3D Velocity Modeling in Complex Thrusted Terrains, SE Oklahoma

Paul Genovese[†] *and Tagir Galikeev*[‡]

[†] *Project geophysicist, Technology Team, Texaco, Denver*

[‡] *Geophysicist, Technology Team, Texaco, Denver*

ABSTRACT

We propose that structural complexity in an overthrust belt in SE Oklahoma requires a more robust velocity analysis than that derived from semblance in the processing sequence provided by the contractor. We produced an interpolated velocity model in g0cad by integrating migrated 3D seismic data and velocities, surface geology, and sonic logs and checkshots from deep wells. We first used our velocity model in an "in-house" post-stack time migration and again as a starting velocity model for pre-stack depth migration.

TSurf velocity boundaries were used to create SGrids that, in general, have grid cells parallel to the lower boundary and truncated by the top. This cellular geometry is consistent with the phenomena of decollment thrusting observed here.

Velocity data available were used to populate the SGrids in the final velocity model. Only two deep wells had sonic logs available. The third sonic log was generated using neural network techniques. Our final integrated velocity model included interval velocities derived from seismic velocities, interval velocities from well data including neural-network generated velocity logs, and check-shot data. We used the original velocity analysis in fault blocks that wells did not penetrate. A single SGrid was created from the multiple SGrids in order to smooth otherwise sharp velocity contrast across SGrid boundaries.

Post-stack time migration using our velocity model produced better results than the one from contractor with stacking velocities. Initial pre-stack depth migration results are acceptable and the velocity field is being revised to incorporate reflection tomography velocities.

AVAILABLE DATA

In the course of this project we attempted to use all available data, including log and checkshot data of the well being drilled in the area. Data used for velocity field building are described in Table 1 and illustrated graphically in Figure 1. Only two wells had a good log coverage in the area of interest. To increase well coverage we decided to generate a sonic log for the third well using neural network techniques.

Data type	Description	Source	Domain
Seismic	RMS velocities	3^{rd} party (seismic data processing contractor)	time
	Key horizons	In-house (project geophysicist)	time
Well logs	Neural Network generated sonic logs	In-house (technology support)	depth
	Instantaneous interval velocities (computed from sonic logs)	3^{rd} party (well logging contractor)	depth
	Interval velocities from checkshot survey	3^{rd} party (well logging contractor	depth
	Deviation survey	3^{rd} party (well logging contractor	depth
Geology	Geological framework of the area	In-house (project geophysicist)	virtual

Table 1. Data used in the project.

Seismic data

Seismic data processing contractor provided us with an ASCII file of final RMS velocities. This ASCII file was reformatted and input into gOcad's as a pointset. Velocities were then transferred to SGrid, smoothed, converted to interval and smoothed again. This velocity was only used for the shallower part of the final velocity model, mainly where well velocities did not exist.

We recognized that the most abrupt velocity contrasts in the vicinity occur across major thrust faults. The transition from Pennsylvanian clastic sediments to higher-velocity lower Paleozoic carbonates occurs at a well-defined boundary and, together with the major thrust faults, account for the key horizons we used in the velocity model.

Surface geology maps indicate that formations dip steeply to the south over much of the 3D survey area and are poorly imaged. Seismic data show that the faults and associated strata dip less steeply at depth where they yield a reasonably good seismic image. The surface geology constrains how we extend the key horizon interpretations up through the shallow, poorly imaged part of the survey. Figure 2 shows the integration between seismic data, surface geology, DEM, and key horizons. The thick red lines show the surface traces of the major thrust faults on the map.

Key horizons were initially picked in GeoProbe and were imported into g0cad as VSets. The VSets were then used to guide the picking of PLines on parallel property sections of the seismic voxet. TSurfs of key horizons were constructed from the PLines.

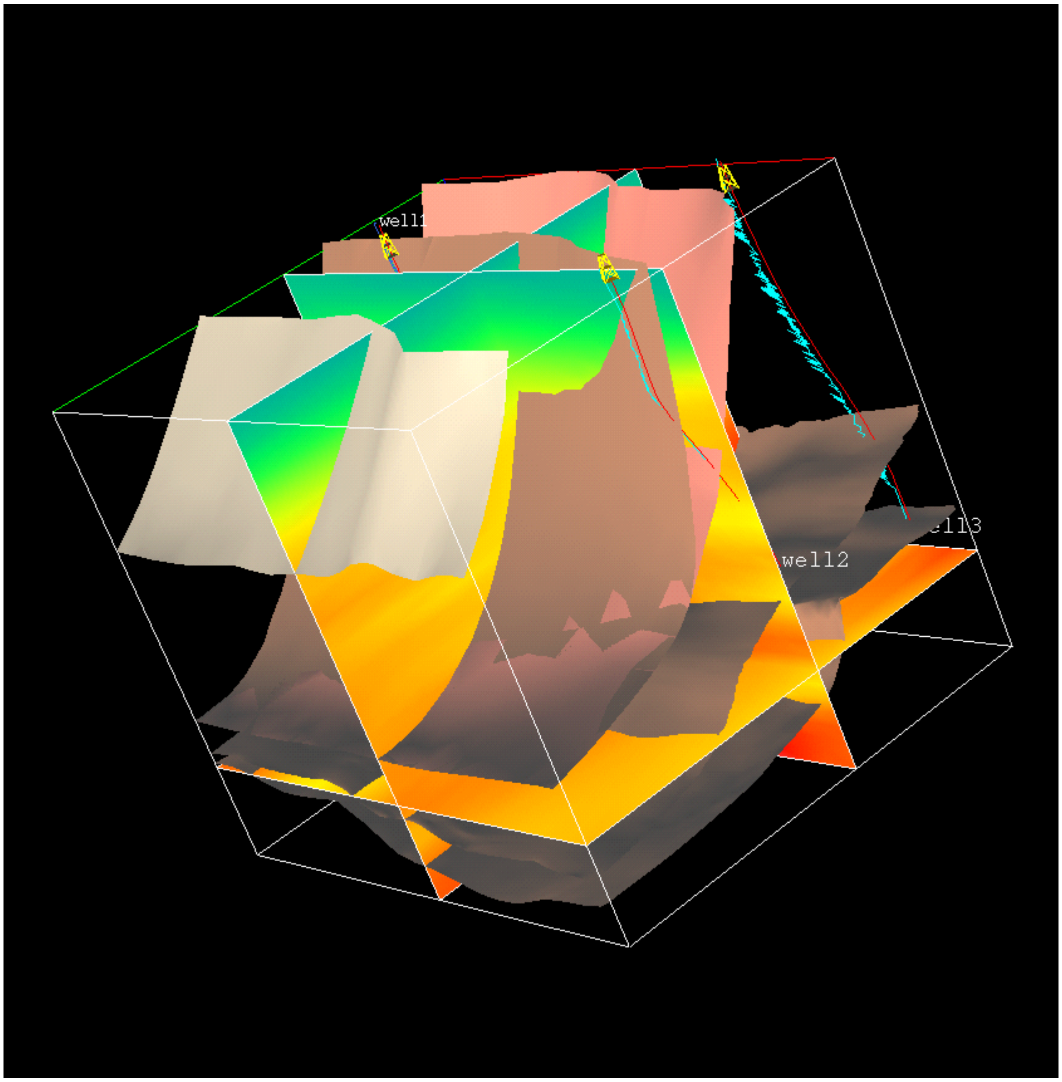

FIG. 1. Input data in gOcad.

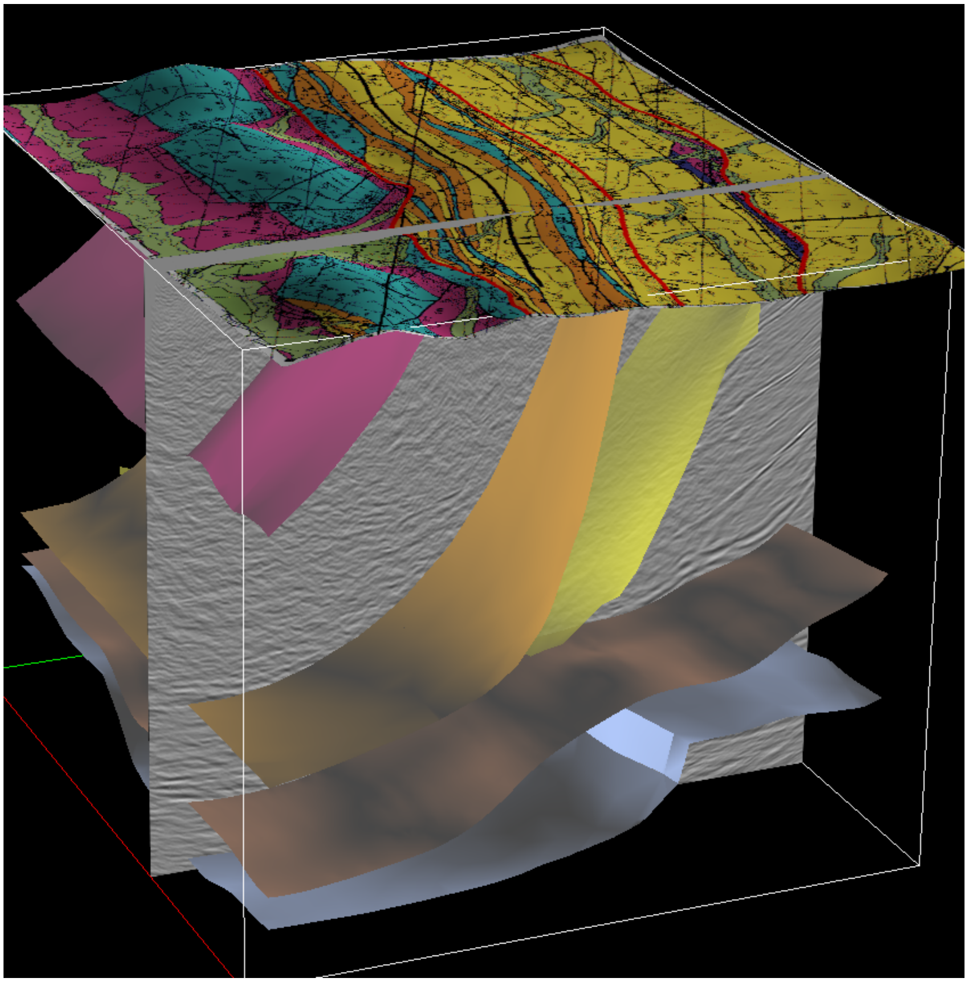

FIG. 2. Key horizons with overlayed geological map.

Well data

Well data were provided in LAS format and were reformatted into gOcad external well representation format. Deviation data were added before reading them into gOcad. It was mentioned above that we had only two wells with relatively good quality of logs and depth coverage. Another nearby well had a recent suit of logs, but lacked sonic log. It was decided to use in-house expertise to generated a sonic log for this well using neural network techniques. Quality of generation was cross-checked by using trained neural network to generate a GR log and compare it to the original one acquired in the field (shown in Figure 3). They match really well. Next, we converted well logs from depth to time domain using gOcad scripts.

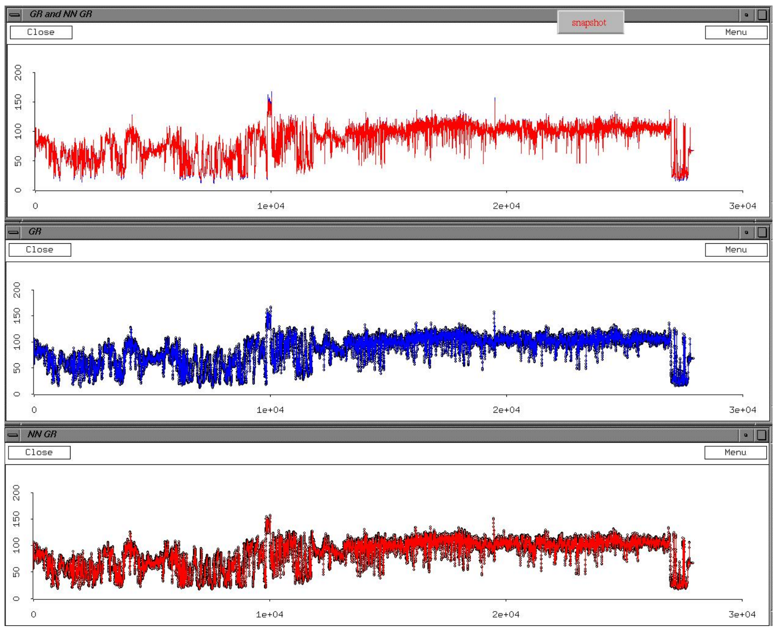

FIG. 3. Neural network QC.

VELOCITY MODEL BUILDING

In velocity model building process we have decided to use SGrids instead of 3-D model objects. Two reasons influenced our decision:

1. relative simplicity of the framework

2. we wanted to capture known unconformities and reflect truncated and parallel nature of the geological boundaries

First the prototype SGrid was created with dimensions reflecting the desired resolution of the output velocity field. Multiple copies of this SGrid were created and used in the process of SGrid editing when they were conformed to the key horizons.

This insured the same vertical sampling for all SGrids. Some of the horizons had to be modified to ensure a proper SGrid fitting between the horizons (Figure 4).

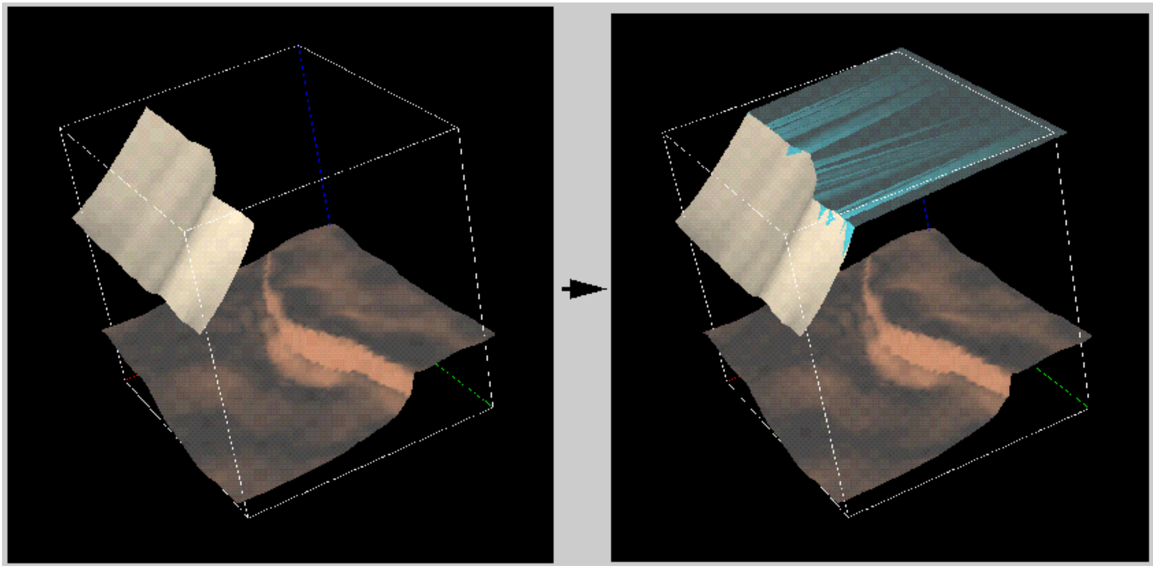

FIG. 4. Horizon modification for SGrid fitting

After all the SGrids were created they were populated with velocities and merged into the final SGrid (Figure 5). Final SGrid had its velocities interpolated.

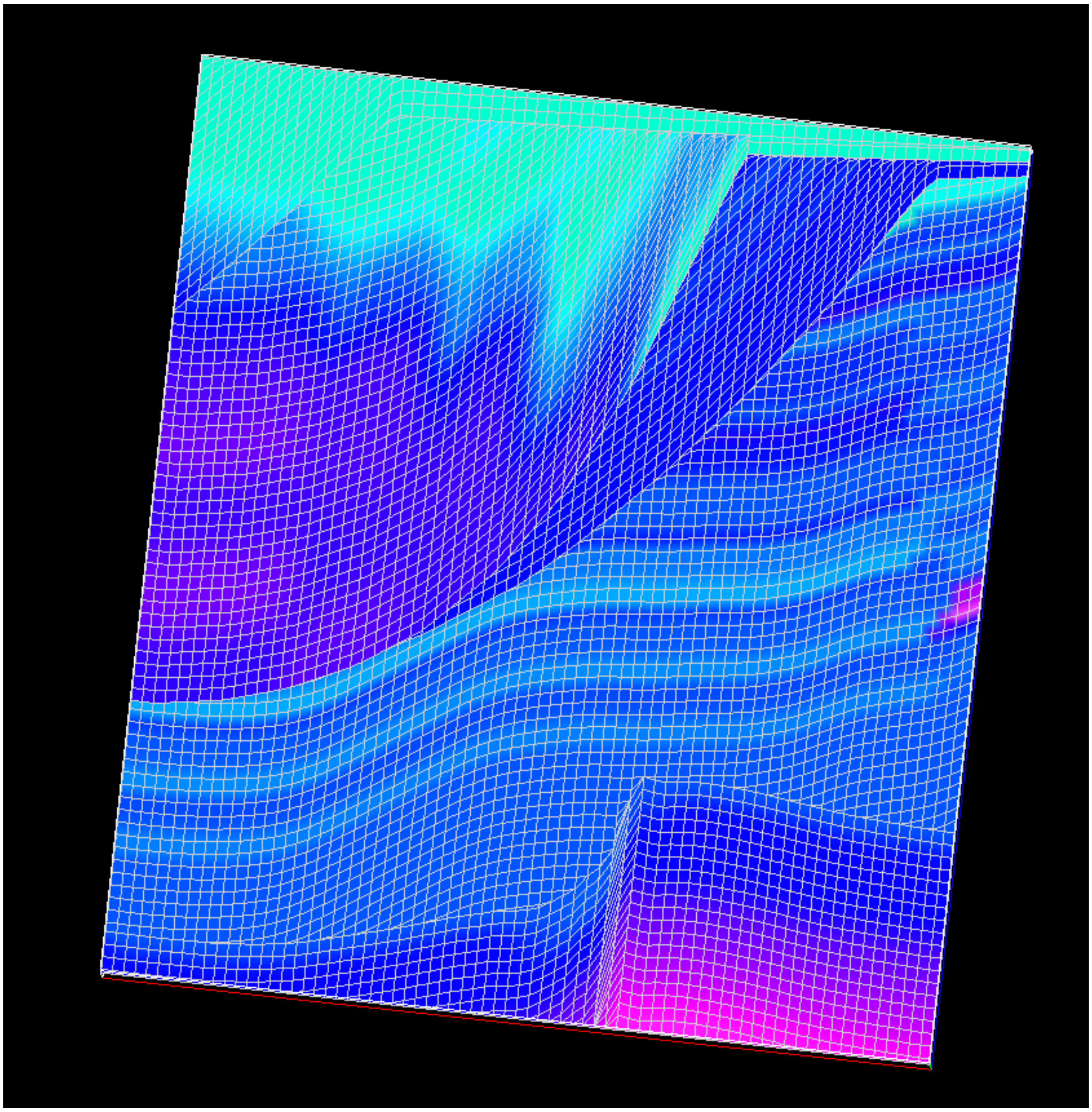

FIG. 5. Final SGrid populated with velocities (not yet interpolated). One section shown