file - abstracts

March 5. 1987

Mr. John McKee
C/O Sanchez O'Brien
19 Briarhollow Lane #200
Houston, Texas 77027

Gulf Coast SEG

Dear Mr. McKee:

Enclosed is the abstract we discussed over the phone. The title is: "Integrating Seismic and Subsurface Date - An Interactive Interpretation Case History from Sterling County, Texas."

Please let me know the session, day, and time. Either Kevin or myself will present the paper, depending on travel schedules.

Best Regards,

Roice Nelson

H. Roice Nelson, Jr.
Landmark Graphics Corpaoration

CC: Kevin and Chuck

Integrating Seismic and Subsurface Date - An Interactive Interpretation Case History from Sterling County, Texas

By: Kevin Donihoo
H. Roice Nelson, Jr.
E. C. (Chuck) Brede
Landmark Graphics Corporation

Subsurface control from nine wells and five seismic lines were used to define a new prospect using an interactive interpretation system. Tops from up to 13 horizons were triangulated and displayed in map and perspective to give a feel for trends at different geologic times. A new well, the Harris #1, showed a porous and prospective, but wet, carbonate section at the Wichita Albany. Time velocity pairs were used to convert these depth maps to seismic time. The time horizons were projected onto five seismic lines that were available. These were adjusted to fit the reflectors. The seismic time horizons were converted to depth using the same layer cake velocity assumptions. Depth values from the seismic and well control were gridded, smoothed and displayed as final depth maps.

Stratal patterns were also interpreted on the seismic between the Wichita Albany and Base Wolfcamp horizons. These patterns were tied between lines and displayed in cross-section and fence diagrams. The sonic and density logs from the Harris #1 well were used to calculate the reflection coeffecient and create a synthetic trace which was overlaid on the seismic. Sections were flattened on the San Angelo to study the shape of the proposed reef at that time. Sags that could be due to velocity pushdowns were noted under the prospect. Horizons were displayed in map, cross-section and perspective to cross-check the interpretation in as many ways as possible. A synthetic section was made along a critical line using an advanced ray trace modeling package.

The interactive interpretation system provided a unique and useful method for integration and detailed evaluation of the subsurface and seismic data. The capability to try out different interpretation concepts quickly, zoom on windows, build perspective maps and fence diagrams, dynamically change the color control, do seismic instantaneous phase analysis, as well as the map building tools provided multiple cross-checks on the prospect interpretation. This type of quality interpretation is required to reduce the number of dry holes.

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Integrating Seismic and Subsurface Date - An Interactive Interpretation Case History from Sterling County, Texas

Fellow explorationists:

Last year's economic collapse of oil and gas prices and the resulting impact on our careers will be remembered by our children, in the same way my generation remembers the great depression. It is easy to look at other industries, like the commercial airline business, that reach a level of maturity and then go through a major transition in their way of doing business, and say "they deserve that." But it seems different, when our jobs, or our friends jobs, are on the line. So how do we and the industry respond?

There are two basic responses, either to work within the bounds presented by the new circumstances, or to take advantage of them. In other words, to rearchitect the way we do business or become predatory. In regards to oil companies, it should be obvious which camp (preditor or architect) the corporate takeovers fall in, and in which camp companies implementing new technologies to help architect a new future for our industry fall in. It is very exciting being at the forefront of introducing new interpretation technology to the oil and gas industry. Today's presentation is based on the belief that there are new technologies that can enhance our transition into a new way of doing business.

#1L
New Technology and Exploration
by: H. Roice Nelson, Jr.

Exploration is the search for commercial deposits of useful minerals, including hydrocarbons, according to Sheriff's dictionary. With the technology base presently available to our industry this search is mostly a problem of interpretation. To quote from Nigel Ansteys remarks at the opening of the EAEG last summer in Ostend: "If we mounted a tremendous research effort, and triumphed over all the traditional problems of geophysical field work and processing . . . . we would raise the success rate only from one in seven to one in six." He went on to generalize the reasons for the other six dry holes: one because there was no source or reservoir rock; two because of lateral variations in the reservoir rock; and two for reasons concerned with the trap. In other words, the new technology our industry needs to implement and get trained on, in order to keep our jobs, is largly based on solutions to interpretation problems. To illustrate this, and highlight examples of interpretation technology, as described in Peter Vail's comments quoted on the right slide from last month's AAPG Explorer, we will present examples from an active exploration prospect in Sterling County in west Texas.

#2L
Location Map

This location map and a Lotus spread sheet defining tops for nine wells, were sent via facimile Thursday morning February 19th. By noon the tops had been typed into a workstation and 13 depth maps were completed. After lunch those maps were read as horizons into a binned or gridded surface, and used to create critical depth cross-sections to check the relationship of the different horizons. There are several hundred oil producing wells just to the northeast of our area of interest. The nine wells we had tops on are circled on the base map.

#3L
Greyburg Tops

The Greyburg Tops were only picked on 4 of the 9 wells. Notice how these points define a simple plane dipping to the southwest.

#3R
San Andres Tops

The San Andreas shows a slight north-south ridge with a strong change in dip of the layer to the the far west well. Making maps with a linear interpolation like this is very quick and it highlights problems that might not make geologic sense and might need to be checked more thourghly. At 1200 feet depth, having a 300 foot drop over about a 2000 foot run is not unreasonable.

#4R
Upper Clearfork Tops

The Upper Clearfork nicly shows a north-south ridge through the prospect area. This ridge will become much better defined as we integrate the seismic picks with the subsurface information.

#5L
Lower Clearfork Tops

The Lower Clearfork clearly illustrates a high in the center of the prospect area. This high is interpreted as being an expression of drape over a reef.

#7L
Cisco Shale Tops (Base Wolfcamp)

The Cisco Shale map, which is also the Base of the Wolfcamp, shows a similar trend to the Swastika.

#9L
Penn Lime Tops

The Penn Limestone shows to be a fairly flat platform, on which the other layers were built. The important point here is that these 13 maps were generated in a couple of hours using a workstation. Isopach, smoothed or hand contoured maps based on the linear interpolations could have just as easily been generated, and in fact you will see examples of how these types of maps were used later on in the presentation.

#11R
Gridded and binned Wichita Albany

The slide on the right shows the Wichita-Albany well top map after it was binned or gridded. This process takes about 2 minutes once the bins are set up and tied to real world coordinates. The location of the five available seismic lines are also shown. The colors are intended to give an impression of depth, going from bright for the shallow to dark for the deep. In addition, each color is graded to black over about a 60 foot interval. Notice how using just the well control the reef is centered over the LJA Harris #1, but noses to the southeast. All of these pictures are simply an history file of the interpretation process. This type of pictoral history file provides another type of check-klist for the exploration manager.

#12L
Location Depth Section downdip the proposed reef nose

The slide on the left is the same as the previous slide, with the addition that an arbitrary line has been drawn down the nose of the structure to show the location of the depth cross-section on the right hand screen.

#12R
Depth Section downdip proposed reef nose

The Wichita Albany is in light blue, and implies the forereef is to the north-west and the back reef is to the south-east. This would fit the concept of the reef sitting on a nose from the south-east.

There was an interesting quotes along these lines from months AAPG explorer. "Many officials agreed the companies equipped to offer high tech services will be the ones to survive the slump and emerge as strong competitors."(Fritz) At Landmark we have found the largest companies and the youngest companies are the first to use these types of new technology. The largest companies use the newest technology as a normal method of competition. The youngest companies use new technology to leverage themselves and become competitive more quickly. However, there presently seems to be a large gap in the midsized and more established companies. The company that provided this data is one of several clients that are much younger than

Landmark.

#13L
Location Depth Section across proposed reef nose

This slide shows the location of a depth cross-section to be interactively brought up across the nose.

#13R
Depth Section across proposed reef nose

Notice how the structure carries from the Canyon (red) all the way up to the Upper Clearfork (pink), with even a hint of structure at the San Andreas (gold).

Next we will look at other ways can we use the new workstation technology to work with well control.

#14L
Log Interpretation Mask

Using GeoSim's Synthethics Plus Package we specified the top and bottom depths of our well logs to display. In working with well logs, in addition to single valued tops, there is the extra dimension of one value for each depth, and it is necessary to start defining display options like where to locate the sonic and density logs on the screen(s).

#14R
Sonic and Density Log

The right screen shows the sonic log on the left, and the density log on the right. These logs can be blocked, edited and otherwise interpreted. In fact, the editing options are so general that a log from any field can probably be made to tie a section. This is an example of where the exploration manager might want to insist on a history file of pictures, summarizing the input log, the critical editing and blocking decisions, and the final results to quality control the interpretation process.

#15R
Time vs Depth Table

The slide on the right is another example of a typical hardcopy plot. In this case, the vertical axis is travel-time in multiples of 10 ms, while the horizontal axis specifies travel-time in 1 ms intervals. This makes it easy to look at 1014 ms and determine the depth is 8015 feet. Computers are very good at these types of calculations, and the key to interactive use is the proper development of a easy user interface.

#16R
Reflection Coefficient and Synthetic Trace

The slide on the right is the display is of 5 traces at 5 inches

per second, starting at 900 ms and going to 1070 ms, with timing lines every 10 ms.

#18L
Isopach Map

This location map also shows the relative location of the well control. The reason the seismic lines are colored is because they show the thickness in feet of the Wichita Albany to Upper Clearfork Isopach as calculated from the seismic picks using the well velocity control just described.

#17R
Line 4, EW Black to White Variable Density

The slide on the right is a black to white variable density display of the second west-to-east seismic line from the top (north), Line 4.

#18R
Line 4, EW with horizons

The slide on the right shows the interpretation of four horizons in time. The yellow horizon is the San Angelo, and the green the Wichita Albany. Note that the thickening towards the east (right) is shown on the map as color changing from blue to red to white. The Wichita Albany minus San Angelo isopach ranges from 2057 to 2458 feet thick. The forereef break is highlighted by the blue to red boundary at a thickness of about 2350 feet. The red ranges from 2100 to 2150 feet thick and the thinnest section, at the top of the reef, is 2050 feet.

#19R
Line 4, EW with horizons and stratal pattern interpretation

Here we have redisplayed line 4, but the interpretation of every peak and trough is overlaid between the Wichita Albany and the Base Wolfcamp (called the Cisco Shale in the first maps we looked at). Using Peter Vail's terminology of a new interpretation technology, as referenced at the beginning of the paper, these picks define the stratal patterns. We will look at these patterns in more detail later.

#20L
Line 4, EW Wiggle Trace

Workstation technology allows the interpreter to quickly change the display format. In this case every trace is displayed as a wiggle trace.

#20R
Line 4, EW Wiggle Trace with horizons

The slide on the right is the same West-to-East line, with the interpretation overlaid on the wiggle traces.

#25R
Lines 4&6, with horizons and stratal pattern

#26L
Lines 4&6, with color bar

Color can further ehnance the display and guide the interpretation. In this case, the Wolfcamp "platform" is highlighted by stressing the strongest amplitudes by coloring them yellow and orange. In addition, continuity is enhanced by grading from black to white across the zero crossing and giving a phase appearance to the data.

#27L
Lines 4&6, with horizons and stratal patterns

These two slides show the same sections with the horizons and stratal pattern interpretation overlaid. The right slide is simply a pixel zoom.

#27R
Lines 4&6, pixel zoom of left screen

#28L
Lines 4&6, with projected synthetic and software zoom window

Earlier we showed the calculation of a synthetic trace for the LJA Harris #1 well. These two slides show that synthetic projected onto lines 4 and 6. A picture of a software zoom of the synthetic was taken, and overlaid on the previous section display, both with no picks and with horizon picks. Although this example does not provide new insights, the concept of interactively tieing subsurface and seismic data is a valid new interpretation technology. Part of the reason the synthethic does not clearly tie is because the well was projected about 1000 feet to the east-west line and about 2000 feet to the north-south line.

#52L
Lines 4&6, instantaneous phase with horizons and stratal pattern

These two sections show the instantaneous phase with the horizons and the stratal patterns. The right screen is a pixel zoom of the left screen. Note the velocity sag.

#29R
Lines 4&6, flattened on San Angelo with horizons and stratal pattern

Besides tieing in geologic control and flattening sections, interactive workstations also provide interpretive tools that can be used to do required post stack processsing, check the earth model created during the interpretation, modify the interpretation based on differences between a forward model created from the interpretation and the raw seismic data, and generally help in minimizing exploration risk. The workstation environment encourages the interpreter to try out different interpretational concepts. On a small project like this, there might not be the same order of magnitude improvement in the time to do an interpretation there is with a large survey. However, there are many more cross-checks made on the interpretation, and a much more quality interpretation can be developed.

The need to understand the different sources of possible risk for seismic or well top picks made on a depositional surface or on an erosional surface encourages the interpreter to create picture history files of interpretative decision points. Properly labeled, these pictures provide the exploration manager a quick review of key interpretative decision points. Why was the upper seismic leg taken instead of the lower leg? How does the isochron map help show which of two different interpretations make more geologic sense? How good do specific well tops correlate with specific seismic picks or to calculated lithologic boundaries? If exploration managers know the questions to ask and can obtain the correct answers, then prospects can be graded, risk reduced and there will be fewer dry holes.

#31R
Pixel zoom of flattened section with horizons and stratal pattern

The economic changes mentioned earlier, are having a major effect on exploration and make it even more important that we drill fewer dry holes. Technology changes are providing a key means of reducing the number of dry holes. Aggressive exploration managers are moving quickly to adopt these technologies and to make sure risk is minimized. Reducing risk requires making sure all available data is used and then asking hard questions about the data and how it confirms or questions each prospect. For an explorationist to know the answers, or an exploration manager to know the questions to ask, requires expertise. It is estimated that a world-class expert has 50,000 to 100,000 chunks of heuristic information about their specialty. Each chunk, with all its myriad associations, can be retrieved, examined, and utilized at will. Further, psychologists believe that it takes at least 10 years to acquire 50,000 chunks. [Harmon and King]

This means experience translates into expertise. Retirements and other staff reductions have resulted in a general loss of the available body of knowledge for most companies. However, this loss in experience need not lead to more dry holes. New computer technologies are available that can quantitatively and qualitatively enhance the probable success of drilling decisions.

#32L
Lines 4&6, just smoothed horizons

These two slides show just the horizons, and the horizons and stratal patterns on the intersection of lines 4 and 6, with the seismic data all colored the same color of gray. Note that these sections were flattened on the San Angelo.

#32R
Lines 4&6, smoothed horizons and stratal pattern

Of paticular interest is the apparent velocity sag on several reflectors, underneath the highest portion of the Wichita Albany. This kind of cross reference can certianly improve the grade give to a prospect.

#33L
Map and five sections with stratal patterns

Here we are looking at a map of the relative line locations, and cross-sections highlighting the stratal patterns. Line six is above the map, with south on the left and north on the right. The four west-to-east cross-sections are Line 1 at the top, then Line 4, Line 2 and Line 3 at the bottom.

#33R
Perspective of map and stratal patterns

The perspective relationship of these patterns and three horizons of iterest is shown on the right screen. The horizons are the Upper Clearfork (yellow), Wichita Albany (green) and Canyon (red).

#35L
Lines 4&6, WENS stratal patterns

Here we have displayed portions of lines 4 and 6 so that they tie. To visualize the three-dimensionality of the data, these two sections are displayed in perspective on the right screen. This perspective is looking at the sections from the southwest.

#35R
Perspective lines 4&6 from southwest

#36L
Perspective lines 4, 6 & 2 from southwest

By changing the map coordinates displayed in the perspective window, line 2 was added to the perspective display on the left screen. The stratal patterns from all 5 lines are displayed in perspective on the right screen.

#36R
Perspective all 5 lines with uninterpreted stratal patterns

#37L
Map and 5 cross-sections with interpreted stratal patterns

The next interpretational step was to relate stratal pattern picks on the different sections. The left screen shows the map location and the interpretation on all five sections. The right screen shows a perspective of the interpreted stratal patterns on lines of lines 4, 6 and 2. If a prospect is valid, this type of display can encourage management to drill it.

#37R
Perspective lines 4, 6 & 2 from southwest with interpreted stratal patterns

#38L
Perspective all lines from southwest with interpreted stratal patterns

The slide on the left shows the interpreted stratal patterns on all five lines looking from the southwest. The slide on the left is a detail look at lines 4 and 6 from the same direction. Line 4 is on the left and goes from west-to-east, then line 6 goes from north-to-south.

#38R
Lines 4&6, WENS with interpreted stratal patterns
From the SouthWest

#39L
Perspective all lines from southwest with interpreted stratal patterns

These two slides are similar, except that on the right slide we are looking at the intersection from the southeast. Line 6 is on the left going from south to north, and then is line 4 going from west to east. Notice that even though the east end of line 4 is the highest part of the structure it is not interpreted as perspective (yellow), based on the stratal pattern.

#39R
Lines 4&6, SNWE with interpreted stratal patterns
From the South East

#40L

Composite subsurface and seismic Upper Clearfork map with 5 cross-sections

These pictures illustrate the structural relationships of the Upper Clearfork horizon after merging subsurface and seismic information. Since there was only a single well, simplified layercake velocity assumptions were used to convert the seismic time horizons to depth. The results tied quite well as shown by these smoothed contour displays. The left slide shows a map view of the Upper Clearfork and the interpretation along the location of the five seismic cross-sections. Bright colors note the shallowest, and dark colors highlight the deepest portions of the surface. Note the ridge that runs north-south through the prospect area. The three-dimensional relationships are highlighted on the perspective display on the right screen.

#40R

Prospective composite Upper Clearfork map

#41L

Linear interpolation composite map Wichita Albany

After converting the seismic times to depth, and before smoothing the map, it is a good idea to display a linear interpolation between picks and see if there are any major busts. The slide on the left is a surface created by fitting a trianglized surface to the control points. The right screen shows the same map after smoothing it with a 3300 foot square smoothing operator. This is about two-thirds of the distance between the east west lines. Without doing any hand-contouring, and honoring all control points we have created a respectable map of the Wichita Albany. We have two branches to the high, the left of which has reef characteristics based on the stratal pattern interpretation. (It is also on the acreage owned by the small oil company doing this play.)

#41R

Smoothed composite map Wichita Albany

#42L

Composite subsurface and seismic Wichita Albany map with 5 cross-sections

These slides show the Wichita Albany in map view, as well as the relationship to the Upper Clearfork in both cross-section and perspective views.

#42R

Perspective Wichita Albany and Upper Clearfork maps

#43R

Perspective wells and cross-sections relative location

#46L
Both horizons fault color

Here both horizons have been put together and displayed in their individual colors. The slide on the right has the well locations and the ends of the seismic lines posted as white lines. Notice that the display has been rotated around, and we are looking at it from the north. Where the seismic control intersects the horizon is shown by the colored lines along the horizons.

#47L
Both horizons depth color

The only difference from the previous slides is that the horizons are colored as a function of depth. The depth scales are posted on the left. The intersection of the LJA Harris #1 well in the middle of the red contours is seen on the slide on the right.

#47R
Both horizons depth color with well and seismic location

#48L
All 3 horizons and location of depth cross section

Interactive interpretation allows complicated displays that help coceptualize complex spatial relationships that are not possible using traditional techniques. The map on the left slide shows three horizons overlaying each other. The density display is the Wichita Albany horizon. The white contours are the Upper Clearfork. The colored contours, most obvious in the upper right corner, are of the Breckenridge Limestone. This same process can be used to overlay overthrust horizons. Notice that the well locations, seismic line locations, and the location of the depth cross-section displayed on the right screen are also posted on the map.

#48R
Cross-section with three horizons

The cross-section is seismically controlled about half way across, and then is controlled by the well tops.

#49L
AGS ray paths on composite cross-section

Modeling was not of particular benefit on this particular project. However, these slides show ray-trace diagrams generated across the previous depth cross-section and the resulting synthetic time section. The modeling was done using AGS 3D.

#49R
AGS synthetic section

#54L
Final Map Upper Clearfork

#54R
Final Map Wichita Albany

#55L
ISM map of Wichita Albany

#55R
ISM perspective display of Wichita Albany

#56R
Hand contoured map Wichita Albany with most optimistic oil water contact

#57R
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