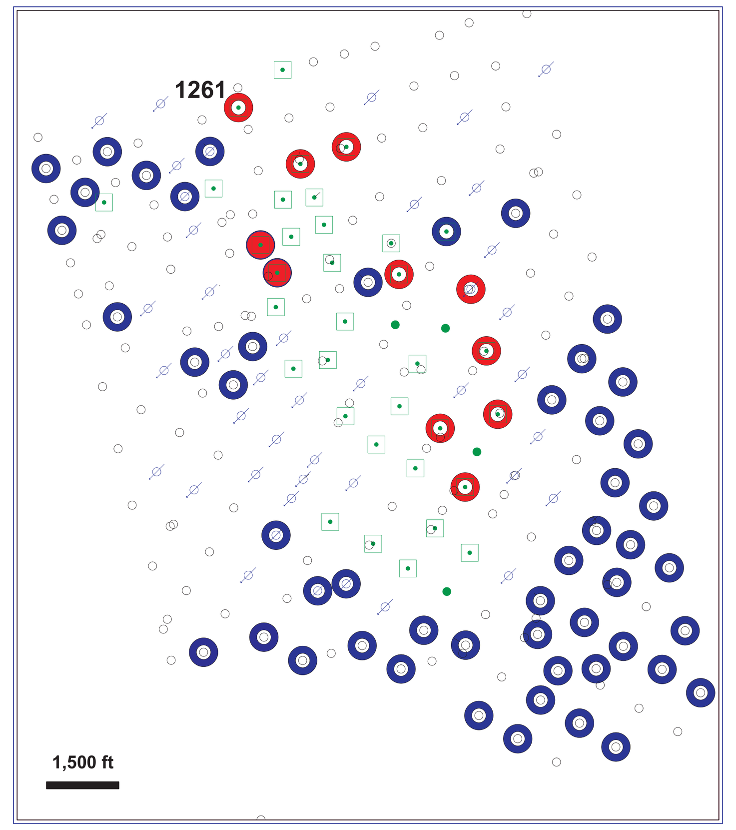
SEISMIC HORIZON ANALYSIS AND RESERVOIR CHARACTERIZATION

We interpreted data from a 3D seismic volume in a 2.5 mi x 3.4 mi (4.1 x 5.4 km) area surrounding the "high volume area" in Waddell Field. Our goal was to map the configuration of key horizons between well control and estimate the lateral distribution and continuity of petrophysical properties.

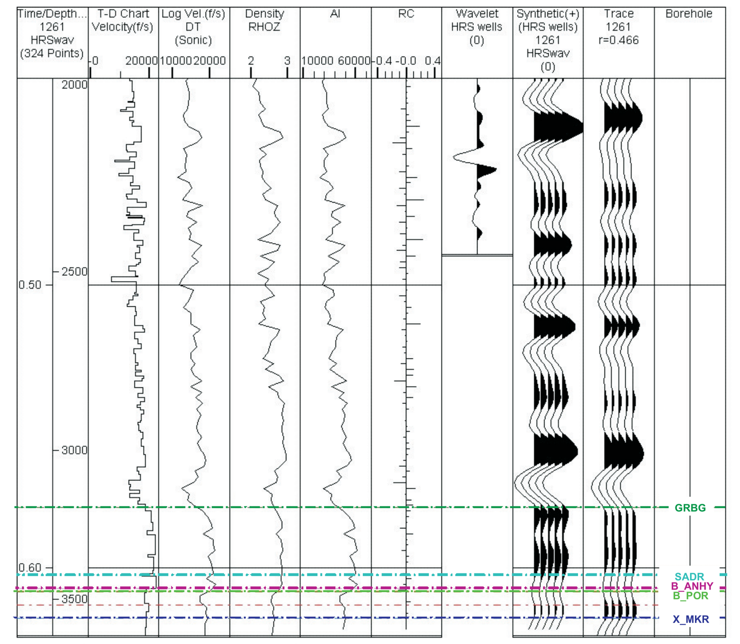
SEISMIC TIED TO FORMATION TOPS

Formation tops were tied to seismic horizons using synthetic seismograms. Synthetic seismograms were constructed for 11 wells in the study area with both sonic and density logs and an additional 51 wells with sonic logs only.

The synthetic seismograms show that there is not a significant impedance contrast at the top of the San Andres Formation in the study area, and therefore, this stratigraphic boundary does not correspond to a seismic reflection. There is an impedance contrast at the base of the karst zone between non-porous anhydrite and porous reservoir, however. Similarly, there is a positive impedance contrast at the "x" marker, although it does not correspond to a clear seismic peak.



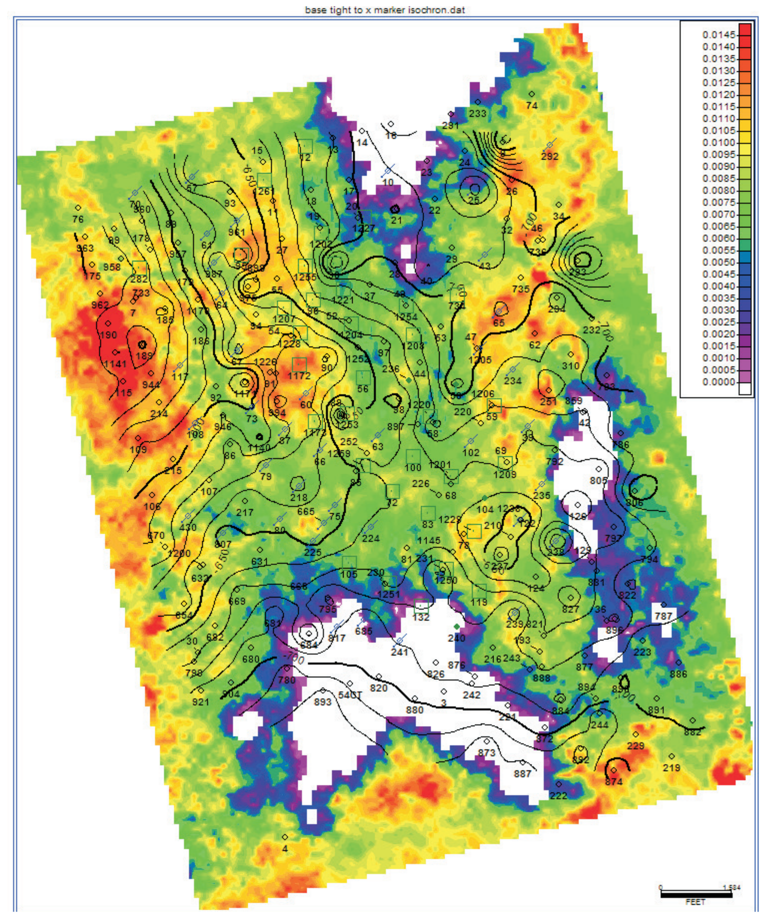
Locations of wells in the Waddell Field study area with sonic logs (blue) and both sonic and density logs (red).



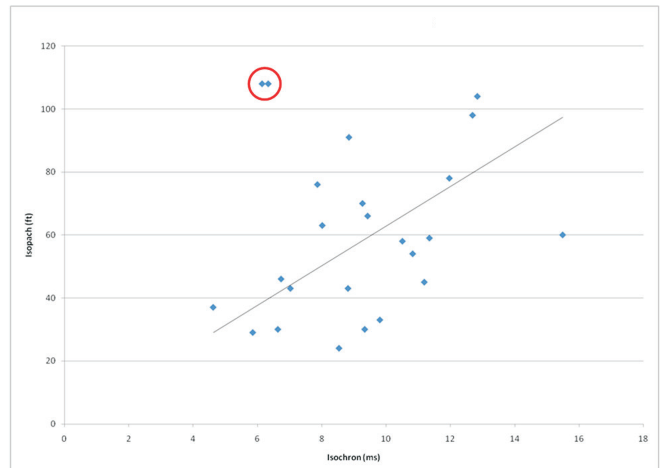
Synthetic seismogram for well #1261 showing tie with seismic data. Labeled tops are: top Grayburg (GRBG; dark green), top San Andres (SADR; cyan), base of anhydritic section beneath the top of San Andres (B_ANHY; magenta), base of tight zone beneath top of San Andres (B_POR; light green), "x" marker (X_MKR; blue).

ISOCHRON MAPPING

A map has been generated of the isochron between the base of karst and "x" marker horizons. A cross plot of this isochron versus the isopach values generated from well tops has a generally good correlation, suggesting that the seismic isochron can be used to approximate changes in interval thickness in locations without well control. The seismic isochron map clearly shows several approximately north-south-trending thicks and thins in the reservoir interval, which appear to swing around from a north-northeast trend in the east to a north-northwest trend in the west. The isochron is locally thin in the saddle area of the southeast-trending anticline. The isochron map also shows areas where the x marker has been truncated by the karst (white areas on the map). These areas are located on the flanks, rather than the top, of the San Andres structure and have a primarily north to northeast orientation. In the southern part of the map, however, the area where the "x" marker is absent shows both a northeast trend that lines up with the saddle and a northwest trend that parallels the main trend of the anticline.



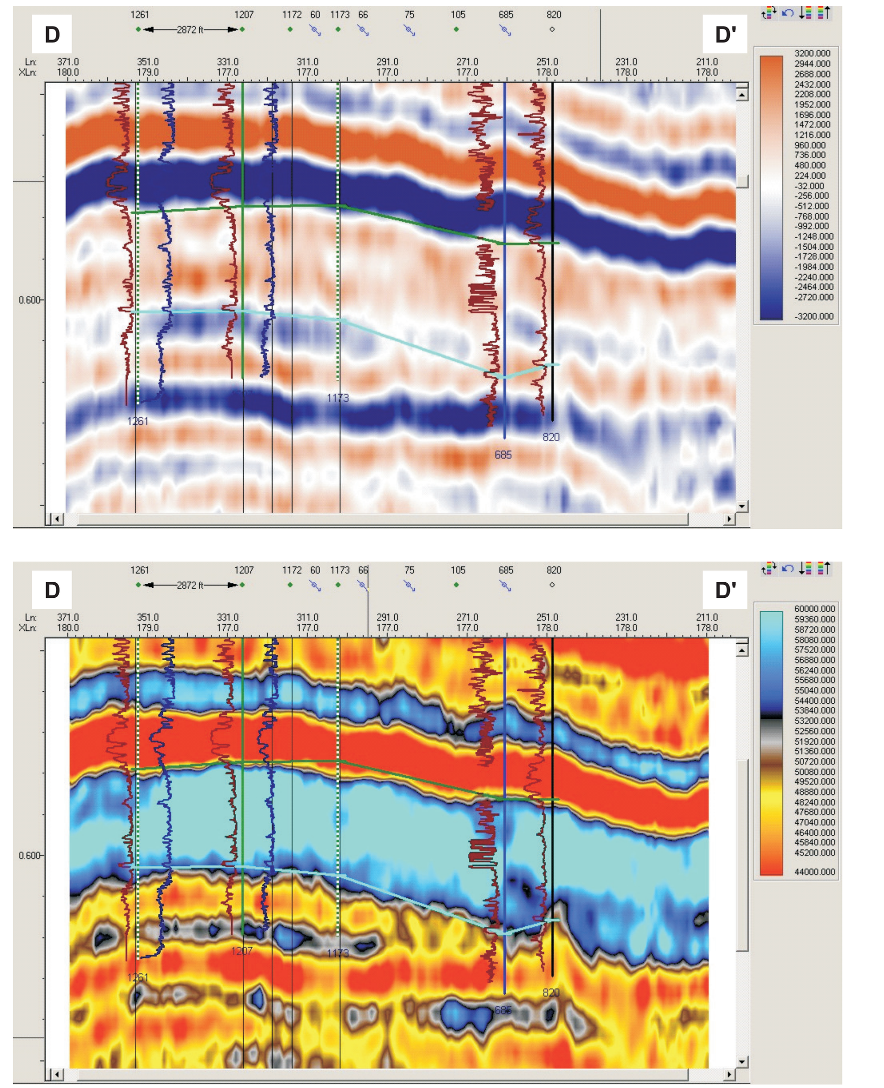
Seismic isochron map (in two-way travel time) of the interval from the base of karst to the "x" marker with top of San Andres subsea depth contours superimposed.



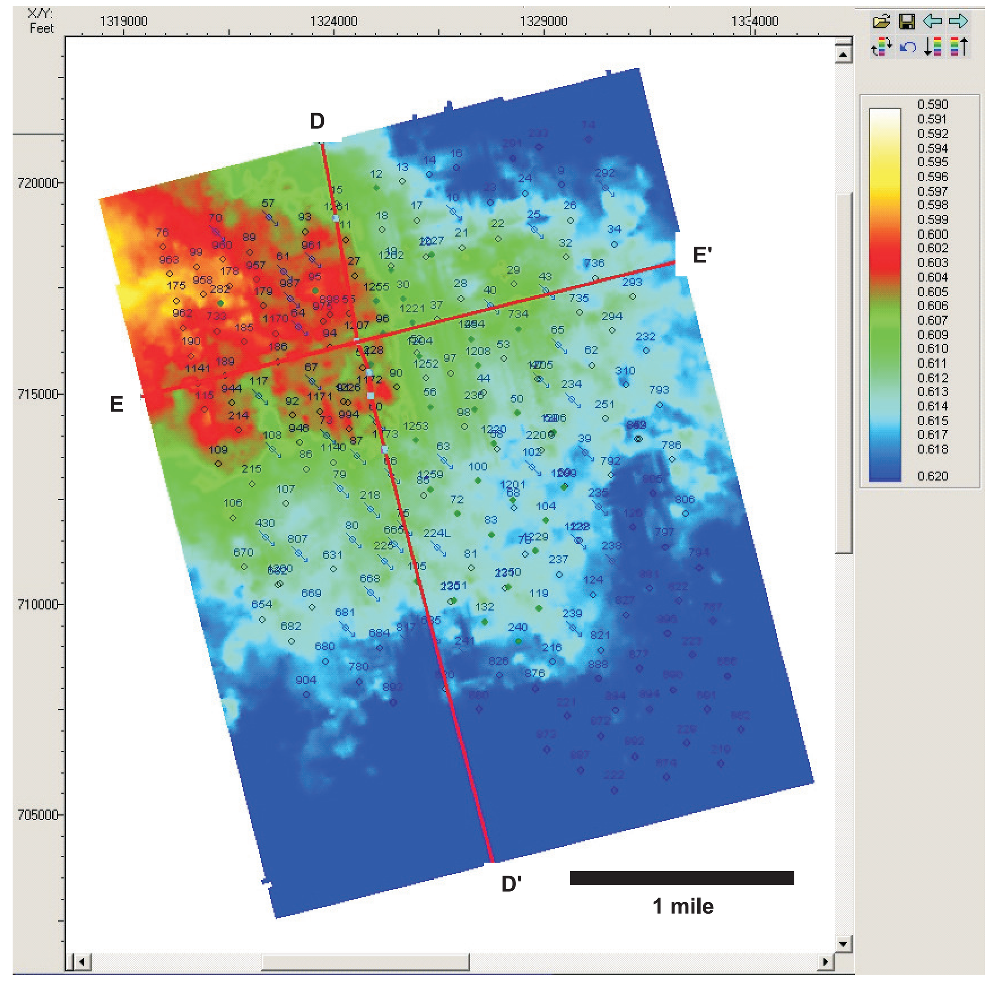
Cross plot of isopach vs. seismic isochron for the base of karst to x marker interval. The correlation is generally good. The two outliers circled in red at the top of the plot are locations where the "x" marker picks in the wells are questionable and may need to be adjusted.

HORIZON INTERPRETATIONS USING SEISMIC IMPEDANCE VOLUME

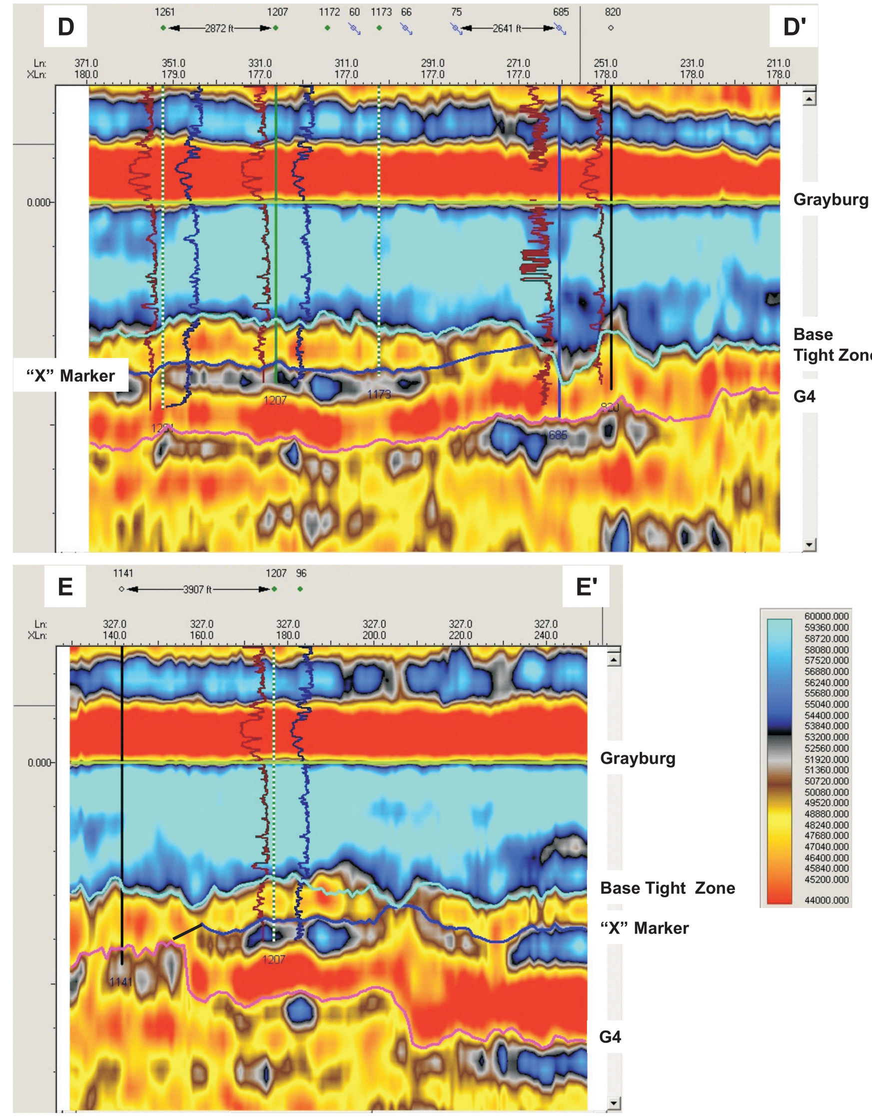
In order to improve our interpretations of the base of karst and "x" marker horizons, we have generated a model-based impedance inversion of the seismic amplitude volume in the "high volume area". Our starting model was based on the 11 wells in the area with sonic and density logs. The base of karst and "x" marker are much better defined in the resulting impedance volume than in the original amplitude volume.



Vertical section D-D' through the seismic amplitude volume (top) and an acoustic impedance volume (bottom) generated from the seismic amplitude data using model based inversion. The top Grayburg (green) and base of tight, anhydritic karst (cyan) interpreted from well data are shown connected by straight lines. Well logs displayed are sonic (dark red) and density (dark blue).



Time structure map of the base of karst horizon below the top of the San Andres Formation. Cross sections D-D' and E-E' are located.



Vertical sections D-D' (top) and E-E' (bottom), flattened on the Grayburg horizon, through the East Ranch acoustic impedance volume. Note that the "x" marker horizon is truncated by the base of karst horizon at several locations and appears to onlap the G4 horizon.

A horizon corresponding to the contrast between higher impedance above and lower impedance below that corresponds to the base of karst has been interpreted across the study area.

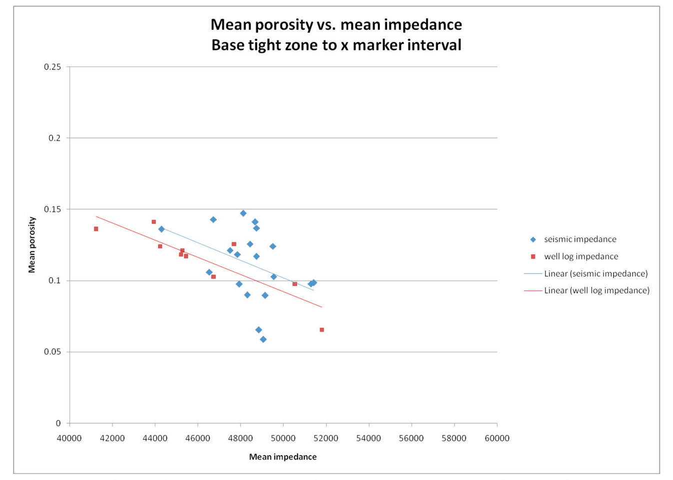
A horizon corresponding to the "x"-marker can also be interpreted on the impedance volume. The "x" marker appears to be truncated by the base of karst horizon in the southern portion of the study area and locally in other areas. In the western part of the study area, the "x" marker appears to onlap onto a deeper horizon, interpreted as the top of G4.

POROSITY AND SEISMIC IMPEDANCE

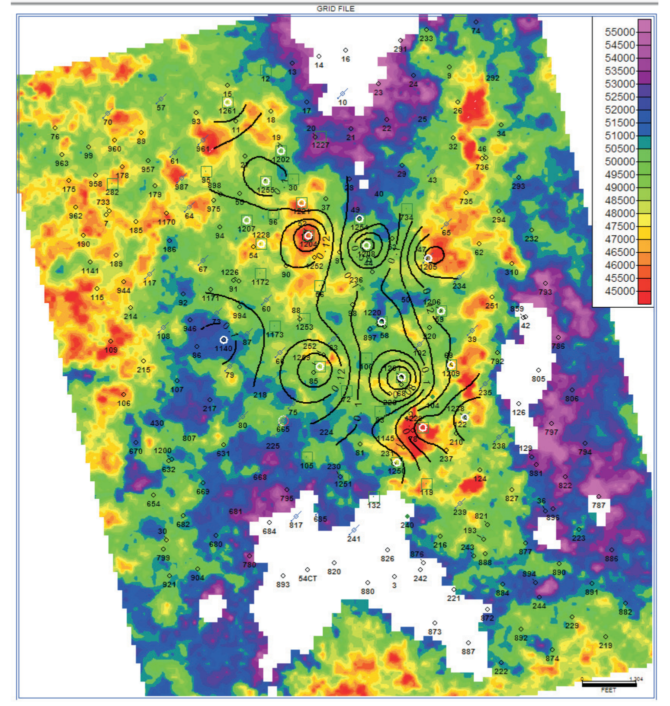
To evaluate the potential usefulness of using seismic impedance to predict porosity, we first computed well log impedance for all wells containing sonic and density logs. From this log impedance, we calculated the mean impedance for the base of karst to "x" marker interval. A cross plot of the mean log impedance versus the mean porosity for the same interval shows that the two measures are well correlated.

Mean impedance was also generated from the seismic data for the interval between the base of karst and "x" marker horizons. This mean seismic impedance is also cross plotted against mean porosity at the well locations. Although there is more scatter than for the log data, the seismic data show the same trend of decreasing porosity with increasing impedance. This correlation between impedance and porosity allows us to use a map of mean seismic impedance from the base of karst to "x" marker to approximate the distribution of mean porosity in areas with poor well control.

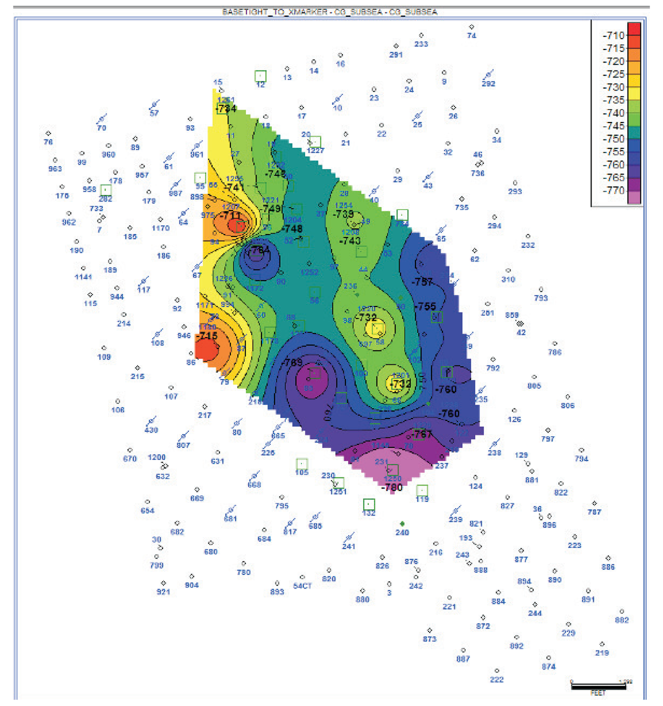
The mean impedance shows bands of north-northeast-trending highs and lows that are oblique to the main structure in the area. The high impedance areas may correspond to the locations of porous San Andres shoals.



Cross plot of mean porosity versus mean impedance from well logs (red) and from seismic data (blue) for the interval between the base of the tight (karst) zone and the "x" marker.



Map of mean seismic impedance for the interval from the base of karst to the "x" marker. Mean porosity contours from well logs are superimposed.



Center of gravity of porosity for the interval from the base of karst to the "x" marker measured in feet subsea. Lower center of gravity (blue) corresponds to higher mean porosity.

When mean impedance is compared to the center of gravity of well log porosity, which specifies the depth of the porosity development in the interval between the base of karst and the "x" marker, it can be seen that the easternmost trend of low impedance (high mean porosity) corresponds closely to a low center of gravity, suggesting better developed porosity in the lower portion of the reservoir interval. In contrast, the central high impedance (low mean porosity) trend corresponds to a similar trend of higher center of gravity, suggesting that the porosity has shifted to higher levels in the interval and is of lower magnitude. The westernmost north-south trend of low impedance (high mean porosity) corresponds closely to a low center of gravity, confirming a general relationship that porosity that is developed lower in the interval is greater in magnitude.