Model Based Seismic Data Acquisition in Himalayan Foothills

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Summary

In the area of thrust folded belt like Himalayan Foothills, model based seismic data acquisition is required to ensure the reflection from key portion of the structures. Ray trace modeling study is carried out to design acquisition parameters for 2-D seismic survey in Nahan-Paonta Sahib area in Himalayan Foothills. Synthetic field data (shot gathers) are simulated using common source geometry with several combinations of acquisition parameters over the velocity depth model derived from the interpreted time horizons in the area. These data are processed and analyzed further for getting better continuity of events below the thrust fault. Group interval, shot interval, far offset and spread configuration are analyzed for better time domain mapping as well as depth domain imaging. symmetrical split spread configuration with group interval 20m is giving best result yet asymmetrical split spread configuration may also be considered for seismic data acquisition. Far offset of the order of 1.5 to 2.0 times the target depth is reasonable for velocity analysis required for depth imaging.

Introduction

Hydrocarbon exploration in the area of over-thrust folded belt like Himalayan Foothills poses a challenging problem to the geo-scientific community for imaging the surface anticlines and more complex and deeper imbricates structures. Seismic modeling is an effective tool used not only for interpretation and designing processing parameters but also for designing data acquisition parameters Strong lateral velocity variations associated with theses complex three-dimensional structures causing strong ray bending. Ray trace modeling, suited best for structural definition, represents propagation of seismic wave front indirectly by ray paths and displays the association of reflection points with the shots and receivers. Seismic energy propagation in the physical medium is simulated to generate the real field data i.e. shot gathers. These synthetic data are processed to optimize the different combination of acquisition parameters. This study is carried out at Work Station of Frontier Basins using GXII software and PROMAX processing system and comprises following steps:

- Preparation of subsurface geological model (physical model).
- Simulation of field seismic data (shot gathers).
- Processing of simulated data for optimization of acquisition parameters

Model building

Interpreted seismic section along the seismic line ‘A’, prepared by Himalayan Foothills Block of Frontier Basin, is used for ray trace modeling studies in the Nahan-Paonta Sahib area. Interpreted time horizons along the line ‘A ’are available for 8.5 km only (fig. 1 & 2). It has been extended to 23 km (8 km on the left side and 6.5 km on the right side) for getting full fold data over the structure to be imaged. GXII Software is used to build and test the physical model for studying the dispersal of seismic energy through a multi-layered medium. Velocity depth model (fig. 3) is prepared by layer-by-layer normal incident migration i.e. horizon migration. Since no well information is available in the area, interval velocities of different layers are calculated using Dix equation from r.m.s. velocity functions available on the stack section. Velocity-depth model prepared was used to simulate stacked data using zero-offset ray tracing for interpretation verification. Beneath the velocity inversion surface created by the thrusting no

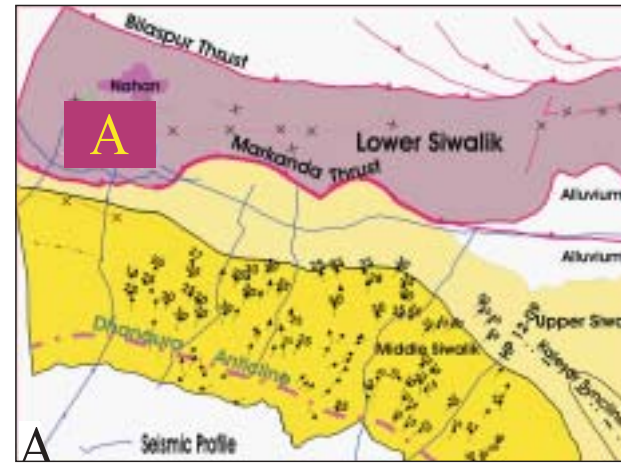

Fig. 1: Geological map

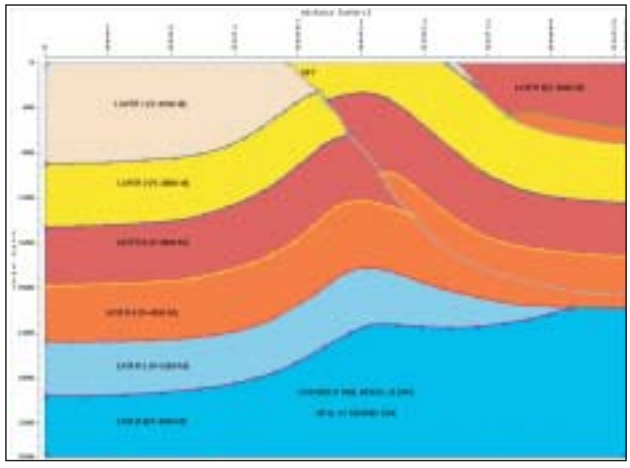

Fig.2 : Depth Model

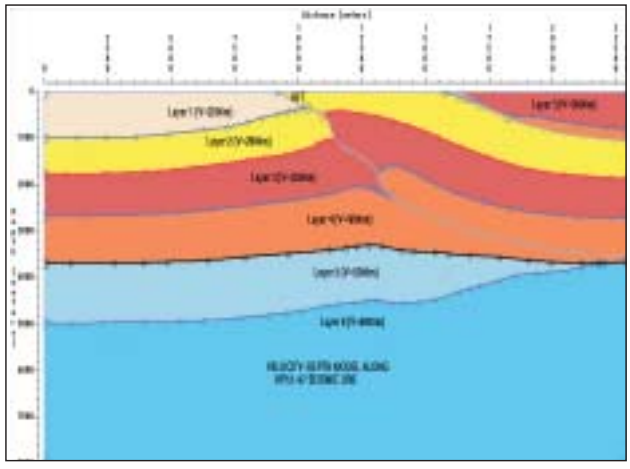

Fig. 3 : Velocity-Depth Model

Allu.+Upper Siwalik
Middle Siwaliks
Lower Siwaliks
Dharamshala & Subathu
Pre-Tertiary Rocks
Pre-Tertiary Rocks

reflection zones (shadow zones) are recorded from some portion of reflectors (fig. 4).

Ray trace generation

Seismic rays are traced from source to reflector and back to receivers over the velocity depth model. Ray path trajectories are governed by following three rules:

i. Ray paths are unbent in constant velocity medium.
ii. Ray paths bent according to the Snell's law as they cross velocity interfaces.
iii. Ray paths reflect at an angle equal to incident angle when they encounter impedance interfaces.

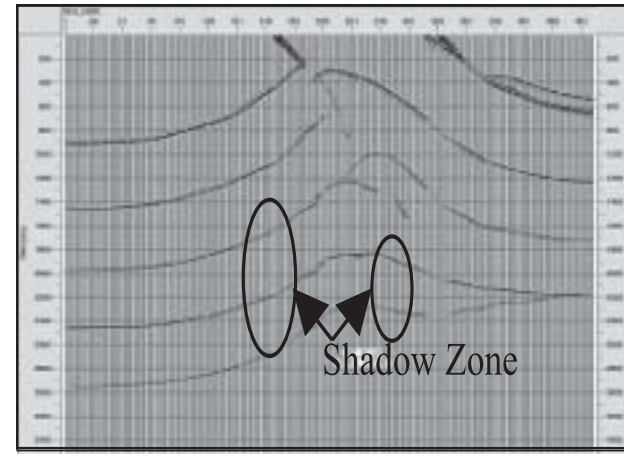

Fig. 4 : Synthetic Section

Speed and path of each ray are determined by the point of origin, material properties of each layers and relative angle of reflecting surface. Arrival time of ray and reflection strength are used to calculate the synthetic traces for each receiver defined on the model. Frequency attenuation and geometrical spreading process are used for trace generation.

Far offset analysis

A symmetrical split spread is shot along the entire model length of 23 Km with receiver and shot interval of 30 m and 60m respectively and a spread of 6000m on either side. Synthetic field data are simulated using common source method and studied for far offset analysis.

Synthetic data are subjected to regular processing sequence up to stack level using different offsets of the order of 6000m, 5400m, 4800m, 4200m, 3600m and 2400m (fig. 5, 6 & 7). It has been observed that below the thrust, amplitude and continuity of reflection remains consistent with the spread length from 6000m to 3600m and reduces further below 3600m. Thus far offset of 3600m is considered to be the optimum for mapping of the structures in time domain.

Group interval analysis

Over the optimum far offset of 3600m, synthetic data are generated with GI = 20m and SI = 40m using symmetrical split spread configurations (fig. 8). These data are processed and stack sections are compared to that of GI = 30m & SI = 60 m keeping same optimum far offset (fig. 9). It is observed that stack section with GI = 20m & SI = 40m shows slightly better continuity as well as amplitude of reflection events below the thrust fault in the sub-thrust

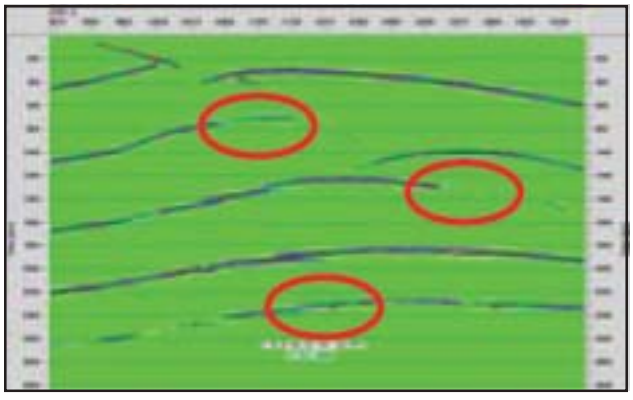

Fig. 5 : Offset=4800m

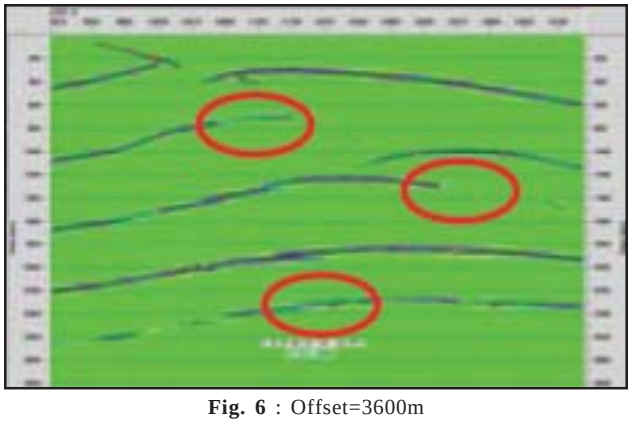

Fig. 6 : Offset=3600m

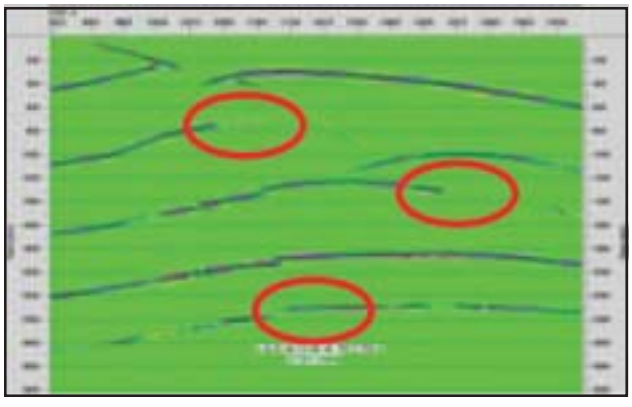

Fig. 7 : Offset=2400m

area. Hence GI = 20m and 3600m far offset is considered optimum acquisition parameters for further studies.

Fold test analysis

Since synthetic data don't include random noise, a high CMP fold test to get better signal to noise ratio is not required.

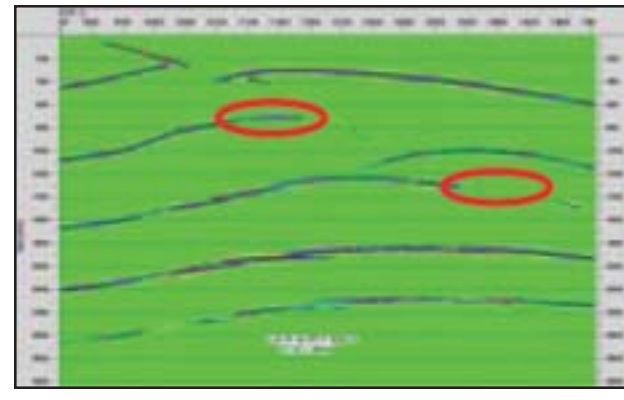

Fig.8 : (GI=20m & SI=40m)

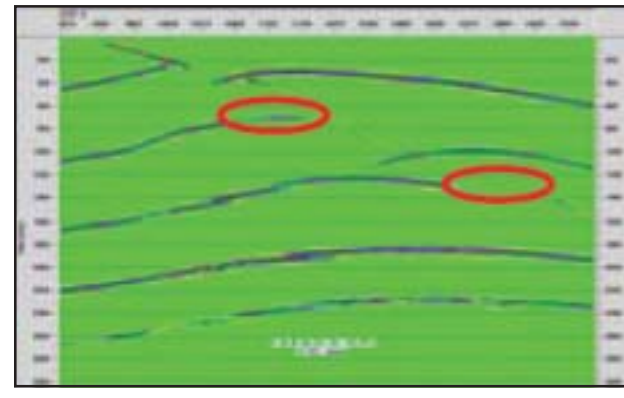

Fig.9 : (GI=30m & SI=60m)

Configuration analysis

Stack output of symmetrical split spread with GI = 20m & SI = 40m and far offset of 3600m is better in mapping the subsurface structure in sub- thrust area compared to that of Asymmetrical Split Spreads and End-On configurations (fig. 10, 11 & 12). Result of Asymmetrical Split Spread is better than that of End-On configuration.

Depth domain modeling

Synthetic shot gathers generated with offset of 7700m over the same velocity depth model and are analyzed for PSTM/PSDM studies. Coherency inversion analysis and velocity model are derived for different horizons for the offset 2030m, 3850m, 5440m and 7700m (fig. 13 & 14). (fig. 13 & 14). PSTM and PSDM are carried out for these offsets with known Velocity and data driven velocities. It is observed that offset 7700m is reasonable good for determining more accurate velocity model.

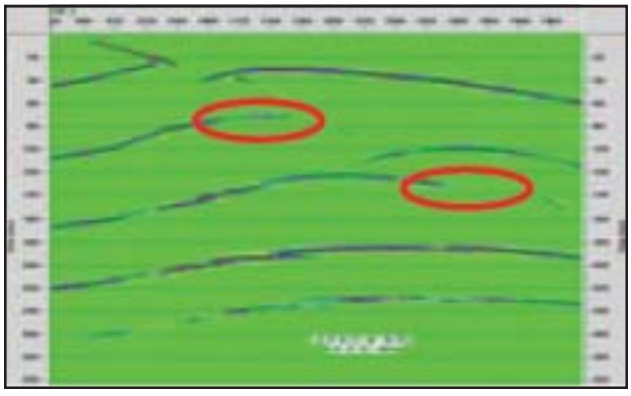

Fig. 10 : Sym. split spread

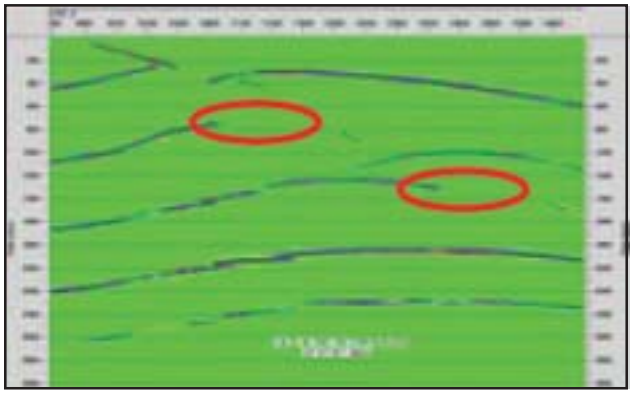

Fig. 11 : Asym. split spread

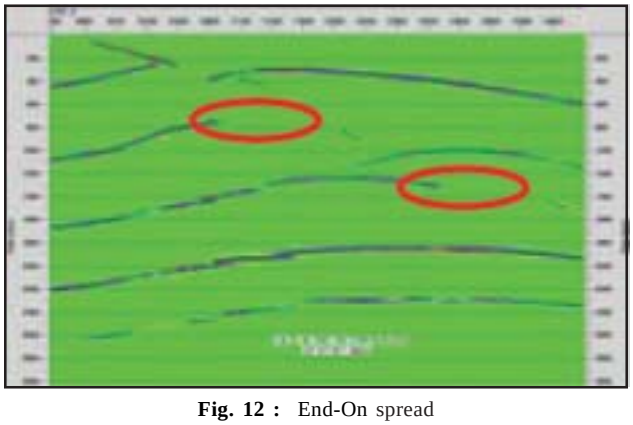

Fig. 12 : End-On spread

Conclusions

Ray trace modeling provides the visual display of the rays for different combination of acquisition parameters. It is observed that 3600m far offset is sufficient for mapping the event in time domain. Group interval 20m is giving slightly better continuity of events than group interval 30m. Although symmetrical split spread is best and providing symmetrical sampling yet asymmetrical split spread is also

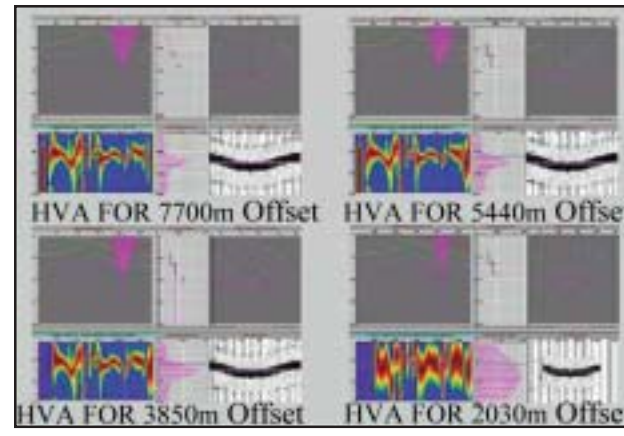

Fig. 13 : Coherency inversion for the pink horizon for different offsets.

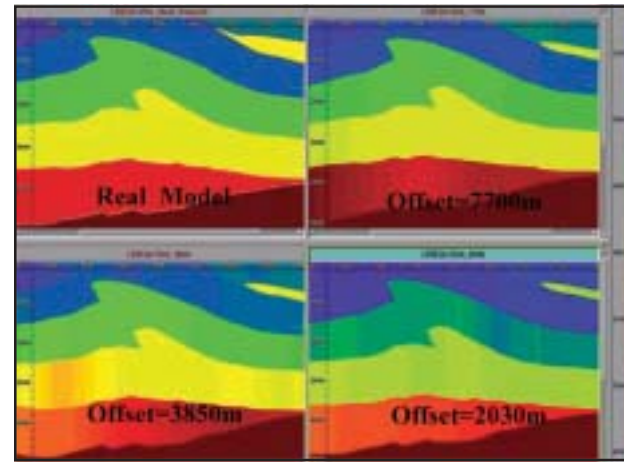

Fig.14 : Velocity model derived for different offsets.

giving reasonable good result. Based on depth domain mapping of subsurface structure, offset 7700m is reasonable good for determining more accurate velocity model. Hence following parameters are found suitable for acquiring seismic data in Himalayan Foothills in Nahan-Paonta Sahib area:

1) Spread Length :7700 for pre-stack depth imaging.
2) Group Interval : 20 m
3) Shot Interval : 40 m
4) Spread Configuration : However symmetrical split spread configuration is giving best result yet asymmetrical split spread configuration may also be considered for seismic data acquisition.

Acknowledgement

Authors are thankful to Shri Manoj Asthana, Basin Manager, Frontier Basins for allowing to publish this paper

in SPG 2006. Encouragement and valuable suggestions given by Shri Jokhan Ram, Ex-Basin Manager; Shri H. Das, HGS; Shri Y. P. Awasthi, Chief Geophysicist (S); Shri M. Singh, CG(s); Shri V B Sharma, Party Chief GP-38 for the improvement of this work are highly acknowledge. GP-38 party members and HF Block members are also acknowledged for their kind support during the completion of this assignment.

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

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