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HYBRID COMPUTATIONAL METHODS IN THE MECHANICS OF COMPLEX NATURAL SYSTEMS

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ABSTRACT

Any arrangement of things composed, at least, by two interactive parts to form a whole unit, is a complex system. The parts of the unity interact with each other in such a way that the separated understanding of the functioning of each part does not guarantee the understanding of the entire system[1, 2, 4]. On the other hand, a characteristic feature of simple systems is that one single cause implies a single effect. The complex system acts as a whole and is not possible to understand its global behavior without considering the interactions among all its parts and between the system and its environment. The human body and the planet Earth, as a geothermal entity, are highly complex systems. The solar set with the sun and its planets, the biological organisms, the geophysical and geological processes of reservoirs containing water, energy, oil, gas or minerals are other types of complex systems. To illustrate several aspects of a concrete natural complex system, the main mechanisms of a submarine geothermal reservoir are described and simulated. The models show the fundamental equations and discuss the diverse problems and aspects of the numerical representation of these systems.

Geothermal reservoirs contain essentially an infinite energy potential. Deep submarine energy manifestations are related to hydrothermal vents emerging in many places along the oceanic spreading centers between tectonic plates. These systems have a total length of about 65,000 km in the oceanic crust. Hydrothermal circulation at the ridges of the deep sea is a fundamental complex process controlling mass and energy transfer from the interior of the Earth through the oceanic lithosphere, to the hydrosphere and to the biosphere. Seafloor hydrothermal circulation is the principal agent of energy and mass transfer from the Earth's crust to the ocean and one of the primary modes of interaction between the solid earth and the ocean/ atmosphere system. The fluid discharged from seafloor geothermal reservoirs cools the submarine hot rock, builds mineral deposits, modifies seawater circulation patterns, supports strange biological communities, and influences oceanic chemistry and biology[3]. Complexity emerges because of the interaction among the basic elements composing these reservoirs. This complexity also produces the emergence of collective phenomena by self-organized mechanisms[1, 5].

Submarine hydrothermal interactions influence the composition of the oceanic crust and the chemistry of the oceans. The fluid circulating in seafloor hydrothermal systems is chemically altered due to processes occurrig in its passage through the oceanic crust at elevated temperatures and pressures. The heated seawater containing H_2S is ejected upward through hydrothermal vents. This mechanism produces hydrothermal vent fields which support diverse and unique biological communities starting from microbial populations. These organisms are living at depths where there is neither sun energy nor sunlight for photosynthesis. Chemosynthetic bacteria use the hydrogen sulfide as a metabolic source of energy and form food for clams, mussels and worms. In this way, submarine geothermal energy becomes the basis of rich food chains at places where photosynthesis is impossible. Convective circulation of seawater through oceanic crust at mid-ocean ridges has also important effects on the heat transport, on the chemical and isotopic compositions of ocean crust and seawater, on the mineralization of the crust and on the physical properties of oceanic basement. The eventual transfer of some gases input by hydrothermal activity from the ocean to the atmosphere, extend the influence of hydrothermal activity to beyond the oceans themselves.

The understanding of mass and energy flows among all these complex subsystems requires the development of integrated models that include the interactions between them. In this research work some of the main multiphysics aspects are presented: the simultaneous flow of mass and heat coming from natural chimneys situated in the Gulf of California, Mexico. The thermal potential of this region is around 1120 MW_T /km^3, at an average temperature of 350°C. The few available data on hydrothermal vents are very useful to calculate the amount of energy flowing from the ocean floor. An analytical model is developed to estimate the amount of heat which outflows the chimney. To estimate the natural state of these reservoirs the classical Boundary Element Method (BEM) is used. The field main functions are pressure and temperature. The BEM relates boundary data and boundary integral equations to the internal points of the solution domain in a very effective and accurate way. This is a suitable method to quickly estimate several possible initial states of reservoirs with few data. The results are easily coupled to Finite Element Methods when more data are available. Using this hybrid technique and knowing only heat fluxes and temperatures at chimneys, results of different boundary conditions and several thermodynamic reservoir initial states are obtained. The poroelastic deformation of the oceanic floor is also discussed.

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