

**Seamless merging of two land 3D seismic data set with different sensors in a carpet 3D:
A Case Study from Cambay Basin**

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Keywords

Digital Sensor SVSM, Moving Coil Sensor Geophone, Seamless Merging, RMS Amplitude Response.

Summary

Ahmedabad south carpet 3D was planned in Nawagam Wasna area under four phases. Seismic data acquisition was completed on Phase-I & II. In Phase-I, land analog geophone was used as sensor whereas in Phase-II, digital sensor SVSM was used. Vector Seis (SVSM) is a 3-component digital sensor uses micro-mechanical as sensing element and provides an output proportional to the acceleration of ground movement whereas traditional seismic Geophone having moving coil sensor provides an output sensitive to velocity of the ground movement. The responses of these two sensors are different in amplitude and Phase from each other. The requirement of seamless merging of these two different data set producing gathers suitable for Pre stack inversion and other attribute studies warranted a new approach in processing. Emphasis was given on bringing the two dataset on same phase and amplitude level. Once the two data sets are on same level careful conditioning of the gathers, removal of noises was carried. Then higher order residual correction, close-grid RMS velocity analysis was done. The presence of thick coal layer present within Kalol formation resulted in the multiple reflections and attenuation of seismic energy. The multiples were attenuated using parabolic radon transform and the energy loss was taken care during preprocessing.

Introduction

The study area is located in the northern rising flank of Tarapur depression, forming northern peripheral part of Cambay-Tarapur tectonic block of Cambay basin (Fig-1). The area is surrounded by oil fields of Nawagam, Wasna in the north; Dholka, Naika, Mahelaj in the west, Asmali and Vatrak in south west and Bhalada, Kanwara in the south. The carpet 3D is acquired with an objective to resolve strati structural prospect at Kalol and Syn. rift sediments of OCS and

Olpad levels. To fulfill the interpretation objective, special emphasis was given to removal of noise pattern and removal of multiples present in the data especially due to coal layers.

General geology of the area

Hydrocarbons have been established in the study area from exploratory wells drilled in Sadra from Kalol Pays (K-VIII, K-IX and K-X). The entrapment style of the upper pays (K-IX+K-X), KVIII units appears to be strati-structural. The upper pays are marked by two distinct coarsening Para-sequences ending with coal. In this area the hydrocarbon entrapment generally depends upon the reservoir development. Structures appear to play little role for the entrapment. The middle pay or younger Cambay shale is also found to be hydrocarbon bearing in Naika-Mahelaj area situated towards west of this area. The entrapment style appears to be stratigraphic in nature. Stratigraphic nature of the reservoir needed special attribute studies to be carried out in this area.

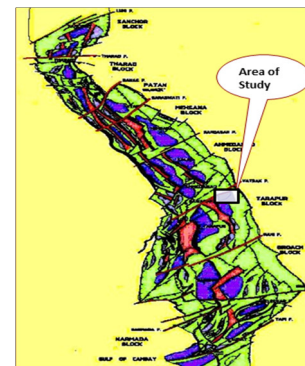


Fig-1: Tectonic map of Cambay Basin with study area.

Acquisition particulars

The data of the study area was acquired during the field season 2016-17. Base map and fold map of study area are shown in Fig-2 respectively.

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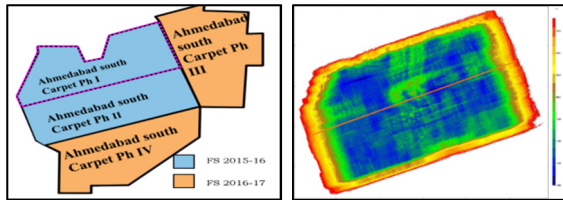


Fig-2: Base map (left) and fold map (right) of the study area.

Methodology adopted for Amplitude and Phase matching of two data set

The merging of two data set and processing was carried out keeping in view the quality of the 3-D image needed for the special studies and in view of the future use of PSTM gathers for inversion and AVO studies. In the present study, the processing sequence was a regular flow that is used in petroleum industry; however, certain refinements and new approach in processing were warranted as the raw data recorded with analog geophone sensor and Digital geophone (SVSM) are different in terms of Phase & amplitude (Fig-3 & 4). The RMS amplitude of analog sensor is around one thousand time more than that of SVSM. The frequency bandwidth of the digital SVSM is better than the analog geophone as SVSM can record a frequency as low as 2 Hz faithfully and its response increases in amplitude proportional with frequency (Fig-5). Hence, data recorded with SVSM was taken as reference & other data was brought to this level for further processing.

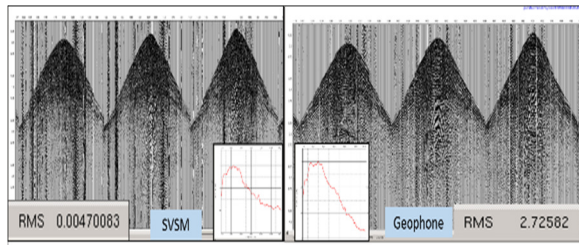


Fig-3: Raw gather comparison of SVSM and Geophone data.

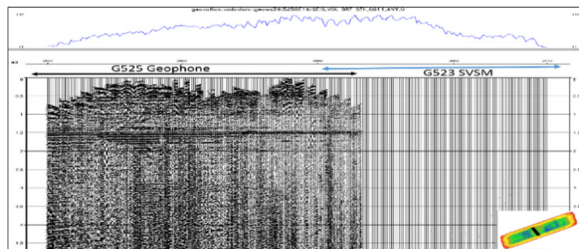


Fig-4: Raw stack showing amplitude difference.

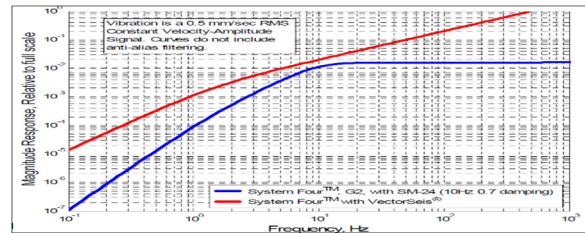


Fig-5: Amplitude response of Geophone and SVSM.

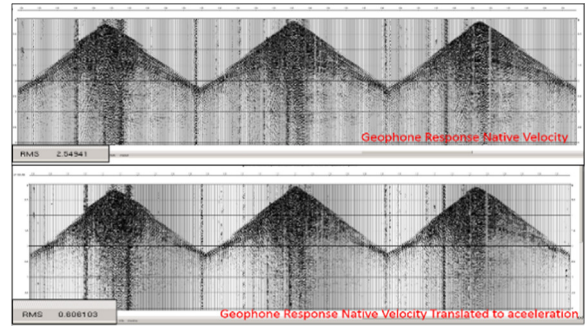


Fig-6: Raw gather before and after translation.

- 1) The data of analog geophone was first differentiated to make it equivalent to SVSM output which records the change in velocity. The differentiation of analog data introduces a phase difference in the data set. The amplitude and phase difference needs to be compensated (Fig-6).
- 2) To make these two data set equivalent to each other we took the raw gathers of two common area Sw-9 of northern part and Sw-10 of southern part which is having a common 8 receiver line. As these 8 receiver lines were laid exactly at common place (Fig-7). Gathers from these common CDP was edited for any high amplitude DC bias and spikes and stack of these two data set at common CDP was prepared.

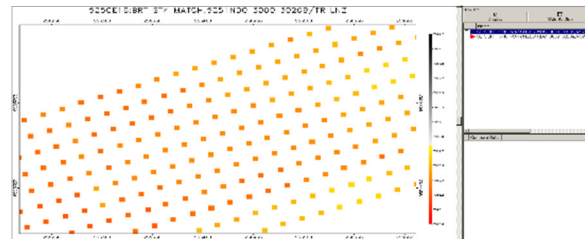


Fig-7: Stack QC of two different data set in common area.

- 3) These two stack data is taken as inputs to a module MQC2V which compares multiple QC attributes of two volume having same characteristics.

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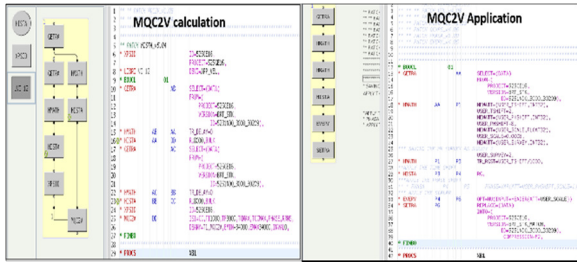


Fig-8: Amplitude and Phase matching modules.

INTRA	CROSSLINE	CURVE	CENTER	RMAS
2914	30000	29823	0.000000	0.000000
2915	30000	29824	0.000000	0.000000
2916	30000	29825	-1.000000	-1.000000
2917	30000	29826	0.000000	0.000000
2918	30000	29827	0.000000	0.000000
2919	30000	29828	0.000000	0.000000
2920	30000	29829	0.000000	0.000000
2921	30000	29830	-1.000000	-1.000000
2922	30000	29831	1.000000	1.000000
2923	30000	29832	0.000000	0.000000
2924	30000	29833	1.000000	1.000000
2925	30000	29834	0.000000	0.000000
2926	30000	29835	-1.000000	-1.000000
2927	30000	29836	0.000000	0.000000
2928	30000	29837	0.000000	0.000000
2929	30000	29838	-1.000000	-1.000000
2930	30000	29839	0.000000	0.000000
2931	30000	29840	0.000000	0.000000
2932	30000	29841	0.000000	0.000000
2933	30000	29842	0.000000	0.000000
2934	30000	29843	0.000000	0.000000
2935	30000	29844	0.000000	0.000000
2936	30000	29845	0.000000	0.000000
2937	30000	29846	0.000000	0.000000
2938	30000	29847	0.000000	0.000000
2939	30000	29848	0.000000	0.000000
2940	30000	29849	0.000000	0.000000
2941	30000	29850	0.000000	0.000000
2942	30000	29851	0.000000	0.000000
2943	30000	29852	0.000000	0.000000
2944	30000	29853	0.000000	0.000000
2945	30000	29854	0.000000	0.000000
2946	30000	29855	0.000000	0.000000
2947	30000	29856	0.000000	0.000000
2948	30000	29857	0.000000	0.000000
2949	30000	29858	0.000000	0.000000
2950	30000	29859	0.000000	0.000000
2951	30000	29860	0.000000	0.000000
2952	30000	29861	0.000000	0.000000
2953	30000	29862	0.000000	0.000000
2954	30000	29863	0.000000	0.000000
2955	30000	29864	0.000000	0.000000
2956	30000	29865	0.000000	0.000000
2957	30000	29866	0.000000	0.000000
2958	30000	29867	0.000000	0.000000
2959	30000	29868	0.000000	0.000000
2960	30000	29869	0.000000	0.000000
2961	30000	29870	0.000000	0.000000
2962	30000	29871	0.000000	0.000000
2963	30000	29872	0.000000	0.000000
2964	30000	29873	0.000000	0.000000
2965	30000	29874	0.000000	0.000000
2966	30000	29875	0.000000	0.000000
2967	30000	29876	0.000000	0.000000
2968	30000	29877	0.000000	0.000000
2969	30000	29878	0.000000	0.000000
2970	30000	29879	0.000000	0.000000
2971	30000	29880	0.000000	0.000000
2972	30000	29881	0.000000	0.000000
2973	30000	29882	0.000000	0.000000
2974	30000	29883	0.000000	0.000000
2975	30000	29884	0.000000	0.000000
2976	30000	29885	0.000000	0.000000
2977	30000	29886	0.000000	0.000000
2978	30000	29887	0.000000	0.000000
2979	30000	29888	0.000000	0.000000
2980	30000	29889	0.000000	0.000000
2981	30000	29890	0.000000	0.000000

Fig-9: Amplitude and Phase matching recorded in XPS.

This module calculates Time shift, Phase rotation and RMS amplitude value difference at each common CDP point. Here the first data taken is the reference data which is acquired with SVSM and the second input is data which is to be modified acquired with land Geophone. From this common data set available at common CDP time shift, Phase shift and RMS amplitude value is calculated. From these numerous value we calculate the average of each parameter. More the common sample value better is the averaging. These average values are applied on Land Geophone data to make it equivalent to other data through MQC2V application module (Fig-8 & 9). Once the time shift, phase shift & phase rotation and RMS ratio calculated is applied on the other dataset the two data sets are now at par with each other and ready for further processing. The corresponding raw stack and de noised section after Phase and amplitude correction shows seamless merging (Fig-10 & 11).

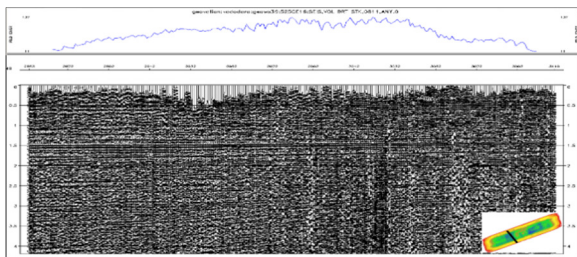


Fig-10: Raw stack after amplitude and phase matching (along cross line).

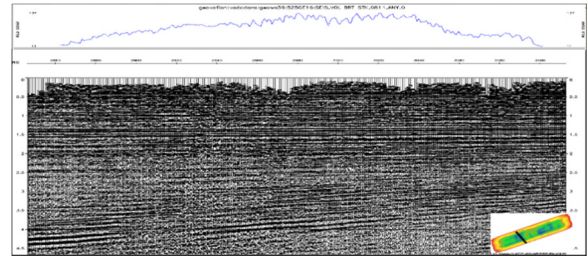


Fig-11: De noise stack after amplitude and phase matching (along cross line).

In the present study, the processing sequence was regular flow that is used in petroleum industry; however, certain refinements in processing were made. The generalized processing flow is as below.

Processing Sequence

- Format Conversion
- Geometry Merging
- Geometrical Spreading Correction($T^{*1.8}$)
- Amplitude and Phase matching
- Denoise (removal of Interference Noise)
- Surface Consistent Amplitude Correction Applied for Source, Receiver, Offset
- Surface Consistent Deconvolution
- 3D Residual Statics – Two Pass
- Demultiple through Radon transform
- Residual Velocity Analysis Two Pass
- Pre STM On Target Lines
- RMS Velocity Analysis
- Final PSTM Kirchhoff algorithm
- Residual noise and multiple attenuation through radon transform on PSTM gathers, 4th order ETA correction applied
- Final PSTM Stack
- Post Stack Processing(3D Random Noise Attenuation)

1) Emphasis was given to the removal of noises. Gathers was scanned for any high amplitude DC bias which was present. Noise was removed in 3D mode also by generating cross spread and applying conical shaped filter in F-Kx-Ky domain. F-K filter was applied on shot gather data to remove the ground roll effect. As two parties were working simultaneously adjacent to each other seismic interference noise were recorded on many records despite taking precautions during data acquisition (Fig-12 & Fig-13).

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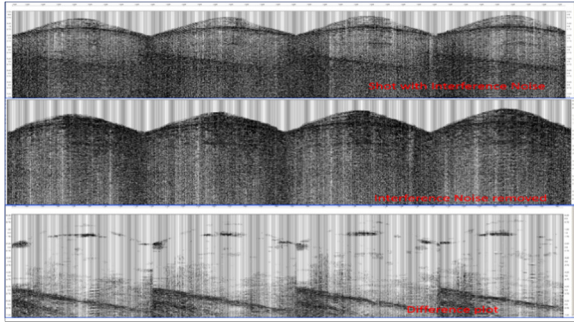


Fig-12: Raw record infected with interference noise.

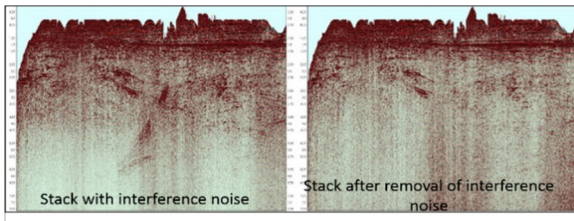


Fig-13: Stack section before & after removal of interference noise.

2) To restore the distortion in amplitude along offset surface consistent amplitude scalars in shot, receiver and offset domain were calculated and applied to prestack gather.

3) Broad band filtering was applied to remove the unwanted frequencies after adequate testing. A careful but adequate denoising was carried out to preserve maximum frequency present in raw record. A sample raw gather & conditioned gather is shown below (Fig-14).

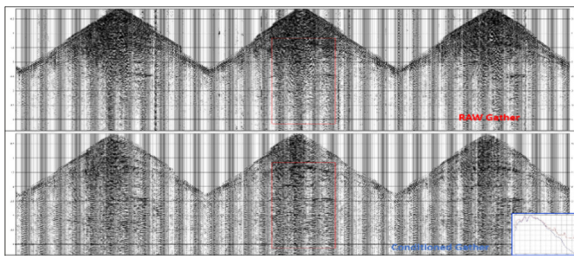


Fig-14: Raw Gather and Denoised gather (sample).

4) To improve the resolution of pre stack data, it is important to choose optimum decon parameters in the form of prediction distance, operator length, white noise and window for designing the inverse operator. We tested these parameters for single trace & multi trace deconvolution and chose surface consistent deconvolution (multi trace) and applied in

shot, receiver, offset and CDP domain. Velocity analysis was done in close grid.

5) Two pass surface consistent residual statics correction was carried out & each pass is followed by close grid velocity analysis, we have observed multiples in zone of interest. Stack section of different stage along Inline AA is shown in Fig-15 to 18. Time Slices were generated at each level of processing as a quality check (Fig-19 & 20). The time slices shows at different level shows the reduction in noise level sharpening of the events as we move from raw to PSTM stage.

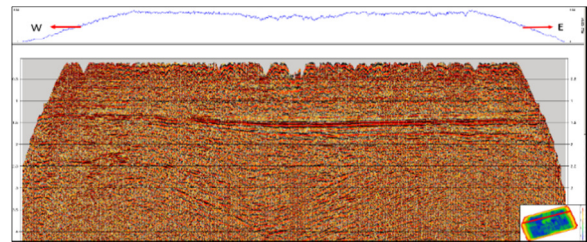


Fig-15: Brute stack of representative inline: AA.

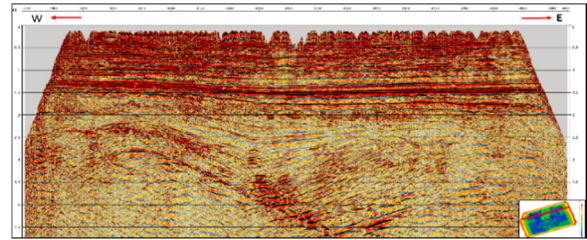


Fig-16: Denoise stack of representative inline: AA.

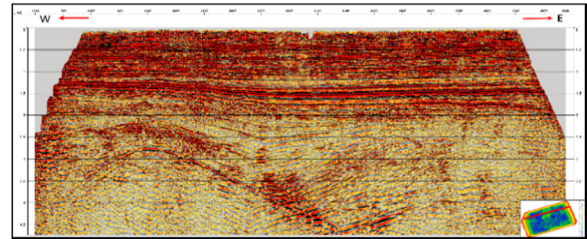


Fig-17: Regularized stack of representative inline: AA.

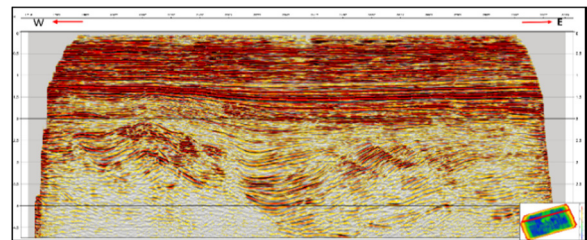


Fig-18: PSTM stack of representative inline: AA.

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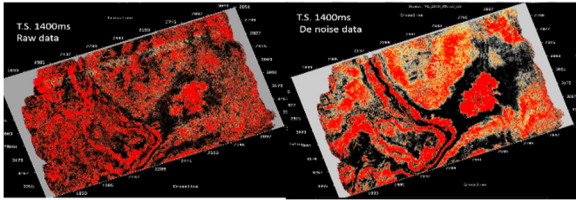


Fig-19: Time Slice at 1400ms (Raw & Denoise Volume).

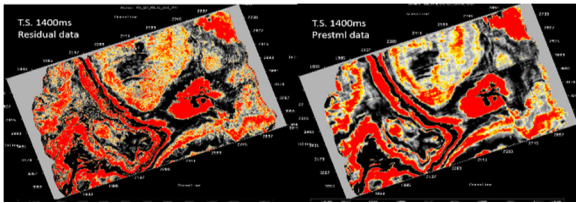


Fig-20: Time Slice 1400ms (Residual & PSTM Volume).

Methodology of Demultiple

Presence of thick coal bed in this area resulted in inter bed multiple which was evident from the velocity semblance panel. The multiple attenuation was carried out using high resolution radon decomposition in Tau-P domain.

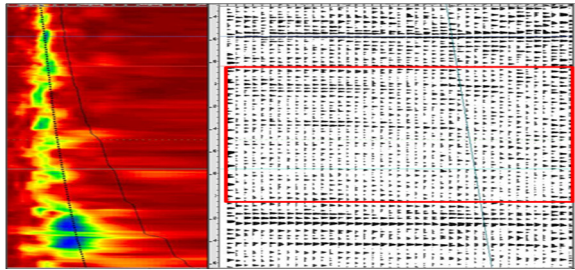


Fig-21: Velocity semblance with multiple gather.

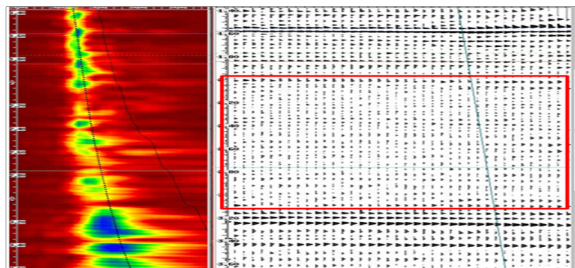


Fig-22: Velocity semblance with Demultiple gather.

Once multiples are attenuated, we again carried out velocity analysis on the demultiple gathers as shown in Fig-21 & 22 to generate velocity field for running migration on target lines. We carried two passes velocity analysis that include horizon based velocity analysis and also followed by higher order residual

velocity correction to get the flattened gathers. After finalizing the velocity field PSTM was run on the entire volume.

The client's requirement was to have noise free PSTM gathers amenable for attribute study hence we again conditioned the PSTM gathers for residual noise. High density velocity picking and 6th order residual correction was done to obtain the final PSTM stack section. Random noise attenuation and Acquisition foot print removal was carried on the final section. Final PSTM section of representative inline & cross line are shown below in Fig-23 to 24.

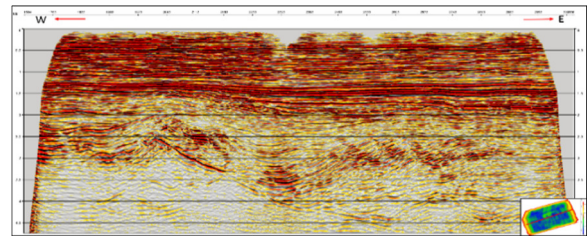


Fig-23: PSTM stack of representative inline: BB.

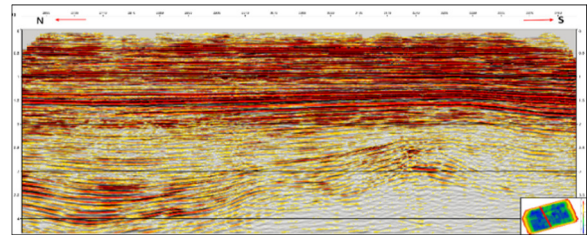


Fig-24: PSTM stack of representative cross line: CC.

Results and Discussion:

Our main aim was to get conditioned PSTM gathers amenable for attribute studies. Hence during every step of processing we studied amplitude and noise pattern and then used noise removal technique to attenuate them and generated quality control plots at each steps.

- It is observed from the shot record, that the field record is contaminated with high amplitudes ground rolls, high frequency noises and interference noise. Careful conditioning was done to get a balanced record.
- Our main stress was to achieve the amplitude and Phase balanced gathers from two data set. The balancing of the gathers was done before the de

noising so as the two gathers can be treated similarly during later stage of processing. At each stage the cross line plot was generated from the volume to ascertain the amplitude level.

- After conditioning the PSTM gathers flatness of the events along the zone of interest has increased but variation in the wavelets peak alignment was observed, so we decided to apply Trim statics to entire PSTM gathers. After fixing the mute carefully we generated a PSTM stack volume.
- Remarkable improvement is observed in Kalol, OCS, Olpad and Synrift sequence in the zone of interest (Fig-23 to 24).

Comparison with earlier processed data

On comparing the reprocessed data with earlier processed section as shown in Fig-25 to 28 we found, that the continuity and resolution of the events has increased and micro faults are clearly seen on our zone of interest on reprocessed section.

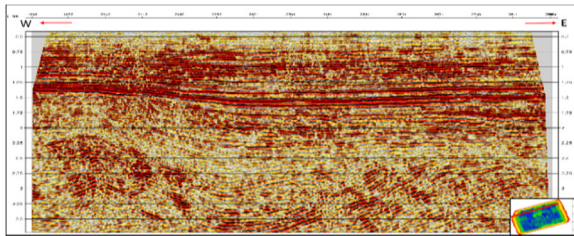


Fig-25: Earlier PSTM section of representative inline: DD.

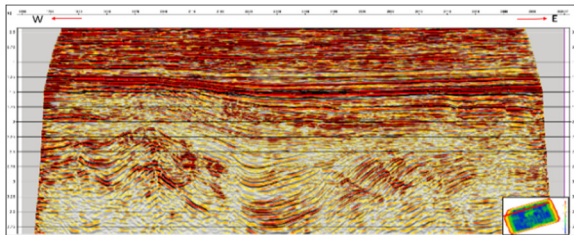


Fig-26: Recent PSTM section of representative inline: DD.

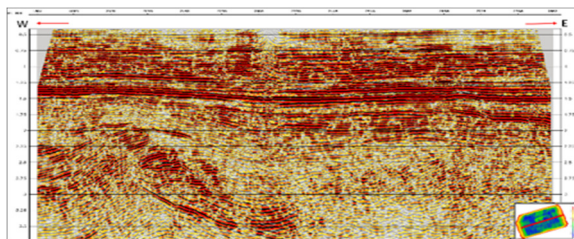


Fig-27: Earlier PSTM section of representative inline: EE.

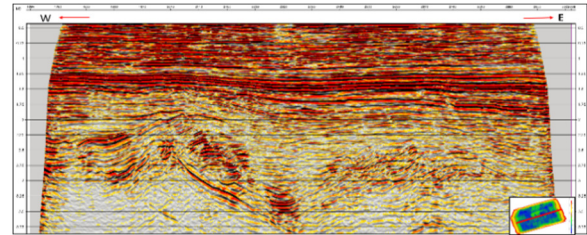


Fig-28: Recent PSTM section of representative inline: EE.

Conclusions

- Whenever dataset recorded with different type of sensors e.g. Geophone-Hydrophone or Geophone - SVSM must be matched with each other in phase shift, phase rotation and RMS amplitude and then should be processed as single volume.
- Objective oriented reprocessing has brought up good results and the final products i.e., PSTM stack and gathers shall be helpful in carrying out further attribute studies.
- The results when compared with the previously processed data clearly indicate much better events in terms of continuity, resolution and fault definition.

References

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N.B: The views expressed in the paper are solely of the authors and not necessarily of the organization in which they are working.