Naturally Fractured Tight Gas Reservoir Detection Optimization

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TABLE OF CONTENTS

1.0 3D-3C SEISMIC ACQUISITION _____ 3

2.0 3D P-WAVE ALTERNATE PROCESSING _____ 8

1.0 3D-3C SEISMIC ACQUISITION

Northern Geophysical, Denver, CO was selected to acquire the 3D-3C seismic survey. They began their work on August 15 with the drilling program. A schedule of the 3D-3C data acquisition is given in table 1-1

Table 1-1 3D-3C Schedule	
Date (1995)	Activity
July	Permits obtained with landowners.
August 6	Surveying of ground locations for 3D-3C. Acceptance of environmental documentation by DOE.
August 15	Drill crews arrive on site. Start-up meeting with State Oil and Gas Commission and BLM.
October 9	Completion of drilling.
October 13	Arrival of acquisition crew in field. Begin deployment of 3C geophones.
October 18	Deployment of cables.
October 20	I/O System 2 recording unit arrived in field. QA/QC testing of system.
October 24	Test shots detonated for QA/QC.
October 25	Production shots begin on a 24 hour per day schedule.
October 28	Completion of seismic acquisition. Two and one half hours lost due to adverse weather. Demobilization begins. Hole plugging of two holes.
November 3	The field was cleared of all activities.
December	Release of permits by State Oil and Gas Commission and BLM.

Drilling of the shot holes was completed by October 9. Three types of drill rig were used namely a conventional air drill, a buggy air drill and an auger drill. The breakdown of drilling is given in table 1-2.

Table 1-2 Drilling Rig Type	
Drill Hole Type	Number of Holes
Conventional	504
Auger	258
Buggy	110

Each hole was loaded with 20 lb. of explosive consisting of Vibrogel with a double cap Figure 1-1a. The minimum depth to the top of charge was 51 ft. The final shot and receiver layout is shown in Figure 1-2.

The acquisition crew for the 3D-3C arrived on site on October 13. Table 1-3 details the final acquisition parameters designed for the survey and Figure 1-3 shows the layout details of the receivers for this survey.

Table 1-3 Acquisition Parameters	
MFG. TYPE	I/O System 2
Sample Rate (MS)	2
Record Length (SEC)	10
Recording Filters (Hz/Slope, db/OCT) Antialias - 3/4 Nyquist High:	High: 207; Notch: Out; Low: 3
Pre-amplifier Gain (dB):	48 dB
Tape Format/BPI	SEGD 8048/6250 BPI 9 track
Spread Type	Multi-line layout,
Channel Distribution	Static patch
Spread Dimension (Feet)	9 lines at 660 ft separation, each
Station Spacing (Feet)	220 down line
Total Receiver Stations	458 3 component groups
Receiver Group Center on	About the survey station, bury phones, lay cable flat to reduce wind vibration
Geophones/Group	12
Phone Spacing (Feet)	20-30 ft diameter circle
Leakage Specification (Kilo-Ohms)	500 K-ohms [I/O internal "common mode" test @ - 65 dB range]
Geophone string resistance (Ohms)	OYO-Geospace GS- 20DX or SMT-70 3- component elements per case, 10 Hz, 70% damping, wired 12 in series $R_{tot} \approx 850\Omega$
Acceptance Tolerance (%)	5%, +/- 43 Ω or 807-893 tolerance range
SOURCE ARRAY	
MFGR Type	Explosives #20 Vibrogel (non-cast exp.)
General Geometry (Feet)	Single point, double cap/51 ft top depth (9 ft charge)
Number of Points/Distribution	Single Shot
Source Interval (Feet)	Variable 220 ft inside spread, 440 ft outside
Total Shot	872
Statistics Listing for	
Stations	
Station Lines	9
Total Stations	458

Station Spacing	220 ft
Line Spacing	660 ft
Survey Size	
X-Extent	25648.12 ft
Y-Extent	18215.00 ft
Bins	
Width	110 ft
Height	110 ft
Inline Bins	167
Crossline Bins	234
Total Bins	39078
Total Traces	399376
Shots	
Shot Lines	37
Total Shots	872
Shot Spacing	variable
Line Spacing	550ft and 1100ft
Template Size	
Total Channels	458 each component
Nominal Fold	10
Max Fold	110
Min Offset	76.00 ft
Max Min Offset	17889.00 ft
Min Max Offset	9091.00 ft
Max Offset	21453.00 ft

All of the receivers were deployed by October 20 and each individual receiver was checked for orientation by a representative of Blackhawk Geosciences after which the receivers were buried. This ensured that each receiver was to within 5 degree of East-West for H1 and 5 degree of North-South for H2 with the p-wave or vertical channel positioned using a bubble level on the top of the geophone case.

Cables were laid out from October 18 to 24. Each of the lines were then checked by Blackhawk for consistency in hooking up the receivers. In addition, Blackhawk conducted polarity checks on the receivers before deployment in the field and also spot checks when they were deployed. These checks consisted of tap tests on the top of the geophone case for vertical elements and taps in the arrow directions for the horizontal components, and impact tests when the phones were buried. An example of the results of these tests is shown for the H2 phone in Figure 1-4 where a negative break (a deflection to the left on these plots) confirms the correct SEG polarity for the geophones. These checks are

critical in multi-component recording as the polarity of shear wave arrivals must be known for the processing sequence to perform correctly.

Further to this work in the field, Blackhawk also conducted downhole measurements of 30 buried geophones. The buried phones were deployed at the base of the dynamite charges and consisted of 3 component geophone receivers. An impact shear wave source was then used to measure the shear wave travel times for S1 (the fast shear wave) and S2 (the slow shear wave) (Fig 1-1b). The magnitude and direction of shear wave anisotropy near the surface is critical for correctly evaluating the shear wave static corrections during processing of the mode converted surface 3D reflection survey.

Royal Watts (DOE METC) visited the field at this time to review the progress of recording.

The recording unit, an I/O System 2, arrived on site on October 20 and tests of the system began immediately. The configuration of the recording unit is given in Figure 1-5. Tests were also conducted on the timing of the source controller. These tests consisted of two types. In the first, a blasting cap was detonated in a manner consistent with firing an actual shot. The depth of the cap was approximately 1 ft in the ground and therefore the arrival time to the uphole sensor and a coincident geophone group were within one sample of the seismic system. Uniformity of all dynamite blasting units were performed using an inductive method rather than exposing the Blasting Operator to the risks of handling additional blasting caps. This method consisted of attaching a coil of wire to the output leads of the blasting unit (thus replacing a blasting cap). The coil was then wrapped by another coil of wire which will sense the induced blast signal and the output is sent to a geophone input on the recording system. This method is demonstrated in Figure 1-6. Each blasting system performed within the specifications of the QA/QC plan.

Once all system checks had been conducted in accordance with the QA/QC plan test shot locations were picked. These locations were at 511-158, 576-151, 611-140, 651-138, and 731-160. The purpose of the test shots was to further ensure that the correct polarity was achieved in deployment of the sources, that there were no dead channels, and receivers and that the recording system was functioning within specifications of the QA/QC plan. Paper copies of the test record were made for observation in the field together with digital records for evaluation on the field QA/QC system.

On October 24 and 25 the test shots were fired and the records analyzed for compressional wave and shear wave reflections. Initial inspection of the data showed good quality reflections for the vertical geophones, some reflections for the inline horizontal geophones and some energy on the cross geophones. The data was reviewed by Blackhawk in the field and also faxed to Lynn Inc. Example records from the first test shot is shown in Figure 1-7.

Production shooting began on the morning of October 25 and was completed in 4 days. Every shot was monitored for noise vs. signal by alternately plotting the vertical channel and the two horizontal channels. During this time the weather cooperated and only 2 and one half hours were lost because of excessive wind noise. The burial of the geophones helped greatly in this respect by reducing the wind noise. Also throughout the survey no more than 0.4% of the recording channels were subject to failure, which was well within the QA/QC plan requirements of 2%. Throughout acquisition, Northern Geophysical acted in a

responsible workmanlike manner and are highly commended for their effort. Only two shots from a total of 874, could not be made to fire in the field and these were remediated in a manner acceptable to the Wyoming Oil and Gas Commission for hole plugging. The double capping ensured that this low misstine rate was achieved. Only 11 holes experienced blowouts or partial blowouts. Each of these was also remediated in a manner acceptable to the Wyoming Oil and Gas Commission. The small number of blowouts compared to conventional dynamite shooting was attributed to the use of the bentonite capsules which have a lower blowout potential. This low blowout rate (less than 1.5%) means that more of the energy is transmitted into the ground, and thus, better seismic data is obtained.

Copies of the field data tapes were made by Blackhawk in order that preliminary analysis could be conducted in their office and that duplicate tapes could be sent to different processing companies if necessary when the processing contracts are awarded. It is critical that processing begins as soon as possible in order to leave sufficient time before the end of the contract for interpretation.

After a final inspection of the archaeological sites and drill holes for drill plugging, release of all permits was granted by the BLM and State Oil and Gas Commission in December. No environmental impacts were caused as a result of the seismic survey and no remediation was necessary.

(A)

(B)

DAS-1 RECORDING SYSTEM AND
SURFACE TO DOWNHOLE SURVEY

VIBROGEL EXPLOSIVE

FINAL 3D-3C S LOCAT

LEGEND

SHOTS = RED CROSSES

RECEIVERS = BLUE SPHEROIDS

SCALE IN

SHOT-RECEIVER ON MAP

FEET

6000 8000 10,000 12,000

FIGURE 1-2

\\PROJECTS\\BGD6805\\CADMAP\\QTRMAP1.DWG

Receiver Line Layout

FIGURE 1-3

TAP TEST

HAMMER TEST

EXAMPLE OF POLARITY TESTS
FOR 3-C GEOPHONES

Recording Truck Configuration

FIGURE 1-5

Timing Test for Source Controller

FIGURE 1-6

EAST-WEST

NORTH

SECONDS

1.0

2.0

3.0

4.0

5.0

SOUTH

VERTICAL

FIGURE 1-7

2.0 3D P-WAVE ALTERNATE PROCESSING

Processing continued at Western Geophysical. The final residual migration were output and tapes plus paper monitors produced for Lynn Inc. and Blackhawk. These volumes will be loaded onto the owner/operators workstation for interpretation by Blackhawk and Palantir.

The owner/operator used the N-S and E-W data processed under the DOE contract to construct maps of the Lower Fort Union horizon. It was the owner/operators opinion that the separately processed volumes rather than the all azimuth volume produced crisper, cleaner, higher quality reflectors at the Fort Union time that were easier to use for structural mapping. Examples of this are shown in figure 2-1a for the all azimuth volume, figure 2-1b for the North-South volume and 2-1c for the East West volume. Subsequent to this the time horizons were converted to depth horizons using a combination of velocities from the survey and well control. This information was presented to the owner/operators partners (this group includes small independent gas producers and large producers) during a quarterly meeting and was of great interest.

Palantir continued to monitor the final stages of processing at Western which included the processing of the separate AVO volumes. Tapes for these will be cut in early January.

Western Research in Houston demonstrated their model and test data using azimuth bin #3. The final results of this were presented to the owner/operator and Blackhawk and will be written up in a final report. A good correlation was obtained with the preliminary results obtained under the DOE contract thus verifying both methods.

Colorado School of Mines, Center for Wave Phenomena continued their review of the processing flow and anisotropy in the data. Their results will be available for review in the first quarter of 1996.

SOUTH

IN-LINE 137
ALL AZIMUTHS

NORTH

FIGURE 2-1A

SOUTH

IN-LINE 137
N-S AZIMUTHS

NORTH

FIGURE 2-1B

SOUTH

IN-LINE 137
E-W AZIMUTHS

NORTH

0 2200 4400

SCALE IN FEET

FIGURE 2-1C