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SHALLOW GAS STUDY AT THE 15/9-18 WELL LOCATION

by

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December 12, 1983

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1. CONCLUSIONS

- No additional drilling hazards have been exposed by the Offset Panel method at the 15/9-18 location.

- Several velocity anomalies that might be assosiated with shallow gas have been observed, but these are all situated off the well location.

- At 170-200 m RKB there are strong indications of gas 1100-1200 m south of the well location. Also, 200-400 m east of the well velocity anomalies are observed at this level.

- A channel is recognized in the well from 185-210 m RKB. The channel is filled with low velocity material which could be sand. The sand might be gas filled in an updip position, 200-400 m south-east of the well.

- A diffraction 320 m north of the well at approximately 330 m RKB is most likely related to a boulder or lithological change. However, a minor gas pocket is also a possible explanation.

- At 630-650 m RKB, a reflector showing considerable amplitude variations is observed. This represents a possible gas accumulation.

2. INTRODUCTION

The 15/9-18 well location is situated in the central part of block 15/9. Major discoveries have been made to the northwest (Sleipner Field), northeast (Gamma Field) and southeast (Mu discovery). Closest offset wells are 15/9-10 (dry) lying 3 km further southwest and 15/9-8 (gas discovery) 4 km to the northwest.

None of the wells in the block have encountered shallow gas problems. However, channeling in the shallow sediments has been recognized from site-survey data. If sand filled, such channels could act as traps for shallow gas.

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, we intended to interprete "Offset Panels" which are 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 Merlin Geophysical.
  ST 8381-309 is shot south-north. ST 8381-113 is shot east-west.
  Both lines go through the well location.

- One 3D line shot with airgun array and recorded with a 2459 m, 96 channel cable, sample rate was 4 ms. The survey was

operated by Geco. ST 8215-122 is shot south-north 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.

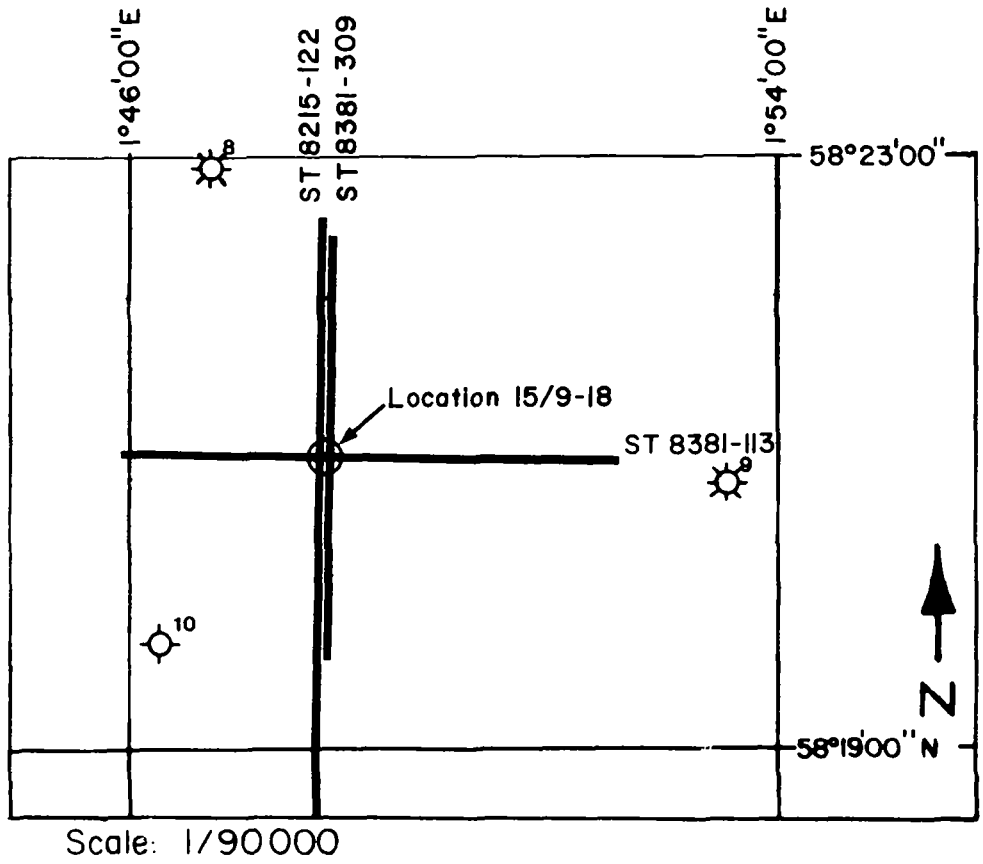

Fig. 1. Line configuration

3. DEEP SEISMIC DATA (3D)

Line ST 8215-122, sp. 380-590, direction S-N,
15/9-18 well location at sp. 500.

3.1 Processing

3.1.1 Filtered Stack

Encl. 1 and 2.

The data was processed from field tapes to final stack with the intension to enhance the shallow part. The field data was of good quality as expected from a recent 3D survey. Demultiplexing was done with no missing shots. Prior to CDP sorting a gain test was run. Exponential gain correction of 30 dB from 0-4.0 sec. was applied. No sphercial divergence correction was applied. Various deconvolution parameters were tested on CDP data. A predictive decon with 24 ms and operator length 336 ms, designed over one window 200-2500 ms, was applied. Velocity analysis was done with coherency calculations (VSTUDY) and velocity function analysis (SVEL) at 5 locations along the line including the well location. The CDP data was stacked 48 fold. For decon after stack a double decon was chosen: 1) Min. pred. distance 24 ms, operator: 336 ms. 2) Min. pred. distance 100 ms, operator 150 ms. This decon after stack (DAS) was designed to attack the remaining parts of the water bottom multiple. Summation of two adjacent traces and mixing of traces were done. Before display of final section the data was frequency filtered and scaled in zones.

Comparing this filtered stacked data to the 3D processed line processed by Geco, the Statoil processed line ST 8215-122 is more continuous in the shallow part of the section, because parameters were designed on the shallow part and no 3D cell sorting was done.

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.

2 suites of Offset Panels were prepared from line ST 8215-122. The first suite contained the 5 nearest offsets, the second 5 offsets distributed along the cable. The processing prior to offset sorting was deconvolution 24/336 (gap/operator lenght ms) and gain correction.

3.2 Interpretation

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

i) Boulder beds
ii) Gassy unstable mud
iii) Near surface channels and faults
iv) Overpressured shallow gas

Especially overpressured shallow gas represent 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:

i) Lateral reflection amplitude variations
ii) Subsequent reflections delayed
iii) Reflection phase change
iv) Reflection amplitude as a function of offset
v) Offset refractions delayed
vi) Diffraction amplitude as a function of offset

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 & 4.1.2).

3.2.1 Filtered Stack

Encl. 1 and 2.

The quality of the 0-1.5 sec. data on the original 3D line ST 8215-122 was not satisfactory for shallow gas detection. There is occasionally not full CDP coverage (f.inst. CP 712-727) and also the processing was optmized for data below 2.0 sec.

The processing described in section 3.1.1 represent a definite improvement of the data quality from 0-1.5 sec. The reflectors have better definition and continuity, especially above 1.2 sec.

The frequency content appears to be comparable, with possible somewhat better resolution on the reprocessed data.

The sea-bottom multiple at 0.290 sec. is very clear across the line. None of the processing tools were able to remove it.

Further FK-testing might have reduced the multiple.

The filtered stack is displayed both in 1:25000/10 cm per second (Encl. 1) and 1:10000/30 cm per second (Encl. 2). The former

correlates with the original 3D line, the latter is equivalent with the scale most frequently used for site-survey data.

Both "true amplitude" and "time variant scaled" versions are presented in Encl. 2.

An erosion channel can be interpreted at the well location approximately 0.210-0.240 sec. (190-225 m RKB).* If such a channel is filled with sand and capped by shales, it could represent a trap for shallow gas. The 15/9-18 well is located on the edge of the channel. There are no amplitude variations suggesting that the channel is gas filled.

The reflector at approximately 0.360 sec.(330 m RKB) shows increase in amplitude at SP 435-444 and SP 500-515. The 15/9-18 well is located on SP 500. These are particularly well recognized on the true amplitude section (Encl. 2). However, the amplitude anomalies are not related with delay of underlying reflectors and are not interpreted to represent a drilling hazard.

3.2.2 Offset Panels

Encl. 3 and 4.

Two Offset Panels were displayed: Near traces (200-400 m) with 50 m interval between offsets and middle to far traces (200-2575 m) with 600 m interval between offsets. To make it easier to interprete the Offset Panels the source and receiver diagonals at the well location were marked with vertical arrows.

* Constant velocity of 1800 m/s in the upper sediments has been used for all subsequent tim-depth conversions.

The diagonals show the positions of the source and receiver at the various offsets. This helps correlation of events from one offset to another. The water bottom multiple is marked on the near offset (200 m) and the arrival of the direct wave through water is indicated on the far offsets (800-2575 m).

On the near offset a channel, which was also identified on the filtered stack, is marked by an arrow and the letter C. This channel appears to be filled with low velocity material which could be sand. The assumption of lower velocity material north of the well location is based on refraction delays along the receiver diagonal (Encl. 4). The low velocity material could be sand but there is no real evidence for overpressured gas.

The reflector at 0.700 sec. (630 m RKB) shows lateral variations in amplitude. The well is located on the southern flank of a high amplitude area. This could represent a possible shallow gas accumulation, but can also be interpreted as lithological changes at the Pliocene/Pleistocene boundary.

Further indications of shallow gas on the Offset Panels have not been identified.

4. SITE-SURVEY DATA (MINISLEEVE)

Line ST 8381-309, sp.1-365, direction S-N,
15/9-18 well location at sp.197.
Line ST 8381-113, sp.1-484, direction E-W,
15/9-18 well location at sp.296.

4.1 Processing

4.1.1 Filtered stack

Encl. 5 and 7.

Demultiplexing of field tapes was carried out by Merlin Geophysical. Demultiplexed data from Line ST 8381-309 contained some bad records, especially at the beginning and towards the end of the line. This may be observed on the final stack section at sp.40, sp.340 and sp 365,

Gain correction 20dB exponential from 0-2.0 sec. was applied. CDP sorting, 24 traces per CDP. Deconvolution parameters were tested ending up with a water bottom multiple rejection decon: 100/50 (gap/operator length ms), designed over two gates.

The stacking velocities for Line ST 8381-309 were taken from the parallel conventional Line ST 8215-122. Stack velocities Line ST 8381-113 were produced by velocity analysis at 3 locations including well location.

The CDP-data was stacked 24 fold and mixed. Two final displays were produced for each line, one filtered stack version displayed without scaling to enhance amplitude contrasts and one filtered stack version displayed with the conventional scaling in zones.

By comparing these two versions one should get information about amplitude anomalies possibly caused by hazards from the unscaled version. The scaled version should give a picture of the structural events.

4.1.2 Offset Panel

Encl. 6 and 8.

One suite of Offset Panels were prepared from each mini-sleeve line.
On Line ST 8381-309, near traces were missing in the current area. The display of the second nearest traces at offset 62 m was therefore produced.

5 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 ST 8381-309:

Encl. 5.

On the true amplitude version there are a couple of events that need to be discussed.

The channeling is much better resolved than on the conventional data. There appears to be a diffracion within the channel at sp.188. This represents most likely a boulder or lithology change, but the presence of gas should not be overruled.

A point diffraction is also present at sp.223. However, this is well off the 15/9-18 location and should not represent any drilling hazard.

The reflector at 0.700 sec. again shows amplitude variations as discussed in section 3.2.2.

On the amplitude scaled version of Line ST 8381-309 there is one additional feature subject to discussion.

From sp.195-235 there is evidence of a slight reflection time delay. This is particularly visible on the 0.630 sec. (570 m RKB) reflector (marked by an arrow) but can be traced as high as 0.435 sec. (395 m RKB), possibly even higher. The delay is interpreted to be due to channel infill of low velocity material between 0.200-0.270 sec. (185-245 m RKB). It could be caused by structural relief.

Line ST 8381-113:

Encl. 7.

Channeling between 0.200-0.270 sec. (185-245 RKB) is again observed with deepest erosion west of the well location.

The reflector at 0.700 sec. (630 m RKB) shows quite distinct changes in amplitude.

4.2.2 Offset Panels

The source and receiver diagonals were marked by vertical arrows and the sea-bed multiple was indicated before starting the actual interpretation.

Line ST 8381-309:

Encl. 6.

Several interesting features were identified on the Offset Panel.

At sp.106-117, 0.180 sec. (165 m RKB) a very pronounced amplitude increase is identified. Phase reversal and delay of subsequent reflections is also observed. There is an amplitude contrast decrease with increasing offset. All criteria indicate the

presence of a low velocity layer, possibly shallow gas. The zone is approximately 1100 m south of the well location.

High amplitude events are observed from sp.165-195 at 0.325-0.350 sec. (295-320 m RKB). Reflection phase (white trough) and lack of other low velocity criteria leads to the interpretation of a positive impedance contrast.

The diffraction at 0.380 sec. (345 m RKB) and a possible low velocity layer at 0.700 sec. (630 m RKB) identified in previous sections are also observed on the near offset.

The short maximum offset available with site-survey data does not allow interpretation of refracted waves.

Line ST 8381-113:

Encl. 8.

From sp.274-300 at 0.200 sec. (185 m RKB) a series of high amplitude reflections with possible phase change is observed on the near offset (37 m). At the 187 m offset the amplitude contrast can hardly be recognized. This event may correlate with the event at 0.180 sec. (165 m RKB) seen on Line ST 8381-309, hence emphasizing a possible hazard, However, at the well location there is no hazard indications at this level.

5. SUMMARY AND CONCLUSIONS

- Reprocessing of 3D line ST 8215-122 in order to improve shallow data quality (0-1.5 sec.) was successful. Reflectors are more continuous and frequency content slightly higher than on the original version.

- Offset Panel displays are most useful on data recorded with long cable. Two sets of panels were constructed for ST 8215-122, near traces with short offset intervals (50 m) and middle and far traces with 600 m offset intervals. The offset Panel yields useful information about reflected and refracted energy. The unique property of the Offset Panel is the ability to combine interpretation of these events and observe amplitude variations with offset. Refraction delays were observed north of the well location, but is interpreted to represent channel infill of low velocity material. The absence of positive gas accumulations makes it difficult to conclude on the general validity of the method, but in our experience the Offset Panel gives valuable supplement to site-survey data.

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

- Offset Panels were prepared also for the two site-survey lines. The short cable gives limited information of refracted energy. But near offset amplitude changes supported identification of several, possible gas accumulations of the well location.

- No additional drilling hazards have been exposed by the Offset Panel method at the 15/9-18 location.

- Several velocity anomalies that might be assosiated with shallow gas have been observed, but these are all situated off the well location.

- At 170-200 m RKB there are strong indications of gas 1100-1200 m south of the well location. Also, 200-400 m east of the well velocity anomalies are observed.

- A channel is recognized in the well from 185-210 m RKB. The channel is filled with low velocity material which could be sand. The sand might be gas filled in an updip position, 200-400 m south-east of the well.

- A diffraction 320 m north of the well at approximately 330 m RKB is most likely related to a boulder or lithological change. However, a minor gas pocket is also a possible explanation.

- At 630-650 m RKB, a reflector showing considerable amplitude variations is observed. This represents a possible gas accumulation.

6. RECOMMENDATIONS

- The Offset Panel method should be applied to 3-5 more well locations, especially a few where shallow gas is known to be present, in order to test the validity of the method.

- The Offset Panel will help to identify shallow gas at an early stage, so that the well, as early as possible, is 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 spread throughout the cable. One display of the near traces (up to 500-600 m), and one of the middle and far traces. Amplitude level should not be too high, so that amplitude contrasts are easy to detect. The need for deconvolution of offset panel is debatable. On one hand decon organizes the data and suppresses multiples. On the other hand there is the danger of disturbing primary data, f.inst. refractions. Our experience is that decon on ST 8215-122 (24 ms gap/336 ms operator) had a positive effect on the data. However, the use of spiking decon is not recommended.

- 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.

Acknowledgements

We would like to thank Mr. T.K. Fulton, Gulf Development & Reseach Company for his valuable help and advices during interpretation of the Offset Panels.

SIE/JEH

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

LIST OF ENCLOSURES

Encl. 1 : Filtered Stack, Line ST 8215-122
(1:25000, 10 cm : 1 sec.)

Encl. 2 : Filtered Stack, Line ST 8215-122
(1:10000, 30 cm : 1 sec.)

Encl. 3 : Offset Panel, Line ST 8215-122
(5 panels, 50 m offset intervals)

Encl. 4 : Offset Panel, Line ST 8215-122
(5 panels, 600 m offset intervals)

Encl. 5 : Filtered Stack, Line ST 8381-309
(1:10000, 30 cm : 1 sec.)

Encl. 6 : Offset Panel, Line ST 8381-309
(5 panels, 150 m offset intervals)

Encl. 7 : Filtered Stack, Line ST 8381-113
(1:10000, 30 cm : 1 sec.)

Encl. 8 : Offset Panel, Line ST 8381-113
(5 panels, 150 m offset intervals)