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Compositional Grading and Reservoir Oil Composition Variation with Depth Experiment by PVTi Software with Lab Data

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Abstract: ***Heavier molecules tend to migrate towards the bottom of column. Gross assumptions in PVT experiment are that the system is in gravitational and diffusive equilibrium. Starting from an oil and moving up a column, the fluid will become lighter and tend towards a gas (condensate). Two types of grading are possible. The first one is of the fluid going from an oil to a gas with a distinct gas-oil contact at some unique depth. If this situation occurs, it will be predicted. The second one is the Fluid grading from an oil to a gas without a contact. This case corresponds to the critical temperature of a composition within the reservoir equalling the reservoir temperature. In compliance with compositional grading study, the API and some properties of the reservoir oil composition such as sulphur and CO2 contents vary with the reservoir depth. Most of the time the gas-oil contact (GOC) is named as the reservoir datum depth. In this paper, the study of compositional grading and reservoir oil composition variation with depth experiment by PVTi software with lab data has been achieved and some good conclusions have been gained.***

Keywords: ***Compositional Grading, PVTi Software and Lab Data, Gas-Oil Contact (GOC), Datum Depth.***

I. INTRODUCTION

The compositional grading is a phenomenon that could be seen in many of the world hydrocarbon reservoirs. This phenomenon points to the molar variations of oil and gas components in reservoirs in the vertical direction with depth and in some cases in the horizontal direction. Compositional Grading in oil and gas reservoirs proposes examples, and case studies on how to respond the problems of a compositional gradient subject. Once to aid engineers with stronger production curves, reserve assessment, and design of future development strategies, the meticulous study of this phenomenon is compulsory. Multiple case studies are available to show the application of the theory from very simple to more complicated systems, such as actual reservoirs influenced by thermal diffusion and gravity once at a time.

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An example includes a layer where asphaltene deposition happened in the reservoir and three phase flash algorithms for liquid-liquid-vapor equilibrium calculations, detailing the strategies required to ensure convergence. COMPG reservoir output results show a deeper level of detail on the heterogeneity composition and thermo-physical properties of petroleum fluids in the reservoir, methods on how to add the reliability of reservoir simulation, the sense of compositional grading, with coverage on both theory and application. Knowing the primary state of an oil reservoir is critical in order to optimize its development plan. This knowledge depends on a proper description of the spatial distribution of the fluid components. The compositional variations are pivotally because of gravitational segregation and thermo-diffusion phenomena. Usually, an apt assessment of the steady state spatial distribution of the components is gained by thermodynamic modeling on the basis of an EOS. In reservoir simulation, the fluid composition is usually assumed uniform for the entire of reservoir, in the condition that in many reservoirs, oil and gas composition changes with depth. This phenomenon which is known as compositional grading could be very important in heavy oil reservoirs. In these reservoirs, biodegradation and asphaltene precipitation are considered as the main reasons behind this phenomenon. Compositional grading in heavy oil reservoirs could affect fluid viscosity. The reservoir fluid data are gained from both the surface and subsurface samples and the PVT tests and are mainly reported for the entire of reservoir. In many reservoirs, the oil and gas composition changes with depth. Ignoring compositional grading or its wrong anticipation brings about a bad estimation of initial hydrocarbon values and wrong oil recovery predictions in reservoirs. As mentioned, the asphaltene deposition leads to huge variations in oil viscosity. Biodegradation is another factor in the formation of the compositional grading in heavy oil reservoirs. For example, this factor leads to an intensive compositional grading in the Peace River and Athabasca reservoirs in Canada. Another example is the Grosmont reservoir and largest fractured carbonate bitumen reservoir in the world, located in the Alberta state of Canada. Oil viscosity gradient and different API gravity values (5–9) resulted from biodegradation in this reservoir. In this paper, the study of compositional grading and reservoir oil composition variation with depth experiment by PVTi software with lab data has been achieved and some good conclusions have been gained. **[Alizadeh, N.2015]** [1]

II. MATERIALS AND METHODS

The main factors that cause composition variations with depth are as below:

- In the case of the migration of hydrocarbons is not yet ended, time is required for the diffusion and displacement of hydrocarbons.
- Biodegradation in vertical and horizontal directions brings about variations in oil viscosity and API gravity.
- Gravity force segregates the heavier components toward lower parts of reservoir and lighter components toward the upper parts.
- Thermal diffusion drives lighter components toward the lower parts of reservoir in which temperature is higher and heavier components toward the upper parts and lower temperatures.
- Asphaltene deposition in the lower parts of the reservoir during migration causes the different oil types in the pay zones.

III. RESULTS AND DISCUSSION

Gibbs free energy of a component can be related to a change in the log of that component fugacity:

$$dG_i = RTd(\ln f_i) \qquad (i = 1,2,\ldots,N_c) \tag{Eq.1}$$

The change in Gibbs energy can also be related to mole weights.

$$dG_i = M_i gdh \qquad (i = 1,2,\ldots,N_c) \tag{Eq.2}$$

Where g is the gravitational constant. dh is the change in height from a specified reference which will subsequently be denoted with the superscript 0. Integrating gives:

$$\ln f_i = \ln f_i^o + \frac{M_i g}{RT}(h - h^o) \tag{Eq.3}$$

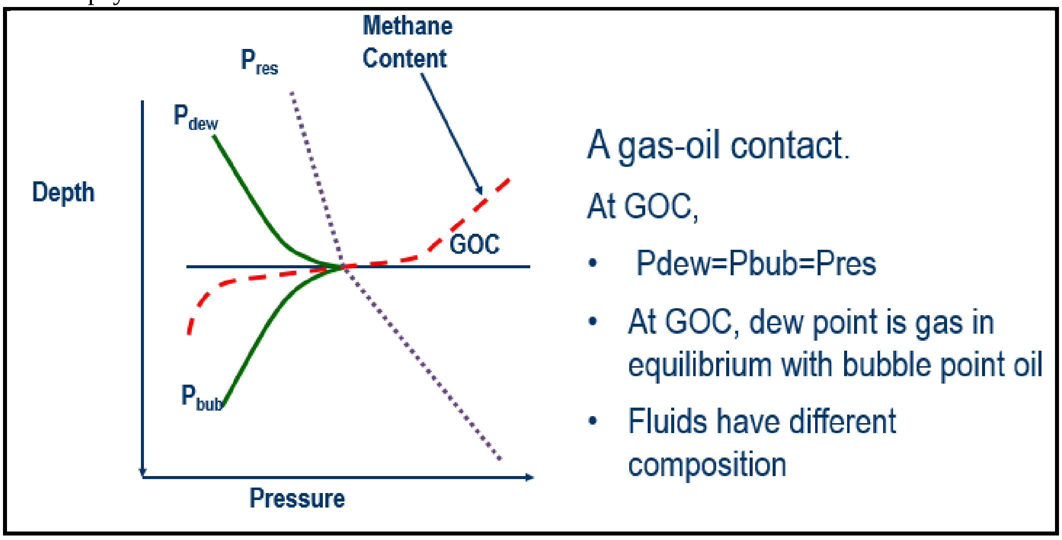

Figure: 1. A Reservoir with sharp GOC [Schlumberger]

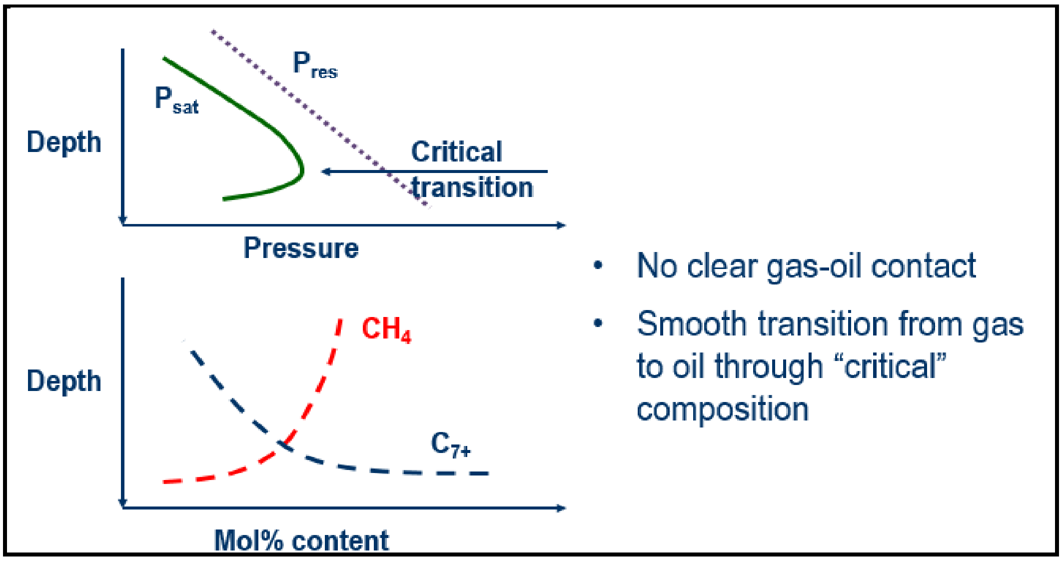

Figure: 2. A Reservoir with no GOC [Schlumberger]

In a miscible WAG process by PVTi software, the following results have been gained:

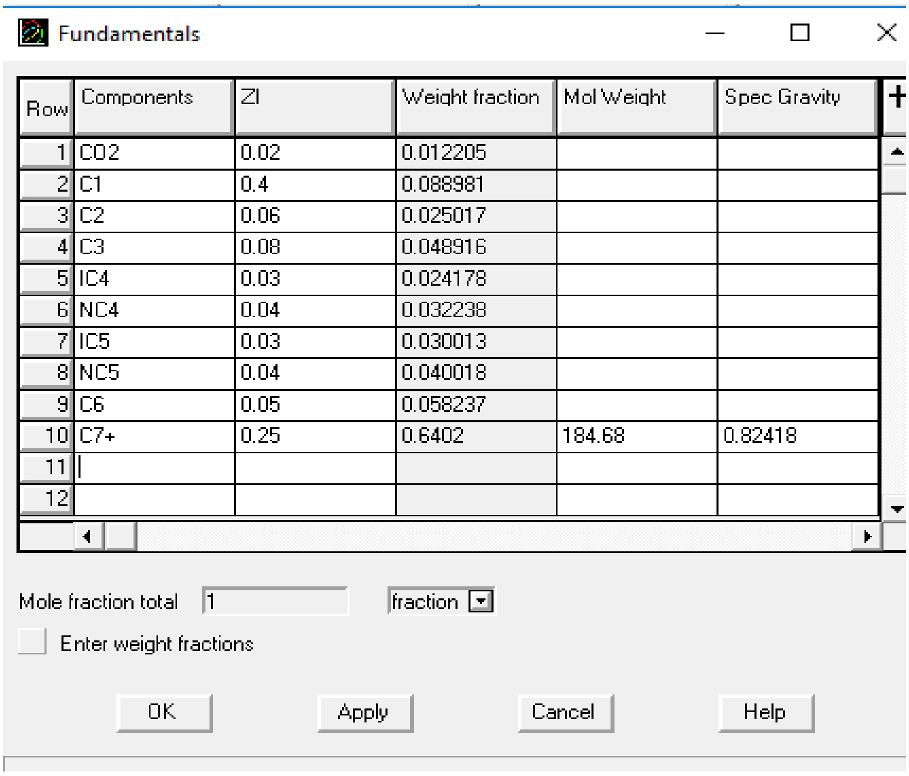

Figure: 3. A reservoir oil sample composition[Schlumberger]

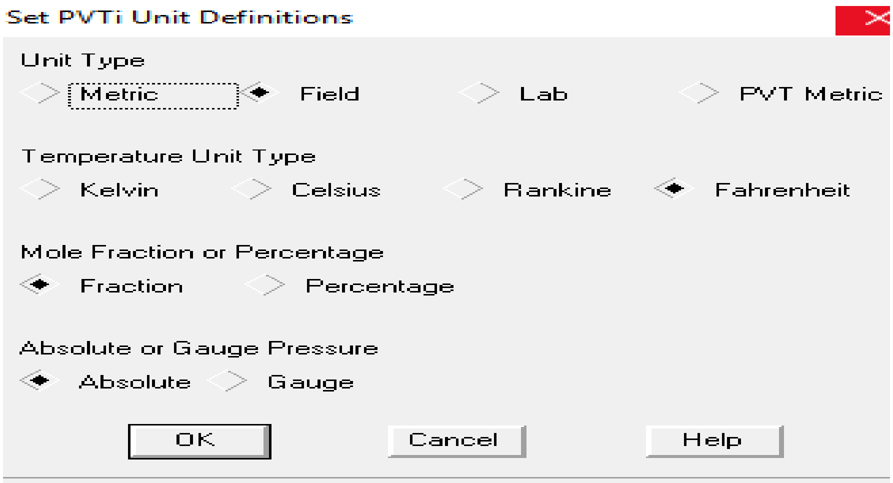

Figure: 4. The reservoir oil sample units

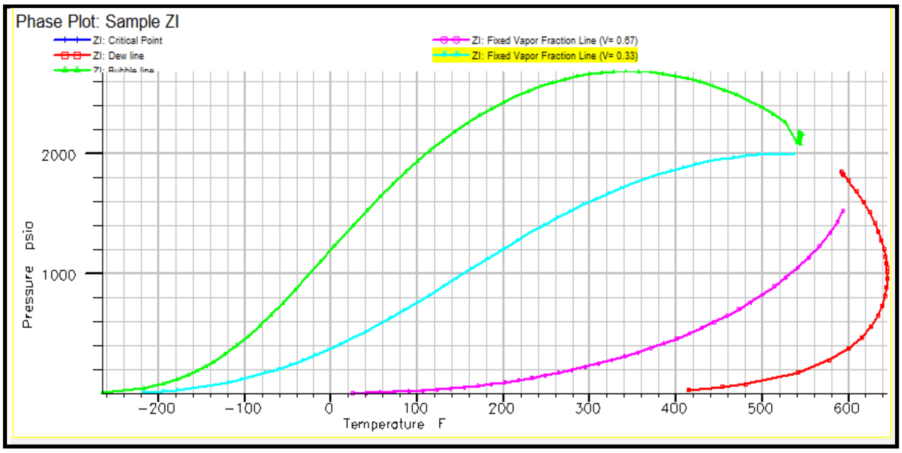

Figure: 5. The reservoir oil sample Phase plot

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Expt BUBBLE1 : Bubble Point Pressure Calculation

Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation

Specified temperature Deg F 200.0000
Calculated bubble point pressure PSIA 2434.3111

Fluid properties		Liquid Calculated	Vapour Calculated
Mole Weight		72.1186	22.9956
Z-factor		0.6841	0.8297
Viscosity		0.1366	0.0197
Density	LB/FT3	36.2502	9.5301
Molar Vol	CF/LB-ML	1.9895	2.4130

Molar Distributions Components Mnemonic	Number	Total, Z Measured	Liquid,X Calculated	Vapour,Y Calculated	K-Values Calculated
CO2	1	0.0200	0.0200	0.0265	1.3267
C1	2	0.4000	0.4000	0.7914	1.9785
C2	3	0.0600	0.0600	0.0614	1.0240
C3	4	0.0800	0.0800	0.0540	0.6754
IC4	5	0.0300	0.0300	0.0147	0.4907
NC4	6	0.0400	0.0400	0.0171	0.4281
IC5	7	0.0300	0.0300	0.0096	0.3193
NC5	8	0.0400	0.0400	0.0116	0.2909
C6	9	0.0500	0.0500	0.0097	0.1948
C7+	10	0.2500	0.2500	0.0038	0.0152
Composition Total		1.0000	1.0000	1.0000	

Figure: 6. The reservoir oil sample bubble point calculations equal to 2434.3111 psia

Expt COMPG1 : Compositional Grading Experiment

Peng-Robinson (3-Parm) on ZI with PR corr.
Lohrenz-Bray-Clark Viscosity Correlation

Reference temperature Deg F 200.0000
Reference pressure PSIA 5000.0000
Reference depth FEET 4000.000

Viscosity units are CPOISE
Pressure units are PSIA
Specific volume units are CF/LB-ML
Density units are LB/FT3

Temperature Gradient Active of deg F/ft 0.2000

Depths FEET	Inserted Point	Pressure Calculated	Psat Calculated	Mole Weight Calculated	Density Calculated
4000.000	- Dref	5000.0000	2434.3111	72.1186	38.6135

Depths FEET	Inserted Point	Viscosity Calculated	Z-Factor Calculated	Specific Vol Calculated
4000.000	- Dref	0.1915	1.3192	1.8677

Molar Distributions Fluid, Z	Inserted Point	Com(1 ,CO2) Calculated	Com(2 ,C1) Calculated	Com(3 ,C2) Calculated	Com(4 ,C3) Calculated
4000.000	- Dref	0.0200	0.4000	0.0600	0.0800

Molar Distributions Fluid, Z	Inserted Point	Com(5 ,IC4) Calculated	Com(6 ,NC4) Calculated	Com(7 ,IC5) Calculated	Com(8 ,NC5) Calculated
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure: 7. The reservoir oil sample Compositional Grading experiment, bubble point =Psat calculations equal to 2434.3111 psia

Note:

In the above table, we conclude in each depth (from top to the reservoir bottom), the density and viscosity and composition of oil varies (increases) that is called compositional grading.

In above calculations and curves, the discussion and results for Compositional Grading experiment have been shown well. The main factors that cause composition variations with depth are as below:

- In the case of the migration of hydrocarbons is not yet ended, time is required for the diffusion and displacement of hydrocarbons.
- Biodegradation in vertical and horizontal directions brings about variations in oil viscosity and API gravity.
- Gravity force segregates the heavier components toward lower parts of reservoir and lighter components toward the upper parts.
- Thermal diffusion drives lighter components toward the lower parts of reservoir in which temperature is higher and heavier components toward the upper parts and lower temperatures.
- Asphaltene deposition in the lower parts of the reservoir during migration causes the different oil types in the pay zones.

IV. CONCLUSIONS

1. In this paper, the study of compositional grading and reservoir oil composition variation with depth experiment by PVTi software with lab data has been achieved and some good conclusions have been gained.
2. In compliance with compositional grading study, the API and some properties of the reservoir oil composition such as sulphur and CO2 contents vary with the reservoir depth. Most of the time the gas-oil contact (GOC) is named as the reservoir datum depth.
3. Given enough time, heavier molecules tend to migrate towards the bottom of column. Gross assumptions in PVT experiment are that the system is in gravitational and diffusive equilibrium. There is no thermal gradient in the column.
4. Two types of grading are possible. The first one is of the fluid going from an oil to a gas with a distinct gas-oil contact at some unique depth. If this situation occurs, it will be predicted by PVTi. The second one is the Fluid grading from an oil to a gas without a contact. This case corresponds to the critical temperature of a composition within the reservoir equalling the reservoir temperature. If this process occurs, it too will be predicted by PVTi.
5. The compositional grading is a phenomenon that could be seen in many of the world hydrocarbon reservoirs. This phenomenon points to the molar variations of oil and gas components in reservoirs in the vertical direction with depth and in some cases in the horizontal direction.
6. COMPG reservoir output results show a deeper level of detail on the heterogeneity composition and thermo-physical properties of petroleum fluids in the reservoir, methods on how to add the reliability of reservoir simulation, the sense of compositional grading, with coverage on both theory and application. Knowing the primary state of an oil reservoir is critical in order to optimize its development plan. This knowledge depends on a proper description of the spatial distribution of the fluid components. The compositional variations are pivotally because of gravitational segregation and thermo-diffusion phenomena.
7. In the paper calculations and curves, the discussion and results for Compositional Grading experiment have been shown well.

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Authors Contributions	All authors having equal contribution for this article.

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PERFORM, Prosper. Petrel.

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