VENUS QUADRANGLE GEOLOGICAL MAPPING: USE OF GEOSCIENCE DATA VISUALIZATION SYSTEMS IN MAPPING AND TRAINING.

J. W. Head[1], J. N. Huffman[2], A. S. Forsberg[3], D. M. Hurwitz[1], A. T. Basilevsky[1,4], M. A. Ivanov[1,4], J. L. Dickson[1], and P. Senthil Kumar[1,5], [1]Dept. of Geological Sciences, Brown University, Providence, RI 02912 (james_head@brown.edu), [2]Center for Computation and Visualization, Brown University, Providence, RI 02912, [3]Dept. of Computer Science, Brown University, Providence, RI 02912, [4]Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow, Russia, [5]National Geophysical Research Institute, Hyderabad 500007, India (senthilngri@yahoo.com).

Introduction and Background: Traditional methods of planetary geological mapping have relied on photographic hard copy and light-table tracing and mapping. In the last several decades this has given way to the availability and analysis of multiple digital data sets, and programs and platforms that permit the viewing and manipulation of multiple annotated layers of relevant information. This has revolutionized the ability to incorporate important new data into the planetary mapping process at all scales. Information on these developments and approaches can be obtained at http://astrogeology.usgs.gov/Technology/. The process is aided by Geographic Information Systems (GIS) (see http://astrogeology.usgs.gov/Technology/) and excellent analysis packages (such as ArcGIS) that permit co-registration, rapid viewing, and analysis of multiple data sets on desktop displays (see http://astrogeology.usgs.gov/Projects/webgis/).

We are currently investigating new technological developments in computer visualization and analysis in order to assess their importance and utility in planetary geological analysis and mapping [1,2]. Last year we reported on the range of technologies available and on our application of these to various problems in planetary mapping [3]. In this contribution we focus on the application of these techniques and tools to Venus geological mapping at the 1:5M quadrangle scale. In our current Venus mapping projects we have utilized and tested the various platforms to understand their capabilities and assess their usefulness in defining units, establishing stratigraphic relationships, mapping structures, reaching consensus on interpretations and producing map products. We are specifically assessing how computer visualization display qualities (e.g., level of immersion, stereoscopic vs. monoscopic viewing, field of view, large vs. small display size, etc.) influence performance on scientific analysis and geological mapping.

We have been exploring four different environments: 1) conventional desktops (DT), 2) semi-immersive Fishtank VR (FT) (i.e., a conventional desktop with head-tracked stereo and 6DOF input), 3) tiled wall displays (TW), and 4) fully immersive virtual reality (IVR) (e.g., "Cave Automatic Virtual Environment," or Cave system). Formal studies demonstrate that fully immersive Cave environments are superior to desktop systems for many tasks [e.g., 4]. There is still much to learn and understand, however, about how the varying degrees of immersive displays affect task performance. For example, in using a 1280x1024 desktop monitor to explore an image, the mapper wastes a lot of time in image zooming/panning to balance the analysis-driven need for both detail as well as context. Therefore, we have spent a considerable amount of time exploring higher-resolution media, such as an IBM Bertha display 3840x2400 or a tiled wall with multiple projectors. We have found through over a year of weekly meetings and assessment that they definitely improve the efficiency of analysis and mapping. Here we outline briefly the nature of the major systems and our initial assessment of these in 1:5M Scale NASA-USGS Venus Geological Mapping Program (http://astrogeology.usgs.gov/Projects/PlanetaryMapping/MapStatus/VenusStatus/Venus_Status.html).

1. Immersive Virtual Reality (Cave): ADVISER System Description: 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. We have developed ADVISER (ADvanced VIsualization for Solar system Exploration) [1,2] as a tool for taking planetary geologists virtually "into the field" in the IVR Cave environment in support of several scientific themes and have assessed its application to geological mapping of Venus. ADVISER aims to create a field experience by integrating multiple data sources and presenting them as a unified environment to the scientist. Additionally, we have developed a virtual field kit, tailored to supporting research tasks dictated by scientific and mapping themes. Technically, ADVISER renders high-resolution topographic and image 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 [5] and is highly interactive; for example, vertical exaggeration, lighting geometry, image contrast, and contour lines can be modified by the user in real time. High-resolution image data can be overlaid on the terrain and other data can be rendered in this context. A detailed description and case studies of ADVISER are available [1,2].

Assessment for Venus Geological Mapping: We found that the IVR ADVISER platform was very useful for the immersive environment and all participants reported a strong sense of excellent regional perspective on terrain distribution and geological map unit distribution and relationships. The platform was limited however, by the relatively low resolution of the Magellan radar image data and the very low resolution of the altimetry data. A desire to use topographic data to examine key stratigraphic relationships was often frustrated by the broad nature of the topography relative to fault and lava flow morphological relationships. Also, detailed features visible in the images (for example, small shield volcanoes <20 km diameter) were not visible in the altimetry data although it was clear that they must possess some topography. A benefit of IVR ADVISER was that several people could participate in the visualization and analysis at the same time and hold excellent discussions on the broad geological relationships. We found that the range of tools developed for ADVISER was better suited for Mars applications than Venus applications because of the much higher-resolution image and altimetry data available for Mars. In summary, we found that for Venus mapping, the IVR ADVISER platform was best utilized for initial reconnaissance work in gaining familiarity with the major topographic elements, the broad distribution of features and units, and the general discussion among a small group of mappers of the major issues and approaches to resolving them.

2. Adaptation of ADVISER Functions to the Desktop Environment: The desktop system has a high-end nVidia graphics card; 2GB RAM and a Pentium 4 processor. A video game controller (Logitech dual-action gamepad) is used to provide navigational input to the program. In order to optimize the most useful functions of ADVISER for Venus mapping, we have exported many of the functions to the desktop environment and made comparisons of the utility and productivity of the two media [1,2]. ADVISER was originally designed for a 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.

Assessment for Venus Geological Mapping: We found that the desktop system was very useful for the detailed geological mapping and the portrayal of key relationships needed to finalize unit contacts and map out and specifically delineate structures. A limitation of the desktop was the difficulty of involving more than two people in the discussion, and the overhead on panning in and out and changing contrast, and displaying multiple datasets in a time-efficient fashion.

3. High-Resolution Wall Displays: Exploration of the Middle Ground: We are now beginning to explore the middle ground between Desktop displays (DT) and Cave displays (IVR) in terms of both 1) availability to a wide range of users, and 2) utility for scientific analysis and geological mapping. In our preliminary assessment we have found that the most effective capabilities in the middle range include the semi-immersive "fishtank display" (FT) and high-resolution tiled-wall displays (TW). Among the intermediate systems are the Geowall (http://www.geowall.org) that utilizes a 1-wall stereo display. Such systems are less expensive than the Cave and are potentially better suited for wider deployment.

In our analysis of this middle ground, we have employed a 9-projector, active stereo, tiled-wall display with an effective resolution of 2400x1800, available next to the Cave in the Brown University Center for Computation and Visualization. Recent commercial demand for high-definition and high quality display (driven by the video game industry) has helped improve our capabilities in this area.

Assessment for Venus Geological Mapping: The exploration of this middle-ground has been shown to be very useful, particularly in terms of tiled displays for group discussion and analysis in the geological mapping on Venus. We found that the ability of the RAPIDVIEW system [6] was extremely helpful in panning in and out to view both high-resolution and context almost simultaneously. Furthermore, the ability to seamlessly move between superposed layered displays of radar image, topography, and geological map was essential to presentation of arguments and the development of a consensus among a large group of participating scientists that could readily view the data.

4. Summary and Conclusions: Caves in general provide for a better immersive experience, and desktops are brighter and crisper than our current Cave, but their display area is relatively small. Our current tiled wall is a middle ground and has bright, crisp images on a large display surface. This has proven most useful for fully integrated group analysis for Venus geological mapping discussions and the establishing of major questions and resolving major issues. We are currently exploring in more detail the Fishtank VR system that is most similar to a regular desktop system, but adds head-tracked stereo viewing, and typically 3D tracked input devices. The effect is comparable to looking into a fishtank where objects appear in stereo, but the working volume is physically small, effectively producing a diorama-like "world in miniature."

5. Use of Visualization Systems in Broader Education and Training in Geological Mapping: The ADVISER system was developed primarily to assist graduate-level geoscience research, but its basic function of interactively navigating 3D terrains also serves as an educational tool for training in the basic principles of geological mapping at all educational levels. We have tested these systems in Geological Sciences 5 (Mars, Moon and the Earth), an introductory geosciences course at Brown University. Students learn about scientific study and analysis, and how geologists make a multitude of observations in order to document the nature of geological processes and to unravel the history of the Earth and planets. These platforms are an engaging mechanism to illustrate how geologists use geological mapping in order to organize and document the host of scattered observations that are the clues to planetary history. Furthermore, the total immersive experience of IVR brings home immediately both the wealth of observations that can be made, as well as the need to organize these observations into important generalizations that are the core of geological mapping. Clearly, these capabilities need to be incorporated into classes in geological analysis and mapping at all levels in the future.

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