A 3D GEOSCIENCE DATA VISUALIZATION SYSTEM FOR MARS APPLIED TO UNDERGRADUATE LABORATORIES. Prabhat[1], A. S. Forsberg[2], J. W. Head[3], N. Petro[3], and G. Morgan[3], [1]Center for Computation and Visualization, Brown University, Providence, RI 02912 (prabhat@cs.brown.edu), [2]Dept. of Computer Science, Brown University, Providence, RI 02912, [3]Dept. of Geological Sciences, Brown University, Providence, RI 02912.

Introduction: Geological Sciences 5, entitled "Mars, Moon and the Earth" is an introductory geosciences course at Brown University. Students learn about scientific study and analysis, how the Earth works, where the Earth fits into the solar system, the themes in the formation and evolution of the planets, and how this information relates back to a better understanding of the Earth. The course consists of lectures, reading assignments, homework, and laboratory exercises.

Students learn that geologists study the Earth and its evolution through field work and analysis of the geological record at various points on the Earth's surface. Geologists then integrate these individual data points about the Earth's surface by means of more synoptic analyses, often aided by the perspectives seen from image and topographic data acquired from Earth orbit. In contrast, planetary geoscientists commonly work in the reverse order, since the distances and times involved in acquiring data dictate that the first data from individual moons and planets comes from flybys and orbital spacecraft. Later, in some cases, more detail comes from the deployment of a few landers and rovers and, in the case of the Moon, human explorers. Consequently, there is a huge difference today between the local analysis of the Earth and the remote analysis of other planets. For example, while Earth geoscientists employ the 3D in-situ strategies described above in analyzing their data, most planetary geoscience analysis is done using either static or interactive 2D visualizations.

To help do fieldwork in remote places, immersive virtual reality (IVR) systems let one or more people visit a computer generated world. Thanks in part to the video game industry and other new technologies, VR worlds can be explored interactively and contain amazing detail. The experience can be similar to an interactive stereo IMAX film, with wide field-of-view display and a strong sense of spatial relationships between visual features. Geoscientists use IVR to recreate and interact with distant places by using both remotely obtained data such as topography and images of the surface as well as simulated data (like atmospheric conditions varying with time) as a foundation of a visual world (Fig. 1-2). There is a spectrum of IVR systems that range in level-of-immersion. While some systems have wide fields-of-view and offer stereo viewing, others run on conventional desktop systems (Fig. 1). An open question is which IVR environment, an immersive or desktop system, is most effective for what tasks? And, in particular, which has real scientific or educational value for the student and researcher, and is not just a engaging experience?

We are developing the ADVISER system (see System Description below) primarily to assist graduate-level geoscience research, but its basic function of interactively navigating 3D terrains also serves as an educational tool. Accordingly, each year Geo5 students use ADVISER to complete a laboratory exercise about the geological history of Mars. In this exercise groups of three students first pose questions about the geology of Mars and subsequently "virtually" visit Mars's surface using ADVISER. During their "visit" the students search for evidence pertaining to their questions. After three years of successfully running and customizing the lab, this past year we formally collected information from students about the educational experience and report it here.

ADVISER: System Description: We are developing ADVISER (ADvanced VIsualization for Solar system Exploration), a NASA Applied Information Systems Research funded project, is a tool for taking planetary geologists virtually "into the field" in support of three high-level science themes (Mars Polar Evolution, Mars Tropical Mountain Glaciers, and the Noachian Hydrological Cycle). The project aims to create a field experience by integrating multiple data sources and presenting them as a unified environment to the scientist. Additionally, we are developing a virtual field kit, tailored to supporting research tasks dictated by the three science themes. Technically, ADVISER renders high-resolution datasets (8192x8192 samples) in stereo at interactive frame-rates (25+ frames-per-second). The system is based on a state-of-the-art terrain rendering system [4]. High-resolution image data can be overlaid on the terrain and other data can be rendered in this context. A detailed description and five case studies of ADVISER are available [2-3].

ADVISER was originally designed for a "Cave Automatic Virtual Environment" or Cave [1] because we believed the Cave's large-scale stereo display was most appropriate for doing "virtual fieldwork", but we are adapting its functionality to run on conventional desktop systems for two reasons: 1) to make it more generally accessible, and 2) to help us learn about the relative value of the information that can be gathered from both systems. While the Cave and desktop represent possibly two extreme ends of the VR spectrum, there are other intermediate systems, such as a Geowall (see http://www.geowall.org) which utilize a 1-wall stereo display. Such systems are less expensive than the Cave and are potentially better suited for wider deployment. We did not have access to such a system for conducting this exercise. For the purpose of the educational exercise described here, we ran the ADVISER system on both a conventional desktop system and the immersive Cave system.

The desktop system had a high-end nVidia 4500 card; 2GB RAM and a Pentium 4 processor. A video game controller was used to provide navigational input to the program. Our Cave system is an 8'x8'x8' cube with four projection surfaces (three walls and the floor). Four linux machines (identical in performance to the desktop machine) provide data for the Cave. Users utilize a handheld 3D tracked input device to navigate. Our 3D input device has a joystick and is simple to use. To navigate, the user simply points in the direction he/she wants to fly and pushes the joystick forward or backward to move relative to that direction. The user can push the joystick to the left and right to rotate his/her position in the virtual world. A collision detection algorithm is used to prevent the user from going underneath the surface.

Laboratory Exercise: The goals of the laboratory exercise are to expose students to the topography and geology of the planet Mars, to get them thinking about the diversity of features found on the surface, and to have them formulate a few questions that they then try to answer in the exercise. Prior to entering the Cave, students are given a handout with the following questions: 1) Choose three areas on Mars that you would like to explore. What is the reason for your choice? 2) What final target was chosen by your team? What was the reason for the consensus choice? 3) What are the three main questions that you have about this region? Also before using the Cave, they are instructed to use Google Mars (see http://mars.google.com) to review their selected areas. Google Mars provides easy access on standard web browsers to 2D maps of topography, visible and infrared imagery. While Google Earth (see http://earth.google.com) provides for 3D viewing capabilities, exploration in Google Mars is currently restricted to 2D views. Students form teams of three, select an area on Mars for exploration and then start the exploration on the desktop or Cave platforms. Students were supervised by class TAs in their exploration.

Online Survey and Results: Following their experience in the desktop and Cave environments, students are asked to respond to a voluntary survey. Questions in the survey gauge students on their desktop and Cave experience. These questions are quantitative and responses are measured on a Leikert Scale of 1-7. Ninety students participated in the Lab exercise; 78% male, 22% female; 42% freshmen, 16% sophomores, 16% juniors and 26% seniors; 40% had not decided on their major; 60% indicated majors in diverse disciplines (commonly the humanities and social sciences). Fig. 3 identifies regions chosen by students for their exploration session. Students then responded to the questionnaire in the following manner: 80% said that they were able to answer the main questions. 20% said that they were able to partially answer the questions. 44% responded that they could not have answered the questions at all without VR. 14% responded that they could have partially answered the questions. We note that the remaining students (42%) thought that they *could* have answered their questions using traditional media (lecture slides, books, 2D maps, images). However, *all* students indicated that VR helped them in the exploration process; they reported VR made them more confident and effective while making the exploration process easier and engaging. 100% agreed that the VR experience helped them to understand the region better.

We asked students to rate different media (in terms of insights gained) and selecting between the desktop and Cave environments for future exploration (Fig. 4). Their responses clearly indicate that they prefer the Cave most for gaining insights. Statistical significance tests (using ANOVA analysis in SPSS) indicate that the Cave is rated higher than the Desktop ($F=11.594$, $p=0.001$) and Lectures ($F=29.91$, $p=0.000$). Desktop is not significantly higher than Lectures ($F=2.726$, $p=0.101$). Lectures are rated higher than Textbooks ($F=13.769$, $p=0.000$) and there is no statistical difference between Textbooks, 2D maps and Google Mars). It is important to note that while 3D exploration in the Cave is rated the highest, 3D exploration on the desktop is rated to be higher than conventional media (textbooks, 2D maps, Google Mars). Finally, we asked students about choosing a single platform for future examination; 72% students indicate that they would prefer to use a Cave system; 28% chose the Desktop. In our opinion, this clearly indicates that students find the Cave more useful and would likely be more confident in their exploration on that system.

Conclusions: We have presented results from conducting a user study for a relatively large number of undergraduate students. In general students highly prefer a Cave-like system to a conventional desktop display for learning about geology and topography datasets. This preference is indicated by their ratings and choice of Cave as the preferred medium for future exploration. Both Cave and desktop media are preferred, however, to a standard 2D image-based investigation. Students report positively about the insights gained from the Lab exercise; an indication that 3D visualization is a valuable tool in teaching students about topographic and geologic datasets.

References: [1] Cruz-Neira C. et al (1993) 20th Annual Conf. on Computer Graphics and Interactive Techniques SIGGRAPH '93, 135-142. [2] Forsberg, A. et al. (2006) IEEE Computer Graphics and Applications, 26:4, pp. 46-54. [3] Head, III, J.W. et al. (2005) Photogrammetric Engineering and Remote Sensing (PE&RS), Vol. 71:10. [4] Hwa, L.M. et al. (2005) IEEE Transactions on Visualization and Computer Graphics, 11: 4, pp. 355-368.

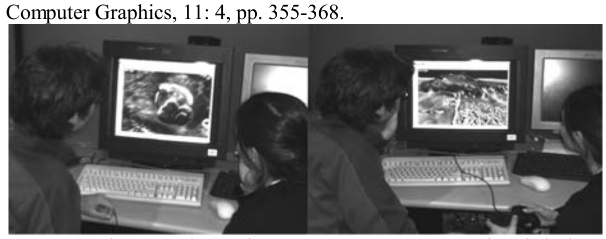

Fig. 1. Students explore Olympus Mons at a conventional desktop system. A videogame-like controller lets the students navigate around the volcano. A view from the top of the caldera is on the left, and a perspective view closer to the flanks of the volcano is on the right.

Fig. 2. Students fly through Valles Marineris in a Cave. A 3D wand input device lets the students interactively fly freely around the terrain in search of important geological features.

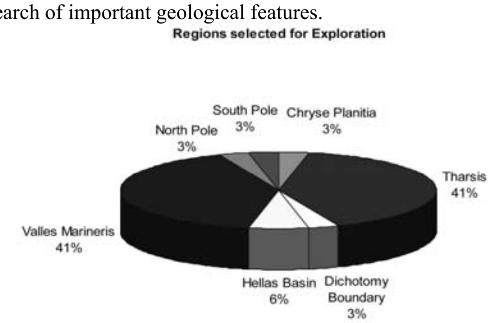

Fig. 3. Distribution of regions selected for exploration on Mars.

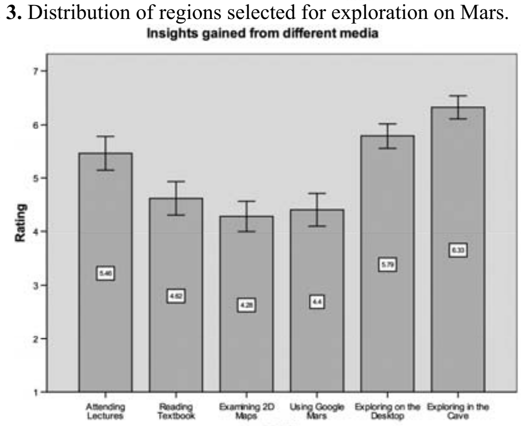

Fig. 4. Student ratings for different media for gaining insights. Mean Ratings are displayed with error bars corresponding to 95% confidence intervals.