

Mapping Imbricate Structures in the Thrust Belt of Southeast Turkey by Large-Offset Seismic Survey

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Summary

Turkish Petroleum Corp. conducted a multichannel large-offset 2-D seismic survey in the Thrust Belt near the town of Adiyaman, Southeast Turkey, in 2007-2009. The objective is to map the complex, imbricate structures associated with the target Cretaceous carbonates. The survey consists of NS and NW-SE dip lines and E-NE strike lines with a total linear length of nearly 400 km. The data were acquired using split-spread recording geometry with 15,000-m maximum offset and 1,200 receiver groups at 25-m interval.

Land seismic data acquisition with conventional spread length (3,000 m) and conventional processing in midpoint-offset coordinates may fail to image complex imbricate structures associated with overthrust tectonics. Irregular topography associated with a rugged terrain, complexity of the near-surface that includes high-velocity layers and outcrops with significant lateral velocity variations, complexity of the overburden caused by allocthonous rocks, and the complexity of the target imbricate structures themselves, all pose challenges to exploration in thrust belts. The shot-domain analysis of the data from the large-offset Adiyaman seismic survey, on the other hand, has indeed made it possible to exploit the large-amplitude wide-angle reflections outside the surface-wave cone to image the imbricate structures. The resulting structural map not only ties with the existing wells but also has enabled to spot new exploration wells.

Data analysis includes modeling of the near-surface by nonlinear traveltimes tomography applied to first-break picks and image-based rms velocity estimation to image the subsurface by prestack time migration (PSTM).

Data Acquisition

Shown in Figure 1 is the base map for the large-offset seismic survey. The surface geology in the survey area includes the Miocene Shelmo clastics and basalt in the south, Hoya-Midyat Miocene limestone with karstic texture in the middle, and the allocthonous Karadut-Kochali complex in the north. The imbricate structures in the NS direction were formed by the Upper Cretaceous and Lower Miocene tectonics.

The acquisition parameters for the large-offset survey are listed in Table 1. Figure 2 shows a typical shot record from

the survey. Note that at small offsets the field record is overwhelmed by Rayleigh waves (ground roll), and essentially is void of reflection energy. When the same field record is examined at far offsets beyond the conventional spread length, note the presence of wide-angle reflections at large offsets. These reflections have been known to early researchers in exploration seismology (Richards, 1960) and have been used to image complex structures (Yilmaz et al., 2005a,b).

Table 1. Acquisition parameters for the Large-Offset Adiyaman Survey

Source	Dynamite, single hole with 40-m average depth, 40-kg average charge size
Total linear length of the lines in the survey	400 km
Total Number of shots	4,606
Shot interval	100 m
Receiver group interval	25 m
Receiver Array	12 bunched geophones
Number of channels	1,200
Spread	split-spread
Minimum offset	12.5 m
Maximum offset	14,987.5 m
Fold of coverage	150
Elevation range in the survey area	600-1,400 m
Recording length	10 s

Data Analysis

Starting with the field records, we picked first-arrival times and edited traces. By using a nonlinear traveltimes tomography (Zhang and Toksoz, 1998), we estimated a near-surface velocity-depth model for each line. The nonlinear tomography solution is based on not just the first-arrival times, which may include wave types other than refraction, but also changes in traveltimes gradient. As such, within the near-surface, we were able to resolve strong lateral velocity variations associated with high-velocity outcrops. In deriving a final model for the near-surface, the traveltimes tomography is iterated until the difference between the modeled and the actual traveltimes, measured as the rms error in inversion, has been reduced to

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a sufficiently small value comparable to the reciprocal traveltimes. From the near-surface model, we picked a floating datum that is a smoothed form of the topography along each line and the intermediate datum that defines the interface between the near-surface and the subsurface. Also, we defined a replacement velocity taken as the lateral average of the velocities along the intermediate datum. Finally, using all the relevant information about the near-surface velocity-depth model, we computed the shot and receiver statics. We also calculated shot and receiver residual statics based on the first-arrival times (Zhang and Yilmaz, 2005).

From the average amplitude spectra of selected shot records, we observed that the reflection signal at large offsets is within a bandwidth of 6-48 Hz. We applied a parsimonious signal processing sequence (Yilmaz, 2001) to the shot records that include (a) outside mute to remove ambient and environmental noise before the first arrivals, (b) t -squared scaling, (c) predictive deconvolution, and (d) f - x dip filtering to attenuate the dispersive surface waves and guided waves. Finally, we applied the near-surface corrections and placed all the shots and receivers to the floating datum. Figure 2 shows a shot record before and after the signal processing.

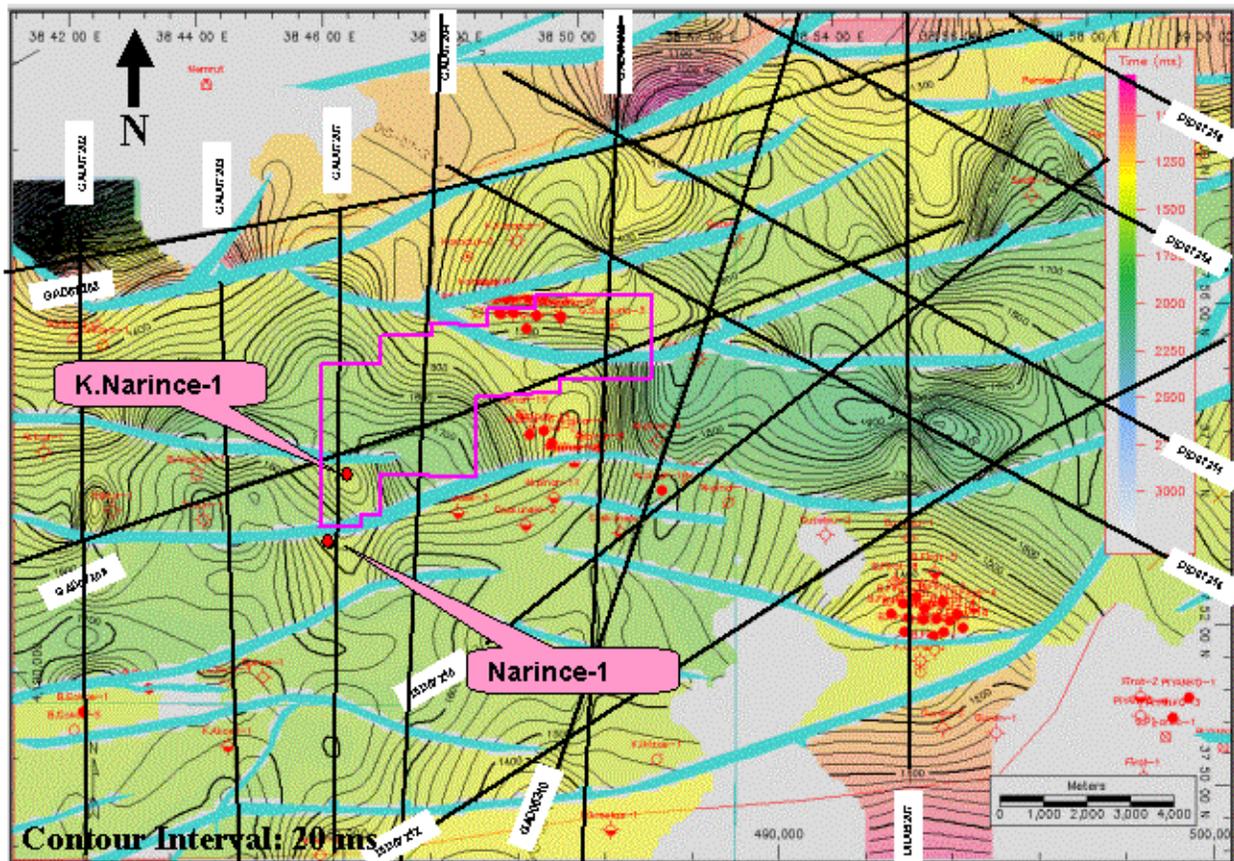


Figure 1. The time structure map for the Cretaceous Mardin carbonates based on the large-offset seismic survey. The black lines represent the line traverses in the survey. Acquisition parameters are listed in Table 1. There is a producing field in the area. Narince-1 and K. Narince-1 are the wells spotted based on this structure map.

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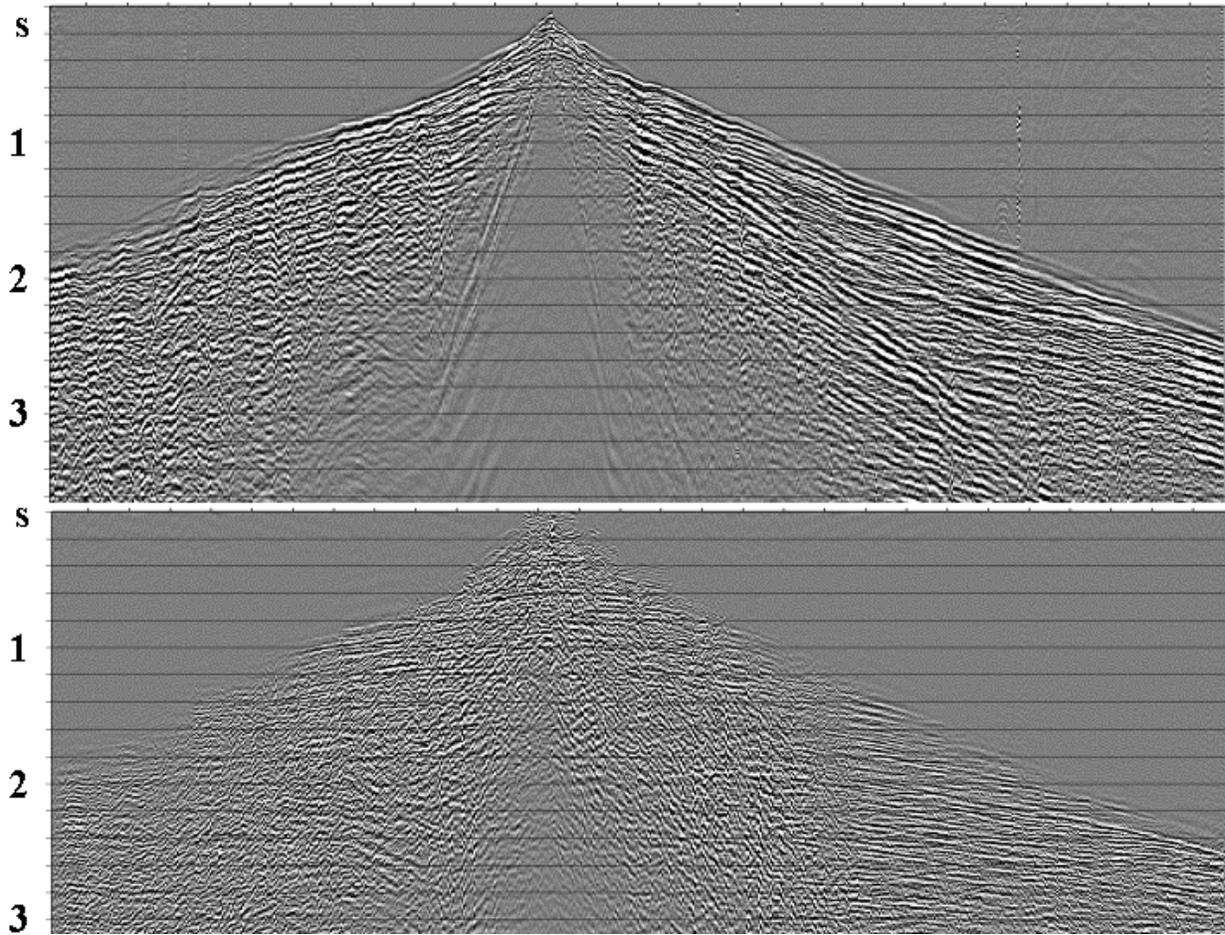


Figure 2. Top: A portion of a field record (from -6 to $+8$ -km offset range) from the large-offset Adiyaman Survey with 15,000-m maximum offset. Note the presence of reflections at large offsets and the predominance of the ground-roll energy at near offsets. Bottom: the same shot record after signal processing.

Next, we performed an image-based rms velocity estimation. We migrated all of the shot records using a range of constant velocities and formed a velocity cube (Shurtleff, 1984) that consists of a set of image panels. We used the three cross-sections of the velocity cube --- the X-T plane (the distance along the line traverse versus event time after migration for a given rms velocity) --- the V-T plane (the rms velocity versus event time after migration for a specific location along the line traverse) that represents a semblance spectrum, and the V-X plane (the rms velocity versus the distance along the line traverse for a specific time) that represents a time slice from the rms velocity cube. We used all three cross-sections of the velocity cube for picking the rms velocities. We then migrated all of the shot gathers, individually, from the

floating datum with the rms velocity field derived from the interpretation of the velocity cube, and obtained the image for each line from prestack time migration (Reshef, 1991).

Figures 3 and 4 show the images from PSTM of the data from two large-offset lines. For comparison, also shown in these figures are the images from poststack time migration of the data from two vintage lines recorded with conventional spread length (less than 3,000 m) along nearly the same line traverses as those of the large-offset seismic lines. Note the absence of any coherent signal in the vintage sections. It would not matter if the imaging was performed before or after stack, in time or in depth --- the primary cause of the poor image is that the shot records from the vintage lines contain weak reflection signal

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overwhelmed by strong surface waves within the conventional spread length that corresponds to the subcritical region of wave propagation. In contrast, in prestack migration of the data from the large-offset line, we made use of the supercritical reflections recorded at large offsets.

Conclusions

The Adiyaman large-offset land seismic survey has indeed provided immensely valuable information for the delineation of target imbricate structures associated with overthrust tectonics in the Southeast Thrust Belt of Turkey. The images from prestack time migrations along the large-

offset line traverses clearly exhibit structural features that have not been previously observed in the seismic sections derived from conventional surveys with spread lengths less than 3,000 m. The resulting structural map shown in Figure 1 has enabled to spot additional wells in the survey area.

Acknowledgements

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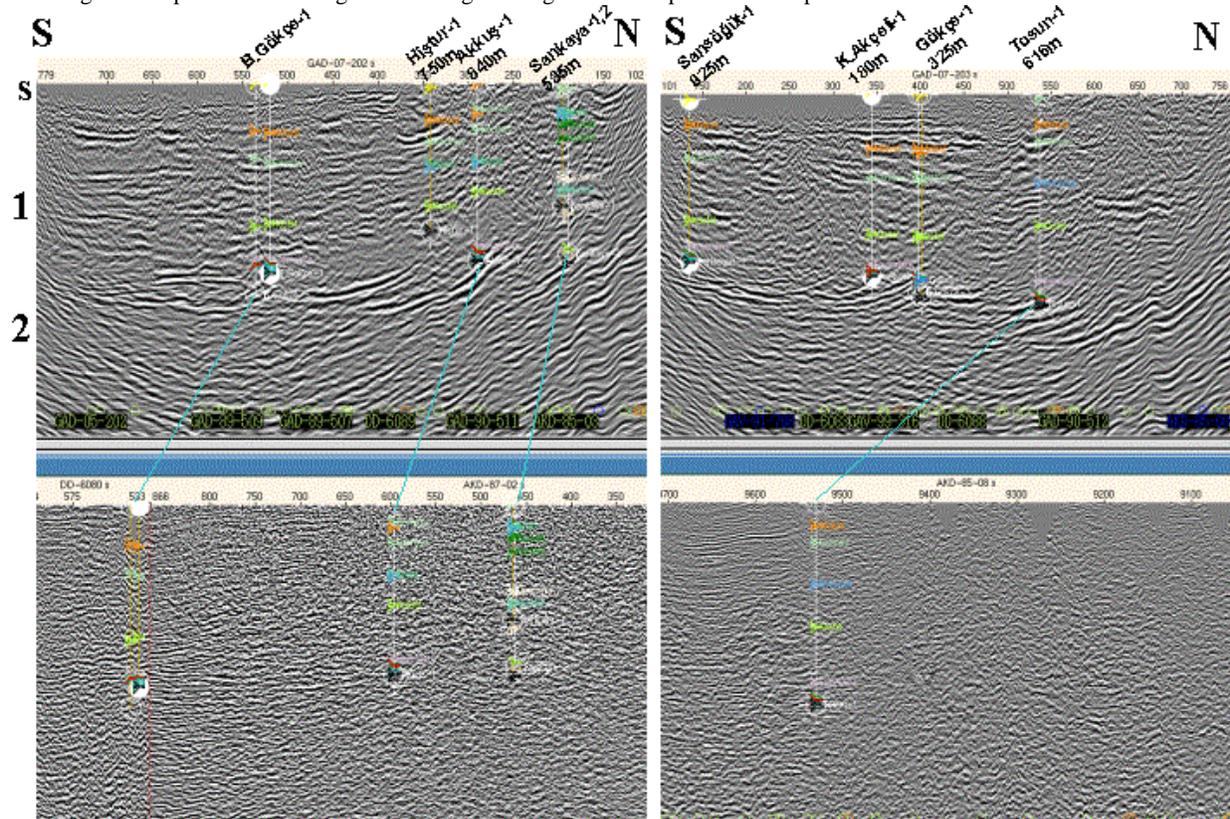


Figure 3. Top: Prestack time migrated sections of the large-offset data along two NS line traverses. Bottom: Portions of the poststack time migrated sections of the data recorded with conventional spread length (less than 3,000 m) along nearly the same line traverses as for the large-offset seismic lines. The large-amplitude events between 1-2 s in the top section correspond to the target Cretaceous Mardin carbonates. The existing wells in the area tie with the target events in the image sections on top.

EDITED REFERENCES

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