

emphasized the importance of studying permeability trends related to the fracture pattern to determine if grouting curtains are needed and what their design might be to most effectively stabilize the rock mass. He also points out, as does Jumikis (1966) and Secor (1965) that the hydraulic pressure within the fractures influences the behavior of the rock mass just as it does in the pores of the coherent rock sample. Jumikis mentions that noncommunicating ground water pressure can be higher than the normal hydrostatic head and cause lifting up and breaking off of shale slabs. The noncommunication is sometimes caused by clay-fillings in the macrofractures and by local faults which act as barriers. The need for proper drainage should be recognized.

An illustration of the importance of water pressure in macrofractures is afforded by accounts of earthquake activity near Denver, Colorado, which was presumably stimulated by pressure injection of waste water in a disposal well (Evans, 1966; and Bardwell, 1966). The well is bottomed in fractured Precambrian gneiss at a total depth of 12,045 feet. Since the fluid injection began, 710 earthquakes have been recorded (magnitude range: 0.7 to 4.3 on the Richter scale), which have epicenters within a 5 mile radius of the well. The statistical correlation between volume and pressure of the fluid injection and the seismic activity is most convincing. Evans suggests that the rock movements are due to the increase of fluid pressure within the macrofractures. Other interesting aspects of this situation are (1) the suggestion that the rock mass appears to be in a rather delicate state of rest such that fluid injected at wellhead pressures up to 1050 psi cause the rock movements; (2) there is evidence that the displacements causing the seismic activity are occurring along a plane (fault) that dips eastward and passes beneath the disposal well at a depth of 6.5 miles (Wang, 1965); and (3) that macrofractures open to fluids can exist to a depth of at least 12,050 feet and, if point (2) is valid, to as much as 6.5 miles!