Carbonate Reservoir Characterization – An Integrated Approach and Future Research Needs

J. Frederick Sarg

Colorado Energy Research Institute, Colorado School of Mines, Golden, CO 80401, USA
jsarg@mines.edu

1. Introduction

Many carbonate reservoirs today occur in mature production environments. The remaining oil in most mature carbonate fields is generally contained within low porosity and low permeability reservoirs, and optimizing recovery will require new technology and work flows that focus on these hard to produce reservoir units. The carbonate reservoirs of the Middle East region are in an emerging mature province. They have undergone a complex depositional, diagenetic, and tectonic history. In general, these Mesozoic and Tertiary-aged reservoirs were deposited on broad ramps, where facies tracts are aerially extensive. They do, however, have complex depositional geometries and multi-component pore systems that require an integrated approach to build a working geologic model appropriate for reservoir simulation (e.g., [1,2]). Depositional facies in this region appear to exert a first order control on most reservoirs. The pore systems can be modified by both early (e.g. marine cementation, karsting, and dolomitization), and late burial diagenesis. Tectonic fracturing and faulting further overprint permeability and flow pathways. All of these factors must be accounted for in any geologic model.

2. Key Features

The first step in building this model is to construct a depositional and sequence stratigraphic framework using available core, outcrop, well, and 3D seismic data. This includes integrating core description of facies with analogous outcrop, and then tying this data into a well log and 3D seismic stratigraphic interpretation, where depositional geometries can be identified and mapped. Calibration of facies, porosity, and permeability in wells and on the seismic allows the model to be populated with quantitative reservoir property data. Where resolution is good, multiple attribute analysis of the 3D seismic data can significantly enhance and constrain three dimensional reservoir frameworks [3,4]. To illustrate this integrated approach to reservoir characterization, two examples are presented from mature carbonate fields in the US. The first example comes from Devonian-aged siliceous carbonates of West Texas, where reservoirs are low porosity, low permeability siliceous sponge spicule packstones and grainstones. An integrated reservoir analysis was done here to test the feasibility of attempting a CO2-flood program. Core description tied to wells and seismic provided a stratigraphic framework for the Devonian interval. Well log porosity, calibrated by whole core analysis was used as input to the neural network analysis of 3D seismic to quantify and map porosity [3]. These maps delineated undrilled areas of left-behind oil and delineated distinct, depositionaly controlled porosity trends that provided opportunities for potential horizontal drilling. The second example comes from Upper Permian San Andres Formation oil reservoirs of West Texas, where a poorly performing water flood program has resulted in re-examination of the reservoir characteristics, including bed continuity. Core analysis tied to nearby analog outcrops [5] provided a framework for field-wide parasequence or cycle correlation. A significant sequence boundary and subaerial exposure event at the top of the reservoir interval is interpreted to have enhanced the permeability of a capping nonskeletal dolograinstone unit. This grainstone has been acting as a thief zone for injected water. Mapping injection profile data within the parasequence framework has highlighted areas where this thief zone is having a major impact on producibility, and has helped provide a strategy for mitigation.

3. Conclusions

The examples above addressed current production problems. For the future, an ongoing fundamental problem is to predict the lateral and vertical permeability and flow pathways (i.e., connectivity) within tight carbonate reservoirs. Future advancement in this area has to occur on a multidisciplinary level, and will, most likely, focus on (1) improved facies models that link paleoclimate and paleoceanography controls to reservoir development; (2) reactive transport models to predict diagenesis; (3) the ability to better use log character to identify facies, and link multi-component pore systems to log character; and (4) improvements in our ability to quantify and map permeability using seismic attributes in conjunction with the other geologic and rock physics data.

4. References

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Author Biography

Dr J. Frederick (Rick) Sarg received his Ph.D. (1976) in Geology from the University of Wisconsin-Madison. He holds an M.S. (1971) and a B.S. (1969) in Geology from the University of Pittsburgh. He has extensive petroleum exploration and production experience in research, supervisory, and operational assignments with Mobil (1976), Exxon (1976-90), as an Independent Consultant (1990-92), with Mobil Technology Company (1992-99) where he attained the position of Research Scientist, and with ExxonMobil Exploration (2000-05). Rick was a member of the exploration research group at Exxon that developed sequence stratigraphy, where his emphasis was on carbonate sequence concepts. He has worldwide experience in integrated seismic-well-outcrop interpretation of siliciclastic and carbonate sequences and has authored or co-authored 27 papers on carbonate sedimentology and stratigraphy. Rick achieved the position of Stratigraphy Coordinator at ExxonMobil Exploration Company, and since 2005, had been working as a senior advisor and instructor with William M. Cobb & Associates, Inc. The Cobb group specializes in water and CO_2 floods. In August of 2006, Rick joined the Colorado Energy Research Institute at the Colorado School of Mines as a Research Professor. Rick recently completed a term as President of the Society for Sedimentary Geology (SEPM) (2004-05).