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Geologic Risking with Bayesian Methods: Fracture Case Study in an Unconventional Setting

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ABSTRACT

The prediction of geologic parameters in the early stages of exploration is challenging due to limited data. Geoscientists need to provide early guidance for well planning and resource evaluation, even though uncertainties are likely to be large. As new data are acquired, scenarios for subsurface geology evolve, requiring time-consuming updates to models and simulations. To address these challenges, we present a machine learning method to predict first-order geologic factors on regional scales. The method is illustrated using an application to predict the likelihood of natural fractures in an unconventional setting. A Bayesian belief network with nodes linked to map-based inputs is used to represent the influence of geologic variables on fracture generation over geologic time. Factors such as proximity to faults, burial and thermal histories, mechanical heterogeneity and pore pressure are included. These inputs influence other factors in the network (nodes) that combine to predict a probability distribution for five fracture likelihood classes. Further nodes serve as “symptoms” of fractures and can be used for validation. The node states of the Bayes net can be defined by data, interpretations or expert judgment. Expert judgment, in this case, refers to the selection of geologic characteristics guided by knowledge and experience of geoscience experts. Rock-property data could be used to define the rock-stiffness node state as a single class (e.g., low or high stiffness) or as a distribution representing the likelihood of each of three possible classes. If rock property data were missing, an expert could define the node state based on knowledge of rock stiffness from a geologic analog. Initial predictions from the case study provide a map of the likelihood of fractures over a play-scale region. With this method, early insights can be achieved with limited data. As more data are acquired, the prediction is likely to improve. The way that new information impacts predictions and decisions, such as well planning, can also be quantified. In this example, the fracture likelihood predicted from the Bayesian network correlates well with production rate data. The speed and flexibility of the overall method permit rapid testing of sensitivities to different geologic assumptions. Importantly, the process of constructing a Bayesian belief network promotes a cross-disciplinary discussion surrounding geologic uncertainties and the data needed to reduce them.