

PRACTICAL RESERVOIR CHARACTERIZATION FOR THE INDEPENDENT OPERATOR, COMPUTER TECHNOLOGY FOR COMPREHENSIVE RESERVOIR CHARACTERIZATION

BOTTOM LINE

The focus of the workshop was adapting advanced reservoir characterization technologies for independents use in identifying reservoir compartments. Seismic detection and reservoir analysis, facies descriptions, borehole imaging, dipmeter logs and software analysis package technologies developed by the Majors, universities and large research facilities can be understood and used cost-effectively by independent operators.

PROBLEM ADDRESSED

Volumes of research have been published on reservoir characterization and the value of applying geologic parameters to porosity and permeability questions to determine reservoir compartments. The problem for independent operators has been how to find the best approach for their specific reservoirs. How to determine reservoir size? Shape? Well spacing? Vertical vs. horizontal or slant drilling? When to waterflood or not? How to overcome resistivity problems? Perhaps the most asked question about reservoir characterization is, What went wrong? And what should I do next? Independent operators need short, quick answers to these questions so they can use the best available technologies in a prudent, cost-effective manner. Independents need to be aware of the vast amount of new data that is available through low-cost databases and over the Internet, the pros/cons of software packages in different price ranges, and how to select the right package for their application.

KEY WORDS:

Compartmentalized reservoirs
Facies analysis
Flow Units
GIS mapping
Reservoir
Characterization
Sequence stratigraphy
Software and Internet
Databases

TECHNOLOGY OVERVIEW

Compartmentalized reservoirs present a challenge to independent operators because reservoir performance is governed by complex features, which may be difficult to detect. Recognition of reservoir compartments relies on seismic data, knowledge of reservoir pressures, geochemical analysis of fluids and saturations, fluid contacts, and gas, oil and water rates. Technological advances in subsurface well logging, mapping, correlation, seismic analysis, borehole imaging, outcrop analogs, sample analysis and software are the basis of understanding static reservoir properties including: stratigraphy, geometry, lithology, porosity, permeability, capillary pressure and structure. For independent operators with limited manpower and resources, selecting the right technique is the key to successful management.

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SPEAKERS:

Practical Reservoir Characterization For The Independent Operator
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Computer Technology for Comprehensive Reservoir Characterization
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COMPARTMENTALIZED RESERVOIRS

Compartmentalized reservoirs are common to most types of sedimentary deposits and may result from either primary stratigraphy or structure. Common stratigraphic examples from the Rocky Mountains and Mid Continent occur in shoestring channel sands and overbank splays in fluvial and deltaic deposits. Salt diapers cause abrupt compartmentalization in Gulf Coastal and offshore settings. In carbonate plays compartmentalization may be related to reef or algal mound formation, but is more commonly caused by post-depositional changes in formation water and cementation.

GEOLOGIC CONTROLS ON POROSITY AND PERMEABILITY

Porosity and permeability are controlled by grain size distribution and sedimentary processes. Cores and logs are the best source of information on lithology, bed thickness and facies changes, which affect porosity and permeability. The primary effect of post-depositional burial compaction and cementation is reduced porosity and permeability. Correlating porosity and permeability changes between wells is vital to optimizing drilling. Permeability is more sensitive to variations in grain size than is porosity. Advances in seismic porosity detection can achieve resolutions fine enough to aid in solving interwell correlation problems. Successful application of 3-D seismic analysis in a carbonate reservoir was demonstrated through improved calibration of seismic amplitude to porosity in the detection

of porous zones in the Red River Formation of the Williston Basin.

FLOW UNIT DETERMINATION AND CHARACTERIZATION

A combination of geological and petrophysical properties can be used to characterize reservoirs and determine flow units within reservoirs. Depositional models based on facies distribution maps use modified Lorenz plots of storage capacity and cumulative flow to reduce the number of variables affecting fluid flow in compartments. Neural networks are a relatively new but useful tool for developing permeability logs and defining flow unit zonation.

BASICS OF SEQUENCE STRATIGRAPHY

Global sea level curves used to define stratigraphic sequences are ranked cycles of relative sea level tied to the geologic time scale. Coastal onlap and offlap deposits occur in complex stacked cycles of deposition. Interpretation of the sequence of deposition in deltaic, barrier island and shoreface sediments is used to determine facies tract relationships and compartmentalization. Sequence boundaries separate vertical sequences, which are normally incomplete in a given place, due to the geographic position of water and sediment sources at the time of deposition within a basin. Both lithostratigraphy (correlation of rock units) and sequence stratigraphy (correlation of units based on time-equivalent surfaces) are necessary to understand cross-cutting boundaries, which create flow units and reservoir compartments.

FLUVIAL DEPOSITS AND RESERVOIRS

Point bars, braided streams, alluvial fans and incised valley fills include classic compartmentalized reservoirs formed by fluvial systems. Vertical stacked sequences and lateral channel migrations pose problems for drilling and completing reservoir units. Incised valley fill sequences can be particularly difficult to identify. The periods of cut and fill during rising and falling sea levels deposit marine, estuarine and fluvial sediments forming good stratigraphic traps encased in marine shales. Complex fluvial and incised valley compartments can be revealed by seismic imaging, core analysis and pressure tests.

EOLIAN DEPOSITS AND RESERVOIRS

Wind-blown desert and marine sands form extensive, often thick sandstones with good porosity and permeability. The importance of dune migration processes, dune shape and boundary surfaces are illustrated in examples from the Tensleep sandstone (Wyoming), based on 3-D modeling efforts.

SHOREFACE DEPOSITS AND RESERVOIRS

The dynamics of deposition and burial of shoreface and barrier island sediments affect porosity and permeability of the deposits. Post-depositional changes in salt and fresh water fluctuations and burrowing influence reservoir communication and compartmentalization. Classic progradation and transgressive cycles have been used to interpret shoreface deposition and account for lateral facies changes and marine shales, which isolate individual sandstone units.

Porosity and permeability values vary with facies changes from Upper, Middle and Lower shoreface, and require high-resolution sequence stratigraphy to map and correlate. Porosity and permeability values from barrier island deposits vary with both facies and grain size. In addition to the internal complexity of barrier islands, associated lagoonal shales tend to isolate sandstone units.

DELTAIC DEPOSITS AND RESERVOIRS

The multiple environments of deltas (delta plain, delta front, prodelta, river channel, splays, channel mouth bar) and the influence of river, wave and tide on deposition reveal a complex of potential reservoir compartments. Deltas are perhaps the most studied clastic environments, and there are models and worldwide examples of River-Dominated, Wave-Dominated and Tide-Dominated deltas. Illustrations provide useful information on interpretation of facies relationships and stratigraphic traps to improve reservoir management.

DEEP WATER (TURBIDITE) DEPOSITS AND RESERVOIRS

Clastic sediments transported beyond the shelf edge into deep water by sediment gravity flow processes and deposited on continental slope and basins create compartmentalized reservoirs, which are a significant source of hydrocarbons in sedimentary basins world-wide. There are three primary types of turbidites: sheets, channel-fill, and levee or overbank deposits. Growth faulting and basin subsidence have contributed to deposition of stacked turbidite sequences often ranging to hundreds of feet thick. Many turbidite deposits are located in deep water where seismic advances are vital to identification of sediment type, compartments and optimizing drilling and production operations. Outcrop analogs provide useful data on reservoir architecture, scale and connectivity of compartments, and interpretation of seismic data.

BOREHOLE IMAGE AND DIPMETER LOGS AND APPLICATIONS

Electrical and acoustic logging tools developed in recent years provide internal, 360° images of boreholes. Borehole imaging was first applied to interpretation of faults and fractures, and can be used to differentiate natural from induced fractures. Interpretative techniques can now be applied to identification of sedimentary and stratigraphic features at resolution sufficient to reveal bedding types, internal structures and continuity beyond the wellbore. Borehole images and dipmeter reading used in combination are good for correlation between wells.

STRUCTURALLY COMPARTMENTALIZED RESERVOIRS

Complex structurally faulted reservoirs in fold belts and orogenic regions are common in regional trends across the Cascade Range to the Rocky Mountains and the Ouachitas; down the length of California, and the Basin and Range Providence through Nevada, Arizona and New Mexico. Faults may be beneath the level of seismic resolution, requiring detailed mapping. Sealing faults may be cemented or gouge filled. Production data on GOR's can be used to

detect sealing faults in the absence of pressure data. Fault interpretation is one of the major uses of seismic technology, and advances in 4-D and time-lapse seismic are continually suggesting new ways to interpret reservoirs.

COMPUTER TECHNOLOGY FOR COMPREHENSIVE RESERVOIR CHARACTERIZATION

The four most compelling reasons for independent operators to use computers are: the ability to process large volumes of data quickly and easily, the ability to perform mathematical operations on data accurately, computers can accommodate changes during the interpretation process, computers allow the operator to visualize reservoir three dimensional features. Digital, on-line sources for geological and engineering data for hydrocarbon exploration are increasing each year and many states have free or low-cost databases in addition to those available from service companies. The Internet is a vast and rapidly increasing source of data and reservoir interpretive information.

Software packages for mapping, wireline logging, digitized logs, reservoir management, and other essential analysis and planning functions are available in a wide range of costs, and a variety of experience levels necessary to use them. Neural networks and use of entrained data for drilling and performance predictions are available to help compensate for missing data. Reasonable costs for both data and analysis software make computers essential to all independent operators. Shop the vendors to match service offers and prices. Evaluate costs in relationship to the value of your geologists and petroleum engineers. How can computers maximize their time and increase their efficiency?

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