Designing of Geometry to Reduce Acquisition Footprints in Slant Geometry Being Used in ONGC

Lavendra Kumar*, C.B. Yadava & A. Saha
ONGC, Dehra Dun

Summary

It is important to choose an acquisition technique and geometry, which produces minimum footprints. Uniform distribution of fold, offset and azimuth for all the bins will reduce the footprints to a great extent but it is not achievable in any 3D practical geometry. Achieving the uniform nominal fold and minimizing the variation of offset and azimuth sampling across the bins is also the prime objective of the designer in designing the 3D survey geometry so that the geometry creates minimum footprints.

The Slant geometry, which provides better offset distribution but narrow azimuth, is widely used in acquisition of 3D seismic data by Geophysical Crews of ONGC. In all the investigations carried out with Slant Geometry in acquiring 3D seismic data, the active spread for all the shots of salvo had been kept same. But the variation of Xmin, Xmax provided by the slant geometry as used in ONGC is more. It has been analyzed and found that by keeping the near offsets same for all the shot points of the salvo will provide uniform fold, equally good unique foldage, offset and azimuth but with minimum variation of Xmin, Xmax and Xavg across the bins. Hence, this suggested option of slant geometry will minimize the acquisition footprints. The analysis of the two options is compared in detail and it is shown that new options will have minimum acquisition footprint.

Introduction

Amplitude pattern seen on time/horizons slices which is typical for the acquisition geometry used in the 3D seismic survey is referred as geometry imprint or acquisition footprints. Typically, for streamer survey, the variation of amplitude is slow in the inline direction and rapid in the cross-line direction. The shot and receiver line pattern may be visible in the seismic amplitude of land data (Fig. 1a, b).

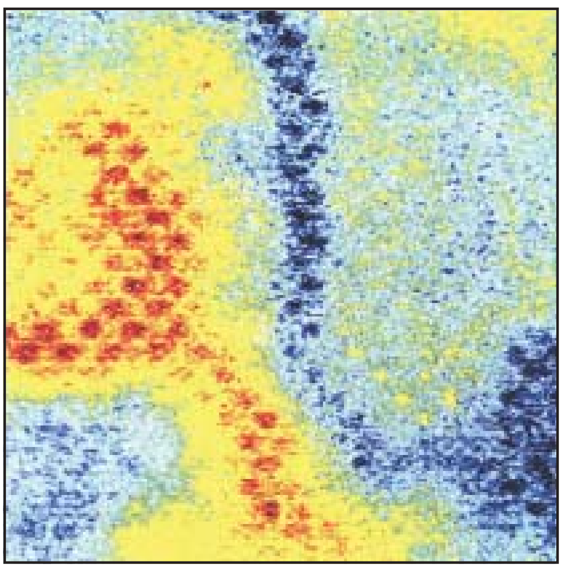

Fig.1a: Acquisition footprints in Land data-: Source lines of Double Zig-Zag geometry are visible.

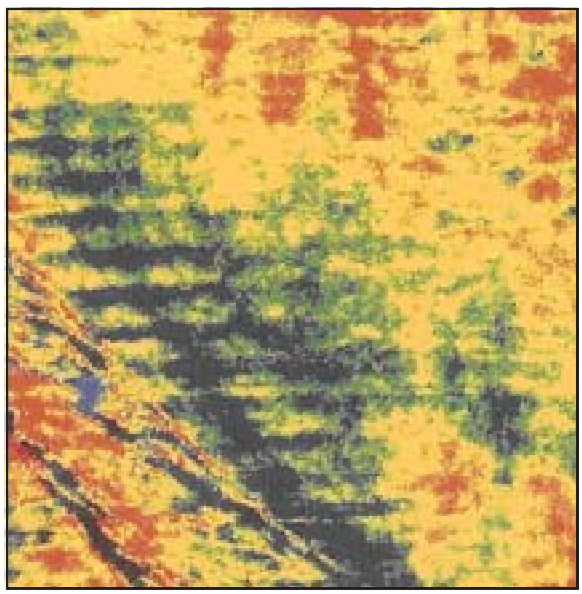

Fig.1b : Amplitude footprints in 4/4 geometry of streamer survey.

The geometry imprint is directly related to the fold, offset and azimuth distribution as a function of bin. Systematic variation in fold, offset sampling or periodicities in the offset distribution may create corresponding variations in amplitude. To avoid or minimize the footprints, all the bins should have same number of traces with similar offset and azimuth sampling. However, this condition is not fulfilled in any the 2D or 3D surveys geometry except 2D Split Spread geometry with Shot Interval equal to Group Interval and keeping shot in-between the pickets. Even in 2D End-on survey with shot at each receiver pickets will have two types of CMP as far as offset sampling is concerned (Figure 2a). One group of CMPs have traces having offset of even multiple of group interval while another group have traces having offset of odd multiple of group interval. These two types of offset sampling are alternatively repeated along the CMP line. The number of types of offset sampling will increase as the shot interval increases in relative to group interval as shown in figure 2 b. As the shot interval is increased to the twice of group interval, the number of type

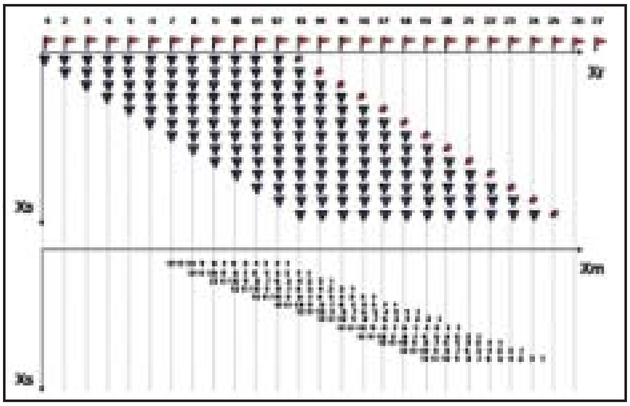

Fig.2a: Stacking diagram for 12 Channels End-on geometry with shot at each picket. Note the offset sampling of odd and even CMP

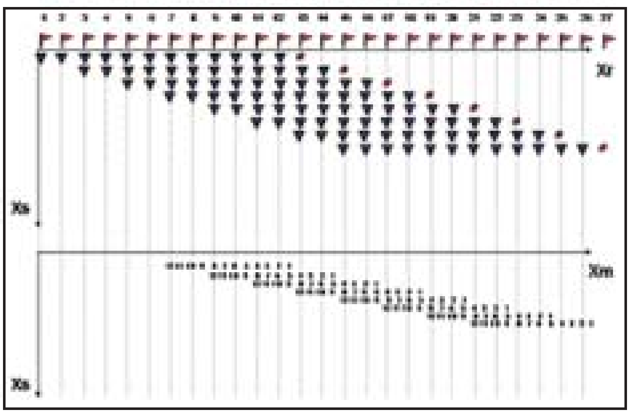

Fig.2b: Stacking diagram for 12 Channels End-on geometry with shot at each alternate picket. Note the four type of offset sampling of CMP.

of offset sampling of CMP has increased to four. The effect of variation of offset sampling in 2D is so small that it did not produces visible effect in amplitude on stacking. However, it has been reported that stacking of odd/even or near/far produces different stacked (G.J.O. Vermeer, 2002) traces.

The number of types of offset sampling is much more in 3D survey and variation in offset sampling from one bin to another is much more. Therefore, it produces visible effect in amplitude on stacking especially time slices at shallower level. Because noise events, whose characteristics vary with offset, have been sampled at different offsets and the amplitude of the primary varies with offset stacked amplitude depends on the offset sampling of the bin. Systematic variations in offset sampling or periodicities in the offset distribution create corresponding variations in amplitude.

The ideal way of reducing the geometry imprint to a minimum is by fine and regular sampling of offsets in each bin. In streamer survey, though parallel geometry is used to provide regular offset but regularity of sampling is not achievable due to uncontrollable feathering of the streamers. The sampling of middle and far offsets in streamer surveys may vary more than the sampling of near offsets. The degree of variation may differ from one sail line to another and hence the variation of amplitude is rapid in the cross-line direction. In land 3D survey geometry, the offset sampling is usually highly irregular unless parallel geometry is used. In general, the near offsets sampling in orthogonal geometry (which is most common geometry for Land survey) vary more across the bins than far offsets. However, geometry may be optimized so that it minimizes the variation of offset sampling across the bin. In the present work various options were studied and an option has been suggested for slant geometry as used in ONGC so that it provides minimum variation in offset sampling across the bins.

Why the offset sampling affects the amplitudes

The enhancement of signal and suppression of random as well as coherent noise in CDP method depends upon the number of traces to be stacked and their offsets as well as azimuths. The characteristics of signal as well as coherent noises depended upon the offset and may depend upon azimuth. The suppression of random noise is proportional to the square root of the fold to be stacked. If the geometry provides variation in nominal fold from one bin to another, the stacking of variable number of traces may cause visible amplitude variation due to variation in S/N ratio. The stacking of traces of different offset causes averaging of coherent noise events sampled at different offsets. Similarly, as amplitude varies with offset for the primaries, the stacked amplitude is the averaged amplitude of the primary reflection sampled at different offset. Primaries, Multiples and Mode converted waves with residual NMO (Stephen Hill, 1999) may contribute to the acquisition footprints.

Slant geometry in practice

The variety of templates used in 3D surveys seems limited only by imagination. The 3D survey geometry may be grouped into two classes: Areal and Line. The line geometry may further be classified into Parallel, Orthogonal, Slant and Brick. The templates may be useful for solving the particular problems. The Brick geometry has been used for better offset and controlled azimuthal distribution than orthogonal geometry. However, the common receiver gathers

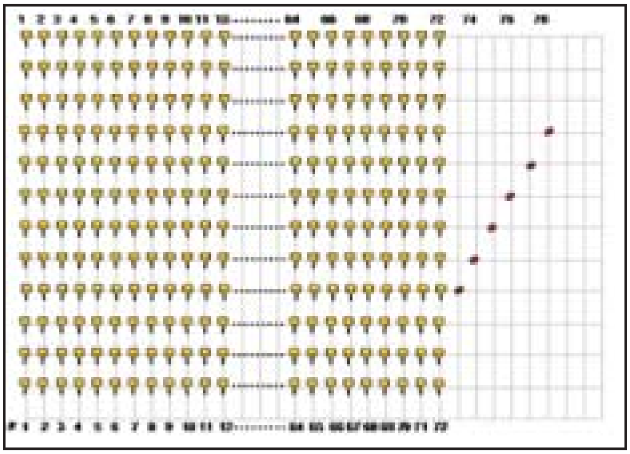

Fig.3: Typical slant geometry used in ONGC

of brick geometry are broken into small segments causing loss of some benefits of brick geometry. A lesser publicized but widely used template (D.G. stone, 1994) is the slant geometry. It provides better offset distribution with narrow azimuth than brick geometry. The merits of the slant sources are relative to the survey objectives. If the structure to be imaged is complex, reducing the azimuths would seem to be detrimental.

Slant geometry first time used in ONGC in 1997 in western onshore basin (Sastry M.H. 1996, 2000) and since then the slant geometry or its different variation had been utilized in many of the 3D investigations in Western Onshore basin and other work centers of ONGC. However, in all such cases of slant geometry, all the shot points of the salvo are shot with same active spread i.e. changing the near offset for different shots of the salvo. Figure 3 show a typical example of slant geometry with 12 receiver lines having 72 channels in each line and six shots in a salvo (hereafter referred as the option A). The inline roll equal to six group interval and half swath roll in cross line direction provides 36 nominal fold. All the six shots of the salvo are shot with same active spread.

Suggested option and analysis

The template, as in option A, but all shots of the salvo having same near offset by moving the spread in inline direction by proper distance for each shots of salvo. This option, hereafter referred as option B, is analyzed for different

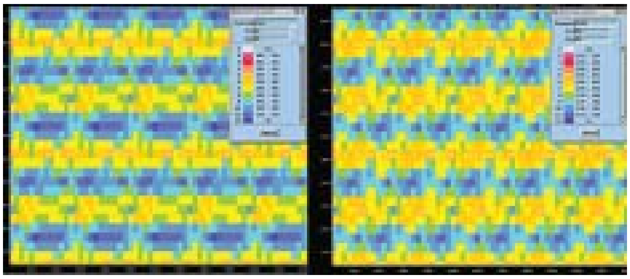

Fig 4 a & b: Unique foldage (Tolerance 40 mts) varying from 26 to 33 in both the options.

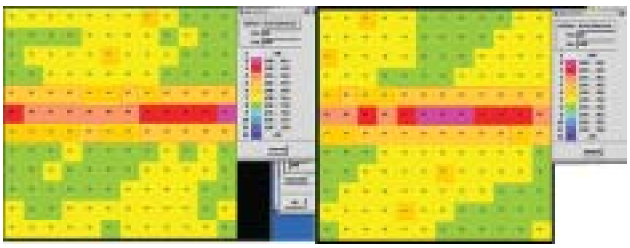

Fig.5 a & b : Quantified offset distribution varying between 82 to 93 in both the options.

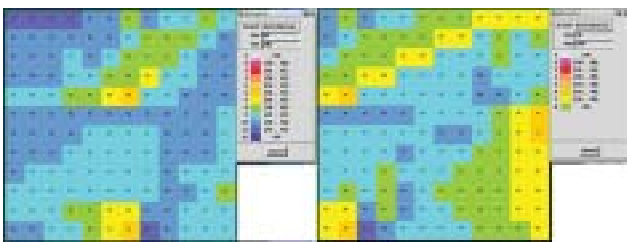

Fig.6 a & b : Quantified azimuth distribution varying between 94-99 in both the options

bin attributes. This rolling in of the spread while shooting of different shot points of the salvo will provides uniform fold of 36 and similar unique fold (Figure 4a,b). In both the cases the non-redundant foldage (assuming tolerance equal to Group Interval) is varying from 24 to 33. Quantified offset and azimuth distribution for the unit cell (Andreas Cordsen, 2000) as obtained with option A and Option B is also compared in Figures 5a, 5b, 6a, 6b and they are found almost

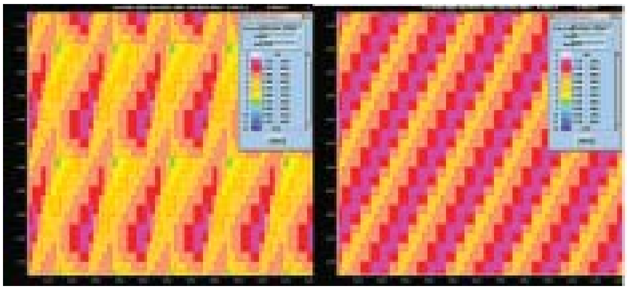

Fig.7 a & b : Xmin varying 40 – 600 mts in option A and 40-360 mts in option B

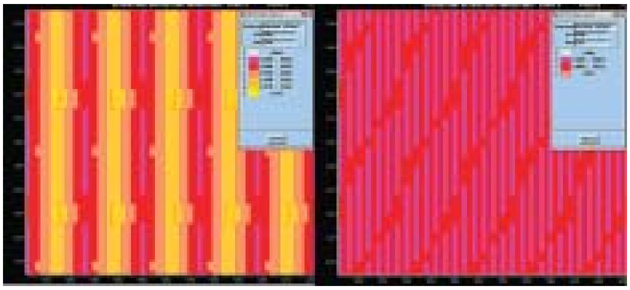

Fig. 8 a & b : Xmax varying 2800-3146 mts. In option A and 2800-2951 mts in option B

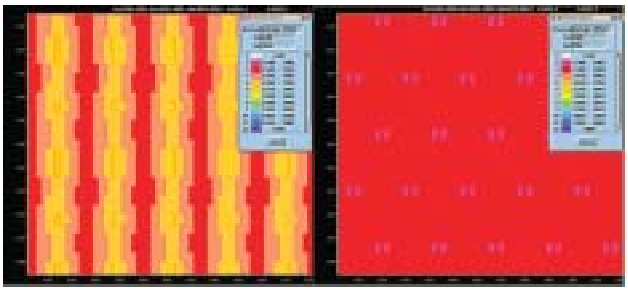

Fig.9 a & b : Xavg in varying 1480-1800 mts in option A and 1400-1560 mts in option B.

similar. However, the degree of variation of Xmin and Xmax across the bins in option B is much lesser than option A. Figure 7 a, b shows the variation of Xmin in the option A and Option B. The variation of Xmin in option A is 40 mts to 600 mts whereas it is only from 40 mts to 360 mts in option B. Thus 40 % of reduction in Xmin variation is achieved with this option. Figure 8 a,b shows the variation of Xmax for both the options A & B. The variation of Xmax in option A is from 2800 mts to 3146 mts. while it is only 2800-2961 mts for the option B. Thus Xmax variation is reduced to great extent in the unit cell. This lesser degree of variation in Xmin and Xmax will definitely cause lesser acquisition footprints. The average offset is compared in figure 9 a,b for the two options and it is clear from the figure that average offset is almost uniform across the bins in option B.

Conclusion

The acquisition footprints which depend upon the degree of variation of fold, offset and azimuth across the bins are most undesirable for stratigraphic as well as structural interpretation of 3D data. Minimizing the variation of Xmin and Xmax across the bins will produce the lesser footprints. The suggested option of slant geometry will have all the benefits of slant geometry in getting the higher unique foladge and better offset & azimuth distribution. But it will provide minimum footprint due to restricted range of variation of Xmin and Xmax and Xavg across the bins.

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