The World Wide Web as a Resource for Earth Science Educaion

Glenn A. Richard
Center for High Pressure Research
Department of Earth and Space Sciences
State University of New York at Stony Brook
Stony Brook, New York 11794
richard@sbmp04.ess.sunysb.edu
World Wide Web site for this article: **www.chipr.sunysb.edu/journey/wwweduc/**

Introduction

The World Wide Web (the Web) is an effective and flexible means of delivering information to students enrolled in Earth Science courses and other educational programs, both on a secondary school and college level. While it is not normally a good substitute for a textbook, some advantages that the Web has over printed material are that: 1) It is easy to develop, post, and update customized course material on the Web; 2) With the click of a mouse, hyperlinks can lead the reader from brief references to particular subjects to other documents that provide more detailed information on that subject. Often, this more detailed material has been created by other authors; and 3) Java, Javascript, and other technologies are being used to develop interactive material on the Web that enables students to enter quantitative data in order to manipulate visual models of natural phenomena and scientific equipment. In order to use the Web effectively as an educational tool, authors and consumers must understand the technical and cultural factors that influence its development and use.

The popularity of the World Wide Web as a medium of information exchange has increased tremendously during the past several years. As can be expected with a frontier technology that has not yet established a well-bounded role within our culture, the Web brings with itself certain assets and liabilities that are difficult to assess in a traditional manner. The diversity of subject matter on the Web rivals that of the world of print. Similarly, the range of the quality of this information parallels that of the total collection of printed and broadcast material.

Several factors have contributed to the rapid increase in the volume and variety of information on the Web. Most prominent are the following:

1. The proportion of our population that is comfortable with the use of computers has been increasing steadily for the past several decades.
2. The speed, bandwidth, and number of communications lines have grown rapidly over the past several years, although the pace has lagged behind demand.
3. It is relatively inexpensive to create documents in electronic form compared to the costs associated with publishing printed material.
4. The Web supports document formats that go beyond printed matter in their ability to be interactive and hyperlinked.

5. With a minimum of effort, the author of text or graphical material, or anyone else who views it, can copy and paste it from one document into another, either in its original or modified form.

Utilizing Existing Web Sites: The Quality Control Issue

The ease of creating material for the Web allows authors to surmount hurdles that, in the printed and broadcast world, have served as filters that are reasonably effective in enforcing various forms of quality control. This is not meant to imply that these filters have prevented low-quality information from reaching mass audiences. Rather, they have subjected informational content and presentation to two strenuous types of litmus tests: 1) academic review; and/or 2) profitability in the marketplace. Most people have developed an intuitive sense of how to distinguish printed or broadcast material that has survived academic review from that which has succeeded because it enjoys appeal in the mass market. However, the effortlessness of posting material on the Web easily short-circuits these hurdles. This requires academic users of the Web to exercise a more sophisticated approach toward separating the quality material from that which is best discarded than is sufficient in a library of printed matter. The hastily-composed material is generally fairly easy to identify. One of the most difficult tasks in making a judgment on quality is to recognize documents that are an amalgam of truthful material and well-crafted fiction, masquerading as fact.

Course instructors who wish to have their students make use of the Web can take steps to assist them in finding reliable information. However, there is no simple, easily-applied formula for assessing the quality of the material obtained from an unknown source. To ensure quality, one could restrict one's use of material to that obtained from established sources of high-quality information, however, in the creative and chaotic culture of the Web, new sources of good material come into existence many times every day, and it is certainly advantageous to be able to use this information.

One effective strategy for making the Web available as a source of information to participants in educational programs and courses is to develop Web sites specifically tailored to each program. The instructor of the course or program can develop these documents directly, or may enlist the service of teaching assistants or other individuals. In either instance, the instructor should exercise strict editorial control over the content and format of the site.

The most effective course sites include a combination of original material and links to other sites of known high quality. When this strategy is used, students can trust the material on the official course site as well as the sites that are directly linked. However, these linked sites can, in turn, link to others, and it is impractical for the instructor of the course to maintain control over every site that can be reached indirectly from the home site. A good practice is for students to be told that they can trust the course site, directly linked sites, and other known sites of high quality. Beyond that, they must either rely on their own ability to assess the quality of the information they find, or have the course instructor examine the material before they use it.

World Wide Web Projects in Earth Science Education at Stony Brook

The Center for High Pressure Research (CHiPR), which is a National Science Foundation Science and Technology Center with headquarters at SUNY Stony Brook, conducts a multifaceted educational program to provide students with opportunities to experience science as a process of discovery, and to facilitate the development of their ability to think analytically. The component educational projects are conducted either entirely by CHiPR staff, or in collaboration with other educational entities. Several of these programs utilize the Web as an educational tool, including: 1) Project Web Page; 2) Long Island's Natural Environment Online; 3) Let's Make Diamonds!; and 4) Project Java. After a brief discussion of the other projects, this article will focus on Project Java.

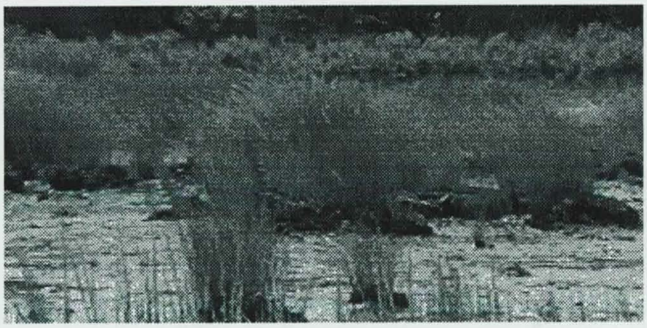
Project Web Page

This project, instituted by the Department of Instructional Services on the SUNY at Stony Brook Campus, provides small grants to students who have been selected by instructors to develop supporting Web sites for their courses. Each course instructor who wished to make use of this program during the spring of 1997 was required to submit a proposal to Instructional Services prior to the beginning of the semester. The Center for High Pressure Research provided additional funds in order to increase the number of courses within the Department of Earth and Space Sciences that were to develop Web sites. In total, funds from these two sources are supporting the development of sites for four undergraduate geology courses this semester. One of these courses is GEO 201: Environmental Geology of Long Island and Metropolitan New York (pbisotopes.ess.sunysb.edu/geo201/).

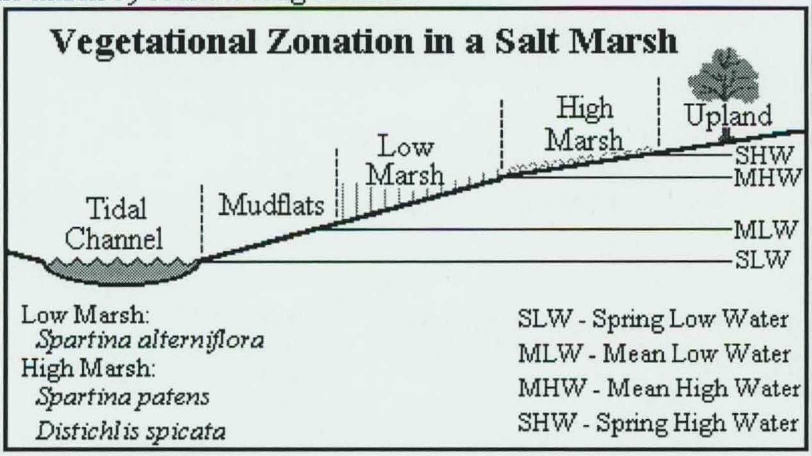
In addition to the Project Web Site student, several other individuals are contributing to the development of the GEO 201 site. The site includes a course description, syllabus, lecture notes, a list of field trips, and links to other reliable sources of material on geology. Future plans include the posting of guides to the optional field trips for the course. The class notes are being assembled into HTML documents primarily by Janet Niebling, Educational Specialist for the Center for High Pressure Research. Glenn Richard, who delivered a guest lecture on wetlands, assembled an illustrated set of class notes to cover that subject. The illustrations consist of diagrams created with software, and video still-frames that were recorded with a video camera, then converted to images, using a Snappy video capture board manufactured by Play, Incorporated. Other illustrations for the site have been scanned and subsequently cleaned up, using the standard paint program that is packaged with Microsoft Windows 95 and NT 4.0.

Long Island's Natural Environment Online (LINE Online)

LINE Online (www.chipr.sunysb.edu/longis/) is an integrated collection of illustrated documents and links that present an overview of Long Island's geological and ecological environment. Its target audiences are secondary school science classes and members of the general public who are interested in learning about Long Island's geologic history, groundwater system, shoreline, and biological environment. Figure 1 represents a portion of a document that discusses the Flax Pond salt marsh, and figure 2 contains a diagram from a page that focuses on hydrogeology.



The vegetation in a Long Island salt marsh occurs in zones that are determined by the tides. The lowest parts of the salt marsh are always covered by water and are called tidal channels. These are bordered by mudflats which are mostly devoid of rooted vegetation and are exposed to air only during the lowest tides. Masses of rockweed and other algae often grow here. The otherwise barren mudflats are interrupted by clumps of Spartina alterniflora and ribbed mussels called tussocks. These tussocks may have originated as pieces of the low marsh that were carried out onto the mudflats as ice was rafted about by the tides. Like storms, episodic occurrences of thick ice may significantly alter the surface of the marsh by redistributing sediment.



Adjacent to the mudflats, and higher in elevation is the zone where Salt Marsh Cordgrass grows. This is called the low marsh and its upper limit, as far as elevation is concerned, corresponds to the average height of the high tide (mean high water). Where the low marsh meets the mudflats is where the tallest *Spartina alterniflora* grows. If you look closely at the grasses in a salt marsh you may see the salt marsh

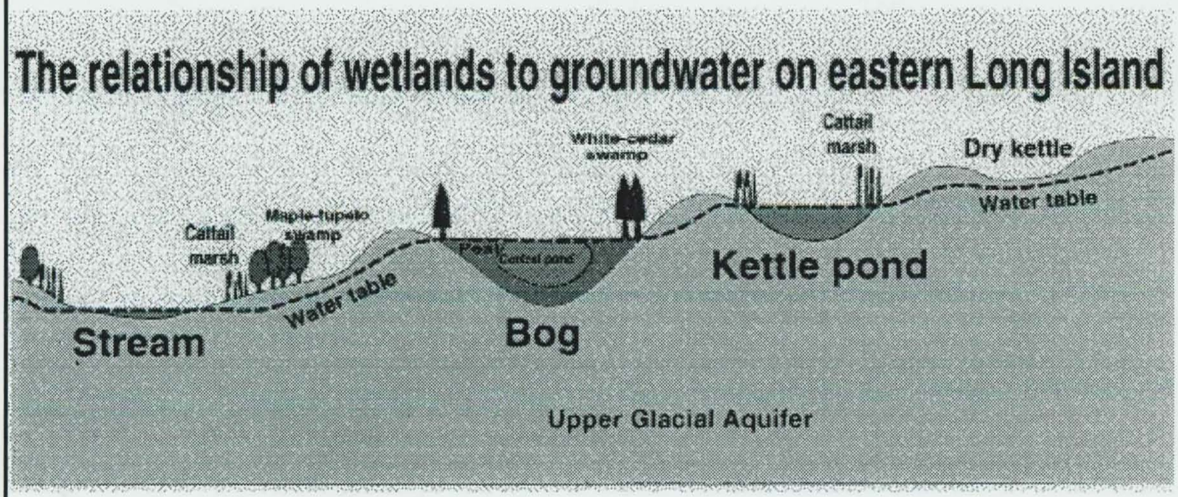
Figure 1. A portion of the Flax Pond Web page of LINE Online

Let's Make Diamonds!

The core of this CHiPR educational program is an experiment in which participants use high pressure and temperature to convert ordinary graphite into diamond. *The High Pressure Laboratory* and *Bragg's Law and Diffraction* applets, discussed below as components of Project Java, are used as exercises that provide students with background understanding for this program.

The enrollees are expected to write and illustrate a report that describes the goals, methods, and results of their experiment. Participants provided to CHiPR through the Women in Science and Engineering program (Project WISE) on the SUNY Stony Brook campus are asked to design their reports for posting on the World Wide Web (www.chipr.sunysb.edu/wise/). Figure 3 is a portion of the report created by a group of undergraduate Project WISE students in March, 1997. The Let's Make Diamonds! program provides students with first-hand participation in the process of science and enhances their ability to use Web technology as a medium for information-gathering and communication.

Groundwater may exit the aquifer system through subsurface flow into surrounding bodies of salt water, through entering streams that carry to water to the shore, or through uptake and transpiration by plants. Water also may evaporate from ponds. In addition, humans extract water from the ground through supply wells.



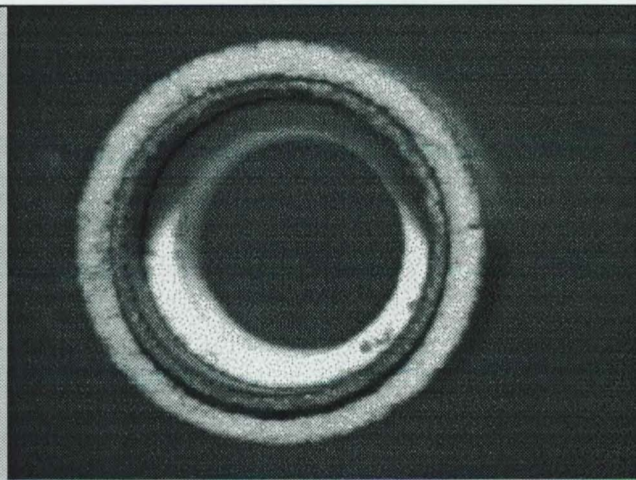
Most ponds, streams and wetlands on Long Island are actually surface expression of the groundwater. The surfaces of these bodies of water are the exposed water table.

Figure 2. An illustration from the hydrogeology section of LINE Online

Project Java

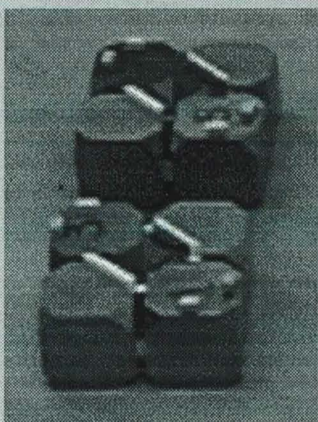
One area of potential on the Web that is in need of further attention is the delivery of educational material that is genuinely interactive. Project Java (www.chipr.sunysb.edu/ProjectJava/) is a collaboration between CHiPR and the Long Island Consortium for Interconnected Learning (LICIL) that is designed to help address this need. This endeavor is supervised by CHiPR Educational Coordinator, Glenn Richard and Educational Specialist, Janet Niebling, and utilizes the talents of undergraduate computer science majors who are developing interactive educational material, using the Java programming language. The three original Project Java students are Konstantin Lukin, Yevgeniy, Miretskiy, and Mikhail Sabaev. Faculty of the Department of Earth and Space Sciences provide ideas for programs, and advice regarding their user interfaces. This project has a dual educational role in that it creates new educational tools, and provides the student programmers with practical experience in their trade of choice.

The Java language is architecture neutral (platform independent) and object oriented. Programs written in an architecture neutral language run nearly identically on a Java, Macintosh, UNIX, or Wintel platform. Object oriented languages focus on the building and utilization of objects, which are reusable program parts that contain data and methods for manipulating that data, as well as other objects. Java programs that are accessed via the World Wide Web are known as and temperature graphite is more stable than diamond. Although diamonds can exist under room conditions, the carbon-to-carbon bonds break over very long periods of time. It may take millions of years for natural diamonds to form, but with technological advances this process can be achieved in the laboratory within a matter of a few hours.



Methods and Materials

To replicate the mantle environment where diamonds can form, we needed the following materials: graphite, a catalyst, 8 tungsten carbide cubes, pyrophyllite gaskets, wooden spacers, an MgO octahedron containing a furnace, teflon gaskets, laminated plastic, and copper electrodes.



A good pressure medium for creating diamonds is an MgO octahedron. Since an octahedron is in the isometric crystal system, it is very symmetrical. This is beneficial, since it allows for a hydrostatic pressure, meaning equal pressure is applied from each direction. The tungsten blocks are cut at each corner and when gathered together to form a cube, an octahedron-shaped void is left in the center of the cube. This octahedral space in the center of the tungsten blocks is where the MgO octahedron resides during the experiment. Within a hole drilled inside the octahedron is the furnace.

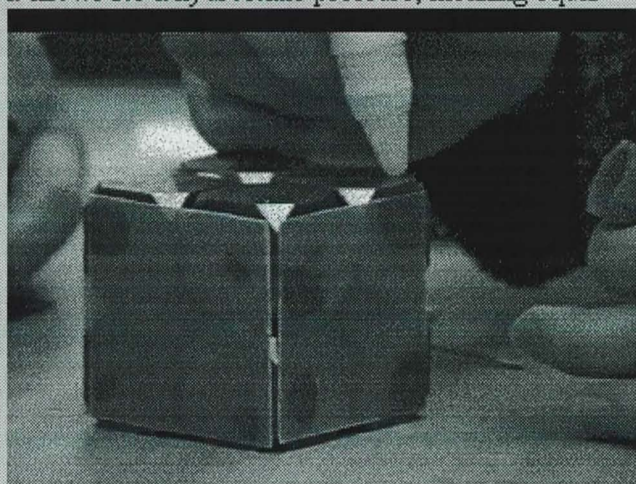


Figure 3. A portion of an undergraduate Project WISE Let's Make Diamonds! Web page posted in March, 1997

applets, and execute in the browser on the client machine rather than on the server from where they originate. These programs are transmitted in the form of bytecode, which is intended to be architecture neutral, however, in practice, some programs perform properly on one platform, but experience glitches on another, necessitating workaround solutions. Another problem associated with bytecode is that it tends to execute more slowly than machine code.

Our primary reasons for selecting Java as a programming language for this project are that its inherent object orientation facilitates the re-use of program components that can either be

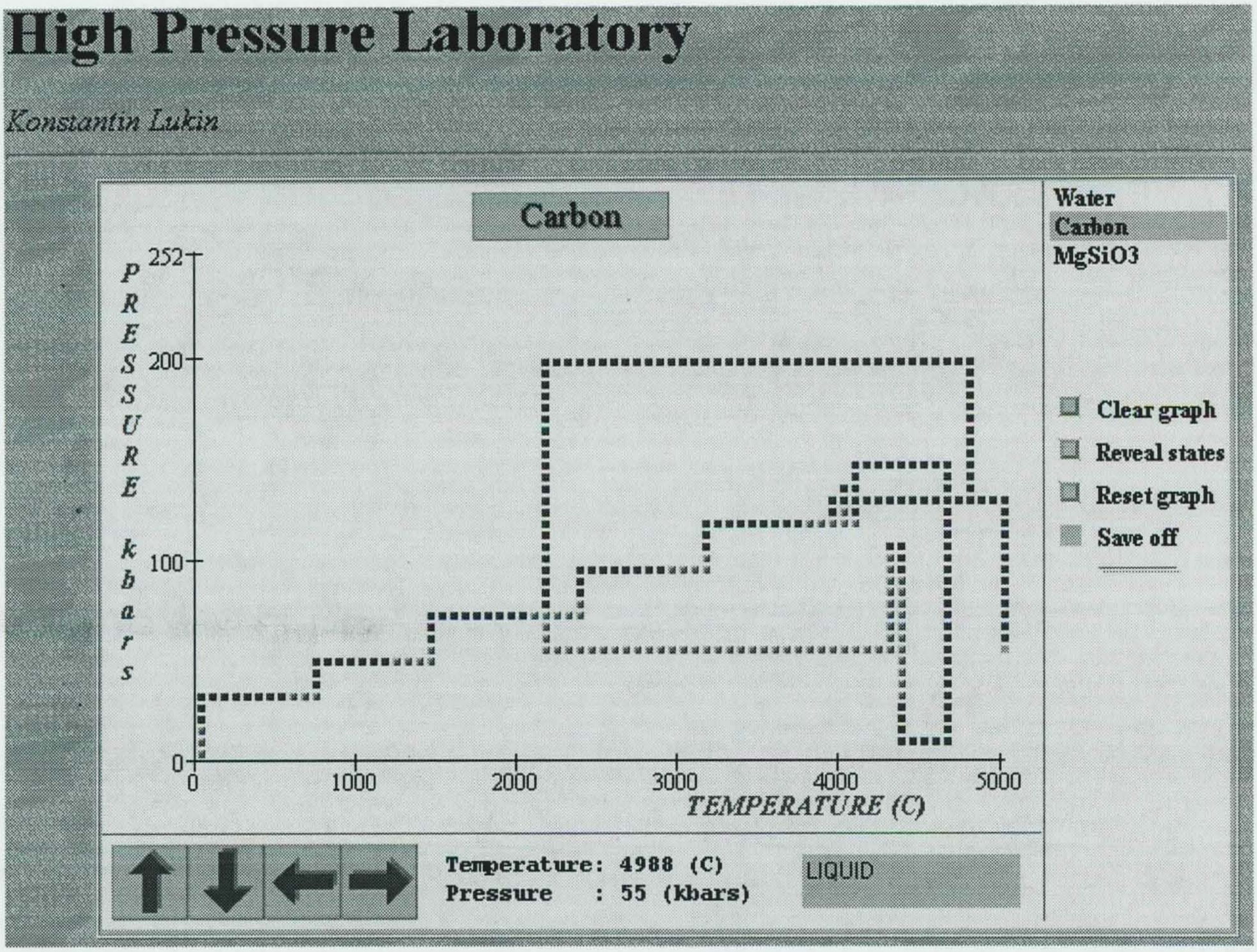


Figure 4. The High Pressure Laboratory applet

created for a particular project or obtained from another source, and that the language comes quite close to accomplishing its mission of being architecture neutral. Future technological advances are expected to enhance the speed of execution of Java Programs and to address the, as yet, incompletely realized goal of platform independence.

The Project Java applets included in this discussion are entitled: 1) High Pressure Laboratory; 2) Pollutant in a Pond System; 3) Radioactive Decay; 4) Bragg's Law and Diffraction; and 5) Finding Earthquake Epicenters. Each of these are illustrated and discussed below.

The *High Pressure Laboratory* applet is a virtual version of the presses that CHiPR uses in the laboratory to perform actual high pressure-high temperature experiments. This applet is used primarily in CHiPR education programs that focus on states of matter. Like the other programs that comprise Project Java, it is posted on the World Wide Web, and can be accessed by anyone who has a connection. It is most effectively used as part of an introduction to phase diagrams.

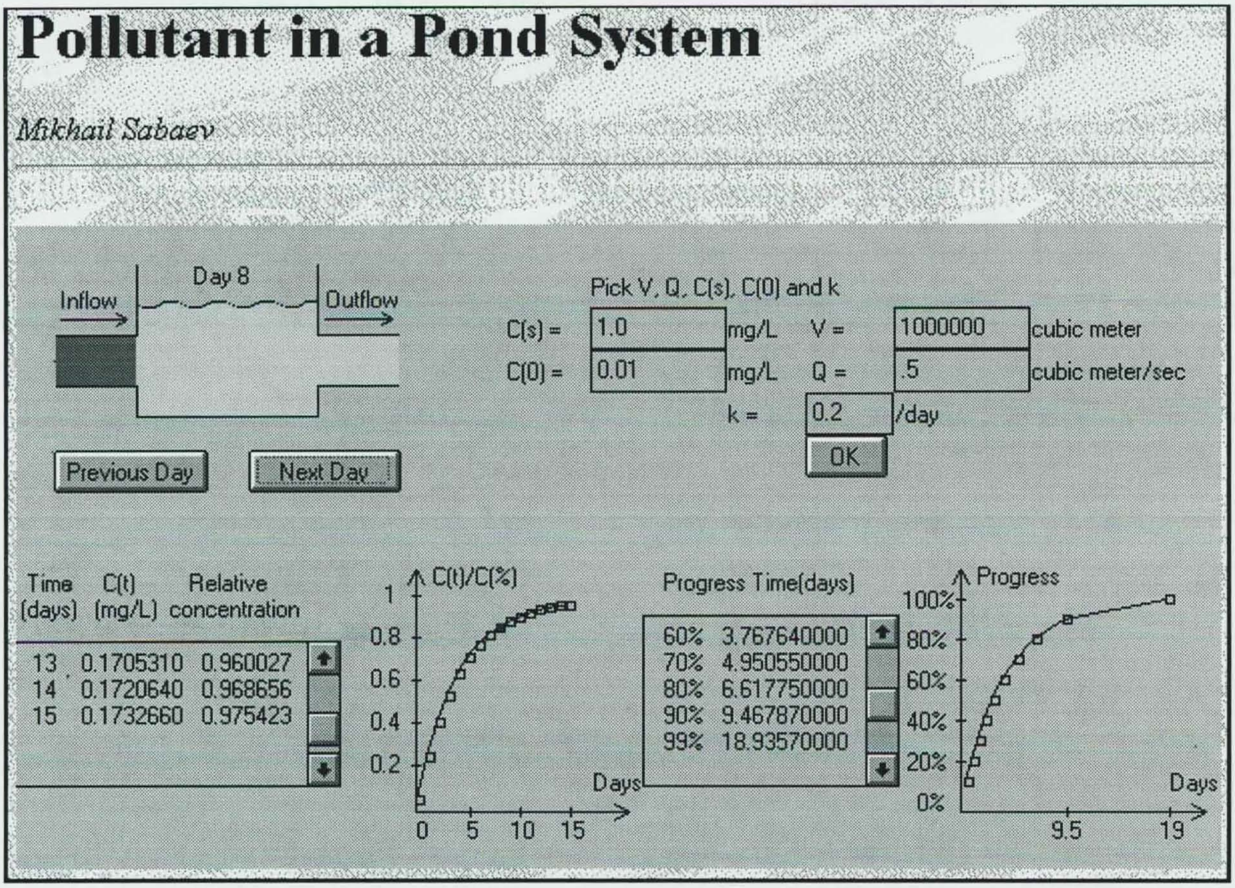


Figure 5. The Pollutant in a Pond System applet

Therefore, it is a useful tool for educators who, although they do not have access to high pressure equipment, have decided to teach their students about phases of water or any other material.

The applet enables the user to select a substance, such as water, carbon, or $MgSiO_3$, and to perform a virtual high pressure and temperature experiment on that substance. Each phase of the substance is color-coded. The user navigates through the pressure-temperature space by using the arrow buttons. Square dots trace the path that the user has followed, with the color of each dot representing the stable phase at each point. The bottom panel indicates the current temperature, pressure, and stable phase.

By pressing the *Reveal states* button, the virtual experimenter can fill in the entire pressure-temperature space with dots, representing the phase diagram of the selected substance.

The *Pollutant in a Pond System* applet models a pond with an input and outflow stream. The user can specify five parameters: 1) C(s) - the concentration of a pollutant in the inflow stream; 2) C(0) - the starting concentration of the same pollutant in the pond; 3) V - the volume of the pond; 4) Q - the rate of flow of the input stream, which is equal to that of the outflow stream;

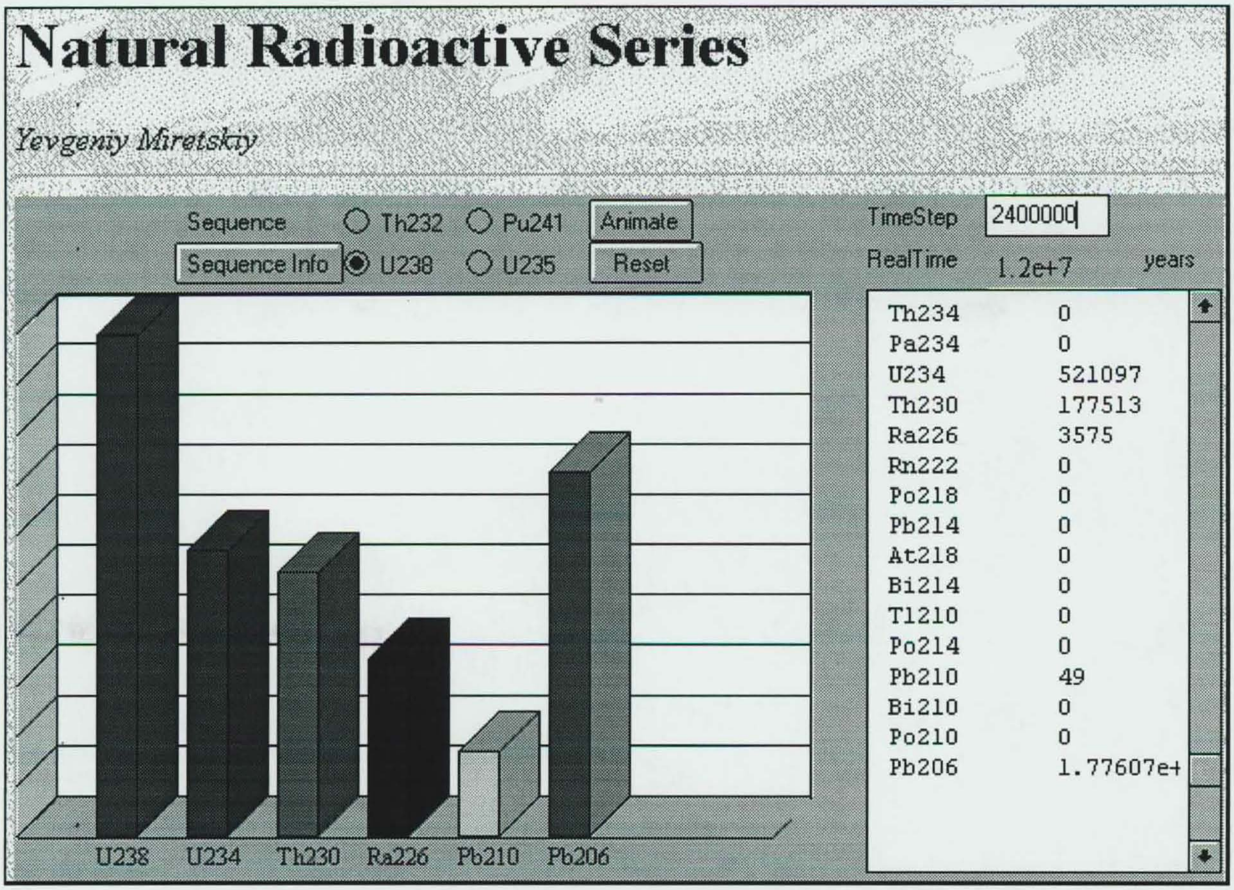


Figure 6. The Natural Radioactive Series applet

and 5) the decay constant of the pollutant in the pond. Simplifying assumptions made in the applet are that there is no evapotranspiration or subsurface flow.

The applet computes an approached limit for the pollutant concentration in the pond, and creates charts and graphs that depict progress toward that limit, plotted against time. Depending on the values given for the parameters, the concentration may rise or fall to approach the limit. This quantity is actually determined by all parameters except the initial concentration in the pond, unless the decay constant and the flow are set to zero. With a given limit, the initial concentration of the pollutant in the pond will determine in which direction the concentration must change in order for it to be approached.

This applet was inspired by and modeled after Martin Schoonen's *Lakes* Excel spreadsheet, which he developed and uses as an educational tool. Dr. Schoonen is a faculty member of the Department of Earth and Space Sciences and the Long Island Groundwater Research Institute.

Four decay series are illustrated graphically in the *Natural Radioactive Series* applet. The vertical scale represents the number of atoms of each substance, and is logarithmic, with each line representing a multiple of ten. The *Sequence Info* button reveals a diagrammatic representation of the decay series that is currently selected. The radio buttons along the top of the applet are used to select a parent product.

In order to view the proportions of parent and daughter products over time, the user can click the *Animate* button. Alternatively, a quantity of years can be entered in the *TimeStep* text field, and each step can be activated with a press of the *Enter* key. Initially, the half-lives of the parent and each daughter product are shown in the scrolling text area to the right. As steps are activated or the animation progresses automatically, the proportion of each isotope is shown, instead of the half-lives. The *Reset* button returns the system to time zero.

Ideas for this applet were provided by Dr. Daniel Davis and Dr. Gilbert Hanson of the Department of Earth and Space Sciences. Future revisions will enable the user to track the ratios of the quantities of the isotopes.

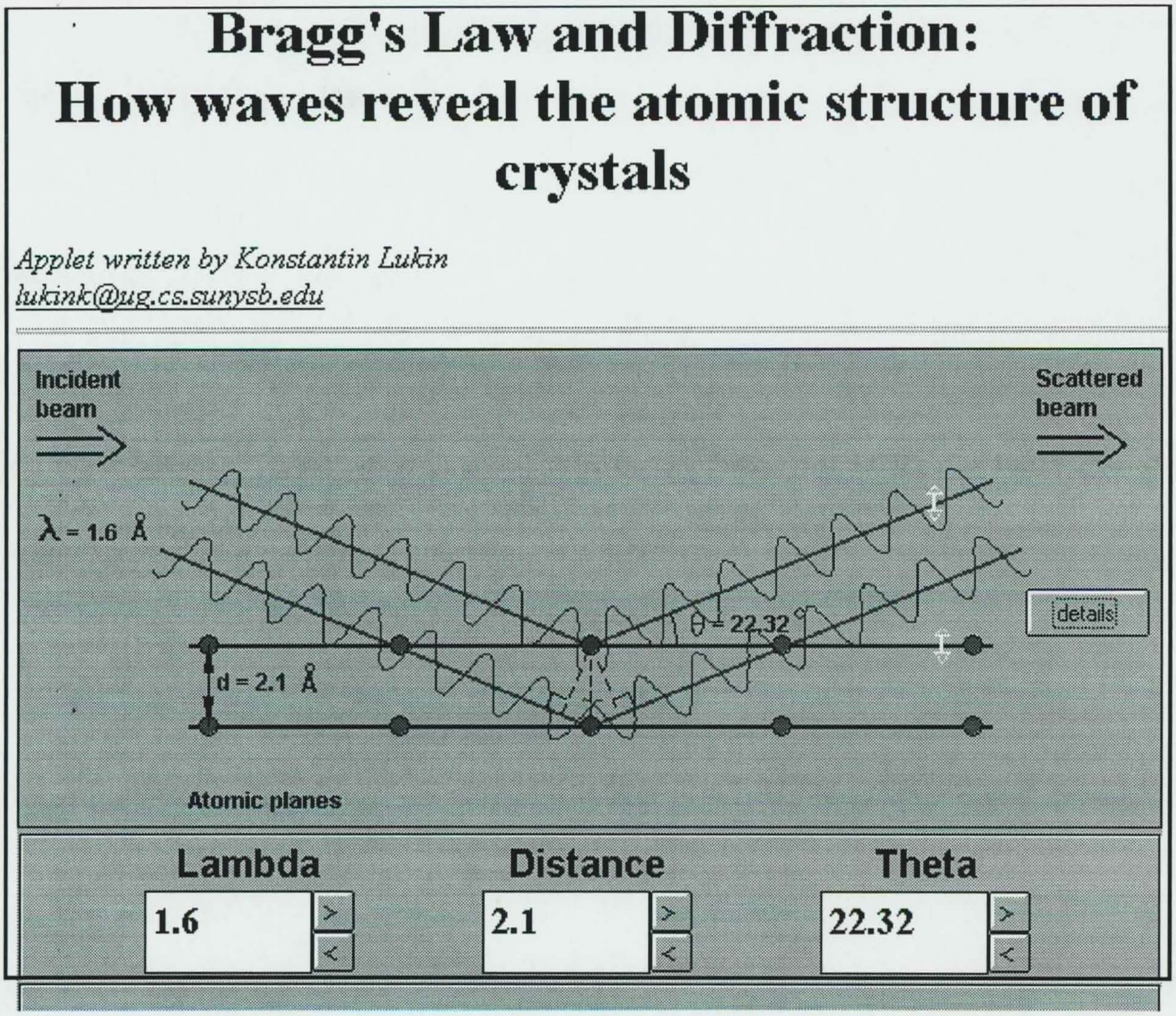


Figure 7. The Bragg's Law and Diffraction Applet

The Bragg's Law and Diffraction applet is designed to provide students with an understanding of the principles on which x-ray diffraction is based. The user enters a value for the x-ray wavelength (lambda) and one of the d-spacings for a particular substance. The theta angle can then be set to a starting value. Subsequently, theta can be changed incrementally until constructive interference of the scattered rays is achieved. This occurs when the rays in the scattered beam are in phase. The *details* button opens a window with a graph that indicates the phase relationship. Each theta that yields an in-phase condition corresponds to a two-theta angle associated with a peak on an x-ray diffraction printout.

This applet is used in CHiPR's *Let's Make Diamonds!* Program, in which participants perform an experiment designed to convert graphite into diamond. In this education program, we often use x-ray diffraction to determine the identity of the resulting product. The *Bragg's Law and Diffraction* applet provides students with a good understanding of this technique.

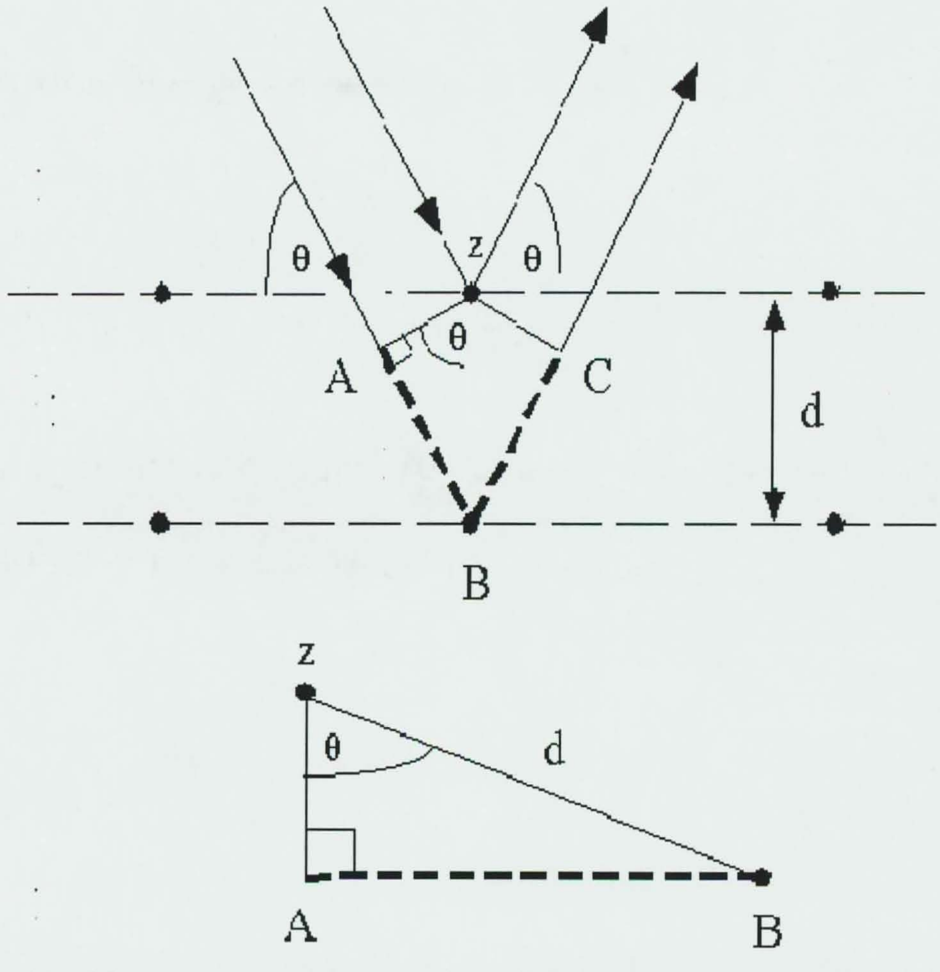


Fig. 1 Deriving Bragg's Law using the reflection geometry and applying trigonometry. The lower beam must travel the extra distance (AB + BC) to continue traveling parallel and adjacent to the top beam.

Figure 8. Diagram used to explain Bragg's Law, drafted by Dr. Paul Schields

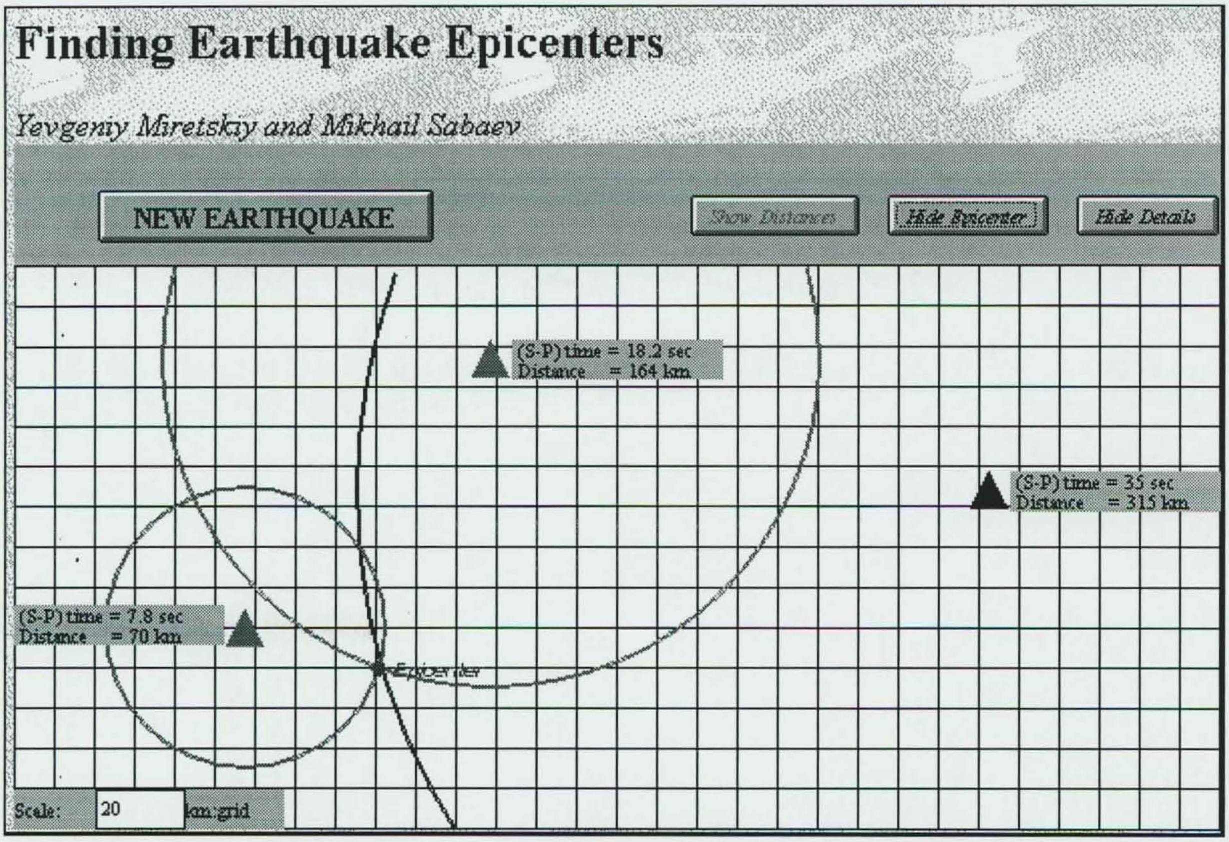


Figure 9. The Finding Earthquake Epicenters applet

When we conduct the *Let's Make Diamonds!* Program in the laboratories of the Center for High Pressure Research, educational staff are available to provide each user of the *Bragg's Law and Diffraction* applet with first-hand guidance. However, visitors to our site on the Web need to be given some other source of background information when they use this or any of our other interactive programs. Therefore, we have included pertinent information on each applet page. Dr. Paul Schields of the Center for High Pressure Research provided us with the text and diagrams that facilitate the user's understanding of Bragg's Law. In addition, this and the other applets are accompanied by information on how to enter parameters, the functions of the buttons and other controls, and how to understand the output.

The *Finding Earthquake Epicenters* applet is available in three versions on the Project Java site, and is designed be used as a drill for practicing the technique of using P and S wave arrival times to calculate the epicenter of a seismic event. In the version illustrated in figure 9, the *NEW EARTHQUAKE* button randomly generates data for an event and prints the S-P values for each station on the screen.

A *Show Distances* button adds the distance of the event from each of the stations to the display. The user can click on the screen to postulate an epicenter for the event, and the applet responds by stating how far the click was from the correct location. A *Show Epicenter* button can be pressed to reveal the arcs that represent the distances of the event from each station. When this is done, the epicenter is shown at the intersection of the arcs, and the button's function changes, along with its label, as it converts to a *Hide Epicenter* control.

Request for Feedback

An important advantage of the Web over printed material is that it is relatively inexpensive to make updates to electronic information. The comments of those who have used our HTML documents and Java applets are invaluable to us in our efforts to implement improvements, and they can also be a rich source of new ideas. The Project Java team and the other Web page developers at CHiPR invite you to browse our sites and provide us with feedback via email. A visit to the set of World Wide Web documents designed to accompany this article, at www.chipr.sunysb.edu/journey/wwweduc/, may also be of interest.