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3D-3C Seismic data acquisition – survey design and implementation: A case study NAS Block, A & AA Basin

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Summary

Mode conversion of elastic wave takes place at the discontinuity during propagation due to impedance contrast in the sub-surface, when the incident angle is not normal at the discontinuity. Multi-Component seismic recording (measurement with vertical- and horizontal shear component along with P) captures the seismic wave field more completely than conventional P-wave techniques. Evaluating P and S-wave data together provides additional information to reduce uncertainty in prospect evaluation. The current study in NAS Block of ONGC, Jorhat is aimed to understand various multi-component acquisition aspects.

***Keywords:** Mode conversion, Four corner shooting, Digital sensors, Amplitude burst.*

Introduction

A new technology, multi-component seismic has been introduced to meet the demand of modern hydrocarbon exploration. In multi-component acquisition, three sets of data is received at each receiver, P or the primary wave and two measurements (X, Y) of the shear wave (Fig.1).

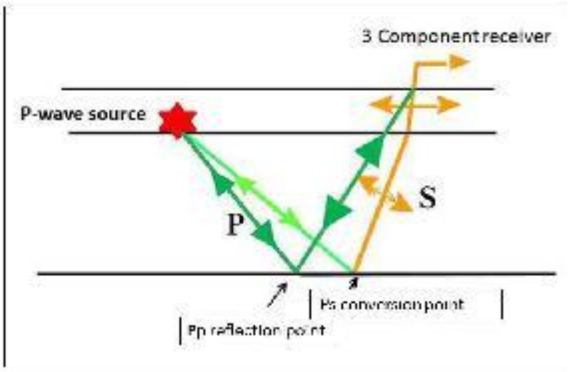

Figure.1: P-S mode conversion

In conventional 3D, we acquire only P-wave. P- wave reflection can't image fluid saturated zones properly. But information obtained from S wave passing through fluid saturated medium is better interpretable in reservoir characterization. The current study in NAS Block (Fig.2) of ONGC Jorhat is aimed to understand various multi-component acquisition aspects ranging from unique survey geometry designing, implementation of geometry, understanding of whole new sets of ground electronics specially, three component digital sensors and quality barriers analysis. The motivations for multi-component seismic (especially converted P to S) data acquisition in this area are several fold including improvement of the P- wave section (via multi-component filtering techniques), developing new strati-structural details (minor faults, compartments, closures) using PS wave images, assisting with new stratigraphic features and providing some large scale lithology (e.g. Sand versus shale) information, fractures' orientation and anisotropy study. The data acquired in this survey will help to bring out the hydrocarbon bearing reservoir distribution from Tipam sands along with any strati-structural features from the deeper Barail Main sands (BMS) and Tura plays.

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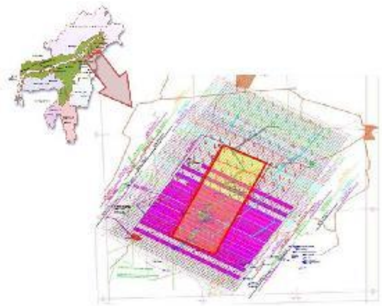


Figure.2: Study area in NAS block

Acquisition geometry

The principles followed in designing 3D-3C acquisition geometry are determined by the propagation nature of converted wave at CCP (Common Conversion Point) and the V_p/V_s value. A model is simulated by ray tracing that ensures reasonable CCP folds w.r.t offsets (maximum offset 3500 mtrs) and target depth. Due to inadequate ground electronics data was acquired with an unconventional template of 16 receiver lines (2304 active channels,144 channels per receiver line) with shot points located at the four corners of the template shown in Fig.3.

This geometry was chosen for its wide angle azimuth (360° up to 3500 mts. Fig.4), uniform distribution of offset and folds for both Pp and Ps for azimuthal velocity analysis. The Gamma function (ratio between V_p and V_s) was calculated to be 2.7 using dipole sonic log data of two adjacent wells in the area. Pre and post-acquisition fold distributions are shown in Fig-5a & 5b. Different acquisition and recording instrument related parameters are shown in Table-1 & Table-2.

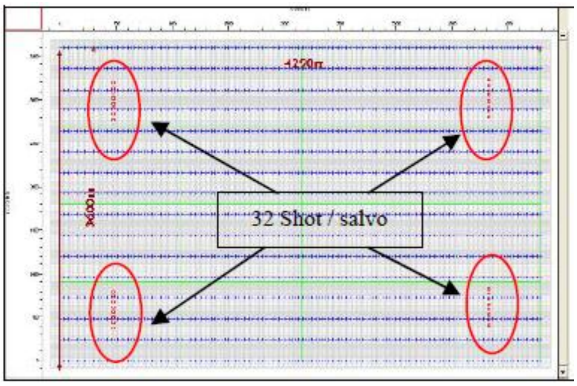


Figure.3: Unit template showing unique four corners shooting.

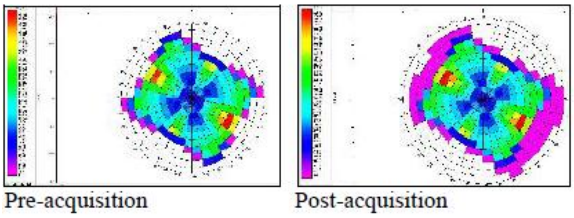


Figure.4: Full azimuthal coverage upto 3500 mtrs.

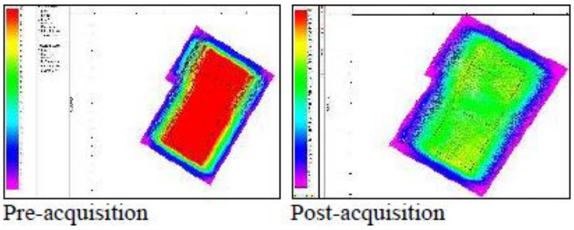


Figure 5a: Pp nominal fold

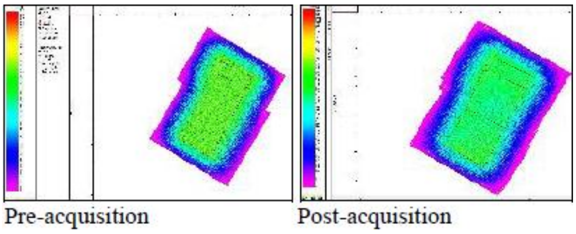


Figure.5b: Ps nominal fold

Acquisition parameters	
Bin size	15 X 15 mtrs
Fold	72
Receiver line interval	240 mtrs
Group interval	30 mtrs
Shot line interval	240 mtrs
Shots/salvo	32
Aspect ratio	0.84
Line bearing (Degree)	121.2

Table 1: Acquisition parameters

Instrument Parameters	
Seismograph	ION Scorpion System Digital
Recording format	ION SEGY
Sampling interval	2 ms
Pre-amp gain	0dB
High cut filter	187 Hz
Low cut filter	Out
Recording length	10 sec
Sensor type	Digital sensors (3 component)
Sensor orientation	Vertical with X component in the direction of receiver line (121.2^o)

Table 2: Instrument parameters

P and S-Wave Source

For interpretation in multi-component domain, P- wave and S-wave data are compared. So independent P and S-wave source are not required. Hence converted S-waves generated from P-wave source was used in the survey.

Multi-component receivers

Geophones which function as velocity meter are used in conventional seismic to record only P-wave. Special type of digital sensors (Fig. 6) is used to record multicomponent seismic data. This is basically accelerometer. The sensor at the core of the unit is a set of three micro machined accelerometers which measures the acceleration due to ground vibration along the axes X, Y and Z. Characteristic properties like high Vector Fidelity, VOR, Sensor Offset, Gravity value and Spread Noise criteria have made it an ultra-sensitive machine. Also in digital sensors, Single Point Recording (SPR) allows for better recording of true particle motion.

Spike analysis and Value addition

During data acquisition it was observed that some of the digital sensors were exhibiting spiky signatures without following any pattern. During normal operational day, it was not feasible to replace 100% faulty digital sensor due to time constraint. The ultimate aim was to record spike free data to improve the quality at acquisition level. Further experiment was carried out over three field seasons to know the causes of spike generation in digital sensor and minimize its occurrence to improve the data quality.

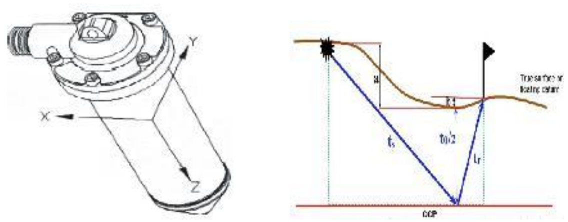


Figure.6: Acceleration vector measured by the digital sensor

Testing during field operation

Noise monitors were recorded with actual field condition for entire spread, after plantation and powering up the sensors in the spread. One sample line is shown in Fig.7. The ambient noise in the spread in AGC monitor can be seen without any spiky trace, however this noise doesn't affect the trace in any of the component, as evident from de-float record. It was observed that no amplitude burst was seen in the noise monitor; however few sensors crossed the threshold limit for spread noise.

Further during regular production work in field, the exercise was carried out on a particular line after replacing spiky sensors. More spikes were observed (Fig.8) as line was passing through a village and parallel to the road. The same was repeated with different combination of ground electronics. This noise subsequently settled over a period of time. However in some cases where noise level crossed its threshold limit, the sensors exhibited spiky signatures. Field experiment showed that the spikes were generated due to strong vibrations from external sources, apart from abnormality in gravity and offsets of the sensors. The spiky station varied with the moving of noise sources over the spread.

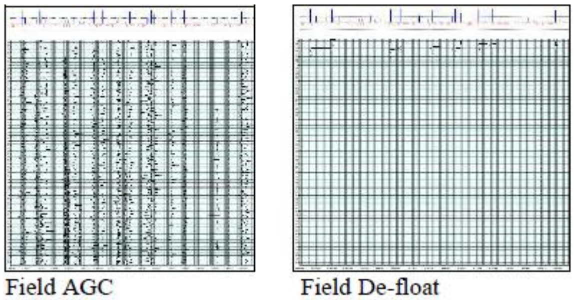


Figure.7: Recorded spread noise in field

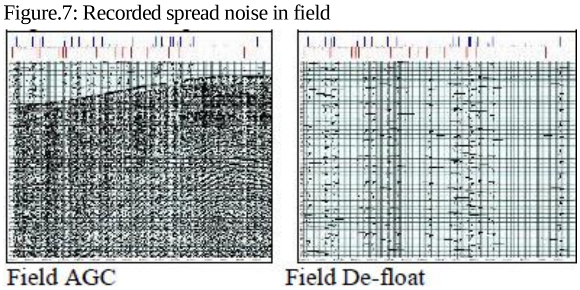


Figure.8: Recorded data in a active line

Testing at camp site

The second part of exercise was carried out in mid of next field season, on a leveled ground, adjacent to camp site of the Geophysical Party. Approx. 2400 sensors were planted at a uniform spacing of 12 lines. The field records were generated during this exercise with simulated noise without changing parameters. The records (Fig.9) displayed with AGC as well as in de-float mode to verify the signature of the sensors. It was observed that the spread noise for most of the sensors was closed to its normal value.

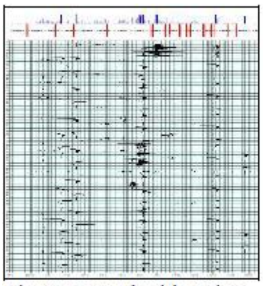
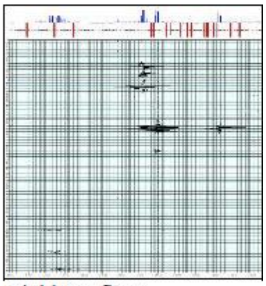


Fig.9: Record with noise



Field De-float

Results

Based on the analysis following observations are made.

- Gravity values dependent on Sensor offset.
- Sensor offset changes with total gravity variation.
- Spread Noise independent of above two parameters.
- The Spikes mainly follow the sensors offset and Spread Noise. Spread Noise is due to disturbances or vibrations near sensors.
- The spread noise has its limitation up to threshold level and after crossing the threshold, it gives the amplitude burst.
- Moisture or humidity leads to malfunctioning and failure of sensors in prevailing ground condition of North-East.
- Spread noise sustained its value for some duration and subsequently leads to critical / fatal error in sensors.

Parameters of all sensors were plotted against the stations to develop the correlation among gravity, sensor offset and spread noise in Fig.10.

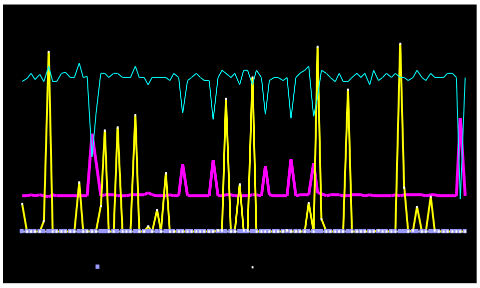


Figure.10: Correlation among of Gravity, Spread noise and Offset.

Spike minimization

Spikes were minimized using the BITS (Built–in-Test) and RTS results. The reduction in spikes can be seen from the records shown in Fig.11 recorded during FS 2010-11. Digital sensors with higher gravity values were segregated for repair. The data analysis was carried out in RCC, Jorhat (Fig. 12 and 13).

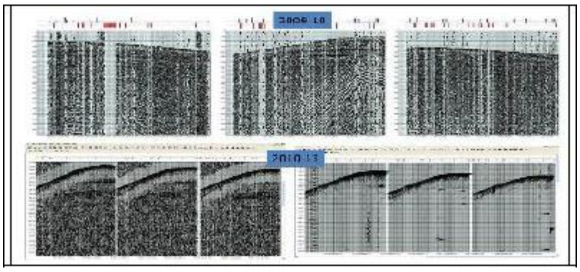


Figure.11: Field records of FS 2009-10 & 2010-11.

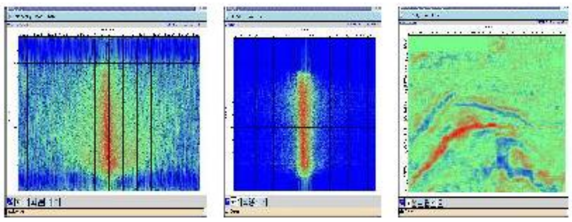
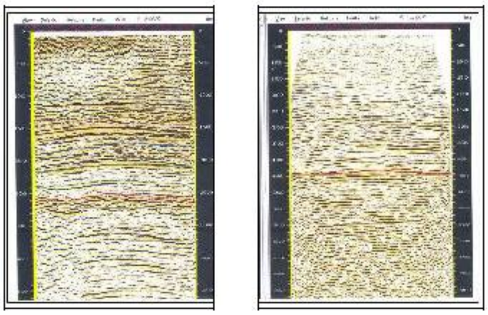


Figure.12: FK spectrum with and without noise, Time slice



Test processed Ps stack

Figure.13: Test processed Pp stack

Spike analysis over three field seasons was carried out and result is shown in table 3. Improvement has been done through

- Handling in field & transportation through tailor-made sensors carry boxes.
- Cyclic testing & isolation of failed sensors in Gravity & Offsets.
- Monitoring of over scaled sensors especially higher spread noise and control thereof.
- Increased the duration between shots.
- Monitoring road & rail traffic and oil & gas pipelines network and installations in the study area.

Field Season	Start	Mid	Last	Average %
I	5.7	7.5	9.4	7.5
II	9.2	8.5	9.6	9.1
III	2.0	2.4	2.1	2.2

Table 3: Spike analysis over three field seasons

Conclusions

The geometry was designed for uniform distribution of offset, higher multiplicity and wide angle azimuth for both compressional (Pp) and mode converted waves (Ps), which necessitate for azimuthal velocity analysis of Pp and Ps mode propagation.

It is time to consider the use of 3D-3C acquisition. Even if the shear wave data will not be used immediately, it is worth weighing the potential long-term benefit compared to the incremental cost. The single sensor per receiver point, the digital sensor systems provide some strong benefits like

- Isotropic recording.
- Less attenuation caused by intra-array statics.
- Potential for multi-component noise filtering.

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