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Estimation of receiver shear statics from multicomponent uphole survey

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Summary

Converted wave (PS) total field statics comprises of P wave shot statics and receiver shear statics.In multicomponent seismic data acquisition and processing computation of receiver statics for converted waves has been a challenge to the field crews and is often left for the processing center wherein the shear statics is estimated from indirect methods based on the data. Generally shear statics is estimated from shifts in shallow horizon or alternatively, in absence of trackable horizon by scaling PP receiver statics.Converted shear waves travel with very low velocity in near surface resulting in large static effects. Uphole surveys are used frequently for computation of near surface P wave velocity model and computation of PP statics. Uphole survey with 3C sensors offers a direct method of computing near surface shear wave velocity model. The main issue in this approach is identification of the shear events in the near surface and distinguishing it from surface waves. The paper demonstrates the methodology for acquisition of 3C uphole data and distinguishing the shear events from rayleigh waves. Uphole data of different areas of Gandhar and Kalol in Cambay Basin and Changmaigaon in Assam & Assam Arakan Basin were studied for the purpose. The velocities thus obtained in the Kalol area was used to derive shear statics. The stack after application of shear statics derived from uphole shows improvement when compared with stack with conventionally derived shear statics.

Keywords: *Receiver shear statics, Multicomponent uphole*

Introduction

Uphole surveys are integral part of seismic data acquisition wherein the first break derived from uphole data is used to determine near surface P wave velocity model. This model serves the dual purpose of placement of charge in high velocity medium and computation of PP statics for shots and receivers. In C-wave recording energy generated from shot travels with the velocity of P wave till it reaches the conversion point where it gets converted into shear wave and thereafter it travels with shear wave velocity till it reaches the receiver (fig 1). Shear statics of receivers plays a vital role in processing of C- wave data. In near surface shear wave velocity is much lower than P wave velocity hence small variations in near surface manifests into large static shifts. Various methods both direct and indirect exist for shear statics computation but due to low signal to noise ratio often indirect ways are preferred.

Recording of uphole with 3 component sensors offers a methodology to directly compute near surface shear wave velocity model in line with near surface P wave model. But the problem in all this is to identify the event corresponding to the shear waves from the several events as seen on raw record (fig 2.)

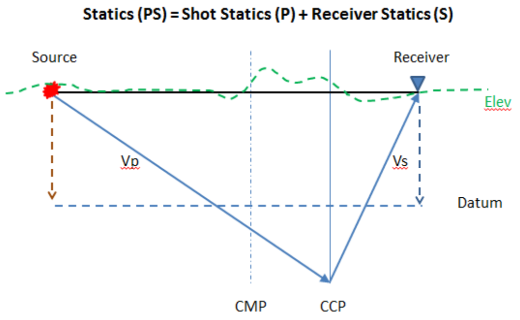

Fig 1: Ray diagram of C-wave recording

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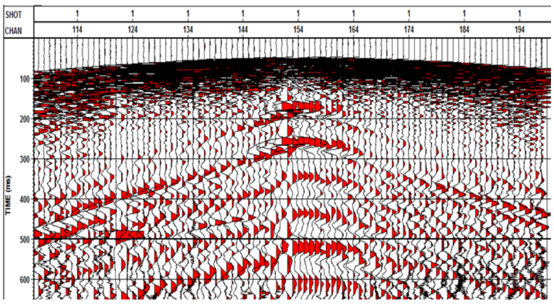


Fig 2: Raw record from uphole

Theory and Method

Shear events recorded in multicomponent uphole is often masked due to low signal to noise ratio of shear waves as compared with P waves. The very first doubt raised is, can shear waves be generated in borehole where small charge size in form of detonator is used. Sharpe (1942) and Horton (1943) reported secondary events from explosive sources but concluded them as tube waves and formation waves respectively. Lash (1985) showed explicitly that shear waves are generated from explosive sources.

The problem next is to identify the kind of shear event, whether it is converted PS or direct shear. Further, question that comes is whether the events picked are really shear waves or ground roll i.e. Rayleigh waves.

The shear waves can be either direct shear or converted shear wave. To analyze converted shear i.e. PS waves the knowledge of lithology is must and unfortunately in near surface this is not known. The average PS velocities are slower than P wave velocity but faster than S wave velocities. The energy of P waves is much more as compared with that of PS waves and hence PS is masked by P energy and is difficult to identify.

The direct shear in such a case is of advantage as it travels with much slower velocity and is recorded at time when there is lesser contamination due to P waves. Shear wave velocity is close to Rayleigh wave velocity and hence for near surface shear wave velocity estimation Rayleigh waves have been used in past e.g. MASW (Multichannel Analysis of Surface Waves). In this work effort was made to derive velocity model directly from shear waves.

Multicomponent upholes recorded in different areas like Gandhar and Kalol of Western Onshore Basin of Gujarat and Changmaigaon area of Assam were studied.

Field Layout

The data was acquired in Gandhar and Kalol areas with the layout as in (fig 3) with fifty one 3C sensors (vectorseis) placed on each side of source in two orthogonal receiver lines with group interval of 3m. In both the lines sensors were oriented such that X component was parallel to horizontal line (Line2) and Y component parallel to the orthogonal line (Line1). For the analysis we used the convention of Q1-Q4 as in fig 3. Detonators were used as the source. Shots were recorded at an interval of 1m up to the depth of 60m.

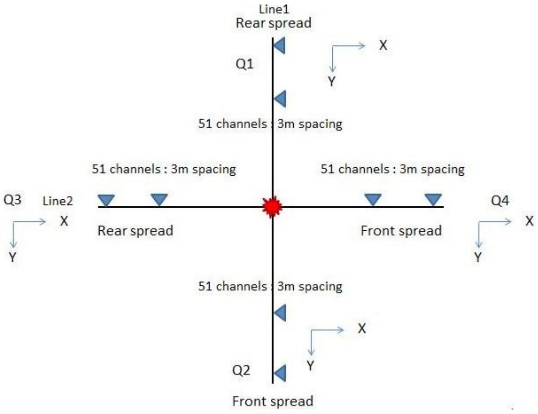


Fig 3: Field Layout

Observations

The data was analyzed without separating X, Y and Z components (fig 4). The first arrival is always P wave event but when the second major event was analyzed it was observed that only on one of the horizontal components an event is seen. This event is not seen even on the vertical component. Further the components were separated and analyzed. Fig 5 shows separated X, Y & Z components of Changmaigaon area. The steep event seen on horizontal components is not seen distinctly on vertical component.

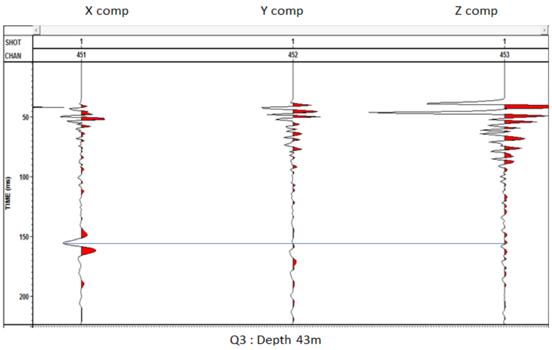


Fig 4: Horizontal and vertical components from uphole in Gandhar area with shot depth of 43m and offset 13m

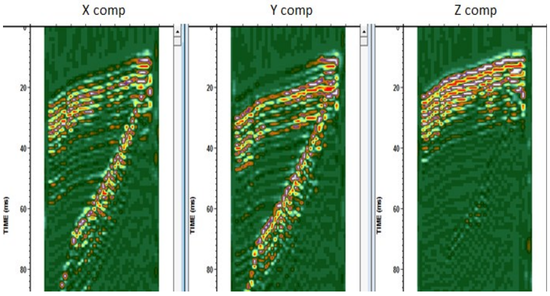


Fig 5: Common Receiver gathers from uphole in Changmaigaon area where Offset is 5m and depths vary from 2m to 48m

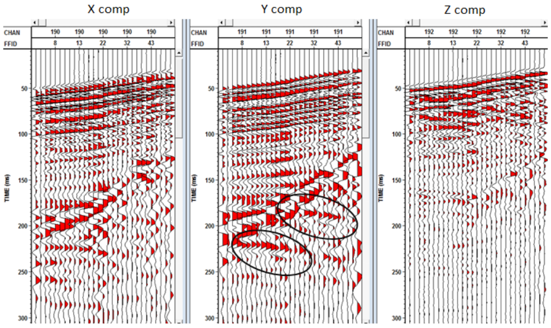


Fig 6: Common receiver gathers from Gandhar area at an offset of 31m

The result was similar in Gandhar area (fig 6) where low frequency steep event present in Y & X is not seen on Z component data. The uphole data can be considered as inverse VSP. The first arrivals in all the three components correspond to P waves. The two encircled events in Y component (fig 6) indicate reflected event from the corresponding depths. The presence of this reflection confirms that the steep event picked is body wave and not ground roll. Similar events were seen in upholes of Kalol area also.

To further distinguish the picked events from Rayleigh waves polarization analysis was used. Particle motion of Rayleigh waves is retrograde ellipse. Hodogram analyses of the events indicate its linear polarization.

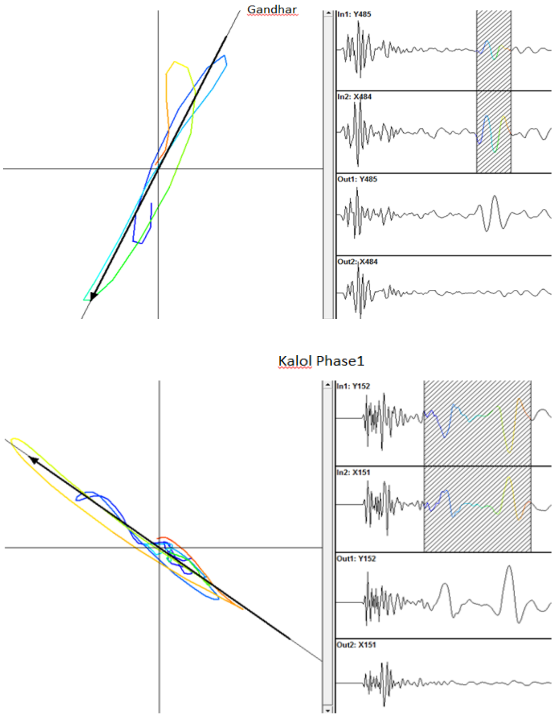
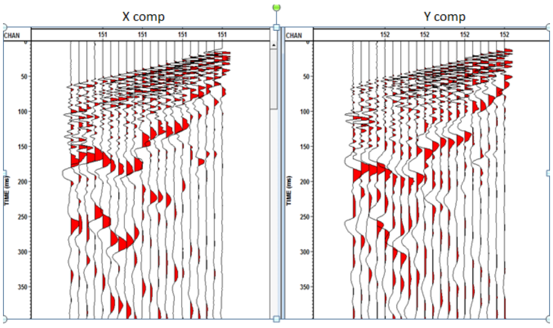


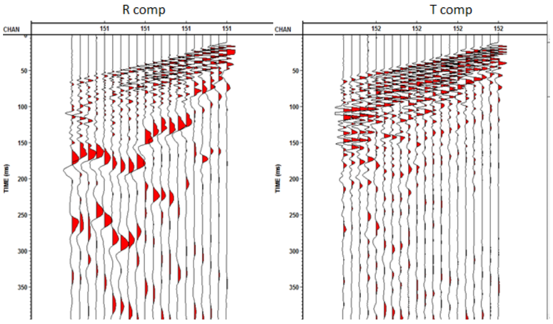
Fig 7: Hodogram analysis of X and Y components in Gandhar and Kalol area.

Second major event seen on both X and Y components was analyzed (fig 7). The presence of event with high amplitude on both the horizontal components may indicate the presence of ground roll. If after rotation the event is seen on both the radial and transverse components it is indicative of Rayleigh waves. Linear polarization of the events rules out the presence of Rayleigh waves and when X and Y components are rotated with the angle corresponding to the direction of polarization the energy present on both X and Y component is transferred to one of the components corresponding to radial and there is no energy on the other output corresponding to transverse component.

Based on these criteria the events were identified from the uphole data of Kalol area. Common receiver gathers of X and Y components at an offset of 13.5 m were analyzed. The secondary event with low frequency are seen on both X and Y components. The data was rotated to Radial and transverse based on polarization angle (fig 8). The energy is transferred from X and Y to radial component and no energy is seen on the transverse component.



a) X and Y components from Kalol area

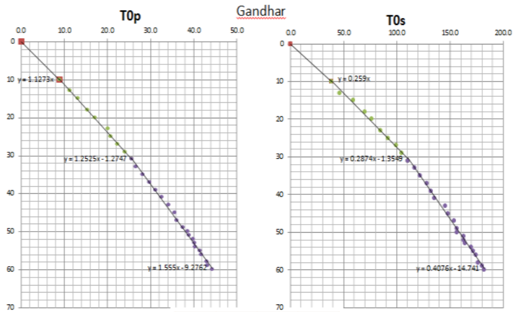


b) R and T components after rotation

Fig 8: Rotation of horizontal components by angle of polarization in Kalol area.

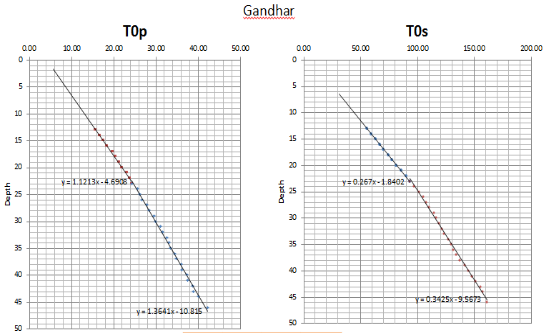
Results and Discussion

The results of computation of velocity for different upholes of Gandhar and Kalol are shown in fig 9.



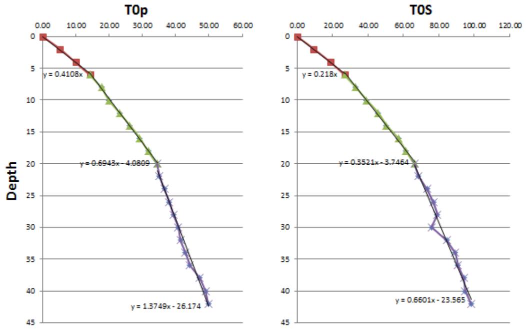
Depth	Vp	Vs	Y
10	1130	260	4.3
32	1250	300	4.2
	1560	410	3.8

a) Time-Depth plot of first arrivals of P and S wave from Uphole in Gandhar area at offset 37m



Depth	Vp	Vs	Gamma
23	1121	267	4.20
	1364	342	3.99

b) Time-Depth plot of first arrivals of P and S wave from another Uphole in Gandhar area at offset 25m



c) Time-Depth plot of first arrivals of P and S wave from Uphole in Kalol area at offset 4.5m

Fig 9: Time depth plot of first arrivals of P and S wave in Gandhar and Kalol area along with gamma values.

The results of velocity estimation were consistent in near surface of Gandhar area with Vp/Vs ratio varying from 4.3 to 3.9 at different depths. In the Kalol area velocity of shear wave varies from 220m/s to 660m/s at different depths. At shallower depths below 12 m due to contamination with PP energy and interference of other seismic event identification of shear events becomes ambiguous.

With the computed shear velocities from upholes at different locations the receiver statics was computed. The statics was also computed by conventional methods. In Kalol area horizons were not seen on receiver stack hence statics computation based on shifts in horizons failed to provide any improvement. From the PP and PS seismic data two way time at a major marker (Kalol formation) was picked. Gamma value was estimated using the relation:

Gamma = (2Tps/Tpp) - 1

Where, Tpp is two way time of an event on PP section and Tps is two way time of the same event on PS section.

Receiver statics for PS data was computed by scaling the PP receiver statics by this average gamma value and applied to the data.

The CCP stack with receiver statics computed from shear wave velocity derived from 3C uphole showed improvement when compared with the CCP stack with conventionally computed receiver statics (fig 10).

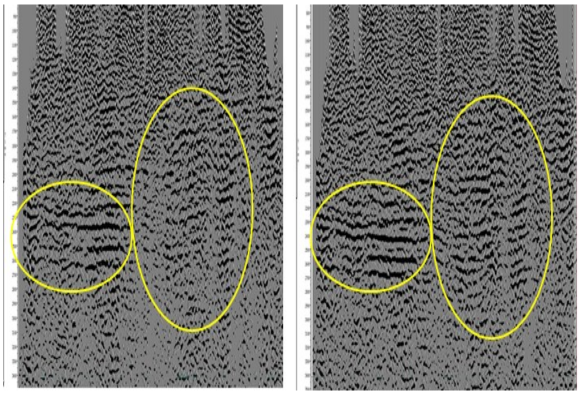

Conventional statics Uphole derived statics

Fig 10: CCP stack with receiver statics computed from (left) conventional method and (right) shear wave velocity derived from 3C uphole.

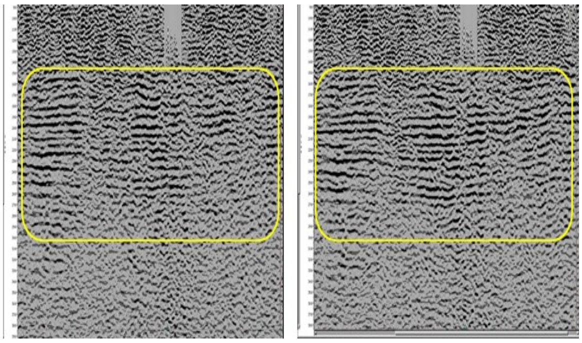


Fig 11: CCP stack after application of residual statics over (left) conventionally computed shear statics (right) shear statics derived from 3C uphole.

Conclusion

The data from a number of upholes survey from different areas with different geological setups were studied. The identification of the shear events is the main issue. From the data it is evident that shear waves are generated and can be used for near surface S wave modeling. The velocity model thus generated is useful in computation of shear statics for PS data processing. The method is more helpful in the areas where the signal to noise ratio is low in PS data and tracking of horizons is difficult. The methodology adopted was tested at different offsets, different locations and was found consistent. The Vp/Vs ratio derived using multicomponent upholes can be used for other geotechnical studies also.

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The views expressed in the paper are solely of the authors and do not necessarily reflect the views of the organization which they belong to.

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