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Effective Testing Method in Thin Bedded Waxy Oil Reservoirs

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Page-1 : Innovation Feature

Thin beds are a prominent feature in many recently discovered hydrocarbon reservoirs around the world. Not only are they typically difficult to evaluate, which leads to high reserves uncertainty, they are also frequently associated with inconsistent well performance. One of the main challenges in the evaluation of thinly-bedded reservoirs is an accurate productivity assessment. Reliable formation evaluation requires further high-resolution petrophysical and geophysical logs (for an initial permeability estimation, free fluid volume, saturation, formation anisotropy and structural information). However, as per reservoir testing information (pressure, fluid types, PVT properties, permeability and producibility), this dynamic reservoir characterization method needs to be properly planned and evaluated. In the past, the use of full scale Drill Stem Test and Production Tests were conducted to obtain reservoir parameters including zone productivity. However, to reduce potentially high operational costs, different scales of pressure transient test have been introduced. This is the cooperative work between Mubadala Petroleum and Schlumberger where we look into the alternative testing method to provide reservoir information. This is the first time that we have done this systematic work in the Gulf of Thailand.

The work starts with simulation to theoretically evaluate the use of smaller scale of pressure transient compared to the full scale testing method in the thin bedded reservoirs. This yields a robust comparison of pressure transient data obtained from several scales of measurement when reservoir heterogeneity, i.e. shale streaks and shale layers, is present in the reservoirs. After the simulation suggested that the reservoir parameters can be obtained using smaller scale of testing, different scales of testing methods were executed during the exploration campaign in 2009 and 2010. After that, the actual field data were analysed (analyzed) to compare results from different scale of testing method. The high resolution logging with advance log interpretation techniques were also applied to properly evaluate these reservoirs. The summary of work flow is:

1. The uses of high solution logs such as NMR and electrical image logs to predict the zone producibility before the actual testing were executed. Do you mean high resolution?

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2. The single well predictive model was used to predict zone permeability and producibility from the high resolution logs and this can be compared with the actual test later.
3. Pre-job planning for wireline logging to make sure that the job objective can be met within the effective time frame.
4. The petrophysical evaluation was performed as soon as the first logging run was finished. The testing intervals were selected based on the job objectives.
5. Different types of probes and packers, as shown in Figure1, were planned for different scales of testing methods. The jobs were executed based on selected intervals and job objectives.
6. The use of build-up using single probe formation testers was suggested for thin sand intervals. This is the first time of using this smaller scale pressure transient in the GoT to obtain pressure transient in thinly bedded zone.
7. Pressure derivative was monitored in real time to make sure that the testing objectives can be met in the effective time frame.
8. The Downhole Fluid Analyzer was used to measure the in-situ viscosity of waxy oils. The lab results were then compared with real time measurement. The agreement between lab and downhole viscosity allows us to have confident in our measurements in this environment. By having the in-situ viscosity value, the testing time can be optimized.
9. The deconvolution method was used to analyse (analyze) pressure transient data. This is a first time that reservoir engineers applied the deconvolution technique in the small scale of pressure transient data.
10. Zone permeability thickness obtained from full scale testing method, dual packer and single probe formation testers were then compared for each testing intervals (as shown in Tables 1 and 2). The core permeability values are also used to compare with smaller testing method.

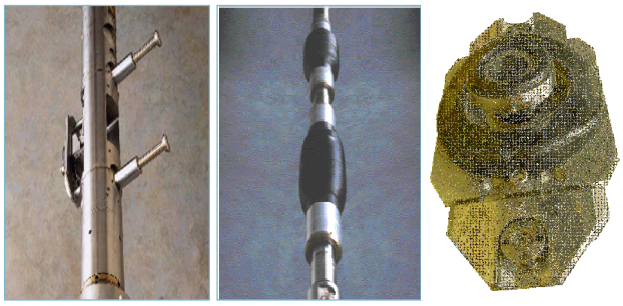

Figure 1 Different Probes and Packers for the smaller scale of Pressure Transient Tests (The technical term is Interval Pressure Transient Test-IPTT)

Page-2 : Thailand E&P industry impact and values

Tables 1 and 2 are zone permeability and permeability-thickness obtained from smaller scale testing methods (Single Probe and Dual Packer IPTT) compared to the full scale testing (TST). The good agreement between smaller and larger scale testing gives us confidence in using smaller scale testing in the thin bedded reservoirs. The zone productivity can be accurately calculated straight away after logging operations are completed. With this novel work, now Mubadala can save significant rig time and cost, as shown in Table 3. The environmental benefit of this work is that there is no flare during the test using wireline testing tools. In addition, the working space on the rig can be significantly reduced due to no separator facility being required on board. Numbers of crews and engineers for wireline logging is also less compared to full scale testing. As a result, this can help to minimize the operation risk associated during the operation.

This work would provide the alternative way of testing in the thinly bedded reservoirs in the GoT where reservoirs are very compartmentalized. Results of this work can be applied for numbers of reservoirs in the GoT such as waxy oil, gas with high CO_2 and gas condensate.

Table 1 A Comparison between Dual Packer Testing (IPTT) and Full Scale Testing (TST) in the same sand

Sand	Zone Thickness	Time Per Test (hrs)		Permeability (md)		kh (md-ft)	
	(ft)	Dual Packer IPTT	TST	IPTT	TST	IPTT	TST
X	18	0.85	26.5	1,688	1,560	28,700	26,520
Y	22	0.45	20	941	1,170	20,700	25,700
Z	50	0.3	13.8	692	1,010*	8,990	13,100*

Table 2 A Comparison between Single Probe IPTT, Core Permeability and TST

Sand name	Single probe IPTT							TST				Core			
	Well name	Test depth (MD-ft)	Test Interval (ft)	R_{inv}(ft)	k_h (md)	k_v (md)	k_v/k_h	Well name	Test depth (MD-ft)	Test Interval (ft)	k_h (md)	Well name	Depth (MD-ft)	Φ (%)	k_h (md)
3.4*	X-02	3300	16	73.2	151	59	0.39					X-02	3300	31.7	146
7.4*	X-02	3441	8	72.2	244	74	0.30					X-02	3442	31.9	153
2.4	X-02ST							X-02ST	3350 – 3370	20	9000	X-02ST	3345	23.0	188
01	X-02ST	4653	11	233	5160	10 3	0.00 2	X-01	4074 - 4085	11	4 000	X-02ST	4650 4655	16.1 26.9	26 10905

Table 3 Time and Money save for each testing zone

	Dual Packer IPTT	TST	Cost and Time Saving by Dual Packer IPTT per Test
Cost (MM$)	0.37	2.67	2.29 MM$
Time (Days)	0.33	6.34	6.01 Days

- The main benefits to Mubadala from the application of these smaller-scale pressure transient testing methods are :-
- Ability to test a larger sample of the field's reservoirs because the costs associated with each test are far low than conventional large-scale pressure transient testing methods such as TST;
- Enhanced ability to calibrate poro-perm and similar relationships obtained from wireline logs;
- Availability of fluids information in real time to allow a high-confidence preliminary assessment of the formation to be made almost immediately, which has benefits in terms of the acceleration of studies leading to field development.

Page-3 : Essay, Why this project should win the award?

In Asia Pacific region, there are many thinly bedded reservoirs which are composed of interbedded porous and permeable sands with variable proportions of thin silt and clay beds. These reservoir sand bodies range from millimeters to tens of meters in thickness. Though the reservoirs are highly permeable, reservoir heterogeneity caused by silt and clay laminations affect recovery and sweep efficiency.

In the Tertiary Basins of the Gulf of Thailand and Northern Malay Basin, thinly bedded hydrocarbon sandstone reservoirs have been encountered in several geological settings. In the northern Gulf of Thailand, Kra Basin, subaqueous lacustrine fan delta sandstones of between 1 to 4 feet have developed as a result of episodic deposition. In the Southern part of the Pattani Basin adjacent to the Narathiwat High, thinly bedded reservoirs of less than 1 to 7 ft were deposited in marginal marine, tidally influence estuarine channel fills settings and also in more proximal fluvial crevasse splay deposits.

The typical way to test such formations is to use full scale well testing, even for relatively thin zones. In the GoT, a Tubing Stem Test (TST) is widely used to test each individual zone for reservoir parameters. During a TST, quartz gauges are run on wireline and the selected zone is perforated. However, with this full scale testing method, the time that is required to test each zone usually take several days or a week. This time consuming process results in an increase in the operation cost. In addition, the viscosity of the waxy oil reservoirs can be very different even between closely-spaced zones at similar temperatures. As a result, the viscosity values from the PVT lab were required to obtain accurate zone parameters from the pressure transient analysis. The lab analyses for viscosity usually take three to six months to provide

downhole condition of the viscosity value from fluid sampling taken at surface or downhole condition.

The wireline Formation Testers (FT) have also been increasingly used in the GoT for measuring formation pressure, mobility and collecting reservoir fluids. More advanced FT tools, e.g. dual packers and Downhole Fluid Analyzers (DFA) were recently introduced to test each zone to help defining reservoir characteristics in more detail. A single probe FT deployed for pretests and fluid sampling can be used to obtain transient data during the shut-in periods after sampling in relatively thin zones. The data from these Interval Pressure Transient Tests (IPTTs) can be used to interpret reservoir parameters such as vertical to horizontal permeability ratio and horizontal permeability.

With a systematic working approach, we are now confident of the uses of such smaller scale pressure transient data to provide zone permeability-thickness that is required to predict zone productivity. Not only the rig time and operation cost can be saved using this novel technique, there are also environmental and health and safety impacts associated with this work. In addition, with the cooperative work between geoscientists, field engineers, reservoir engineers, operation petrophysicist and asset team, this work allows us to have number of technical papers presented at the SPE and IPTC conference since 2010 as listed below. This project provides a strong technical back ground as well as the application to the Gulf of Thailand.

1. Kiatpadungkul, W., Daungkaew, S., Athichanagorn, S., Mohd Nor Hisham Azam, H. , van Doorn, J., Haddad, S.: “Formation Evaluation Challenges in Thin Bedded Reservoirs: How to Effectively Test This Formation?,” SPE 133961, paper presented at the SPE Asia Pacific Conference and Exhibition, held in Brisbane, Queensland, Australia, 18–20 October 2010.
2. Kanjanavasoontara, C. K., Daungkaew, S., Yimyam, N., Platt C., Houtzager, F.: “Success Story of Downhole Fluid Sampling in a Very Challenging Environment in the Gulf of Thailand,” SPE 133896 paper presented at the SPE Asia Pacific Conference and Exhibition, held in Brisbane, Queensland, Australia, 18–20 October 2010.
3. Platt, C., Houtzager, F., McClure, J., Kanjanavasoontara, C. K., Daungkeaw, S., Farag, S., Yimyan, N.: “Applications of Newer Wireline technologies, Some Examples from Pearl Oil Thailand Gulf of Thailand 2009/10 Exploration Drilling,” DMF 4th Petroleum Forum Bangkok, 26-27 May 2011.
4. Chokthanyawat, S., Daungkaew, S., Athichanagorn, S: “Well Productivity Prediction for Laminated Reservoirs using the High-Resolution and the Electrical Image Logs,” IPTC-14399-PP, paper will be presented at the Internal Petroleum Technology Conference and Exhibition, Bangkok, Thailand, 15-17 November 2011.

5. Duangprasert, T., Daungkaew, S., Paramatikul, R.: “New Phase of Formation Evaluation in the Gulf of Thailand,” IPTC 14401, paper will be presented at the Internal Petroleum Technology Conference and Exhibition, Bangkok, Thailand, 15-17 November 2011.
6. Houtzager, F., Platt, C., Voradejviseskrai, S., Storer, A., Last, N., Limniyakul, T., Tabmanee, P., Panyarporn P., Grinham, S., Kiatpadungkul, W., Daungkaew, S., Chokthanyawat, S., and Ayan, C.: “IPTT vs. Well Testing and Deconvolution Applications for the Thinly Bedded Reservoirs: Case Studies from the Gulf of Thailand,” IPTC -14601-PP, paper will be presented at the Internal Petroleum Technology Conference and Exhibition, Bangkok, Thailand, 15-17 November 2011.
7. Daungkaew, S., Fujisawa, G., Chokthanyawat, S., Ludwig, J., Houtzager, F., Platt, C., Last, N., Limniyakul, T., Phaophongklai, W.: “Is There A Better Way to Determine The Viscosity in Waxy Crudes,” poster presented at the at the AAPG ICE in Singapore, 17-19 September 2012.
8. Daungkaew, S., Fujisawa, G., Chokthanyawat, S., Ludwig, J., Houtzager, F., Platt, C., Last, N., Limniyakul, T., Phaophongklai, W., Comrie-Smith, N., Thaitong, T.: “Is There A Better Way to Determine The Viscosity in Waxy Crudes,” SPE 159337, paper presented at the at the SPE Asia Pacific Oil and Gas Conference and Exhibition held in Perth, Australia, 22–24 October 2012.

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