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TOPOGRAPHIC DATA IN THE CARTOGRAPHIC SUPPORT OF GEOLOGICAL EXPLORATION: CURRENT STATE AND PROSPECTS

ABSTRACT

The purpose of the current study is an attempt to characterize the scientific and practical issues of modern topographic data preparation and its use in geological exploration. The study is based on the long-term author's experience in cartographic support of field and cameral geological and geophysical works and on the analysis of modern research in topographical mapping. The specifics of providing access to modern topographic data in the Russian Federation, the Republic of India and the Republic of Colombia, where the main experimental work has been carried out, are briefly described. The content features of the topographic map sheets of these countries are shortly summarized. Practical results of solving such exploration tasks as survey network design, creation of terrain sketch, processing and interpretation of geological and geophysical data, creation of digital terrain models, and preparation of base maps for web services are presented. The prospective directions for further research in improving the use of topographic data in geological exploration are given. It has been found that topographic maps and data are increasingly being used as base layers in the creation of the modern web map services. A balanced and critical approach to the use of global topographic data resources is need for geological exploration as a state's strategic activity. The industry needs publicly available national multiscale topographic maps as well as theoretical and methodological foundations for the use of web mapping advances in mineral prospecting and exploration.

KEYWORDS: cartographic support, geological exploration, geophysical survey, topographic maps, topographical mapping

INTRODUCTION

Topographic data, including topographic maps and plans, is being used during the entire production cycle at all stages of geological exploration. Geological exploration is carried out in regional, prospecting, appraisal and exploration stages. Each stage has specific goals and objectives, spatial coverage of the object of study. Work is being performed in various physical and geographical conditions; a large number of high-precision equipment is being used, and constantly requires all objects to be spatially referenced on the ground. Topographic data is needed everywhere: from planning of the survey network and topographic and geodetic support for field work [*Gura* et al., 2017] to the cameral processing, interpretation and design of the final results.

Related normative documents on topographic and geodetic support and geophysical surveys by different methods (gravimetry, seismic surveying, magnetic surveying, etc.) go back to the experience of work in the 20th and early 21st centuries. They describe the basic principles of working with topographic maps, as well as the requirements for the accuracy of the surveys and the materials involved. Maps allow the user to explore the landscape before field survey and to provide a wide range of tasks. For example, the planning of exploration works starts from

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assessment of the land passability (including preparation of surface slope maps), hydrological conditions (calculation of flood-prone land) and availability of transport and socio-economic infrastructure. All factors have an influence on the subsequent economic analysis of the feasibility and choice of methodology for performing field geophysical surveys. In this respect, the first geophysical surveys and the beginning of systematic geological mapping in early stages in the 20th century [*Albert*, 2019] were consistently based on the use of state topographic maps as the main achievement of geodesy and cartography of the countries around the world.

The creation of topographic maps relies on the scientific foundations and modern advances in cartography. The transition to electronic topographic maps is a response to the digitalization of cartography and the development of geographic information mapping. The universal classification of each content element makes it possible to move smoothly to the vectorization and coding of objects, with the subsequent creation of spatial databases with all the necessary characteristics. Thus, electronic topographic maps are now the primary means of topographic data availability. Electronic form allows for computer analysis of the data for decision making of various kinds. For example, calculation of the transport accessibility schedule, automated selection of optimal drilling rig routes to field exploitation management [*Dubrovsky, Malygina*, 2015] can be reached. New direction of the digital field and digital twin of a seismic crew, as well as the pipeline [*Eremin, Eremin,* 2018] is beginning to develop. Such solutions, which are oriented towards automating the production process of all phases of geological exploration, are based on the topographic data.

Nowadays it is becoming increasingly popular to use open topographic data from Google, Bing, Yandex, and other web services to access volunteered geographic information (VGI) such as OpenStreetMap, Wikimapia, etc. The result of enthusiasts' work is topographic data, which is no less detailed than electronic topographic maps. Moreover, this data is often the most up-to-date due to the fact that one knows that a new item has been built near his house, a forest has been planted, etc. A government system of updating electronic topographic maps might simply have no time to update the content (apart from on-duty topographic maps, where changes are made rapidly) [*Babashkin* et al., 2016].

Another important advantage of open topographic data is its ability to be used as base layers in geoportals, web-based mapping services, GIS atlases and unique interactive maps. The data exchange standards developed by Open Geospatial Consortium (OGC) allow for the immediate connection of open-source information. Data can be used both in the web interface and in the desktop GIS, where the modern cartographer's main place of work is located. In summary, the basic functions of topographic maps have expanded considerably with the development of new forms of representation and ways of providing access to data.

However, no matter how beautiful OpenStreetMap or Google Maps are, the accuracy and reliability of most objects can be questionable, especially in less populated areas, which include areas where exploration is taking place [*Al-Bakri* et al., 2016]. Moreover, despite detail, the main content of VGI resources relates more to cultural and entertainment features [*Davis, Kent*, 2022]. On the contrary, Soviet topographic maps and town plans have a greater emphasis on displaying geographical features, landscapes, and terrain characterization, which is more important for geological exploration.

As a result, the role of topographic data in cartographic support for geological exploration is changing as new forms are becoming available. But there is no change in the requirement for accuracy and the ability to provide valid orientation on the ground. In this way it is very important to highlight the practical experience of using official state topographic data and experience in creating own products with topographic functions. It can be helpful to define prospective directions of this type of mapping in the context of field and cameral geological and geophysical works.

MATERIALS AND METHODS OF RESEARCH

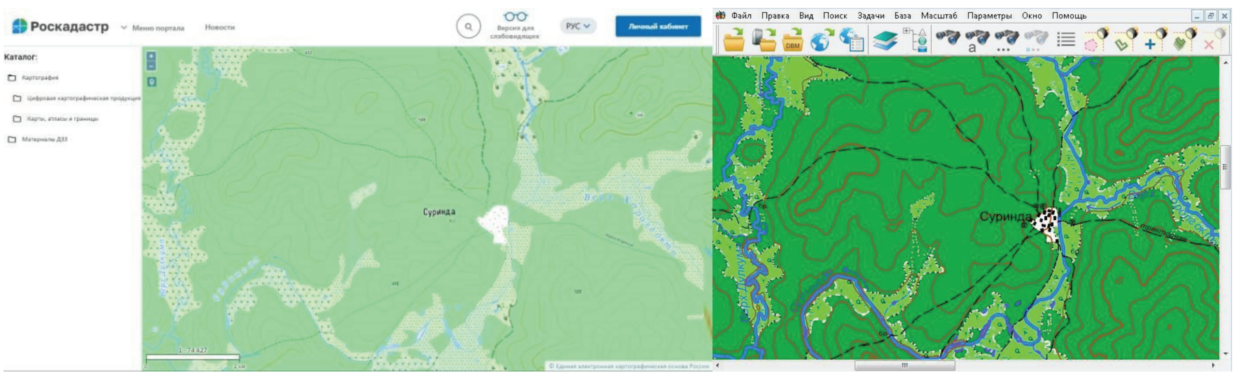
The current work is based on author's research, which was carried out during cartographic support of geological exploration in the Russian Federation, the Republic of Colombia and the Republic of India since 2014. A set of works, including digital terrain models preparation for the needs of oil and gas companies, was carried out using geo-information methods. Web mapping technologies have been used to create own web mapping services to support field and cameral projects, to provide rapid access to topographic and thematic data for a wide range of users with different specialization and qualification.

RESULTS OF RESEARCH AND THEIR DISCUSSION

Exploration by different geophysical methods begins with the questions "where is the area of interest?" and "what is located on it?" Cartographic support is supposed to answer these questions. The cartographer's or GIS specialist's journey starts with getting access to the spatial data collections of the country in which the geological and geophysical survey will be carried out. Spatial Data Infrastructure (SDI) creation and providing access to geodata (including topographic maps) are the current focus of government organizations responsible for geodesy and cartography. Of course, each country has a different history, tradition and policy on access to topographic data. Due to the national importance, the task of ensuring access and timely updating the content of electronic topographic maps using modern technologies comes to the fore [*Karimova*, 2018]. Below there is a brief overview of the current state of topographic mapping and the specifics of map delivery in the countries where the author had experience in large-scale topographic and geodetic data capture.

Russian Federation. Electronic open access topographic maps with 1: 50 000, 1: 100 000 and smaller scales can be searched and ordered through the official website of the Federal Portal of Spatial Data[1] (fig. 1, a). Data is searched by attribute (e. g. sheet name, administrative unit, map scale, survey type point), or by spatial search (by coordinates, GeoJSON download, polygon drawing). The electronic topographic map by nomenclature sheet in *.sxf format (fig. 1, b) with the classifier in *.rsc format is a result of the request.

Open access topographic maps have a simplified content in contrast to restricted-use maps. For example, elements of mathematical and geodetic basis, semantic characteristics of some objects (for example, relief, hydrography, road network, vegetation) are missing. Maps contain a simplified set of industrial, agricultural and socio-cultural objects, as well as semantic characteristics (e. g. for swamps), etc. Nevertheless, the open-use electronic topographic maps allow performing a wide range of tasks that arise for specialists during field and cameral geological and geophysical works.



a) b)

*Fig. 1. Reduced fragments of the electronic open-use 1: 50 000 scale topographic map: a) in Federal Fund of Spatial Data website window, b) in GIS Panorama window from *.sxf*

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1 Federal Portal of Spatial Data. Web resource: https://portal.fppd.cgkipd.ru/main (accessed 01.02.2023).

It should be noted that back in 2015, the ordering of electronic topographic maps and geodetic information was carried out by personal contact to the main and local funds. This required the completion of various bureaucratic procedures. As a result, the user received the maps after approximately one month. Now the procedure has been simplified and accelerated due to the new form of access to the data by geoportal.

Currently, the creation of a Unified Electronic Cartographic Framework (called EECO) through the efforts of the Rosreestr and subordinate organizations is in its final stage. EECO is a systematized set of spatial data on the territory of Russia. Data can be provided by means of TMS (and WMTS), WMS, WFS in state, local and international coordinate systems. The implementation of EECO will improve the quality and availability of thematic data generated from it for mapping activities in various sectors of the economy [*Tararin*, 2022].

Republic of India. The official topographic maps of the Republic of India are provided by Survey of India (SOI). SOI is the premier state mapping agency for land surveying and mapping, geodetic, geophysical surveying, etc. As per the National Mapping Policy adopted in 2005, two series of analogue and digital topographic maps in 1: 50 000 scales are being produced: "Defense Series Map" for defense and national security needs and "Open Series Map" for civil use. The Open Series Map sheets are available to Indian citizens free of charge in *.pdf format for the entire country, except for areas falling under the Restricted Area category. These topographic maps can be accessed through the official website[1] and available in *.gdb, *.shp, *.tiff formats for a charge. The required map sheets can be searched through the list of administrative units, or by directly entering the sheet nomenclature in the old Everest system (although Open Series Map sheets have a different nomenclature). Despite that the maps are available free of charge only in *.pdf, the use of data in this format makes it possible to solve many tasks of geological exploration.

Each Open Series Map sheet is published in UTM projection on WGS84 ellipsoid in English and in Hindi. Layout has a map, scheme of map sheet location, conventional symbols (fig. 2, a), notes, information about projection and datum, magnetic declination, graphic, numerical and named scales and output data. All data are presented digitally and organized by next categories: buildings, hydrography, communications, land cover, utilities, boundaries, hypsography, vital installations, map frame and text (fig. 2, b). The description for object groups, coding and semantic characteristics is given in the instructions of Survey of India.

Other data are available through the website, such as the official boundary of India, administrative boundaries of states, districts and sub-districts (in Lambert Conformal Conic projection) in *.shp format. In addition to the design of the final exploration maps in GIS, they also allow for a comprehensive analysis of the study area location in relation to transport routes and natural features (reserved and restricted forests, etc.).

Republic of Colombia. The Geographic Institute Agustín Codazzi (IGAC) is the principal authority on geodesy, photogrammetry and cartography and is responsible for the production and distribution of Colombian topographic maps. Today, the "Colombia en Mapas geoportal"[2] is the main gateway for geodetic, gravimetry, cadastre and other geodata. This platform is an updated version of the Institute's previous geoportal, which the author used for geodetic data capture in 2015. Today geoportal is designed to integrate and make geographic data available via an open and easy-to-use platform for citizens and organizations. Centralized data is available on 23 topics, including historical topographic maps, cadastre, geodesy, map sheet databases, digital elevation models, orthophotomaps, geology, etc.

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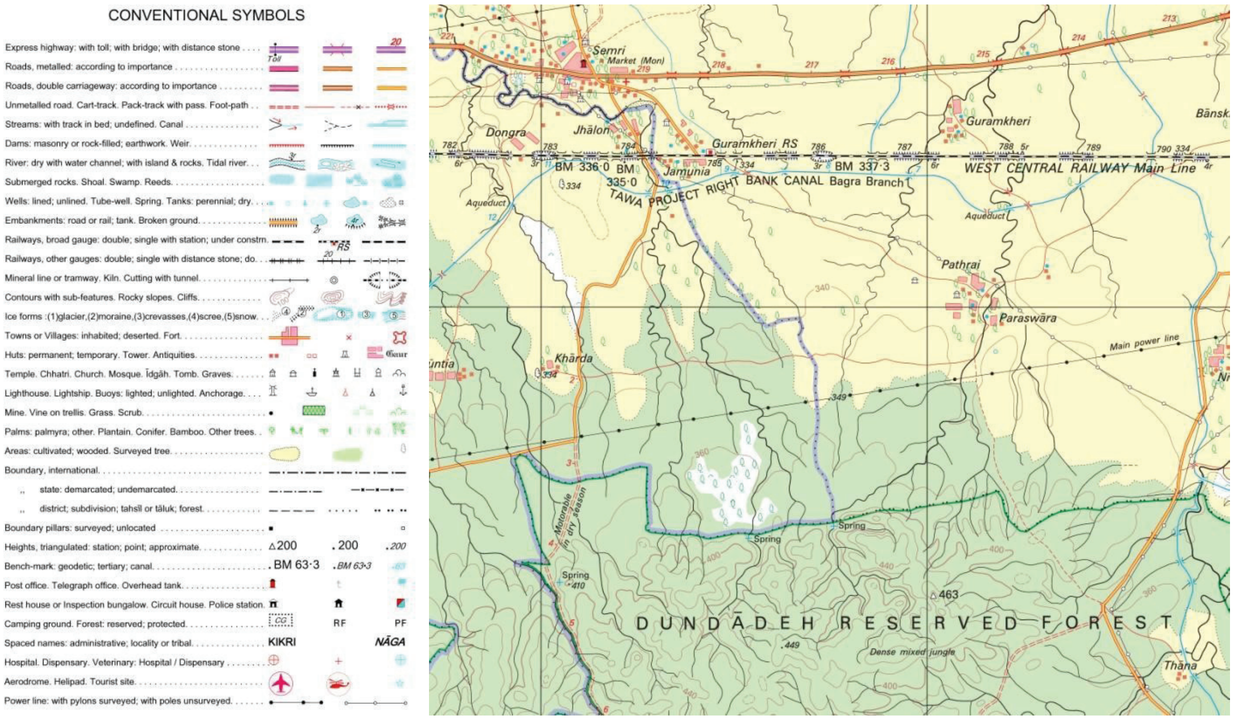
1 Survey of India. Web resource: https://surveyofindia.gov.in/ (accessed 01.02.2023).

2 Colombia en Mapas. Web resource: https://www.colombiaenmapas.gov.co (accessed 01.02.2023) (in Spanish).



a) b)

Fig. 2. Example of the 1: 50 000 scale Open Series Map sheet:
a) legend, b) reduced map fragment with typical landscape

The main topographic maps currently supported by the IGAC are the 1: 25 000 and 1: 100 000 scale series. They are available both in desktop and mobile (fig. 3, a) geoportal versions in the "Vector database per map sheets" section. The required sheets (and other data) can be searched both by the address list of the main administrative units of Colombia and by selecting an area of interest of any form directly from the geoportal interface. For example, a list of coordinates is the result of selecting geodetic information. It is important information for creating a geodetic reference network for topographical and geodetic support for field geophysical surveys.

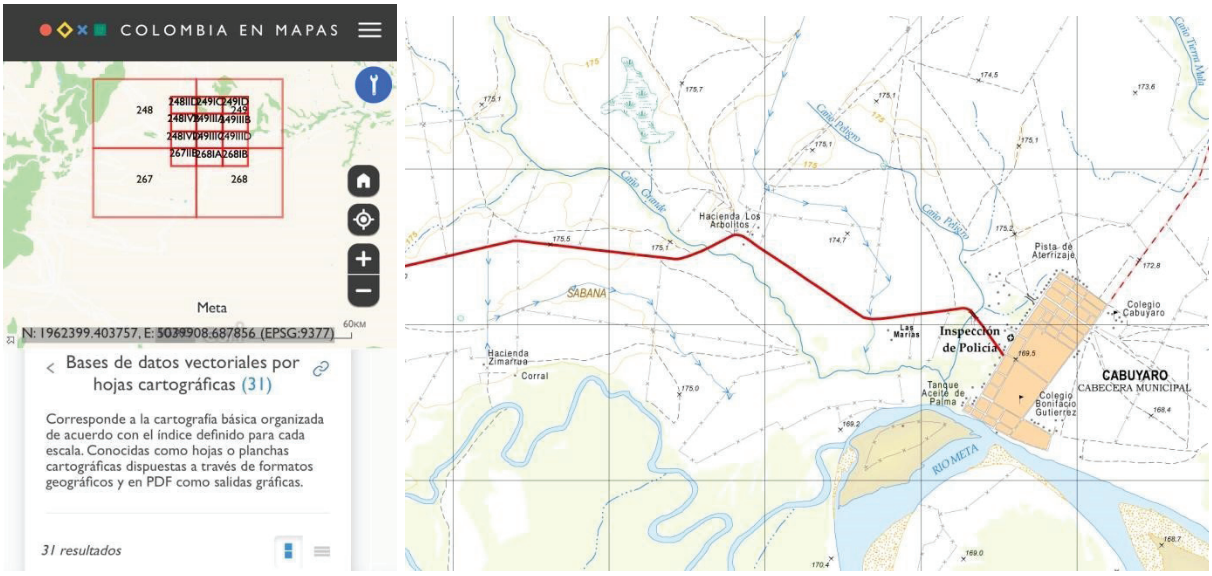
The result of a topographic map search can be downloaded depending on availability in *.pdf format, *.gdb, *.gpkg, *.shp. The topographic map sheets on scales 1: 25 000 and 1: 100 000 are presented in Spanish in Gauss-Krueger projection with Magna-Sirgas geodetic datum and GRS80 ellipsoid. The sheets contain the map itself, all kinds of scale representation, a uniform legend, a table of abbreviations, information about the projection, scheme of map sheet location, output data. The maps have the following content elements: points of the geodetic network, vegetation, structures, transport (road network and structures), hydrography, relief.

The experience of the Russian Federation, India and Colombia, briefly described, shows the relevance of the work of government agencies responsible for geodesy and mapping in providing access to topographic data through web services and geoportals. The improvement of geoportals continues and is gaining national specifics and approaches to the development of these services. The experience can be useful in the development of SDI geoportals for regions and commonwealth countries (e. g. CIS).

Totally, the information from geoportals allows a high level of cartographic and topographical support for geological exploration, including the solution of such issues as:

1) orienteering;
2) comprehensive analysis of all available remote sensing, landscape and geological-geophysical data with topographic features;

3) planning of geological exploration works;
4) studying the geological structure and oil and gas potential of sedimentary basins;
5) monitoring and collection of statistical data on the oil and gas facilities operation;
6) identification of hazardous areas and selection of optimal routes for relocation of geophysical equipment and movement of field crews;
7) managerial tasks, planning, control of field infrastructure areas, underground gas storage facilities, pipelines and other.
8) localization of accidents and emergency situations (including oil spill control, damage assessment, etc.).
9) other tasks.



a) *b)*

Fig. 3. Colombian topographic maps:
a) mobile version of the "Colombia en Mapas" geoportal,
b) reduced fragment of 1: 25 000 scale topographic map sheet

Experience of preparing and using digital topographic data for some geological exploration tasks. The following section presents the author's practical experience of preparing topographic data and using it for decision making in some exploration tasks.

Design of the survey network. The planning of the survey network for various geophysical survey methods is directly based on knowledge about terrain. It can be obtained by careful reconnaissance or by distance analysis of topographic maps or remote sensing data. Combination of these data sources makes possible the analysis of geographical features and their characteristics in the study area, such as passability [*Rylskiy* et al., 2022], terrain roughnesses, forest cover, seasonal flooding, transport accessibility, presence of settlements, communications, agricultural fields, etc. This information is necessary to minimize the influence of natural and anthropogenic factors on subsequent survey picketing and measurement of geophysical field values at each survey point. It is especially important for seismic acquisition, where the seismic field is generated and recorded using heavy and expensive equipment. Therefore, knowledge of each knoll is the key to timely execution of work and obtaining primary material on the geological structure of the study area.

The ideal seismic acquisition survey network is carried out along regular lines. Under real-world conditions, equipment and field crews will naturally be in the way of various objects (such as lakes, rivers, gullies and marshes) that need to be bypassed. As a result, a displacement of one or another seismic shot point will produce a loss in signal multiplicity and consequently the quality of survey. The greater the number of skips or noise generating objects like power lines, railways, roads, settlements, slopes (fig. 4), the worse the final result. Therefore, point shifting is performed by geophysicists in accordance with a pre-defined methodology [*Cordsen* et al., 2011], which is based on knowledge about terrain topography. For this purpose, topographic maps, remote sensing images can be connected as base layers in the geophysical survey network design software, and vector data can be loaded. After the joint analysis of the topographic data, the final choice of survey configuration and its parameters (e. g. distance between lines and their direction) is made.

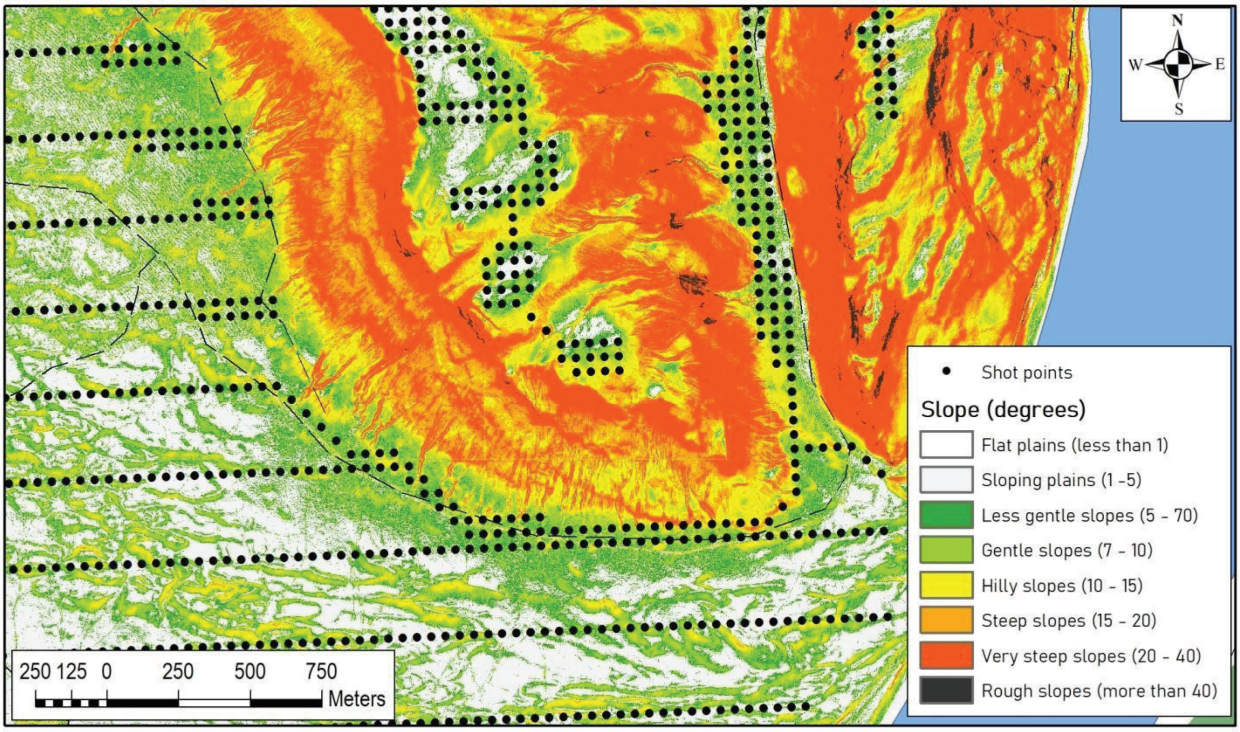


Fig. 4. Example of seismic survey points offsets due to slope calculated from topographic data (Krasnoyarsk Krai, Russian Federation)

In addition, the quality of the field survey is influenced by the cadastral situation of the study area. Not every landowner grants permission for a piece of geological and geophysical survey to be carried out on their property, especially in the midst of harvesting. To minimize the economic cost of the work and potential problems due to lack of field permits, cadastral data is used in conjunction with topographic maps. The survey is designed to minimize the number of physical observations on agricultural areas, plantations and private property, while maintaining the quality of the survey results. Thus, the analysis of the terrain topography and other geodata at the survey network design stage helps to minimize potential problems that may arise in the field.

Terrain sketch creation. The topographic and geodetic works are the first priority during the field geological and geophysical surveys. It is the responsibility of topographic teams to reconnaissance survey picketing and create catalogs of survey points coordinates. Also, one of the important tasks is creation of the terrain sketch — a large-scale map with detailed indication of potentially interfering feature location that cannot be read from topographic maps. Everything that affects the safe transport of geophysical equipment and personnel to the survey area should be mapped on the sketch. It is information about the impassable forests, trenches, lakes, marshy meadows, areas of high risk for human life (habitats of insects and poisonous reptiles), crossings, public roads, communications (pipelines, power lines, industrial buildings and constructions) and other data.

The sketch is based on information from topographic maps as well as information obtained by surveyors during their inspection of the study area. The surveyors collect information about terrain, as they are the first ones to pass through the survey area. All information is recorded in individual field logbooks. The field cartographer compiles the data by producing a final electronic terrain sketch in GIS. The cartographer uses remote sensing data to specify the locations of the objects described into logbooks. The author directly performed this kind of work during the field 3D seismic acquisition at the Colombian license block in Meta Department in 2015.

While an electronic sketch is used in various gadgets, a paper version is also needed cause difficult terrain and work conditions. The paper version is prepared for tasks assigned to the surveyors, drilling crews and geophysicists, and the current daily work location. Automated printed layouts with thematic information were produced using the "Data Driven Pages" function in ArcMap 10.2. Since the fieldwork is carried out along seismic lines, the route map mode was used, where the survey line serves as a baseline (fig. 5). In this way, a terrain sketch allows proper planning of the survey time, considering the complexity of the individual parts of the terrain.

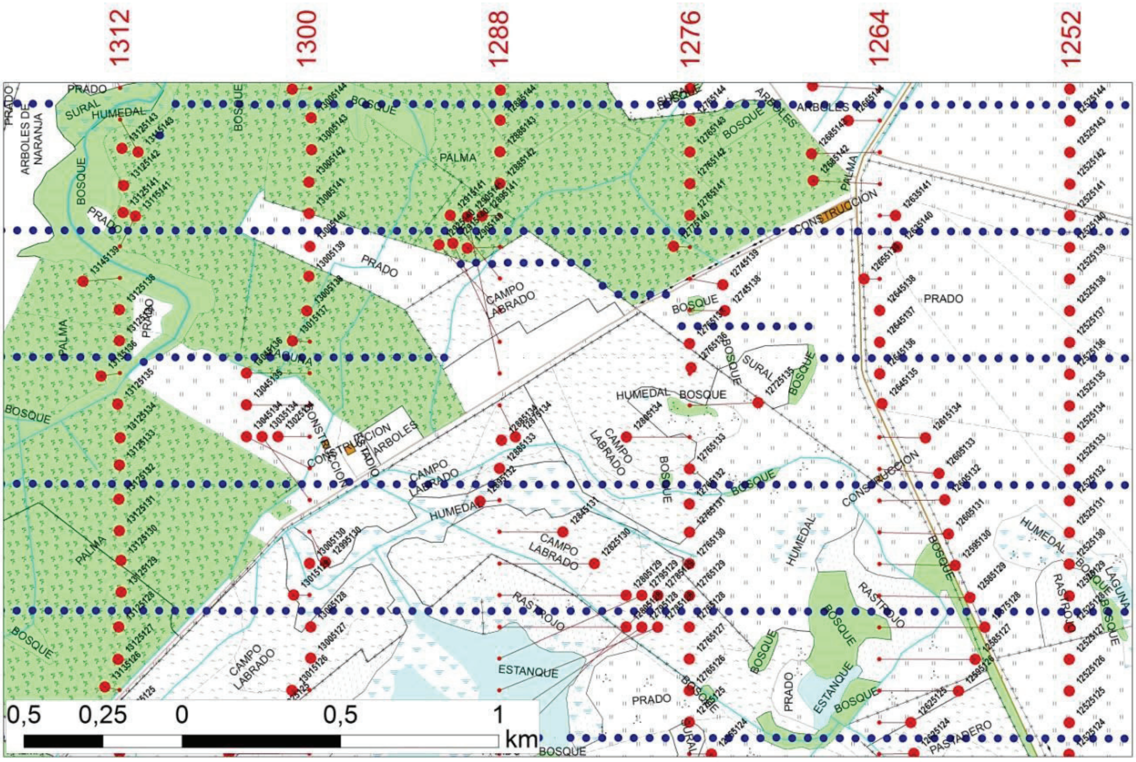


Fig. 5. Reduced fragment of the terrain sketch for cartographic support of drilling and other geophysical works (Meta Department, Colombia)

Processing and interpretation of geological and geophysical data. Next stage — geological and geophysical data processing and interpretation — is based on field geophysical survey results. This stage is the most time-consuming in terms of data analysis and interpretation, because the main objective is to study and clarify the geological structure of the study area and to identify promising oil and gas bearing zones and other challenges. A wide range of data is involved: from archival materials and results of past surveys to modern digital models of geophysical fields, geological maps, etc. In addition, the full range of topographic data is used: from digital topographic maps, elevation and terrain models, to Earth remote sensing data with various spatial resolutions (up to ultra-precise lidar survey).

Topographic data provide an opportunity to compare the situation on the ground with observed seismic signal skips during cameral processing of initial seismograms and time sections. It is important, e.g. in identifying the causes of abnormal changes in signal-to-noise ratio and in phase tracing during seismic horizon correlation. Also, with the help of topographic data, it is possible to establish the causes of shift in the survey lines, which ignorance may have a bad influence on the subsequent data interpretation stage. The latest case of how the joint use of geodata has influenced additional 2D seismic acquisition in one of the poorly explored sedimentary basins in the Republic of India is discussed in detail in [*Loginov*, 2022].

The interpretation results are presented in report maps (isochrone, structural (depths), thicknesses maps, etc.), which should include topographical data for georeferencing in addition to the thematic content (fig. 6). This requirement for topographical data to be plotted on geophysical maps is an international practice, as confirmed by geoscientific map analysis study in [*Pal, Albert*, 2021].

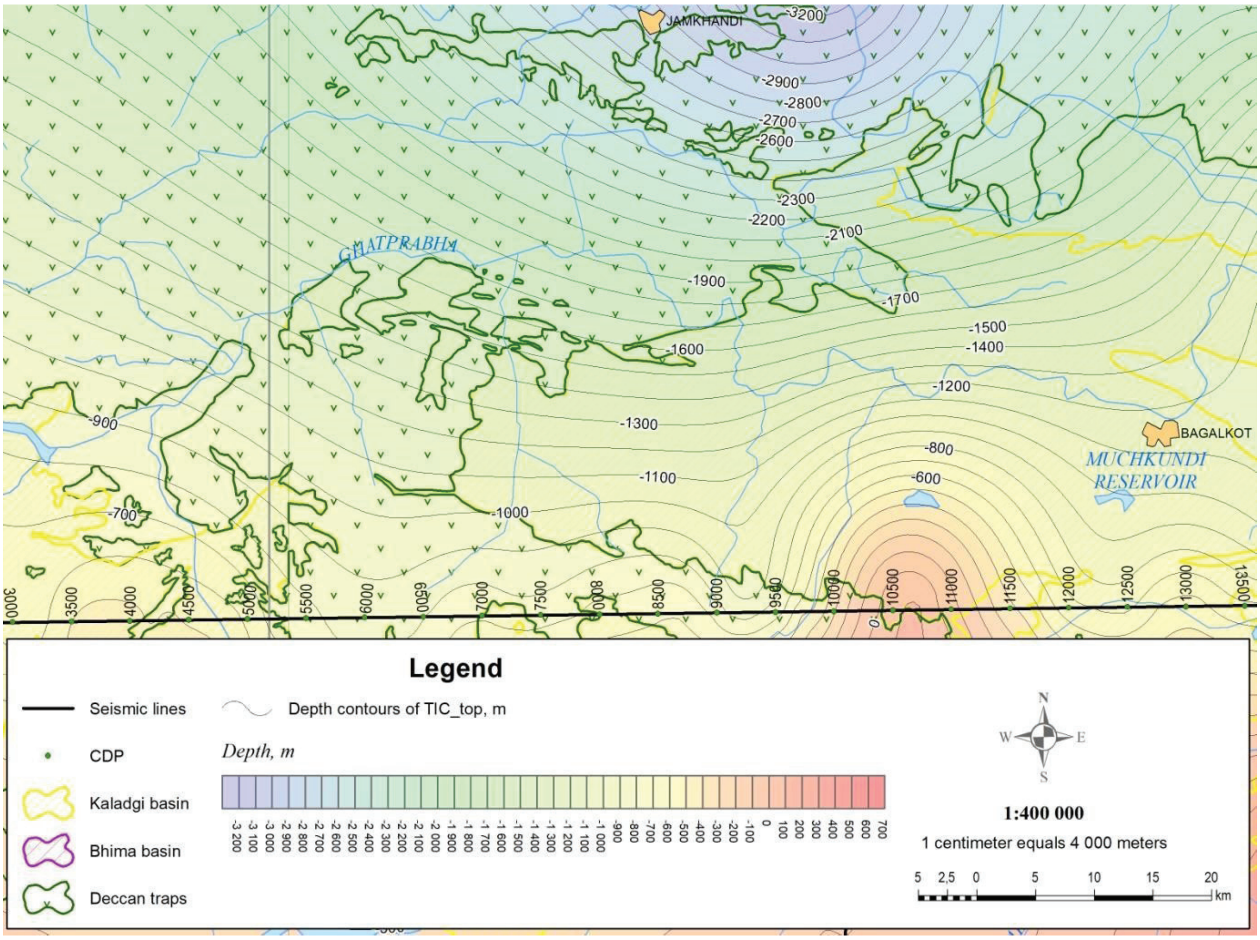


Fig. 6. Fragment of structural (depth) map with topographic elements (Kaladgi sedimentary basin, India)

Creation of digital terrain models. The results of the comprehensive processing and interpretation of geological and geophysical data (including the results of mineral resource estimation) are important for further decisions of exploration. If geological conditions are favorable, the well drilling will be carried out. In case of success, the subsequent exploitation of the identified deposit will be done. These activities rely on detailed information about the topography of the study area, which can be presented with a large-scale digital terrain model (DTM) for license blocks. Major Russian oil and gas companies order such works with mandatory use of up-to-date remote sensing data and airborne laser scanning data. The update of existing DTMs provides up-to-date topographical data for various activities, such as infrastructure and facilities monitoring in the oil and gas industry.

The author has developed and tested a methodology for creating DTM for cartographic support of underground gas storage facility construction in the license area in the Amur Oblast, Russian Federation. Methodology is based on using the initial data frame from 1: 25 000 and 1: 50 000 scale open-use digital topographic maps described earlier. Further updating of metric and semantic characteristics of objects by means of high spatial resolution remote sensing data interpretation was done. The structure of DTM is specified and designed according to the classifier accepted in topographic-geodetic service of the Customer's organization. The results are the geodatabase (*.gdb) and GIS-projects (*.mxd) for each nomenclature sheet (fig. 7), digital elevation models and hard copies of maps with object content that corresponds to the list adopted for open publication.

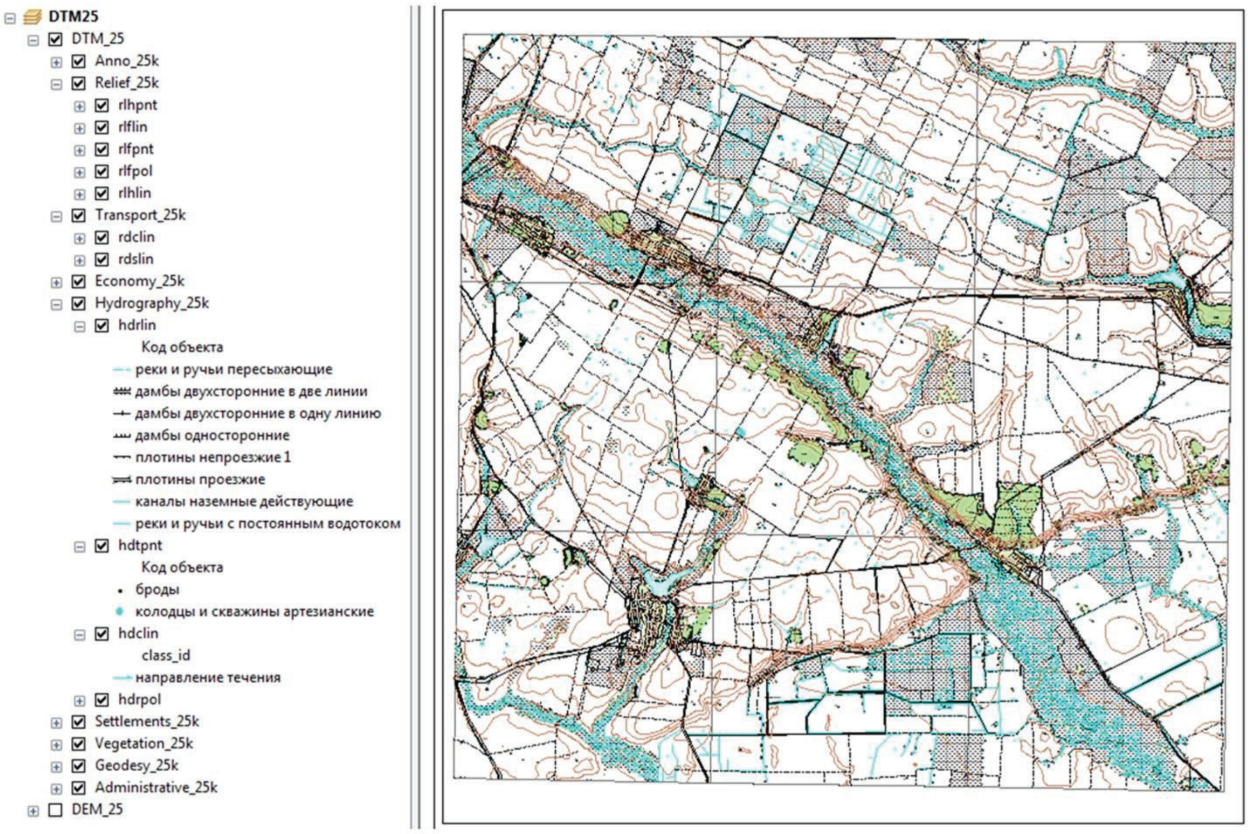


Fig. 7. ArcMap 10.4 window with digital terrain model layout (Amur Oblast, Russian Federation)

The experience of using open electronic topographic maps as a base source for this kind of work showed the need to update state electronic topographic map sheets used as a frame. This is because the contents of the map sheets are dated 2011. So, there have been updates of semantic characteristics and coding of objects (e. g. changing the area code from "under construction" to "built-up"), editing of metrics for road network, hydrography and objects of economic activity, up to and including the vectorization of newly appeared terrain objects. The updated DTM is now used to create thematic maps, documents and materials required to develop project documentation. Also, DTM is used in the additional geological study of the previously identified structures and assess their suitability for the construction of underground gas storage facilities.

Preparation of base maps for web services. The development of own web services is an actual direction for cartographic support of the field and cameral geological and geophysical research for exploration [*Loginov*, 2021]. Topographical data retains the basic functions discussed earlier in these kinds of products. At the same time, global web services and VGI from OpenStreetMap, Google Maps, Bing, ESRI and others are widely used as base maps. However, the accessibility generates contradictions and many solutions to the single question "what is here?" It is a fact that the detail, accuracy, and even more so the design, have major differences on the available base maps. Web application developers for the oil, gas and mining industry should therefore be careful in their choice of base maps, depending on the goals they have in mind when creating their own web resource.

Here is a practical example. The author used the 1: 50 000 scale Open Series Map (fig. 8a) and Google Maps (fig. 8b) as a topographic data when was preparing a web service for 3D seismic acquisition monitoring in Odisha state (formerly Orissa), India. With the same scale level, there is a minimal graphical load (density of mapped objects and their conventional signs) of the open Google data, even though the Open Series Map sheets for this area were published in 2009 and 2011, and major details were updated in 2005−2006. This case confirms the need to use government topographic maps as base maps, especially in rural and low population areas.

However, global topographic data should not be discounted when it comes to preparing web maps with medium and small-scale coverage. Global maps help geologists and geophysicists to deal with the spatial orientation during cameral processing and interpretation, especially in cases when national multi-scale topographic base maps are not available.

Prospects. The delivery of topographic data through web services and geoportals is a promising trend not only for web mapping, but also for topographic mapping in general. Many branches of the earth sciences are interested in this data, including geophysics and geology, as has been shown in previous sections of this article.

Research on the use of databases for multi-scale web mapping is relevant, e. g. [*Krylov, Mosolov*, 2022]. The reason for this is that increasingly web-based resources are being used to provide access to topographic data, including in the form of base maps in various thematic web resources. In this case, another promising direction is the development of technical issues of preparing raster topographic maps for publication by WTMS services. The spatial resolution of images and map scale should be taken into account in order to provide access to data without time delays and in high-demand conditions.

In addition to purely topographic geoportals, it is important to develop web mapping of individual terrain elements, e. g. geoportals and datasets on protected areas [*Alekseenko* et al., 2019], seasonal roads [*Nokelaynen*, 2021], etc. These data separately contain specialized information, which is updated by specialized departments and research institutes more frequently here than on topographic maps. Such sources of topographic data are useful both at the planning stages of the survey (e. g. in accounting for exclusive zones) and during the actual process. Also, these geoportals can be helpful in making recommendations for drilling new wells in promising zones identified at the cameral processing and interpretation stage of geological exploration.

The timely updating of electronic topographic maps by the responsible agencies is also an important issue. The "why do we need maps when we have OpenStreetMap" approach, if it helps in other branches of science, is unacceptable in geological exploration. Especially in most cases where surveys are conducted for example in low-populated areas of the Russian Far North and taiga, Colombian densely forested jungles or in deserts, forests and highlands of India.

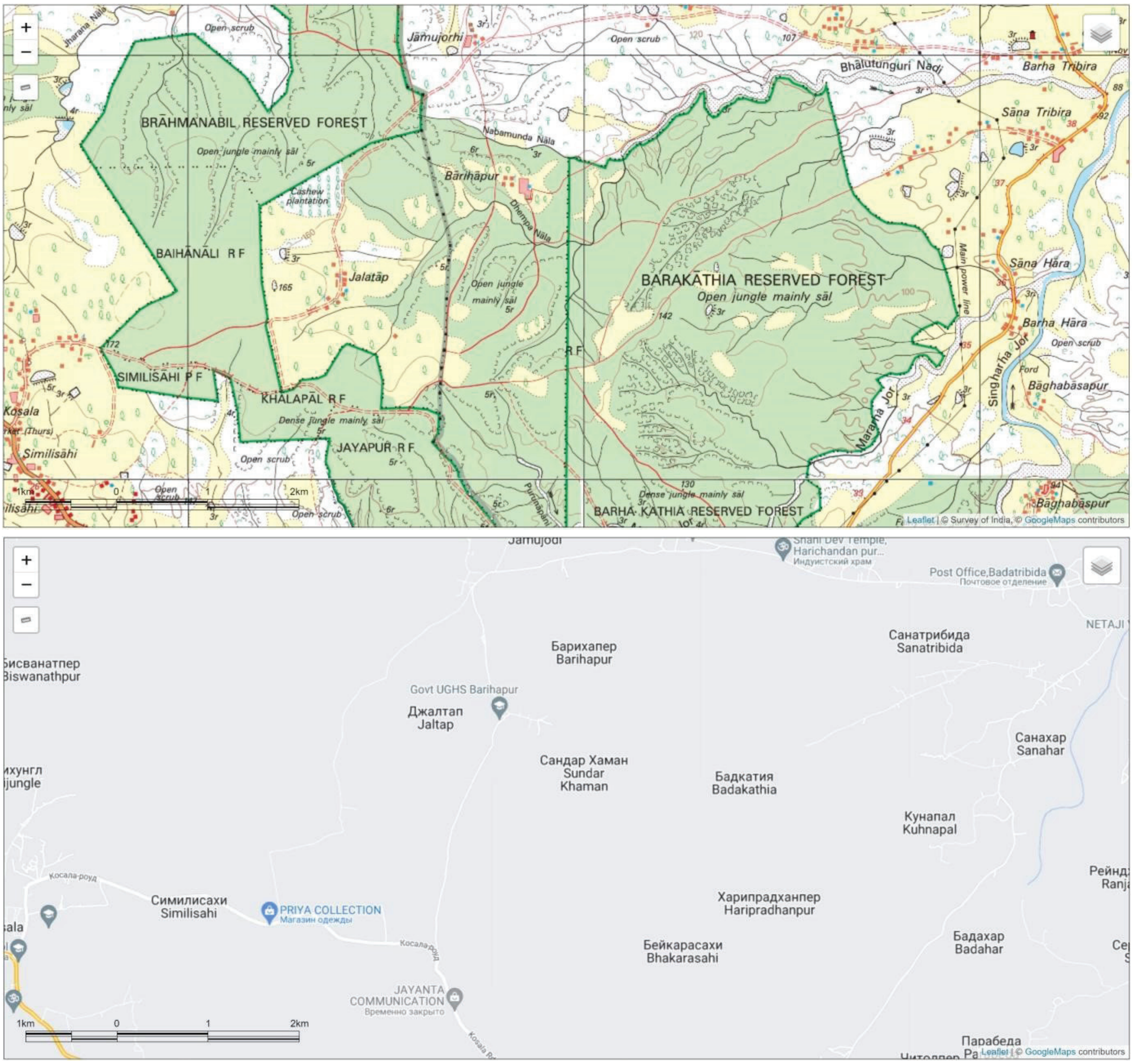


Fig. 8. Density of topographical objects for study area (Odisha state, India):
a) on the 1: 50 000 scale Open Series Map; b) on the Google Maps base map

CONCLUSION

A large part of today's mineral, oil and gas industry is directly linked to the use of accurate spatial information. Topographic maps and other geospatial data are actively used for tasks of different scales, spatial coverage and areas of activity.

The examples of topographic maps preparation and use discussed in the article allow evaluating the variety of forms of modern topographic data representation: from paper and electronic maps, to GIS-projects and web applications. Modern methods of access allow topographic data to be involved in the work of public companies, service organizations, and research institutes. This allows cartographic support of such tasks as creation of geoinformation databases, own web services, digital twins of objects and enterprises of the oil and gas industry, etc.

The reviewed experience of cartographic support of various stages of geological exploration shows that a balanced and critical approach to the use of global topographic data resources in such a strategic activity as exploration is required. The industry needs public multiscale topographic maps as well as theoretical and methodological foundations for the use of web mapping advances in mineral prospecting and exploration.

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