

Determination of Carbonate Permeability Category using Hybrid Neural Network and Fuzzy Inference Systems

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We present a technique employing a hybrid system to determine the permeability category of carbonate rocks using well logs. The hybrid system consists of a single adaptive resonance theory (ART) neural network and multiple fuzzy inference systems (FISs). Based on the concept of "permeability index" (logarithm of the permeability values represented in millidarcies), a "permeability category" is employed as the intended target permeability value instead of continuous values. There are five permeability categories defined: "NOT PERMEABLE", "VERY LOW", "LOW", "MODERATE", and "HIGH."

In carbonate rocks, permeability values commonly are neither well-bounded nor stable. For this reason, ART neural networks, with topological effects and dynamic architectures (e.g., increasing the output nodes if needed) are employed here to meet the needs posed by natural variation in petrophysical variables.

Geology is sometimes viewed as a "soft" science because it requires both qualitative (soft) and quantitative (hard) information to provide explanations and predictions of the characteristics of studied systems. Experience and/or knowledge acquired by domain experts; e.g., geologists, usually are composed in the form of rules, and may be expressed as "if-then" rules, such as "IF the reading of gamma ray is high, THEN the lithology is shale." Therefore, techniques, such as fuzzy inference, capable of incorporating both a domain expert's knowledge and numerical data, are greatly preferred. Fuzzy inference is also able to process uncertainties associated with qualitative (domain knowledge) and quantitative (numerical data) information. The experts' opinions are inherently imprecise; imprecision is not a result of observation errors. Moreover, complete, representative numerical data sets are usually not available for subsurface environments. With insufficient numerical data, expert opinions processed using FIS can compensate for these deficiencies. Hence, we use a hybrid of ANN and FIS systems, taking advantage of the numerical processing power and the uncertainty handling capability of these two methods, to determine permeability category. A schematic of the hybrid system is shown in the figure. The well log data used in this study were from the Smackover Formation in Appleton Field, Escambia County, Alabama.

The hybrid system predicted the permeability category correctly in 68% of the cases, and missed by no more than one category in 95% of the cases. Because the permeability categories employed are broad, one might prefer to count all mismatches as incorrect. Even by this stringent rule, the program was remarkably successful (161 matches out of 234 total).

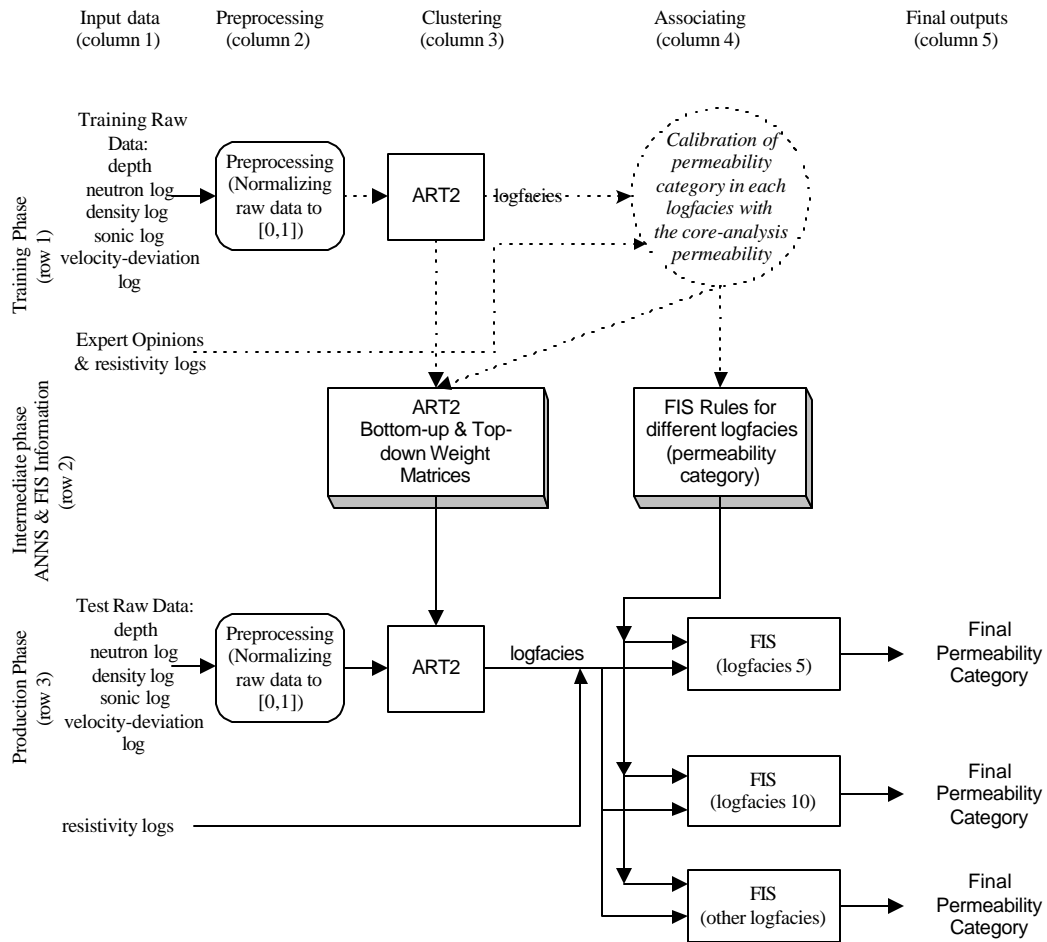


Figure. The single-multiple ART2-FISs system for determining permeability category.