Imaging in Complex Structures by Post-stack Time Migration and CRS Stack

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Abstract

Time and depth imaging in complex structure is one of the crucial tasks in seismic data processing. There are several methods introduced for this problem. The Common reflection surface stack is one of these methods that could give a suitable stacked input for migration. In this study, a seismic data from north east of Iran selected for processing. The stacked section contains an unconformity above mud volcano. The boundary of mud volcano and detection of conflicting points between dipping layers and horizontal layers above the unconformity are interests here. Therefore the common reflection surface stack applied on the seismic data. The stacked section could image most of the reflectors, but the problem of mud volcano boundary detection did not resolved well. The velocity model made by velocity scanning that gave a complicated model. The stacked section used as an input for migration. The migrated section resolved the ambiguities in the stacked section. The boundary of mud volcano could be detected in some parts. The confliction between dipping layers and horizontal layers were also cleared well. Some faults also detected in the upper parts of the section that continued through depths and did not imaged well in the conventional imaged section.

Introduction

The objective of seismic reflection imaging is to provide an image of the subsurface from multicoverage seismic reflection data by enhancing genuine reflection signals and suppressing unwanted energy in the form of coherent and random ambient noise (Jäger 1999). In many imaging techniques we need an appropriate macro velocity model in order to calculate further parameters and make geological section to interpret. Hubral (1999) derived a velocity model independent description of traveltimes in the vicinity of a chosen central ray. This traveltime formula depends on three parameters and can be considered as the reflection response of a circular reflector mirror segment, the so-called common-reflection-surface (CRS). The optimal stacking operator is determined by coherency analysis (Mann et. al. 1999). Thus, not only a high quality stacked section but also important attributes to determine a velocity model can be obtained by this method. The CRS stack method, in comparison to traditional methods, follows a more general approach that considers the location, local orientation and curvature of the reflector in the subsurface. The NMO/DMO/stack surface doesn't fit well with travel time surface. However, the idealized CRS operator which has been built with all CRP trajectories takes much larger part of the multi coverage dataset into account than NMO/DMO operator (Mann 2001).

Basic concept of the CRS

The CMP stack makes use of a traveltime surface approximation that is of second order in the half offset coordinate. The concepts of using second order traveltime approximation for stacking can be generalized to include also the midpoint coordinate. The stacking operator in 2D is then no longer a trajectory in time-half offset-midpoint coordinate, but is an entire stacking surface, which extends not only in the offset, but also in the midpoint direction, (Mann 2001):

$$t^2(x_m,h) = (t_0 + \frac{2\sin\alpha}{V_0}\Delta x)^2 + \frac{2t_0\cos^2\alpha}{v_0}\left(\frac{(x_m - x_0)^2}{R_N} + \frac{h^2}{R_{NIP}}\right)$$

Here α is the emergence angle of normal ray at x_0, while R_N is the wavefront curvature of hypothetic normal wave and R_{NIP} is the wavefront curvatures of hypothetic normal-incidence-point wave.

The basic idea of the CRS stack method (Jäger 1999) is to use traveltime approximation of the form of equation above as stacking operator to coherently stack reflection amplitudes in the multicoverage data in the vicinity of each zero offset sample (t_0,x_0), thus obtaining stacked zero offset section .The shape of the traveltime surface defined by equation above is controlled by three parameters; α, R_N and R_{NIP}. During the CRS stack process, optimum values for these parameters are automatically determined independently for each zero offset sample (t_0,x_0) to be simulated. This is realized by varying the parameter values (and thus the operator shape) and performing a coherence analysis along the stacking operator in the multicoverage data. The CRS stack can thus be seen as a generalization of conventional stacking velocity analysis. The three parameters yielding the highest coherency are also called kinematic wavefield attributes. The number of traces contributing to stack for each zero offset location is considerably increased, which results in an improved signal to noise ratio (S/N) compared to conventional stacking methods.

The geology of study area

The Gorgan region is located in the north east of Iran that has been located between two different geological zones. These two zones are among the several sedimentation basins that had been distributed between Iran, Turkmenistan and Afghanistan. The region is made of thick sediments from Jurassic to Miocene. These sediments are made of shale, limestone, marn, sandstone and sometimes conglomerate and evaporate. This sequence is beneath an unconformity of Pliocene conglomerates. Above this conglomerate, there exist Quaternary sediments made of river, shore and delta sediments. The Gorgan region and kopeh-dagh zone are continued in Turkmenistan, also. There are several gas reservoirs in this region that are sometimes in common between Iran and Turkmenistan. In Gorgan region, most of these reservoirs are accompanied by mud volcanoes. Therefore, mud volcanoes could be a key to locate the seismic line and search for gas reservoirs. Many exploration efforts like gravimetric 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 in seismic section is one of the difficulties in time or depth imaging in data from this region. 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. 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.

Application of CRS stack and post stack time migration

The seismic data of Gorgan region has been taken under the optimized CRS stack process to obtain the optimized stacked section shown in figure 1. As it could be seen on the section, there exists an unconformity in the section that separate the overlaying quaternary sediments from the underlying sediments consists of sequence of shale, limestone, marn and sandstone. The upper sediments are gently dipping to the right of the section. The underlying layers are dipping to left in some parts and dipping to right in the other parts, this is obvious in the first 600 CDP numbers. The dipping layers and flat ones above the unconformity show confliction in some parts of the section. These conflicting points however are not clearly imaged in stacked section, except the left most confliction in time 1500ms. Some faults are imaged in the upper layers in the right part of the section. Detecting and tracing the faults especially below the unconformity is difficult in this section. It is due to the smoothness nature of CRS stack method and it also relates to the type of rocks of the layers that are made of alluvium, river and deltaic sediments that could easily deform by the stresses. However, these faults maybe better imaged in migration section or by applying some other imaging methods like as common diffraction surface stack (Soleimani et al, 2010).

The big concern in this section is imaging the mud volcano boundary below the unconformity. The study area has two mud volcanoes. The major one is not exactly located in the seismic line, but with an offset of 200 m on the surface from the right part of the section. However, it effects the seismic line in depths cause its boundary is divergence through depths.

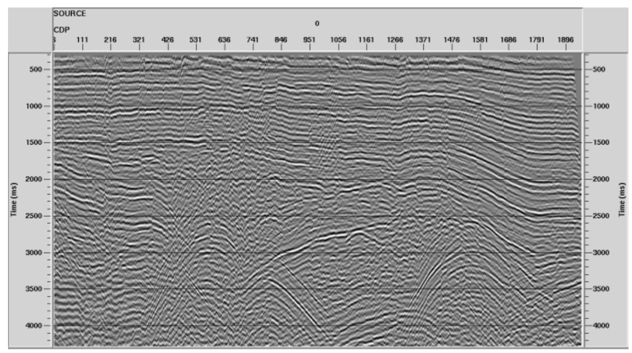

Figure 1 The CRS stack section. The unconformity and diffraction patterns due to the mud volcanoes are clear on the section.

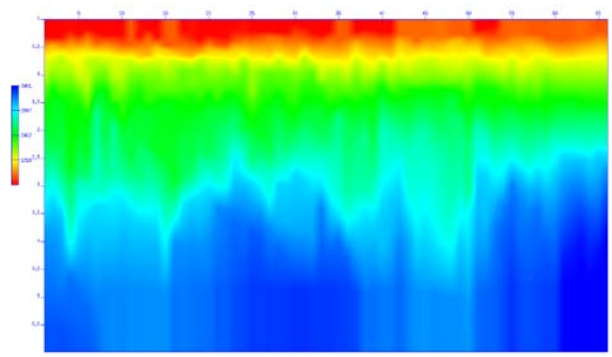

Figure 2 The velocity model obtained by the velocity scanning.

The minor one is somehow captured by the seismic line and is located in the left part of the section, in CDP numbers from 300 to 800 and in times from 2500 ms to the end of the section. As it could be seen, the minor mud volcano completely destroyed the reflection and diffraction events in the lower left of the section. However, some diffraction events that are due to the confliction of mud volcano boundary and dipping layers are clear. The effect of the major mud volcano also could be seen in the lower right part of the section. To perform migration on the stacked section, the accurate velocity model of the section was obtained by velocity scanning. The velocity model is shown in figure 2. Although the accuracy of the velocity model is an important task in any migration method, but this accuracy was not much of interest here. The CRS stacked section was used as an input for post stack time migration done by Kirchhoff migration. The result of the migration is shown in figure 3. In the first glance, some of the geometrical distortions that were corrected by the migrated section are obvious in the section. The confliction of the dipping layers below the unconformity and the overlaying layers are better imaged in CDP 1100 and 1370 in times 2000 ms and 2100 ms, respectively. The faults in the upper right are also imaged better. They could be traced even below the unconformity. The boundary of mud volcano could be detected here well.

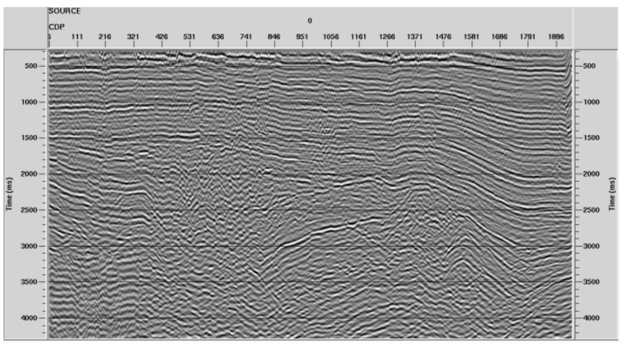

Figure 3 The post stack time migration section. The migration has been performed on the CRS stacked section.

Conclusions

The extended search strategy of Mann (2001) in optimized CRS stack method have been used for imaging the seismic data on a complex structure from northeast of Iran. The aim of processing was to image the mud volcano and its boundary. The first step in processing was obtaining the kinematic wave field attributes of CRS stack method and an optimized stacked section. Although the result of this step was a stacked section, but due to the nature of the imaging method, the signal to noise ratio of the section and some ambiguities of the section that were not cleared by the conventional NMO/DMO/Stack method, were resolved here. The major part of processing here was applying migration on the CRS stacked section. Regardless of the accuracy of the velocity model, the migrated section here showed that a suitable stacked section as an input for migration could be a key to overcome some of the problems of imaging in complex structure. The good imaging result here showed that the CRS stack method, somehow could handle the complexity of the structure in imaging. However, some other methods like as partial CRS stack or common diffraction surface (CDS) stack may be able to handle it better than the CRS stack method.

References

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