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EIGHTH INTERNATIONAL CARTOGRAPHIC CONFERENCE

USSR, MOSCOW, AUGUST, 1976

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By Prof. Dr. Sc. Volkov N. M., Prof. Dr. Sc. (Eng.) Bolshakov V. D.

THEMATIC MOON SURFACE CARTOGRAPHING BASED ON THE
SPACE PHOTOS

(The National Committee of Cartographers, USSR)

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THEMATIC MOON SURFACE CARTOGRAPHING BASED
ON THE SPACE PHOTOS

This paper deals with the problems of technology of compiling general purpose maps of the Moon surface during the spacecraft missions around the Moon. The paper is based on the materials obtained by means of an automatic interplanetary station (AIS) "Zond-6" that has flown around the Moon by the elliptical orbit and has returned to the Earth.

Direct cylindrical conformal projection was chosen for compiling the map. Two adjacent quadrangular maps in the 1:1 000 000 scale were plotted with the latitudinal size of the frames of 8° and the longitudinal - 12° each.

On the enlarged space images identified control points were obtained, their coordinates fixed, and the grid plotted.

Thus, there appeared the possibility to tie the Moon's photos covering the Moon surface to the cartographic grid in accordance with the sheet of the map.

These two sheets containing cartographic grids and the whole image tied to them proved to be the basis for map compilation. With this purpose they were photographed from the negatives and blue prints were made for cartocompiling.

Photo image of those blue prints proved to be of a rather high quality, which enabled to start with the plot-

ting the relief map of the Moon in the 1:1 000 000 scale. Such a scale, which is many times larger than that of the maps available, enabled us to enrich the content of the map in comparison with the maps existed at that time. We managed to create a special legend including a number of objects, not shown on the maps up to now and apply new methods for presenting its content.

The main method of the content presentation remained the same: shading based on the traditional method: the steeper the slope the darker the colour of the shade. Though this shading was possible to be added by hatching which enabled us to show sharp changes on rough surface of the ground such as : edges, axed of valleys, lines of bridges of mountains that is - all the elements of the relief having linear character.

By hachures we managed to show closed features of sharp breaking of the terrain, shorelines, closed hollows, lines of clearly distinguished mountain tops etc.

The attached legend enables to see the variety of relief elements shown by symbols, drafts of ordent features of the relief and different kinds of hachures to characterize the botton surface.

To represent linear character of the area three different colours are used: red (for young forms of the relief), green (for older ones) and black (for old, ancient). Besides the described above variant two more variants for each sheet of the map are presented.

In the "variant A" sheet the relief of the Moon surface without any additional characteristics is given by means of shading. In the "variant B" sheet an attempt is made to characterize the surface relief by means of grey shading, but not by means of colour shading of the given plot of the Moon surface and its formations. This attempt is also made to show the features of middle age by blue colour and more younger by red.

There were given no other additional characteristics in this variant.

The map compiled may be used as a basis for compiling special maps.

Technology of compiling the maps of the Moon
based on the materials of "Zond-6" and "Zond-8"

AIS "Zond-6", "Zond-7" and "Zond-8" have taken the photographs for the first time and delivered them directly to the Earth. In spite of the comparatively small scale of photographing the photographs show high quality and allow considerable enlargement. It gave the possibility of compiling maps of such large scales as 1:2 000 000 and 1:1 000 000 comparing with the scale of taken photographs.

Large overlaps of photos in strips admit their stereoscopic examination, which provides high quality interpretation of their content. These factors give opportunity both

to enrich the content of maps and to use such methods which had never been used before. The main method of surface relief representation by hill shading is added by hachuring characterizing the degree of relief forms destruction, steepness and step-shaped slopes, the structure of the surface, etc. Apart from that hachuring gives the opportunity to show small relief forms on a map as well as to single out surface plots with a lot of homogeneous objects, which cannot be expressed only by symbols, such as knobby surface etc.

The examination of the Moon surface using these photos gave us the opportunity to come to the conclusion concerning the age of relief forms by such factors as the degree of their destruction, the sequence of shape formation and so on. As a result we received the possibility to characterize indirectly the age of the relief surface of the Moon.

A lot of information obtained from the photographs makes it difficult to show it on one map. And as a result it became necessary to compile some maps representing each of cartographed plots. With this aim in view let's examine each of the strips and the corresponding photos.

"Zond-6" took photographs of the Moon at 2 seances. At the first of them photographing was made from a considerable distance and so the photographs include almost the full disk of the Moon. Consequently almost half of the visible hemisphere of the Moon (the Western part of it) and the Eastern half of its invisible hemisphere were seen

on these photos. It gives the possibility to transfer the coordinates of points from the visible hemisphere to the invisible one.

The photos of the second seance cover a part of the equatorial band of the invisible hemisphere of the Moon and allow us to transfer the coordinates from the visible side to the invisible one and to create the map grids on the basis of the second seance photographs. Using them we are able to assemble a mosaic for a part of the equatorial zone of the invisible hemisphere of the Moon.

"Zond-7" delivered some photographs of the Moon surface band lying along the 90^{th} meridian, the terminator being near it ("Zond-7") at the moment of exposure. This band is stretched within the limits of -20° $+60^{\circ}$ in latitude, and is several hundred kilometers wide. This information may be used for the Moon cartographing before we get some other materials concerning this region.

"Zond-8" took the Moon photographs from the distance about 11 000 km. while approaching it. The set of these photographs includes the disk of the Moon within the limits of about 30° - 187° of Western longitude, so involving both some part of the visible side of the Moon and a considerable part of the invisible side of it.

"Zond-8" transmitted some photographs of the Eastern part of the Southern hemisphere of the invisible side. This mission beginning at the edge of the invisible side of the

Moon stretched up to the Meridian with the latitude of 166° of eastern latitude in the form of strip going South from the equator and gradually approaching it.

Let's examine in details the map of 1:2 000 000 compiled on the basis of the materials of "Zond-8".

At the first seance of photographing the Moon from "Zond-6" at the distance of about 900 km some small-scale photos including almost half of its visible surface alongside with its invisible from the Earth part of the Moon were obtained. At the second seance some photos of the dark side of the Moon in larger scales were obtained. Using the photos of the second seance a sheet of map of 1:2 000 000 was compiled. For connecting the photos of the second seance photo N^o 12 of the first seance was used. Photo N^o 12 map grid in the outer geometrical projection with the positive image was calculated on the coordinates of points N (nadir point and optical center) and terrain clearance H. For orienting the map grid in photo N^o 12 twelve points, whose coordinates were known from the catalogue GA USSR, were identified. These coordinates were recalculated into the same cartographical projection of photo N^o 12.

Photo N^o 106 of the second seance was chosen as the main photo for the map being compiled since it was in the projection of this photo that the greater part of a compiled map sheet was represented. Making use of the nadir point coordinates and the optical center of this photo there was calculated the

cosmic projection of photo N° I06 onto the whole area $\pm 20^{\circ}$ in latitude and from 200° - 270° in longitude i.e. onto the whole area covered by the photos of the second seance at a general scale.

The subsequent work was in transformation of the second seance photos into this grid with the help of FTB from negatives according to check points. The general map scale of 1:2 000 000 is kept at the nadir point with coordinates = $\pm 8^{\circ}39'02''$ and $200^{\circ}21'19''$.

The main purposes of map compiling are the following. The prominent relief features such as circuses, craters or central heills, mountain ridges, mountain valleys are shown by shading. Characteristic relief features of the Moon surface structure should also be shown by shading. They are the step-shaped mountain slopes, craters, circuses, sea shore slopes, the destruction of crests and their slopes, variations in slope steepness, their breaking, swell divisibility and cracks intersecting them. Shading must expose ridge location of craters, marine faults, swells, mountain ravines forms, splits and so on.

Hachure conventional signs are meant for making out sections with various relief structure with great amount of small-size relief forms whose representation by separate signs is difficult on a given scale map and is conjugeted with its overloading and reading deterioration.

On the other hand hachure conventional signs are meant to show the plots of homogenous relief structure of great area in which there may be met objects requiring representation or shading without their marking out according to the contour points which are used for contour singling out with different content.

Four different variants of the map scale of 1:2 000 000 for the part of equatorial zone of the Moon invisible hemisphere were compiled.

Variant A-basic, contains the Moon relief characteristics reproduced by shading, shading character represents slopes structures, their steepness degree, their divisibility, splits intersecting them, most distinctly visible and so on. Relief forms destruction degree and to a certain extent formation succession is shown by shading.

Variant B. Moon structure morphological map made in hachure conventional sign system is represented on the variant B. When singling out the Moon relief forms it was decided to subdivide them according to age characteristics. Three age stages are chosen lower (most ancient) middle, upper.

Variant C. There is an age characteristic of the Moon surface relief on the variant B made by means of colour shading. According to age forms and elements are subdivided into three systems, the same case being in the variant B. The lower system is shown by shading in grey-brown colours, being the

common base, overlapping by shading in such colours that correspond to the middle and upper system relief forms. The lower system elements are characterized by extensive destruction and overlapping them by the forms of the younger systems.

Middle system structures and forms representation is made by additional shading in blue colours. All elements of this system are characterized by less destruction and smoothness. They are often located on the lower system destructed elements but they also happened to be overlapped by the upper system forms.

Good preservation and distinct representation in the Moon relief surface, increasing from the ancient complex to the newest one is common for upper system forms and structures. A violet colour of shading is used for showing upper system elements.

Variant D has the nature of a topographic map, containing besides relief shown by shading the Moon surface characteristic expressed by hachure conventional signs.

Objects, characterizing relief are both separate relief forms and separate objects of considerable size not requiring shading for their representation, but hachuring or combining numerous homogenous objects of small size on great areas, requiring common contour characteristic.

All the objects which are to be represented by hachure symbols on this map are divided into three groups: area objects, linear objects and point objects.

1:1 000 000 scale map, compiled on the
"Zond-8" data

1:1 000 000 scale may be used for this map sheets because of photograph scale and their quality.

Further development of using on the map of 1:2 000 000 scale representation of not only relief but also topographic and age surface characteristics- its morpho-structure - is possible in this case.

Straight conform cylindrical sphere projection (Mercator projection) having uniform scale of 1:1 000 000 on the equator is adopted for this map sheets.

For each of these map sheets of this scale three variants are made.

Variant A contains the characteristics of the surface relief, shown by means of shading. The shading was carried out by eastern light and with small altitudes of the Sun above the horizon. On the western side of sheet N 1 the altitude of the Sun at the moment of photographing equals 6° and increasing gradually reaches at the border meridian of sheet N 2 - 30° . Small altitudes of the Sun result in deep long shadows which in western parts of sheet N 1 hide the largest part of the bottoms of craters causing unpenetrating incident and proper shadows. This factor deprives us of the possibility to identify these surfaces, that is why they are shown by general shading without outlining any relief features and while editing they are covered with li-

thographic grids.

The content of variant A shows the relief of the mapped locality. The means of its depicting is shading intensified at some spots by "strikes". The nature of shading conveys the construction (the stages of the construction) of slopes, the degree of their steepness, their breaking up, their clearly shown intersecting cracks, etc. The degree to which the relief forms are destroyed and to some extent the succession of shape-forming is shown by means of shading.

Variant B also shows the relief of the Moon surface by means of shading, and additionally by hachures for the characteristics of the surface. The general purpose of these hachures is to characterise the objects from the point of view of their qualitative properties as well as from the point of view of their age. On the other hand hachures are meant to convey the structure of the surface, formed by numerous homogeneous objects and urging general contour characteristics. Such homogeneous plots of the surface are contoured with dotted lines. Such plots may both be placed between the craters and comprise craters shown by means of shading, as well as be located inside craters, etc. As compared to the map of the scale 1:2 000 000 such a method is greatly enriched. The hachures of the map content, depending on the age of the objects, are of three different colours; morphostructures and morphosculptures are painted black; the

less worked out morphostructures and morphosculptures of the mid-system are painted green; forms and elements of the upper system are painted red.

Contours conventional signs are widely used in the map of the scale 1:1 000 000, where their number reaches 9 (on the map of the scale 1:2 000 000 they are only three).

The pictures of hachure representation of morphostructures and morphosculptures are the same in all the sheets. As to the differences inside the systems, dotted lines are applied for earlier subsystems, interrupted lines are applied for mid-systems and continuous lines are applied for later systems. The age distinctions are shown by the colours of these lines respectively.

There are great difficulties in the attempts to classify the spots according to certain combinations of features. The quality of pictures, their scale, the quality of photographs, the possibility of applying of stereoinstruments, etc. are of great significance. The lightning of the Moon surface at the moment of photographing (the angle of incidence of the Sun rays) is of great importance.

Let's return to the technology of compiling these maps. This technology was as follows, though there is some difference in the details with reference to different sheets.

The photographing from each AIS was carried out in several seances at different distances to the Moon. The photos of the first seance were of a smaller scale and covered great parts of the Moon surface including the parts of both

visible and invisible hemispheres. This provided the possibility to construct on such photos a universal cartographic grid of lines of meridians and parallels for the whole region of survey and to determine the selenographic coordinates of points of the Moon surface according to this grid.

To connect the photos of the first and of the second seances it was necessary to determine from these grids the coordinates of nadir and optical centre in these photos and to calculate according to them the cartographic grids for each of the photos and to construct these grids on them.

The further work consisted in transforming and assembling these grids into the projection of the compiled map, making use of available both in the photos and on the base of identical cartographic grids.

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