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LIST OF ENCLOSURES

Encl. 1: Filtered Stack, Line ST 8315-106
(1 : 25000, 10 cm : 1 sec., DBS, DAS).

Encl. 2: Filtered Stack, Line ST 8315-106
(1 : 25000, 10 cm : 1 sec.).

Encl. 3: Filtered Stack, Line ST 8315-106
(1 : 10000, 30 cm : 1 sec., DBS, DAS).

Encl. 4: Offset Panel, Line ST 8315-106
(7 panels, 50 m offset intervals).

Encl. 5: Offset Panel, Line ST 8315-106
(7 panels, 400 m offset intervals).

Encl. 6: Filtered Stack, Line ST 8378-110
(1 : 10000, 30 cm : 1 sec., DBS, F/K, DAS).

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(1 : 10000, 30 cm : 1 sec., DBS, F/K, DAS).

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(7 panels, 100 m offset intervals).

1. CONCLUSIONS

- Two amplitude anomalies (192 m RKB and 462 m RKB) have been identified in well location.

- An erosional surface is recognized in well location at 220 m RKB. Gas may be accumulated in an updip position to the south and west.

- Above the highest point of the erosion surface, approximately 350 m to the south, a high amplitude event occurs.

- At 950 - 1000 m RKB a strong amplitude anomaly is seen north and east of the well location.

2. INTRODUCTION

The 15/12-4 well location is situated in the south-eastern part of block 15/12. Major discoveries in the area are the Maureen oil field in the UK sector, approximately 15 km to the northwest and the Sleipner gas province 30 - 50 km north of the well location.

The three wells previously drilled in block 15/12 were dry apart from 15/12-1 which had minor oil shows.

Shallow gas is not known to have caused problems in any of the 15/12 wells.

2.1. Purpose

The aim was to perform a shallow gas study, in addition to the site-survey report, using both high-resolution site-survey data and deep seismic data through the well location. In addition to interpreting ordinary CDP stacked sections, interpretation of "Offset Panels" were performed. The method is described by Fulton, 1981.
The Offset Panel displays common offset trace gather and plots were made for various cable offsets. They contain both reflected and refracted energy. The interpretation of refraction waves may lead to detection of shallow gas not otherwise detected.

2.2. Data

The data set for this study consists of:

- Two site-survey lines shot with a minisleeve source and recorded with a 600 m, 24 channel cable. Sample rate was 1 ms. The site-survey was operated by Odin Survey. ST8378-304 is shot south-north. ST8378-110 is shot west-east.

  Both lines go through the well location.

- One deep seismic line shot with super wide airgun array and recorded with a 2375 m, 96 channel cable. Sample rate was 4 ms. The survey was operated by Geco. ST8315-106 is shot east-west and goes through the well location.

The line configuration is shown in Fig. 1.

All three lines, for the purpose of this study, have been processed by Statoil Seismic Processing Centre.

The following discussion of processing and interpretation is organized in the succession the data is normally available i.e. conventional deep seismic followed by site-survey data.

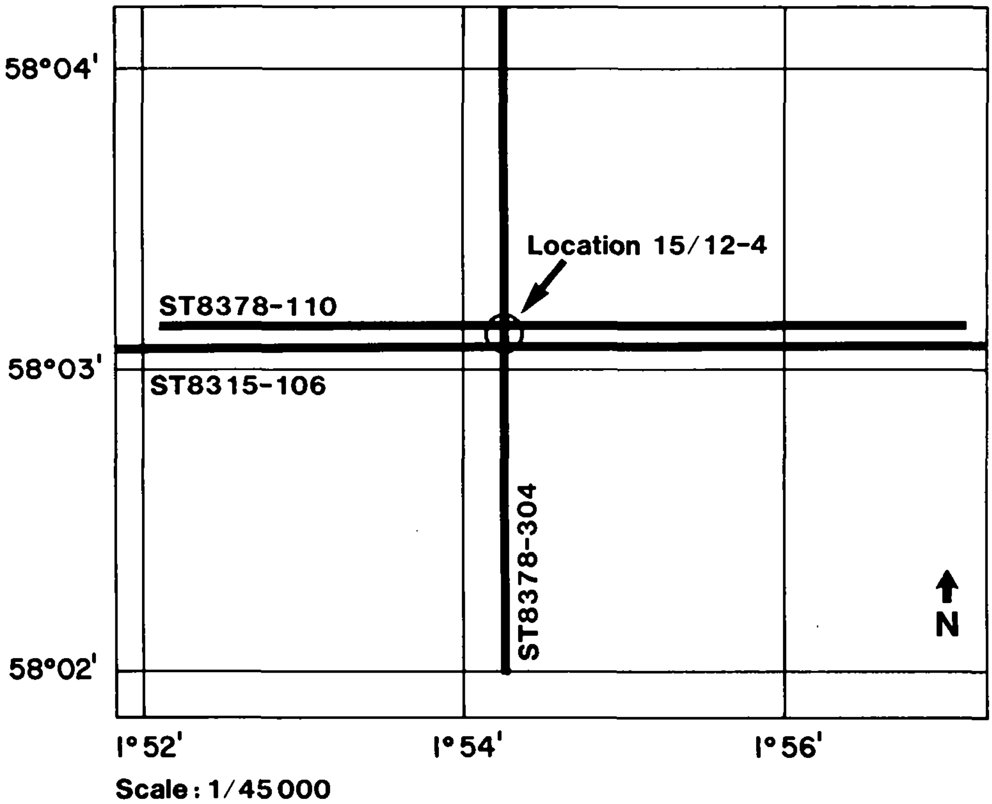

Fig. 1. Line configuration.

3. DEEP SEISMIC DATA

Line ST8315-106, sp. 1800 - 2355, direction E-W, 15/12-4 well location at sp. 2105.

3.1 Processing

3.1.1 Filtered Stack

Encl. 1 and 3.

The data was processed from field tapes to final stack. The field data was of good quality. Demultiplexing of 0 - 6000 ms was done. Prior to CDP sorting a gain test was run. No spherical divergence correction was applied. Various deconvolution parameters were tested on CDP data. A predictive decon with 20 ms gap and operator length 120 ms, designed over two windows 0 - 2000 ms and 1800 - 3400 ms was applied before stack (DBS). Velocity analysis was done by velocity function analysis (SVEL) at 14 locations along the line including the well location. The CDP data were stacked 48 fold. For decon after stack the same parameters as for DBS were chosen.

Encl. no. 1: scale is 1:25000. Summation of two adjacent traces and 1:3:1 mixing was done before display. The data is scaled in zones.

Encl. no. 3: scale is 1:10000. Two versions of the shallow part are presented, one with scaling and one "true amplitude".

Encl. 2.

In encl. no. 2, no decon is applied to the data to make sure that the decon operator is not disurbing real data that can be seen between the multiples and compare the behavior of the multiples with and without decon.

Comparing this filtered stack to Geco section it seems that the Geco data have been processed with too much smoothing. Resolution has been improved by the new processing.

3.1.2 Offset Panel

The Offset Panel is a method to sort and display seismic data to locate shallow drilling hazards. Single channel profiles are displayed below one another and arranged vertically by offset and horizontally by Common Depth Point (CDP). This arrangement causes effects due to near surface geologic changes to generate geometric patterns that are different from patterns due to changes in seismic source or receiver. Both reflection and refraction data are used in the display. Reflection data of the near trace or offset are at the top of the display and indicate the presence of acoustic boundaries. The refractions observed on the distant traces are sensitive to changes in the near surface. By studying alterations in transit times and amplitudes it is possible to determine the properties of shallow acoustic layers. A shallow gas drilling hazard is a low velocity zone at less than about 700 metres. A seismic reflection from that zone will give a high amplitude. Refractions which transit the zone will be delayed because of low velocity and attenuated because of transmission loss. The Offset Panels allow correlation of high amplitude reflections on the near trace with delayed refraction breaks on the far traces thus identifying the hazards.

Encl. 4 and 5.

2 suites of Offset Panels were prepared from line ST8315-106. The first suite contained the 7 nearest offsets, the second 7 offsets distributed along the cable. The processing prior to offset sorting was gain correction.

3.2. Interpretation

Velocity differences in the shallow subsurface, often cause drilling hazards. Such hazards may be:

- a) Boulder beds
- b) Gassy unstable mud
- c) Near surface channels and faults
- d) Overpressured shallow gas

Especially overpressured shallow gas represents a hazard in North Sea exploration wells. A shallow gas zone is characterized by low velocity which can be demonstrated by one or several of the following criteria:

- a) Lateral reflection amplitude variations
- b) Subsequent reflections delayed
- c) Reflection phase change
- d) Reflection amplitude as a function of offset
- e) Diffraction amplitude as a function of offset
- f) Defractions delayed

The first three criteria may be identified on conventionally processed data (site-survey or deep seismic) while the three last require an Offset Panel (ref. sections 3.1.2. and 4.1.2.).

3.2.1. Filtered Stack

Encl. 1.

Line ST8315-106 was reprocessed in order to improve data quality both in the shallow (0 - 1.5 sec) and deep (below 2.0 sec) part of the section. Only the 0 - 1.5 sec part, which is relevant to shallow gas detection, will be discussed here.

The processing sequence discussed in section 3.1.1. represents an improvement of the shallow data quality. The reprocessed section has a slightly higher frequency content. Also scaling gives it a better visual appearance. An erosion surface is more accurately picked, particularly around the well location. The structural high from 500 m east of the well and 1000 m westwards is hardly recognized on the original version, but on the reprocessed it can easily be picked, at least on the northern flank. Possibly shot sum, dip filter and 1-1-1 trace mix has obstructed this important primary event on the original data.

Encl. 2.

A stacked section without DBS and DAS was displayed in order to observe deconvolution effects. No primary events have been obscured by decon. The data have been spiked and energy moved in front of the signal by the DBS and DAS. It has also removed multiple energy.

Encl. 3.

No high amplitude events are observed at the well location by analyzing the true amplitude and amplitude scaled versions.

A reflector at approximately 0.510 sec (462 m RKB)* shows amplitude increase approximately 850 m and 2500 m east of the well location. Reflection phase indicate a positive impedance contrast and not a shallow gas hazard.

Below 1.0 sec (903 m RKB) diffractions are present especially east of the well. They are interpreted to be due to lithological changes or minor faulting.

3.2.2. Offset Panels

Encl. 4 and 5.

Two sets of Offset Panels were displayed: Near traces (175 - 475 m) with 50 m interval between offsets and middle to far traces (175 - 2525 m) with 400 m interval between traces. To make it easier to interprete the Offset Panels, the source and receiver diagonals in well location were marked with vertical arrows. The diagonals show the reflection points corresponding to the source and receiver at the various offsets. This helps correlation of events from one offset to another.

* A constant velocity of 1800 m/s in the upper sediments has been applied for all subsequent time-depth conversions.

The panel displaying near traces (encl. 4) does not show any high amplitude events which can be related to shallow gas.

On the middle to far traces display (encl. 5) no refracted energy delay has been observed at the well location.

The first arrieved energy on the far offsets is believed to be refracted from the surface at 0.510 sec (462 m RKB). This can be demonstrated on the CDP gather by linearly extending the time-depth curve of the deepest refraction so that it becomes a tangent to the 0.510 sec reflection hyperbola. The presence of refracted energy from this level supports the assumption that the surface at 0.510 sec (462 m RKB) is a positive impedance contrast. The high amplitude may therefore be associated with lithological changes.

4. SITE SURVEY DATA (MINISLEEVE)

Line ST8378-110, sp. 1 - 380, direction W-E,
15/12-4 well location at sp. 169.
Line ST8378-304, sp. 1 . 394, direction S-N,
15/12-4 well location at sp. 175.

4.1 Processing

4.1.1 Filtered Stack

Encl. 6 and 9.

Demultiplexing of field tapes was carried out by Seismic Profilers.

Gain correction 28 dB exponential from 100 - 1100 ms was applied. The data was CDP sorted, 24 traces per CDP. Wavelet shaping was done by extracting a wavelet over 60 near traces, with specified frequency interval: 30 - 260 Hz. Then a 100 ms minimum entropy inverse filter was designed and applied.

Predictive deconvolution parameters were tested, ending up with 80/50 (gap/operator length, ms) designed over one gate. An f-k filter was applied, designed to reject water bottom multiples.

For line ST8378-110 velocity analysis was done by SVEL at 5 locations, and for line ST8315-304 at 6 locations. The CDP data were stacked 24 fold. Two final displays were produced for each line, one filtered stack version without scaling ("true amplitude") to enhance amplitude contrasts, and one filtered stack version with conventional scaling in zones.

Before displaying the "true amplitude" version, the original gain was removed and a new gain, 32 dB 100 - 1100 ms is used.

Encl. 7 and 10.

Encl. 7 and 10 show filtered stack without any predictive decon and f-k filter.

For all stack sections a 1 : 3 : 1 mix and TVF was used.

DAS parameters were also tested, but no decon after stack seems to improve the data.

4.1.2 Offset Panel

Encl. 8 and 11.

One suite of Offset Panels was prepared from each mini-sleeve line.

7 offsets distributed along the 600 m cable were made for each line on CDP data. Data quality was considered good without decon.

4.2 Interpretation

4.2.1 Filtered Stack

Line ST8378-110

Encl. 6.

The filtered stack is displayed both in true amplitude and amplitude balanced versions. The true amplitude version was prefered for interpretation. The water-bottom multiple is not completely removed from the data but does not cause any interpretation problems.

An erosional surface between 0.230 - 0.280 sec (210 - 255 m RKB) is very well defined in the central and eastern part of the line. To the west it becomes more difficult to pick. The minisleeve data confirms that the erosion surface which was observed on the reprocessed version of line ST8315-106 is real. It is related to glacial erosion in the Pleistocene and in well 15/9-18 sand is present both above and below a similar erosion surface. The possibility of accumulation of gas at the structural high can not be excluded. In 15/9-18 sand was present down to 320 m RKB with gas reading increasing gradually up to maximum 1.10% at 315 m RKB. No gas was observed on electric logs.

The highest peak of the erosion surface is approximately 400 m west of the well location.

Apart from the distinct erosional feature several high amplitude events have been recognized.

At well location amplitude increase is observed at 0.210 sec (192 m RKB) extending approximately 100 m to both flanks.

Approximately 800 m east of the well, amplitude anomalies are observed at three different levels: 0.510 sec (462 m RKB), 0.630 sec (570 m RKB) and 1.070 sec (966 m RKB). The reflector just below 0.5 sec is believed to be related to the Pleistocene/Pliocene boundary. Drilling results from 15/9-18 shows no permeable layers and no anomalous gas readings at this level.

The event at 0.630 sec (570 m RKB) is probably a multiple of the reflector mentioned above.

At 1.070 sec (966 m RKB) high amplitudes are observed. Being so deep it is not considered to represent a shallow gas hazard.

Line ST8378-304

Encl. 9.

The erosion channel is well defined in the central and northern part of the line. The highest peak is approximately 550 m south of the well location.

Above this peak at 0.190 sec (174 m RKB) there is a high amplitude event with a lateral extent of 250 - 300 m. This may be a shallow gas accumulation.

The reflector at 0.510 sec (462 m RKB) shows again considerable amplitude variations. At well location the amplitude level is low but increases to the south and north. The possibility of gas accumulation should not be excluded, although drilling of 15/9-18 showed no permeable zones and no gas at this level.

At 1.100 sec (993 m RKB) an amplitude contrast is observed from 600 - 1100 m north of the well location. It does not represent a drilling hazard for the 15/12-4 well.

Encl. 7 and 10.

A filtered stack without DBS, f-k filtering and DAS was displayed in order to see the effect of these processing steps. The main observation is that multiples particularly from sea-bed and the erosion channel are very strong, and that the attempt to remove the multiples does not harm the real data.

4.2.2. Offset Panels

Lines ST8378-110 and ST8378-304

Encl. 8 and 11.

The source and receiver diagonals at well location were marked by vertical arrows. The first and second order multiples were identified prior to further interpretation.

Several of the features identified on the stack sections, such as the erosion channel and the high amplitude event at 0.190 sec (174 m RKB) south of the well location, were also identified on the near trace offset panel.

However, with a cable length of only 600 m the information about refracted energy is possible only from the shallowest horizons.

5. SUMMARY AND CONCLUSIONS

- Reprocessing of line ST8315-106 in order to improve data quality from 0 - 1.5 sec was successful. The original 1-1-1 trace mix in time interval 0 - 0.6 sec had a smearing effect and almost totally obscured the glacial erosion surface at approximately 0.3 sec, particularly around the well location.

- Offset Panel displays are most useful on data recorded with long cable. Two sets of panels were constructed for ST8315-106, near traces with 50 m offset intervals and middle to far traces with 400 m offset intervals. Refraction delays related to shallow gas anomalies were not observed. Offset Panels were prepared also for the two site-survey lines. The short cable length, however, gives limited information about refracted energy.

- *The filtered stack of the deep seismic and the two* site-survey lines were displayed in "true amplitude" and amplitude scaled versions. The "true amplitude" versions are useful for detection of lateral amplitude contrasts which may indicate a drilling hazard. The scaled versions are needed for structural interpretation and will also better show reflection delays caused by a low velocity layer.

- Filtered stacks without deconvolution before and after stack (DBS, DAS) were displayed in order to see the effect of the decon operations. Generally the multiples are much stronger without deconvolution.

- Two amplitude anomalies (192 m RKB and 462 m RKB) have been identified at the well location.

- An erosional surface is recognized in the well location at 220 m RKB. Gas may be accumulated in an updip position to the south and west.

- Above the highest point of the erosion surface approximately 350 m to the south, a high amplitude event occurs.

- At 950 - 1000 m RKB a strong amplitude anomaly is seen north and east of the well location.

6. RECOMMENDATIONS

- The Offset Panel method should be applied to a few more well locations, especially where shallow gas is known to be present, in order to enhance the validity of the method.

- The Offset Panel will help to identify shallow gas at an early stage, so that the well can be located away from possible hazard areas.

- The Offset Panel is most useful on conventional seismic data. With a cable length of 2500 m, refractions from as deep as 500 ms may be detected. Two separate displays, each with 5 - 7 offsets, should be made to get a good distribution throughout the cable. One display of the near traces (up to 500 - 600 m), and one of the middle and far traces. Display level should not be too high, so that amplitude contrasts are easy to detect.

- In site-survey recordings a short cable is used. Generally, only sea-bed and very shallow refractions will be recorded. But the Offset Panels can still be useful in detecting reflection and diffraction variations with offset, which are important criteria for presence of shallow gas. It should be sufficient to have one display, 5 - 7 offsets equally spaced over the cable length.

- In addition to the Offset Panel, Diffraction Panels could be a useful tool in the detection of drilling hazards. Such a display may indicate presence of channels, faults, boulder beds and shallow gas.

References

T.K. Fulton, 1981: Offset Panel Locates Shallow Drilling Hazards (joint SEG/CGS Meeting, Beijing).

T.K. Fulton & R.T: Hsiao, 1983: Diffractions Reveal Drilling hazards (OTC 4507, Houston).

LIST OF ENCLOSURES

Encl. 1: Filtered Stack, Line ST 8315-106
(1 : 25000, 10 cm : 1 sec., DBS, DAS).

Encl. 2: Filtered Stack, Line ST 8315-106
(1 : 25000, 10 cm : 1 sec.).

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(7 panels, 100 m offset intervals).