Can Shallow Refraction Survey Replace Uphole Survey?

K. P. Singh and Brijesh Kumar
Geophysical Services, ONGC, Jorhat, India

Summary

Depiction of depth through different experiments for placement of charge is a prerequisite for seismic data acquisition. A study has been conducted to compare shallow refraction survey vis-à-vis uphole survey carried out at the same spot and finding the feasibility whether SR survey can reliably replace uphole survey. The experiment was repeated at six different locations in Dhansiri valley of Assam and Assam Arakan Basin, India. The near surface geology of the area of study is comparatively stable, homogeneous and consistent. Time and cost estimates have also been carried out for both uphole and SR surveys.

Both SR and uphole gave remarkably similar and comparable layer pattern at all the six locations. Both methods produced three layer model of the near surface. The depth and velocities in these layers from two methods are in close proximity and show marginal difference only.

Static corrections and their extrapolations have been calculated and studied. These corrections are found to be matching perfectly with 2.5% difference in values at the depth of 150 meter.

It is also evident from the time and cost analysis that in a 3-D project consisting an area of 144 sq. km., an amount of Rs 5.5 – 7.5 lacs and 4–20 days can be saved by judicious mixing of SR and uphole surveys.

Introduction

Near surface modeling is an integral part of any seismic survey for two reasons. One is the placement of the dynamite at the right depth and second, the role it plays in reducing the seismic data to a specified datum. The most important and widely used methods for modeling of near surface are uphole and shallow refraction surveys(Dobrin).

The uphole survey provides information about the near surface velocities, depths and thickness of the layers. They also provide the lithological information of the near subsurface at the point of drilling through cuttings. The first break amplitudes are also studied to identify the high velocity medium. The uphole survey, when conducted at close intervals in a stable area, deciphers the proper depth for the source of energy to be placed at. The energy generated from such depth is good in terms of frequency contents, capable of traveling to sufficiently longer distances minimizing the problem of ground roll.

Shallow refraction surveys do give the velocity information of the subsurface and their processing can depict parameters like depth of different near surface layers and velocities within those layers.

The uphole survey has it's own demerits related to logistics, drilling resources, time and economy of the survey. The difficulties faced, resources required, cost involved and the time consumed in conducting uphole surveys and operational convenience of SR survey have prompted this study.

Limitations of uphole survey

1. Requirement of drilling resources like drilling rig, water and water tanker etc.
2. Requirement of considerable time for the drilling process.
3. Requirement of other resources like pulley, pulley stand, charge holder, shooting wire and lot more man power make an uphole survey tedious, time consuming and expensive.
4. Drilling process changes the lithology in the vicinity of the borehole due to formation of mud cake (Mike Cox).
5. Uphole gives the near surface information at the point of survey only and no information in lateral direction can be derived.
6. Possibility of human error while loading/firing (eg wrong pair of wire leading to wrong readings) the charge and data loss due to misfires in simultaneous loading methodology.
7. If separate and successive loading/firing methodology is adopted, man power requirement increases considerably.
8. Requirement of considerable time for survey operation.
9. Abandoning of the operation due to collapse of bore hole.
10. All factors mentioned above hamper and slow down the process of seismic data acquisition.

Advantage of SR survey

1. No drilling rig, water and water tanker required.
2. Time taken to complete a SR survey is less than UH survey.
3. Equipments like pulley, pulley stand, charge holder, rope, shooting wire etc. not required.
4. Easy to accomplish, time efficient and more economic (costs one-sixth of the uphole survey).
5. SR survey gives the information about the near surface over the length of the laid spread.

Methodology

For recording of uphole and SR data, the seismograph is required along with the synchronizer and blaster. Uphole data can be processed by any available software and can be interpreted manually. In case of SR survey, dedicated software is required for data processing and interpretation in view of large data set.

Uphole surveys were conducted by placing source charges at every 2m from bottom of the bore-well upto the depth of 30 m and at every 1m upto the depth of 1m in locations A, C, D and F. These intervals could not be maintained at locations B and E due to varying depths and interval was 2m for depths from 41 to 21m and 48 to 8m at B and E locations respectively whereas, interval for shallower depths was 1m. The simultaneous loading and successive shooting methodology was adopted in all uphole surveys discussed in this study. The recording was done by using single geophone receivers placed at 1, 3, 5 and 15m and the trace corresponding to 3m was used for analysis and interpretation of the data after correcting slant time into vertical time.

SR surveys were recorded using 24 single geophone channels, placed at an interval of 5/4m and the shot at 2.5/2m from the nearby trace, with the spread length of 120/96m accordingly. Three shots, one each at the ends of the spread called forward and reverse shot in conventional terminology and third shot was taken in the middle of the spread (split-spread type) to enrich the data by generating CMPs at every 1.25m instead of 2.5m generated by conventional two shots methodology (Figure 1).

These surveys were carried out using "Summit Compact" system which is based on state-of-the-art sigma/delta A/D converter technology(Summit user manual) and equipped with dedicated processing software "Reflexw". This software is based upon the inversion of wave fronts by downward continuation technique with finite difference iterative scheme(Saudueier). Three shots were combined to produce a raw data of 72 traces (Figure 2) which on processing of the picked up first breaks gives travel time curve (Figure 3).

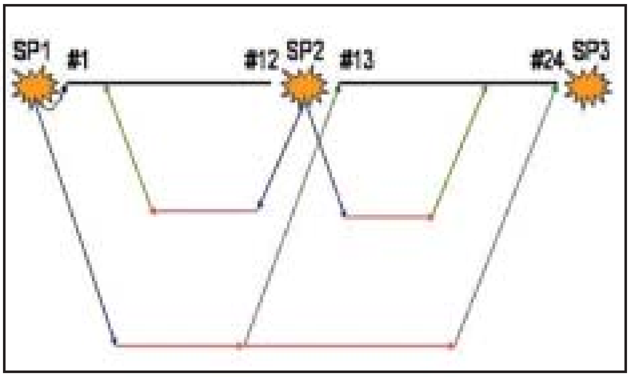

Fig. 1: Schematic diagram of SR geometry

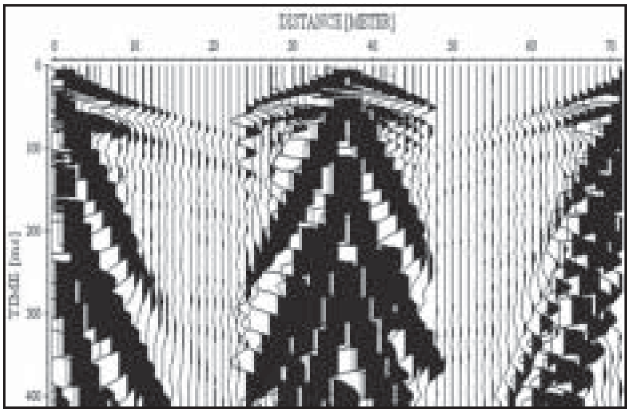

Fig. 2 : Combined raw plot of three shots

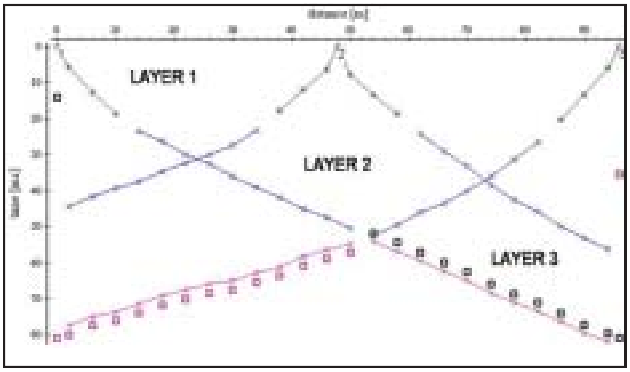

Fig.3 : Layer segments on combined travel time curves

Can uphole survey be replaced by SR survey ?

To study whether SR survey can reliably be substituted for uphole survey, both SR and uphole surveys

Fig. 4 : Location map

have been conducted side by side at six different locations (Figure 4) in Dhansiri valley of Assam and Assam Arakan Basin. The data so obtained were analyzed in detail and results have been compared.

Examples

The data of uphole and SR at six locations named as A, B, C, D, E, and F has been studied. The interpretation of both sets of data indicates that the near surface geology of the area of study consists of three layers. The first two layers together form the weathering layer and the third layer is the high velocity medium called the sub-weathering layer (Figures 5 and 6).

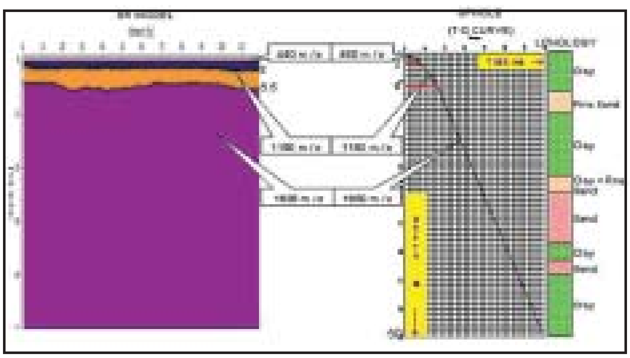

Fig.5 : Comparison of SR model with T-D curve at location A

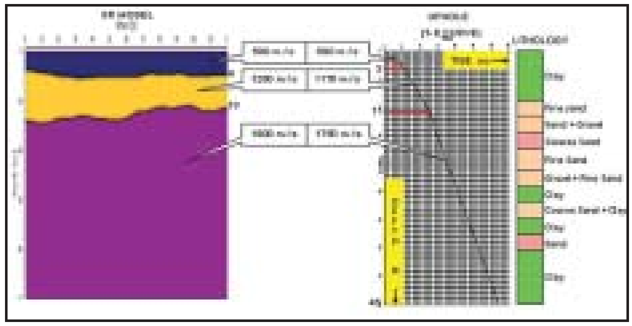

Fig.6 : Comparison of SR model with T-D curve at location B

The first layer is the top loose medium having depths varying from 2 to 5m and velocities from 440 to 600 m/s. The depth of this layer from SR method is perfectly in match with uphole method at locations A, C, E and F

Table I : Comparison of SR and UH results.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

whereas at locations B and D it shows little difference of 0.5m to 1m.The results of both techniques for the second layer also corroborate each other. The depths of second layer vary from 5.5m to 18m and difference in depths obtained from SR and uphole at location A is 0.5m, difference at locations C, D and E is of the order of 1m and at locations B and F, it is 2 and 1.5m respectively. The whereas at locations B and E the difference of 110 and 180 m/s is observed which does not have any influence on weathering depth and has insignificant bearing on values of static corrections.The velocities in third layer i.e., sub-weathering layer are in the range of 1635-1800 m/s and are matching fairly well at locations A, C, E and F with difference varying from 05 to 30 m/s whereas in other locations this is of the order of 50 m/s. The results obtained are tabulated in Table I.

Calculation of static corrections

Near surface information obtained from SR and uphole data have been used for calculation of two sets of static corrections. The logged depths of bore-wells used for uphole surveys vary from 41 to 58m and are mentioned in TABLE I. Beyond these depths the velocity function has been extrapolated with the value of sub-weathering velocity. The velocity of third layer has been used for extrapolation from top of the third layer to the depth of the analysis of these calculated static corrections placed in calculation ie, 150m in case of SR. Table II show the remarkable agreement between the values obtained from two methods. The variation between the values derived from uphole and SR is of the order of 2% except for location E, where it is of the order of 5.5% at a depth of 50m. The corrections converge further as depth is increased to 150 meter where these differences are of the order of less than 2.5%. Therefore, it is concluded that both the methods lead to identical values of static corrections and corroborate each other.

Table II : Comparison of static corrections.

Depth (m)	STATIC CORRECTIONS (in milliseconds)											
	LOC A		LOC B		LOC C		LOC D		LOC E		LOC F	
	UH	SR	UH	SR	UH	SR	UH	SR	UH	SR	UH	SR
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Cost and time analysis

The cost and time study were also carried out and the details are provided in Table III. Area of 12X12 sq. km. is considered for the study. The cost of uphole and SR cover the prevailing shot hole drilling and job service rates. The number of upholes required to cover the whole area in 1x1 km. grid is 169, costing Rs 10.14 lacs and consuming as many as 84 days at the rate of two uphole surveys per conducted in a 4x4 km. grid and SR in 1x1 km. grid including at the uphole locations, the cost can be reduced by Rs 7.5 lacs and 20 days can be saved. The cost of an SR survey has been calculated as Rs 1000/- per SR assuming that three SRs can be conducted in a day. Thus, by substituting SR for UH, Rs 5.5 – 7.5 lacs and 4 to 20 days can be saved in a 3-D project comprising of 144 sq. km., if sampling is done in 1x1 km. grid.

Conclusions

1. SR survey can reliably be substituted for uphole survey.
2. SR is economical, time efficient, easy and simple operation.
3. SR, unlike uphole gives a trend of near surface in lateral direction over the length of the spread.
4. In areas where subsurface changes rapidly and very close sampling is necessary, uphole surveys are uneconomical and time consuming.

Table III : Comparison of time and cost.

CASE		I	II	III	IV
UH GRID SIZE		[illegible]	[illegible]	[illegible]	[illegible]
SR GRID SIZE		–	[illegible]	[illegible]	[illegible]
NUMBER OF UH SURVEYS		169	[illegible]	[illegible]	[illegible]
COST OF UH SURVEYS (RS IN LACS)		10.14	[illegible]	[illegible]	[illegible]
NUMBER OF SR SURVEYS		–	[illegible]	[illegible]	[illegible]
COST OF SR SURVEYS (RS IN LACS)		–	[illegible]	[illegible]	[illegible]
TOTAL COST (RS IN LACS)		10.14	[illegible]	[illegible]	[illegible]
NUMBER OF DAYS REQUIRED		84	[illegible]	[illegible]	[illegible]
SAVINGS	RS IN LACS	–	7.5	[illegible]	[illegible]
	NUMBER OF DAYS	–	20	[illegible]	[illegible]

5. Judicious mix of uphole and SR can provide cost effective near surface model.
6. The SR conducted in close grids (say at 500X5000 m) which is affordable, both in terms of time and money, will provide better control of static correction resulting in more accurate image of sub-surface.

Limitations

1. SR survey does not give any information about lithology which at times is very useful for determination of optimum depth of the shot hole.
2. SR may mislead if a low velocity layer is encountered between two high velocity layers as a thin low velocity layer is lost in refracted first break times and depth of deeper layers is miscalculated.
3. It may not distinguish between two layers if velocity anomaly between them is not appreciable.

Acknowledgements

Authors are grateful to Oil and Natural Gas Corporation Ltd., India, for granting permission and providing necessary facilities to conduct this work. Authors express their gratitude to Shri G. Sarvesam, GM(Geoph)-Head, Geophysical services, Jorhat , Assam for his guidance and valuable suggestions during the study. Authors are also thankful to all crew members of GP-09 for their cooperation in the field work.

Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

References

Cox, Michael J.G, Static Corrections For Seismic Reflection Surveys, 9 Geophysical Reference Series, Society of Petroleum Geophysicists.

Dobrin Milton B, Introduction to Geophysical Prospecting.

Summit Uuser Manual , DMT, Germany.

Saudueier K. J, Reflexw version 3.5,1998-2004