Probabilistic characterization of subsurface stratigraphic configuration with modified random field approach

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Abstract

The geological model is indispensable in geotechnical engineering, petroleum, or mining engineering project. Due to budget constraints, it has insufficient drilling boreholes to interpret for some places to which have complicated stratigraphy, lead to the availability of borehole data is limited. Hence, the stratigraphic and geo-properties uncertainties are poorly understood. Interestingly, the probabilistic modeling approaches based on the coupled Markov chain (CMC) & stochastic Markov random field can solve this problem. However, it depends on the engineer's experience. To solve that problem, in this study, the author proposed a new method that has many advantages for characterization of the subsurface stratigraphic configuration with limited borehole data with modified random field approach. A new method has proposed via three steps: first, the initial subsurface stratigraphic configurations were sampled with the conditional random field theory. Second, the maximum likelihood method was applied to the spatial correlations of the existence of the strata from the borehole data. Third, the initial stratigraphic configurations are further updated by using Markov Chain Monte Carlo (MCMC) method, so the maximum-a-posteriori (MAP) estimates of the initial stratigraphic configurations can be collected. The paper has given a modified approach to overcome the limitations of the existing random field-based approach. As the evidences, the 2D and 3D models successfully illustrated the subsurface stratigraphic configuration and its uncertainty of Western Australia and some others places. The results are more consistent with the stratigraphic dips and the strata boundaries are smoother than the old method. In general, this study contributes the literature on stratigraphic uncertainty characterization and provides a basis for a risk-based geotechnical assessment that considers geological and geotechnical uncertainties.

Keywords: Stratigraphic uncertainty, Conditional random field, Markov Chain Monte Carlo.

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ABSTRACT

Accurate and precise characterization of the subsurface stratigraphic configuration (geological model) at a given site is crucial to geotechnical engineering work. The uncertainty in the derived stratigraphic configuration can be significant, due to the strata's complexity and inherent spatial variability coupled with the limited availability of borehole data. The characterization and reduction of this uncertainty should be part of any site characterization project. This paper presents a method for characterization of the subsurface stratigraphic configuration with limited borehole data. Within the framework of the proposed method, the spatial correlation between the existence of a stratum in one subsurface zone and that in the other subsurface zone (or the spatial correlation of the existence of the stratum) is captured by an autocorrelation function determined with the maximum likelihood principle. The initial stratigraphic configurations are first sampled with the conditional random field theory. Next, the maximum-a-posteriori (MAP) estimates of the initial stratigraphic configurations are derived using Markov Chain Monte Carlo (MCMC) and taken as the final stratigraphic realizations. The effectiveness of the proposed method and its advantages over the existing stratigraphic characterization methods are demonstrated through a series of comparative analyses. The versatility of the new approach in modeling the 3-D stratigraphic configuration is further revealed through a case study of a site in Western Australia. This paper adds to the literature on stratigraphic uncertainty characterization and provides a basis for a risk-based geotechnical assessment that considers geological and geotechnical uncertainties.