Reservoir geophysics: what went wrong?

Richard Cooper[*] and Richard Uden of Rock Solid Images ask some searching questions no one dares to ask about the slow development and take-up of the promised benefits of reservoir geophysics using 4D seismic and other advanced techniques.

In the mid-1990s, our industry was forecasting a huge increase in activity as we transitioned from 3D to 4D seismic. This growth was expected to rival or exceed the tremendous increase in fortune our industry enjoyed 20 years earlier with the commercial development of 3D seismic as an advance over 2D, or the even earlier move from analogue to digital recording and processing.

So, what happened? Clearly time-lapse, or 4D seismic, has not catapulted the geophysical industry into a new golden age of wealth and power. This article attempts to provide some reasons as to why the take-up has been somewhat slower than anticipated.

We begin by placing 4D within the broader concept of 'reservoir geophysics'. 3D seismic was successful because it developed rapidly as the exploration tool of choice. Structural and stratigraphic risks could be greatly reduced through the interpretation of 3D seismic volumes. Continued technology advances such as 3D pre-stack depth imaging, seismic attribute analysis and volume visualization extended the benefit of 3D seismic as a robust, reliable and cost-effective exploration tool.

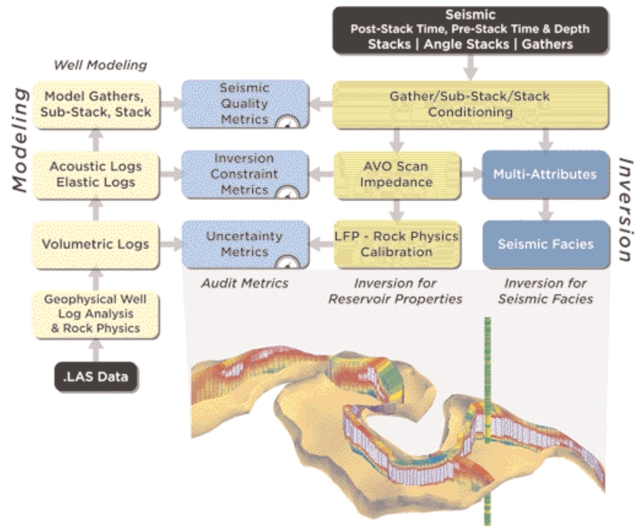
How does reservoir geophysics differ from exploration geophysics? Though there is no hard and fast boundary between these two disciplines, reservoir geophysics can be considered as the application of geophysical methods to determine reservoir properties, both static and dynamic, such as fluid type and saturation, porosity (and maybe permeability?), mineralogy and pressure and temperature.

So, why aren't reservoir engineers beating a path to our door to unlock all this new information we can provide on reservoir properties and conditions? We would argue that there are many reasons for this somewhat lacklustre interest from our engineering colleagues.

Reservoir geophysics: the roadblocks

It's difficult!

Moving from 2D to 3D was not too difficult for our industry. We were able to successfully scale-up our acquisition methods and, fortuitously and most importantly, Moore's Law ensured we had ready access to exponential increases in compute power. Many of the basic imaging algorithms were already known: the story of the development of 3D time and depth imaging is as much about the development of computer-aided interpretation tools as it is basic geophysical know-how.



A complex, multi-disciplinary reservoir geophysics workflow

Unfortunately, reservoir geophysics is hard! For starters, it's a multi-disciplinary task. A successful reservoir geophysics project requires the integration of a number of geosciences, notably petrophysics, geology, and engineering with geophysics. This is not at all easy. Despite some valiant efforts, this integration is slow in coming. The upstream G & G professions are fragmented, with a high-level of knowledge within each discipline, but very little awareness of needs outside our areas of expertise.

A good example of this is the humble synthetic seismogram. Synthetic seismograms or seismic models have been around for decades. Most geophysicists understand how to combine a Vp and density log (and maybe Vs too) to generate a vertical model of acoustic impedance and reflectivity. These seismograms are invaluable interpretation aids in allowing us to transfer geologic markers onto our exploration seismic datasets.

The synthetic seismogram plays a vitally important role in reservoir geophysics too. Driving both our interpretation of our seismic data and our well-data is the 'earth model'. If our synthetic seismogram and surface seismic data 'tie', then we are safe in assuming a common earth model for both datasets, at least at the well location. We would argue that if the surface seismic and well-data have been appropriately processed, then an optimum well-tie should result. Without

[*] *E-mail: r.cooper@rocksolidimages.com; tel: +1 713 783-5593.*

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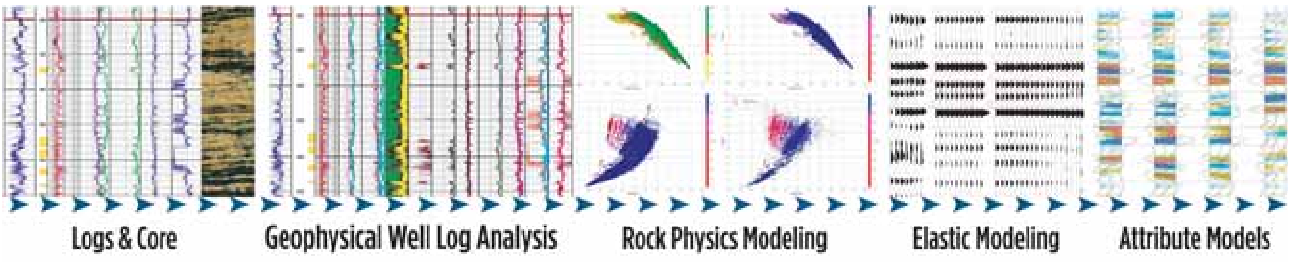


Synthetic seismograms require the integration of petrophysics and geophysics

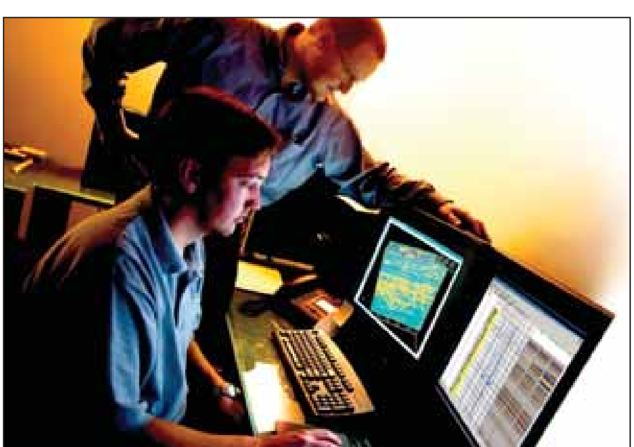
this tie, we cannot extrapolate the earth model into the seismic volume away from the well location.

Unfortunately, obtaining optimally processed seismic and well datasets is not easy. A geophysicist's know-how is required to prepare the 3D seismic data; a petrophysicist is required to pre-condition the log data. Herein lies the problem: most petrophysicists are not aware of the geophysicists need for a high-quality and consistent suite of Vp, Vs, and density data for the entire log run to complement more basic petrophysical properties such as Vclay and fluid-type. Without the availability of a consistent suite of well data, synthetic seismogram quality will be poor and, though perhaps still adequate for exploration purposes, will be unusable within a reservoir geophysics modelling and calibration workflow.

If we are serious about reservoir geophysics, we will need to develop multi-disciplinary workflows and tools which take into account not just the expertise within each discipline, but also recognize the different data needs as we cross boundaries between geophysics, geology, petrophysics, and engineering.

Lack of customer confidence

Who is the customer for reservoir geophysics? In many cases, the ultimate end-user will be the drilling and reservoir engineer. This contrasts with exploration geophysics where generally we see geophysicists working with other geophysicists to develop tools and datasets.



Multi-disciplinary teams are essential to success

As geophysicists, we often joke that 'engineers don't understand us'. We believe there is indeed a lack of understanding between geophysicists and engineers. In fact, we would argue that the problem goes deeper than this: engineers simply don't see the value in our data and, in many cases, engineers are right to be sceptical!

Addressing the issue

What can we, as geophysicists, do to address this issue? We would suggest attention be paid to three complimentary areas.

Turnaround

Though it may be possible to acquire a 3D survey in a couple of weeks, and fast-track process in another two weeks or so, the reservoir characterization process often takes several more months. We have already suggested why some of those turnaround times are so long: the task of data integration and interpretation is multi-disciplinary and complex. Nevertheless, the time value of data is important. If we deliver datasets after the decision point, the value of the data effectively drops to zero.

We need to develop reservoir geophysics workflows such as pre-stack inversion and well-driven rock physics calibration that can executed in days if not hours, not months or weeks. Certainly the acquisition, processing, and interpretation cycle has to be shorter than the time-lapse interval!

Robustness

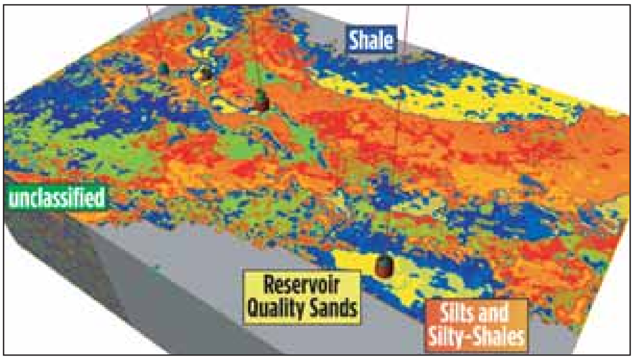
We've all heard the old joke that if you give three identical datasets to three different processing companies, you'll receive back three different results. Sadly this is often still true, but the joke is no longer funny.

As an industry, we must work hard to develop standards and common methods and procedures. Whilst the human elements of experience and expertise will always be present, we can do a lot to develop more robust and reliable tools and workflows which guarantee not just faster turnaround, but more consistent results. Without this consistency, and companion methods which allow us to quantify the accuracy and precision of our predictions, we will not be successful in filling the engineers need for reliable and timely reservoir data.

Relevance

Another old joke - 'how much is two seconds of pipe?'. Engineers don't deal in acoustic properties. Converting reflectivity values to acoustic impedance or lamda-rho/mu-rho may be an entertaining pastime for a geophysicist, but these datasets will be of little value to an engineer. Put simply, engineers want reservoir data (such as porosity, saturation, and mechanical properties), in-depth, with un-certainties. That's it, and nothing else will do.

So, although AVO, impedance inversion and rock physics models are essential tools, we need to take our technology and datasets through to the true end-user product if we want to interest our engineering customers.



Seismic volume - calibrated to geologic properties

Commercial models

We mentioned above the successful commercial development of 3D seismic from 2D, begun in the 1970s. Paralleling this technology advance was a new commercial model which developed in the 1980s and continues to this day: the development of multi-client or speculative seismic datasets.

If we look back over the history of geophysics in the petroleum industry, in the early pre-war days it was normal for oil companies to own and manage their own data acquisition crews, and perform in-house processing and interpretation. As the geophysical service industry developed in the 1950s, E&P companies began increasingly to outsource acquisition and processing, though this was still done in a proprietary fashion. i.e., a service company might perform the data collection and processing, but both the field data and any processed results would be delivered to and owned by the oil company.

As multi-client models developed, this situation changed again, with the geophysical service companies undertaking the acquisition and processing of seismic data, which were then licensed to as many oil and gas companies as possible. Given the right combination of data location and data quality, this proved an enormously successful business model for both service and oil companies alike, and the geophysical industry flourished.

Will this multi-client model work for reservoir geophysics? The short answer is no! We see two large differences between seismic datasets for exploration versus those likely to be used for reservoir geophysics:

- *Size:* Seismic surveys for reservoir use are likely to be much smaller (in area) than exploration datasets. The reason for this is simple - we already know where the reservoir is!
- *Proprietary:* Seismic reservoir characterization is a proprietary operation, performed on behalf of the operators and their partners of any given field.

For these two reasons, large, multi-client commercial data models will not apply for reservoir geophysics. This means it's harder for service companies to justify investment in improved reservoir geophysical methods as the potential market is likely to be smaller, not larger, than the existing exploration market for geophysical products.

Looking further into the future, we can see a trend developing where oil and gas companies may own permanently installed seismic source and receiver arrays, in much the same way that they own and operate other surface infrastructure elements. So, maybe the industry is coming full circle, back to where we started with the E&P companies owning equipment and technology and with the geophysical companies providing products and services to maintain this environment?

Competing technologies

3D seismic is not the only game in town. Recently we have seen increasing interest in a number of competing geophysical tools, notably 3D-VSP, microseismic data, and controlled source electro-magnetics (EM). Each of these methods can provide additional data to complement, but perhaps replace, surface 3D seismic for both exploration and reservoir needs.

Also, as geophysicists competing for an engineer's dollar, we are up against other technologies. For example, an engineer might choose to allocate budget to drilling a series of multi-lateral wells, fully instrumented with pressure, temperature and flow sensors to provide real-time and continuous reservoir monitoring. Ultimately, this is our competition.

Conclusion

As geophysicists we can be proud of the contribution we've made to the development of global hydrocarbon resources by providing valuable exploration data. However, we are wrong to assume that the technology and business models which have served us so well in this area will simply migrate cleanly to the world of the drilling and reservoir engineer. This article has discussed several of the challenges we face as an industry if we want to remain relevant in the field of hydrocarbon production. We believe it is important for all geophysicists, whether in oil companies or in the service sector to recognize these challenges and work hard to overcome them.