A process to identify world-class research for a Deep Underground Science and Engineering Laboratory (DUSEL) in the USA has been initiated by NSF. While allowing physicists to study, inter alia, dark matter and dark energy, this laboratory will create unprecedented opportunities for biologists to study deep life, geoscientists to study crustal processes and geoengineers to study the behavior of rock, fluids and underground cavities at depth, on time scales of decades. A substantial portion of the nation’s future infrastructure is likely to be sited underground because of energy costs, urban crowding and vulnerability of critical surface facilities. Economic and safe development of subsurface space will require an improved ability to engineer the geologic environment. Because of the prevalence of sedimentary rock in the upper continental crust, much of this subterranean infrastructure will be hosted in sedimentary rock.

Sedimentary rocks are fundamentally anisotropic due to lithology and bedding, and to discontinuities ranging from microcracks to faults. Fractures, faults and bedding planes create structural defects and hydraulic pathways over a wide range of scales. Through experimentation, observation and monitoring in a sedimentary rock DUSEL, in conjunction with high performance computational models and visualization tools, we will explore the mechanical and hydraulic characteristics of layered rock. DUSEL will permit long-term experiments on 100 m blocks of rock in situ, accessed via peripheral tunnels. Rock volumes will be loaded to failure and monitored for post-peak behavior. The response of large rock bodies to stress relief-driven, time-dependent strain will be monitored over decades. Large block experiments will be aimed at measurement of fluid flow and particle/colloid transport, in situ mining (incl. mining with microbes), remediation technologies, fracture enhancement for resource extraction and large scale long-term rock mass response to induced stresses – with parallel geophysical imaging of the rock mass (and subsequent verification) flow and transport processes, and time-dependent stress and strain.

An experimental advantage of sedimentary rock is the presence of pervasive mechanical interfaces (bedding planes), which suggest a host of experimental designs on large rock blocks and slabs (induced flexure, shear strength of interfaces, etc). Thus DUSEL will enable fundamental research about the behavior of a layered rock mass – the dominant structural architecture in near-surface environments worldwide. A further benefit is the natural suitability of sedimentary rocks for experiments related to oil and gas production, or to CO_2 sequestration. For example, fluid-induced fracturing of sedimentary rock has long been used by the hydrocarbon industry to improve oil and coal bed methane recovery. Since some fracturing agents are potential contaminants, a major concern and legal responsibility in the US is ensuring the integrity of nearby aquifers. Hydraulic fracturing from a sedimentary rock DUSEL will be followed by injection of low viscosity grout. The rock mass will then be mined back to expose network characteristics of the induced hydraulic fractures. Key questions related to hydrocarbon extraction, CO_2 sequestration, waste isolation, and remediation of subsurface contaminants depend critically on the connectivity and architecture of fractures and on coupled thermal, hydrological, mechanical and chemical processes. Fluid flow, particle transport and reaction transport processes are coupled to the stress across fractures, and to thermal, chemical and hydraulic gradients. All can best be studied via large block tests in a subterranean laboratory, ideally in a sedimentary environment.