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

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SUMMARY

Time and depth imaging in complex structures 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 set from north east of Iran was selected for processing. The geology of the region contains an unconformity above two mud volcanoes. The boundary of mud volcanoes and detection of conflicting points between dipping layers and horizontal layers above the unconformity are of interests here. Therefore, the common-reflections-surface stack method was applied on the seismic data. In the stacked section, most of the reflectors were imaged well, but the problem of mud volcanoes boundary detection was not resolved. The velocity model made by velocity scanning yielded a complicated model. The stacked section was used as an input for time migration. The migrated section resolved the ambiguities in the stacked section. The boundary of the mud volcano could be detected in some parts. The intersections between dipping events and horizontal events were also cleared well. Some faults were also detected in the upper parts of the section that continued to larger through depths and did not imaged well in the conventionally imaged section.

INTRODUCTION

Schleicher et al. (1993) derived a velocity model independent description of traveltime 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 main advantage of the CRS stack method is that it does not require any knowledge about a macro-velocity model but only the near-surface velocity v_0 of the uppermost layer. 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. Thus, the CRS operator takes a much larger part of the multi coverage dataset into account than the NMO/DMO operator.

Methodology

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 approximations 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):

$$t^2(x_m,h) = \left(t_0 + \frac{2\sin\alpha}{V_0}\Delta x\right)^2 + \frac{2t_0\cos^2\alpha}{v_0}\left(\frac{(x_m-x_0)^2}{R_N} + \frac{h^2}{R_{NIP}}\right) \quad (1)$$

Here, α is the emergence angle of normal ray at x_0, while R_N is the radius of wavefront curvature of a hypothetic normal wave and R_{NIP} is the radius of wavefront curvatures of a hypothetic normal-incidence-point wave. The basic idea of the CRS stack method (Jäger 1999) is to use a traveltime approximation of the form of the 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 a stacked zero offset section. The shape of the traveltime surface is controlled by three parameters; α, R_N, and R_{NIP}.

The geology of the study area

The Gorgan region is located in the north east of Iran that has been located in two different geological zones. These two zones are among the several sedimentation basins that are distributed between Iran, Turkmenistan, and Afghanistan. The region is made of thick sediments from Jurassic to Miocene. These sediments are made of shale, limestone, marl, sandstone, and sometimes conglomerates and evaporates. This sequence is beneath an unconformity of Pliocene conglomerates. Above this conglomerate, there exist Quaternary sediments made of river, shore, and deltaic sediments. The Gorgan region and Kopeh-Dagh zone are continued in Turkmenistan, too. There are several gas reservoirs in this region that are sometimes in common between Iran and Turkmenistan. In the Gorgan region, most of these reservoirs are accompanied by mud volcanoes. Therefore, mud volcanoes could be a key to locate the seismic line to search for gas reservoirs.

In most of the 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 mud volcanoes. Defining the boundary of a mud volcano in a seismic section is one of the difficulties in time or depth imaging in data from this region. The other severe problem that may occur 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. One of the alternatives that could be used in this situation rather than the conventional processing methods is the common reflection surface (CRS) stack method (Mann et. al. 1999).

Application of the CRS Stack

The seismic data of the Gorgan region has been taken under the optimized CRS stack process to obtain the section shown in figure 1. As it could be seen, there exists an unconformity in the section that separates the overlaying quaternary sediments from the underlying sediments consisting of a sequence of shale, limestone, marl and sandstone. The upper sediments are gently dipping to the right, while the underlying layers are dipping to the left in some parts and dipping to the right in the other parts. This is obvious in the first 600 CDPs . The dipping layers and the flat ones above the unconformity show conflicting dips in some parts of the section. However, these conflicting points however are not clearly imaged in the stacked section, except for the left most confliction at 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. This is due to the inherent smoothing nature of the 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 be easily deformed by the stresses. 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 beneath the seismic line, but with an offset of 200 m on the surface from the right part of the section.

However, it affects the seismic line in depths because its boundary is diverging through depths. The minor one is located in the left part of the section, at CDP numbers from 300 to 800 and at 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 the mud volcano boundary and the dipping layers are clear. The effect of the major mud volcano also could be seen in the lower right part of the section

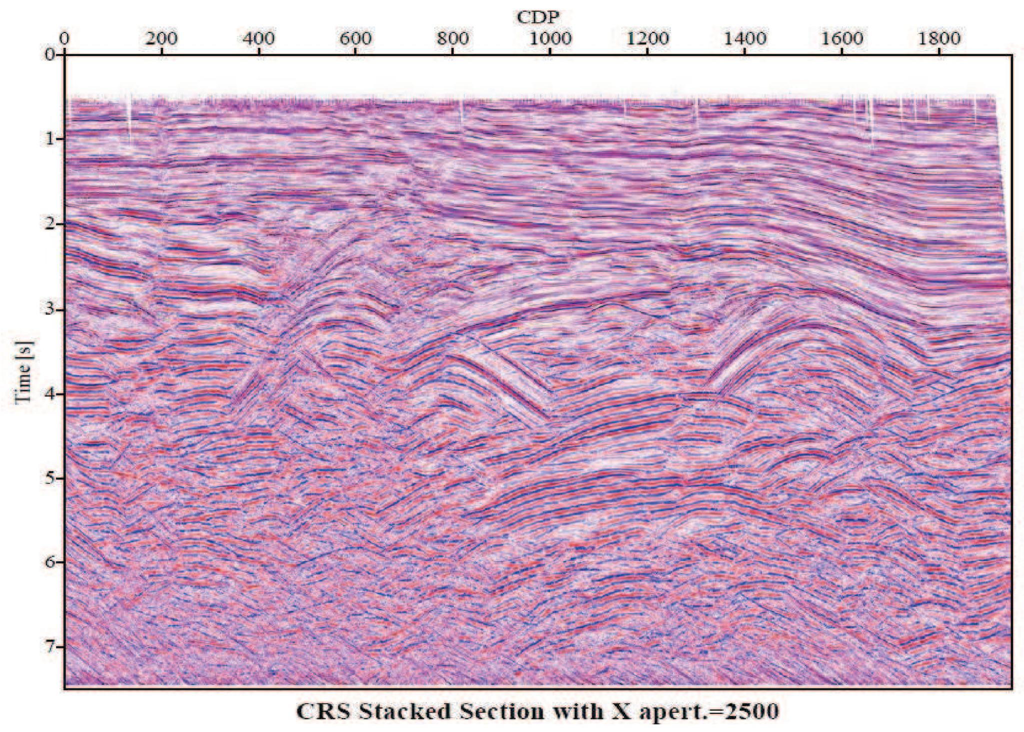

Fig. 2, The CRS stack section. The unconformity and diffraction patterns due to the mud volcanoes are clear on the section.

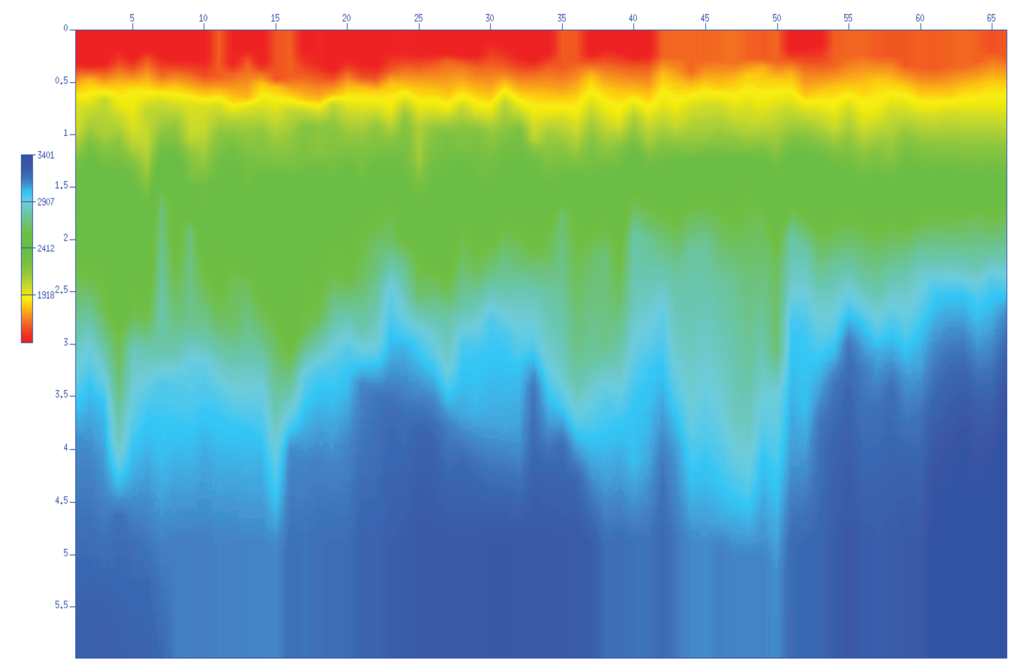

Fig. 2, The velocity model obtained by the velocity scanning.

Velocity model building and poststack time migration

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..

At the first glance, some of the geometrical distortions that were corrected in the migrated section are obvious in the section The intersections of the dipping events below the unconformity and the overlaying events are better imaged in between CDP 1100 and 1370 and times between 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 the mud volcano could be detected here well.

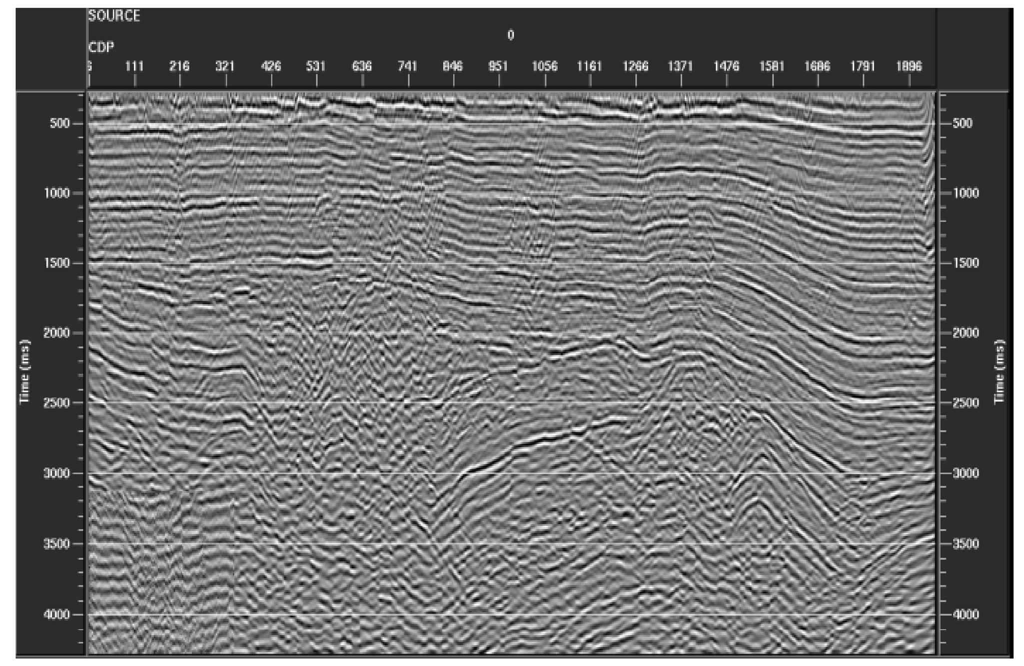

Fig. 3, The post stack time migration section. The migration has been performed on the CRS stacked section.

Conclusions

The optimized CRS stack method has been used for imaging the seismic data on a complex structure from north east of Iran. The aim of processing was to image the mud volcano and its boundary. In the first step, an optimized CRS stacked section was obtained. 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 structures. The good imaging result here showed that the CRS stack method, somehow was able to handle the complexity of the structure in imaging to some extent.

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