Numerical modeling of oil shale geomechanical behavior during ExxonMobil's in situ oil shale conversion process

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ExxonMobil is developing its in situ oil shale technology for subsurface conversion of oil shale to producible oil and gas. Oil shale is heated by an in situ planar heater filled with an electrically conductive material. Electricity is conducted from one end of the heating element to the other. The heat converts kerogen in the oil shale to oil and gas, which is then produced by conventional wells. The oil shale exhibits characteristic geomechanical behavior during in situ conversion process. The behavior is dictated by a combination of 1) spatial and temporal temperature variation that may build thermal stress, 2) fluid generation that may increase pore pressure and cause the rock to expand, and 3) rock geomechanical property variation, which strongly depends on temperature and chemical reaction extent. To model this unique process, a coupled simulator was developed. It integrates CMG STARS, a commercial thermal reservoir simulation code accounting for heat transfer, fluid flow, and chemical reaction, and ABAQUS, a finite element code for simulating plastic geomechanical behaviour of oil shale. The geomechanical part of the coupled simulator accounts for a variety of plastic failure modes including tensile failure, shear failure and pore space compaction, which jointly govern the rock deformation during the conversion process. The model utilizes experimental data from literature and lab characterization based on oil shale cores. As an application of the developed tool, the simulator was used to predict the heave and subsidence of overburden during a commercial-scale in situ conversion process for a wide range of cold pillar sizes. The results provide insight into balance between subsidence mitigation and resource recovery. The model was also used to calculate geomechanical strain on production wells, which may be used to guide well placement.