Geostatistical 3D Reservoir Modeling of Mississippian St. Louis Carbonate Reservoir Systems, Kansas

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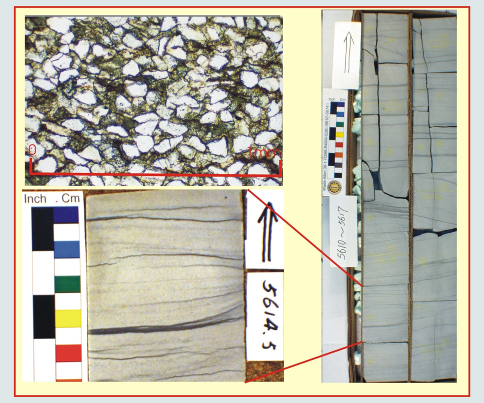
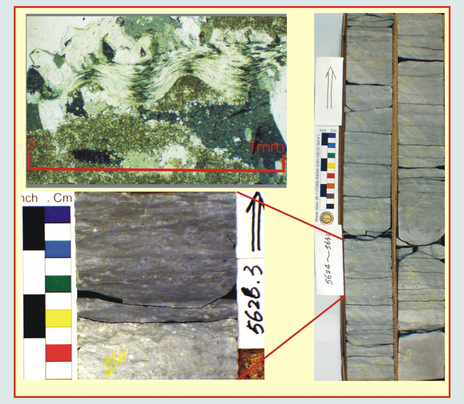
Lithofacies



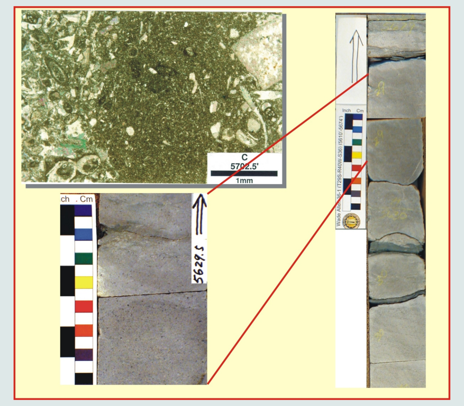
Lithofacies 1
Cross-bedded Quartz-rich Carbonate Grainstone

Mixed siliciclastic and carbonate grainstone contains very fine quartz (up to 40 ~ 50%) and medium grained peloids, skeletal fragments, ooids. Inverse translatent stratification and stylolites are common. Angles of cross bedding most commonly are in the 10 to 20 degree range. Permeability is less than 1md, most <0.01md. Non-reservoir facies.



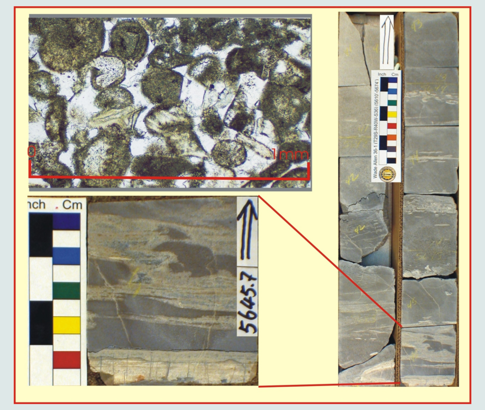
Lithofacies 2
Argillaceous Limestone

Thin, laterally extensive condensed section, characterized by thin bedded, often fissile olive green to gray argillaceous limestone. Primarily wackestone /packstone with abundant bryozoans and crinoids and minor brachiopods and ostracods. On electric logs, displays a distinctively higher gamma-ray response. Non-reservoir facies.



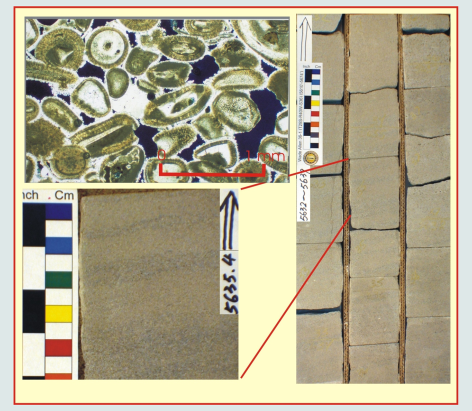
Lithofacies 3
Skeletal Wackestone

Very poorly sorted, greenish to dark yellowish-brown wackestone with large, relatively un-abraded skeletal fragments. Crinoids and fenestrate bryozoans are the most abundant skeletal fragments, with echinoderms, brachiopods, gastropods and foraminifera also present. Porosity averages less than one percent, with permeability of 0.01 md. Non-reservoir facies.



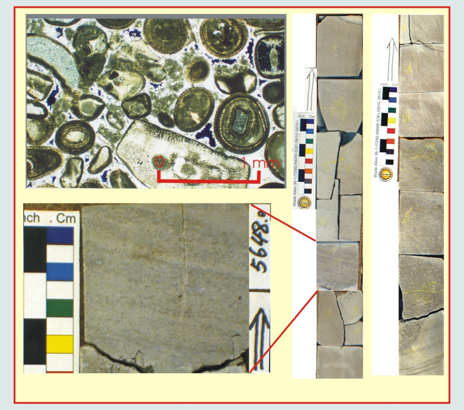
Lithofacies 4
Peloidal Grainstone/
Fenestral Limestone

Very fine peloidal grainstone with some very fine quartz, and fine ooid grains. The fenestral limestone is characterized by "bird's-eye" or fenestral fabric (indicator of intertidal to supratidal deposition). Typically occurs adjacent to the ooid-skeletal grainstone facies. Non-reservoir facies.



Lithofaices 5
Ooid Skeletal Grainstone

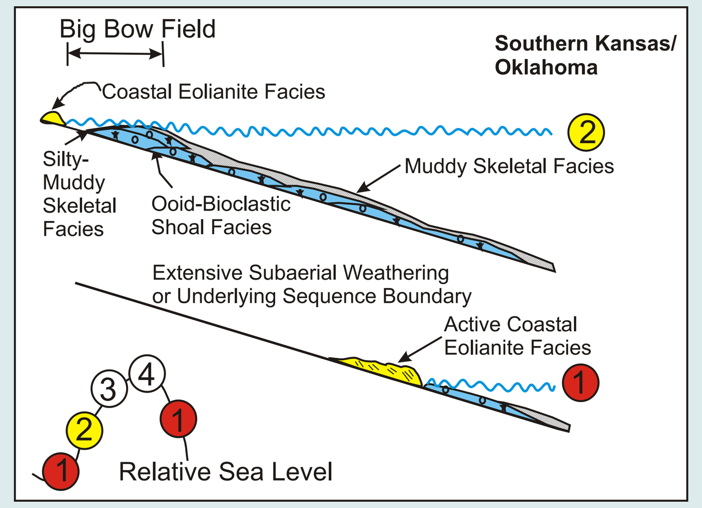
Reservoir facies characterized by medium to very coarse size moderately sorted ooids. The ooids have a radial concentric structure and are usually unbroken. Large skeletal grains, and peloids present. Main porosity is interparticle with minor moldic porosity. Total porosity ranges from 3 percent to 20 percent. Distinctive log response with higher porosity and lower resistivity. Accumulates in a high-energy, open-marine environment.

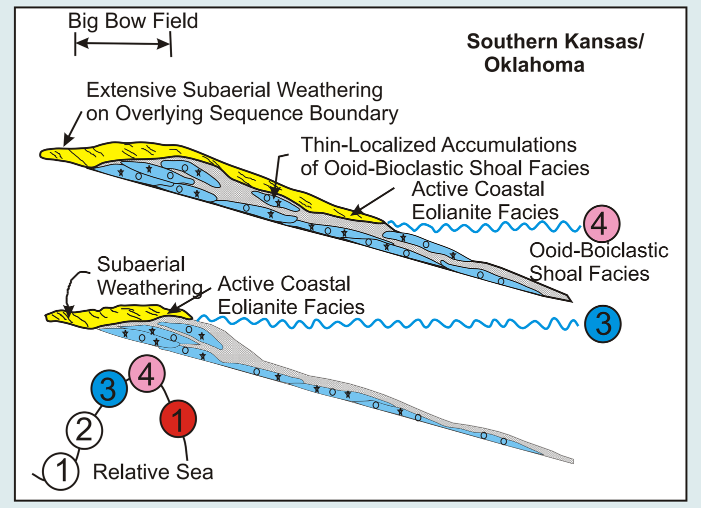


Lithofaices 6
Cemented Ooid
Skeletal Grainstone

Composed of medium to very coarse size and moderately sorted ooids. The ooids have a radial concentric structure and are usually unbroken. Large skeletal grains, especialy crinoids, and peloids are present. Heavy syntaxial cementation occludes interparticle voids. Porosity and permeability are very poor. Non-reservoir facies.

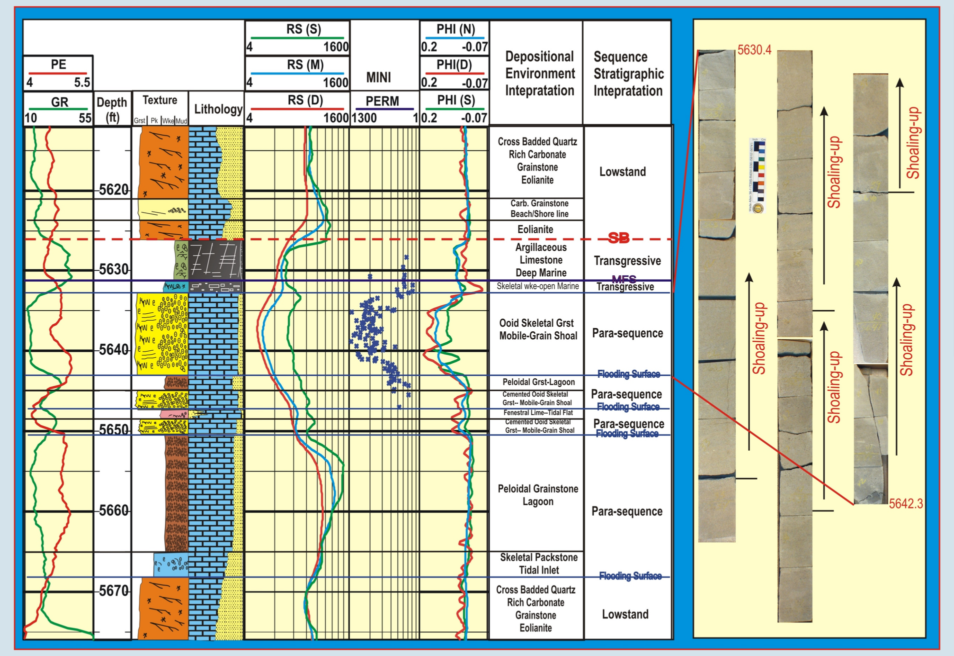
Stratigraphy Model



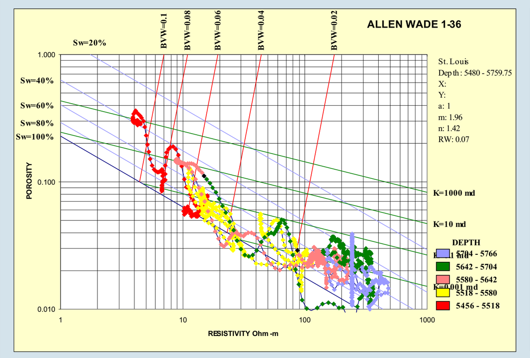


Carr & Lundgren, 1999

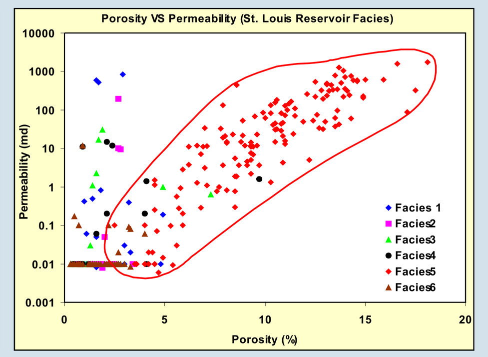
Cored Well Wade Allen 1-36 (St. Louis)



Pickett plot of Wade Allen 1-36

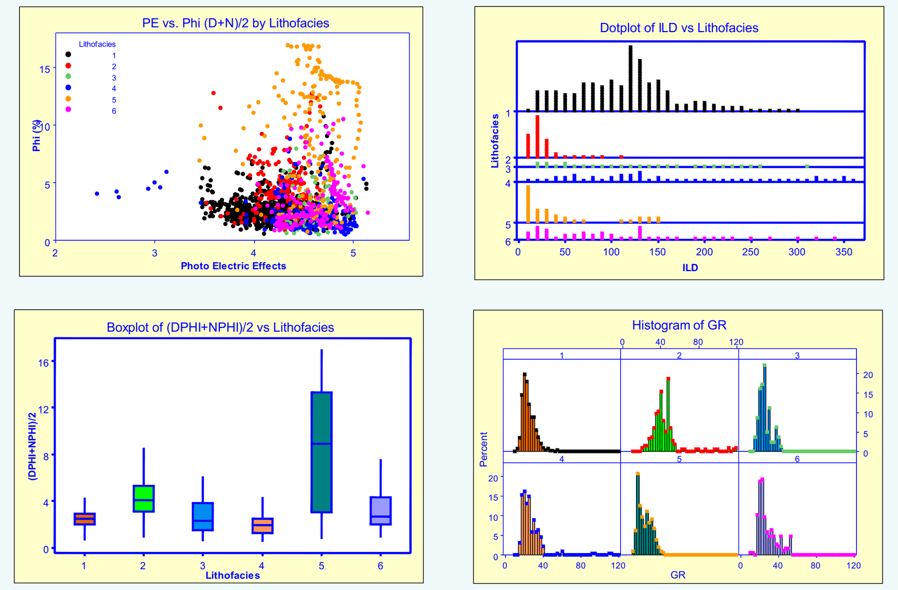


Correlation of porosity & permeability



The pay zone, oolitic shoal interval, has a log response with the lowest RT value and highest porosity on log. Based on available data, porosity shows an exponential relationship with permeability. Porosity distribution ranges from 2 to 15 percent. However, the distribution of permeability displays high heterogeneity, from less than 0.01md to more than 1,000md.

Neural Network and Lithofacies Prediction

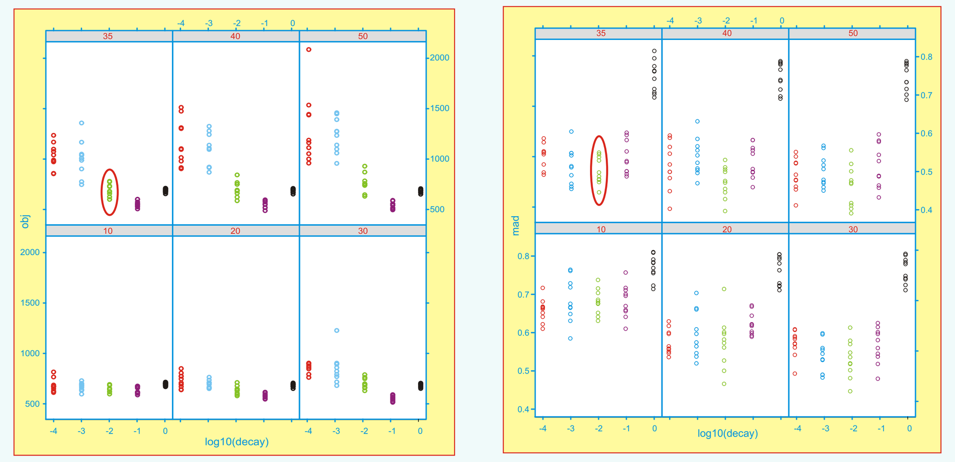


Determined predictor variables (GR, ILD, ILM, PE, NPhi, DPhi) and lithofacies categories were used to build Neural Network models. The size of network and damping parameters were optimized using cross-validation and repeat testing with whole training data and randomly chosen partial data sets.

Predicted Lithofacies Scorecard (Counts) for 10 key trained wells with PE Curve

Actural Facies	Predicted Facies 1	2	3	4	5	6	Grand Total	Absolute Accuracy	Counts within 1	Accuracy Within 1 facies
1	1074	14	4	11	4	6	1113	96.50%	1089	97.84%
2	15	199				1	215	92.56%	214	99.53%
3	11	4	57	1	5	3	81	70.37%	62	76.54%
4	26	1	1	172	5	16	221	77.83%	178	80.54%
5	9	2	2	1	188	5	207	90.82%	194	93.72%
6	17		1	9	7	152	186	81.72%	168	90.32%
Grand Total	1152	220	65	194	209	183	2023			
Propotion Percent	103.50%	102.33%	80.25%	87.78%	100.97%	98.39%		Absolute Accuracy	Within 1 facies	#Pred/#Actural F5,
Difference	39	5	16	113	12	24	209	91.05%	94.17%	99.75%

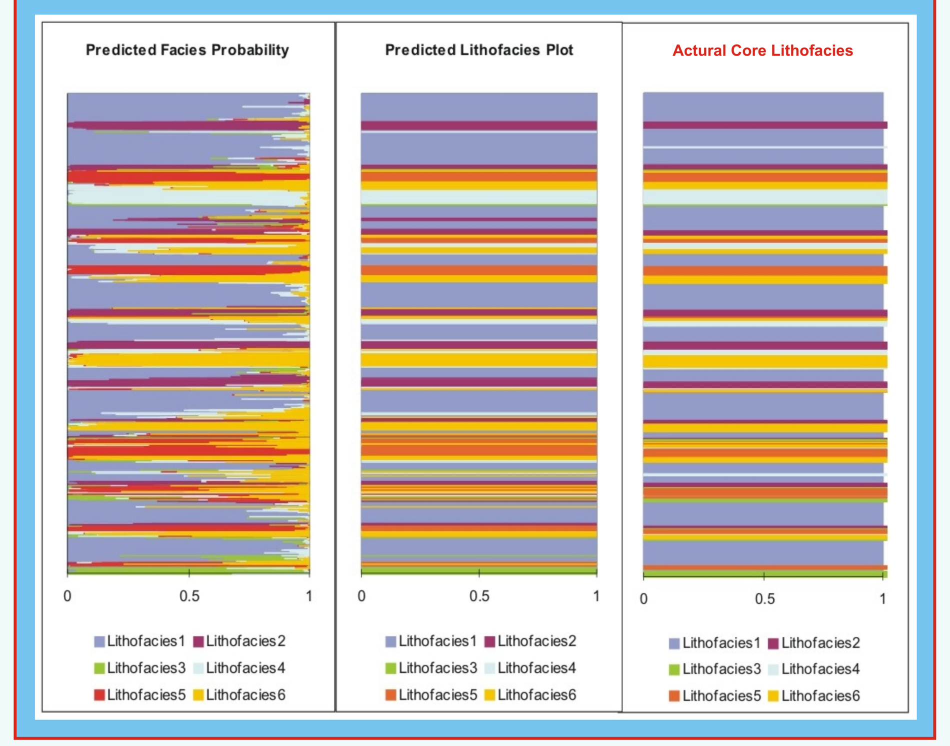
The results of model with network size (number of hidden layers) 35 and damping parameter 0.05 for 10 key wells with PE log. The absolute accuracy for this model is 91%. For a few wells without PE curve, the results decreased but an absolute accuracy of approximately 85% is still attained.



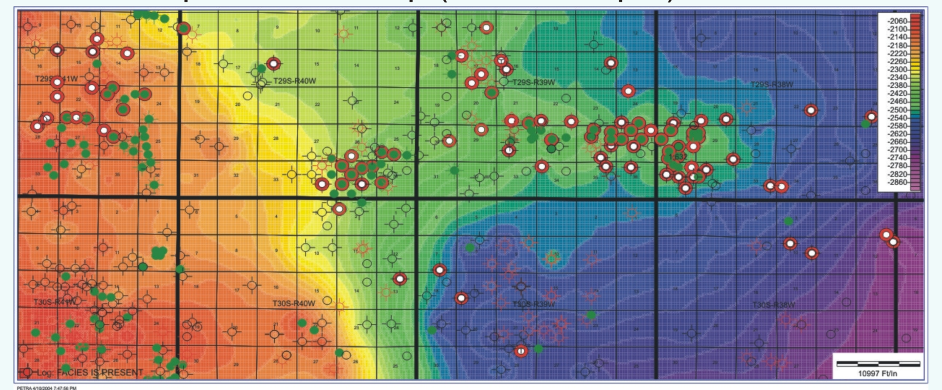
Cross validation performed on different network size and damping parameters with objective function and mad parameter, which is mean absolute difference between the predicted and actual facies number. Neural network model (size=35, damping =0.05) was selected for facies prediction.

Predicted Lithofacies Results for 10 Key Cored Wells

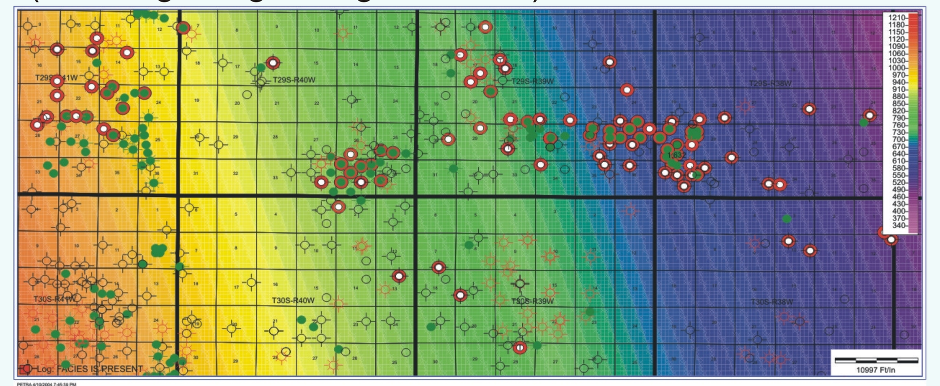
Model With PE Curves



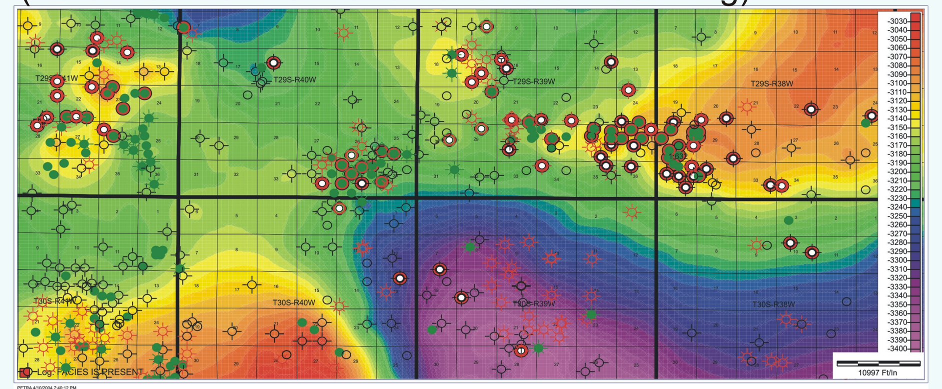
St Louis top structure map (Subsea depth)



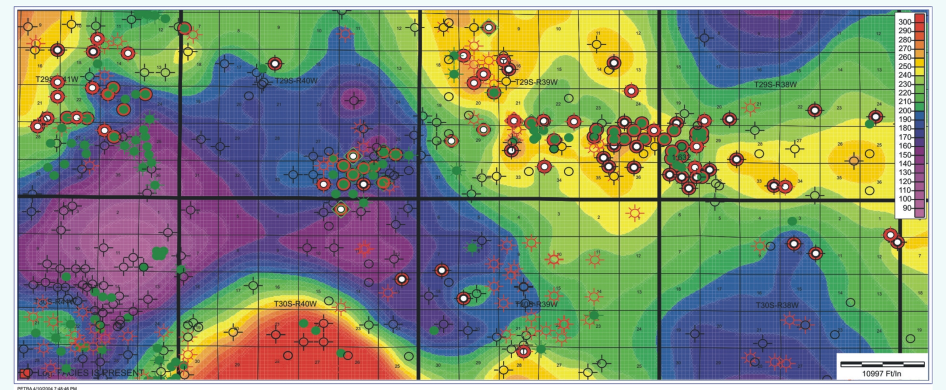
Fort Riley (Permian) structural map
(Showing tilting during Laramide)



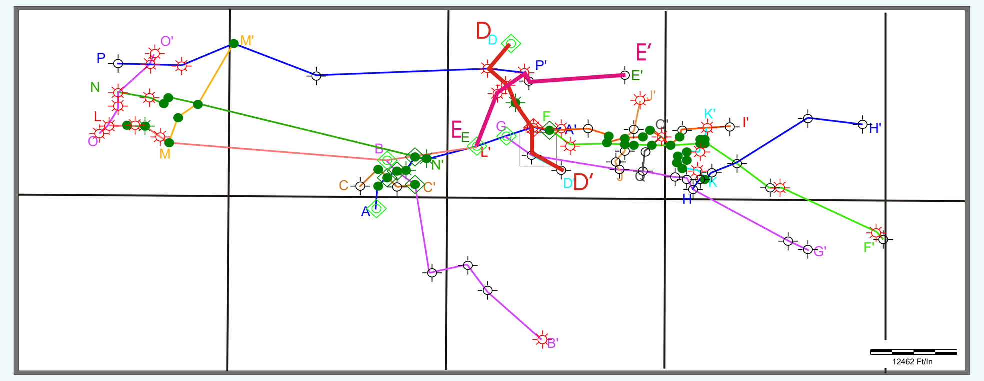
Interpreted St Louis paleo-structural map
(Datum on Permian to remove Laramide tilting)



St Louis Limestone total isopach map

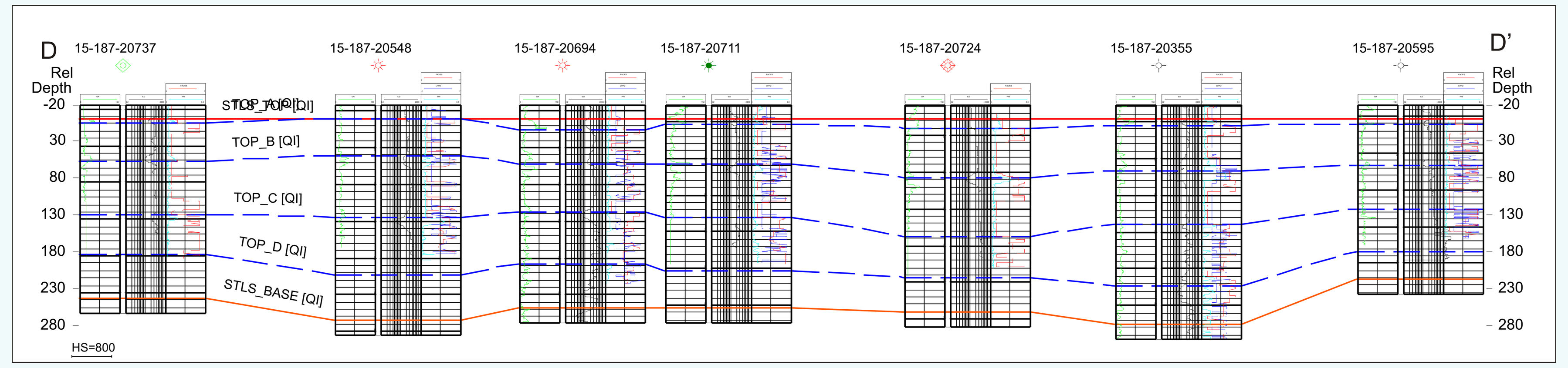


Cross section lines in study area

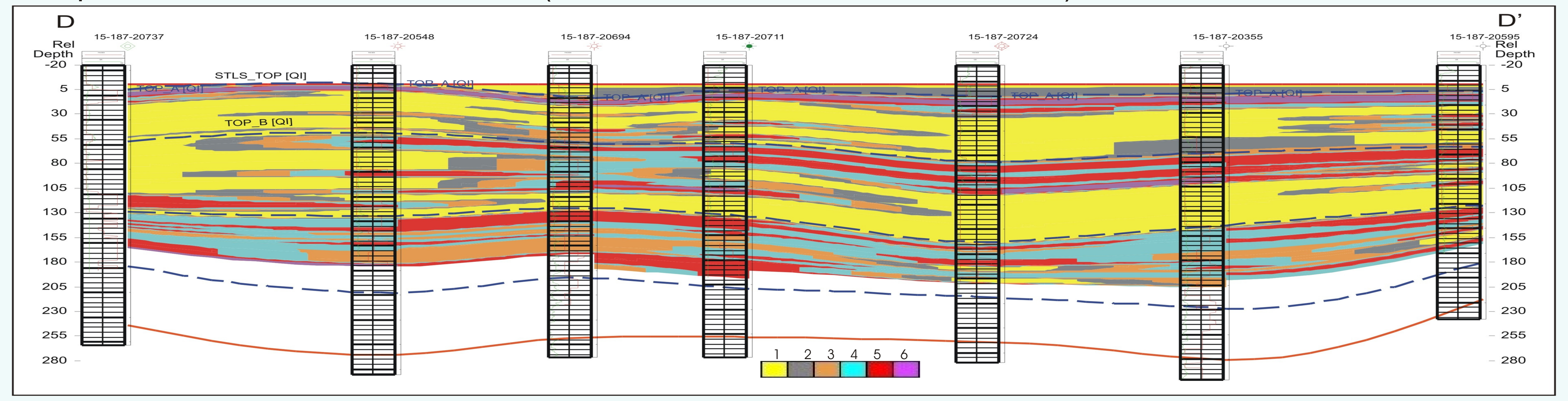


Sample Cross-Sections

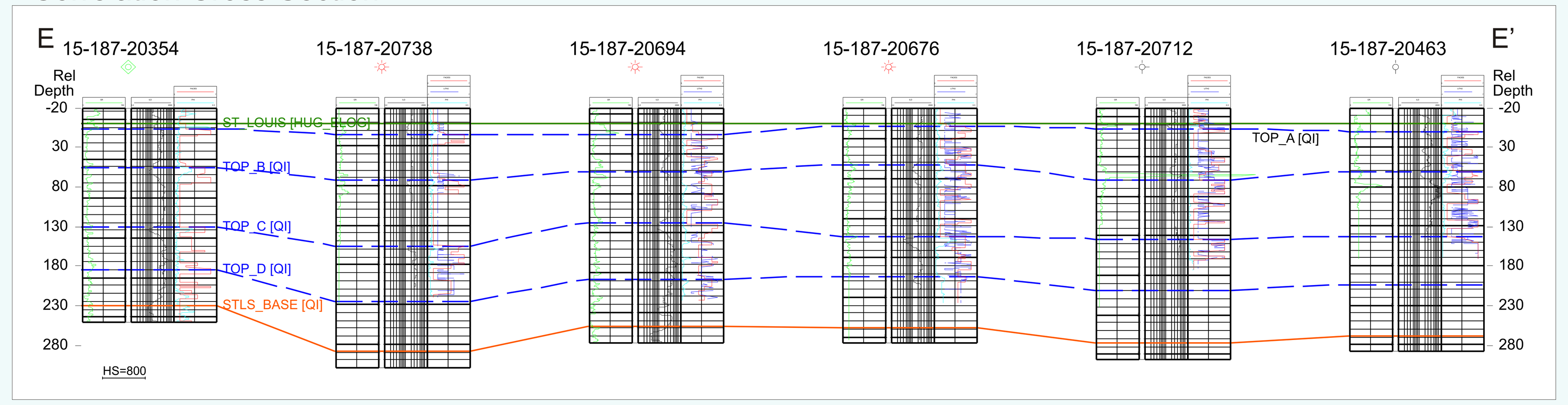
Correlation Cross Section



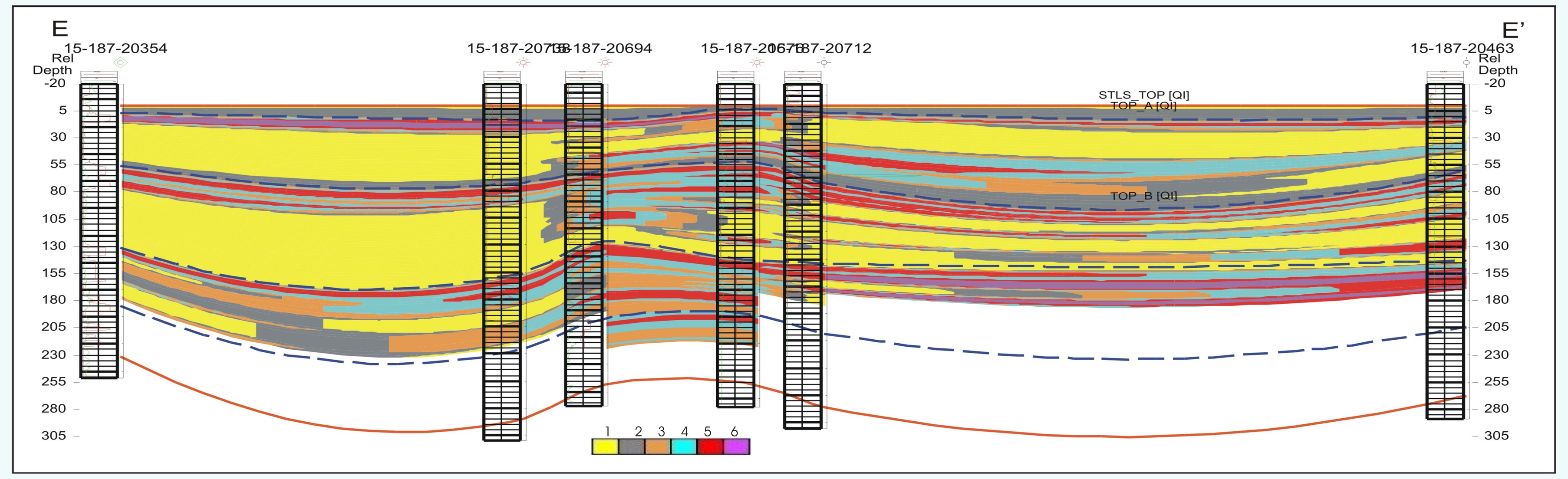
Interpolated Lithofacies Cross Section (Predicted from Neural Network Model)



Correlation Cross Section



Interpolated Lithofacies Cross Section (Predicted from Neural Network Model)



Lithofacies predicted from Neural Network model were input into PETRA to evaluate correlations and geological significance. St Louis A, B, C and D surfaces were picked as parasequence surfaces. The interpolated lithofacies profiles illustrate the St Louis Limestone geometries and depositional patterns. The oolite shoals were deposited on the structural highs during the transgressive and high-stand periods. Oolite shoal deposits have an ellipsoid elongated geometry, and display aggradational and progradational accumulation patterns.