PHOBOS AND DEIMOS– A NEW MAP IN THE SERIES OF MULTILINGUAL RELIEF MAPS OF TERRESTRIAL PLANETS AND THEIR MOONS
(preliminary version)

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Within the scope of an international Russian-German-Canadian project under the guidance of the ICA Commission on Planetary Cartography a preliminary version of a Martian moons (Phobos and Deimos) Map was prepared. It belongs to a series of multilingual relief maps of terrestrial planets and their moons. The idea to compile such a series was first discussed by K. Shingareva and M. Buchroithner in Barcelona during the ICA Congress in 1995. The first official map of the series was presented at the ICA Congress in Ottawa, Canada, August 1999. Next was the Venus Map, (China, the ICA Conference in August 2001), and the Moon Map (Russia, the Intercarto-8 Conference, May 2002). The most recent contribution to this series was the Mercury Map, (the ICA Congress in Durban in August 2003).

Besides the shaded relief representation each map of this series included information about various parameters of the respective celestial body (astrophysical, geodetic etc.), a list of Latin terms for relief feature designation and another list of relevant space missions to the planet or to the planet's moon. This information is printed on the back side of the map in 5 languages, namely German, Russian, English, French and Spanish. The dimensions of the map sheet are the same for all of the map series. That is why the diameters of the map hemispheres are the same but the scales are different and given with approximation. In contrast to the other maps of this series Phobos and Deimos are each represented in two different projections, namely in the compound tri-axial ellipsoid projection and the morphographic projection. This unusual method of presentation is made possible by the relatively small dimensions of the Martian moons, and is made necessary by their distinctly irregular forms. In this case the morphographic projection gives us a visual impression of the real shape of a celestial body but the tri-axial ellipsoid projection is a more precise analytical representation.

1. Introduction

It is clear that mankind has some great achievements in space activities up to the beginning of the new millennium and it seems that these will continue. Evidence for this includes manned flights to the International Space Station and regular launches of automatic stations to Mars in spite of some failures, the successful exploration of the Saturn system, asteroids etc. Within the last few years it became quite clear that in the future more and more planetary lander and orbiter missions will be carried out. On the other hand, the average knowledge about the atmospheres, shapes and relief of the planets is still rather meager.

In order to supply the interested public as well as experts with information about extraterrestrial geography, and in particular the relief of celestial bodies, a new series of relief maps has been launched. Mars, Venus, Moon and Mercury Maps were published during the last five years and this series now continues with a new map of Phobos and Deimos.

The Mars Map demonstration at the 1999 ICA Conference in Ottawa made it clear that the international interest in such a map series certainly justifies its production efforts. We decided to go the same way by the compilation of the other maps in this series, namely at first to show preliminary version of Phobos and Deimos map during the 2005 La Coruna ICA Congress. This international Russian-German-Canadian project was developed under the guidance of the ICA Commission on Planetary Cartography. We expect to produce a map of increased quality after some discussion of the map contents during the Commission meeting at the Conference. We hope to be able to include additional information before we print the final version.

The “preprint” has a format of 55 cm x 84 cm, the maps themselves covering a printing area of 47 cm x 78 cm. In addition to the maps proper, collateral information concerning the map production is also printed under the maps in five languages. The color of the map fields proper is a bright dark brown and light grey, with all the lettering in black.

2. **Production basis**

At that time the project continued to develop on the base of close scientific cooperation between the Moscow State University for Geodesy and Cartography (MIIGAiK), Institute of Geography, Russian Academy of Science, the Institute for Cartography of the Dresden University of Technology (TUD) and University of Western Ontario (Canada). Since the main goal of the envisaged maps of this series was the high-accuracy depiction of its overall relief, we were looking for an adequate representation. A "classical" relief representation was chosen as was already used for the other maps/ 10 /. Original pencil-made manual hill-shading relief maps of Phobos and Deimos were prepared in MIIGAIK . They simulated

West illumination with an elevation angle equal/smaller 40^0. So far, this pencil drawing on film seems to be the most impressive depiction of geomorphologic features of the whole celestial body and relief features are perceivable quite clearly. Thus one can obtain a good impression of relief details of the Martian moons and, hence, simultaneously get an idea of their physiology as a whole. The overall quality, richness in detail and original size of the shading suggested final maps scales of about 1:200 000 and 1:150 000 correspondingly.

In contrast to the other celestial bodies of this series Phobos and Deimos are represented by two maps for each body in two different projections, namely in a compound tri-axial ellipsoid projection and a morphographic projection (showing the whole body as two hemispheres). This unusual method of presentation is explained by the relatively small dimensions of Mars moons and their distinctly irregular forms. In this case the morphographic projection gives us a visual impression of the real form of the celestial body but the tri-axial ellipsoid projection is a more precise analytical representation / 3, 5, 6, 7/.

However, it was not possible to use the existing Phobos map at once without some additional work. The original Phobos map was prepared for the "Atlas of Terrestrial Planets and their Moons" published in 1992 / 1 /. It needed to be revised according to the new coordinate catalogue. Then the new shaded drawing had to be done on this base.

The Deimos map must be compiled from the very beginning because it was not included in /1/. Very small celestial bodies which have too little mass to form spheres or rotation ellipsoids may have very irregular shapes. For these bodies a method of mapping / 5 / was proposed to build a model which is as close as possible to the real form of the body on the basis of an existing coordinate system with a large number of control points. Such a model was named a phoboid. The morphographic projection using an azimuthal projection with variable radii was developed for these cases.

The main peculiarity of this projection was that the map compiled in it represents the form of a celestial body very well. It is useful for small celestial bodies which have irregular forms and are not well known, but it does contain some distortions. The variable radii are calculated using a special method / 6 / for a sufficiently detailed cartographic net (as a rule in 5 degrees/ on the base of published coordinates of control points and existing images of some celestial body /2/.

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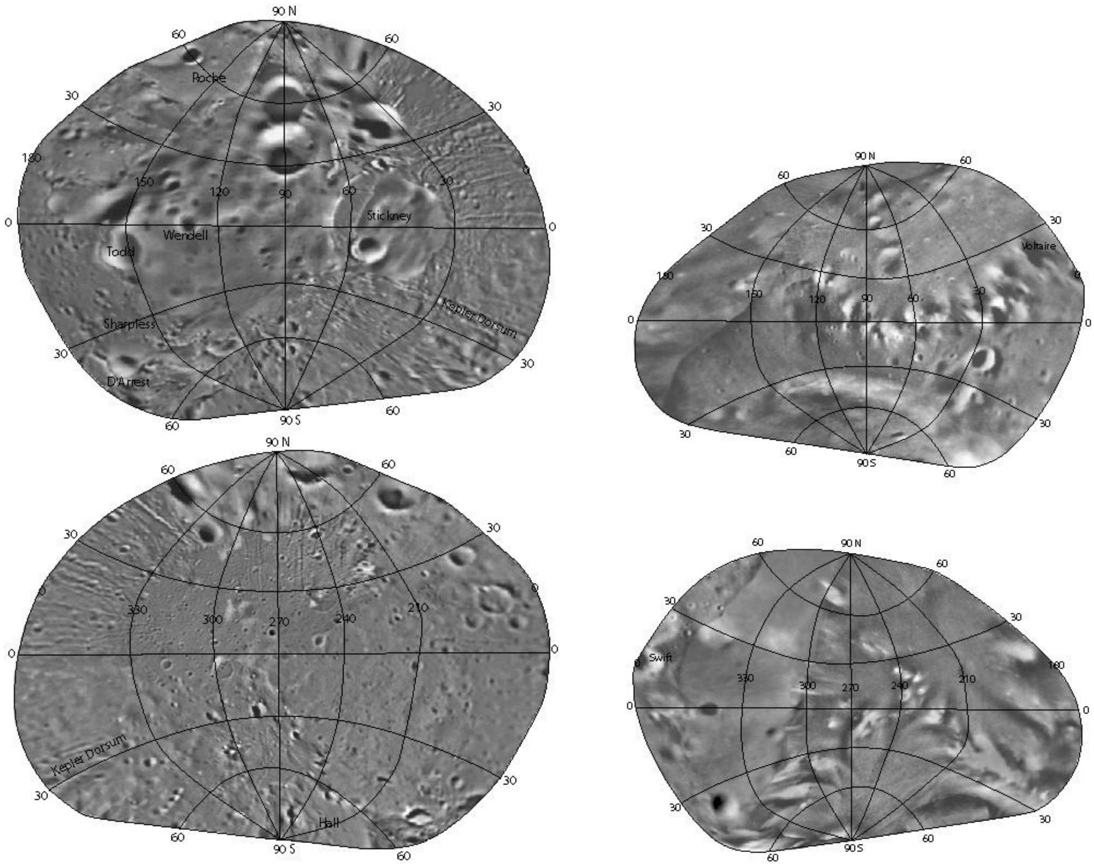


Fig. 1 a and b. Phobos and Deimos maps in morphographic projection.

However besides the morphographic projection's visual impression it is also useful to have a classical analytical representation of small irregular bodies. The compound projection of a triaxial ellipsoid was developed for this purpose./ 3, 4 / On fig.2 the cartographic grid in this projection for a Deimos map is represented (semi-axis are 7.5 km, 6.1 km, 5.2km) /9/.

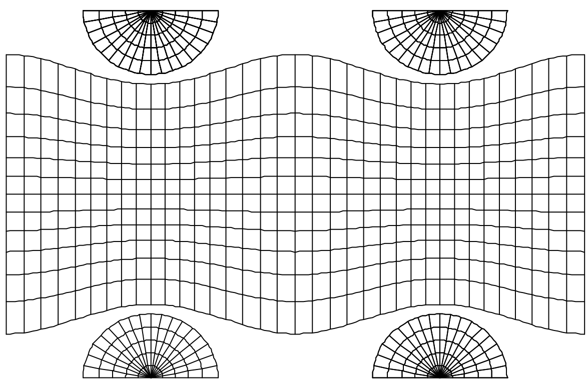


Fig 2 Map grid in a compound projection for Deimos

The image transformation from a morphographic projection into a given cartographic projection and back is performed by using cartographic grid knots as control points. On the Fig.3 there are given two versions of Deimos hemisphere, namely in morphographic projection (before transformation) and in compound triaxial ellipsoid projection (after transformation).

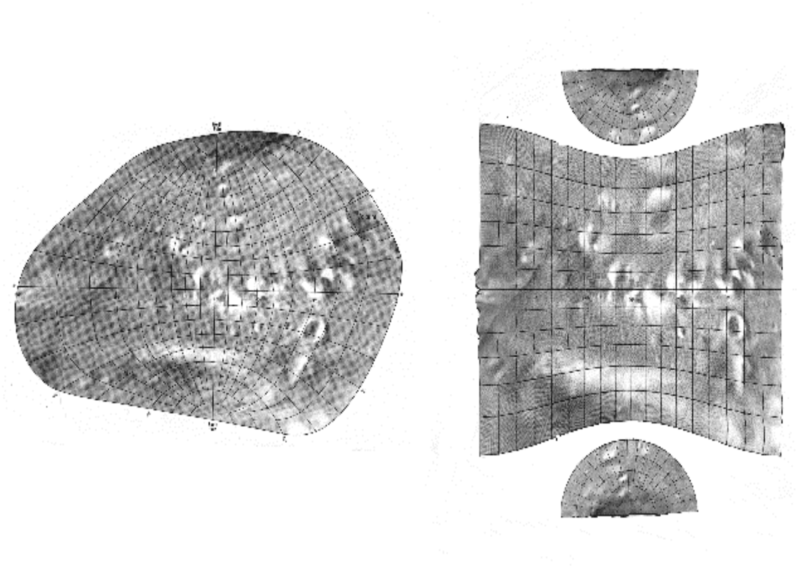
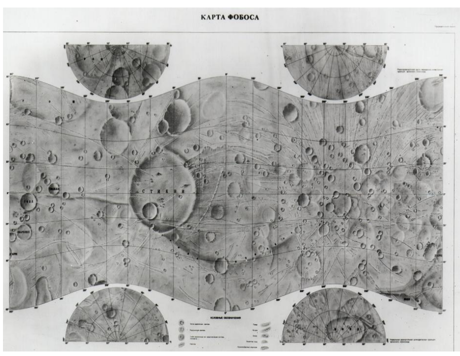


Fig.3 Deimos hemisphere before and after transformation

The transformation was made by using the local-affine transformation on cartographic grid knots in GeoGraph 2.0 program. 247 control points were used for transformation in the cylindrical projection and 192 control points for transformation in azimuthal projection. The primary control points were got directly from contact screen image and the final ones were calculated on the formulae of cylindrical and azimuthal projections. It is also possible to calculate the coordinates of final transformation points if we have the data about the variable radii. In this case it will perform the exact analytical calculation for coordinates of cartographic grid knots from one projection to another. The quality of images depends on the cartographic grid knots intervals or density.

In Fig. 4 and 5 are shown the Phobos and Deimos maps in compound projections for tri-axial ellipsoid (8, 9).



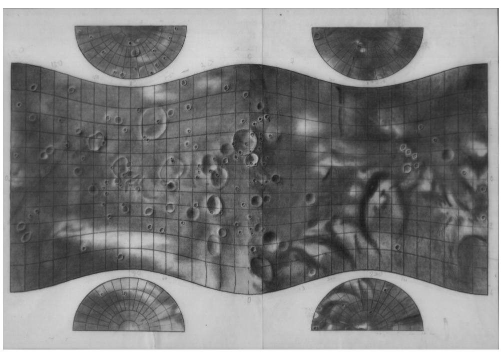


Fig.4 and 5 Phobos and Deimos maps in compound triaxial ellipsoid projection

3. **Map production**.

For the production process conventional reprographic methods were applied, using a repro screen of 54 points/cm for the relief shading original. A few attempts were made in order to optimize the reproduction of the relief representation, in particular to balance between the bright tones of the highlands and the darker tones of the lowlands.
The lettering is kept in black and displays different fonts: for craters 7 point Arial, capital letters; for mountain ranges 7 point Arial, italic, capital letters. Thus it gives explanations on all known and named geographic features. The type of lettering allows to deduce the geomorphologic categories.
For the printing three colors have been used. All lettering has been printed in black. The background of the whole map is kept in "night-blue", representing the darkness of the outer space and using special printing ink, the text is given in white color.
The printed area in the back amounts to 43 cm x 81.5 cm. This is the size of a frame which contains explanatory texts about the map and the Martian moons themselves.The front side includes collateral information about the map designer, printer, editor, cartographers and consultants.
The back displays geophysical information about Phobos and Deimos including density, reference datum, equatorial radii, volume, albedo, orbit inclination , rotation period, and more (Fig. 6).

Data on Phobos:
Mass: 1.08 x 10^{19} g**.**
Density: 2.0 g cm^{-3}.
Reference Datum: triaxial ellipsoid **Equatorial Radius:** **A:** 13.0 km; **B:** 10.7 km; polar **C:** 9.6 km.
Surface: 1 600 km^2. **Volume:** 5 800 km^3
Gravitational Acceleration: **at the Equator:** 0.5 m s^{-2}
Axial of rotation axis: 1,1°. **Orbit Inclination**: 1.02°. **Average orbital speed**: 2.14. km s^{-1}

Orbital Period: 0.32 days.
Rotation Period: 0.32 days

Albedo: 0.06.
Maximum Brigthness: 11.6 mag.

Data on Deimos:
Mass: 1.8 x 10^{18} g
Density: 1.7 g cm^{-3}

Reference Datum: triaxial ellipsoid
Equatorial Radius:
A 7.5 km; **B:** 6.0 km; polar **C:** 5.5 km
Surface : 500 km^2

Volume: 1000 km^3
Gravitational Acceleration
at the Equator: 0.028 m s^{-2}

Axial Inclination: 0.9 – 2.7^0
Orbit Inclination: 1.82^0
Average orbital speed: 1.47 km s^{-1}

Orbital Period: 1.26 days.
Rotation Period: 1.26 days.

Albedo: 0.07.
Maximum Brigthness: 12.7 mag.

Fig. 6. Geophysical background information about Phobos and Deimos.

Besides a list of imaging Phobos and Deimos probes (Figure 7), a complete glossary of their morphologic terms completes the backside information.

Mars Probes:
(having imaged Phobos)

1971 Mariner 9 (USA).
1975 Viking 1,2 (USA)
1988 Phobos 2 (USSR)
1998 MGS (USA)
2005 Mars Express (ESA)

(having imaged Deimos)

1971 - Mariner 9 (USA)
1975 - Viking 1,2 (USA)

Figure 7. Probes which have imaged Phobos and Deimos.

Basic Data:
The Phobos figure has been approximated by a triaxial ellipsoid. Geometric base is the Phobos Shaded Relief Map 1:200 000(Atlas of Terrestrial Planets and their Moons, MIIGAiK, 1992).

Relief Forms of Phobos:
Crater: round depression.
Dorsum (Plural Dorsa): elongate hill, mountain ridge.
Fossa: graben, long, flat and narrow depression.
Relief forms of Deimos
Crater: round depression

Fig. 8. Glossary of morphological terms occurring in the Phobos and Deimos maps.

All this information is given (from left to right) in English, German, French, Spanish and Russian (in cyrillic letters), each text block being printed in a light-grey, screened, elongate box of 14.6 cm x 39.8 cm.
The first edition of the multilingual Phobos and Deimos map amounts to 300 copies. Depending on the demand further print series will be produced.

4. **Concluding Remarks**

With all its features like easy-to-perceive relief representation, using two different projections, glossary of morphological terms, and its five-language multilingualism the described Phobos and Deimos maps are unique world-wide. The international sales and distribution are carried out by the Institute for Cartography of the Dresden University of Technology.

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