# The Expanding Role of Large User Facilities in the Earth Sciences and the New Research Opportunities They Create

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Discoveries in science are often associated with major advances in experimental methods and instrumentation, in theory and modelling capabilities, and, over the past few decades, in computational power. The fields of geo-chemistry and mineralogy have clearly benefitted from such advances, particularly in the areas of earth materials characterization and the modelling of geochemical and mineralogical processes. Here we will focus on the increasingly important role being played by large scientific user facilities, particularly synchrotron radiation (SR) sources, x-ray free electron lasers (XFEL), and neutron scattering facilities. The termendous increases in brightness and decreases of emittance of SR sources since 1st generation sources in the 1970's (~$10^{13}$ increase in brightness) have revolutionized the types of experiments now possible on earth materials, ranging from diffraction, spectroscopy, and tomographic imaging of samples simulating Earth's deep interior at ultra-high pressures to nanoscale imaging and x-ray spectroscopy on complex environmental samples. The first XFEL at SLAC (the LCLS) is now producing hard x-rays that are $10^9$ times brighter than 3rd generation SR sources, allowing for the first time XRD experiments on single nanoparticles. The pulsed time structure of the LCLS, with pulses as short as a few fs, allows for the first time detection of transition state complexes in catalytic reactions on solid surfaces. The Spallation Neutron Source at ORNL produces the most intense pulsed neutron beams in the world allowing higher resolution experiments in complex sample environments, including the unique sensitivity of neuttrons to H. Some of the discoveries made possible by these advances in large user facilities will be discussed.