[PS]Preliminary Lithofacies Interpretation from Formation Micro-Imager (FMI) Logs in the Katz Field Unit, North Central Texas*

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Abstract

Katz Oil Field miscible CO_2 flood (Katz Strawn Unit; KSU) is located on the Eastern Shelf of the Midland Basin (Permian Basin) and covers portions of northeastern Stonewall, King, Knox, and Haskell counties of North Central Texas.

Three cores from the Pennsylvanian Strawn Formation in the Katz field and one core from the adjacent Orsborne Field were logged with particular attention given to identifying lithofacies. Fourteen image logs of varying vintages within the field have recently been analyzed to correlate lithofacies seen in the core and to document new and similar lithofacies above and below core depth coverage.

Direct comparisons between physical core and image logs are available in the field within the same borehole. This primary calibration of core data to image log was used to produce a borehole image lithofacies catalog for the Katz Field Unit (lithofacies A through L). Secondary calibration points also provided correlative information (i.e., cores and image logs with data points separated by < 200 ft). Wireline log data was also incorporated for assisting in lithofacies determination including: spectral gamma ray, compensated neutron-lithodensity, resistivity, microlog, PE, and calculated lithology curves.

Previous core lithofacies analysis detailed six major (primarily) siliciclastic lithofacies including: 1) lenticular- to wavy-bedded mudstone, 2) flaser- to wavy bedded sandstone, 3) carbonate-rich sandstone, 4) ripple-laminated to trough-cross-stratified sandstone with convolute bedding common, 5) trough cross stratified sandstone with abundant mud rip-up clasts, mud balls, and siderite nodules, and 6) heavily bioturbated sandstone. These lithofacies were also identified in image logs. Resolution differences between the core and image logs, however, led to the grouping of some core lithofacies in the Katz Field Unit image catalog based on sedimentary features generated in similar depositional

environments. For example, lenticular- to wavy-bedded mudstone and flaser- to wavy bedded sandstone have been combined into Facies C) flaser- to lenticular- to wavy-bedded sandstone and mudstone. Ripple-laminated to trough cross-stratified sandstone with convoluted bedding and ripple laminated to trough cross-stratified sandstone have been combined into Facies E) ripple- laminated to trough cross-stratified sandstone.

Combined lithofacies identified in core and image logs beyond core coverage include the following: A) mudstone to bioturbated mudstone, B) parallel laminated to bioturbated sandstone to shaley sandstone, C) flaser- to lenticular- to wavy-bedded sandstone and mudstone, D) heavily bioturbated sandstone, E) ripple-laminated to trough cross-stratified sandstone, F) ripple-laminated to herringbone cross-stratified sandstone, G) cross-bedded sandstone, H) interbedded sandstone and limestone, I) wavy- to parallel bedded limestone, J) cross-bedded limestone, K) diagenetic-nodular/brecciated limestone, and L) interbedded limestone and shale.

Accessories commonly associated with lithofacies in both core and FMI include: bioturbation, carbonate bioclasts, carbonate breccias, carbonate cement, plant debris, siderite nodules, slumps and contorted bedding, microfaults, mud balls, and mud rip-up clasts.

Although ichnofacies play a significant role in the Katz Field Unit, discerning exact ichnogenera within the resolution of the image logs with the exception of a few well-defined examples of *Asterosoma* and *Ophiomorpha* is difficult. Core and image log lithofacies associations suggest that paleoenvironments of the Katz Field Unit included a bayhead delta, back-barrier estuary embayment, carbonate-rich flood-tidal delta, tidal flat, and upper to middle shoreface.

The integration and interpretation of the Katz Field Unit core data and image log lithofacies help to guide the propagation of lithofacies to a larger area within the unit leading to a clearer understanding of the distribution of lithofacies between wells both horizontally and vertically at depth. This assists in the identification and correlation of lithofacies geometries supporting our current conceptual reservoir model and the identification of potential pay and flow barriers without investing in an extensive coring campaign.

PRELIMINARY LITHOFACIES INTERPRETATION FROM FORMATION MICRO-IMAGER (FMI) LOGS IN THE KATZ FIELD UNIT, NORTH CENTRAL TEXAS

Jesse Garnett White (Consulting Geologist), Valentina Vallega (Schlumberger), Peter P. Flaig (Bureau of Economic Geology, University of Texas at Austin), and Stephen T. Hasiotis (Department of Geology, Univeristy of Kansas, Lawrence)

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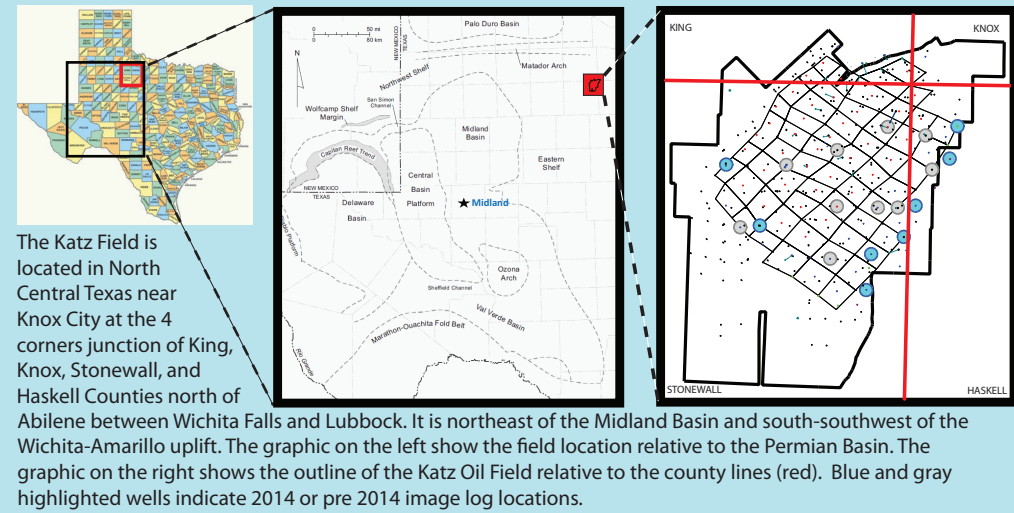
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KATZ FIELD LOCATION

The Katz Field is located in North Central Texas near Knox City at the 4 corners junction of King, Knox, Stonewall, and Haskell Counties north of Abilene between Wichita Falls and Lubbock. It is northeast of the Midland Basin and south-southwest of the Wichita-Amarillo uplift. The graphic on the left show the field location relative to the Permian Basin. The graphic on the right shows the outline of the Katz Oil Field relative to the county lines (red). Blue and gray highlighted wells indicate 2014 or pre 2014 image log locations.

METHODOLOGY

1) Detailed lithofacies core descriptions focusing on sedimentology and ichnology
   A) 3 cores in the Katz Field and 1 core in the Orsborne Field were described
2) Core to FMI image calibration
   A) Core shift
   B) Scale differential and lumping of some core facies
3) Definition of discrete lithofacies based on core to image calibration, basic log response, and calculated lithology log
4) Interpretation of lithofacies associated with the FMI image response
5) Interpretation of lithofacies associations relating to depositional environment hypothesis
6) Lithofacies coded and entered into Petra as a log
7) Lithofacies based cross sections for interpretation of lithofacies distribution

INTERPRETED LITHOFACIES BASED ON CORE AND FMI CORRELATION

A- Mudstone to bioturbated Mudstone
B- Parallel laminated to bioturbated sandstone to shaley sandstone
C- Flaser- to lenticular- to wavy-bedded sandstone and mudstone
D- Heavily bioturbated sandstone
E- Ripple to trough cross laminated sandstone
F- Ripple to herringbone cross laminated sandstone
G- Cross bedded sandstone
H- Interbedded sandstone and limestone
I- Wavy to parallel bedded limestone
J- Cross bedded limestone
K- Diagenetic nodular/brecciated limestone
L- Interbedded limestone and shale
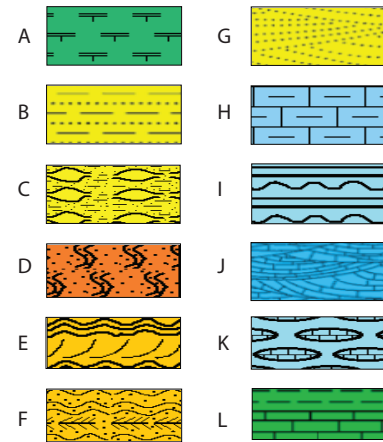
EXAMPLE OF DELIVERABLE PRODUCT

Note scale 1:240 on poster for display purposes. Logs delivered at 1:10 scale. The second to the last column to the right represents the facies log based on core to FMI image calibration and extrapolation. The last column on the right exhibits annotated observations such as bioturbation, calcium carbonate cement patches, brecciated zones, siderite nodules, and mud rip ups.

## MAP OF CURRENT FACIES CROSS SECTIONS

Correlation of major lithofacies including sand, shale, and limestone using both core data, FMI facies information, and wireline logs.

Note how the limestones seem to be suggesting channelization into what we are calling carbonate rich flood tidal deltas. Some channels are long lived while others are not.

Note that the map cross - sections are labelled (A-A', B-B', etc...), the FMI locations are circled and fault trends are indicated by thick black lines extending from Caddo up through Strawn sands.

Facies A through L are color coded and represented as a log in the Petra cross section.

KATZ FIELD UNIT FMI FACIES CATALOGUE
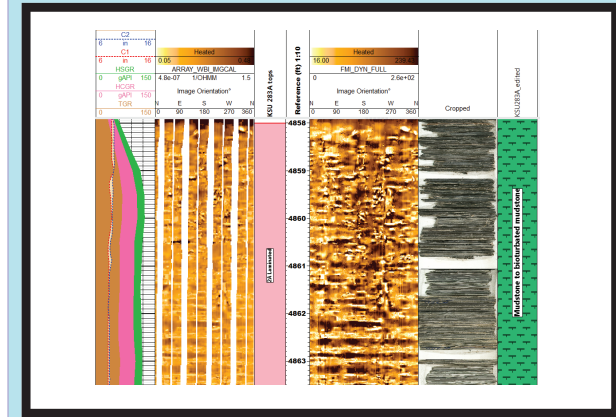
Mudstone to bioturbated mudstone (Facies A):
Highly rhythmic. Facies dominated by mud with very fine grained planar laminated sandstone. On the image logs, highly conductive, parallel laminations may be visible depending on bioturbation level.
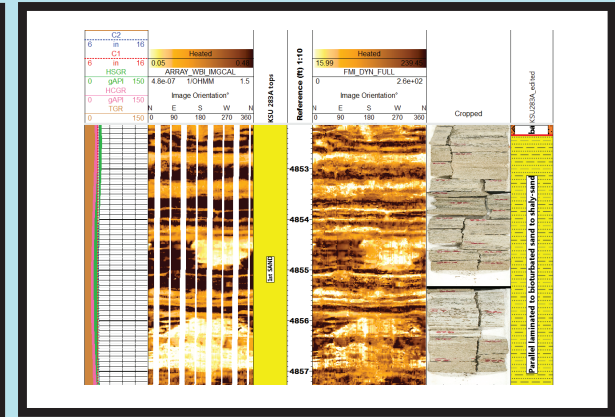
Parallel laminated to bioturbated sand to muddy sandstone (Facies B):
Fine grained sandstone. Bedding obscured by bioturbation. Rare minor ripple cross laminations may be present. Carbonaceous mud drapes are occasionally observed. Some small rounded to elongate siderite nodules have been observed. On the image log calcium carbonate cement patches are visible.
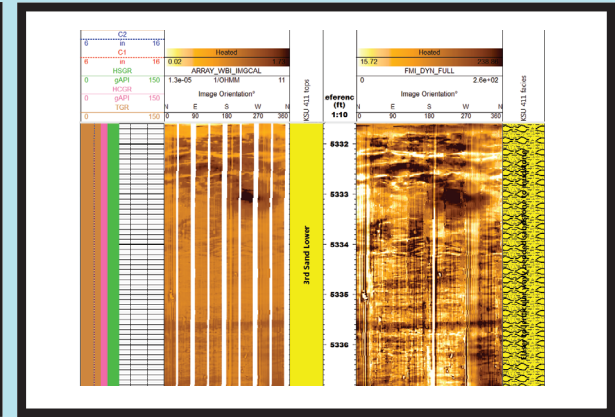
Flaser to lenticular to wavy bedded sandstone and mudstone (Facies C):
Black to dark gray lenticular to wavy bedded mudstone encasing light gray lenticular siltstone to muddy very fine sandstone. Some horizons are calcareous. On the borehole image we can see the discontinuity of the more conductive mud, being deposited on the underlying wavy bed. The increase in mud can be observed on the GR readings.
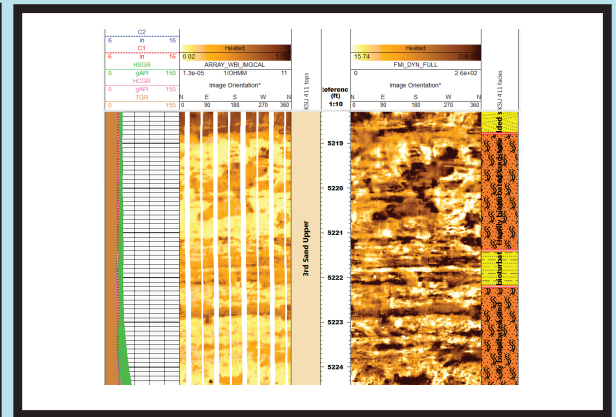
Heavily bioturbated sandstone (Facies D) :
Usually contains a high-diversity of trace fossils and also an abundance of mud. Generally associated with fully marine to middle shoreface environments. On the borehole image it is easily recognized as all the original features (cross laminations or beddings) are totally altered. This snapshot on the side shows the difference between the highly bioturbated intervals and the parallel laminated interval in between.
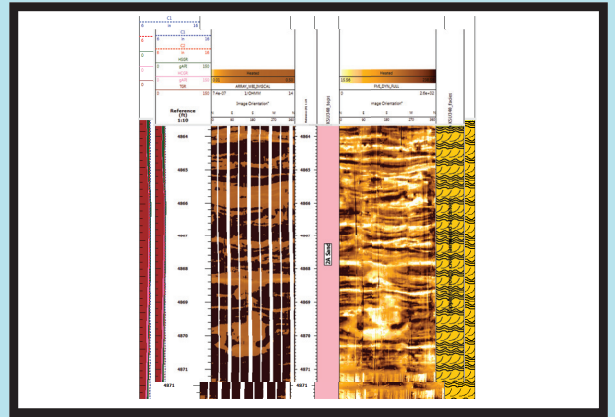
Ripple to trough cross laminated sandstone (Facies E):
Trough cross-laminated fine to coarse-grained sandstone. Some ripple cross laminations. Associated with fluvial deltaic, subaqueous terminal distributaries, and subaerial distributary channels. On the borehole image, the beddings planes do not form straight sinusoids but have irregularities at lamination contacts.
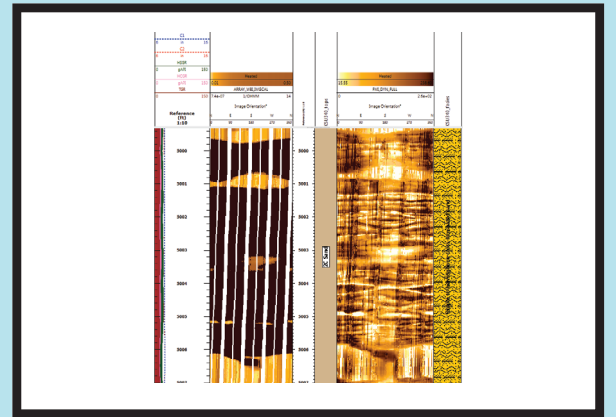
Ripple to herringbone cross laminated sandstone (Facies F):
Very fine grained sandstone with influx of organic rich mudstones and occasional bioturbation. On the borehole image, herringbone cross stratification is easily identified as cross lamination sets with a dip direction 180 degrees apart.
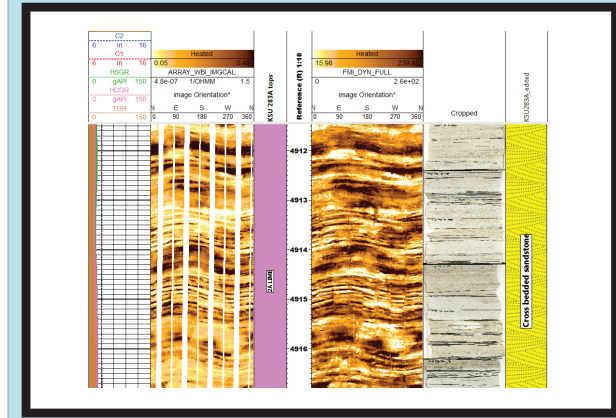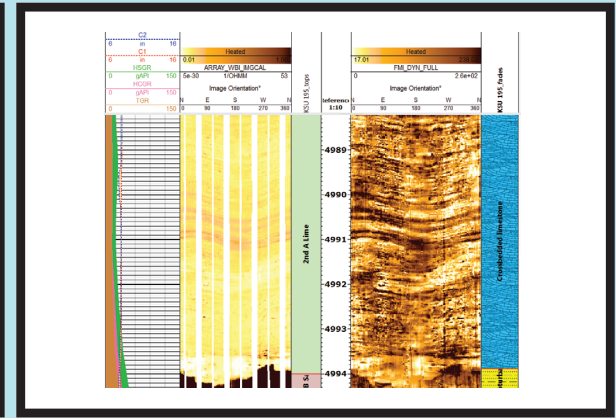
Cross-bedded sandstone (Facies G):
Presence of some lime cement at intervals. On the borehole image, high angle dip differentiate the cross bedded sandstone from the parallel laminated one. Associated to a shorefacies deposition.
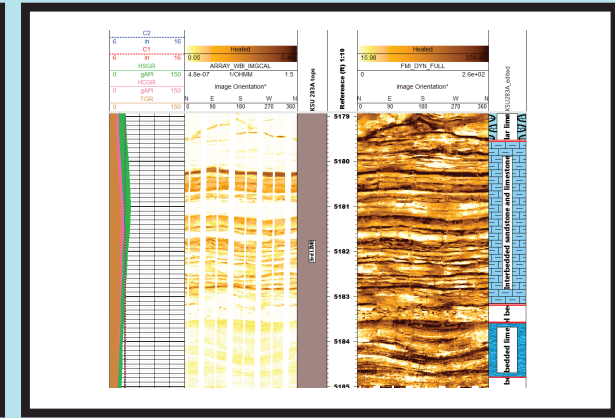
Interbedded sandstone and limestone (Facies H):
No core available. Not easily recognizable on borehole image. Lithology logs computed from triple combo data provide valuable help for this facies identification. Bedding within these units have sedimentary angles varying from sub horizontal to 20 degrees.
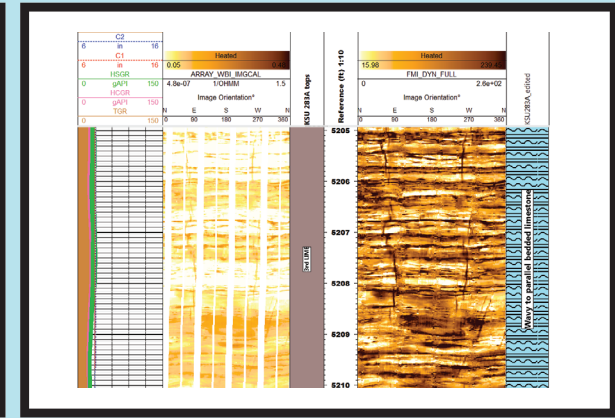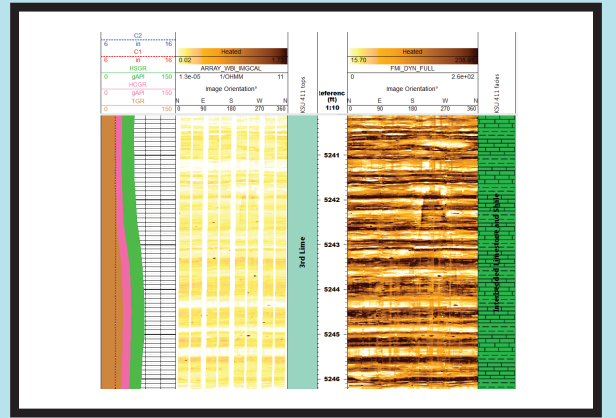
Wavy to parallel bedded limestone (Facies I):
No core available. Wavy bedding surfaces characterize this facies on borehole images. The presence of shaly laminations are shown by the more conductive lamina. Depending on the energy at time of deposition, the bedding morphology varies from wavy to parallel bedded.
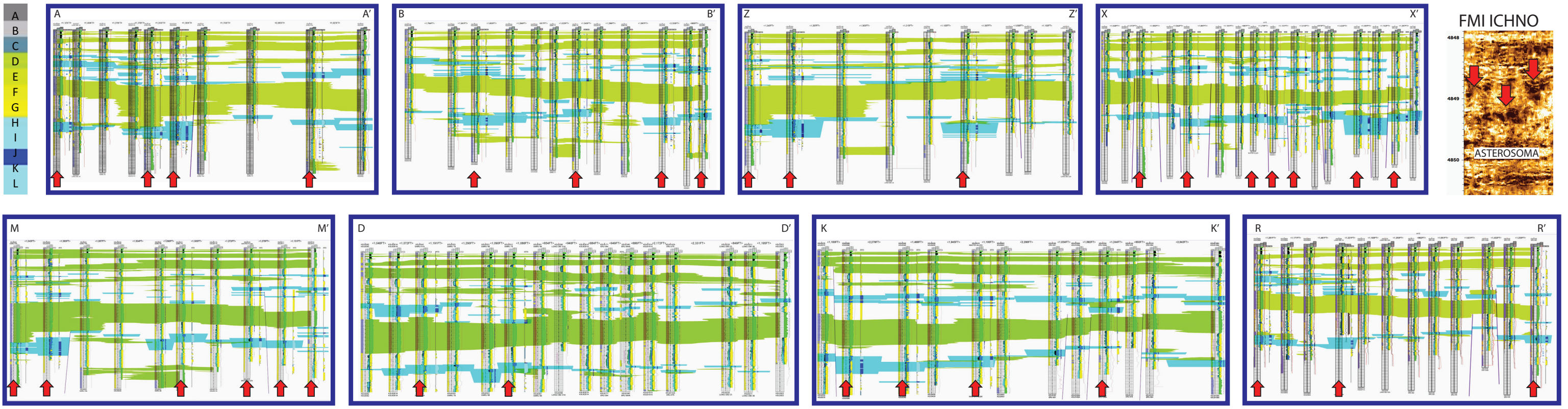
Crossbedded limestone (Facies J):
Crinoid bioclastic packstone. Textures vary from faintly laminated to cross laminated to very high angle cross bedding. Shale drapes on foresets are rare but do occur. High dip angles differentiate the cross bedded limestone from the parallel laminated limestone on the borehole image logs.
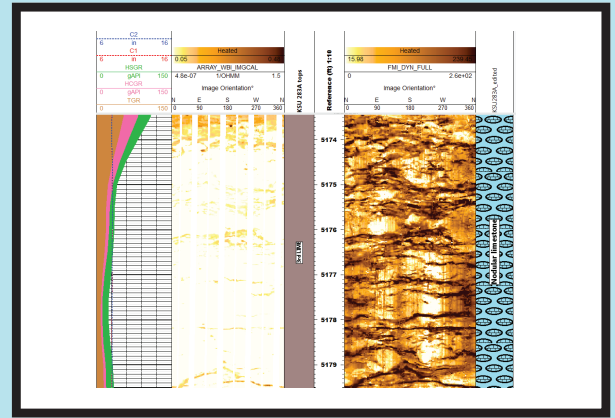
Diagenetic nodular/brecciated limestone (Facies K):
No core available. Refers to diagenetically altered limestone where dissolution along specific pathways generates the formation of a separate fragments producing a nodular look. Some of these facies are associated with subaerial exposure episodes (epikarst breccia). The term "nodular" in this case does not refer to an in situ growth of calcium carbonate nodules.

Interbedded limestone & shale (Facies L):
No core available. Characterized by sequences of carbonate rich layers alternated with shale beds. The contacts between layers present smooth and sharp boundaries.

PROPOSED BLOCK DIAGRAM ANALOGUE

The 3D block cartoon represents a bayhead delta discharging fresh water and sediment into a brakish water estuary and associated tidal flats that is partially enclosed by sand bars and/or barrier islands. The estuary has a free connection to the open sea. This connection is where the carbonate-rich flood tide deltas enter into the sytem.

The siliciclastic sand supply for sand bars is likely deposited by longshore drift reworked from other deltas along strike. The carbonate sand supply is being incorporated in the tidal deltas from nearby seaward carbonate build ups.

The sand bar is effected by open ocean waves on the seaward side but behind the sandbar where the back barrier tidal flats are deposited is largely protected from ocean waves with the exception of storm washover.

http://www.ozcoasts.gov.au
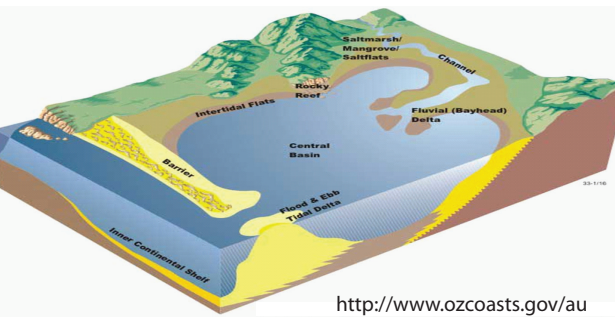
PROPOSED MODERN ANALOGUE

The proposed modern analogue to these mixed siliciclastic and carbonate sedimentary facies is the northeast coastline of Queensland, Australia in the areas of Moreton Bay and Harvey Bay. In both bays, barrier low reef shorelines and low relief barrier islands are present with multiple openings to the fully marine system of the Coral Sea which also contains the Great Barrier Reef system. This allows for the formation of carbonate-rich flood tidal deltas. Both bays also have siliciclastic-rich bay head deltas that include stream mouth bars produced from the seasonal flow from the rivers that terminate there.

POSTER SUMMARY

The integration and interpretation of the Katz Field Unit core and image log lithofacies have helped to guide the propagation of lithofacies to a larger area within the unit leading to a clearer understanding of the distribution of lithofacies between wells both horizontally and vertically at depth. This assists in the identification and correlation of lithofacies geometries supporting our current conceptual geologic model and the identification of potential unrecovered pay, consistent flow units, and flow barriers without investing in an extensive coring campaign.

Cross sections across the field are preliminary but suggest that the lithofacies are heterogeneous and have been deposited in a complex carbonate-siliciclastic depositional environment.

The integration of sedimentary lithofacies and ichnofacies analysis from core with recent and vintage borehole imaging data suggests that the paleoenvironments of the Katz Field include:

1) bayhead delta, 2) back barrier estuary embayment, 3) carbonate rich flood tidal delta, 4) tidal flat, and 5) fully marine upper to middle shoreface.

ACKNOWLEDGMENTS

Introducing the 2015 Southwest Section of the AAPG Annual Convention
AAPG
ROCK THE FALLS
Evaluating the Past, Exploring the Future
April 11–14, 2015
Wichita Falls, Texas

FMI ICHNO

ASTEROSOMA

PRELIMINARY RESULTS

Red arrows = wells with FMI or other image log. Green shading = shale, blue shading = limestone, and white = sandstone. The high density of wireline and image log data across the field allows for simplified cross sections in various directions. These cross sections highlight the lateral and vertical litho-heterogeneity and variability of the various depositional systems. Limestone bodies previously thought to be continuous across the reservoir cannot be correlated from well to well across the field indicating separate depositional systems. The analysis of limestone suggests the carbonate flood tide deltas that are stacking both vertically and laterally cutting through and interfingering with estuarine sediments, tidal flats, and bayhead delta sands. Lithofacies analysis has refined our understanding of how the sands correlate between wells. The analysis of the sands shows lateral variation and that single sand units cannot always be directly correlated from well to well. The analysis of the sands suggests a series of bayhead delta channel deposits that are stacking both vertically and laterally cutting through and interfingering with estuarine muds and tidal flats. The interplay of flood tide delta carbonates and bayhead delta sands with estuarine muds and tidal flats results in a complex reservoir system.

Schlumberger