SPECIFIC FEATURES OF USING GIS ATLASES IN THE GEOPHYSICAL MAPPING

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Abstract
The modern atlas mapping is actively using a new form of information transmission – GIS atlases. GIS atlases also uses in the geophysical mapping, which represented information about Earth's geophysical fields at the global and local levels of mapping. The development of multiscale electronic geophysical mapping will provide an opportunity to getting actual information about those processes, which are directly influence on the geological structure of the Earth and the overall health of humanity.
Some GIS atlases creating by state organizations (geological surveys, scientific institutes, etc) was analyzed by author. The estimate of geophysical maps representation was complete in this study with some criteria including content completeness, type of presented data, convenience of GIS atlas interface, the possibility of interactive creating own maps, coherence of geographic and thematic contents, et al. It was concluded about the current state of atlas mapping in geophysics and highlighted possible ways to improve a geophysical GIS atlases.

Keywords*: geophysical mapping, GIS atlases, geophysical maps, cartographic databases.*

INTRODUCTION

Geophysical mapping is one of the fastest growing directions of thematic mapping. It's of great importance for scientific and practical studies of the Earth geological structure and near-Earth space, and the impact of geophysical field on human activity. Geophysical mapping has more than three centuries history from the date of creating first maps of magnetic declination, which are used for navigation purposes in the Age of Discovery. Today these maps are particularly important for search and exploration of mineral resources (especially hydrocarbons), however, the subject of mapping (geophysical fields) allows solve another tasks, including a development of atlas mapping. The appearance of geophysical maps in complex atlases is associated with the accumulation of information and the improvement of atlas sections structure. Any full atlas can't be imagined without the geophysical section, although its location hasn't yet been decided. For example, geophysical maps of the National Atlas of Russia (4 Chapters) are situated in «Geological structure and subsoil resources» section, while these maps are presented in «Natural landscape, Energy» in the National Atlas of Czech Republic; in Geoscience Atlas of Svalbard geophysical maps are making own section «Geophysics». This fact indicates a lack of explanation of the atlas geophysical mapping problem and acquires a special character with the spread of geoinformation technologies.

Today atlas mapping is rapidly moving towards GIS technologies, and therefore actively used a new form of information transmission – GIS atlases. The author has set the task to consider the specific features of using GIS atlases in the geophysical mapping. Several GIS atlases of various organizations (Geological Surveys, research institutes, et al) was analyzed by author. The estimate of geophysical maps representation was complete in this study with some criteria including content completeness, type of presented data, convenience of GIS atlas interface, the possibility of interactive creating own maps, coherence of geographic and thematic contents, et al. The analysis will assess the current state of atlas mapping in geophysics and define future directions to improve using GIS atlases in geophysical cartography.

GIS ATLASES IN GEOPHYSICS: OVERVIEW

The appearance of GIS technologies in atlas mapping at the end of the 20th century was opened a new capabilities for representing and using maps, including multiscale mapping. GIS atlases structure and form are given opportunity to store and organize any large amounts of data that is so necessary to geophysics. Today GIS form is an integral part of work in many organizations, including Geological Surveys, which are responsible for information both on the

geological structure of specific areas, as well as on the distribution of geophysical fields on area mapping. GIS atlases uses for next general purposes:

- Cartographic visualization of geophysical data;
- Storing and accessing metadata;
- Operative creation of maps with geophysical information.

More then a dozen GIS atlases of Geological Surveys of different Europe countries were analyzed by author. Each atlas was created and designed depending on the general level of geophysical mapping development in country, interest in geophysical data (for example, due to a high share in the mining economy) and geophysical mapping traditions. Further, the results are considered for each chosen criterion.

THE STUDYING OF GEOPHYSICAL GIS ATLASES SPECIFIC FEATURES

The overall theme of the atlas

The overall theme of the atlas is directly influence on the composition of maps in it. Taking into account the historical features of the geophysical mapping, which is developed in many countries like a branch of geological mapping, there are two variants are possible: geophysical atlas or atlas combining geological and geophysical maps. In first variant geophysical maps are dominate, and in second variant the geophysical information is accompanying geological maps. The analysis found that about 60% of GIS atlases are combining geological structure data with information about geophysical surveys infrastructure. The main content of geophysical part of these atlases is the data of shooting profiles location of different types survey (advantageously, gravity and magnetic techniques), and also the general maps of gravity and magnetic fields.

The content completeness

Under the content completeness author understands to how much detail provides information about basic geophysical fields in this atlas. It is known in practice of exploration geophysics has study six types of fields: gravity, magnetic, electric, seismic, thermal and radiometric. According to how many fields are presented in mapping form, it is possible to judge the quality of GIS atlas and its information content as a whole.

However, an existing need to use geophysical maps and an expansion of the mapping object structure were led the tendency to make maps of specific geophysical fields, which aren't including into existing classifications. The field of study (knowledge) is such as abstract field, because «it isn't direct reflection of natural phenomena, which is most often encountered in the preparation of geophysical maps, but rather a more abstracted notion and expresses a generalization of the available data» [1]. The emphasizing of «study field» maps into a separate group of geophysical maps due to their wide use in the GIS atlases. In 10 of 12 examined atlases these maps are presents for different types of exploration geophysics (Figure 1). The data about existence of other field maps are presented in Table 1.

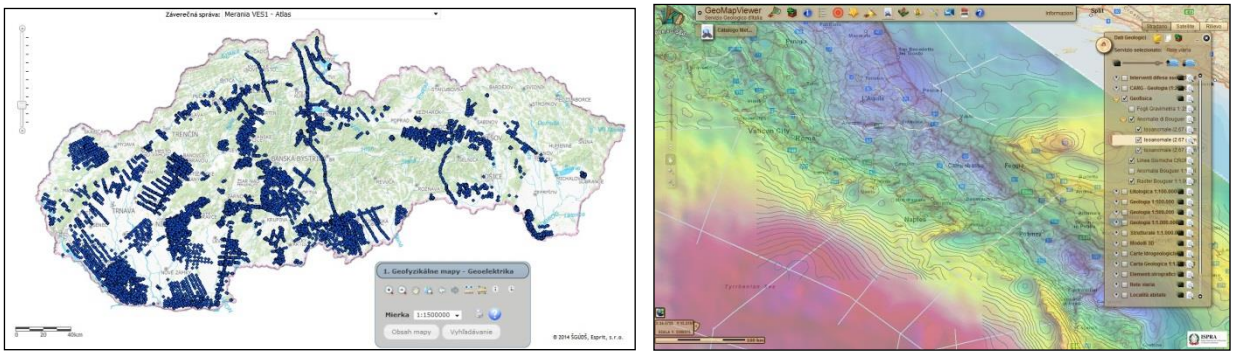

Figure 1. Maps of GIS atlases: vertical electrical sounding (VES) measurements map of Slovakia by SGIDŠ (left), Map of Bouger isoanomaly by ISPRA (right)

Also Table 1 shows that the data of gravity and magnetic fields are most widespread in GIS atlases (Figure 1). Taking into account the overall theme of atlas, for example, may specify the GIS atlas of the State Geological Institute of Dionyz Stur (SGIDŠ, Slovakia), containing data about all of known geophysical fields (thermal field maps are separated in special atlas) [3,11]. Opposite the GIS viewer of Central Geological Database by Polish Geological Institute (PGI)

[4] more aimed at the transfer of information about the geological structure, so only maps of study are represented in it. At the other GIS atlases the set of geophysical maps slightly different, but they represent at least maps of three fields.

Table 1. The overall theme and content completeness of geophysical section in analyzed GIS atlases

Overall theme	Atlases (lead organization)	Country	Geophysical fields						
			Gravity	Magnetic	Electric	Seismic	Thermal	Radiometric	Field of study
Geophysics	Map Portal (SGIDŠ)	Slovakia	+	+	+	+		+	+
	Atlas of Geothermal Energy of Slovakia (SGIDŠ)	Slovakia					+		
	Geophysics Database DRAGON (NGU)	Norway	+	+					+
Geophysical section of complex atlas	National Atlas of Spain, 2nd edition (IGN)	Spain	+	+		+	+		+
Geology and Geophysics	GIS atlas «Subsoil of Russia» (VSEGEI)	Russia	+	+					+
	Central Geological Database (PGI)	Poland							+
	GeoLOG (PGI)	Poland	+	+	+	+			+
	GEOINDEX OFFSHORE (BGS)	United Kingdom	+	+		+			+
	GEOINDEX ONSHORE (BGS)	United Kingdom	+	+		+		+	+
	Map viewer, Map generator (SGU)	Sweden	+	+				+	
	GeoMapViewer (ISPRA)	Italy	+			+			+
	Mineral Deposits and Exploration (GTK)	Finland	+	+	+			+	+

GIS atlases interface

The interface of GIS atlases is also a part of quality estimate, namely its convenience, opportunity of interactive creating own maps, type of data representing, et al. The geoportal is most optimal form for data storage and getting access to information. It is differs in a number of features, including services for web mapping. For example, ArcGIS online (ESRI), Mapserver, Geoserver and also Leaflet, OpenLayers are most popular cartographic services for representing geophysical data in GIS atlas form.

One of the main criterion to estimate interface of atlas is the character of data representation, namely the format of data. The most convenient for the user data format is vector. Download data clipped to an area of interest can be from

geoportals «Geoindex Offshore» and «Geoindex Onshore» by the British Geological Survey (BGS) [5,6], geoportal «Mineral Deposits and Exploration» by the Geological Survey of Finland (GTK) [13], et al. The data will be extracted in a zip file as shp-file and geodatabases (Figure 2).

Most often, the data presented in raster form, therefore they are difficult to reuse, but user can handle smaller amounts of data in interactive maps analysis. The WMS allow user to connect to the database by means of any GIS product, simply indicating a link. Ability to connect WMS is available in the State Geological Map Database of Russia (VSEGEI), the British atlases, GeoLOG from PGI [7] and others. Download the data in most cases can be done in PDF or in raster maps form.

Separately should mention about the possibility of appeal through the Geoportal to archived data. This task for geophysical and geological mapping is particularly acute in mind the accumulation of large data volumes by Geological Surveys and interest of specialists to these reports. The storing data on the geoportal accelerates the process of obtaining the necessary information, as well as visually allows to estimate their location on the ground, comparing the information with each other. From the considered GIS atlases most successfully cope with the task of Slovak Map Portal (SGIDŠ). The portal allows user to receive both general information about previously conducted by surveys, and more detailed information until the reporting documentation. This option makes the GIS atlas an indispensable assistant geophysics in the planning of new surveys and for other tasks.

All atlases it is possible to create interactive maps, but in different ways. The print of current window with the entire interface of the portal is the fastest way, because it requires some efforts to develop. However, almost all the above GIS atlases have special ability to organize the layout of printed map sheet, for example, the addition of a compass needle, numerical and graphical scale, print date, etc. The default format of a future map is PDF. For example, in the Finnish GIS atlas user can select a file format, as well as its resolution in the case of the publication of the raster document. For publishing maps from GIS atlas of Geological Survey of Sweden by SGU [12] a separate module Map Generator allows to control the layout of the sheet process up to a choice of multiple scale and size of the printed sheet (Figure 2).

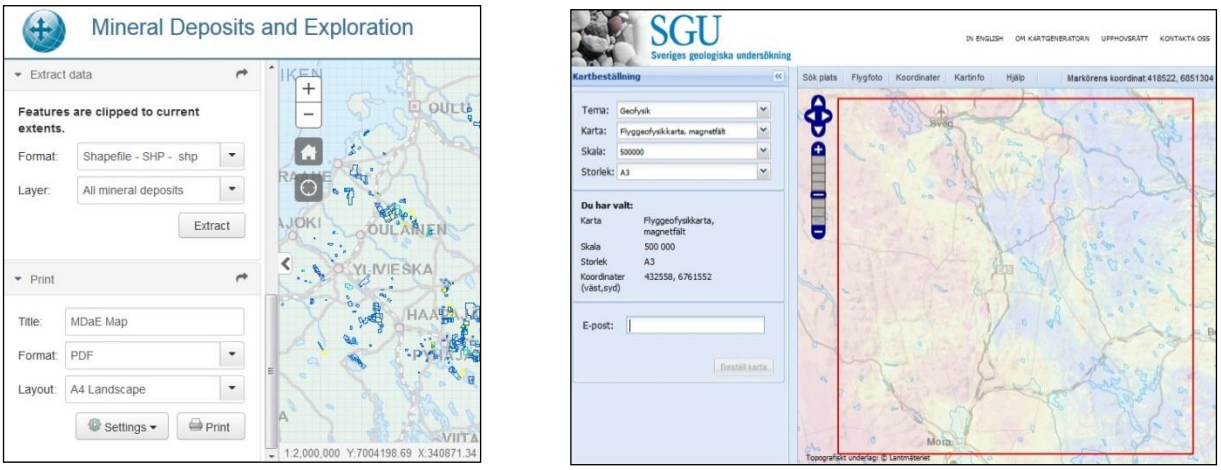

Figure 2. Dialog window «Extract Data» and «Print» in GIS atlas by GTK (left), Dialog window of interactive map creation by SGU (right)

The interactive capabilities of GIS atlases, namely, the map zooms, switching layers to visualize, to obtain information about the objects, coordinates, measure distances and areas, are improved the use of the portal, as these operations are carried out on an intuitive level. The implementation of these actions in the analyzed atlases has some differences. So not all the portals can obtain information about the coordinates of the current position of the mouse – the implementation is available in half of the analyzed atlases. It is noteworthy that the coordinates are often presented in a projected coordinate system. So British Geoindex Onshore, Swedish, Finnish portals and Norwegian Geophysics Database (DRAGON) by NGU [9] are uses for data in national projected coordinate systems. Only the portal of the State Geological Map Database of Russia, Geoindex Offshore by BGS and the Italian GeoMapViewer by ISPRA [8] uses geographic coordinates of latitude / longitude.

Almost all atlases implemented tools to measure distances and areas (exception – Russian and Swedish GIS atlases, as well as National Atlas of Spain, 2nd edition by IGN [14], which, in fact, not a portal, but is implemented as an electronic version of paper version) and doesn't give to user the function of unit selection (kilometers are default). However, in the atlases of Italy, Poland, Sweden and the UK, it is possible to select units from a limited list.

Another important element of the atlas interface is to provide background information about the object. This feature is important for any GIS atlas, but in a special way, it is necessary for the geophysical atlases, because the information user need to get on each object, whether it is profile, well or field value at a particular point. The implementation of information is carried out in several ways: the selected object or group of objects on the frame (in most atlases), specifying a buffer zone along the facility to obtain the information objects that lie inside (Polish atlas), a reference to the maps metadata (atlas of Finland, Spain, etc.).

Cartographic representation of geophysical maps in GIS atlases

Topographic (general geographic) elements

The content of geophysical map as well as any thematic map is consisting of topographic (general geographic) and thematic elements, and also elements of mathematical basis (projection, scale, etc). The visualizing information in geoportals often doesn't provide a thorough compilation of all elements, which ultimately affects the quality of the map. It is important to understand that electronic maps should be created by the same rules and requirements as traditional paper maps. The compliance of the generalization principles to a GIS atlases are even more acute than ever, because now geoportals are implementing multiscale thematic mapping, and therefore general geographic basis elements (rivers, lakes, roads, settlements, etc) suitable for small-scale display cannot be used for larger scale maps. This principle is taken into account in the basic multilevel rasters (basemaps), which are actively used as a geographic basis element in the GIS atlases, including geophysical GIS atlases. The most popular source of topographic elements – ArcGIS online – is used in the atlas of Italy and the UK.

Despite the availability of such a geographical basis, the other geophysical atlases for GIS elements general geographic content using their own state topographic base map. The use of these databases ensures compliance with the principles of generalization and preservation of optimal graphic density of objects and graphic load on different scales. An example is the base of Lantmäteriet (Swedish atlas), a digital topographic map of Russia (GIS atlas «Subsoil of Russia» by VSEGEI [10]), and cartographic databases with a set of elements layers in .MXD format (Slovak atlases). Cartographic bases for each scale are also used in atlases of Poland, Finland and Norway (Figure 3), but the source of the information is not explicitly specified.

However, the use of topographic base maps should also take into account the subject of geophysical maps to ensure the harmonization of topographic and thematic content. The fact that the geophysical maps imposes rather strict selection of elements, to qualitatively show the distribution of geophysical fields in the contour lines form, while preserving elements of the general topographic elements. The specificity of display of geophysical field by contours and color levels with possible shading of pseudo relief forces to withdraw from the map terrain and vegetation, to thin road network and settlements images, to selected hydrographic objects, etc. In the case of study maps on the contrary it is important to show the nearest settlements, transport accessibility to the shooting profile or well, administrative value, etc. I.e, the approach to the formation of general topographic (general geographic) elements should be selective and take into account the purpose of map.

This principle partially implemented in only a few atlases. For example, in the atlas of Slovakia in the large-scale map of study by electrical instead previously connected database of geographical objects used raster topographic maps 1:10 000. The atlas of Poland and Norway can interactively change the composition of the site-general geographic elements, which certainly allows adjusting map content to fit map purpose.

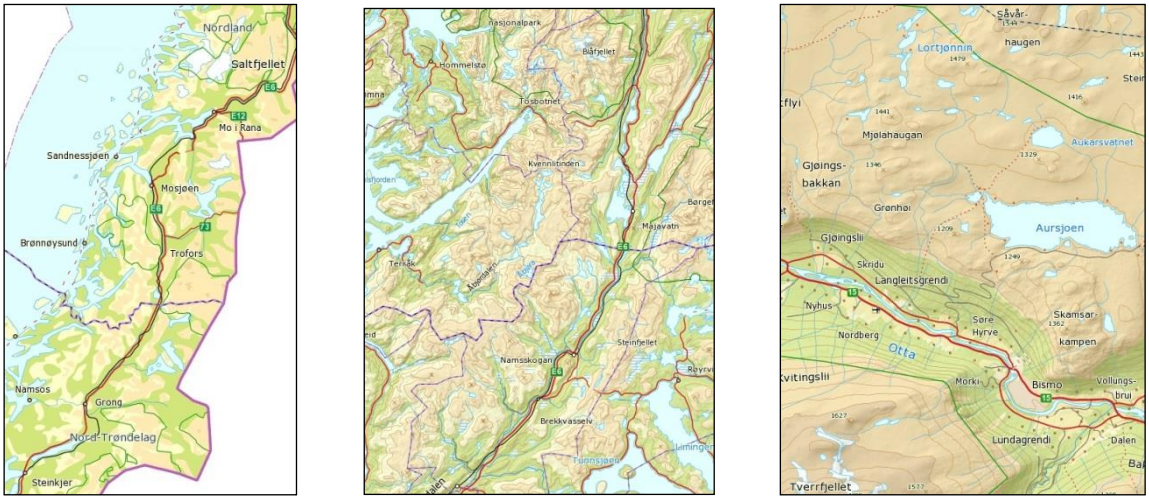

Figure 3. Topographic (basic geographic) elements at the different scale of visualization in GIS atlas of NGU (Norway): 1:2 000 000 (left), 1:500 000 (center), 1:50 000 (right)

Thematic elements

The content completeness is directly influenced on thematic elements composition of geophysical maps presented in the GIS atlases. Depending on the data template (raster or vector) different ways to cartographic display are applied. The most common and reasonable method is the isolines (contours). It is supplemented often by background color steps between the contours, which provide unique color scales [2]. The shading of pseudo relief is adding element of map design. If the geophysical field displayed in a matrix form (grid) is used background color for the cell grid. Accordingly, in such cases, the issue of harmonization of general geographic and thematic elements becomes even more urgent. In particularly, there are no clear instructions for selection of contour interval to geophysical maps, depending on the field nature, value distributions and morphological features of the fields, so now used irregular contour interval. However, for example, in Italian GIS atlas contours of the gravitational field is provided with different leveling on different scales – 10, 6 and 2 mGal at three range of map scale.

The informativeness of thematic basis and variability of its content is an important question. The magnetic field maps and maps of study were the most diverse in their subject. For example, the maps of Z and T vector are in the Slovak atlas, including grid representation; maps of another four elements of the total intensity magnetic vector are presented in the atlas of Spain; maps of magnetic field derivative, magnetic anomalies are included in other atlases (e.g. Russian). The study maps of almost of all geophysical exploration types are presented in atlases of Poland and Finland.

Mathematical basis elements

The mathematical basis element – map scale, map projection, layout of content – defines shape, arrangement and measuring capacity of topographic and thematic elements. There are different guidelines for its formation in the analyzed GIS atlases.

The map scale range of visualization levels for each atlas is unique since different geographical coverage mapping territory. In practice, consistent order and arbitrary scale change are implemented. The consistent consolidation (step by step) implemented the principles of generalization as mentioned earlier. The most comprehensive range of map scale reflected in atlases of Sweden, Finland and Norway (11 different scales). The use of multiple scales provides continuity of content and allows user to create high-quality reporting maps directly from the GIS atlas.

The visualization of all data in the GIS atlases carried in map projections optimally suitable for mapping the territory of a particular state. As a rule, using of conformal projections is transmitted without distortion angles and directions. For example, in the atlas of Slovakia implemented Krovak universal conformal conical projection on ellipsoid Bessel 1841, in Swedish atlas – SWEREF99 TM / RT90, etc. The Russian atlases in mind a large extent the territory used by several projections, particularly for small entities apply the projection Gauss-Kruger or the UTM, and for the length of the territory are taken Equidistant Conic.

Another element of the mathematical basis – layout of content – directly affects the map data visualization. According to the results of GIS atlases analysis it is determined that an image is used floating arrangement of the main area (atlases

of Poland, Russia, Slovakia), linking with neighboring countries, thus preserving the continuity of space (Finland, Norway, Spain, Sweden), or the world layout in general (Italy, UK).

Figure 4. Layout of content: left – whole country (Polish Central Geological Database), center – with neighboring countries (Interactive National Atlas of Spain), right – whole world (Geoindex Offshore by BGS)

The ways to solution of geophysical GIS atlases

The analysis of the content and design of the existing GIS atlases allowed making certain conclusions on the current state of atlas mapping in geophysics and identifying possible improvements on the basis of it.

11. The extension of maps themes and sections structuring – incomplete coverage of the whole variety of geophysical fields was revealed on the results of the analysis. Gravity and magnetic field maps are most common, while maps of remaining fields are not present in all atlases. The inclusion of other fields' maps will enhance the informativeness of atlas content, its functionality and application in integrated studies of geophysical phenomena within a particular territory. Sections of GIS atlases should be clearly structured in accordance with the classification of geophysical maps [1], and also should comply with the current level of development of geophysical mapping.
12. The data presentation in WMS, WMF and WCS – today the data are presented in raster form in most atlases, including a WMS, which limits the data analysis only visual method. The best option is expected formation of cartographic databases for re-use of data and the WMF operating with vector data. Other data formats for geophysical mapping can serve as a matrix form of grids in WCS format. Such a representation would enhance the role of the GIS atlases as a reliable source of cartographic information with a view to medium- and small-scale geophysical mapping.
13. The development of GIS atlases as a storage tool – prospects of GIS atlases like atlas systems and databases lies in addressing the problems of collecting, storing and processing large amount of data, which include geological and geophysical data. Active implementation of cloud technologies to form a geoportals will enable not only to store archived data, but also to the remote interactive access to speed up the process of obtaining information and its use in research.
14. The extension of interactive map creating possibilities – the formation of report maps on the basis of data from the atlas is another promising way for improving the functionality of the GIS atlases. The analysis showed that today already have a realization of automated map layout creating. This process can add new features, such as allowing user to change the position of the maps elements at its discretion.
15. Interface GIS atlases development – interface directly affects the interactive possibilities of GIS atlas. The obtaining of metric, geographic and other background information, which is now realized in not all of atlases. The interface improving in this field will allow the user to better navigate in the electronic space, it needs to obtain background information to conduct spatial analysis of data, etc.
16. Creation and using of specialized topographic base elements – it is proposed to form the basic cartographic database, which can be used to create topographic elements on different display scale levels, taking into account the image graphics load the and the specifics of display topographic elements on the geophysical maps. The national topographic base maps with minor adjustments in content depending on the type of maps can be used as such databases. It will implement the principles of the traditional atlas mapping with preservation of consistency and unity as the general geographic and thematic content.

17. Optimization of selecting contour intervals and map design – the thematic content should be carried out in accordance with the experience of the global geophysical mapping, such as selecting contour intervals and color scales for isolines geophysical maps. The consideration of these factors will significantly improve the visibility of the transmitted information.

CONCLUSIONS

Technologies of geoinformation atlas mapping are used extensively in the field of geophysical mapping, whose interests include the display of data on the Earth's geophysical fields at both the global and local levels. Given the specificity of presenting data in the information space, GIS atlases may include more information and provide the user with an interactive control content of atlas. The analysis of existing GIS atlases geophysical subjects revealed a good level of use of new technologies for mapping geophysical data visualization, storage and accessing the metadata, as well as for operational creating of geophysical maps. Most of atlases include a narrow range of themes for maps, the most common of which is the distribution of gravitational and magnetic fields on the mapping area. Many atlases provide information in raster form, which allows for data analysis only visual means.

GIS atlases interface provides multilevel representation by changing the display scale, the choice of site-specific data from the tool highlighting areas of interest, and also provides access to the metadata. Other tools allow user to prepare a map displayed on the screen to print a paper version.

The development of multiscale electronic atlas geophysical mapping is one of the priority tasks of this branch of thematic cartography, as new technologies make it possible to obtain relevant information about the geophysical processes that directly affect both the geological structure of the Earth, and the human activity. In this direction, the GIS technology allows geophysical mapping to reach new heights.

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BIOGRAPHY

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