AAPG Annual Convention and Exhibition
April 1-4, 2007 • Long Beach, CA

DE ROS, LUIZ FERNANDO; GOLDBERG, KARIN Institute of Geosciences, UFRGS, Porto Alegre, Brazil; Institute of Geosciences, UFRGS, Porto Alegre, Brazil; ABEL, MARA; VICTORETTI, FELIPE; MASTELLA, LAURA and CASTRO, EDUARDO Institute of Informatics, UFRGS, Porto Alegre, Brazil

Advanced Acquisition and Management of Petrographic Information from Reservoir Rocks Using the PETROLEDGE® System

Abstract
The precise and comprehensive description of the textural and compositional features of reservoir rocks is crucial in petroleum exploration. However, in order to substantially contribute to decrease exploration risks and increase hydrocarbon production efficiency, petrographic reservoir characterization must include not only information on the volumes of detrital and diagenetic constituents and pore types, but also a detailed record of their habits, locations, modifications and paragenetic inter-relations, which strongly control porosity and permeability, as well as log and seismic signatures. The Petroledge® system is an intelligent database application created to support the detailed petrographic analysis and interpretation of reservoirs, combining resources from relational databases and knowledge-based expert systems. Systematic description is facilitated by the use of flexible menus with standardized nomenclature and parameters, what radically reduces description time and errors. An integrated electromechanical microscope stage allows an optimized modal quantification through point-counting, as well as the generation of a virtual map of the thin section, storing the spatial position of each petrographic feature and associated information. A relational database system guarantees safe data storage, distribution, integrity and recovery. The system provides compositional classifications, interpretations of tectonic provenance modes and diagenetic environments using Artificial Intelligence methods, along with multidimensional online consultation, statistical and graphic processing of petrographic data, which are essential for the design of reservoir, optimized recovery and quality prediction models.

Introduction
The petrographic characterization of reservoir rocks provides information on their origin, evolution and quality. This information is essential for the development of accurate tri-dimensional models for oilfield simulation, development and production, as well as for the explanation and prediction of quality during exploration. However, in order to substantially contribute to decrease exploration risks and increase hydrocarbon production efficiency, petrographic reservoir characterization must include not only information on the volumes of detrital and diagenetic constituents and pore types, but also a detailed record of their habits, locations, modifications and paragenetic inter-relations, which directly control porosity and permeability, as well as log and seismic signatures. With the aim of supporting the advanced petrographic characterization and evaluation of petroleum reservoirs, an intelligent database application named Petroledge® was created through a research and development project entitled PetroGrapher (Abel et al., 2004a; 2004b; 2005). The ultimate goal of Petroledge® is the precise and comprehensive description and interpretation of reservoir rocks and associated sedimentary rocks.

Description of the Petroledge® system

Petroledge® features include an optimized support for the petrographic description of clastic and carbonate reservoirs and other sedimentary rocks, following a standard workflow and technical petrographic nomenclature that insures consistency of stored information, security information access control for several classes of users, and a large expert knowledge base on sedimentary petrology that guides all system functions. The system guides sample description, according to a systematic order, allowing the standardization of geological terminology for all aspects of description, providing the automatic generation of textural, compositional and provenance classification diagrams, as well as interpretation of diagenetic environments. The information is stored and processed within a relational database system that is processed and distributed in a corporate environment. The system comprises several modules. The Identification Module controls the user permissions of data access and stores information on the spatial and geographical location of samples. The Textural Description Module provides standard nomenclature and format for the qualitative and quantitative description of sedimentary structures, texture and fabric, including structure type and scale of color, grain size, sorting, particle shape and fabric in macroscopic and microscopic scales. The Compositional Quantification Module allows description and quantification of all important detrital, diagenetic and pore type constituents, which can be associated with several habits, locations, paragenetic relations and modifiers simply by clicking the mouse (Fig. 1). A large compositional nomenclature database is available, comprising the ontology of all primary, diagenetic and pore type constituents commonly found in both siliciclastic and carbonate sedimentary rocks.

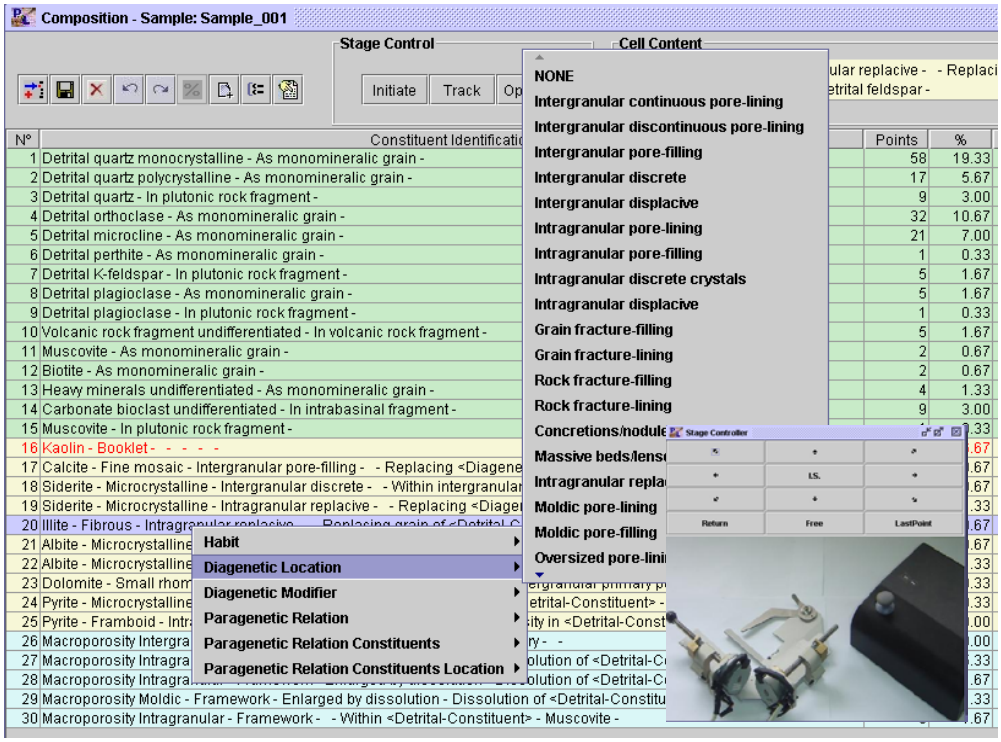

Figure 1: Example of the Compositional Quantification interface from the description of a sandstone sample. Constituents, habits, locations, modifications and paragenetic relations are selected with the mouse, and then points can be counted for each line of description. Inset illustrates the Stageledge® electromechanical microscope stage and its controls.

Stageledge®, an electromechanical microscope stage fully integrated and controlled by the system, is available for automatic quantification (Fig. 1 inset). Stageledge® allows precise movement control of the thin section. A compositional map of the quantification pathway is recorded and associated with the described constituents. The Image Annotation Module allows the association of important petrographic features annotated onto photomicrographs with the corresponding textual descriptions and the coordinates in the compositional map (Fig. 2).

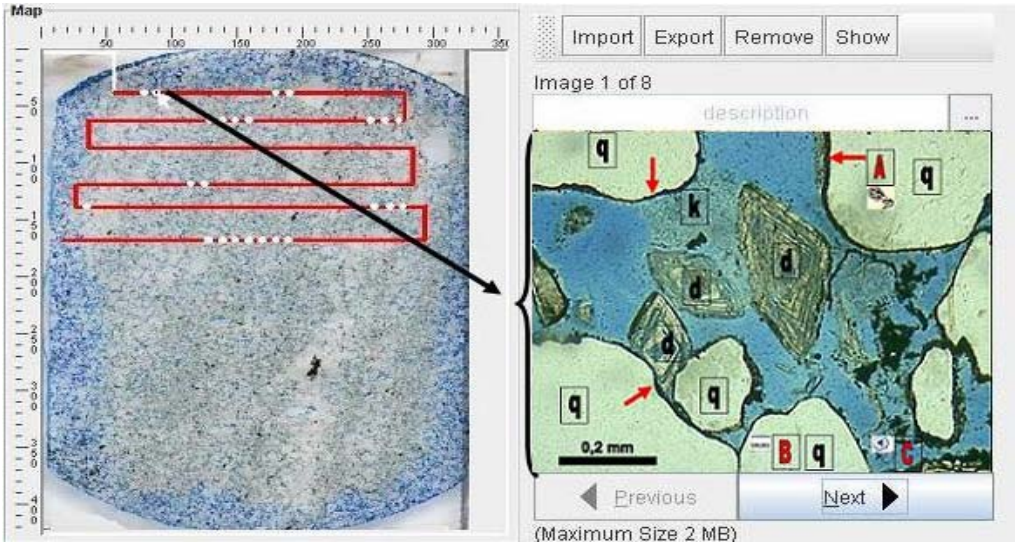

Figure 2: Interface of the Image Annotation Module, which allows the association of features in the photomicrographs to textual comments, WEB links or voice recording files, keeping precise spatial referencing of each image. A map of the analytical pathway and points is shown over a scanned image of the thin-section (left).

The Interpretation Module provides automatic generation of petrologic interpretation, including compositional, textural and provenance classification diagrams (Fig. 3, left), as well as artificial intelligence inference on diagenetic environments (Fig. 3, right). The Exportation module: complete textual descriptions are exported in XML and HTML formats for easy integration with reports and documents. Data are exported as XLS, LAS or WITSML supporting easy integration with reservoir modeling products and further analysis through Excel or other spreadsheet or statistical programs.

Petrographic information stored in Petroledge®

The porosity, permeability, log and seismic signatures of reservoirs are controlled not only by the depositional structures, textures and types of primary and diagenetic constituents, but strongly as well by the habits, location, distribution and spatial inter-relations (paragenetic relations) of constituents. Petroledge® allows the detailed description and quantification of structural, textural and compositional attributes, which are essential for reservoirs characterization and modeling. Figure 4 provides an example of how the petrographic aspects are described and stored by Petroledge®, what indicates the level of information detail available in the system. Such detail is essential for the evaluation of the role of specific constituents, their habits, locations, modifications and inter-relations on porosity, permeability, resistivity, acoustic properties, and on interpretations of sedimentary provenance, depositional and diagenetic environments, etc.

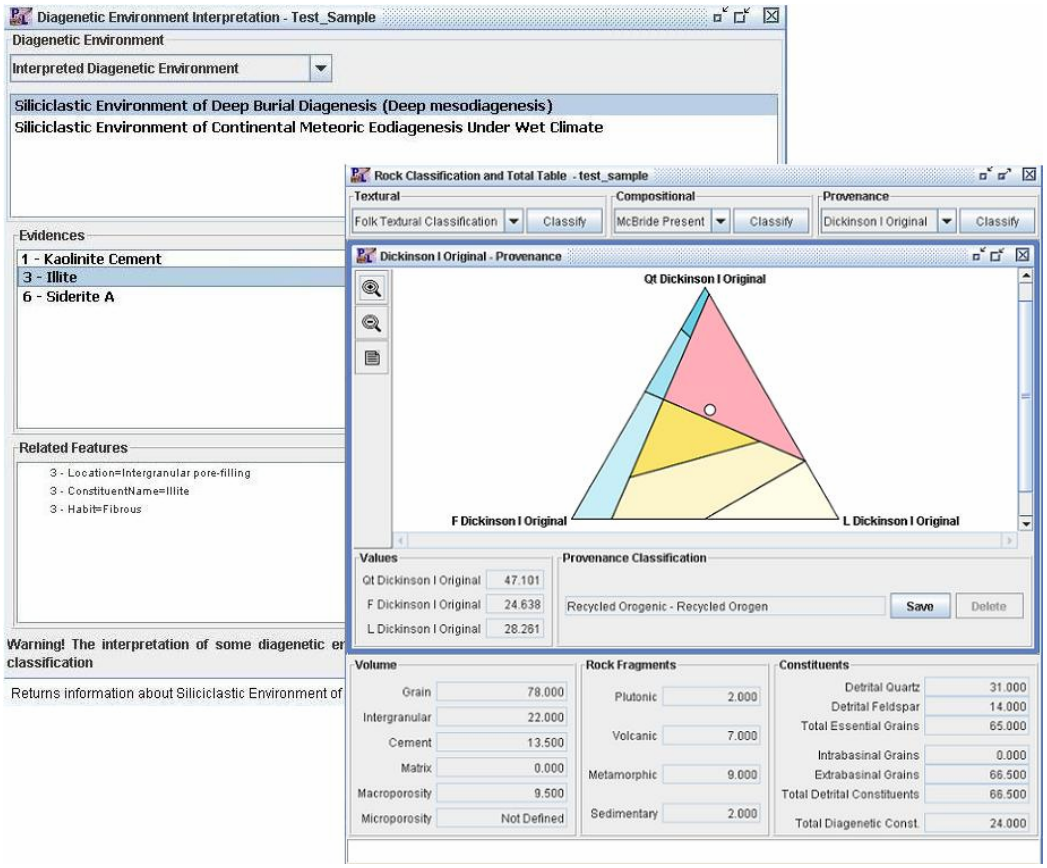

Figure 3: Interface of the Interpretation Module, showing at left a diagenetic environment interpretation, with the corresponding criteria, and at right a provenance detrital mode interpretation (cf. Dickinson, 1985) of a sandstone sample.

In the example of Figure 4, the main diagenetic constituent is smectite, which displays different habits and paragenetic relations at A and B. At A, smectite occurs as an intergranular, continuous pore lining, whereas at B it is microcrystalline smectite replacing a volcanic rock fragment. The difference between the two smectite types would be described and stored by Petroledge® as: **A:** Diagenetic constituent <smectite>, Habit <rim>, Location <intergranular continuous pore lining>, Paragenetic relation <covering detrital constituent>, Paragenetic relation constituent <detrital undifferentiated>; **B:** Diagenetic constituent <smectite>, Habit <microcrystalline>, Location <intragranular replacive>, Paragenetic relation <replacing grain of detrital constituent> Paragenetic relation constituent <volcanic rock fragment>. The two habits and locations of smectite imprint very different effects in terms of reservoir quality, since smectite at **A** impacts permeability significantly, whereas smectite at B has no influence on permeability whatsoever. Likewise, pore types may be described in detail using Petroledge®. Figure 4 **C** represents a shrinkage pore due to the contraction of smectite rims, and D, an intergranular primary pore. This information is recorded as: **C**: Macroporosity <Macroporosity shrinkage>, Location <interstitial>, Paragenetic relation <contraction of diagenetic constituent>, Paragenetic relation constituent <smectite>, Location <intergranular continuous pore lining>; **D**: Macroporosity <Macroporosity intergranular>, Location <interstitial>, Paragenetic relation <primary>.

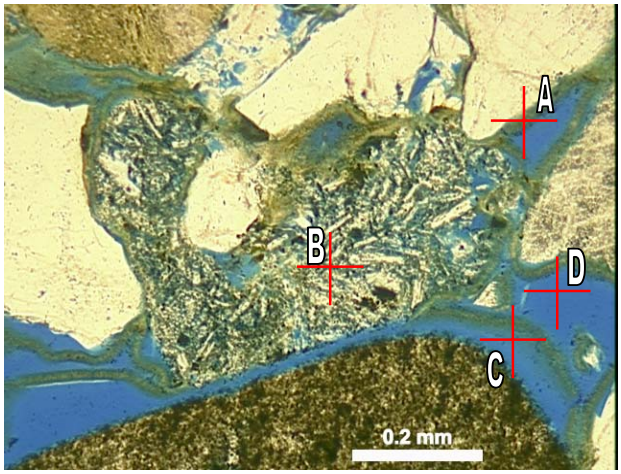

Figure 4: Example of Petroledge® descriptive information of a sandstone sample. Comments in the text.

PetroQuery®

PetroQuery® is an independent on-line analytical tool that provides easy multidimensional consultation on the stored petrographic information within the corporate environment. The PetroQuery® modules access a centralized petrographic data repository generated and controlled by Petroledge® in order to support exploration and production decision-making. PetroQuery® allows easy selection and combination of multiple query criteria (Fig. 5). For example, a query to identify samples from a specific oilfield in the Sergipe-Alagoas Basin, where enhanced porosity and permeability is controlled by dissolution during telodiagenesis, which is indicated by the presence of more than 1% intergranular kaolinite would be: Basin <Sergipe-Alagoas>, Oilfield <Camorim>, Stratigraphic Unit <Carmópolis>, Diagenetic constituent <kaolinite>, Habit <intergranular>, Volume % <greater than 1>. The results of consultations can be saved and exported in standard data formats (.xls), or refined. For instance, the previous consultation could be refined to retrieve only the thin sections with intergranular kaolinite volume less than 5% or to perform any complex combination of criteria stored in the database.

Advantages of use of Petroledge®

Petroledge® allows the standardization of geological terminology for all aspects of rock description and provides a workflow for the detailed description and quantification of sedimentary rocks. Moreover, tools such as the Interpretation Module and PetroQuery® provide speedy and accurate interpretations of the petrographic data and efficient data recovery. The main differential that Petroledge® offers for the characterization of reservoirs, however, is that it enables the detailed record of habits, locations, modifications and paragenetic relations of constituents, sharing the whole information through the corporate database without loosing the complexity and semantic of the petrologic information. This is possible due the knowledge-engineering techniques applied to represent the information that is essential for the modeling of reservoir optimized recovery and quality prediction. The system is fully compatible with Oracle®, Sybase®, Informix®, MySQL® and other relational database systems, as well as with Windows®, Unix®, Linux® and Macintosh® platforms. Moreover, the ability to export as LAS and WITSML formats, commonly used in modeling applications, allows the easy retrieval and integration with other applications, such as for 3D reservoir modeling and flow simulation software.

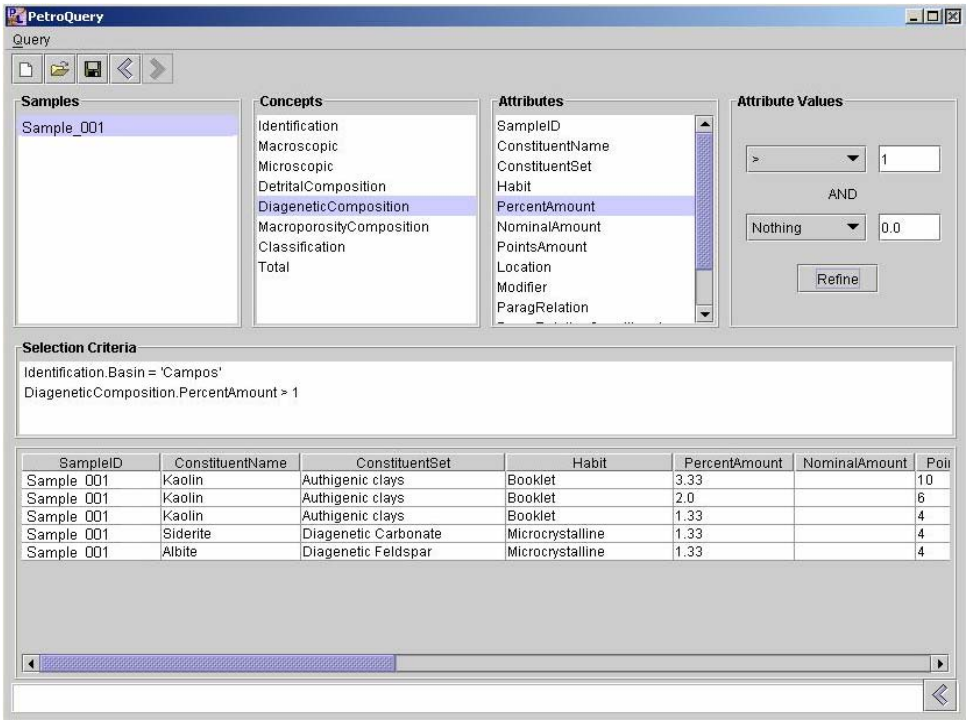

Figure 5: PetroQuery interface illustrating a simulated consultation for the identification of samples with more than 1 % of diagenetic kaolinite in Campos Basin.

Future developments

Upcoming versions of Petroledge® will enable the interpretation of diagenetic sequences applying Artificial Intelligence methods for temporal reasoning over the petrographic data. Furthermore, neural networks have shown potential in evaluating the role of compositional and textural petrographic parameters on reservoir porosity and permeability. These methods will be available in the ResQual system, a package of applications dedicated to reservoir quality modeling, to be integrated to Petroledge® functionality.

References cited

Abel, M., L. A. L. Silva, J. A. Campbell, and L. F. De Ros, 2005, Knowledge acquisition and interpretation problem-solving methods for visual expertise: A study of petroleum-reservoir evaluation: Journal of Petroleum Science and Engineering, v. 47, p. 51-69.

Abel, M., L. A. L. Silva, L. F. De Ros, L. S. Mastella, J. A. Campbell, and T. Novello, 2004, PetroGrapher: Managing petrographic data and knowledge using an intelligent database application: Expert Systems with Applications, v. 26, p. 9-18.

Abel, M., L. Mastella, L. A. L. Silva, J. A. Campbell, and L. F. De Ros, 2004, How to model visual knowledge: a study of expertise in oil-reservoir evaluation: 15th International conference on Database and Expert Systems Applications - DEXA, Zaragoza, Spain, Springer, p. 455-464.

Dickinson, W. R., 1985, Interpreting provenance relations from detrital modes of sandstones, *in* G. G. Zuffa, ed., Provenance of Arenites: NATO-ASI Series C, v. 148: Dordrecht, The Netherlands, D. Reidel Pub. Co., p. 333-361.