UNLV Mineral Physics

The largest part of the Earth including the core and the lower mantle are not directly probed as exposed rocks or xenoliths. Yet, without understanding these regions, which are 80% of total Earth, we will not fully understand the processes at its surface. We know that there is convection involving the whole mantle of the Earth, while the transition between upper and lower mantle, which is also a transition in structure and density of the rockforming minerals, decelerates convective motion. More effective mass transport and chemical exchange is controlled by regions where partial melting of rock occurs. Interestingly they establish only a small fraction of total Earth.

Partial melting of rock occurs within and underneath continental and oceanic crust as consequence of plate tectonics. Other common zones of partial melting are subduction zones where melting occurs due to dehydration of the subducted crust.

However, there are two other major melt zones in present and one in ancient Earth: a)
In the Transition zone (440 – 660 km depth) where second dehydration melting is possible, b) in the deepest mantle, close to the core-mantle boundary, where partial melting occurs due to the very steep geothermal gradient between mantle and core, c) in the early Earth there was a global magma 'ocean' as the result of frequent impacts of large planetesimals and of heat released during core-formation.

Textbook Earthscience may mention that 'plume' related volcanism such as at Hawaii has its origin either in melting in the transition zone or even at the core-mantle boundary. However, we do not know

- the structure and properties of melts of the high density of these deep regions in the Earth. Therefore, we cannot assess if and how such melt migrate
- the partitioning of elements between residual rock and melt at such depth. Therefore we cannot constrain how much deep melts contributes to observable volcanism at the surface, e.g. in Hawaii.
- The early 'magma ocean' of the Earth determined fundamental geochemical and geophysical conditions of present Earth. Yet, without knowledge of density gradient, thermodynamics, and viscosity of this melt we cannot define constraints which link its actual former state and evolution to observed geochemical signatures.

High Pressure Mineral Physics aims to determine the properties of rock and melts in the Earth's interior: How viscous is lower mantle rock and by what mechanisms does it flow? Where does crossover from radiative to convective heat transport occur in deep Earth and how does this effect the net heat flux out of the core and to the surface? How much of the heat of the core comes from its formation, how much from radioactive decay? Can we correlate seismic anomalies in the deep mantle to chemical and/or thermal anomalies? What parameters control formation and evolution of deep melts and of their host rock? Because the deep mantle is not probed by xenoliths Mineral physics strongly relies on experiments simulating the deep Earth and on determining physical and chemical properties of the phases occuring in the Earth's interior. Simulation of the deep Earth is based on devices generating ultra-high pressures and according high temperatures such as with externally and laser heated diamond anvil cells, multianvil apparatus, and shock compression devices. Moreover, the properties of matter compressed in these devices has to be probed by sophisticated methodologies of micro-spectroscopy and X-ray- and neutron scattering from very brilliant light sources such as synchrotrons. All this together makes mineral physics a highly challenging and still very open field for revolutionary basic research.

Our current projects involve:

- Partitioning of REE and HFSE between hydrous melts and minerals of the transition zone of the mantle. Partial melting in the transition zone is expected to generate ‘hot spot’ volcanism and to influence global geochemical heterogeneities. However, any firm statement requires knowledge on how significant tracer elements partition between melt and rock under conditions of the transition zone. A collaborative effort between researchers from UNLV and NIU Earthscience Departments aims to simulate transition zone rock-melt interaction in experiments at the High Pressure lab at UNLV and at the Advanced Photon Source in Chicago. We want to determine partition coefficients of trace elements, solubility of Mg and Si in hydrous fluids, the structure of hydrous melts under conditions of the deeper Upper Mantle.
- Studies of the structure of iron-bearing silicates at core-mantle boundary conditions. We use optical and X-ray spectroscopy and single crystal diffraction to characterize metasilicate with varying amounts of Fe, Al, Ca. Density, elasticity, and minor element distribution of these phases are used to evaluate thermodynamic phase boundaries in the MFAS diagram at the extrem conditions of the core-mantle boundary of 1.3 Mbar and 2500 to 3500 K. High P-T experiments are performed with powerful mid-IR lasers heating diamond anvil cells at UNLV. The cells, kept at 1Mbar of pressure, are subjected to X-ray diffraction at the Advanced Photon Source in Chicago
- the structure of silicate melts between 200 and 500 kbar of pressure. We generate silicate melts by shock compression at the Los Alamos National Lab and at Caltech. The melt is recovered as glass and examined by magic-angle NMR at Seoul National University and by neutron- and high energy diffraction at the neutron spallation source ISIS in Great Britain and at the Cornell Synchrotron (CHESS). The structure of dense silicate will allow us for constraining viscosity and siderophile element partitioning in a magma ocean on the early Earth
- Direct partitioning studies of siderophile elements between silicate melts and metal. Such studies provide constraints on mass balance between core and mantle and are correlated to geo- and cosmochemical observations of element abundances. Ultimately, we hope to reveal fundamental parameters that controlled core formation of the Earth.