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

F Prakojo1,3, G Lobova1,4 and R Abramova2

1 Department of Geophysics, Institute of Natural Resources, National Research Tomsk Polytechnic University, 30 Lenin Ave., Tomsk, 634050, Russia
2 Department of Foreign Language, Institute of Natural Resources, National Research Tomsk Polytechnic University, 30 Lenin Ave., Tomsk, 634050, Russia

E-mail: † felix.santo@yahoo.com, ‡ lobovaga@tpu.ru

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 J11) in one S-E Western Siberian deposit were conducted. Comparing forecasting to actual testing data of layer J11 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 (table 1, 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, dunes, biogenic structure      | 5–20         | 50–800            |
|              | Fluvial: pebble bed, channel of clastics, cross bedding, hilly oblique bedding, cut-and-fill     | 0–23         | 0.001–1000        |
|              | structure, occurrences, ripple marks, channels and pits                                        |              |                   |
|              | Alluvial: mud cracks, micro-thin layers, parallel bedding, climbing ripples, flaky laminated     | 3–15         | 1–50              |
|              | silt and clay, columnar structure                                                               |              |                   |
| Coastal      | Delta: lenticular bedding, swaley bedding, flaser bedding, cross bedding, herring-bone cross-     | 12–34        | 10–1500           |
|              | bedding, linear ripples, plane stratification, foreset bed, ploughing structure traces,        |              |                   |
|              | biogenic structure                                                                              |              |                   |
|              | Lagoon: fine-layered structure, bioturbation abundance as a result of plant roots, lenticular,  | 6–19         | 10–1500           |
|              | sawley, herring-bone cross-bedding                                                             |              |                   |
|              | 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,    | 10–25        | 1–2400            |
|              | torch structure, contorted (crinkled) bedding                                                  |              |                   |
|              | Landslide: boulder sand and silt, landslide structure                                           | 10–25        | 1–100             |
|              | Abyssal-marine: parallel bedding, bioturbation, micro-thin layers, carbonate silt, cupola,     | 2–23         | 0.09–10           |
|              | ball-and-pillow structure, dropstone, hilly oblique bedding, compressed-fractured structure,   |              |                   |
|              | stromatolithic structure, biogenic structure                                                    |              |                   |

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 (J1formation), 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- J11 layer, J12 layer and J13 layer based on the classification of investigated cross-sections. These layers had the following thicknesses: J11 layer from 5 to 12m.; J12 layer from 3m to 13m.; and J13 layer from 8m to 30m.
According to the discussed sedimentary models, logging characteristics, lithological interpretations (A Ezhova) [9], J₁₄ 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).

| 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 m³/daily | Medium-fine grained sandstones oil-saturated | Coastal-marine-delta | 12–34 %, 10–1500 mD | Productive reservoir |
| 2190–2198   | Oil influx rate 1.2 m³/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 J₁₄ layer. There is no data concerning reservoir properties and well productivity in the remaining 12 wells. In this case, the logging data of J₁₄ 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 J₁₄) in one S-E Western Siberian deposit were conducted. Layer J₁₄ 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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