CONCEPTION OF DATA ARCHIVING AND MANAGEMENT FOR GEOLOGICAL MAPPING OF MARTIAN SURFACE ILLUSTRATED BY AN "ANALYSIS AND INTERPRETATION OF A VALLEY NETWORKS ON MARS"

A. Nass[1,2], R. Jaumann[2,3], Sebastian Walter[3], H. Asche[1]

[1] University of Potsdam, Faculty of Mathematics and Natural Sciences, Institute for Geography, Division Geoinformatic, Potsdam, Germany
[2] German Aerospace Center (DLR), Institute for Planetary Research, Department of Planetary Geology, Berlin, Germany
[3] Freie University Berlin, Department of Earth Sciences, Institute of Geological Sciences, Division Planetary Sciences and Remote Sensing, Berlin, Germany.
(andrea.nass@dlr.de / Fax: 00493067055402)

Abstract

Due to the rapid technical development in remote sensing and the number of planetary missions with multiple set of instruments the amount of planetary data is increasing permanently. This, the new scientific cognitions, and the rising use of Geographic Information Systems (GIS) in this filed require a structured management of the raw and derived data sets. For that reason a conception is developed to create a user-related and logically linked data structure. Baseline of this concept is the integration of observations and derived/interpreted data by a detailed description (metadata). The analysis and interpretation of valley networks on Mars serves for the implementation in this approach.

This conception focuses on a GIS-based realization of standards in planetary geology and an efficient archival and management of interpreted and derived data. The dataset is consequently composed of thematic results like topography and geological maps, but also of derived data like length, depth, slope and again deduced data like discharge, valley density or volume.

I. Introduction

Mars enjoys special attention in the field of planetary research because of its specific geological similarity to Earth w.r.t. fluvial features. Together with the rapid technical development in remote sensing and the increase of Mars missions this provides different but complementary datasets (e.g. images, digital terrain models, spectral data, maps and derived information). These datasets become more and more quantified and provide complex interpretations by mapping the surface.

A geological map is defined as "a cartographic product that portrays information about the geologic character of a specific […] area. It is a two-dimensional representation […] of three-dimensional geologic feature. A geologic map uses graphical elements to express detailed information about the different kinds of […] materials, the boundaries that separate them, and the geologic structures that have subsequently deformed them“ [FGDC, 2006]. This definition is also valid in planetary geology. Further “maps help to understand the local- and regional-scale processes that have shaped the landscape and formed its materials” as described by Tanaka [2009].

Planetary evolution and the geological context of life are main research topics within the Helmholtz Alliance [http://www.dlr.de/pf/desktopdefault.aspx/tabid-4843/] and the European Planetary Network [http://www.europlanet-eu.org/]. This contains questions like “Are there habitable zones on Mars?” or “Where are possible landing sites on Mars?” To answer these questions geological maps, analysis of fluvial features and morphometric measurements have to be performed and a strategy how to manage and archive highly inhomogeneous datasets and derived information for the utilisation by different operators has to be developed.

II. Dataset

The analysis and interpretation of valley network in Western Libya Montes on Mars is used as scientific test case for the data management and utilization concept. The first step is to create a geological map based on stratigraphical, morphological, and morphometric relations. The geological data base refers to on various basis data composed of multi-and hyper spectral images, digital terrain models, and thematic maps.

The investigation area is bounded between 79° E to 86° E and 2° S to 5° N. The baseline raster data consist of images of the High Resolution Stereo Camera (HRSC/ESA) [Neukum et al., 2004; Jaumann et al., 2007], the Thermal Emission Spectrometer (THEMIS/NASA) [Christensen et al., 2004], the Mars Orbiter Laser Altimeter (MOLA/NASA) [Smith et al., 2001], the Mars Orbiter Camera (MOC/NASA) [Malin and Edgett, 2001] as well as derived terrain model (DTM/DLR) [Jaumann et al., 2007; Gwinner et al., 2005]. The HRSC nadir images support the mapping of overall geological features and fluvial shapes in particular with resolution up to 12.5 meter per pixel (m/px). They allow deriving the detailed crater distribution frequency of a geological unit that enables the estimation of age models [Hartmann and Neukum, 2001] and the derivation of stratigraphic relations. THEMIS Infrared-nighttime images display the thermal characteristics of the surface with a resolution of 100 m/px and enabling mapping of unconsolidated (e.g. gravel) and consolidated (e.g. basalt) surface materials The MOLA data (463 m/px) provided information about the topographical context for the investigation area. HRSC digital terrain model (75 m/px) serves as basis for morphometric measurements (Fig. 1) [Jaumann et al., 2009]. Where MOC images were available they supported the geomorphological mapping with detailed data with a resolution of 7 m/px [Malin and Edgett, 2001].

Furthermore existing the geological maps covering the Western Libya Montes (scale 1:5 Mio.) [Meyer and Grolier, 1977; Schaber, 1977] were used for the regional context.

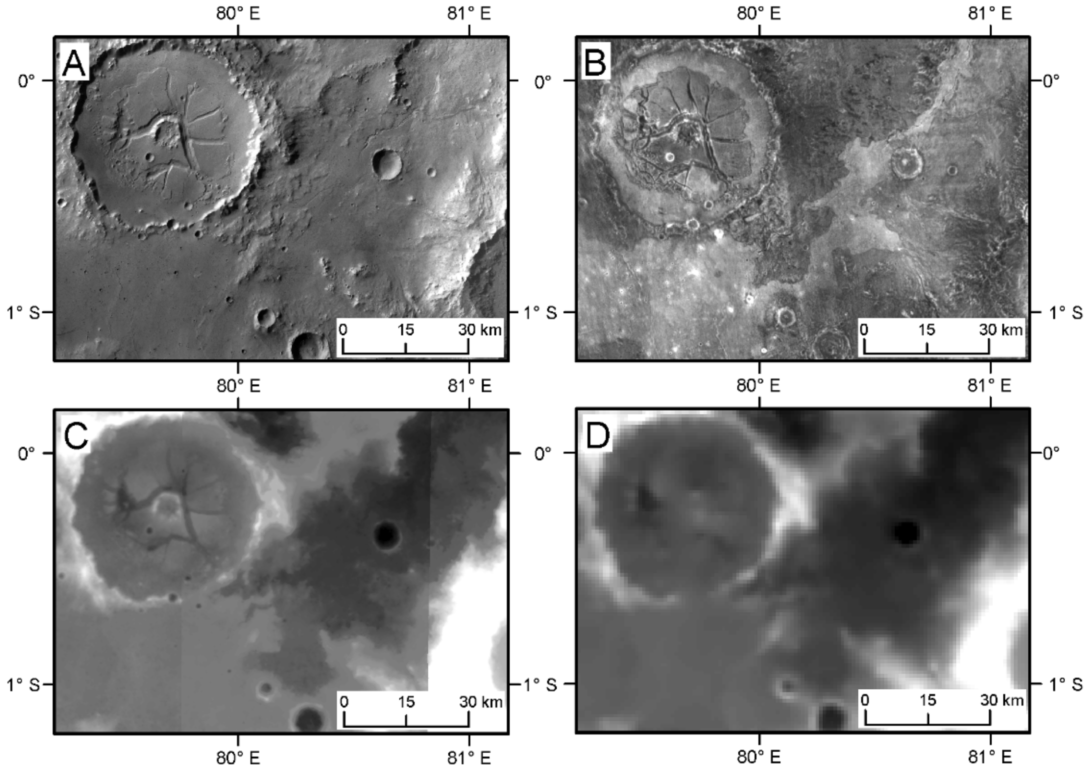


Fig. 1: Comparison between A: HRSC nadir image mosaic (12.5 m/px), B: THEMIS mosaic indicating basalt material by higher brightness temperature values (100 m/px), C: HRSC DTM (75 m/px) and D: MOLA (463 m/px).

III. Objectives

As there are already existing and adequate web-based search engines (e.g. Mars global Data Access [http://global-data.mars.asu.edu], The Planetary Data System [http://pds.jpl.nasa.gov], HRSCview [http://hrscview.fu-berlin.de]) and partly automated possibilities for processing and projecting the row data to referenced images the proposed concept is focuses on standardizing the mapping approach as well as managing and achieving all derived data (Fig. 2).

Implementation focuses on two purposes: A) a GIS-based realization of the representation of standards in planetary geology where the digital mapping process is simplified and results with similar topics like “Interpretation of the fluvial networks on Mars” will be comparable for further scientific statements. B) Efficient archiving and management of interpreted and derived data is achieved by combining the standardised definition of metadata with a visualisation on a map server structure.

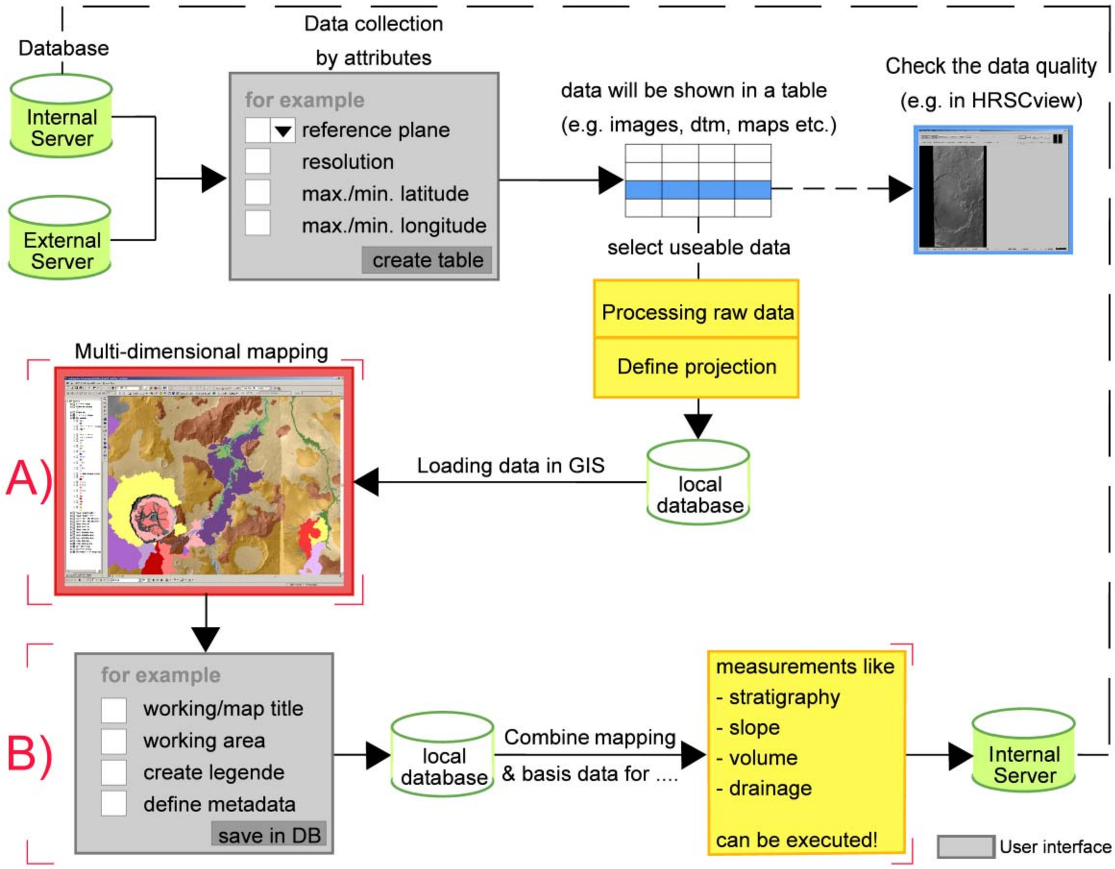
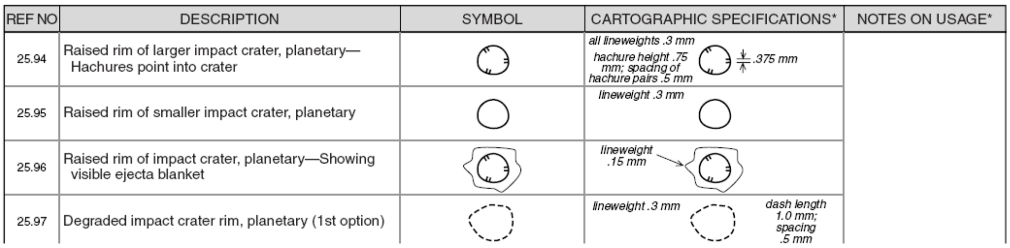


Fig. 2: Working process for comprehensive geomorphologic questions (large letters indicate focused areas, see text above for discussion [Nass, 2009].

The realization of these two areas is mostly relying on proper standards because standards "are simply engineering documents that describe how to solve the interoperability problem". They supported interoperable solutions which are enabling the developers to make complex spatial information accessible and useful [http://www.opengeospatial.org/]. The used standards are discussed in the following.

As describes by Tanaka [2009] the "quality of mapping results relies not only on the data available but also on the skill and experience of the mapper, on the mapping techniques and on digital tools applied." To avoid quality loss in the mapping process the symbolization as defined in the "Digital Cartographic Standard for Geological Map Symbolization" [FGDC, 2006] will be used for this approach (Fig. 3).
The objective of this standard is to aid in the production of geological maps and related products, as well as to help provide geological maps and products that are more consistent in both, their appearance and their underlying database content" [FGDC, 2006].



REF NO	DESCRIPTION	SYMBOL	CARTOGRAPHIC SPECIFICATIONS*	NOTES ON USAGE*
25.94	Raised rim of larger impact crater, planetary—Hachures point into crater		all lineweights .3 mm; hachure height .75 mm; spacing of hachure pairs .5 mm; .375 mm	
25.95	Raised rim of smaller impact crater, planetary		lineweight .3 mm	
25.96	Raised rim of impact crater, planetary—Showing visible ejecta blanket		lineweight .15 mm	
25.97	Degraded impact crater rim, planetary (1st option)		lineweight .3 mm; dash length 1.0 mm; spacing .5 mm	

Fig. 3 Extract of the "Digital Cartographic Standard for Geological Map Symbolization, Appendix A, 25.Planetary Geology Features" [FGDC, 2006].

As Hansen [2000] mentioned, geological mapping itself is an interpretation used for further interpretation of geological processes. Therefore the maps "must be conducted in a fashion to ensure that any operative process can be discovered".

The content of a geological map therefore provides information about the geographical locations and orientation of each mapped object or feature as well as a detailed geological description of this object or feature [FGDC, 2006].

To accomplish this description and realize the arrangement system standards for metadata definition are used. These describe for example the content, quality, condition, database etc. of the data. Through this characterization other users or applications are able to make use of the data [Nogueras-Iso et al., 2005]. This approach will be based on the standard of "Geographic information – Metadata" developed by the International Organisation for Standardization (ISO) [http://www.iso.org/iso/home.htm].

IV. Methodology

Mapping is executed by using commercial GIS ArcView Desktop developed at the Environmental Systems Research Institute (ESRI) Inc. This system enables the simultaneous processing of a great quantity of data [http://www.esri.com/]. Furthermore, all data sets from different missions can be viewed and prepared in one system for different cartographic applications. Subsequently, new information through semantic generalisation is obtained in form of geological maps [Hake and Grünreich, 2002].

Hansen [2000] describes the purpose of geological mapping as a determination of the geologic history at a specific area in context of a larger region.

The mapping in this approach is primarily based on a HRSC nadir mosaic [Jaumann et al., 2007] and relies on geomorphological, photometric and spectral information. The mosaic delivers very detailed information about the geomorphological conditions over the entire area. For the regional topographic context it is complemented by the global network of 3D- measured points of the Mars Orbiter Laser Altimeter [Smith et al., 2001]. These datasets are supported by the THEMIS night-time images [Christensen et al., 2004] which enable the identification of different surface material like consolidated material e.g. lava versus loose sediments. The MOC images with a resolution up to 2.8 m/px [Malin and Edgett, 2001] cover only a few locations of the valley system but provide detailed considerations.

Stratigraphic (timely) relations of surface units are deduced from crater size frequency distributions [Hartmann and Neukum, 2001] and are displayed in different colours (e.g. Nm = Noachian massif) (Fig. 4) [Jaumann et al., 2009].

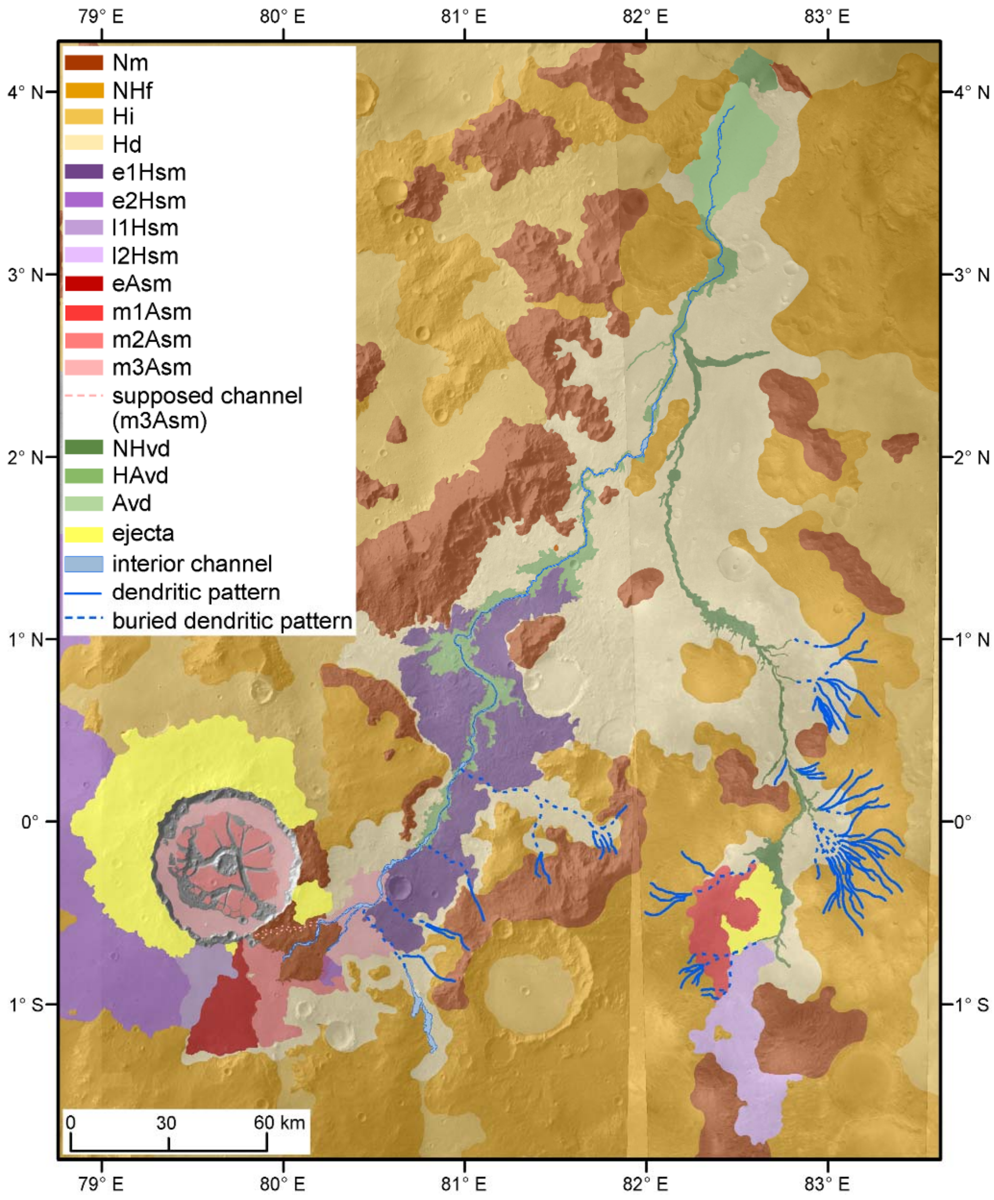


Fig. 4 Geological Map of the Western Libya Montes Valley System based on HRSC mosaics of orbits 0922 0000, 0933 0000, 0944 0009, 2206 0002 [Jaumann et. al, 2009].

In addition morphometric describing specific structures such as valleys are derived from the topographic information as determined by digital terrain models [Jaumann et al., 2007; Gwinner et al., 2005]. Parameters those are necessary to proximate calculations, for instance valley widths, lengths, depths and slopes, are directly measured in the digital terrain model. From this derived parameters such as volumes and discharges are deduced. For example, the calculation of discharge allows conclusions about the forming process of the valley system. The correlation and dependence of the particular parameters are shown in Fig. 5.

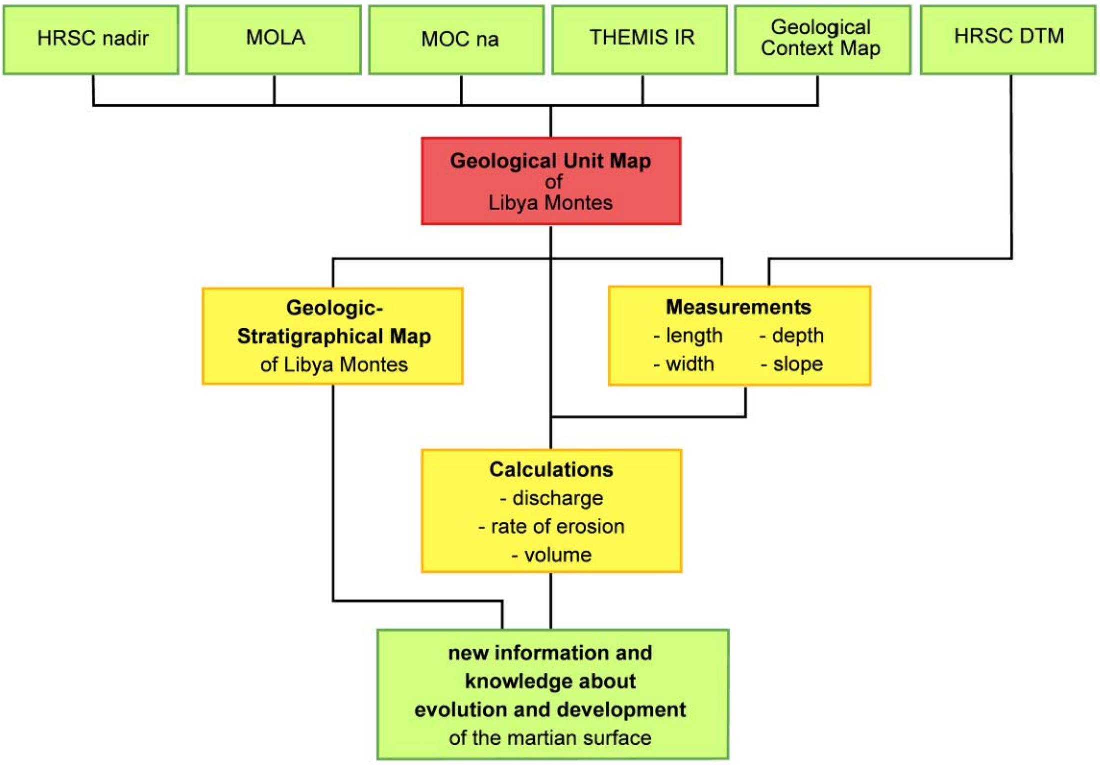


Fig. 5 Flowchart of the several input and output data during the mapping process.

The geological map, including all measurements and calculations will be archived in a common system.

V. Results - Approach to solution

For the implementation of standardizations and the definition of metadata ArcView Desktop will also be used. To realize the representation standards (Fig. 2 A) for planetary geological map symbols, a category of "planetary geology" has been created. This representation tool will establish a rule-based symbolization. For example, a feature symbol for a global presentation can only be used and displayed up to a beforehand defined scale.
Thus the person who maps will sustain the possibility to access the pre-built signatures and apply them to the map features (Fig. 6). This serves as a simplification of the mapping procedure as well as a standardisation of geological maps for further comparison and analysis.

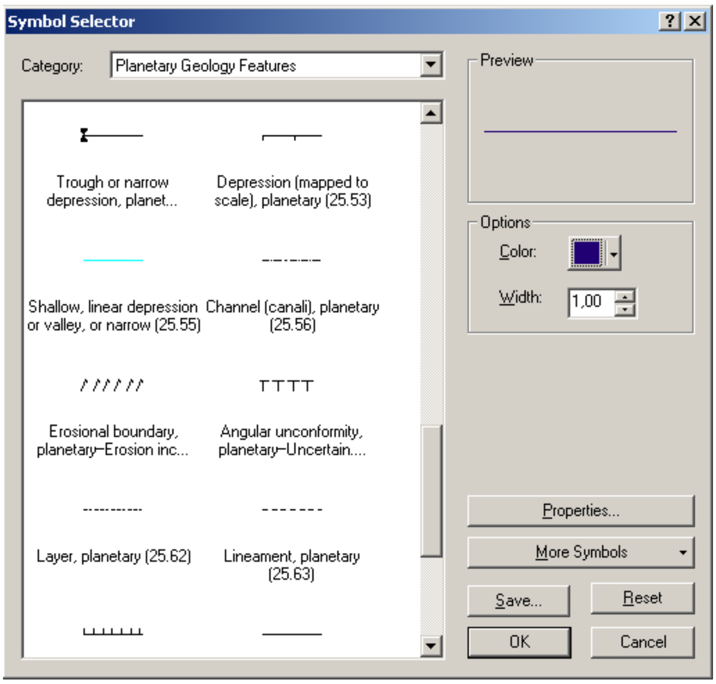


Fig. 6 Example for selectable symbols.

An application oriented metadata style sheet will be created and enabling an efficient data management (Fig.2 B). This system leads to an economic storage of the derived data on network level. It provides a good traceability and utilisation of interpreted data as well as a reduction of data redundancy. In order to achieve this, the person who maps has to add to the automatically generated metadata like file name and location, the interpretation results like surface ages, slopes etc. to the metadata records.

Consequently digital results like maps, calculations, diagrams are collected, presented and compared on a local mapserver structure via the spatial context.

The results will be available as secondary base data for further cross-correlations of basic and derived data. This enables the user for example to add new morphometric measurements to the bases of the earlier results. Consequently the database will be filled with new data and information permanently.

VI. Conclusion - Outlook

For the visualisation of the great amount of different data the creation of a mapserver is also in progress (Fig. 7). By this the person who maps will have the possibility to sift all available data at a glance.

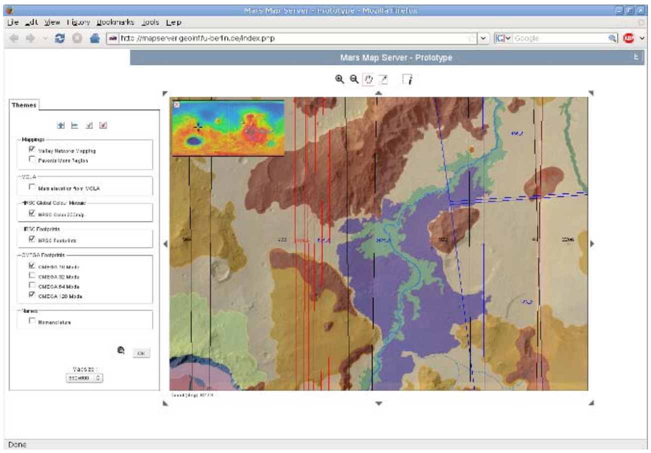


Fig. 7 A prototype mapserver application based on the CartoWeb framework. The view shows footprint outlines on top of a mapping of Martian valley networks.

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