Methods for Determining Interwell Facies Boundaries (and Constraining Geostatistical Correlation)*

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Summary

Using carbonate examples, some methods for determining facies boundaries at the interwell scale, and therefore potentially constraining geostatistical correlation, are presented. Modern environments and outcrops are valuable as reservoir analogs. Crosswell seismic profiles and horizontal well data are direct detection methods within a reservoir. Although all of the methods have shortcomings, they should be utilized to the fullest extent possible, in conjunction with geostatistical approaches, during a reservoir characterization effort.

Contents

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Methods for Determining Interwell Facies Boundaries (and Constraining Geostatistical Correlation)

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SUMMARY

Using carbonate examples, some methods for determining facies boundaries at the interwell scale, and therefore potentially constraining geostatistical correlation, are presented. Modern environments and outcrops are valuable as reservoir analogs. Crosswell seismic profiles and horizontal well data are direct detection methods within a reservoir. Although all of the methods have shortcomings, they should be utilized to the fullest extent possible, in conjunction with geostatistical approaches, during a reservoir characterization effort.

INTRODUCTION

Robust statistical programs for characterizing and mapping facies from core, log, seismic, and engineering data are developing at a rapid pace. These programs present to the subsurface geologist opportunities for portraying spatial facies relations to use in building reservoir models. Varying certain geostatistical parameters creates multiple correlation scenarios (realizations) that honor existing data and collectively can be used to determine probabilities for various aspects of the correlation between wells. The ease with which geostatistical correlation is developed and displayed makes the approach a necessary one, but there is also a down side from the geological perspective. Time and budget limitations often create situations in which available geological data that should be viewed as possible constraints for the geostatistical correlation are overlooked.

Knowledge of the spatial distribution of carbonate facies is necessary to determine patterns of heterogeneity within a reservoir layer or to predict a reservoir's regional extent. This facies dimension information is critical for improved reservoir characterization in determining facies boundaries between well locations. From the standpoint of building reservoir models and assigning properties within a reservoir layer, facies dimensions are necessary for constructing variograms, designing templates for attribute distribution, and indicating directional bias for interpolation. What are some sources of information for enhancing the interwell correlation of facies and potentially guiding geostatistical correlation?

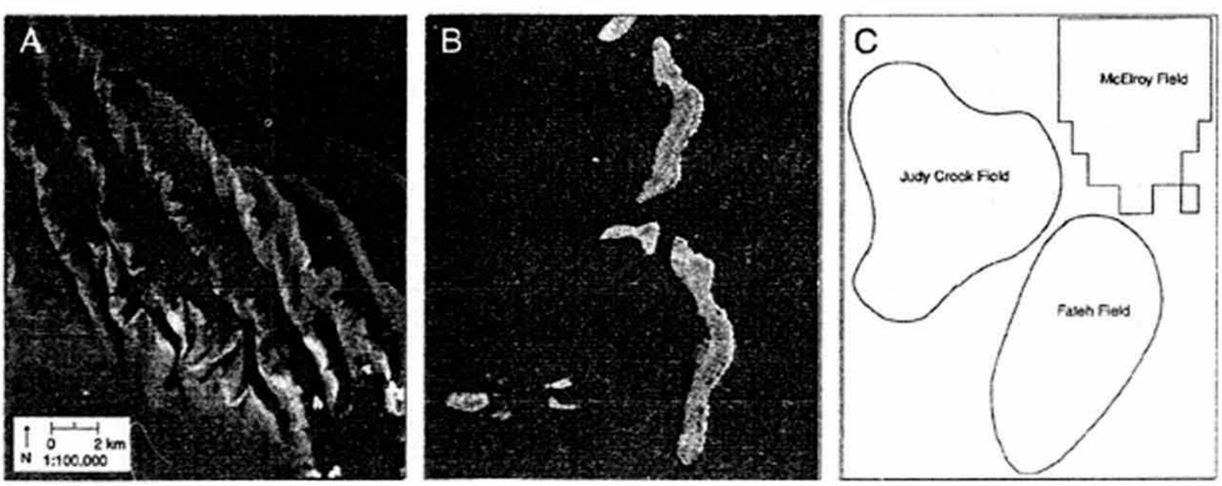

Figure 1. Subscenes of Landsat TM images from Harris and Kowalik (1994) showing details of (A) the tidal bar belt of ooid sand shoals rimming the cul-de-sac of Tongue of the Ocean on Great Bahama Bank, and (B) shelf-edge ribbon reefs in the northern Great Barrier Reef of Australia. (C) Outlines of the Judy Creek (Devonian, Alberta), McElroy (Permian, Texas), and Fateh fields (Cretaceous, Dubai) at the scale of the Landsat images to show the potential importance of the modern analogs in illustrating facies variation on a reservoir scale.

METHOD

Four types of information that can improve correlation are briefly introduced. Information from modern and outcrop examples is valuable as analogs for a particular reservoir, whereas crosswell seismic profiles and horizontal well data are direct sources of information from the reservoir.

MODERN ANALOGS

Holocene environments are valuable as analogs for conceptualizing facies patterns within a single reservoir layer. As examples, satellite images, e.g., Harris and Kowalik (1994), aerial photographs, or surface sediment maps illustrate facies trends and dimensions and can be used to show patterns for a particular depositional setting relative to simulated well spacing (Figure 1). However, of more value in visualizing the anatomy of a reservoir layer are the results of coring studies from modern environments, e.g., Major and others (1996), where the spatial distribution of facies within a depositional cycle is documented. How well the facies patterns from a Holocene example actually compare with a particular reservoir or reservoir layer is always a cause for concern and therefore a shortcoming. In addition, Holocene studies are often insufficient analogs for portraying reservoir quality variations because of their limited stratigraphic thickness and lack of diagenetic complexity.

OUTCROP ANALOGS

Outcrop analogs provide two- or even three-dimensional views of facies with greater diagenetic overprint than is found in the modern examples and over a more substantial stratigraphic thickness, i.e., for a stack of depositional cycles. Porosity and permeability, when measured on outcrop within a cycle/ sequence and facies framework, are used to illustrate fluid flow scenarios (Figure 2). As such, outcrop analogs provide a more complete view than subsurface data of both facies and reservoir quality dimensions, e.g., Eisenberg and others (1994). The stratigraphic and facies relations recognized on outcrop are reasonably used as a template for correlating subsurface data. Questions always remain, however, on how well the details of facies and diagenesis from an outcrop actually compare with a particular reservoir or reservoir layer.

CROSSWELL SEISMIC PROFILES

Crosswell seismic profiling is a suitable method of directly measuring interwell changes of petrophysical facies. High vertical resolution crosswell data collected in carbonate reservoirs with close well spacing detects interwell variations of impedance that can be related to porosity (Bashore and others, 1995). When combined with downhole log and core data and compared with porosity models, the seismic data map porosity, but not necessarily permeability, between wells (Figure 3; Tucker and others, in press). These petrophysical facies relate directly to depositional facies in simple cases, or relate to some combination of depositional facies and postdepositional modification in more diagenetically complex examples. In a similar sense, 3-D seismic data, when combined with existing wells and larger-scale porosity models, provide

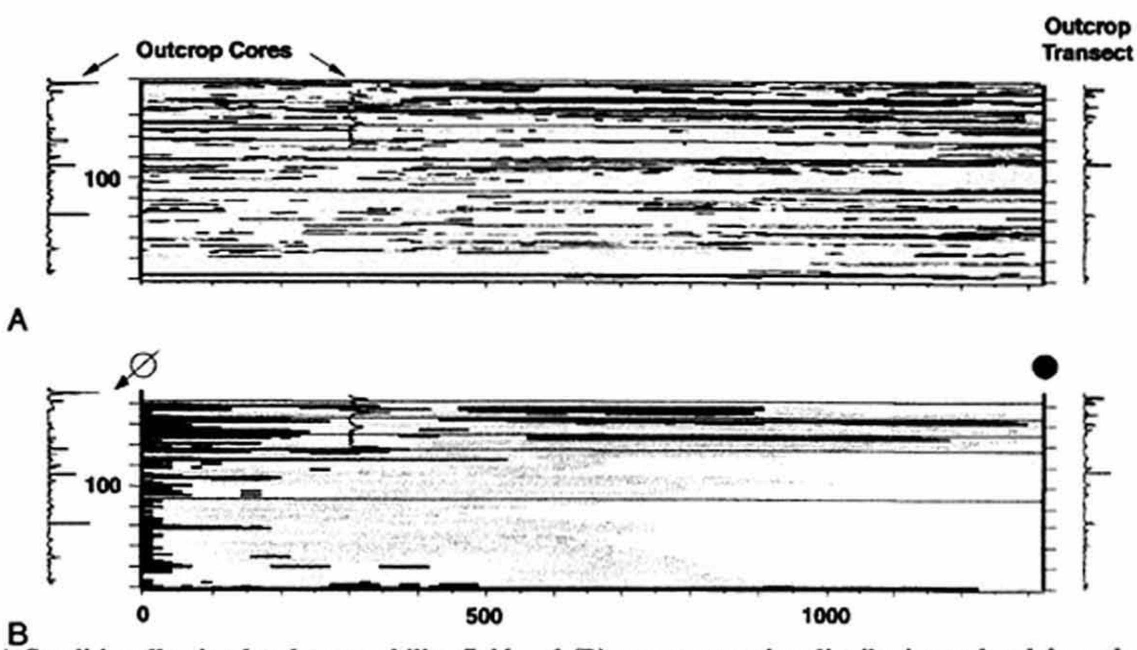

Figure 2. (A) Conditionally simulated permeability field and (B) water saturation distribution at breakthrough for a simulated waterflood generated from an outcrop study by Eisenberg and others (1994). Vertical and horizontal correlation structures and the layering scheme for the models were obtained from outcrop measurements. Permeability traces from outcrop wells and transects are shown. Higher permeability and water saturation shown by darker shades. Scale in feet.

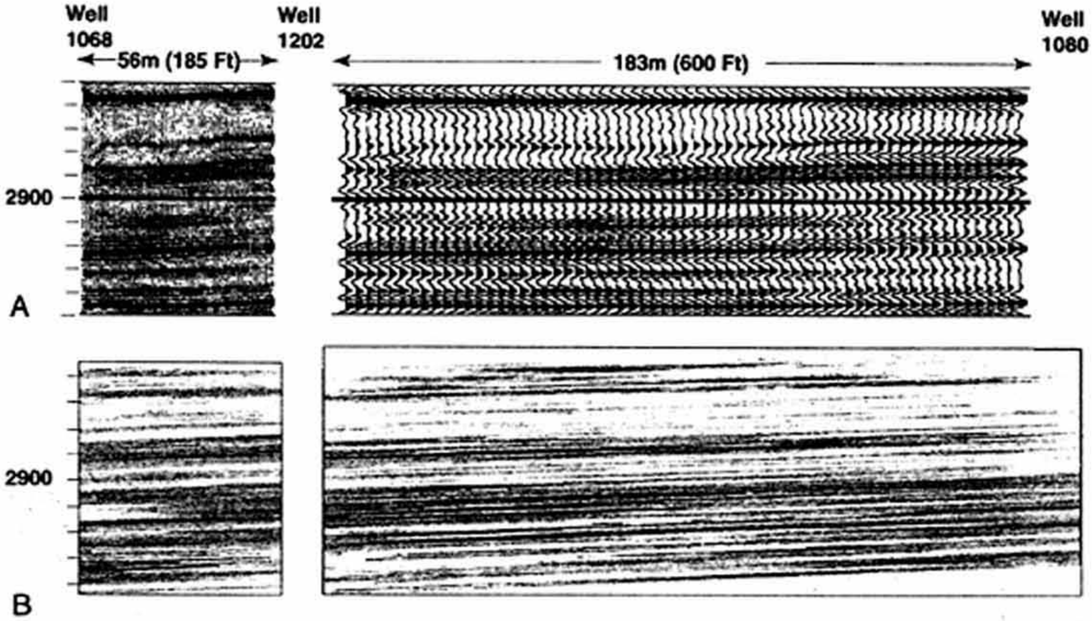

Figure 3. Comparison between (A) S-wave crosswell seismic reflection images and (B) geostatistical porosity models from Tucker and others (in press). The cross-section simulation of porosity is based on log facies that are derived by cluster analysis of log data. Higher porosity is indicated by darker shades.

a crude approximation of interwell facies distribution. Shortcomings of using crosswell seismic data to define facies boundaries are understanding the exact relationship between impedance and porosity for the particular reservoir and, although dropping dramatically, cost for acquisition and processing.

HORIZONTAL WELL DATA

Log and core information from horizontal wells directly detect facies and petrophysical changes between vertical wells. By combining horizontal and vertical well information, a 3-D view of depositional and petrophysical facies boundaries is determined. As valuable as this information is for the particular drilled layer, drawbacks of horizontal well data are likely to be the number and orientation of wells, hole problems that affect logging, and the relatively small area of investigation of each wellbore.

CONCLUSIONS

Modern and outcrop analogs remain valuable sources of facies dimension information, although they are not direct comparisons for a reservoir, especially for petrophysical properties. Crosswell seismic and horizontal well data directly detect interwell facies and petrophysical boundaries, but not enough of either type of data is often available due to cost and area of investigation. Given the shortcomings of the various methods, some choose to ignore these potentially valuable sources of information. Instead, they should be utilized to the fullest extent possible during a reservoir characterization effort. Information from the different methods must be examined quantitatively where possible to apply facies boundary insight throughout a reservoir model and better constrain geostatistical correlation.

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