FINAL REPORT FOR AWARD # 0435812

Shirley P Dutton ; *U of Texas Austin*
Workshop: Curation of Terrestrial Scientific Cores, Samples and Collections

Participant Individuals:
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Participants' Detail

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SAMPLES Working Group: Collaborative Research

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Activities and findings:

Research and Education Activities:

Acquisition of terrestrial cores, rock samples, and fossils is critical for conducting much of the geologic research in the Earth Sciences, but at present no NSF-supported central facility exists for the long-term curation and dissemination of this material to the academic community. A workshop held in May, 2004 at The University of Texas at Austin Houston Research Center (HRC) brought together experienced curators and geoscientists working with terrestrial rock material acquired as part of academic research projects funded by the

National Science Foundation Earth Science Division (NSF/EAR). The primary goal of the workshop was to visit a public-sector, state-of-the-art sample repository where space is currently available to the academic community and other researchers for long-term storage, curation, and easy access to rock material and other collections. Participants identified the needs of the research community and prioritized the facilities, equipment, and metadata storage that would best suit the different types of geologic material to be curated. The HRC was identified as well suited and appropriate for curation of terrestrial cores, samples, and other collections acquired for NSF/EAR-funded research. A core and sample storage facility at the HRC would advance knowledge and understanding in Earth Science by preserving precious rock material acquired with public funds, providing a public catalog of the material, and making samples readily available to the research and education community.

INTRODUCTION

Acquisition of terrestrial cores, rock samples, and fossils is critical for conducting much of the geologic research supported by NSF/EAR. Because of the volume of rock material involved and disinterest among host research institutions, long-term storage, preservation, and curation of these materials are beyond the resources of most NSF/EAR-funded academic researchers. Most researchers have a place where cores, samples, and fossils can be accessed during the initial stages of research and sampling, but lack an adequate facility where these materials can be permanently preserved, accessed, and sampled/resampled as needed. Moreover, the samples are commonly discarded after the study due to a lack of storage space either by the PI or by the host institution. When the PI retires, in most cases the samples are discarded by the institution, making them inaccessible to further study by the greater Earth Sciences community.

At present no NSF-supported facility exists for the permanent storage and curation of terrestrial rock cores, samples, or paleontologic collections acquired during NSF/EAR-funded research for continental-based projects. Such facilities are in place for cores collected by the Ocean Drilling Program (ODP), and for marine core and dredge samples collected on NSF-funded cruises (e.g. Texas A&M, LDEO, WHOI, FSU, Scripps, Oregon State). Lacustrine sediment cores are stored at LacCore, operated by the Limnological Research Center; this national facility for curation of lacustrine sediment cores at the University of Minnesota is funded by NSF/EAR. Samples from the Antarctic and Arctic are now being archived at the U.S. Polar Rock Repository at the Ohio State University. However, no comparable facility exists for non-polar continental drilling cores or for important terrestrial rock samples. Similarly, no central site exists for the storage and curation of key paleontologic collections that are not amenable for archiving in museums.

An NSF workshop, 'Curation of Terrestrial Scientific Cores, Samples, and Collections' was held in May, 2004 at the HRC to address the need for a facility to permanently store and curate terrestrial rock materials and fossils acquired during NSF/EAR-funded research for continental-based projects (Dutton and Goldstein, 2004). The workshop brought together experienced curators and geoscientists working with terrestrial rock material acquired as part of academic research projects. The workshop was chaired by Shirley P. Dutton and Steven L. Goldstein. The workshop focused on three central issues: (1) determining the type of facility, equipment, and policies that would best curate, and provide access to, important geologic rock materials; (2) developing standards for which samples merit curation and which do not; and (3) discussing what metadata are necessary to accompany the

material and the best ways to manage the metadata.
Need for a Storage and Curation Facility
In 2002, the National Research Council published a report titled Geoscience Data and Collections: National Resources in Peril (National Research Council, 2002). The report documents the types and volumes of geologic materials that are at great risk of being lost because of lack of space and resources to store and curate them. The report concludes that this heritage is in great danger and that valuable geoscience data and collections will be lost through mismanagement, neglect, or outright disposal unless immediate action is taken.
The following bullets are some excerpts from the Executive Summary:
• 'Geoscience data and collections record the history of processes that operate on the Earth today and in the past and provide insights that lead to improved prediction of hazards, both immediate and long term. The geoscience community has amassed an enormous wealth of data and collections, most of which remain potentially useful and would be costly to replace, and much of which cannot be replaced. The diversity and quantity of these geoscience data and collections continue to expand, and as they have, so has need for space and funding to support their preservation and accessibility.'
• 'The committee concludes that immediate action is needed to stop the loss of irreplaceable geoscience data and collections in areas containing the greatest volume of at-risk material.'
• 'Well-maintained and well-documented geoscience data and collections have both immediate and long-term value. The nation has assembled a wealth of geoscience data and collections. Some of these already have been lost, and many more are in imminent danger of being lost—through mismanagement, neglect, or outright disposal—if immediate action is not taken. The recommended solutions that this committee proposes represent a strategy for such immediate action. Future generations deserve the opportunity to build upon existing successes and avoid repetition of our failures. Geoscience data and collections are national resources, and are a part of our nation's heritage. Preservation of geoscience data and collections is a comparatively small investment in our past, our present, and our future, with both immediate and long-term benefits.'
Previous Workshops
As a follow-up to the NRC Report, NSF sponsored a workshop in which the academic research community addressed the issues of long-term storage and curation of valuable scientific research materials. The workshop 'Preservation of Geoscience Research Cores and Collections: The View from Academic Researchers' was held in Bloomington, Indiana in January 2003 and chaired by Dr. Christopher Maples. The goals of the workshop were to (1) evaluate need of the academic community for storage space for geoscience research cores and collections and (2) propose a solution, so that those data and collections could be maintained and be easily accessible to the academic community (Maples, 2004). Of particular concern were cores and samples that are acquired at great expense, require a significant amount of space to store, and may be difficult or impossible to reacquire if lost. A specific recommendation from the workshop was that NSF support a facility that can accommodate the storage of terrestrial cores, rock samples, and paleontologic collections that were procured during NSF/EAR-funded academic research projects (Maples, 2004).
The need for a facility to archive and distribute important terrestrial petrology-geochemistry and structural geology samples for the academic research community was independently recognized and forwarded by the geochemistry community at the GERM (Geochemical Earth Reference Model) meeting in La Jolla, California in March 2001 (Goldstein and Melson, 2001) and by the broader Solid Earth Science

community at the Workshop on Cyberinfrastructure for the Integrated Solid Earth Sciences (ISES-CI) held in Lawrence, Kansas in March 2003. Both of these groups are supported by NSF/EAR. The ISES-CI workshop formed the SAMPLES Working Group (Sample Archive and Management PLanning for the Earth Sciences) with the mandate to explore the options to save precious samples and to make them readily available to researchers (c.f. section by Goldstein and Kimberley in the ISES-CI Report: Walker and Carlson, 2003).
In contrast to marine samples, there are no established procedures for the preservation and distribution of terrestrial samples. As summarized in the SAMPLES Working Group section of the ISES-CI Report (Walker and Carlson, 2003), there are pragmatic reasons to develop a systematic approach to archiving and distributing important petrology-geochemistry and structural geology samples.

- Petrology-geochemistry and structural geology studies require a large public investment in sampling, analyses, and evaluation.
- These studies are commonly global in scope and target samples from the far reaches of the Earth.
- Many important sample localities are difficult to access because of logistics or politics.
- There are cases where entire classic outcrops have been destroyed or covered by natural or human forces, thus precluding the possibility of obtaining new samples.
- Studies of archived marine samples, for example, have had a fundamental influence on the development of the plate tectonics paradigm and on our understanding of the Earth system over a range of disciplines, from marine geology and geophysics, to global climate change, to mantle dynamics.
- In geochemistry, there are still too few samples that have been properly characterized for their petrology and comprehensive suite of chemical and isotopic compositions. Comprehensive geochemical data sets are often the result of many stages of analyses over long periods of time by different research groups.
- Geologists often accumulate important terrestrial sample suites over the course of a career. Many such suites have been discarded after a project is finished or an investigator retires.
- Major advances in geochemistry often occur in tandem with new analytical developments. For example, geochemistry is currently experiencing an analytical revolution with the development of plasma-source mass spectrometry. The first samples that investigators want to analyze are well-characterized, previously studied samples.

WORKSHOP: CURATION OF TERRESTRIAL SCIENTIFIC CORES, SAMPLES, AND COLLECTIONS

Building on the recommendations of the NRC report and the Indiana and Kansas workshops, a workshop was held May 27, 2004 at The University of Texas at Austin Houston Research Center (HRC), which is operated by the Bureau of Economic Geology. The workshop brought together researchers and curators to discuss the needs of the academic community for storage of scientific terrestrial cores, samples and other collections. The goals of the workshop were to: (1) visit a public-sector geologic core and sample repository that has space to house terrestrial samples, cores, and collections; (2) discuss standards for determining which materials should be archived and which should not; (3) determine the specific needs (type of facility, shelving, equipment for sampling and research, metadata, etc.) to best curate, and provide access to, the different types of sample suites; (4) identify ways that the HRC can best work with academic researchers that are experiencing problems storing rock material and have a need

for long-term curation; and (5) make recommendations to EAR/NSF for meeting current and future needs (Dutton and Goldstein, 2004).

Rationale

As part of proposals to NSF/EAR, researchers must state their plans for permanent storage of samples, cores, and other data collected during the project within a short time frame from the end of the project (see NSF Division of Earth Sciences Guidelines for Geoscience Data and Collections Preservation and Distribution, 2002). EAR guidelines state that 'Preservation of all data, samples, physical collections and other supporting materials needed for long-term earth science research and education is required of all EAR-supported researchers' (NSF, 2002).
Many academic researchers have access to space where cores, samples and collections can be stored during the initial stages of research and sampling but lack an adequate place for long-term storage and curation. As a result, materials may be stored under inadequate conditions and may not be accessible to other researchers. In addition, universities and research institutions are generally unwilling to serve as sample repositories and often request that the space be freed for other uses when a principal investigator retires or when a project is finished. It thus becomes difficult for researchers to fulfill their obligation for preservation of terrestrial geoscience cores and collections.
The academic community has determined that there is a need for the establishment of a scientific sample repository for terrestrial cores and samples (Maples, 2004). A key issue for the Houston workshop was to define the function of a facility of this type. The function will be defined by (1) volume of existing and projected future material, (2) space, equipment, and logistical support needed by researchers to view and sample the material, and (3) metadata that will accompany the material.
Workshop Results and Recommendations
The NSF workshop 'Curation of Terrestrial Scientific Cores, Samples, and Collections' was chaired by Shirley P. Dutton, Senior Research Scientist with the Bureau of Economic Geology, The University of Texas at Austin, and Steven L. Goldstein, Associate Professor at Lamont-Doherty Earth Observatory of Columbia University. Goldstein chairs the SAMPLES working group, and both Dutton and Goldstein conduct research using terrestrial cores and samples and have long-standing interest in the preservation and curation of scientific research materials.
The workshop began with presentations by researchers working with core, samples and other geologic collections acquired for NSF-funded research projects, curators of geologic samples, and database experts. Breakout sessions focused on topics related to preservation of, and continued access to, geologic research materials. The results of breakout-session discussions were summarized by group leaders and reporters to capture key recommendations.
A workshop Web site has been established at: http://www.beg.utexas.edu/crc/nsf-workshop.htm. PowerPoint presentations made at the workshop are available on the Web site as pdf documents, and a summary report about the workshop and its recommendations is posted (Dutton and Goldstein, 2005).

Workshop Agenda

8:00 am - 8:15 am Welcome and overview of the workshop: rationale, goals, and tasks - Scott Tinker, Steven Goldstein, and Shirley Dutton

'Why do we need a sample repository?'– Steven Goldstein

8:15 am - 8:45 am Review of January 2003 NSF workshop
'A Report from the Indiana University Workshop Preservation of Geoscience Research Cores and Collections: the View from Academic Researchers'–Christopher Maples

8:45 am - 9:30 am Tour of HRC, led by Beverly Blakeney DeJarnett and Laura Zahm

9:30 am - 9:45 am Break

9:45 am - 11:30 am Brief presentations by members of interest groups

Curation needs of researchers from scientific drilling programs

'The San Andreas Fault Observatory at Depth (SAFOD): Testing Fundamental Theories of Faulting and Earthquake Mechanics through Drilling'–Stephen Hickman

'Introduction to DOSECC: Drilling Observation and Sampling of the Earth's Continental Crust, Inc.' and 'The Rutgers/NJGS Core Library'–Kenneth Miller

Curation needs of researchers working with other geologic data

'Curation of terrestrial scientific cores, samples, and collections'–Paul Renne

'Paleontologic collections'–Donald Mikulic

Curators of cores and other collections

'Lamont-Doherty Deep-Sea Sample Repository, Columbia University: 55 Years of Coring the Ocean Floor'–Rusty Lotti Bond

'The Gulf Coast Repository of the Integrated Ocean Drilling Program'–John Firth

'National Lacustrine Core Repository LacCore'–Emi Ito

'158 Years of Rocks at the Smithsonian: The Rock and Ore Collections, National Museum of Natural History, Smithsonian Institution'–Sorena Sorensen

'American Museum of Natural History'–Ed Mathez

11:30 am - 12:00 noon
Database Perspectives: handling metadata for cores, samples, and paleontologic collections; Geoinformatics

'Sample Curation as Part of the Geoscience Cyberinfrastructure'–Kerstin Lehnert

Geoinformatics–Walter Snyder

12:00 - 12:30 pm.: Lunch and informal discussions

12:30 pm - 1:45 pm: Breakout sessions

1. Design of a geologic sample repository
    a. Space and shelving needs
    b. Equipment needs
    c. Sampling needs

2. Geologic sample repository Advisory Committee
    a. Maximizing scientific usage and results
    b. Policy on acquisition and deacquisition
    c. Review of facility operations and usage

3. Storage of Metadata
    a. What data should accompany the rock material?
    b. How should the metadata be stored and made available?
    c. What is the best way to be in step with Geoinformatics initiative?

1:45 pm - 2:00 pm: Break

2:00 pm - 3:30 pm: Report of breakout sessions

3:30 pm - 5:00 pm: Summarize recommendations for NSF

Summary of Workshop Presentations

After introductory remarks by Scott Tinker and Shirley Dutton about the goals and schedule of the workshop, Steve Goldstein summarized the reasons why the workshop was convened (Goldstein, 2004). Acquisition of terrestrial samples is critical for conducting much of the geologic research in the Earth Sciences, and continued access to original samples collected with public funds by the entire research community is essential to create a truly reproducible science. At present no facility exists for the long-term curation and dissemination of terrestrial cores and samples, but such facilities are supported by NSF for marine cores and dredges, lake cores, ice cores, meteorites, and Antarctic samples. Goldstein, who chairs the ISES-CI SAMPLES working group, reported that the terrestrial geoscience community recognizes the problem and strongly supports terrestrial sample preservation. SAMPLES members provide broad coverage of the solid-earth geosciences.

Chris Maples summarized the results of the 2003 NSF workshop 'Preservation of Geoscience Research Cores and Collections: The View from Academic Researchers.' Of particular concern to the workshop participants were cores and samples that are acquired at great public expense, require a significant amount of space to store, and may be difficult or impossible to reacquire if lost. A specific recommendation from the workshop was that NSF support a facility that can accommodate the storage of terrestrial cores, rock samples, and paleontologic collections that were procured during NSF/EAR-funded academic research projects (Maples, 2004).

Talks by Stephen Hickman (Hickman, 2004) and Ken Miller (Miller, 2004a) described the current and future curation needs of researchers from scientific drilling programs. The San Andreas Fault Observatory at Depth (SAFOD) project, described by Hickman, is part of the NSF EarthScope project. The goal of SAFOD is to directly measure the physical and chemical processes that control deformation and earthquake generation within an active plate-bounding fault zone. Forty meters of core from the San Andreas fault zone have already been collected, with an additional 1000 m planned. The core needs to be curated under conditions that (1) preserve in-situ structures, (2) maintain original pore-fluid saturation and chemistry, (3) minimize

geochemical alteration of mineral phases, (4) minimize biological contamination, and (5) make it readily accessible to the user community. Core curation records will have to be integrated with the ICDP data base. Ken Miller summarized the DOSECC program (Drilling Observation and Sampling of the Earth's Continental Crust), whose goal is to facilitate and support scientific investigations through drilling. DOSECC represents U.S. interests in the international scientific drilling community. Many recent and planned DOSECC projects involve drilling lake sediments, which are curated at the LacCore facility in Minnesota. Hard-rock cores have been collected recently for the Hawaii Drilling project (stored at the American Museum) and are planned from the Chesapeake Bay Impact Structure (2,500 m) and the San Andreas Fault Zone (SAFOD project) (1,000 m). In addition to these DOSECC projects, the Plate Boundary Observatory (PBO) component within the EarthScope project will collect approximately 5,300 m of core from 175 strain-meter boreholes drilled as part of a large geodetic network in the western US.

Paul Renne and Don Mikulic presented talks about the curation needs of researchers working with other geologic data. Paul Renne summarized the difficulty of obtaining geochronology samples in the absence of a system of archiving and sharing terrestrial samples obtained with public funding (Renne, 2004). Sample material is not always available for replication or application of new methods due to insufficient material, proprietary attitude, or inadequate curation practices. He concluded that huge scientific benefits would be realized if all researchers had access through a public repository to all samples. Don Mikulic, co-chairman of The Paleontological Society's Collections Committee, summarized curation needs associated with fossils and unprocessed material. Each individual specimen would ideally be stored in its own box and labeled. Type specimens are the most important material to save, but many existing fossil collections have historical value and should be kept together as a group, along with metadata such as field notes, maps, and correspondence. More problematic are unprocessed material, fossils from cores, and insoluble residues.

A series of presentations by curators of cores and other collections summarized their facilities, metadata management, and policies for sample acquisition and deacquisition.

- Ken Miller described the Rutgers University/New Jersey Geological Society Core Library (Miller, 2004b);
- Rusty Lotti Bond described the Lamont-Doherty Deep-Sea Sample Repository, Columbia University (Bond, 2004);
- John Firth described the Gulf Coast Repository of the Integrated Ocean Drilling Program, Texas A&M University (Firth, 2004);
- Emi Ito described the National Lacustrine Core Repository LacCore, University of Minnesota (Ito, 2004);
- Sorena Sorensen described the Rock and Ore Collections at the National Museum of Natural History, Smithsonian Institution (Sorensen, 2004); and
- Ed Mathez described the collections of the American Museum of Natural History.

The final talks of the workshop focused on geoinformatics. Walter Snyder spoke on the general topic of geoinformatics, and then Kerstin Lehnert presented 'Sample Curation as Part of the Geoscience Cyberinfrastructure.' A goal of the emerging geoscience cyberinfrastructure is to link physical samples to digital sample-based databases (Lehnert, 2004). A web-based curation information system for terrestrial cores and samples should be integrated with other sample catalogues and with all sample-based data and information systems. The curation database will archive curation-specific metadata associated with materials stored at the

facility, and appropriate links should be provided to data derived from the samples and stored at other, discipline-specific sites such as PetDB or NAVDAT.

Findings:

INTRODUCTION
Workshop participants identified the needs of the research community and prioritized the facilities, equipment, and metadata storage that would best suit the different types of geologic material to be curated. The HRC was identified as well suited and appropriate for curation of terrestrial cores, samples, and other collections acquired for NSF/EAR-funded research. A core and sample storage facility at the HRC would advance knowledge and understanding in Earth Science by preserving precious rock material acquired with public funds, providing a public catalog of the material, and making samples readily available to the research and education community.

SUMMARY OF BREAKOUT SESSION RECOMMENDATIONS

In the final part of the workshop, participants were divided into three breakout sessions: (1) Design of a geologic sample repository; (2) geologic sample repository advisory committee; and (3) storage of metadata (Dutton and Goldstein, 2005).

Breakout Session 1—Design of a Geological Sample Repository: Needs and Issues

Steve Goldstein—Session Facilitator
Sherwood Wise—Session Recorder
Beverly Blakeney DeJarnett
John Firth
Anne Grunow
Steve Hickman
Emi Ito
Jay Kipper
Joanne Kluessendorf
Charlotte Sullivan

Summary of Recommendations

A facility to curate terrestrial cores and samples must have basic equipment for storing the materials (shelving, boxes) and collecting samples (saws, plugger) requested by researchers. Visitors to the facility should have at their disposal computers with high-speed or wireless internet connections, digital photographic equipment, binocular microscopes for viewing samples, cores, and microfossils, and petrographic microscopes for viewing thin sections. The goal is for researchers to have all of the basic equipment necessary to examine and sample rock materials at the facility. Analyses of samples, however, will be conducted by the scientists at their own institutions. Reference collections of material for educational and outreach activities should be assembled.

Report of Breakout Session 1

1. Construction: expect permitting delays up to one year. (Note: this does not apply to the HRC, because the facility is already in place.)

2. Equipment and services offered:

a. Rock preparation: strive to conserve material and unnecessary return of residual material (the 80-gram test)
1. Rock saws: 18'
2. Drill press: for paleomagnetic sampling and subsamples; plugging
3. Thin-section equipment/technician: best to contract samples out for cost/quality/staff time
4. Most destructive processing should be done in home lab
5. Disaggregator (electric-shock technology)? Probably not
6. Magnetic separator? Probably not

b. Imaging:
1. Digital pictures: from copy stand of sample boxes/samples for incoming cores or on demand for legacy collections (and for www, etc, internet access: Wireless)
2. Geotek core scanner/imager

c. Analytical equipment:
1. Microscopes
a. petrographic with epi-fluorescence capabilities
b. microfossil
3. Multisensor Track (MST):
a. digital image log: whole core and split core
b. other non-destructive measurements
4. GeoWall? Or, at least a mini-permeameter and gamma ray.

d. Reference collections for investigators, education and outreach:
1. microfossils
2. thin sections
3. rocks

3. Space and storage
a. Shelving and cabinetry: Must be flexible for all types of rocks (metal, wood, size as required by sample type
b. Packaging and Preservation:
1. Food-industry technology?
2. Freezing of unconsolidated samples
c. Financial Model: Must calculate costs/space for type and size of collections donated (cost per unit - based on sample type)

Breakout Session 2—Geologic Sample Repository Advisory Committee

Paul Renne—Session Facilitator
Ed Mathez—Session Recorder
Rusty Lotti Bond
Shirley Dutton
John Flynn
Rich Lane
Don Mikulic
Ken Miller
Scott Tinker

Summary of Recommendations

The group recommended that two Advisory Committees were needed, one

for the terrestrial core and sample repository, and a separate, national Advisory Committee to review all NSF-funded repositories. The Advisory Committee for the terrestrial repository should consist of members of the academic community who would review operations and policies and provide advice on NSF curation activities at the facility. The Advisory Committee would guide policy for acquisition, deacquisition, sampling, and distribution of NSF materials. Members of the Advisory Committee should represent the various areas of the academic constituency of the facility, including (1) members of the current SAMPLES Working Group, generally representing solid-Earth scientists, (2) researchers from projects acquiring terrestrial cores, such as DOSECC and EarthScope (SAFOD and PBO), (3) paleontologists familiar with the curation of fossil collections, and (4) researchers experienced in scientific curation.
A national Advisory Committee would (1) establish and review needs and polices for archiving of geological samples whose acquisition has been funded by NSF, in consultation with constituent communities; (2) evaluate the existing resources and recommend priorities for funding of new and existing facilities; (3) review and evaluate the operations and policies of repositories; (4) liaise with organizations involved in international archiving efforts.

Report of Breakout Session 2

We see the need for a national Advisory Committee (AC) as well as Advisory Committees for specific facilities.

The national AC should:
(1) establish and review needs and polices for archiving of geological
samples whose acquisition has been funded by NSF, in consultation with

constituent communities;
(2) evaluate the existing resources and recommend priorities for funding of
new and existing facilities;
(3) review and evaluate the operations and policies of repositories;
(4) liaise with organizations involved in international archiving efforts.

A national AC should consist of individuals in all disciplines covered by EAR and different organizations, including universities, museums, other academic research institutions,
national labs, and relevant government agencies such as USGS and state

surveys.

It should also include individuals, such as journal editors, that deal with data reporting and from professional organizations, such as AGI.

The composition of the AC should evolve as the issues facing it evolve. There should be specific terms; the size of the committee should be
limited to a manageable size (i.e., 6-8 at any one time).

Breakout Session 3—Storage of Metadata: Issues Related to Metadata and Databases at a Repository for NSF Samples

Lee Allison–Session Facilitator
Kerstin Lehnert and Laura Zahm–Session Recorders
John Els
Jeannine Honey
Chris Maples
Walt Snyder
Sorena Sorensen
Julia Smith Wellner
Fred Weaver

Summary of Recommendations

An integral part of the terrestrial core and sample repository will be a user-friendly web-based catalog that will allow researchers to find the samples they need from their desktop, and this catalog will be integrated in the emerging Geosciences Cyberinfrastructure. The Information Technologist in charge of the database will therefore need to be familiar with ongoing efforts in the field of Geoinformatics and Cyberinfrastructure database design. The database of NSF materials will be in compliance with, and linked to, that system. The database will archive curation metadata associated with NSF materials stored at the facility and work with researchers to provide appropriate links to data derived from the samples and stored at other sites. Sample metadata must be transmitted to the Information Technologist at the time the rock material is transferred to the facility for storage, to be posted to the Web site.
Mandatory curation-specific metadata include (1) the location (latitude and longitude) of the sampling site and the SESAR (Solid Earth SAmple Registry) unique sample identifier code (http://www.geosamples.org), (2) the date the core/samples were collected, (3) the name of the collector or project Principal Investigator, (4) for cores, the depth of the cored interval, (5) the name, age, and lithology of the formation that was cored/sampled, and (6) sample type (whole core, slabbed core, hand samples, cuttings, thin sections).

Report of Breakout Session

Only a small percentage of Web data sites have metadata (~34%)
A tiny fraction have advanced metadata (e.g., 0.3% Dublin Core)

Minimum Data:
The minimum metadata necessary for some users may be one valid item. (Some piece of information to lead to other data, for example: location, age of sample, etc.)

Researchers' needs should not be arbitrarily constricted by data providers.

Metadata:
More information increases the value of the rock material.
Sample type
Source of sample, who was researcher
References for published work

Geoinformatics/Linked Databases:

Catalog or linked sites that will point to multiple regional centers where rock material and analyses are curated. Repositories to serving data on the web and link to distributed databases, servers, and

systems, and publish metadata.

Relational database management systems are the more robust than flat files, and the wave of the future. Likewise, geographically-identified data are of particular value in the geosciences.

Databases can be voluntarily registered via centers and portals. There needs to be a reward system to encourage this (NSF requirements, recognition for promotion)

Recommendations to NSF:

Require investigators to reposit samples, data, and metadata. Reward compliance.

Provide funds to investigators for repositories, archives, and data management systems

HOUSTON RESEARCH CENTER

The Houston Research Center provides a solution to the problem recognized by the academic community. Sufficient space is available in the HRC to store and curate terrestrial scientific cores, samples, and collections procured through EAR/NSF-funded research projects so that they can be easily accessed by the academic community for further investigation.
HRC Facility History

The Bureau of Economic Geology, a research unit within The University of Texas at Austin, acquired a world-class, public-sector core and sample research facility through the donation in 2002 of two warehouses, a research building, and 12 acres of land from BP. As a result, important geologic specimens can be professionally preserved in this facility and made publicly accessible to scientists and students for research. The facility, originally constructed by Amoco, was designed expressly for storing and studying geological material; therefore, no modifications were needed to make it operational. The donation included forklifts for moving heavy material and specially designed layout tables for core viewing. The Houston facility has office, laboratory, and layout space available for visiting scientists (fig. 1) in a 22,000-ft2 research building. Two conference rooms accommodate guests attending short courses and seminars. The HRC is accessible for people with disabilities.

Figure 1. Space designed for layout and viewing of cores.

The two warehouses have state-of-the-art design for curation of geologic materials (fig. 2). The total square footage of the warehouse buildings is 88,000 ft2, which provides space for the storage of 900,000 boxes of core. A three-tier layout allows forklifts to move material from the different levels throughout the warehouse. All indoor space, including the warehouses, is climate controlled and lighted, and wide aisles allow easy access for forklifts to move materials between the shelves and layout rooms. The HRC currently contains approximately 500,000 boxes of core and samples, almost all of which were obtained as a result of exploration for oil and gas.

Figure 2. State-of-the-art warehouse for storage of rock cores and samples.

The HRC is centrally located within the U. S. It is located on the west side of Houston (fig. 3) and is easily accessible by any of the major Houston freeways. The HRC is located 23 mi from George Bush Intercontinental Airport (GBIA), the major international airport in Houston, and 29 miles from Hobby Airport, which is served by Southwest Airlines. Many hotels and restaurants are convenient to the facility.

Fig. 3 Location of Houston Research Center (star) in west Houston.

Equipment at the HRC includes saws for cutting cores and taking samples, digital cameras, petrographic and binocular microscopes, and equipment for making thin sections. Office equipment includes computers with high-speed Internet connection and laser printer, a copier, scanner, and fax machine. Two conference rooms are equipped with LCD projectors, overhead projectors, dry erase walls, and a PA system. A break room, offices, and lab space can also be used by visiting scientists. A professional geoscience and engineering library valued at nearly $5 million is also available for use by visiting researchers. The library includes books, journals, monographs, maps, and State and Federal geological reports primarily in the areas of geology, geochemistry, geophysics, and petroleum engineering.

HRC Space for EAR/NSF-Funded Research Materials

An area of approximately 9,600 ft2 within the HRC will be dedicated to the storage of materials procured through EAR/NSF-funded research projects. An area of 5,250 ft2 will be used for core storage (fig. 4). This area will hold approximately 4,380 linear feet of 3-ft wide shelving. Cores would be stored in 3-ft-long boxes stacked on the shelves. Space is sufficient in that area for storage of approximately 159,000 ft of core (53,000 boxes). Another area of 3,400 ft2 will be used for storing samples and other collections. Small samples could be stored in sample bags placed in core boxes, and larger samples could be stored in heavy-duty plastic storage boxes on the shelves. Scientists having materials for curation at the HRC, as well as experienced curators and the Advisory Committee, will be asked to provide guidance on the best way to store samples and fossil collections.
In addition to the space dedicated to storage of EAR/NSF-funded cores and samples, 4,500 ft2 of shared space is available for core layout and viewing and for core sampling. The modern core- and sample-examination room is equipped with roller tables (fig. 1), binocular microscopes, and excellent lighting. Offices next to the NSF core-storage area are available for the use of visiting scientists (1,450 ft2), as are the library (3,500 ft2), petrographic microscope lab (150 ft2), and conference rooms (2,700 ft2). The HRC space available for EAR/NSF core and sample storage and for use by visiting scientists is comparable to the ODP Gulf Coast Repository in College Station and larger than the Lamont-Doherty Earth Observatory Deep-Sea Sample Repository, the Antarctic Research Facility at Florida State University, and the National Lacustrine Core Repository at the University of Minnesota.

Figure 4. A 5,250-ft2 area will be dedicated to storage of EAR/NSF research cores. An additional 3,400 ft2 of space on the second floor

will be used for samples and collections.

Advisory Committee

An Advisory Committee consisting of six members of the academic community will be established to review operations and policies and advise the Bureau on EAR/NSF-curation activities at the HRC. Members of the Advisory Committee will represent the various areas of the academic constituency of the HRC, including (1) members of the current SAMPLES Working Group, generally representing solid-Earth scientists, (2) researchers from projects acquiring terrestrial cores, such as EarthScope (SAFOD and PBO) and DOSECC, (3) paleontologists familiar with the curation of fossil collections, and (4) researchers experienced in scientific curation. The Principal Investigators of the EAR/NSF sample storage facility at the HRC will also be members of the Advisory Committee. The Director of the Bureau of Economic Geology will appoint one ad-hoc member of the committee to assure that the overall facility maintains the standards required to meet the needs of the research community.

The Advisory Committee will guide policy for acquisition, deacquisition, and sampling of EAR/NSF materials. Its members will be selected after consultation with representatives of the groups listed above and with NSF. Committee members will serve staggered, three-year terms; the committee Chair will be selected from the outside (non-PI) members. The Committee will meet each year at the HRC to review operations and provide advice, and the HRC Curator will send an annual report of operations to NSF and the Advisory Committee.

HRC Services for the Academic Research Community

The main function of the EAR/NSF sample storage facility at the HRC is to provide a service to the academic research community. There will be no cost to researchers for storing research cores and samples procured through EAR/NSF-funded research projects at the HRC, but researchers are responsible for the cost of shipping material to the HRC. In addition to cores, samples, and digital data, the HRC can store thin sections, field notebooks, maps, and handwritten data sheets. Downhole logging data will be accepted in digital and paper form for cored wells. The Advisory Committee will guide policy for EAR/NSF core and sample acquisition and sampling. Researchers who send cores and samples to the HRC will want to keep them proprietary for a period of time, when they will be available only to scientists on the project or those designated by the PI to have access. The length of the moratorium period will be determined by EAR/NSF policies.

Facilities and equipment will be provided at the HRC to allow researchers to examine cores and other material and collect samples as needed. Scientists engaged in geoscience research may either make an online request that samples be collected by HRC staff and shipped to them, or they can visit the repository to view the material and request samples in person. The HRC will pay the cost of shipping samples to researchers, within limits to be established by the Advisory Committee. Requests that exceed established limits will be reviewed and researchers may be asked to pay shipping costs. Researchers will be required to return leftover materials, assuming there is sufficient material to return. For researchers who travel to Houston in order to directly sample NSF specimens and cores, HRC staff will assist them, for example, by laying out the material for viewing and cutting samples at no charge.

The facility will be open for visitors Monday through Friday during normal business hours, but visits during other days or times will be negotiable. Visitors will have at their disposal computers with

high-speed Internet connection, digital photographic equipment, binocular microscopes for viewing samples and cores, and petrographic microscopes for viewing thin sections. The goal is for researchers to have the basic equipment necessary to examine and sample rock materials at the HRC. Analyses of samples, however, will be conducted by the scientists at their own institutions.
Curation Database

An integral part of the planned system will be a user-friendly web-based catalog that will allow researchers to find the samples they need from their desktop, and this catalog will be integrated in the emerging Geosciences Cyberinfrastructure. The HRC Information Technologist will therefore be familiar with ongoing efforts in the field of Geoinformatics and Cyberinfrastructure database design. The HRC database of NSF/EAR materials will be in compliance with, and linked to, that system. The HRC database will archive metadata associated with NSF/EAR materials stored at the facility and work with researchers to provide appropriate links to data derived from the samples and stored at other sites. Sample metadata must be transmitted to the HRC database group at the time the rock material is transferred to HRC for storage, to be posted to the HRC Web site.
The Integrated Core and Log Database (IGOR) is a searchable database for all core and well cutting holdings currently held at the HRC. The database for NSF/EAR-funded research materials stored at the HRC will be compatible with the IGOR database and will have GIS-based search capability. Metadata accompanying terrestrial scientific cores/samples that are sent to the HRC for curation will be expected to include (1) the location (latitude and longitude) of the sampling site and the SESAR (Solid Earth SAmple Registry) unique sample identifier code (http://www.geosamples.org), (2) the date the core/samples were collected, (3) the name of the collector or project Principal Investigator, (4) for cores, the depth of the cored interval, (5) the name, age, and lithology of the formation that was cored/sampled, and (6) sample type (whole core, slabbed core, hand samples, cuttings, thin sections), and any other information deemed necessary by the Advisory Committee. For many important legacy samples, we recognize some of the desired metadata may not be available. Care will be taken to make sure the catalog and metadata are linked to other databases and to avoid redundancy. For example, storage of the metadata in SESAR may suffice, to the extent that the linkage to the HRC is transparent to the user. The information on samples stored at the HRC, including photos of samples and thin sections, linkages to published data, and information on samples taken, will be available through the HRC website.
The HRC does not consider itself to be the repository of data derived from the cores and samples. We expect that they will be placed in an appropriate publicly available database, such as the NSF-supported Chronos System (www.chronos.org), PetDB (www.petdb.org), NAVDAT (navdat.geo.ku.edu/), or GEOROC (georoc.mpch-mainz.gwdg.de/georoc/), and/or in a public data archive such as NGDC (www.ngdc.noaa.gov).
Sampling Policy and Procedures

The policy and procedures for distributing samples from NSF cores and other material stored at the HRC to research scientists, curators, and educators will be formalized by the Advisory Committee. We will propose to the Advisory Committee that the general procedures in place at the ODP sediment-core storage facility at Texas A&M University (Ocean Drilling Program, 2002) or the Lamont-Doherty Deep Sea Core Repository (Lamont-Doherty Deep Sea Core Repository, 2005) be used as guidelines. The Advisory Committee will also define the obligations

that sample and data recipients incur. The objectives of the sampling policy are to (1) encourage scientific analyses over a wide range of research disciplines by providing samples to the scientific community, and (2) preserve core material, rock samples, and collections as an archive for future research. In principle, we expect to maintain a system in which all reasonable requests from researchers for sample aliquots will be fulfilled. The sampling policy and a sample-request form will be available online.
Opportunity for Expansion

The HRC property currently includes 6 acres of land. The Bureau has the option of building an additional warehouse on this property. Thus, this facility has the capacity to accommodate increased usage by NSF-funded scientists into the foreseeable future.
The University of Texas at Austin will maintain the NSF/EAR sample storage facility through its funding of HRC utilities, building maintenance and supplies, and other costs.
Business Plan for NSF Materials

Curation of NSF-funded terrestrial rock material at the HRC will require a dedicated geological Curator, Materials Handler, and an Information Technologist to manage the database. They will store and curate the core and other samples, respond to requests by researchers for samples, assist visiting researchers at the facility, establish the database, and maintain the metadata associated with the samples. NSF-curation operations at the HRC will be overseen by Principal Investigator Shirley P. Dutton and during the initial start-up phase by co-Principal Investigator Steven L. Goldstein. They will work directly with the HRC employees in designing the working operation. Both Dutton and Goldstein conduct research using terrestrial cores and samples and have long-standing interest in the preservation and curation of scientific research materials.
The Curator will be a geologist who will be responsible for NSF operations in the facility, including interacting with the scientific community, responding to requests by researchers for samples, assisting visiting researchers at the facility, and working with the Information Technologist to ensure that the database meets the needs of geologic researchers. The Principal Investigators and the Curator will travel to selected professional meetings to present information about the HRC NSF facility and services to the academic community. The Materials Handler will be responsible for labeling, photographing, and storing the material, retrieving samples for viewing by researchers, cutting requested samples, shipping approved materials, and associated data entry into the database.
The Information Technologist will be responsible for designing and programming the database, ensuring that it is compatible with other databases, and for maintaining the Web site. The database is crucial to maintaining the integrity of the collection and provides the portal for the scientific community. Database design, data loading, quality assurance, and revision will be a priority activity requiring a substantial commitment of time from the database manager. The database of NSF material will be compatible with emerging Geoinformatics and cyberinfrastructure protocols of the geoscience community.
SUMMARY

At present no NSF-supported facility exists for the permanent storage and curation of terrestrial rock cores, samples, or paleontologic collections acquired during NSF/EAR-funded research for continental-based projects. The workshop participants recommended the establishment a center to curate this material and facilitate

continued access to, and use of, the material by researchers in the academic community. The HRC was identified as well suited and appropriate for curation of terrestrial cores, samples, and other collections acquired for NSF/EAR-funded research. By affiliating with an existing core repository, the NSF/EAR facility at the HRC represents an opportunity to meet the needs of the academic community with a much lower public expenditure than building a new repository. Participants identified the needs of the research community and prioritized the facilities, equipment, and metadata storage that would best suit the different types of geologic material to be curated. A core and sample storage facility at the HRC would advance knowledge and understanding in Earth science by preserving precious rock material acquired with public funds, providing a public catalog of the material, and making samples readily available to the research and education community.

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Training and Development:

A graduate student from Rice University was invited to participate in the workshop.

Outreach Activities:

An abstract has been submitted for presentation at the 2005 annual meeting of the Geological Society of America, and most of the workshop presentations have been posted on the workshop Web site (http://www.beg.utexas.edu/crc/nsf-workshop.htm)

Journal Publications:

Dutton, S. P., Goldstein, S. G., and DeJarnett, B. B., "Curation of Terrestrial Scientific Cores, Samples, and Collections.", *2005 Geological Society of America Abstracts with Program volume*, vol. , (), p. . Published

Book(s) of other one-time publications(s):

Other Specific Products:

Teaching aids

Dutton, S. P., Goldstein, S. G., and DeJarnett, B. B., Curation of Terrestrial Scientific Cores, Samples, and Collections.

The following abstract has been submitted for presentation at the Geological Society of America 2005 annual meeting:

Internet Dissemination:

http://www.beg.utexas.edu/crc/nsf-workshop.htm

Copies of the PowerPoint presentations given at the workshop can be accessed from this page, and a summary report about the workshop and its recommendations is posted.

Contributions:

Contributions within Discipline:

A facility for storage and curation of terrestrial scientific cores, rock samples, and collections acquired by NSF-funded research projects will become a key resource for researchers in the Earth sciences. The participants in the workshop recommended that invaluable geologic samples be professionally preserved and made accessible to the academic community.

Acquisition of terrestrial cores, rock samples, and fossils is critical for conducting much of the geologic research supported by the NSF Division of Earth Sciences (NSF/EAR). Because of the volume involved, long-term storage, preservation, and curation of these materials are beyond the resources of most NSF/EAR-funded academic researchers. Most researchers have a place where cores, samples, and fossils can be accessed during the initial stages of research and sampling but lack an adequate facility where these materials can be permanently preserved, accessed, and sampled/resampled as needed by the wider academic community. The workshop recommended establishment of a facility for the permanent storage and curation of terrestrial rock cores, samples, and paleontologic collections acquired during NSF/EAR-funded research for continental-based projects.

It has been recognized on the national level that this is a legacy in peril and that a system needs to be instituted in order to preserve terrestrial samples and cores and make them easily accessible to researchers, in a manner similar to the way deep sea cores are stored

and distributed. In 2002, the National Research Council published a report titled Geoscience Data and Collections: National Resources in Peril. The report documents the types and volumes of geologic materials that are at risk of being lost because of lack of space and resources to store and curate them. The report concluded that valuable geoscience data and collections may be lost through mismanagement, neglect, or outright disposal unless immediate action is taken. As a follow-up to the NRC Report, NSF sponsored a workshop in which the academic research community addressed the issues of long-term storage and curation of valuable scientific research materials. The workshop 'Preservation of Geoscience Research Cores and Collections: The View from Academic Researchers' was held in Bloomington, Indiana in January 2003 and chaired by Dr. Christopher Maples. The goals of the workshop were to (1) evaluate need of the academic community for storage space for geoscience research cores and collections and (2) propose a solution, so that those data and collections could be maintained and be easily accessible to the academic community (Maples, 2004). Of particular concern are cores, samples, and collections that were acquired at great expense, require a significant amount of space to store, and may be difficult or impossible to reacquire if lost. A specific recommendation from the workshop was that NSF support a facility that can accommodate the storage of terrestrial cores, rock samples, and paleontologic collections that were procured during NSF/EAR-funded academic research projects (Maples, 2004).

The need for a facility to archive and distribute important terrestrial samples for the academic research community was independently recognized and forwarded by the geochemistry community at the GERM (Geochemical Earth Reference Model) Meeting in La Jolla, California in March 2001 (Goldstein and Melson, 2001) and by the broader Solid Earth Science community at the Workshop on Cyberinfrastructure for the Integrated Solid Earth Sciences (ISES-CI) held in Lawrence, Kansas in March 2003. Both of these groups are supported by NSF/EAR. The ISES-CI workshop formed the SAMPLES Working Group (Sample Archive and Management PLanning for the Earth Sciences) with the mandate to explore the options to save precious samples and to make them readily available to researchers (c.f. section by Goldstein and Kimberley in the ISES-CI Report: Walker and Carlson, 2003). As summarized by the report of the SAMPLES working group, there is a need to develop a systematic approach to archiving and distributing important terrestrial petrology-geochemistry and structural geology samples.

Archived samples must be accompanied by metadata and be accessible to the research community through a database compatible with emerging GeoInformatics and cyberinfrastructure protocols. As part of proposals to NSF/EAR, researchers must state their plans for permanent storage of samples, cores, and other data collected during the project within a short time frame of the end of the project (see NSF Division of Earth Sciences Guidelines for Geoscience Data and Collections Preservation and Distribution, 2002). In the developing Geosciences Cyberinfrastructure, information about the location and condition of samples should be linked to sample-based data and information systems.

The geologic core-storage and research facility operated by the Bureau of Economic Geology in Houston, Texas fills an important need of the Earth science community. The HRC has dedicated space to curate terrestrial cores, and samples, and collections and facilitate continued access to, and use of, the material. The HRC provides a

means to implement the NSF/EAR guidelines in a way that will allow the entire research community to access important information about the samples as well as the samples themselves.

Contributions to Other Disciplines:

The rock materials curated at the HRC are likely to be useful data sources for other fields of science and engineering. For example, samples of sedimentary rocks may be used by climate modelers to gather data on earth conditions through time. Cores from shallow boreholes may be of particular use to civil engineers, such as the cores being collected in a large area of the western U.S. and Canada for the Plate Boundary Observatory (about 150 boreholes to depths of 200-300 m).

Contributions to Education and Human Resources:

Field trips and opportunities to see and touch rocks are popular educational activities that can lead K-12 students to consider earth science as a career. Outreach activities provide all students with a better understanding of the importance of earth science to society. The geologists at the HRC visit schools and lead tours of the HRC to talk about the importance of geology in our every day lives. The HRC staff has also conducted many tours of the HRC for professional geoscientists and geoscience students at the collegiate level.

The HRC facilities and collections have also been used by classes for undergraduate and graduate students, as well as professional classes. Rock material curated at the HRC can be viewed, described, and sampled for teaching and educational purposes. Materials that are abundant in the collection are available to educators for sampling.

Contributions to Resources for Research and Education:

The purpose of this workshop was to discuss and make recommendations regarding shared support to provide the research community with a state-of-the-art facility for curation of geologic materials. The workshop also considered the equipment that should be available at the facility and what metadata should accompany materials submitted for curation. Such a facility will have a major effect on the way research in the Earth sciences is conducted by providing an easy means for researchers to access extensive collections of terrestrial rock samples that have been previously investigated. Major advances in Earth science are commonly the result of many stages of analyses over long periods of time by different research groups. This is only possible to the extent that rock material is preserved and made available to the research community in a timely manner and at a reasonable cost.

The HRC facility will also enhance the infrastructure for education by making samples available for student research. Rock material curated

at the HRC can be viewed, described, and sampled for teaching and educational purposes. The HRC offers a broad and successful outreach program to both K-12 and university students in the Houston area that will continue be expanded and will continue to be a resource for furthering the appreciation of the importance of the geosciences to the general public.

Contributions Beyond Science and Engineering:

Earth science research contributes to public welfare and national need. The cores and samples that are preserved for future use at the HRC may be used to investigate topics including earthquake science; geological hazards; energy, mineral, and water resources; global climate change; land-use planning; and public education.

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