

**Title: Interactive GEOWALL visualization modules for Introductory Geology**

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## Introduction

Earth Science education requires that students understand complex spatial and temporal relationships. These concepts are traditionally introduced using 2D representations (maps and figures). The students frequently have difficulty conceptualizing 3D (space) and 4D (space + time) problems. For example, topographic maps represent topography using contour lines and geologic maps use colors and lines to represent rock types and geologic structures. Even though the shape of the Earth's surface is familiar to everyone, students have great difficulty visualizing a 3D land surface from contour lines on paper, and even greater difficulty understanding the relation between the geology and the topography or "lay of the land." Commonly one or two laboratory periods are spent on interpreting topographic maps and another one or two on geologic maps so that the lab can go forward with other concepts. Conceptualization of other more important concepts such as Plate Tectonics is even more difficult for students because they do not have a conceptual framework as they do for topography. Plate Tectonics is the grand unified theory of the Earth Sciences upon which all other processes of the physical earth are based. Tectonic plate boundaries are defined by the location of earthquake epicenters. The location of these earthquake epicenters defines the 3-dimensional geometry of plate margins, the relative movement of adjacent plates, and complex movement along faults. These concepts, which are the foundation of earth science education, are typically presented with maps and figures, largely ignoring the spatial relationships (3D) and the evolution of the Earth's surface over time (4D).

The GEOWALL is a new technology that makes it possible to develop teaching tools that instructors can use to teach concepts that involve 3D and 4D models. Basically the GEOWALL is a stereo projection system for a classroom that is composed of a desktop computer connected to a pair of polarized computer projectors. The stereo image can be viewed from anywhere in the classroom by wearing an inexpensive pair of polarized glasses. The principle is the same as a child's "viewmaster" or a stereopticon. Originally developed under the UNIX operating system, the GEOWALL is now available for both the Windows and Macintosh environments making it possible to hand over its operation to a TA or the students themselves. This development means that not only can an instructor use it as a passive teaching tool; s/he can turn it over to the students who can actively interact with the information presented, a strategy which has been demonstrated to increase student comprehension.

UMD is a member of a consortium of 11 institutes from around country that is working on developing technology and teaching modules to use in the GEOWALL. Primarily composed of geoscience institutes, the consortium now includes users from different areas who see the potential of the system as a teaching and research tool. The UMD Department of Geological Sciences purchased a GEOWALL in 2002 but as yet has not actively participated in the development of new modules for the consortium or integrated it into its courses.

## Goals

The long-term objective of the Department of Geological Sciences is to use the GEOWALL in many of its courses. The goal of this project is to conduct a pilot study to develop GEOWALL modules for the Introductory Geology course (GEOL 1110). This course traditionally has a large enrollment (500+ in 2003) most of whom are non-science majors. If successful, the tools and techniques developed for this introductory course will be transferred and adapted for other courses offered by the department, including courses at the graduate level.

Although the GEOWALL will be used in a passive way by the instructor in lectures to illustrate concepts to the class, most of the modules developed in this project will be primarily used in the GEOL1110 laboratory with active participation by students (students meet for one two-hour session each week). As much as possible, the modules will be drawn from local examples. The modules will be:

- based upon tools developed by the GEOWALL consortium;
- constructed from the IRIS Explorer Toolkit. Using this toolkit reduces the need to develop software from scratch and will reduce the time taken to bring a module on-line. The tools available in the toolkit will be supplemented with UMD-specific components that will be developed using a lower level programming language;
- Web-linked. The modules will allow students to download and use data available from sources on the web. This will help to keep the material "current" and interesting to the students.

## Phase 1

During Phase 1 of the project, GEOWALL modules will be created for a revised Introductory Geology course. The new modules will be used both in the lecture and associated labs. The modules will emphasize active, collaborative and inquiry based use of the resource by students.

One of the key benefits derived from using the GEOWALL in the department's teaching is the ability to take Virtual Field Trips (VFT). The VFT format makes it possible to visualize a variety of different geological data in the virtual world. For example, students could take a VFT to the San Andreas Fault and selectively look at seismic data, the distribution of earthquakes, surface deformation etc. This information sheds new light on the processes occurring at the site, observations the students clearly would not be able to do in a traditional field-trip.

The following table outlines a restructured outline for the Introductory Geology lectures and labs. The table summarizes how the students would use the GEOWALL and how they would benefit from its availability.

Week	Topic	Description of GEOWALL visualizations – each lab will have a set of questions pertaining to the visualizations. Answers will vary from simple calculation to paragraph-length discussions.
1	Introduction to Earth's dynamic systems	Introduction to the solid earth, oceans, and atmosphere. Introduction to the GEOWALL using a variety of 3D animations. Students first exposure to operating the GEOWALL. Including walk/fly-throughs, introduction to digital elevation models and other 3D spatial data sets and 4D types of simulations.
2	Earthquakes and Earth's Interior	Earthquake generation along faults (3D stereo views of motion on faults), propagation of seismic waves, recording and interpretation of seismic waves, epicenter locations and earthquake distribution, 3D geometry of Earth's interior (layering topography of boundaries)
	Plate Tectonics	Interactive map of the globe to be operated by students and viewed in stereo. Location and geometry of mid-ocean ridges and subduction zones, relationship to volcanoes and earthquake epicenters (3D exploration of plate boundaries). Time-lapse images of plate motion.
3	The Earth's surface: topography and geology I	Introduce "flat" maps in paper and on GEOWALL, use Digital Elevation Models (DEMs) to illustrate topography in 3D, superimpose map on DEM and generate 3D landscape with map features, compare 3D with flat map. Use Minnesota examples of Duluth, Twin Cities, SE Minnesota, and Glacial Lakes State Park.
4	The Earth's surface: topography and geology II	Introduce geologic maps on paper and on GEOWALL, overlay geologic map onto DEMs. In 3D evaluate topography in relation to rock type and structure. Use Minnesota examples of Duluth, Twin Cities, SE Minnesota, and Glacial Lakes State Park.
5	Igneous processes, rocks, and minerals	Exercise: geology of NE Minnesota – Duluth complex/North Shore Volcanics. Use DEMs and geologic maps to study the geometry of intrusive/extrusive complexes. Students will manipulate the DEM, overlay the geology, compare topography with rock type and structure.
6	Metamorphic processes, rocks, and minerals	Exercise: geology of east-central Minnesota – the Penokean Orogeny. Use DEMs and geologic maps to study the geometry of fold and thrust complex associated with the Proterozoic Penokean Orogeny. Students will manipulate the DEM, overlay the geology, compare topography with rock type and structure.
7	Sedimentary processes, rocks, and minerals	Exercise: geology of southeastern Minnesota – the Paleozoic. Use DEMs and geologic maps to study the geometry of the Paleozoic marine sedimentary rocks of SE MN. Students will manipulate the DEM, overlay the geology, compare topography with rock type and structure.
8	Rock deformation and structure	Introduction to deformation of rocks – folding and faulting. 3D simulations of stress, strain, faulting, and folding.
9	Drainage basins and hydrology I	Drainage patterns and relation to geology – introduction to stream networks, drainage patterns, stream order. 3D simulation of stream network evolution using computer program of Mooers and Shaw. Exercise: Root River (karst), Nemadji River (deeply incised glacial lake plain), Pelican River (Glacial landscape). Use DEMs to generate 3D fly-overs
10	Drainage basins and hydrology II	Relation of topography and geology to stream flow hydrographs. Fundamentals of stream hydrology – precipitation, infiltration, runoff, and stream flow hydrographs. Continue developing the Nemadji, Root, and Pelican river simulations with emphasis on characteristics of stream runoff.
11	Glacial processes and landforms I	History of the Ice Age and the mechanics of glaciers with emphasis on glacial landscape evolution. 4D simulations of ice sheet growth and decay through time. Examine the anatomy of glaciers and ice sheets with DEMs and images of Greenland and Antarctica. Introduce the Minnesota landscape.
12	Glacial processes and landforms II	Focus on topography and geology of three glaciated areas of Minnesota. Itasca moraine, Wadena drumlin field, Glacial Lake Agassiz.
13	The virtual field trip: Leif Erickson Park	Use DEM and geologic map with links to stereo photography of the site. Conduct fly-by and walk-through of site with emphasis on features that will be easily recognized on the field trip.
14	Earth history and geologic time 1	Introduction to the vast expanse of geologic time. 4D visualizations of earth formation and early history, the Precambrian geology. Examples from northern Minnesota: the Superior Province of the Canadian Shield and the mid-continent rift.
15	Earth history and geologic time 1	Paleozoic and Mesozoic: 4D visualizations of major events of the Paleozoic and Mesozoic including the meteor impact and associated catastrophic events at the end of the Cretaceous.

## Phase 2

Responsibility for teaching GEOL 1110 is shared by several members of the Geology faculty (PI Mooers is currently teaching GEOL 1110 this semester). In Phase 2, the mentoring phase, two other members of the faculty (Drs. John Goodge and Vicki Hansen) who teach this class will be mentored in the use and development of GEOWALL modules. It is expected that other members of the Geology faculty will wish to take advantage of the GEOWALL in their teaching. The PIs and project programmer will assist in the technology transfer and module development.

## Expected Outcomes and Project Evaluation

The expected result of this pilot project will be that students taking Introductory Geology will develop a better understanding of the 3 and 4D concepts presented to them. This will be reflected in higher test scores. The success of this study will be evaluated by tracking the scores of test groups, comparing their performance in classroom tests against control groups that follow more traditional passive

instruction. The lab sections of the course will be sub-divided into three groups; one third that do not use the GEOWALL; a third that use the GEOWALL, but it is operated by the TA; one third that uses the GEOWALL and operated by the students. The value of the GEOWALL will be assessed by monitoring the group's performance on standardized classroom tests. At the end of each semester, the results of the classroom tests will be evaluated and used to refine the modules and shape the design of new ones. The number of modules used over the course of the semester will increase with each new round of tests. At the end of the project the results of the testing will be evaluated and a decision will be made regarding the future use of the GEOWALL in GEOL 1110 and its possible adoption by other courses taught by the department.

### **Relation to College's Strategic Initiatives for Integrating Technology in Undergraduate Education.**

The project addresses the college's declared intent to develop and integrate state-of-the-art educational technology throughout the curriculum as a means of providing its' students with a world class education (CSE TECHNOLOGY STATEMENT, 2002).

### **Timeline**

GEOL 1100 is taught both Fall and Spring semesters. The first release of GEOWALL modules for the course will be available in time for Fall 2003. Over the lifetime of the project, we plan to test the benefit of using the GEOWALL with three sets of GEOL 1110 students, Fall 2003, Spring 2004, and Fall 2004. Beginning in Spring 2004, Phase 2 technology transfer will begin. Over the course of the year, as the faculty become familiar with the GEOWALL, new modules will be developed. These modules will be developed collaboratively by the PIs, faculty mentees and the project's programmer. As faculty gain experience in the use of the GEOWALL, it is expected that they will want to develop GEOWALL modules for their other classes.

#### **Phase 1 Development**

03/03 – 02/05	Module development for GEOL 1110. Initial suite of modules to be ready for Fall 2003.
08/03 – 12/03	Module implementation and testing in GEOL 1110 (Fall 2003).
12/03 - 02/04	Evaluation of GEOL 1110 testing, revision of modules.
01/04 – 05/04	Spring 2004 GEOL 1110 testing.
06/04 – 08/04	Evaluation of GEOL 1110 testing, revision of modules.
09/04 – 12/04	Fall 2004 GEOL 1110 testing.
01/05 – 02/05	Analysis of GEOL 1110 tests.

#### **Phase 2 Mentoring/Technology transfer**

03/03 - 12/03	Mentee recruitment
01/04 – 08/03	Module development for mentee's course(s).
08/04 – 12/04	GEOWALL implementation in mentee's course(s)

### **Budget**

		<b>TEL</b>	<b>Department/College</b>
Year 1	Programming Support(\$15/hour x 600 hrs)	\$4500	\$4500
	Hardware (upgrades/maintenance)	\$500	\$500
Year 2	Programming Support(\$15/hour x 600 hrs)	\$4500	\$4500
	Hardware (upgrades/maintenance)	\$500	\$500
Total:		\$10000	\$10000

### **Budget Justification**

The primary need for this project is programming support for the PIs. A student programmer will be hired to assist the PIs in implementing the modules. The primary responsibilities of this individual will be to maintain the GEOWALL, assist in the construction of modules using Iris Explorer and to write UMD specific components to integrate with those available from Iris Explorer.

Funding is also sought to cover the cost of maintaining and upgrading the GEOWALL. Some of these funds will be spent in Year 1 to upgrade the system's video board to a GeForce 4 board. This will reduce the computation times required to refresh the display and permit more realistic, smoother real-time animation in virtual images.