PS Semi-Automatic Sedimentary Analysis from New High Resolution Oil-based Mud Borehole Resistivity Image*

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Abstract

Detailed sedimentology interpretation is often conducted from core or borehole image data manually. Different interpreters may produce significantly different descriptions and interpretations for the same borehole image. To improve at the same time the efficiency and the consistency of the sedimentary structure interpretation, a new semi-automatic sedimentary structure analysis from borehole image dips is proposed in this paper. First, the sedimentary structure boundaries dip and internal laminations are picked from borehole image and classified and processed to remove the structural dip component. Then, they are processed to remove their structural dip component. The dip trend of each sedimentary structure is automatically compared with different pre-defined geometrical types. These pre-defined geometrical types are editable to better match the characteristics of the depositional environment. Finally, an interpretation of the sedimentary structures is automatically proposed. We present a case based on a new oil-based imager acquisition, logged in the Devonian sand of Catoosa, Oklahoma. This image tool provides a high resolution of sedimentary features with its nominal resolution of 0.2 in from 192 buttons and 98% borehole coverage in an eight-inch hole. The resulting discrete sedimentary structure interpretation log allowed to distinguish five micro-facies that we validated by the comparison with standard water based borehole image data and outcrop descriptions.

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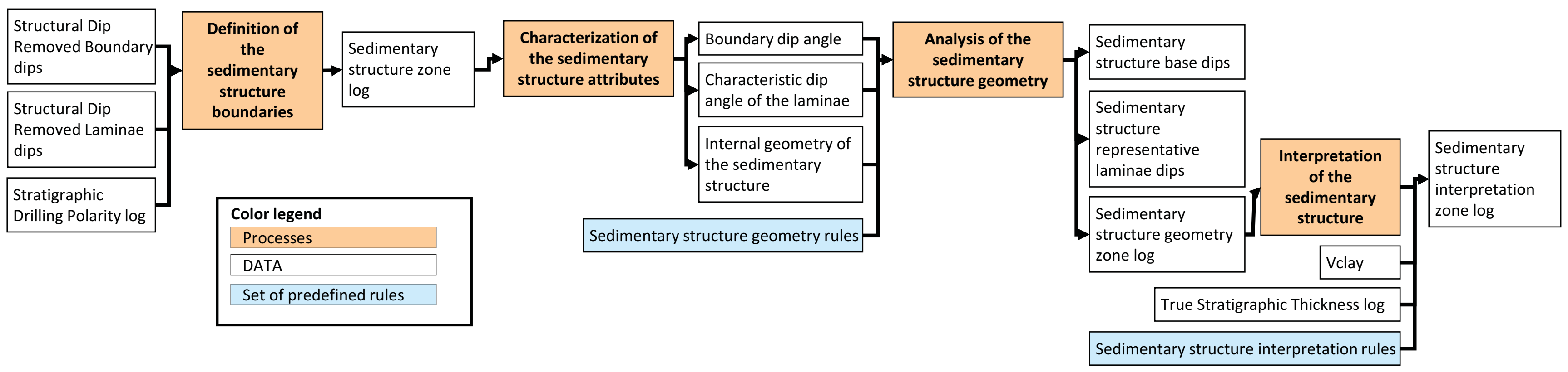
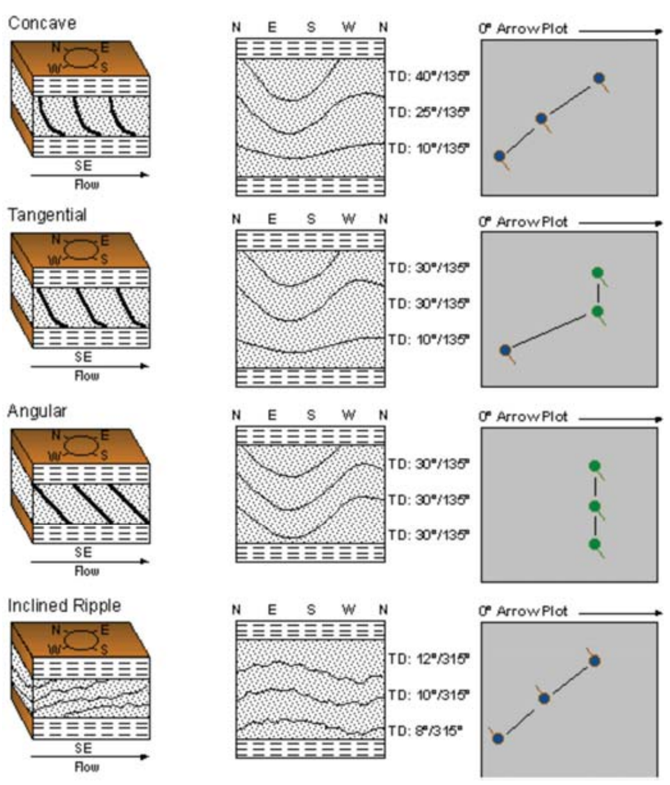
Semi-automatic sedimentary analysis workflow

First, the sedimentary structure boundaries dip and internal laminations are picked from borehole image and classified. Then, they are processed to remove their structural dip component. Secondly the dip trend of each sedimentary structure is automatically compared with different pre-defined geometrical types. These pre-defined geometrical types are editable to better match the characteristics of the depositional environment. Finally, an interpretation of the sedimentary structures is automatically proposed.



Semi-automatic sedimentary analysis workflow chart



Standard dip patterns

There are more than 20 sedimentary structure geometry and more than 30 sedimentary structure type was predefined based on experts' experience and calibrated with core.

	Sedimentary structure geometry	Boundary dip angle	Characteristic laminae dip angle	Internal geometry
01	Horizontal laminae	Horizontal	Horizontal	Constant parallel
02	Horizontal laminae fill (high angle base)	High angle	Horizontal	Constant oblique
03	Horizontal laminae fill (low angle base)	Low angle	Horizontal	Constant oblique
04	Xbed Planar	All	High angle	Constant oblique
05	Xbed Planar (low angle)	All	Low angle	Constant oblique
06	Xbed Tangential	Horizontal	High angle	Increasing tangential
07	Xbed Tangential	Horizontal	High angle	Increasing oblique
08	Xbed Tangential	Horizontal	Low angle	Increasing tangential
	Xbed Tangential			

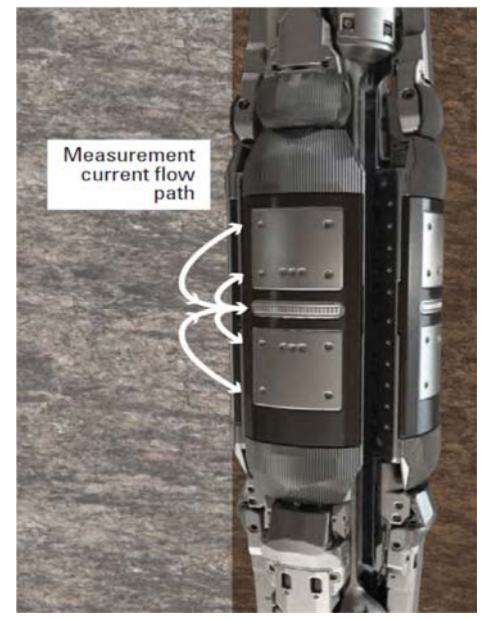
Predefined sedimentary geometrical types

	Sedimentary structure interpretation	Sedimentary structure geometry	Average VClay	TST of sedimentary structure
05	Gutter fill	Horizontal laminae fill (low angle base)	Low clay content	small
06	Channel fill	Horizontal laminae fill (low angle base)	Low clay content	medium
07	Large channel fill	Horizontal laminae fill (low angle base)	Low clay content	large
08	Trough cross bed	Xbed Trough	Low clay content	medium
09	Cross bed	Xbed Tangential	Low clay content	medium
10	Cross bed	Xbed Sigmoid	Low clay content	medium
11	Overturned cross bed	Overturned laminae	Low clay content	medium
12	Large sand wave	Xbed Trough	Low clay content	large

Sedimentary structure interpretation

New photorealistic microelectrical imager for oil-based mud (OBM)

This imaging tool provides excellent resolution of sedimentary features with its nominal resolution of 0.24 in from 192 buttons and 98% borehole coverage in an 8 in hole.

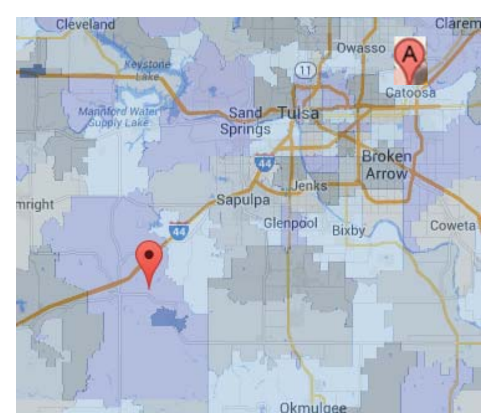


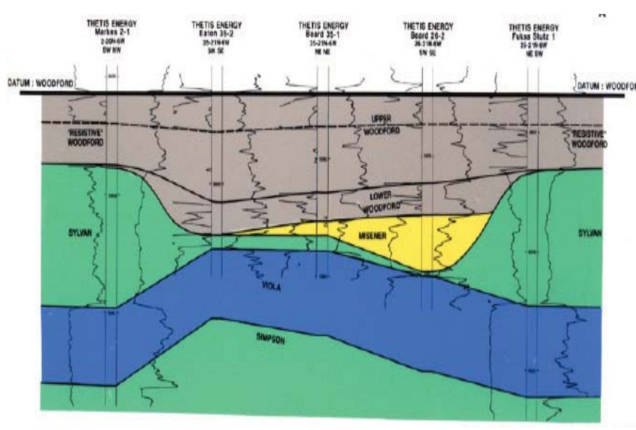
Electrical current return

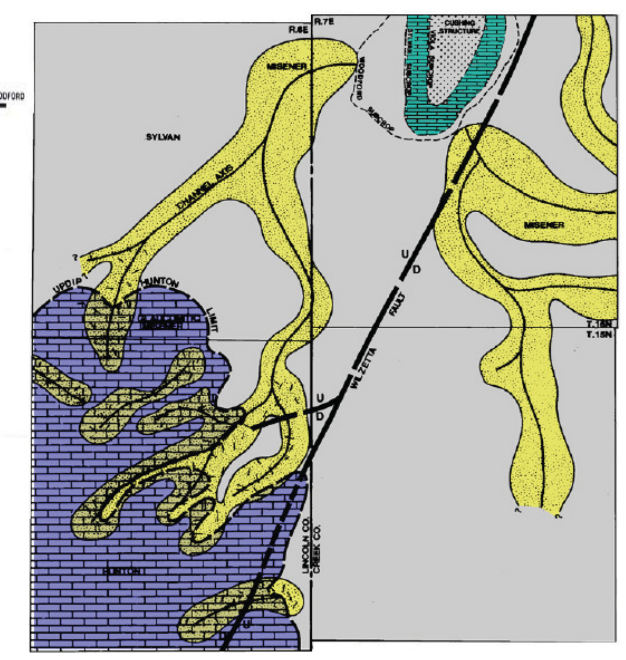
There are 4 upper pads and 4 lower pads with around only 1.0 meter vertical separation. The symmetric current return reduces artifacts to provide a more natural, photorealistic image

Capabilities	
Measuring Sensors	192 micro-electrodes
Vertical Resolution	0.24 in.
Horizontal Resolution	0.13 in.
Depth of investigation	0.2 in.
Formation Resistivity Range	0.2 - 20,000 Ωm
Circumferential Coverage	98% in 8-in. hole
Max Logging Speed	3600 ft/h (0.2-in. sampling) 1800 ft/h (0.1-in. sampling)
Drilling Fluid	Non-conductive mud (e.g. oil-base mud)
Hole Size	7.5 – 17 in.
Temperature	350 degF (177 degC)
Pressure	30,000 psi
Logging Direction	Log down and Log up

Sedimentary analysis case study from Catoosa, Oklahoma



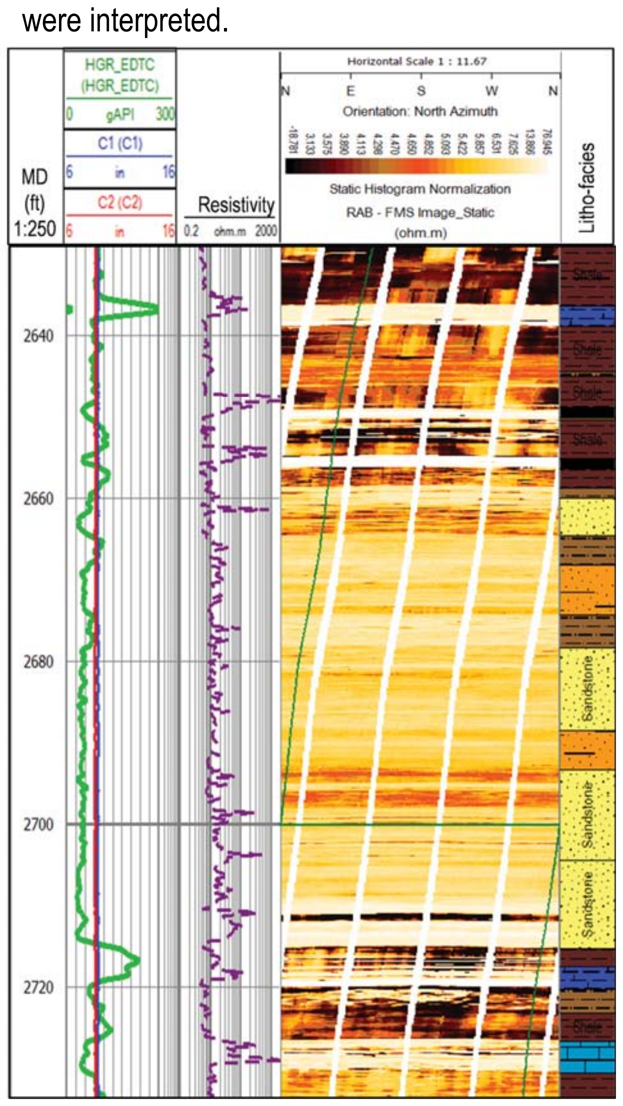




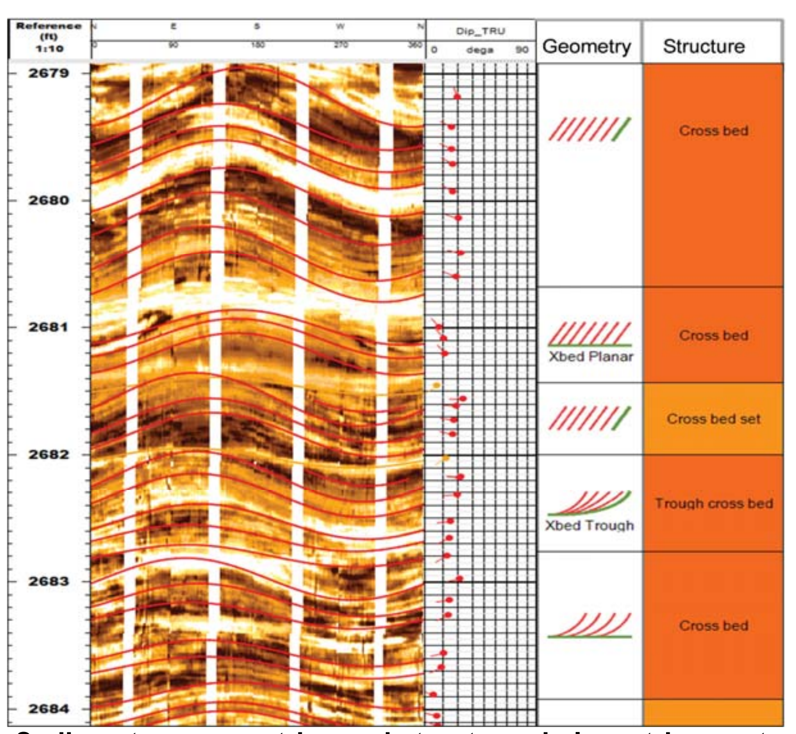
The Devonian Misener Sandstone represents incised valley-fill deposits. The early sand source was probably the quartzose Simpson subcrops at the northeast, later replaced by marine currents bringing sand from the east. (M. Kuykendall and R. Fritz 2001).

Single well sedimentary analysis from oil-based image

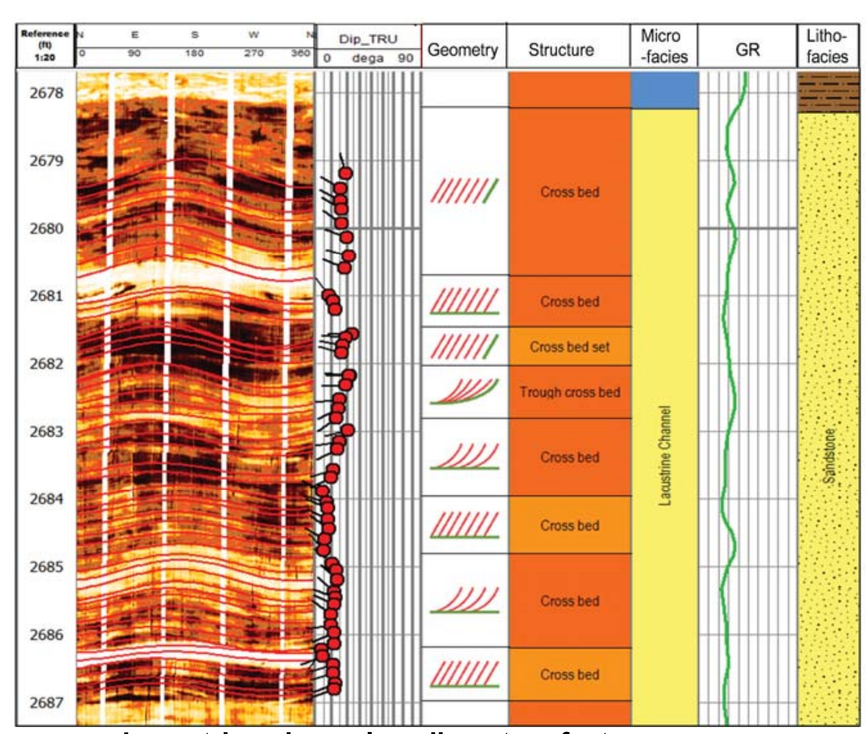
One well was drilled at Catoosa, Oklahoma USA with oil-water ratio of 78/22 with a deviation up to 30 deg. 7 lithofacies were classified with GR, derived resistivity curve, texture features from image. 6 sedimentary geometries and 5 structures were automatically computed. Finally 6 depositional environments were interpreted.



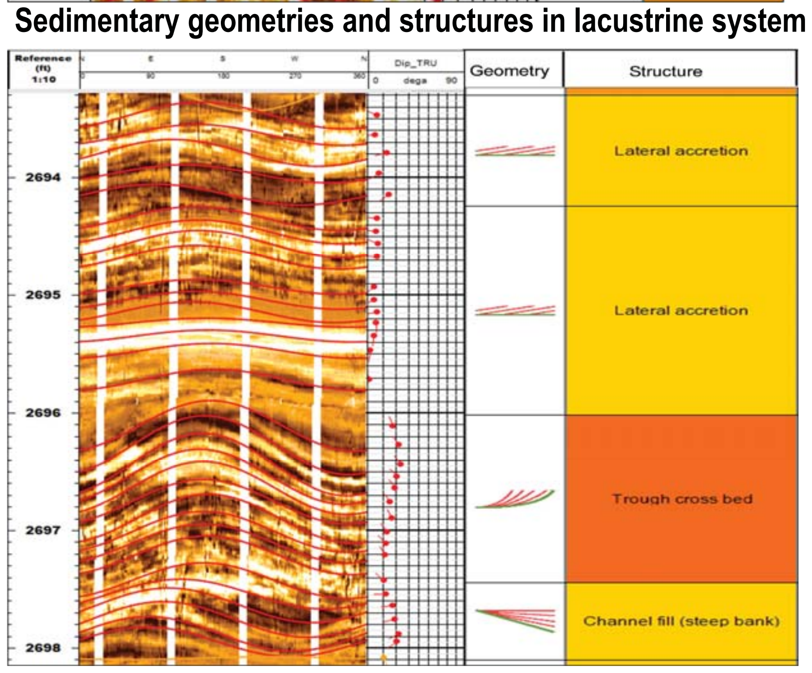
Single well litho-facies classification



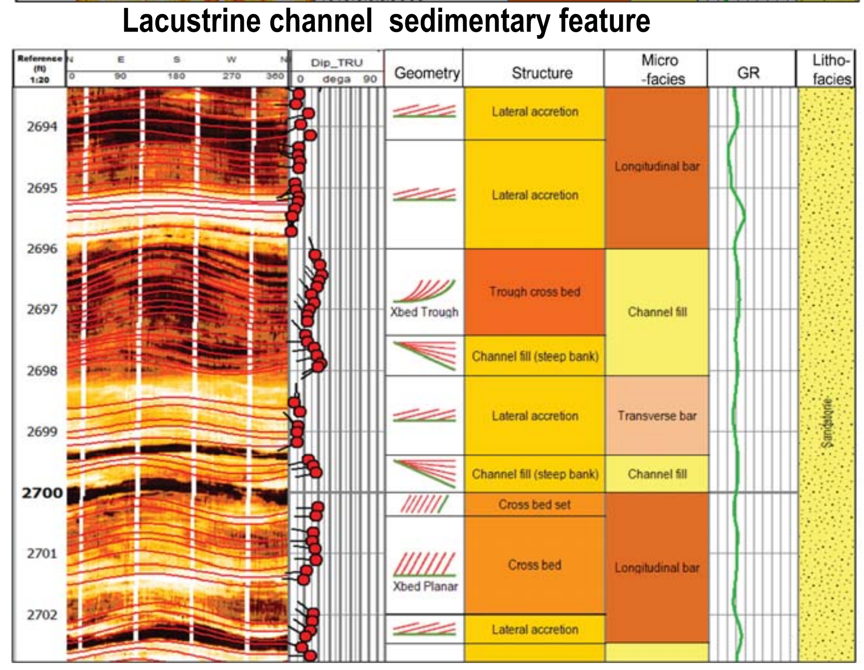
Sedimentary geometries and structures in lacustrine system



Lacustrine channel sedimentary feature

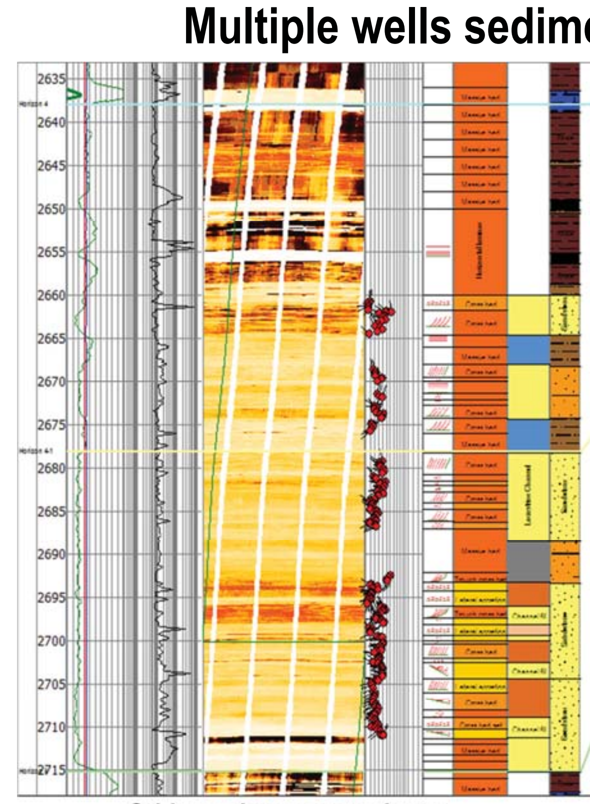


Sedimentary geometries and structures in fluvial system

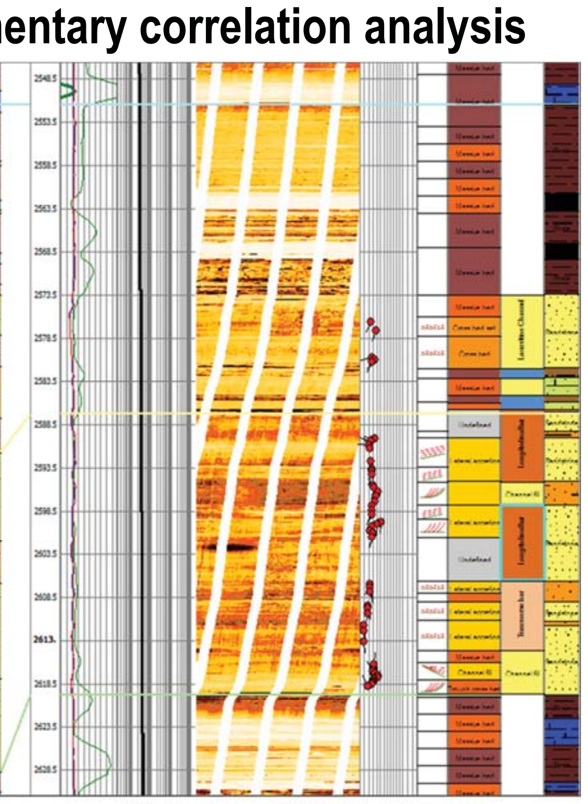


Multiple cycle channel depositions in braided river system

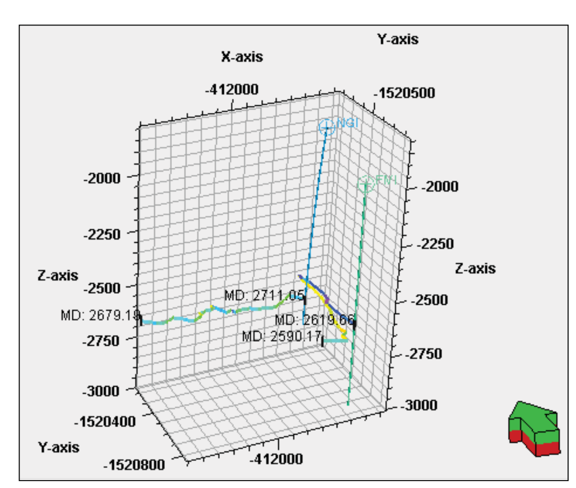
Multiple wells sedimentary correlation analysis



Oil based image analysis



Water-based image analysis



3D paleocurrent direction analysis from two wells image data

Based on two wells correlation analysis, the lithology is matching perfectly and depositional environment is consistent including channel filling, longitudinal bar, transverse bar, abandoned channel and lacustrine channel and offshore.

The depositional environment interpretation is confirmed with outcrop report from bottom channel valley filling to top marine and lacustrine system.

The sand source was coming from northeast and east, which is consistent with outcrops.