Processes for in-situ extraction of usable liquid or gaseous hydrocarbon products from kerogen-rich formations generally require aggressive thermal exposure. Operationally, there are geomechanics issues associated with such in-situ activities. At high temperature, the impact of confining pressure on compressive strength may become rather erratic. With increasing temperature, kerogen becomes much softer than the matrix minerals. When the organic matter is heated to temperatures above 450°C, about 90% of the organic volume is no longer solid. Lean oil shales - due to the high volume of minerals - can maintain their structure. In contrast, rich oil shales lose much of their strength when the organic matter is decomposed. After thermally-accelerated yield, permeability reduces substantially due to additional compressive strain. The time for the permeability to degrade depends on the compressive stress, the richness of the oil shale and the heating rate (Tisot, 1970).

During thermal treatment one expects expansion associated with the heating schedule, potential heaving of surrounding and overlying material, modification of permeability and porosity with changes in the kerogen and mechanical deformation associated with changes in the pore-filling material and phase. With the exception of several key legacy publications and ongoing proprietary measurements the thermo-mechanical response of representative oil shale is speculative.

1. Porosity And Permeability
   For example, in-situ thermal processes use high temperature to decompose kerogen. The consequence is generation of liquid and gaseous products. Much of the porosity available can be envisioned to be created by the consequent phase/compositional changes. This porosity may be accompanied by at least a temporary increase in permeability (Eseme, 2007).

   Thomas (1966) demonstrated an increase in porosity and permeability with retorting temperatures (up to 1000°F) for a constant confining pressure of 1000 psi. In addition, at a given temperature, porosity and permeability increased with hydrocarbon yield, in agreement with intuition. Shale oil began to evolve at 700°F from an unstressed shale. When the applied stresses were 2000 and 2500 psi, the minimum retorting temperatures for oil production were 630° and 605°F, respectively. This suggests that above confining pressures of 1000 psi, the minimum temperature required to create pore structure decreases as the overburden pressure increases. This, of course is based on a restricted number of tests.

2. Compressive And Tensile Strengths
   With conversion of kerogen, creation of porosity and potentially permeability via microfracturing and interconnection of voids is anticipated – at least on a temporary basis. One also anticipates a reduction in strength with increasing temperature and increased deformation even at relatively modest temperatures. Plastic deformation of kerogen will likely be accompanied by generation and expulsion of petroleum, associated with elevated pressures in the pores. Tisot, and Sohns (1970) experimentally found that both compressive and tensile strengths of oil shale decrease significantly with temperature. Mechanical resistance also decrease with richness at a given temperature. The constitutive behavior is extremely complex and representing the temporal behavior of an evolving solid as a temperature sequence is applied is a research goal.

3. Thermal Properties
   Thermal properties are also important for numerical representations and design of pilot programs. Thermal conductivity and specific heat have been determined on a limited sample basis (Thomas, 1966; Dubow, 1980). However, the in situ coefficient of thermal expansion is crucial for assessing the generation of thermally-related stresses and there is little available public domain information on this property.

References


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Figure 1 is a machine drawing.
Figure 2 is photograph of the vessel during an acceptance test at an internal pressure of 2000 psi.

The apparatus will accommodate samples up to 4 inches in diameter and 8 inches long. The geologic environment is simulated by applying axial stress with a 200 ton hydraulic actuator reacting against the upper end cap, and radial confining pressure (pneumatic pressure to 1500 psi; typical liquid confining fluid will settle down at the temperatures to be simulated). Heating to 1000°F is accomplished by electrical clam shell heaters positioned around the oil shale sample. Increasing temperature will transform kerogen in the samples into liquid and gaseous products which are captured and quantified outside of the pressure vessel. Force, stress and deformation are recorded. Nitrogen gas will be used to sweep pyrolysis products through the sample axially and allow for measuring the permeability. These pyrolysis products will be collected, condensed and evaluated outside of the vessel in real time. The permeability measurements will be carried out to assess the evolution or degradation of transport and mechanical properties.