Statistical Rock Physics: Combining rock physics, information theory and statistics to reduce uncertainty.

Chapter 3. Quantitative Seismic Interpretation (Avseth, et al, 2005)

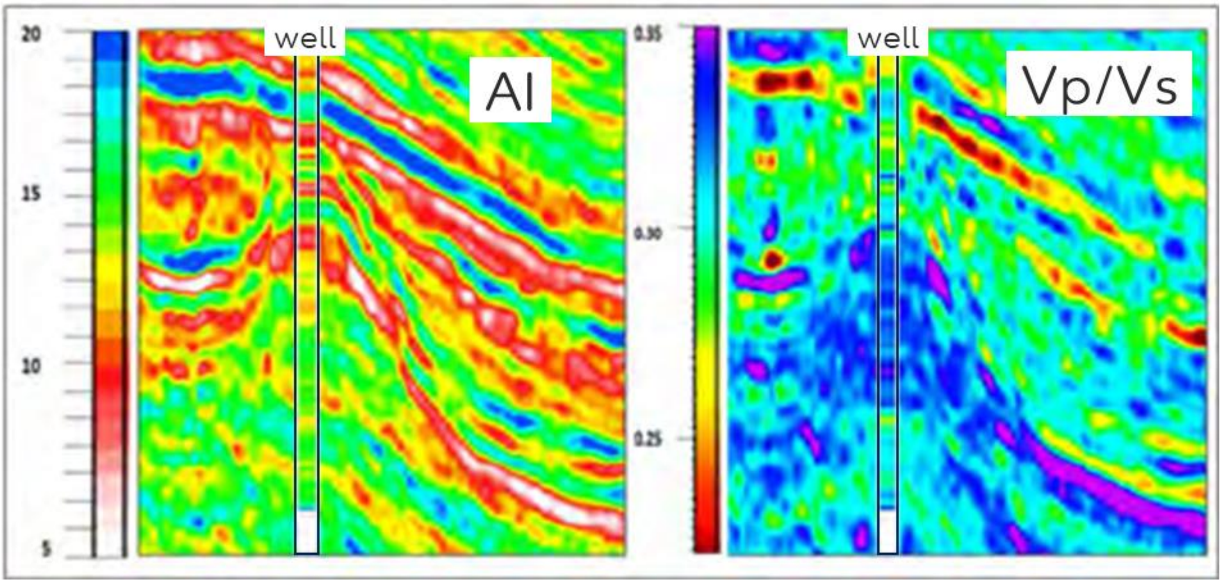
"The language of probability allows us to speak quantitatively about some situation which may be highly variable, but which does have some consistent average behavior." Richard Feynman.

The title is from a book, Quantitative Seismic Interpretation, which outlines a methodology to mathematically quantify the well result with the seismic result.

A bit of background … Rock physics was developed to provide a link between well log data and seismic data. If you make a lot of assumptions about how the earth reacts to the input of acoustic energy then you can parameterize the subsurface using compressional velocity, Vp, shear velocity, Vs, and density.

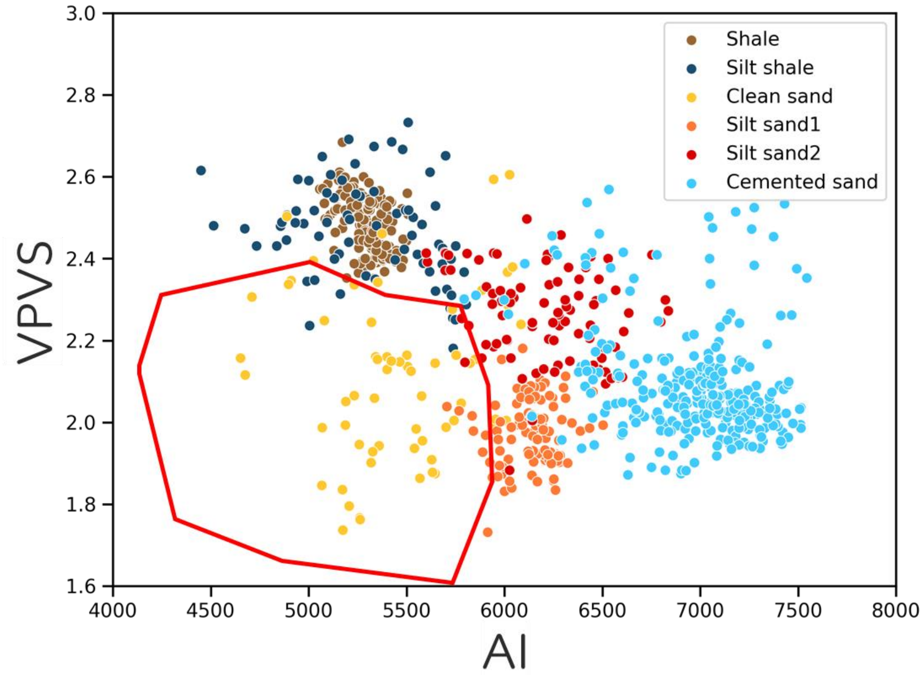
At the well log we measure these parameters directly and we know the answer. We know the lithology and fluid type at every point down the well bore and we have the corresponding Vp, Vs, density measurements.

As opposed to the seismic data where although we have Vp, Vs & density, the values are non-unique – we don't know the answer. That is, a particular Vp, Vs, rho might be an oil filled cemented sand or a brine filled shale. So there is inherent uncertainty in the seismic data.

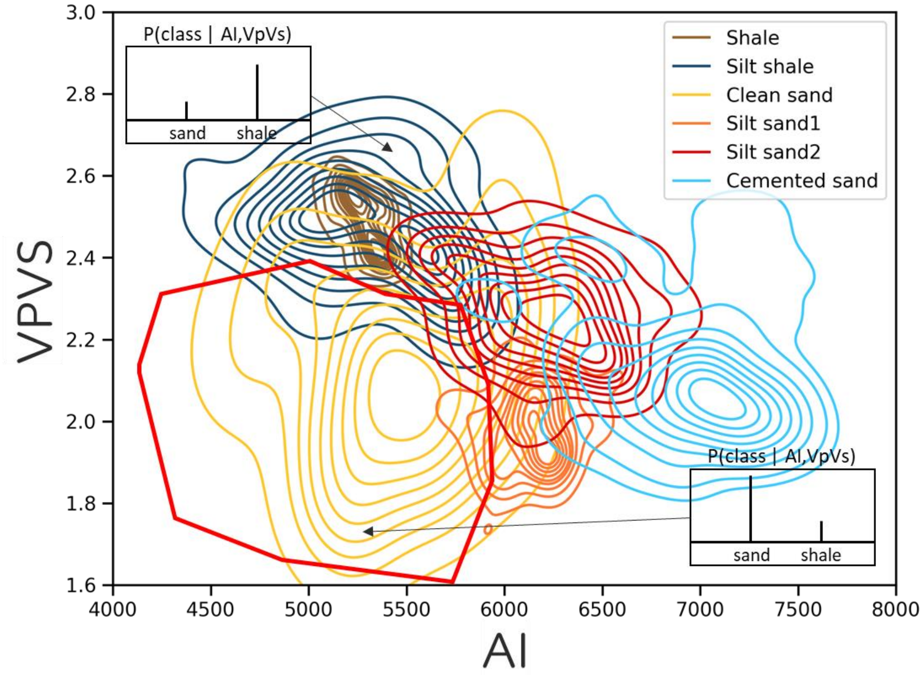


The methodology in the book is about quantifying the rock physics link – the link between the well data where we have the answer and the seismic where we have uncertainty. When I talk about quantifying, I can compare that to a qualitative link which would be visually comparing the well log result to the seismic result (figure above). If I compare the well log (in black border) acoustic impedance (AI) with the seismic AI I can see that, visually, the match looks close. Knowing the rock/fluid response at the well, I can follow that same response laterally from the well.

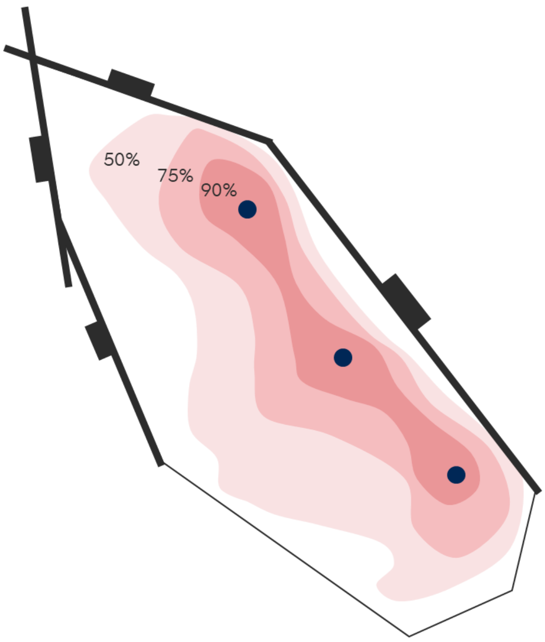
A semi-quantitative link might be looking at a cross-plot of the seismic AI and VpVs data and knowing from the well data that the rock/fluid response of a particular facies lies in a particular range of AI and VpVs, I could select those data points and software would highlight those values in the seismic cross-section.



The methodology described in Quantitative Seismic Interpretation, mathematically formalizes the link through a probabilistic framework. What that means is that when I select points, as I have done here, am I selecting only a particular rock/fluid pair (as in the red polygon above)? Am I 100% certain? If it were yes, what about areas where points start overlapping? Maybe there's a section where there's a bit of overlap but it's still more likely to be a specific rock/fluid pair than not. Maybe that probability is 75%, or 50%, or 5%. A statistical rock physics approach can completely quantify every data point in the well and using that, can classify every point in the seismic data in terms of a rock/fluid pair and the probability of it being that classification (see figure below).



Because I know the answer at the well and I have a rock physics link between the well and the seismic data, I can create a model that predicts these gross classifications, and I can test it at the well location to see how good it is. Then I can apply the predictive model to the seismic data and end up with a spatial arrangement of, for instance, all predictions of a rock/fluid pair (e.g. oil saturated clean sand), or predictions of a rock/fluid pair greater than 75% (see figure below). And because I can calculate probability density functions based on the data, I'm not assuming any particular distribution (eg normal, lognormal).



As more wells are drilled, the model gets updated and the area of uncertainty decreases.