P 321

Near surface shear velocity distribution: challenges and its solutions (A case study from Upper Assam Basin, India)

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Summary

Shear wave is highly sensitive in presence of fluid and fractures in rock matrix. The shallow subsurface typically consists of unconsolidated sediments characterized by very high ratios of compressional (P) to shear (S) wave velocities (Stumpel et al. 1984). One of the challenges associates with imaging of full wave (Three component) onshore seismic reflection data (PP, PSh and PSv reflections) is estimation of near surface shear velocity distribution which helps for shear static solutions.

Direct P waves are the first arrivals in the seismic record which play a key role to estimate near surface P wave velocity distribution. Direct shear waves are the late arrivals in the seismic record which are far from direct P arrivals and nearer to ground roll (Rayleigh waves). Phase identification of direct P and direct shear waves in common shot gathers of full wave uphole seismic data is one of the key steps in data analysis. Common receiver gather of full wave uphole seismic data is the direct relation of time and depth where slope of time-depth plots gives velocity & intercepting times helps to compute thickness of layers.

***Keywords**: Full wave Uphole seismic survey.*

Introduction

Estimation of near surface shear velocity structure is one of the challenges to compute optimum shear statics (receiver statics) in full wave onshore reflection seismic data. Shear wave is highly sensitive in presence fluid in rock matrix, especially in case of loose and unconsolidated sediments at the near surface.

Therefore, near surface is characterized by very high ratios of compressional (P) to shear (S) wave velocities with complex shear velocity distribution.

It is well aware that direct P wave arrivals are being used in conventional uphole seismic data for near surface P wave distribution. Similarly, utilization of direct shear wave information is now possible in full wave (Three components) uphole seismic data for near surface shear velocity distribution. In this paper phase observations of direct P waves and direct shear waves in common shot gathers are made on full wave uphole seismic data in one of the OILs operational areas of Upper Assam. These phases are similar in nature as arch shaped events but not same which depends on near surface velocity distribution of both P and Shear waves. Common receiver gathers of vertical sensors uphole seismic data and East-west sensors uphole data are being used for analysis of time – depth relations that will give the near surface information in terms of layer thicknesses and velocities, both P wave and shear wave.

Full wave uphole seismic survey

Geometry of the survey:

There are 12 sensors or DSUs (Digital Station Units) are laid out on either side of drilled hole. The sensor interval is one meter. 12th and 13th DSUs are planted one meter away from the drilled hole on the surface. Detonator is used as a seismic source in drilled hole at the following depth series;

Depth series: 100 , 90, 80, 70, 60, 55, 50, 45, 40, 35, 30, 25, 22 , 19, 16, 13, 10, 7, 5, 3, 1 in feet.

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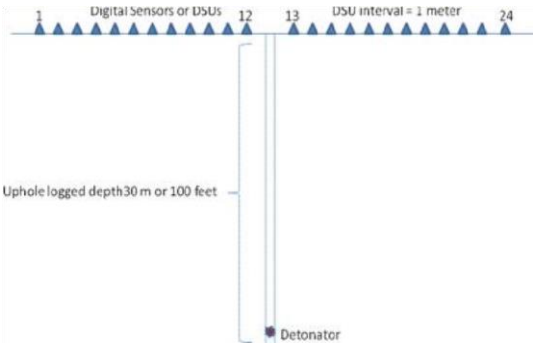

Figure-1. Schematic geometry of full wave uphole seismic survey.

Direct ray path of common shot gather in uphole survey

The tentative ray path of direct P or Shear waves connecting one source to all receivers are showed in Figure-2.

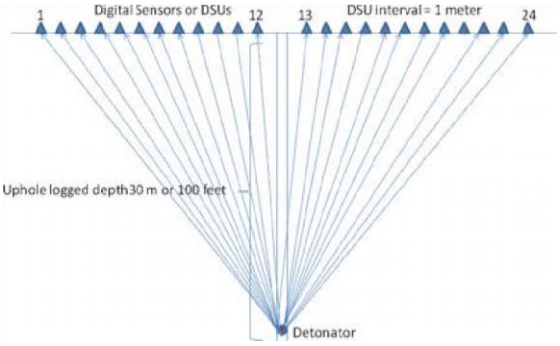

Figure-2. Schematic direct ray path of common shot gather in full wave uphole seismic survey. Direct waves visualize as arch shaped events or hyperbolic events in uphole shot gather.

Full wave uphole Raw seismic data:

Uphole data has been acquired with 0.25 ms sample interval of 2 sec record length. Since total 24 DSUs are planted on the surface, raw shot gather contains 72 traces in which 24 traces belongs to vertical sensor gather, 24 traces belongs to East-west sensor gather and rest 24 traces belongs to North-south sensors gather. One of such shot gather is showed in Figure-3

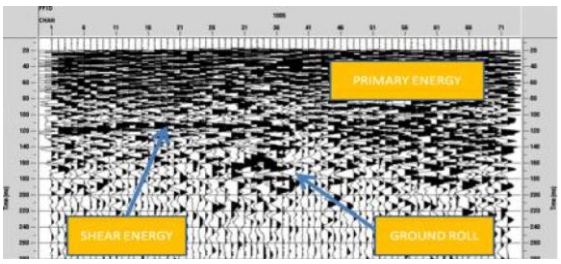

Figure-3. Raw shot gather for source depth at 70 feet of full wave uphole seismic data. Note primary energy (Direct P, PP reflections & PS reflections), Shear energy (Direct S) followed by ground roll.

A few of such uphole shot gather data comprises 72 traces at 55 feet, 35 feet, 16 feet of source depths, have been segregated as vertical, North-South and East-West sensors data and they showed in Figure-4.

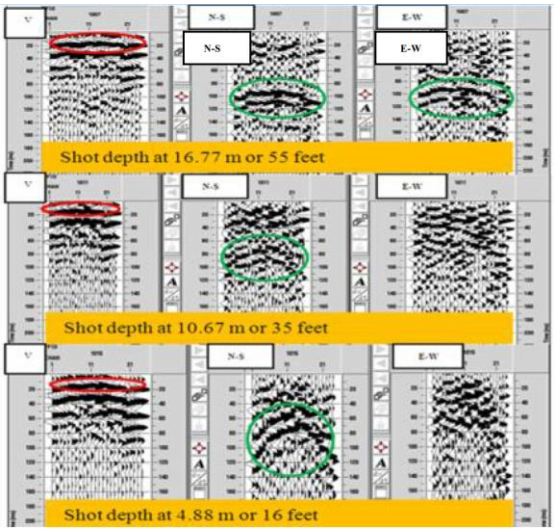

Figure-4.Band pass (6-12-60-70) applied full wave uphole shot gathers of Vertical (V), East-west (E-W) and North-south (N-S) sensors (Left to Right). Note arch shaped events with high energy indicate the direct waves. Possible phase of direct P waves are highlighted in red color and for direct shear waves, it is highlighted in green color.

It is observed in the study that direct shear waves are clearly noticed in shot gathers of North-South sensors data for all shot depths compared to that of East-west sensors data. Therefore, phase analysis has been made on North-South sensors data for direct shear waves.

Phase of direct wave arrivals in full wave uphole raw shot gathers:

Fundamentally seismic energy spreads spherically in all directions from the blasted seismic source, the direct P or S-waves can be appeared as arch shaped events or hyperbolic events in an uphole shot gathers. Therefore, phase of direct wave arrivals of both P and shear waves in uphole shot gathers could be similar but not same which depends on velocity distribution and appears as arch shaped events as shown in Figure-5 & 6.

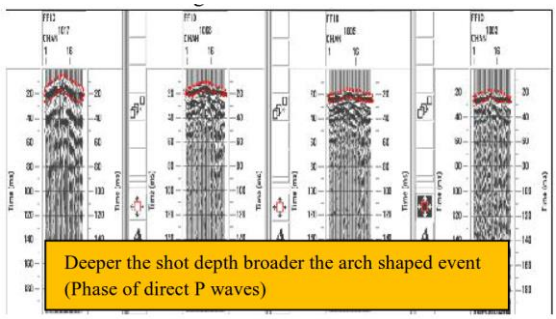

Figure-5. Uphole shot gathers of Vertical sensors data at source depth 10 feet, 50 feet, 70 feet & 90 feet(Left to Right). Note arch shaped events with high energy indicate the direct P waves (highlighted in red color).

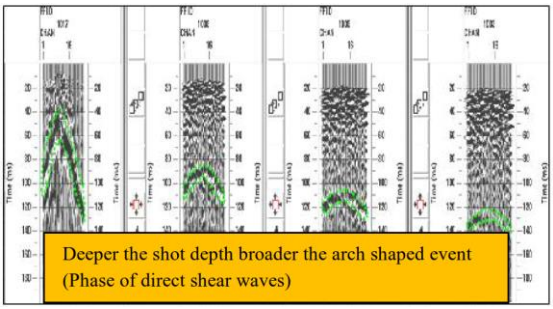

Figure-6. Uphole shot gathers of North-south sensors data for shot depths 10 feet, 50 feet, 70 feet & 90 feet(Left to Right). Note arch shaped events with high energy indicate the direct S waves (highlighted in green color).

Basically, recorded waves at DSUs were passing through all possible layers in the near surface from seismic source. Therefore, the arrival times of direct waves which are in arch shaped events in shot gathers could be considered as average times. At constant source depth, direct P-waves show the broader arch shaped event compared to that of direct shear waves in the uphole seismic data. Deeper the shot depth, broader the arch shaped event of direct waves, as the average velocity of direct waves are normally more at deeper shot depth than that of at shallow shot depth. Common receiver-shot gathers can be generated from all shot gathers. Since near offset first arrivals are direct waves, direct wave analysis can be easily done on near offset receiver-shot gathers to give the direct relation between depth and arrival times for near surface information in terms of velocity and thicknesses of the layers.

Direct ray path for near offset common receiver –shot gather:

Tentative direct P or Shear wave ray path is connecting near offset receiver to all shots at different depths as shown in Figure-7.

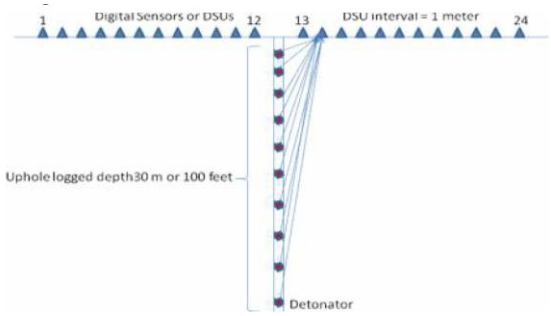

Figure-7. Schematic direct ray path for common receiver-shot gather in full wave uphole seismic survey

Here, DSU which is planted 2m away from drilled hole has been selected to generate Common receiver –shot gathers of both vertical sensor data and North-South sensor data as shown in Figure-8 a, b.

Based on the time information of phase of direct shear arrivals in shot gathers and respective time information in common receiver shot gather collectively suggest the first time breaks of direct shear arrivals.

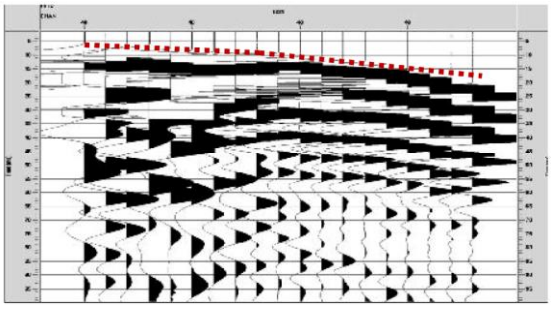

Figure-8a. Near offset common receiver–shot gather of vertical sensor. Note direct P-wave time breaks are highlighted in red color dotted line.

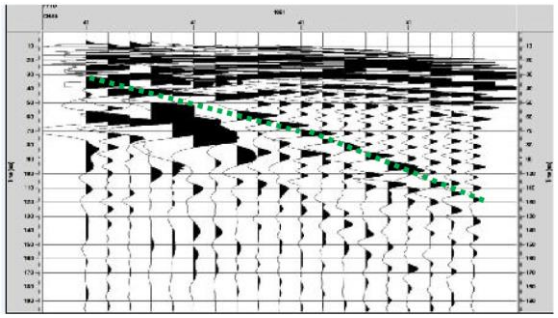

Figure-8b. Near offset common receiver shot gather of North-South sensor. Note direct shear-wave time breaks are highlighted in green color dotted line.

Time-Depth Plots-Near surface interpretation:

Time breaks of direct P-waves, direct shear waves and depths information helps to compute near surface information in terms of layer velocities and thicknesses as shown in Figure-9 & 10.

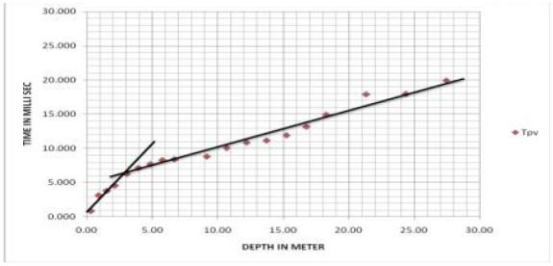

Figure-9. Time-depth plot for direct P–wave information shows two velocities for possible two layer case.

Interpretation: Direct P wave information suggets two layer case where first layer(weathering layer) velocity is 500 m/s and its thickness is 3 m and below weathering layer velocity is 1820 m/s

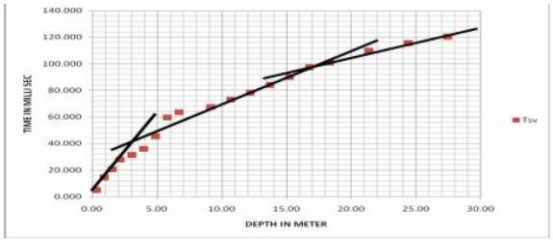

Figure-10. Time-depth plot for direct S –waves show three velocities, may be due to presence of fluid in second layer.

Interpretation: Direct shear wave information suggets three velocities within two layer case as 100 m/s, 208 m/s and 460 m/s as shear is sensitive in presence of fluid in rock matrix. Pictorial representation of interpretation of full wave near surface velocity distribution with respect to depth. As shown in Figure11.

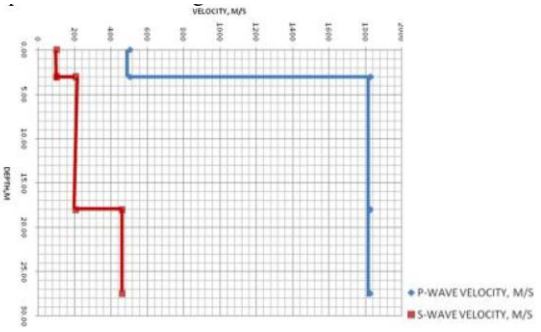

Figure-11. Pictorial representation of interpretation of full wave near surface velocity distribution with respect to depth.

Full wave Uphole grid of 1 km x 1 km in the any study area can be used to prepare near surface velocity structure for both P-wave and S-wave and this can be useful to compute seismic field statics including shear receiver statics in addition to compressional wave statics for all source-receiver locations of full wave on shore seismic reflection data.

Conclusion

The first time breaks of both direct P-wave and direct shear wave in the full wave uphole seismic data and basic Time-Depth plots helps to know the near surface P and shear wave velocity. In place of conventional uphole survey grid (1km X 1km), full wave uphole survey grid (1km X 1km) plays a key role to estimate near surface P & shear wave velocity structure. The estimated full wave velocity structure helps to compute full wave seismic field statics includes both P & shear wave statics for all source and receiver locations of full wave on shore seismic reflection data. In place of conventional uphole seismic surveys, full wave uphole seismic surveys will definitely add value to the full wave onshore seismic reflection data processing.

Acknowledgement

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References

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