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NORWEGIAN OFFSHORE AREA - PRELIMINARY REPORT NO. 3A

Project No. RRI/789/IIB/2676

PRELIMINARY RESULTS OF PETROLEUM GEOCHEMICAL STUDIES

OF THE PHILLIPS NORWAY 16/11-1 WELL

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I

INTRODUCTION

Petroleum geochemical studies have been carried out on samples received from the Phillips Norway 16/11-1 well. The samples were received at varying intervals and were selected for analysis by compositing at 80 or 60 feet intervals dependant on lithological and log data. After compositing, samples were washed with cold water as necessary to remove drilling mud, and air dried at 50°C. No core samples were available from this well section.

Relevant drilling information for this well may be found in NPD Paper 4. The well was drilled with a sea water based drilling mud throughout

The samples were of good quality for geochemical analysis. Compositing was started at 3000 feet so that representative material below the mid-Miocene unconformity has been analysed. The analytical procedures used include organic carbon analysis on all the bulk cuttings samples at 60 feet intervals and also on individual lithologies where bulk samples consisted of more than one

lithotype. Extractive source rock analysis has been carried out on samples containing more than 0.5% organic carbon at approximately 250 feet intervals. Gas chromatographic analysis has been carried out on alkane fractions from samples containing greater than 100 ppm of hydrocarbon. Pyrolysis source rock evaluation using the IFP/Fina ROCK-EVAL apparatus has been carried out on the same samples as used for extractive analysis, on samples where insufficient material was available for extractive analysis and also on samples of picked lithologies where composite samples contained more than one significant lithotype. Kerogen composition has been assessed on a semiquantitative basis by visual estimation of the kerogen components in unsieved, unoxidised, palynological preparations.

Maturity levels have been assessed in this study using principally spore colouration analysis on sieved unoxidised palynological preparations and vitrinite reflectivity on kerogen concentrates. In assessing maturity level, reference may also be made to the temperatures of maximum pyrolysis rate which give useful indications of maturity level when used in conjunction with the kerogen type.

## II

### RESULTS AND INTERPRETATION

The results of the various analyses carried out on the 16/11-1 well are presented in Tables 1 to 3 and are represented graphically in Figures 1 to 4. Table 1 lists data on maturity level in the section along with the kerogen composition data for the same samples. The spore colouration and vitrinite reflectivity trends with depth are shown in Figures 1 and 2 respectively. Table 2 lists the organic carbon and extractive source rock evaluation data

while pyrolysis data are presented in Table 3. Pyrolysis data are represented graphically against depth in Figures 3 and 4. A detailed graphic compilation of all the data will be presented later in the compilation report.

#### MATURITY DATA

Our assessment of the spore colouration data is that the Lower Tertiary sediments in the analysed interval below 3000 feet are at an early stage of maturity for oil generation given the presence of oil-prone organic matter (see source rock evaluation). No reliable spore colour data have been obtained in the Lower Cretaceous interval but spore colour values in the Upper Jurassic seem to indicate a continuous maturity gradient. The Upper Jurassic Kimmeridgian rocks have spore colours which indicate that sapropelic organic matter would be capable of sourcing heavy to medium gravity oils.

Vitrinite reflectivity data give a trend rising from about 0.38% at 3000 feet to about 0.5% at the base of the Tertiary. A value of 0.35%, which we consider can indicate the onset of maturity for oil generation in a Tertiary basin, has therefore already been reached in the analysed interval of the Tertiary. The reflectivity level in the Lower Cretaceous is not defined as no clearly identified vitrinite was seen in this interval. However, in the basal Upper Jurassic and Middle Jurassic two samples contained abundant humic organic matter with plentiful vitrinite, which had a reflectivity of around 0.56%.

#### HYDROCARBON SOURCE POTENTIAL DATA

On the basis of the geochemical data obtained, the following breakdown of the analysed interval of the 16/11-1 well is made:

Interval 3000 to 4880 feet - Interval is represented by variously coloured green-grey, medium grey and brown-grey shales and mudstones with slightly above average organic carbon content (typically 2% to 3%) although some lithotypes are considerably

richer.

The organic matter in this interval is entirely humic in origin and is mostly vitrinite. The interval is at an early stage of maturity and is unlikely to have any significant source potential. Solvent extractable hydrocarbon contents are variable, generally low but at two horizons are high, indicative of migrant oil or contamination. Pyrolysis data confirm there is no present hydrocarbon potential and give indications of poor hydrocarbon yield at optimum maturity.

- Interval 4900 to 5360 feet - Samples consist of variegated grey and brown shales. The organic carbon content is about average at 1% but composition is similar to the overlying interval and is predominantly vitrinitic. Although mature, no significant source potential is anticipated and minor quantities of gas are the only likely product at optimum maturity.
- Interval 5360 to 6600 feet - Chalk - organically lean with no hydrocarbon source potential. Caving contamination in the upper part of the interval.
- Interval 6600 to 6880 feet - Lower Cretaceous marls. Variable but generally low content of organic matter which is predominantly inertinitic. No source potential.

Interval 6940 to 7330 feet - Jurassic shales and sands. The upper part of the interval down to about 7050 feet is represented by shale of Kimmeridgian age which is underlain by Oxfordian (?) sand and shale. The greater part of the interval is Middle Jurassic sandstone with shale and coal at the base. The Kimmeridgian interval is represented by several shales varying in colour from medium grey through to black. The medium grey shales have about average carbon content and appear to have poor hydrocarbon generating potential at present and at optimum maturity. The dark grey shale, however, has high carbon content (7%) and pyrolysis indicates a good potential source rock at optimum maturity for oil and gas. The organic matter appears to be a mixture of humic materials (inertinite mostly) and sapropel. There was too little material available for extractive analysis. The Oxfordian (?) shales appear to be poor source rocks and the sandstones are not likely to have any source potential.

It is notable that in the interval 7100 to 7280 feet, there are dark grey shales which when picked for organic carbon and pyrolysis analysis had similar characteristics to the

dark shale from 7020 to 7080 feet. These samples are believed to be caved from the same horizon and correspond to the high gamma ray 'Hot' shale which is logged at about 7000 feet.

Interval 7340 to 7640 feet - This interval is of Triassic and Permian age consisting of Triassic reddened shales and sands overlying Permian age anhydrites and dolomites. No source potential is anticipated.

TABLE 1 MATURITY EVALUATION DATA

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH (FEET)	SAMPLE TYPE	GENERALISED LITHOLOGY	SPORE COLOUR INDEX (1 - 10)	VITRINITE REFLECTIVITY IN OIL, R <sub>av</sub> %	KEROGEN COMPOSITION (%)		
					INERTINITE	VITRINITE	SAPROPEL
3000-040	Ctgs	Brn-gy/med gy sh	3.5	0.38 (25)	50	50	*
3240-280	"	Ditto	3.5	0.39 (20)	30	70	*
3560-600	"	Gn-gy/med gy sh	3.5	0.38 (26)	30	70	*
3800-840	"	Ditto	4	0.40 (25)	30	70	*
4120-160	"	Ditto	4	0.40 (26)	40	60	*
4440-480	"	Ol-gy/brn-gy sh	4	0.45 (26)	40	60	*
4680-720	"	Ditto	4	0.44 (34)	30	70	*
4900-970	"	Ol-gy sh	4	0.47 (24)	20	80	*
5090-150	"	Med gy/brn-gy sh	4	0.49 (32)	30	70	*
5270-330	"	Med gy sh	4	0.52 (21)	30	35	35
6600-620	"	Lt gy marl	*	*	100?	*	*
6700-720	"	Ditto	*	*	90	10	*
6940-7000	"	Dk gy sh	5	*	50	*	50
7100-160	"	Ditto	5	0.57 (24)	60	25	15
7290-320	"	Dk gy/brn-gy sh	5.5	0.56 (37)	15	80	5

## SOURCE ROCK EVALUATION DATA

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH ( FEET) OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT PPM	EXTRACT % OF ORGANIC CARBON	HYDRO- -CARBONS PPM OF ROCK	HYDRO- CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO CARBONS
3000- 040	Ctgs	Brn-gy/med gy/gn-gy sly sh+mnr crs snd	2.24					
3080- 120	"	Ditto+mnr ditto+mnr lt gy lstn	1.71					
3160- 200	"	Ditto+mnr ditto+mnr ditto	1.17					
3240- 280	"	Ditto+mnr ditto+mnr ditto	2.00					
3320- 360	"	Ditto+mnr ditto+mnr ditto	1.93	2450	12.6	1045	43	5.9
3400- 440	"	Ditto+mnr ditto+mnr ditto	2.06					
3480	"	Gn-gy/med gy sh+mnr lt gy lstn	2.88					
3560- 600	"	Ditto+mnr ditto	2.95					
3640- 680	"	Ditto+mnr ditto	2.92					
3720- 760	"	Ditto+mnr ditto	2.21					
3800- 840	"	Ditto	2.54					
3880- 920	"	Ditto	2.07					
3960-4000	"	Ditto	1.71					
4040- 080	"	Ditto	2.37					
4120- 160	"	Ditto	2.61	1375	5.2	770	56	>95
4200- 240	"	Lt ol-gy/gn-gy sh	2.68	1225	4.5	55	5	71
4280- 320	"	Ol-gy sh	2.51					
4360- 400	"	Ditto	2.71	1010	3.7	40	4	64
4440- 480	"	Ol-gy/gn-gy/brn-gy sh	2.44					
4520- 560	"	Ditto	2.91	980	3.3	50	5	58
4600- 640	"	Ditto	2.43	995	4.0	60	6	86
4680- 720	"	Ol-gy/brn-gy/med-dk gy sh+10% dk gy sh	2.05					
4760- 800	"	Ditto+10% ditto	2.34					
4840- 880	"	Ditto	2.05	870	4.2	70	8	70
4900- 970	"	Ol-gy sh+mnr med gy sh	1.75					
5000- 060	"	Vgt med gy/lt ol-gy/ brn-gy/brn-red sh	1.34					
5090- 150	"	Ditto	0.74					
5180- 240	"	Ditto	0.96	625	6.5	55	9	76



## SOURCE ROCK EVALUATION DATA

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH ( FEET ) OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M.	EXTRACT % OF ORGANIC CARBON	HYDRO- CARBONS P.P.M. OF ROCK	HYDRO- CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO- CARBONS
5270- 330	Ctgs	Med gy sh+40% vgt sh	1.06					
5360- 420	"	Chk+60% med gy sh	0.77					
5450- 510	"	Chk+90% gy sh	0.69					
5540- 600	"	Chk+90% gy sh	0.47					
5630- 690	"	Chk+40% gy sh	0.39					
5700- 760	"	Chk+50% med gy sh+40% vgt bl-gy/gn-gy sh	0.62					
5780- 840	"	Chk+40% vgt sh	0.29					
5870- 930	"	Chk+10% ditto	0.20					
5950-6000	"	Chk+10% ditto	0.17					
6020- 080	"	Chk	0.51					
6100- 140	"	Chk	0.07					
6160- 220	"	Chk	0.11					
6240- 300	"	Chk	0.13					
6320- 380	"	Chk	0.16					
6400- 460	"	Chk	0.12					
6480- 520	"	Chk	0.12					
6560- 580	"	Chk	0.11					
6600- 620	"	Lt gy marl	0.28					
6640- 680	"	Ditto	0.36					
6700- 720	"	Ditto	0.51					
6740- 800	"	Vgt lt gy/red-gy/bl- gy marl	3.88					
6820- 880	"	Ditto	0.87					
6940-7000	"	Med gy/med-dk gy/blk sh+20% vgt sh	1.56					
7020- 080	"	Ditto+mnr vgt sh	3.19	1145	3.5	45	4	75
7100- 160	"	Ditto	1.66					
7180- 240	"	Ditto	3.30					
7250- 280	"	Wht glauc sst+30% med-dk gy sh	1.14					
7290- 320	"	Med-dk gy/brn-gy carb sh	3.13					
7340- 400	"	Vgt gy-red/brn-gy sh/ marl+sst	1.18					
7410- 470	"	Wht/pnk-gy lstn+wht crs snd+mnr vgt sh	3.50					

## SOURCE ROCK EVALUATION DATA

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH ( FEET ) OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT PPM	EXTRACT % OF ORGANIC CARBON	HYDRO- CARBONS PPM OF ROCK	HYDRO- CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO- CARBONS
7480- 530	Ctgs	Wht/pnk-gy lstn/dol+ 10% sst+anhydrite+mnr vgt sh	5.53					
7540- 550	"	Ditto+ditto+ditto+ ditto	7.07					
7580- 640	"	Ditto+ditto+ditto+ ditto	4.13					
<u>PICKED LITHOLOGIES</u>								
3000- 040	"	Gn-gy sh	1.14					
3000- 040	"	Med gy sh	4.22					
3080- 120	"	Gn-gy sh	1.18					
3080- 120	"	Med gy sh	3.77					
3160- 200	"	Gn-gy sh	1.10					
3160- 200	"	Med gy sh	4.67					
3240- 280	"	Gn-gy sh	1.35					
3320- 360	"	Ditto	1.27					
3320- 360	"	Med gy sh	2.72					
3400- 440	"	Gn-gy sh	1.10					
3400- 440	"	Med gy sh	2.80					
3480		Gn-gy sh	1.36					
3560- 600	"	Ditto	1.09					
3640- 680	"	Ditto	2.05					
3720- 760	"	Ditto	2.51					
3800- 840	"	Ditto	1.40					
3800- 840	"	Med gy sh	4.04					
3880- 920	"	Gn-gy sh	2.11					
3960-4000	"	Ditto	1.79					
4040- 080	"	Ditto	2.76					
4120- 160	"	Med gy sh	5.12					
4120- 160	"	Gn-gy sh	1.37					
4200- 240	"	Ditto	1.99					
4280- 320	"	Ditto	1.27					
4280- 320	"	Med gy sh	3.58					
4360- 400	"	Gn-gy sh	1.00					
4360- 400	"	Med gy sh	3.06					
4440- 480	"	Gn-gy sh	1.18					

## SOURCE ROCK EVALUATION DATA

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH ( FEET ) OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT PPM	EXTRACT % OF ORGANIC CARBON	HYDRO- CARBONS PPM OF ROCK	HYDRO- CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO CARBONS
4440- 480	Ctgs	Med gy sh	3.73					
4520- 560	"	Gn-gy sh	1.13					
4520- 560	"	Brn-gy sh	2.13					
4600- 640	"	Ditto	1.72					
4680- 720	"	Ditto	2.40					
4760- 800	"	Ol-gy sh	1.39					
4760- 800	"	Med gy sh	2.90					
4840- 880	"	Ol-gy sh	1.00					
4840- 880	"	Lt brn-gy sh	2.17					
4900- 970	"	Ol-gy sh	0.66					
4900- 970	"	Lt brn-gy sh	2.23					
5000- 060	"	Ol-gy sh	1.05					
5090- 150	"	Ditto	0.42					
5090- 150	"	Lt brn-gy sh	1.89					
5540- 600	"	Med gy sh	0.74					
5540- 600	"	Chk	0.04					
5630- 690	"	Med gy sh	1.51					
5630- 690	"	Chk	0.08					
5700- 760	"	Med gy sh	0.68					
5700- 760	"	Chk	0.18					
5780- 840	"	Med gy sh	0.93					
5780- 840	"	Chk	0.07					
5870- 930	"	Med gy sh	1.25					
5870- 930	"	Chk	0.07					
7020- 080	"	Blk sh	7.22					
7020- 080	"	Med-dk gy sh	0.64					
7100- 160	"	Dk gy sh	7.19					
7180- 240	"	Ditto	7.04					
7250- 280	"	Ditto	7.04					
7410- 470	"	Ditto	5.57					
7410- 470	"	Gy-red sh	0.32					

TABLE 3A

## ROCK - EVAL. PYROLYSIS DATA

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH ( FEET ) OR NOTATION	GENERALISED LITHOLOGY	ORGANIC CARBON (%)	TEMPERATURE (°C)	HYDROGEN INDEX	OXYGEN INDEX	PRODUCTION INDEX	POTENTIAL YIELD (PPM)
3080- 120	Med gy sh	1.71	430	36	150	*	600
3160- 200	Ditto	1.17	431	40	218	*	500
3320- 360	Ditto	1.93	421	29	193	*	500
3640- 680	Gn-gy/brn-gy sh	2.92	432	15	95	*	400
3800- 840	Ditto	2.54	416	13	155	*	300
4120- 160	Ditto	2.61	410	14	94	*	400
4200- 240	Lt gy/gn-gy sh	2.68	415	30	146	0.06	800
4360- 400	Ol-gy sh	2.71	416	13	164	*	300
4520- 560	Ditto	2.91	408	20	205	*	600
4600- 640	Ditto	2.43	418	10	115	*	200
4840- 880	Ditto	2.05	416	33	102	*	700
5000- 060	Med gy sh	1.34	419	79	166	*	1000
5180- 240	Ditto	0.96	420	13	355	*	100
5270- 330	Ditto	1.06	420	5	76	*	100
6940-7000	Med-dk gy sh	1.56	425	29	69	*	500
7020- 080	Ditto	3.19	425	168	67	0.01	5400
7100- 160	Ditto	1.66	415	69	86	*	1100
7180- 240	Ditto	3.30	426	177	41	0.03	5800
7290- 320	Med-dk gy/brn-gy sh	3.31	436	116	54	0.06	3600
7410- 470	Wht lstn+gy sh	3.50	421	23	17	*	800
PICKED LITHOLOGIES							
3000- 040	Med gy sh	4.22	418	74	75	*	3100
3080- 120	Ditto	3.77	413	63	83	*	2400
3160- 200	Gn-gy sh	1.10	413	44	142	*	500
3160- 200	Med gy sh	1.71	436	224	112	*	3800
3320- 360	Gn-gy sh	1.27	426	180	312	*	2300
3320- 360	Med gy sh	2.72	*	*	74	*	*
3400- 440	Ditto	2.80	425	38	94	*	1000
3480	Gn-gy sh	1.36	414	85	189	*	1100
3720- 760	Ditto	2.51	415	25	98	*	600
3800- 840	Brn-gy sh	4.04	242	63	95	*	2500
4040- 080	Gn-gy sh	2.76	422	15	114	*	400
4120- 160	Brn-gy sh	5.12	430	61	61	*	3100

TEMPERATURE (°C) = TEMPERATURE AT MAXIMUM RATE OF PYROLYSIS  
PRODUCTION INDEX = AN ESTIMATE OF PRESENT HYDROCARBON GENERATING POTENTIAL  
COMPARED TO THAT AT OPTIMUM MATURITY  
POTENTIAL YIELD = AN ESTIMATE OF HYDROCARBON PRODUCTION AT OPTIMUM MATURITY

TABLE 3B

## ROCK - EVAL. PYROLYSIS DATA

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH ( FEET ) OR NOTATION	GENERALISED LITHOLOGY	ORGANIC CARBON (%)	TEMPERATURE (°C)	HYDROGEN INDEX	OXYGEN INDEX	PRODUCTION INDEX	POTENTIAL YIELD (PPM)
4200- 240	Gn-gy sh	1.99	426	42	145	*	800
4280- 320	Med gy sh	3.58	428	32	97	*	1200
4360- 400	Ditto	3.06	419	15	116	*	500
4440- 480	Ditto	3.73	421	17	104	*	600
4520- 560	Brn-gy sh	2.13	425	20	149	*	400
4680- 720	Ditto	2.40	420	46	137	*	1100
4760- 800	Med gy sh	2.90	419	54	89	*	1600
4840- 880	Ditto	2.17	418	59	75	*	1300
4900- 970	Ditto	2.23	436	77	327	*	1700
5090- 150	Ditto	1.89	427	40	64	*	700
5630- 690	Ditto	1.51	430	30	77	*	500
7020- 080	Dk gy sh	7.22	425	245	81	*	18000
7020- 080	Med gy sh	0.64	*	*	223	*	*
7100- 160	Dk gy sh	7.19	426	291	37	*	21000
7180- 240	Ditto	7.04	431	144	21	*	10000
7250- 280	Ditto	7.04	427	267	19	*	19000
7410- 470	Ditto	5.57	425	4	18	*	200
7410- 470	Gy-red sh	0.32	*	*	121	*	*

TEMPERATURE (°C) = TEMPERATURE AT MAXIMUM RATE OF PYROLYSIS  
 PRODUCTION INDEX = AN ESTIMATE OF PRESENT HYDROCARBON GENERATING POTENTIAL  
 COMPARED TO THAT AT OPTIMUM MATURITY  
 POTENTIAL YIELD = AN ESTIMATE OF HYDROCARBON PRODUCTION AT OPTIMUM MATURITY

FIGURE 1 SPORE COLOURATION INDICES AGAINST DEPTH

WELL : 16/11-1

LOCATION : NORWEGIAN NORTH SEA

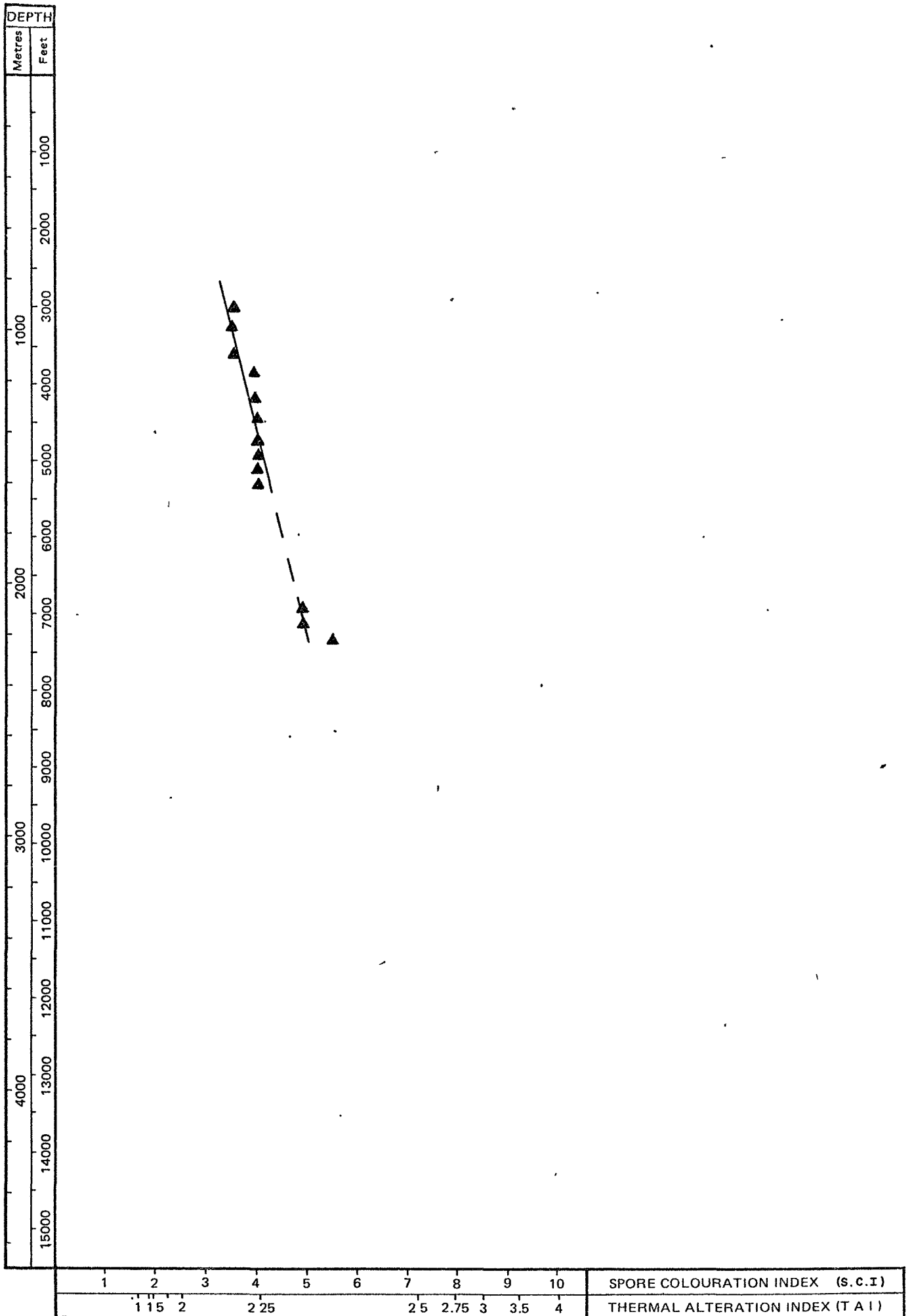


FIGURE 2 VITRINITE REFLECTIVITY AGAINST DEPTH

WELL: 16/11-1

LOCATION: NORWEGIAN NORTH SEA

