ONE GIS-BASED DATA STRUCTURE FOR GEOLOGICAL MAPPING USING 15 MAP SHEETS – DAWN AT CERES. A. Nass, and the Dawn Mapping Team
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Introduction: One aim of the NASA Dawn mission is to generate global geologic maps of the asteroid Vesta and the dwarf planet Ceres. To accomplish this, the Dawn Science Team followed the technical recommendations for cartographic basemap production, as outlined by [1]. The geological mapping campaign of Vesta was completed and published, e.g. [2], but mapping of the pwarf planet Ceres is still ongoing. The tiling schema for the geological mapping is the same for both planetary bodies and for Ceres it is divided into two parts described in [3]: four overview quadrangles (Survey Orbit, 415 m/pixel) and 15 more detailed quadrangles (High Altitude Mapping HAMO, 140 m/pixel). The first global geologic map was based on survey images (415 m/pixel) [4]. The combine 4 Survey quadrangles completed by HAMO data served as basis for generating a more detailed view of the geologic history and also for defining the chronostratigraphy and time scale of the dwarf planet [5]. The most detailed view can be expected within the 15 mapping quadrangles based on HAMO resolution and completed by the Low Altitude Mapping (LAMO) data with 35 m/pixel. For the interpretative mapping process of each quadrangle one responsible mapper was assigned.

Unifying the geological mapping of each quadrangle and bringing this together to regional and global valid statements is already a very time intensive task. However, another challenge that has to be accomplished is to consider how the 15 individual mappers can generate one homogenous GIS-based project (w.r.t. geometrical and visual character) thus produce a geologically-consistent final map. Our approach this challenge was already discussed for mapping of Vesta in [6]. To accommodate the map requirements regarding rules for data storage and database management (e.g., [7]), the computer-based GIS environment used for the interpretative mapping process must be designed in a way that it can be adjusted to the unique features of the individual investigation areas. Within this contribution the template will be presented that uses standards for digitizing, visualization, data merging and synchronization in the processes of interpretative mapping project. Following the new technological innovations within GIS software and the individual requirements for mapping Ceres, a template was developed based on the symbology and framework described in [8] and [9].

Environment and Data: The GIS environment is organized in a structure that allows preparation, analysis, storage, management, and visualization of spatial data. Once the final map products are finished, all datasets must be merged in ESRI's ArcGIS™.

Mapping template: The mapping template is based on the ArcGIS format file-geodatabase (FGDB). In the ArcMap environment of ArcGIS, the FGDB can be edited in three main layers: the *geologic mapping layer* (*gml*), the *map sheet layer* (*msl*), and the *basis data layer* (*bdl*). The *bdl* is generated as placeholder within a bottom-most layer which holds the map-projected images (raster format), upon which the geologic mapping is based on. Within the *msl*, the map graticules (10x10° and 30x30° grid) and the different quadrangle boundaries are included. The *gml,* or geologic mapping layer, contains the layers into which the geologic features of the surface of Ceres will be digitized. Thus, the Ceres *FGDB* includes:

- 5 *feature classes* representing specific types of geologic features as vectors: *PointFeature*, *LineFeature*, *GeoContact*, *SurfaceFeature* (thin deposits or surficial geomorphological objects), and basic *GeolUnits*.
- *Subtypes and Domains* are hierarchical, or domain-controlled, attributes that are coordinated within each *FC*. By this a thematic/genetic and predefined description of the objects is managed.
- *Cartographic symbols* follow the FGDC recommendation [10] as far as possible. For the implementation into ArcGIS, we used a predefined symbol set [8] that will be modified and expanded for the individual quadrangle mapping of Ceres.
- *Speciality:* the colors for the geological units were defined by individual needs and requests within the mapping team. The color choice was based on established color values used in former geologic maps, e.g., generated by USGS.

In addition to the GIS-based template the mappers are also supported by an instruction document. This document contains all necessary information about how to use, update and modify the *FGDB*. In order to ensure a uniform description across each of the individual map quadrangles, an additional metadata template was provided that is to be filled out by the mappers. This template uses standardized metadata keywords, e.g., defined in [11], and [12].

Beside the GIS-based mapping template also another template was generated which supports the mappers to arrange the different map components on a predefined map sheet. To achieve this the vectorbased graphic software *Illustrator* (by Adobe) was used. The mappers could use this template to easily import just the map content (export from ArcGIS), update the legend entries, and finally export it as an image for the supplemental material.

Current status and critical review: The scientific papers containing the geologic map quadrangles as supplemental material are either ready for submission or already under revision for a special *Icarus* issue. The current template has served as a necassary basis for the mappers to generate their individual but comparable maps, and thus gives the possibility to merge the 15 quads in the future to one global map. The current status and general information of the mapping project are summarized in [13]. Because the creation of the mapping template was and is an iterative process which is still in progress, there are still some topics (focus on GIS and cartographic visualization) to discuss on the way to a homogenous and comparable map layout. These are:

1) *Boundary regions*: Within the review process the mappers again should go in a strong discussion with all quad neighbors to enable a clear and consistent description of Ceres.

2) *Map scale and minimum object dimension*: Mapping scale and minimum dimension of the planetary objects have to be fixed during the mapping process and double checked during the review process. Otherwise the impression may arise that some regions are more detailed than others, where the differences are only a result of the different mapping techniques and style of the individual mapper.

3) *Boundaries of the quad maps as supplemental material*: The map boundaries defined by the HAMO atlas schema should be consistent for the supplemental material map sheets, independently of whether or not important objects are fully included. Otherwise it would lose the character of the schema which is established for giving a first fully covered and consistent description of the geologic/geomorphologic of Ceres – visual similar to the HAMO atlas [3] .

4) *Additional units and colors*: The color schema was generated by defining one color for each of the units expected by the mappers. These colors should be distinguishable on the map sheet but should still allow a visual affiliation or distinction of the units. Thus, it has to decided very carefully if additional colors for individual and regional phenomena should be used. The global color scheme will be updated if all geological units are clearly interpreted.

5) *Nomenclature*: Mappers should use the same font type, and font size (for labels and the different object types for areal, linaear and point features), as well as the same status of nomenclature which is approved by and available on the IAU page.

6) *Additional information on map sheet*: to support the general understanding of the map content it can be useful to position additional information (like DTMs, quad schema, or CoMU) on the map sheet. If so, this information should be included uniformly for all map sheets.

7) G*lobal relevant feature catalogue*: to describe the different units and features generically and visually it would be useful to combine an updated version of the already existing feature catalog (done by Katrin Krohn, DLR) and the generated map legend (applicable to all map quads). This will provide a first global overview of the objects and units identified on Ceres and could be used for more detailed investigation in the future.

8) *Transferable template*: Beside the proprietary usage within ArcGIS the current GIS-based template is also used in the open source software *QGIS*. However, this needed some additional adaptions that were done by the mapper Alessandro Frigeri (INAF). The template for the final graphical work was transferred into an open format **.svg*, so it could be used in every kind of graphic software, e.g., in *Inkscape*, and web-based environments. In the future the *FGDB* schema will also be made transferable to open-source database systems (e.g., *PostgreSQL*).

Conclusion: The template for (GIS-base) mapping presented here directly links the generically descriptive attributes of planetary objects to the predefined and standardized symbology in one data structure**.** Using this template the map results are more comparable and better controllable. Furthermore, merging and synchronization of the individual maps, map projects and sheets will be far more efficient. The template can be adapted to any other planetary body and or within future discovery missions (e.g., *Lucy* and *Psyche* which was selected to explore the early solar system by NASA) for generating reusable map results.

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