Recommendations and Progress Report from the Workshop on CyberInfrastructure (CI) for the Integrated Solid Earth Sciences (ISES)

ISES-CI Steering Committee

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Framing Statement

The Integrated Solid Earth Science (ISES) effort arose from the Solid Earth Sciences workshop held in conjunction with the 2002 Geological Society of American meeting. The goal of ISES is to create a common voice for areas of geology that focus on the solid earth, including geochemistry, geochronology, paleontology, petrology, sedimentology, stratigraphy, structural geology, tectonics, and volcanology (essentially the disciplines in the CD, GE, CH and TE Programs, and to an extent PH and IF Programs, within the Earth Sciences Division of the National Science Foundation). This alliance formed in the Fall of 2002 because of a grass-roots effort, and the Solid Earth Science community is actively working to coordinate and articulate common community visions for science, research, and participation in the CyberInfrastructure revolution. The last aspect, which is termed ISES-CI, was the focus of a NSF-funded workshop held at the University of Kansas on March 28 and 29, 2003. This report and the development of an ISES-CI organization follow on the community consensus built at this workshop. This ISES-CI effort is ongoing, is separate from, but coordinated with, the ISES role in helping create a science vision for the contributing domains.

> ***ISES-CI*** *is the vehicle for participation of ISES domains in the CI revolution. Several working groups formed to take advantage of community consensus reached at the ISES-CI workshop. These working groups will foster new areas of effort, help nurture nascent areas, and work to solidify collaborations among mature endeavors.*

The ISES-CI workshop concluded that there is a pressing need to develop databases and analysis and synthesis tools, and to ensure interoperability of ISES datasets and tools in keeping with other disciplinary CI efforts at NSF. At present, there are many ongoing collaborative efforts that need to be fostered, there are natural collaborations that need to be cultured, and there are others that have yet to be organized but are identified. The process of evaluating needs, developing consensus, and building community support was started during the ISES-CI workshop by selecting key scientists to serve as steering committee leaders for each of these areas. The resulting working groups will help facilitate the ISES communities through ISES-CI in the overall Geoinformatics efforts in the Geoscience community.

> ***Watchwords for ISES-CI:*** *Integrative, inclusive, easy, distributed but seamless. The ISES-CI workshop concluded that a system must be developed for easy data upload and transfer with embedded tools for initial analysis that creates seamless integration and visualization of distributed datasets, and that empowers the larger community to join in the CI revolution.*

ISES-CI Working Areas

The ISES-CI workshop identified ten priority areas that are critical to the future progress of the ISES and their integration into the broader spectrum of Geosciences and other related areas of science. Working groups for the priority areas have been established, and it is anticipated that most of the working groups will make presentations at the ISES meeting held at the Geological Society of America meeting in Fall, 2003. Group leaders are listed for each subject area and a brief report on area activities follows.

1) Geochemistry of Igneous and Sedimentary Rocks

Kerstin Lehnert (Chair, LDGO - PetDB)
Al Hofmann (Max Planck Institut fur Chemie, Mainz - GEOROC)
Richard Carlson (DTM - NAVDAT)

This working group includes members of the three functioning on-line relational databases for geochemical analyses of igneous rocks (PetDB, GEOROC, and NAVDAT) from both continents and the ocean basins. Working together, these databases have outlined a series of tasks to be pursued in a cooperative manner that will bolster the coverage, utility, and ease of use of the datasets, starting with a common entry page, www.earthchem.org. Coordination with Bruce Wardlaw of CHRONOS will ensure compatibility with the sediment geochemical data to be compiled as a part of the CHRONOS effort. This working group represented ISES-CI at the Geoinformatics and GERM workshops in May 2003, where avenues of collaboration with the GERM effort were developed. They also are planning an IT development workshop for geochemical databases that will be held in fall of 2003 prior to the next ISES meeting.

2) Geochronology and Thermochronology

Mark Schmitz (Co-Chair, DTM and U. Idaho)
Dan Stockli (Co-Chair, U. Kansas)
John Gosse (Co-Chair, Dalhousie)

This group primarily will serve to keep ISES-CI familiar with the planned efforts of the CHRONOS program on the structure and extent of geochronologic efforts. The working group has made contact with CHRONOS Director Bruce Wardlaw, and with the geochronology member of CHRONOS, Anthony Koppers, and will monitor the developments in the design of the radiometric geochronology database planned by CHRONOS. After working with CHRONOS, these group leaders will form a working group to deal with developing databases and access tools for thermochronologic and cosmogenic age data. It is clear that much of the database schema for thermochronologic and cosmogenic data will be similar, but it is critical to provide input in areas where elaboration is needed.

3) Geochemistry of Metamorphic Rocks and Metamorphic Petrology

Frank Spear (Chair; Rensselaer Polytechnic Institute)
John Brady (Smith College)
Barbara Dutrow (LSU)
William Carlson (UT Austin)
Tom Foster (U Iowa)
David Pattison (U Calgary)
Michael Williams (U Mass, Amherst)

This group will meet over the summer of 2003 to identify important issues relating to the MetPetDB (Metamorphic Petrology DataBase) and to begin preparation of a white paper for presentation at the Solid Earth Sciences meeting to be held before the GSA meeting in Seattle, fall 2003. The working group chair visited Kerstin Lehnert at LDGO on May 13, 2003 to get an overview of PetDB and to discuss possible strategies for a MetPetDB. There are (at least) two types of information that a needs to incorporate:

- Raw data with sufficient documentation that a petrologist can use these data for scientific discovery. These include data such as assemblage information, textures, microprobe analyses, BSE, SE, X-ray images, photomicrographs, along with associated spatial data such as location of sample, location of microprobe analyses, etc.
- Interpretative data such as peak P-T conditions and rock P-T path, fluid-rock ratios, cooling/heating rates with associated metadata.

An additional consideration is the development of tools for analysis of information in the database such as programs to do geothermobarometry, P-T path calculations, thermal modeling, and thermodynamic calculations of various sorts.

4) Structural Geology

John Oldow (Chair, U. of Idaho)
Jeff Lee (Central Washington U.)
C.J. Northrup (Boise State)
Basil Tikoff (U. of Wisconsin)

The working group has already obtained funding for a workshop to start developing of a cyberinfrastructure for research and education in structural geology. Twenty-five participants representing a wide range of expertise are being drawn from the structural geology community and will assemble at the University of Idaho facility in McCall, Idaho on 3-4 October, 2003. Many of the anticipated workshop participants have experience in database development, information management, and the application of data analysis tools. Individuals without these skills are also included to establish a broad perspective of the cyberinfrastructural needs for the entire community. Workshop goals are to: (1) identify the database needs and analysis tools required by modern structural geologists, (2) outline a vision for the architecture of a structural geology cyberinfrastructure and its relation to existing or planned cyberinfrastructural initiatives in the earth sciences, (3) initiate a discussion on data standards, required metadata, and information formats for databases, and (4) develop a strategy for community involvement and implementation of the cyberinfrastructure.

The findings of the workshop will be presented to the structural geology community at the National Meeting of the Geological Society of America on 2-5 November, 2003. Community participation and acceptance is vital for the success of this effort and a website is under construction to facilitate broad-based community discussion and input to the final report, which will be available for general consumption in early 2004. The report will be published in GSA Today and will be presented to the National Science Foundation together with recommendations

5) Physical properties of rocks and minerals

Tracy Rushmer (Chair, U. Vermont)
Herb Wang (U. Wisconsin)
Nik Christianson (U. Wisconsin)
Steve Kirby (USGS)

The main need here is to establish accessible databases and exploration tools for the fundamental properties of rocks, including attenuation, rock density, seismic velocity, magnetic properties, permeability and anisotropy. Some of required data will be populated in other databases. Access to these data in an integrated form is critical to many aspects of ISES research and especially to the new EarthScope effort. Action steps to be taken include:

- Determine the current level of thinking in the community on a PPRM digital database and what is currently available.
- Identify the critical areas where available data can be compiled digitally.
- Identify the critical areas where additional data are needed to better represent identified research focus areas.
- Work with the PPEM (Physical Properties of Earth Materials) community that is already established.

6) Field Data Acquisition Techniques

Carlos Aiken (Chair, UT Dallas)
Kelin Whipple (MIT)
Doug Walker (U. Kansas)

There is much active research on using new technologies for field data acquisition. The groups working on this have made great progress, but because the field is so new, there has been no attempt to organize the community of researchers. The ISES-IC committee recommends that these efforts coordinate under an organization we call INTERFACE (**INTER**disciplinary alliance for digital **F**ield data **AC**quisition and **E**xploration). This is viewed as an alliance that will involve not just geoscientists, but also biologists, ecologists, geographers, and any other domains that rely on field data acquisition by individuals or small groups. Because of the broad goals and areas envisioned for this effort, the group leaders are still working on a more concrete vision for INTERFACE and starting to identify the non-geology participants. The group leaders intend to prepare a workshop proposal before the fall GSA meeting.

7) Geological and Geophysical Maps

Doug Walker (Chair, U. Kansas)
Clark Burchfiel (MIT, President GSA)
Bruce Wardlaw (USGS, CHRONOS)

Because the spatial content of most ISES data is critical, the creation of maps is vital. Maps of interest run all the way from the basic field data and relations presented on geologic maps, to geophysical measurement of gravity, magnetics, and crustal properties, to the critical insights possible from creating and using derived maps such as paleogeography, paleotectonics, and palinspastic reconstructions. Coordination with the USGS and GSA is critical to this because of ongoing efforts of these groups to publish maps and charts. The working group leaders will monitor activities at the USGS and GSA and then act to coordinate these with community efforts. The start of this groups activity will correspond to the ISES meeting at the GSA fall meeting.

8) Stratigraphy.

Vladimir Davydov (Co-Chair, Boise State)
Rebecca Dorsey (Co-Chair, U. of Oregon)
Tim Carr (Co-Chair, Kansas Geological Survey)

This working group is starting efforts to understand the needs of the stratigraphic and larger geological community. In addition, there are a variety of data and tools available already to work on stratigraphic information, as well as some ongoing CI efforts in this direction. The working group leaders will work to determine what sorts of additional efforts are needed. The current plan is to start coordinating efforts before the GSA fall meeting, but to probably do most of the work at or after this meeting.

9) Tools for Data Visualization, Integration, and Exploration, and Creating the *ISES Colaboratory*.

Jonathan Lees (Chair, U. of North Carolina)
Randy Keller (UTEP)
James Handschy (ConocoPhillips)
Eric Frost (Cal State San Diego).

All of the efforts described above would benefit greatly from the ability to visualize and analyze diverse datasets and models in a 3-D and 4-D environment. The group leaders are starting efforts to create or foster such a system. Integrative efforts are necessary, and tools envisioned by the ISES-CI committee would allow for the seamless blending of ISES data with those coordinated by CHRONOS, GEON and any geophysical-CI groups (e.g., CI products from IRIS and UNAVCO). These tools also will help enable the type of integrative research at the heart of the EarthScope Program. In addition, the ISES-CI group considers a Colaboratory effort (e.g. a distributed laboratory) that allows for interdisciplinary interactions (including integrating real-time field data acquisition into office efforts) to be an appropriately ambitious goal.

Because of the nature of this effort, the working group is just starting to organize and identify participants. The group leaders intend on finishing organization and preparing a workshop proposal before fall GSA meeting. The effort can be discussed at the ISES session there. In addition, because of the integrative nature of the visualization and colaboratory, presentations from this group will also be done at the fall AGU meeting.

10) Sample Archiving.

Steven L. Goldstein (Co-Chair, LDEO)
Paul Kimberley (Co-Chair, Smithsonian Institution)
Roberta Rudnick (U. Maryland)
Terry Plank (Boston U.)
Charlie Langmuir (Harvard U.)
Paul Renne (Berkeley Geochronology Center)
Scott McLennan (SUNY Stony Brook)
Sam Bowring (MIT)
Alan Glazner (U. North Carolina)
Richard Carlson (DTM)

The ISES-CI Workshop recognized that all geochemical data and much structural data are associated with physical samples, and therefore data preservation must be accompanied by a system that insures sample preservation and community access. It is important to be able to revisit studied samples for further investigation or to reassess previous conclusions. Discarding of samples after an investigation is finished or when an individual retires has been a common practice at many universities and research institutions. Therefore, many unique samples and collections have been lost to the community for future studies.

The mandate of the SAMPLES (**S**ample **A**rchive and **M**anagement **PL**anning for the **E**arth **S**ciences) working group is twofold. (1) Recognizing the need to preserve precious *petrology-geochemistry* and *structural geology* samples for posterity, the SAMPLES Group will assess archival options and make recommendations for their implementation. (2) Taking into account the practices of other Earth and Planetary Science communities where samples are widely accessible, the Group will recommend a set of protocols to increase community access to samples.

Concluding Remarks

To make progress on the areas describe above, the ICES-CI committee and the working group leaders have agreed upon the following time line. The effort started at the workshop in March 2003. Most working groups will prepare detailed recommendations by the time of the GSA and AGU meetings in the fall of 2003; some groups will have already held domain workshops by this time, while others will still be making plans in this direction. After developing community consensus, the working groups will spawn proposals to implement the ISES-CI system at the start of 2004. Within 1 to 2 years, these proposals will start to produce results that will foster a cultural shift in the ISES community toward the adoption and integration of the ISES-CI system. At first, the effort will involve small groups. This will expand to the community level to build consensus. After this, it is anticipated that smaller functional groups will organize to prepare the ISES-CI proposals. The working system in the end will then be used across the entire community.

> ***ISES-CI along with GEON, CHRONOS, GERM and the EarthScope*** *data management programs, will provide the mechanism to facilitate truly interdisciplinary/integrated science that will lead to more developed understanding of the Earth as a complete and interacting system involving its solid earth, oceans and atmospheric shells.*

Reports from Working Groups

Databases for ***Igneous Geochemistry***

Kerstin Lehnert (Chair, LDGO - PetDB)
Al Hofmann (Max Planck Institut fur Chemie, Mainz - GEOROC)
Richard Carlson (DTM - NAVDAT)

At both the small and large spatial scale of investigation, the quantity and detail of geochemical data now available requires the assistance of modern information technology approaches in order to use the data in the most flexible, complete and effective way. This need is exacerbated by the dramatic increase in production of geochemical data as a result of advances in analytical instrumentation. Currently, three database efforts for igneous rock geochemistry are either functioning or under development. These include:

Database	URL	PI's	Content
PetDB	petdb.ldeo.columbia.edu	Charlie Langmuir (Harvard), Kerstin Lehnert (Lamont)	Mid-Ocean Ridge Basalts
GEOROC	georoc.mpch-mainz.gwdg.de	Al Hofmann, Baerbel Sarbas (Mainz)	Ocean Island , Convergent Margin, Continental Flood Basalts
NAVDAT	navdat.geo.ku.edu	Doug Walker, Ross Black (U. Kansas), Allen Glazner (UNC), Lang Farmer (U. Colorado), Rick Carlson (DTM)	Cenozoic igneous rocks from western North America

GEOROC, NAVDAT and PetDB have produced relational databases that serve geochemical analyses of igneous rocks and minerals to the broad community of Earth scientists capable of using these results for improved understanding of Earth characteristics, processes and evolution. Collaboration between the three independently developed database efforts has ensured that by sharing the basic data schema employed the data in the individual databases eventually can be seamlessly integrated through future developments in information management.

PetDB, NAVDAT and GEOROC recently defined a coordinated work plan for further development of the databases, without interfering with the commitments and goals of the individual efforts. All three database groups will continue to be confronted with the labor-intensive effort of populating their databases with the data relevant to their disciplinary science goals. Coordination of effort can work to the mutual benefit of all in the migration of these databases from storehouses of legacy data into dynamically populated datasets that can aid the rapid dissemination of data produced by future research efforts. The three efforts also can be improved by incorporation of a number of tools including: more versatile query capabilities; geochemical modeling tools that can aid in interpretation of the data and in its applications in modeling of Earth processes; and in providing spatial and temporal analysis tools to examine data trends in 4-D. Given the similar data schema employed in the three databases, the way that the tools interact with the datasets will be similar. Consequently, any tool developed by one of the efforts can be easily incorporated into all, as long as this cooperative goal is kept in mind from the beginning of tool development. Besides providing dramatic improvements in operability, this level of cross database compatibility will allow closer cooperation, and more easy integration, of these geochemical database efforts with broader pan-Geoscience information technology developments (GEON, CHRONOS, ISES-CI, ISS, GERM).

The following list provides some suggestions for the most pressing development needs for NAVDAT, PetDB and GEOROC.

1) Creation of a common web "front page" for the three databases at www.earthchem.org. The first goal, realized as of June 4, 2003, is to provide a common point of entry into the databases, and one that can be rapidly and easily found by web searches even by those unfamiliar with the databases. This can work to maximize dissemination of these datasets to the broad community (geochemists, solid earth scientists, educators, students and the general public) that likely do not currently know of their existence. At first, this page can serve simply as the entry point to the individual databases. Eventually, seamless cross-database search capabilities will be incorporated to allow a user to get the most relevant datasets for their needs, regardless of which database actually contains the data.

2) Develop user entry forms that allow future data to be submitted directly to the databases by those creating the analyses. This effort will require a somewhat automated process of quality control to make sure that the entries meet a certain level of completeness and accuracy.

3) Another item working towards easing the entry of future data into the datasets is an appeal to publishers and editors to define and enforce certain minimum standards of completeness for data publications. Some progress on this issue was made in discussions with representatives of AGU and Elsevier, along with a number of geochemical journal editors present at the recent GERM meeting. One of the key issues here is creation of a "unique sample identifier" that will allow multiple datasets derived from independent studies of the same sample to be integrated in the databases. Coordination with the SAMPLES archiving effort is essential in order to ensure that archived samples can be accurately linked to whatever geochemical data may exist for a given sample. The geochemical databases and SAMPLES working groups have overlapping membership, which will ensure that this coordination occurs.

4) Create map interfaces so that the data can be selected and/or analyzed in a geospatial context. This effort will allow the data to be examined against different types of base maps, for example, gravity, topography, bathymetry, aeromagnetics, seismic tomography, etc.

5) Integrate data analysis tools – PetDB has initiated an effort with Mark Ghiorso to establish links between the MELTS application and PetDB in a way that will eventually be transportable to both GEOROC and NAVDAT. Other tools under consideration include plotting routines and petrologic plots.

6) Expand user queries to provide users more flexibility in extracting data from the databases, e.g. allow the combination of data from different analyses in the dataset, such as the combination of glass (or mineral) major element measurements with whole rock isotope data.

7) Create a common interface that will allow simultaneous and seamless access to all databases. This likely will require the assistance of IT specialists from either CIESIN (Lamont) or the Kansas Geological Survey (NAVDAT).

8) Revise database schema in the interest of flexibility and compatibility and perhaps the eventual expansion to include geochemical data for other types of Earth materials.

Realizing this list of tasks will be achieved by close collaboration as the three database efforts continue their development with support already provided by NSF and the Max Planck Society. Communication between the efforts will be assisted by a database "nuts and bolts" session at the annual NAVDAT workshop, along with continued interaction with other CI efforts such as CHRONOS, GEON and GERM. The more IT intensive aspects of the above tasks will be discussed in a workshop planned for this fall that will attempt to bring together the IT specialists in these databases (CIESIN at Lamont, KGS at NAVDAT) along with representatives from GEON and GERM in an attempt to ensure that these activities are coordinated, and hence more likely to be integrated into, broad earth science CI activities.

***MetPetDB**- Database for Metamorphic Petrology*

Item 1: Building a working group

The first charge of the chair was to build a working group to address the significant issues that must be considered in the development of a database for metamorphic petrology (MetPetDB). The criteria used for identification of possible participants were (a) innovation in research, especially with computer applications; (b) representation of diverse parts of the metamorphic petrology community; (c) demonstrated ability of accomplishment in a timely fashion; (d) international representation. At this stage it was also considered desirable to keep the group relatively small (5-10 individuals).

Seven individuals have been contacted and six have agreed to serve. The current members of the working group are:

Frank Spear (Chair - Rensselaer Polytechnic Institute)
John Brady (Smith College)
Barbara Dutrow (LSU)
William Carlson (UT Austin)
Tom Foster (U Iowa)
David Pattison (U Calgary)
Michael Williams (U Mass, Amherst)

Also contacted but not yet responded is:

Simon Harley (U. Edinburgh)

Item 2: Planning a meeting of the working group

It is the intention of the chair to have a meeting of the group over the summer to identify important issues relating to the MetPetDB and to begin preparation of a white paper for presentation at the Solid Earth Sciences meeting to be held before the GSA meeting in Seattle. The meeting will most likely be held in July or August. One excellent possibility that we are currently exploring is to hold the meeting either during or immediately following the workshop on Teaching Petrology that will be held in Boseman, Montana in early July. Several of the MetPetDB workshop group will be attending this meeting, as well as a large number of petrologists with potential interest in our project.

Item 3: Coordination with PetDB

The chair visited Kerstin Lehnert at Lamont on May 13 to get an overview of PetDB and to discuss possible strategies for a MetPetDB.

Item 4: Initial thoughts on a strategy for MetPetDB

The chair made notes of his thoughts for a MetPetDB following the CI meeting at KU, in March. These notes have not been sent to working group members yet, and are included here to give an idea of things the group will be considering.

1. General considerations
    a. There are (at least) two types of information that a MetPetDB needs to incorporate:
        i. Raw data with sufficient documentation that a petrologist can use these data for scientific discovery. These include data such as assemblage information, textures, microprobe analyses, BSE, SE, X-ray images, photomicrographs, along with associated spatial data such as location of sample, location of microprobe analyses, etc.
        ii. Interpretative data such as peak P-T conditions and rock P-T path, fluid-rock ratios, cooling/heating rates with associated metadata.
        iii. It is anticipated that different users will wish to make use of these different types of information for quite different purposes.
        iv. These data must all have associated metadata that address
            1. Quality issues (very tough – and somewhat subjective)
            2. Structural setting of result
            3. General regional geologic considerations
            4. Access to information on methods used
    b. An additional consideration is the development of tools for analysis of information in the data base such as programs to do geothermobarometry, P-T path calculations, thermal modeling, and thermodynamic calculations of various sorts.
2. Requirements for "raw data" database
    a. Sample identification
    b. Spatial information – a sample coordinate system (GIS of a thin section)?
    c. Rock type, assemblage, facies, rock name
    d. Types of images and considerations
        i. General considerations
            1. Tags for mineral names that occur in images
            2. Image location in sample coordinate system
        ii. Thin section scans
        iii. Photomicrographs
        iv. BSE, SE images
        v. X-ray maps
            1. Location
            2. Element
            3. Map information
                a. Scale (pixel size)
                b. Composition scale

        4. Probe settings for element map
            a. Current
            b. Spectrometer crystal
            c. Dwell
            d. KV
    e. Spot analyses
        i. Mineral type
        ii. Probe settings
        iii. Standards used (should be databased separately for cross reference)
        iv. Spot location (in sample coordinate system
            1. This could be tricky if images don't align perfectly. There is always some distortion between images, so spot must be located relative to one image, which is not necessarily the same as its location in another image. I'm not sure how to best handle this at the moment.

3. Requirements for "interpretative data" database
    a. How to deal with interpretive data? Papers come with P-T estimates, P-T paths, cooling rates, ages of metamorphism. Many users want this information, and don't want to recreate it from the raw data. In fact, most users wouldn't have the skills or time to do it properly. So, some means to incorporate these data must be possible, with appropriate metadata so user can evaluate results.
    b. Types of interpretative data
        i. P-T conditions
        ii. P-T paths
        iii. Cooling rates
        iv. Fluid-rock ratios
    c. Considerations for interpretative data
        i. These data aren't generally specific to a single sample, but the interpretation is based on a number of samples, either from the same locality or from a small region. We need to be able to incorporate this into the database.
        ii. We need to permit user to access raw data on which interpretations are based. I'm not sure how this should work – I suppose it depends on what the user wants to do.
            1. P-T points could be keyed to the appropriate spot analyses. This is pretty straightforward.
            2. P-T paths involve multiple samples and multiple data types
                a. P-T points – could be keyed to samples as in (1)
                b. Zoning interpretations – these could be keyed to relevant data.
                c. Textural interpretations based on grids or pseudosections
                    i. Reaction textures
                    ii. Pseudomorphs
                    iii. Inclusion data.

            3. This is essentially an access bridge between two fundamentally different datasets and will require appropriate tools to make navigation possible.
    d. Work closely with tectonics group so that this part of the database is properly designed to provide the information necessary.
        i. Questions to ask tectonics community
            1. What types of interpretative data are desired?
            2. What would they like to do with these data?
            3. What do they need to know about these data?
    e. What metadata are required for interpretative data
        i. Structural setting
        ii. Style of metamorphism (contact, regional, etc.)
        iii. Quality issues
        iv. Should there be an "open forum" discussion section? Interpretations do vary, and the input of researchers who have re-examined the data, or who have used the data, could be quite valuable.
        v. Should there be a way to incorporate a re-analysis of the data by a new investigator into the database, or should this be restricted to peer reviewed publications?
4. Petrologic tools
    a. General mineral data tools
        i. Recalculation programs for different minerals, especially amphiboles, pyroxenes, etc, that have ferric iron.
        ii. IMA mineral naming tools
        iii. Plotting routines – standard and using projective transformations
    b. Data analysis tools
        i. Thermobarometry calculations
            1. A program like GTB that coverall all published
            2. Self consistent (TWQ) calculations.
        ii. Pseudosection calculation
        iii. Gibbs – PT path calculations
        iv. Phase diagram calculation
        v. Diffusion programs
        vi. Heat flow programs
    c. Vision of what could be done:
    A user could generate microprobe analyses that would be uploaded automatically to the database. The data could be instantly accessed, manipulated, reduced, plotted, etc. with a variety of tools.
5. Development of database standards
    a. Any successful database must incorporate standards for inclusion of data. Development of these standards will be topic of discussion for the working group.
    b. Society support will be essential for success
        i. MSA, GSA, GCA, Metamorphic Studies group
    c. Survey efforts have standardized field aspects. E.g. USGS, Canadian Survey, Australian, UK,
    d. International commission on naming metamorphic rocks

e. PetDB has large history. MetPetDB should be compatible
    i. I need to learn more about PetDB and relational databases in general so I know where critical links must be established from the start.

6. Community buy-in
    a. It is essential to have buy-in of community for the MetPetDB effort to be successful. How to achieve this? There were several ideas presented at the Kansas workshop that will be discussed by the MetPetDB working group.
        i. Mandate from the database community
        ii. Mandate from NSF to store data
        iii. Availability of tools could serve as enticement
        iv. Generate feeling that this is “the right thing to do”
        v. May require a cultural shift
            1. Idea that data belongs to community, not individual
            2. Samples belong to community
            3. A higher level of documentation of sample data than is generally published will be required. This could be good for science, but more work for researchers. How to soften the blow of doing this (more below).
        vi. Associate with a professional society (MSA?) to endorse, and perhaps develop standards.
        vii. International community should be included from the start, if possible

Workshop to Develop a CyberInfrastructure for Research and Education in ***Structural Geology***

John Oldow (Chair, U. of Idaho)
Jeff Lee (Central Washington U.)
C.J. Northrup (Boise State)
Basil Tikoff (U. of Wisconsin)

Introduction

The beginning of the twenty-first century has witnessed a technological and cultural revolution in the earth sciences. Advances in information technology coupled with the successful community planning and implementation of the National Science Foundation EarthScope Initiative precipitated efforts to organize and coordinate development of an earth science cyberinfrastructure. The community response to this need ranges from overarching earth science – computer science fusions such as the National Science Foundation funded project GEON (http://www.geongrid.org) tasked to develop a CyberInfrastructure for the Earth Sciences to grassroots development of disciplinary databases. As part of this effort, solid earth scientists recently instituted the Integrated Solid Earth Sciences alliance devoted to the development of a vision for solid-earth science research and education and articulation of the cyberinfrastructural requirements needed to revolutionize how earth science research and education is carried out.

As part of this community effort, a workshop will be convened to initiate the development of a cyberinfrastructure for research and education in structural geology. Twenty-five participants representing a wide range of expertise are being drawn from the structural geology community and will assemble at the University of Idaho facility in McCall, Idaho on 3-4 October 2003. Many of the workshop participants have experience in database development, information management, and the application of data analysis tools, but individuals without these skills are also included to establish a broad perspective of the cyberinfrastructural needs for the entire community.

Workshop Objectives

Workshop goals are to: (1) identify the database needs and analysis tools required by modern structural geologists, (2) outline a vision for the architecture of a structural geology cyberinfrastructure and its relation to existing or planned cyberinfrastructural initiatives in the earth sciences, (3) initiate a discussion on data standards, required metadata, and information formats for databases, and (4) develop a strategy for community involvement and implementation of the cyberinfrastructure. Below we outline in more detail the overarching objectives of the workshop.

Recognition and Identification

The first step in developing a community cyberinfrastructure is to recognize existing databases and to outline known or anticipated data needs. An integral part of this process is to establish benchmarks for basic data analysis tools and visualization schemes needed for access to and implementation of the database. Where compilations or databases exist, methods to address accessibility and interoperability may range from the need to establish simple links amongst databases to efforts requiring the development of web-based translators and query tools. Structural geology is a rich discipline characterized by a broad range of research objectives employing an expansive array of data types. Data resources constitute a remarkably heterogeneous range of formats needed to capture information represented by geologic maps, structural fabric data, geomorphic surface analysis, and trench logs, to name only a few. The workshop must address what constitutes the fundamental needs of the community and what format or formats are best suited for data presentation.

Collaboration and Standards

Acceptance by the structural geology community is a central requirement for the successful deployment of the proposed cyberinfrastructure. Utilization of the database is predicated on implementation and acceptance of community defined standards for data. Careful consideration is required to balance the often opposing desires to instill a regime of high data quality and to establish an open environment for data contribution from members of the community. Along these lines, longevity of archival data must be reviewed in the context of database distribution (central site versus distributed network), content modification, and metadata requirements. We do not suggest that all of these issues will be resolved at this workshop, but some first-order recommendations must be made and presented for discussion by the community.

Collaboration and coordination between members of the structural geology community and other disciplines in the earth sciences will be a vital element in the developing earth science cyberinfrastructure. Data formats, analysis tools, and information retrieval and query systems must be interoperable to maximize the impact of the cyberinfrastructure on the research and education that is performed. A means of developing and maintaining interoperability within a rapidly evolving database system will require some level of infrastructure not yet in existence within the earth sciences and presents a challenge to the community that must be addressed at the workshop.

A central theme in most research and educational aspects of structural geology lies in the need to characterize the three-dimensional spatial distribution and to quantitatively describe the three-dimensional geometry of earth structures. This requirement poses significant database development challenges beyond those found in many research activities. We anticipate the need to work closely with IT researchers to utilize existing and/or to develop needed database structures. Furthermore, given the three-dimensional characteristics of structural geology data, visualization is a vital analysis tool that must be included in any community database infrastructure. The workshop participants must identify existing tools, access the utility of using open source versus proprietary resources, and consider optimal means for delivering database resources to the community.

Vision and Planning

The workshop participants must begin the process of addressing several issues surrounding long term database development and maintenance. For this cyberinfrastructure to be successful, a cultural change is required in how data is used and viewed by the community. Issues surrounding ownership, access, citation, and database modification must be carefully considered, and discussion parameters defined and presented to the community for input. Many issues will evolve as database access and utilization becomes ingrained in the scientific method, and we suspect that many of these issues will be long lived topics of deliberation in future workshops and meetings. Nevertheless, the workshop will provide the opportunity to begin the community dialog on these important considerations.

An overarching objective of the workshop is to establish a visionary framework for the development and maintenance of the structural geology database. Based on our experience in similar workshops, such as the recent ISES-CI meeting, we suspect that many philosophical tenants concerning database development and management already exist within the community and that the workshop will provide a vehicle for their explicit definition. An expected workshop outcome is a recommendation for an organizational structure that is responsive to community input and capable of interacting with other disciplinary database development efforts.

Workshop Products

A preliminary report and presentation will be prepared for community discussion and distribution at the National Meeting of the Geological Society of American to be held on 2-5 November, 2003 in Seattle, Washington. The report will outline the primary findings of the workshop and will serve as a forum for further discussion and recommendations by the community. Community input will be solicited at the Geological Society of America meeting and via a post-meeting website designed to facilitate continued discussion. Once the community input has been acquired and synthesized, the information will be incorporated in a final report that will be presented to the NSF and published in GSA Today in early 2004.

Physical Properties of Rocks and Minerals
*Towards the development of a **PPRM** Digital Database*

Physical properties of rocks and minerals. (ISES-PPRM): The main need here is to establish accessible databases and exploration tools for the fundamental properties of rocks, including attenuation, rock density, seismic velocity, magnetic properties, permeability and anisotropy. Some of required data will be populated in other databases. Access to these data in an integrated form is critical to many aspects of ISES research and especially to the new EarthScope effort.

Actions to be taken before November 2003:

- Determine the current level of thinking in the community on a PPRM digital database and what is currently available.
  Status: Nik Christianson talked about a physical properties database at the Denver EarthScope Complementary Geophysics meeting. He reviewed the existing ones such as the GSA Memoir edited by S. Clark, Jr., Bob Carmichael's 3 volume set, the CRC set edited by Tom Ahrens. Nik Christianson was a contributor to the Carmichael volume. Herb Wang was co-author of a single-crystal elastic properties compilation.
- Identify the critical areas where we already have available data that can be compiled digitally.
- Identify the critical areas where we need to accrue data to better represent identified research focus areas.
- Work with the PPEM (Physical Properties of Earth Materials) community that is already established. We have a list server through AGU (address: minrkphys@agu.org) and a newsletter that is used to advertise meetings and other community activities. This is the ideal venue for recruiting participants and providing input into a community-based digital database. Both the critical areas and access to already available datasets.

Identified participants:

Participants in this aspect of ISES-CI are needed to form the nucleus of a group that can cover the variety of topics under PPRM. The core needs to include mainly people who have been interested in putting together a database and those that represent different sub-disciplines.

Potential participants:

Alan Byrnes (Petroleum Research, Kansas State Geological Survey)
Tracy Rushmer (experimental deformation/melting experiments)
Herb Wang (single-crystal elastic properties, geomechanics)
Nik Christianson (rock velocity)
Steve Kirby/ USGS rock deformation group (experimental rock deformation database)

Additional participants will be included as we identify core areas that need representation.

INTERFACE (INTER*disciplinary alliance for digital* ***F****ield data* ***AC****quisition and* ***E****xploration)* ***Working Group****.*

Carlos Aiken (Chair, UT Dallas)
John Oldow (U. Idaho)
Kelin Whipple (MIT)
Doug Walker (U. Kansas)

Acquisition and depiction of field data is the cornerstone of the solid earth sciences and provides the context for most geologic-process oriented inquiries. Digital representation of data in a geospatially rectified environment provides the basis for information transfer, scale and projection manipulation, and registration between disparate data sets required for integrated earth science investigations. The utility of digital databases has revolutionized many aspects of scientific inquiry but has not been fully integrated into the acquisition of field data and the production of geologic maps.

Field data collection in general and the construction of geologic maps in particular largely has remained non-digital because existing technology has proven to be relatively efficient and cost effective. With the advent of Global Positioning System (GPS), the wide availability of space imagery, digital orthophotoquads (DOQ), and digital elevation models (DEM), however, the opportunity to acquire digital field data has been realized. Digital data acquisition provides direct development of geological databases, efficient data interoperability, and possibly more importantly, improves data quality and accuracy.

The Geoinformatics revolution has facilitated the implementation of computer information technologies and methodologies to scientific research utilizing spatial-temporal coordinates at all scales. Implementation of a community wide shift from analog to digital field data collection, however, is inhibited by the lack of experience by most geoscientists in the use of the new methodologies and by the capitalization costs associated with implementing new technologies. To alleviate these obstacles we propose the institution of INTERFACE (Interdisciplinary Alliance for Digital Field Data Acquisition and Exploration) that will provide equipment, training, data processing and data archiving .Currently, only a very small part of the geosciences community is involved in the development and/or use of these technologies and methods for direct digital data acquisition. We visualize the structure for INTERFACE as a distributed community facility composed of several nodes that will respond to regional needs. This would complement programs such as the EarthScope and GEON (Geosciences Network).

Various groups are using different combinations of the technology to capture digital geological data in the field depending on the specific application and the needed scale of observation. The most fundamental digital field mapping consists of the definition and location of geologic contacts, the logging of information, utilizing lightweight rugged computers with appropriate software. This can improve the quality of geologic observations through the integration of GPS, space and airborne imagery and DEMs.

Since position is so important to field data mapping there have been a variety of survey devices such as total stations. Global Positioning Systems now provides a simple, inexpensive method to globally position and is the basis to which other observations can be linked locally and globally.

Some studies require high density, high resolution, 3 dimensional images. Reflectorless laser range-finding devices can acquire such three dimensional data at a rapid rate from a single location. They range from the inexpensive reflectorless handheld lasers to expensive high data acquisition reflectorless ground laser scanners sometimes called ground LIDAR (Light Detection and Ranging) systems.

Some specialized studies require high resolution characterization of the surface which can be accomplished by the integration of photography taken at close range and “texture mapped” or “draped on digital terrain models to create 3D photorealistic models, capturing the visible features of interest to geosciences.

INTERFACE can provide the link between the groups currently collecting and interpreting digital data in the geosciences. This group would serve to establish data standards, disseminate data collection techniques and technology, and facilitate the development of interpretation tools. Commercial software can be expensive and complicated, requiring long learning curves. INTERFACE would provide the accessibility for such specialized software with training in such software, or providing data processing services and the development of appropriate freeware that can be widely used by academic community. INTERFACE would have devices like GPS, handheld lasers, field rugged computers, and software for research and instruction, and more specialized items such as high-resolution scanners and digital cameras for research.

To carry this out a series of centers could be funded for a term of several years to provide a stable basis for teaching, developing and mapping assistance to the users. The developers generally have a variety of approaches and expertise so these centers would also be centers for specific approaches and expertise. These groups will have the state of the art equipment and software in their areas of expertise and orientation, and personnel, and be a resource for support of other academic groups as well as their own research (e.g., Biologists, Ecologists, etc.). From these activities many more groups will initiate and enhance their capabilities and spread the digital data acquisition initiative throughout geosciences.

***SAMPLES** (**S**ample **A**rchive and **M**anagement **PL**anning for the **E**arth **S**ciences) Working Group*

Steven L. Goldstein, Lamont-Doherty Earth Observatory of Columbia University
Paul Kimberley, Smithsonian Institution

The ISES-CI Workshop recognized that all geochemical data and much structural data are associated with physical samples, and therefore data preservation must be accompanied by a system that insures sample preservation and community access. It is important to be able to revisit studied samples for further investigation or to reassess previous conclusions. Discarding of samples after an investigation is finished or when an individual retires has been a common practice at many universities and research institutions. As a result, many unique samples and collections have been lost to the community for future studies. Thus the Workshop concluded that sample preservation and access is a pressing need to be addressed.

The mandate of the SAMPLES Working Group is twofold. (1) Recognizing the need to preserve precious *petrology-geochemistry* and *structural geology* (*PG-SG*) samples for posterity, the SAMPLES Group will assess archival options and make recommendations for their implementation. (2) Taking into account the practices of other Earth and Planetary Science communities where samples are widely accessible, the Group will recommend a set of protocols to increase community access to PG-SG samples.

The SAMPLES initiative comes at an opportune moment, as there is increased recognition by the geoscience community that mechanisms must be established to insure sample preservation and to increase access. A recent National Research Council Report (NRC 2002) analyses the problems in detail and emphasizes the need to institutionalize a means for sample preservation, although this Report did not focus on the needs of the PG-SG community. In addition, the GERM (Geochemical Earth Reference Model) Steering Committee, representing an international grass-roots geochemistry initiative, has endorsed the need to explore the issues of sample preservation and access (Goldstein and Melson 2001). The SAMPLES Working Group will be a joint ISES-GERM venture.

In contrast to terrestrial samples, procedures have been long established for the preservation and distribution of meteorites, lunar samples, marine and ice cores, fossils, and sea floor dredges. Communities who use these samples accept the notion that they belong in the public domain, and recognize the scientific benefits. There are important historical reasons why these samples are actively curated and accessible to the research community. Collection requires obvious large-scale public expenditure, and in most cases re-collection is not a viable alternative. Irrespective of the historical background, archival and community accessibility to these samples have been important factors in the development of our knowledge of the Earth and the Cosmos. Until now, there have been only limited attempts at PG-SG sample preservation, mainly by museums, especially the U.S. National Museum and the American Museum of Natural History.

There are a number of pragmatic reasons to develop a more systematic approach toward archiving and distribution of important PG-SG samples.

- PG-SG studies require a large public investment in sampling and analyses or evaluation.
- PG-SG studies are often global in scope and target samples from the far reaches of the Earth.
- Many important sample localities are difficult to access due to logistics or politics.
- There are well-known cases where entire classic outcrops are destroyed or covered up by natural or human forces, thus precluding the possibility to obtain new samples.
- In geochemistry, there are still far too few samples characterized for their petrology and a comprehensive suite of chemical and isotopic compositions.
- Geologists often accumulate important terrestrial sample suites over the course of a career. As previously noted, many important sample 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 good reasons, the first samples that investigators want to analyze are well-characterized previously studied samples.

The SAMPLES Working Group has been partly constituted as of the due date of this report. Representatives are being recruited from major sub-disciplines covered by ISES-CI and GERM. In the Solid Earth Geochemistry-Petrology community, the aim is to include prominent individuals representing igneous rocks, xenolith suites, sediments, metamorphic rocks, surface studies (cosmogenic isotopes), U-Pb geochronology, and K-Ar geochronology. There will be two members from the Structural Geology community. Although paleomagnetism is not directly covered by ISES-CI, this community will be represented as it has similar preservation needs. In addition, paleomagnetic samples are generally drilled cores that avoid surface alteration. As a result they are often good geochemical samples. SAMPLES will attempt to include a curator from a major museum and a major sample repository. Although ISES-CI is a US project, GERM is an international initiative and there will be some international representation.

The SAMPLES Working Group will consider the practical issues required for efficient and cost-effective implementation of this initiative. At the ISES-CI Workshop, possible archival models were discussed, ranging from enhancement of current museum and university collections, to establishment of repositories, to a decentralized system dependent on individual investigators. Common to any approach will be the need for a centralized web-based archive database that will allow users to access information about samples. In addition, it is important to build upon presently existing sample collections, ensure linkage to the larger ISES-CI database endeavor, and to establish appropriate metadata policies. Criteria and protocols will have to be established to decide which samples should be preserved. Implementation will require cooperation of funding agencies. The NRC Report (2002) discusses many of the practical issues.

The SAMPLES initiative thus addresses an existing problem that is an important complement to data issues to be addressed by ISES-CI. It is expected that a rational sample archival and access policy will have a revolutionary impact on the way Petrology-Geochemistry and Structural Geology are conducted and will have an invigorating effect on our science.

References:

Goldstein, S.L., and Melson, W., "Geochemistry in the 21st Century: a new GERM Initiative", *Geochemical News* 108 p. 20-21, 2001.
National Research Council, "Geoscience Data and Collections: National Resources in Peril", National Academies Press, 128 pp, 2002.

Data Visualization, Integration, and Exploration

Jonathan Lees (Chair, U. of North Carolina)
Randy Keller (UTEP)
James Handschy (ConocoPhillips)
Eric Frost (Cal State San Diego)

The ability to visualize data routinely in 4-D is clearly a need in Integrated Solid Earth Science. There is a lot research underway in this area, but by its embryonic nature, this work is heading in many directions. Thus, the community needs some way to openly access modern but standardized software and hardware for visualization without investing weeks to learn a cutting edge system that is in a state of flux. The GeoWall effort is certainly a good step in this direction, but as would be expected, has some limitations. Industry has some very advanced techniques available, but gaining access to this technology is a challenge in the present environment. A solution to this need will clearly take time, thought, and coordination.

Some examples are listed below. This working group will consider plans to expand these efforts, and to branch into further directions such as an ISES-CI colaboratory effort.

San Diego Super Computer Center
(University of California at San Diego)

The San Diego Computer Center is a major partner in the GEON (GEOsciences Network; www.geongrid.org) NSF ITR project. A significant part of their mission in this project is visualization of multiple datasets. Separate from GEON, SDSC has a significant visualization effort (http://vis.sdsc.edu/) that provides some free software downloads that can help many applications (http://www.sdsc.edu/Software/vis.html).

The GeoWall Consortium

The GeoWall Consortium (http://geowall.geo.lsa.umich.edu/) is an example of a group of researchers funded by the NSF ITR program and other sources. This consortium has developed a cost-effect hardware and free software system that is making 3-D visualization available to the scientific community.

> From the GeoWall website:
> ”A good understanding of spatial relationships is a fundamental requirement in the study of the Earth Sciences. Traditional teaching methods have strongly relied on the 2D representations through maps and profiles that are occasionally augmented by physical models. Although most Earth Scientists have been trained to understand the 3D structure from such representations, the extrapolation requires spatial thinking skills that are difficult to learn and often form a stumbling block for students at the introductory level.
> The GeoWall mission is to broaden the use of scientific visualization tools for Earth Science research and education by the use of low cost virtual reality visualization devices.”

GEOTOUCH software package

(Jonathan Lees, University of North Carolina)

An example of an individual investigator developing a software package and making it available to the scientific community is GEOTOUCH (http://www.unc.edu/~leesj/Geotouch/). This package was primarily developed to display geophysical data in 3-D, but can display other types data.

> J. M. Lees (1999), Geotouch: Software for Three and Four-Dimensional GIS in the Earth Sciences, *Computers & Geosciences* 26(7) 751-761
>
> Abstract
>
> A new program for exploratory data analysis in three and four dimensions is presented and described. Interactive communication between diverse datasets is stressed as the main gestalt of the Geotouch program. The primary kinds of data include point, vector, raster and wireframe data sets, in addition to specialized forms such as focal mechanisms and ellipsoidal information. The software includes methods for cutting cross sections at arbitrary angles, spinning objects in three space and animating time series of punctual data, such as hypocenter series and volcano eruptions. The program is written in POSIX compliant C using X-windows for Unix systems and has been ported to Linux. Free access, via the Internet, to executable binary, source code and documentation make this package an attractive alternative to expensive or unwieldy commercial options.

University of Colorado

The petroleum industry has developed visualization technologies that are very advanced but also very expensive. British Petroleum (BP) donated such a facility to the University of Colorado. However, the high cost of maintaining this facility requires it to be operated on a largely commercial basis.

> From the BP Center for Visualization website:
>
> "The BP Center for Visualization (http://www.bpvizcenter.com) was established in October 2000 as a new research Center at the University of Colorado as part of both the College of Engineering and Applied Sciences and the College of Arts and Sciences. Sponsored by the Departments of Aerospace Engineering Sciences, Computer Sciences and Geological Sciences, the Center is devoted to the research and development of advanced visualization technology across a wide range of disciplines. The Center is developing an extensive program of research and development initially focusing on the energy industry, aerospace and medical visualization."

Mission of the BP Center for Visualization
* Visualization research and development applied to a wide range of disciplines
* Visualization in education and outreach
* Application of visualization technology as a technical service for industry and government
* Commercialization of the technology

Initial areas of focus
* Oil and Gas/Geological Sciences applications
* Immersive environments and human machine interfaces
* Aerospace applications
* Medical visualization
* Telecollaboration

Appendix 1. ISES-CI Background

Steering Committee:

Chairs: Doug Walker (KU) and Richard Carlson (DTM) Chairs

Members: Michael Brown (University of Maryland), Jeff Freymuller (University of Alaska), Randy Keller (UTEP), C. J. Northrup (Boise State University), and John Oldow (University of Idaho)

Workshop Participants:

Carlos Aiken - University of Texas, Dallas
Lee Allison - Kansas Geological Survey
Chaitan Baru - University of California, San Diego
Tim Carr - Kansas Geological Survey
Mark Ghiorso - University of Washington
Art Goldstein - National Science Foundation
Steve Goldstein - LDEO
James Handschy - ConocoPhillips
Paul Kimberly - Smithsonian Institution
Jeff Lee - Central Washington State University
Kerstin Lehnert - LDEO
Jonathan Lees - University of North Carolina
Phil Piccoli - University of Maryland
Dogan Seber - Cornell
Krishna Sinha - VPI
Frank Spear - RPI
Dan Stockli - University of Kansas
Basil Tikoff - University of Wisconsin, Madison
Walt Snyder - National Science Foundation
Bruce Wardlaw - USGS
Xueming Xu - University of Texas, Dallas

Workshop Agenda:

Friday March 28, 2003

Morning sessions – Background information, examples of other efforts, goals and format of workshop.

8:30 to 9:30 Overview, Perspectives of NSF and CyberInfrastructure committee – Walt Snyder (NSF), Lee Allison (KGS).

9:30 to 10:30 Demonstration of Existing databases and projects – PetDB (Lehnert), Kansas Geological Survey system (Tim Carr), and CHRONOS (Bruce Wardlaw).

10:30 to 10:50 Break

10:50 to 11:40 New science efforts – GEON (Seber) and EarthScope (Carlson).

11:40 to 12:00 Goal of workshop, topics for breakout groups, nature of final report.

12:00 to 1:00 Lunch

Afternoon sessions – Identification

1:00 to 4:00 Breakout groups.

Group 1. Existing and needed databases and data types (Walker and Carlson).

Group 2. Existing and needed data analysis and modeling tools (Oldow and Brown).

Group 3. External databases and tools to complement Tectonics and Petrology/Geochemistry (Keller and Northrup).

4:00 to 5:45 Plenary session on group results.

6:30 to 9:00 Group Dinner at Pachamamas Restaurant.

Saturday, March 29, 2003

Morning session – Collaboration and Standards

8:45 to 9:00 Plenary session for intermediate planning.

9:00 to 11:00 Breakout groups.

Group 1. Standards for data and metadata (Carlson, Northrup, Oldow).

Group 2. Collaborations – internal and external, issues and potentials (Walker, Keller, Brown).

11:00 to 12:00 Plenary session on group results.

12:00 to 1:00 Lunch

Afternoon session – What next – vision and strategic planning

1:00 to 1:10 Plenary session.

1:10 to 3:00 Breakout groups.

Group 1. Tectonics (Northrup, Oldow, Keller).

Group 2. Petrology/Geochemistry (Walker, Carlson, Brown).

3:00 to 4:30 Plenary session on strategic recommendations.

4:30 to 10:00 First draft of report (Steering Committee).