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Various Practices to Compute Seismic Statics -A Case Study from Oil India Limited's Operated Digboi- Margherita 3D

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Summary

Static corrections in general are undoubtedly applied to all onshore seismic reflection data to eliminate the disturbing effects due to weathering layer or near-surface low velocity zone and changes in topography. The low-velocity layer of only a few feet thickness can also have a profound static effect which would distort the spectrum of the signal and result in aberrations on final stacked data. Integration of various data and numerous simulations become very necessary to arrive to an optimal static corrected model for any particular area.

The present paper describes a case study from Oil India Limited (OIL) operated Digboi-Margherita 3D block wherein statics pose an imminent threat to acquired seismic data. Subsequently, various velocity-models and several simulations were generated using all available data such as Shallow-Refraction / LVL survey, Uphole survey etc., to successfully compute the optimum corrections to be applied to arrest the statics effect.

***Keywords**: Static correction, LVL, Up-Hole, Shot-Hole Depth, modeling / simulations*

Introduction

Static corrections to seismic reflection data compensate for velocity and thickness variations within the "weathered zone." The significance of the weathered-layer compensation problem becomes evident if velocities on the order of 200 to 300 m/s are encountered in near-surface materials. An error of only 1 m in calculating the thickness of near-surface material with a velocity of 300 m/s results in a static-correction error of 3.3 ms. Hence it becomes essentially important to accurately estimate the velocity and thickness of this low-velocity material to compensate for such errors. The present case study is an attempt towards computing the velocity-thickness model for the shallow layer by the judicial use of all available near surface data.

Theory and Formulae

Let us assume a simple-point source/receiver array with flat topography on semi-two layer case ($V_1 > V_0$, h) in which surface alluvial velocity is V_0 and thickness is h & underlying layer velocity is V_1 as shown in left side of Figure 1.

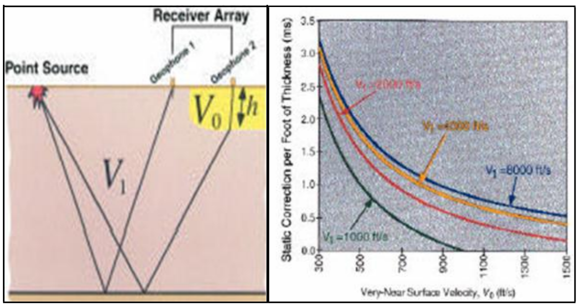

Figure 1: Simple point-source/receiver array model with flat topography (Left), Static correction in ms/ft for various surface alluvial velocities (V0) and various under lying layer velocities (V1) (Right)

In the above model, static shift from Geophone 1 to Geophone 2 is,

$$\Delta t \text{ Static} = (h/V_0)-(h/V_1) \quad \text{eq (1)}$$

Where, Δt Static is first order approximation.

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The situation of Static correction in ms/ft for various surface alluvial velocities (V_0) and various under lying layer velocities (V_1) is being modeled by using formula (1) and is showing in right side of Figure 1.

The following formulae can be used to compute statics where the data base contains uphole times and shot hole depths from observer's report along with LVL & Uphole data.

Source Statics, ms $= - ((E\text{-}d\text{-}D)/ V_1)*1000$, eq (2)

Receiver Statics, ms= - Tup + Source Statics, eq (3)

Statics, ms $= - ((h/ V_0) + (E\text{-}h\text{-}D/ V_1))*1000$, eq (4)

Where E = Elevation above MSL

d = Shot hole depth, m

D = Datum, m

V_0 = Weathering layer velocity, m/sec

V_1 = Sub weathering layer velocity, m/sec

h = Weathering layer thickness, m

Tup = Up-hole times, ms

Weathering Layer Thickness,

$$h = (Xc/2)* ((V_1\text{-} V_0)/ V_1* V_0), \qquad \text{eq (5)}$$

Where Xc = critical distance (an orthogonal line to offset axis passing through intersecting point of two slopes of Offset-Time Plot)

Study Area

The area under study is the Digboi-Margherita 3D block located in OIL's prolific oil producing thrust belt area of Assam. Oil & gas reservoirs in this area pertain to Oligocene-Miocene and Paleocene-Eocene age with depth ranges varying from 2000-5000m respectively. The objective of the survey was to delineate these different reservoirs and identify stratigraphic and structural prospects in the area. The main surface topography within the study area is the undulated terrain covered by Tea gardens, reserve forests of Digboi, Upper Dihing and Kakojan and also Digboi town. Figure 2 is the actual Source and Receiver Positions of this 3D block being superimposed on Base map.

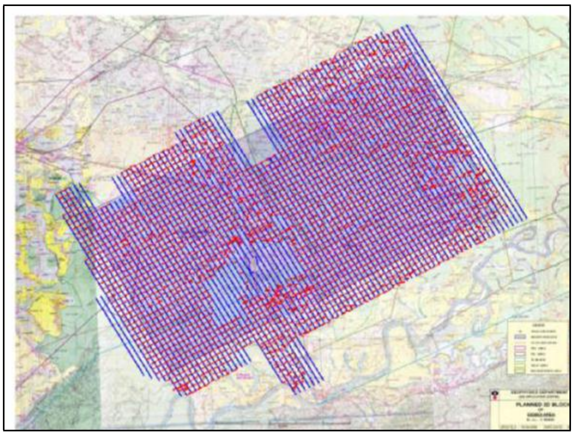

Figure 2: Superimposed actual Source and Receiver Positions of Digboi-Margherita 3D block on Base map

The noticeable big gap in source positions is because of the residential area of Digboi town, where there was no possibility to take recovery shots as per offset rules. The table below is the 3D Seismic survey designing parameters of the 3D block.

S.No.	3D Seismic Survey Designing Parameter	
1	Bin size (Br X Bs) (m)	25 X 50
2	No. of acive lines per swath	10
3	No. of acive channels per line	198
4	Receiver line Interval (m)	400
5	Source Line Interval (m)	450
6	Allocations offsets(m)	4900-25-0-25-4900
7	Max. Min. Offset (m)	551
8	Max. Offset " Sh - Rec" (m)	5641
9	Fold	11 x 5 = 55
10	Aspect Ratio	0.37
11	Spread Type	Symmetrical split spread Orthogonal Geometry

Available Database – It's Sampling

Following was the available database utilized to optimally compute statics to the datum (92.41m) for the study area:

- Uphole times from observer's report with sampling of 100m x 450m.
- Shot-hole depths from observer's report with sampling of 100m x 450m.
- Uphole data with sampling of 2000 m x 2000 m.
- LVL data with sampling of 1800m x 1800m.

Methodology

The computation of statics involves the generation and simulation of surface / near surface models. The basic methodology includes generation of:

- Elevation model from all receiver and source information.
- Weathering layer model of velocity & thickness from Uphole / LVL data and using both merged data.
- Sub-weathering layer velocity model from Uphole / LVL data and using both merged data.
- Shot hole depth model from observer's report for all sources.
- Uphole time model from observer's report for all sources.
- Final optimized statics model using eq (1-5) and resultant source and receiver statics.

Elevation Model

The general topography of the study area can be assessed by the elevation model generated using elevation data mainly from the fine interval spacing of both receivers and shot points

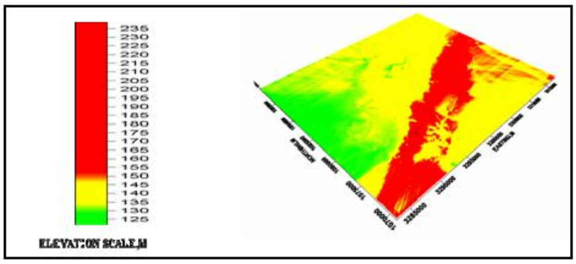

Figure 3: Elevation model for Digboi -Margherita 3D Block; Elevation varies from 125 m to 235 m

The elevation model (Figure-3) of the Block depicts huge elevation variations of 125 m to 235 m above Mean Sea Level (MSL).Therefore the correction to be applied should be very precise so as to correctly account for the statics in the Block.

LVL and Up-Holes

LVL & Up-holes were used to compute near surface velocities and thicknesses model. This is very necessary in particular to arrive to an optimal weathering static corrected model. A total of 320 LVLs & 186 Up-holes were carried out on the Receiver lines in the block in square grids of 1.8 KM X 1.8 KM & 2.0 KM X 2.0 KM respectively. Figure 4 is the grid depicting the layout for the respective surveys. To obtain better resolution of near surface information, the LVL and Uphole survey were carried out in a way that one LVL was placed between four Up-holes and vice versa.

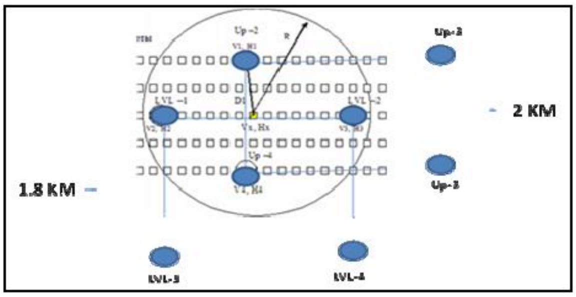

Figure 4: LVL & Upholes square grids

LVL Survey

LVL Surveys were carried out on or parallel to receiver lines or SE-NW direction of the 3D block i.e., along the dip direction of the formation. Hammer-Plate was the seismic source in both ends of LVL Spread. Shallow refraction data was acquired with sampling interval of 0.5 ms and 1s record length by the means of 24 channels placed along 100 m spread length, with forward and reverse shootings.

The first breaks of all channels in both forward and reverse records of time sections were carefully picked, and Offset-Time Plots were analysed. The gradient of the plot relates to the velocity of the near surface model, and eq (5) computed the weathering layer thickness. The near surface model was thus generated utilizing the LVL information. One should be aware that the computed receiver statics using LVL data are subject to the following limitations

a) LVL spread should be laid out along the dip of the formations. i.e., along the receiver lines.

b) Thin low velocity layer may not trace in some cases like V1> V2< V3.

Uphole Survey

Uphole Surveys were carried out on Receiver lines i.e., SE-NW direction of the block. Detonators / caps were used as seismic source at fixed intervals of depth profile of 35 m as shown in Figure 5.

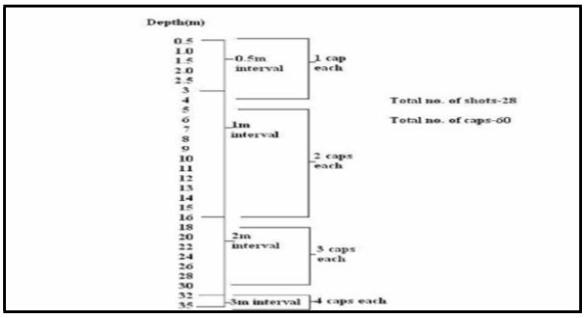

Figure 5: Uphole depth profile and caps / detonator information

The Uphole spread geometry involves four geophones placed at 1m & two geophones placed at 4m and 7m away from drilled hole as shown in Figure 6.

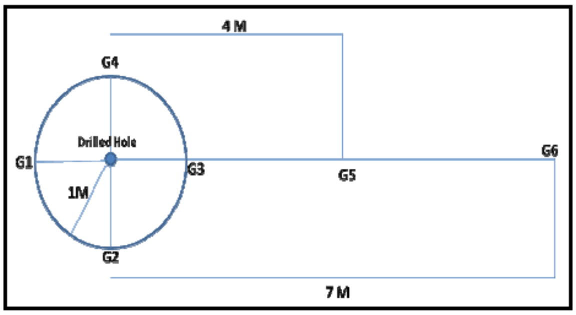

Figure 6: Uphole Spread Geometry & Geophone positions

Seismic data was thus acquired from 6 geophones at different depth levels with sampling interval of 0.25 ms and 0.5s record length.

The first breaks of channels at all depths were picked, analysed and Zero Offset Corrected time-Depth (T-D) Plot was generated. Slope of the plot provide the velocities and thicknesses are derived from the depth axis, which is the orthogonal line to depth axis, passing through intersecting point of two slopes in the T-D Plots. The near surface model was thus generated utilizing the Uphole information.

Merged LVL & Uphole data

Weathering and sub-weathering layer velocity and thickness models (Figure 7, 8 & 9) were even generated using the merged LVL and Uphole data. From this it was observed that in the study area, good sampling of surface and very near surface information is very essential to compute good statics model in order to eliminate the disturbing effects due to weathering layer and changes in topography.

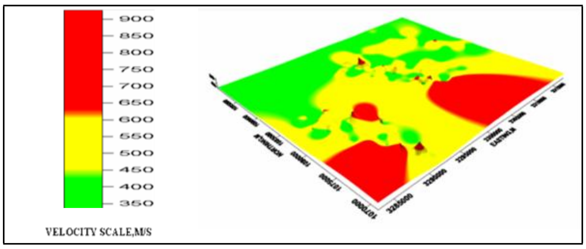

Figure 7: Weathering layer velocity model for the Block; Velocity varies from 350 m/s to 900 m/s

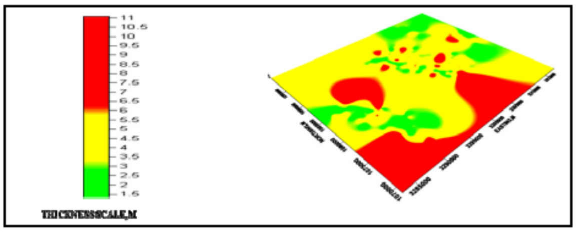

Figure 8: Weathering layer thickness model for the 3D Block; Thickness varies from 1.5 m to 11 m

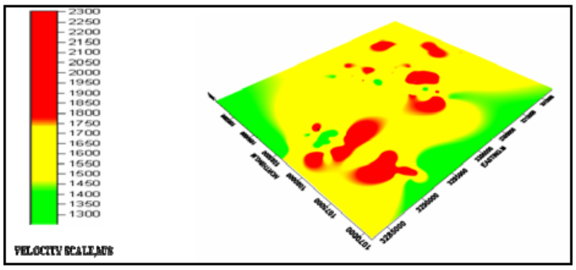

Figure 9: Sub-Weathering layer velocity model for the 3D Block; Velocity varies from 1300m/s to 2300 m/s

Shot-hole Depth & Uphole time Model

The statics model eq (2) requires the need for a shot-hole depth model. Subsequently, the depth model (Figure- 10) was derived using the observer's report at all shot holes. Dominant depth varies from 15m to 20m. Additionally, for receiver statics model eq (3) require the Uphole time model, this was also generated using the uphole times of the observer's report. Figure -11 is the generated Uphole time Model for the block under study. Dominant Uphole times vary from 10 ms to 18 ms.

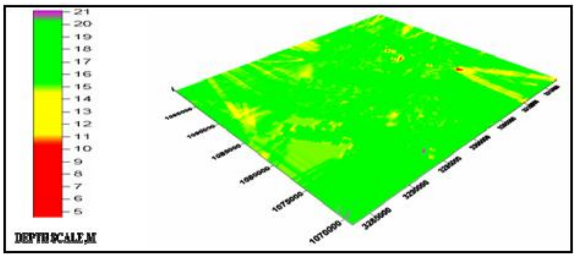

Figure 10: Shot hole Depth model for the Block

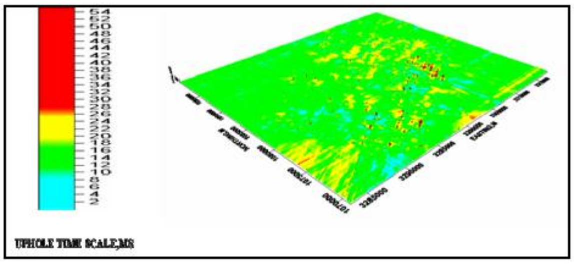

Figure 11: Uphole time model for Digboi - Margherita 3D Block

Statics Model

Source / receiver static models / simulations were generated from eq 2, 3 & 4 by employing all the models generated earlier for the following available data

a) Interpreted data from Up-holes
b) Interpreted data from LVLs
c) Merged interpreted data from both LVLs & Up- holes
d) Uphole times and shot hole depths from observer's report

Receiver & Source statics were also computed. Table B & C are the static corrections for few points of receivers and sources respectively.

Table B:

RP	REC STATICS,MS				Remarks
	From UPHOLE TIMES	From UPHOLES	From LVL & UPHOLE	From LVL	
10015251	-46	-39	-64	-59	Taper Area
10015252	-40	-34	-57	-52	
10015253	-38	-33	-55	-50	
10015254	-41	-36	-58	-53	
10015255	-48	-41	-65	-60	
10415318	-53	-54	-59	-60	Full Fold Area
10415319	-57	-58	-63	-65	
11215357	-30	-29	-27	-31	
11215358	-30	-28	-26	-31	
11215359	-30	-29	-26	-31	
11215360	-30	-28	-26	-31	
11215361	-29	-28	-25	-31	
14095288	-40	-40	-36	-60	
14095289	-41	-41	-38	-62	
14095290	-44	-44	-40	-66	
14095291	-41	-41	-39	-62	
14095292	-38	-38	-36	-58	

Table C:

SP	SOURCE STATICS, MS		REMARKS
	From LVL	From UPHOLE	
51181177	-25	-18	Taper Area
51181179	-25	-18	
51181181	-25	-18	
51181183	-25	-18	
51991431	-27	-26	Full Fold Area
51991433	-27	-26	
51991435	-26	-25	
51991437	-26	-25	
51991439	-25	-24	
53701319	-19	-17	
53701321	-19	-17	

Observations & Results

On comparison of the computations in Table B & C from various models, following are the key observations noted:

In 3D Taper Area:

- Maximum deviations in receiver statics of order of 20 ms are observed.

- Maximum deviations in source statics of order of 7 ms are observed.

In 3D Full Fold Area:

- Minor deviations of the order of 7 ms in receiver statics are observed.

- Maximum deviations are observed in receiver statics of order of 20 ms which are only computed by LVL data subjective to the limitations.

- Receiver statics computed from both Up-hole times and Uphole data are almost similar and equal.

The above observations suggests that the receiver statics/ Source statics obtained from Uphole times, shot hole depths taken from observer's report and Uphole data is an optimum model for all receivers including in the taper area.

The computed statics when applied to the data during data processing proved very effective. The brute stack shown in Figure 12 clearly demarcates few reflectors especially between 1400 ms to 3800 ms, pertaining to the target formations of Oligocene-Miocene and Paleocene-Eocene sediments.

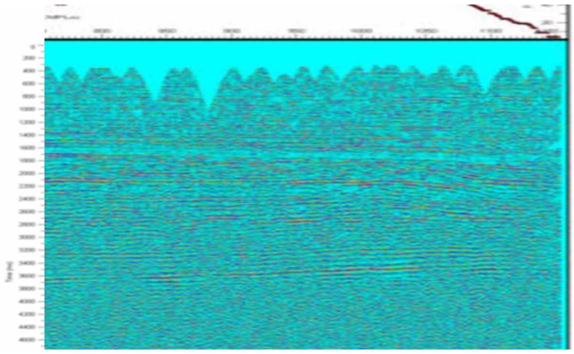

Figure 12: Brute Stack after static correction applied showing the reflectors clearly.

Conclusions

An optimal receiver static corrected model corrected even at the taper ends, is a valuable information as it improves the lateral resolution at the edges of full fold area, which is very essential especially while data Migration.

It was observed that Receiver / Source statics computed by Up-hole data gave an optimum statics model in full fold area of the block under study which may not be possible by LVL data alone. .

From the present study and further modeling, it would like to bring to kind notice that Receiver / Source Statics being computed by Up-holes data with sampling of 1000 m x 1000 m. would always give an optimum statics model for onshore data involving any type of energy sources.

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