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An Integrated Global Knowledge-Information-Data System for Geological Analogs

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There is a great wealth of E&P knowledge in geological analogs, especially in the mature oil and gas fields that have been through a full cycle of exploration, development and production. The use of geological analogs has been a common practice among geoscientists and engineers in solving challenging problems in exploration, development and production (Bhushan & Hopkinson, 2002; Piantanida et al, 2002; Sun and Wan, 2002; Allan and Sun, 2003; Larue and Yue, 2003; Sun and Sloan, 2003). In the past 10 years, we have been developing an efficient, intuitive and cost effective global Digital Analogs Knowledge system with nearly a thousand of important oil and gas fields and reservoirs from all around the world. The system allows one to quickly gain knowledge-information-data on any type of fields and reservoirs and apply the lessons learned in exploration, development and production in order to improve efficiency and reduce risks.

Survey on the Use of Geological Analogs

Recently, we completed a survey on the application, data sources and benefits of geological analogs in the E&P industry. The survey was participated by geoscientists, engineers and managers from twenty-three major, national and independent oil and gas companies in six countries. Most of the survey participants have twenty or more years of E&P experiences (Fig.1).

The survey results show that nearly all E&P companies use analogs extensively. Most of the survey participants indicate that analogs are widely used in both exploration and field development. Some companies indicate their usage mostly in exploration or in development (Fig. 2).

The benefits of applying analogs in exploration and production are widely recognized. The following are the key benefits realized by the industry:

- "Risk reduction from greater certainty on decisions"
- "Gives confidence to the geologist and reservoir engineer that their ideas are grounded in reality—shows them what is known versus unknown"
- "Greatly enhances field development decision-making"
- "Gives insight to the explorationist on the critical elements of a specific play that may be prospective"
- "Uncovers subtle opportunities that may not be apparent from any other technique or technology"
- "Improves predictive capabilities on the upside development potential"
- "Convinces management, investors and partners in commercial viability of a prospect or merits of a field development program"

The sources of analog data and information vary from company to company (Fig.3). The un-organized analogs from various sources in different formats, on different media and variable quality make it ineffective and unpractical to use analogs in the increasingly fast and complex E&P workflow. The time involved in pin-pointing the right analogs worldwide becomes unmanageable with the conventional methodology. While some recognize the value of "casting a global net" to find relevant analogs, many still rely on the practice of "close-ology" when analogs are used. As a result, the use of analogs has been informal and inefficient.

There is a great need for an efficient, cost effective and intuitive platform specially designed for the E&P industry to effectively access the right analogs for exploration and development whenever and wherever needed. The design and implementation of such a global analogs system should have a clear set of goals to: i) assist E&P industry in reducing hydrocarbon finding and producing costs; ii) provide objective information for each of the decision making processes in E&P workflow; iii) help reduce E&P risks; and iv) improve operational efficiency.

A K-I-D Based Global Analogs System

At C&C Reservoirs, we have realized the needs of the industry and made great efforts in the past decade in developing an efficient, intuitive and cost effective global analogs system, namely DIGITALANALOGS™ E&P Knowledge System. It has been adopted by the E&P industry worldwide since its inception.

In the information age, we are overwhelmed by "data" or "databases". However, in reality our decisions can not be made on data alone. It is the knowledge or understanding of the data and information that determines decision-making in the E&P endeavors. Instead of simply building a database of analogs, we applied the concept of *Knowledge-Information-Data (K-I-D)* system (POSC, 2003) in the design and implementation of the global analogs system. A K-I-D analogs system must follow the principles of *data entropy, document and database integration, and context integration*. In such a system, a K-I-D item is an integral information unit that carries the complete information of an analog. The following steps outline the life cycle of design, implementation and update of a K-I-D analogs system:

- Define business processes/decision points in E&P workflow;
- Identify and classify Knowledge, Information and Data (K-I-D) needed at each decision points;
- Establish K-I-D model for the analogs;
- Populate and maintain the K-I-D model;
- Store, retrieve and interact with K-I-D of analogs through an intuitive GUI;
- Deliver K-I-D of analogs through the internet/intranet; and
- Apply K-I-D of analogs in decision making processes and update K-I-D with additional analogs and new information.

A K-I-D item in our global analogs system contains the following elements:

- *Data:* Observations and measurements reconciled from various data sources. For example, the reservoir and field analogs data include 50 field parameters and 170 reservoir parameters in a relational database covering general field and reservoir description, trap characteristics, reservoir architecture and properties, source rock/seal properties, reserves and production, hydrocarbon composition and engineering and recovery data.

- *Information:* Data plus relevance and purpose (composed and in context) described in a comprehensive report. For example, each of the field and reservoir evaluation report covers exploration history, play concept, basin evolution, petroleum systems, structural features, trapping mechanisms, stratigraphy, depositional facies, diagenesis and reservoir properties, reservoir architecture, production-engineering analysis and list of pertinent references and sources of information.

- *Knowledge:* Information plus application and use (associated with action) in form of well classified and analyzed analog data with lessons learned and applications in E&P workflow. For example, we have synthesized nearly 1000 reservoir analogs to address E&P issues concerning particular types of reservoirs or plays and come up with a comprehensive series of E&P Treatise on carbonate reservoirs, clastic reservoirs, fractured reservoirs, stratigraphic/subtle traps and deepwater reservoirs.

Our global analogs system is an internet/intranet application with an intuitive graphical user interface and powerful multi-criteria and GIS search engines to allow the access of the right analogs by users whenever and wherever needed in the world. The analog K-I-D items can be analyzed online or downloaded to the users' computer for analysis at the click of a mouse. Users in every segment of E&P workflow can easily evaluate the exploration and development challenges and opportunities with a global perspective.

Application of A Global Analog System

The K-I-D based Digital Analogs system is customizable to include user's field analogs. It presents analogs as a distilled form of knowledge, represents reality faithfully and objectively, captures the ideas and creativity of the pioneers, records the reservoir performances in response to various development and production efforts, serves as a laboratory to stimulate and test geo-scientific, engineering and business ideas and is applicable in every segment of E&P upstream workflow. It has a wide range of applications including new venture exploration, prospect generation, portfolio management, development optimization and production enhancement. To illustrate its application, let's look at two examples in exploration and development.

Reducing Exploration Risks in Deepwater Reservoirs

The un-explored deepwater hydrocarbon potential worldwide has attracted large number of E&P companies to get into more and more frontier deepwater provinces where risks are high and data are scarce. Great geoscientific and engineering challenges and high E&P costs warrant closer look at the risks for the exploration and production of deepwater reservoirs, e.g. risks of i) source rock maturation and hydrocarbon charge; ii) prediction of sand fairway and reservoir properties; iii) hydrocarbon trapping mechanisms, area and column; iv) seal rock properties and effectiveness; v) low saturation gas; vi) high drilling costs; and vii) determination of optimal development and production strategies.

Risks in the expensive endeavor of deepwater exploration can be reduced with the knowledge acquired in the exploration and development in other deepwater fields and reservoirs worldwide. The Digital Analogs system contains more than 110 deepwater reservoirs which provide objective information needed to better evaluate the exploration opportunities and reduce un-necessary risks (C&C, 2003). Beside the detailed reservoir evaluation report for each of the deepwater analogs, the 170 reservoir parameters (e.g. trapping mechanisms in Fig.4 and net:gross ratio vs. recovery efficiency in Fig. 5) on worldwide deepwater reservoirs help guide reserve estimation and risk assessment and help evaluate economics based on realistic development and production assumptions.

Field Development and Production in Organic Buildup Reservoirs

Carbonate reservoirs are notorious for their variable recovery factors. This, together with unpredictability in reservoir geometry, continuity and quality, often leads to great uncertainty in evaluating the economic potential of carbonate prospects. Lack of consistent criteria and reliable data for definition and calculation of recovery factors creates further problems. The capability of predicting reservoir performance and recovery efficiency directly impact the field development and production of carbonate reservoirs.

There are more than 250 carbonate reservoirs in the Digital Analogs system that can be analyzed and compared based on their depositional facies, diagenetic modifications, rock properties, fluid types, drive mechanisms, development strategies, EOR techniques and production histories. The multi-criteria search engine allows us to easily find all of the carbonate reservoirs in the system and group them into five reservoir types, i.e. (1) heavy and viscous oil reservoirs; (2) karstic/fractured carbonate oil reservoirs; (3) conventional carbonate oil reservoirs; (4) organic buildup oil reservoirs; and (5) gas/condensate reservoirs. Using this data, we are able to systematically evaluate genetically related reservoirs and identify the common factors that control reservoir performance and recovery efficiency in each group. For example, by studying all the analogs on organic buildup oil reservoirs we have recognized that their recovery factor is primarily controlled by nature and size of organic buildups, diagenetic modifications and EOR techniques applied (e.g. recovery factor of organic buildup in Fig. 6 and productive area vs. recovery factor in Fig 7). Examination of actual case histories reduces uncertainty in pre-development prediction of recovery efficiency of new fields or re-development of old fields.

Conclusions

A wide range of applications of geological analogs in E&P workflow are well recognized by the industry. The advent of the Digital Analogs knowledge system makes the efficient use of analogs as integral part of E&P work flow from exploration to production. Many lessons can be learned from analogs of oil and gas fields worldwide. Application of an effective analogs system can help reduce exploration risk, optimize field development options and enhance field productions.

Acknowledgement

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Figures

Figure 1. Years of experiences of participants of survey on the use of geological analogs in E&P upstream industry. The job title of participants include vice president and director of exploration, general manager, chief geologist, chief geoscientist, chief reservoir engineer, chief petrophysicist, reservoir characterization manager, basin study manager, stratigraphy team leader, sedimentologist, geologist, reservoir engineer and global database manager (Sun and Wan, 2002).

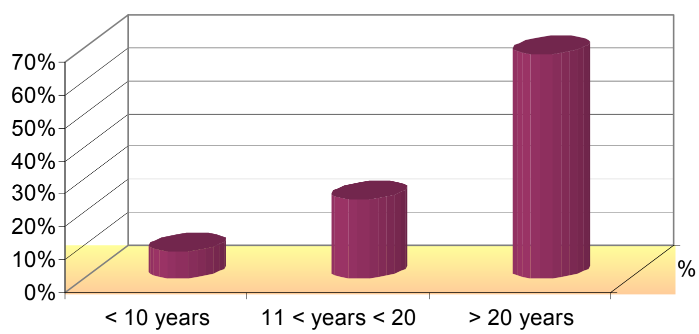

Figure 2. Survey results summary on the application of analogs in E&P workflow (Sun and Wan, 2002).

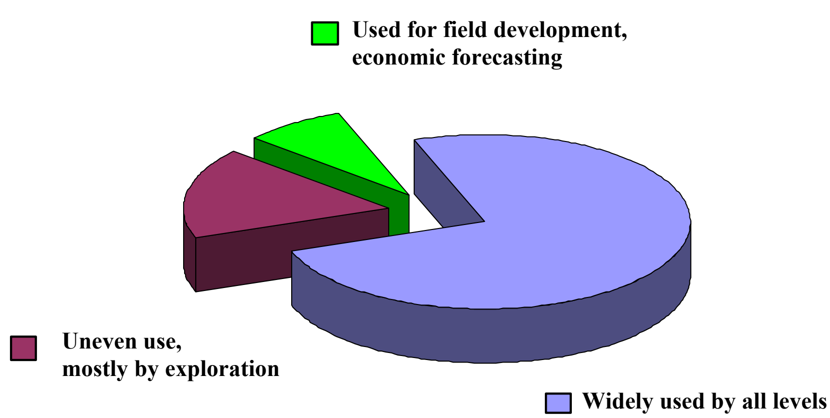

Figure 3. Survey results summary on the sources of analogs (Sun and Wan, 2002).

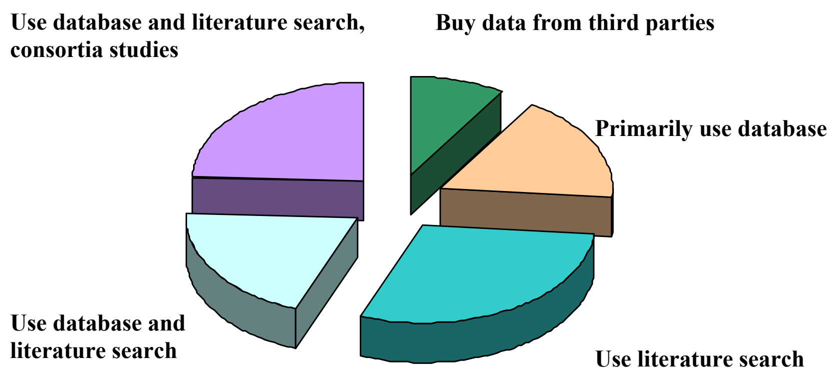

Figure 4. Trapping mechanism distribution of deepwater reservoirs from 30 basins worldwide (C&C, 2003).

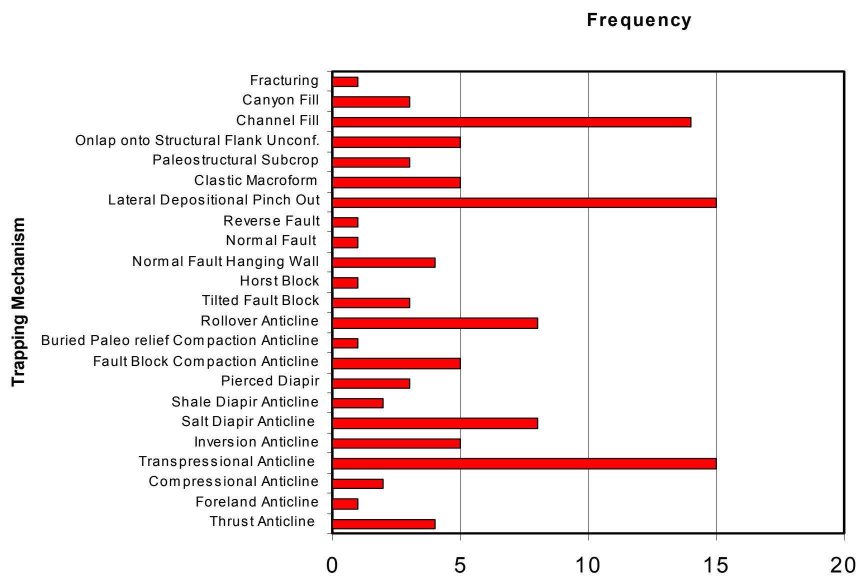

Figure 5. Net : Gross ratio vs. recovery factors of conventional oil in deepwater reservoirs (C&C, 2003).

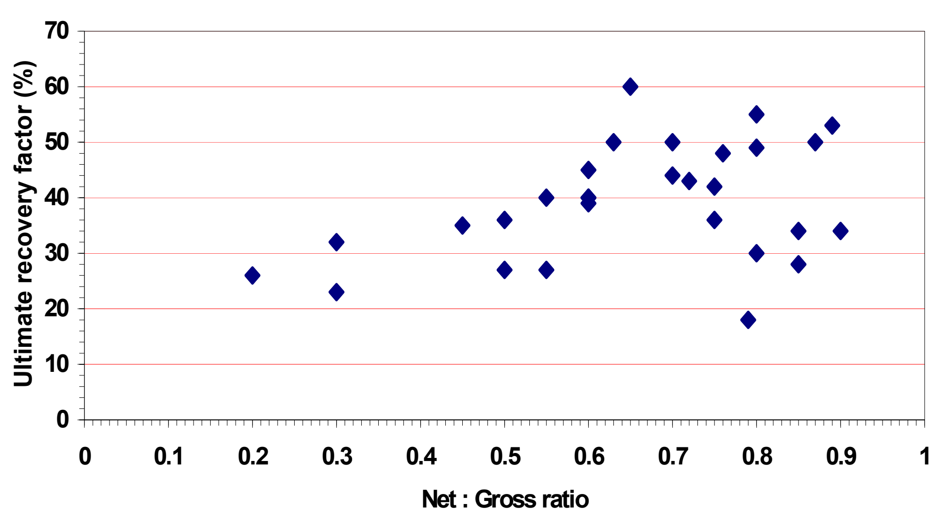

Figure 6. Recovery factor and its key controls for organic build-ups (Sun and Sloan, 2003).

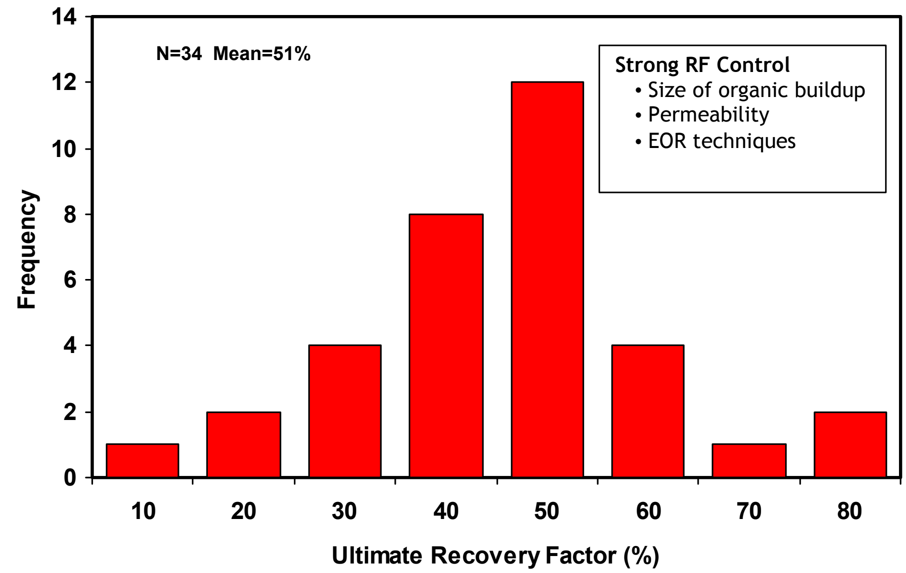

Figure 7. Productive area vs. recovery factor for organic build-ups (Sun and Sloan, 2003).