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Research Paper

Optimisation of Parameters in Seismic data acquisition for better subsurface imaging in Eastern Gamij, Gujarat.

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ABSTRACT: *Well-designed and optimised seismic data acquisition geometry illuminates the subsurface. While designing the geometry we have to think about the available resources for data acquisition and also implementation difficulties in the working area and most importantly technical requirements of Interpreter should be strictly considered. The main objective of a better survey design is to image subsurface structures. Generally, the data acquisition parameters are selected and designed by considering simplified subsurface model. In this work the real subsurface model of the area is constructed in the laboratory with the help of a new state of art software NORSAR and the data was artificially acquired. Several acquisition geometries were used for acquiring data in laboratory conditions and a final geometry is selected with optimised parameters resulted in the proper illumination of subsurface structures up to the basement. The illumination maps generated in laboratory play key role for finalising acquisition parameters and results are well matching with the real results after seismic data processing.*
Keywords: *NORSOR Software, Subsurface Structures, Cambay Basin, Olpad formations*

I. INTRODUCTION

The area is located in the East of Ahmedabad city and falling under the administrative control of Gandhinagar district. Location of the survey area is shown on Tectonic map in Fig-1.

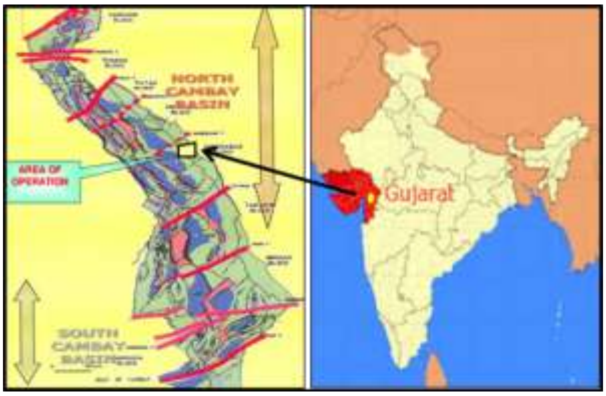

Fig-1 Location of the area shown over Geographic and Tectonic map.

Geology of the Study Area:

The Cambay basin is an intra-cratonic basin which came into existence at the close of Mesozoic period by the development of tensional faults along its margins. It is a narrow elongated graben running approximately NNW-SSE direction. It is flanked on the NE by the Aravalli swell and on the west by the Saurastra Craton (Nagabhushan Rao.,2013). The Deccan craton lies to the east and south-east of the basin.

The major longitudinal faults are aligned along the Dharwar trend running parallel to the basin trend. The entire Cambay basin is divided into five tectonic blocks based on transverse fault system which might possibly be subsequent to the longitudinal fault system, although originating within the basement itself.

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From north to south these tectonic blocks are as follows:
1. Patan- Tharad- Sanchor
2. Mehsana – Ahmedabad
3. Cambay –Tarapur
4. Jambusar – Bharuch
5. Narmada –Tapti

The basin came into existence during late Jurassic. During late Cretaceous major volcanic eruption activities took place and Deccan trap made technical basement of the basin (Biswas,1987; Biswas, 2005). Subsequently, different depositional units came into existence under different depositional environment. The study area lies on the eastern margin of Mehsana – Ahmedabad tectonic block of Cambay Basin(Mondal 2007; Mishra et al., 2015). On the rising flank, Unava, Mansa, Limbodra, Halisa and Gamij fields are located from North to South and all the fields are hydrocarbon bearing.

The geology of the area is well known as a number of wells have been drilled in the Gamij field. The sedimentary section encountered in the area is correlatable with general stratigraphic sequence established in Cambay Basin. A series of faults have been mapped in the area including the Eastern Margin fault. Several fault closures have been delineated at Kalol and Olpad level. Most of the wells drilled in the area have penetrated up to Deccan trap, the technical basement in this area.

Experiment

Considering the geology and major Eastern Gamij fault, we have designed the best seismic geometry for this area. Initially, Basic MESA software is used for seismic geometry design and after many studies on geometries we decided final geometry as, Asymmetrical Split Spread of 12 receiver lines with 120 channels in each line and total of 1440 actives channels per shot is found to be most appropriate in terms of subsurface illumination (ONGC Report 2012). A cartoon showing the Geometry parameters and spread is shown in Fig-2.

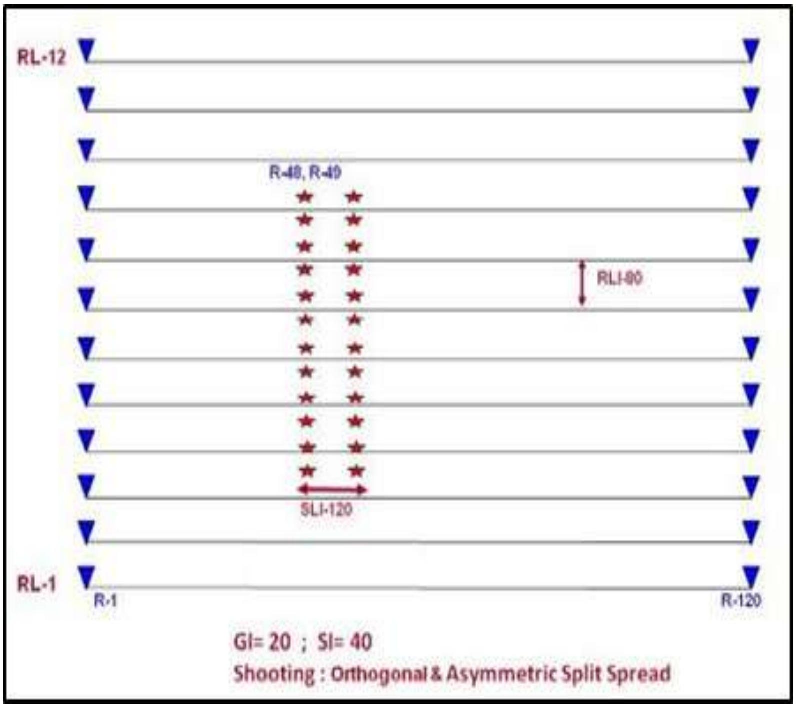

Fig-2 Cartoon showing Geometry parameters and spread.

Initially, finalised geometry was then tested in Basic MESA software and the result of illumination map (or Fold Map) is shown in Fig-3.

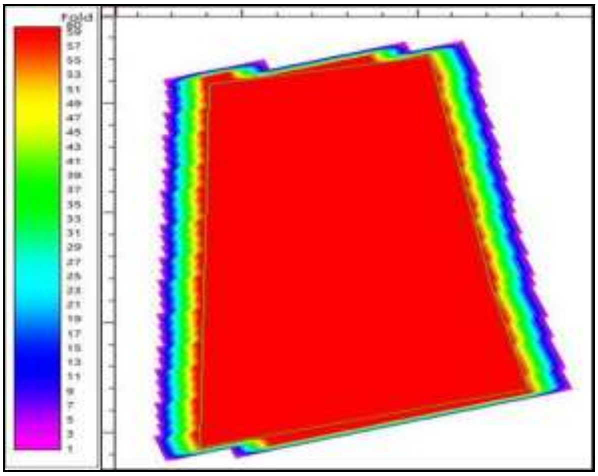

Fig-3 Illumination map (Fold Map) from MESA software using above geometry.

Now in order to further validate the geometry, we switched the entire project to the new modelling technology software called NORSAR (Carlos and Clara 2007). NORSAR 3D is a software for seismic modelling in three dimensions. The method used for modelling is the ray tracing to wave front construction. This algorithm was developed by NORSAR´s researchers (Vinge et al., 1993).

The Common Shot Wave front Tracer is used which is based on a concept developed by NORSAR called wave front construction. This modelling method is based on ray tracing to interpolate a wave front in intervals of a given time. The purpose of this method is to simulate the seismic wave field and placing a number of shots on the surface, with a certain number of receivers associated to each shot. To execute this tool, three elements were used: (a) A valid seismic model generated in NORSAR's Model Building tool, which should be validated and have assigned properties such as the velocity and the density; (b) A seismic geometry, (i.e., shots, receivers and its relation) to be validated and (c) The Ray Code, which specifies the trajectory of the rays through the model (Norsar, 2003b).

The inputs for this modelling are the depth horizons and the subsurface velocity and density. For the velocity information, velocity data of earlier 2D seismic data falling in the area and VSP (Vertical Seismic Profiling) data of few wells in the area are considered for making a velocity cube. We then created a Subsurface model in Model Builder function with four horizons namely Tarapur, Kalol, Cambay Shale and Olpad respectively downwards and major Eastern Gamij fault as shown in the Fig-4. This final model with horizons and fault data loaded with velocity and density is assumed to be the true replica of our study area (Watanabe et al., 2006). The selected geometry is now tested in the ray trace modelling software NORSAR.

Illumination Maps are one of the important attributes for validating the geometry. The illumination maps evaluate the design of seismic acquisition on the horizon of interest. These maps are built in the NORSAR 3D using the events registered in the seismic modelling.

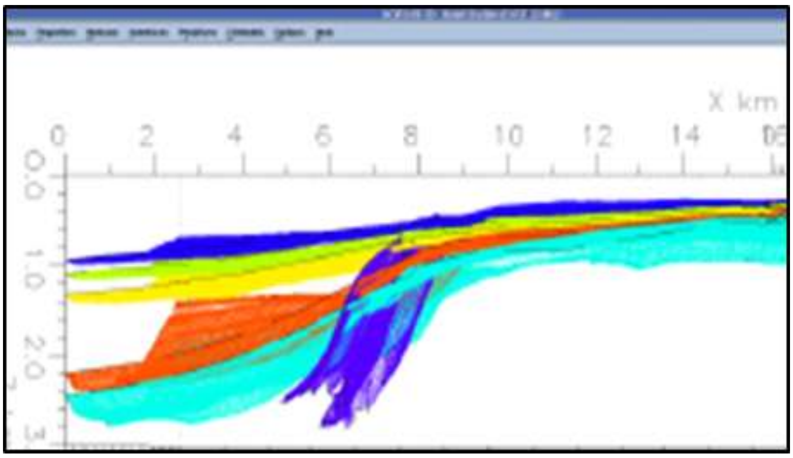

Fig-4 Subsurface Model of the study area generated in NORSAR software showing subsurface structures and faults.

Several functions can be visualized on the illumination maps like Hit-map, Hit-density, incidence-angle maps etc. Hit-map function, equivalent to the seismic fold shows the effectiveness of the seismic design.
Ray trace modelling at the basement level in the Hitmap clearly shows that the seismic geometry initially selected on the basis of initial studies could not able to map basement at the major high dipping eastern marginal fault which is present in the study area. So the major drawback of this geometry could not be found in initial studies. At the major high dipping fault, the entire energy got reflected and the designated receivers could not receive the energy. The improper illumination of the structure in Hit-Map is shown in Fig-5.

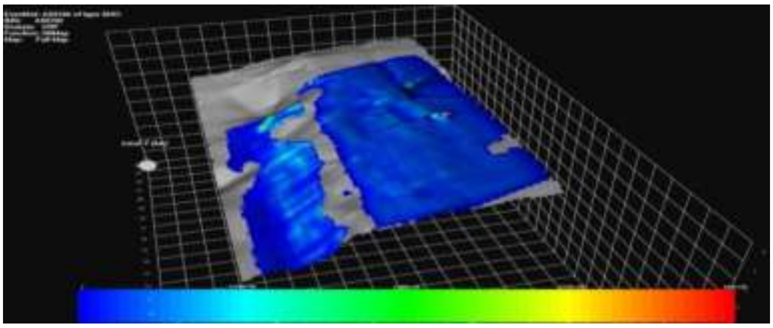

Fig-5Illumination map showing the improper illumination of the basement structure.

The reason for improper illumination of basement near the fault is due to most of the energy is going beyond the geophone spread for a particular surface shot and is clearly depicted by wave front travel images from NORSAR software Fig-6A.Fig-6B shows the proper illumination at shallow level where energy is received by all the designated geophones for the surface shot.

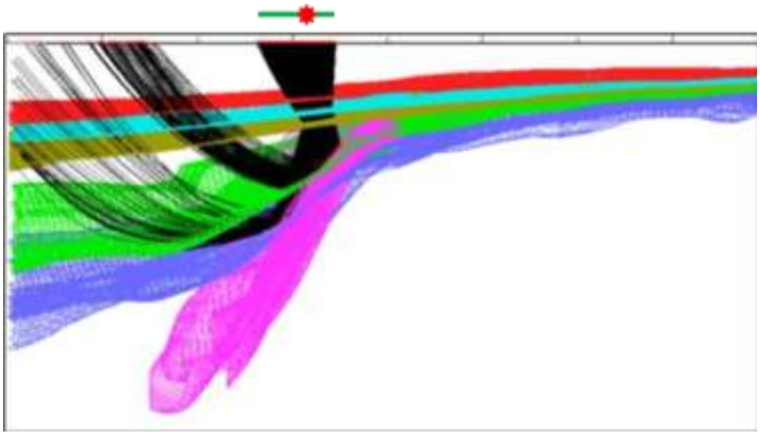

Fig-6A Shows shot location at fault plane where most of the energy is going beyond the geophone spread.

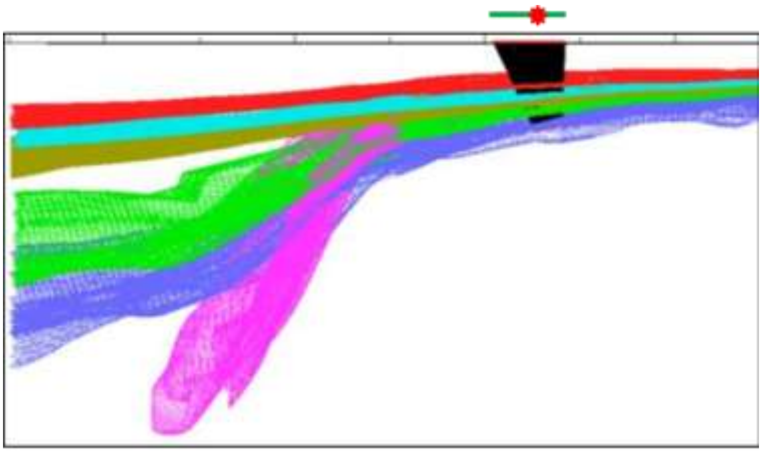

Fig-6B Shows all geophones within spread are receiving energy for a sample surface shot location.

To get through this basement illumination problem at the fault plane, two different geometries were designed for shallow and deeper prospects in the area keeping more fold at the fault plane. For shallow prospect the geometry is kept as Asymmetrical Split Spread of 12 receiver lines with 120 channels in each line and total of 1440 actives channels per shot and for Deeper prospect the geometry is End-on Spread of 12 receiver lines with 160 channels in each line and total of 1920 actives channels per shot. The details of parameters are as shown in Fig-7.

PARAMETER	SHALLOW PROSPECT	DEEPER PROSPECT
Shooting geometry	Orthogonal Asymmetric Split Spread	End-On
No. of receiver lines	12	12
No. of channels per line	120 (48+72)	160
Total active channels	1440	1920
Shots/Template	12	24
Receiver /Shot interval	20/40m	20m / 40m
RECEIVER LINE BEARING	72°	72°
Receiver / Shot Line interval	80 / 120m	160 m / 160 m
Spread length	1430 + 950 m	3190 m
Nr trace offset –Inline/ X-line	22 / 650 m	22 / 1340
Far trace off. - Inline / X-line	1430 m / 1572 m	3190 m / 3460 m
Bin size	10 m x 20m	10 m x 20m
Fold	10x6 = 60	10x6 = 60
Direction of shooting	West to east	West to east
Swath roll	South to North	South to North
Energy source	Dynamite	Dynamite

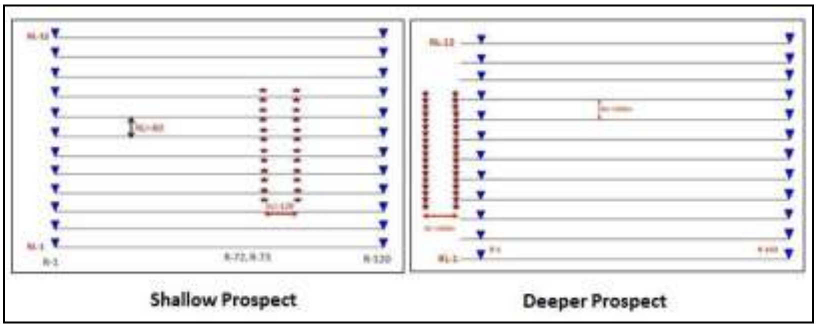

Fig-7 Re-designed two geometrieslayout and parameters.

With these two geometries for shallow and deeper prospects for the study area 3D Seismic data was acquired in the field using UL 408 instrument.

II. RESULTS

The 3D Seismic data is acquired with re-designed adopted geometries using NORSAR ray trace modelling software. The data is processed and the basement is clearly illuminated at the major fault location. The seismic sections obtained by processing of the seismic data at GEOPIC show the proper illumination of basement near major Eastern Gamij fault. Illumination maps generated from NORSAR software play key role in deciding the suitable geometry for proper illumination of subsurface. Laboratory studies of seismic data acquisition have helped in acquiring seismic data suitable for proper imaging of the basement structures. Seismic sections at two locations showing proper illumination at Eastern marginal fault are shown in Fig-8A & 8B and chair-cut view of 3D volume is shown in Fig-9.

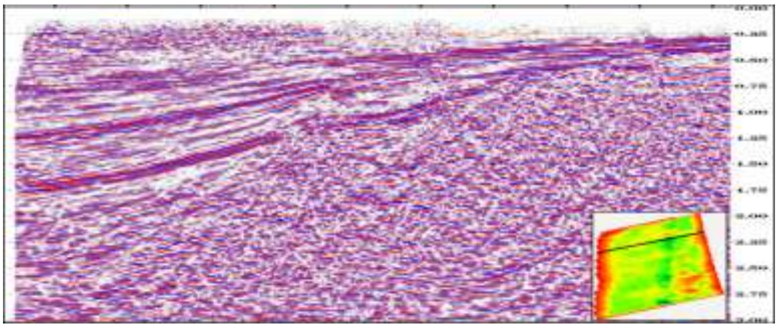

Fig-8 AProcessed seismic section showing the subsurface structures inTime along with location map in inset. (Location-A)

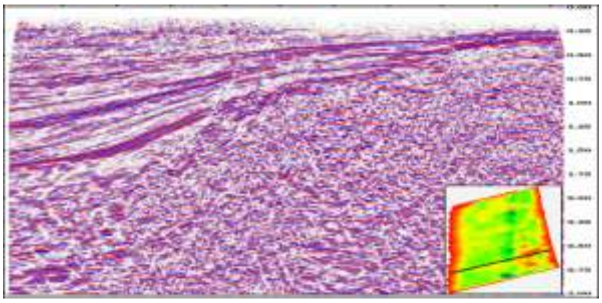

Fig-8 BProcessed seismic section showing the subsurface structures in Time along with location map in inset. (Location-B)

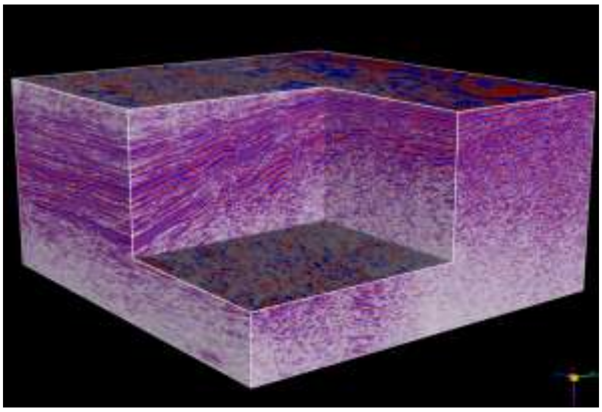

Fig-9 Chair-cut view of 3D Seismic Volume of the area showing the subsurface structures.

III. CONCLUSIONS

Designing proper Seismic data acquisition geometry plays key role in illuminating the subsurface structures in the area. Seismic modelling using the described methodology proves to be an excellent tool for the validation of the seismic geometry design. The complexity of this area makes it necessary to use this Seismic modelling by NORSAR.

Ray tracing involves great computational efficiency because of the great deal of data that has to be calculated especially in 3D data. The poor knowledge of the seismic velocities on the deeper structures is one of the key issues and it is the reason one should use the model without limitations. The different variations on the seismic geometry design offer a lot of possibilities of experimentation like usage of Hit maps for the illumination of the horizons, especially on geologically complex structures present beneath the subsurface.

Laboratory studies of seismic data acquisition geometries have helped in acquiring the seismic data suitable for proper imaging of the basement structures in the study area.

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