

Z-99 Neural Network Training For Reservoir Characterization of Litho Facies

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Abstract The use of neural networks to characterize reservoir litho facies from seismic data volumes has grown in popularity in recent years. The different approaches range from unsupervised to supervised training methods, conducted over constant windows to produce litho facies maps, or within volumes to produce litho facies volumes. As a necessary prelude to supervised training of the neural network, this paper discusses the generation of pseudo wells that are used to provide adequate sampling of the expected litho facies variations in the appropriate sub volume of seismic data. The pseudo wells are used to generate elastic synthetics (stacked and un-stacked) from which attributes are computed for training. In exploration settings, there are often insufficient wells to provide adequate training data. Seismic modeling determines the relevance of the perturbations of the petrophysical parameters of interest, such as fluid saturation, porosity and clay content. Pseudo wells provide seismic responses that adequately sample the ranges of petrophysical parameters. Various training schemes are examined after which the derived transfer function is applied to wells or pseudo wells with held from the training data set to verify the accuracy of the predictive power of the method. Data from the Norwegian Ormen Lange fields is primarily used in the paper. The objective of the workflow is to determine the transfer functions that will generate seismic scale litho classes from a seismic volume penetrated by the wells being used.

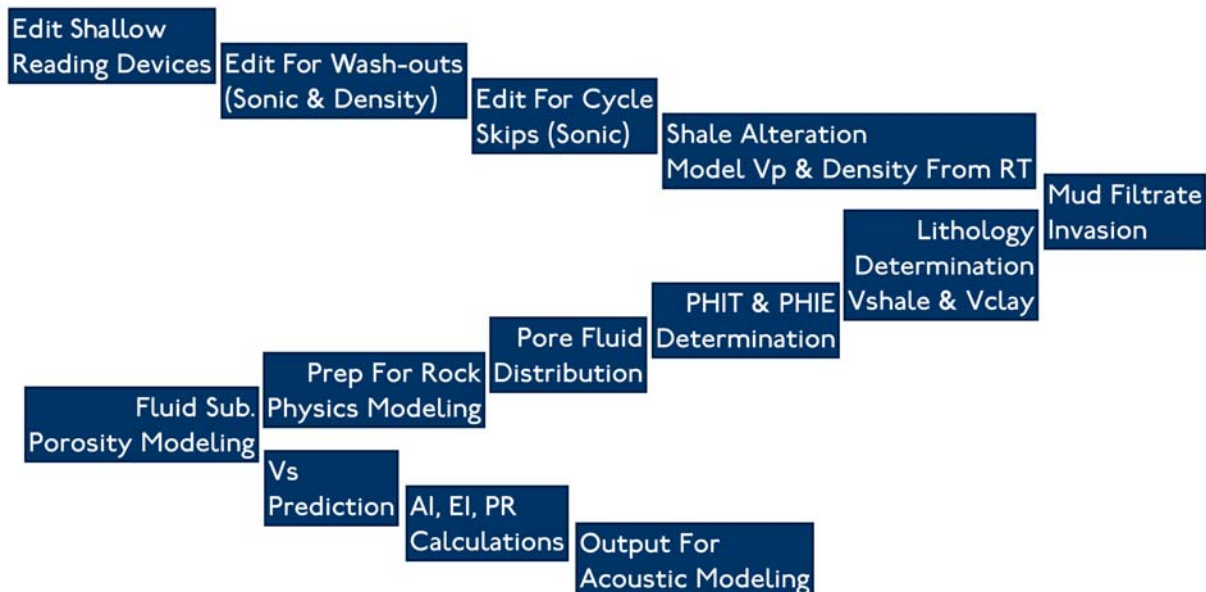


Figure 1: GWLA workflow summarizing the processes

Petrophysical Analysis Geophysical well log analysis is conducted over the entire log extent, both within the reservoir rock zone and within the reservoir encasing rocks. This

process often requires corrections for mud filtrate invasion and estimation of missing logs such as shear wave log.

Well Litho Classes Additionally a litho classes log curve is numerically computed from appropriate log curves, and used as the training target.

The most appropriate method for lithology classification is chosen from a number of possible methods, based on core and curve availability and data quality.

a) An artificial neural network is trained to predict the lithology classification from selected log curves using core data as the training set. These log curves usually include density, total porosity, V_p , V_s , clay volume, and water saturation. This procedure will produce a training set comprising neural weights and scalars by iterative correction to minimize the discrepancies between the predicted lithology results and the actual classes. The training will be conducted over a limited range of depths encompassing the reservoir interval. Once the training operations have been completed and validated, the neural network weights and scalars will be applied to the processed logs to obtain a reservoir classification or lithology column at each well.

b) A rule-based method is employed to use appropriate log curves – similar to above - to define the lithology classes.

c) An interpretive method is used that combines complex litho facies into groups, such as laminated sands, blocky sands and so on.

The purpose of this step is to:

- Define lithology and saturation classes to be identified at the wells and ultimately across the 3D volume.
- Build a classification scheme using neural network training to predict the lithology and saturation classes.

Pseudo Wells The Pseudo Well process applies perturbational rock physics modeling via the use of Biot-Gassmann's relations and other rock physics "effective medium" models to create "pseudo-wells" in which rock and fluid properties can be varied over a reasonable range for the field under investigation. This range is established using a rigorous rock properties analysis procedure that we call Rock Physics Diagnostics and Matrix Modeling (see above). The fluid moduli and density vary with pressure and temperature and these values can be measured in the lab or in some cases can be computed from empirical relations.

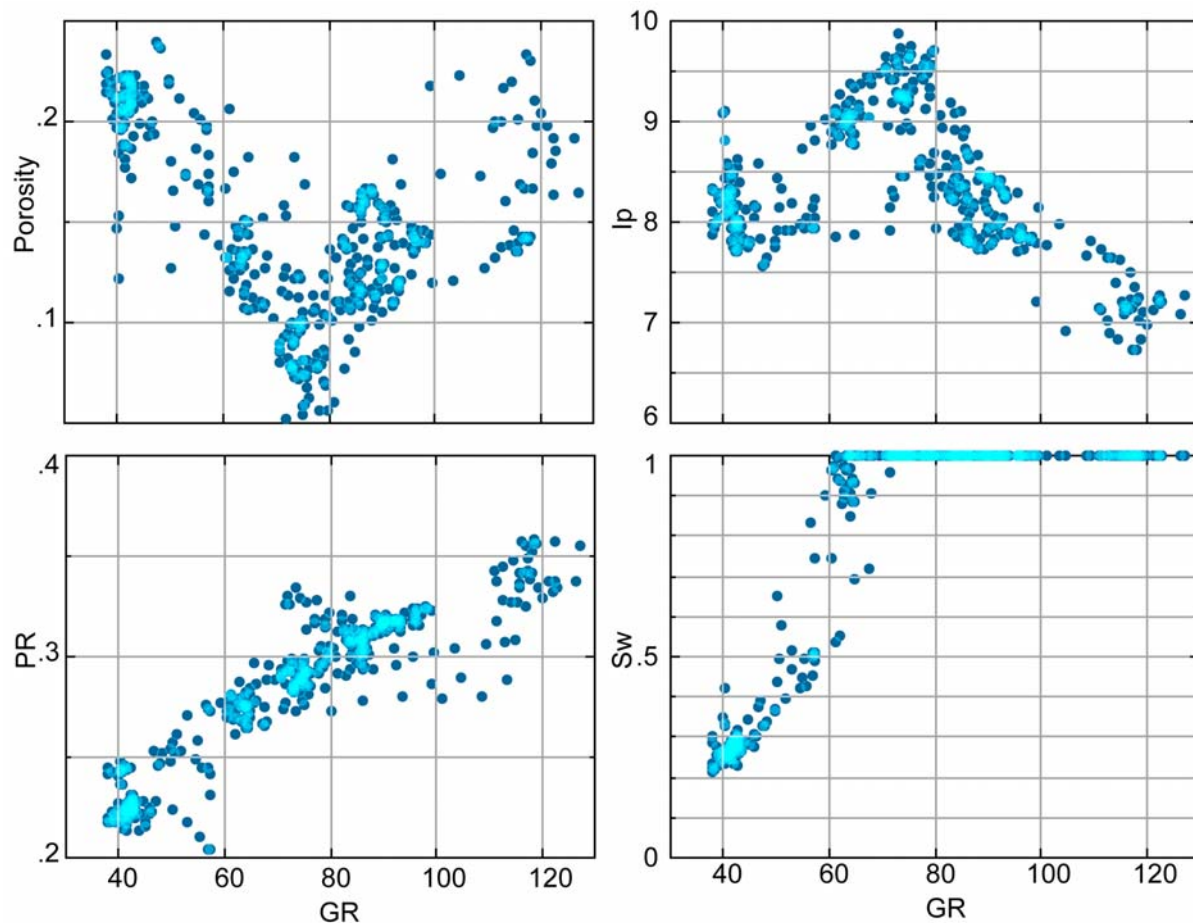


Figure 2: Matrix Modeling cross plot showing interdependency between rock properties

A fundamental application of rock physics modeling to seismic reservoir characterization is the ability to generate multiple instances of rock property variations to synthesize wire-line log responses, and ultimately, to capture the seismic expression of rock and fluid properties that may exist within a particular reservoir but which have not been sampled by drilling a well. This process is often referred to as perturbational rock physics modeling or pseudo well generation. The perturbations that are performed by this modeling are, by convention, conducted for one physical property at a time, e.g. porosity, saturation, thickness, etc. However, cross-plot analysis (Rock Physics Diagnostics) of physically and acoustically relevant log values (Figure 2) reveals that there is often a clear link between clay content, saturation and porosity that should be represented in the modeling process.

Synthetic Seismic Attributes Seismic attributes, both pre-stack and stack, are generated on the in-situ wells and the pseudo wells. We aim to sample the range of the expected reservoir heterogeneities at seismic scale and use these attributes to train the neural network using a litho facies description. A suite of petrophysically perturbed zero-offset and non-zero-offset synthetic seismograms are generated for each of the modeled pseudo-wells. The attributes are analyzed for sensitivity to the modeled rock and fluid properties. Those attributes that are determined to be both physically meaningful and which produce the most effective artificial neural network training set for predicting the lithology classes will be selected. They will then be input, along with the time domain lithology columns, to an artificial neural network to minimize the discrepancies between the predicted results and the actual lithology classes. Elastic seismic synthetics are generated from the pseudo wells, from which pre-stack and post stack attributes are computed. Typically attributes include layer attributes such as – P-impedance, S-impedance, and Pseudo Poisson's Ratio – to target the elastic response. Other attributes target the wave-shape or waveform of the seismic response, which provide

characterization by addressing the complex interactions between thin beds within the reservoir zone. The attribute responses provide feedback to identify what petrophysical properties can reasonably resolved by the workflow. A rich diversity of attributes offering a high degree of vector orthogonality is just what neural network applications work best with.

Neural Network Training The attributes generated on the synthetic data should be compatible with attributes generated on the seismic data. It is important to upscale the log data to seismic scale in order to properly assess how well the classification works at seismic scale. The pseudo well attributes are trained by the network to predict the litho classes from the wells (Figure 3). The training result is compared across wells and adjustments made to the attribute mix based on how well the attribute derived classification matches the well classification.

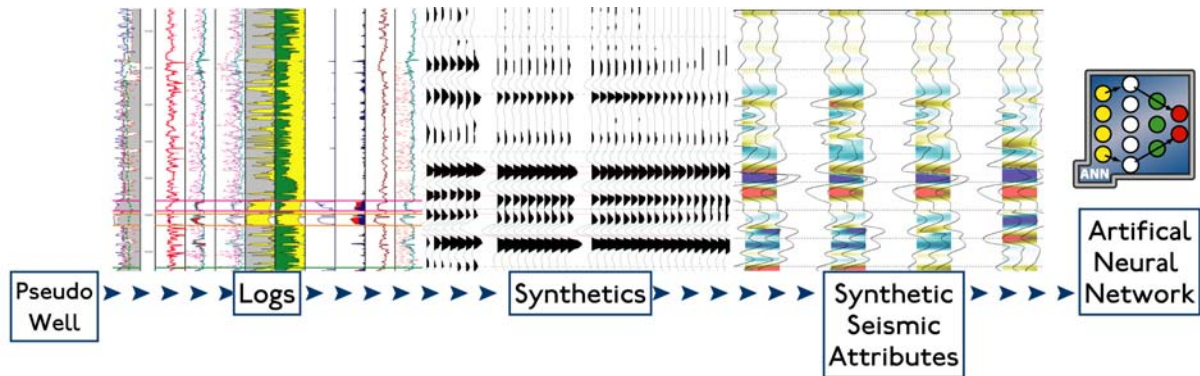


Figure 3: Schematic Diagram showing the path from logs to ANN training

This process is iterated until an acceptable convergence is achieved, at which point, the neural network will have been optimally trained and the neural weights and scalars comprising the learning set are applied to the seismic attribute traces. This step is used to validate the classification in the seismic domain, which is the ultimate target of the project. Applying the transfer function to both pseudo wells used in the training and also to others not used in the training tests the accuracy of the network's prediction. The suitability, resolution of petrophysical parameters is recognized by the workflow – all that remains is to apply the transfer function to equivalent seismic volume attributes.

References

- Dvorkin, J., Carr, M.B., Berge, T., and Uden, R., 2002, Rock Physics Diagnostics in Sand/Shale Sequence, 64th EAGE Annual Conference & Exhibition, Florence, 2002.
- Walls, J., Taner, M.T., Taylor, G., Smith, M., Carr, M.B., Derzhi, N., Drummond, J., McGuire, D., Morris, S., Bregar, J. and Lakings, J., 2002, Seismic reservoir characterization of a U.S. midcontinent fluvial system using rock physics, poststack seismic attributes, and neural networks, *The Leading Edge*, Vol 21, No 5, 428-436.