Towards coupled simulations on unstructured meshes for CO2 geological storage

# Margaux Raguenel¹,\*, Jeanne Pellerin¹, Pierre Samier¹ and Gilles Darche¹

1 TotalEnergies

\*margaux.raguenel@totalenergies.com

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Modelling the subsurface in the frame of underground CO2 storage implies the simulation of fluid flows and geomechanical effects within geological layers. Solving the equations governing multiphase flows and geomechanical effects involves the generation of a mesh that faithfully represents the structure of the porous medium and adapts to the subsurface heterogeneities. This challenging mesh generation task is greatly simplified using unstructured meshes that conform to the complex geometric features of the subsurface (geological structures, well geometries). This mesh can then be the support for coupled simulations tackling both problems on the same mesh.

However, running a million-cell flow simulation problem on an unstructured mesh for a real, faulted geological field case remains a challenge for two main reasons. First, the operational simulation workflow is developed for structured meshes and must be adapted to the unstructured case. Second, unstructured meshes do not satisfy the K-orthogonality property, and advanced numerical schemes preserving result accuracy and reducing potential mesh orientation effects are needed [1]. These two challenges are at the center of the present paper.

This work presents the global workflow built to manage large-scale flow and geomechanical simulations in subsurface reservoir using unstructured meshes. Then, it illustrates the application of this workflow focused on fluid flow simulations for various cases (synthetic box, real field case with complex well patterns, real field case with faults). We consider several types of meshes: 2.5 D Voronoï, 3D tetrahedral, 3D hex-dominant, with the classical corner-point structured mesh as a reference. Through these examples, we also compare several types of discretization schemes used to manage the inter-cell flows in unstructured meshes: Two-Point and Multi-Point Flux Approximation (respectively, TPFA and MPFA) schemes, the cell- and vertex-centered Vertex Approximate Gradient (VAG) scheme, and the cell- and face-centered hybrid Mimetic Finite Difference (MFD) scheme. When possible, the results will be compared in terms of accuracy, robustness, and computational cost.

**REFERENCES**

[1] K.-A. Lie, *An Introduction to Reservoir Simulation Using MATLAB/GNU Octave: User Guide for the MATLAB Reservoir Simulation Toolbox (MRST)*. Cambridge University Press, 2019.