DIGITAL MAPPING T. M. Hare and K. L. Tanaka, Astrogeology Team, 2255 N. Gemini Dr., U.S. Geological Survey, Flagstaff, AZ, 86001; thare@usgs.gov

Introduction.

Planetary geologic mappers are increasingly compiling their geologic and structural maps completely within a digital domain. This not only benefits the mapper but also the publication process. As stated in the *Note to Authors Preparing Digital Planetary Maps* [1], "authors are encourages to submit digital files whenever possible." That document lists commonly used graphical and image-processing software tools as generating some of the acceptable file formats. While these formats are great for producing published maps, we also plan to convert these digital files into a format compatible with a Geographic Information System (GIS) for visual overlays, analysis, and use on the World Wide Web. This paper will attempt to list some of the tools we have begun to use at the U.S. Geological Survey, Flagstaff, Arizona for compiling maps in a GIS or that can be easily converted to a GIS.

GIS compilation.

The benefits of compiling a geologic map in a GIS system are too numerous to list completely. These tools give the users the ability to overlay registered base maps, topography, high-resolution imagery, and thematic physical-property maps, to name a few. For Mars mappers, Mars Orbiter Laser Altimetry (MOLA) data is turning out to be a great "false-image" mapping base. A MOLA shaded relief map can reveal features that are not apparent in available imagery. Shading can be generated to simulate any sun angle, which can help to resolve subtle and/or linear topographic features. Slope, contour, and slope-aspect (orientation) maps may also be generated. While GIS tools are great for analysis and visualizing, we have found that their learning curve is high and their editing tools unwieldy. While some may be hesitant to invest the money and time into learning a GIS, we feel that the benefits will ultimately out weigh the costs.

As one compiles a geologic map, GIS programs allow the user to characterize each feature with an attribute. In turn, this attribute can be assigned a unique color or fill pattern. This significantly helps in the reduction of attribute errors. Most GIS programs also have specialty line and polygon editing routines like intersecting, unioning, and subtracting. Once a contact is complete, adjacent polygons can be added that share borders with a preexisting polygon. The user can also add features in any projection supported and actually switch to a different projection at any time.

At the USGS in Flagstaff, we mainly use the GIS program ArcView [2] by Environmental Systems Research Institute (ESRI). This program is the most popular desktop GIS system, but it is rather expensive. While we heavily support ArcView with new planetary tools and tutorials, many other good GIS tools exist. Programs like MapInfo [3], Erdas [4], ErMapper [5], Envi [6], and ect [7] all have mapping tools. Manifold [8], probably the cheapest GIS with a graphical user interface, also has great potential (albeit this software only works on PC's).

A goal that we have at the USGS is to make web editing of GIS-based maps freely available to the planetary mapping community. While this technology currently exists in PIGWAD [9,10], it has not fully matured. This technology will ultimately allow the user to visualize multiple datasets and to add, edit, and attribute maps in an online environment.

Adobe Illustrator and Canvas.

Illustrator [11] and Canvas [12] specifically perform digital drafting. Both these programs come with a wealth of editing tools, although some may find that these programs also require a high learning curve. These tools allow multiple layers to be visualized, but the user has to manually coregister and scale multiple datasets. These programs also must rely on other programs to generate derivative products such as shaded relief maps. Illustrator and Canvas also do not come out-of-the-box with any tools to attribute their features with additional information such as unit names, although colors can be used to delineate units. During the conversion to a GIS format, these unique colors can be converted to unit attributes.

In order to give Illustrator some GIS-like capabalities, a plug-in called Map Publisher [13] can be installed that allows the user to add features using the normal Illustrator tools but also gives the user access to attribute the map with tabular data. This program also supports many different projections, although we have not analyzed if it has the capability to define spheroids for planetary work.

Longitude and Latitude.

Unlike Earth, most other bodies in our solar system are defined with a positive-west longitude system. Although this seems like a trivial problem, most GIS and remote-sensing applications cannot handle this longitude system. While a simple shift in longitude values fixes the problems, there is a lot of potential for confusion. We use a positive-east longitude system for our digital GIS files, but for output we use the positive-west convention for referencing and labeling.

Many current and future instrument teams will be using a positive-east coordinate system and a planetocentric-latitude system for all of their Martian products. The conversion from planetocentric to our current standard system, planetographic, is not just a simple latitude shift. And although the conversion equation is simple, when dealing with imagery it requires a resampling step. This has caused much concern in the planetary community since there are thousands of older maps and papers that reference the positive-west coordinate system and planetographic system. Even with this concern, there is a push to change Mars and possibly all bodies to use a positive-east, planetocentric system. While the transition may be unpleasant, in the long run it will make using commercial programs and handling digital files much less confusing.

Summary.

While digital mapping may be frustrating and a little expensive to get started with, the user will ultimately benefit. After maps are finalized, the data can be further exploited for analysis. These datasets also can be readily modified and updated. And if the planetocentric system is approved, it will be easy to translate any geologic or structural vector map to the new system.

References.

Note: Description of any commercial software does not represent an endorsement of the product.

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