

MODERN METHODS FOR CREATING GEOLOGICAL MAPS

Zayniddinov F.A

Alimov M

Khusainov Kh.A

Toshtemirov Sh

National University of Uzbekistan

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Abstract. This article was prepared with extensive use of the laboratory facilities and software of the Center for Remote Sensing of the Earth and GIS Technologies. It provides important information on using modern ArcGIS-ArcMAP software products for geological mapping and data digitization. The analysis of achievements in digital cartography is highlighted based on specific, factual data from work on digitization and digital map creation being carried out in the territory of Uzbekistan.

Keywords: remote sensing of the Earth, satellite image, digital map, software, modern, laboratory, technology

Introduction. The use of geoinformation technologies in geological exploration is one of the most effective methods worldwide for mineral prospecting. Today, geoinformation technologies are widely used in three of the most important fields of geology.

1. Creating digital maps. Creating geological maps of various scales using GIS technologies relies on computer systems that, in the future, will enable the integration of users of this ready-made cartographic and geodatabase product, facilitate their search and input of necessary data, and organize the information into a usable format.

2. The application of digital formats of existing geological, geophysical, and geochemical data in forecasting promising areas. Today, the widespread use of geoinformation forecasting methods in geological research is a priority direction for unconventional geological studies. The identification of promising areas for mineral resources and their recommendation for further geological exploration is a common practice worldwide.

3. Given the steady global growth of online activity, digital technologies, and internet adoption, the digitalization of geology is a pressing and high-demand task across the world.

A geological report is the final document reflecting the results of geological subsoil studies. It consists of geological materials compiled and maintained for state records in accordance with various guidelines, and is subject to requirements for its storage and use.

Geological maps, textual reports, and their accompanying explanatory notes, published in accordance with the requirements of special instructions, were submitted in triplicate to the All-Union Geological Fund and in duplicate to the respective territorial funds. For decades, subordinate geological exploration organizations and research institutes have been accumulating materials in their archives in hard-copy paper format.

The planned digitization of geological data is a key objective within the IT strategy of the Ministry of Mining and Geology of the Republic of Uzbekistan. The archival materials collected over the years by the Geological Survey of Uzbekistan will be sorted by priority, geography, and demand, then progressively converted to a digital format. This approach will allow for the transition of individual units first, followed by all enterprises, while adhering to a balanced annual budget for the digitization projects.

The digitization of geological maps involves representing all elements of a geological map as a collection of points, lines, and area objects (polygons), whose spatial positions are referenced within a specific coordinate system. Coordinate systems can be local (conditional) or global, with the latter being adopted for individual countries, regions, or the entire world. In local systems, map objects are linked to arbitrary rectangular coordinates; for example, a zero coordinate value might be set at the bottom-left corner of the map. In global systems, all objects are referenced using a global rectangular or geographic coordinate system. The software that enables the creation of digital maps in global coordinate systems is called a Geographic Information System (GIS). Examples of GIS commonly used by geologists include PARK, GeoShaper, MapInfo, ArcView, and ArcGIS. All other programs, such as CorelDraw—which is widely used by many geologists—are not GIS, even though they allow you to draw maps; they are simply convenient graphic editors. A geological map and its elements created in such a program cannot be positioned on the Earth's surface without a special spatial reference. Therefore, in this context, we will only refer to maps created in a GIS as digital geological maps.

Thus, the first and most important feature of digital geological maps is their ability to depict geological mapping objects and the conditions of their spatial relationships based on real geographical coordinates. Additionally, satellite data, along with observation and testing sites, can be used directly to create geological map objects.

The second feature of digital geological maps is the ability to enter information about the objects depicted on them into special attribute tables, which are an integral element of each cartographic object. These tables contain mandatory service data regarding the type of cartographic object and, at the author's discretion, any substantive geological information about the objects being mapped. This is the basis for referring to GIS as an information system. In contrast, graphic editors are unable to carry any information about a mapping object beyond its visual component.

The third feature of GIS and digital maps is the ability to change the coordinate system (reprojecting data) and, accordingly, to display all cartographic data in any known cartographic projection of the world.

The fourth feature of digital maps is the ability to use attribute data to create labels and design cartographic objects in both automatic and interactive modes (if completed attribute tables are available), as well as to form selections and queries of any type.

A digital geological map should be a logical-production model of the geological structure of a territory (TM). Structuring consists of distributing information into various thematic layers, which facilitates obtaining information about objects and visualizing the elements of interest to a geologist. An important component of structuring is assigning objects to various metric types.

In general, cartographic objects are defined by one of their geometric characteristics:

- point,
- linear,
- areal.

In their application, distinguishable and indistinguishable objects can be derived within each of these types.

An indistinguishable point object is a non-scale object whose geometry is fully described by a pair of coordinates (X,Y) defining its position in the XOY plane. Indistinguishable point objects are always represented as points in the model. A well is an example of an indistinguishable point object.

A distinguishable point object is a scaled object whose geometry is related to its position coordinates (X,Y) and information about its "orientation" (direction in the XOY plane). An example of a distinguishable point object is a survey benchmark.

Objects included in the point path data are represented as specified in the CM, and data regarding the website's direction is entered into the attribute table.

Linear objects are always represented in the volumetric model as polylines consisting of multiple segments. If the direction of the converging line conveys important information about the object, it belongs to the subclass of directed linear objects. If the direction of the converging line is irrelevant, it is a non-directed linear object. Examples of a directed linear object include a non-conformity boundary or a thrust fault; examples of a non-directed object include a conformity boundary or a vertical fissure.

To define the geometry of a non-delineated area object, it is sufficient to bound this object by its area. The design of territorial objects with directed hatches is associated with polygonal movement directions and the vehicles associated with them. An example of a non-oriented area object is the depiction of rocks with an intrusive body, a granitization zone, or oriented bodies such as gneisses, various shales, etc.

In general, the arrangement of thematic layers and document titles is standardized, but authors may implement it based on personal preference. However, 10 years ago, -1000/3 and is effective in obtaining loads and GK. Each CM contains information about a single control of the area's structure.

Analytical summary of the division of the CM for geological production at a scale of 1:200,000 into thematic layers (packages):

- main section package;
- set of structures with surficial deposits;
- set of metamorphic facies;
- set of secondary alterations;
- set of isolines;
- bedding package;
- Set of paleontological finds and locations of geochronological dating points;
- set of planning objects (wells, mine workings, etc.).

For a more complete explanation of the digital layering, let's describe the content of the main packages mentioned above.

It reflects the spatial division of a unit with geological features, the geological boundaries of the area unit and the faults that intersect them, and the general characteristics for point objects.

Areal Objects of the Package

An areal (polygonal) theme that includes lithostratigraphic units drawn at the map's scale—series, formations, beds—or chronostratigraphic units—systems, divisions, stages—as well as non-stratigraphic units, such as intrusive, subvolcanic, and metamorphic complexes.

a. Linear Objects of the Package

b. Point objects of the package.

A point theme, which includes explosion pipes, kimberlite pipes, dikes not to scale, sills, etc., not expressed at the scale of the legal document.

This package contains information about mapped areas of two- or three-layered structures, including exposed intrusive bodies. The structure of the package's themes is similar to the surface geology of a geological map.

This package reflects the distribution areas of regional metamorphic rocks and their boundaries. In a conventional representation, these are areas covered with patterns representing facies of regional metamorphic rocks, separated by the boundaries of subfacies and metamorphic zones.

a. Areal objects of the package

One or several (if similar) areal themes, which include the distribution areas of greenschist, epidote-amphibolite, amphibolite, granulite, high-pressure glaucophane metamorphism facies, and others.

b. Linear objects of the package

A single linear theme that includes the boundaries of metamorphic facies and subfacies, and the boundaries of metamorphic zones within a facies and subfacies.

This set reflects the distribution areas, linear bodies, and off-scale objects of secondarily altered rocks (metasomatites, tectonites, weathering crusts, etc.).

a. Areal objects of the package

One and/or several (if they are similar) areal themes that include the distribution areas of secondarily altered rocks.

b. Linear objects of the package

A single linear theme that includes the boundaries of secondarily altered rocks.

c. Point objects of the package

A single point theme that includes off-scale, secondarily altered elements.

ArcGIS is a modern software product from ESRI, one of the world leaders in the development of geographic information systems. It represents the next stage of development for the ArcInfo GIS system. It should also be noted that the program is constantly evolving. The first configuration version appeared in 2002 under the name ArcGIS 8.2. This version was not yet sufficiently functional and was essentially a combination of the ArcInfo 8 and ArcView 3.3 packages. In 2004, the new multifunctional ArcGIS Desktop 9 platform was released, which served as the basis for the 2005 version, ArcGIS 9.1, the 2006 version, ArcGIS 9.2, and the later 9.3 version. In 2013, a slightly revised version of ArcGIS was released—ArcGIS 10.1 and ArcGIS 10.2. The latest version, ArcGIS 10.8, proved to be the most successful in terms of functionality and convenience for solving problems faced by creators of digital geological maps, and many enterprises in the geology industry switched to using it.

For users, ArcGIS is available in several configurations, which differ in their level of functionality and, accordingly, their cost.

To solve many of the problems that arise when creating geological maps, the first component of the package, ArcMap, is generally sufficient. However, given the specific nature of the operations required in the technological process—such as constructing polygonal themes from linear ones, working with overlays, etc.—the geologist ultimately needs to have the full version.

The ArcGIS 10.x software suite includes the following software packages:

- License Manager: a set of programs for configuring and managing the license collection for all programs in the suite.
- ArcCatalog: an analogue of the Windows File Manager, oriented towards working with geographic information system files.
- ArcMap: the main application of the suite for viewing, analyzing, and editing maps.
- ArcScene: an application for visualizing three-dimensional images of the Earth's surface.
- ArcToolbox: a collection of auxiliary tools not included in the aforementioned applications, integrated under a common management application. This is where you find tools for importing and exporting geographic information system formats, as well as tools for converting geographic projections. Additionally, the user can add any of their own custom tools here.
- Desktop Administrator is an application that allows you to view the current configuration status of an installed software package and the licenses for the software products it contains.

Since ArcGIS is a further development of the ArcInfo and ArcView series, all files created in ArcView can be easily loaded into ArcMap, and vice versa. Unfortunately, this does not apply to design elements. ArcView's *.apr projects and *.avl legends can be converted to ArcMap to

varying degrees. However, it is important to remember that any design elements created in ArcMap and saved in *.lyr data files or *.mxd projects can no longer be visualized in ArcView.

Also, the names of some key terms have been changed in ArcMap, so a correspondence table between ArcView and ArcGIS terms is provided below. Furthermore, throughout this description, we will continually draw parallels with ArcView's functions, as it is the most common GIS in geological practice and is known to some extent by a wide range of geological users (Fig. 1).

For the user, creating a digital geological map model in ArcGIS begins with launching the ArcMap application (Fig. 2).

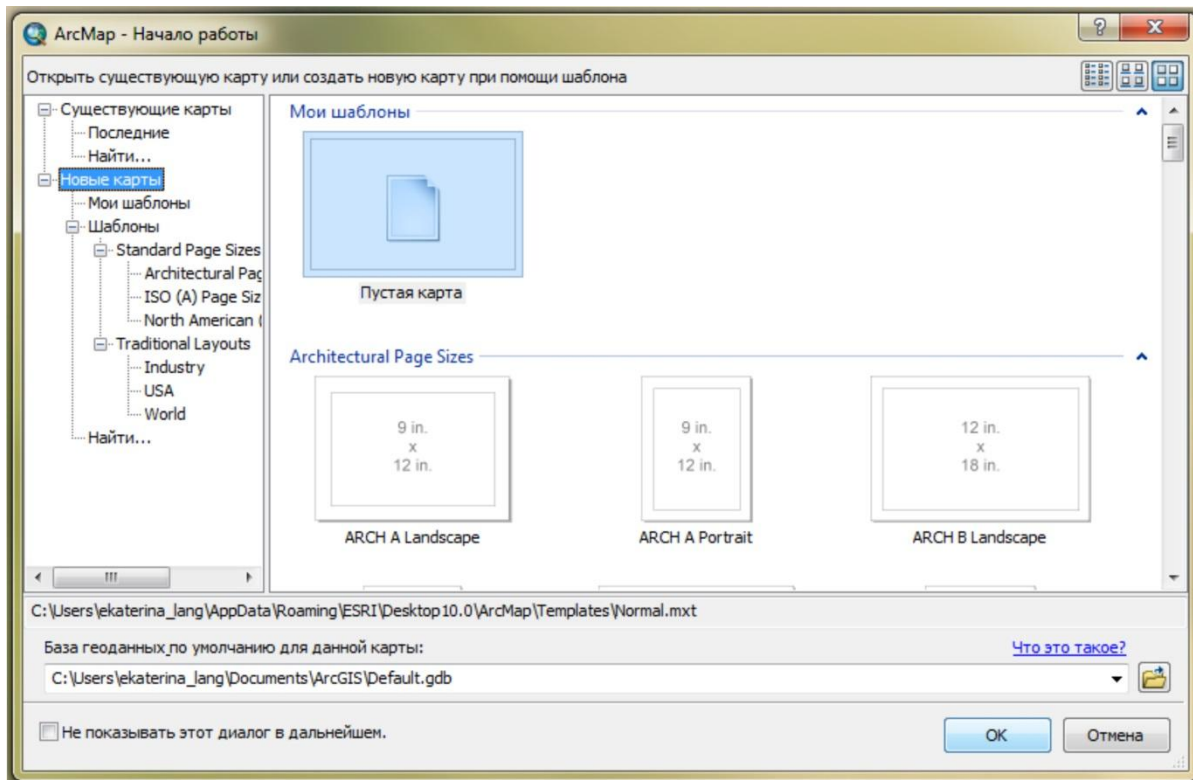


Figure 1. Creating "New Maps" (in this case, selecting this option and clicking "OK" will open a blank ArcMap document, ready for further work).

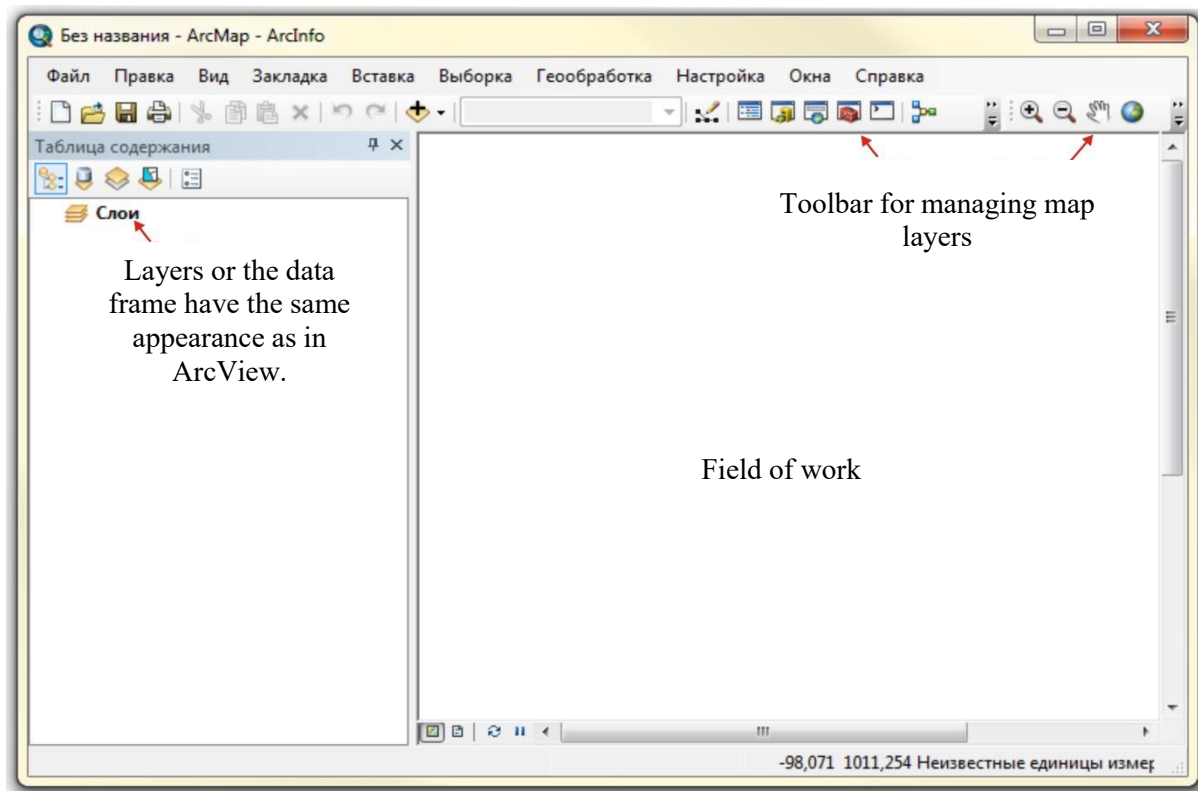


Figure 2. Display of the created map

The Equidistant Conic projection is used for mapping areas larger than one million map sheets. In this case, you must sequentially select "Predefined" @ "Projected Coordinate Systems" @ "Continental" @ "Asia" @ "Asia North Equidistant Conic" (Figure 3).

It should be noted that Pulkovo 1942 Zone 11 applies to the entire territory of the Republic of Uzbekistan and, at the same time, its central part. If you are working on a project for a specific region, then it is preferable to work in Pulkovo 1942 Zone 10 for the Ustyurt region, and in Pulkovo 1942 Zone 12 for the territory of Eastern Uzbekistan.

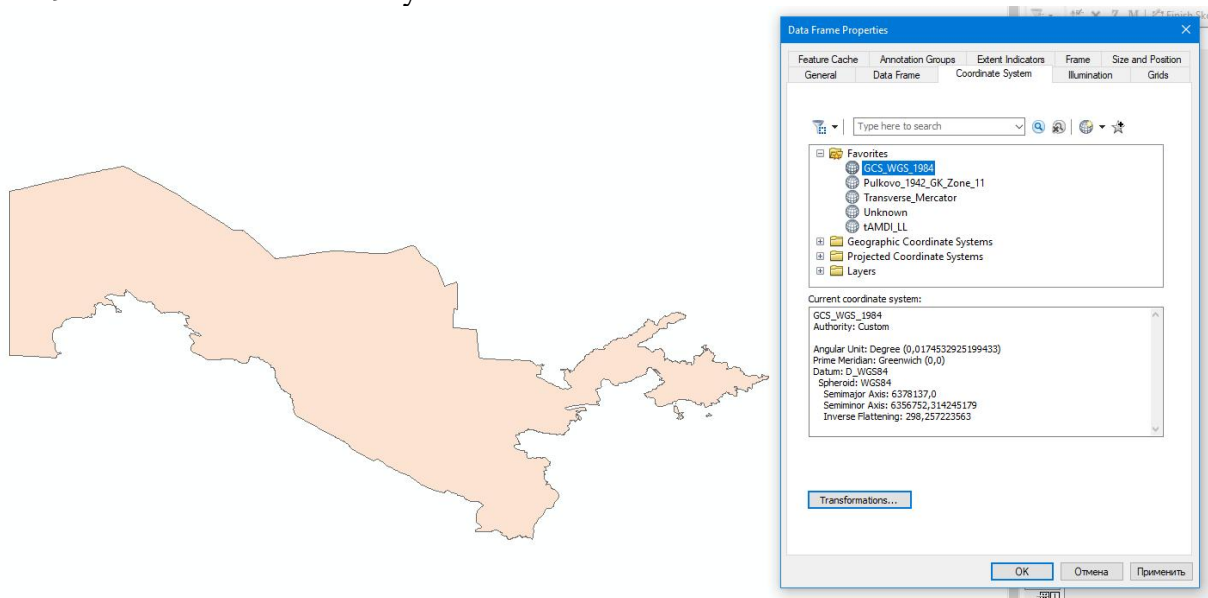


Figure 3. The territory of our republic displayed in the WGS-84 coordinate system.

Performing operations with ARCCatalog and creating a geodatabase.

All files are displayed in the Catalog workspace. If they are not visible, they can be created using the "Connect to Folder" command. For example, if a geodatabase is to be created in D:\Distance Education\GIS\Geodatabase, this file path is first displayed.

Creating a Spatial Object Class. A spatial object class is created in the geodatabase. To do this, select the geodatabase file in the Catalog window, right-click on it, and select the "New > Feature Class..." commands from the context menu.

First, a file name is selected (for example, Spatial_Object_Class); there must be no spaces between words.

Conclusion. In modern GIS technologies, methods that involve combining data from various thematic layers of vector and raster maps are increasingly used for analyzing materials (geological, geophysical, etc.). Remote sensing of the Earth facilitates the spatial integration of processed materials in GIS programs and also allows for the combination of geophysical, geochemical, and geological data. A layered map type allows multiple maps to be viewed as one. Thematic layers enable us to analyze maps with a high level of detail.

In this regard, significant progress is being made in expanding our country's mineral resource base. Specifically, geological research has made it possible to forecast and identify numerous new prospective areas.

At the current stage of geological exploration for various minerals, enhancing the effectiveness of Uzbekistan's geological industry and increasing its global market competitiveness must be based on continually growing scientific activity. This requires training highly qualified specialists who possess modern capabilities for collecting, systematizing, analyzing, and rapidly processing information using digital technologies, which enables optimal management decisions while minimizing risks.

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