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Improving the Seismic Image Quality in Semi-complex Structures in North East Iran by the CDS Stack Method

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SUMMARY

One of the main problems in processing is imaging complex or semi-complex structures. A modified version of the CRS stack, the common diffraction surface (CDS) stack, is a method that, could solve the problem of conflicting dips that may happen frequently in complex and semi-complex structures. To investigate whether it could solve the imaging problem in such media, a seismic data set from north east of Iran was selected for this purpose. The CMP-stacked section of this data shows an unconformity that separates horizontal event from dipping events. The problem is the part of the section below the unconformity, where the reflection and diffraction events are not imaged well, like as the faults in horizontal events. Therefore, the CDS stack method is applied to the seismic data to solve some of the imaging problems in semi-complex structures. The CDS-stacked section imaged many reflection events missing in the CMP-stacked section. The problem of conflicting dips is also resolved in that section. The faults can be located and the reflection events at larger travel times are also well imaged. Finally, the CDS-stacked section shows that this method could resolve some of the ambiguities of imaging in semi-complex structures.

Introduction

Working in complex and semi-complex structures requires new processing's methods to solve the problems of imaging in those situations. In those geological conditions, some problems like as defining the boundary of salt diapers or mud volcanoes, defining the location of faults, folding systems and unconformities, identify the reflection events below that structures and the problem of conflicting dips, are difficult to handle. The newly introduced method of common reflection surface (CRS) stack (Hubral, 1999) and the later method that was a modification of CRS stack under the name of common diffraction surface (CDS) stack (Soleimani, et. al., 2009b) beside the technique of prestack depth migration (PSDM) could be used in such situations. To solve the problem of imaging in this situation, a seismic data set was selected for application of the CMP stack method, defining the problems in imaging and solves the problems by applying the CDS stack method to them. The seismic data was selected from a sedimentary basin in north east of Iran, Gorgan.

The Gorgan region

The Gorgan region is located in the north east of Iran, near the Turkmenistan border. Therefore, it could be assumed that the region is rich in gas reservoirs. It is also near some of the large gas reservoirs in north east of Iran. Thus, many exploration efforts like gravimetry and seismic surveying have been done in recent years. In most of these surveying, the mud volcanoes were a key guide for locating the line of the seismic surveying. Therefore, many seismic sections related to this region are influenced by the effect of mud volcanoes. Defining the boundary of a mud volcano is one of the difficulties in time or depth sections in data from this region. This problem could be worst when it combines with unconformities without clear boundary. It will introduce many diffraction hyperbolas that not only increase the noise in the data but also enforce the use of other processing techniques apart the conventional steps. The other severe problem that may happen in such complex geological conditions is the problem of conflicting dips that will be addressed later. The other problem that is the result of this geological condition is the continuity of the events that is not well preserved in the seismic sections in such situations. Some of the alternatives that could be used in this situation rather than the conventional processing methods are the common reflection surface (CRS) stack method or the common diffraction surface (CDS) stack method.

Conventional imaging

To see whether the problems addressed above could be solved, a seismic data obtained near a mud volcano was selected for processing. Although this profile has 200 m offset from the location of the mud volcano, its effect could be easily seen on the data. Firstly, the data was processed with the conventional NMO/DMO/Stack method, after applying pre-processing on the data. The surveying has been performed on a flat surface. Therefore, there was no necessity to perform a static correction. However, filtering and deconvolution were the other steps performed on the data. Figure 1 shows the result of CMP stacking. As it could be seen on the section, the upper part of the section, at small travel times, there are horizontal flat events. The obvious unconformity could be easily seen under these horizontal events. The unconformity is not horizontal but dips to the right. Therefore, the thickness of the top flat layers is increase through the right. The unconformity is imaged well in this section and could be easily traced in the entire section. The exact location of the intersection of the dipping events under the unconformity with the horizontal events is an important question in this section that happens in the left end of the section. The top events in the right part of the section are not horizontal anymore but have an anticline shape. Figure 1 shows that many events below the unconformity are not imaged well, especially at travel times larger than 4 s. It could be seen in the section that below this traveltime, there are some reflection events that are not imaged well in the stacked section. In the left part at times between 2 s and 4 s, many diffraction events are present that intersect with the reflection events. Diffraction events increase to the right where many diffraction events intersect each other and will make it difficult to have a suitable image of the events below the unconformity. Diffraction events also exist in the far right of the section that cover the middle part of the section. However, between two distinct diffractions in CDP numbers 800 and 1500, below the unconformity, a dipping reflection event of low continuity could be seen: It disappears in some parts where it intersect the strong diffraction event in its right. The other questionable parts in the section are the reflection events between the above mentioned CDP numbers but at times between 5 s and 6 s. These reflection events are only imaged in this part, while they could not be traced any more in the other parts of the section. All the problems that exist in the CMP stacked section can be summarized as follows: defining the boundary of the unconformity and the exact intersection location of the dipping events and horizontal event in the left of the section, the discontinuity of the reflection events in most parts of the section especially in the mid part, the conflicting dips problem of the diffractions and reflections that becomes severe in the right of the section, and imaging missed reflection events through the section and below the time of 4 s. These are important problems in the section, beside the signal-to-noise ratio which is another problem that should be addressed here.

CRS & CDS stack methods

The Common-Reflection-Surface (CRS) Stack (Hubral,1999), is a data-driven imaging method to simulate a zero-offset (ZO) section. Introduced by Müller (1998) as a ZO simulation method for 2D, it does not require an explicit knowledge of the macro-velocity model. For the 2D case, the shape of the operator depends on three parameters and can be considered as the reflection response of a circular reflector mirror segment, the so-called CRS (Jäger, 1999). Any contributions along any realization of this operator are tested by coherence analysis for each ZO sample. The CRS stack has the potential to sum up more coherent energy of the reflection event which results in a high signal-to-noise ratio in the simulated ZO section (Mann et al., 1999a). However, in each ZO section we could see that in some cases the events intersect each other. It is obvious that at samples where such events intersect, a single stacking operator associated with only one triplet of optimum attributes is not sufficient. This is the case in the CMP-stacked section shown in Figure 1. The CRS equation with its three attributes reads (Jäger, 1999)

$$t_{\mathrm{hyp}}^2(x_m,h)=\left[t_0+\frac{2\sin\alpha(x_m-x_0)}{v_0}\right]^2+\frac{2t_0\cos^2\alpha}{v_0}\left[\frac{(x_m-x_0)^2}{R_{\mathrm{N}}}+\frac{h^2}{R_{\mathrm{NIP}}}\right] \qquad (1)$$

where R_{NIP} is radius of the normal-incidence-point (NIP) wave, R_N is the radius of the normal wave, and α is emergence angle of the normal ray. In the CRS stack method, the same idea as DMO was used to overcome the problem of conflicting dips. In this case, the shape of the operator in the depth domain is no longer the ZO isochrone but it could have any arbitrary shape. The number of conflicting dips is not of interest here, because any conflict that could be present will contribute to the stack for the sample. For each sample, a coherence analys is done for a range of angles. In the ZO section, we often encounter intersections of reflection events and diffraction events. Solving the problem of conflicting dips will enhance the usually weak diffraction events in the stacked section. As the new improved strategy not only addresses reflection events but in particular diffraction events, it is called common diffraction surface (CDS) stack (Soleimani et al., 2009a). For true diffraction events, the radii of the NIP wavefront and the normal wavefront coincide, $R_{NIP}=R_N$. Nevertheless, we can use the traveltime approximation for a diffraction event to perform stack also for reflection events. The only attribute to be searched for in a fixed emergence angle, is a combination of R_{NIP} and R_N, called R_{CDS}. The CRS operator reduces to (Soleimani et al., 2009b)

$$t_{\mathrm{hyp}}^2(x_m,h)=\left[t_0+\frac{2\sin\alpha(x_m-x_0)}{v_0}\right]^2+\frac{2t_0\cos^2\alpha}{v_0R_{\mathrm{CDS}}}\left[(x_m-x_0)^2+h^2\right] \qquad (2)$$

where the radius R_{CDS} is a combination of the radii of the NIP and normal wavefronts. Each sample in the ZO section will receive contributions from any possible optimum operator for each angle that we are searching for. Obviously, this not only increases the signal-to-noise ratio, but also enhances any weak reflection and diffraction events which were obscured by dominant coherent events. The strategy used here differs from the pragmatic CRS strategy (Müller, 1998) and the extended CRS strategy (Mann, 2001) in its way to find the optimum wavefield attributes. In this case, we require access to the entire pre-stack dataset, not only to a sub-domain of it. Furthermore, neither the automatic CMP stack nor the ZO search steps are suited to address this problem. Instead, the only option is to directly go through the whole prestack data, and search for the only variable, the attribute R_{CDS}. The target zone, the aperture, and the range for minimum and maximum stacking velocity are defined as for the pragmatic search strategy. By implicit knowledge of the value of R_{CDS}, the shape of the operator could be defined in terms of a moveout range. By coherence analysis the optimum value of R_{CDS} can be calculated in the next step.

CDS imaging

Figure 2 shows the result of applying CDS stack method to the data. As it could be seen at first glance, the quality of the section is increased and we could say that the signal-to-noise ratio is increased here. However, the most significant improvement is observed for the continuity of the events. The reflection events, especially the horizontal events in the top part are well imaged. These events are curved in the right part, but the fact that they do not show up in the CMP-stacked section, is a fault in the corresponding layers. The CDS stack operator gathers the energy that might be lost in the previous section; therefore more events with more details are imaged. It makes the imaging methods applicable to locate the location of faults and show up their trends. Imaging the events below the unconformity is the greatest advantage of using the CDS stack on this data. Differences between two the sections in this part are so evident that they could be easily seen at first glance. All the reflection and diffraction events missing in the CMP-stacked section are imaged well here. The dipping event between two distinct diffractions and the events under the diffraction in right side at large traveltimes are well imaged here. The problem of conflicting dips also solved here, although this can hardly be seen in such this small figure of such a large section with 34 km length of profile and 7 s of recording time. In some parts, especially at the location of the intersection points of the flanks of diffraction and reflection events, this fact can be seen.

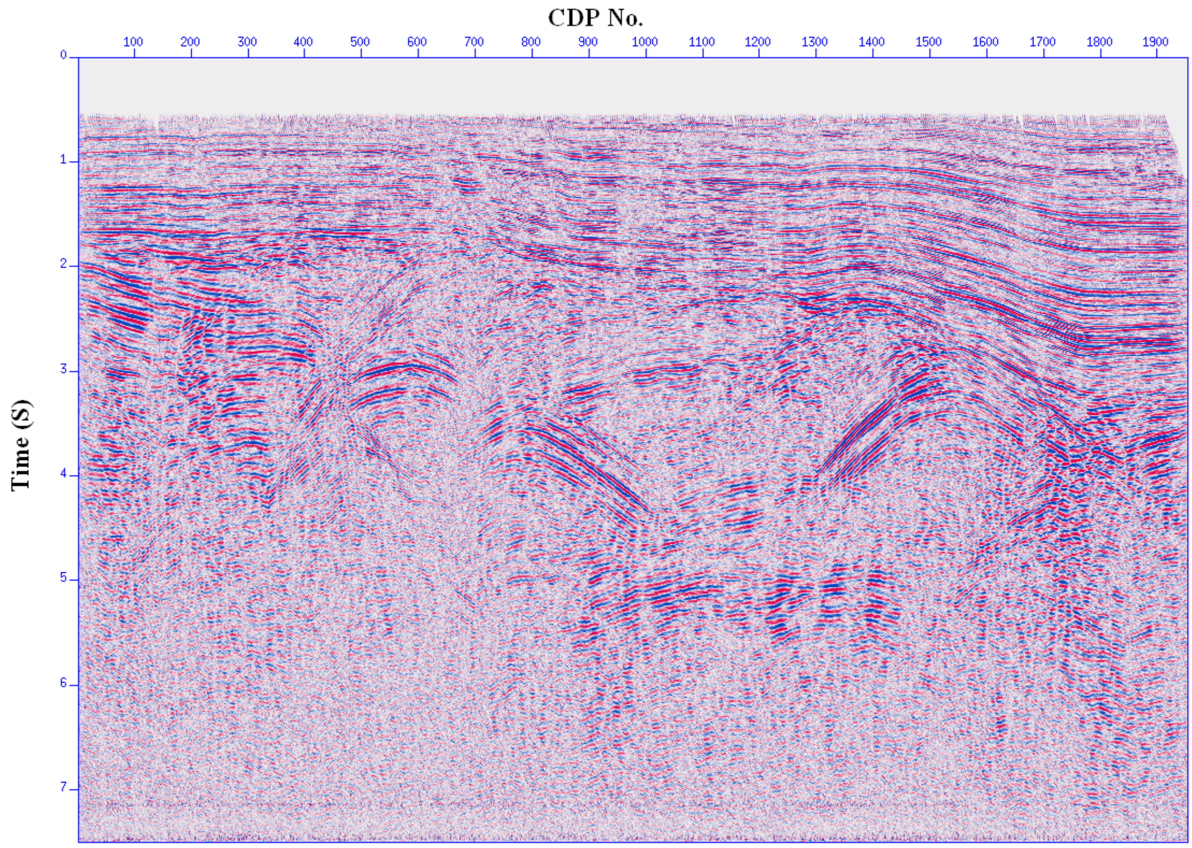

Figure 1 *The CMP-stacked section of the Gorgan data.*

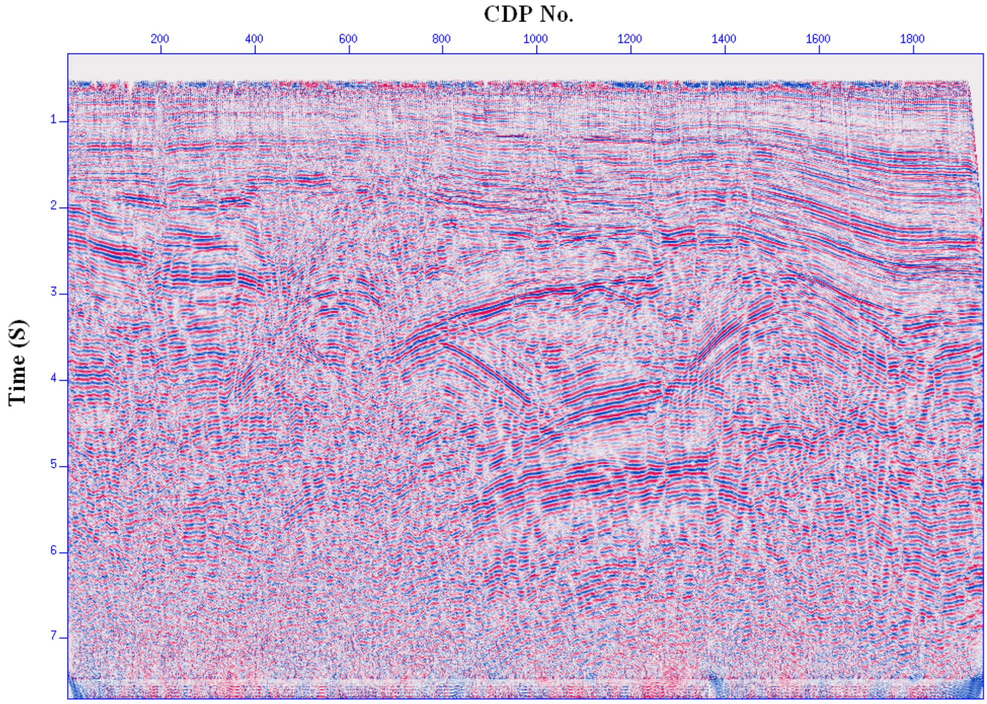

***Figure 2** The CDS-stacked section of the Gorgan data.*

Conclusions

The problem of imaging of semi-complex structures and the quality of seismic sections in such situations cannot be properly solved by conventional stacking methods. The application of the new CDS stack method to such data shows that the CDS stack method is able to overcome some of the problems in this case. The CDS-stacked section here clears most of the reflection and diffraction events that were missing in the CMP-stacked section. Although we only presented time domain images, it is evident that it will also yield a depth image by poststack depth migration with more details of the events.

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