Correlating well markers with the aid of seismic interpretation

Huw James and Taoufik Ait Ettajer of Paradigm, exploration and production geoscience software manufacturer, illustrate the possibility of correlating well markers with the aid of seismic interpretation and seismic data in section and 3D views.

Display of seismic and well data together can strengthen the interpretation of both. The complex field of seismic data acquisition requires reliable software that can link disparate data and disciplines together, while offering computer assisted tools to help users acquire crucial geological cross sections. Marker correlation for horizontal and highly deviated wells can be supported by using vertical traverses through well markers or by correlating well markers in 3D views, both methods allow the well, seismic and interpretation data to be spatially correlated and avoid the problem of losing positional reference when converting deviated wells from measured depth to true vertical depth or onto vertical sections.

Exploration and asset development teams are composed of multiple disciplines which use different tools to analyse different data types in different disciplines. This means seismic data has not been readily available to petrophysicists and that geologic cross sections have been unavailable to seismic interpreters.

But 3D visualisation systems have been successful in capturing 3D seismic interpretation tasks.

As more data types such as well, satellite imagery and downhole measurements have been added to these displays, for the benefit of seismic interpreters, geologists and petrophysicists have also benefitted.

Seismic data and seismic analysis tools are now readily available from 3D and 2D seismic surveys for use by geologists building cross sections, petrophysicists analysing log curves and drillers planning wells.

Modern systems can add data from multiple 2D and 3D seismic surveys; data from multiple well data bases and multiple seismic interpretations to a single section or 3D view.

This makes comparison of different interpretations far easier than before, and enables the construction of consolidated interpretations across many interpreters as well as across many disciplines.

We can now see seismic interpreters using the cut-offs and cross plots of petrophysicists; geologists using the picking and drawing tools of geophysicist, and all disciplines performing both structural and stratigraphic interpretation, using facies analyses of well and seismic data and using flattened and proportionately sliced displays.

The use of common section and 3D views enables all disciplines to benefit from the same developments and share in the costs, but more importantly, it enables different disciplines to collaborate in the same scenes and lowers the barriers between them caused by the use of different tools.

This enables much better communication between various disciplines in exploration and asset teams, which may result in a much better synthesis of all available data.

This unified interpretation means anomalies become easier to see, resolve and integrate, or throw doubt on the interpretation. Many plausible interpretations in any one discipline can be vetoed once all the available data is integrated.

Next generation software

The seismic components of next generation software can be characterised by the increasing availability of computer assisted tools. The most obvious of these has been 3D seismic horizon trackers. These tools have been augmented by 2D seismic horizon pickers, computer assisted fault pickers, and various real time tessellation schemes that bring modeling into the interpretation workflow.

These have been joined by log correlation methods that can follow geologic rules, filtering techniques that can enhance continuity or discontinuities for horizon and fault picking respectively; and of course the myriad of attributes, facies analysis and inversion schemes that can process multiple seismic channels and data sets into various physical measurements such as Fluid Factor or enhance particular aspects of the seismic data.

Geologists and petrophysicists are now benefitting from similar computer assisted methods that allow thousands of faults to be extracted from 3D data sets and then analysed for orientation between successive unconformities.

The statistics resulting from massive amounts of data can reveal quite subtle trends in the orientation of faults over time. With partial automation, large amounts of well log data can be analysed similarly and subtle relationships of curve data are found for particular geologic intervals and areas. This can lead to much better and precise estimates of rock properties. These tools are making today an exciting time for earth scientists.

Down to Earth

To get practical, the simplest way of showing the benefits is to define lines of section or traverses between wells on a base map.

Once this traverse is defined, 3D seismic data can be extracted along the traverse to indicate changes in structure and stratigraphy between the wells. This was one of the first immediate uses of 3D seismic interpretation systems and it greatly simplified fault interpretation from well data. The main difference today is that the seismic data is live for the geologists to use. It can be filtered with structurally oriented filters that preserve discontinuities or it may be pre-stack gathers along the traverse which can be examined for AVO effects. Dead seismic has been replaced by live seismic that can provide better integration with well data.

The ease of generating all available data along any well traverse means interpreters can interpret in many different azimuths through the survey, and that they are no longer constrained to the acquisition directions of in-line and cross line. Traverses can be dip and strike or radial and tangential around circular features such as salt domes.

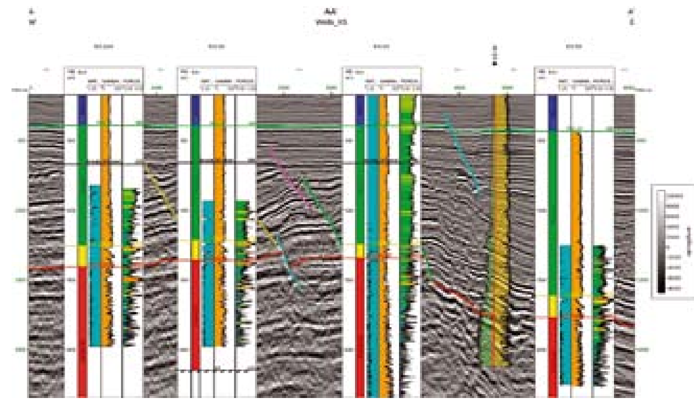

Figure 2 shows a sample cross section with well log panels inserted that combine seismic data and seismic interpretation with the well data and a stratigraphic column.

This case is quite simple, but obviously the different well tracks can be used to display biostratigraphic, lithostratigraphic, chronostratigraphic, computed log, perforation, pressure test, fluid data and seismic synthetics.

If the wells are not vertical, the interpreter can define the well traverse through any marker including the bottom hole marker in order to keep the vertical curtain assumption of a simple cross section as close to reality as possible.

So long as the wells are not horizontal there will be a limited vertical plane that is close to the well bore for any particular depth or time interval. Such cross section displays enable well data to be visually correlated with the seismic data which in turn drives the correlation of well data from well to well.

There are many instances in Figure 2 where a particular log response correlates to large seismic amplitudes with significant structure from well to well. For example, a yellow peak in the porosity log on well KG-5X at @ 1650 ms can be relatively reliably correlated with a similar peak in well KG-2AX @ 1300ms.

Without the seismic data this correlation would be difficult to carry across well KG-1X with its different shape of the gamma ray curve.

Conversely, the injection of the well data

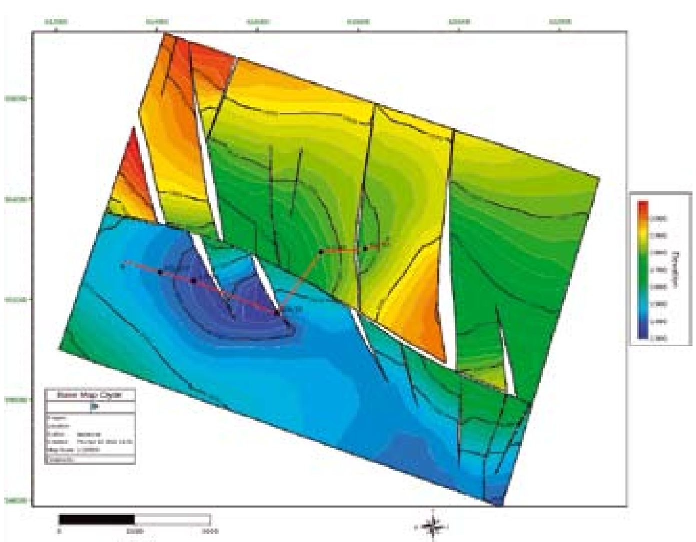

Figure 1 shows a simple time structure base map with fault outlines and a simple traverse through five wells.

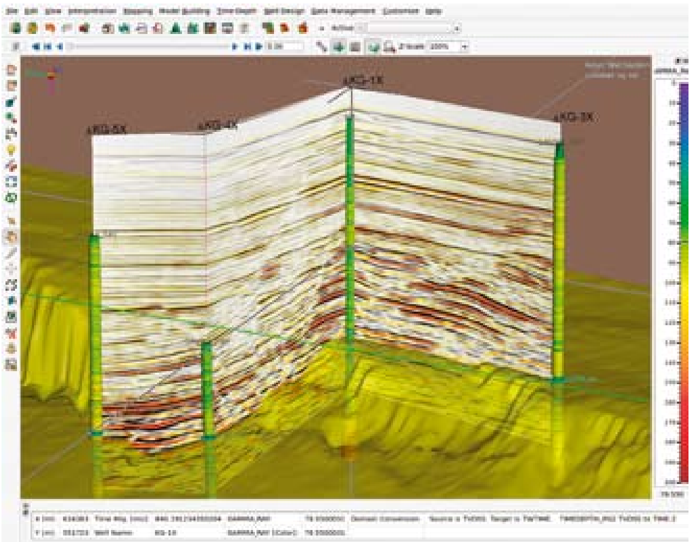

Figure 3 shows a 3D view across a major fault with about 600 metres of relief.

into the seismic traverse also illuminates the seismic interpretation and causes some re-appraisal of the seismic data around well KG-2AX.

You can easily see how seismic interpretation methodology could switch from one of interpreting and propagating horizons from views in in-line and cross line space, skipping use of arbitrary traverses for propagation and settling on views of well traverses so that interpretation data will be more closely tied to well data.

3D structure and views

Section views are sufficient to interpret layer cake geology with simple dip and strike directions and vertical wells. If the geologic targets are 3D in nature, for example channel fan complexes, reefs or complex structures, then 3D views can be very beneficial for the interpreter.

3D visualization enables the interpreter to effortlessly see the structure, and then use their brains to understand the details in the data, rather than to be fully engaged in constructing a mental image of the structure.

3D views also allow groups of interpreters to collaborate more easily. When each interpreter makes individual images of a 3D structure, it is difficult to ensure everyone's images are aligned.

But, when the structural image is generated by computer, alignment is forced upon the interpreters. The computer generated image has to be visually plausible to satisfy most geologists - because their brains are well practiced at creating their own 3D images and implausible or inaccurate displays can be painful for such an audience!

The interpreter automatically understands when part of the traverse is along strike and when part of the traverse is perpendicular to strike. This understanding would be much less direct for an interpreter viewing a section. The azimuth of the section with respect to strike would be unknown. The structural reference is extended out into the view with the aid of a partially transparent horizon surface. Here the 3D view of the data aids the interpreter because of the 3D geometry of the structure.

Channel-levee-fan complexes are also much better viewed in 3D where the full 3D structure can be seen in a single view rather than in multiple section views where the 3D structure has to be built up in the mind of an interpreter. If the section views are at unfortunate angles to the structure it may escape recognition when viewed slice by slice.

Deviated and horizontal wells

Horizontal wells are difficult to correlate from 1D log displays. Curves from two wells that are close in the subsurface may be far apart in measured depth because of differences in the two borehole trajectories.

It is not possible to convert horizontal wells to true vertical depth without losing large quantities of data in the horizontal sections. It is also difficult for the brain to construct internal 3D images of boreholes relative to the 3D structure if the boreholes are not parallel or otherwise simply arranged. 3D views allow the boreholes to be placed correctly in 3D space and the 3D structure can be added to the view with 3D views of horizon and fault surfaces.

Adding extracted seismic data to the surface joining two well bores enables the intervening space to be inspected for faults or changes of stratigraphy indicated by the change in the pattern of seismic data.

Vertical curtains of seismic traverses can also be added to give the interpreter extra clues about the structure and stratigraphy of the volume. A sandy bed indicated by a blue shade of the gamma ray log can be correlated between the wells and

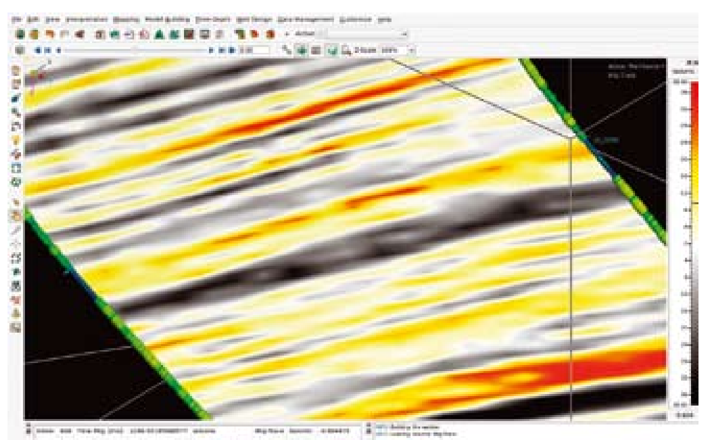

Figure 4 shows two almost horizontal wells with gamma ray log curves and a seismic well section extracted from a 3D data volume.

the intervening space can be inspected for indications of seismic or sub-seismic faults. In this case there is a hint of a subtle fault.

Summary

If you view the figures - and try to observe your brain in action - you should be able to see your mind interpreting the well data, and then inspecting the seismic data; followed by the reverse process of interpreting the seismic data and then trying to understand its relationship to the well data.

This deepens the seismic interpretation from one of picking structure to one of seeking reservoir material, in this case fairly thin sands. Then, when the seismic and well data do not correlate well, the brain tries to remove the conflict.

On a workstation the interpreter would take a look at an alternative view to seek resolution of any problem. This is not possible from hard copy.

So just placing the data in spatial proximity helps correlation of both seismic to seismic, well to well and well to seismic. Placing the data in a 3D view is of great help when there is significant structure and is hugely beneficial if the wells are horizontal.

The data used in this paper is from offshore Indonesia courtesy of Clyde Petroleum.