PS Rock Type Analysis of 1000 Wells Using Computational Classification Techniques. A Case Example in the Lower Cretaceous Centenario Formation, Neuquén Basin, Argentina*

M. Arcuri[1,2], C. Zavala[1,2], J. Iparraguirre[1,3], E. Buciak[4], J.M. Herrera[4], L. Venara[4], M. Di Meglio[2], and A. Zorzano[2]

Search and Discovery Article #10926 (2017)**
Posted March 27, 2017

*Adapted from poster presentation given at AAPG/SEG International Conference and Exhibition, Barcelona, Spain, April 3-6, 2016
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[1]Universidad Nacional del Sur, Buenos Aires, Argentina
[2]GCS Argentina, Buenos Aires, Argentina (marcuri@gcsargentina.com)
[3]UTN BHI, Buenos Aires, Argentina
[4]Pluspetrol S.A., Buenos Aires, Argentina

Abstract

The Lower Cretaceous Centenario Formation is a conventional shallow clastic reservoir developed close to the northeastern border of the Neuquén Basin, Argentina. This unit has only been recognized in the subsurface, and is composed of thick-bedded sandstones and conglomerates interbedded with shales. Its depositional model has not been deeply studied, and has been interpreted as fluvial, deltaic and shelfal deposits. Recently, a revision of the sedimentology of this unit was conducted throughout the study of 200.11 meters of cores corresponding to eight wells in the Rialto, Colorado Area. The deposits are dominated by m-thick massive sandstone beds with minor cross-bedded intervals and shales, which have been interpreted as shallow shelf sediments accumulated as channel-fills and lobes by hyperpycnal flows. Facies analysis allowed the recognition of twelve sedimentary facies suggesting traction and fallout processes from turbulent suspensions with limited bedload, and fallout deposits in an offshore marine/prodelta setting. Sedimentary facies were physically characterized by a number of conventional analyses and calibrated with logs, aimed to determine the main correlation between sedimentary facies and electrical well logs. In this case, GR (Gamma Ray) and SP (Spontaneous Potential) logs were selected as the best describing metrics. Using the selected registers, an electrofacies classification was independently performed taking into account SP and GR cut-off values in the eight studied wells. Four electrofacies were recognized from the aforementioned classification. The population of these electrofacies with facies and facies associations allowed the definition of four rock types. Based on the calibrated rock properties and cut-off values of rock types, an automated computational classification was applied to a larger available well database composed of more than 1000 wells, using in-house developed software. The results not only show an accurate correspondence between manual and automated classification, but also allow the construction of detailed reservoir maps focused in the understanding of sandbodies and properties distribution along the entire area.

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1: Universidad Nacional del Sur; 2: GCS Argentina; 3: UTN BHI; 4: Pluspetrol S.A.

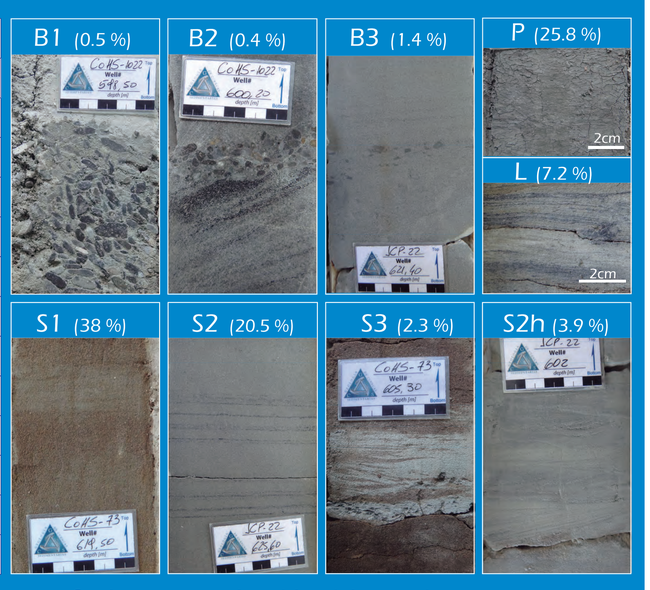
1. Introduction

The Lower Cretaceous Centenario Formation is a conventional shallow clastic reservoir developed close to the northeastern border of the Neuquén Basin, Argentina. This unit has only been recognized in the subsurface, and is composed of thick bedded sandstones and conglomerates interbedded with shales. Its depositional model has not been deeply studied, and has been interpreted as fluvial, deltaic and shelfal deposits. Recently, a revision of the sedimentology of this unit was conducted throughout the study of 200.11 meters of cores corresponding to eight wells in the Río Colorado Area. The deposits are dominated by m-thick massive sandstone beds with minor cross-bedded intervals and shales, which have been interpreted as shallow shelf sediments accumulated as channel-fills and lobes by hyperpycnal flows.

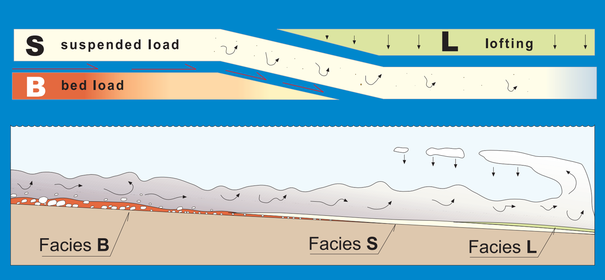
2. Sedimentary Facies Analysis

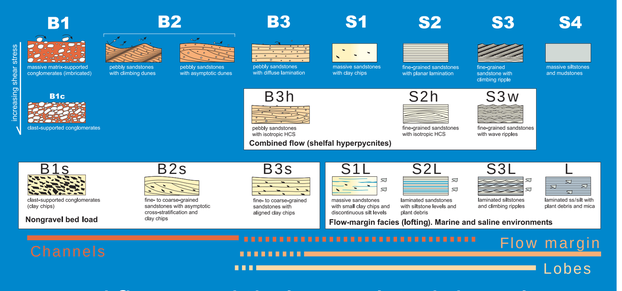
Facies analysis allowed the recognition of thirteen sedimentary facies suggesting traction plus fallout processes from turbulent suspensions with limited bedload, and fallout deposits in an offshore marine/prodelta setting. Sedimentary facies were physically characterized by a number of conventional analysis and calibrated with logs, aimed to determine the main correlation between sedimentary facies and electrical well logs. In this case, GR (Gamma Ray) and SP (Spontaneous Potential) logs were selected as the best describing metrics. Using the selected registers, an electrofacies classification was independently performed taking into account SP and GR cut-off values in the eight studied wells.

	Facies	Lithology	Sedimentary Structures	Origin
Bed Load	B1	Matrix-supported fine-grained conglomerates	Massive, clay chips	Bed load related to the overpassing of long-lived turbulent flows
	B2	Fine-grained conglomerates and conglomeratic sandstones. Clay chips	Low-angle cross-stratification	Bed load. Migration of asymptotic dunes
	B2s	Medium- to coarse-grained sandstones. Abundant clay chips	Low-angle cross-stratification	Bed load. Migration of asymptotic dunes
	B3	Fine-grained conglomerates and conglomeratic sandstones. Clay chips	Diffuse horizontal lamination, Aligned clasts	Bed load. Drag and rolling
	B3h	Fine-grained conglomerates and conglomeratic sandstones. Clay chips	Low-angle lamination (hummocky-like)	Bed load. Drag and rolling. Combined flow
Traction Plus Fallout	S1	Medium- to fine-grained sandstones	Massive, small clay chips, dish	Progressive aggradation from quasi-steady turbulent flows
	S1L	Medium- to fine-grained sandstones. Discontinuous silt levels	Massive, clay chips, dish, load structures, plastic clay chips	Progressive aggradation from quasi-steady turbulent flows (levee transition)
	S2	Medium- to fine-grained sandstones	Planar lamination	Progressive aggradation from quasi-steady turbulent flows
	S2h	Medium- to fine-grained sandstones	Low-angle lamination (hummocky-like)	Progressive aggradation from quasi-steady flows (combined flows)
	S2L	Fine-grained sandstones. Levels of silts and plant debris	Planar lamination	Progressive aggradation from quasi-steady turbulent flows (levee transition)
	S3	Fine-grained sandstones	Climbing ripples	Traction plus fallout in quasi-steady turbulent flows
Lofting	L	Fine-grained sandstones and siltstones, plant debris, and micas	Massive to laminated	Fallout from lofting plumes
	P	Fine-grained sandstones and mudstones	Massive to laminated. Highly bioturbated	Fallout (offshore/prodelta - shoreface)

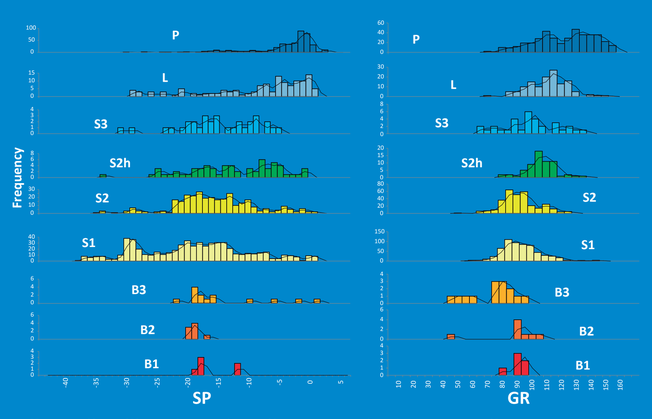


General characteristics and examples of sedimentary facies recognized in this work.

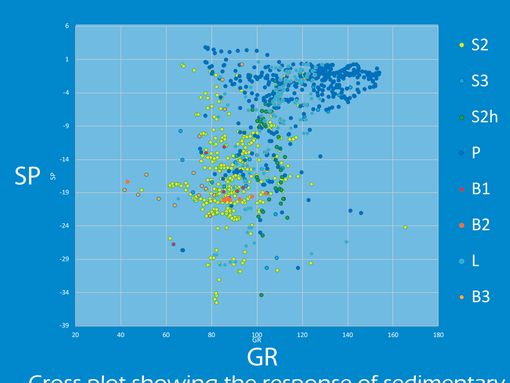




Genetic facies tract for the understanding of hyperpycnal flows and their associated deposits.



Overall calibration of sedimentary facies according to Gamma Ray and Sp logs.



Cross plot showing the response of sedimentary facies according to Gamma Ray and SP logs

3. Electrofacies Analysis

Four electrofacies were recognized from the afore mentioned classification. The population of these electrofacies with facies and facies associations allowed the definition of four rock types.

First manual approach on cores

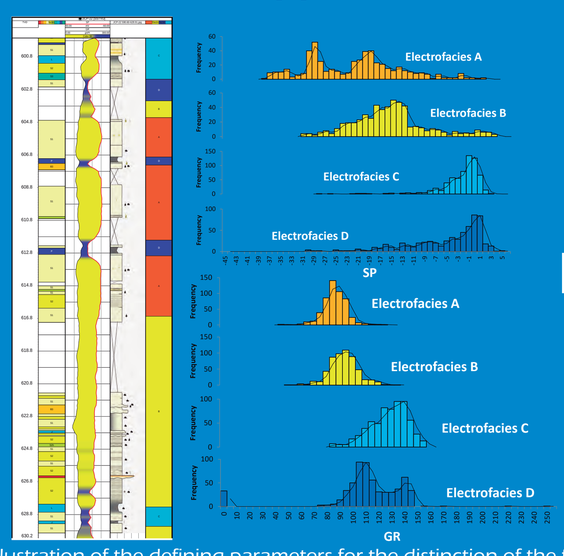
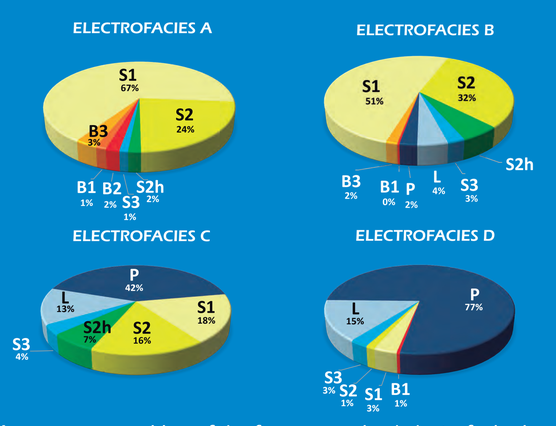


Illustration of the defining parameters for the distinction of the four recognized electrofacies according to Gamma Ray and SP logs

What does Electrofacies can see?

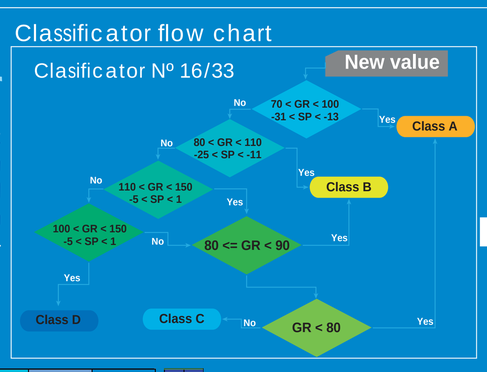


Average composition of the four recognized electrofacies in terms of sedimentary facies. Note that bedload facies mostly belong to electrofacies A

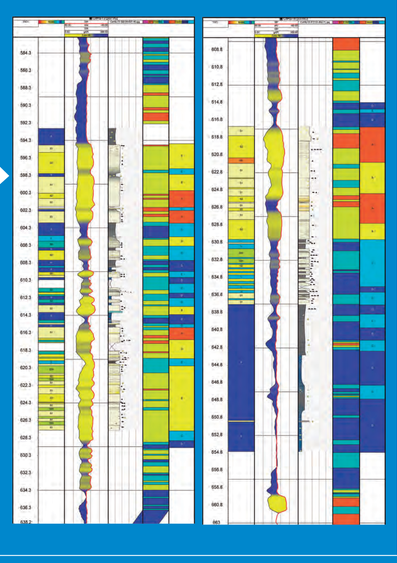
Finding the best classificator

Procedure for the automatic electrofacies definition using a classificator. Note the overall good approximation between manual and automatic classification

Classificator flow chart



Testing (8 wells)

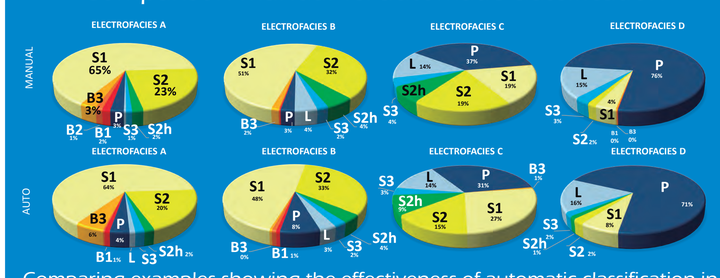


Results

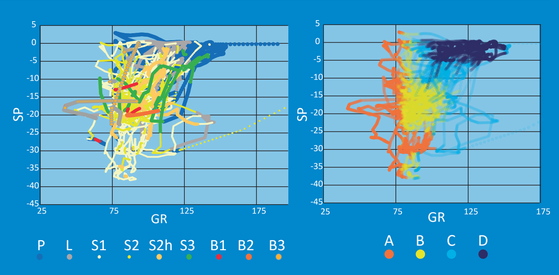
Electrofacies	A	B	C	D	TOTAL
COINCIDENCES	3354	5550	2878	5288	17070
NO COINCIDENCES	3126	2296	2758	1315	9495
SUM	6480	7846	5636	6603	26565
% EFFECTIVENESS	52%	71%	51%	80%	64%

Electrofacies	A	B	C	D	TOTAL
COINCIDENCES	13163		10431		23594
NO COINCIDENCES	1163		1808		2971
SUM	14326		12239		26565
% EFFECTIVENESS	92%		85%		89%

Comparison manual vs. automatic classification



Comparing examples showing the effectiveness of automatic classification in determining facies types in the four recognized electrofacies



SP-GR crossplot showing the correspondence of sedimentary facies (left) and electrofacies (right)

4. Applying the classificator to 1000 wells

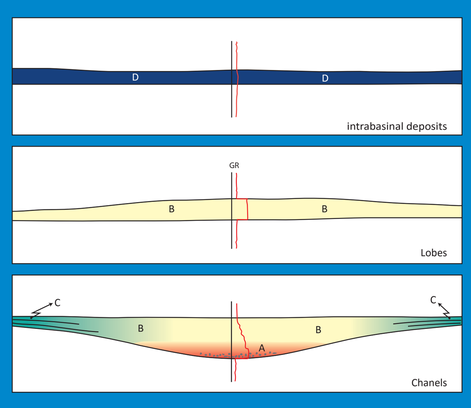
Based on the calibrated rock properties and cut-off values of rock types, an automated computational classification was applied to a larger available well database composed of more than 1000 wells, using an in-house developed software.

las .files → software → new .las file

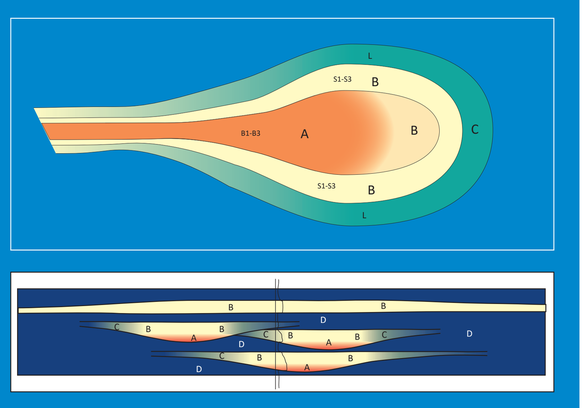
5. Electrofacies vs Sedimentary Facies associations

Correspondence between architectural elements and electrofacies. Key points for paleoenvironmental analysis.

Facies assoc vs Electrofacies	B1+B2+B3	S1+S2+ S2h+S3	L	P
Electrofacies	A	B	C	D
COINCIDENCES	257	6836	479	2566
NO COINCIDENCES	181	5713	871	1794
SUM	438	12549	1350	4360
% EFFECTIVINESS	59%	54%	35%	59%



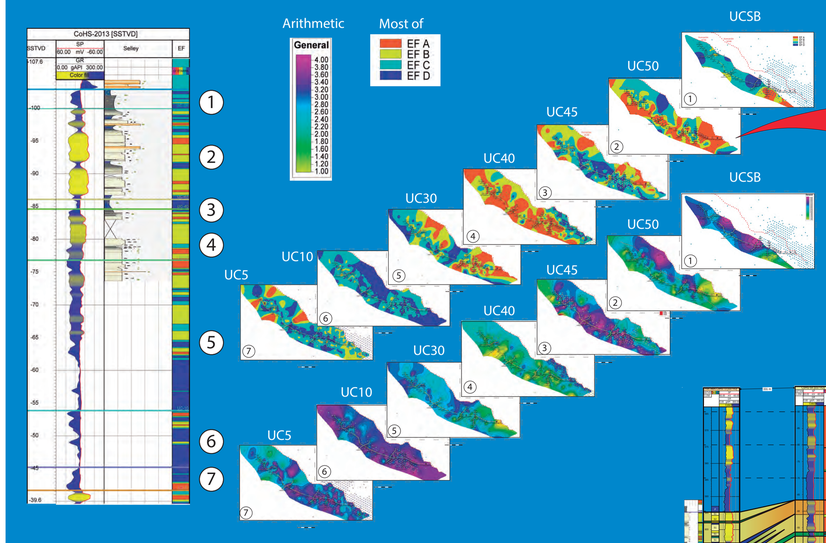
Architectural elements



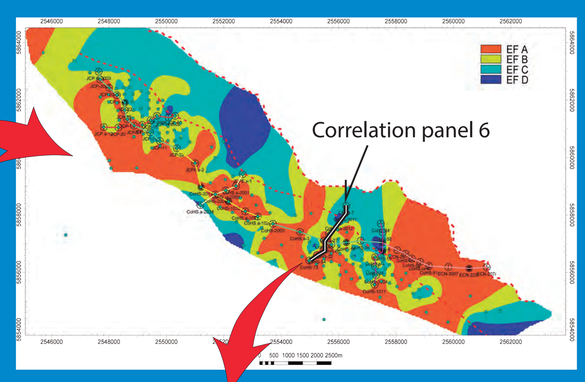
Depositional model

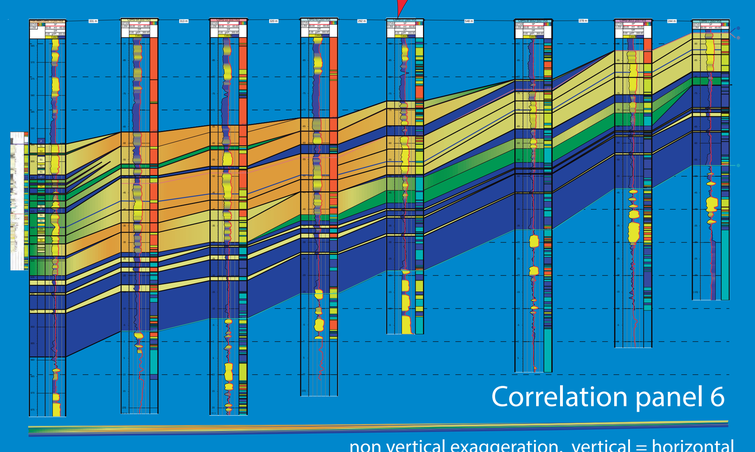
6 Results

The results not only show an accurate correspondence between manual and automated classification, but also allow the construction of detailed reservoir maps focused in the understanding of sandbodies and properties distribution along the entire area.



Electrofacies maps can be performed at different time slices based on a detailed regional correlation. The last allows to reconstruct step-by-step the stratigraphic evolution





non vertical exaggeration. vertical = horizontal

7. Conclusions

The automatic electrofacies definition allowed to manage and process a large log database with sedimentologic/reservoir purposes. The calibration of electrofacies with the main architectural elements provides a powerful tool to obtain multiple detailed reservoir maps at a whole field scale.