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3 Component Uphole survey for estimation of shear wave static

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Summary
To explore the feasibility and to understand the behavior of shear waves generated at various interfaces due to mode conversion in weathered/sub-weathered zone, the idea of 3 component (3C) uphole was conceived in 2008. Geophysical party No. 06 of ONGC, successfully carried out experimental 3C Uphole survey in June 2008 by deploying three component digital sensors (SVSM) laid in specified star pattern geometry. This was probably the first ever attempt to acquired 3C uphole data in ONGC.

Based on the above experience, 3C Uphole data were acquired at selected locations using digital sensors (SVSMs) while conducting multicomponent survey in Padra area of Cambay basin during field season 2009-10. This was the first ever attempt in ONGC to calculate/ estimate near surface S-wave statics for PS data while 3D3C survey.

Consequent upon success of this study, 3C uphole surveys have been carried out on regular basis during subsequent 3D3C surveys in all three phases in Gandhar and Kalol areas of Cambay basin during FS 2011-12, 2012-13 & 2013-14 with more refined acquisition parameters.

The present paper briefly describes the methodology adopted, results and the lessons learnt by this historic 3C uphole survey carried out during 2008 & 2009.

Introduction
Shear wave seismic data have been playing important role in petroleum exploration. Difficulties in deployment of shear wave sources have constrained to depend on converted wave exploration. In this method the shear waves due to mode conversion of longitudinal waves generated by traditional explosives energy source at various interfaces. The total wave field is recorded at each receiver location simultaneously through three mutually orthogonal analog or MEMS based digital sensors who record signal along 3 directions ie, x, y, z corresponding to converted shear waves (SH & SV) and vertical (P wave).

The mode converted data is processed by Common Conversion Point (CCP) binning rather than Common Mid Point (CMP) binning as shown in fig 1. Due to uncertainty in position of conversion point, computation or estimation of shear wave statics is a real challenge. This problem is further aggravated due to lack of any measurement on propagation of shear waves through loose, unconsolidated weathered layer. Even the Dipole Sonic logs in this near surface zones are not very reliable and are seldom recorded. Hence the shot and receiver statics are computed by estimation based on correlation and matching of prominent events on PP and PS data.

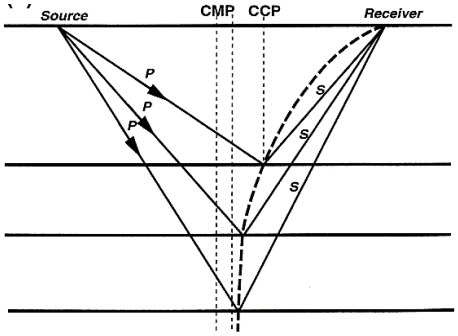

Fig 1 position of CMP & CCP for PS survey

While conducting 3D survey using 3 component (3C) sensors in Cambay-Tarapur block of Cambay basin during FS 2007-08 considerable energy was observed on horizontal components (Hx,Hy) which indicated mode conversion in the area. To explore the feasibility and to understand the behavior of shear waves generated in weathered/sub-weathered zone and to bring out the near surface model for shear waves, the idea of 3C uphole was conceived in 2008. This was probably the first ever attempt to acquire 3C uphole data in ONGC.

Geophysical Party No. 06 of ONGC, successfully carried out experimental 3CUphole survey in June 2008 at nearly end of field season 2007-08 by deploying three component digital sensors laid in specified geometry.

Methodology

To estimate the mode conversion along different direction and anisotropy of PS waves, experimental data was recorded with 8 arm star pattern receiver spread with up hole drilled at center of star as shown in Fig 2a.

Considering the near surface arm length of 250m was found as optimum. However, for reference and to make a comparison, two out of 8 arms aligned along inline direction of normal 3D seismic data acquired in the area were extended upto 3000m. The arms of star were numbered as 355,361,367,373, 379,385, 391 and 397 as shown in fig 2b. For simplicity receivers along each line were assigned picket number 1 at the center and increasing radially outward say 1 to 50. Line 379 was deviated to some extent to avoid an obstruction.

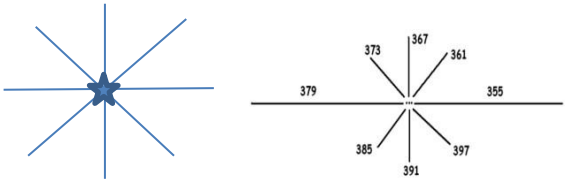

Fig 2a,b Sketch showing star pattern receiver layout

50 SVSM's were planted at 05m interval along 6 arms namely 361, 367, 373, 385, 391 and 397 making a spread length of 250m whereas 300 SVSM's were planted at 10m interval along two lines 355 and 379 resulting in spread length of 3000m.

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The depth of up hole was 60 m. The depth of two experimental shotholes located at 2m on both side of up hole was 20m which was the optimum depth for 3D survey at that location with spread geometry as in figure 2b. The recording parameters of 3C uphole and experimental shots are given as below:

Spread geometry as in figure 2b
Seismograph Scorpion I/O 4
Record length 8 sec.
Sample interval 2 msec.
Charge size 2 kg
No of Detonators for uphole:
60-48m depth at 2m interval - 8 nos.
40-10m depth at 1m interval - 5 nos
08-02m depth at 2m interval - 2 nos

Monitor record along 6 lines are shown in fig 3 &4

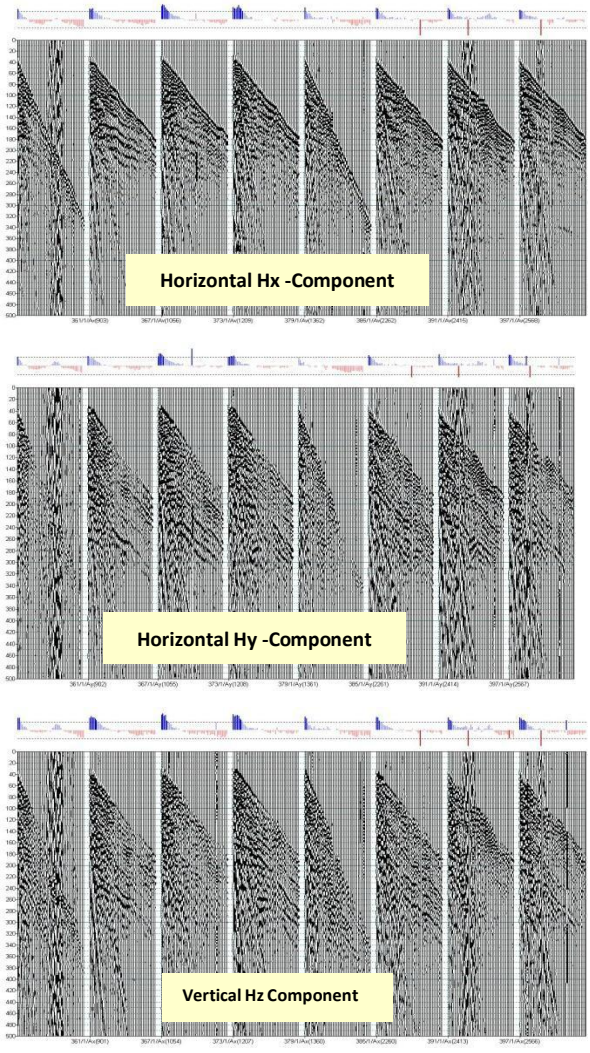

Fig.3: Monitor record along 8 lines

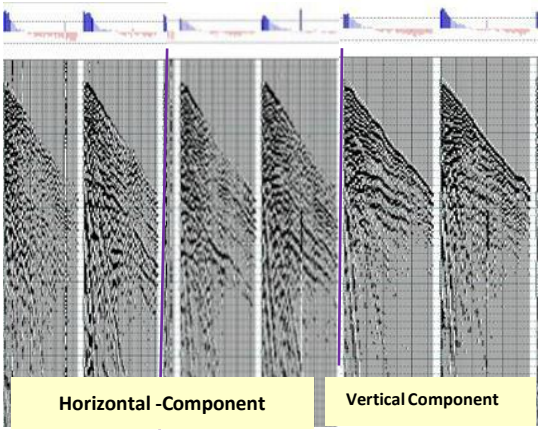

Fig.4: Monitor record along 2 lines

3C uphole survey in Padra area:

Based on the feedback and experience of experimental results, 3C Up-hole surveys were conducted at seven locations using digital sensors (SVSMs) alongwith normal upholes using analog geophone while 3D3C survey in Padra area of cambay basin during field season 2009-10. This was the first ever attempt in ONGC to acquire 3C Up-hole data while 3D3C survey to calculate/ estimate near surface Shear wave statics for PS data.

3C Uphole data were acquired with Scorpion system by deploying 13-14 receivers placed along orthogonal directions from the hole at 1m, 3m and 5m distance and 10 SVSMs at 20m apart (5m on each side) as shown in fig 4. UH data was also recorded with Summit Unit and analog geophones for comparison.

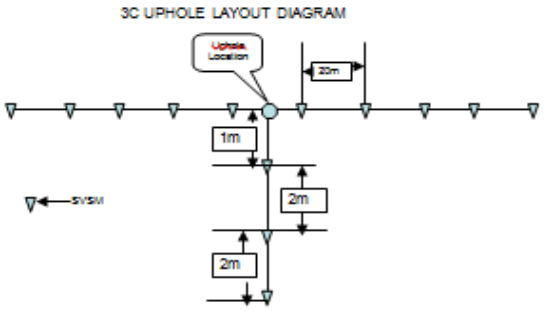

Fig 5 Layout for 3C uphole survey in Padra area

The first breaks of UH conducted with Summit Unit from analog receivers were picked by using Reflex software and near surface model prepared using Surfer software. The first breaks of 3C UH recorded with Scorpion system were processed by CGG software.

Initially there was difficulty in recognizing shear wave events and processing of 3C uphole data. They were mainly identified based on their character, speed wave shape and correlation with p wave data.

The 3 components have been displayed in 10-360 Hz frequency range with an AGC vs Time for clarity. The up hole plots from different receivers are shown in fig 6- 10.

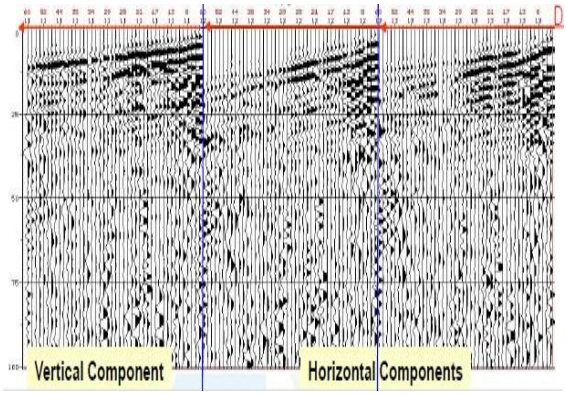

Fig.6: 3C Uphole record at 5m offset.

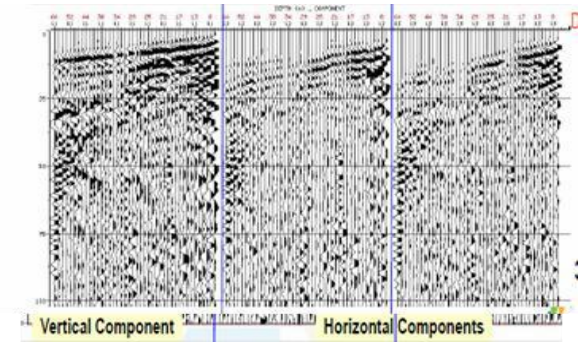

Fig.7: 3C Uphole record at 1m offset.

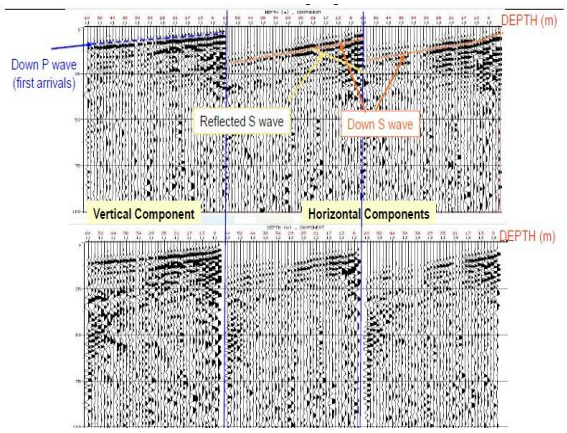

Fig.8 : Different waves identified from uphole data

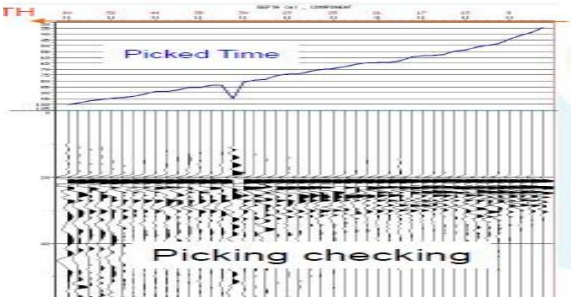

Fig. 9 : QC plot to check picking of events.

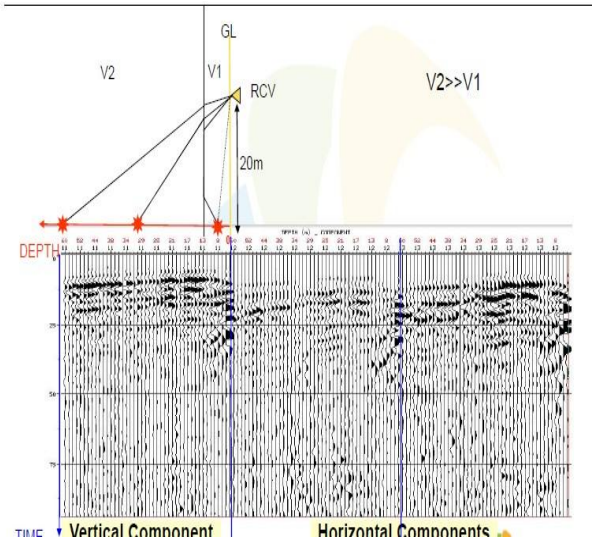

Fig. 10 : 3C Uphole record at 20 m offset.

It was observed that in spite of the good data quality and presence of the abnormal noise resulted in likely error in the reliability of the first break picking, which affected the velocities obtained & time-depth relationship.

The down going shear wave were clearly seen on the horizontal components and their time (and then the velocities) helped to understand the shear wave propagation.

A simple wavefield separation (P down and S down) helped to improve these picked times (P and S) and find out some strong reflectors ahead of the uphole bottom.

Optimization of 3C uphole geometry

Subsequently the method was further refined and the parameters optimized based on the near surface condition of the survey area. In view of the orthogonal acquisition geometry for 3D3C data acquisition in various phases of Kalol and Gandhar areas in Cambay Basin, Cross spread layout was found more suitable and practical with lines oriented along inline and cross line directions. The channel spacing and spread length was kept variable so as to image the shear wave events. The main emphasis was made to recognize and analyze the pattern of converted waves generated from different near surface layers. Few sample records and data after rotation are shown in fig 11 to 17.

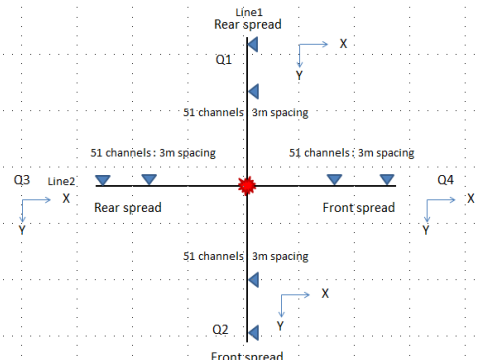

Fig 11 Layout of Uphole spread in Kalol area

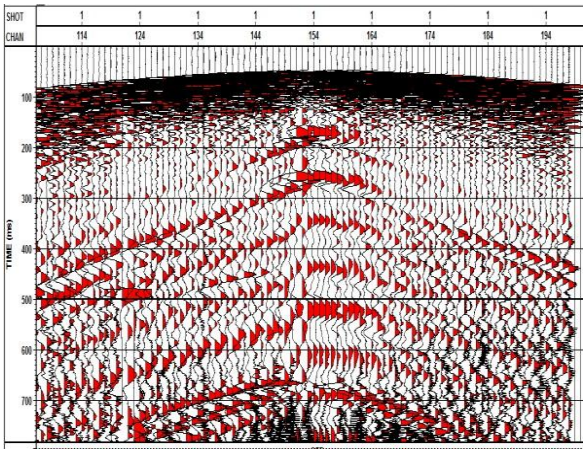

Fig 12 raw record in Kalol area

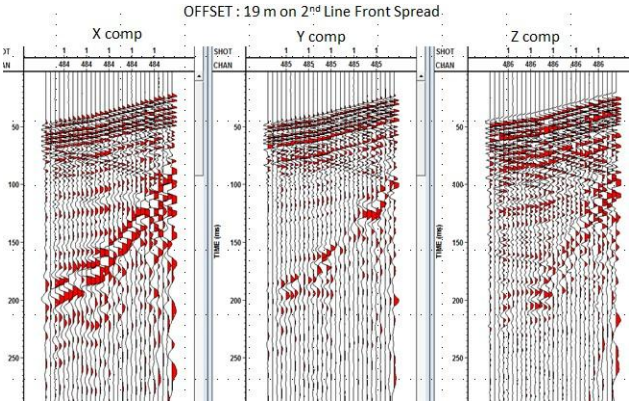

Fig 13 Common Receiver Gather at 19m offset

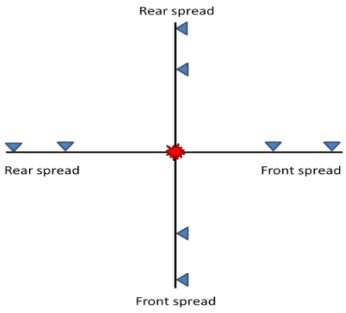

Fig 14 Layout of Uphole spread Gandhar area

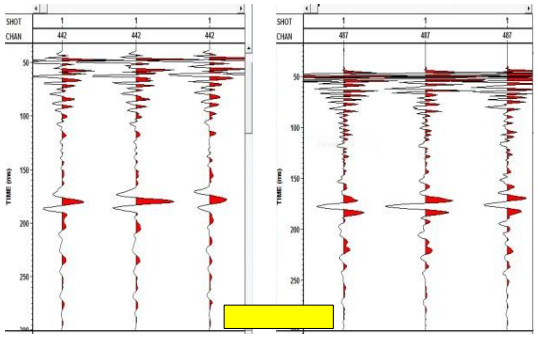

Fig.15 Common Receiver Gathers along 2nd line #442-X, #487-X at offset 22m on both sides of shot

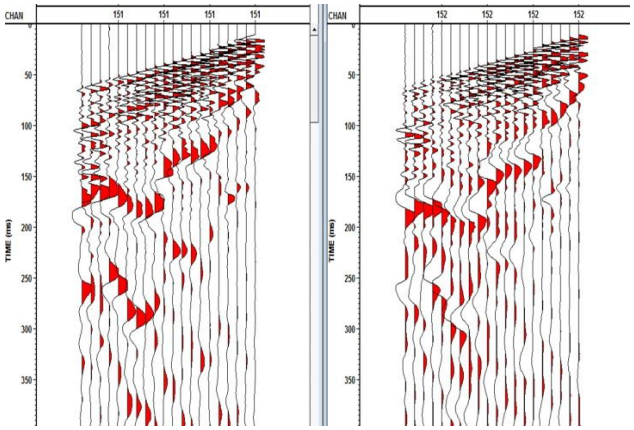

Fig16 Common Receiver Gathers at offset 13.5m Gandhar area

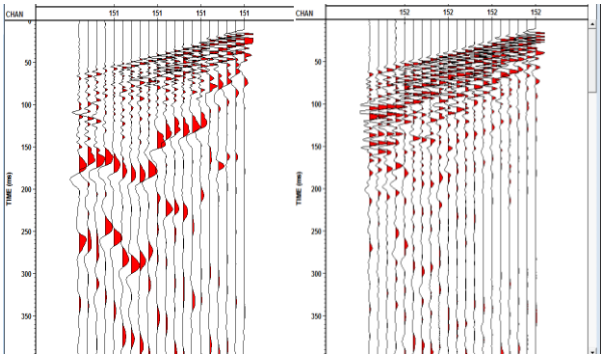

Fig 17 Rotated Common Receiver Gathers at offset 13.5m Gandhar area

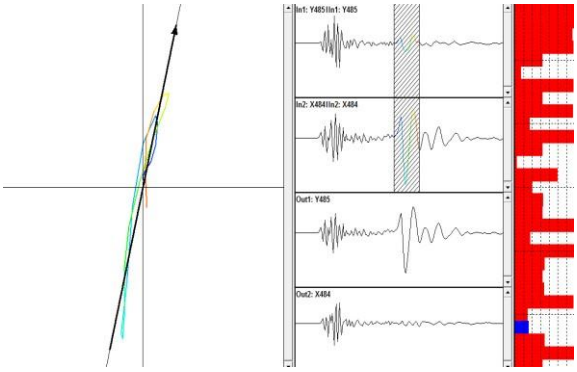

Fig 17 Hodogram Analysis Gandhar area

Observation:

Some of the observations on the rotation of 3C uphole data of Gandhar area and its Hodogram analysis are as below:

- Few events have High amplitude on X or Y component but are very feeble/low amplitude on Z component
- Variation of velocity with depth
- Hodograms indicate presence of Shear wave

Conclusion

In spite of difficulty in design of the optimal geometry, the results were very encouraging. We could recognize shear wave events helpful for near surface and thereafter calculate Vp/Vs ratio

The results proved efficacy of this method which proved to make long term impact in near surface modeling while converted / shear wave data acquisition.

Consequent upon success of this study, 3C uphole surveys have been carried out subsequently on regular basis during 3D3C surveys in Gandhar and Kalol areas of Cambay basin India during FS 2011-12 & 2012-13 with more refined acquisition parameters.

The resulted have contributed in refining the statics computation of shear wave data while processing.

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