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INTEGRATED HYDRAULIC FLOW UNITS ANALYSIS CLASTIC SOUTHTURGAY BASIN'S RESERVOIR

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Abstract: *In following paper different hydraulic flow units approaches has been researched applied to the Kazakhstan reservoir. Hydraulic Flow Units method is the petrophyiscal method to understand the reservoir by dividing it to units with the same flow characteristics. This methodology uses core data to develop an understanding of the complex variations in pore geometry within different lithofacies. Similar flow characteristics is controlled by the pore geometry of the rock. In other words Hydraulic flow unit can be described as: total reservoir rock within which geological and petrophysical properties that affect fluid flow are internallyconsistent and predictably different from properties of other rock volumes.*
Winland R35 method have been applied to classify core data from different reservoirs. Turgay Basin's sandstone has evaluated comparing to limestone and shale reservoirs through RQI's and R35 Windland plot. We can say that this reservoir very heterogeneous and is mainly in conventional and fast delivery reservoirs area. Reservoir quality index has been applied to distinguish the type of reservoir using plot of South Turgay's basin reservoir comparing to Tengiz oilfield petrophysical data and Bakken shale oil reservoir permeability and porosity data.

Keywords: *Hydraulic Flow Units, Petrophysics, Reservoir heterogeneity, Permeability Flow, Winland R35 plot*

ОҢТҮСТІК ТОРҒАЙ БАССЕЙНІНІҢ ШӨГІНДІ ТАУ ЖЫНЫС КОЛЛЕКТОРЫНЫҢ ГИДРАВЛИКАЛЫҚ АҒЫМ БІРЛІКТЕРІМЕН КОМПЛЕКСТІК ТАЛДАУ

Аңдатпа: *Осы мақалада гидравликалық ағым бірліктердің Қазақстан Республикасында орналасқан коллекторға талдау әдістері қарастырылған. Гидравликалық ағым бірліктер коллекторды бірнеше сипаттамалары ұқсас блоктарға бөліп талдау петрофизикалық әдісі. Осы әдістеме кеуектердің геометриясын бір литофациясындағы өзгерістерді анықтауға арналған. Басқаша айтқанда, гидравликалық ағым бірлігін былай сипаттауға болады: бір қабаттың тау жынысының ішіндегі петрофизикалық және геологиялық қасиеттері флюидтің ағымына әсер етіп, басқа тау жыныстан ажыратылуы туралы. Осы зерттеуде Winland R35 әдісі кернның петрофизикалық қасиеттерін талдау үшін қолданған. Талдау бойынша коллектор өте біртекті емес екенін және көп таралған және беріштігі мол коллекторларға жататыны көрсетілген. Коллектордың сапа индексі коллектордың сапасын Теңіз және Баккен кенорындарының петрофизикалық ақпаратпен салыстырылып анықталған.*

Түйінді сөздер: *гидравликалық ағым біріліктер, петрофизика, коллектордың біртекті еместігі, өткізгіштік ағым, Винланд Р35 графигі*

КОМПЛЕКСНЫЙ АНАЛИЗ ТЕРРИГЕННОГО КОЛЛЕКТОРА ЮЖНО-ТУРГАЙСКОГО БАССЕЙНА ГИДРАВЛИЧЕСКИМИ ЕДИНИЦАМИ ПОТОКА

Аннотация: *В этой статье были исследованы различные подходы применения гидравлических единиц потоков применительно к Казахстанскому коллектору. Метод гидравлических потоковых единиц – это петрофизический метод, позволяющий описать пласт, разделив его на блоки с одинаковыми характеристиками потока. Эта методология использует основные данные, чтобы развить понимание сложных изменений в геометрии пор в пределах различных литофаций. Подобные характеристики потока контролируются геометрией пор породы. Другими словами, гидравлическая единица потока может быть описана как: общая пластовая порода, в пределах которой геологические и петрофизические свойства, которые влияют на поток флюида, внутренне согласованы и предсказуемо отличаются от свойств других объемов породы. Метод Winland R35 был применен для классификации данных керна из разных коллекторов. Песчаник в Тургайском бассейне был описан в сравнении с известняковыми и сланцевыми коллекторами по графикам RQI и Windland R35. Можно сказать, что этот коллектор очень неоднороден и находится, в основном, в зоне широко распространенных и хорошо извлекаемых коллекторов. Индекс качества коллекторов был применен для определения качества коллекторов с использованием графика по сравнению с петрофизическими данными месторождения Тенгиз и Баккенского сланца.*

Ключевые слова: *гидравлические единицы потока, петрофизика, гетерогенность коллектора, поток в проницаемости, график Винланд Р35*

1.Introduction

In following paper we analyzed Sandstone reservoir from the Kazakhstan's South Turgay basin's T-field by the Hydraulic Flow Unit method. As we can conclude field has not been analyzed using HFU method before.

Huydralic Flow Unit method theory was firstly suggested by Amaefule et al [1] and developed by the further researchers.[2]

Hydraulic Flow Units method is the petrophyiscal method to understand the reservoir by dividing it to units with the same flow characteristics. This methodology " uses core data to develop an understanding of the complex variations in pore geometry within different lithofacies."[1] Similar flow characteristics is controlled by the pore geometry of the rock. In other words Hydraulic flow unit can be described as: "total reservoir rock within which geological and petrophysical properties that affect fluid flow are internallyconsistent and predictably different from properties of other rock volumes."[2]

Hydraulic units are related to geologic facies distribution. But do not necessarily coincide with facies boundaries. Therefore, hydraulic units may not he vertically contiguous. Hydraulic units are often defined by (a) geological attributes of texture, mineralogy, sedimentary structures, bedding contacts and nature of permeability barriers and by (h) petrophysical properties ofporosity, permeability and capillary pressure.[1]

Permeability can be evaluated using following equation:

$$k=1014*FZI^2 * \frac{\emptyset_e^2}{(1-\emptyset_e)^2}\frac{\emptyset_e^2}{(1-\emptyset_e)^2} \quad (1)$$

where 1014 is the conversion factor for permeability from μm to mD.(Svirskyi et al)[3]. Hydraulic flow units can be used for prediction and classification of the two phase properties of the rock such relative permeabilties and capillary pressure.[3]

"Theory of the HFU approach classification is based on assumption, that porous medium can be represented by a bundle of capillary tubes. Combination of Darcy's law and Poiseuille's law for straight cylindrical tubes yields following relationship" :

$$k=\frac{r^2}{8}\phi_e\frac{r^2}{8}\phi_e \quad (2)$$

The relation between porosity and permeability depends on geometrical characteristics of the pore space - pore size (radius) and pore shape (here, 8 - for cylindrical tubes). For a realistic porous medium Kozeny and Carmen have modified Eq. 1 by adding a tortuousity factor $\tau\tau$ and using mean hydraulic radius, epxressed through surface area per unit grain volume Sgv. The resulting generalized of Kozeny-Carmen equation has the following form:

$$k = \frac{\phi_e^3}{(1-\phi_e)^2}\frac{1}{F_s\tau^2 S_{gv}^2}\frac{\phi_e^3}{(1-\phi_e)^2}\frac{1}{F_s\tau^2 S_{gv}^2} \quad (3)$$

whereF_s is the shape factor, k is in μm^2 and ϕ_e is a fraction.

The group $F_s\tau^2$ is known as the Kozeny constant and was a main limitation in previous attempts to use Eq. 3 for calculation permeability, because actual values of the Kozeny constant are usually not known for particular rocks, and the term S_{gv}^2 was not accounted in calculations.

The HFU approach addresses variability of the Kozeny constant and the term S_{gv}^2 term by classifying parameter FZI (flow zone indicator), which includes all major geological and geometrical characteristics of a porous medium:

$$FZI = \frac{1}{\sqrt{F_s\tau^2 s_{gv}^2}}\frac{1}{\sqrt{F_s\tau^2 s_{gv}^2}} \quad (4)$$

The idea of the HFU approach is to group data according to the FZI values and other petrophysical information using various statistical and graphical methods to obtain classification of the HFU.

To simplify graphical analysis of the data, two additional parameters, RQI (reservoir quality index) and ϕ_z (ratio of pore volume to grain volume) are defined:

$$RQI = \sqrt{\frac{k}{\phi_e}}\sqrt{\frac{k}{\phi_e}} \quad (5)$$

$$\phi_z = \frac{\phi_e}{1-\phi_e}\frac{\phi_e}{1-\phi_e} \quad (6)$$

Using the above parameters, Eq. 8 can be rearranged as follows:

$$\log RQI = \log \phi z + \log FZI \quad (7)$$

According to Eq. 7, a log-log plot of RQI vs$\phi_z$yields a straight line with unit slope and the intercept equal to FZI. Hence, all data points corresponding to one HFU should lie on the same line.[1]

2. Conventional and unconventional resources petrophysical properties comparison

Generally, hydrocarbon resources reservoirs can be classified by the flow units to get better understanding of the reservoir analogues and overall understanding of reservoir properties.

Endowment is the summation of cumulative gas production, reserves and undiscovered gas. Delivery speed, which controls the definition of flow units considered in this research, decreases as we move down the pyramid from conventional to unconventional gas reservoirs. [4]

Conventional and Unconventional Reservoirs

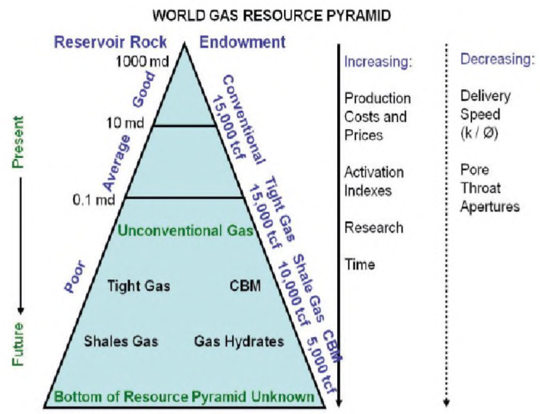

Fig.1 - World Gas Resources pyramid showing endowment of conventional gas, tight gas, shale gas and coalbed methane reservoirs (Adapted from Aguilera et al., 2008).

Turgay basin's sandstone reservoir has porosity 15-22% and permeability 0.031 to 0.22mDand Tengiz limestone reservoir has porosity and permeability, comparing to 0.1-24% and permeability 1 to 30 mD, while Bakken Shale porosity 5% and permeability 0.04 mD.

Making different range of the conventional and unconventional resources porosity and permeability study we can easily classify other potential oilfields to the groups according to analogues. Analogue fields can be act as references and case studies to develop oilfield or make geological model.

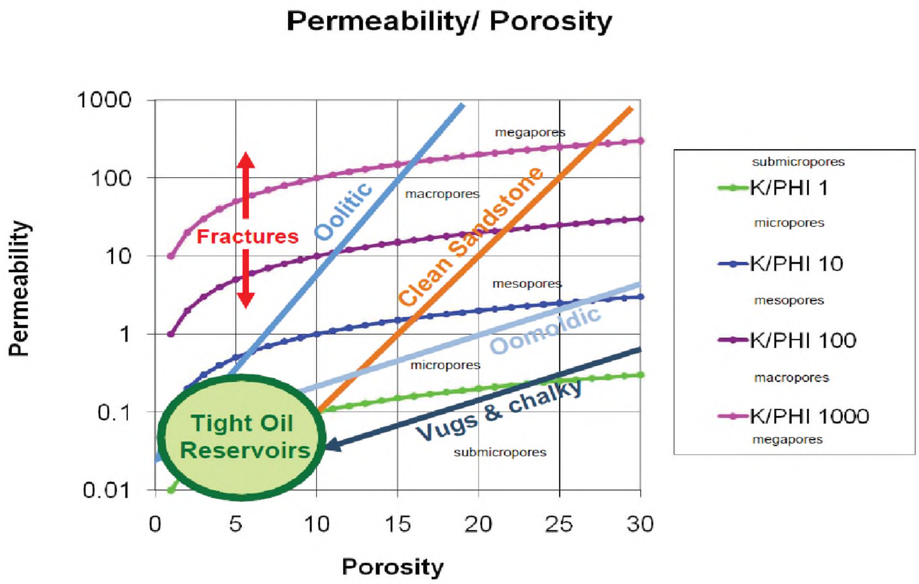

Fig.2-Permeability-Porosity relationship for different ports sizes.From Steve Sonnenberg, Colorado school of mine, Core analysis and Unconventional Reservoirs [5]

As we can see from fig. 2 – different rocks has different port size that depends on porosity-permeability. In this case South Turgay basin's sandstone will be in mesopores and macropores area. That is in conventional reservoirs classification.

Another petrophysical statistical method applied in this study is Reservoir Quality Index that can be used to describe the reservoir property. Plotting data of three types of reservoirs (Fig. 3) sandstone, shale and limestone can help to classify our reservoirs according to flow units. As we can see in plot tight reservoirs can have even lower RQI than the shale reservoirs.

Figure 4 demonstrates that shale reservoirs laying in the 0,5 micron aperture size (microport)

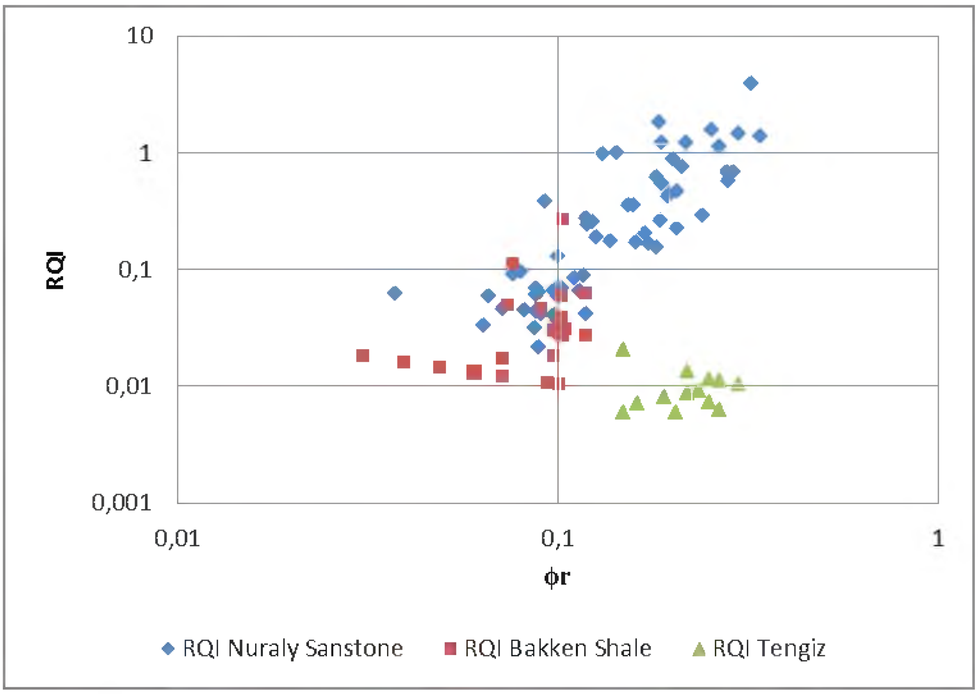

Fig.3 - RQI - ϕ_r- plot of the Sandstone (Nuraly), Shale (Bakken) and Carbonate (Tengiz) types of reservoirs.

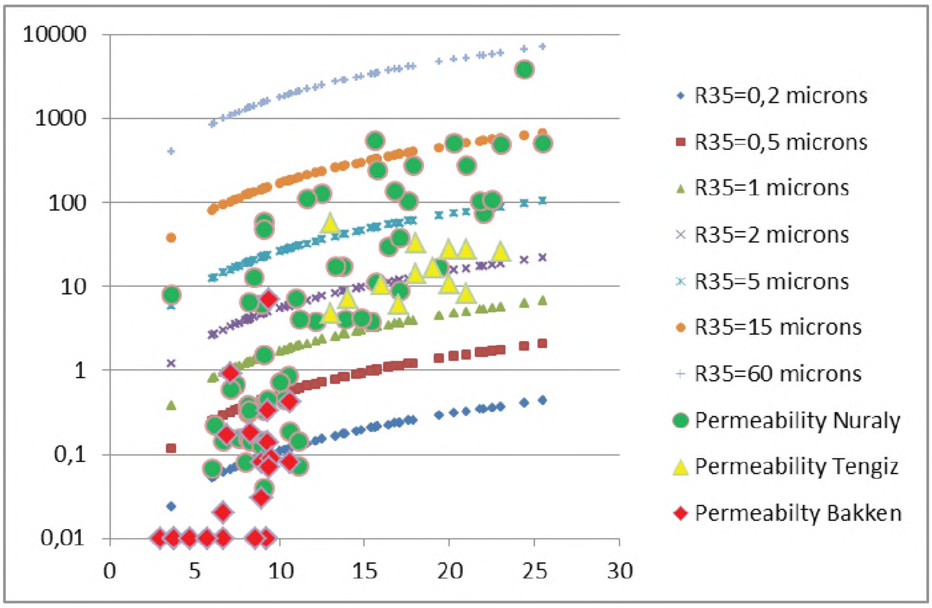

Fig.4 – Winland r35 plot of the Sandstone (Nuraly), Shale (Bakken) andCarbonate(Tengiz) types of reservoirs.

area. Sandstone reservoir has biggest aperture size – megaport type. While the carbonate is laying mostly in mesoport area r>1 micron. That plot shows same properties as figure 2.

Conclusion

Study gives a understanding of geology of the reservoir and can be used for net pay off estimation. Heterogeneity of reservoir can be evaluated with this methods. That will can be used for EOR studies like polymer injection.

Turgay Basin's sandstone has evaluated comparing to limestone and shale reservoirs through RQI's and r35 Windland plot. We can say that this reservoir very heterogeneous and is mainly in conventional and fast delivery reservoirs area.

Nomenclature

FZI – Flow Zone Indicator
GR – gamma ray response
HFU – Hydraulic Flow Unit
k – permeability
r - poreradisus
RQI – reservoir quality index
Sgv – surface area per unit grain volume
ϕ_e – effective porosity
ϕ_z – ratio of pore volume to grain volume
ρ – density
τ – tortuousity factor

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