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Genetic-Like Modelling of Hydrothermal Dolomite Reservoir Constrained by Dynamic Data

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Abstract
Description

Reliability of long-term production forecasts issued from reservoir simulations is strongly dependent on the quality of reservoir models on which fluid flows simulations are run. In carbonate reservoirs, the usual difficulty for building reliable models is emphasized by the natural complexity of the reservoirs : biological aspects of sedimentation make very complex the reservoir architecture, which is usually overprint by early or late diagenesis and/or fracturing. High perm streaks, as well as cemented barriers, that control well productivity and stability of displacement front during production, are usually the result of such diagenetic overprint. Ignoring these geological features while constructing reservoir models may lead to deliver models unable to match actual production history and to carry out reliable production forecast.

It is why, among all the challenging issues that exist in carbonate reservoir modelling domain, three of the main ones are related to :

1. the ability to distribute in 3D, for the whole reservoir, the diagenetic features observed through well data,
2. the management, during the modelling process, of multi-stages diagenesis which makes the reservoir architecture extremely complex with nested structures,
3. the possibility to drive the reservoir modelling by results coming from dynamic data, in order to simplify the history matching stage during fluid flow reservoir simulation.

This paper presents a new and very innovative methodology for meeting those three needs while modelling complex carbonate reservoirs affected by fluid-rock interactions.

Application

The methodology consists in a genetic-like simulation of the fluid-rock interaction and its effects on reservoir properties :

1. Starting from a geological model in which all the heterogeneity from depositional pattern, early diagenesis, and fracturing is already input,
2. A simulation is run to reproduce the evolution of the original reservoir properties during the diagenesis stage.
3. The method consists in a 4D simulation, the reservoir being progressively modified by the circulation of mineralised or aggressive water.
4. At any time-step of the simulation, the interaction between the fluid and the rock is represented through a mathematical function which modifies the probability for fluid displacement at the next time-step.
5. The fluid displacement is driven by both reservoir properties at time of displacement, and by any gradient provided by the geological concept.

6. Facies can react with fluid in a heterogeneous way, and fluid itself can lose or win power of agressivity on rock during the simulation.
7. Nature of fluid-rock interaction, fluid gradient, or any geological parameter may change after a given stage of diagenesis for simulating a following stage.
8. Objective functions are input for some of the reservoir properties, at local, regional, or field scale. Until target values are not reached, simulation goes on and the reservoir is modified. If dynamic properties are input in the objective function, the resulting model of the simulation should consist in an image of the reservoir easily history matched during fluid flow simulation.

Results & Conclusions

This new methodology was applied on a reservoir in which hydrothermal dolomite (HTD) has been identified. In that field, dolomitisation resulting from hydrothermal water circulation is systematically associated with faults and fractures. However, very thin layer can have been affected by fluids diverted in stratigraphic layers while moving up in the fault network. Effects on reservoir properties are locally considerable, reservoir permeability can be multiplied by 1000 after dolomite has replaced original limestone. Reservoir permeability at large scale is documented through well tests and interference tests. These data have helped to constrain the development of dolomite in the reservoir during the simulation.

The evolution of the effects of fluid-rock interaction in the 4D space are really impressive and help to understand the extreme heterogeneity of reservoir properties. As a movie, the displacement of dolomitisation front in the fracture network, and the diversion in some stratigraphic layers, help geologists and reservoir engineers to identify zones with potentially high values of well productivity indexes, as well as zones of high risk for early and unexpected water breakthrough.

Significance of Subject Matter

The efficiency of this innovative approach has also been demonstrated in other types of fluid-rock interaction (meteoric dissolution, mixed water) and it offers a great interest for all carbonate reservoirs in which late diagenesis drives reservoir properties.