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Comparative Analysis of Kirchhoff and Beam Pre-Stack Depth Migration for OML (XYZ) Field Offshore Niger Delta

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Abstract:
3D Seismic data were analyzed for comparisons between unmigrated and migrated seismic section. Kirchhoff and Beam Pre-stack depth migration are two methods used in seismic data processing, a step which focuses events by repositioning dipping reflections into their correct location and collapse diffractions into a point as hydrocarbon reservoir traps could be an anticline, termination of dipping layers at a fault or unconformity. Seismic data were acquired from OML (XYZ) field in Niger Delta and processed for correction of dipping events for proper imaging of subsurface structures. Depth migrationutilizes the assumption that correct velocity model produces flat migrated gathers. Therefore, a velocity model was built and the images obtained after two iterations were used for the final migrationusing Kirchhoff Pre-stack depth and Beam Pre-stack depth methods for comparisons. In area of complex geologic formation, the images of KPreSDM were fragmented and migration artifacts were seen whereas Beam migrated gathers shows continuity for proper identification of faults, folds and diapers. Kirchhoff images had true amplitude which can be used for AVO studies while Beam PreSDM enhances the amplitude seen on the seismic section and this is not good for AVO studies, though could be useful to view the reflectors if they are flat or not. Beam migration is good because they are not easily attenuated.Its ability to penetrate deeper into the subsurface guaranteed it usefulness for Seismic inversion analysis.

Keywords: *Beam, complex geology, depth migration, Kirchhoff, Pre-stack, Velocity model*

1. Introduction

Seismic records are full of diffracted energy and random noises which affect the true image of the earth's subsurface (Gray et al,1998). Seismic migration provides images of the earth's subsurface for geophysicists and geologist to decide on prospective location of hydrocarbon traps (Yan and lines, 1999). Migration is a central step in the seismic data processing flow which is a culminative standard for data process and provides input for several relatively exotic nonstandard processes(Gray et al.,1998, 2002). It is a wave equation based process that removes structural distortion present from early reflection records by moving events to their correct spatial locations, and by collapsing energy from diffractions back to their scattering points. 3D seismic data often produces irregular trace spacing as the sources to geophones distance increases the time for a signal to arrive increases, and when plotted on a time versus distance graph the data forms a hyperbola extending across the traces. This distribution is due to the mathematical relationship relating velocity and offset distance. According to Ducan and Satherwhite (1997) this geometric effect is corrected using a procedure known as Normal move out (NMO) to suppress steep dip energy on stacked records (Gray et al., 1998). When NMO has been accounted for the reflecting surfaces across the traces have not been corrected back to the horizontal position, then it is possible the reflective layer is dipping. Dip move out (DMO) then attempts to correct the seismic recording for the remaining deviation from the horizontal (Ducan and Satherwhite, 1997). If this procedure corrects for the difference, then the degree of dip can be calculated as the slope of the deviation (Ducan and Satherwhite, 1997). If anomalies remain in the distribution of data, other factors such as migration may account for this problem to flatten the reflector. This process may be performed either before or after stacking; hence we have the terms pre-stack and post stack, migration pre-stack migration (Ducan and Satherwhite, 1997). Pre-stack migration is essentially the adjustment of seismic data before stacking sequence occurs. Its application improves the quality of the results obtained in region with highly complex structure and with velocity variation. Pre-stackmigration is run when the post stack migration has failed to resolve the layer or structure.Identification of images of complex structures such as diapirs and salt (Wedge) in the offshore of

Niger Delta had been a challenge due to lateral velocity changes, high velocity contrast to surrounding sediment which create a lens that distorts the wave field probation.Therefore, events observed on seismic stacked section do not relate in an obvious manner to the positions of reflecting interfaces and scatters within the earthas a result ofthe effect on seismic section dipping bodies appearing at different locations rather than directly above the reflectors in terms of depth, length, dip and size of fold limbs(Imuere,2006).This paper compares the Kirchhoff and Beam migration algorithm to see which method gives a better resolution of the subsurface reservoir structures. Since both methods give different result,due to signal to noise ratio enhancement capacities consideration to boast both Kirchhoff Pre SDM and Beam pre SDM to yield better images of the subsurface complex geology, delineate fault planes, discover drilling targets and image reservoir more accurately.3D pre stack depth migration has been conceptually available for decades (Schneider,1978) Pre SDM is required for the production of high quality 3D images where there is strong lateral velocity changes such asat salt wedge and diapirs (Jain and Wren,1980).

2. Kirchhoff and Beam Migrations

Kirchhoff migration has its origin in the diffraction stack methods of the 1960's (Robinson, 1983). French (1975) and Schneider (1978) showed clearly that these methods were founded on Kirchhoff integral solution to wave equation. Kirchhoff migration has been the workhorse of pre-stack seismic imaging for over decades.(Vienna/EAGE, 2006). It allows time and depth migration methods to be incorporated within a single basic program to facilitate target-oriented migration and enables straight forward migration velocity analysis. While the imaging accuracy of single arrival, Kirchhoff Pre-stack depth migration has been sufficient for all but the most challenging structural imaging problems, accuracy comparisons with many wave field extrapolation methods have often brought out its short coming in particular. In complex geology where several arrivals are required to give well image (Vienna/EAGE, 2006). According to Schlumberger (2014) KPre SDM is the most widely usedmethod for migration algorithm in the oil and gas industry today and has set a standard for depth imaging despite its disadvantages. On other hand Beam migration is a CCGV algorithm for migrating of anomalies found in the subsurface. The development of recent technology into Beam migration methods which comprises of combining aspects of Kirchhoff migration with some novel pre-processing led to the result of an enhanced version known as controlled Beam migration (CBM). Controlled Beam migration enhances image signals to noise for better easy-to-interpret structures images in complexgeologic areas. Therefore, it has been widely used for velocity model building, structural imaging and imaging of sparse and noisy data. Features of Beam migration techniques are familiar applications that maintain the flexibility of~~in~~ Kirchhoff migration algorithms. Theseincludes dip imaging, efficient incorporation of anisotropy and target oriented output lines and gathers (Gray et al,2002). The addition of multi-pathing into Beam migration algorithm proved that it can produce better images than single arrival Kirchhoff in more complex geology (Gray and May,1994).

3. Materials and Methods

CGG Veritas acquisition ship with dual sources and 8 streamers was used for the acquisition of 3D seismic data in part of the offshore Niger Delta. The recording length was 7.680s with a 2ms sampling intervals. The area covers were about $390km^2$.The bin size was 12.5m for both inlines and crosslines and CGG Geovasion software was used to build a velocity model for Beam Migration. Seismic reflection data obtained from this 3D survey was acquired by Petroleum Geosciences (PGS) in part of offshore Niger Delta basin and processed using KPrestack and BPrestack depth migration algorithms for accurate interpretation of the subsurface reservoir structure under certain conditions to see which method gives a better image of the hydrocarbon traps. Kirchhoff migration uses ray tracing which deal with single arrival. It is a method that describe the kinematics between the source and a receiver both located on the earth's surface, a sample at time on a primaries only unmigrated trace might contain energy reflected from point in the earth for which the total travel time from source to reflector to receiver is t. in a constant velocity earth, this locus of points is the bottom half of an ellipsoid in three dimensions with a focus at the source and a focus at the receiver therefore a single spike on an unmigrated trace, migration has no choice but to spread out the spike over the locus of all possible reflection points at the bottom of the ellipsoid.(Gray et al.,1998; 2002). Kirchhoff migration works by repeating this process for all samples on all input unmigrated traces, summing each resulting ellipsoid's contribution into the output image as it goes. That is, Kirchhoff migration is obtained by adding together partial images from migrating individuals input traces resulted from density contrast in depth varying velocity fields. This Prestack migration was shot record at a time. The major advantages of Kichhoff migration over other methods are its flexibility and its ability to handle lateral velocity variations with relative efficiency (Gray et al, 1998; 2002) whereas Beam migration is a generalization of Kirchhoff migration that operates in the frequency wave number as well as the time space domain, and allows for multipathing in a natural way. ((Gray and May,1994; Gray et al,1998; 2002) Beam migration as a wave field continuation method operates on common-offset common azimuth data volumes. The wave field continuation itself provides a kinematically correct imaging condition while the migration is similar to Kirchhoff migration. Beams are obtained from the solution of dynamic ray equations; they produce the wave field at points, some distance away from the ray path. Progating the recorded energy along a particular beam and applying an imaging condition gives part of the total migrated image; the total image is the sum of the contribution from all the beams migration solves many of the imaging accuracy problems of single arrival Kirchhoff migration while retaining many of the advantages of the Kirchhoff method including its ability to image steeply dipping or overturned events, as well as imaging in the presence of TT1 anisotropy.

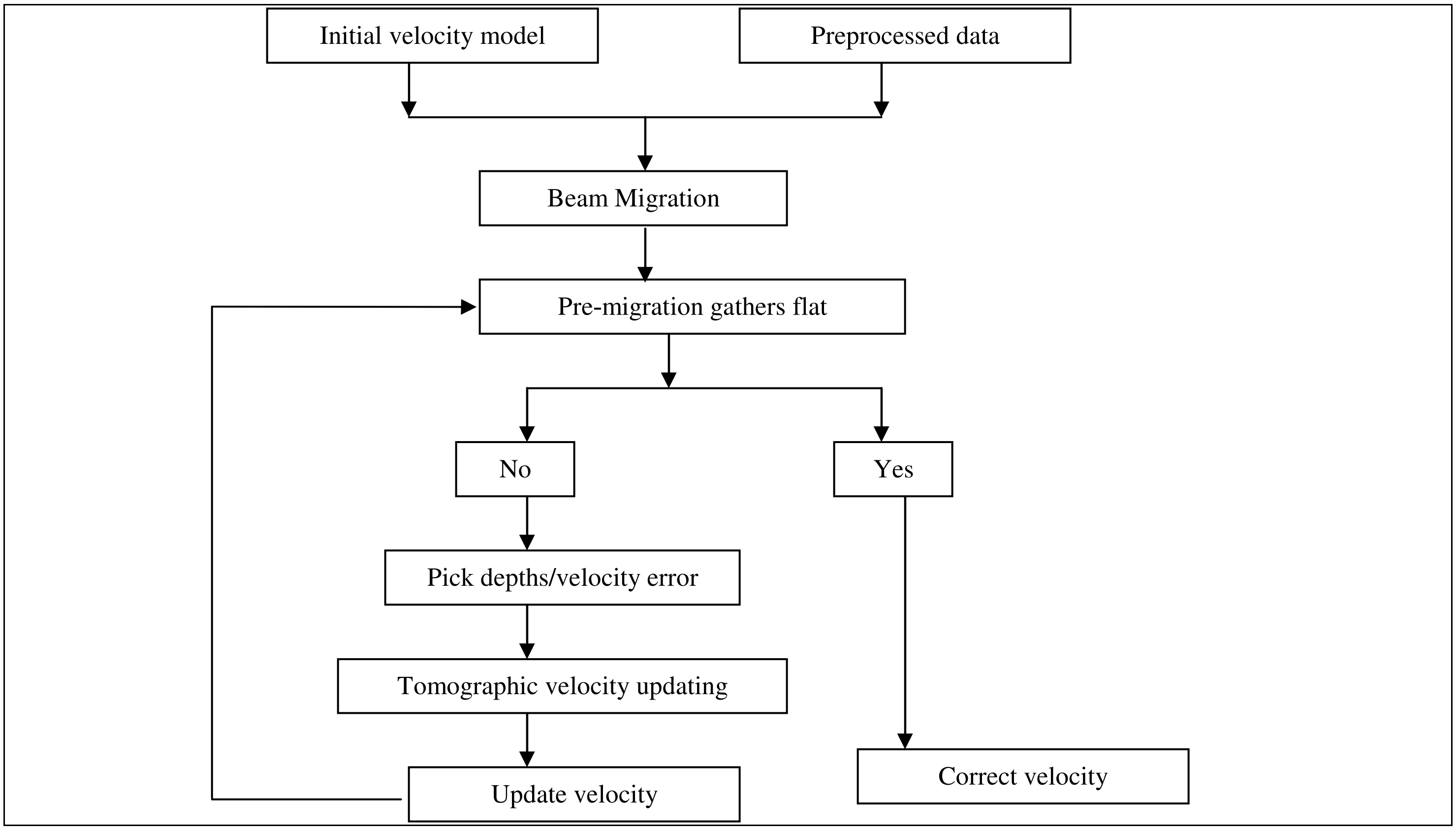

Figure 1: PreSDM work + low showing single velocity iteration

4. Result

Preprocess Prestack unmigrated section is shown in Fig. 2 this is the data input before migration of both methods were done. Fig. 3 and Fig 4 show the diffraction collapsed by both KPreSDM and BPreSDM but Control Beam migration boost the amplitude of the reflectors as shown in Fig. 4. Amplitude is enhanced down dip in the stack and therefore the events are visible. This is as a result of low frequency of Beam migration. But sometimes Beam migration can misrepresent the true amplitude while Kirchhoff preserve the true amplitude that enable it usage for AVO analysis. Fig 5 and Fig 6 shows the result of Kirchhoff Prestrack depth migration around a fault zone with migration artifacts. This resulted from the fact that Kirchhoff migration incorporates a single arrival to image subsurface event. This is why KPreSDM was untenable to image the synthetic growth faults in the region accurately, whereas Fig 6 shows a scale Kirchhoff PreSDM, the events is clear and better than ordinary Kirchhoff section, the reflections are continuous event down dip through migration artifacts are formed along the fault planes which distorts the reflectors and makes it difficult to identify the up thrown and down thrown sides of the faults.

Figure 7 shows Beam PreSDM which vividly images both the regional and antithetic growth faults. Both faults were not properly identified in Kirchhoff PreSDM. CBM (Beam PreSDM's) ability to clearly image the reflectors surrounding the fault is due to the fact that beam uses multiple arrivals to image the subsurface.

5. Discussion

3D Prestack depth seismic data from offshore Niger delta obtained from Petroleum Geosciences (PGS) through the assistance of the Department of Petroleum Resources (DPR)in Nigeria. This offshore seismic data went through all the necessary preprocessing steps, and velocity model was developed, that is, built using the (CGGV Nigeria limited software and tomography update went through two iterations before the gathers were flat enough for migration. This preprocessed data was subjected to both KPreSDM and BPreSDM, both methods used ray tracing and the same input parameters such as 3D seismic data, tilted transverse isotropy (TTI) and velocity model. Prestack depth migration workflow dependson the assumption that correct velocity will produce migrated gathers because if migrated gathers are not flat, itshows the presence of velocity error. The velocity model went through common image gathers (CIG), picking and nonlinear tomography inversion to produce an updated velocity model. The correct velocity model was used for the final migration.

In this work, there were two velocity iterations before the migration gathers were flat enough. The corrected velocity model was used for the computation of a travel time map using a ray tracing algorithms.

5.1. Fault Imaging Along Inline 1290

At inline 1290, we notice clearly the difference in resolution between both migration algorithms, when Kirchhoff PreSDM was enhanced as shown in Fig. 8, the amplitude is good, but it still struggles to resolve faults. Faults are known to be conduits for fluids

movement and also form trapping mechanism for hydrocarbon when the fault is sealed. Failure to identify a fault will lead to failure to identify reservoir; despite the fact that the reflectors are seen continuous across the section.
At inline 1290 shown in Fig. 9, we can also notice the difference when Beam PreSDM algorithm is used to image the same inline. We observed that more anti-regional faults can be seen on the section. The amplitude seems to be artificial which gain will not allow AVO to be done on the data.

5.2. Low Fold Imaging of the Study Area

Fig. 10, 11, 12 and 13shows the results of KPrestack depth migration and BPrestack depth migration for low fold imaging. Beam migration uses multiple arrivals to image fold clearly because it can make use of both narrow and wide Azimuth compared to Kirchhoff whereas KPrestack depth migration could not resolve coherent image below the folds as a result of its use of single ray.
For shale diapers and domes, velocity variation contrast between surrounding sediments field creates a lens that distort the wave field propagation. The application of Kirchhoff and Beam PreSDM, Beam gives a better and clear image of the subsurface event.

6. Conclusion

Obviously, 3D seismic data are full of diffracted energy and noises which affect subsurface images. Secondly, it acquisitions geometries often produces irregular trace spacing and Kichhoff and Beam migration methods are two current practical approach that can be used to remove this effect. Beam migration started out as a niche imaging application to fill the gap between Kirchhoff and one-way WEM methods, but right now it is considered as a powerful imaging tool. This is demonstrated through the range of applications and geographical extent of its usage. It was severally observed that in areas of complex structure and geology, images of KPreSDM were fragmented and migration artifacts were seen on the seismic data. Beam migration was therefore more suited for imaging of faults folds and diapirs better than Kirchhoff migration could in areas of lateral velocity contrast between surrounding sediments field, and velocity changes creates a lens that distort the wave field propagation. Kirchhoff migration images were seen to preserve amplitudes which ~~is~~ are necessary for amplitude variation with offset (AVO) analysis and to mographic velocity estimation while Beam migration sections were seen to have low frequencies. Both migration method mentioned in this study were found to be relevant in subsurface imaging despite the short coming of Kirchhoff migration though Beam migration has the better resolution for depth imaging. I recommend that both the international Oil Companies and Marginal Oil field operators (owners) should consider using Beam migration algorithm for proper imaging of the diapiric structures, faults and folds in area of complex geologic formation as this may lead to clear imaging of the surrounding sediments structures and eventual discovery of more reservoirs downdip.

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Annexure

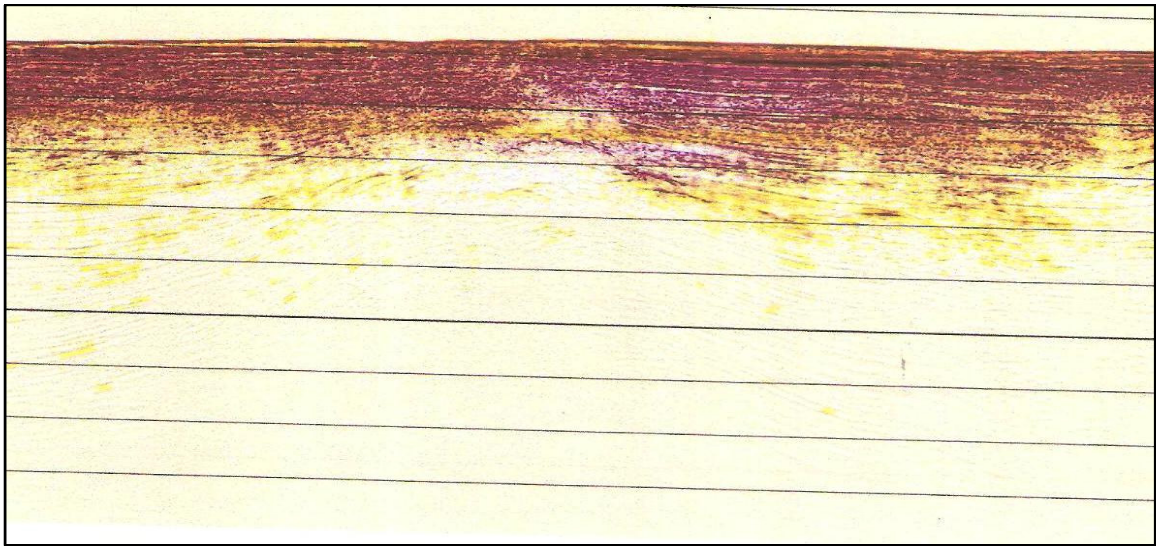

Figure 2: Section shows Input data before Migration. Diffractions are presents

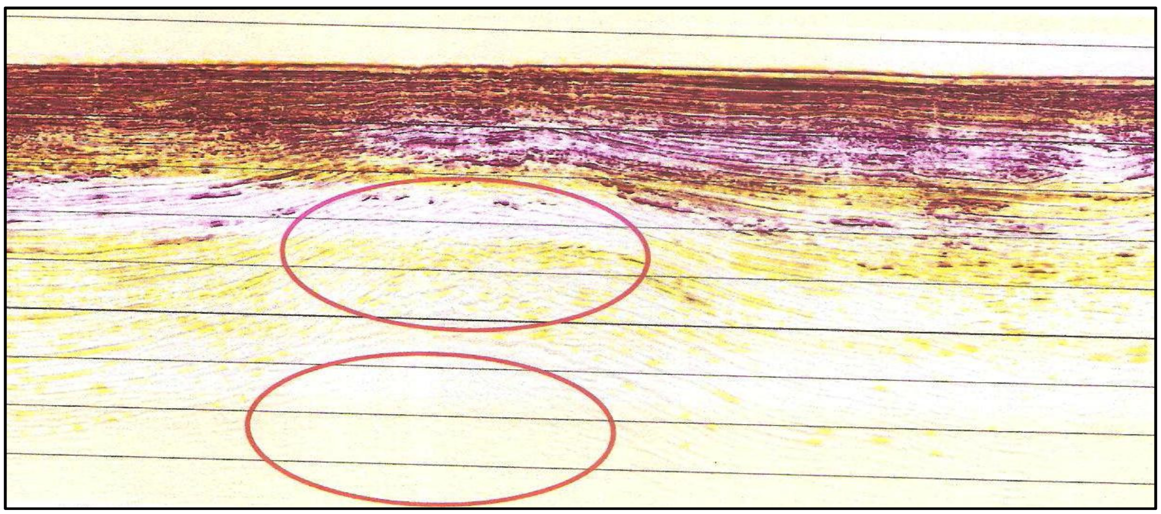

Figure 3: Kirchhoff Pre SDM.

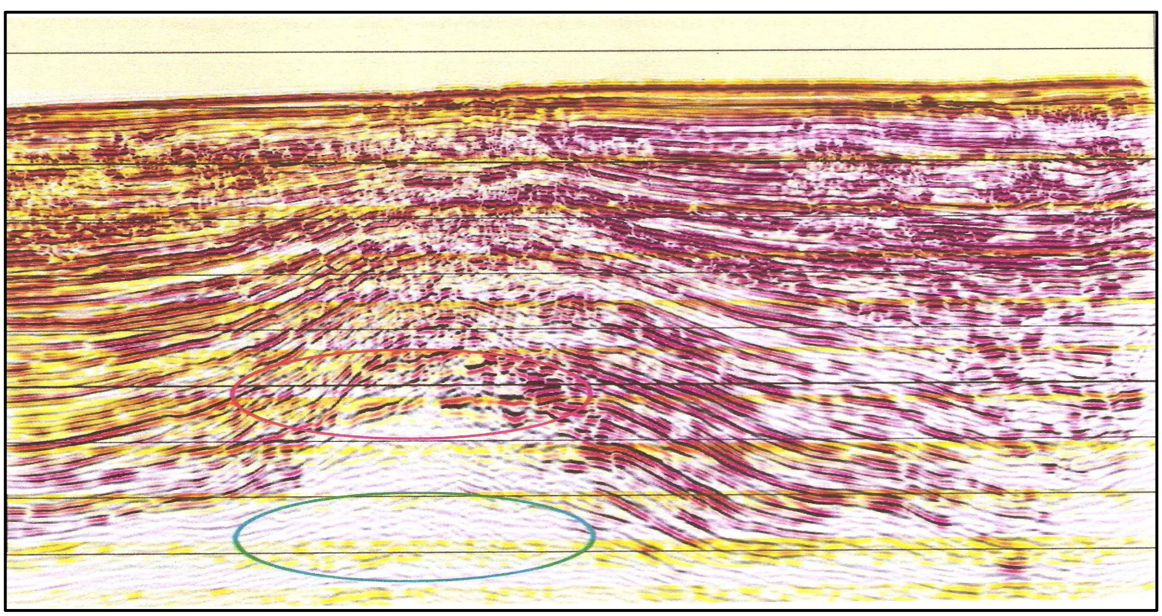

Figure 4: Beam Pre SDM.

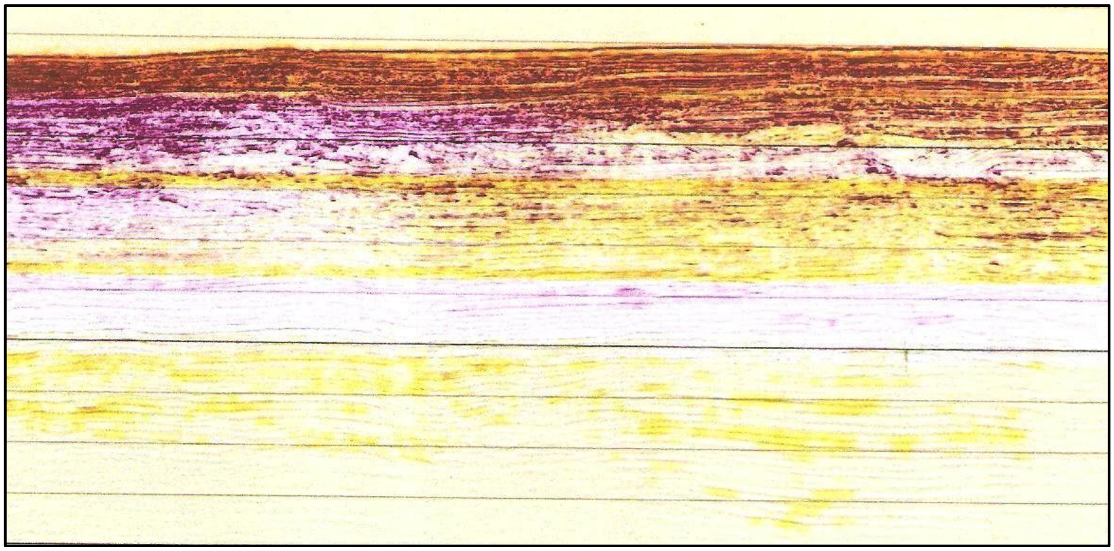

Figure 5: Kirchhoff PRESDM section

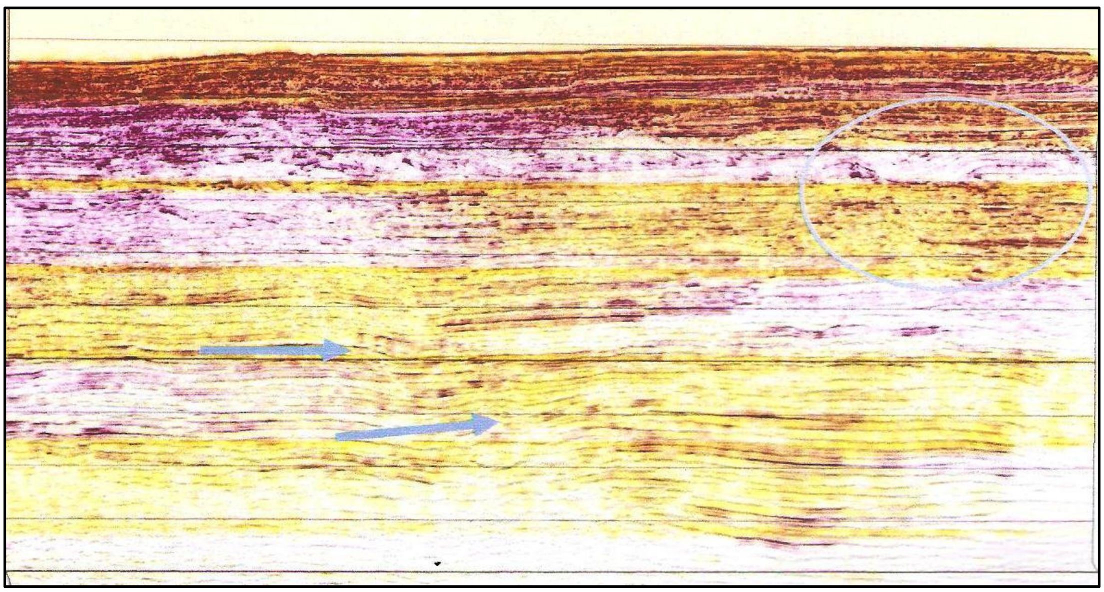

Figure 6: Kirchhoff PreSDM scaled

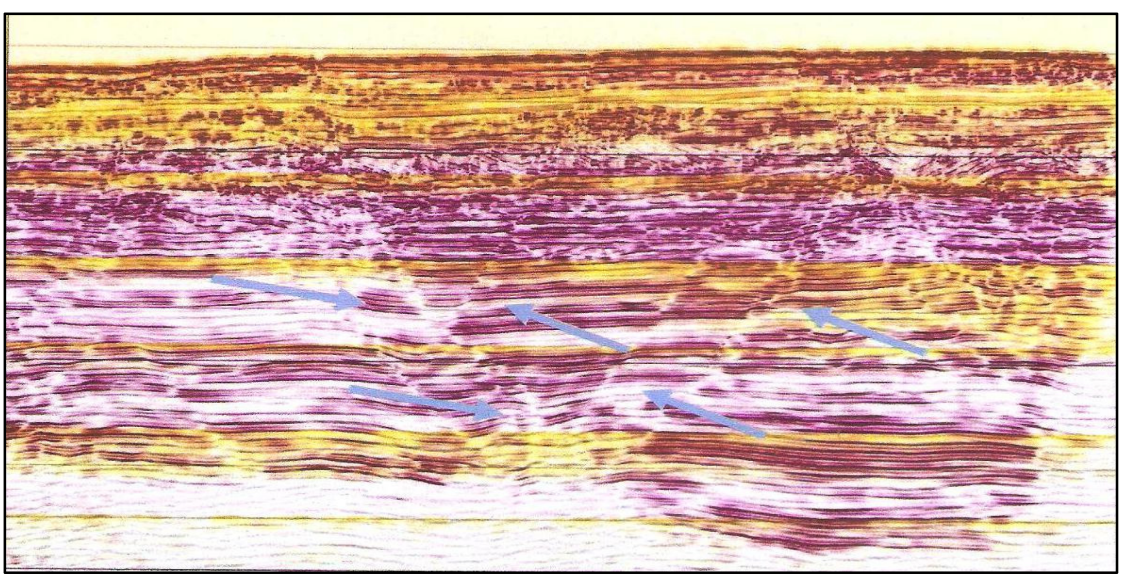

Figure 7: Beam PreSDM Clearly delineates several faults

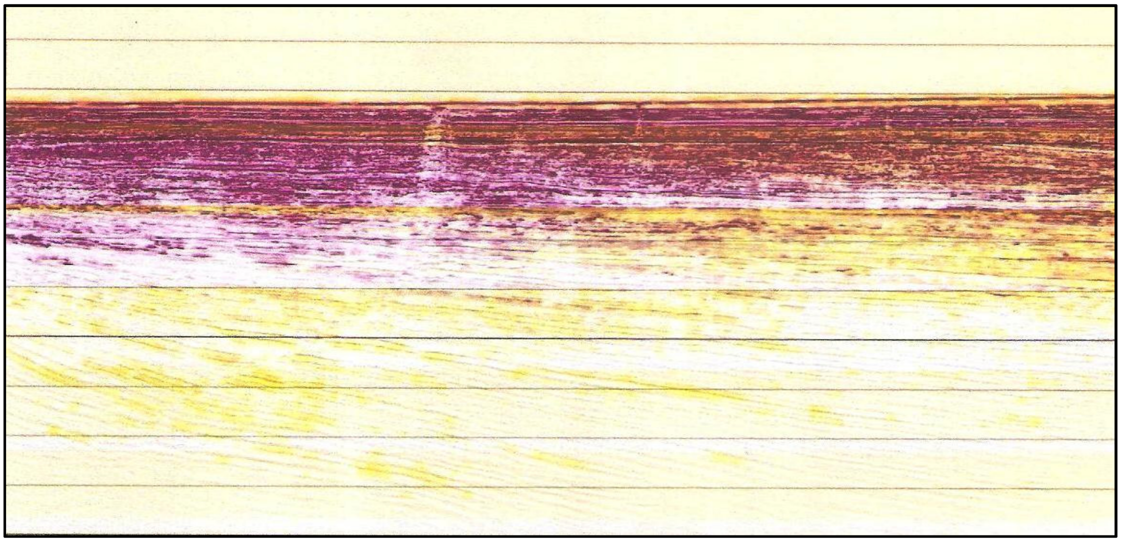

Figure 8: Kirchhoff migration struggle to resolve the faults. At inline 1290

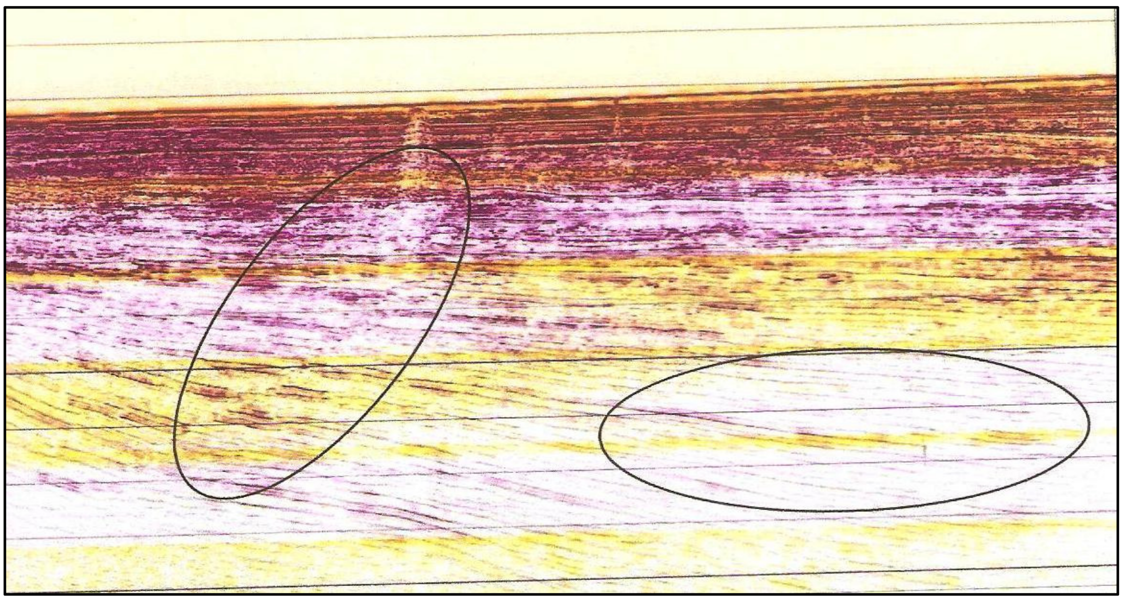

Figure 9: Enhanced Kirchhoff shows migration artifacts

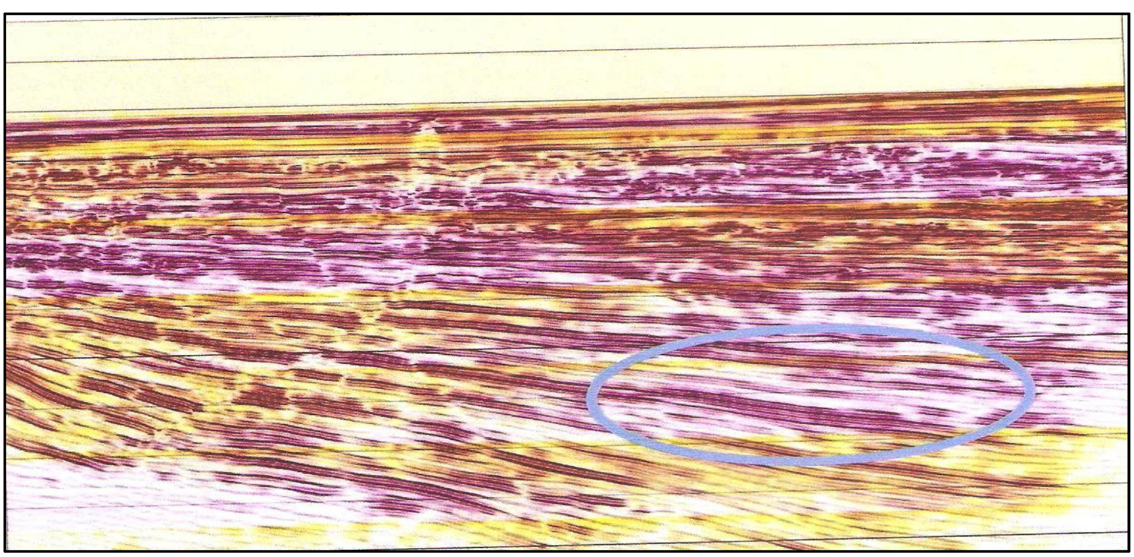

Figure 10: Beam PreSDM resolves faults (below) inline 1290

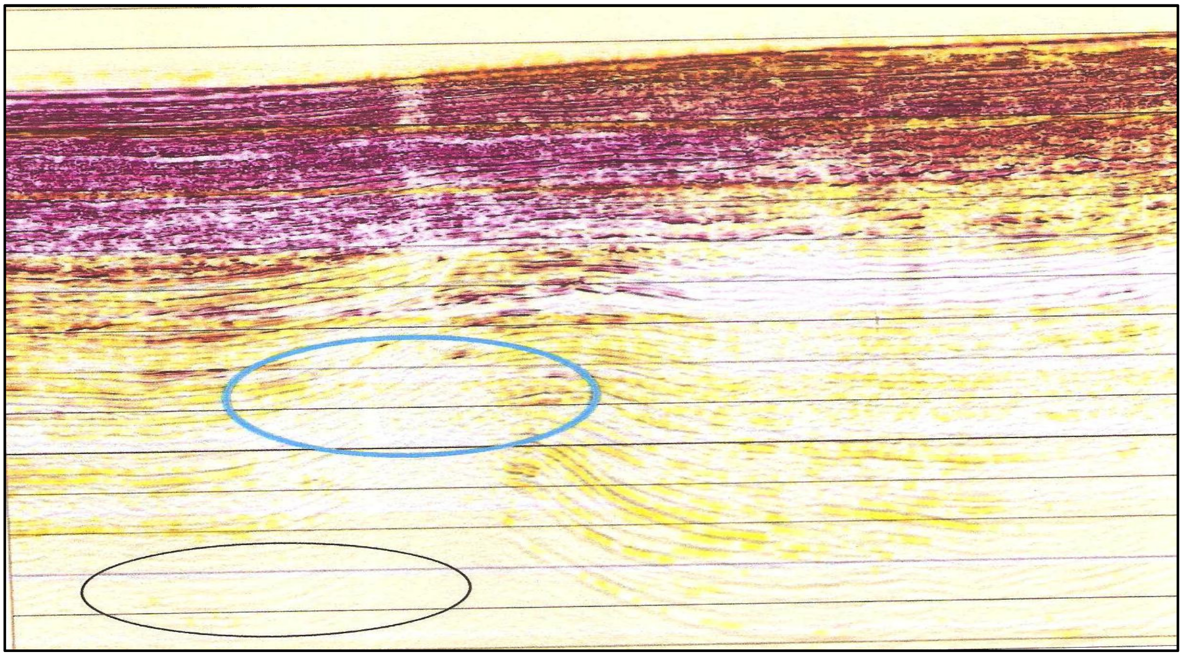

Figure 11: Kirchhoff imaging of low fold. It is noisy and no coherent image below the fold

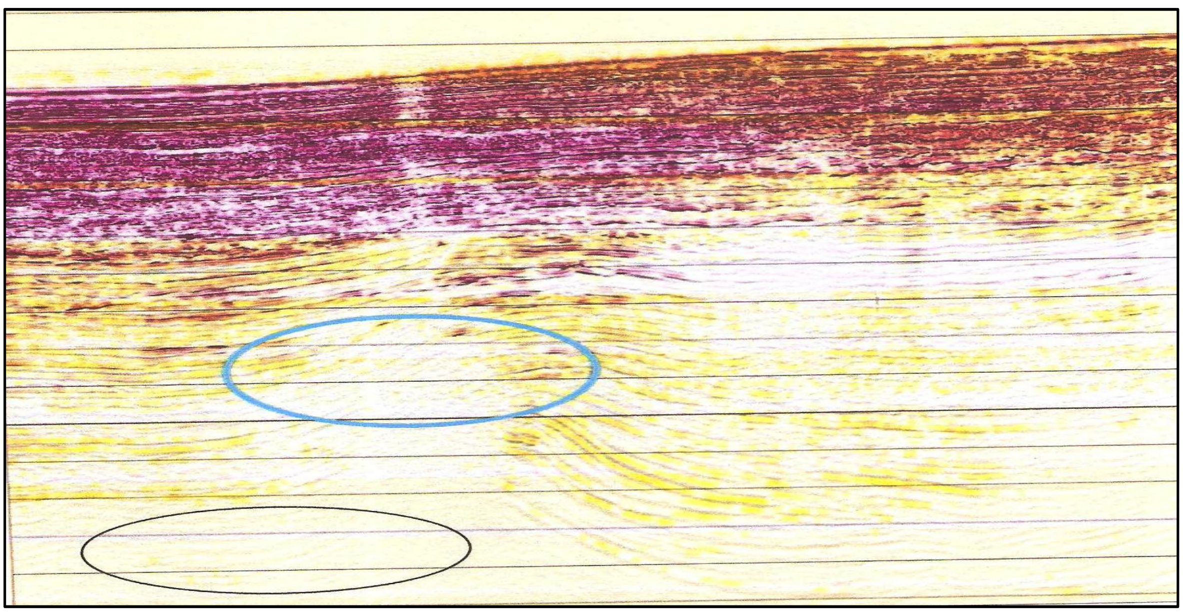

Figure 12: Kirchhoff Migration imaged completely the fold and the reflectors where continuous

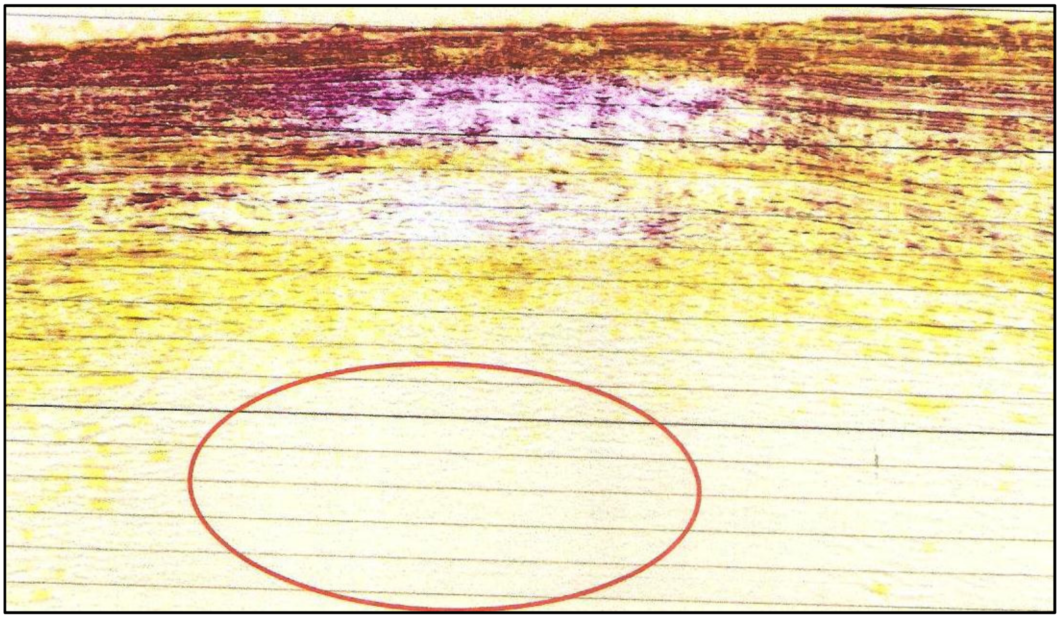

Figure 13: Kirchhoff Migration nosy and showed low amplitude

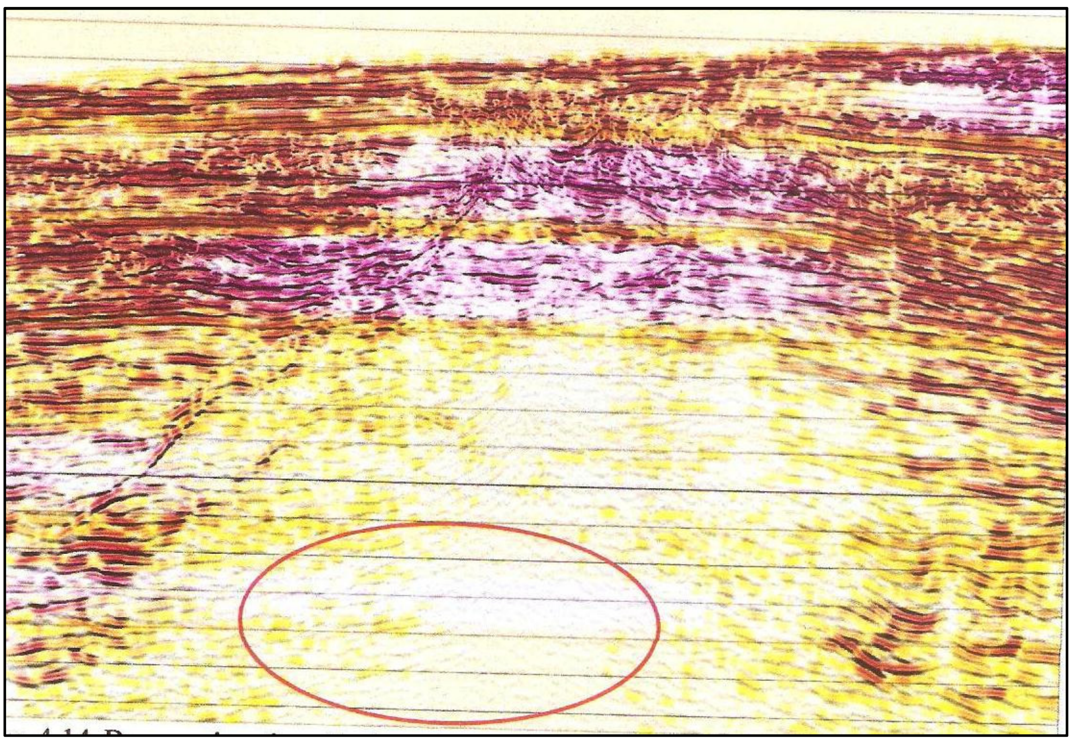

Figure 14: Beam Migration displaced clearly the reflectors than do Kirchhoff