Synchrotron radiation as a probe of earth's deep interior

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The previous decade has witnessed a number of discoveries that have greatly altered our view of the Earth's deep interior. Major advances have come in two areas: the first is our ability to observe fine details of Earth's interior structure and properties, and the second is in our ability to interpret those observables in terms of the most basic properties, such as chemical composition, mineralogy (or crystal structure), thermal structure, and the presence of solid versus liquid phases (or both) at great depth. Much of the progress in Earth observation has been in the area of seismology, which is now capable of mapping out the fine-scale structure of the interior in terms of acoustic wave velocities. These are some of the most basic clues we have on the variations of chemistry and temperature that are responsible for the density variations that drive convective motions in Earth's mantle and core, and power the plate tectonic activity that we see on the surface of our planet.

Synchrotron radiation plays an essential and ever-expanding role in the interpretation of the observed properties of the Earth, particularly the deepest levels of the Earth from which we have no actual samples and which we cannot directly probe. The high intensity of tightly focused synchrotron x-rays are allowing the identification of new solid phases at ever-increasing pressures on smaller samples. Moreover, the high-energy resolution of synchrotron x-rays now makes it possible to utilize inelastic scattering techniques for a new generation of high-pressure experiments. Two examples would be the determination of acoustic velocities of samples at high pressure (which is of primary importance for geophysical investigations), and electronic phase transitions (which bear on the geochemical and thermal properties of the mantle). In this talk we review some of the recent Earth observations that have stimulated mineral physics research, major questions about the Earth's interior, and synchrotron-based methods that are being used to address forefront issues in studies of the deep Earth. Some examples are the compositional dependence of acoustic wave velocities in the abundant phases of Earth's deep interior (such as silicate perovskite in the lower mantle, and iron alloys the core), acoustic wave anisotropy, and the properties of silicate melts under high-pressure-temperature conditions. We also present some recent efforts to combine Brillouin scattering with synchrotron x-ray diffraction for simultaneous measurement of sound velocities (by Brillouin spectroscopy) and density. This combination of methods may play a critical role in the determination of absolute pressure scales and the more accurate measurement of pressure in diamond cell expeirments.