Processing and Interpretation of Time-Lapse Seismic Data at Gao 89 CO₂-EOR area

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Abstract

SINOPEC Shengli Oil Company began to inject CO₂ into Gao 89 area (Figure 1) in January 2008 in order to improve oil recovery and test CO₂ sequestration. Gao 89 area is in the middle of the Jinjia-Fanjia nose structures, which is in the west part of Dongying depression-Boxing sag, east of China. The oil-bearing area is about 2.6 km². The proven reserve of oil is 1.7 million tons. CO₂ source was from Huagou-Gaoqing gas field near Gao 89 area. CO₂ content in gas filed ranges from 18% to 99.96%. CO₂ is separated and transported by pipeline to injection site. The purity of injected CO₂ is 99.96%. In July 2013, the injected CO₂ was partly provided by the 40,000 tons post combustion CO₂ capture facility near Gao 89 area.

Figure 1 Structure map and well locations of Gao 89 CO₂ injection area (Wang et al,2017).

The main reservoir of Gao 89 area is Member 4 of Shahejie Formation of Paleogene. There were 15 oil producing wells when Gao 89 area were put into operation in early 2004. The oil production reached 92 tons/day in January 2007. Then production declined to about 72 tons/day before CO₂ injection. On January 3, 2008, Gao 89-4 well started to inject CO₂. In July 2009, other three well Gao 89-5, Gao 89-16 and Gao 89-17 were transferred into CO₂ injection wells. Water injection has never been conducted in Gao 89 area.
The Baseline 3D seismic data of Gao 89 area was acquired in 1992. From October to November 2011, the overlay 3D seismic data acquisition was carried out, which is taken as the Monitor 3D seismic data. The geometry of Monitor 3D seismic acquisition is different from that of Baseline (Table 1), which is different from regular 4D seismic geometry for CO2 sequestration (White, 2003). Also, for the purpose of avoiding the noise from CO2 injection pump, all four CO2 injection wells were shut down during Monitor 3D seismic acquisition. This unfortunately made the Gao 89-17 well permanently close because CO2 could not be injected it again.

Table 1. Comparison of Baseline and Monitor 3D seismic acquisition parameters.

<table>
<thead>
<tr>
<th>Year</th>
<th>Observation system</th>
<th>Shooting</th>
<th>Trace/Line (m)</th>
<th>Shot point/Line (m)</th>
<th>Max offset (m)</th>
<th>Trace number</th>
<th>Fold</th>
<th>Bin (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>4L6S</td>
<td>Unilateral</td>
<td>50/200</td>
<td>150/200</td>
<td>3150</td>
<td>240</td>
<td>20</td>
<td>25×100</td>
</tr>
</tbody>
</table>

This is the typical problem that Monitor 3D seismic geometry is different from the Baseline 3D seismic geometry in the oil field. The Baseline 3D seismic data was acquired in 1990’s when the oil field was found and the 3D seismic acquisition parameters were constrained by the old recording system and design. The oil company would not acquire 3D seismic survey before CO2 injection. Then the Monitor 3D seismic data was acquired after about 62,000 tons of CO2 were injected underground. Moreover, the 3D seismic acquisition parameters were improved due to the new recording system. The two different 3D seismic geometries caused difficulties in time lapse 3D seismic processing. However, this is the unique time lapse 3D seismic data for monitoring CO2 injection in China. This time lapse data had not been processed well. Since 2014, we started to process these data and made great progress. The key of our processing steps to process baseline and monitor 3D seismic data with different geometry is to make these two data sets with consistent geometry and can be comparable. The other processing steps are geometry degradation, amplitude preserving and noise remove, object constrained surface consistent time delay correction, frequency consistent processing, space-time energy match processing and improving seismic resolution techniques.

By processing and interpreting these seismic data, we may answer if the small amount of injected CO2 could lead to seismic anomaly and to be monitored in deep and thin reservoir? Moreover, how to interpret these baseline and monitor 3D seismic data?

The key of our work is to make well log data that measured before CO2 injection match the monitor seismic acquisition time. Therefore, we focused on making fluid substitution model that is varying pore pressure and CO2 saturation. P and S wave velocity varies with pore pressure and porosity method was proposed (Li et al., 2017). Based on fluid substitution model, time lapse AVA synthetic seismograms were made and used to calibrated time lapse 3D seismic data. Then AVO inversion and seismic attributes analysis were developed in order to discriminate CO2 flooding area.

References: