Preface

The stages of development of the theory and practice of lunar and planetary cartography in Russia have been directly related to the progress in the field of space research beginning in the second half of the twentieth century. Various overview maps of the lunar nearside were compiled in the pre-space era, generally containing information on the geological structure of the lunar surface, primarily as preparatory material for site selection for detailed research using spacecraft.

Work on the compilation of lunar maps in Russia began in earnest after the successful execution of the epochal space experiment to photograph the farside of the Moon. We may recall that the work on the first maps to include the lunar farside as well as the first globes was considered not only a highly important scientific achievement but also a project of national significance proceeding on the basis of governmental decisions allocating significant funding.

The greatest specialists of the time participated in the technical implementation of the project to photograph the lunar farside. Chief Designer Sergei Pavlovich Korolev led the development of the rocket launcher systems. The complex trajectories of lunar flyby with later returns to Earth were elaborated in a team headed by the leading scientist of the field, Boris Viktorovich Rauschenbach.

On the recommendation of the world-famous astrophysicist, Iosif Shklovsky, the cartographic processing and subsequent image analysis was assigned to a leading scientist of the Sternberg Astronomical Institute (GAISh), Yury Naumovich Lipsky. It is worth noting that Shklovsky's group were among the first astronomers to be included in the development of experiments in space. They developed and realised the "artificial comet" experiment, which gave rise to the technique of determining a spacecraft trajectory by observing its position close to the Moon. Before this, *Luna 1*, which was supposed to have impacted the western region of the lunar surface, passed by the Moon at over 6000 km from the surface, lacking the ability to make a trajectory correction. Having the "artificial comet" experiment on board *Luna 2* ensured an accurate impact into the Moon. The radio tracking techniques used today had not, at that time, reached the necessary levels of precision.

The compilation of the first map of the lunar farside required the solution of new technical problems: the construction, for example, of a new cartographic projection and the determination of selenographic coordinates of many features within a territory which was previously unknown. A partial solution to the problem was inherent in the parameters of the experiment (see Chap. 1). The flight path of *Luna 3* was designed so that not the whole of the far hemisphere was visible from the point of observation, leaving a part of the image covering the eastern edge zone of the Moon. This allowed the coordinate system of known features to be extended into the previously unseen area. At the same time, the observation point was chosen to be able to cover as much as possible of the farside.

This last requirement included an insoluble contradiction. Astronomers knew that the unique reflective properties of the lunar surface were such that the maximum of the reflected light is returned in the direction of the source. In this case, the so-called full-Moon effect occurs, when shadows cast by any relief disappear, and the resulting image becomes "blind": it is possible only to see variations in surface albedo—the reflective characteristic of surface features. The experiment designers' desire to encompass as much territory as possible in their first photographs of the farside resulted in the majority of the image having full-Moon conditions. Lipsky and his group encountered difficulties in the identification of known structures. Despite the use of specially developed enhancement procedures, enabling them to find many dozens of craters, not all of these were re-identified in later images with different illumination conditions.

Chapter 1 shows several variants of the processing of the first images from the farside of the Moon, with detailed analysis of each one.

Nevertheless, the first experience of space photography of the Earth's satellite was recognised as a success, and a government decision was taken to carry out a global survey of the lunar surface with a new space experiment. Six years later, in 1965, *Zond 3* made a new flight around the Moon, sending back images of practically the whole of the lunar globe.

In Chap. 2, we examine the preparation of several editions of a *Complete Map of the Moon* and complete lunar globes: the results of the global survey. At this point of development of Soviet lunar cartography, the astronomers were joined by professional cartographers, in particular from the USSR Topogeodesic Service, bringing their decades of experience of working with cartographic images of the natural surface of the Earth.

In Chap. 3, covering the cartography of the lunar nearside, it is worth noting in particular the description of the large-scale maps of the equatorial zone. This edition, aside from its scientific value, was widely utilised for engineering applications, particularly as an information source for the selection of landing sites for both unmanned and manned spacecraft.

With respect to Chap. 4, it may be noted that in Earth cartography, the fraction of thematic and complex atlas material makes up about 80 % of published material. The experience of compilation of maps for the Earth shows that the cartographic modelling of the diverse natural properties of the environment is an essential element of studying and understanding them. This experience is fully applicable to the study of the nature of planets and satellites in the Solar System. At present, thematic lunar cartography is the most developed among these. Selenographic, gravimetric, hypsometric, structural and morphological, spectral, polarimetric and other types of thematic cartography reflect the characteristics of the nature and structure of the lunar surface. At the same time, the cartographic method of research permits the study of processes of evolution of particular structures and reveals the spatial relationships between the structures and the phenomena which produce them.

As for other fields of cartography, lunar thematic cartography achieved its greatest development simultaneously with the development of the corresponding space technologies. The source of information for the various maps is primarily remote sensing by spacecraft instruments. Spacecraft observations can utilise the entire range of natural and reflected radiation of the Moon. Gamma ray emission, for example, of lunar surface rocks provides data on the presence of natural radioactive elements: potassium, thorium and uranium. Measurement of the x-ray fluorescence of the lunar soil allows the determination of the content of magnesium, aluminium and silicon. Images of solar light in the visible range reflected from the surface are a universal method. These data are used to construct photometric, brightness, polarisation and zoned spectral maps of the surface, which themselves give information about features of the chemical composition and mechanical properties of the surface layer of lunar regolith. Today it is evident that thematic cartography of the Moon and planets needs to be carried out by a large group of specialists in a coordinated programme, to result in a series of maps and atlases offering a complete characterisation of an integrated group of phenomena.

An essential part of the information content of a map consists of the individual names of surface features, which enable both the search for and reference to particular structures. Each name is a short code for a feature's location, characterising its structure, while also attaching a cultural or historical meaning. The toponomy of the Moon has the longest history among extraterrestrial bodies and is employed in Chap. 5 as an example to trace the development of a planetary toponomy and the typical problems which are encountered in naming planetary surface features.

In recent times, not only the Moon but many other bodies of the Solar System have been intensively studied using spacecraft. In Russian lunar and planetary cartography, it has been Mars, with its satellites, and Venus where the most development has occurred in the production of maps, globes and atlases. Besides general geographical maps for these bodies, geomorphological and tectonic maps were also produced. The source materials for the products were the data returned by spacecraft. In the last 30 years, five interplanetary spacecraft were sent to Venus by different national space agencies, while, at the same time, 20 spacecraft of various countries visited Mars and its satellites. The preparation of cartographic products needed to bring together specialists from various fields. As well as the astronomers from the Sternberg Astronomical Institute involved in the thematic mapping of planets and moons, there were also cartographers, geologists and geochemists from various academy, university and specialised Russian organisations. These cartographic materials and various particulars of their production are described in Chaps. 6 and 7.

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