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Correlation of Production to Seismic Attributes Using Bayes’ Theorem: Application to a FWB survey

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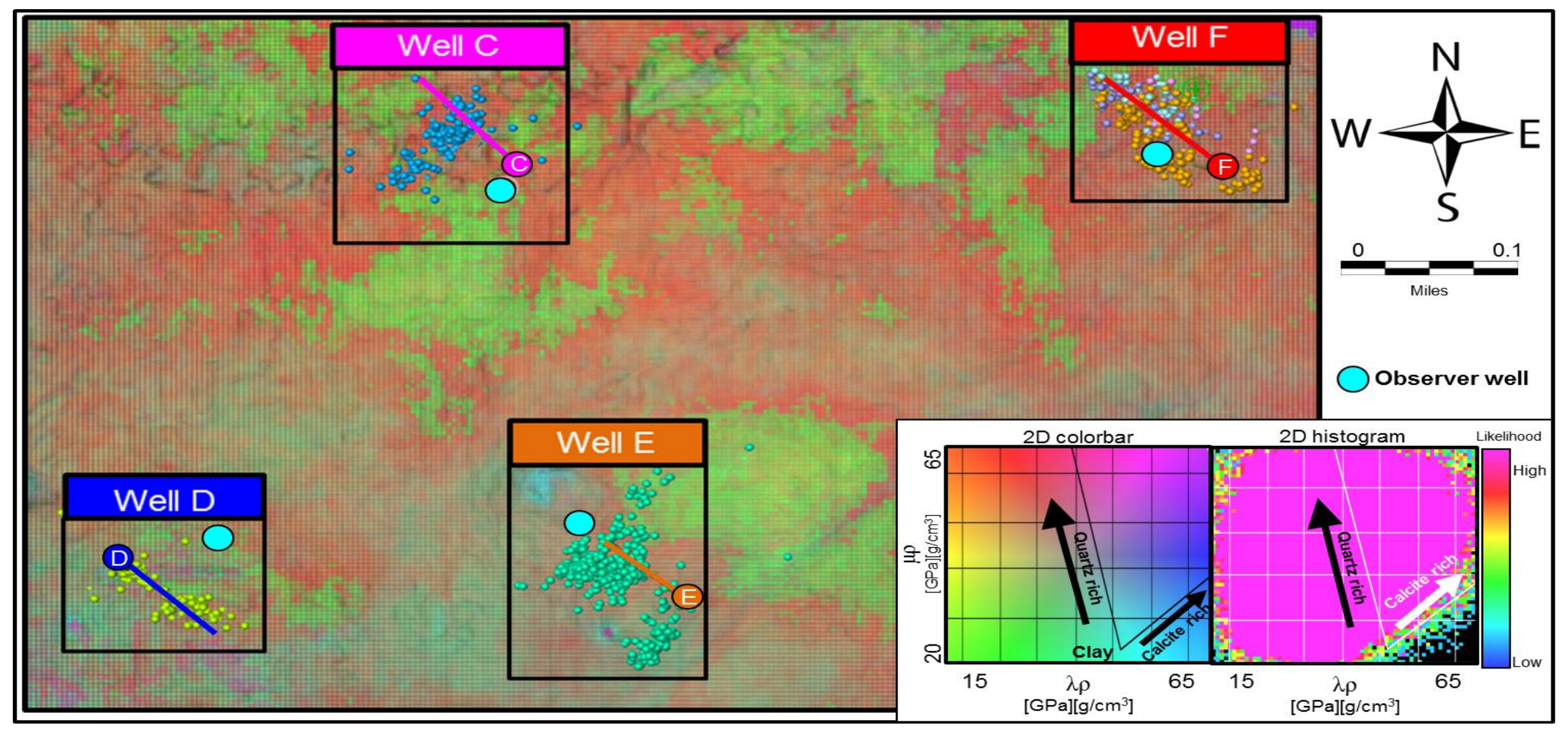
Introduction

The prediction and estimation of production from proposed wells is perhaps the most difficult but important task in resource plays. In this study, I propose to incorporate Bayes’ Theorem with Markov Chain Monte Carlo (MCMC) to estimate well production. Instead of using a single nonlinear regression to fit all the data, I will divide the data into low, medium and high production subsets and use a linear model to fit each of them.

In their clay model experiments, White et al. (2012) observed a nonlinear relationship between curvature and fracture density. Perez and Marfurt (2015) showed a visual correlation between microseismic events and brittleness index while Rich (2015 and Qi) found a good correlation between microseismic and curvature and azimuthal anisotropy. However, Da Silva. (2013) found that linear correlation of attributes to production is poor. For example, a series of linear and nonlinear regression analysis are preformed between seismic attributes and production, weak negative correlations (e.g. R^2=0.21) are found between most positive curvature and production. Hidden in this process is the uncertainty that is associated with the structural and positioning from seismic imaging. Most of the studies didn’t leave any room for random variation. In such models, a given input will always produce the same output, which is not realistic.

Preliminary Correlations



Location of microseismic events displayed on the lambda-rho vs. mu-rho color cross plot. Cyan circles indicate vertical observation wells. Wells C, D, E, and F are horizontal wells with two or three completion stages each. For these four wells, note that the great majority of the microseismic events occur in the red (more brittle, quartz-rich area) and avoid the green (more ductile, clay-rich) areas. (After Perez, 2013).

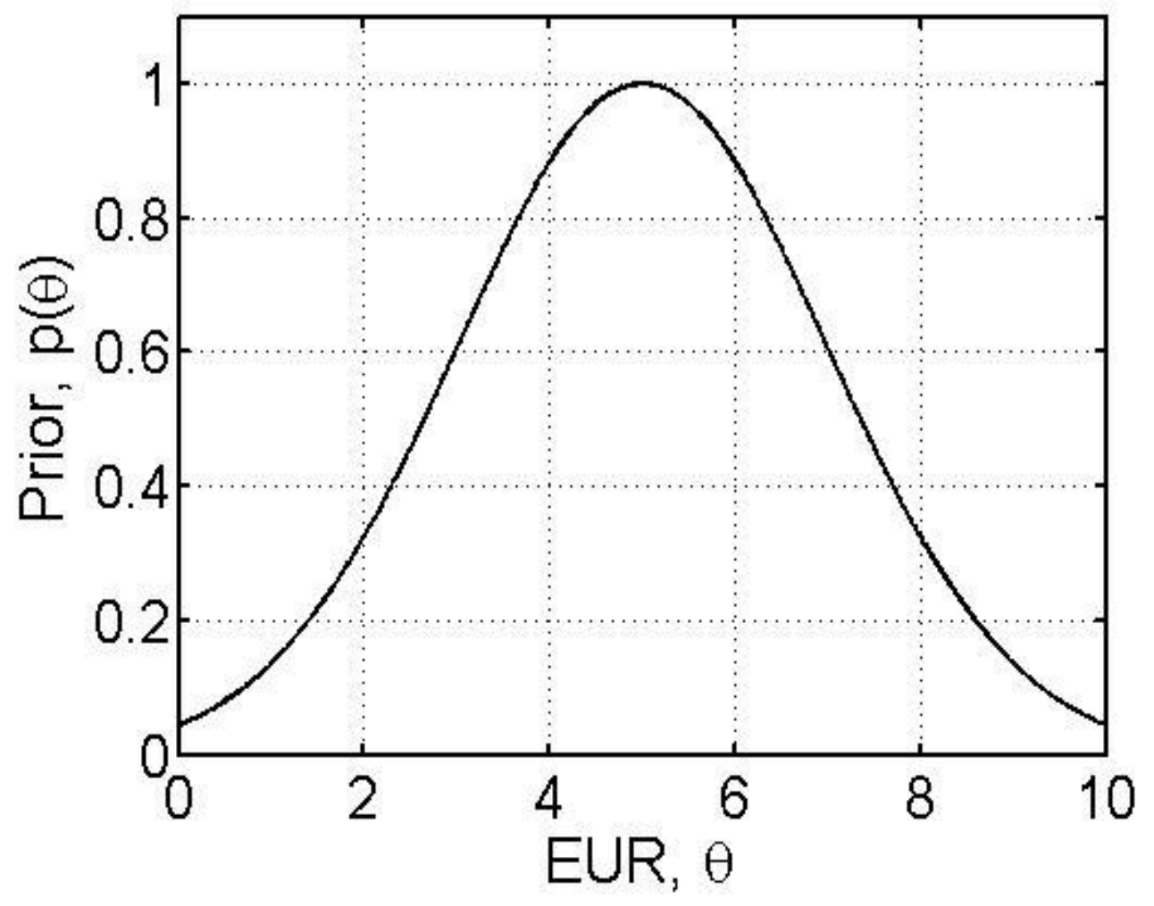
Method

A general description of probabilistic inversion is given by Bayes’ theorem in a form of

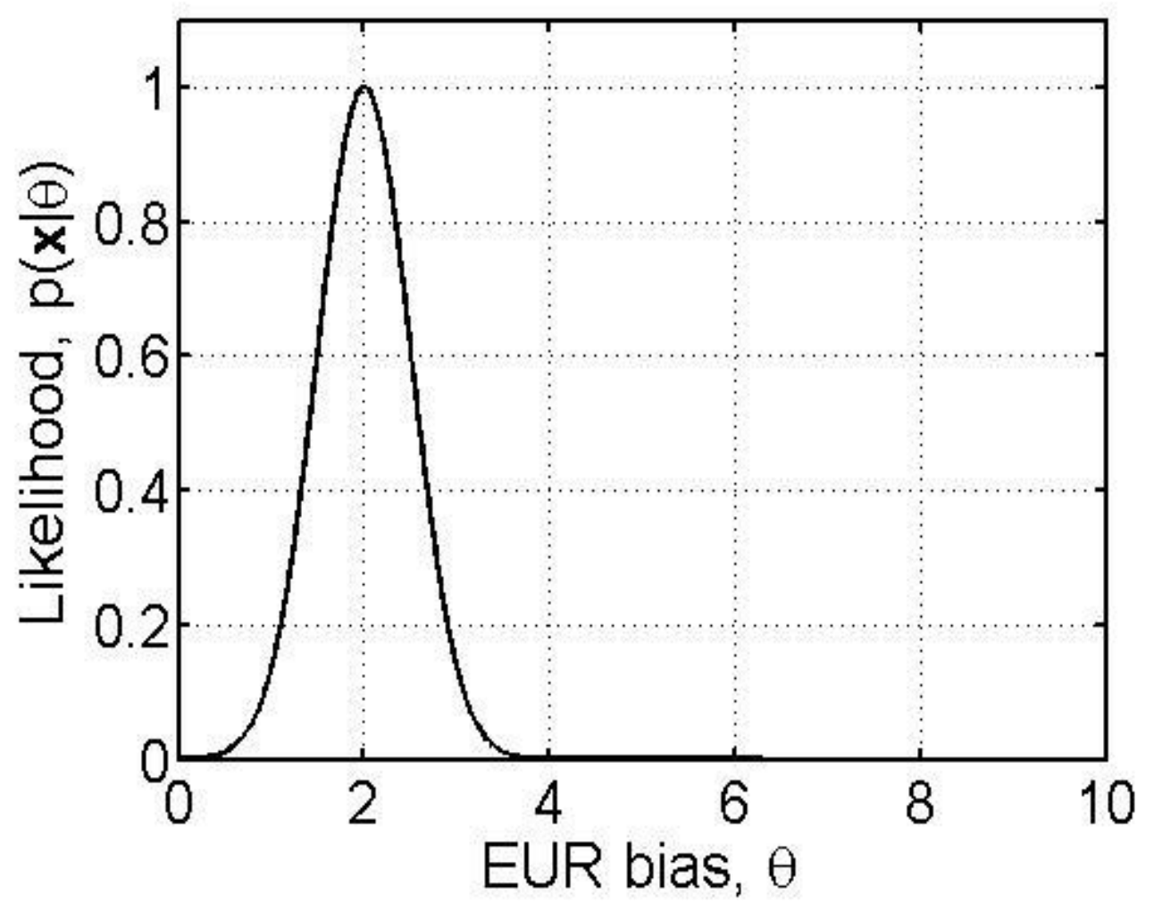
$$p(Z,a_j)=\frac{p(a_j,Z)\,p(Z)}{p(a_j)}$$

where $p(Z)$ is the prior probability density function (PDF) representing prior knowledge about the parameters Z (e.g. production), $p(a_j)$ is the probability of observation of attribute a_j (e.g. curvature), and $p(a_j|Z)$ is the conditional probability density observations a_j on Z (also called the likelihood function of parameters a_j).

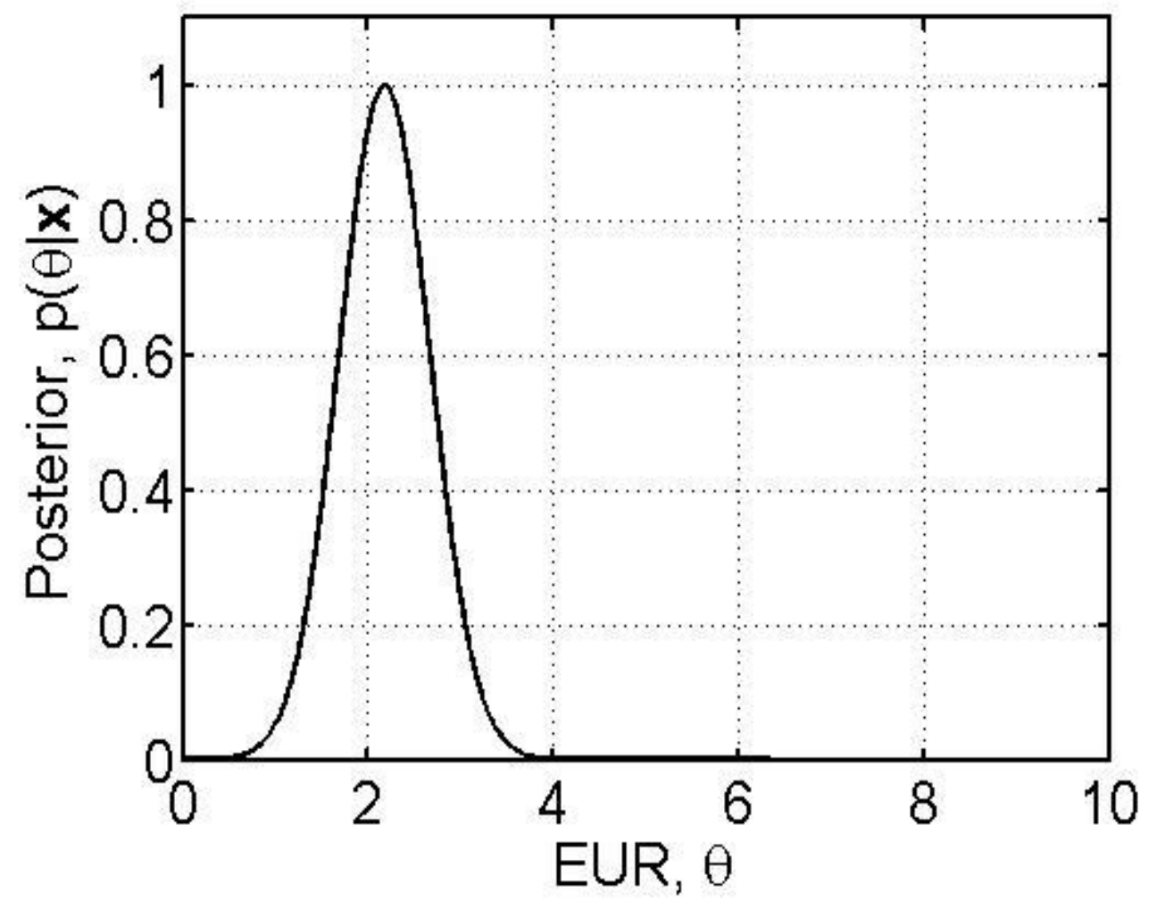
Prior, $p(Z)$



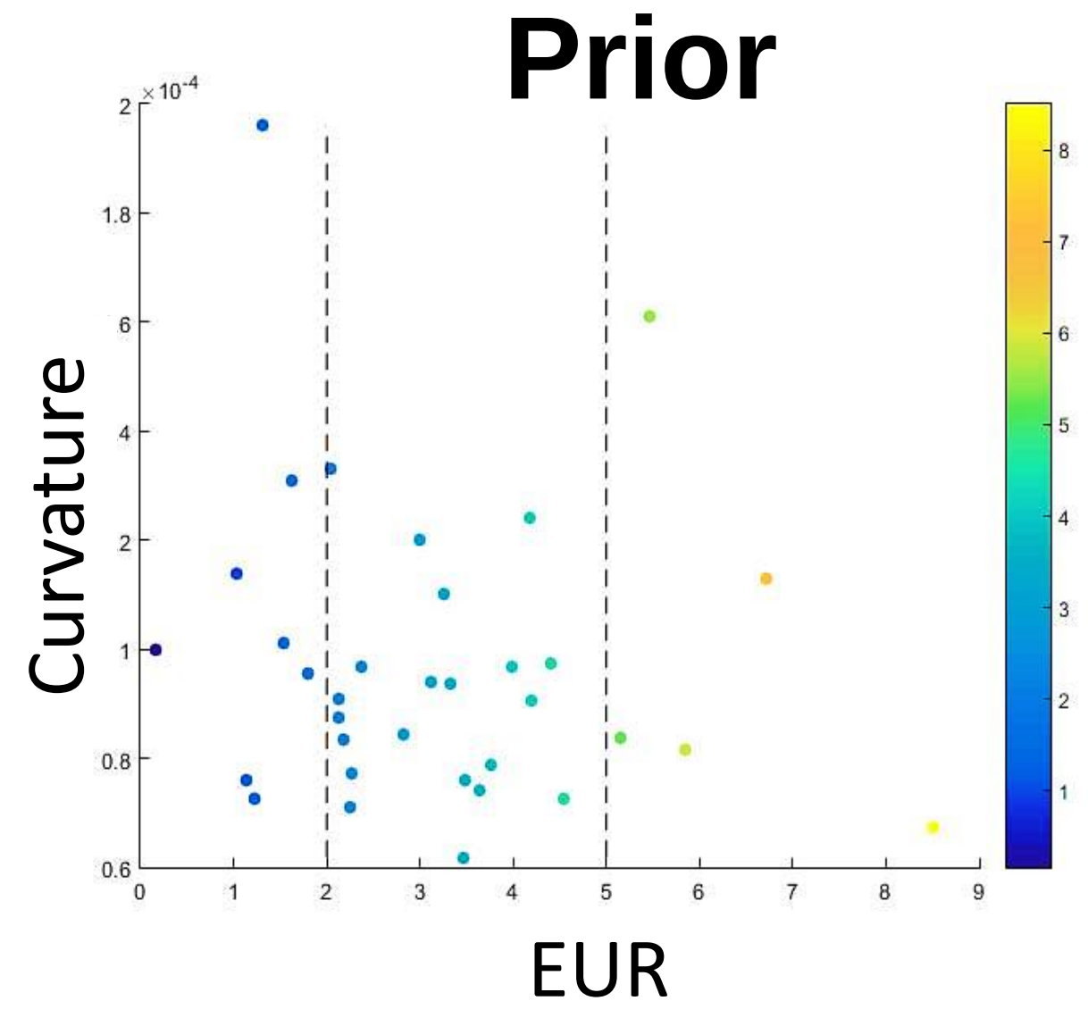
Likelihood $p(a_j|Z)$



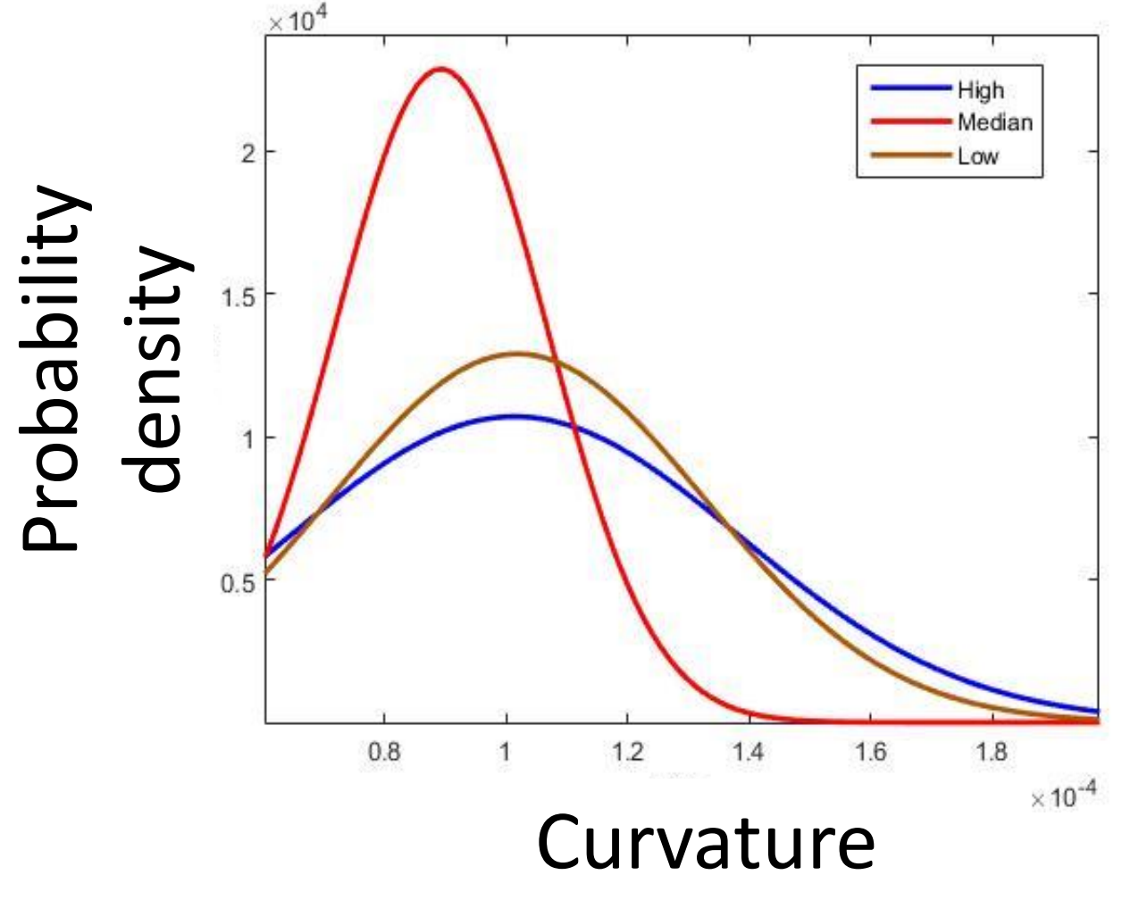
Posterior $p(Z,a_j)$



Prior



Likelihood



Posterior

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Acknowledgements

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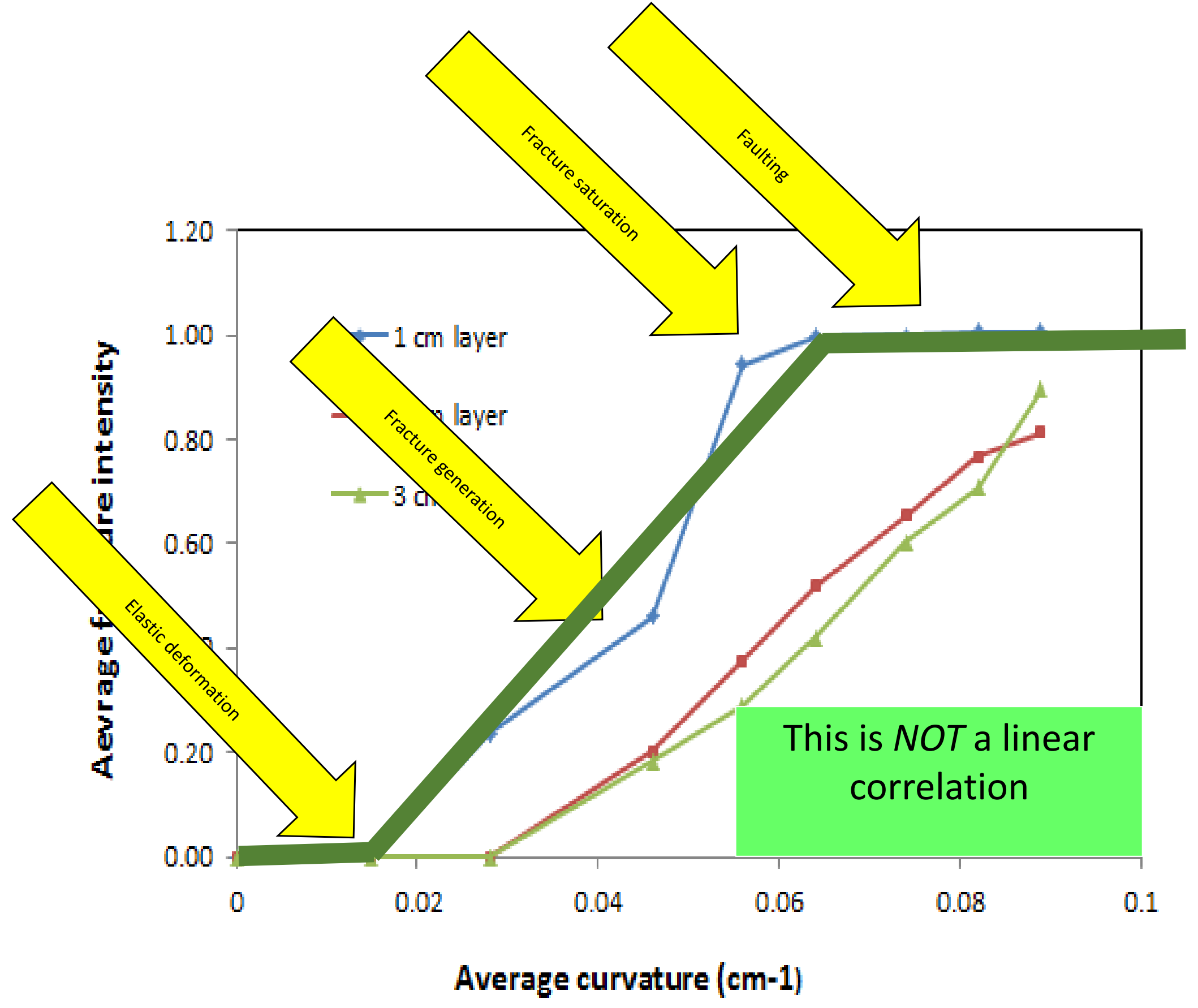
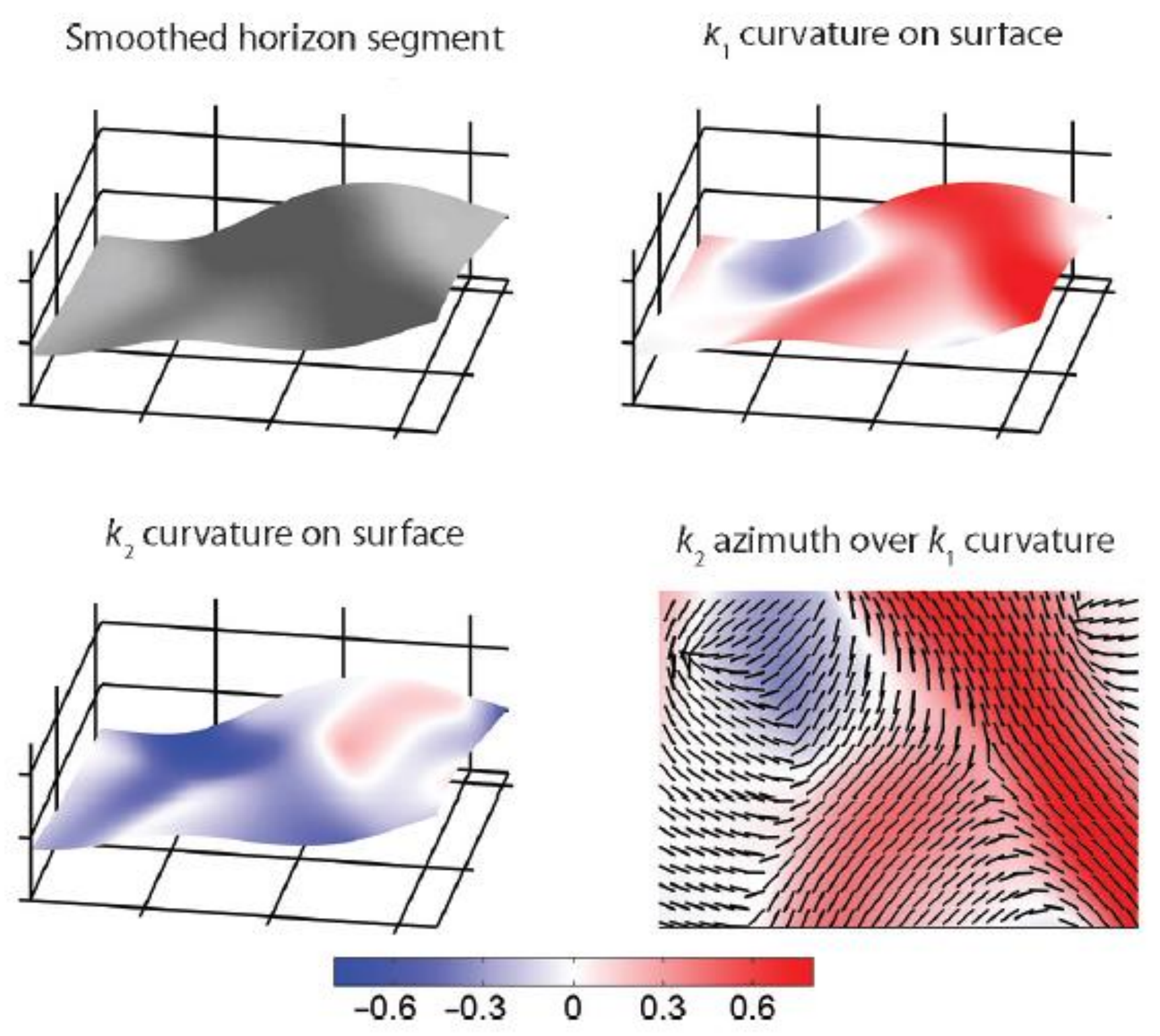
Preliminary Correlations



Graph of average fracture intensity vs. average curvature in 1 cm, 2 cm, and 3 cm experiments. Note the correlation is non-linear, with both a beginning and ending threshold of fracture initiation (After White, 2013).

Well case	After-tax rate of return	
	Gain from initial decline	Gain from initial rate
Base	21.9%	21.9%
Increase of .0379 EUR/1000′	29.5%	31.1%
Increase of .0698 EUR/1000′	35.1%	40.8%
Increase of .1224 EUR/1000′	43.1%	56.0%



Example for effect on rate of return (ROR) by drilling wells with selected curvature cutoffs. ROR here is based on economics for the example area using 2009 figures. The increase in EUR is assumed to result from either a decrease in initial decline rate or a higher initial production rate.