Using Image Logs to Identify Facies in Heterogeneous Turbidite and Basinal Organic Mudstone Systems From the Wolfcamp Formation, Delaware Basin, West Texas, USA *

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Abstract

Integration of core facies, image log facies (ILF) and wireline logs from heterogeneous turbidite and basinal organic mudstone systems, increases the confidence levels for the database for building regional scale depositional models. Image logs provide a key link to characterize facies and processes in comparison to wireline logs, and can be used to bridge the correlation between core facies and wireline logs for up-scaling. Systematic use of ILF as part of the correlation increases the data set for facies interpretation, as there is greater availability of image logs compared to core. This presentation details a method that uses borehole image logs to extend core-based facies and process analysis to intervals that lack core, in above-mentioned sedimentary systems. The method is successfully used in a workflow that distinguishes carbonate, quartz, mud-rich turbidites and debris flows deposited with organic-rich silicic mudstones in an unconventional play of the Delaware basin. When using this method, electrode data from each pad of the micro-resistivity imaging tool (in water-based mud) is mathematically shifted to generate synthetic micro-resistivity logs that follow the trend of the shallow resistivity logs. The high-resolution electrical data that best represents the sedimentary facies derived either from a single pad, or the averages from multiple pads of the imaging tool is selected. Next, the high-resolution electrical data and detailed sedimentary textures visible from the image logs are used to identify the ILF and in turn calibrated with core facies. Caution is taken while using electrical data for facies identification as those can be severely affected by pore fluid properties. In the current effort, triple-combo logs are considered for identifying broad lithological variation and ILF for more detailed characterization. The results show that of the 10 detailed core facies from cored intervals of mud-dominated turbidite sequences from lower and middle part of Wolfcamp Formation, six can be identified

from the image logs. Within the sand-dominated turbidite sequence from upper most part of Wolfcamp Formation, three different ILF are identified out of four core facies. Four different types of sedimentary processes are also identified from the image logs. Finally, the ILF are successfully extended to identify the sedimentary facies and processes of Wolfcamp Formation over those imaged intervals that lack core in a specific well and in the nearby wells.

Reference Cited

Silver, B.A., and R.G. Todd, 1969, Permian cyclic strata, northern Midland and Delaware Basins, west Texas and southeastern New Mexico: AAPG Bulletin, v. 53, p. 2223-2251.

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Denver

June 1st, 2:20 pm

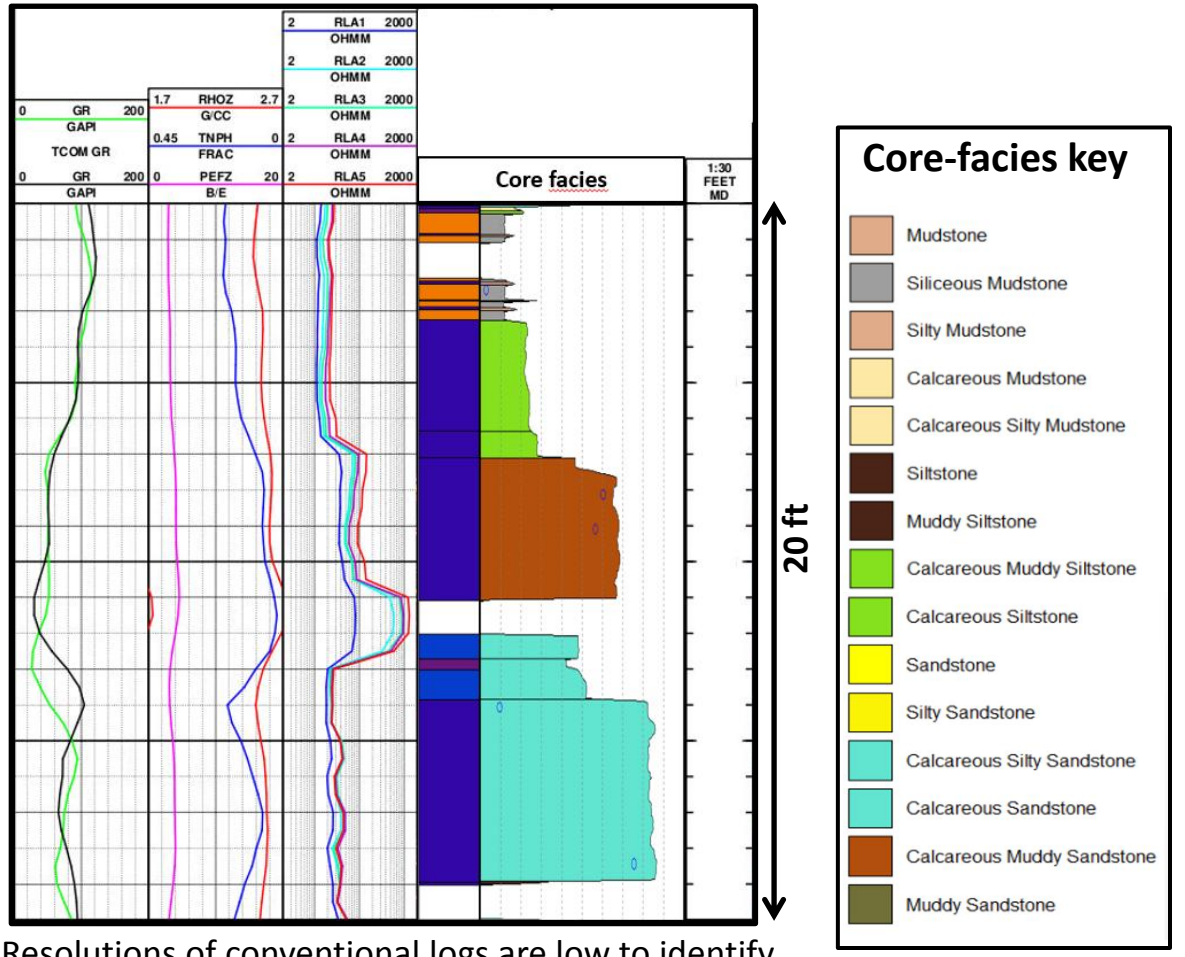
* Colorado School of Mines, ** ConocoPhillips

Topics

- Objective
- Introduction
- Work flow
- Atlas of Image log facies
- Image log facies: Scope of application
- Limitations
- Conclusion and path forward

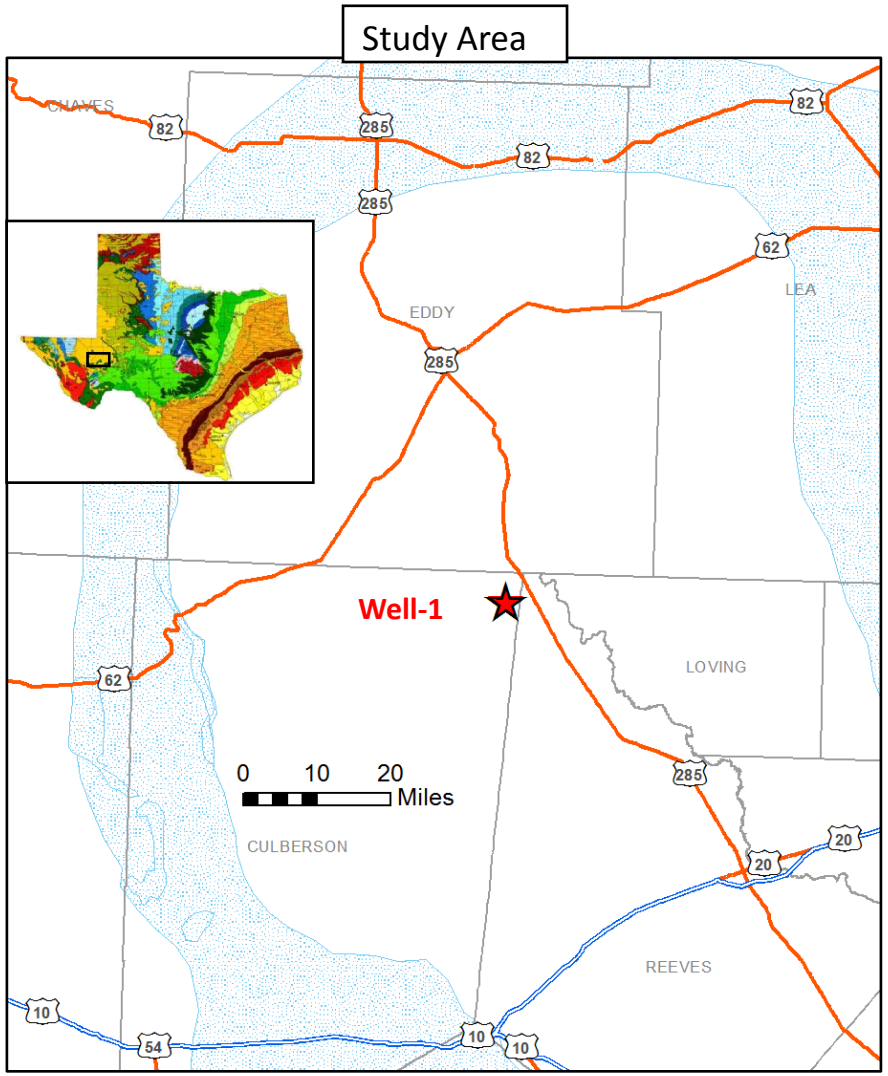
Objective

- Develop a methodology to use Image logs for characterizing core-calibrated sedimentary facies.
- Prediction of core-calibrated sedimentary facies over intervals without core.



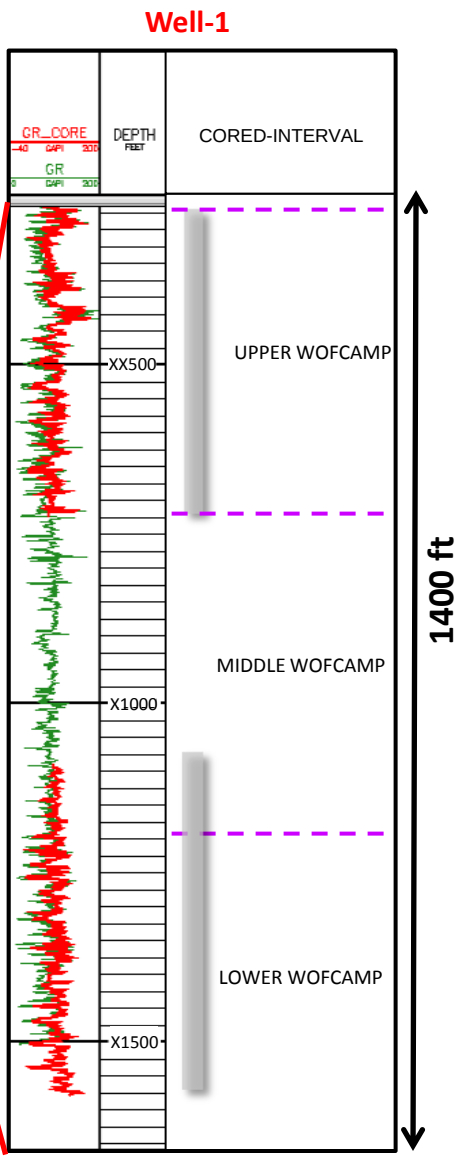
Resolutions of conventional logs are low to identify detail sedimentary facies in this hetereogeneous system

Introduction

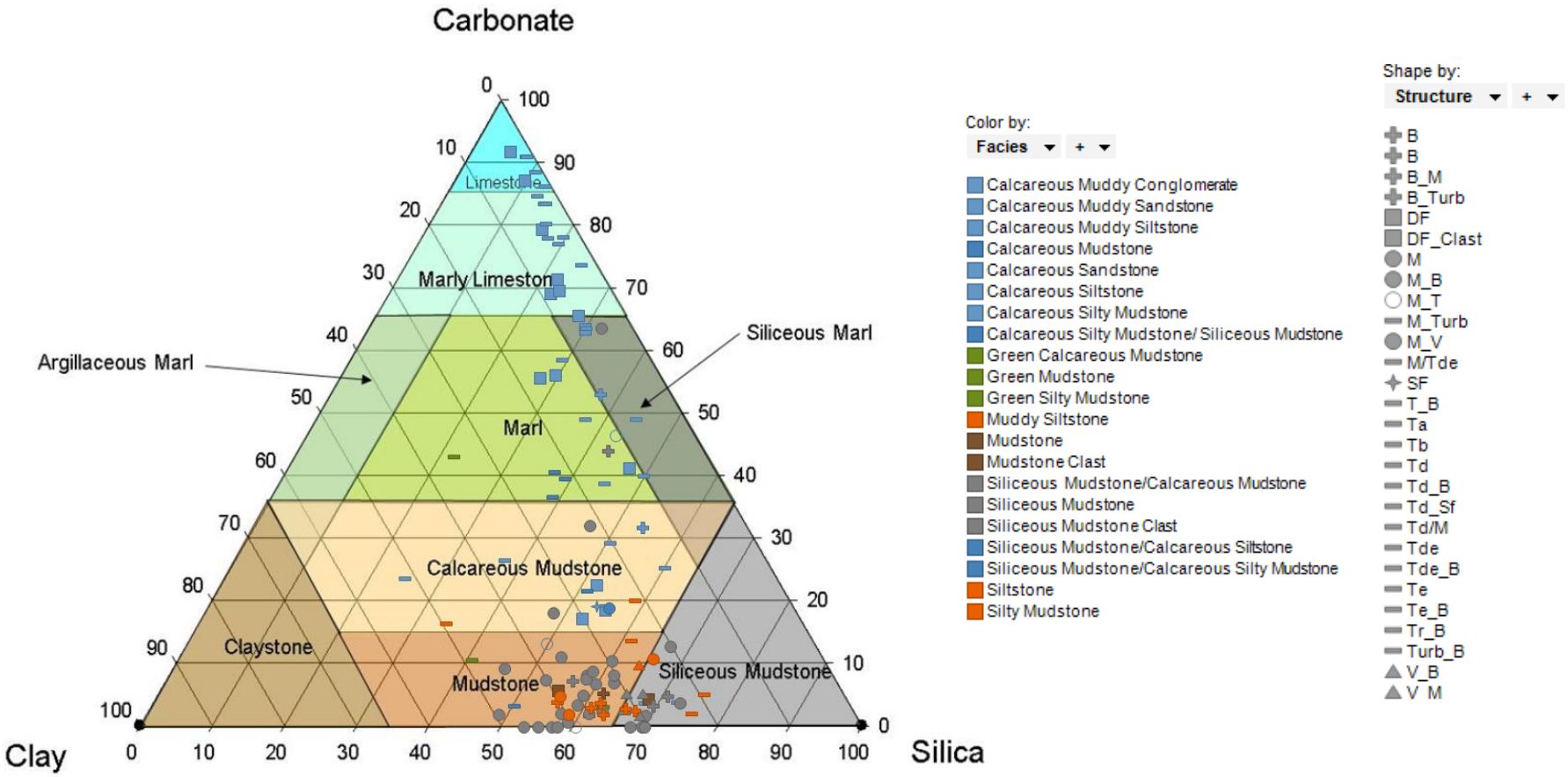


AGE		Stratigraphic Unit
SYSTEM	SERIES	DELAWARE BASIN
PERMIAN	Ochoan	Dewey Lake
		Rustler
		Salado
		Castile
	Guadalupian	Delaware Sands: Bell Canyon
		Cherry Canyon
		Brushy Canyon
	Leonardian	Bone Spring
	Wolfcampian	Wolfcamp
PENNSYLVANIAN	Cisco	Cisco
	Canyon	Canyon
	Strawn	Strawn
	Atokan	Atoka

Silver and Todd, 1969



Well-1 - Litho-facies from Core



- Ternary diagram displays wide compositional variation of different mudstones identified from core, well-1.

Work Flow

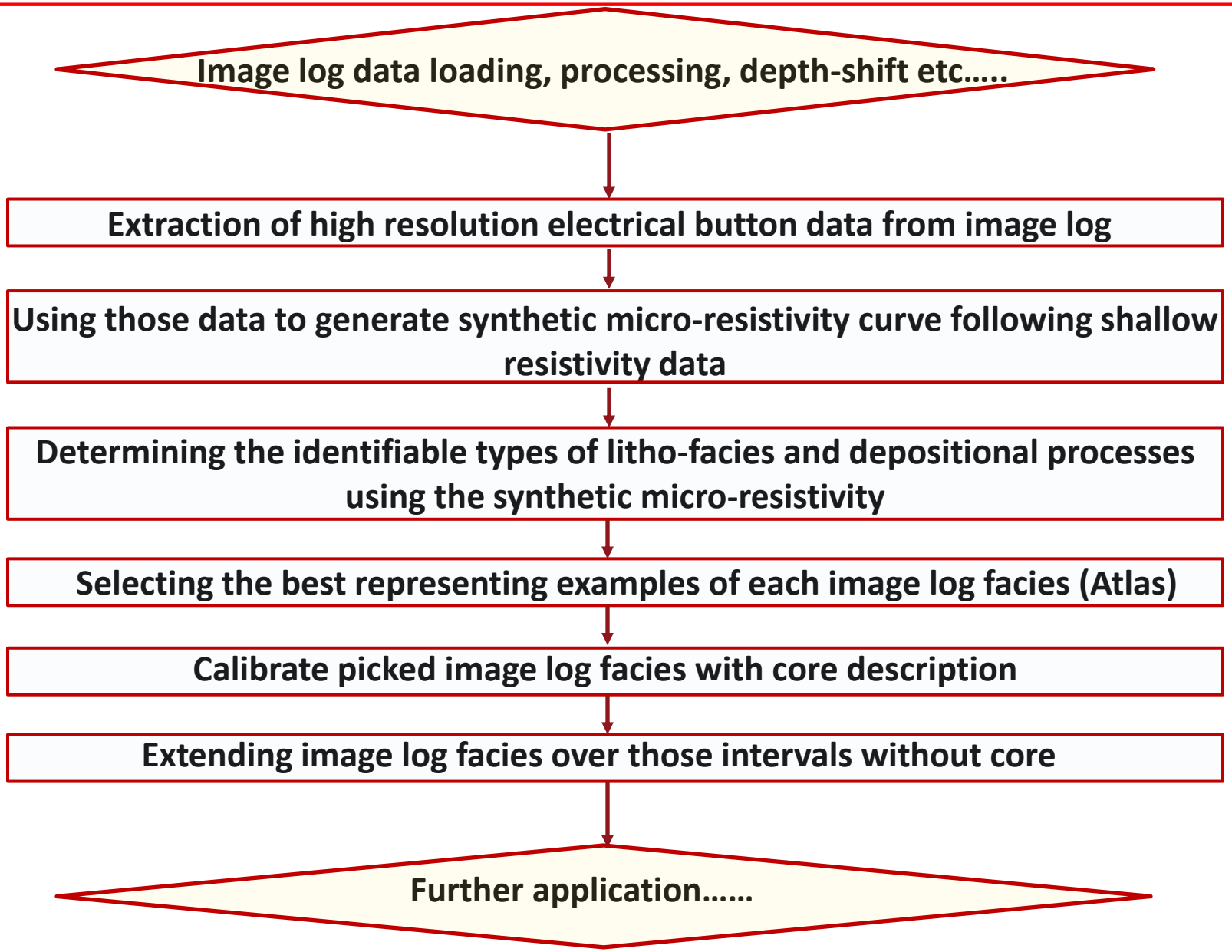
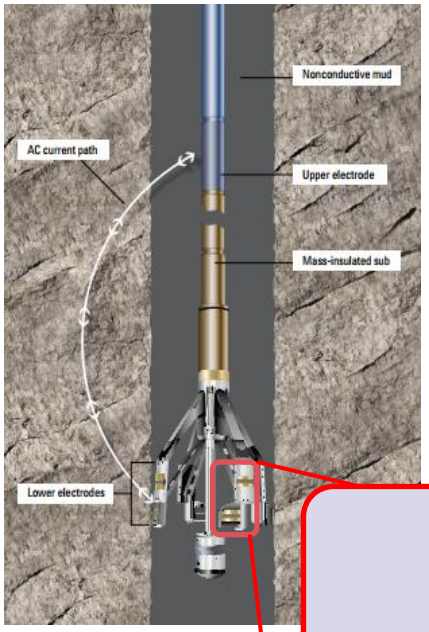
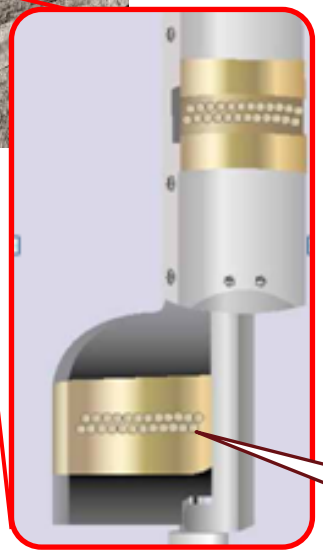


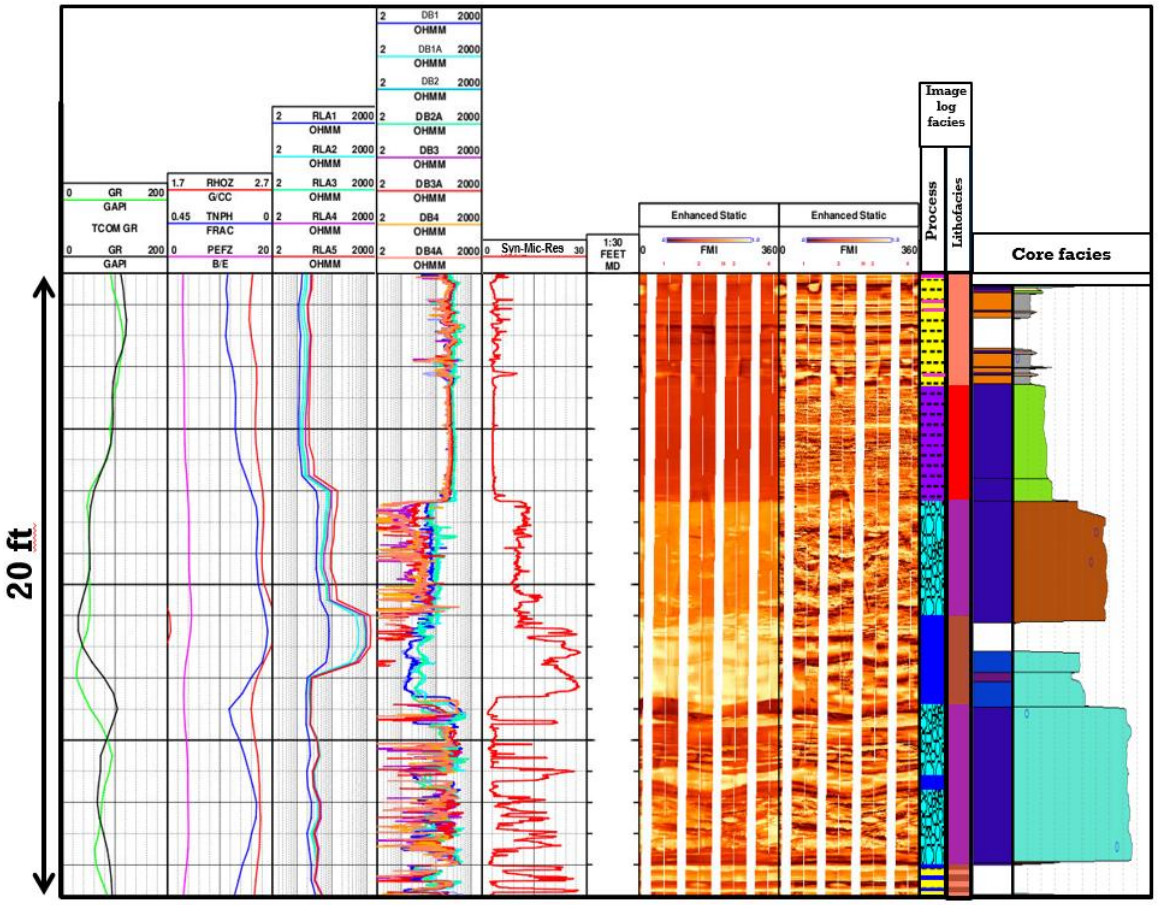
Image log data loading, processing, depth-shift etc.....
Extraction of high resolution electrical button data from image log
Using those data to generate synthetic micro-resistivity curve following shallow resistivity data
Determining the identifiable types of litho-facies and depositional processes using the synthetic micro-resistivity
Selecting the best representing examples of each image log facies (Atlas)
Calibrate picked image log facies with core description
Extending image log facies over those intervals without core
Further application.....

Generating Synthetic Micro-resistivity Curve





FMI tool diagram
Courtesy slb.com



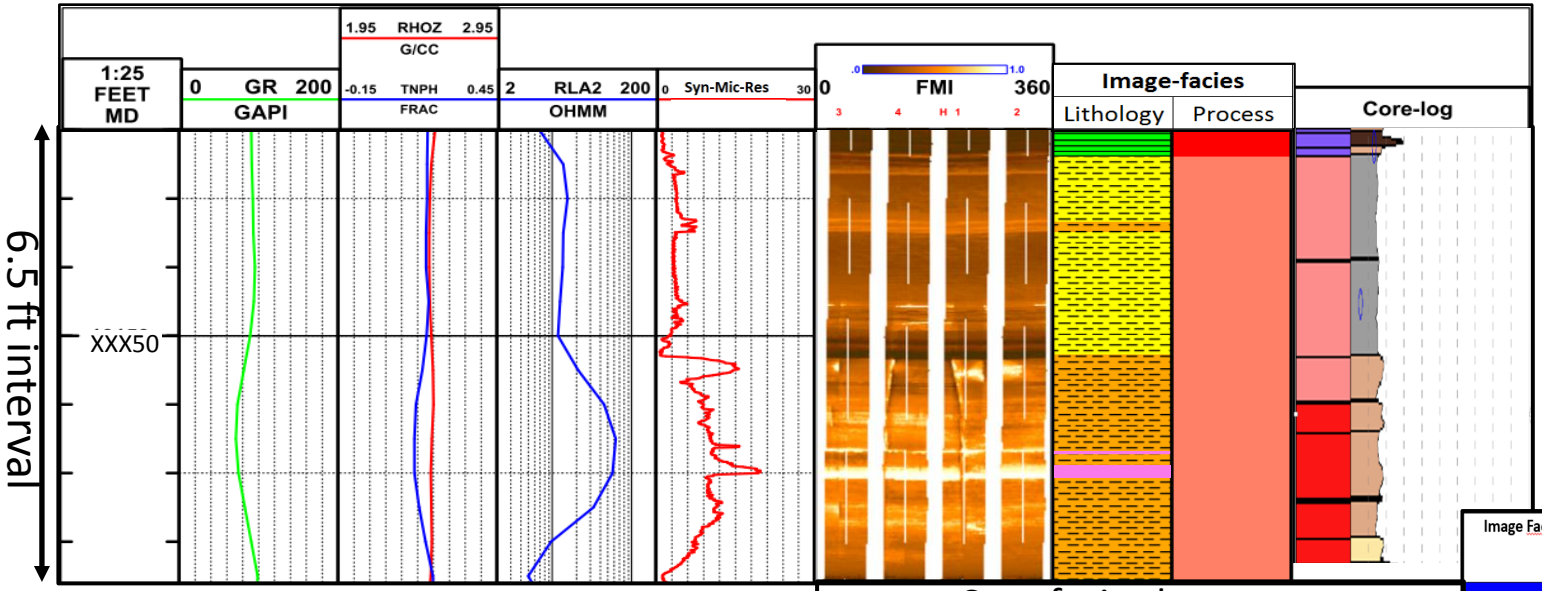
Buttons on individual pad/flap of FMI tool

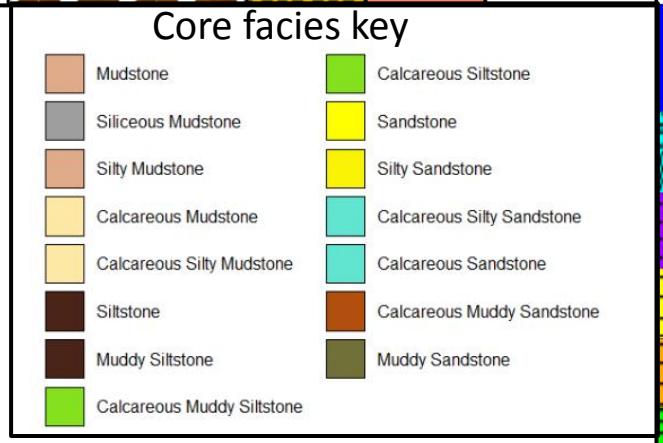
- Button data from each of the pad/flap of FMI tool are shifted using an algorithm to generate the synthetic micro-resistivity curves

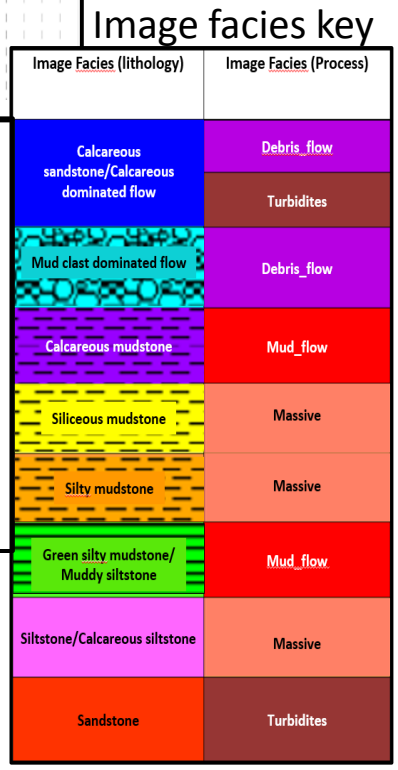
Identifiable Image Log Facies

Core Description (Facies+Process) 15 facies	Image Facies (lithology) 9 facies	Image Facies (Process) 4 processes	Comment
Calcareous Sandstone/ Calcareous Silty Sandstone/ Calcareous Muddy Sandstone_Debris flow	Calcareous sandstone/Calcareous dominated flow	Debris_flow	Debrites
		Turbidites	Turbidites (principally HDT's)
Mud Clast dominated_Debris Flow	Mud clast dominated flow	Debris_flow	Debrites
Calcareous Mudstone_Mudflow	Calcareous mudstone	Mud_flow	Slurry Flows (often distal mmbr of debris flow)
Siliceous Mudstone (Massive/Bioturbated/ Varved_Bioturbated)	Siliceous mudstone	Massive	Silty Facies (Biogenic silica or windblown dust); varying carbonate content. Windblown dolomite behaves as stable clast.
Mudstone/Silty Mudstone (Massive/Bioturbated)	Silty mudstone	Massive	
Green Mudstone/ Green Silty Mudstone/ Green Calcareous Mudstone/ Silty Mudstone /Muddy Siltstone	Green silty mudstone/ Muddy siltstone	Mud_flow	Terrigenous clay (slurry flows)
Siltstone/Muddy sandstone/calcareous siltstone(massive/bioturbated)	Siltstone/Calcareous siltstone	Massive	Turbidites (HDT/LDT)
Sandstone/Silty sandstone (massive/bioturbated)	Sandstone	Turbidites	Turbidites (HDT/LDT)

Atlas: Siliceous Mudstone and Silty Mudstone







- Using synthetic micro-resistivity cut-off values to distinguish different mudstone variety.
- Caution for fractured intervals.

Atlas: Calcareous Sandstone_LDT/HDT & Calcareous Mudflow

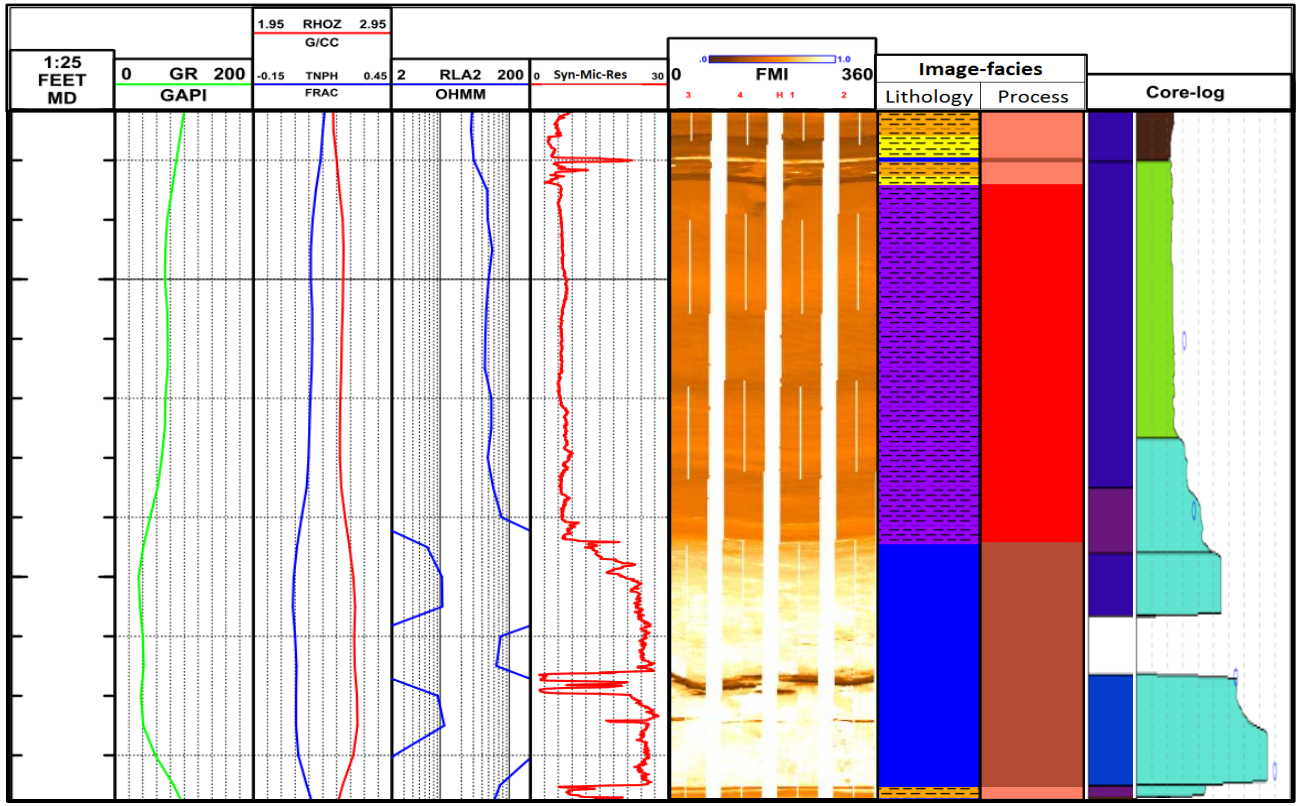
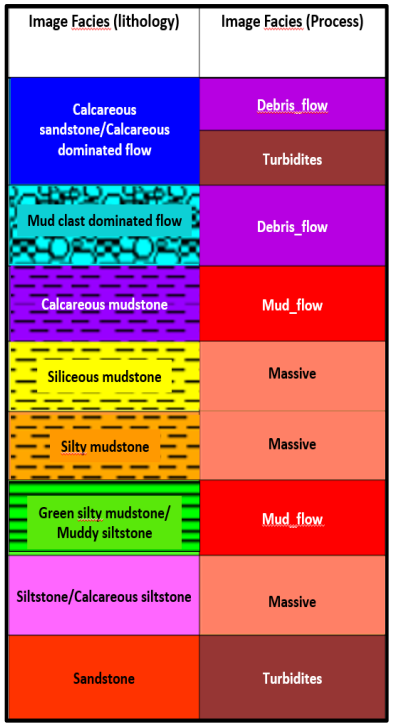
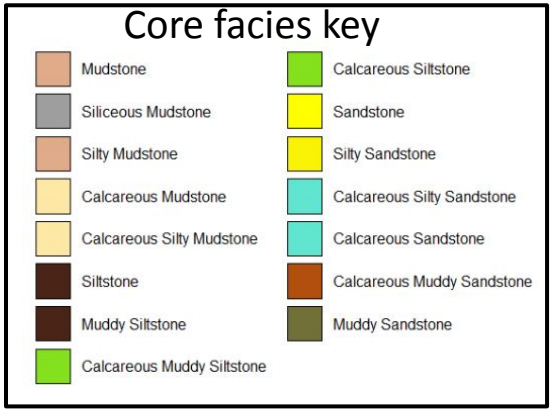


Image facies key



Core facies key



- In addition to the micro-resistivity cut-off values, image log features need to be considered for characterizing facies.

Atlas: Debris Flow with Calcareous Sandstone & Mudclast

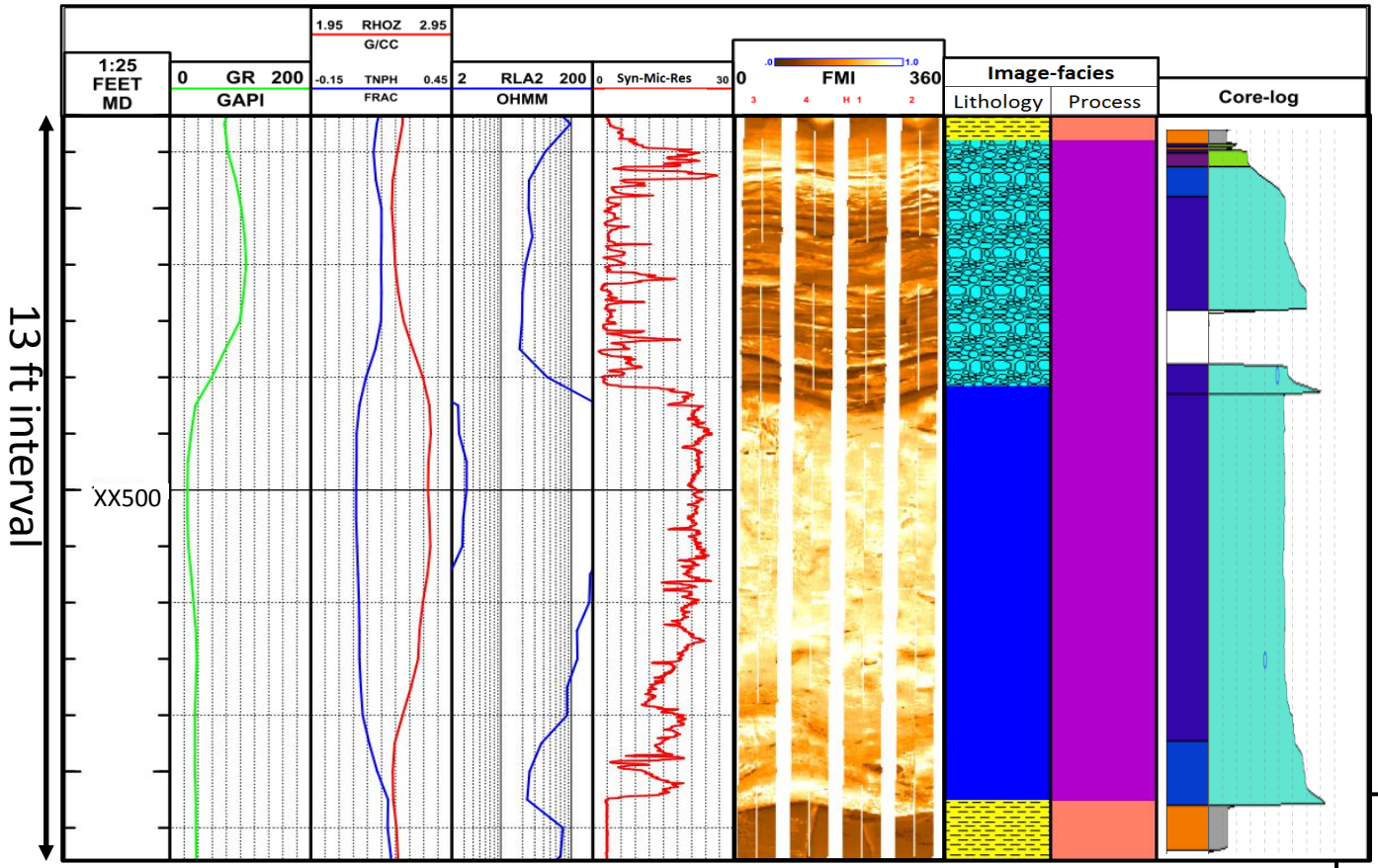
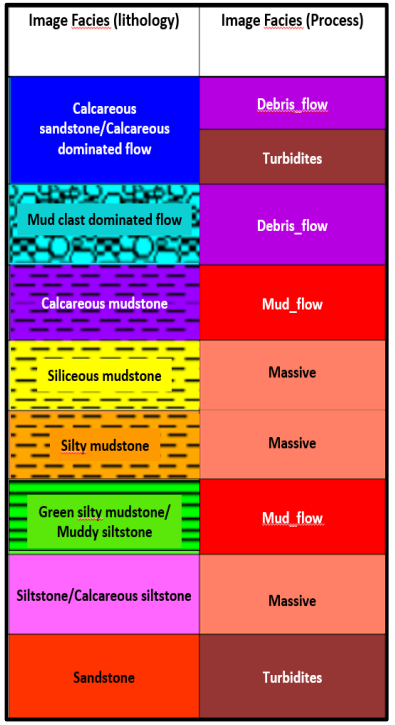
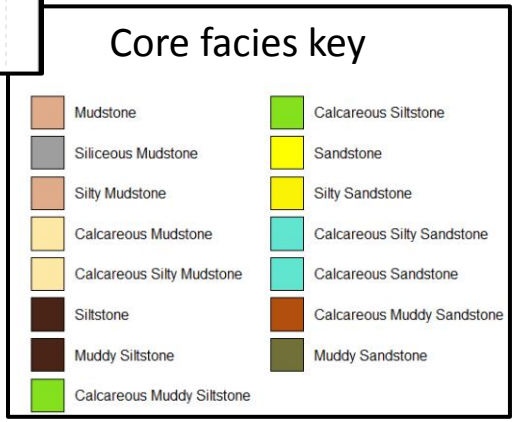


Image facies key

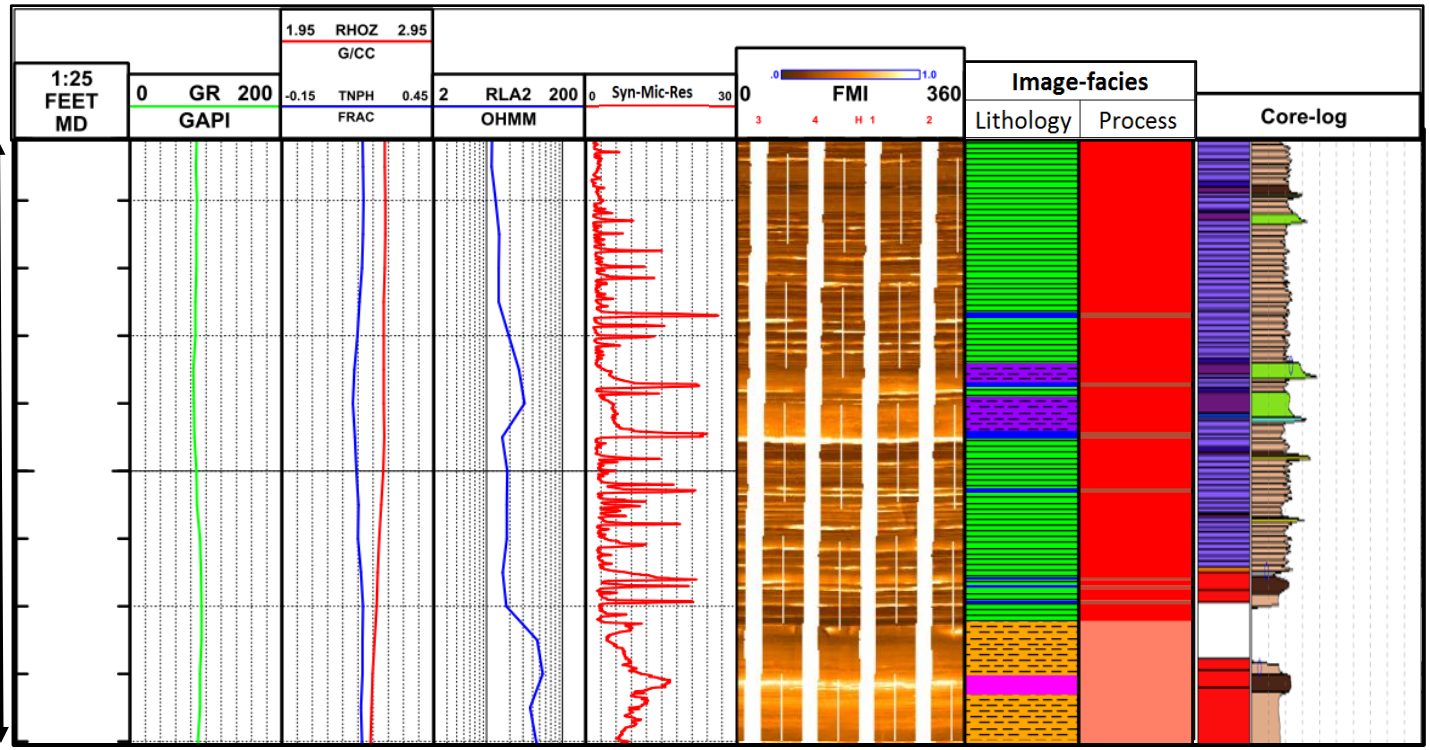


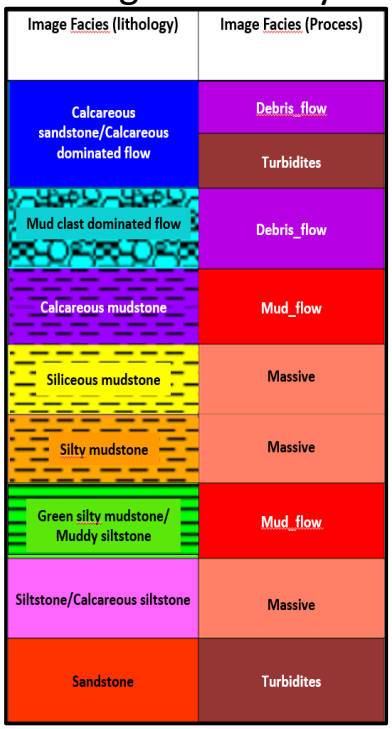
Core facies key

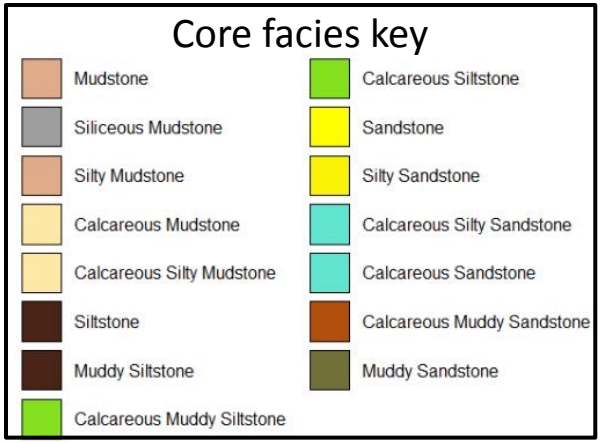


- Both micro-resistivity cut-off values and image log features are considered to distinguish between different debris flow type.

Atlas: Green Mudstone/Green Silty Mudstone Mudflow







- Micro-resistivity curve and image features characterize fine mudstone lamination.

Predicting Facies over Intervals Without Core

- Image log facies are calibrated with detail sedimentary facies from core.
- The image log facies model is used to predict sedimentary facies over intervals without cores.

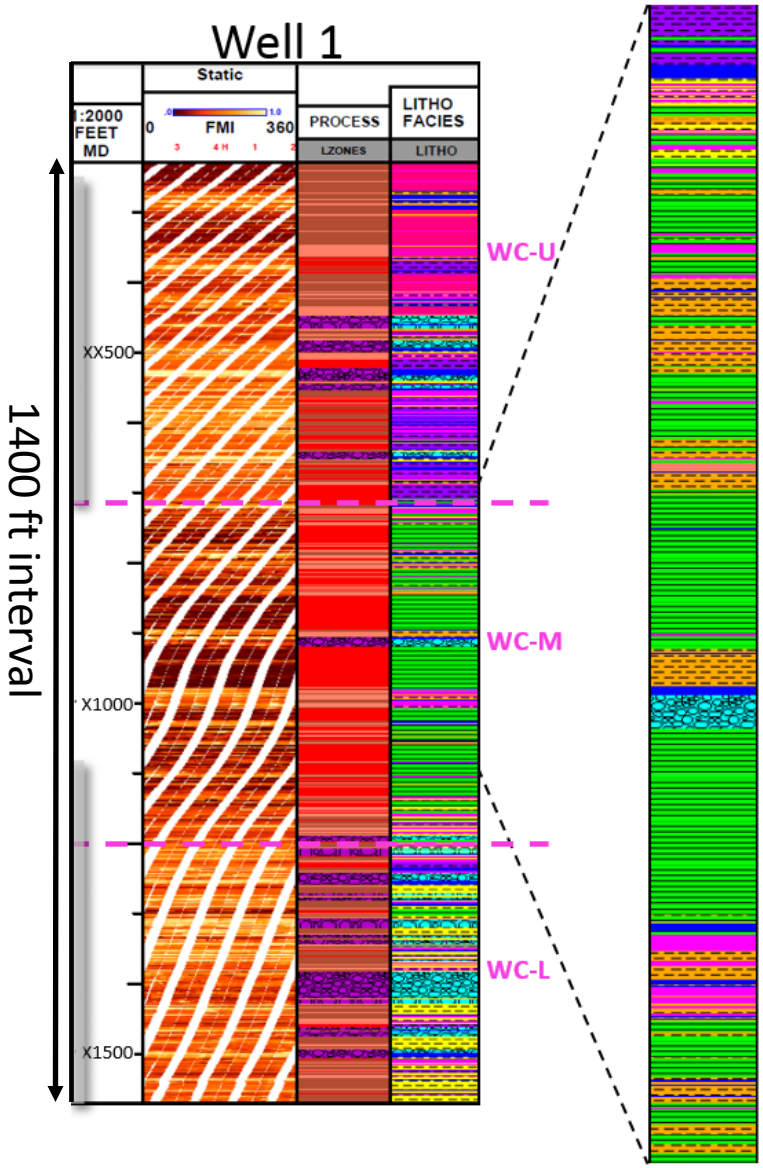
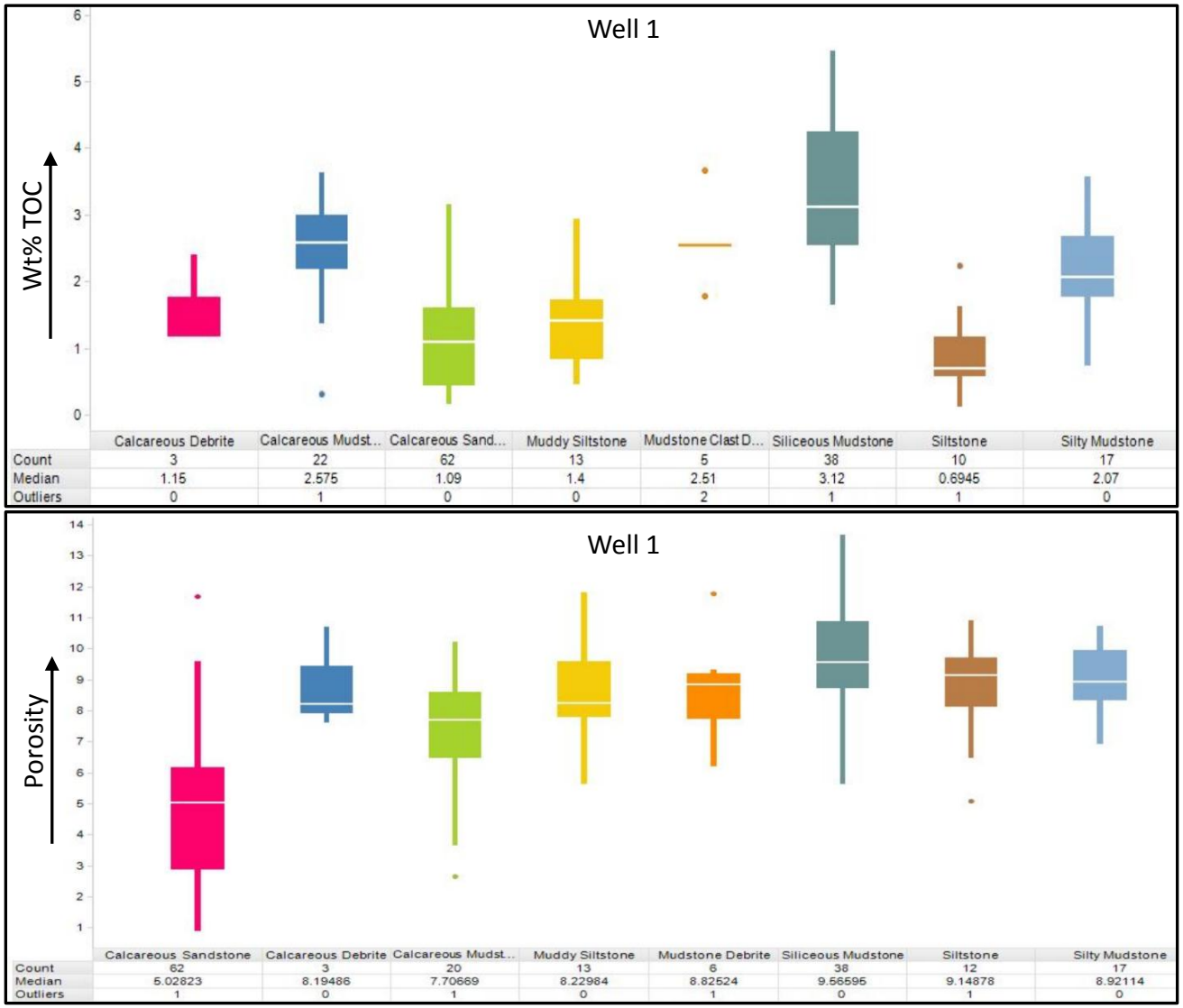


Image facies key

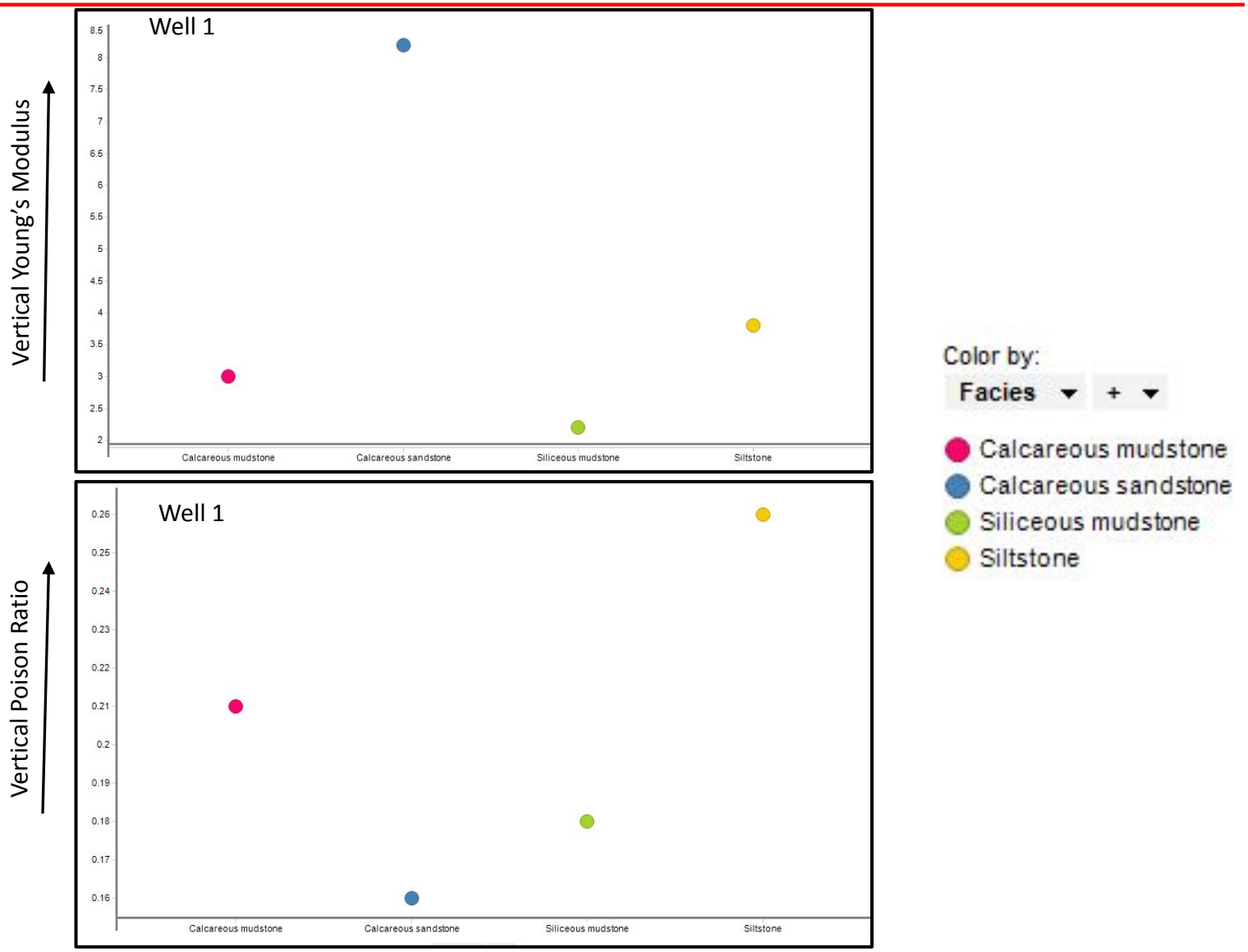
Image Facies (lithology)	Image Facies (Process)
Calcareous sandstone/Calcareous dominated flow	Debris_flow
	Turbidites
Mud clast dominated flow	Debris_flow
Calcareous mudstone	Mud_flow
Siliceous mudstone	Massive
Silty mudstone	Massive
Green silty mudstone/ Muddy siltstone	Mud_flow
Siltstone/Calcareous siltstone	Massive
Sandstone	Turbidites

Correlation of IMF with Reservoir Character



- Image log facies display variation of TOC and mechanical properties

Correlation of IMF with Rock-mechanics Data



- Image log facies display variation of mechanical properties.

Limitations

- Button data (in WBM) needs to be calibrated for each well and vendor.
- Electrical Button data can be severely affected by fluid properties, need to be calibrated with conventional logs.
- Very fine scale heterogeneity is beyond image log resolution.

Conclusion and Path Forward

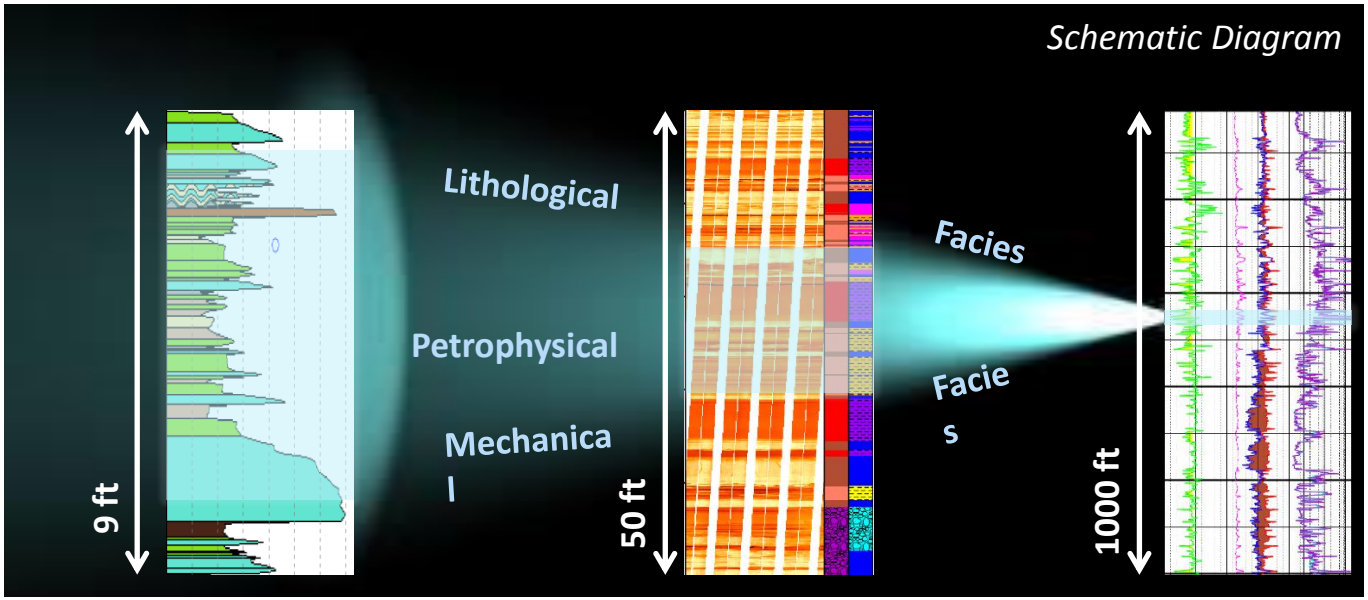


Image Log Facies,

- Bridge between core-facies and petrophysical-facies to support rock-typing
- Increase confidence in regional depositional model
- Can correlate with reservoir quality to identify ‘sweet spot’
- Can correlate with rock-mechanics data to identify mechanical stratigraphy

Acknowledgement

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