*NATIONAL SCIENCE FOUNDATION*
*DIVISION OF EARTH SCIENCES*
*INSTRUMENTATION & FACILITIES PROGRAM*

# *GUIDE TO SUPPORTED MULTI-USER FACILITIES*

Last updated August, 2001

## *INTRODUCTION*

At the time of this writing the Instrumentation & Facilities Program of the Division of Earth Sciences (IF/EAR) at NSF supports thirteen multi-user facilities on behalf of the earth sciences research community. Although ranging widely in the scope and cost of their individual operations, all of the facilities share a common attribute. They provide to their respective basic research communities on a national or regional scale certain complex and expensive technical and logistical capabilities that would otherwise be impractical to make available to individual or small groups of investigators.

This ***Guide to Supported Multi-User Facilities*** is intended primarily as a service to the potential user who needs an introduction to the range of services available. In assembling the guide, each facility director was asked to provide a description of their facility. Interested researchers are encouraged to contact the facility directly for further information.

All facilities described in this guide are reviewed on a regular basis by the NSF merit review system. The ability of a facility to provide the basic research community efficient and timely access to its technical capabilities is one of the important criteria used by IF/EAR in reviewing performance. Comments on the performance of these facilities or on any other topic relevant to the material presented in the guide are welcome.

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### *Facility Description:*

IRIS was formed in 1984 by twenty-six universities to provide a national focus for the development, deployment, and support of modern digital seismic instrumentation. Today, membership in this nonprofit consortium numbers over ninety institutions, and IRIS supports the research needs of Earth scientists in the U.S. and around the world. IRIS consists of four management programs:

**PASSCAL**

The Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL) provides portable instrumentation and support facilities for temporary deployments in studies of seismic sources and Earth structure. Data loggers developed to PASSCAL specifications form the core of the program. These data loggers are extremely flexible in their ability to respond to a variety of deployment schemes -- mobile arrays for recording of planned explosions; temporary deployments for aftershock studies; longer term deployments for observations of teleseismic events. Over 600 instruments are available and individual experiments involving more than 300 PASSCAL instruments have been supported. The instrument center for maintenance of PASSCAL equipment is located at New Mexico Institute of Technology in Socorro, NM. Data from PASSCAL experiments are distributed through the IRIS Data Management Center. As the program moves towards acquisition of the eventual goal of 6000 channels, current emphasis is on supporting field experiments; maintaining equipment; implementing improvements in hardware; and developing software for efficient data collection and initial processing.

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**GLOBAL SEISMOGRAPHIC NETWORK**

The Global Seismographic Network (GSN) is the focused effort of the U.S. seismological research community to provide a state-of-the-art, broadband, digital network of seismic instrumentation for research on the three-dimensional structure of the Earth and the study of earthquakes and other seismic sources. The GSN is a partnership between IRIS and the U.S. Geological Survey, cooperating under a Memorandum of Understanding. GSN stations are installed and operated by the U.S. Geological Survey Albuquerque Seismological Laboratory and by the IDA project at the University of California, San Diego. IRIS GSN global siting plans are coordinated with other international networks through the Federation of Digital Seismic Networks (FDSN), of which IRIS is a founding member. Beginning in late 1986 with the installation of the first broadband seismometers, the GSN has seen steady progress toward its long-term goals, and serves as a fundamental resource in the study of earthquake dynamics and tomographic analyses of the elastic and anelastic structure of the Earth.

Rhett Butler, GSN Program Manager

**DATA MANAGEMENT SYSTEM**

The IRIS Data Management System (DMS) is the primary conduit for data flow within IRIS and to data users. The DMS acts as the archive for all data collected by the IRIS GSN and IRIS PASSCAL programs. The DMS also receives, archives and distributes data from a variety of other data sources, most notably the Federation of Digital Broadband Seismographic

Networks(FDSN). All broadband data, from the GSN, PASSCAL and FDSN are available in a seamless fashion from the DMC in SEED format. Active source data are available in SEG-Y format. At the end of 1999, the IRIS Data Management Center (DMC) had more than 10 terabytes (10,000,000,000,000 bytes) of seismic waveform data in more than 1,000,000 files. The IRIS DMS typically services several tens of thousands of requests for seismic data each year.

The core of the IRIS DMS is the IRIS Data Management Center (DMC) located in Seattle. Other nodes of the system include the IRIS/IDA Data Collection Center at UCSD, the IRIS/USGS DCC at Albuquerque, the DMC Host at the University of Washington, the Waveform Quality Center at Harvard and the Moscow Data Analysis Center in Moscow, Russia.

The IRIS DMC recently acquired a multi-terabyte mass storage system with the capacity and performance to serve the IRIS community's needs for several years.

In addition to its role of archiving and distributing data, the IRIS DMS is responsible for all quality control of IRIS generated data and has a well established mechanism in place to monitor and correct data problems as they are discovered.

The IRIS DMS has developed novel means of accessing data in near real time through systems such as SPYDER developed by the University of Washington and NRTS developed by the University of California at San Diego, and the LISS System developed by the USGS in Albuquerque. These systems provide researchers access to data within minutes of a seismic event of interest.

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## EDUCATION AND OUTREACH

The IRIS Education and Outreach (E&O) program, in collaboration with the seismological and educational communities, develops and implements IRIS programs designed to enhance seismology and Earth Science education in K-12 schools, colleges and universities, and in adult education. Current E&O efforts are focused on teacher training workshops (nationally such as at the NSTA meeting, regionally such as at the East Coast Teach For America conference and locally via IRIS member institutions), museum displays ("Earth in Motion" display forms part of the Franklin Institute traveling exhibit "Powers of Nature"), production of educational materials (1-pagers and posters), ongoing web page development, involvement in the Princeton Earth Physics Project (PEPP) and the establishment of an undergraduate summer internship program.

John Tabor, E & O Program Coordinator

## IRIS, SEISMOLOGY, AND THE PUBLIC INTEREST

While the advancement of science is the primary goal of IRIS, perhaps an equal achievement of the Consortium has been to demonstrate that the national and international scientific communities can cooperate on programs that not only advance our understanding of the physical world, but also address the current needs of our society. Through special Congressional interest and support, IRIS is working with federal agencies to enhance IRIS facilities into multi-use resources for the international verification regime of a Comprehensive Test Ban Treaty. Many nations are using IRIS GSN stations as their contribution to the International Seismic Monitoring System. Instruments from the IRIS PASSCAL program are used by scientists funded with Department of Defense and Department of Energy research grants to characterize seismic wave propagation in areas of concern for treaty monitoring. IRIS also works in partnership with the U.S. Geological Survey, both in developing the IRIS GSN and in making the data from these stations available for use by the National Earthquake Information Center in their location and cataloging of global seismicity. Through the PASSCAL program, the RAMP initiative (Rapid Array Mobilization Program) provides portable instruments for use in the detailed study of aftershocks immediately following important earthquakes.

Gregory van der Vink, Director of Planning

IRIS publishes a newsletter twice a year. In addition to the newsletter, IRIS produces other publications available to the scientific and educational communities. To subscribe to the IRIS newsletter please send your name, institution, address, telephone, fax number and e-mail address to:

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Educational and not-for-profit institutions chartered in the U.S., with a major commitment to research in seismology and related fields, may become members of IRIS. Research institutions and other not-for-profit organizations both inside and outside the U.S. engaged in seismological research and development, which do not otherwise qualify for IRIS membership, may be elected affiliates or foreign affiliates.

Additional information on membership can be obtained by sending a request to membership@iris.edu.

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## *Center for High Pressure Research (CHiPR)*

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***Facility Description:***

The Center for High Pressure Research, established in 1991 as a multi-institutional NSF Science and Technology Center, combines the resources and facilities of the Mineral Physics Institute of the State University of New York at Stony Brook, the Thermochemistry Facility of the University of California at Davis and the Geophysical Laboratory of the Carnegie Institution of Washington in a cooperative program in high-pressure research.

Understanding of the state and processes of the Earth's interior is tied to our understanding of the properties of the materials that make up the Earth. Our program encompasses a wide range of experimental activities from the high-temperature, high-pressure synthesis of Earth materials to the characterization of such materials using state-of-the-art analytical approaches. The Mineral Physics Institute (MPI) houses several types of multi-anvil apparatuses for experiments from pressures of 2 GPa to 30 GPa and simultaneous temperatures to 3000 K. These solid-media devices are distinguished by their large sample volumes and by the ability to adjust and control the temperature and stress environment surrounding the sample. New developments combine ultrasonic interferometric techniques to measure elastic wave velocities in polycrystalline and single crystal specimens to P & T conditions representative of the transition zone of the Earth's mantle (400 to 700 kilometers depth). MPI scientists and collaborators can also use synchrotron radiation to probe samples at high-pressure and temperature. The synchrotron facilities are located at the National Synchrotron Light Source at Brookhaven National Laboratory.

The Thermochemistry Facility produces experimental data that are fundamental to understanding the behavior of geological materials at high pressures. It is equipped with eight high-temperature calorimeters of several custom designs to measure the energetics of oxides and silicates by direct phase transformation at 300 to 1800 K or by dissolving samples in a molten lead borate solvent at 973 K

At the Geophysical Laboratory, high-pressure research centers on both the diamond-anvil cell and multi-anvil apparatus. Diamond-anvil cells employ two brilliant-cut diamonds (1/8 - 1/3 carat) pressed together with a mechanical device so that they in turn compress a polycrystalline or single-crystal sample. In addition to its extreme hardness and compressive strength, diamond is a unique material that permits it to be used to achieve very high pressures up to and beyond 360 GPa, the pressure at the center of the Earth. Various kinds of spectroscopy and x-ray diffraction are used to characterize samples at high pressure using equipment at the Geophysical Laboratory and several different synchrotron sources. The multi-anvil apparatus consists of three split-cylinder cubic-anvil presses that are used for experiments up to 20-30 GPa and 2300-2800 K.

In addition to training pre- and post-graduate students, CHiPR also maintains programs for undergraduates and K-12 students. Summer Scholars programs at Stony Brook and the Geophysical Laboratory bring undergraduate students from across the country to their institutions for an intense ten-week period of research apprenticeship with CHiPR scientists. Students at CHiPR have enhanced opportunities to work across institutional barriers to integrate high-pressure science and technology research with analytical studies in mineral physics and solid-state chemistry.

Visitors are an essential aspect of the Center's activities. They are important for the transfer of scientific and technical knowledge both into and out of the Center. Many of our visitors are drawn from the mineral physics and mineral chemistry communities, but we are also working to develop workshops directed at colleagues in seismology, geochemistry and geodynamics to keep them up-to-date on the exciting scientific problems being addressed and solved by high-pressure research. CHiPR also invites visitors from the private industry sector and has cultivated a growing community of users from this area.

***WWW Home page URL:*** http://www.chipr.sunysb.edu/

## *University NAVSTAR Consortium (UNAVCO)*

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### *Facility Description:*

The precise positioning provided by the Global Positioning System (GPS) is becoming a powerful tool for studies of diverse Earth processes including plate tectonics, the earthquake cycle, mountain building, volcanism, plate rigidity and intraplate deformation, hydrology, ice dynamics and sea level change, and atmospheric dynamics, as well as contributing to many education and engineering activities, as summarized in http://www.unavco.ucar.edu/community/brochure.

Infrastructure to support such studies by NSF investigators is provided by the University Navstar Consortium (UNAVCO) an organization of more than 100 universities and other research institutions, whose goal is to promote the acquisition, archiving, and distribution of high-precision GPS data for investigation of Earth processes and hazards.

UNAVCO seeks to make the use of GPS, which is intrinsically very "big" science, into almost-"small" science that can be conducted at institutions both large and small. Many of the investigators assisted are interested in advancing space-based geodesy. Others, however, wish to use these techniques as tools to solve geological, geophysical, and glaciological problems. Hence, for example, UNAVCO seeks to make it possible for investigators interested in monitoring crustal motions, tracking ice sheet flows, or mapping uplifted terraces, to focus on their scientific goals rather than on the GPS technology. A third group are interested in using or synthesizing the results of various studies, in many cases conducted by others.

To meet these diverse needs, UNAVCO provides a focal point for the broad community of Earth scientists interested in either conducting studies with GPS geodesy or using its results. Much of UNAVCO's work is conducted by its Boulder Facility, which assists NSF- and NASA- funded principal investigators. Support is provided at various levels, depending on project needs. This can include GPS equipment, field engineering, technology development, training, technology transfer, data management and archiving. In many cases, UNAVCO provides assistance to universities which have their own GPS receivers, often acquired via a discounted bulk purchase or grant organized under UNAVCO auspices. Projects supported include GPS campaigns, where sites are occupied for short periods, and local and regional networks of continuously recording GPS receivers. UNAVCO also provides technical and operational support to the permanent GPS stations in NASA's Global GPS network, many of which contribute to the International GPS Service (IGS) global network.

UNAVCO also works collaboratively with other research institutions in the areas of data processing, technology development, and data archiving. In addition, UNAVCO supports scientific interchange among investigators doing GPS-related science, both from UNAVCO and from other institutions, via an annual community meeting, scientific working groups, and other forums.

The UNAVCO Web page provides information about research support including:

Data acquisition support includes use of a community pool of high accuracy GPS receivers. Field engineering, training, and technology transfer support is provided for GPS data collection in both campaign style and with continuously operating permanently installed networks of GPS receivers. Data analysis support is provided under UNAVCO auspices by groups at MIT (GAMIT) and the University Corporation for Atmospheric Research (Bernese).

Data archiving and distribution is supported for campaign and continuous GPS data, via ftp and an archive accessible via a relational database. This archive allows query by data location, date of collection, equipment used, principal investigator, and other "descriptors". A program jointly conducted by the UNAVCO Facility, the Scripps Institution of Oceanography, and many other participants, is working to develop "seamless" access so users can obtain data from multiple archive centers without knowledge of the individual archive holdings or data structures.

Research toward improved GPS accuracy support is coordinated by the Smithsonian Astrophysical Observatory, with support from MIT and the Boulder Facility. Activities include testing and evaluation of new GPS equipment and technology, and development of techniques for measurement and reduction of factors degrading GPS data quality. UNAVCO is also promoting the use of GPS to study volcanic processes and synthesis of both a global GPS velocity field and a denser field for western North America that will provide valuable new tools for tectonic studies.

UNAVCO is governed by a Steering Committee elected by member representatives. The Committee works with the GPS research community to promote a broad interdisciplinary research agenda based on applications of GPS technology, to identify investigator needs for infrastructure support, to develop proposals to appropriate sponsors to maintain that infrastructure capability, and to ensure that the UNAVCO Facility and associated activities provide high quality, cost-effective, and responsive support.

UNAVCO is principally organized to support NSF and NASA-funded Earth science investigators and projects but it also provides keystone support for wider interdisciplinary GPS applications at the international level. Many of the GPS tools and techniques developed by the UNAVCO community are publicly available via the UNAVCO Web site.

UNAVCO welcomes inquiries from prospective users of GPS for either recognized or new applications of this exciting technology.

***WWW Home page URL:*** http://www.unavco.ucar.edu

## *GeoSoilEnviroCARS Synchrotron Radiation Beamlines at the Advanced Photon Source*

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See Scientist in Charge

### *Facility Description:*

GeoSoilEnviroCARS (GSECARS) is a national synchrotron radiation user facility for earth science research at the Advanced Photon Source (APS), Argonne National Laboratory. The APS is a 7 GeV storage ring producing extremely high brilliance X-ray beams using undulators, wigglers and bending magnets. The GSECARS sector, consisting of an undulator beamline and a bending magnet beamline, is being developed and operated by the Consortium for Advanced Radiation Sources, which is managed by the University of Chicago.

Most principal synchrotron-based analytical techniques in demand by earth scientists are available at GSECARS including:

- X-ray diffraction in the diamond-anvil cell using both monochromatic and energy-dispersive techniques including double-sided laser heating apparatus
- X-ray diffraction in the large-volume press using both monochromatic and energy-dispersive techniques. A 250-ton press is operational on the bending magnet beamline and a 1000-ton press is installed and being commissioned on the undulator beamline.
- Powder diffraction, surface diffraction, and single-crystal micro-diffraction
- X-ray absorption spectroscopy including micro-spectroscopy with beam sizes near 1 micron, and surface studies
- X-ray fluorescence microanalysis
- 3-D computed microtomography

Principal research areas include (1) speciation and microdistribution of metals and radionuclides in soils, (2) redox reactions, transport processes and kinetics of metals in soils, (3) sorption processes and reactions of metals at mineral-water interfaces, (4) role of biota in transport processes, (5) evaluation of potential waste cleanup protocols, (6) metal partitioning and speciation in hydrothermal fluids, (7) crystal chemistry of rare, complex minerals, (8) dynamics of fluid transport in rocks, (9) equations-of-state of mantle phases, (10) rheology studies at high pressure, (11) determination of melting points and the densities and viscosity's of melts, and (12) phase transitions and relationships in mantle minerals and candidate core materials.

The design and operation of the experimental stations and instrumentation is coordinated by five international teams of interested Earth scientists (leaders in parentheses):

- X-ray diffraction and scattering (John Parise, SUNY Stony Brook)
- Diamond-anvil cell (Russell Hemley, Carnegie Institution of Washington.)
- Large-volume press (Donald Weidner, SUNY Stony Brook)
- X-ray absorption spectroscopy (Glenn Waychunas, Lawrence Berkeley National Laboratory)
- X-ray fluorescence microprobe and microtomography (Stephen Sutton, University of Chicago)

A research environment is provided where users receive expert assistance in planning and conducting experiments, and with data analysis. This service-oriented mode of operation allows the facility to be accessible to the entire spectrum of synchrotron radiation users from novices to experienced investigators. During the initial phase of operations, there are no user fees.

Beam time at the GeoSoilEnviroCARS facility is available to all interested Earth scientists through a web-based proposal system (http://gsecars.uchicago.edu). In addition to the beamtime application form, the GSECARS web page contains announcements of proposal deadlines, GSECARS staff contacts for experiment design information, descriptions of available instrumentation and capabilities, hardware and software tutorials, photographs of the facility, recent scientific results and a publication list. Over one hundred beamtime proposals have been received since implementation of the beamtime proposal system in 1998. Over one hundred and forty visiting scientists have conducted experiments on the GSECARS sector since 1997.

In addition to the experimental stations, GeoSoilEnviroCARS has laboratories for sample preparation and characterization, and office space with computer workstations for users. Convenient lodging for visitors is available on the Argonne Campus at the Argonne Guest House

(http://www.aps.anl.gov/travel/anlghhome.html)

***WWW Home page URL:*** http://gsecars.uchicago.edu

## *Diamond Cell X-Ray Diffraction Facility at the National Synchrotron Light Source (NSLS)*


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### *Facility Description:*

The Diamond Cell X-Ray Diffraction Facility at the National Synchrotron Light Source (NSLS) of Brookhaven National Laboratory consists of two experimental stations, X17B1 and X17C, of the superconducting wiggler beamline X17. The high critical energy (20 keV) and high photon flux are particularly suitable for diamond-cell applications.

X17C is fully dedicated to diamond-cell applications. It has been commissioned since January 1991 with an established base of permanent equipment. Users need to bring only their own diamond cells to conduct Energy Dispersive X-Ray Diffraction (EDXD) experiments. Maintenance and continuing development of the experimental station have been supported by NSF and a diamond-cell user consortium (IDT) including the Naval Research Laboratory, Lawrence Livermore Laboratory and Carnegie Institution of Washington. The facility provides the following experimental capabilities.

- EDXD for polycrystalline samples in diamond cells up to 300 GPa at ambient temperature.
- EDXD for resistively heated polycrystalline samples in diamond cells up to 1100K at 100 GPa.
- Single-crystal x-ray diffraction up to 100 GPa.
- Single-crystal x-ray diffraction for microscopic samples below 1 micron.
- Ruby fluorescence spectroscopic system for pressure calibration.
- Off-line laser-heating equipment for temperatures up to 4000K at high pressure.

X17B1 beam time is allocated 1/4 to diamond cell and 3/4 to other applications. A diamond cell facility was developed in 1998 as a result of joint support from an NSF/IF grant to Carnegie Institution of Washington and a NSF/MRSEC grant to Arizona State University. X17B1 has significantly larger hutch space than X17C, and provides complementary capabilities that are unfeasible in the restrictive X17C space. At X17B1, accurate determinations of phase diagrams and P-V-T equations of state of Earth materials can be obtained at cryogenic temperatures and along the entire geotherm from the crust to the core.

- Single-crystal EDXD in liquid helium cryostat to 4K and high pressures.
- laser-heating equipment for EDXD of samples at simultaneous high temperatures (up to 4000K) and pressures.

Beam time of both facilities (100% of X17C and 1/4 of X17B1) is allocated 75% to IDT members and 25% to NSLS. NSLS assigns the 25% time to general users on the basis of merit of users' proposals rated by a panel that does not include IDT members. General users could also access the 75% IDT time through collaborative projects.

## *Purdue Rare Isotope Measurement Laboratory (PRIME Lab)*

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***Facility Description:***

Purdue Rare Isotope Measurement Laboratory (PRIME Lab) is a dedicated research and service facility for accelerator mass spectrometry (AMS). AMS is an ultra-sensitive analytical technique for measuring low-levels of long-lived radionuclides and rare trace elements. We are using the accelerator to measure both man-made and cosmic-ray-produced radioisotopes such as $^{14}C$ (half-life 5730 years), $^{10}Be$ (1,500,000 years), $^{26}Al$ (730,000 years), $^{36}Cl$ (300,000 years), $^{41}Ca$ (100,000 years) and $^{129}I$ (16,000,000 years) in natural samples having isotopic abundances down to $10^{-15}$.

Although the instruments and detection methods are those of nuclear physics, research applications are concentrated in the Earth and planetary sciences. Applications include measuring the exposure time and erosion rate of rocks on the surface of the Earth in the range 5,000 to 1,000,000 years, dating and tracing of ground water, $^{129}I$ as an oceanographic tracer, measuring solar and atmospheric variability using $^{10}Be$ and $^{36}Cl$ in precipitation and ice cores, radiocarbon dating of archaeological artifacts, tracing the global carbon cycle with $^{14}C$, determining terrestrial ages of meteorites recovered from the Antarctic ice sheet, and tracing of $^{14}C$-labeled compounds, aluminum, and calcium in biological systems. Our publications, newsletters, and annual report are available on request.

PRIME Lab is an active teaching facility training graduate and undergraduate students in the departments of Physics, Chemistry, and Earth and Atmospheric Sciences. Every year several Purdue students obtain advanced degrees using AMS and over 100 external scientists and their students use PRIME Lab.

PRIME Lab is based on an upgraded FN (nominal 8 MV) tandem electrostatic accelerator. With higher energies than most accelerators dedicated to AMS, it has the capability to measure the full range of radionuclides including $^{10}Be$, $^{14}C$, $^{26}Al$, $^{36}Cl$, $^{41}Ca$, and $^{129}I$. The PRIME Lab building on the Purdue campus contains 31,000 sq. ft of floor space with 14 offices and 16 laboratories.

Chemistry operations are an integral part of PRIME lab, offering users not wishing to prepare their own samples the unique opportunity to have their samples physically and chemically prepared for AMS measurements. Separate laboratories allow us to analyze samples covering a wide range of specific activities. Analytical methods have been established for diverse sample matrices, such as rock, soil, sediment, and water, for all nuclides measured by AMS at PRIME Lab. Methods include physical pretreatment as well as chemical separation procedures. We also assist users in planning their sampling trips, to ensure maximum scientific quality. In-house training programs are available for users to learn to prepare their own samples.

Purdue University dedicated its tandem accelerator to accelerator mass spectrometry in 1989; external funding began in April 1990; and the first AMS measurements took place in early 1991. The internal upgrade of the accelerator, which included new acceleration tubes and a new charging system, took place from December 1993 through April 1994. We chemically prepare over 300 samples per year and perform AMS measurements on over 3000 samples per year. We continually work to improve AMS methods and develop detection of new nuclides.

PRIME Lab is currently available to the research community for measurements of the nuclides $^{10}Be$, $^{14}C$, $^{26}Al$, $^{36}Cl$, and $^{129}I$. In addition, we can determine carbon and chloride concentrations using isotope dilution. Sample requirements, performance for each nuclide, and prices are available on our web site. Contact us if you have any questions.

***WWW Home page URL:*** http://primelab.physics.purdue.edu

## *NSF - University of Arizona Accelerator Mass Spectrometer (AMS) laboratory*


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***Facility Description:***

The NSF - University of Arizona Accelerator Mass Spectrometer (AMS) laboratory is a national facility dedicated to radioisotope research. The purpose of the facility is to provide radioisotope measurements for a broad range of scientific and historical studies. The facility is financed by the National Science Foundation and by funds received from user charges.

The AMS laboratory is primarily devoted to radiocarbon measurements. Samples are submitted by scientists from around the world. A typical sample is pretreated, converted to $CO_2$, and reduced to graphite. The ratio of $^{14}C/^{13}C$ in the graphite is measured in the accelerator and used to calculate a radiocarbon age. A conventional stable isotope mass spectrometer is available to provide $\delta^{13}C$ measurements. These $\delta^{13}C$ measurements will be provided for all samples except some sediments, and this information is used to correct the $^{14}C$ ages to $\delta^{13}C$ of -25 ‰, as by convention, before reporting them.

For samples younger than a few thousand years, the $^{14}C/^{13}C$ ratio is measured with a standard deviation of about 0.5%. This precision yields an uncertainty in the radiocarbon age of approximately ± 40 years. Published tree-ring calibration curves are used to determine calendar ages. The uncertainty in the calendar age is generally larger than the uncertainty in the radiocarbon age, and depends on the location of the calculated age in the calibration curve. For samples with ages greater than about 11,000 years, only radiocarbon ages are quoted. For special cases, better precision can be achieved by analyzing several targets made from the same material. This improves the standard deviation of the averaged result by a factor of sqrt(n), where n is the number of independent analyses. The best precision obtained to date is 0.2%. The maximum radiocarbon age that can be measured at the facility is about 48,000 years B.P.

The AMS facility is also equipped to provide $^{10}Be$ measurements. Beryllium oxide targets are used in the accelerator to measure the $^{10}Be$ content of samples. For samples with ratios of $^{10}Be/^{9}Be = 10^{-13}$, $^{10}Be$ rates of about 3.5 counts per minute can be obtained.

The laboratory facilities have recently been expanded by the addition of a second AMS instrument. We expect that this addition will improve the reliability of the operation of the laboratory, and allow the analysis of additional cosmogenic isotopes.

For current sample size requirements and fees, see our web page, or contact the laboratory directly.

***WWW Home page URL:*** http://www.physics.arizona.edu/ams

## *Institute for Rock Magnetism (IRM)*

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### *Facility Description:*

The Institute for Rock Magnetism (IRM) was established in the fall of 1990 to provide the Earth Science research community with no-cost access to state-of-the-art facilities and technical expertise for magnetic material characterization. Visiting scholars and resident researchers utilize the resources of the IRM to study contemporary topics in rock magnetism, paleomagnetism, and a broad range of interdisciplinary fields.

The same physical principles that govern magnetic information storage in audio/video recording media and in computer disks also operate in geological recording media: rocks and sediments. The processes involved in natural magnetic recording are both complex and inefficient, and the characteristics of natural particulate storage media vary strongly with the mineral composition and grain size of the ferromagnetic particles. The recorded signal of geomagnetic field behavior through time is inevitably distorted by variations in these properties of the recording medium, and the signal is moreover subject to degradation and overprinting by stress, thermal perturbations and chemical alteration. High-fidelity geomagnetic signal recovery depends on separating out this geological "noise," which itself, of course, contains significant information about Earth processes that have affected the medium. Research at IRM thus aims at separate recovery of both the geomagnetic and geological signals in the magnetism of Earth materials.

The instrumentation at IRM enables measurement of the magnetic properties of materials, including AC and DC magnetic moments and Mössbauer spectra, over a wide range of temperatures (4.2 K - 1000 K) and magnetic fields ($10^{-5}$ T - 5 T). In addition, magnetic domain structures may be imaged by various means, including the magneto-optic Kerr effect (MOKE) and magnetic force microscopy (MFM). Research goals have both fundamental and applied aspects. Fundamental rock-magnetic and mineral-magnetic studies are leading to a better understanding of the origin and geological stability of remanent magnetization in fine particles (10 nm - 100 µm) of magnetic oxides, sulfides, and other natural materials or synthetic analogues. Fundamental research is also leading to improved understanding of how measured magnetic properties depend on particle size, shape, stress, and other physical characteristics. This knowledge is simultaneously being applied throughout the geosciences with the development of sensitive magnetic proxies of chemical and grain-size changes caused by tectonic activities, and climatic and environmental change.

Current in-house projects include magneto-optic and magnetic-force microscope studies of interactions between magnetic domain walls and crystal defects, developments of magnetic proxy indicators of paleoclimate variations, biomineralization of magnetic material, and fidelity of paleomagnetic field records in sediments. Examples of recent research by Visiting Fellows include investigations of the origin of stable magnetic memory in relatively large multidomain particles, using low-temperature measurements; and studies of climate-driven periodic variations in the physical and chemical characteristics (particle size distribution, mineral composition) of marine sediments, using suites of field- and temperature-dependent magnetic measurements. Undergraduate seniors from small colleges and universities in the upper mid-west carry out senior thesis research under guidance from IRM faculty and staff. Since 1992, four biennial conferences have been held in Santa Fe, NM, organized by IRM to advance new interdisciplinary research utilizing rock-magnetic techniques; the fifth conference is planned for the summer of 2000.

Cooperative efforts with magnetics groups from nearby companies (Seagate Technology, Imation, and Web Research) lead to the productive exchange of ideas and provide fertile ground for the development of new technology.

Interested scientists are encouraged to apply to become Visiting Fellows or Visiting Students. Applications are accepted twice a year for work to be done during the following half year. Proposals are due by December 15 for stays during spring and summer (March 1 to August 31), and by June 15 for stays during the fall and winter (September 1 to February 28). To help defray travel costs, we offer a limited number of grants for up to $750 each as seed money to researchers who submit outstanding proposals. (There are no funds available for per diem personal expenses.) Shorter, less formal visits from other researchers are readily arranged through the laboratory manager. There are no fees for use of IRM facilities.

The IRM Quarterly includes abstracts of current articles, news about IRM equipment, reports from Visiting Fellows, updates on meetings, and other relevant information. It reaches people on all continents. Contact the lab to be added to the mailing list.

***WWW Home page URL:*** http://www.geo.umn.edu/orgs/irm/irm.html

## W.M. Keck Foundation Center for Isotope Geochemistry - National Ion Microprobe Facility



| ***Scientist in Charge:*** | ***Contact Person(s):*** |
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***Facility Description:***

The principal resource of the W.M. Keck Foundation Center for Isotope Geochemistry is a CAMECA ims 1270 high resolution, high sensitivity ion microprobe. A LEO 1430 VP scanning electron microscope is available for sample characterization in support of ion microprobe analyses. The Division of Earth Sciences of the National Science Foundation provides a portion of the support for the Keck Center to enable us to host external users from the geological and related communities. We seek to provide the user with a world-class instrument that is developed to support applications that both take advantage of its unique capabilities and are at the forefront of scientific investigations.

Two application areas have been developed for the ims 1270, a large-radius, triple-focusing mass spectrometer: U-Th-Pb measurements of accessory minerals, and stable isotopic analysis of silicate, carbonate, and oxide minerals. U-Th-Pb analyses are conducted using a primary beam of O- ions that can be focused to spots from 1 to 30 µm on 1" polished thin sections or grain mounts. A slit-lens transfer optical system and the 585 mm radius magnet achieve high secondary ion transmission at the mass resolving power of ~5,000 required for these analyses. Isotopic ratios are measured by rapid peak-switching in to a pulse-counting electron multiplier. Measurements of U-Th-Pb systematics of zircon [e.g. X. Quidelleur et al., The thermal evolution and slip history of the Renbu Zedong Thrust, southeastern Tibet. J. Geophys. Res. 102, 2659, 1997 ] and monazite [e.g., Harrison et al., Earth Planet. Sci. Lett. 133, 271, 1995] yield high Pb sensitivities (up to 20 cps/ppm/Pb/nA) and typical age accuracy of ±2%.

Stable isotope measurements of oxygen and carbon in carbonates, silicates and oxides are undertaken using a $Cs^+$ primary beam and yield typical precision for $\delta^{18}O$ and $\delta^{17}O$ of 1.0 ‰ for 15 minute analysis times and 15 mm diameter spots [e.g. B.-G. Choi *et al*. Origin of magnetite in oxidized CV chondrites: *in situ* measurement of oxygen isotope compositions of Allende magnetite and olivine. Earth Planet. Sci. Lett. 146(2), 337-349, 1997; L.A. Leshin *et al*., The oxygen isotopic composition of olivine and pyroxene from CI chondrites. Geochim. Cosmchim. Acta 61, 835, 1997]. The same precision has been obtained for $\delta^{13}C$ in carbonates under similar analytical conditions.

Geoscientists are welcome to request utilization of the ion microprobe by contacting Dr. Chris Coath or Dr. Kevin McKeegan. Dr. Coath is responsible for scheduling access for U-Th-Pb measurements and Dr. McKeegan for stable isotope investigations. Instrument time is available subject to several conditions including: that time set aside for external investigators is available, the investigator is currently funded by NSF, and the request matches current application development. Typically, external investigators will be expected to collaborate in the investigation with a member of the Center staff. It is expected that any data obtained from the ion microprobe will be written up for publication in a refereed journal in a timely fashion. Investigators currently funded by NSF pay a subsidized user rate of $100/hour. Non-NSF supported external users pay the full rate of $250/hour.

***WWW Home page URL:*** http://oro.ess.ucla.edu/ionprobe/home.html

## *Northeast National Ion Microprobe Facility at Woods Hole Oceanographic Institution*


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***Facility Description:***

The NENIMF is an outgrowth of the Woods Hole Oceanographic Institution (WHOI) Regional Ion Microprobe Facility, and is a consortium effort involving WHOI, Massachusetts Institute of Technology (MIT), Brown University, Rensselaer Polytechnic Institute (RPI), Lamont-Doherty Earth Observatory (LDEO) and the American Museum of Natural History (AMNH). The facility is equipped with Cameca IMS 3f and IMS 1270 ion microprobes, and with complementary sample preparation equipment.

The NENIMF members themselves cover a broad range of geochemical research; from solar/presolar materials and processes, early Earth evolution, mantle dynamics, crustal processes and evolution, to environmental monitoring and experimental geochemistry. Measurements of both the abundances of diverse trace elements (REE, HFSE, LILE) and of stable and radiogenic isotopes are essential components of this research. Thus, there are a large number of technique developments continually underway as the facility expand its capabilities.

The IMS 3f has historically been used for a wide spectrum of geochemical studies, and remains highly effective for in situ trace element and REE analysis of rock-forming minerals and glasses (spatial resolution better than 10µm). More recent application developments for the IMS 3f include i) measurement of $\delta^{11}B$ in melt inclusions, and in natural waters (prepared by evaporation) and, ii) measurement of Sr, Mg and Ba in carbonate marine skeletons for paleotemperature and other studies.

The IMS 3f continues to be readily accessible to scientists from the United States and beyond. Current provisional user fees for this instrument for geochemical research are $60/hour for weekday day shifts (9 am - 9 pm) and $40/hour for weeknights and on weekends/holidays.

The IMS 1270 is a new generation high transmission-high mass resolution SIMS instrument with a great number of extended capabilities for geochemical analysis. Existing analytical platforms at NENIMF include in situ Pb isotope measurements in glasses, sulfides and silicate minerals. Also available is a novel technique for the high precision analysis of $^{232}Th/^{230}Th$ in Th separates from volcanic rocks.

Current platforms in development include HMRP trace element analysis in sulfides and carbonates and HMRP REE pattern analysis in specific silicates. A large development effort in 2000 will be focused on implementing $\delta^{18}O$ and (and $\delta^{13}C$) measurement in simple matrices such as silica, carbonates and some rock-forming silicates.

The IMS 1270 is accessible to outside users for geochemical research at a provisional rate of $100/hour, and usage of the existing analytical platforms enumerated above is particularly encouraged. A verbal or written request for machine time to the contact person and the scientist in charge will initiate discussion of scheduling and conditions of use for both IMS 3f and IMS 1270 instruments.

***WWW Home page URL:*** http://www.whoi.edu/nenimf/

## *Carnegie Institution of Washington-NSF National Ion Microprobe Facility*



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| --- | --- |
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### *Facility Description:*

The centerpiece of the CIW-NSF National Ion Microprobe Facility is a Cameca IMS 6f ion microprobe. Support from the Division of Earth Sciences of the National Science Foundation allows the CIW-NSF facility to host external users from the geological and cosmochemical communities for the purposes of data acquisition on the instrument. We seek to provide a facility that offers a wide variety of instrument capabilities to support scientific research at the forefront of geology, geochemistry and cosmochemistry.

The facility offers a variety of analysis routines:

***Trace Element****s* in silicate glasses and minerals (Li, Be, B, K, Ti, Sc, Cr, Rb, Sr, Y, Zr, Nb, Ba, REE, Hf, Pb, Th, U) are analyzed by energy filtering using a O- primary beam with spot sizes from 1 to 30 microns.

***Volatile Analysis*** in silicate glasses and minerals include abundance determinations of $H_2O$, $CO_2$, F, S and Cl (6 minutes/analysis) and D/H ratios (30-60 minutes/analysis). Spot sizes are 20-30 microns and detection limits are <30 ppm for $H_2O$ and <2 ppm for $CO_2$, F, S and Cl. Hydrogen isotope reproducibility is around 5‰ after correction for matrix effects. Sample preparation is of utmost importance in this type of work; contact Erik Hauri or Jianhua Wang before scheduling time for volatile analyses.

***Li and B Isotopes*** are analyzed in silicate glasses using a O- primary beam at mass resolutions of 600 (Li) and 1600 (B). Precision is dictated by Li and B abundances, but is usually around 2-3‰ in mid-ocean ridge basalt glasses (<4 ppm Li, <1 ppm B). Each analysis requires 1-3 hours depending on Li and B abundance.

***Carbon Isotopes*** are analyzed in graphite, diamond, carbonates and microfossils with a Cs+ beam. Graphite and diamond analyses utilize extreme energy filtering, while carbonate and microfossil analyses require high mass resolution (MRP=3500). Precision is <0.5‰ for graphite and diamond, and around 1-2‰ for carbonates and microfossils (depending on thickness and C content). Each analysis is 30-45 minutes in duration.

***Nitrogen Isotopes and Concentrations*** are analyzed in diamonds using a Cs+ beam at high mass resolution (MRP=7000). N abundance analysis takes 5 minutes and is accurate to 10% with a detection limit of <5 ppm. N isotope analysis requires N concentrations >15 ppm and durations of 1-3 hours depending on N abundance and desired precision. Reproducibility of better than 1‰ has been attained on diamonds with 1000 ppm N.

***Oxygen Isotopes*** are analyzed in silicate minerals and glasses, as well as carbonates and anhydrite, using a Cs+ primary beam and extreme energy filtering. Typical reproducibility is around 1‰ after correction for matrix effects. Analysis times are 30-60 minutes.

***Sulfur Isotopes*** are analyzed in sulfide minerals using a Cs+ beam and extreme energy filtering. Typical reproducibilities are <0.5‰ for a 30 minute analysis after correction for matrix effects.
***Isotope Anomalies*** in meteorite phases have been examined for the isotopes of H, C, N, O, Mg, Si, K, and Fe using high mass resolution techniques.

***Extinct Radioisotope Systems*** examined include $^{26}Al$-$^{26}Mg$ and $^{53}Mn$-$^{53}Cr$. Specific methods depend on the material analyzed.

Scheduling of analysis time on the instrument is reserved on a first-come first-served basis by contacting Erik Hauri or Jianhua Wang; plan 3-4 months in advance. Scheduling preference is given to academic researchers in geology, geochemistry and cosmochemistry. Academic users of the facility are charged a user fee of $60/hour; rates for non-academic users are negotiated on an individual basis. It is expected that data collected at the CIW-NSF facility will be published in peer-reviewed journals on a timely basis.

***WWW Home page URL:*** http://www.ciw.edu/DTM-ionprobe.html

## *High-Resolution Computed X-ray Tomography Facility*


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***Facility Description:***

The high-resolution computed X-ray tomography facility at the University of Texas at Austin makes state-of-the-art industrial tomographic imaging capabilities available to the scientific community. Our principal focus is on research applications in the earth sciences. The facility combines a custom-designed tomographic scanning system with a digital image-analysis laboratory to provide data analysis and visualization.

High-resolution X-ray CT (computed tomography) is a completely non-destructive technique for visualizing and measuring features in the interior of opaque solid objects, and for obtaining digital information on their 3-D geometries and properties. It is useful for a wide range of materials, including rock, bone, ceramic, metal, and soft tissue. High-resolution X-ray CT differs from conventional medical CAT-scanning in its ability to resolve details as small as a few tens of micrometers in size, even when imaging objects made of high-density materials. Examples of tomographic imagery are maintained on the facility's website.

Applications include internal inspection of rocks, fossils, artifacts, organisms, and organic tissues; quantitative textural analysis of crystalline rocks; porosity/permeability assessment; description of 3-D fracture patterns in aquifer and reservoir rocks; determination of physical heterogeneity and flow properties of sediment columns; and any physical, morphological, or textural analysis that formerly required tedious physical serial sectioning combined with photography or drafting to document features.

The centerpiece of the facility is a tomographic scanner designed for three modes of operation: high-energy and high-resolution computed tomography; real-time microradiography; and digital radiography. For high-penetration tomography of large and dense objects, a 420 kV X-ray source is employed, with either a solid-state linear array detector, or a high-resolution radiographic line scanner detector. For micro-tomography of smaller objects, a 200 kV microfocal X-ray source with image intensifier is employed.

The facility encourages use by external investigators: in calendar year 1999, more than half of the imaging done by the facility was for outside users. Investigators working on NSF-funded projects receive priority scheduling and a reduction in user fees to 50% of normal rates. Full information on the facility's capabilities, costs, procedures for access, and answers to FAQs are available on the facility's website.

***WWW Home page URL:*** http://www.ctlab.geo.utexas.edu/

## *Facility for Electromagnetic Studies of the Continents (EMSOC)*

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***Facility Description:***

The EMSOC facility provides equipment for inductively sensing the electrical conductivity structure of the Earth's interior. Electrical conductivity is related to temperature and the presence and connectivity of fluids or other interstitial conductive material such as graphite that are difficult or impossible to sense by other means.

The facility presently consists of fourteen long period (10-30,000 s) magnetotelluric (MT) systems and 2 wideband (.002 to 500 s) MT systems. Together, these systems are suitable for targets ranging from the near surface (tens of meters) to the upper mantle (~400 km depth). They are owned respectively by the University of Washington (UW), the University of California at Riverside (UCR), and the University of Utah (UU).

The fifteen-channel, wideband MT system of UCR is commercially manufactured and is suitable for either continuous tensor MT profiling (an electromagnetic equivalent of seismic reflection profiling) or simultaneous multi-site MT using GPS synchronization. The second existing wideband system has been developed by UU. While also functioning similarly to the commercial units, the latter addresses additional research situations, such as deployment on ice sheets or radio telemetry, which are not currently possible commercially. This system is currently being rebuilt to allow simultaneous multi-band acquisition, GPS synchronization, and higher bandwidth and telemetry rates. Five additional long-period instruments are to be purchased.

Although the MT equipment is owned by the grantee institutions above, its use is open to the U.S. academic community. Users are expected to pay for expendables (e.g., batteries, wire, electrodes), shipping, insurance and training. Users are required to be trained and to archive data according to the IRIS Data Management System under rules similar to those governing PASSCAL seismic data.

The Facility is governed by the EMSOC Facility Steering Committee (EFSC). This committee presently consists of three representatives from the three grantee institutions and three representatives from other academic institutions. The EFSC sets policy, oversees operations, allocates equipment use through an open application process and organizes training opportunities. All actual equipment use is coordinated by the Scientist-in-Charge to whom inquiries regarding equipment availability should be addressed.

***WWW Home page URL:*** http://vortex.ucr.edu/emsoc/index.html