[PS]Three-Phase Darcy Migration in Basin Modeling*

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Abstract

The understanding of hydrocarbon fluids generation and migration within sedimentary basins is one of the main purposes of basin modeling. For relevant pressure and temperature conditions of sedimentary basins, the hydrocarbon fluids can exist in two different thermodynamic states: liquid and gas. Until nowadays, the Darcy hydrocarbon migration in TemisFlow[TM] simulator, is modeled by a two-phase flow thermodynamic scheme: an aqueous phase and a single hydrocarbon phase, whose properties result from the lumping of a mixture of the hydrocarbon components. Once the migration calculation is done, the properties of each phase are determined by thermodynamic calculations in post-processing. However, to take into account complex phenomena occurring along the migration pathway, such as appearance/disappearance of one phase, difference of migration velocity between liquid and gas phases, or the potential dissolution of some components in water/hydrocarbon phases, the three phases (aqueous phase, liquid hydrocarbon, gas hydrocarbon) flow modeling is mandatory. The modeling of such coupled thermodynamic and migration phenomena remains an important challenge at basin scales, often related to thermodynamic flash convergence criteria, which increases drastically the simulation time with the number of components. To face this issue, a new approach is proposed by using several hypotheses to manage the thermodynamic model with care of ensuring accuracy on phases exchange and numerical performance of the computations.

The determination of phase equilibrium has been optimized by being performed on a pre-processing step. So, during the migration process, appropriate phase properties such as liquid-gas equilibrium constants or components density/viscosity are interpolated from the tabulated values as a function of pressure, temperature and global composition. The computation of the phases composition is thus eased and the coupling with fluid displacement calculation speeded up. The results obtained on models inspired from real basins show that a three-phase flow migration scheme can be simulated at the basin time and size scales with manageable simulation time. It can improve the precision of the structural traps load history, especially in petroleum systems where gas presence plays an important role, such as methane or acid gases dominant reservoirs.

Three-phase Darcy migration in basin modeling

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1. Introduction

The understanding of hydrocarbon fluids generation and migration within sedimentary basins is one of the main purposes of basin modeling. For relevant pressure and temperature conditions of sedimentary basins, the hydrocarbon fluids can exist in two different thermodynamic states: liquid and gas. Until nowadays, the Darcy migration in TemisFlow™ is modeled by a two-phase flow thermodynamic scheme: an aqueous phase and a single hydrocarbon phase. However this methodology does not allow to account for the difference of migration velocity between gas and liquid phases.

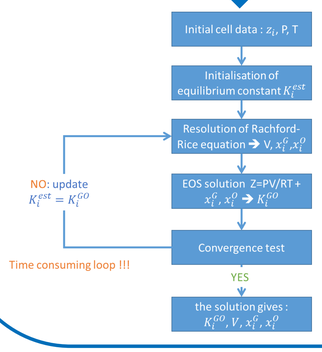
A new approach is proposed to model a real three-phase flow with the care of ensuring accuracy of phases exchange and numerical performance of the computations. This new approach will be presented in this poster with an application to a real case.

2. Workflow

The resolution of three-phase flow is a classical problem, particularly in geosciences. Consequently, there are two main methodologies to solve the problems related to thermodynamic equilibrium:

1. Solving an Equation of State in each cell, at each timestep of the calculation
   - **+** It gives the most accurate results because it accounts for variations against T, P and compositions
   - **-** But it is the most time consuming because of the necessity of solving a loop

Classical algorithm of resolution



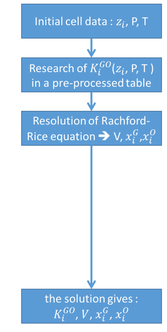
2. Tabulating equilibrium constants (K_i^{GO} and K_i^{GW}) as a function of P and T
   - **+** It allows faster computation
   - **-** But it gives less precise results in particular when HC composition changes
   - **-** Needs a pre-processing to generate tables

Based of these observations, the idea is:

+ To generate K_i^{GO} and K_i^{GW} tables as a function of P, T and composition with a pre-processing tool in basin representative conditions

+ To read, when needed, K_i values in huge tables, avoiding the solve of iteration loop

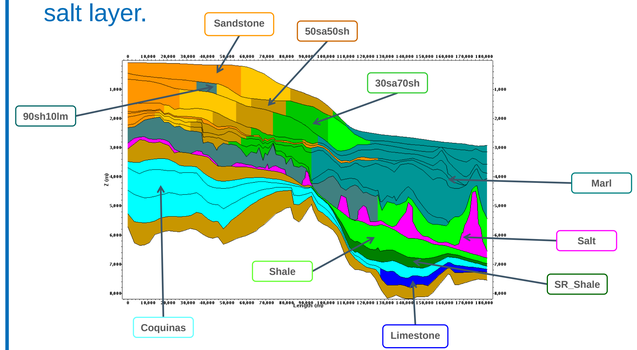
New algorithm of resolution



3. Case study

The case presented as an application for our new approach is a 2D section of Campos basin, Which is located in Brazil.

The lithofacies distribution and present day geometry of the studied section shows that the source rock is located in SR_Shale, underneath a salt layer.



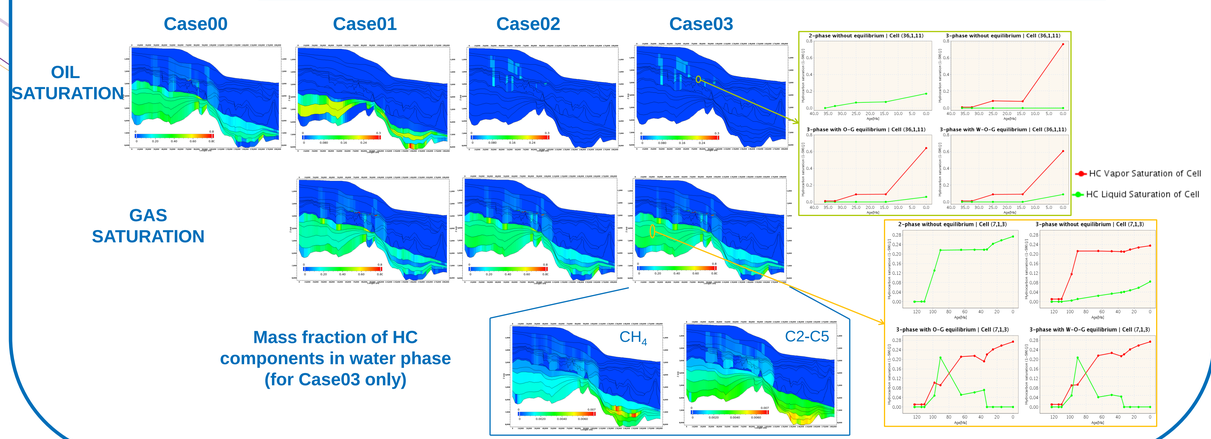
The hydrocarbon part of the studied fluid is composed with CH_4, C2-C5 and C6+.

The goal of this work is to estimate whether the account for 3-phase flow and equilibrium modeling improves the accuracy of oil and gas migration.

4. Results

On the same 2D section, 4 different scenarios with an increasing thermodynamic complexity have been performed. In the following table there is the allowed distribution of each component in each phase for the four scenarios:

	WATER	OIL	GAS
Case00: 2-phase without equilibrium	H_2O	CH_4, C2-C5, C6+	
Case01: 3-phase without equilibrium	H_2O	C6+	CH_4, C2-C5
Case02: 3-phase with O-G equilibrium	H_2O	CH_4, C2-C5, C6+	CH_4, C2-C5, C6+
Case03: 3-phase with W-O-G equilibrium	H_2O, CH_4, C2-C5	CH_4, C2-C5, C6+	CH_4, C2-C5, C6+



5. Conclusions

This study shows that it is possible to perform 3-phase flow modeling at basin scale thanks to an original approach that allows to manage O-G and G-W equilibrium in pre-processing. In this way the calculations allows to account for hydrocarbon accumulations that are not observed with a 2-phase simulation.

However, it remains some difficulties in particular regarding the phase identification in monophasic areas. The future developments are dedicated to improve the phase identification and to a more accurate description of triphasic properties. Moreover an important work will be lead to continue to optimize the algorithm.