PHASE FIELD MODEL FOR THE NUMERICAL SIMULATION OF SALT DIAPIRS EVOLUTION

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ABSTRACT: Salt is mechanically weak and may flow like a fluid. The term salt will be used here as a generic name for rock bodies composed essentially by halite. The formation of salt diapirs plays a major role in the evolution of geological structures in the Earth's crust. Geologists and reservoir engineers have devoted great effort to qualitatively and quantitatively understand this phenomenon that has a strong impact in oil and gas exploitation offshore Brazil, specifically in the so-called pre-salt layer. Usually the main driven force arises from buoyancy, since the salt is lighter than the overburdening sedimentary material. Thus, the diapiric growth may be recast within Rayleigh-Taylor theory, describing the evolution of the gravity instability among fluids or media layers. The typical geological time scale of the diapiric growth is of the order of millions years. As an example, offshore Brazil, it's assumed that salt diapirism started around 112 My (million years) and ended near 65 My ago, a total duration around 50 My. Diapirism evolving can be simulated using Lagrangian or Eulerian mechanics. We prefer a fully Eulerian approach, where salt and overburden evolution are treated as viscous fluids and a marker function is used to track the interface between them. Instead of the classical volume of fluid (VOF) and level-set (LS) methods to deal with the evolving interface, the phase field model considers a different approach to this problem. The phase field model assumes a (thin) diffuse transition region where the interface is specified by a scalar variable (the phase field, ϕ) in the range $\phi(\mathbf{x},t)=[-1,1]$. Thus, a continuous transition zone among phases is introduced, defined by this additional field variable describing the evolution and shape of the interface implicitly obtained where $\phi(\mathbf{x},t)=0$. The interface is then represented by a slim layer with continuously varying properties. In this work, we applied the residual-based Allen-Cahn phase field model to numerically simulate diapir motion. The phase field model is able to track the interface between the two media as well to minimize volume losses. The numerical formulation includes mesh adaptivity, which aims to better resolve the interface between different layers. Due the materials high viscosity, the incompressible Navier-Stokes equations are reduced to the Stokes problem coupled with the transport of the phase field scalar. It is assumed that the rheology of salt and surrounding rocks in geological time scale behaves as Newtonian fluids. The implementation has been performed using the *libMesh* finite element open source library, which provides support for adaptive mesh refinement and coarsening (AMR/C) and parallel computations. We applied the model to numerical simulate a two layer problem in a 2D geometric domain. The salt layer is completely covered by a heavier material. In the center of the horizontal domain we create a small geometric perturbation over the salt top. Parallel adaptive simulations for the two-layer system show the effectiveness of the present approach. Future works include consideration of temperature effects and more complex rheology and geometries.

KEY-WORDS: Salt Tectonics, Finite Element Method, Mesh Refinement.