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Applying the CRS Stack Method to Solve the Problem of Imaging of Complex Structures in the Zagros Overthrust, South West

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SUMMARY

Imaging in complex structures poses difficulties that could not be solved by conventional processing. In such cases, applying a full prestack depth migration (PSDM) is an alternative. However, this may not be applicable in all situations due to difficult migration velocity model building. The other alternative for imaging in complex structures is to perform poststack migration on a suitable stack section. Using a time section obtained by the Common Reflection Surface stack method could partially solve some of the imaging problems without requiring a prestack depth migration. A seismic data set of a mountainous area from the complex structure of the Zagros overthrust in south west of Iran was processed by the conventional NMO/DMO/Stack. The CMP-stacked section contained a folding system and dipping layers, but both of them not well imaged in the section. Then, the common reflection surface stack method was applied to data. In the CRS-stacked section, the folding and dipping layers were clearly observed. The other reflection and diffraction events at large travel times were also imaged. Therefore, the CRS-stacked section showed that the common reflection surface stack could be used to partially solve some of the problems with complex structures.

Introduction

Imaging beneath complex structures is always of much interest in all time and depth imaging techniques. Although many imaging methods are based on the assumption of layered media, simple modifications of the basic algorithms could make them applicable for situations with mild lateral velocity variation. The situation is different when strong lateral velocity variation is present in the subsurface. In that case, simple algorithm modification could not solve the problem of imaging in complex structure. Instead, other imaging techniques should be used such as prestack depth migration. The application of this approach has limitations, especially concerning the determination of a sufficiently accurate migration velocity model. In certain cases, prestack partial migration (DMO) can resolve some of the ambiguities. However, strong lateral velocity variation is associated with a complex overburden structure. An example of complex structure is the systems of folding that are present in many folding mountains range or folded belts, like in the study area, the Zagros overthrust.

The Zagros overthrust

The Zagros overthrust is a part of folding system that occurred in the south west of Iran due to the compression force from the Arabian plate to the central Iranian plate. The Izeh region is located in the centre of the Zagros folding system. The region is a part of the Zagros overthrust with complicated geological conditions. Numerous foldings, faulting and overthrusts in the Zagros mountain range make it a complex structure difficult for imaging. However, many anticlines in the Zagros mountain range acting as hydrocarbon traps that enforce many attempts to have better images of the subsurface. Among the different locations in the Zagros mountain range, the Izeh region is known to show the most complex structures and the most difficult structures to image. Because of this complexity in some cases, even with very accurate surveying, suitable results could not be drawn from the seismic data. Therefore, testing new ideas and applying new methods to seismic data from this region may help to resolve some ambiguities in the results of the conventional processing methods. A 2D seismic data set from the Izeh region is selected for imaging with conventional processing steps and then for resolving some of the problems that may happen during the imaging of complex structures by the capabilities of CRS stack method.

Imaging in complex structure

To see whether the imaging problem is too severe, the conventional NMO/DMO stack method was applied to the data after some pre-processing such as filtering and deconvolution. Static correction was a key part in the pre-processing steps for this data due to the mountainous and rough along the profile. The NMO correction and velocity analysis showed the high degree of complexity of the subsurface with very complicated velocity spectra, as shown in Figure 1. In many velocity spectra, not even a single point could be selected as stacking velocity, but the normally increasing trend in velocity is not visible here. However, it could be described by the geological history of the region. As mentioned above, the overthrust folding has put older layers above younger layers and, therefore, causes a reduction in the velocity trend. The velocity saturation could also be seen in many parts along the profile. In this situation the roll of density becomes more important than the roll of velocity variation. The problem of multiples is also another severe problem in all the seismic data gathered in that region.

The result of the CMP stack after NMO/DMO corrections and velocity analysis is shown in figure 2. As can be seen from the stacked section, the complexity of the structures in this region is such severe that conventional stacking fails to yield a good image. In the upper right of the section, a syncline can be observed that is a part of folding system. However, the continuity of the events is not preserved in the section such that the continuation of the folding system could not be traced in the other parts of the profile. In addition to the syncline, the only other event that could be seen in the section is an event in the lower left of the section. The remaining part of the section is fully covered by noise caused by the complexity of the subsurface. No events could be imaged there.

To overcome this problem, the common reflection surface (CRS) stack method has been applied to the data. The common reflection surface stack method is an imaging method that uses kinematic wave field attributes for imaging. It is one of the so-called data-based seismic imaging methods to simulate a ZO section. It has a great advantage that is independent of an explicit velocity model (Hubral, 1999). As shown in Figure 1, the velocity spectrum in this data is very complicated as a result of the lateral variation in velocity and also the complexity of the structure. Therefore, using these velocities will introduce errors in the later stacking step. Applying the CRS stack method in this region may resolve some of these difficulties. This advantage can also be seen in the comparison between the CMP and CRS traveltime equations. Müller (1998) showed that CMP stack operator is only a special case of CRS stack operator. The second order traveltime equation of the CRS method can be derived by paraxial ray theory which yields a spatial stacking operator. The basic idea of this method is to take the kinematic reflection response of a segment of the reflector with defined curvature and orientation. The corresponding stacking attributes are two wavefronts curvatures of so-called eigenwaves and the emergence angle of the central ray. One eigenwave is obtained by placing a point source at a point on the reflector that produces the so called upgoing normal-incidence-point (NIP) wave. An exploding reflector experiment yields the second upgoing eigenwave called normal (N) wave. To apply the CRS stack in data-oriented way, its attributes have to be determined automatically from the prestack data. The most efficient solution of CRS equation (Mann et Al, 2001)

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

where R_{NIP} is radius of the NIP wave, R_N is radius of the normal wave, and α is the emergence angle of the normal ray, can be achieved by decomposing it into three separate optimization problems with a search for one parameter in each step (Jäger, 1999). Basically, they are related to the reflector's dip and curvature and the average properties of its overburden. The CRS stack method, unlike the CMP stack, is not restricted to a subset of multicoverage data, but works on the full data volume. Therefore, the CRS stack yields a higher signal-to-noise ratio and more continuous events compared to the CMP stack. For that reason, the CRS stack method was applied to this seismic data. As mentioned before, the velocity is increasing rapidly in this region and, thus, the velocity saturation occurs for larger traveltimes. Thus, the velocity search range in the CRS stack method has to specified sufficiently large in order not to loose the events in later stacking step. The large stacking aperture was selected (1300m) to be close to the Fresnel zone size and also to increase the signal-to-noise ratio and the continuity of the events. In the first attempt, the aperture was set to 700 m. The stacked section obtained with this aperture exposed a low continuity of the events especially at larger traveltimes, and the continuity of the folding also could not be traced well. By increasing the aperture, these problems disappeared.

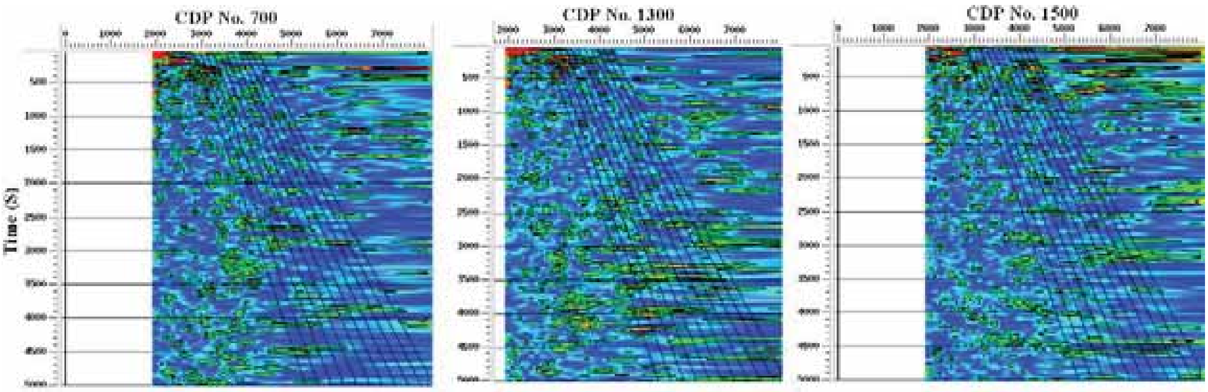

Figure 1 *The Velocity spectra for some CDPs that shows the difficulty of velocity picking for this complex structure.*

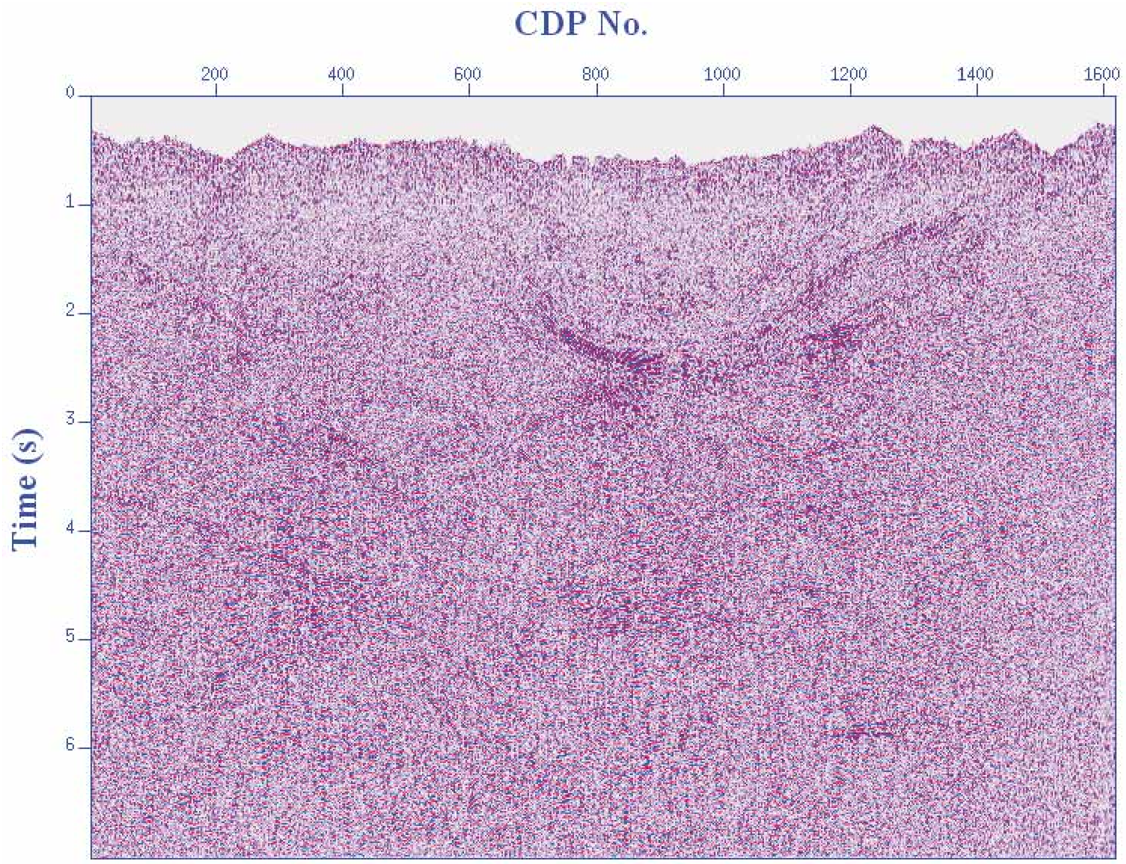

Figure 2 *The CMP-stacked section of the Izeh data. The S/N ratio of the section is low due to the complex structure. Many events are missing for the same reason.*

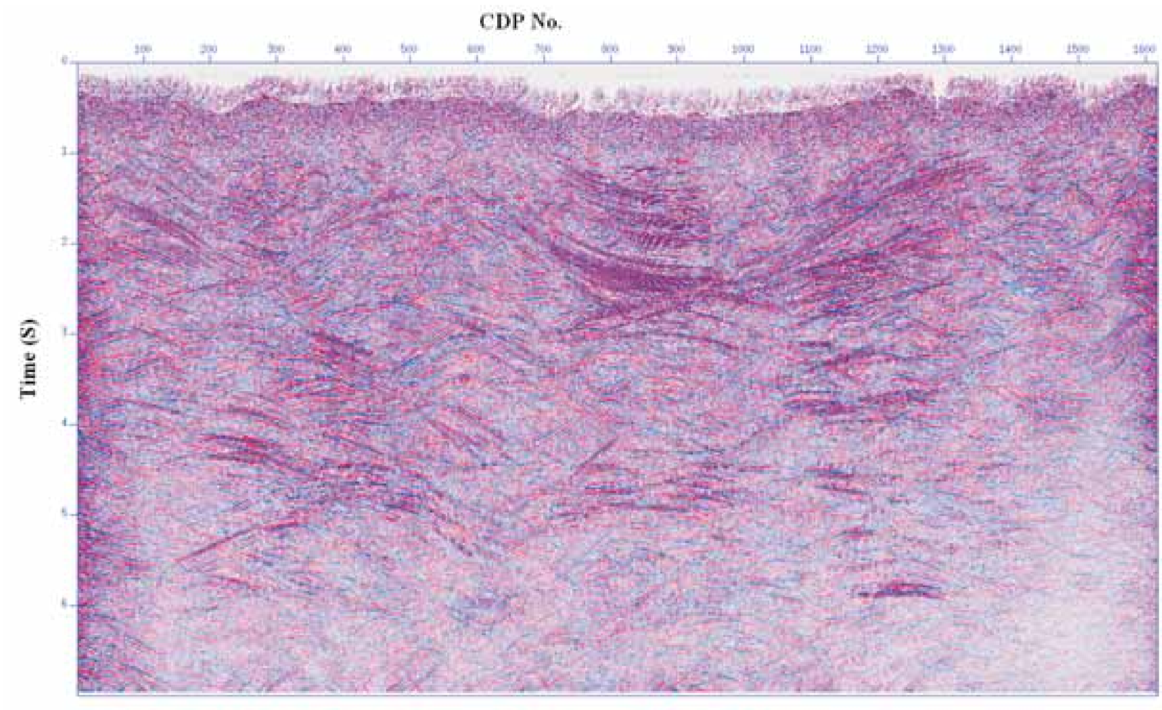

Figure 3 *The CRS-stacked section of the Izeh data. The S/N ratio of the section is significantly high and more events can be seen that completely show the folding.*

The CRS-stacked section is shown in Figure 3. As can be seen in the figure, the quality of the CRS-stacked section is better than the CMP-stacked section. Therefore, it could be concluded in the first step that the CRS stack method succeeded to increase the signal-to-noise ratio. In the CRS-stacked section, more events could be seen and the continuity of events is better preserved. Some of the ambiguities that were visible in the CMP-stacked section are resolved here. The folding system especially in the upper right of the section appears much clearer. The syncline is continued by other anticlines and synclines that were not present in the CMP-stacked section. They are now extended through the entire profile. Below the outstanding syncline, another folding is visible that is also not present in the CMP-stacked section. In the CMP-stacked section, only the top parts of the anticline have been imaged, but in the CRS-stacked section, it completely appears at large travel times. In the left part of the section, dipping layers are present that can hardly be seen in the CMP-stacked section. However, the problem of conflicting dips occurs here between the diffraction events and the reflection events. Therefore, it might be useful to apply the common diffraction surface (CDS) stack method to these data. In view of all these improvements, we can conclude that the CRS method could partially solve the problem of imaging in complex structures.

Conclusions

The conventional processing steps have some limitation in imaging of complex structures. However, applying the partial stack migration in some cases and applying prestack depth migration in more complex media could give an acceptable image, but in many cases, imaging beneath the complex structures is very difficult and time consuming task. In one try to image a very complex structure in Izeh region in Iran, no acceptable results were obtained due to strong lateral velocity changes. To overcome to this problem, the common reflection surface stack has been applied to the data. In most part of the section, the events show up clearer and more structures could be observed than in the CMP-stacked section. It is obvious that this time section gives a suitable image of the subsurface here. Therefore, we conclude that the CRS stack method could be applied to complex structures to resolve some ambiguities of imaging in such structures. A final depth conversion of this time section might yield a better image and reveal further details.

References

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