7th Petroleum Geology Conference - Queen Elizabeth II Conference Centre, London - 30th March - 2nd April 2009 Inconsistency of Hydrocarbon Generation Potential and Production Data The Bakken Play of North Dakota

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INTRODUCTION.

The Bakken Formation of the Williston serves, are based on the assumptions Basin has been described to hold an un- that we are dealing with a tight continudiscovered volume of 3.65 BBbls of oil ous unconventional play in which all and 1.84 trillion cubic feet of generated hydrocarbons persist in the associated/dissolved natural gas by the formation and can be produced in each USGS (Pollastro et al., 2008). These new location individually. But how can these assessments, which make the Bakken assumptions be in agreement with the one of the largest North American re- production data?

OVERVIEW

Important anticlines are indicated below.

Location of the Williston Basin esask.uregina.ca

Chevron

devon

StatoilHydro

PETROBRAS

ConocoPhillips

The bowl-shaped intercratonic Williston The stratigrapic column consists of an Basin stretches across the border of Canada almost complete record from the Camand the USA. Structural impact is limited. brian to recent times, including several source rocks for gas and oil.

> The Late Devonian to Early Mississippian Bakken Formation consists of a productive siltstone layer that is encased within the source rocks of the upper and lower Bakken Formation.

pge ^{ll}	MOI Ero	System	Sequ	ance Thick	nes nes	estric	onne Fornotic	ŝ		o Okadaa		
	Z.	Quaternary		315	X		Glacial Dep.	z				
2.5	CENC	Tertiary	TEJAS	740	X		White River Golden Valley Fort Union Gr.	MISSISSIPPIA	600	Mission Canyon		
0, _	MESOZOIC	Cretaceous	INNZ	1590	X	X	Montana Gr. Colorado Gr. Dakota Gr.			E Lodgepole		
140 =		Jurassic		370	X	X	Swift Rierdon Piper		9 27	wpper Shale widdle Silt- stone"		
200 -		Triassic	IA ABSAROKA	225	X		Spearfish	ov.	17 75	Three Forks	7,7,7,7,7,7,7	
250	PALEOZOIC	Permian		132	X		Minnekahta	١Ň	140	Duperow		
290		Pennsylv.		215	X	X	Minnelusa	٥	105	Souris River		
365		Mississipp.		135 600		X X X	Big Snowy Gr. Madison Group BAKKEN FORMA	TION				
		Devonian	KASKASK	735		X	Three Forks Prairie Salts	hree Forks trairie Salts			Stratig	
405		Silurian		335		X	Interlake			of +	ho	
500		Ordovician	CANC	435		X	Red River Winnipeg Gr.	led River (innipeg r.			Willicto	
570		Cambrian	SAUK	300	300 📈 📈 Deadwood					vviiist(
PRECAMBRIAN										Musc	101	

The TOC of the source rock members ranges from 10 to 15%; Typ II Kerogen.

> Bakken Formation overpressured

Upper Bakken

Middle Bakken

Lower Bakken

TMAX AND HYDROGEN INDEX MAP

Maturity (Tmax) and generation potential (Hydrogen Index - HI) maps were compiled with new data and already published data from Webster (1984), Muscio (1995) and Price et al. (1984).



Tmax values indicate a good • 435 - 440 correlation of maturity and • 410 - 420 depth (LeFever, 2008).



The HI map shows similar maturity distributions as the lepth are given especially in the deeper western

If a continuous, unconventional tight oil play is proposed, it should be expected, that in-place hydrocarbons should predominantly reflect the original source rock maturity or the degree of transformation in any given location.

COMPOSITION OF PRODUCED HYDROCARBONS



the oil gravity (API°). parameter. GOR and API°) and depth.



Gas Oil Ratio [Sm³/Sm³]

Plotting the Gas-Oil-Ratios (GOR) in the location of their respective well indicates that a correlation with depth is not given, whereas highest values can be found in the location close to the major anticlines. Similar clustering can be monitored for

Further, no correlation of GOR and API° with depth can be seen. Still, GOR and API° ranges are very narrow, indicating a homogenous source rock. This is underlined by the histograms of each

The expected correlation of GOR and API° is not given. This could indicate a moderate migration in the middle member, which erased the clear relationship of petroleum maturity (expressed by

Oil Gravity [API°] Bakken Depth Below MS





PHASE KINETIC APPROACH



Using PhaseKinetics the composition of the generated hydrocarbons (HC) at different transformation stages of the Bakken were calculated. Knowing the composition, the phase of the cumulative hydrocarbons under variable pressure-tempera- 48°0'"N ture (PT) conditions could be determined. Based on the burial depth and standard PT gradients the HC in the Bakken should be in an undersaturated phase. Therefore, it would not be possible for a 47°0' fractionated gas phase to migrate individually. Further, the cumulative GOR at different transformation ratio could be calculated. These are in agreement with most of the GORs that are found in the areas away from the anticlines.







pecial thanks to the supporting industrial partners indicated in the left bottom



CONCLUSION _

Natural fluid properties (GOR, API°) indicate that structurally influenced areas, such as the main anticlines, contain petroleum compositions that are improbable when assuming a continuous unconventional system. Best explanation for lighter petroleum composition is given by dominance of a late generation phase, i.e. an instantaneous as opposed to a cumulative composition. Early generated hydrocarbons in the areas with structural impact could have been lost, while late stage lighter compositions are still available. It appears that the formation is partially a unconventional formation, closed while areas with structural deformation have characteristics that hint at a conventional petroleum system setup.