PGON2015 IOP Publishing
IOP Conf. Series: Earth and Environmental Science **27** (2015) 012024 doi:10.1088/1755-1315/27/1/012024

Predicted facies, sedimentary structures and potential resources of Jurassic petroleum complex in S-E Western Siberia (based on well logging data)

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Abstract. This paper is devoted to the current problem in petroleum geology and geophysics-prediction of facies sediments for further evaluation of productive layers. Applying the acoustic method and the characterizing sedimentary structure for each coastal-marine-delta type was determined. The summary of sedimentary structure characteristics and reservoir properties (porosity and permeability) of typical facies were described. Logging models SP, EL and GR (configuration, curve range) in interpreting geophysical data for each litho-facies were identified. According to geophysical characteristics these sediments can be classified as coastal-marine-delta. Prediction models for potential Jurassic oil-gas bearing complexes (horizon J_1^1) in one S-E Western Siberian deposit were conducted. Comparing forecasting to actual testing data of layer J_1^1 showed that the prediction is about 85%.

1. Introduction

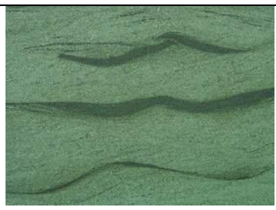
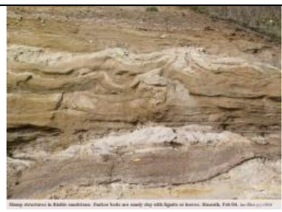
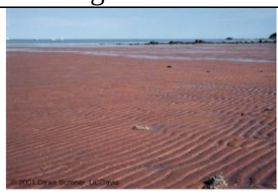
Today, a highly topical problem in geology and geophysics is predicting sediment facies through formation evaluation. Well logging characteristics of sedimentary structures provide data on facies types and reservoir properties [1–3].Substrata formation conditions determining the types of sedimentary structures are generated during sedimentation [4]. Three major facies systems were described: continental including eolian, fluvial and alluvial facies; coastal-marine including delta, lagoon and shelf facies; and sea (marine) including turbidite, landslide and abyssal-marine facies [5–7].

The attributes and behavior of each facies type were determined on the basis of well logging data (SP, EL and GR) and reservoir properties (porosity and permeability). The proposed classification is based on real drilling and deep well logging data from one area in northern Tomsk Oblast (S-E Western Siberia).

2. Research methods

Sedimentary structure types, their reservoir properties, logging curve attributes in real reservoirs were analyzed via acoustic method. This method involves the systemization (based on reference data and individual observations of cross-sections and core samples) of sedimentation systems which are associated with coastal-marine sediment facies types (table1, examples).

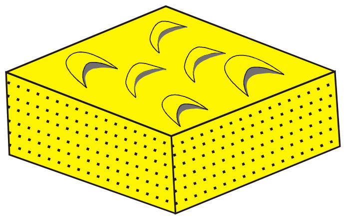
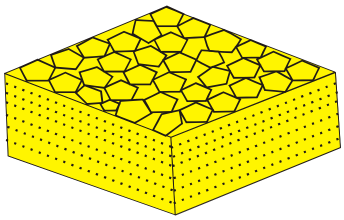
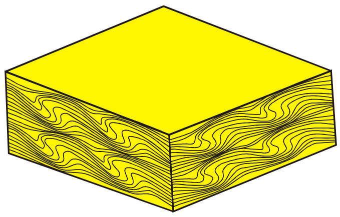
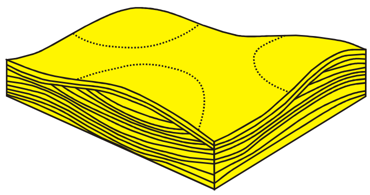
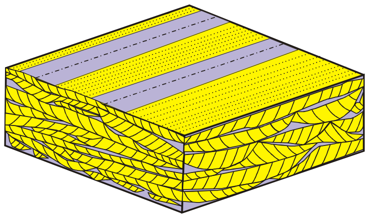
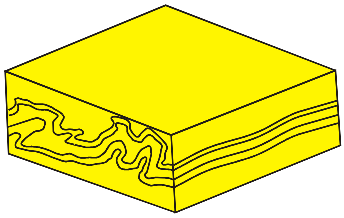
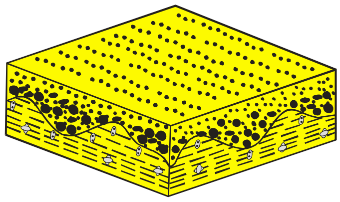
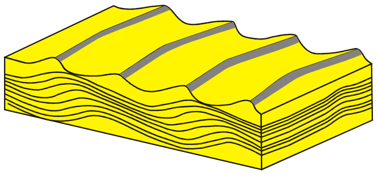
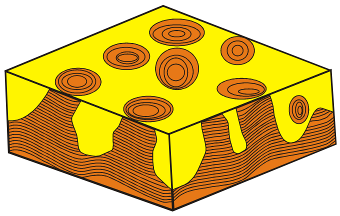
Table 1. Examples of sedimentary structures in outcroppings (Internet sources).

Continental zone	**Coastal zone**	**Marine zone**
Eolian facies	Lacustrine facies	Turbidite facies
		
Gran Canaria, Spain, Duna	Colorado River, Utah, USA Mud cracks	Newfoundland, Canada Contorted (crinkled) bedding
Fluvial facies	Delta facies	Landslide facies
		
Near Kodi, Wyoming, USA Hilly oblique bedding	Pennsylvania	Bournemouth, England Landslide structure
		
	Kentucky, USA Flaser bedding	
Fluvial facies	Lagoon facies	Abyssal-marine facies
		
Baraboo, Wisconsin, USA Channel and pit	Broome Town Beach, Western Australia Linear ripples	Lester Park, Saratoga Springs, New York, USA Stromatolithic structure

3. Sedimentary structure models

Sedimentation types and sedimentary structure forms of coastal facies are complicated and diverse (table 2, examples), including continental genesis sediments, proper coastal and shelf zones and continental slope.

Table 2. Sedimentary structure models of coastal-marine sedimentation.

Continental zone	**Coastal zone**	**Marine zone**
Eolian facies	Lacustrine facies	Turbidite facies
		
Duna	Mud cracks	Contorted (crinkled) bedding
Fluvial facies	Delta facies	Landslide facies
		
Hilly oblique bedding	Flaser bedding	Landslide structure
Fluvial facies	Lagoon facies	Abyssal-marine facies
		
Channels and pits	Linear ripples	Stromatolithic structure

4. Summary reservoir property characteristics of sedimentation facies

Three major facies systems were embraced: continental including eolian, fluvial and alluvial facies; coastal-marine including delta, lagoon and shelf facies; and sea (marine) including turbidite, landslide and abyssal-marine facies. Sedimentary facies structure types, as a geological information feature, indicate this or that reservoir property (table 3).

Table 3. Summary of sedimentary structure characteristics and reservoir properties of typical sedimentation facies.

	Facies types	Possible sedimentary structures	Porosity (%)	Permeability (mD)
Continental	Eolian	Foreset bed, cross-bedding, bioturbation, stratification, dunas, biogenic structure	5–20	50–800
	Fluvial	Pebble bed, channel of clastics, cross bedding, hilly oblique bedding, cut-and-fill structure, occurrences, ripple marks, channels and pits	0–23	0.001–1000
	Alluvial	Mud cracks, micro-thin layers, parallel bedding, climbing ripples, flaky laminated silt and clay, columnar structure	3–15	1–50
Coastal	Delta	Lenicular bedding, swaley bedding, flaser bedding, cross bedding, herring-bone cross-bedding, linear ripples, plane stratification, foreset bed, ploughing structure traces, biogenic structure	12–34	10–1500
	Lagoon	Fine-layered structure, bioturbation abundance as a result of plant roots, lenticular, sawley, herring-bone cross-bedding	6–19	10–1500
	Shelf	Lenticular, flaser and herring-bone cross-bedding, geopetal texture	1–22	Less than 0.0001, 0.002–0.174
Marine	Turbidite	Normal sedimentary structure and reverse layers, silt-sorted sands, concretions, torch structure, contorted (crinkled) bedding	10–25	1–2400
	Landslide	Boulder sand and silt, landslide structure	10–25	1–100
	Abyssal-marine	Parallel bedding, bioturbation, micro-thin layers, carbonate silt, cupola, ball-and-pillow structure, dropstone, hilly oblique bedding, compressed-fractured structure, stromatolithic structure, biogenic structure	2–23	0.09–10

5. Logging models and testing of prediction models

Litho-facies interpretation of geophysical data was assigned to determined logging model (SP, EL and GR) for each facies. The geophysical prediction of Jurassic sediment facies in northern Tomsk Oblast was conducted. Specific characteristics of sedimentogenesis and reservoir properties of Jurassic sediments (J_1formation), the thickness of which ranged from 3 to 30m., were identified according to the integrated litho-facies analysis results and on-the-spot GIS data (SP, EL, IR and GR logging curves).

Three sediment layer types were identified in the Vasugan suite- J_1^1 layer, J_1^2 layer and J_1^3 layer based on the classification of investigated cross-sections. These layers had the following thicknesses: J_1^1 layer from 5 to 12m.; J_1^2 layer– from 3m to 13m.;and J_1^3 layer from8 m to 30m.

According to the discussed sedimentary models, logging characteristics, lithological interpretations (A Ezhova) [9], J_1^1 layer embraces predominately medium-fine grained sandstones, aleurolites, carbonaceous argillites which are in – situ oil saturated. The interpretation of logging curves showed that according to geophysical characteristics these sediments can be classified as coastal-marine-delta (table 4). It should be noted that in 7 out of 8 well models the above-mentioned facts were verified (actual productivity according to testing results).

Table 4. Example of predicted and comparable facies types in J_1^1layer.

Interval, m.	Logging	Actual productivity	Lithology (according to [9])	Facies type (author classification)	Porosity, permeability (according to author)	Productivity (according to author)
2190–2198		Oil influx rate 1.2 m^3/daily	Medium-fine grained sandstones oil-saturated	Coastal-marine-delta	12–34 %, 10–1500 mD	Productive reservoir
2190–2198		Oil influx rate 1.2 m^3/daily	Medium-fine grained sandstones oil-saturated	Coastal-marine-delta	12–34 %, 10–1500 mD	Productive reservoir
2210–2215		Dry	Medium-fine grained sandstones carbonceous argillites	Coastal-marine-delta	12–34 %, 10–1500 mD	Productive reservoir

According to the logging data of 14 wells, only in 2 wells, the facies type (coastal-marine-delta) was observed in J_1^2 layer. There is no data concerning reservoir properties and well productivity in the remaining 12 wells. In this case, the logging data of J_1^3 layer was applied in predicting in-situ facies types.

6. Conclusion

More than 100 world-wide deposits were analyzed by applying the acoustic method and the characterizing sedimentary structure for each coastal-marine-delta type was determined. The summary of sedimentary structure characteristics and reservoir properties (porosity and permeability) of typical facies were described. Logging models SP, EL and GR (configuration, curve range) in interpreting geophysical data for each litho-facies were identified.

Prediction models for potential Jurassic oil-gas bearing complexes (horizon J_1^1) in one S-E Western Siberian deposit were conducted. Layer J_1^1 embraces predominately medium-fine grained sandstones, aleurolites, carbonaceous argillites which are in – situ oil saturated. According to geophysical characteristics these sediments can be classified as coastal-marine-delta.

It should be noted that in 7 out of 8 well models the above-mentioned facts were verified. Comparing forecasting to actual testing data showed that the prediction is about 85%. Excluding logging curve analysis could result in an improper interpretation of facies based on the analysis of sedimentary structures.

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