

CHRONOS

Geochemical Cycles Workshop Report

June 25-26, 2004

St. Anthony Hotel, San Antonio, Texas



Workshop Organizers

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CHRONOS *Geochemical Cycles Workshop Report*

Coordinators: Ethan L. Grossman (Texas A&M University), John McArthur (University College London), Cinzia Cervato (Iowa State University)

The chemical and isotopic compositions of sediments, and the fossils they contain, provide a boundless archive of the history and evolution of the Earth. This archive has provided the evidence that photosynthesis started early in Earth's evolution ($\delta^{13}\text{C}$) and that meteorite impacts may be linked to mass extinction (iridium). Moreover, geochemical evidence is irreplaceable for evaluating the causes of climate change and has shown us that gas-hydrate emanations at the Paleocene-Eocene boundary changed climate abruptly ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$), and that variations in Earth's orbits are the "Pacemaker of the Ice Ages" ($\delta^{18}\text{O}$, metal/Ca). The wide use of time-dependent geochemical data in the Earth Sciences, which is only touched on here, has overturned paradigms, opened new avenues of inquiry, and helped launch international programs of research (e.g., DSDP). Alongside their ability to reveal much about important events in Earth history, geochemical records preserved in sediments are increasingly important for global correlation; indeed, for Precambrian and anoxic sediments, chemical and isotopic methods are indispensable and provide the main basis for correlation.

During the past decade, advances in automation, notably the development of the inductively-coupled plasma mass-spectrometers (ICP-MS), and their increasing accessibility, have renewed interest in accessing Earth history through paleo-proxies both established ($^{18}\text{O}/^{16}\text{O}$, $^{13}\text{C}/^{12}\text{C}$, $^{87}\text{Sr}/^{86}\text{Sr}$, Sr/Ca, Mg/Ca) and new (Ca, Os, Fe, Os, Mo isotopes). These analytical developments have also made analyses much faster and easier. As a consequence, interest in paleochemical studies has grown dramatically, the result of which has been an explosion of chemical and isotopic data. This abundance of time-series data relevant to CHRONOS is close to becoming unmanageable for specialists, and can be overwhelming for non-specialists interested in integrating data from disparate sources in the search for linked themes in Earth's evolution. As a consequence, the problems of collation and analysis of data translates into an effective loss of information and into lost opportunities to advance our understanding of Earth-history. Worse, the problems arising from the collation and analysis of data across broad interests leads to the duplication of effort (and funding) and to misinterpretation of results. The science community, especially those dealing with chemostratigraphy and paleochemistry, need to develop now – at the beginning of this data explosion – universal standards for data collection and metadata reporting, and to do it within an accepted IT-system that is accessible to all. To prepare for the future, it is also vital that information on paleochemical methods and the problems they solve be made accessible in the classroom so that it can be integrated into the science curriculum and embedded in the comprehension of the next generation of scientists.

Finally, and most importantly, technological advances in dating are making revision of the Earth's timescale far more rapid than in the past. The science community must be able to tie their data to a time-scale that is accurate, fluid, and up-to-date, rather than struggling individually to repeatedly cross-match to hard-copy timescales that are fixed in stone for decades (e.g., Harland et al., 1990). Real-time testing of correlation schemes will greatly improve our ability to identify global geochemical events and distinguish them from more regional, local, and time-

transgressive phenomena. Clearly, the time has come to develop an information system with stratigraphic correlation tools that will permit, for the first time, the integration of a broad array of geochemical data that can be used to document and understand the history of the Earth.

The CHRONOS Geochemical Cycles (CHRONOS-GC) Workshop

To launch the paleochemical component of CHRONOS, a group of twenty-seven scientists and IT specialists gathered in San Antonio, Texas on June 25-26. The emphasis of the workshop was on data related to the chemistry of the Earth through time (“Paleochemistry”), and the need to collate and integrate chemical data, through the CHRONOS package, with stratigraphically-bounded data and evolutionary trends in biology. The participants represented 22 institutions in Australia, France, Germany, the UK and the USA, and the sponsor, the National Science Foundation. Scientific expertise ranged from isotope and trace-element geochemistry, through paleoceanography, paleobiology, stratigraphy and sedimentology, to Earth-system modeling, and covered a timescale ranging from the Quaternary to the Archean. IT specialists participated from CHRONOS, PaleoStrat, EarthRef (GERM), and PetDB (SedDB).

The Workshop comprised a series of talks to inform participants of the latest developments in chemically-oriented paleo-proxy research, and about the IT-systems being developed to handle the results. These talks were accompanied by breakout sessions during which participants discussed major issues for CHRONOS and provided real-time feedback about what the science community wanted. The talks presented the wide range of chemical paleo-proxies now available, the cross-disciplinary needs for such proxy data, and the problems, pitfalls, and opportunities for handling it that modern IT presents. Participants heard about the wide-ranging agenda for e-information (Cyberinfrastructure Initiative) of NSF, and of the wider CHRONOS project and its related web-based IT systems, and heard from IT-specialists about other databases such as PaleoStrat, EarthRef (GERM), and PetDB (SedDB), and of the research, educational and outreach potential of CHRONOS.

Three breakout sessions and one group discussion focused on four specific questions:

- What chemical data and metadata should populate the database?
- What visualization and computational tools are needed to view geochemical data?
- How to maximize outreach and use in education at all levels?
- How to enlist community support and participation?

These sessions were lively, informative, and productive and resulted in the following consensus opinions and action items.

What data and metadata should populate the CHRONOS Geochemical Cycles Database?

The point was emphasized that the primary interest was in data specifically tied to time, and so could represent climate trends and trends in the composition of the Earth’s reservoirs through time. The tie to time is the unique aspect of CHRONOS, and what gives it coherence and vision. With regard to what data are needed, the consensus was that any chemical and isotopic data that are tied to time are acceptable. This includes stable isotopes (*e.g.*, H, He, B, Li, C, N, O, Si, S, Mg, Ca, Fe, Cr, noble gases), shorter-lived radioisotopes (*e.g.*, ^{14}C , ^{210}Pb , Th-series, Be, U-series), radiogenic isotopes (*e.g.*, Sr, Os, Pb, Nd, Hf), and trace metals and anions (Mg, Sr, REE,

Al, Ti, sulfate, etc.). The interest in, and special needs of, data for biomarkers and the whole gamut of organic geochemical data were emphasized. The sole caveat placed on data was that it should be of publishable quality. Participants also made the point that physical data (with links to JANUS) and mineralogical data, that were also tied to time, would be very valuable additions to the database (*e.g.* sediment characters such as lithology, grain-size, mineralogy, size-fraction data). Participants noted that the reporting of primary data (termed by some *level-zero data*), that have been corrected for analytical bias but was otherwise not manipulated, was preferable to the reporting of derived data, *i.e.* data that had been manipulated, filtered, or otherwise altered from the original, before inclusion in the CHRONOS database. Data should be reported with full attribution to the originator and a full citation to the data source.

Agreement was reached on the issue of metadata - data that describes data. It was agreed that the metadata accompanying a sample should be as comprehensive as possible, so that users could evaluate the value and quality of data by reference to the type and amount of metadata given, and use metadata as search criteria to retrieve only chosen data from the CHRONOS database. A sampling of metadata discussed appears in Table 1. Metadata must answer questions regarding the who, what, where, and how of sample and data collection, and sample analysis. Information must be included on originators and laboratories, sample material, identifiers, and sample- and data-quality; sample locality and age; and analytical methods. CHRONOS-GC participants would guide the selection of metadata, working closely with the coordinators of existing databases (*e.g.*, PaleoStrat, GERM, and PetDB; for example, see Staudigel et al. 2002, and Goldstein et al., 2003). Co-operation with Kerstin Lehnert and Steve Goldstein's SedDB initiative to compile sedimentary geochemistry data will help insure interoperability between databases.

Table 1. A small selection of metadata needs discussed at the CHRONOS-GC workshop.

Investigators	Sample Material	Sample Locality	Sample Age and Stratigraphy	Sample Pretreatment and Analytical Methods
Names Addresses Email addresses Link to publications Data Report References to original publication and updates Comments	Unique sample identifier Lithology and lithological context of samples Sample type, phase, and mineralogy Taxonomy Size fraction Facies Comments	Latitude and longitude Geographic entity Sample position referenced to a defined strat-datum Geological setting Paleoenvironment Paleolatitude and paleolongitude Comments	Biostratigraphy Lithostratigraphy Magnetostratigraphy Chemostratigraphy Cyclostratigraphy Numerical age-model(s) defining numerical ages for each of the above stratigraphic schemes Method(s) of interpolating numerical ages between tie-points in above schemes Comments	Sample collection and sample storage Sample handling Analytical method and data analyzed Analytical uncertainty Normalization and standardization methods Method citation Comments

What visualization and computational tools are needed for viewing geochemical data?

Participants were agreed that visualization and computational tools are critical to the future success of CHRONOS-GC; nevertheless, the view was expressed that most users had access to well-developed tools *via* commercial software packages so, in the early stages, CHRONOS

should provide tools that are not available commercially or are simple to implement. In the initial stages, CHRONOS should provide a numerical, searchable, database from which data could be downloaded by geochemists and modelers directly into packages already available (*e.g.*, MATLAB, Octave, S-Plus, Excel, Gsharp *etc*). It was acknowledged that visualization tools enhance data comprehension and interpretation and will attract potential users to help populate the database. Therefore, simple tools should be provided from the outset from open-sources products to enable users to plot simple scatter-diagrams, and do simple statistics, unit conversion, paleotemperature conversions, and data normalization and re-standardization.

A primary purpose of CHRONOS-GC would be to enable users to meld to a common timescale trends through time in the composition of the Earth's many geochemical reservoirs. To do this, CHRONOS should implement a tool that will allow users to recalculate, to the most recent timescales, the numerical ages associated with new and legacy data. This will be done *via* the bio-, magneto-, chemo- and cyclo-stratigraphic schemes used to derive original ages and would mean building into CHRONOS links between the age models and the CHRONOS timescale (GTS2004) and its real-time updates.

The database must be searchable in a flexible way to allow users to draw out data using search-criteria based on both data and metadata. For ease of use and efficiency, a "Google-type" search engine and seamless linkages to other databases would be the way forward here. Participants suggested Java applications to use on your own desktop and within the web data system.

Table 2. Visualization and computational tools discussed at the CHRONOS-GC workshop.

Visualization Tools	Computational Tools
<ul style="list-style-type: none"> • Wrapper around data for standard visualization software • Publication quality data presentation through plug-in modules • Plotting tools <ul style="list-style-type: none"> ○ Multivariate plots ○ Time series plots ○ Histogram plots ○ 3-D plots (<i>e.g.</i>, time vs. frequency vs. amplitude) ○ Categorized plots: show different data types with different symbols and colors, vary scales (log, zoom), <i>etc.</i> • Publication-quality locality maps with projection options • Paleogeographic reconstructions with locality plotter (<i>e.g.</i>, <i>Plate Tracker</i> by C. Scotese) • Contouring in paleogeographic reference frame • Stratigraphic column • Lithological log with metadata • Specimen visualization—specimen, thin-section, SEM, stratigraphic section or core • Correlation of sections, core, and different data sets with options to screen and cull data, and choose different correlation schemes • Geographical query tools, integration with other data sets • Data index by time: scroll down time scale for data discovery • Age model visualizations 	<ul style="list-style-type: none"> • Data normalization • Data restandardization • Unit conversion • Statistical tools <ul style="list-style-type: none"> ○ Means, running means ○ Error propagation ○ Curve fitting ○ Correlation analysis ○ Time-series analysis ○ ANOVA • Curve differentiation and integration • Fractionation corrections • Paleotemperature conversions • Age models • Simple mass balance models

How to maximize outreach and use in education at all levels?

Workshop participants appreciated the importance to the success of CHRONOS of outreach and education, and proposed many ways this could be achieved – given appropriate funding. The websites of many museums and government agencies have excellent educational features that can serve as models, and sites to which CHRONOS should link. These include NASA, NSF, USGS and NOAA (*e.g.*, “Tapestry of time”; <http://tapestry.usgs.gov/default.html>), and the National Museum of Natural History (*e.g.*, <http://www.mnh.si.edu/mammals/>), American Museum of Natural History, and the Museum of Paleontology at UC Berkeley (*e.g.*, <http://www.ucmp.berkeley.edu/historyoflife/histoflife.html>). Furthermore, The Digital Library for Earth System Education (DLESE; <http://www.dlese.org/dds/index.jsp>), an NSF-funded program, provides a wealth of information on Earth system education at all levels.

Educational resources should be provided for students and teachers at the K-12, undergraduate, and graduate levels. Participants acknowledged that geochemical data are intensely interesting to geochemists, but not to the public at large. For the public, the interest is in what the data show about major events in Earth's history, such as the climatic impact of plate tectonics, the end-Cretaceous extinction, global warming in Earth history, gas-hydrate expulsions, and the beginnings of life. We must develop educational games, images, and text that relate geochemical data to such fascinating events in Earth history. Appropriate material might include age-appropriate “stories”, problems, homework assignments, demonstrations, ideas for science projects, and PowerPoint presentations. The assignments and projects would allow students to carry out simple-to-complicated tasks using the data and visualization tools of CHRONOS and independent programs. Games, artwork, animations, fossil locality maps, and panoramas of ancient landscapes would attract web-surfers of all ages. Above all, interfacing with the system must be made simple and intuitive. Below we present a summary of outreach and educational activities that will help make CHRONOS a home page for Earth science educators and students.

- Fun for kids – games, art and stories, activities, fossil locality maps, information for parents
- K-12 education
 - Featured topics, fossil images, panoramas, internet links, multimedia, simple ideas for science projects, glossary, interactive geological time scale.
 - Simple database tools and user tutorial.
 - Career-related: career information, meet a geologist, interviews with scientists, brief biographies of geoscientists, career links (AGI, AAPG, GSA).
 - Project ideas, homework assignments, demonstrations, lesson plans, PowerPoint presentations, internet links.
 - CHRONOS adopt-a-school program.
- Undergraduate education
 - Learning resources: Featured topics, fossil images, panoramas, glossary, interactive geological time scale, advanced reading, PowerPoint presentations, internet links
 - Project ideas, demonstrations, fossil maps
 - Intermediate-level tools and tool tutorial

- CHRONOS chat room for students
- Career-related: career information, meet a geologist, interviews of scientists, biographies of famous geoscientists, career links (AGI, AAPG, GSA, etc.)
- Graduate education
 - Learning resources: Featured topics, fossil images, panoramas, glossary, interactive geological time scale, advanced reading, PowerPoint presentations, internet links
 - Thesis and class-project ideas
 - Advanced tools and user tutorial
 - CHRONOS chat-room for students
 - Career-related: career information, meet a geologist, biographies of famous geoscientists, interviews of scientists, career links (AGI, AAPG, GSA, etc.)
- The Public
 - Great issues forum
 - Ask a geologist
 - Educational features discussed above
- Industry
 - Clearing house for donated data
 - Resource for stratigraphic information and age determinations
 - Ask a specialist
- Media and politicians
 - Fact sheets, Press releases, images
 - Statistics on website use
 - List of publications citing CHRONOS with links
 - Industry use and partners

The educational and outreach features presented above will require funding for professional personnel. Because scientists tend to overcomplicate the presentation of science, it will be necessary to hire educational professionals to develop educational materials in conjunction with CHRONOS participants. Specialists in IT and professional artists are required to produce quality products. Importantly, the educational components of the system must be supported through regular monitoring and regular updates. User comments solicited through the contact page must receive quick and satisfactory responses. Finally, individuals associated with CHRONOS must make personal contacts through talks and demonstrations at public schools, universities, companies, and government agencies. The system must be advertised through articles published in education (*Science Education, Journal of Geological Education*) and science publications (*Geotimes, Science, Nature, EOS*). Articles demonstrating the use of CHRONOS in journals such as the *Journal of Geological Education* and *Science Education* should be a priority.

How to enlist community support and participation?

Workshop participants suggested many ways to enlist community support. More importantly, participants showed their support by volunteering to provide data and serve on working groups. Researchers are often too busy, and are not funded, to input legacy (previously published) data and metadata into a database, thus funding for a dedicated scientist to perform

this task is important. Nevertheless, there are other equally important mechanisms for promoting population of new and legacy data in the database.

The establishment of working groups at the workshop, defined by method and materials, is already enhancing community support and participation. These working groups are (1) helping to design and review the database schema, metadata categories, and visualization and computational tools; (2) serving as experts to answer queries from IT specialists; (3) enlisting community support to populate and use CHRONOS-GC. Participating geochemists enthusiastically volunteered to serve on working groups (See Action items and timetable). Modest support (\$5K pa) should be provided for working group meetings. An additional support (\$5K pa) should be provided for a one-day biennial workshop, tied to a major meeting, for all CHRONOS-GC participants.

A natural and easy way to ensure database population by researchers is to provide data so accessible and tools so useful that CHRONOS-GC becomes essential for paleoclimate, chemostratigraphy, and paleochemistry research. Examples of such tools are age model computations, timescale inter-converters, paleogeographic mapping tools, and stratigraphic correlation tools. In addition, the ability to use CHRONOS to plot one's own data alongside, or integrated with, legacy data should be a strong enticement to interact with CHRONOS. A demonstration project (the Permian-Triassic time-slice) that features the utility of the system is urgently needed.

To encourage population of the database, NSF could require that data and metadata derived from NSF-supported activities be submitted to NSF-approved database systems. Journal editors and associate editors could make submission of data to a database a requirement of publication. CHRONOS could provide a service to journals by storing appendices of papers in the original form, as well as having the data accessible through CHRONOS. Data could also be directly linked to publications.

We can combine CHRONOS-GC's education and research missions by encouraging working-group participants and others, to have students populate and use CHRONOS-GC for class projects and papers. To simplify the process, we could produce a list of potential projects that would require data population and evaluation.

NSF and CHRONOS appear willing to set aside \$60-70K per year for small grants to fund the population of databases by graduate and undergraduate students, who would input legacy data. Typical grants would be \$5 - \$10K. These funds could also be used to support travel for training and workshops, summer internships, and tools development. Research Experiences for Undergraduates (REU) supplements could also be used for this purpose.

Action Items and Timetable

Formation of working groups. Working groups are tasked with assisting CHRONOS-GC develop. This action was initiated at the workshop. The preliminary list of working groups is as follows:

Version 1 (from Workshop)

Carbon isotopes: Michael Joachimski, Rob Ripperdan, Matt Saltzman, Graham Shields
 Oxygen isotopes: Ethan Grossman, Linda Ivany, Miriam Katz, Michael Joachimski. Jim Zachos
 Sulfur isotopes: Adina Paytan, Harald Strauss
 Sr isotopes: John McArthur, Graham Shields
 Osmium isotopes: Bernhard Peucker-Ehrenbrink
 Nd isotopes: Debbie Thomas
 Metal/Ca ratios: Bas van de Schootbrugge, Yair Rosenthal
 Terrestrial environments: Huiming Bao, Harald Strauss
 Organic geochemistry and stable isotopes: Kate Freeman
 Paleo-pCO₂ proxies: Dana Royer

Version 2 (based on post-Workshop communications)

1. Whole sediment and sedimentary rock (C, N, O, S, and Sr isotopes): Michael Joachimski, Rob Ripperdan, Matt Saltzman, Graham Shields
 2. Whole sediment and sedimentary rock (Os, He, other[?] isotopes): Bernhard Peucker-Ehrenbrink
 3. Carbonate microfossils (B, C and O isotopes): Jim Zachos, Mimi Katz*
 4. Siliceous microfossils (Ge/Si; O and Si isotopes):
 5. Carbonate macrofossils (B, C and O isotopes): Ethan Grossman, Linda Ivany *, Michael Joachimski
 6. Microfossils and macrofossils (x/Ca and y/CO₃): Yair Rosenthal, Bas van de Schootbrugge
 7. Microfossils and macrofossils (Heavy isotopes Ca, Fe, Sr, Pb, etc): John McArthur,
 8. Sulfate minerals and carbonate-associated sulfate (O, S, Sr isotopes; S content): Adina Paytan, Harald Strauss
 9. Phosphates (O, C, Sr, Nd isotopes, etc.): Michael Joachimski, Debbie Thomas
 10. Sedimentary organic matter (H, C, O isotopes, etc.): Kate Freeman
 11. Soil carbonates and oxides (C, O, S, Sr isotopes, etc.): Huiming Bao, Harald Strauss
 12. Paleo pCO₂ (stomatal indices, geochemical models, etc.): Dana Royer*
- *Post-meeting additions

Working groups are open to all wishing to participate. In our continuing development of the program, we are working towards having evolving groups comprising three to six members, with one or more coordinators. We have already enlisted additional members in the larger working groups (*e.g.* Linda Ivany, Mimi Katz, and Dana Royer) and continue to do so in order to ensure we have a complete coverage of potentially useful fields.

Provide data to help with data schema and metadata design. A body of data are needed for Pat Diver to begin to set up the database schema and metadata fields. Several participants volunteered to send data compilations to Pat and have now done so: John McArthur and Graham Shields have provided strontium-isotope data for the Phanerozoic, Ethan Grossman has provided databases on the composition of Tertiary mollusks and Late Paleozoic brachiopods, and Adina

Paytan has provided sulfur isotope data and metadata. Additional databases have been sent by Linda Ivany and Dana Royer. Finally, Harald Strauss and Michael Joachimski are inquiring into the possibility of housing in CHRONOS the Devonian-Permian data being compiled by a European consortium.

With the databases he has received, Pat Diver hopes to have a prototype data schema and metadata design ready in three months. Cinzia Cervato suggested that an accessible and usable database could be ready by Spring, 2005.

Other activities.

CHRONOS-GC can organize special sessions at national and international meetings such as the theme session organized for the fall GSA meeting by Cinzia Cervato and Walt Snyder. The Earth System Processes meeting in Calgary in August, 2005 is a perfect opportunity to highlight CHRONOS-GC and paleochemical research.

Timetable

Below is a tentative timetable for the implementation of the Geochemical Cycles component of CHRONOS over the next two years.

TASK	July- Sept., 2004	Oct.- Dec., 2004	Jan.- Mar., 2005	Apr.- June, 2005	July- Sept., 2005	Oct.- Dec., 2005	Jan.- Mar., 2006	Apr.- June, 2006
Working group formation	X	X						
Pilot data submission	X	X	X					
Data schema		X	X					
Metadata		X	X	X				
Database usability and accessibility				X	X	X	X	X
Database population				X	X	X	X	X
Tools development					X	X	X	X

References

- Goldstein, S.L., Deines, P., Oelkers, E.H., Rudnick, R.L., and Walter, L.M., 2003. Standards for publication of isotope ratios and chemical data in Chemical Geology. *Chemical Geology* 202:1-4.
- Harland, W.B., Armstrong, R.L., Cox, A.V., Craig, L.E., Smith, A.G., and Smith, D.G., 1990. A geologic timescale 1989. Cambridge, Cambridge University Press, 263 p.
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APPENDIX 1**CHRONOS Geochemical Cycles Workshop Agenda
St. Anthony Hotel, San Antonio, Texas, June 25-26**

Talks: 20-25 minutes including discussion

Breakout sessions: 60 minutes

Presentation and discussion of breakout session results: 40-50 minutes

Meeting room: St. Anthony Club Room (lobby level)

Breakout rooms: Coronado Room and Boardroom (third floor)

Friday, June 25, 2004

7:30 AM Breakfast in Loggia area (by bar, lobby level)

8:30 AM - 12:30 PM Friday morning session

8:30 – 8:45 AM Welcome (Ethan Grossman and John McArthur)

Introduction to CHRONOS

8:45 - 9:05 AM NSF Perspectives on IT Research (Walt Snyder or Rich Lane)

9:05 - 9:30 AM What is CHRONOS? (Cinzia Cervato)

9:30 - 9:50 AM The CHRONOS Geochemical Cycles (GC) Domain: Why do we need it? (E. Grossman)

9:50 - 10:10 AM The CHRONOS Climate-through-Time Domain (Linda Hinnov)

Break**Application of the CHRONOS Geochemical Cycles Domain**

10:30 - 10:55 AM GC data and the history of life (Paul Wignall)

10:55 - 11:20 AM GC data and the sedimentary record through time (Bill Hay)

11:20 – 11:45 AM GC data and Earth system models (Yannick Donnadieu)

11:45 – 12: 35 PM LUNCH (Loggia area, lobby level)**IT Database Programs in the Earth Science**

12:35 - 1:00 PM The Ottawa-Bochum Database and its uses (Graham Shields)

1:00 - 1:25 PM GERM, MagIC and RiG under the EarthRef.org Umbrella Website (Anthony Koppers)

1:25 – 1:50 PM PetDB (Kirsten Lehnert)

1:50 - 2:10 PM PaleoStrat: Part I. Overview (Tyson Taylor)

Break**Integration of Data and Metadata**

2:30 – 2:55 PM Integration of isotopic proxies (Jim Zachos)

2:55 - 3:20 PM Integration of trace-metal proxies: a review (B. van der Schootbrugge)

3:20 - 3:45 PM Integration of isotopic and chemical data from organic geochemical proxies (K. Freeman)

Break

- 4:00 - 5:00 PM **Breakout session:** What types of data and metadata should be included in the CHRONOS database?
 5:00 - 5:40 PM Presentation and discussion of breakout results.
 6:00 - 7:15 PM **Informal mixer and poster viewing (Lobby and Lounge)**
- 7:30 - 9:00 PM DINNER (Jefferson Manor, lobby level)**

Saturday, June 26, 2004

7:30 AM Breakfast (Loggia area)

9:00 AM - 12:00 PM Saturday morning session

Information Technology: Programmer and User Needs

- 9:00 – 9:15 AM PaleoStrat: II. IT aspects of database and visualization tools (T. Taylor)
 9:15 - 9:45 AM IT aspects of CHRONOS: database and visualization tools (P. Divers)

Break

- 10:05 - 10:15 AM Introduction to breakout session
 10:15 - 11:15 AM **Breakout session:** What types of visualization and computational tools are desirable for the GCD theme?
 11:15 - 12:05 AM Presentation and discussion of breakout results
- 12:05 - 1:05 PM LUNCH (Jefferson Manor, lobby level)**

1:05 PM - 5:00 PM Saturday afternoon session

Information Technology: Outreach and Education

- 1:05 - 1:15 AM Introduction to breakout session (L. Hinnov)
 1:15 - 2:15 PM **Breakout session:** Outreach and Education programs
 2:15 - 3:05 PM Presentation and discussion of breakout results

Break

Implimentation

- 3:25 - 4:15 PM **Group discussion:** Enlisting community participation in populating and using database
 4:15 - 5:00 PM Closing remarks, summary, and action items

Refreshments

Dinner (no scheduled dinner; participants may break up into groups for dinner)

APPENDIX 2

CHRONOS Geochemical Cycles Workshop Participants

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