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Joint Oceanographic Institute- U.S. Science Support Program

COREWALL VISUALIZATION WORKSHOP REPORT

SEEING THE FOREST AND THE TREES

May 8-10, 2006
Joint Oceanographic Institutions
Washington, D.C., 20005

CoreWall Consortium* and CoreWall Steering Committee‡

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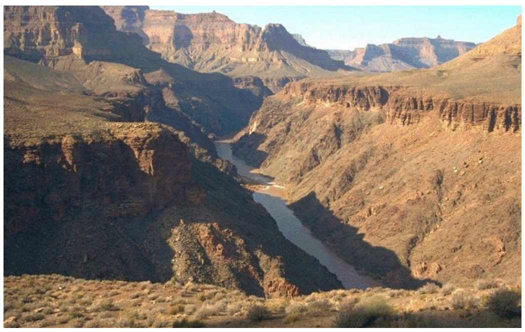
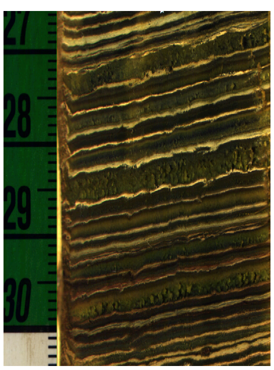
For Further Information: www.corewall.org

Why CoreWall ?

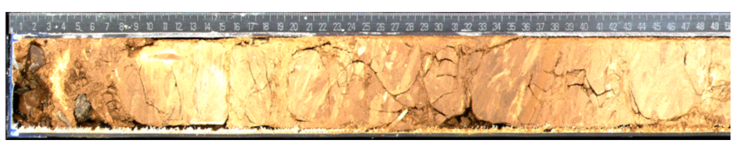
The first question that must be answered is why do we need a CoreWall Project at all? As with almost scientific fields over the last decade, informatics has become a new subdiscipline that, in combination with explosion of Internet capabilitiy/availability, database development, and the digitalization of almost all data, strives to find ways to integrate and make sense of these rich sources of information. Within the realm of geosciences, some of the most powerful sources of information are images. Whether it be awe inspiring outcrops in the Grand Canyon, sediment cores from the ocean, annually-layered ice cores, finely-laminated lacustrine cores, or hard-rock cores and thin sections, our interpretations are derived largely from what we can see. Unfortunately for most of us, traveling to the Grand Canyon routinely is not an option, nor is revisiting most or our field sites in the ocean, lakes, or ice-sheets.



Up to now, we have been left with a collection of "family snapshots"of individual static images stored in databases, a "barrel sheet" summaries on CD's or print, written descriptions, and maybe, an occasional visit to a core repository for sampling where often the cores have oxidized, shrunk, etc. If we want to integrate this information, it becomes a quite tedious task of assembling all the various bits and pieces together using any number of software programs that must be repeated every time we do it.

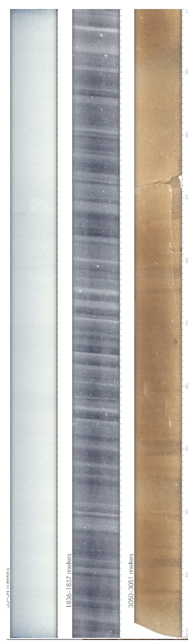


Photograph, left, of finely laminated lacustrine sediments (mm-scale) (Courtesy of Anders Noren-LacCore, U.Minn.). Core image, below, of sediments from ODP Site 1218 (Courtesy of IODP).

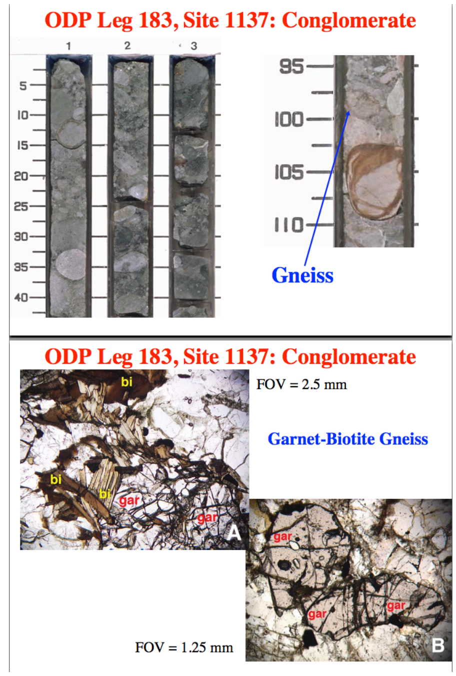


With the parallel development of global databases and portals, we need better tools for visualizing all this data as well. Different questions need to be asked:

How can we make better use of all the investment that's been made in collecting this material?? How can we use these digital images to improve, simplify, and capture core descriptions? How can we bring these image to life and make them the digital whiteboard where we can overlay other data? What if we could download an entire expeditions worth of images anytime we wanted and its associated data ? What if we want to visually correlate a collection of cores in real time to guide coring ? What if we can combine our visual observations with high-resolution digital images to enhance what we see? What if we can make measurements on the images that wouldn't require the physical core? How can we develop strategic sampling plans and keep visual track of sampling at repositories? Can we use these digital archives to create teaching opportunities for educators with limited access to the primary materials?



Photograph of ice cores, left, collected from Greenland showing effects of compaction on lyers at different depths in ice. On right, compliation of images showing hard rock cores and thin section micrographs from ODP Leg 183 (courtesy of Clive Neal).



These are the questions that drove the Corewall Project group's interest in developing visualization and data integration tools that empower the geoscience community's access to both the rich variety and the exponentially growing data that is being collected worldwide.

Introduction

The CoreWall Project consists of an integrated suite of software applications that is being developed with funding from NSF-OCE over the next two years as a data visualization environment to enhance interpretation of geoscientific data. Collectively, these applications are termed the CoreWall Suite (CWS) and are intended for use on all types of core materials including sediments, hard rocks, and ice cores. Prior to NSF funding, development has been driven by more "informal" collaborations between JOI, the LacCore facility at the University of Minnesota, National Center for Earth-surface Dynamics (NCED), ANDRILL, and the Electronic Visualization Lab at the University of Illinois at Chicago. The shared goal in these collaborations was improved data and image visualization, which is at the heart of CoreWall. As an open source development project, it aims to empower individual users such as most lake core scientists or groups such as ANDRILL with a new set of powerful visualization tools that can be used easily, shared, and are customizable by the user community.

The CoreWall Consortium is hoping that the CWS provides a strong "visual" foundation that will significantly change and improve current approaches used for description and analysis of sediment and rock cores by integrating these activities. For that vision to become reality, further development of the CWS needs to be carried out in broad collaboration with stakeholders in these science communities. The Consortium needs to make sure that the software development does not occur independent of related IT activities, in particular, the development of the U.S. IODP-Phase 2 Scientific Ocean Drilling Vessel (SODV).

Workshop Goals

As an integral step towards engaging a broad stakeholder group and establishing our specifications and requirements for the CWS, this USSAC-sponsored 3-day workshop assembled plenary speakers from IODP, ANDRILL, ICDP and other drilling or core-based project entities, various databases, repositories, and data visualization fields (See list of participants below). One of the big concerns driving this workshop beyond gaining reassurance that this project was worthwhile was to make sure that the CoreWall Project remained a focused effort and not promise too much. To accomplish this, the plenary introductory talks on the first day were followed by three breakout group discussions over the next two days to examine typical user scenarios for different groups, technical issues (databases) and obstacles (formats) for sharing data, and education and outreach impacts. Many different scale user groups were represented at the workshop including representatives from each of the IODP platforms (Riser Vessel Chikyu, JOIDES Resolution, European Mission Specific Platforms), ICDP projects, large and small lake coring projects, and even outcrop studies. By splitting up the groups in different ways, we were able to discuss and obtain inputs about visualization issues both in general terms and in more detail on individual project scales. These user scenarios gave us invaluable information on common as well as individual needs. Many needs are common to all groups (see, e.g., IODP Minimum Measurements List). It became clear early in the meeting that there was a strong agreement and convergence on a subset of common needs that are critical for the adoption of the CWS. These "common needs" will become the focus of implementation during the current funding period.

The CoreWall Suite of Applications

There are 4 independent but integrated parts to the CWS of applications and each has a different visual/ data integration or exploration purpose (Figure 1).

- **Corelyzer**- Primary visual integration workspace that allows you to view depth-registered data, images from any compatible databases. At the workshop, we used all the data and images from ODP Leg 199 and from ICDP/NSF Lake Titicaca drilling project as examples of how the Corelyzer can scale from medium- to large-scale projects and handle large datasets. Corelyzer is easily expandable through the development of custom plug-ins. Because individual user communities will always want to integrate new functionality and features into the CoreWall Suite, we have created a plug-in structure that allows programmers to extend the functionality of the base software on their own. Corelyzer can also pull data from the Web, which was demonstrated at the workshop with a newly developed CHRONOS Web Data Portal plug-in.

- **Workflow Database**- A local working database(s) that allows for (a) local interaction with data, (b) data synchronization between multiple CoreWall setups/databases, (c) remote collaborations where data/images are being shared, and (d) interaction with web services and other databases.

- **CoreCLIP (Core-Log-Integration-Platform)**- The revised SPLICER (stratigraphic composite builder) and SAGAN (core-log mapping) software that was previously a UNIX application used mainly by ODP. CoreCLIP will provide a standalone application and a Corelyzer-ready plug-in with many new features such as the ability to use images to assist stratigraphic composite building, an integrated text parser to improve data entry, contextual help and tutorials, and add new depth correlation algorithms to improve composites and depth mapping results.

- **CoreNavigator**- A data discovery tool that has the ability to browse data in a 2- or 3D geographic "GIS-like" context. Using VRML, it gives a visual way of comprehending cored stratigraphic datasets integrated with seismic and oceanographic data where that exists. CoreNavigator displays are computed directly off databases.

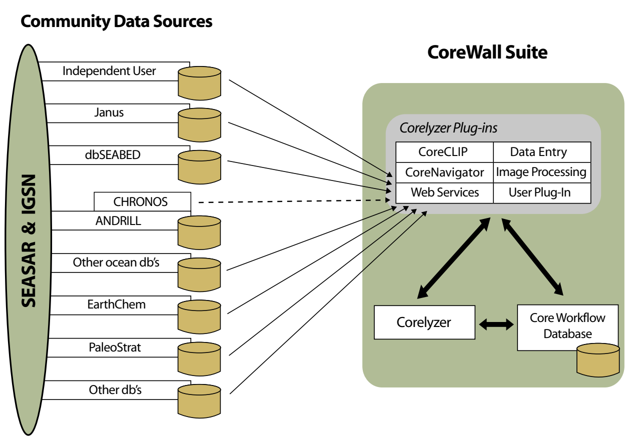


Figure 1: Schematic diagram of the relationships of the CWS components to each other and possible interactions with outside data sources via web services.

Summary of Workshop Agenda

Day 1: May 8th-Monday

As an integral step towards engaging a broad stakeholder group and establishing our specifications and requirements for the CoreWall Project, this USSAC-sponsored 3-day workshop assembled plenary speakers from IODP, ANDRILL, ICDP and other drilling or core-based project entities, various databases, repositories, and data visualization fields (See list of participants below). One of the big concerns driving this workshop beyond gaining reassurance that this project was worthwhile was to make sure that the CoreWall Project remained a focused effort and not promise too much. To accomplish this, the plenary introductory talks on the first day were followed by three breakout group discussions over the next two days to examine typical user scenarios for different groups, technical issues (databases) and obstacles (formats) for sharing data, and education and outreach impacts. Many different scale user groups were represented at the workshop including representatives from each of the IODP platforms (Riser Vessel Chikyu, JOIDES Resolution, European Mission Specific Platforms), ICDP projects, large and small lake coring projects, and even outcrop studies.

Day 2: May 9th- Tuesday

Days 2 and 3 were all designed round breakout group discussions. Day 2 groups gave quick reports in the morning of the Day 3 in order to provide more material for discussion for the Day 3 breakout sessions. In the subsequent sections of this report, the issues that were raised by these breakout groups are discussed.

We began Tuesday with 2 concurrent breakout sessions: Broader Impacts, and Tools and Web Services. The participants were free to choose the breakout group and they split into nearly equal size groups. The Broader Impacts group discussed potential deployment of the CWS in both informal and formal education settings. Pat Hamilton, director for Earth and Environmental Sciences at the Science Museum of Minnesota, and Dana Brown, the MS PHD'S student from Georgia State University, provided valuable inputs. This group's report forms the core of the "Broader Impacts" section of this report.

The Tools and Web Services quickly got down to brass tacks and discussed data push/pull, anchored annotation in Corelyzer, registration of core images to a 2D coordinate system, necessary metadata associated with annotations, provision for hardcopy to be produced from Corelyzer displays, display of annotated graphs such as well log data, and integration with other VCD applications such as PSICAT being developed by CHRONOS for ANDRILL through plug-ins to Corelyzer via Core Workflow Database. The report from this group is incorporated throughout the section "Using the CWS Applications", below.

After lunch, the participants split into 3 preassigned breakout groups and discussed common topics. The first topic was to consider different working environments and their workflow requirements. The participants had some introduction to the range of these environments and requirements from the 3 plenary presentations Monday morning. The second topic was to explore the differences and similarities in the VCD requirements, the types of data acquired, and the VCD approaches for soft-rock (mud) and hard rock communities. We hoped to include ice cores in this discussion but were unable to secure any participants due to scheduling conflicts. These topics were further developed by the breakout session on

Day 3 when participants were asked to separate according to user communities and further discussed workflow scenarios of VCD.

Day 3: May 10th- Wednesday

Day 3 started with short reports by the breakout group recorders from Day 2. Because neither Corelyzer nor PSICAT had much time during the workshop to provide hands-on demonstrations, an hour was set aside for this purpose before the start of the last breakout session. The breakout groups for the last session consisted of the IODP, Lakes & UNOLS core community, ANDRILL and ICDP, and Outreach & Education communities. The first represents a factory-like environment where VCD has to keep up with the rate at which the cores are recovered. The second group can only do the VCD or even the whole core multi-sensor core logging, quite a bit later, usually at a repository. The third group may have some laboratory facility at the drill site for the whole core multi-sensor logging, but VCD is generally done at a repository. IODP Mission Specific Platform projects usually fall in this category. The last group consisted of participants who are passionate about improving the delivery method of scientific content to students and the public. The reports from these breakout groups are also incorporated into all subsequent sections of this workshop report. Recorders of these breakout groups gave the last set of presentations. After a brief summary of what we saw were the common needs that merged during breakout sessions, we thanked the participants and adjourned the workshop at 2 PM.

Using The CWS Applications

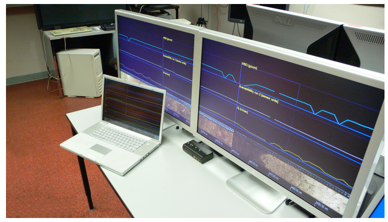
Corelyzer: Data Visualization, Integration, and Analysis

<u>On the fly data integration and visualization</u>

The beauty of the CoreWall Suite is the ability to display multiple datasets next to each other, which allows better integration of the different science streams generated for a given core section. For example, change in texture can be tracked with photomicrograph images down a core, which can be correlated with changes in physical properties (e.g., density, p-wave velocity, etc.). These different datasets are generated independently as the core is processed, either on site or at a shore-based repository and are most useful when the CWS can access these datasets as soon as they are generated. Therefore, the CWS should be able to regularly request data from each database and as soon as it becomes available, and integrate them with the scanned image. This integrated approach to core data display will facilitate much better strategic sampling of each core, which in turn produces better science.

Figure 2:

An important feature of Corelyzer is that it is scaleable and works on laptops to large multi-panel displays. Corelyzer is also crossplatform and works on Mac, Windows, and Linux OS environments.

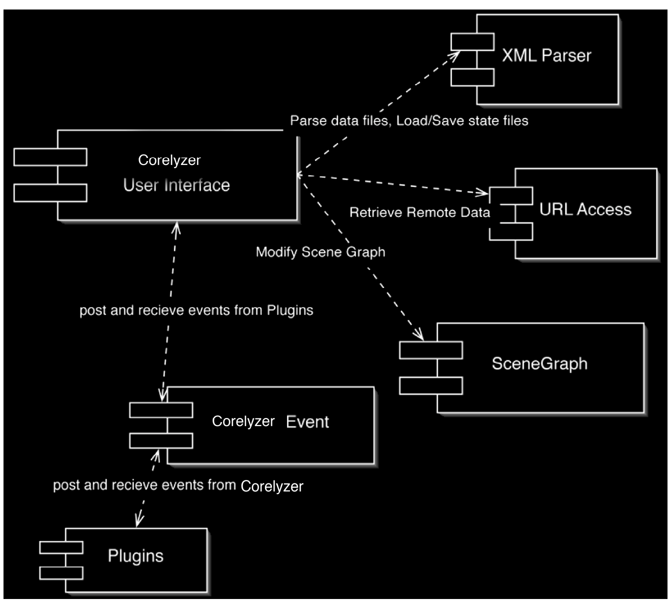


Another increasingly important aspect of integration is core-log-seismic. The seismic part of this includes both site survey data as well as check shots at the completion of a hole. The CWS should be able to display seismograms against core images and data, although the depth scale on the site survey seismograms needs to be adjusted to that from the seismic check shot. If there is no check shot, seismic integration may be more cumbersome.

- **Current Functionality**

High Resolution Imagery	Display Depth Scale	Mouse Based Interaction
Load & Display Datasets	Annotate Imagery	Web Access
Save and Load Work	Scalable	Visualization Hardware Accelelerated
Plug-in Support	Multi-platform	

Figure 3: Components of Corelyzer



New Data Creation and Acquisition

As alluded to above, the CWS should regularly request data from each database as the core is processed. This could be every five minutes or every hour, but it should be flexible and dependent on the rate of core being drilled and the needs of the scientific party as well as the connectivity between sites. As new data are acquired, they will need to be related to the base Corelyzer image of that core section. The question then becomes *how* will CWS relate the new data to the image, i.e., what depth scale will be used? Initially, this will be easiest if it is meters below seafloor or the equivalent if on land, but CWS should be able to easily and seamlessly change this scale so that all related data sets are also plotted with the new depth scale on Corelyzer. This allows the integration and display of geochemical, petrographic, paleomagnetic, and physical properties data on the same depth scale.

Another important feature of CWS would be to make the Corelyzer images and graphic displays available to project scientists who are away from the initial description/data gathering site. Making images available for analysis by off-site or off-repository scientists would be not only be useful but perhaps necessary feature for lacustrine or Antarctic communities and scientists participating in mission specific platform projects.

Quantitative Analysis of Core Photos

Corelyzer will contain the basic function of displaying digital core photos and annotating them. However, tools for performing quantitative analyses of images would meet the oft-voiced wish of sedimentologists and hard-rock petrologists alike. Such tool can easily be provided through user-commissioned plug-ins. The goal would be to provide scientists with ways to automate frequency and abundance analyses of some feature made on the digital core photos. A sedimentologist might like to select an interval on a photo, and have the software count light/dark banding to determine the number and frequency of layers and laminations. An igneous petrologist would like to use edge detection tools to determine the percentage of phenocrysts, clasts or vesicles in a selected area of the core photo. These functions will greatly increase the productivity of a scientist analyzing the cores.

Preparation for Sampling of Cores

The ability to display different data together at a common depth scale would be very useful during the sampling of cores, either on a research expedition or back in a core repository. By displaying data from various instruments next to the core photo at a common depth scale, the curator can make better decisions on what material to select for various research projects. In addition, any information that is available about sampling history can be displayed on the core photo, allowing anyone who is making a sample request to be aware of what has already been taken from the core. This allows him/her to request an interval where material is still available. If information about who took the previous samples is available, say by a lookup through the IGSN (International Geo Sample Number) of the sample, this will allow the researcher to trace the sample to the person who currently has it in order to request a sub-sample, or perhaps to simply utilize the results of the previous study.

Core Workflow Database: The Behind the Scenes Accountant and Traffic Controller

Keeping track of local user's actions

The fundamental role of the Core Workflow Database is to keep track of everything that is done in/with Corelyzer by a user without the user being aware of its presence: it should create metadata for every annotation made on the core image, and keep track of the sources of any data pulled in, whether from other databases through plug-ins or web services, or directly from local user's instruments.

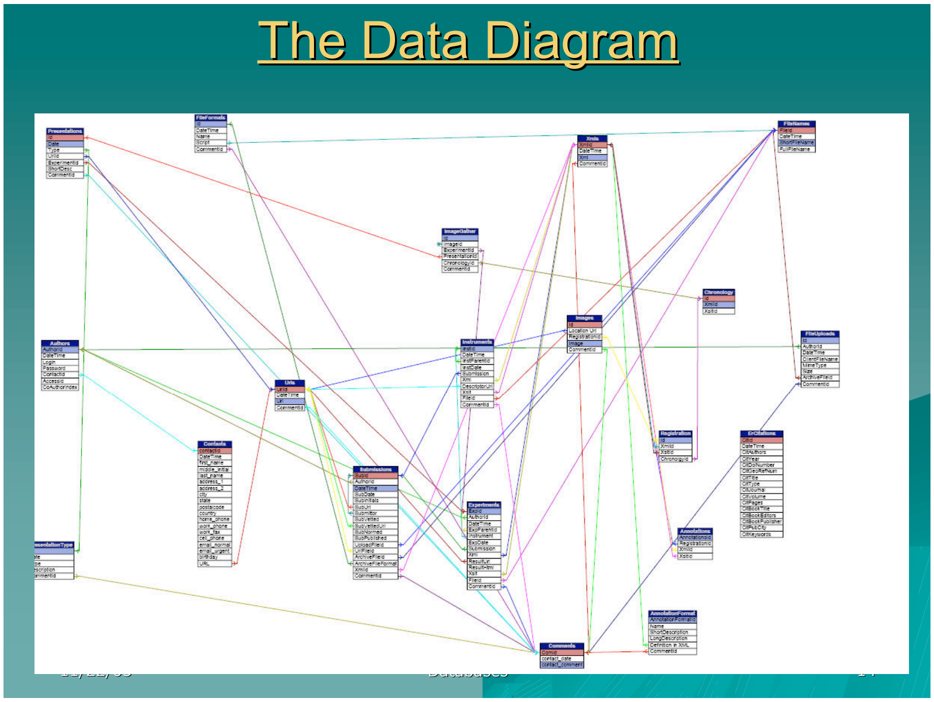


Figure 4: This diagram highlights the potential complexity of potential user-database interactions handled in the background by the Workflow Database so all of these requests are done transparently to the users.

Synchronization and Data Push/Pull

Visuals and data should be refreshed automatically at regular intervals (i.e., every time the CWS requests data) as well as manually (i.e., every time a scientist adds an annotation, etc.). This may involve synchronization across multiple platforms and multiple users. Issues that need to be dealt with include: if multiple users are viewing the same data (e.g., core image) and are generating more data (e.g., VCD), how would the users know that they are looking at the most up-to-date version of the data and remain aware of the changes (e.g. via RSS feed); who controls what gets sent to all users (e.g., VCD at multiple stations or institutions based on images); and keeping track of multiple VCD entries for a single feature by generating appropriate metadata for each VCD entry. New data need to be written elsewhere as they are generated. This includes cache in the Core Workflow Database and permanent storage in some database, perhaps back to where the original data came from.

The synchronization and data push/pull scenarios are inherently different for IODP factory environment (Chikyu and JOIDES Resolution) where everything is done on site, and for ICDP, lakes, UNOLS or even IODP Mission-specific platform projects where limited to no documentation occurs at the drill site and initial core description (including multi-sensor core logging and VCD) occurs at an off-site laboratory or a repository.

Remote Collaborations
The Core Workflow Database should enable the project scientists who are away from the initial description/data gathering site to see the Corelyzer images and graphic displays as well as allow collaboration involving multiple locations (e.g., project scientists in their respective institutions). The Workflow Database thus needs to mastermind several key events depending on the predetermined use scenario. Pertinent issues were already discussed under Synchronization and Data Push/Pull.

Web Services
The Core Workflow Database will support open standards and protocols. This will ensure interoperability across platforms as well as making it easy for programmers to develop plug-ins for the Corelyzer.

CoreCLIP: Core-Log Stratigraphic Correlation and Depth Mapping

In the early 1990's, the Core-Log Integration Plaform (CLIP) software was developed with NSF support at L-DEO (Peter DeMenocal, Ann Esmay, and Suzanne O'Hara). The CLIP package consisted of two software applications, SPLICER and SAGAN, that are used for the following tasks:

SPLICER:
- Ensuring a complete stratigraphic sequence was obtained when drilling multiple holes at a site by being able to align common Core data features and providing feedback to drillers to obtain proper overlaps.

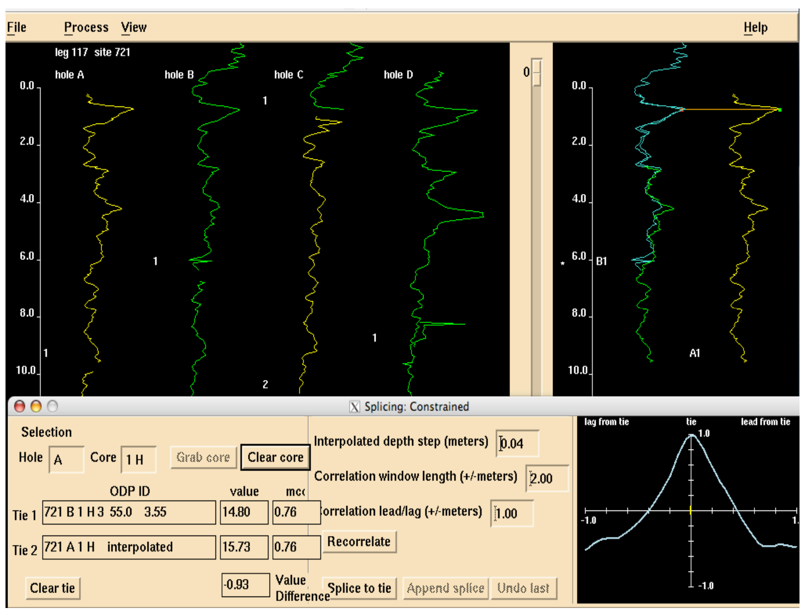


Figure 5: Screen shot of Splicer software showing both compositing (left) and splicing functions (right window). Feedback via correlation window (bottom right) and user settings (bottom) are provided.

- Building a "spliced" record from cores of multiple holes so that a complete stratigraphic section could be constructed for guiding sampling.

- Key features: No stretching or squeezing of data, cores are moved intact relative to one another. Output of data related meters below seafloor (mbsf) to new meters composite depth (mcd) for spliced record.

<u>SAGAN</u>:

- Mapping of Core data into Downhole Log data to correlate relevant features and to account for core expansion and map back into estimated "in situ" depths.

- Key features: Core stretching and squeezing was allowed to map core data into log depth scale. Both auto correlation and manual tie lines were available to accomplish correlation down to ~m scale or less depending on resolution of log data. Output of data related mbsf to mcd to new depth scale defined as equivalent log depth (or estimated log depth) (eld).

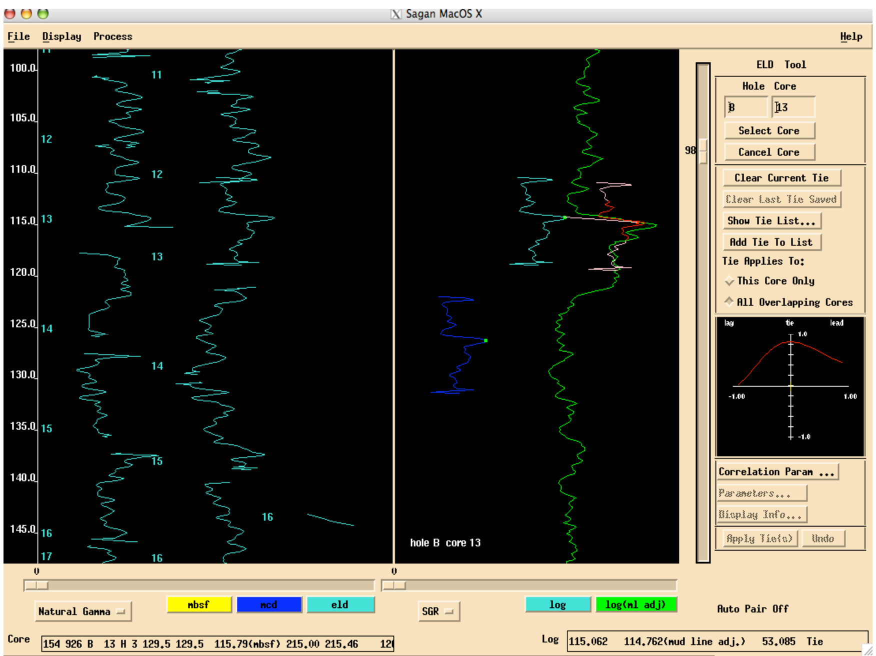


Figure 6: Screenshot of Sagan software with core natural gamma data on lefthand side of window that has been correlated with natural gamma (SGR) downhole log data. Sagan keeps track of depth scale mappings between meters below seafloor (mbsf) to meters composite depths(mcd) (eg. Splicer output), and equivalent log depths (eld).

In practice, SPLICER is the primary "field tool" deployed by ODP and IODP for the practical task of stratigraphic composite building. SAGAN is not made available on the ODP ship and is typically used by logging scientists “post-cruise” to analyze core-log relationships. Despite SAGAN’s many correlation capabilities including time series, it’s potential has not been realized, in part because it also lacked almost any documentation which limited its use.

As part of the CoreWall Project, CoreCLIP is being developed to enhance the capabilities that these two applications provide by accomplishing the following:

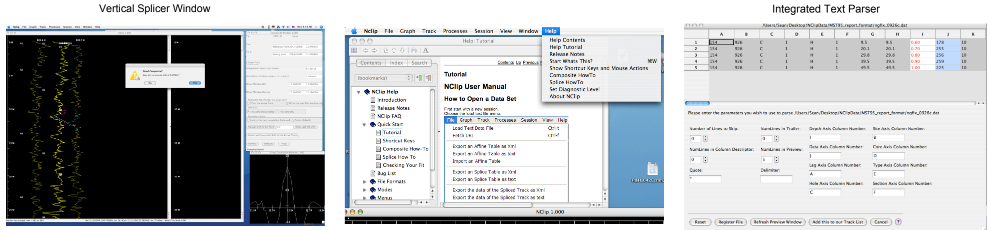
<u>CoreCLIP New Features</u>:

1) Re-writing code into a cross-platform version that will work in Mac, Windows, and Linux
2) Combining the processes from both applications into a single application and making improvements to compositing, splicing, and correlation algorithms where possible.
3) Make data entry and export much easier by allowing users to create their own formats by use of a new integrated text parser.
4) Support multiple data formats so differently scaled data (eg. natural gamma, magnetic susceptibility) can be used to construct splices.
5) Provide significantly improved help (contextual help) and tutorials to make it easier for novice users to get started.
6) Support for more depth scales and ease of import/export of depth scale relationships.
7) Possible support for using digital images as part of the compositing/splicing process as a visual QA/QC tool but also as an output that can be exported (i.e. Splice image could be brought up in Corelyzer).
8) Creating ability to save work “sessions” that can be then saved and shared amongst multiple users.
9) Annotations within data track for “text” comments within a session.
10) Web support so that data can be retrieved from remote databases.

Figure 7: Example Screenshots from new CoreClip software under development

A) Compositing/Splicing Window B) Tutorials/Help Menus C) Integrated Data Loading

Vertical Splicer Window Integrated Text Parser



<u>CoreCLIP- Standalone Application vs. Plug-in?</u> :

CoreCLIP is envisioned primarily as a standalone application that will be able to export a variety of depth related and spliced datasets that will be available for use in other applications. For example, exporting a “spliced” digital image from CoreCLIP for use in Corelyzer would be a very useful for providing a visual guide for comparisons to individual cores or for planning sampling strategies. Providing spliced datasets for any physical properties would also be quite useful.

CoreCLIP will run within the Corelyzer environment as well if desired. Potentially, running CoreCLIP as a plug-in to Corelyzer would benefit from the larger screen space that would be useful for looking at larger number of cores, images, and MSCL datasets.

CoreNavigator, GeoMapApp, and the "Google Earth" Paradigm

CoreNavigator is envisioned to solve two problems with data discovery and visualization of existing data and databases that users may have when using the CoreWall suite. The first solution involves the browsing of existing data from databases of which the user may be unaware. The first version of this application is built in Google Earth and draws data from the database dbSeabed (http://instaar.colorado.edu/~jenkinsc/dbseabed/). Scientists can select a geographic area of interest and view the distribution of drilling sites.

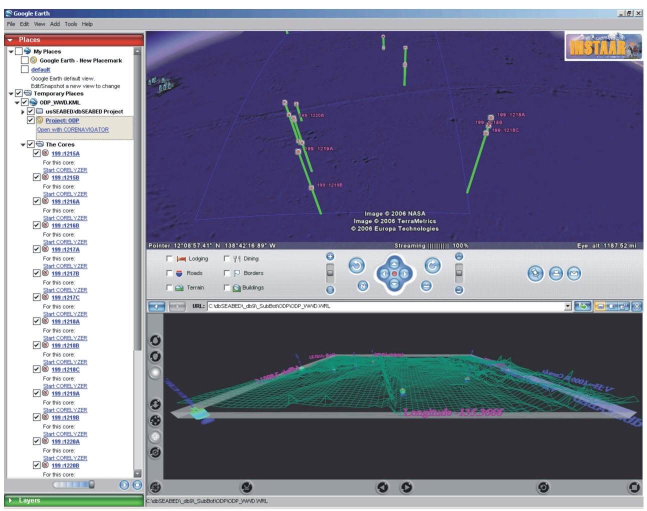
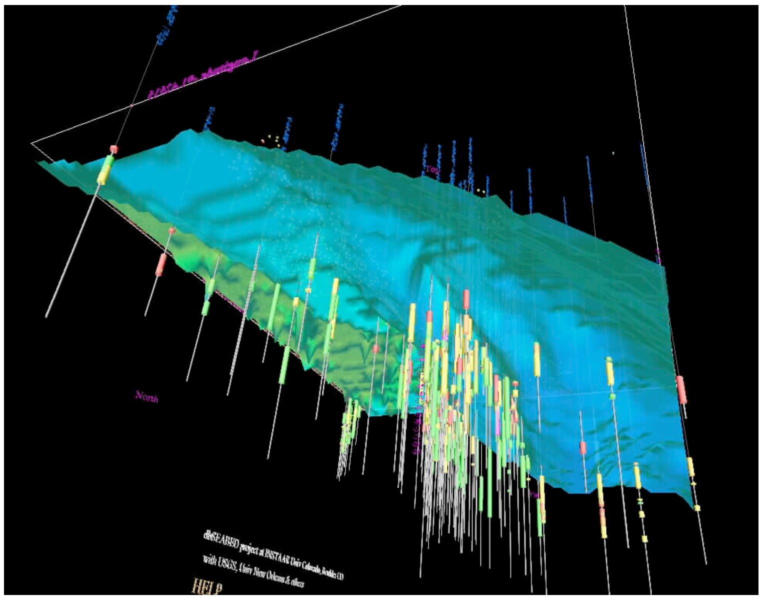
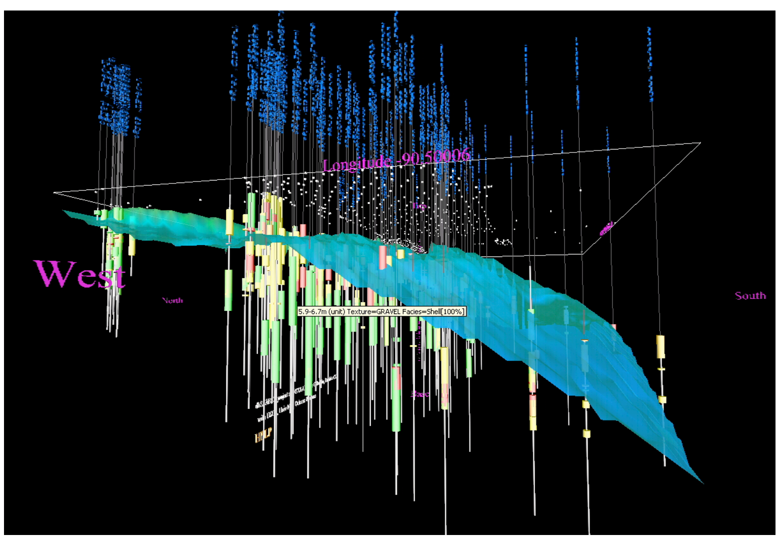


Figure 8: A CoreNavigator prototype display with multiple drill sites shown in the google earth interface on the top right of the window. Note that the lower right is the same area in the Cortona VRML plug-in. The left part of the window gives the user the ability to select any one of the cores being visualized.

The second application is to visualize three dimensional geologic structure using individual cores. This is not a new concept as it can be performed in a number of software packages including goCAD and EarthVision. The innovation is the potential coupling of the core databases, visual core description and the three dimensional display. Below is an example of the Ship Shoal region of the Mississippi Delta. The surface is the local bathymetry and each pin is encoded with the lithology that has been interpreted. If a scientist clicks on a pin the appropriate core image comes up for that part of the core. We envision that in the future, a user can bring up the proper core image, core data, and interpretation from anywhere on the Internet.

Figure 9: Ship Shoal Visualizations (courtesy of Chris Jenkins):
3-D renderings of hundreds of cores in Ship Shoal area, Gulf of Mexico that interactively can show the users lithologies and other available datasets. In addition views can be rotated to highlight other important features.





This project is taking full advantage of the current state-of-the-art in web mapping applications. We do not wish to reinvent Google Earth or the like. Our team also intends to fully take advantage of efforts such as GeoMappApp at LDEO which has much of the software infrastructure to support the two dimensional geographic visualization needed for CoreNavigator.

Integrated CWS Applications:
Data Discovery, 2D and 3D-Visualization, and Proposal and Project Planning

Existing Data Discovery:

As an environment for integrating and visualizing data from different sources, CWS could play a valuable role in proposal preparation and site survey planning for IODP and other expeditions. IODP drilling proponents must document their proposed sites with a variety of data types, seismic, swath bathymetry, magnetics, gravity, bottom photography and video, etc., before the sites are approved for drilling. These data are often collected on multiple site survey cruises, by different institutions, and may be in a variety of formats. A great benefit to the user would be a tool to assemble these disparate data into a coherent package, at a single scale and in a single projection. This would allow the data to be easily reviewed by the IODP Science Advisory Structure using a relatively lightweight tool that is widely available.

Additionally, it would be helpful if each item on the display were user selectable and could be tagged with user-supplied metadata. Selecting a seismic track in the CoreNavigator should open the seismic display for viewing the seismic section in the Corelyzer. An export function should allow these data to be output into standard image formats with associated metadata. This will allow the user to pick the most appropriate items from a data package for submission to the IODP Site Survey Data Bank. Additionally, the entire data package could be provided to the Implementing Organization of each IODP Expedition for use as the shipboard site survey package. Some of these features will require grid computation and reprojection of data. Many of these functions are available in the open source Generic Mapping Tools (http://gmt.soest.hawaii.edu), and could be utilized by CWS.

Using CWS for Post Processing Data Acquisition/Mining

Once the initial drilling and core description is complete, the CWS should continue to request data updates so that post expedition/drilling work can be incorporated and publications referenced. Samples taken to be analyzed at a later date should have a place holder that designates where in the core it was taken and also that the data will be generated after the expedition/drilling is complete. This place holder should alert the CWS to periodically search the publications database for data regarding these samples.

CWS Extensibility: The Plug-In Strategy

An important part of the CWS project is that we want it to be community friendly by allowing others to add capabilities that we could not hope to add or predict in the current scope of the project. So far, that strategy has enabled to work with CHRONOS and Andrill to meet their objectives and show the power of these plug-ins. The Janus Plug-In alone allows very easy image loading of any ODP digital core images and aligns them automatically at the correct depths.

User-Defined Plug-Ins :

Corelyer was purposely rewritten as our first priority since March, 2006 into the JAVA programming language to make it easier to add and let others add more functionality via plug-ins.

Existing or Planned Plug-Ins:

- PSICAT and ANDRILL via CHRONOS
- Janus Image Database via CHRONOS

Examples of Plug-ins for Possible Future Development by User Community

- NIH's IMAGE-J for quantitative analysis of core images
- Lorraine Lisiecki's Match software which allows dynamic auto-correlation of core data to achieve better final spliced and correlated datasets.

Broader Impacts

As a visual environment, the CWS can be very useful in making science more friendly and understandable to the public and to K-12 and college-level formal and informal education. Adoption of the CWS in formal curriculum is likely predicated on how complete a package can be offered to harried teachers at grade-appropriate levels. Such curricula may make use of a number of core "best hits" that highlight catastrophes (such as extinction events), changes in carbon cycling (and related them to tectonic, climatic, or evolutionary events), relationship between humans and climatic/environmental change, or illustrate sequence stratigraphy, marine and lacustrine isotope record and its relation to climate, past climatic variability and extreme events including Heinrich events and Younger Dryas. Museum exhibits need to grab attention and hold it so that visitors don't wander away after a minute or two while retaining key messages and allowing for deeper inquiry.

K-12 Education

Core images can be a powerful tool to explain the concept of geologic time. Specific features in the core can be used to discuss geologic events, climate change. The images may be printed out and spliced together and displayed down a staircase, and shown along other data on a projector**.**

K-12 education is now standards based so that curricula developed to utilize the visualization feature of the CWS must bear these standards in mind. Individual teachers typically have no time to develop their own lesson plans, and they may not be familiar with the concepts. Therefore any curriculum created to utilize the CWS must provide a through background information such as the purpose of a particular cruise or project (e.g., plate tectonic, climate change), key points of the lesson plan, a discourse of related and background issues (e.g., how one studies past climate changes or past plate tectonic events). Curriculum development must be done in consultation with K-12 educators and tested in classrooms and evaluated. School of Rock teachers may be ideal consultants and testers. During these tests, a set of FAQs can be compiled and made available to teachers. The pre-packaged complete curriculum and other resources might be stored on www.joilearning.org.

Informal Education

Well-executed museum displays grab public attention and can hold it for much more than the usual 2 minutes per display. For example The Big Backyard outdoor miniature golf course designed jointly by the Science Museum of Minnesota (SMM) and the National Center for Earth-surface Dynamics (NCED) is a dynamic participatory multi-faceted display that explains erosion, transport and sediment accumulation that successfully hold attention for well over 15 minutes. Visualization is an important tool for study of processes too large or at spatial scales too small or large to study without computation advantages. SMM is now designing a large traveling exhibit called Water Planet that will likely use a vertically mounted CoreWall display on a wall. It will use the core image and notable geologic events recorded in specific layers of a core as a jumping off point to provide multimedia illustration and explanation of such events as the K/T boundary, marine anoxia and extinction events, or major climate change events or past periods when the Arctic was warm.

College Education

In the college or a university setting, geology courses are offered to non-majors and majors. The non-major courses can easily use some of the K-12 materials, whereas the undergraduate majors can handle more abstract and/or personal examples and the teachers require less background material. The majors have the ability and the interest to utilize more features or the CWS than non-majors. Stratigraphy and sedimentology classes, basin analysis, and upper level Earth System Science classes are a natural for adoption of some CWS based mode of inquiry.

Promoting and Nurturing a User Community

During the current funding period, CoreWall needs to continue to strengthen working relationships with IODP, in particular their data management system. However, this visualization technology promises to have wide application in the geosciences. The wider adoption and use need to be promoted and nurtured.

Other Geoinformatics Projects

CoreWall can be viewed as part of a larger cyberinfrastructure for the geosciences, and as such, it must work with and be complimentary to these efforts. To do so, CoreWall must have a clear definition of what it is and what it wants to become. The workshop demonstrated that CoreWall is designed to utilize and adapt to tools others will or have developed - thus minimizing unnecessary duplications and competition - **don't duplicate, don't compete**. For example the plug-in approach provides for both system growth and the ability for users to select whichever tool they prefer. CoreWall needs to work to become an integral part of other database efforts (Figure 1).

Demonstration projects

The workshop also underscored the potential importance of developing demonstration projects with the other geoinformatics projects to better demonstrate its adaptability. Working with these other projects (e.g., ANDRILL via CHRONOS) via plug-ins will strengthen the development of CoreWall's development and ability to adapt to a range of specific needs and workflows of these other programs.

Standards

Standards or QA/QC, are very important in database, and CoreWall must encourage the user communities to work collaboratively with other geoinformatics facilities on these issues. For example, ANDRILL and LacCore, both confirmed users of the CWS, have decided to pursue the option of using the LIMS system that will be used by IODP-USIO.

Summary of CWS Development Challenges

The breakout group sessions allowed the workshop participants the opportunity to address a large number of potential issues that might effect both successful development and deployment of the CWS applications. Overall, there was broad support and excitement expressed for the development of better visualization, data discovery, and stratigraphic correlation tools proposed as part of the CWS project. However, it's important to note that despite this support, it was clear, as expected, there are things that CWS cannot or probably should not try to be. For example, Corelyzer does not need to be a Visual Core Description system but should be able to support multiple systems: DIS, DescInfo, JCores, and PsiCat as part of its requirements. The community was somewhat split on the idea of whether Corelyzer, in particular should be a purely visualization tool or analyis/data capture tool. The issue was raised where there are instances where images may not be available yet like whole core multi-senor logger data that may not be available (initially anyway) so Corelyzer would not be a necessary interface. That's an example where CoreCLIP could be used instead for both data display or stratigraphic correlation with output that could be exported into Corelyzer with digital split-core images later in the workflow.

There were constant reminders from the community workshop members to stay clearly focused on the CWS strengths of visualization, correlation, and data integration but, at the same time, remain flexible to allow it to work with other tools, and expandable via plug-ins so the community could participate in its future development. With those cautions in mind, we explored the challenges that need to be addressed which generally fall into following categories:

CWS Challenges

1) Technical: Database Access, formats, displaying graphical data, output, workflow database
2) Workflow: Where/How should CWS pieces be implemented
3) Data Access (Moratoriums)/Interface implementation/Ergonomic: Public or Private data access and sharing, user interfaces, physical implementation or hardware setup.
4) Paper vs plastic: Written vs Digital capture of core description/annotation information
5) Visualization vs Data Capture: Should Corelyzer be primarily visualization tool or a combination of visualization, data capture, and analysis tool.

Below, we present a brief bullet summary of comments, questions, and issues raised in the breakout sessions that the CWS group must address in collaboration with scientific drilling operators and the community. We encourage readers to go to www.corewall.org to look at online workshop presentations for more detail.

1) Technical Questions

- Do you know you are looking at the most up-to-date version of the data and remain aware of the changes (e.g. via RSS feed)
- Multiple layers of annotations Can a better job be made to show where core non-recovery occurred in a given core?

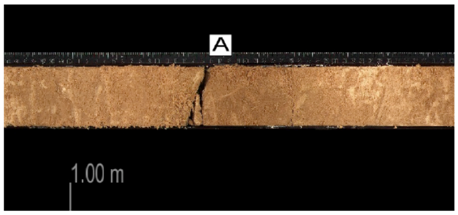
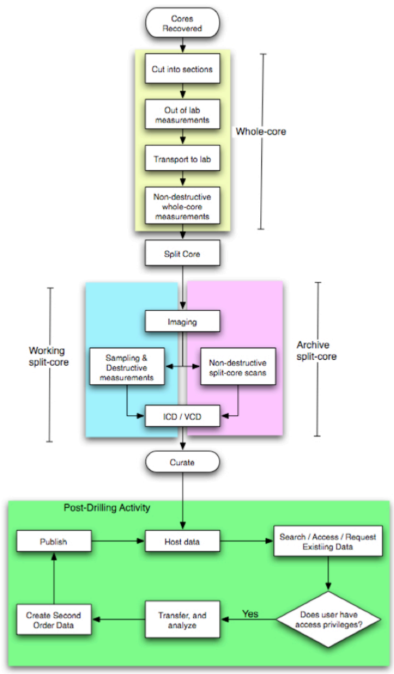


Figure 10: (Left) Example of text annotation marker use in Corelyzer that can be opened and edited by clicking on marker. (Rao, 2006)

Figure 11: (Below) Generalized Workflow diagram for all scientific coring operations that depicts possible interaction points with CWS applications

- Need access to operations database (tool depth, penetration rate, torque on bit) -recorded based on time.
- Need to translate this to depth to map it to the core CoreWall should display this as a bar graph.
- Logging-while-coring data in real time.
- CoreWall needs to know where you are in some frame of reference (coordinate grid) see multiple depth scales simultaneously (MBSFMCD) one main scale, others potentially discontinuous.
- Which depth scale? Plot all and be able to normalize to any one of them in real time.
- Each item entered has either interval or position, and is stored independently. Can be tagged with metadata



2) Working Environment / Work-Flow Questions

- CoreWall could be the portal for entering the description to the respective IO database?
- May be some synergies with J-CORES open-source java version for data entry Tablet PC, drawing/annotating, pull down lists, etc.
- Have Tablet PC located on CoreWall image put descriptions in at relevant areas.
- Scan working half core after sampling -see where samples were taken.
- For paper drawings, descriptions, CoreWall needs to be able to display files scanned into different IO databases at the correct locations.
- CoreWall needs to be able to display data entered into IO databases.

3) Data Access (Moratoriums)/ Interface Implementation /Ergonomic

- What is the expected interaction paradigm for visual observations of VCD (eg. Textures, structures, abundances, etc.)?

- Three types of annotation

a.) Simple freeform notes
b) Components tied through dictionary to classification
c.) Drawing tool (points, lines, polygons)

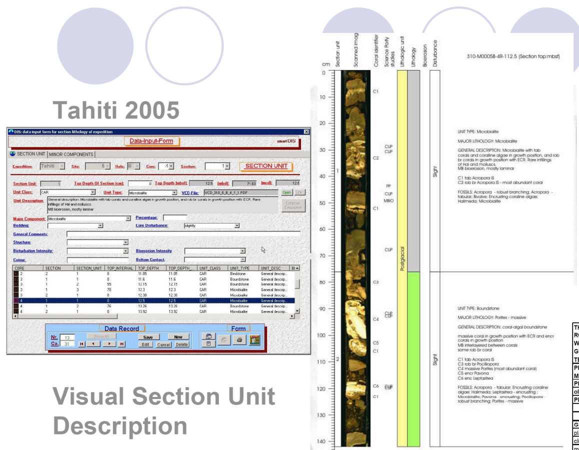
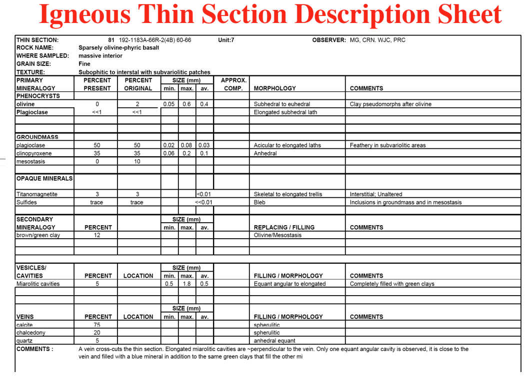


Figure 12: Different methods of VCD descriptions. DIS system on left and, below, Excel template for Thin Section description for ODP



Igneous Thin Section Description Sheet

THIN SECTION: 81 192-1183A-66R-2(4B) 60-66 Unit:7 OBSERVER: MG, CRN. WJC, PRC
ROCK NAME: Sparsely olivine-phyric basalt
WHERE SAMPLED: massive interior
GRAIN SIZE: Fine
TEXTURE: Subophitic to interstal with subvariolitic patches

PRIMARY MINERALOGY	PERCENT PRESENT	PERCENT ORIGINAL	SIZE (mm) min.	max.	av.	APPROX. COMP.	MORPHOLOGY	COMMENTS
PHENOCRYSTS								
olivine	0	2	0.05	0.6	0.4		Subhedral to euhedral	Clay pseudomorphs after olivine
Plagioclase	<<1	<<1					Elongated subhedral lath	
GROUNDMASS								
plagioclase	50	50	0.02	0.08	0.03		Acicular to elongated laths	Feathery in subvariolitic areas
clinopyroxene	35	35	0.06	0.2	0.1		Anhedral	
mesostasis	0	10						
OPAQUE MINERALS								
Titanomagnetite	3	3			<0.01		Skeletal to elongated trellis	Interstitial; Unaltered
Sulfides	trace	trace			<<0.01		Bleb	Inclusions in groundmass and in mesostasis
SECONDARY MINERALOGY	PERCENT		SIZE (mm) min.	max.	av.		REPLACING / FILLING	COMMENTS
brown/green clay	12						Olivine/Mesostasis	
VESICLES/ CAVITIES	PERCENT	LOCATION	SIZE (mm) min.	max.	av.		FILLING / MORPHOLOGY	COMMENTS
Miarolitic cavities	5		0.5	1.8	0.5		Equant angular to elongated	Completely filled with green clays
VEINS	PERCENT	LOCATION	SIZE (mm) min.	max.	av.		FILLING / MORPHOLOGY	COMMENTS
calcite	75						spherulitic	
chalcedony	20						spherulitic	
quartz	5						anhedral equant	

COMMENTS : A vein cross-cuts the thin section. Elongated miarolitic cavities are ~perpendicular to the vein. Only one equant angular cavity is observed, it is close to the vein and filled with a blue mineral in addition to the same green clays that fill the other mi

- Use spreadsheet for data capture?
- Use large displays for data retrieval?
- Use Psicat diagram next to the core
- Excel spreadsheet alone may not be sufficient for sedimentologists.
- How to describe multiple cores simultaneously?

- Should data be made available publicly? Moratorium issues need to be structured into database access via passwords.
- Is this data "public" or private
- Other methods of data capture: Touchscreens/Voice recognition
- User friendliness is the key to the interface so its intuitive and learning curve is short.

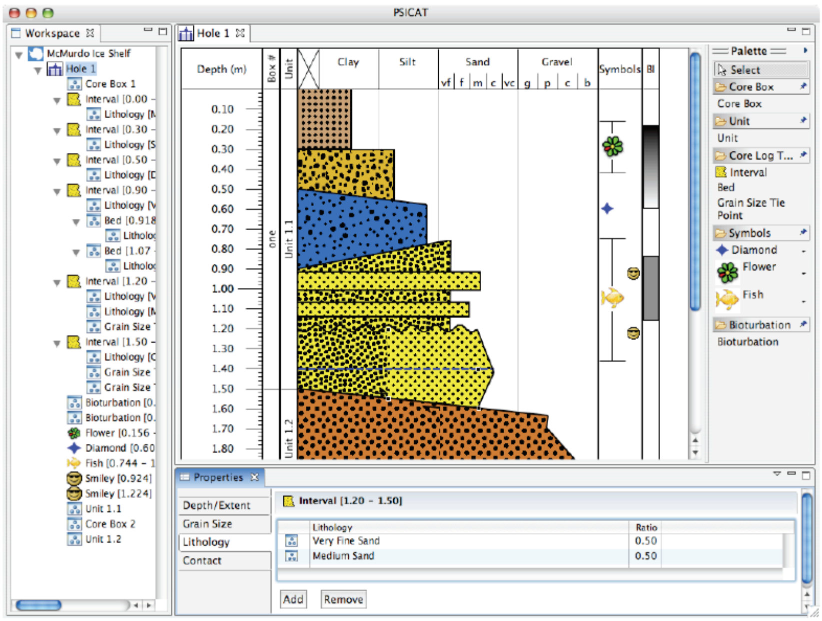


Figure 13: A complex diagram made with PSICAT (courtesy of CHRONOS) . PSICAT is an application used for Visual Core Description (VCD) and creation of summary barrel sheet. This system will be deployed by Andrill in Fall 2006. (Adapted from Rao, 2006)

4) Paper vs. Plastic:

- J-CORES: When using digital versions of data a lot of prior context may be lost. Currently capture of data occurs on paper first and then re-entry using tablet PC. Paper barrel sheet becomes a "verification" of conflicts in digital records. Is the capture of observational notes important? There is much that gets captured on paper that is potentially lost when entered into software systems. Also the desire for a hardcopy version as a backup if for e.g. laptops in the lake.
- Can CoreWall facilitate paperless core description?
- Does the computer slow you down?
- People entering data on paper and then transferring it to the computer = duplication of effort?
- If paperless, core description via CoreWall needs to be easy -point-and-click capability, pull-down-menus.
- If paper used, it needs to capture details that enhance (not duplicate) core description (e.g., sketching of features/structures, etc.). These notes need to be scanned in and attached to CoreWall as PDF/text/audio/video annotations.
- Would need graphical libraries and extensive dictionaries.
- CoreWall needs to support/enhance DESCINFO, J-Cores,DIS systems not replace them etc.
- Chris went thru scanned handwritten notes for Leg 199 and says they were illegible and essentially as good as useless/lost.

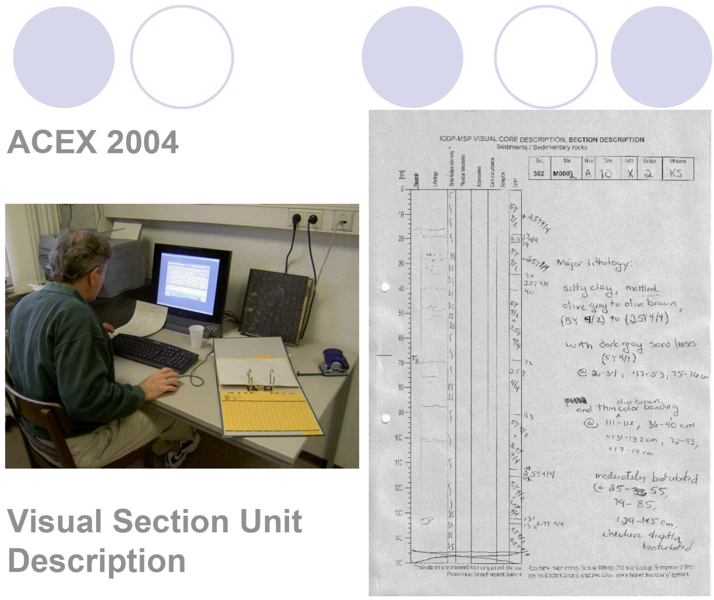


Figure 14: Current mode of operation for ESO-ICDP using DIS database system. Notes are collected first on written notes as hardcopy, then transferred into database. (Courtesy of Hans-Joachim Wallrabe-Adams, Ronald Conze, Colin Graham)

5) Visualization, Data Capture, and Analysis

- Belief is that no single tool will do everything
- Tools for edge detection would be very useful for both sediments (burrowing), hard rock (vesicles & phenocrysts) and lake/ice core/tree ring (layer counting?)
- Need to develop a user community for continued input (listserv/wiki, version tracker)
- Tool to view cores data in 3D:–Basic (rolled or unrolled) –Enhanced (volumes)
- Output is user defined and variable format, and printing should be WYSIWYG
- Data Visualization Issues with CoreWall: Visualization vs Capture ??? Depth of Information ?? Links to other Information??
- Sedimentology
- Clast Count Curve
- XRCT images (fabric studies)
- Facies Codes
- Downhole Geophysics log data
- Borehole televiewer or Formation MicroScanner Images
- Want cylindrical view of log/core images –
- Petrology
- XRF scanner - Intensities/ Ratios/Calibrated Data
- Spot sample XRF data
- Thin section/Smear Slide images
- Paleontology?

- Access to microfossil images
- Access to key taxonomy of images
- Microbiology Images ? Microscope images useful??

Initial CWS Project Requirements and TimeLine

Items Needed to support Minimal CoreWall Features for Fall 2006

- Display High Resolution Imagery, registered to a 2D Display High Resolution Imagery, registered to a 2D coordinate system, relative to the top of the core.

- Support anchored annotation within the above that:
  a.) Shows text, and HTML
  b.) Supports hyperlinks
  c.) Supports the use of a locally defined dictionaries
  d.) Can be saved, exported, and imported

- Pull Data from External Sources, e.g. Databases and/or URL's

- Resolve the Image with a Universal Sample ID that is inherited by the annotations

- Provide methods of exporting output for printing/publication. Output formats to be determined by users. Both the file formats and the type of data printed need to be refined by further discussions with user community.

- Annotated graphs, e.g. well logs. (CoreClip)

- PSICAT integration for Andrill deployment in September, 2006.

Examples of items scheduled for later delivery in response to User Prioritization

- Methods of resolving the anchors as depth data.
- VCD using an externally developed specification Sample Plugins Sample Plugins
- CoreClip as a Plugin
- Anchor to depth conversion
- Backstripping
- Expert content Analysis: image tools, automated feature picking, hyper-picking, hyper-spatial fitting, etc.

Workshop Participant List and Breakout Groups

Groups for Breakout Sessions 2 and 3 (**bold = moderator**, *italics = recorder)*

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Jose Tirado	sith_or_jedi@hotmail.com	Howard U

References:

Rao, A.G.G.*CoreWall: A Methodology for Collaborative Visualization of Geological Cores*, MS Thesis, University of Illinois at Chicago, 2006.

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Appendices

A. Workshop Packet : PDF Document describing workshop to participants

Attached as separate document.

B. List of Presentations and Posters:

All Presentations are available for download at www.corewall.org website.

Emi Ito
Workshop Agenda

Sean Higgins
Introduction: SPLICER and SAGAN

Paul Morin
The CoreWall Suite

Richard Levy
ANtarctic DRILLing and the CoreWall Suite

Anders Noren
CoreWall at LacCore

Clive Neal
What is the Workflow for Hard Rock Visual Core Description and How Will it Benefit from CoreWall
Bernard Miville

SEDIS Phase 1

Shin-ichi Kuramoto
An Introduction of J-CORES

Hans-Joachim Wallrabe-Adams, Ronald Conze, Colin Graham
Visual Core Description and Information Structure

Paul Foster, David Fackler, Peter Blum, David Houpt
Analytical Information Management for the IODP Riserless Drilling Vessel

Peter Blum, Zenon Mateo, Paul Foster
DESCINFO: A Descriptive and Interpretative Information System for the IODP Riserless Drilling Vessel

IODP
IODP Related Acronyms

Kerstin Lehnert
PetDB, SedDB, EarthChem & SESAR - Resources for CoreWall: Geochemical Data & Unique Sample Identifiers

Joshua Reed, Cinzia Cervato, Chris Fielding, Douglas Fils
CHRONOS's Paleontological-Stratigraphic Interval Construction and Analysis Tool (PSICAT)

Bill Ryan
Advancing CoreWall : Lessons learned from my own visualization experiences

Walt Snyder
PaleoStrat : Digital Information System for Deep-time Earth Processes

Workflow Issues Group A presented by Joe Ortiz
Day 2 - Group A Breakout Session Summary

Workflow Issues Group B presented by Sean Higgins
Day 2 - Group B Breakout Session Summary

Workflow Issues Group C presented by Clive Neal
Day 2 - Group C Breakout Session Summary

Broader Impacts Breakout presented by Paul Morin
Day 2 - CoreWall Broader Impacts

Tools and Web Services Breakout presented by Bill Kamp
Day 2 - CoreWall Technical Requirements

Workshop IODP Group Breakout presented by Bernard Miville
Day 3 - IODP Use Scenario Breakout Session
Workshop Lakes & UNOLS Group Breakout presented by Joe Ortiz

Day 3 - Lake/UNOLS Breakout Session

ANDRILL & ICDP Group Breakout presented by Emi Ito
Day 3 - ANDRILL and ICDP Use Scenario

Outreach Group Breakout presented by Paul Morin
Day 3 - Outreach Breakout Session