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Representing a relation between porosity and permeability based on inductive rules

Luis Carlos Molina Félix[a,*], Lluís A. Belanche Muñoz[b,1]

[a]Data Mining Group, SAS Institute, Edificio Torre Mayor, floor 38, 06500 Mexico, D.F., Mexico
[b]Dept. de Llenguatges i Sistemes Informàtics, Universitat Politècnica de Catalunya, Jordi Girona 1-3 C6 214, 08034 Barcelona, Spain

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Abstract

The objective of this work is twofold: the acquisition of symbolic rules in a geological domain and the representation in graphical form of the behavior of the different geological labels. We are particularly interested in a rule-based description of permeability (an important attribute in petroleum geology) that only uses porosity and spatial information. More precisely, a model of petrophysical properties is obtained using a hybrid discretization method to obtain permeability levels and the C4.5 method to obtain a rule-based representation. This model is simple and reasonably accurate and allows representation in graphical form.
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1. Introduction

Permeability is a very important petrophysical variable for both petroleum geology and petroleum engineering. Measuring permeability, directly or indirectly, is a difficult and expensive undertaking. Further, the inter-relationships between permeability and porosity and other rock properties are very complex and area-specific (Rogers et al., 1995).

There are some geological applications using neural networks or fuzzy logic to predict or to identify these inter-relationships (Baldwin et al., 1990; Osborne, 1992; Huang et al., 1993; Rogers et al., 1995; Helle et al., 2001). This growth has been due to several distinct advantages over more traditional statistical approaches (such as regression analysis). These techniques can be difficult to tune and be time-consuming. Hence, reported results could be made better or complemented in a number of ways by using other machine learning techniques.

The objective of this work is to represent the behavior of permeability in a graphical form, based on previously obtained inductive rules. Only the porosity

* Corresponding author.
E-mail addresses: luiscarlos.molina@sas.com (L.C. Molina Félix), belanche@lsi.upc.es (L.A. Belanche Muñoz).
[1] Fax: +34 93 4017014.

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and spatial references (minimum information) are used to predict permeability levels and are to be represented in a graphical form.

The information herein used was obtained from six oil wells located at the Smackover Formation in Big Escambia Creek (BEC) field, Alabama, USA. The entire data were recollected from logging instruments that are lowered in the wells and by core analysis on reservoir rock material that is obtained from the well with a hollow drill bit. This domain is characterized by high noise levels, some missing values and several considerations coming from human expertise, explained in Section 5.

In BEC field, petrophysical characteristics of nonselective dolostone are decoupled from depositional facies, there is substantial megascopic reservoir heterogeneity, and porosity is the strongest known correlated of permeability. The effect of *X*–*Y* variation in rock type on porosity and permeability is minimized in this work by using a relative laterally homogeneous part of the field (Kopaska-Merkel et al., 1994; Bradford, 1984). Lithologic information has not been used because our objective is to represent initial knowledge that can be portable to other fields, where addition of other available variables can further refine and improve on the obtained model.

In order to do so, the first step is the obtention of basic symbolic rules, so that it is necessary to transform the class-attribute (permeability) represented as a continuous attribute into a nominal attribute. We apply the hybrid discretization method (Molina et al., 2000) to achieve this. In this way and by means of symbolic rules, the behavior of the interrelationships between permeability, porosity and spatial information can be described. In the next step, we represent the rules in a graphical form. This representation can give useful and practical information to experts. Problems as data pre-processing, discretization and a posteriori knowledge analysis are specially discussed.

2. Geological setting

Big Escambia Creek field is located in the Conecuh embayment, which also contains the giant Jay field. The effects of several episodes of dolomitization and calcium-carbonate dissolution dominated the diagenesis of the Smackover in this area. Dolomite is responsible for formation or preservation of many permeable Smackover pore systems. The formation in this area is characterized by pellet wackestone/mudstone and oolitic grainstone in the upper Smackover; fossiliferous and laminated mudstone in the middle Smackover; and microbial laminite, oncoid pellet packstone, and coated fossil packstone in the lower Smackover. In terms of original rock fabric, reservoir rock is composed by dolomitized oolitic grainstone and spatially associated dolomitized lime mudstone. In terms of existing rock fabric, reservoir strata are dominated by nonselective idiotopic dolostone. The percentage of dolomite varies from 100% to locally less than 10%. Nondolomitized strata in BEC field are impermeable (Bradford, 1984).

This field has been selected for the task because there exist sufficient core derived porosity and permeability data available (Rogers et al., 1995). Six cored wells provide observed porosity and permeability values in 1-ft intervals. These wells were drilled in a part of the field that is relatively laterally homogeneous from a lithological point of view (Bradford, 1984).

3. Context of the problem

Porosity is a measure of the ability of a rock or sediment to hold a fluid, expressed as the fraction of the total volume taken up by pore space. The porosity of a rock is a function of rock sorting, compaction, cementation and an important consideration when assessing the potential volume of hydrocarbons that it may contain.

Permeability is a measure of the ability for a fluid to pass from a pore space to another pore space (by capillary action). Permeability in petroleum-producing rocks is usually expressed in darcies or millidarcies. Normal values may range from few millidarcies to several darcies. Permeability is of great importance in determining the flow characteristics of hydrocarbons in oil reservoirs. The reservoir is a porous and permeable lithological unit or set of units that holds the hydrocarbon reserves.

In general, permeability is a function of rock porosity, grain size and packing arrangement (size and

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