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Center for Nanoscale Control of Geologic CO2: A new U.S. Department of Energy Frontier Research Center

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It is becoming increasingly widely recognized that geologic sequestration of CO2, when combined with economical means of capture, may be one of the most effective approaches to reducing net CO2 emissions to the atmosphere over the next century. The U.S Department of Energy (DOE) has developed programs during the past ten years to help prepare the way for large-scale geologic CO2 sequestration. Much of the effort has been in applied research and demonstration projects funded through the Office of Fossil Energy, coordinated through the National Energy Technology Laboratory, and involving a large number of industrial, academic and government partners. The DOE Office of Science, and in particular the Office of Basic Energy Sciences, whose roles include the funding of basic research related to energy technologies, used a series of large workshops over the past six years to develop roadmaps describing the basic research needs for a range of advanced energy technologies, including geologic CO2 sequestration. The workshop reports provided groundwork for a new research program called "Energy Frontier Research Centers," for which a competition was held with proposals due in late 2008 (http://www.sc.doe.gov/bes/EFRC.html). EFRC's are multi-investigator, multi-institution centers designed to carry out focused basic research in areas that support critical energy technologies. Two such centers with a focus on geologic CO2 sequestration were funded out of a total of 46 centers covering the broad range of energy technologies. One of the two CO2 centers is led by the Lawrence Berkeley National Laboratory, in collaboration with Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, U.C. Berkeley, U.C. Davis and MIT. The LBNL-led center has a research focus on the nanoscale processes and characteristics of CO2-brine-rock systems that control the flow and trapping of carbon.

The objective of the Nanoscale CO2 Center is to use new investigative tools, combined with experiments and computational methods, to build a next-generation understanding of molecular-to-pore-scale processes in fluid-rock systems, and to develop an ability to control critical aspects of these processes. The stated goal is to use molecular, nanoscale, and pore-network scale approaches to control flow, dissolution, and precipitation in deep subsurface rock formations to achieve the efficient filling of pore space with injected supercritical CO2, with maximum solubility and mineral trapping and near-zero leakage. Advanced knowledge of these small-scale processes is expected to lead to an improved predictive capability for reactive transport of CO2-rich fluid that is applicable for 100-1000 years into the future.

The research plan of the Center is predicated on the idea that in order to achieve the full potential for subsurface CO2 storage (10 to 40% of the needed reductions in CO2 emissions over the next century; IPCC, 2005), it will be necessary to use as much of the available subsurface pore space in sedimentary formations as possible. This means that, in addition to the use of depleted oil and gas reservoirs, for which considerable characterization has been done and experience exists, it will also be necessary to use a wide range of other sedimentary rock formations, most of which have not been previously characterized, and most of which have pore space filled with salt-rich aqueous fluid (brine) that would be displaced by injected CO2. Hence the Center's research is primarily focused on the processes and properties relating to CO2 in saline formations.

Even after decades of experience, and considerable success in many arenas, it is still the case that we can muster only crude control over subsurface fluids. Improvement in our ability to control, monitor, and predict the behavior of deep fluids must be a long-term goal to achieve a secure energy future. It can be argued that a major advance in the ability to control and predict the behavior of CO2 added to subsurface geologic rock formations is the single greatest, and most immediate, geoscience issue related to future energy and environmental security of the world. However, the general issue of subsurface fluid control, monitoring, and prediction extends beyond CO2 storage to include, for example, efficient hydrocarbon resource extraction, mining of latent underground geothermal resources, and safe underground storage of nuclear power byproducts (e.g., BES, 2007).

The major technological gaps to controlling and ultimately sequestering subsurface CO2 can be traced to far-from-equilibrum processes that originate at the molecular and nanoscale, but are expressed as complex emergent behavior at larger scales. Essential knowledge gaps involve the effects of nanoscale confinement on material properties, flow and chemical reactions, the effects of nanoparticles, mineral surface dynamics, and microbiota on mineral dissolution/precipitation and fluid flow, and the dynamics of fluid-fluid and fluid-mineral interfaces. The construction of quantitative macroscale process models based on nanoscale process descriptions is a critical additional need.

The Center involves scientists with expertise in hydrology, geochemistry, materials science, mineralogy, chemistry, microbiology, geophysics, and reactive transport modeling and simulation. The research will involve the use of synchrotron light sources, neutron scattering methods, NanoSIMS, molecular dynamics simulations, thermochemistry, molecular biology, nanotechnology, laboratory scale experiments, and advanced computation applied to flow and reactive transport in heterogeneous porous media. The new Center will commence operations in August 2009 and welcomes input, connections with ongoing field experiments, and additional research collaborations.

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