T V Vereshchaka

TOPOGRAPHIC MAPS

The Scientific Principles of their Content

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This book considers the content of topographic maps in theoretical and practical terms. It traces the stages in the development of topographic cartography in Russia, describes the characteristics of foreign maps and offers valuable expertise in making the best mapping products. It considers ways of improving maps and formulates a conceptual model of their content for topographic information organised on a systems basis, including digital data holdings and geographic information systems. It examines the mapping of areas of water, as well as specialized types of map.

The book is designed for cartographers, geographers and those involved in making topographic and geodetic products, as well as for undergraduates and research students.

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SPECIALIZED TOPOGRAPHIC MAPS

INTRODUCTION

The state of topographic mapping of Russia has always reflected the degree of knowledge of the country and the level of progress in science and culture.

In the course of its existence Russia's state geodetic and cartographic service has carried out an enormous amount of survey work and produced major maps which have played an important role in the various stages of the nation's development. The country is now fully covered by topographic maps on scales from 1:25,000 to 1:100,000, while some 30% of its area is covered by maps on a scale of 1:10,000. Cities, towns, other built-up areas and industrial zones are mapped at 1:5000 and 1:2000 and sometimes on larger scales. Topographic and geodetic products over a wide range of scales are used in virtually all sectors of the economy.

Maps and plans on a scale of 1:10,000 and above are essential for the project survey operations associated with terrestrial and marine geological exploration and the activities of extractive enterprises in the coal, metallurgical, oil, gas and chemical industries. They are equally essential for the usage and registration of land, the construction of hydrotechnical installations, housing and industrial facilities, the laying of underground services, and the compilation of various types of cadastre – urban, land, water etc.

Maps on scales from 1:25,000 to 1:100,000 meet the cartographic needs of larger regions. The first topographic map covering the whole country was a 1:100,000 map, which played a particularly important role in the taming of the North and Siberia. 1988 saw the completion of a 1:25,000 national topographic map covering the entire territory of the former USSR.[1] The 300,000 sheets of the map contain unique information and are of great social, economic, scientific, engineering, cultural and historical importance. Demand for these maps is constantly increasing.

The compilation of topographic maps is an essential prerequisite for the development of the country's productive forces and the consolidation of its defence capability. Major construction projects and industrial and agricultural complexes generally require a comprehensive cartographic underpinning. The areas affected by the construction of the Baikal-Amur Railway provide a graphic example. These were surveyed on a scale of first 1:100,000 and then 1:25,000. The results were employed for planning the railway and selecting the final route (some 420,000 printed sheets were issued to the design organisations). Special highly accurate geodetic networks were developed, 1:10,000 photographic maps produced and large-scale (1:5000 – 1:500) surveys carried out for the construction of the engineering installations and services of the North Muysk and Baikal tunnels. Another example is the geological and geophysical investigation and exploration of mineral resources in ice-free land areas of Antarctica, which also required a coordinated aerial photography, astro-geodetic and topographic effort.

Even though the entire country is covered by a 1:25,000 map, the 1:100,000 map remains important, especially for the preparation of new editions of overview topographic maps. It is well known that topographic maps over the entire range of scales facilitate general geographic, thematic and integrated mapping.

Topographic maps are a source of diverse spatial and temporal information, incorporating remote sensing data, statistics and a multiplicity of details of natural and social/economic features. Thanks to the high accuracy of the plan and height data on which the maps are based, features can be assessed in terms of a wide range of attributes: location (coordinates), dimensions (length, area, volume, height, depth), orientation (aspect, slope),

[1] Surveying for this began in 1946.

shape (general outlines, elongation, sinuosity, curve), density (thickness, concentration), and surface dissection (general, vertical, horizontal). These metric characteristics are intimately associated with the genetic and dynamic characteristics that determine the way in which geographic systems develop. Natural-territorial systems are represented on topographic maps at various scales; and depending on the territorial scope, level of detail and purpose, investigations can be carried out at different levels corresponding to given map scales (or groups of scales).

Maps enable us to make judgements about the environment-shaping, environment-protecting, resource and recreational functions of nature from edificatory features and structures, distribution and linear transport barriers (orographic and hydrographic), plant communities and the disturbance to these that are shown. The interplay of these features determines local climate, drainage patterns, the circulation of air masses, migratory processes, geodynamic activity, and ecologically aggressive effects arising from human activity. The set of natural and social/economic features depicted highlights patterns of land use and the traditional and historical ways in which resources have been managed. Topographic maps enable characteristics (morphometry, woodedness, swampiness, degree of karst formation) to be derived for various fields of research. Targeted analysis of maps on different scales brings out the typological features of nature and the level of economic organisation, and enables identification of structures and systems at various levels (local, regional, federal and global) that are arranged hierarchically and incorporated in one another, thereby permitting theoretical generalizations and conclusions.

The extensive scope for the use of topographic maps necessitates research into their content and information value. As long ago as 1916 V I Vernadskiy, in a paper to the General Meeting of the Academy of Sciences on the organisation of topographic surveys in Russia, stressed that a correct, accurate map of the whole country was urgently required for the most important tasks, whether practical (relating to national needs or everyday amenities) or of a purely scientific character. Then in the 1920s F N Krasovskiy and A A Borzov raised the issue of representing reality properly and correctly conveying the interrelations between natural and social/economic features on topographic maps. It was then that the terms “geographic conformity” and “geographic faithfulness” began to be used to give a broader definition of the correctness of maps, in terms not only of their geometric accuracy, but also of the comprehensiveness and objectivity of their content. These issues were dealt with in publications by S P Al’ter, Ye I Ardab’yeva, L I Bogomolov, M K Bocharov, A S Vasmut, N M Volkov, R I Vol’pe, L M Gol’dman, Ye I Yefimenko, I P Zarutskaya, E Imhof, A M Komkov, V M Lozinova, N I Lyubvin, S A Nikolayev, N S Podobedov, Ye M Pospelov, A I Preobrazhenskiy, A B Rogov, L Ye Smirnov, A I Spiridonov, Yu V Fillipov and many other Soviet and foreign scholars. Research continued actively into the 1980s, as was shown by the issuing of new editions of tables of symbols.

The USSR’s unified cartographic and geodesic service ceased to exist on 1 January 1992 and the new mapping tasks dictated by the political and economic development of the country became the responsibility of Russian state cartography. Many important new fields emerged for the use of maps. Topographic and geodetic underpinning was required for the delimitation, demarcation and validation of the national border and of the boundaries of constituent regions of the Federation within the country. There was a growing need for prompt information to facilitate administration and planning, the reshaping of economic relations, forms of ownership and property laws, land reform, environmental problems (including emergencies), the recording and monitoring of the natural resources and ecological potential of different areas, the analysis of labour resources and population movements, and so on.

The informatization of society in these areas is occurring against the background of the adoption of modern IT in cartography, with the development of digital and electronic

maps, federal and regional cartographic data banks, and geographic information systems (GIS). Federal and regional geographic information scientific-production centres have been established in Moscow, St Petersburg, Yekaterinburg, Novosibirsk and Khabarovsk. Topographic maps, as the basic maps of the country and documents for multiple uses, also provide the basis or main component for the formation of data banks and geographic information systems.

The bodies of information that are being established should take account of the needs of the largest possible number of users, including cartographers themselves for the creation of new maps or the updating of traditional maps. Research into the information content and improvement of maps is vital for cartography, for the earth and social sciences, for the various sectors of the economy and for the country's defence.

The development of geographic information infrastructure and the conversion of the vast holdings of topographic and geodetic information into digital form require a common methodological basis for the classification, encoding and presentation structure of information. This applies equally to the content of maps, the documents which regulate them, and the language used in maps.

In the present book the evaluation of the content of maps is based on a geographic systems approach. This is perhaps the first publication to consider the improvement of the representation in topographic maps not of individual content elements, but of the entire set of natural and social/economic features across a wide range of maps for different purposes, with due regard to key current areas of diverse use. From the outset the study is grounded in the concept of building a classification for mapping objects based on a scientific geographic approach and in the development on that foundation of a content model which ensures a scientific basis for content and a systems organisation for holdings of topographic information.

The book examines the content of topographic maps in terms of theory and methodology, as well as in its practical aspects.

Chapter 1 considers topographic maps of Russia and foreign countries, dynamics and trends in topographic mapping, and the general classification of topographic maps and plans. The object of this part of the book is to analyse the valuable experience embodied in the best cartographic products, which have played a role in improving maps, and the preconditions for the creation of these products. The periods associated with major changes in the content of Russian maps are identified, and areas of progress are formulated. The distinctive features of foreign maps are discussed in terms of a set of basic parameters: depth of topographic study, cartographic services, mathematical basis, and content.

Chapter 2 sets out the theoretical principles regarding the content of general-purpose topographic maps. It characterises the type of the topographic map as it has developed historically, analyses the current set of conventional symbols, and gives an account of the essence of the systems approach, how it manifests itself in topographic mapping. and its relevance to the improvement of maps.

For the first time ever definitions are offered for the basic concepts relating to the type and content of maps, together with a model and a conceptual structure for the content of maps devised by the author.

Reasoned proposals are made, component by component, for improving the way in which features are represented. The theoretical argument is accompanied by practical solutions for the representation of natural and social/economic features by a recommended set of symbols.

Next come chapters dealing with the topographic mapping of water areas and specialized topographic maps. Chapter 3 examines the topographic mapping of water areas (marine shelves and inland bodies of water) with a view to the presentation on maps of an integrated picture of dry land and the bed of water areas as genetically interrelated parts. Based on an analysis of topographic maps, topographic bathymetric charts and marine navigation charts, both Russian and foreign, together with a purposeful examination of the relevant genetic classifications, a system is proposed for the integrated representation of the bottom relief, sediments, flora and fauna and water properties and dynamics of the mapped water area, as well as a programme for its textual geographic characterization on the sheet or set of sheets. The desirability of devising a separate set of symbols for maps of this type is discussed.

Chapter 4 considers the grounds for dividing topographic maps into basic and specialized maps with a view to centralizing and regulating topographic surveys in order to satisfy the requirements of the economy for cartographic products that meet the needs of specific sectors in terms of content, accuracy and format. A number of theoretical principles are covered with regard to this subject: the definition of the term “specialized map”, ways in which content can be specialized and within what limits, and the classification of maps. The relevance of specialized maps for the improvement of general-purpose maps is examined. A reasoned description is given of the type of the specialized map for a specific purpose.

The Conclusion looks at possible ways of making practical use of the studies and research that have been carried out.

The monograph distils the results of many years of scientific research and practical activity by the author in surveying for, compiling, updating and editing maps of various scales and types in various parts of the country, including ground and aerial visual field surveying.

I am grateful to the teaching staff of Moscow State University of Geodesy and Cartography and to specialists at other scientific and production organisations for contributing to the discussion of various aspects of the book at seminars, meetings and conferences arranged by the Geographic Society.

I feel the deepest gratitude towards the late Professor Irina Pavlovna Zarutskaya, my teacher and an outstanding scholar and practical cartographer. I am also indebted to Ye K Khlyapova and V P Polishchuk for additional material, to my colleagues and pupils Ye V Baranova, O V Kovaleva, I Ye Kurbatova, O V Sakovnina and O A Tertyshnikova, and to Yu V Khmel’shchikov for assistance in preparing the manuscript.

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Chapter 1

RUSSIAN AND FOREIGN TOPOGRAPHIC MAPS

1.1. PRINCIPAL STAGES AND TRENDS OF DEVELOPMENT OF TOPOGRAPHIC CARTOGRAPHY IN RUSSIA. COMPILATION OF THE BASIC SET OF STATE TOPOGRAPHIC MAPS.

The outline of the development of topographic cartography given in this chapter is based on historical studies by P A Denzin (1909), A V Postnikov (1989, 1996), K A Salishchev (1944, 1948), A N Baranov, M K Kudryavtsev (1967), S G Sudakov (1967), A M Komkov (1967), S A Nikolayev (1970) and many other authors, as well as works published by the USSR Main Directorate for Geodesy and Cartography to mark major anniversaries, and instructions, manuals, and tables of symbols published at various dates [101, 134, 138, 167, 192, 208, 227, 228, 235-240, 244, 259, 271-273, 280, 298, 313, 331-338]. The object of this part of the book is not to present new historical research, but to analyse the valuable experience embodied in the making of the best maps, Russian and foreign, which played a role in advancing mapping and consider the conditions that were necessary for their creation. Many documents and maps that have long since become obsolete in terms of their content are of interest as the immediate ancestors of modern topographic maps. The best of them are distinguished by great expressiveness in the way they represent terrain, an expressiveness which was lost in many sheets in subsequent surveys.

Topographic mapping developed hand in hand with the practical activities of people in concrete historical circumstances. Major changes in its pace and level of development were associated with the provision of maps not only to the civilian, but the military departments of state.

From the outset Russian cartography followed a distinctive path. It has long been distinguished by the "field" nature of its initial data, collected by direct terrain description, and by the state-orientated nature of cartographic activity.

The first Russian listings and drawings by government servants who had the skills to observe, note, and convey realistically the results of their observations related predominantly to routes between places. They were collected in government offices and often collated into maps of districts (*uyezds*), regions (*oblasts*) and towns. Of these the collated maps of Siberia deserve particular attention. While imperfect in mathematical terms, they are of interest and relevance to us in their wealth of detailed economic, ethnographic and military-political information and their desire to present a comprehensive picture of the natural features of the terrain based on experience and a genuine knowledge.

Systematic work on a state survey of the country – the "Senate surveys" – was triggered in 1720 by an edict of Peter the Great's. On Peter's initiative, for the first time in history the training of surveyor-geodesists was organised for this work at the Moscow School of Mathematics and Navigation (founded 1701), as well as at the Naval Academy in St Petersburg (1715), where a special geodesy class was established. This period also saw the establishment of a map publishing office in Russia. The Civil Press, founded in Moscow in 1705 under the management of V O Kiprianov, published textbooks for the School of Mathematics and Navigation. The surveys continued until 1744. This was the first, unreferenced survey of Russia. It was conducted district by district. Traverses were run along roads radiating from the main town of each district, the length of lines being measured by surveying chain and angles of rotation by a theodolite with peep sights. The latitude was determined by sextant at the boundary of every district main town. Built-up areas situated to the sides of the traverse were mapped by intersection or, if they were out of sight, by

information from local inhabitants. In addition to built-up localities the surveys also covered highways, byroads, mills, canals, locks, woods, clearings, steppes, marshes, ancient earthworks and the ruins of former settlements. The survey was complemented by area descriptions. In addition to their inland surveys, Peter's geodesists did a great deal of work on mapping the shores of seas, oceans and lakes and took part in expeditions to study the northern and eastern fringes of the country, resulting in the amassing of a vast amount of factual material, both cartographic and descriptive.

Most of the maps published in the 18th century were geographic overview maps, but they cannot be ignored, since subsequent efforts were based on the surveys and other legacies of the Petrine era, distilled in such works as the first geographic overview map of Russia, the "General Map of the Russian Empire" (1734), as well as the "Atlas of the Russian Empire…" published by the Geographical Department of the Academy of Sciences in 1745. The progress of cartography during this period is associated with the names of I V Kirillov, V N Tatishchev, L Eyler and M V Lomonosov. The enormous body of work done by the geodesists and astronomers of the first half of the 18th century provided the foundations of Russian cartography until new surveys were organised by the Corps of Military Cartographers.

An enormous amount of survey material was obtained in Russia from a general survey of land boundaries which began in 1765. The survey was begun by graduates of the Naval Academy and continued by surveyors from the Konstantinovskiy Land Surveying School, founded in 1779.

This work is of interest as an experiment in large-scale surveying carried out for the first time to a standardized set of scales and specifications. Plans were initially compiled on a scale of 1:8400 (100 sazhens [2] to the inch). These individual area survey plans were then combined first into district plans on scales of 2 and 4 versts[3] to the inch (from 1768) and then, from 1775 onwards, into district atlases on a basic scale of 2 versts to the inch. They were accompanied by "economic remarks" – valuable descriptions of the economic state of the land.

1766 saw the publication of the "Instructions of the Governing Senate of the Boundary Survey Office…" on the rules and methods for fixing survey boundaries. The Instructions directed that plans should show "the whole internal situation, that is, inhabited localities of different types, villages, works, factories and mills, land occupied by estates, and also ploughland, woods, hay meadows, rivers, streams, mountains, ravines, lakes, mosses, marshes, roads and the like, as they are in nature" [240, p 46]. In surveying the internal situation "special attention is to be paid to measuring woodland fit for building timber, woodland for firewood, cultivable woodland, worthless marshes, that is marshes which it would be impossible or extremely hard to drain, lakes, meadows and, finally, cultivated land. Arable land need not be divided into good, average and poor, since a farmer can make poor land excellent and good land execrable. It is only necessary to record the soil, whether it is sandy, clayey or fit for cereals, … lakes, rivers and streams which never dry up, and gullies which remain in a constant state."[4] And while it was recommended that permanent water courses should be shown, it was directed that the "economic remarks" should provide details of water traffic, width, depth and seasonal changes, the time at which rivers froze and reopened to navigation, etc. Continuing deficiencies of the surveys were the lack of a reference grid and failure to show relief (except for ravines and terraces, including clear-cut river valleys). The General Land Boundary Survey was used to compile the Hundred-Sheet Map of the Russian Empire (1:840,000 – the first detailed national map of Russia).

[2] Translator's note: 1 sazhen = 2.13 m
[3] Translator's note: 1 verst = 1.067 km
[4] Code of Laws of the Russian Empire, Vol 10, Part 2, St Petersburg, 1893, p 131

Major advances in topographic mapping were associated with surveys by the War Office, which made significant progress after the establishment of the General Staff in 1763, the organisation of the Map Depot in 1797 (it became the Military Topographical Depot in 1812) and, finally, the setting-up of a dedicated Corps of Military Cartographers in 1822. For almost 100 years thereafter the latter did a vast amount of geodetic and topographic survey work. In its first period of activity, from 1822 to 1872, the Corps of Military Cartographers carried out a large number of large-scale plane table surveys on scales of 1:21,000 and 1:16,800 (up to 1845) and on a scale of 1:42,000 (from 1845 to 1870) in Russia's European territory and the Caucasus. These surveys were used to compile a three-verst map, a five-verst map (of the Caucasus, 1864-1869) and a ten-verst map (1864-1871). From 1849 to 1866 the Corps of Military Cartographers collaborated with the Land Boundary Survey Office on surveys for land boundary atlases.[5]

During its second period, from 1872 to 1917, the Corps concentrated on border areas, where accurate new half-verst (up to 1907) and one-verst maps (1907-1917) were made on the basis of instrument surveys carried out from 1886 to 1901 in accordance with specially devised instructions. Small new survey areas were opened up in Central Asia, Eastern Siberia, the Far East and the Caucasus.

The best products of military cartography were the manuscript "Atlas of the Campaign by the Russian Imperial Forces in Switzerland" of 1779, which is remarkable for its pictorial qualities and realism, on the maps of which Russian topographic artists for the first time produced a modelled colour portrayal of the Alpine relief, the (Hundred-Sheet) Detailed Map of the Russian Empire in 107 sheets – the first multi-sheet national map (1801-1804), the three-verst Military Topographic Map of Western Russia (1845-1863), which showed relief by shading and used a novel shading scale for lowland relief, and the ten-verst Special Map of European Russia (1865-1872) in 152 sheets, edited by I A Strel'bitskiy, which went beyond the bounds of a purely military map and was used for scientific, practical and scientific purposes.

The half-verst, one-verst and two-verst military topographic maps are valuable in many respects. The two-verst map of the Western border area was one of the earliest topographic maps to use contour lines to show relief. It was distinguished by an expressive representation of relief (lost in many sheets in subsequent editions), clear mapping of the steepness, form and ruggedness of slopes, and the use of the method of merging contours. Many of the sheets reflect the great skill of the Russian military topographers, who combined the knowledge of the engineer with the eye of the naturalist and the artistry of the painter.

The topographic survey conducted between 1845 and 1866 by the Boundary Survey Corps under the direction of General A I Mende produced remarkable materials – in some cases masterpieces of terrain representation. This was an example of a judicious combination of general state mapping with surveying for departmental needs, and it produced topographic maps that were valuable in both content and accuracy.

The old Russian cartography produced a vast body of primary factual material from field surveys, as well as a number of remarkable end products. At the same time, there remained a lack of uniformity in respect of scales and mathematical basis, and no common editorial policy for maps. By 1917 the overall depth of topographic coverage of the country was uneven, with a large part of its territory still not covered.

[5] Examples of two-verst 1:84,000 scale maps compiled by the War Office and Land Boundary Survey Office are shown on the flyleaves of this book. The years of publication are 1860-92 (sheet IV-4 of map of Moscow Province, 1860) and 1846-1866 (Topographic Land Boundary Map).

Russian topographic maps underwent a constant process of improvement, expressed in the progressive enrichment of their content in step with the growing needs of the times. The symbols used on topographic maps were revised and reissued many times. In the Soviet period alone they went through more than ten editions (1921, 1924, 1931, 1934, 1940, 1946, 1951, 1959, 1963, 1973, 1983).

The history of the geographic study and mapping of Russia up to the beginning of the 20th century is described in detail in A V Postnikov's lavishly illustrated books of 1989 and 1996. We shall therefore dwell only on the later and the modern periods in the development of topographic maps, highlighting the main stages in the evolution of their content.

The period from 1919 to 1930, during which Soviet cartography found its feet, was characterized by the development of the main characteristics and content of topographic maps and the devising of map-making methods. The Higher Geodetic Directorate (VGU), established in 1919, switched from the outset to the metric system, together with a common system of numbering and nomenclature. The set of scales that was adopted – 1:10,000, 1:25,000, 1:50,000, 1:100,000, 1:200,000, 1:500,000 and 1:1,000,000 – proved very sensible and viable. While some continuity was maintained with pre-Revolution maps, progress was made in selecting contour intervals, enriching maps with economic information, and improving their format, with the switch to colour printing.

Survey and geodetic operations became more systematic in 1922-23, after the end of the Civil War. Specialists from the Moscow Boundary Survey Institute (the former Konstantinovskiy Land Surveying School, which had gained institute status in 1835) were employed for surveys from 1917 onwards, topographic technical schools were set up in the period 1919-21, and geomorphology was introduced into the training programme for topographers. Regional branches of the VGU were set up and the production of geodetic instruments was organised. 1929 saw the establishment of the Central Research Institute for Geodesy and Cartography and the subordination of the Dobrolet and Ukrvozdukhput' aerial photography organisations to the Geodetic Directorate. Aerial surveying became part of topographic and geodetic operations through the medium of photoplans and photoplan-based surveying (the contour combined method), increasing the accuracy and detail of maps, as well as productivity. The formation of the Moscow Geodetic Institute from the Geodetic Department at the Boundary Survey School in 1930 immediately ensured the training of highly qualified personnel in many fields. In 1929-30 cartographic sections were established in the departments of geography at the Universities of Moscow and Leningrad. On the initiative of F N Krasovskiy new principles were adopted for survey operations that took account of the distinctive physical and geographic features of the USSR and the economic importance of individual areas. Surveying began initially in the European USSR and was then extended into Central Asia, Western Siberia, the Transbaikal region and the Far East. The systematization and improvement of survey work was reflected in the drafting of the first series of mandatory topographic and cartographic instructions.

The instructions and symbols of the 1920s and 1930s were short-lived. They were constantly revised, leading to a lack of uniformity in the content and format of maps. Figs 1.1 and 1.2 show symbols for natural features approved in 1924 for topographic survey field maps.

Fig 1.1. Representation of hydrography by 1924 symbols

Fig 1.2. Representation of vegetation by 1924 symbols

Among the best topographic maps from the early days of Soviet cartography we should mention the sheets of the 1:100,000 map published in 1926-30 by the cartographic department of the Higher Geodetic Directorate (VGU). The geographic descriptions for each sheet were a genuinely new departure. The value of these descriptions lay in the fact that each one applied specifically to the relevant sheet. Eminent geographers participated in compiling them, and the method used was described later, in 1938, by A A Borzov, I S Shchukin, D N Tugarinov and I P Zarutskaya [47]. These valuable initiatives were of great practical importance for the scientific description of our national territory. This involvement of geographers in map-making marked the beginning of close cooperation between geographers and cartographers in topographic mapping.

The maps produced by the military topographic service had a number of idiosyncrasies, including the retention of the verst-based scales in areas west of the Pulkovo meridian, the retention of the old set of symbols and the old fonts, and the use of the same contour intervals for the 1:50,000 and 1:100,000 maps (to enable the latter to be obtained rapidly by photographic reduction).

Among the best series of overview maps were the six-colour 1:200,000 sheets for Leningrad Oblast' (1931-33), which were uniform in format and content, with expressive representation of relief (with a 20 m contour interval) and a detailed treatment of built-up localities and vegetation cover. In the margins were hypsometric schemes and profiles, schematic explanations of administrative divisions and full tables of symbols. Good 1:500,000 maps were compiled for Arkhangel'sk Oblast'. A tendency to depict specific types of landscape and landscape feature (takyr [clay-surfaced desert], saxaul, kyarizes [underground water-collecting galleries], sardobas [domed rainwater reservoirs] etc) is traceable in the Central Asian series. However, the majority of pre-war topographic overview maps differed considerably from one another in format and content. Particularly striking are the major differences in representation of elevation, in contour intervals (from 5 to 200 m), road classification and projection. The reasons for this were non-existent or unclear standard principles, as well as inadequate and sometimes clearly outdated raw material.

The period from 1930 to 1940 witnessed a fundamental restructuring of the way in which topographic surveys and the publication of basic topographic maps was organised. In order to speed up the mapping of the country 1:100,000 was adopted as the basic survey scale, larger scales being reserved for special requirements. This period was marked by the adoption of aerial surveying for mapmaking and the launching of the geographic studies which played an enormous role in raising the standard of maps.

A task arising from the move to the accelerated creation of a 1:100,000 map covering the entire country (i.e. the former USSR) was that of ensuring that its sheets were uniform, comprehensive and geographically valid. Geographers under the overall direction first of I P Zarutskaya and later of N S Podobedov and Ye I Ardab'yeva began working in aerial geodesy enterprises. A new method of geographic editing of topographic maps was devised. It was particularly extensively applied in areas which were hard to reach and had been little explored. It was used, for example, by N V Dmitriyev in surveying the delta of the river Lena [138], D M Kolosov in the mountains of Yakutia, N I Mikhaylov in Central Asia, and L M Gol'dman in the Bol'shezemel'skaya Tundra and the Polar Urals. Geographic study provided the key to the understanding of the genesis and dynamics of landscapes that was a prerequisite for expanding and refining the content of maps and introducing new notation. Many supplementary symbols that were originally placed in the margins of maps were later adopted as mandatory.

The extensive adoption of aerial surveying, in conjunction with geographic interpretation and editing, ensured a rapid advance in survey coverage. In contrast to the accurate surveys elsewhere, mapping of North-Eastern areas was carried out on a sparser

geodetic basis by the stereotopographic method, with greater tolerances for dilution of accuracy. On-site interpretation of aerial photographs was confined to settlements and the road network, other elements being identified at the desk from field references.

Between 1938 and 1940 a great deal was done to standardize basic instructions. New instructions for topographic surveys on scales from 1:10,000 to 1:100,000 were drawn up and were approved in 1940 for mandatory use by all public departments in the USSR. 1940 also saw the approval of uniform symbols for topographic maps on scales from 1:25,000 to 1:100,000. A much more comprehensive representation of natural features and new economic-related construction marked a qualitative improvement in the content of maps. This period culminated in major preparations for a new edition of the 1:1,000,000 map. The "Manual for the Compilation and Preparation for Publication of the 1:1,000,000 State Map of the USSR", which embodied the expertise and achievements of Soviet cartography in multi-sheet mapping, appeared in 1940. It was accompanied by a list of symbols and by specimens, instructions and illustrations relating to generalization. This manual enabled work to get under way at different enterprises to standard methods under common scientific and technical guidelines.

Between 1941 and 1946 the activities of the topographic service were directed towards providing the army with maps. A good deal of work was done on systematizing the geodetic and level control networks. A new system of coordinates was approved in 1942 and the Baltic System of Heights in 1946. The use of maps for military purposes made a number of specific demands on topographic maps, which were taken into account in subsequent editions of the symbol tables. A typical example was the harmonization of the way in which coasts and navigation hazards were shown on topographic maps and marine charts.

The symbols published in 1946, which were the outcome of work done during wartime, contained major additions relating to all aspects of the natural landscape. Indicators were introduced for the concealment properties and the passability of terrain. The "Hydrography" section highlighted the representation of coasts and specified that their profile should be shown. Numerical characteristics were introduced for the depth of rivers, along with symbols for shoals and inscriptions showing the height of waterfalls. The representation of relief was complemented by a number of symbols for such things as grass-covered terraces and hill brows, growing ravines, landslips, ice-covered areas, rocky rivers, caves etc. The representation of vegetation cover was augmented. Woods were divided by type into conifers, sub-divided into spruce, firs, pine and cedar, and deciduous, sub-divided into broad-leaved and narrow-leaved. Marshes were divided into grassy and mossy. A large number of numerical indicators were introduced. The 1946 symbol tables also differed in structure from earlier editions: symbols for individual features and symbol combinations are given separately. Symbol combinations were used, for example, to indicate hummocky, lichen-covered, sandy, stony and marshy tundra, which had formerly all been represented by the same symbol.

Geographic overview maps continued to be made. The 1:200,000 map was given the designation of a special operational road map by a new instruction issued in 1942. Research into generalization culminated in the publication of a series of practical guides to the compilation of maps, the first of which appeared in 1943 and 1945 [193, 194, 220, 242, 243, 350]. Work got under way on a new 1:500,000 map, dubbed the General Map, which was intended as a flying map for tactical aircraft. Work on the new 1:1,000,000 State Map was completed. This was a map covering the entire USSR, summing up the current state of cartographic and geodetic knowledge of the country. It was awarded the Geographic Society's gold medal in 1947. This marked the culmination of an important stage in the development of the system of Soviet general national topographic maps. The standard types of basic maps, organised in a range of scales, had crystallized.

The post-war years from 1946 to 1956 saw a rapid increase in the volume and pace of surveying. Until the middle of the second five-year period following the War work was in progress on updating and sometimes completely replacing topographic maps of localities altered by war. The objective was set of completing the mapping of the country on a scale of 1:100,000. Surveying of the North-Eastern areas became systematic. The scales were decided for a second round of mapping. In 1948 1:25,000 and 1:10,000 surveys began to be conducted simultaneously with the 1:100,000 surveys, and by 1953 they were well under way.

Mapping on the basic state scale was completed by the end of 1954, and the scale of 1:25,000 was adopted for the new basic map of the country. The "Basic Principles for the Creation of Topographic Maps on Scales of 1:10,000, 1:25,000, 1:50,000 and 1:100,000" were approved in 1956. They detailed the requirements governing large-scale mapping by all departments in respect of map-making methods, content and accuracy. They wholly supplanted the mandatory instructions on topographic surveys that had been in force since 1940. Alongside rapid progress in the techniques and technology of aerial phototopography and map compilation and publishing and in the theory and practice of interpretation of aerial photographs, improving the content of topographic maps was a constant object of research [9, 48, 49, 133, 143, 161, 173, 191, 209, 217, 220, 235, 286, 326, 357]. Map editing was advanced by books by S P Al'ter (1954), L M Gol'dman (1948, 1954), A M Komkov and M K Kudryavtsev (1952), by a number of articles published by the GUGK, by the Proceedings of the Second All-Union Geographic Congress (1948), and the Manual for Unexplored and Little-Explored Areas of the USSR (Podobedov, 1948).

In this period proposals for the improvement of maps were slanted towards the development of a typology for map elements, the standardization of symbols, and the practical application of research into cartographic generalization (L A Bogomolov, 1950, K A Borodina, 1958, Ye I Yefimenko, 1949, 1951, 1958, P A Ivan'kov, V V Sokolov, 1957, N F Leont'yev, 1950, V M Lozinova, 1958, N S Podobedov, 1947, 1948, Z I Tolmacheva, 1954, L S Troitskiy, 1953, 1957, Yu V Fillipov, 1946, S A Khersonskiy, 1950, 1951). The quest for new ways of conveying terrain was reflected in new editions of symbol tables in which the general tendency was towards an increase in the number of symbols.

Fundamental changes in the representation of vegetation cover began in 1951. A classification based on life forms – trees, shrubs, low shrubs, grass, moss and lichen – was adopted. A background colour was adopted for wooded areas. The inept "steep grass-covered slopes" symbol, which had long been used to show the steepness of slopes and which robbed the portrayal of relief on many published sheets of moulding and expressiveness, was finally dropped (Fig 1.3). The scope for representation of landscapes in Northern and Eastern areas was considerably enhanced with the introduction of symbols for patterned, tussocky and hummocky surfaces, dikes, ice crevasses and lava flows. In view of the particular importance of maps for showing the passability of ground, more exacting requirements were established for the representation of marshes.

Fig 1.3. Examples of notation used for representation of relief on topographic maps *a.* Symbol for "steep grass-covered slopes" *b.* Representation of steep slopes. Symbol as shown on map margins [Text beneath *b.* is "Supplementary symbol. Rocky slopes steeper than 30°.] *c.* Detail from topographic map showing relief in 1924 symbols

The period from 1956 to 1966 saw a great deal of topographic and geodetic survey work on scales of 1:25,000 and 1:10,000 in Northern and Eastern areas, where it was planned to step up the development of natural resources. The new demands made of maps, the use of larger-scale aerial photographs, the geographic interpretation of the latter on the basis of expertise gained in making the 1:100,000 map and the results of research during the International Geodetic Year (1957-59) led to a fuller representation of high-mountain terrain and glaciated mountain areas, and this was reflected in the next edition of map symbols,

published in 1959. In 1959 maps began to show glaciers and glacial forms in greater detail, and it became the practice to use contour lines to convey the configuration of glaciers and permanent snow fields. The boundaries of glaciers were now shown by natural outlines which fitted well into the pattern of contour lines of the surrounding terrain. Symbols were introduced for ice precipices and mineral ices, and turquoise was adopted as the colour for all snow and ice features. Uniform symbols had traditionally been published for maps on scales from 1:25,000 to 1:100,000, but they now contained many references to differences in their content, as well as examples of the generalization of area features, particularly in respect of the transition from the more detailed representation of built-up localities to the retention only of the basic features of their planning and development in the 1:100,000 maps. The symbol tables published in 1959 was notably comprehensive. The 1963 table contains 38 fewer symbols, and it was reissued virtually unchanged in 1973.

The refinement of overview topographic maps continued in the post-war years. One addition to the set of Soviet topographic maps in 1947 was a detailed 1:300,000 overview map (it approached the 1:100,000 map in its level of detail). Work began on a new type of map on a scale of 1:200,000 for wider economic purposes. A second edition of the 1:100,000 map was published in the 1950s and 1960s. It was based on homogeneous raw material from the 1:100,000 surveys that were being completed at the time. The need for a third edition became clear in the 1960s and 1970s.

The period from 1966 to 1977 was marked by an increase in the rate and scope of large-scale surveys to satisfy fully the requirements of various sectors of the economy, along with the regular updating of existing topographic maps.

In 1967 the GUGK was made directly subordinate to the Council of Ministers of the USSR. The geographical distribution of GUGK enterprises and topographic/geodetic provision for the areas they served was improved, as was the management and structure of [cartographic] production, and scientific research was expanded. This progress was facilitated by the founding of the Applied Geodesy Research Institute (NIIPG) in 1969, and the establishment of the “Priroda” [Nature] State Research and Production Centre, the “Kartografiya” Cartographic Production Association, and a number of regional geodetic engineering survey institutes. There was a major expansion in topographic surveys on a scale of 1:10,000 for agricultural land amelioration purposes, in surveys of towns and other built-up localities, and in surveys on scales from 1:5000 to 1:2000. Operations were carried on along the route of the Baikal-Amur Railway and in the Non-Black-Earth zone of the Russian Federated Republic, and support was provided for economic programmes in Western Siberia, the Angara-Yenesey and South Tajikistan systems, and industrial/agrarian areas. Separate symbol tables were published in 1968 for 1:10,000 maps, providing continuity and harmonization with the two adjoining sets of scales, from 1:500 to 1:5000 and from 1:25,000 to 1:100,000.

The state service was made wholly responsible for large-scale topographic surveys over large areas with a view to stopping surveys by government departments, which had become more common by 1966, or limiting them to project-related referencing and routing work. The 1966-1970 Five-Year Plan envisaged that [topographic] surveys would proceed in advance of project studies, the scale and pace of which were also stepped up.

This period was marked by the investigation of the needs of various sectors of the economy – land amelioration, agriculture, geological exploration and extraction of minerals, industrial, agricultural, hydroelectric and power line construction, the development of built-up areas and some others – for large-scale topographic maps and plans. Topographic maps and plans were subdivided into basic and sectoral (specialized). In 1970 fundamental principles were worked out for the creation of 1:5000, 1:2000, 1:1000 and 1:500 topographic plans, and

instructions and symbols based on these principles were published in 1973[6]. Contour intervals and sets of symbols were harmonized across the range of map and plan scales. Major changes were made in the symbols for 1:10,000 maps published in 1977 in order to achieve continuity in the representation of basic elements from maps and plans on scales of 1:500 to 1:5000 to maps on scales of 1:25,000 to 1:100,000. A striking example is the harmonization of the representation of built-up areas and the introduction of a common population density scale across the entire range of map scales. The symbol tables of 1977 for 1:10,000 maps and of 1973 for 1:500 to 1:5000 maps contained not only general mandatory symbols for topographic features, but also symbols which were to be shown in compliance with the supplementary requirements of individual government departments or groups of departments. This period also saw the stepping-up of research leading to the development of aerial photographic survey instruments, methods and technologies for large-scale mapping [174, 291, 315].

Research was done into the making of photographic topographic maps [314], the creation of digital terrain models, and the rapid reproduction of topographic maps and plans with multicoloured shading. The All-Union Conference on the Current State and Future Prospects for the Development of the USSR Geodetic Service in 1974 played an important role in defining the thrust of future research.

In the period from 1974 to 1980 the experience gained in putting new techniques and equipment into use was embodied in documents laying down technical standards, as well as in the Fundamental Principles for Making Topographic Plans (1979), and in revised and expanded instructions and guides for various types of work, a new series of which was published in the early 1980s [167-169, 250, 336].

In 1974 the GUGK embarked on the mapping of the entire marine shelf of the USSR. At the same time the need for surveys not only of the marine shelf, but of major lakes, rivers and reservoirs became evident. Relying on over 150 years' experience and scientific progress in hydrography, scientists and specialists tackled the task of creating the geodetic basis, equipment and techniques for surveys of the marine shelf and deciding on the scales and information content of maps.

The period from the beginning of the 1980s to the present has been marked by the development of new ways of working arising from the use of satellite survey materials (satellite survey became available for geodesy and cartography in the 1960s and 1970s) and from research into automation, digital modelling and geographic information systems. The harnessing of high technology was accompanied by the formation of digital and electronic holdings containing 18,000 sheets of maps on various scales, including 1:200,000 and 1:1.000,000, covering the whole of Russia [141]. Russian Federation State Standard GOST R 50828-95 "Geographic information mapping. Spatial data, digital and electronic maps. General requirements" was devised for the creation and use of digital and electronic maps. The updating and maintenance to modern standards of existing cartographic maps across the entire range of scales on the basis of satellite and computer technology was made a key objective.

The symbol tables republished in 1983 [338] incorporated no major changes.

Thus, topographic mapping had passed through a long and complex evolution, in the course of which the depth of study of the country, mapmaking equipment, methods and techniques, and the accuracy and content of maps had undergone changes. A state topographic map system had now been formed that was at a fairly high level in terms of the

[6] The previous editions were the 1:500-1-5000 Instructions of 1955 and 1:500-1-5000 and 1:10,000 Symbols of 1968.

range and usefulness of scales, content, and modernity, as was borne out by the new Fundamental Principles for the making and updating of maps published in 1984 (the most recent edition) [249]. This document enshrined advances in production and science and technology, reflected the various strands of work, and laid down requirements for each type of map across the entire range of scales from 1:10,000 to 1:1,000,000 in line with future topographic/geodetic service tasks. Surveys on larger scales were continuing to be developed and were becoming important as the basis for cadastral studies and large-scale thematic maps. 1989 saw the publication of the current table of symbols for topographic plans on scales of 1:5000, 1:2000, 1:1000 and 1:500, which took some account of requirements enabling the reproduction of symbols by automation equipment [335].

In 1989 the Military Topographic Directorate of the General Staff (VTU GSh) and Roskartografiya began publication of a number of map series for general use in the economy and for sale to the public. These are:
- the 1:500,000 series of overview topographic maps
- the 1:200,000 series of oblast' topographic maps
- the "General Geographic Maps of the Russian Federation" series, covering the constituent regions of the Federation on scales ranging from 1:200,000 to 1:1,000,000. (Maps on smaller scales are also being compiled for constituent regions which cover large areas.)
- the "Topographic Maps of Russia" series
- the "Russian Town Maps" series.

The maps in these series are based on modern topographic maps and plans, using the symbols from their sources, with the principal elements of their content updated on the basis of currently available materials. Most importantly, they meet the standards for open-use maps in terms of accuracy and comprehensiveness of content. The maps are complemented by explanatory text, reference material and diagrams and are supplied with legends and various indexes.

In the last ten years the activities of the state cartographic and geodetic service have been complicated by reforms and changes of organisation and structure, which have led to the curtailment and sometimes the suspension of cartographic projects. In 1992 the USSR State Committee for Geodesy and Cartography was abolished with the establishment of the new independent states. In Russia a state cartographic and geodetic service was established by a decree of the Council of Ministers of the RSFSR of 20 April 1991 [144]. It took over responsibility for the relevant enterprises, institutions and organisations on Russian territory. 1995 saw the adoption of the Federal Law on Geodesy and Cartography, which was designed to create the necessary conditions for satisfaction of the state's requirements for geodetic and cartographic products.

The radical changes that have occurred in the life of the country have presented the Federal Service for Geodesy and Cartography (Roskartografiya) with new tasks dictated by the new political and economic environment. The correct mapping of the national borders and the boundaries of the constituent regions of the Federation and the representation of new geographic names have become matters of urgent importance. The Federal Law on "The Naming of Geographic Features" makes Roskartografiya responsible for compiling and maintaining a State Catalogue of Geographic Names. Updating and reissuing maps and atlases, harnessing the latest technologies, and ensuring that the content of maps meets the needs of important new areas of use are matters of constant concern to Roskartografiya in its activities.

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