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Land 3 – D Surveys :– An improved approach for better Coverage and Cost Reduction

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Summary

Acquisition Geometry Design forms an important aspect in Land 3-D Seismic Survey Design. Different Geometry Methods are used for getting the Coverage in areas with different Seismo-Geological Objectives. These methods differ in optimizing the Cost, available Inputs, Technical requirements and production rates for meeting the survey objectives. Swath geometries using Orthogonal ,Slant and Brick patterns of shot templates are generally preferred designs. In all these types of geometries, only a limited subset of the laid channels are activated per a shot salvo. On a production day, some number of active channels per shot salvo as per the design of the acquisition geometry are laid. Some channels are also laid as advance spread for an optimum production rate. These channels are activated while the active receiver template is "pulled" for subsequent shot salvos. In general, about 70 % of the total available channels are laid as active channels per shot salvo and the rest 30% are equally distributed in the receiver lines as advance spread. This paper analyses the advantages by activating all the channels laid on a production day including the advance spread channels, while acquiring the data without restricting. In a way, the implementation of the Geometry Design is shifted to the Processing center during CMP Binning, in stead of in the field at acquisition stage. The specific Geometry design decided for the area can be selected from the input field data by restricting the offset ranges and azimuth ranges, in the processing center after binning the traces. The Coverage attributes are analyzed, taking a synthetic example case study. On analysis of the coverage attributes, it can be seen that

1. *A marked improvement in Coverage Attributes, viz., Total Fold, Unique Fold, Less variation in Minimum and Maximum Offsets and a better offset distribution is achieved at practically no extra cost.*
2. *Some of the "Recovery" Shots become "Repeat" Shots and Cost of such recovery shots can be saved.*
3. *The areal extent of the coverage loss due to seismic obstacles gets substantially reduced, thus requiring lesser extra effort for getting coverage in these situations.*

Introduction

Land 3-D Survey Design is basically a situation of Optimization of different parameters, viz., Technical Requirements, Cost, Production rates, available inputs etc. for meeting the Survey Objectives. The uniformity in achieving better Bin Coverage attributes is to be balanced, by considering their effect on the technical aspects, such as proper seismic imaging, the subsurface complexity, adequate temporal and spatial sampling, proper illumination of deepest objective, S/N ratio requirement, the Shot / Receiver Location Coupling for a stable Residual Statics solution, the type and sizes of the obstacles present in the survey area. The bin attributes crucial for analysis for arriving at a logical conclusion are 1. Bin Size 2. Total Fold 3. Unique Offset Fold 4. Minimum / Maximum Near Offset 5. Minimum / Maximum Far Offset 5. Azimuthal composition 6. Offset Distribution within the Bin

Seismic Imaging by means of PSTM / PSDM is implemented in Common Offset Mode. Each offset class, starting from Minimum to Maximum offset at regular intervals of Offset increments are Migrated. It is essential that the each of the Offset Classes for PSTM / PSDM are fully populated with all the CMP Bins. This ideal coverage is seldom achieved in practice and Gaps of live traces exist, specially in near and far offset class volumes. Trace Interpolations are a common practice in pre-conditioning the data for PSTM / PSDM.

The Geometry Design which offers the minimal variation in the optimized Bin attributes and the design which populates all the cmp bins with all offsets, is selected for final implementation. In terms of Bin attributes, this means, the geometry which offers, lesser variation in minimum and maximum offsets across the bins is preferable.

Method

The stage of Implementation of the Acquisition Geometry at present and the proposed change is given in Fig. 1. A subset of the total available channel inputs, (about 70 %) are distributed in a set of receiver lines for active acquisition spread per a shot salvo and the rest 30 % are also laid as an advance spread in the same receiver lines for subsequent shot salvos for a production day. Only the 70% channels are activated for a shot salvo and for subsequent salvos, the channels at the back of the spread are de-activated and some of advance channels are activated for subsequent shot salvos. In this proposed new approach, **all the channels** laid for the day (including the advance spread channels) **are activated** and acquired **for all the shot salvos of the day**. It may be noted that a change in the acquisition approach is suggested and this is applicable regardless of the geometry design off-end or split spread, orthogonal, slant, brick etc. An off-end geometry in this new approach may become asymmetric split spread. Off-end or split spread is a survey design criterion and not the favored spread type by this approach. This new approach can be applied for any geometry design.

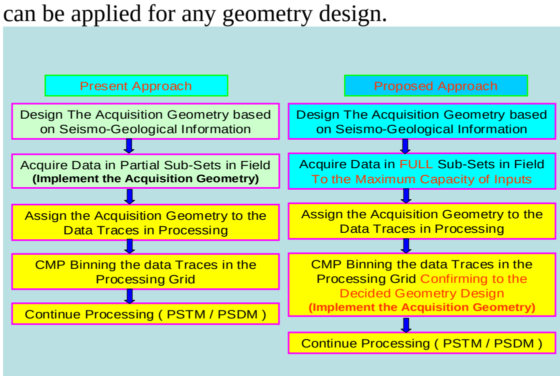

Fig. 1 : The Present and Proposed Acquisition Approaches

A synthetic example with a set of Geometry parameters is used for analysis. The list of parameters used is given in Table-1. A total of 16 swaths were simulated, half of these with active advance spread and other half without active advance spread. The coverage attributes from this example are compared. In another comparison, three obstacles (no shot) of varying sizes are introduced into these two parts and the effect of these obstacles in both the above mentioned cases are studied. Coverage attributes were computed and results were analyzed for both Orthogonal and Slant methods. In comparison between orthogonal and slant, as slant is observed to be giving more amount of Unique Offset Fold, comparison of the new approach using slant method only is given here.

Parameter	Present	Proposed
No. of Rec. Lines	10	10
No. of Channels per Rec. Line	80	105
Total Active Channels per Shot	800	1050
Bin Size	20 x 20	20 x 20
Receiver Line Interval	40 / 120	40 / 120
SP Int. In-Line (Shot Line Int.)	200	200
SP Int. X-Line	80	80
Roll-On In-Line	200	200
Roll-Over per swath	760 / 840	760 / 840
Shots per Salvo	20	20
Nominal Fold	8 x 5	8 x 5 **
Total Swaths	16	16
Binned Offset Range	00 – 3300	00 – 3300
Total Shots	17280	17280
Geometry Method	Ortho/Slant	Ortho/Slant

Table – 1 : Parameter List Used for Synthetic Example

Advantages of Proposed Approach :

a) Regular Coverage

In 3-D surveys, it is desirable to have all the offsets at regular intervals in all the bins. But this is seldom achieved because, as we take the shots at an angle to the orientation of the receiver template, the offsets in the bin gets clustered with some amount of gaps in between the offset clusters. This clustering of offsets in a bin disturbs the uniformity of offsets distribution in the CMP bins and also causes repetition of offsets. These redundant offsets are removed during pre-conditioning of data for PSTM / PSDM. The efficacy of a particular geometry is decided on the amount of **Non-Redundant Offset fold or Unique Offset fold it offers.** When we activate the advance spread channels, some of the offset gaps in the bins get filled up by the contribution of the traces from other side of the shot. Thus the gaps, especially, in the near and far offset zones gets filled up with actual traces. The minimum near offset in the bins get reduced.

b) Less extent of Coverage Loss due to obstacles

Land 3-D survey areas are infested with obstacles of varying sizes in the form of Villages, Ponds, Oil installations etc., which cause the reduction in the nominal fold decided for the area. These less fold areas often require alternate methods of Recovery Plans. The time taken for such extra Recovery plans depend on the extent of the less than optimum coverage area due to Obstacles and the coverage gap created due to "No Shot" and/or "No Receiver" zone of obstacles. The general way of such recovery plans is to keep the spread on the opposite side of the obstacle and take the shots on the other side. By activating the advance spread, it can be seen that the extent of the coverage gaps due to obstacles is substantially reduced.

c) Reduction in Recovery Shots and thereby Cost reduction

When some of the planned shot locations are not accessible due to sporadic obstacles like roads, power lines etc. , the shots need to be "Skipped". The skipped shots cause loss of fold by one, in as many Bins as the number of channels and their corresponding offset contribution for the Bins. For recouping the reduction in fold of coverage due to such in-accessible shots, Recovery shots or Make-up shots are taken. These recovery shots are planned in such a way that the affected CMP Bins get the fold loss recouped. (Standard CMP Recovery). This is accomplished by moving the shot to next or previous accessible location and by changing the active spread by the same amount in the opposite direction. In this process, some times more than one shot is taken at a single location with different spreads. On an average, about 10% of the total shots for a field season are such multiple shots at a single location. When we activate the full spread of the day for all shots of the day, such multiple shots become "Repetitive Shots", as effectively, the same shot at the same location is shot to the same full spread of the day. This is given in Fig. 2 in 2-D Sense.

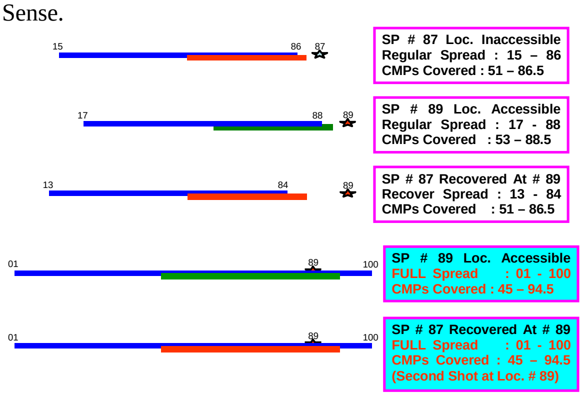

Fig. 2 : Some Recovery Shots become "Repeated Shots"

These repetitive shots can be eliminated from the production shots and considerable amount of Shot Cost can be saved, without losing any technical detail.

The recovery shots taken at locations other than the regular accessible shot locations are also not very much useful for recovering the missing offset in the affected CMP Bins. Though they recover the loss of fold, the offsets offered by these recovery shots are, in general, offer redundant offsets in the affected Bins, which are removed later on in data pre-conditioning. Thus any recovery shots are minimally useful.

Synthetic Examples

A Synthetic Case is taken for comparison of the Bin Attributes. The Geometry Parameters used are given in Table – 1. The Computation of all the attributes, other than Total Fold are done for a restricted range of offset from 0000 – 3300 mt. Traces falling out side this offset range are dropped from the binning.

The Bin Attributes compared are

1. Total Fold
2. Unique Offset Fold (Full / Near / Mid / Far offset ranges)
3. Minimum Offset
4. Maximum Offset

All the above attributes are compared for

1. Slant Geometry (With and Without Active Advance Spread)
2. Slant Geometry with Obstacles (With and Without Active Advance Spread)

Fig. 3 to Fig. 9 give the Bin Attributes without (Left half) and With (Right half) Active Advance Spread in the following order:

Total Fold (Fig.3) We can see more fold with active advance spread. Fig. 4 gives the Unique Offset fold in the offset range of 00 – 3300 mt.

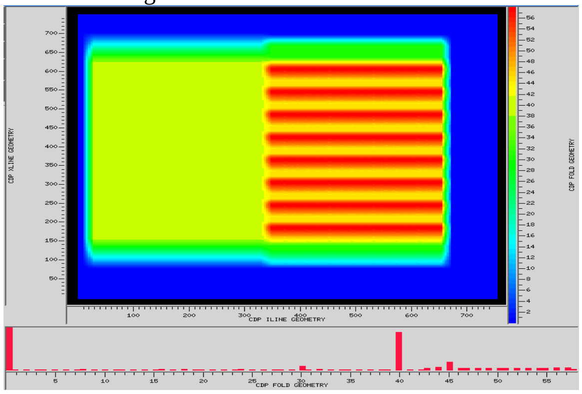

Fig.3:Total Fold with and without Active Advance Spread

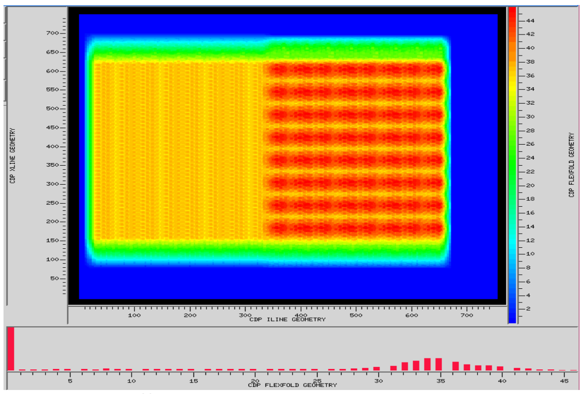

Fig 4:Unique Offset Fold with and without Active Advance Spread

From Fig. 4 we can see that, the range of Non-Redundant Offset Fold improves to 30-44 with Active Advance Spread where as without active advance spread the maximum is only 30.

Fig. 5, 6,7 gives the same Unique Offset Fold for the Near (00 – 1100), Mid (1100 – 2200) and Far (2200 – 3300) ranges respectively. It can be seen that the improvement in the Unique Offset Fold exists in all the three ranges of offsets. So an over all improvement occurs in Unique Offset Fold for the full range of offsets of interest, indicating that the over all Offset Distribution in the CMP bins get much improved.

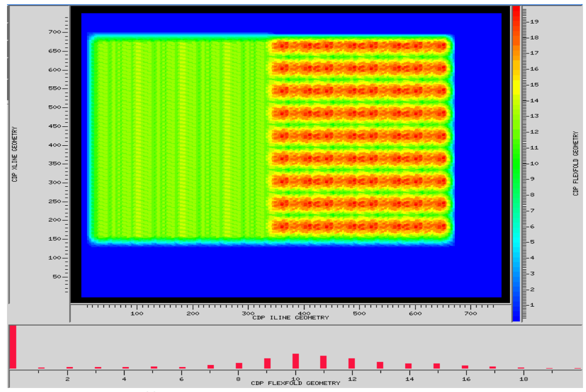

Fig 5:Unique Offset Fold with and without Active Advance Spread in Near Offset Range (0000 – 1100)

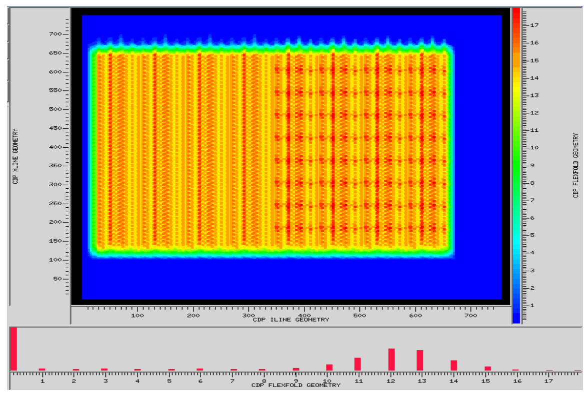

Fig 6:Unique Offset Fold with and without Active Advance Spread in Mid Offset Range (1100 – 2200)

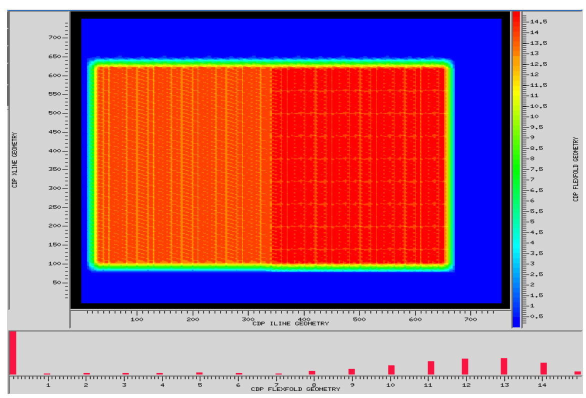

Fig 7:Unique Offset Fold with and without Active Advance Spread in Far Offset Range (2200 – 3300)

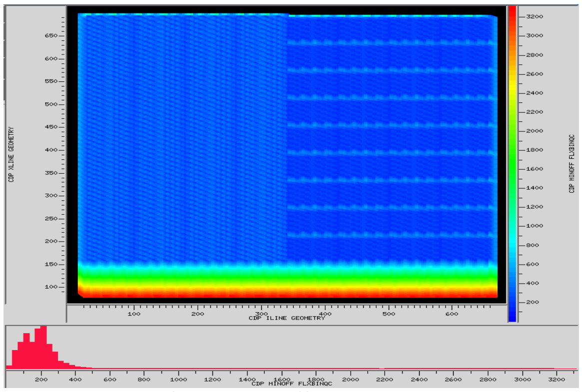

Fig 8: Variation of Minimum Offset in a Bin with and without Active Advance Spread

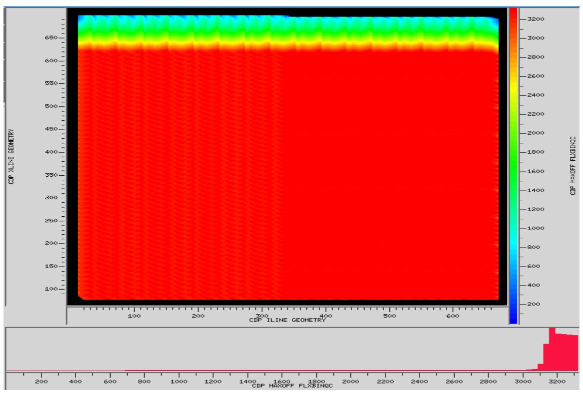

Fig 9: Variation of Maximum Offset in a Bin with and without Active Advance Spread

Fig.8 and Fig.9 give the variation of Near Offset and Far Offset respectively across the CMP Bins. It can be seen that in the case of Active Advance Spread, the minimum offset is considerably smaller and also there is lesser variation across the bins. Similarly, Maximum Offset also is more uniform with Active Advance Spread.

Effect of Obstacles : Three Obstacles (Only No Shot zones) of different sizes (2.0, 1.5 and 1.0 sq. km.) are introduced in the simulation examples both with and without Active Advance Spread. The coverage Attributes are analyzed in both the cases. Fig. 10 give the obstacle effect in Total Fold. On the left part of the figure, the advance spread is not active, whereas on the right part it is active. The size of the obstacles remain exactly same in both parts. We can see that the foldage loss due to the obstacles is lesser when advance spread is active.

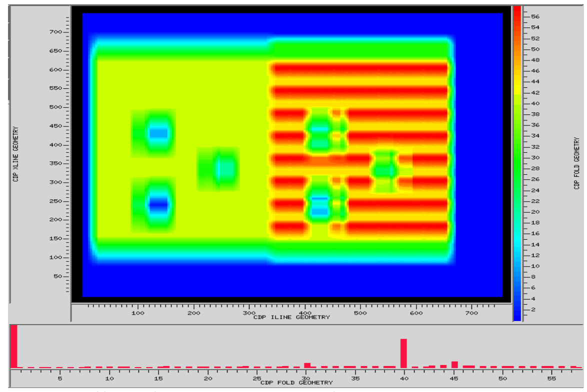

Fig 10: Effect of Obstacles on total fold with and without Active Advance Spread

Fig. 11 gives the effect of Obstacles on the Unique Offset Fold. It can be seen that, Obstacles which are relatively smaller (of the order of one sq. km. or less) gets reasonably good coverage and thus do not require separate recovery plans to be made. Also the extent of the area requires to be planned with a separate Recovery Plan becomes lesser when advance spread is made active.

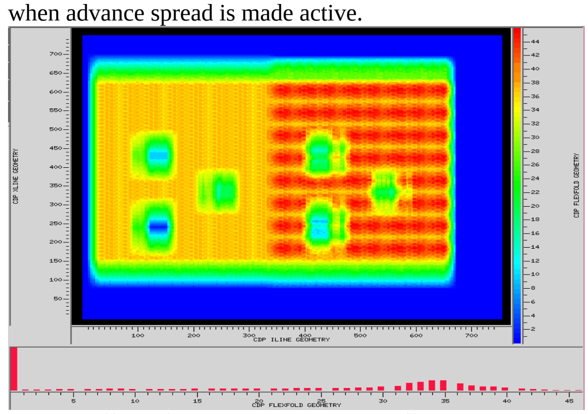

Fig 10: Effect of Obstacles on Unique Offset Fold with and without Active Advance Spread

Conclusions

Thus from the above analysis, we can see that by simply activating the already laid as advance spread for the day, we can achieve advantages in three aspects.

1. Improvement in the general coverage pattern,
2. Cost reduction by means of less number of recovery shots
3. Improved coverage in the obstacle areas.

However, there are some aspects which require some amount of enhanced effort viz.,

1. The active spread are becomes more by about 30%. So for controlling the cultural noise while active operations extra manual efforts are required.
2. In general, in the advance spread the shot hole drilling activity and other cultural noise sources are prevalent, even during active operational time.
3. Restrictions on the shot hole drilling activity are required to be imposed
3. The necessary modifications need to be worked out in the contracts for the services like cable laying, shot hole drilling etc.

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