Improving underlying image by resolving high velocity anomaly using sonic log in velocity model building

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Abstract

In presence of complex geology and lateral velocity variations, unresolved velocity anomalies in the overburden degrade deeper imaging. This makes it very crucial to ensure that all significant lateral velocity variations and anomalous velocities have been dealt with before attempting to image the deeper seismic events. In order to incorporate velocity anomalies into the model, a range of options can be used, depending on whether the geobody geometry alone is discernible, or whether its velocity distribution is also known. In this paper, sonic log is utilized to resolve high velocity anomaly which was difficult to resolve using grid based tomography or any other method of velocity model update due to very high contrast in velocities of the surroundings and the anomalous high velocity geobody, and extension of the geobody. Consequently, improved subsurface image was achieved below the anomalous high velocity zone using anisotropic Kirchhoff PSDM.

Introduction

In presence of lateral velocity variations and velocity anomalies, PreSTM migration is not efficient in producing true subsurface images even if the velocity used for migration is correct. Because PreSTM make the assumption that all traces in a CMP gather should be processed with the same 1D velocity-time function pertaining to that CMP location. The actual velocity function may change laterally, but at any given CMP, traces from all offsets in the gather are treated as if they propagated in the same laterally invariant velocity-time field (Ian F. Jones, 2012). Due to this PreSTM data will exhibit pull up or push down effect depending upon high velocity or low velocity anomaly (T. Armstrong et al., 2001). Fig 1, shows the PSTM stack section, pull up effect can be observed in the seismic reflectors due to overburden anomalous high velocity geobody A which is a tight carbonate.

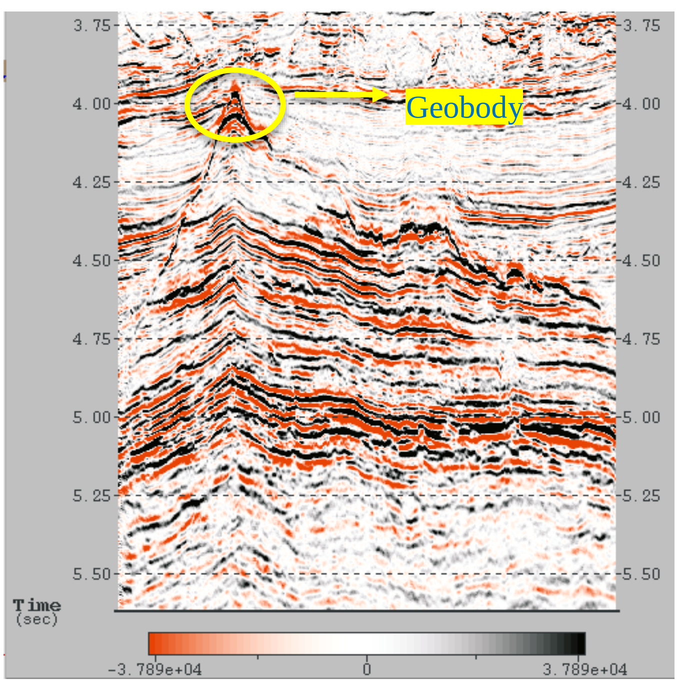


Fig-1: PSTM stack section, Geobody A is a tight carbonate with velocity of the order of 4200 m/s, pull up effect distortion can be observed in underlying seismic reflectors.

In that case, PreSDM can be used to achieve better imaging of subsurface. In this paper, a velocity model building scheme is presented to achieve an enhanced subsurface imaging by Anisotropic Kirchhoff PSDM in deep water of Kutch characterized by carbonate platform. Fig. 2 depicts the area of study located in deep water of Kutch.

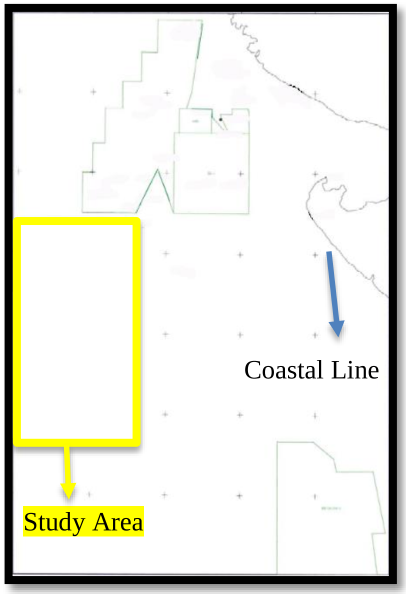


Fig-2: Map of area of study in deep water of Kutch

Initially, Interval velocity was created from RMS Velocity using Dix's conversion and Delta and epsilon were calculated using mis-tie between well markers (using 1 well) and seismic interpreted horizons. Then vertical interval velocity, δ and ε were updated using grid based tomography with 300m X 200X 100 m grid size. After 2 iterations of tomography, anomalous high velocity of geobody A was not resolved since contrast in velocity of anomalous geobody (4160m/s) and surrounding velocity (3200 m/s) was very high and extension of anomalous geobody was of the order of 500m which is very small as compared to the half of the cable length (cable length: 6km). It means that on the same cdp gather, raypaths of some traces will encounter this anomaly and some will not, depending upon the location of cdp with respect to the geobody A.
Allowing the tomography to introduce such a rapid velocity change in the model can result in instabilities in other parts of the updated velocity field or if small changes are allowed in tomography velocity update which is a better way for solution to converge at a reliable and meaningful solution, will take many iterations to resolve this velocity anomaly which is time consuming and costly.

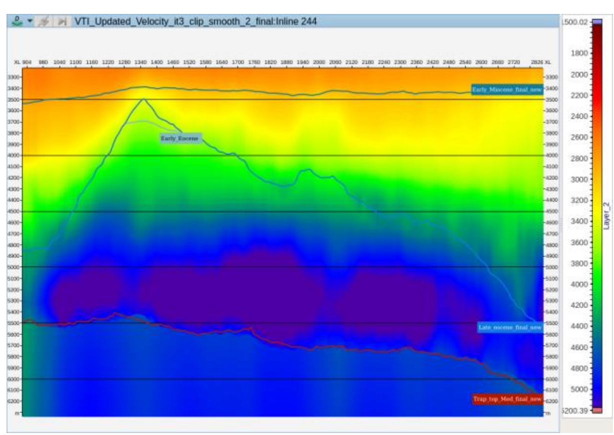


Fig 3: shows vertical interval velocity after 2 iteration of grid based tomography.

Intergrating Sonic log with seimic data to resolve high velocity anomaly

Sonic log (blue color) in fig. 4 indicates high velocity anomaly around 3500m depth (TWT-3950 ms at well location). Velocity of 4000 m/s with gradient was introduced between Late Eocene and Early Eocene level for geobody A using interpreted horizons. This can be done in different ways in different software. In this study, delta volume was created and that volume was used to transform the previous velocity volume to produce the output velocity in such a way that it matches the sonic log in between late Eocene and early Eocene zone. Velocity volume was smoothened. Fig 5(a) and (b) shows the interval velocity section before and after resolving anomalous high velocity respectively.

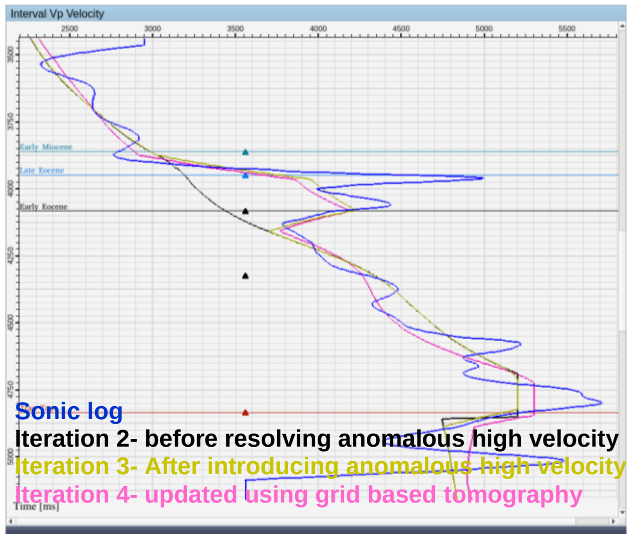
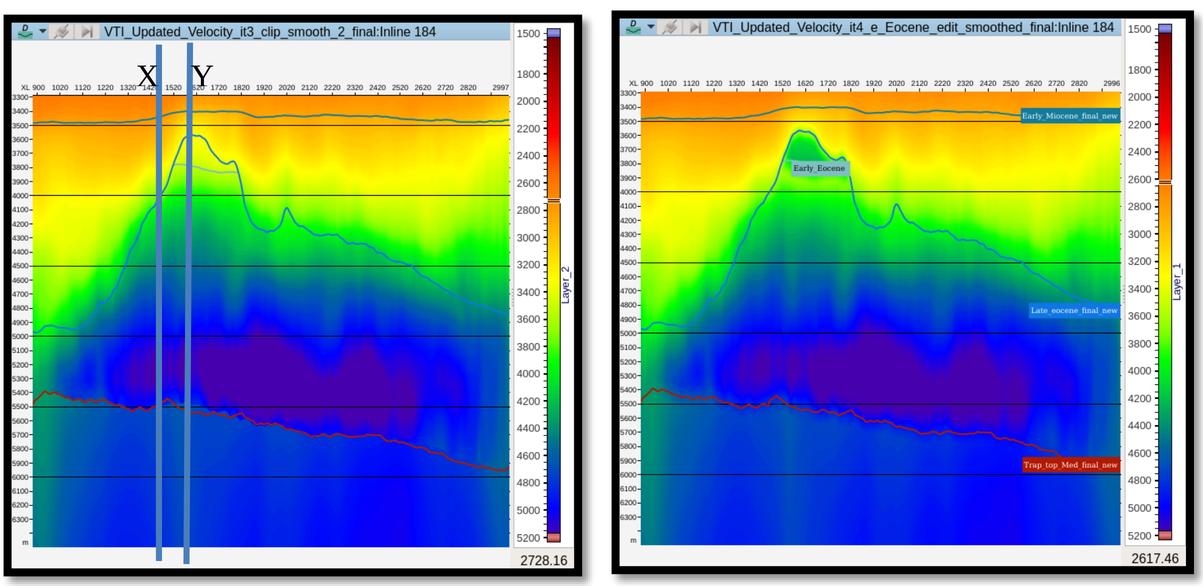


Fig 4: comparison of vertical interval velocity extracted at well location and the sonic log. Blue color shows sonic log, black color shows vertical interval velocity at well location before resolving anomalous high velocity, yellow color shows vertical interval velocity after introducing high interval. Magenta color shows vertical interval velocity after updating iteration 3 velocity using grid based tomography

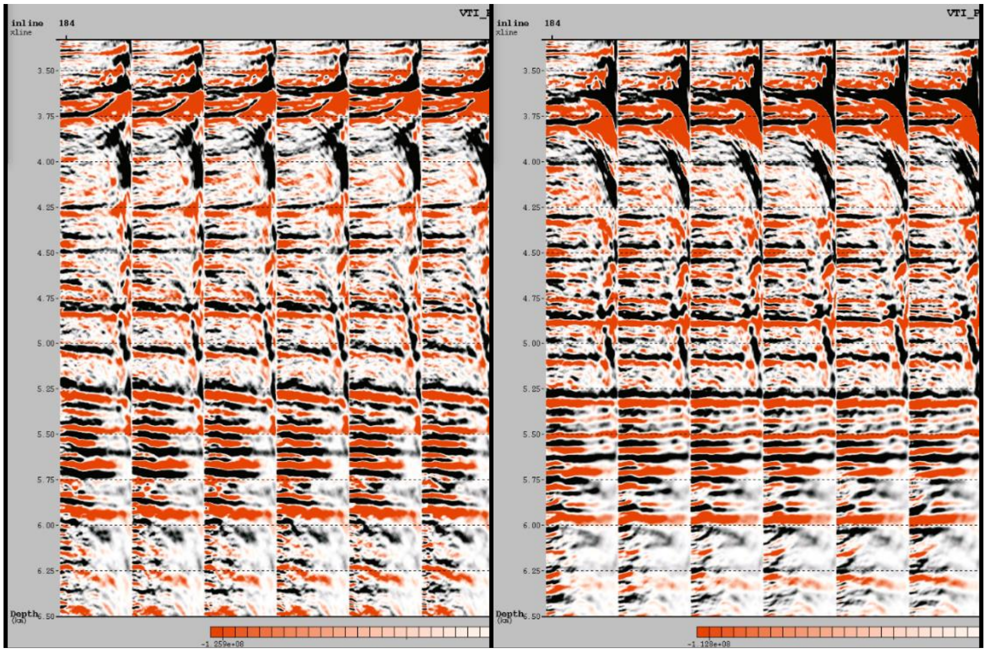


(a) (b)

Fig 5: Vertical interval velocity (a) before resolving anomalous interval velocity (b) after introducing high velocity

PSDM gather comparisons before and after resolving high velocity anomaly

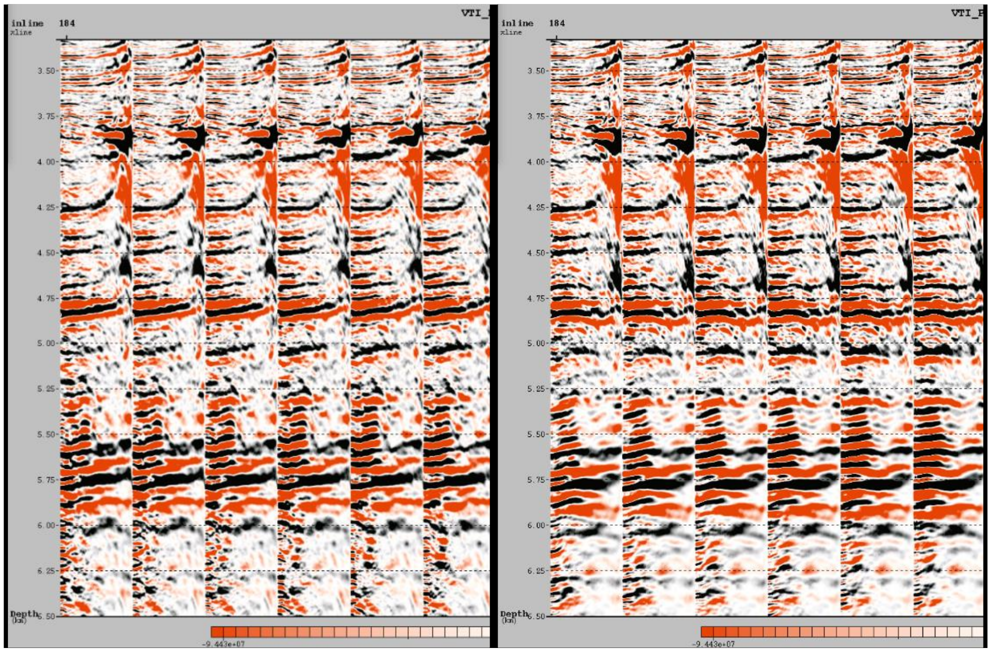
Kirchhoff anisotropic PSDM was ran using vertical interval velocity shown in fig. 5(b). Fig 6(a) and 6(b) shows PSDM Gather before and after resolving anomalous high velocity respectively at CMP location Y, shown using vertical line in Fig 5(a). In fig 6 (a) gathers are showing pull up effect at near offsets. This is because near offset raypaths at CMP location Y are encountering high velocity anomaly. Consequently, with unresolved anomalous high velocity, near offsets traces are being migrated with a velocity too low than the velocity they actually encountered.



(a) (b)

Fig 6: PSDM gathers (a) before resolving anomalous high velocity (b) after introducing high velocity at CMP location Y as shown in fig 5 (a)

Since far offset raypaths are undershooting the anomaly, they are unaffected by it. And as it can be observed in the fig. 6(b), gathers are flattening after introducing high velocity.



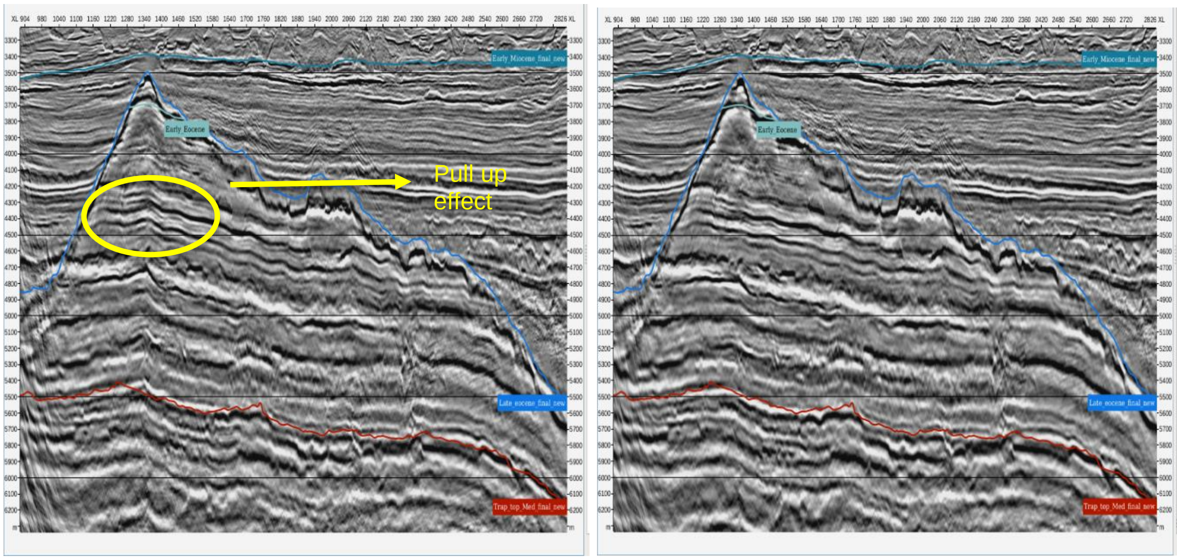
(a) (b)

Fig 7: PSDM gathers (a) before resolving anomalous high velocity (b) after introducing high velocity at CMP location X shown in fig 5 (a)

Fig 7 (a) and (b) shows PSDM gathers comparison before and after resolving anomalous high velocity respectively at CMP location X which is in left of geobody A as shown in Fig 5(a).
Velocity was only changed for the geobody A and no velocity change was introduced at CMP location X. Still gathers are becoming flat after introducing high velocity because raypaths of far offset traces at CMP location X are propagating through the geobody A. Consequently, with unresolved high velocity anomaly, far offsets traces are being migrated with a velocity too low than the velocity they actually encountered, manifesting as pull up distortion at far offsets.
Such raypath distortions resulting from localized heterogeneity can be confused with anisotropic behavior. Although, in some sense, all anisotropy could be described as resulting from heterogeneity, the effects we are reviewing here are velocity changes on a scale length less than the acquisition spread length, but large enough to be readily included in the velocity model. A rule-of-thumb for distinguishing between this class of heterogeneity and anisotropy is the rapidly varying and inconsistent behavior of the phenomenon when it results from heterogeneity. If the observed effect was a result of real anisotropy, there would be some spatial consistency in its higher order moveout behavior (Ian F Jones,2012).

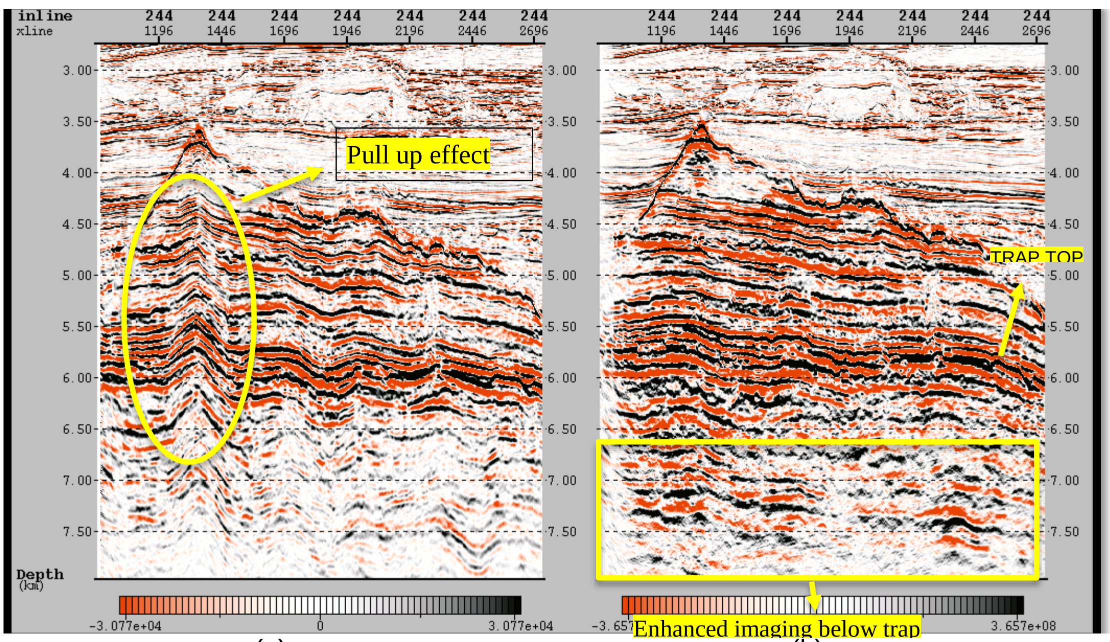
Stack comparisons before and after resolving high velocity anomaly

A. Fig 8(a) and (b) shows stack comparison before and after resolving anomalous high velocity respectively. Pull up effect below geobody A can be observed in fig 8(a) , but after introducing high velocity pull distortion was eliminated and flat layers were achieved below geobody A.



(a) (b)

Fig 8: PSDM stack (a) before resolving anomalous high velocity (b) after introducing high velocity



(a) (b)

Fig 9: Comparison between (a) PSTM stack scaled to depth (b) PSDM stack, showing enhanced imaging below trap top in 8(b), eliminating pull up effect distortions present in PSTM stack due to high velocity anomaly

Comparing the PSTM stack (scaled to depth) and PSDM stack from fig.9, it can be observed that structures below trap (basalt) has been enhanced significantly and distortions that were present in the PSTM stack section are eliminated in depth migration, because of the ability of depth migration to deal with lateral velocity heterogeneity.

Conclusion

Unresolved velocity anomalies of overburden can produce subsurface images which are distorted and restrict better imaging in deeper levels. It misguides our understanding of the area. And hence affects our decision making.
Vertical, interval velocity for geobody A was calculated using sonic log and was used for Kirchhoff migration. Considerable improvement below basalt was achieved after depth migration in comparison to time migration. Comparisons were made before and after the introducing anomalous high velocity. Distortions due to unresolved velocity anomaly were eliminated in final depth migration.

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