GSECARS: A NATIONAL RESOURCE FOR EARTH AND PLANETARY SCIENCE RESEARCH AT THE ADVANCED PHOTON SOURCE, ARGONNE NATIONAL LABORATORY.

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Abstract: The Advanced Photon Source (APS) at Argonne National Laboratory is entering its commissioning phase. Over the next several years, scientific consortia will be constructing beamlines and instrumentation to take advantage of this unique, very brilliant source of hard x-radiation. One such consortium is GeoSoilEnviroCARS, a multi-institutional group of experienced synchrotron users in the earth, planetary, soil and environmental sciences which will construct and operate beamlines at the APS as a national user facility available on a peer review basis. The GeoSoilEnviroCARS facility will have a major impact on the earth and planetary sciences by providing significant advances in analytical capabilities of high pressure crystallography, x-ray absorption spectroscopy, x-ray fluorescence microprobe and microtomography.

Introduction: The Advanced Photon Source (APS), a 7 GeV synchrotron currently under construction at Argonne National Laboratory, has been designed and optimized specifically for insertion devices (undulators and wigglers) which are extremely brilliant sources of hard x-radiation (3 to >100 keV). Since 1988, a multi-institutional consortium of earth, planetary, soil and environmental scientists (GeoSoilEnviroCARS, or GSECARS for short) has been planning to design, construct and operate beamlines at the APS as a national resource to serve the research needs of all US investigators in these fields. The techniques that will be made available on a peer review basis include powder diffraction, microcrystal diffraction, high pressure crystallography with the large volume press and diamond anvil cell, x-ray absorption spectroscopy, x-ray fluorescence microprobe and microtomography.

APS Status: As of Dec., 1994, electrons had been accelerated to 4 GeV and fed through the first two sectors of the storage ring. Commissioning of the entire 1 kilometer storage ring (without insertion devices installed) will commence during January, 1995. Three of the undulators have been received by the APS and are undergoing testing. First x-ray beam from bending magnets is planned for summer, 1995, with the first insertion device radiation available near the end of 1995. The construction of twenty sectors (one sector equals one bending magnet beamline and one insertion device beamline) has been proposed by 16 independent scientific consortia known as Collaborative Access Teams (CATs). Many of these CATs have received funding commitments and are in an advanced design phase. Construction of the first of these sectors is underway.

GSECARS Status: The GSECARS sector will contain 4 experimental stations (3 of which can be operated simultaneously), 2 on the insertion device port and 2 on the bending magnet port. Initially, the insertion device beamline will be equipped with an undulator with plans to possibly add a tandem wiggler in the future. The peaked energy spectrum from the undulator (figure 1) is particularly well suited for experiments requiring tunable monochromatic or pseudo-monochromatic radiation with a microbeam, such as high pressure crystallography and microspectroscopy. The undulator can also be tapered to produce a very bright, pseudo-white energy spectrum for energy dispersive experiments, or experiments requiring high energy resolution scanning of a monochromatic beam, such as in x-ray absorption spectroscopy. The design strategy has been to incorporate a high degree of flexibility. One way in which this is being done is to build experimental stations which are sufficiently large as to allow multiple instruments to remain installed for quick experimental switch-overs. Another feature is the implementation of dynamic focusing optics that can focus monochromatic or white radiation at any position in a station. Prototype testing of microfocusing devices and new, high efficiency, high resolution detector systems has been in progress at existing synchrotrons, e.g., the Stanford Synchrotron Radiation Laboratory (SSRL), the Cornell High Energy Synchrotron Source (CHESS), and the National Synchrotron Light Source (NSLS). The current GSECARS timeline calls for first bending magnet beam in Spring, 1996, and undulator beam in Fall, 1996.

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Impact on Planetary Science: The GSECARS facility will have a major impact on planetary sciences by providing significant advances in analytical capabilities. Some examples are listed below:

High pressure research (Diamond Anvil Cell and Large Volume Press): The availability of the APS will allow high pressure crystallography to be extended to pressure, temperature and compositions currently inaccessible leading to new knowledge in the following example areas: (1) mechanisms of the olivine-spinel transition (origins of deep-focus earthquakes), (2) phase transition and thermal expansion of perovskites (composition and state of planetary interiors), (3) structure of solid hydrogen (structures of Jovian planet interiors), (4) behavior of volatile species at high P,T (volatile budget of the planets), (5) properties of iron and its alloys at core conditions.

X-ray absorption spectroscopy: The availability of the APS will allow x-ray absorption spectroscopy studies to be extended to smaller volumes and lower concentrations than currently possible. Examples of planetary science applications include (1) pressure and temperature induced coordination changes of cations in silicate melts (transport properties of silicate magmas), (2) oxidation states of meteorites (chemical homogeneity of the solar nebula), (3) surface chemistry at sub-monolayer coverage (alteration processes in regoliths).

X-ray microprobe: The sensitivity and spatial resolution of the x-ray microprobe will each be improved by about an order of magnitude allowing the following example studies: (1) oxygen fugacity inferences of solar system bodies through cation partitioning studies on meteoritic minerals, (2) volatile trace element chemistry in micrometeorites, chondrule rims and meteoritic matrices, (3) oxidation state of mantle minerals including diamonds (chemical homogeneity of the Earth's mantle).

Microtomography: The APS will improve the resolution, sensitivity and speed of microtomography studies such as (1) 3D structural mapping of rare Antarctic meteorites, (2) in-situ chemical and oxidation state mapping of friable materials such as carbonaceous meteorites, interplanetary dust particles, chondrule rims and ices, (3) real time, in-situ studies of alteration processes.

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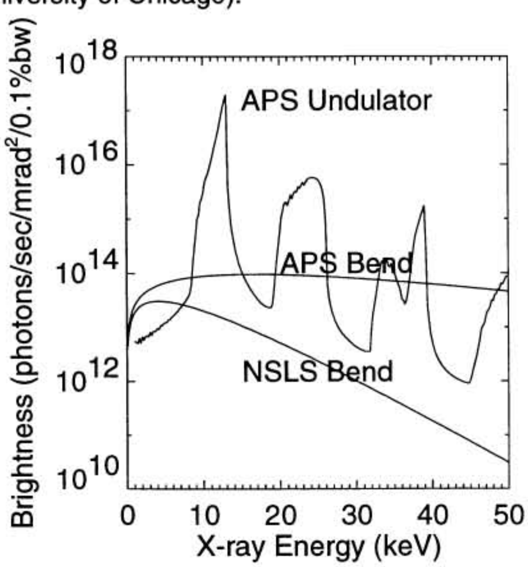

Figure 1: Brightness curves for three synchrotron radiation sources: NSLS bending magnet (currently used for the x-ray microprobe), APS bending magnet and APS undulator. The first 2 devices produce continuum (smooth) spectra while the undulator is characterized by pronounced peaks resulting from interference within the radiation beam. The energies of the undulator peaks can be tuned by adjusting the gap of the device. Both APS sources will be available on the GSECARS beamlines.