Review of modeling and simulation of natural nuclear reactors

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Abstract: The present work intend to share the up-to-date modeling and simulation performed to explain the criticality occurrence in natural nuclear systems. Such systems were ignited 2 billion years ago, in the Oklo Uranium deposit, in Gabon (West Africa). The studied system is modelled by taking into account the geological context. The simulations were carried out with a Monte-carlo based code, known as MCNP; widely used for neutron physics and nuclear reactors calculation. By looking for the criticality conditions we resolved the following equation :

$$k_{eff}(V_{UO2}, \phi_{TOT}, e, R, t_{B10}) = 1 \tag{1}$$

with: V_{UO2}: volume fraction of uraninite, ϕ_{TOT}: totally saturated ore porosity, e, R: geometrical dimensions, t_{B10}: Boron-10 equivalent content.

Numerical simulations carried out with MCNP, generated a set of critical solutions as a parametrical curves, called Isocritical lines. Each point from such a line represent a possible natural critical configuration, given in correpsonding conditions of Oklo case. An isocritical line represent an interface in space parameters, separating a barren space (subcritical system) from fissile space (critical and supercritical systems). Although, any evolving natural nuclear reactor should at least reach the criticality line to start a dynamic which lead it to a new geological and physical state: Fuel burn-up, mineral alteration of the container ore, transmutation, fission products accumulation, etc...

Detailed techniques used to model and simulate such systems are given in previous works [1].

Keywords: Oklo, Modeling and Simulation, MCNP, Monte-Carlo, Uranium, Natural Reactors

References

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