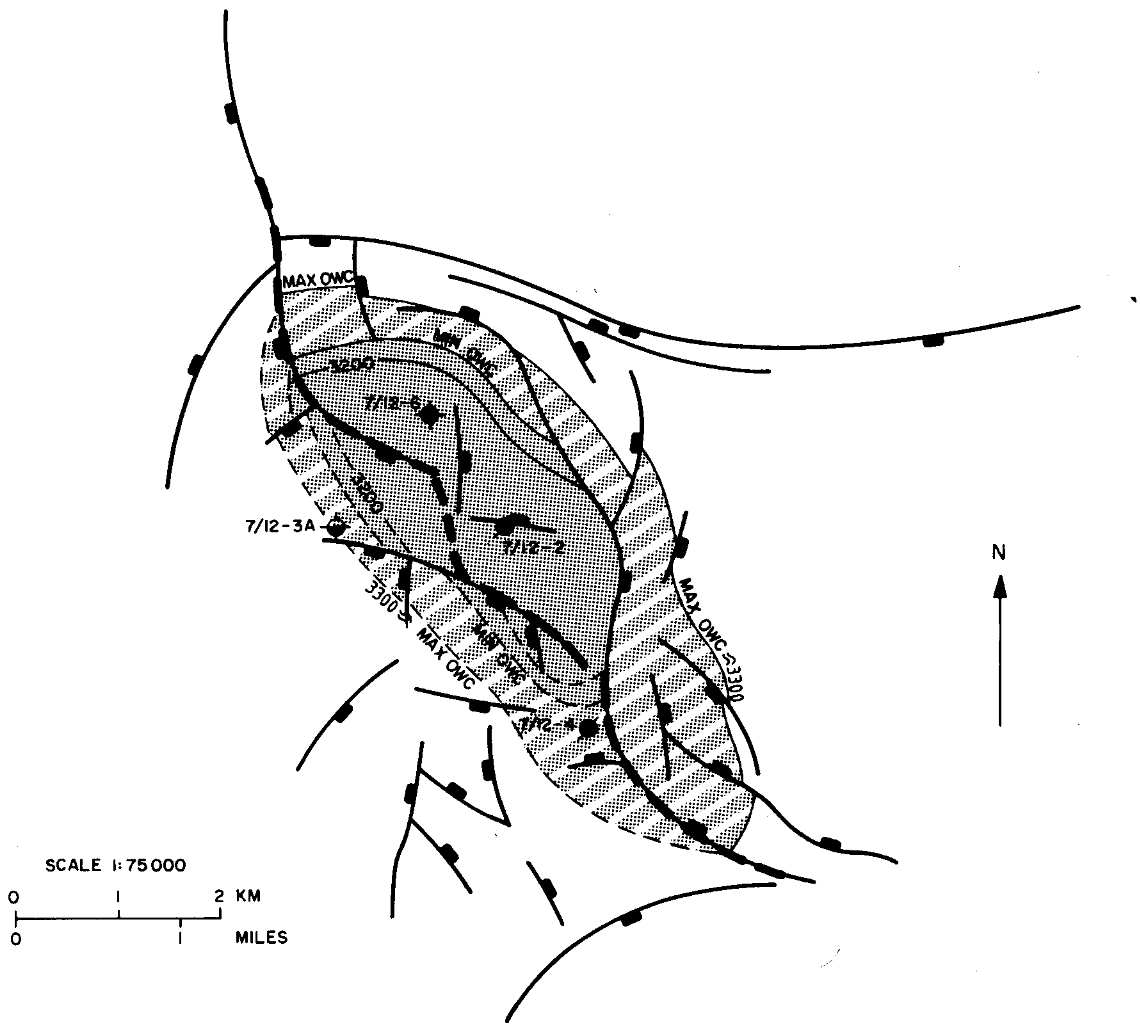
2) The oils from the Ula Fm. Unit V (below the proposed seal Unit IV) correlated well with the Ula oil. Thus Unit IV is not a seal everywhere in the field.

Of the three possible trap types, only the two last (b and c) are left after this study. Both conclude that the Triassic oil is confined to the Triassic rocks. Since the silty section of 7/12-2 above 3620 m does not show oil on the logs (and no shows in cuttings) the model c) above will be preferred here.

4.3 Conclusions about the oil bearing Triassic strata.

The Triassic oil bearing rocks in 7/12-6 and 7/12-2 have been correlated with the Skagerrak Formation. An internal stratigraphy of the Skagerrak Fm. has been suggested and the oil bearing strata are assigned to a micaceous part of the formation not found in 7/12-3A and 7/12-5.

The oil reservoir is thought to have its top at the top of the Triassic rocks in 7/12-6 and extending to the sandy interval in 7/12-2 (3620 m). It is not thought to have been penetrated in 7/12-4. 7/12-3A penetrated sandstones of a different type (non-micaceous) below the oil-water contact (Encl. 4).



TOP TRIASSIC SKETCH MAP

KEY

FAULT

UNCHANGED CONTOURS ON THE NE FLANK

CORRECTED CONTOURS ON THE SW FLANK

LINE SEPARATING THE CORRECTED SW FLANK FROM THE UNCHANGED NE FLANK

AREAL EXTENT OF MIN. OIL ACCUMULATION

AREAL EXTENT OF MAX. OIL ACCUMULATION

CONTOURS IN MSEC.

Fig.10

BP PETROLEUM DEVELOPMENT LTD. NORWAY	
Ref: GL/NO/562	
Author: B. TVEITEN	
Date: MAR. '82	Drg No: 6184

5. DEFINITIONS OF A TOP RESERVOIR SURFACE AND OIL-IN-PLACE ESTIMATES.

5.1 Geophysical difficulties.

In the pre-Cretaceous section three seismic horizons have been mapped, the Red (base Cretaceous), the Green (base Haldager Fm.) and Blue (top salt). The top of the Triassic reservoir is believed to correspond to a top or intra Triassic surface (see section 4.3). It has not been possible to map this surface seismically.

5.2 Construction of necessary maps.

To get a best possible map of the top reservoir surface the map of the base of the Haldager Fm. (Green) was converted to a top Triassic map by removing the Lower Jurassic rocks. The data used for this was the thicknesses and dips of the L. Jurassic rocks in 7/12-3A and 4. The construction of the map is discussed in Appendix 2.

5.3 Oil-in-place estimates in the Triassic rocks in the Ula structure.

The constructed top Triassic map is not a top reservoir map. Top Triassic corresponds to top reservoir in 7/12-6, but not in for example 7/12-2. Instead of trying to improve the map further by subtracting non-reservoir parts of the Triassic, the bulk rock volume of the whole of the Triassic section was calculated from this map (Fig. 10).

Since some parts of the Triassic are non-reservoir, it was estimated how much of the Triassic volume was occupied by sandstone with reservoir parameters equal to or better than in 7/12-6. This estimation was included in the oil-in-place estimates and is called "7/12-6 quality/gross volume" on the printouts. This parameter only was varied on the oil-in-place calculations, i.e. the reservoir parameters were kept constant.

Two cases were calculated:

a) "Minimum" case: OWC at 3661 mBRT which is the deepest oil on logs in 7/12-6.

b) "Maximum" case: OWC at 3795.5 mBRT which is the top of the water wet Triassic sandstones (TVD) in 7/12-3A.

The BRV-calculations and oil in place calculations comprises Appendix 3. The results are summarized as follows:

	MIN	ML	MAX	
OWC at 3661 mBRT	47	58	71	(x 10^6 bbls)
Additional OIP if				
OWC is at 3797.5 mBRT	32	66	136	(x 10^6 bbls)
Total maximum	79	124	206	(x 10^6 bbls)

A deeper OWC is not considered in the oil-in-place calculation, but in the case that 7/12-3A is sealed off from the oil in 7/12-6 and 7/12-2, any OWC down to salt is theoretically possible.

5.4 Oil-in-place estimates in the Triassic rocks in the 7/12-B structure.

In light of the complex and not well known structure in the Lower Jurassic and Triassic rocks in the Ula structure where there are four wells available, even more uncertainties can be expected in the 7/12-B structure where only one well has been drilled. Also, while a map near top reservoir was available in the Ula structure (Green i.e. base Haldager Fm.) only the Red (base Cretaceous) is available in the B-structure.

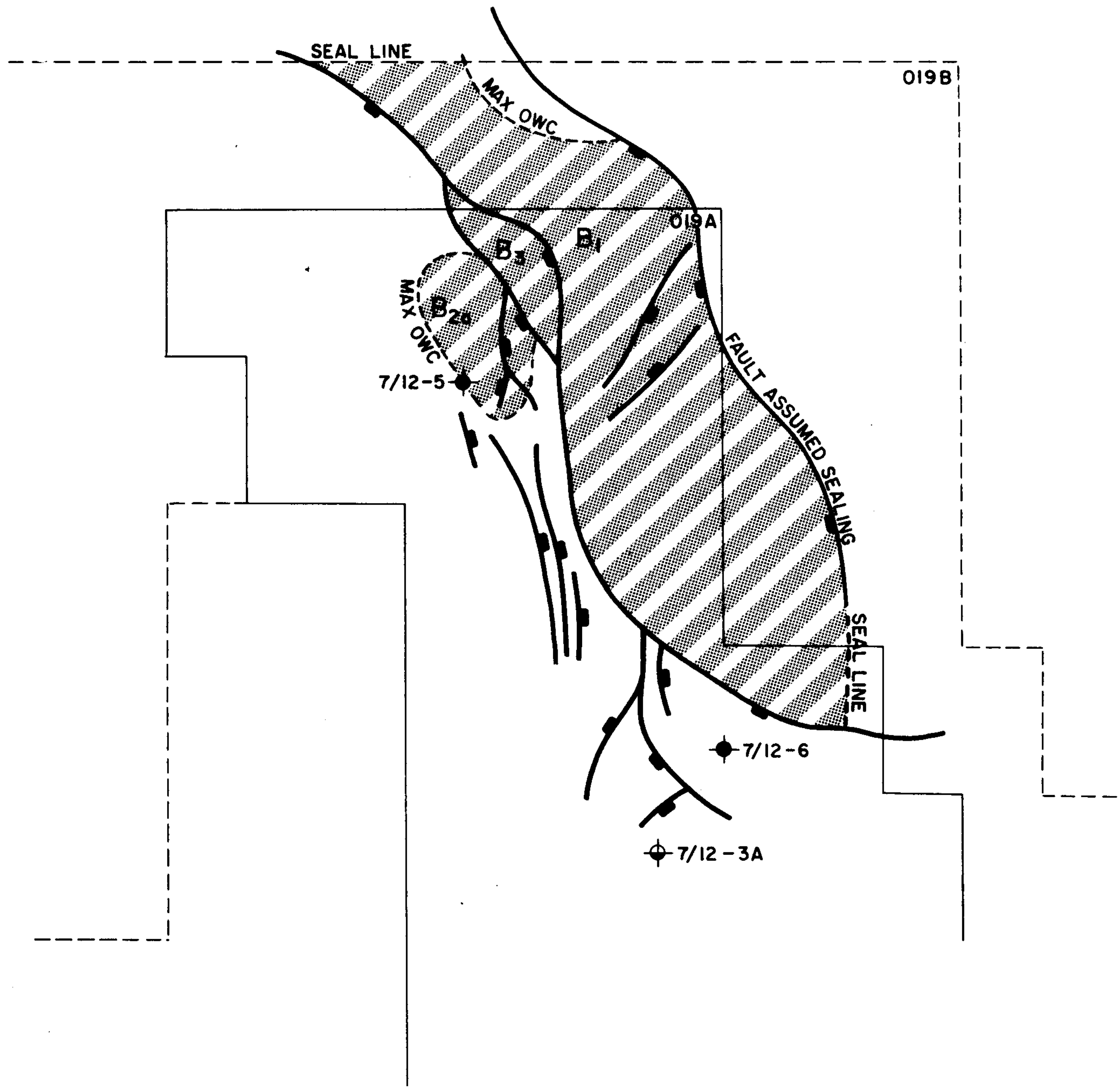
7/12-5 penetrated 492 m of water wet Triassic rocks. A clear dip break from 5-10^o SW in the Ula Fm. to 10-20^o SE in the Triassic section indicates that the same relationship is found here as that in the Ula structure i.e. the structure of the Triassic rocks is different from the structure of the Upper Jurassic rocks.

Due to the lack of data, a very simple method had to be used to estimate possible reserves.
The method is outlined below:

a) The structure of the top Triassic surface had to be assumed to be similar to the base Cretaceous surface of which there was a time map available. This map was used to calculate the bulk rock volume.

b) The top Triassic in 7/12-5 was at 3900 mBRT. This depth was then taken as the deepest possible OWC in the whole structure.

SKETCH MAP OF 7/12-B STRUCTURE



AREA INCLUDED IN BRV CALCULATION

Fig. 11

BP PETROLEUM DEVELOPMENT LTD, NORWAY	
Ref: GL/NO/562	
Author: B. TVEITEN	
Date: APR. '82	Drg No: 6220

c) The three fault segments B_1, B_2, B_3 were assumed to be in communication.

d) As in the Ula area, 7/12-6 reservoir parameters were used and the amount of reservoir of that quality in the total volume was estimated.

e) The structure is not dip closed to the chosen maximum OWC in fault segment B, (see encl. 2 in Tveiten & Mills (1981)). It was therefore necessary to limit the area to be able to calculate bulk rock volumes in this segment. The limit is shown on Fig. 11.

f) Depth conversion was done very simply by using two time-depth pairs, one at the sea surface (0 millisec = 0 meters and one where the well hit the map (3682 millisec) equals top of Triassic sand (3900 m BRT = 3875 m ss).

The reserves figures and computer prints are in Appendix 4 and are summarized below:

	MIN	ML	MAX
In-place-reserves (x 10^6 bbls)	90	190	396

It is important to remember i) that the volume possibly containing these amounts of oil is spread over a large area (up to 25 square km's), ii) the calculation is very inaccurate and iii) no hydrocarbons have been proven in these rocks in this structure yet.

6. CONCLUSIONS

The oil discovery in sandstones of presumably Triassic age in NOCS 7/12-6 has been evaluated.

The rocks are assumed to have been deposited by ephemeral braided streams.

The porosity and permeability are mainly controlled by the primary minerology i.e. grain size and clay content.

The structure of the Triassic rocks is assumed to be different from that of the Ula Fm. rocks, i.e. the Triassic rocks cannot easily be correlated across the Ula structure. The exact structure of the rocks has not been determined.

The rocks containing the oil have been correlated with the Skagerrak Fm. In detail the rocks are assigned to a micaceous top part of the Skagerrak Fm. not found in all wells that have penetrated this formation in the area.

In-place reserves proven by 7/12-6 have been calculated to (most likely) 58 x 10^6 STB. In addition up to max 136 x 10^6 STB may be present below the proven oil column. By using the maximum figures from both calculations 206 x 10^6 STB could be present in the Triassic reservoir.

In-place reserves have also been calculated for the Triassic rocks in the 7/12-B prospect. Most likely reserves are 190 x 10^6 STB, however no oil has been found in the Triassic rocks in this structure yet.

7. RECOMMENDATIONS

The largest gaps in knowledge about the Triassic reservoir beneath the Ula Field are a) its structure, b) the depth to the OWC and c) the stratigraphical and geographical prediction of reservoir quality. Further well data are required. The Petroleum Engineering evaluation report on 7/12-6 (P.S. Buckley 1982B) concludes that this further appraisal is best undertaken by deepening Ula development wells. Also, a 3D seismic survey may be undertaken prior to development. Thus the recommendation of this report is that before the planning of the development of the Ula Jurassic pool is finalized (but after 3D seismic results are available, perhaps) one or more of the development wells should be chosen for drilling on through to top Salt. The first well to be so deepened should be within the area of the minimum Triassic oil accumulation (Fig. 10), located probably crestally on the Ula structure (i.e. close to 7/12-2). It would have the best chance of encountering oil and finding an OWC.

REFERENCES

Bertelsen, F.	1980	Lithostratigraphy and depositional history of the Danish Triassic. (Geological Survey of Denmark. Series B, No. 4) TBK 210
Bockmeulen, H.A. & Ward, H.E.	1981	Ula Field oils correlation study: Block 7/12 Norwegian sector, North Sea. (BP Research Centre report no. GCB 189/81). GL/NO/526
Bowmann, M.B.J.	1981	The sedimentology and reservoir geology of the Upper Jurassic Ula Formation in well 7/12-6 NOCS and its relationship with other block 7/12 wells. (BP Sedimentary Petrology Section report no. OC 18236) NOCS 7/12-6 W24.
Buckley, P.S.	1982A	Well 7/12-6, Petroleum Engineering Completion Report. NOCS 7/12-6w48.
	1982B	Block 7/12 Triassic Reservoir and Economics Study. BP Stavanger PED/82/08
Davies, R.B. the	1981	Sedimentology and diagenesis of (?) Triassic cored interval, well 7/12-6, Norwegian North Sea. (BP Sedimentary Petrology Section report no. OC 18302) NOCS 7/12-6 W24.1.
Deegan, C.E. & Scull, B.J.	1977	A standard lithostratigraphic nomenclature for the Central and Northern North Sea. (Institute of geological sciences, report 77/25 and Norwegian Petroleum Institute, bulletin 1) TBK 223.

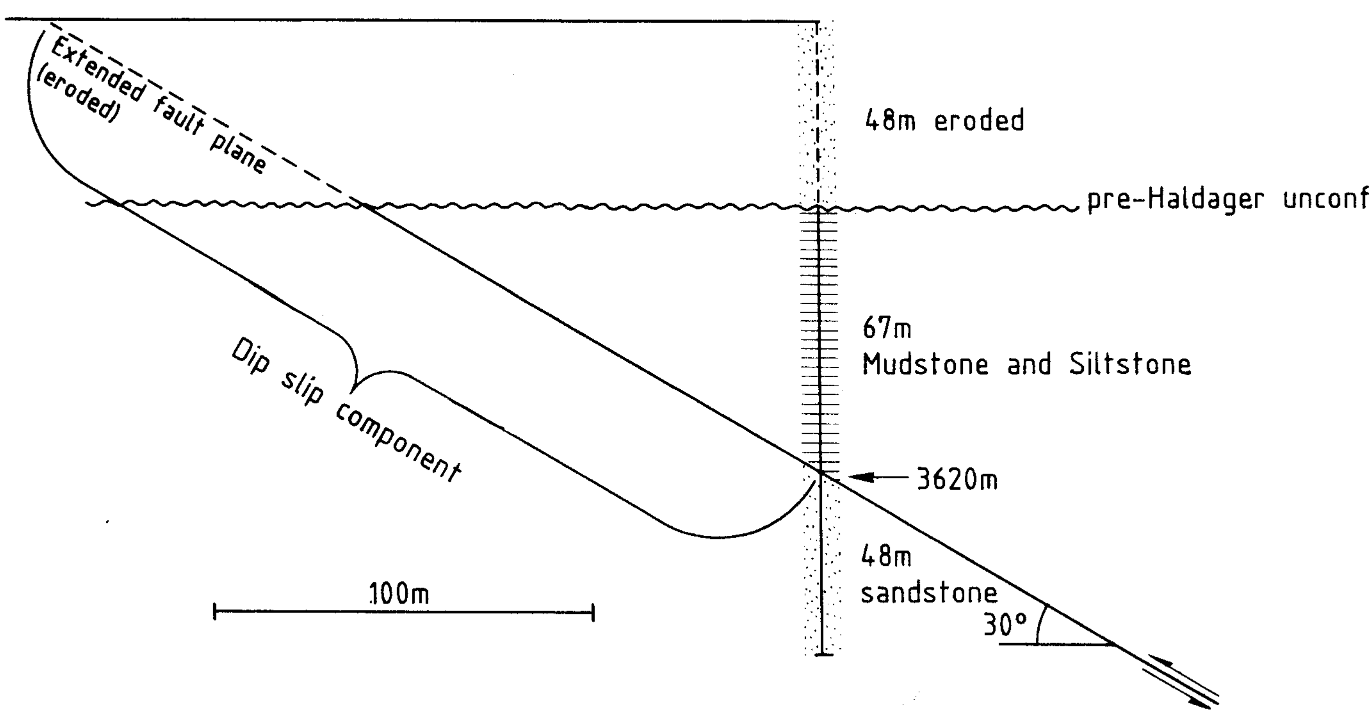
Duxbury, S. et. al.	1977	The biostratigraphy of BP/CONOCO/ PELICAN/STATOIL 7/12-3A (sidetrack) well, Norwegian North Sea (BP Palaeontological Branch note EPR/LPN 3667) NOCS 7/12-3A W.22.23
Jakobsson, K.H. et.al.	1980	Triassic facies in the North Sea North of the Central Highs. (in NPF; The sedimentation of the North Sea Reservoir rocks) TBK 220
Lowe, S.P.	1979	An oil to source and oil to oil geochemical correlation study of North Sea Block 7/12: Norwegian Sector. (BP Geochemical Operational Services Group report ERP/R7068) GL/NO/323
Michelsen, O.	1978	Stratigraphy and distribution of Jurassic deposits of the Norwegian - Danish Basin (Geological Survey of Denmark. Series B, No. 2) SEP 394.
Mills, K.J.	1982	Geophysical evaluation of the Ula Field, NOCS Block 7/12. GP/NO/216.
Price, I.	1982	Reservoir geology of the Ula Formation in the Ula Field, NOCS. GL/NO/520
Tveiten, B.	1981	Geological Completion report, NOCS well 7/12-6. NOCS 7/12-6 w.28
Tveiten, B. & Mills, K.J.	1981	Geological evaluation report, NOCS 7/12-5. NOCS 7/12-5 w.27.
Walls, R.	1978	Norwegian North Sea well 7/12-2, The Triassic section (BP Petroleum Geology Branch report No EPR/R. 8138) NOCS 7/12-2 w.24.4

APPENDIX 1

Calculation of dip slip component for a reverse fault case, 7/12-2, at 3620 m.

In a reverse fault there will be a repetition of strata. In 7/12-2 no such repetition is seen. The beds to be repeated (the sandstones below 3620 m) must therefore have been uplifted and eroded. The uplift must have been greater than the present thickness of the overlying rocks underneath the pre-Haldager unconformity (67 m) + the thickness of the sandstones (48 m) adjusted for the dip of the beds, and the dip of the fault plane. If the beds above and below are horizontal, the dip slip will be about 230 m.

(67 m + 48 m) sin 30 = 115 m/0.5 = 230 m



APPENDIX 2

Methods of (i) constructing "top Triassic" map and (ii) assigning possible OWC's.

(i) The Green horizon (base Vestland Group) (= Ula Fm. + Haldager Fm.) was used as a starting map. This is a time map. Two of the four wells to penetrate this horizon had Triassic rocks directly underneath the Vestland Group (7/12-2 and 7/12-6). The Green horizon therefore represents top Triassic in the vicinity of these wells.

The two other wells, 7/12-3A and 7/12-4 had 90 m and 65 m respectively of Lower Jurassic rocks present between the Vestland Group and the Triassic. It was therefore necessary to convert 90 m and 65 m respectively to time and recontour the map with the new values. Calibrated velocity logs were used to derive the time isopachs. The recontouring was of course very rough because it was based on only two data points. Also it could not be determined with certainty where the Lower Jurassic rocks were present away from the wells and where they were absent i.e. where the map needed recontouring or not.

(ii) After having constructed the map the proven oil column from 7/12-6 was plotted on (min. OWC). Again it was necessary to convert the oil column (140 m) to time. The minimum OWC plots at 3224 millisec. on the map. (= 3636 mss in 7/12-6)

The maximum OWC is defined from the top of the water bearing sands in 7/12-3A (3772.5 mss). Converted to time this is 3250 millisec.

When this figure (3772.5 mss= 3250 millisec) is compared with the minimum OWC derived from 7/12-6 (3636 mss = 3224 millisec) it is apparent that there must be an error somewhere. 136.5m (3772.5m - 3636m) cannot equal 26 millisec (3250 - 3224). This must be due to a lateral velocity variation across the structure. The time-value derived for the max. OWC from 7/12-3A cannot therefore be used around 7/12-6. A time-value for the depth corresponding to max. OWC (3772.5 mss) has been calculated from 7/12-6 to be 3300 millisec.
The value from 7/12-3A was used on the corrected side of the structure and the value from 7/12-6 was used on the unchanged side.

The computer programme was not able to evaluate a structure where the time to the OWC varied over the structure. The max. OWC was therefore called 3300 millisec. on the whole structure. Since the velocity varied across the structure the BRV calculations were simplified by letting 1 millisec = 1 meter i.e. "depth" converting the map.

APPENDIX 3

Oil-in-place calculations in the Triassic section in the Ula structure.

RESERVES CALCULATION FOR :

TRIAS BRV IN ULA STRUCTURE 7/12

byB.TVEITEN on19/3-1982

PROSPECT DATA

crest	3458.0	m
contour interval	133.0	m
min closing contour	3636.0	m
most likely closing contour	3636.0	m
max closing contour	3773.0	m

* *
*   BULK ROCK VOLUME CALCULATION   *
* *

INPUT DATA

Point No.		Contour m	Area in Sq.Km.
1		3458.0	0.000
2		3591.0	4.615
3	min.	3636.0	6.308
4	m.l.	3636.0	6.308
5		3724.0	12.096
6	max.	3773.0	13.937

BRV of minimum solid structure in M.cu.m	552.665
BRV of m.likely solid structure in M.cu.m	552.665
BRV of maximum solid structure in M.cu.m	2000.2495

RESERVES MEANS OIL-IN-PLACE ON THIS PRINTOUT

RESERVES CALCULATION FOR :

TRIAS RESERVES PROVEN BY 7/12-6

by B.TVEITEN on 19/3-1982

RESERVES BASED ON TRIANGULAR INPUT DISTRIBUTIONS AFTER BUCKEE 1977

VARIABLE	TYPE	MINIMUM	MOST LIKELY	MAXIMUM
B.R.V. million cu.m.	C		552.000	
Net to gross ratio	C		0.350	
Porosity	C		0.180	
Hydrocarbon Saturatn	C		0.700	
FVF for oil(Bo)	C		1.300	
Hydrocarbon/Net pay	T	0.300	0.500	0.700
Primary Recovery	C		0.100	
Secondary Recovery	C		0.100	

In Place

Mean value of distribution	5.889181E+07	bbls.
Mode	5.661229E+07	bbls.
Value at one standard deviation	6.835875E+07	bbls.
Standard deviation on median	9.616993E+06	bbls.
Standard deviation of log X	0.1622	
90% confidence level (min)	4.718532E+07	bbls.
Median value	5.812195E+07	bbls.
10% confidence level (max)	7.159348E+07	bbls.

RESERVES MEANS OIL-IN-PLACE ON THIS PRINTOUT.

RESERVES CALCULATION FOR :

7/12 TRIASSIC POSSIBLE RESERVES

by B.TVEITEN on 19/3-1982

RESERVES BASED ON TRIANGULAR INPUT DISTRIBUTIONS AFTER BUCKEE 1977

VARIABLE	TYPE	MINIMUM	MOST LIKELY	MAXIMUM
B.R.V. million cu.m.	R	0.000		1448.000
Net to gross ratio	C		0.350	
Porosity	C		0.180	
Hydrocarbon Saturatn	C		0.700	
FVF for oil(Bo)	C		1.300	
Hydrocarbon/Net pay	T	0.300	0.500	0.700
Primary Recovery	C		0.100	
Secondary Recovery	C		0.100	

In Place

Mean value of distribution	7.724216E+07	bbls.
Mode	4.822832E+07	bbls.
Value at one standard deviation	1.156192E+08	bbls.
Standard deviation on median	4.691397E+07	bbls.
Standard deviation of log X	0.5603	
90% confidence level (min)	3.213313E+07	bbls.
Median value	6.601921E+07	bbls.
10% confidence level (max)	1.356399E+08	bbls.

RESERVES MEANS OIL-IN-PLACE ON THIS PRINTOUT.

APPENDIX 4

Oil-in-place calculations in the Triassic section in the 7/12-B structure.

RESERVES CALCULATION FOR :

7/12-5 STRUCTURE TRIASSIC RESERVES

byB.TVEITEN on16/3-1982

PROSPECT DATA

crest	3355.0 msec
contour interval	100.0 msec
closing contour	3682.0 msec

* *
* BULK ROCK VOLUME CALCULATION *
* *

INPUT DATA

Point No.	Contour msec	Area in Sq.Km.
1	3355.0	0.000
2	3400.0	1.065
3	3500.0	19.066
4	3600.0	21.838
5	3682.0	24.500

Velocity functions used

TWT	depth
0	0
3682	3875

Point No.	Contour (msec)	Depths
1	3355.0	3531.3
2	3400.0	3578.6
3	3500.0	3683.9
4	3600.0	3789.1
5	3682.0	3875.5

BRV of minimum solid structure in M.cu.m	5237.051459188
BRV of m.likely solid structure in M.cu.m	5237.051459188
BRV of maximum solid structure in M.cu.m	5237.051459188

Minimum BRV in m. cu. m	5237.051459188
Most likely BRV in m. cu. m	5237.051459188
Maximum BRV in m. cu. m	5237.051459188

RESERVES MEANS OIL-IN-PLACE ON THIS PRINTOUT.

RESERVES CALCULATION FOR :

7/12-5 STRUCTURE TRIASSIC RESERVES

by B.TVEITEN on 16/3-1982

RESERVES BASED ON TRIANGULAR INPUT DISTRIBUTIONS AFTER BUCKEE 1977

VARIABLE	TYPE	MINIMUM	MOST LIKELY	MAXIMUM
B.R.V. million cu.m.	R	0.000		5237.051
Net to gross ratio	C		0.350	
Porosity	C		0.180	
Hydrocarbon Saturatn	C		0.700	
FVF for oil(Bo)	C		1.300	
7/12-6 quality/gross volume	T	0.200	0.400	0.600

In Place

Mean value of distribution	2.234923E+08	bbls.
Mode	1.365404E+08	bbls.
Value at one standard deviation	3.363922E+08	bbls.
Standard deviation on median	1.393719E+08	bbls.
Standard deviation of log X	0.5731	
90% confidence level (min)	9.079679E+07	bbls.
Median value	1.896395E+08	bbls.
10% confidence level (max)	3.960840E+08	bbls.

RESERVES MEANS OIL-IN-PLACE ON THIS PRINTOUT