Converting 2-D Seismic to Three Dimensions

Jack G. Elam, Ph.D.

The advent of 3-D seismic is causing a revolution in exploratory thinking within the petroleum industry. All of a sudden, it is becoming fashionable to think in three dimensions. until recently, most petroleum industry explorationists were satisfied working with planar sections and models, and they pretty well ignored the fact that 2-D seismic had no satisfactory way of overcoming its single greatest weakness, it's inability to accurately measure True vertical Depth. With 3-D seismic, a myriad of reflections are recorded at every shot point and the computer applies the proper corrections to provide the accurate depth measurements required for 3-D mapping. Fortunately, now there is a relatively new geophysical instrument that has proven capable in the field of providing the proper depth control for 2-D seismic, so these planar lines can now be used to construct maps in 3-D, and at a far lesser cost.

In a 3-day course to be offered at the Permian Basin Graduate Center June 4-6, 1991, I will demonstrate how 2-D seismic lines, used in tandem with this geophysical tool can produce contour maps in 3-D that approximate those constructed using 3-D seismic. However, I have found it is very difficult for an explorationist to map properly in 3-D while thinking and visualizing the solution in two dimensions. Three dimensional thinking is not easily learned!

As a stress analyst researching the rift structures of the Permian Basin for the past 25 years, it has been evident from my earliest research that seismic contours on the producing anticlinoria, based on 2-D shooting, seldom reflect the true structural morphology. That explains why there has been so little agreement as to the stress systems that created the structures. Using the recently developed theological model of the earth, (Vierbuchen et al, 1983), an analyst can easily show that few producing anticlinoria, defined by 2-D seismic alone, represent mechanically viable structures. Three dimensional problems cannot be solved using plane geometry.

That is not to say that 2-D seismic cannot locate the structural highs, rather it is that the seismic contour maps do not often reflect real surfaces, and this is especially true in the deeper basins. This conclusion can be defended because, fortunately, the contours on the Yates or Delaware sands, where there is much better subsurface control, tends to mimic the contours at the Devonian or Ellenburger levels, particularly in the areas where these sands were deposited horizontally. Most importantly, these shallow contour maps consistently define mechanically viable structures.

Obviously, what the 2-D seismic in the Permian Basin has lacked all these years is the ability to measure true vertical depths, and this shortcoming is particularly acute in the deeper basins, especially in areas of extreme salt solution, such as along the ancestral Pecos River. In order to get any usable reflections, very wide geophone spreads are required, and after all this data has been processed and reprocessed, the seismic reflections are averaged or smoothed, and they lack the fine detail required for proper stress analysis. One can often observe the disappearance of the critical second-order data with the additional processing. Because of the abundant faulting in the basin, diffractions also cause severe interpretational problems. In fact in many areas of the deep basins, diffraction highs are more commonly drilled than true structural highs. As a consequence, particularly in recent years, the 2-D seismic interpretations have been producing unacceptable dry hole ratios, and that is causing the industry to turn to 3-D seismic.

What is being lost is the second-order detail that must be available in order to work out the structural mechanics involved. Without this kind of control, impossible structures are most frequently promulgated. Certainly, some areas in the basin are worse than others, and my structural research has been concentrated in seismic problem areas where I have reason to believe undiscovered structures still await discovery.

The tool that very accurately measures TVD is the Petro-Sonde, marketed by Geophysics International of Dallas. It records the telluric currents that are generated at conductivity interfaces within the sedimentary section by the pulsing plasma envelope that surrounds our planet. This tool has been patented, and its workings and theory have been described in the literature (Elam, 1990). Most importantly, these currents are now being digitally recorded, and it is now possible to prove that the telluric currents are present and repeatable. A crude conductivity log is constructed by a Petro-Sonde operator, and this log can be correlated and calibrated for depth with an electric log at an existing borehole in the field.

The Petro-Sonde can measure TVD to 40,000' with an accuracy of 50', and I have personally worked with it below 25,000'. In most cases, I have found that the Petro-Sonde log correlates with a calibration well within a few feet, but there are some days when the logging cannot be done because solar flares and variable atmospheric conditions have affected the telluric current. Thunderstorms in the area quickly shut down the work. In those instances, there is no repeatable data, a fact that is easily discerned by the Petro-Sonde operator.

Instead of treating the Petro-Sonde as threatening, geologists and seismologists need to recognize that the Petro-Sonde, combined with good 2-D seismic, will produce maps in far greater detail than from the seismic alone. The Petro-Sonde endangers only those explorationists who choose to continue to live in a 2-D or planar world. I have used the tool in the field for the past seven years, and everyone of my drilling prospects is contoured in 3-D. One first has to learn how to reconcile the 2-D seismic and the Petro-Sonde data. When you truly understand how the respective data from the two geophysical services is gathered, this is often not all that difficult to do. However, if you end up with conflicting data, you do not have a satisfactory prospect. One uses the Petro-Sonde to explain the 2-D seismic, not to refute it! The more distinctive the stratigraphic section, the more reliable the data. Most Petro-Sonde failures are caused by miscorrelations.

Because of the Petro-Sonde's accuracy in measuring TVD, it can be used the way a Brunton Compass is used by a field geologist, except that the dips and strikes must be fairly uniform over a sizable area. The tool also works well in areas of steep dip, and often, the boreholes can be shown to migrate up structure. Diffractions are never a problem with this instrument, and that is where it is most helpful in unraveling the seismic. Vertical faults are easily spotted too.

Don't think the Petro-Sonde is foolproof. Correlation busts are easier to make than with an electric log, but in solving 3-point problems for obtaining attitudes, there should be fewer correlation errors because of the use of the closely spaced points. I suggest a 500' spread for attitudes. Inasmuch as most Permian Basin structures consist of a myriad of tilted basement fault blocks dipping away from a crestal graben, this structural style is easily recognized when mapping in three dimensions.

There is no way that 3-D visualization can be any more than initiated during this 3-day class period. K.F. Dallmus (1958), who first introduced us to the earth's curvature, was very well received when he was first published in the Habitat of oil. However, his most important geometric concepts were quickly ignored, and few even remember him today, even though his was really the geological contribution of this century. He was the forerunner of 3-D seismic, and prompted my shift to stress analysis.

In the course I plan to present a number of field and mapping problems where the participant will have to come up with answers that will reveal the economic value of living in the real world of three dimensions. Perhaps you will then begin to appreciate the magnitude of the revolution in geological thinking that is taking place to bring our thinking up to grade with our new 3-D seismic technology.

In addition to working with maps and sections displaying 3-D thinking, I have arranged for a one-day field demonstration of the Petro-Sonde. I will attempt to show how this tool should be employed in the field. Petro-Sonde mapping has much in common with surface field mapping. Using it is similar to getting to drill 10 or more deep wildcats every day. I find it fun for that reason.

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