# MAP DESCRIPTION AND MANAGEMENT BY SPATIAL METADATA: REQUIREMENTS FOR DIGITAL MAP LEGEND FOR PLANETARY GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING

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## ABSTRACT:

Instruments carried along on missions to, e.g., Mars, the Moon, Venus, and various Outer-Solar System objects, produce a rich variety of image data recorded in different wavelengths and some of them allow to derive additional datasets (e.g., digital terrain models). These data form the basis for geologically exploring the evolution of planetary bodies by analyzing and geoscientifically interpreting surface structures. By using modern GIS techniques the results are represented in thematic, mostly geological and geomorphological maps and allow to extract additional information, e.g. by means of morphometric measurements. To allow for an efficient collaboration among various scientists and groups, all mapping results have to be uniformly prepared, described, managed and archived. In order to achieve this, GIS-based mapping approaches are currently underway. One of the important aspects in this context is a detailed map description and an efficient management of mapping results by using metadata information. Such data describe, e.g. the geometry, extent, quality, contents and conditions of source data and additionally allow detailed queries for context information.

We are currently working on the evaluation and creation of metadata templates that deal with individually descriptive elements of planetary mapping results. Such templates then form an obligatory component to be filled in by the user/mapper after mapping conduct. The first step on the way to such a generic data-description template is the formulation of metadata requirements which help to establish a common information basis that can be used by the planetary science community to search and understand spatial data products on the level of input data as well as on the level of digital map products. Such a metadata basis therefore forms a way to store information of traditional analog map legends within a digital map product. Such metadata information needs to be implemented as template on two different levels: the individual (vector-based) map level data as well as the (raster-based) dataset level that was used to create the map. Such a metadata template can then be used either in stand-alone GIS projects or it can be integrated into a more sophisticated database model using an XML-structured and standardized vocabulary. The usage of an obligatory map description template facilitates the efficient and traceable storage of spatial data and mapping results on a network level.

## 1. INTRODUCTION AND MOTIVATION

The exploration of the planets in our Solar System, i.e. Mars, the Moon, Venus, and various Outer-Solar System objects, enjoys a steadily growing international interest. The rapid development in space-sensor technology and the curiosity to discover unexplored regions, set off new mission programs and significantly increase the data return. These data depict surfaces in different wavelength ranges permitting the derivation of additional data (e.g., digital terrain models). Through this great variety of surface images it is possible to explore the planetary body by analyzing and geoscientifically interpreting surface structures and processes gaining new and further information about planetary evolution. In the field of planetary geology this scientific workflow is conducted nowadays using modern geographic information systems (GIS or GI systems) and techniques allowing to represent results in thematic maps combined with additional information such as morphometric measurements or results of age determinations of planetary surfaces by impact-crater diameter-size frequency analyses. To allow for an efficient collaboration among different scientists and groups, mapping results have to be uniformly prepared, managed and archived. Therefore GIS-based approaches for optimizing the mapping workflow and data management are currently underway. One project addresses issues such as data integration, management, processing aspects and analysis within a geodatabase context, including the use of secondary relations and topological constraints. The main focus within this project is to generate an extensible, scalable and generic database model for growing scientific and technical needs which allows performing planetary mapping tasks by maintaining topological integrity and without loss of information (van Gasselt and Nass, in press). Another project is dealing with the GIS-based implementation of cartographic symbols for the planetary mapping process. More specifically, this project deals with requirements for planetary mapping symbols, GIS-based implementation and various linkage scenarios for integrating symbologies into the database model (Nass et al., in press). Beside these projects current work is focused on the detailed and efficient description of raster-based image datasets (map-input data) as well as for individual interpretation work wrt planetary surface evolution and processes (scientific output data). Digital descriptions of such data are nowadays implemented by metadata (cf. section 2.2). The contents (i.e., properties and format) of particular metadata entries are defined for instance in standardization initiatives, e.g. the *Content Standard for Digital Geospatial Metadata* (*CSDGM*) (FGDC, 1998, 2000) and *Dublin Core Metadata Initiative* (*DCMI*) (DCMI, 2004) (cf. section 2.3). Considering that developments a uniform mapping process will [1] significantly improve comprehension of digital, scientific mapping results, [2] facilitate a subsequent use of these results as secondary data basis for further investigations, and [3] allow a software-independent exchange of results. For general purposes, a description of digital data is done by defining metadata entries and values. In planetary sciences the present focus on data descriptions has been on the raster-based dataset-level thus far (PDS, 2008). These data serve as basis for the interpretive, mostly geological and geomorphological mapping. In this context image data are described by general attribute information such as unique image number, camera system and parameters and, more importantly, additional spatial information such as reference system, image resolution, time and position of acquisition. This information is linked to the image data directly in order to be able to interpret surface images correctly within their spatial context as defined by the specification of the absolute location. In contrast to raster data an uniform description for vector-based mapping results is commonly not employed. Although such descriptions are produced in the context of US-financed mapping programs (e.g. Astrogeology Science Center, April 2010), metadata descriptions are not obligatory for map publications in the framework of individual scientific publications. A detailed description of data in order to completely understand mapping results is normally given within the publication or in a map legend on an analog map sheet. However, this information is not linked to the digital mapping data itself. One aim of our project and the focus of this paper is the facilitation of storing a traditional map legend for digital mapping products. In usual GI systems there are already possibilities for assign, manage and store metadata following the introduced standards. However, increasing the efficiency of metadata usage it is important to topic-oriented adapt and modify the selection of metadata entries. As one necessary requirement a metadata template has to be substantiated which deals with the detailed data description. With the help of such a template data description is linked to the digital mapping result and a possible database model on which the mapping is based. First, we outline general characteristics and capabilities of spatial data as well as metadata and we will briefly discuss standardization initiatives for metadata. Secondly, we generally describe planetary mapping processes and challenges that serve as reference for a recommendation for a planetary metadata template. Thirdly, we formulate the requirements allowing to generate an applicable and easy-to-use interface for the user/mapper which aids efficient data management, archiving and querying. In order to do this, we address metadata descriptions on two different levels separately: vector-based map outputs and raster-based input datasets. Additionally, and with these requirements in mind, we discuss the usability of existing metadata standards, in order to extract needs for modifications and extensions and for subsequent adaption of existing metadata elements for inclusion into a planetary mapping template. Subsequently, we focus on the exchange and portability of metadata entries and on the possibilities for data queries on the conceptual level.

## 2. BACKGROUND

### 2.1 Terrestrial and Planetary Spatial Data

Digital spatial information (planetary as well as terrestrial) is available as raster and vector data and is spatially related to a predefined reference system. Raster data are pixel-based image matrices with pixel values representing (a) sensor signals recorded in different wavelength ranges (imaging multi spectral-/ hyperspectral sensors, radar images) or (b) results derived from subsequent methods and analyses (e.g. digital terrain model data). Raster data are organized in rows and columns with generally – but not necessarily – a common cell size in x (column, sample) and y (row, line) direction. The x-y-extent of a single cell defines the resolution of data and consequently the accuracy of representing the real world. Every cell holds a single attribute value as defined by the image-producing facility. The spatial context of geo-coded image data is provided either by a detached label file or by an image header. Vector data organization is more complex as it is represented by three different types: point (node), line (edge), and area (polygon). Each point carries the geometric and spatial information; the other simple features (lines and polygons) are based on this definition. The spatial context is provided through the nature of vector graphics (specification of length, direction, and orientation) and the underlying reference system. Vector data generally display components of a thematically generalized map content, e.g. street maps or a geological map of an investigation area. In this respect, planetary data do not differ from terrestrial datasets. The major difference between both working branches is the variety of employed sensors, the thematic contents and the variety of reference systems for different planetary bodies. The spatial reference allows to position and locate as well analyze data within their respective planetary spatial framework and to extract new data, information, and knowledge. Spatial data are produced and generated in a variety of ways. (1) by remote sensing instruments and (2) by in-situ terrain exploration also known as ground truth, and (3) by subsequent manual or automatic analyses and derivation of additional data.

### 2.2 Spatial and Non-Spatial Metadata

Metadata are defined as *data which describes attributes of a resource or data about data* (e.g. Nogueras-Iso et al., 2005). The best example of the metadata concept is a library in which the database, and more specifically, each library item or dataset entry includes information on authors, titles, publication dates, keywords etc. Metadata related to a specific dataset complements the data itself with pieces of encompassing information, and subsequently helps to improve the data management, storage, archiving and querying. Therefore, each metadata record describes a specific resource and groups it into thematic catalogs (Nogueras-Iso et al., 2005). The linking between the actual data and the corresponding metadata is established by either a data record separated from the actual data using keys (e.g. library's catalog) or by embedding metadata into the data directly (DCMI, 2004). Metadata elements are organized hierarchically in three different types: [1] contents of metadata (e.g., language and coding system to understand the metadata of a dataset), [2] directory metadata (e.g., name, origin and distributor of the database to find the location of the dataset), and [3] dictionary metadata (e.g., definition/ organization, syntax and quality of the data to describe the accuracy, reliability, completeness etc.) (e.g. Aalders, 2005). Spatial metadata describes the quality, contents, conditions of data and additional stores information about the absolute spatial location within a defined reference system. Metadata are a special type of non-geometric data and are collected in different ways. In analog maps metadata are primarily contained as part of the map legend. However, in digital mapping metadata can resp. must be ascertained be the mapper. While some pieces of spatial information is usually derived automatically by the GIS environment (e.g. lengths and areas, extents of data layers, and feature counts), the more interpretive and less-spatial information (e.g., research results, owner name, quality estimate, and original source) must be explicitly collected by the mapper and are entered into the database comparable to other attributes (Longley et al., 2005). Spatial data in combination with additional (spatial) metadata characterize data in order to enable other users to query more specifically, to understand data contents, and subsequently to use these data by obtaining further information (Nogueras-Iso et al., 2005). For these reasons and for making metadata a useful piece of information for the user community, it is essential that they follow widely accepted standards, so that metadata can uniformly be generated and upcoming user can work with it (e.g. Longley et al., 2005; Aalders, 2005). To accomplish this, a variety of standardization schemes with different foci on the description and cataloging of metainformation are described in recommendation documents (cf. Section 2.3).

### 2.3 Metadata Standards

A variety of standardization initiatives on a national as well as international level developed metadata standards in the geospatial domain for describing and cataloging metadata elements (e.g. Nebert, 2004; Caprioli et al., 2003). All these standards and references are under revision, are frequently updated and adapted (e.g. Moellering et al., 2008), and put on a more mature level. A selection of the most common initiatives are here introduced.

*The Content Standard for Digital Geospatial Metadata Workbook* (*CSDGM*) was approved by the *Federal Geographic Data Committee* (FGDC) in 1994 and was revised in 1998. This national standard was developed in order to provide support for the establishment of the *National Spatial Data Infrastructure* (NSDI) of the U.S. The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. Meanwhile it has also been adopted by many organizations outside the U.S. and other countries such as Canada and South Africa and are becoming the most widely employed metadata standard in the GIS world (FGDC, 1998, 2000). On the basis of an extensive variety of metadata entries the standard document allows a valuable documentation facilitating efficient discovery, access, use, and archive of geospatial data.

The *International Standardization Organization (ISO) Technical Committee's (TC) 211* approved the standard for *Geographic information - Metadata ISO 19115:2003.* This international standard with more than 350 elements had to contrive a plan to efficiently treat incompatibilities and insufficiencies that occurred after many regional and national metadata descriptions were developed. Thus, the standard was designed to support geographic information in an uniform and international applicable way (Aalders, 2005). The standard is an abstract standard, i.e. it specifies the definition of elements and the relationship among elements but does not provide guidance as to how the content is organized into a formal record and presented to the reader (Kresse and Fadaie, 2004). This standard is for example used in the initiative *Infrastructure for Spatial Information in the European Community (INSPIRE)*[1] aiming at the generation of one European geodata basis with integrated spatial infrastructures.

In the field of Information Technology, e.g. the *Dublin Core Metadata Initiative (DCMI)* (DCMI, 2004) founded in 1995 developed the international standard *Dublin Core.* The basic 15 elements are broad and generic, usable for describing a wide range of resources. This *Dublin Core* has applications in many areas and serves as basis standard for individual metadata collections (e.g. Batcheller, 2008).

More standards that define the content structures for collecting metadata are e.g. the *prENV 12657 Geographic information - Data description - Metadata developed by the Technical Committee of European Committee for Standardization (CEN)*[2] and the *Directory Interchange Format (DIF)* initiated by NASA's Global Change Master Directory (GCMD)[3].

In the field of planetary metadata description special emphasis is put on the standard references of the *Planetary Data System (PDS)* which is financed by NASA's Science Mission Directorate and which focuses on archiving planetary image data products to maximize its usability. In this context the PDS developed standards that address the raster data structure, description contents, media design, and a set of terms for improving the data use by scientists (Planetary Data Service, July 2010). Other documents like, e.g. *Planetary Science Data Dictionary (PSDD)* are prepared for serving as guideline for a correct use and implementation of standards. However, thus far, there is no standardized description for cartographic mapping models (primarily vectorbased data).

### 2.4 Planetary Mapping

Planetary, and more specifically planetary geological and/or geomorphological mapping has been systematically ongoing since the early 1960s (e.g. LPI, 2006, 2009; Astrogeology Science Center, April 2010) and has been mainly initiated in the framework of national agency-funded programs. In the context of these programs, e.g. the geology of Mars has been depicted in global maps at scales of 1:20,000,000 to 1:15,000,000 and in larger-scaled regional to local maps at scales of 1:500,000 to 1:200,000 (e.g. USGS, 2003a). In the framework of other programs geologic map series of Venus and Mercury have been created on the basis of ongoing or completed exploration programs (e.g. USGS, 2003b; LPI, 2007). However, beside such agency-funded geologic mapping programs, other planetary map series are carried out with a focus on photographic and topographic maps (Lehmann, 1996; Buchroithner, 1999; Albertz et al., 2004; Shingareva et al., 2005).

[1] http://inspire.jrc.ec.europa.eu/

[2] http://www.cen.eu/cen/Pages/default.aspx

[3] http://gcmd.nasa.gov/User/difguide/

Regarding the process of map preparation hand crafted maps and analog cartography have been widely replaced by computerized and digital mapping since the beginnings of the 1980s (e.g. Olbrich et al., 2002; Cartwright et al., 1999). Conventional analog maps were still produced but the actual mapping was conducted in the digital domain and with the help of vector- and raster - graphics software. Such software environments come with a variety of design options facilitating the processing, rendering, and communication of different map elements but they usually lack the ability to work with spatial reference systems and geocoded data. Thus, nowadays and for an increased efficiency when working within a common spatial domain and context, mappers/ cartographers commonly use GI systems. These software environments are based upon a spatial database management system and are used for capturing, managing, processing, analyzing, and presenting spatial data (e.g. Longley et al., 2005).

In this respect and in terms of cartography, planetary mapping does not differ much from terrestrial mapping (Nass et al., in press). However, owing to the lack of ground-truth information in planetary science, the planetary mapping process is primarily based on remote sensing data thus far. For this reason and because of the high level of interpretation scientific results have to be stored and communicated appropriately within the map data description. If this description is implemented within the digital data in terms of metadata (cf. section 2.2) the reader of the scientific mapping results has the ability to efficiently evaluate results and to decide about the use of these results for his/her further studies.

## 3. REQUIREMENTS FOR PLANETARY MAP DESCRIPTION

As also stated by Nebert (2004) the first aspect on the way of developing a metadata description is by defining individual requirements. These requirements are acquired and listed with the dominant focus on particular data and its value for the understanding of a digital dataset in terms of visualizing a geological/ geomorphological topic as a result from interpretive mapping work in planetary science/geology (cf. section 1, 2.4). In order to define the required sets of metadata information for planetary mapping results, we formulate the requirements in general and without discussing the implemented scripting/syntax, dataset transfer, database linking etc. The metadata description concerns both, the conducted mapping results as well as the underlying data basis. Therefore, as mentioned above, we subdivided the descriptive metadata entries in two levels, the vector-based map level and the raster-based dataset level.

### 3.1 Level of Description

**3.1.1 Map-Level (Vector):** This level is composed of descriptions for the entire digital object model resp. map results, each spatial object and object classes interpreted and analyzed by the mapper and visualized in a map. Within this map-level the main focus is on vector-based datasets. Thus, metadata descriptions deal with the interpretive background which is visualized by the cartographic map design and which uses used graphical variables such as allocations of color, shapes, sizes etc. The information we need for understanding and further utilizing a digital cartographic model in planetary geology are

1. *Which data serves as data base for the mapping?* As mentioned earlier, planetary mapping is mostly conducted by making use of remote sensing data imaging the planetary surface in different wavelength ranges. Thus, the quality of the mapping results depend on data availability for a specific area and on the selection of such data. By make use of such a data variety the mapper obtains different maps of every image base. However, combining image data and generalizing thematic map content in a comparative GIS-based mapping process allows the mapper to gain a single map result which includes information of each image dataset.

2. *What is the purpose of the mapping conduct?* Beside national founded mapping programs (see section 2.4) most maps in planetary geology are conducted for scientific presentations. These usually present analyses and interpretation results in a paper publication. However, maps can also be part of a cooperative mapping project, e.g. analyzing similar spatial phenomena locally on different distributed areas globally and visualize these in a variety of map sheets.

3. When*, under which guidance and by whom was the mapping conducted?* If there is need for further studies or continuation of a closed mapping project or if there are additional items to be addressed wrt the mapping result it is paramount that the map user can easily extract information about the mapper, the timespan during which the mapping was conducted and under which guidance or in which programmatic context the mapping project was carried out.

4. *Do additional statistics and/or empirical data exist?* Commonly, comparative and interpretive mapping conduct is supplemented by additional data such as morphometric measurements or calculations which consequently influence and shape the map design. Such additional measurements and data can be, e.g. measurements for discharge, slopes and topographic profiles and also impact-crater diameter-size frequency analyses for derivation of surface ages. Beside listing additional data it is also important that the mapper describes in which way these data affect the map design, e.g., coloring, classification, and size for cartographic signatures of spatial objects.

5. *What is the minimum scale of mapped features?* The data quality resp. image resolution varies considerably depending on the image sensor and the viewing body, i.e. on some image data a mapper is able to detect a spatial object which, however, can not be identified on another image with lower spatial resolution. Thus, especially if, e.g. an object classification is based on a quantity of spatial objects or if these quantities are derived from statistical analyses such as –crater diameter-size frequency analyses, it is important that the mapper states a minimum scale for every mapped feature category.

In addition to these manually defined metadata entries by the mapper, further entries are important which are usually stored by the GI system automatically. By storing such metadata the localization and data queries are optimized:

6. *What are the boundary coordinates of the map?* In contrast to an analog map sheet the digital cartographic model does not invariably reveal a coordinate system. However, for a spatial placement it is inevitable to store the numeric maximum and minimum latitude resp. longitude within the digital map result.

7. *Which reference system and projection were used?* If the cartographic model serves as basis for further calculations and measurements the user has to know which reference system and more importantly which projection was employed for the map. Due to the absence of datum shifts, the availability and complexity of various projections is limited, however, the variety of global geographic projections is large enough to cause ambiguities and unwanted effects if not properly communicated to the user.

8. Where*, and in which coordinate system is the position of an individual spatial object defined?* Boundary coordinates and reference systems are not only important on the map sheet level but also on the level of the spatial data object. Thus, it is important that not only specific attributes but also the position and dimension of every particular object are stored inside the database.

**3.1.2 Image/Base data-Level (Raster):** The base-data level dealing with the description of utilized image data, is technically implemented by standardized metadata for planetary raster data (cf. PDS, section 2.3). However, in order to decide (a) which selection of metadata entries should be linked to the database model for planetary mapping, and (b) whether there is a need for modification or extension of the metadata set, the exact definition of descriptions has to be substantiated. Regarding formats for this base-data level the current focus is on raster data. The required descriptions in the field of planetary geology that help understanding the characteristics of base data and subsequently the quality of the elaborated mapping results are:

1. *Which quality resp. resolution has a particular image dataset?* As planetary mapping is primarily based on remote-sensing data information about data quality is essential for rating mapping results. If the map user is informed about particular image resolutions, he/she is able to make statements on the degree of detail and completeness of the map content.

2. *Which boundary coordinates does the particular orbital image have?* The high potential of mapping within GI systems is the ability to work within a precise spatial context. In order to enable spatial analyses between map level data and image base data, corner coordinates (in terms of one corner coordinates tuple and the image extent) of each planetary raster image or mosaic have to be stored inside the metadata and in the data base model, consequently.

3. *At which time/date was the image recorded?* One aim of long-lasting missions is to cover certain areas twice or more times. Seasonal observations provide valuable information about surface changes and also allow to look at a surface under varying illumination conditions (phase angles, solar azimuths and elevations) and within a different context. In particular for geologic and geomorphic mapping, shadows produced by surface features are important characteristics needed for interpretation. Thus, the exact date and time needs to be stored. This becomes even more important in the course of raw data processing in order to unambiguously assign navigation data to a certain image scene.

4. *Which characteristic information is related to a particular image?* The data basis for planetary mapping conduct, independent of the planetary body that is analyzed, contains remote sensing data in different wavelength ranges and in some places even ground-truth data (Moon, Mars, Titan). In the case of Mars, the mapper has access to data which covers the planetary surface in the visible spectrum[4], in several infrared (IR) wavelength bands[5] or the mapper has access to data which represents topographic information[6]. All these raster datasets represent different pieces of information within their gray-value distribution and need to be properly described in terms of, e.g. recorded and calibrated signals, wavelengths, band widths, sensor characteristics, reflectances and radiances. Furthermore, a map user requires the information about the exact data source which, in most cases, is the PDS or the instrument facility.

### 3.2 Metadata Exchange and Querying

Whereas the metadata content deals with properties and format of the particular entries, there is also need to decide how the data are manifested digitally and can be exchanged between different systems. This topic is already treated by early initiatives (e.g. Moellering, 1997) and is the subject of ongoing processes in different fields of application (e.g. Caprioli et al., 2003). For data exchange and storage, the most commonlway is to phrase the metadata by the standardized *Extensible Markup Language (XML)*[7] using the additional documents *Document Type Definitions (DTD)* (defines the individual set of rules for a well-formed XML-document) and *Schemas (XSD)* (regulates the structure of the XML-document) (e.g. Zaslavsky, 2003; Batcheller, 2008). As all standards mentioned in section 2.3 are encoded in XML, those are theoretically capable for managing the metadata. However, because the portability of the entire mapping result is strongly linked to the database model which is still in the conceptual phase (van Gasselt and Nass, in press), we do not specify the implementation of the exchange possibility at the current stage. Regarding the query options that enable an easy access to the mapping results for the potential user, there is also a variety of effort in this field (e.g. Aalders, 2005). As in the case of metadata query the main advantage is data search in textual XML-structured documents, we can use the *XML Query*[8]. Similar to SQL for relational databases, *XML Query* serves the possibility retrieving XML documents or parts of it from an XML data

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[4] High Resolution Stereo Camera (HRSC), Mars Reconnaissance Orbiter-Context Camera (MRO-CTX), Mars Orbiter Camera (MOC), Thermal Emission Imaging System-Visible (THEMIS-VIS)

[5] Thermal Emission Imaging System-Infrared (THEMIS-IR), OMEGA, CRISM

[6] Mars Orbiter Laser Altimeter (MOLA), High Resolution Stereo Camera-Digital Terrain Models (HRSC-DTM)

[7] http://www.w3.org/

[8] http://www.w3.org/TR/xquery-use-cases/

source. To optimize the exchange and query again and binding the metadata directly into the database model, there is the possibility converting the XML document by *XML shredding*. Within this, the *XML* document will be converted into relational database tables storing metadata attributes in rows and columns. Arranging metadata in a way like this the user has subsequently the easy option to search mapping results by simple *SQL* statements.

### 3.3 Applicability of existing standards

Evaluating which standard is the best applicable one for the needs in planetary mapping description, we firstly determine if the standard entries cover all stated requirements. Further on, we assess the complexity of implementation syntax, availability (free of charge or fee required) and portability (between different user and GI systems). Thus, with respect to the introduced spatial metadata standards (cf. section 2.3), all recommended standards serve a uniform portability and simple implementation by XML encoded documents. However, at the current project status two standard documents are on the shortlist. On the on hand the *CSDGM* dealing with every metadata entry needed for map description and is widely used within GI systems already. On the other hand the *Dublin Core* with its 15 elements and the easy possibility of extension is an optimal basis for individual metadata description. Both standards are free of charge and available. Whereas, also the *ISO 19115:2003* is widely used as GIS metadata standard, it is excluded from the shortlist because there is no free of charge availability.

## 4. CONCLUSIONS AND FUTUREWORK

We elaborated the most important requirements for efficiently describing digital map results in the field of planetary science in terms of metadata information required for sustainable data use. In this context we focused on the scientific, and more specifically on geological and geomorphological maps designed to visualizing, e.g. scientific results and analyses in, e.g. a paper publication. With respect to these requirements we conclude with the following final statements

- The listed collection of requirements is the first step to obtain data sustainability by efficiently describing, managing and storing mapping data. It is aimed at serving as a framework for constructive and efficient implementation for a standalone metadata template on the desktop user-level as well, as for subsequent implementation into a more sophisticated mapping database model for planetary mapping currently under development (van Gasselt and Nass, in press).

- Usual GI systems provide sophisticated interfaces for standardized metadata description already. However, only with a task-targeted and focused description as presented by the requirements in this work it may serve as an user-friendly assisting application in the future, so that the user is not confronted with the awkward task of searching for relevant data-entries and explanations.

- The technical implementation and translation of each particular descriptive item is currently underway. Therefore, we will initially use a recommended metadata standard as basis and adapt relevant items to ensure an uniform and widely applicable way of spatial data description.

- At this moment either *CSDGM* or *Dublin Core* appear as most suitable standard variants for issues relevant in planetary mapping as they are both, free of charge and *XML*-encoded. Thus they are easily extensible and can seamlessly integrated within a GIS (only *CSDGM* is currently implemented).

- For portable metadata between different users and GI systems we work on generating a *XML*-structured document derived and translated from standard (obligatory) text fields already implemented in user interfaces. As such an XML document is not directly linked to the underlying database model (neither mapping results nor particular map object layers), it is envisaged to convert the *XML* document into hierarchical attribute values of database relations by *XML shredding*. This relational data structure also provides a convenient query option for the described mapping results as specified by simple *SQL* statements.

The metadata topic discussed herein is a first approach towards metadata standardization. It is part of ongoing work leading to an efficient and software-independent workflow with digital mapping results by describing GIS-based cartographic models in detail. As upcoming tasks we will focus on

- metadata specification and implementation tasks, i.e. the technical creation and translation of the metadata requirements by the most suitable standard and by using *XML*,

- accomplishing the technical implementation of the metadata template for use in GI systems by making use of graphical user interfaces (GUI),

- linking the *XML* metadata sheet into the above-mentioned database model by database *XML shredding.*

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