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SOLVING THE TASKS OF SUBSURFACE RESOURCES MANAGEMENT IN GIS RAPID ENVIRONMENT

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ABSTRACT

Purpose. Solving the tasks of subsurface resources management based on the created GIS RAPID geoinformation technology.

Methods. Close spatial relationships of lineament network characteristics and earthquake epicenters were detected in 3 seismically active areas located in the mountainous regions of Central Europe. Digital elevation models (DEM) based on ASTER satellite surveys and earthquake epicenter data were used. The nature of spatial relationship of lineament network and vein ore objects was studied in the territory of Congo DR, in the Lake Kivu area using space imagery. Gold ore objects were searched and forecasted in Uzbekistan in the site of Jamansai Mountains. High-resolution imagery from QuickBird 2 satellite, geophysical field surveys, geological and geochemical data were used.

Findings. It was found that a significant number of epicenters are located in areas of high concentration of “non-standard” azimuths lineaments – from 27 to 34% of the total number of lineaments. It was revealed that 59.6% of the epicenters are located within 10% of sites with the highest values of complex deformation maps; 50% of the areas with the highest values of these maps contain, on average, 89% of all earthquake epicenters. It was found that satellite image lineament concentration maps with “non-standard” azimuths reflect the spatial relationship with known deposits much better than the concentration map of all lineaments. It was detected that the total area of gold ore objects perspective sites is about 20 km^2.

Originality. The use of GIS RAPID in a number of earth’s crust areas has allowed to establish new regularities linking the networks of physical field and landscape lineament characteristics with ore bodies and earthquake epicenters localization.

Practical implications. A new technology has been developed for solving geological forecasting and prospecting problems. The technology can be used to solve a wide range of practical problems, especially in difficult geological conditions when searching for deep objects weakly presented in external fields and landscape.

Keywords: *geoinformation system, Data Mining, mineral deposits, earthquakes, lineament analysis*

1. INTRODUCTION

Solving of environmental management problems at the current stage involves the use of a large amount of heterogeneous spatial materials – space imagery, cartographic and digital geological, geophysical, geochemical, environmental, meteorological and other geodata. Data handling is unthinkable without information technologies (Pivnyak, Busygin, & Garkusha, 2010; Kuttykadamov, Rysbekov, Milev, Ystykul, & Bektur, 2016). Currently, the creation of software capable to process and analyze efficiently large arrays of heterogeneous and multi-level data is of paramount importance. Such software tools, first of all, include geographic information systems (GIS), which combine the possibilities of storing, processing, analyzing and visualizing spatial data. Their intensive development over the past decades has provided a new qualitative level of spatial information management.

A specialized RAPID (Recognition, Automated Prediction, Data Interpretation) GIS has been created at the Dnipro University of Technology. It is a powerful tool for integrated spatial data analysis based on Data Mining and solving various tasks of subsurface resources use.

2. BASIC INFORMATION ABOUT THE RAPID SYSTEM

2.1. Purpose

The RAPID GIS is focused on processing and intelligent analysis of heterogeneous and multi-level geodata

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and allows solving a wide range of Earth science problems based on general methodological principles: mineral resources forecasting, territory mapping, monitoring and forecasting natural and man-made emergency situations, geo-ecological assessment, etc. (Busygin & Nikulin, 2015).

The system allows using a variety of digital data obtained from space (satellite materials), superterranean (aerial and airborne geophysical surveys), terranean (field geological surveys), or underground space (measurements in mining). The system uses several models of data representation: grid model (geophysical fields and geochemical data), vector model (cartographic layers) and raster model (aerospace images).

A geoinformation technology is created based on the RAPID GIS tools. The technology implements the principle of multivariate problem solving with the help of simulation and computational experiments. It is focused on the establishment of direct links between spatial regularities of objects and phenomena location, on the one hand, and the structure of data describing them, on the other.

A simplified flow chart is shown in Figure 1.

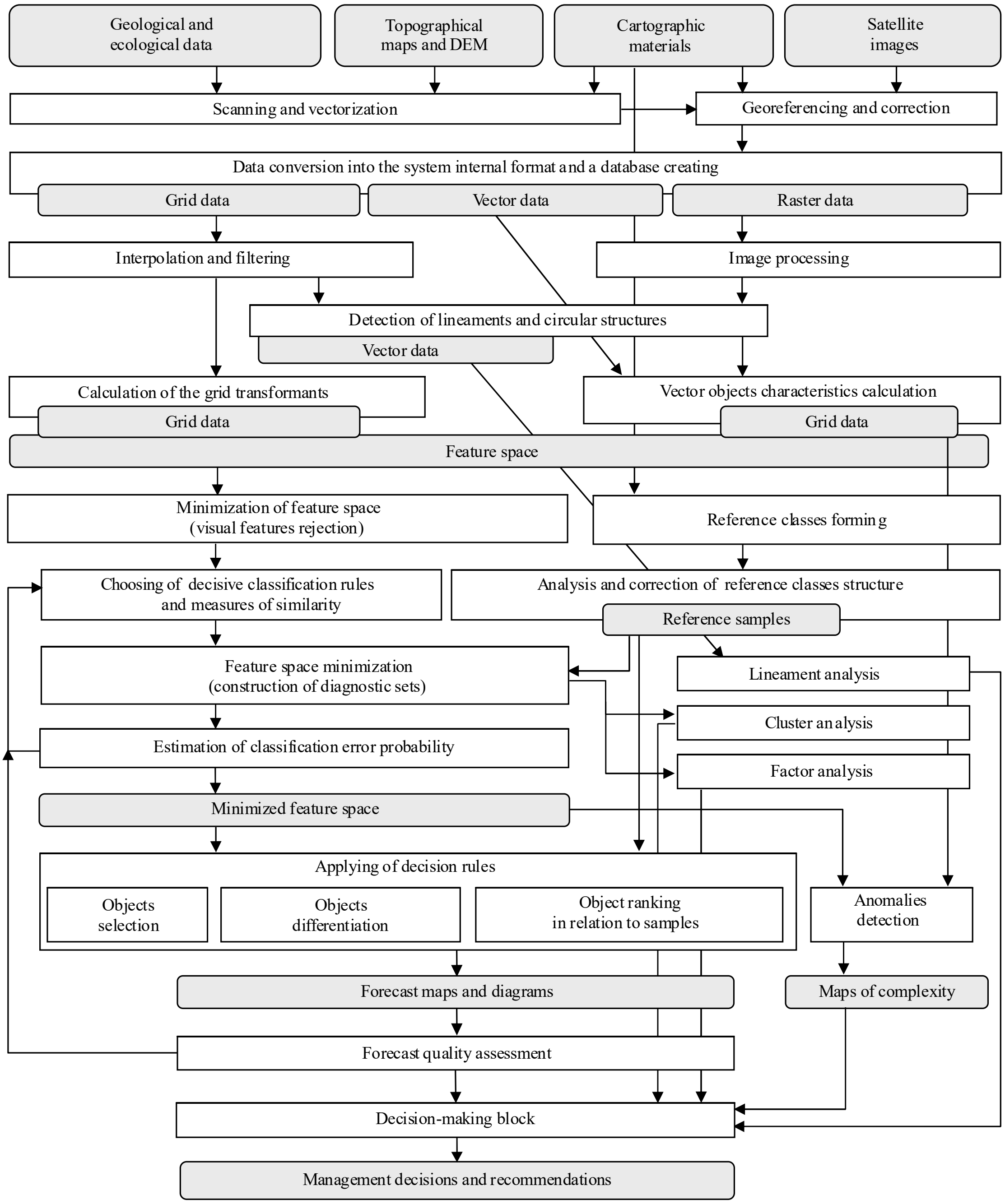

Figure 1. Flow chart for solving forecasting and prospecting problems based on RAPID GIS

2.2. Structure

The system includes data management core, as well as a set of modules grouped into functional subsystems for data management, calculating transformations of initial data and evaluating their informative value, lineament analysis and forecasting based on Data Mining methods, graphs, etc. In total, the RAPID GIS includes about 100 functional modules with a single user interface (Fig. 2).

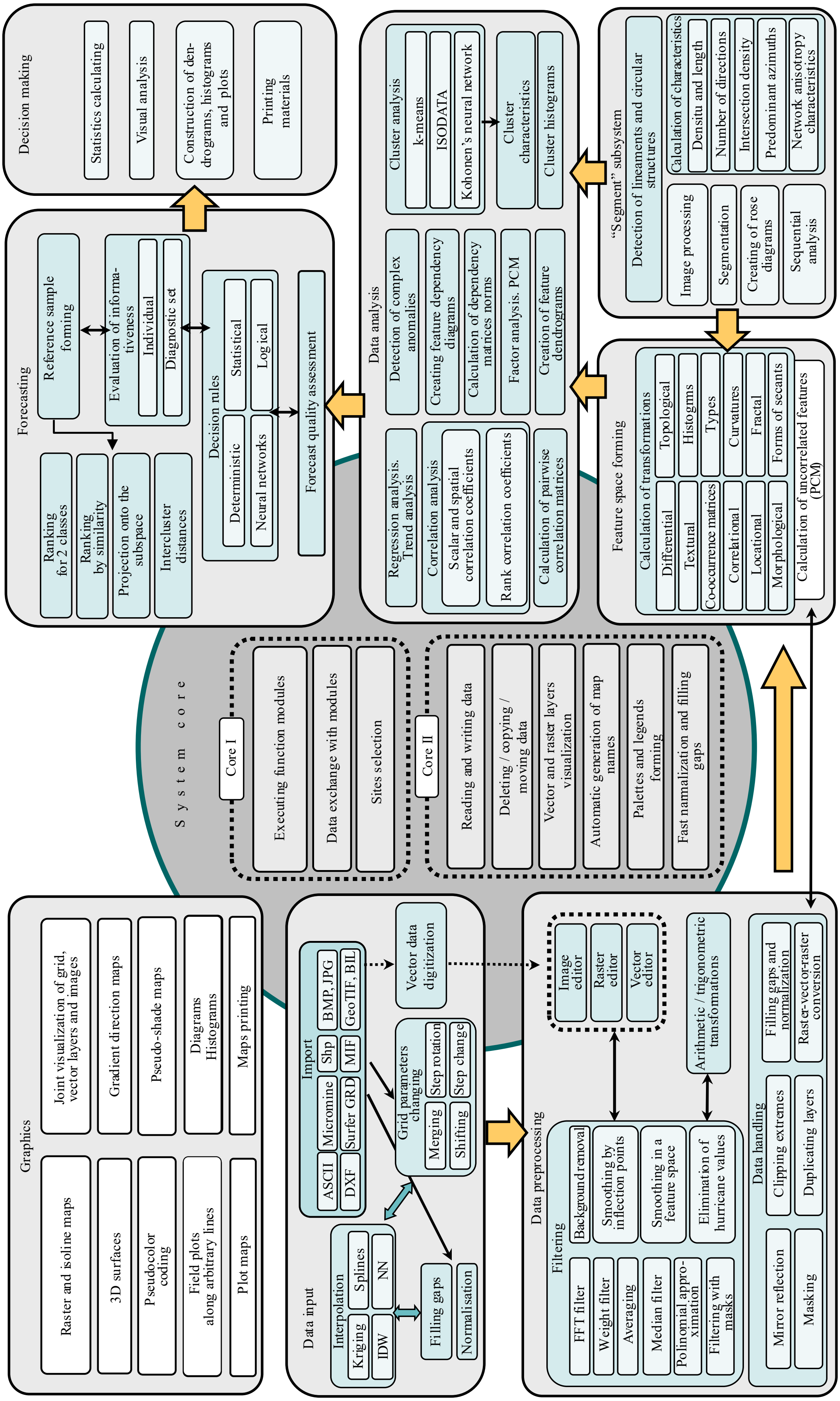

Figure 2. General diagram of the RAPID GIS structure

The system core is a software package consisting of two components. The first is responsible for calling individual modules, for data exchange between different modules (that solve specific tasks of data processing and analysis), as well as between RAPID GIS and such well-known systems as ArcGIS, Micromine, Surfer, and others.

The second component is embedded in all functional modules, manages data streams and provides reading, recording, deleting, visualizing tools and simple transformations (smoothing, filling gaps, normalization). Such structure of the system ensures the simplicity of its expansion and gives the possibility of creating on its base both functional sub-systems and individual GIS intended for solving specialized tasks.

2.3. Special features

The RAPID GIS has a number of features that distinguish it from other systems of this class:

1. The presence of a developed subsystem for calculating transformations of original data and for selecting the most informative of them. Since there are many methods for calculating transformations, and a priori it is impossible to determine which of them are the most useful for solving a specific problem; usually, various transformations are calculated with the subsequent selection of the most informative. The RAPID GIS provides more than 200 transformations, and special optimization methods allow to distinguish among them the groups that ensure problem solutions with minimal error.

2. The unique subsystem of lineament analysis. The subsystem implements a large number of procedures for selecting, processing and analyzing of lineaments – linear fragments of satellite images and physical fields. Unlike most well-known lineament analysis systems, RAPID GIS allows to integrate the subsystem with prediction modules and to use the results of the lineament analysis as input data in Data Mining procedures.

3. A powerful subsystem for solving forecasting and prospecting problems using Data Mining methods (Witten, Frank, Hall, & Pal, 2017). The subsystem includes 18 classification methods (supervised and unsupervised) based on deterministic, statistical, logical and neural network decision rules; 12 criteria for forecasts' accuracy assessment; a specialized graphics editor enabling the formation of learning and control samples in an automated mode (Fig. 3).

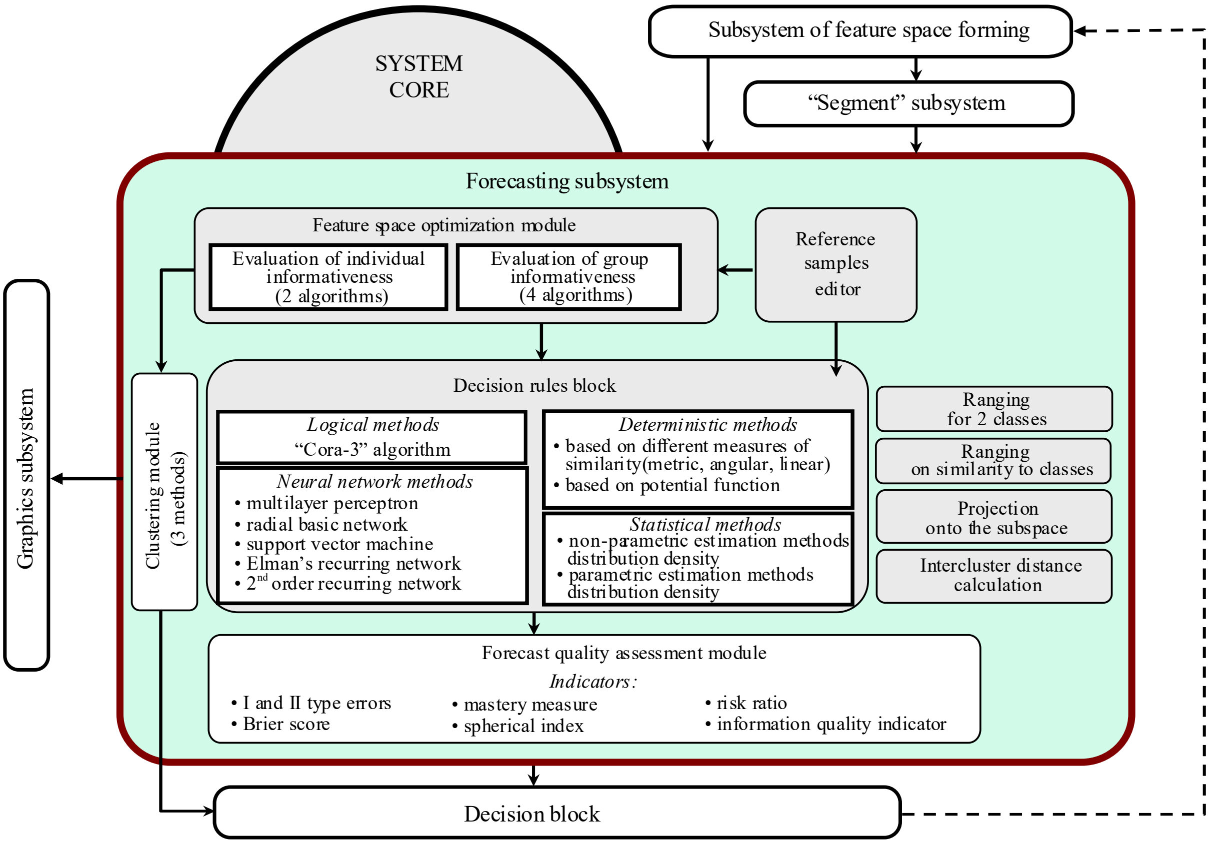

Figure 3. Functional diagram of the forecasting subsystem

3. APPLICATION OF THE RAPID SYSTEM AND TECHNOLOGY

The capabilities of RAPID GIS are demonstrated below with several practical examples illustrating the solution of two problems – investigation of spatial interconnections between landscape lineament networks and spatial distribution of various geological objects, as well as the forecasting of mineral deposits localization.

3.1. Estimation of the interconnection between landscape lineaments and earthquake epicenters

Lineaments correspond to rectilinear structures of a landscape, hydrographic network, etc., which, in turn, are usually associated with peculiarities of the earth's crust structure – geological boundaries, fractures, and fracture networks. Lineaments are ubiquitous and as a rule form networks of orthogonal systems of certain azimuths. Usually, there are 4, less often from 6 to 12 such systems (Florinsky, 2008). In most cases, the clearest are lineaments with azimuths of 0, 45, 90, 135 degrees, which form a global network.

According to modern concepts, the discharge of tectonic stresses causing earthquakes is usually confined to the areas of high lineaments density (concentration), in particular, to their intersections (Masoud & Koike, 2017; Zakharov, Zverev, Zverev, Malinnikov, & Malinnikova, 2017). Consequently, the epicenters of earthquakes are not distributed randomly but are determined by the structure of lineament network. The following studies were carried out on the basis of this principle.

3.1.1. Central Europe

The studies were conducted using the data of three sites located in the mountainous region of Central Europe. Site 1 (156 × 67 km) includes a fragment of the Sudeten Mountains; Site 2 (334 × 132 km) covers a part of the Carpathian Mountains; Site 3 (175 × 175 km) is located in the east of the Austrian Alps (Fig. 4).

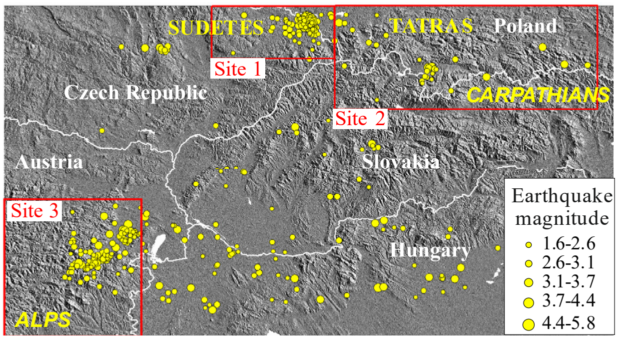

Figure 4. Location of the studied sites on a digital elevation model

Since 1999, these sites have seen around 300 earthquakes with a magnitude of 1.6 to 5.8. During the research, the problem of identifying the closest spatial interconnections of various characteristics of lineament networks and earthquake epicenters was to be solved. We used digital elevation models (DEM) based on ASTER satellite images (ASTER GDEM 2 product, obtained in October 2011; source – earthexplorer.usgs.gov) and data on earthquake epicenters (source – earthquake.usgs.gov).

At the first stage, lineaments were detected on digital elevation models in an interactive mode. Several DEM representations were used in order to improve quality of lineament detection – in the form of a two-dimensional raster, a pseudo-three-dimensional model reflecting slopes of the original DEM, as well as four light-shadow representations with different positions of the light source (at a horizontal angle equal to 0°, 45°, 90° and 135°; the vertical angle being constant and equal to 60°).

Earlier (Busygin & Nikulin, 2016), the authors demonstrated that the epicenters of earthquakes, as anomalous objects, tend to locate near the areas of the earth's crust with a complex geological structure different from the structure of adjacent territories. Hence, the epicenters of earthquakes should mostly occur not close to the actual ubiquitous lineaments, but to the zones of their "anomalous" behavior, where the original lineaments were subjected to deformations. The latter include breaks (points of integrity violation) of lineaments and their rotations relative to the initial position. As indicated above, the global network of lineaments is formed mainly by linear structures with azimuths of 0°, 45°, 90° and 135°. Taking these azimuths as initial, it can be assumed that the lineaments of other azimuths ("non-standard") received the current orientation as a result of the newest tectonic movements, which are especially intense in earthquake-prone areas. Figure 5 shows several maps for Site 3.

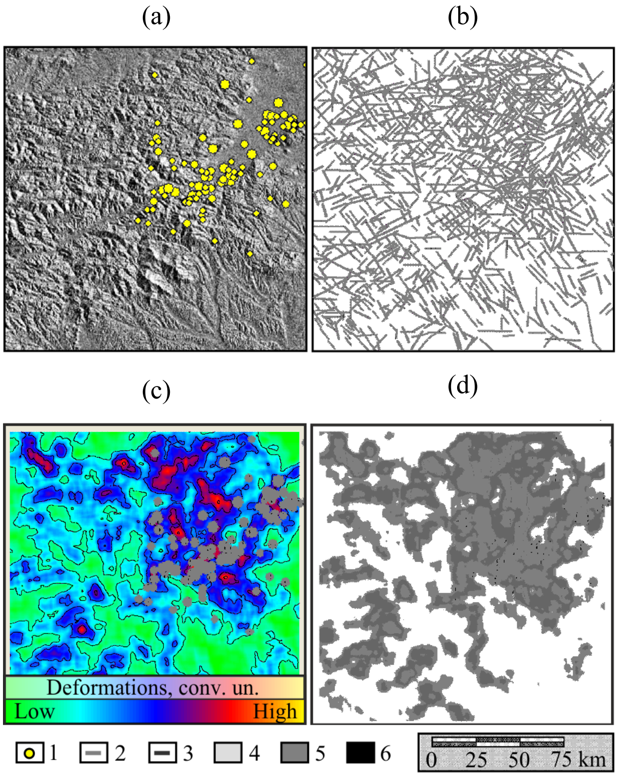

Figure 5. Maps of Site 3: a – digital elevation model; b – network of relief lineaments; c – complex deformation map; d – zones of high values of deformation map at different thresholds; 1 – earthquake epicenters (size depends on magnitude); 2 – lineaments with azimuths in the intervals 0/90/45/135±11.25°; 3 – lineaments with azimuths 22.5/67.5/112.5/157.5 ± 11.25°; 4, 5, 6 – area allocated at thresholds P_{50}, P_{30} and P_{10}

Based on the above, a number of maps were constructed for all the sites, in particular:

A. The length of all identified lineaments inside a "sliding" square neighborhood of 10 × 10 km in size with a "slide" step of 1/3 km.

B. The length of the lineaments with "initial" azimuths of 0 ± 11.25°, 45 ± 11.25°, 90 ± 11.25° and 135 ± 11.25° (the angle of 11.25° is equal to half the angle of 180°/8; where 8 is the total number of allocated "initial" and "non-standard" azimuths).

C. The length of lineaments with non-standard azimuths of 22.5 ± 11.25°, 67.5 ± 11.25°, 112.5 ± 11.25°, 157.5 ± 11.25°.

D. The number of breakpoints (integrity violations) of all lineaments within a neighborhood.

For each map, the percentage of epicenters that fell into zones of elevated values determined by the P threshold was calculated. The P value was chosen so that the selected zones would cover a given percentage of the total area. Three thresholds P_{10}, P_{30}, P_{50} correspond to 10, 30 and 50% of the sites total area.

Analysis of the constructed maps showed that, as in other areas of the earth's crust, most of the lineaments have azimuths of 0 ± 11.25°, 45 ± 11.25°, 90 ± 11.25° and 135 ± 11.25° (Table 1).

Table 1. Total number of lineaments

Site	Lineament azimuths		
	Total	0/45/90/135 ± 11.25°	22.5/67.5/112.5/157.7 ± 11.25°
1	617	450 (73%)	167 (27%)
2	1868	1353 (72%)	515 (28%)
3	1248	823 (66%)	425 (34%)

It should be noted that a significant number of epicenters is confined to areas with increased concentration of lineaments of "non-standard" azimuths (Table 2). Composing from 27 to 34% of the total number of lineaments (Table 1), they control a significant part of earthquake epicenters.

But complex deformation maps are much closer connected to earthquake epicenters. They are created as a result of superposition (summation) of previously normalized maps of types *C* and *D* (Table 3).

Table 2. Number/Percentage of epicenters in the areas of high concentration of lineaments with "non-standard" azimuths

Site	Threshold P_{10}		Threshold P_{30}		Threshold P_{50}	
	number	%	number	%	number	%
1 (total number of epicenters – 161)	63	39.1	105	65.3	126	78.3
2 (total number of epicenters – 30)	11	36.7	21	70.0	24	80.0
3 (total number of epicenters – 102)	17	16.7	51	50	76	74.5

Table 3. Number/Percentage of epicenters in areas of high values of complex deformation maps

Site	Threshold P_{10}		Threshold P_{30}		Threshold P_{50}	
	number	%	number	%	number	%
1 (total number of epicenters – 161)	98	60.8	122	75.8	142	88.1
2 (total number of epicenters – 30)	21	70.0	28	93.3	29	96.7
3 (total number of epicenters – 102)	49	48.0	71	69.6	84	82.3
Average		59.6		79.6		89.0

Table 3 can be interpreted as follows: 59.6% of the epicenters are located within 10% of the sites with the highest values of complex deformation maps; 50% of the territory with the highest values of these maps contain, on average, 89% of all earthquake epicenters.

The results shown in Figure 2 and in Tables 1 – 3, allow to conclude that there exist a fairly close interconnection between the localization of earthquake epicenters and the characteristics of landscape lineament network, and, before all, the network deformation level. The presence of such interconnection is promising for using the methods of lineament analysis in the study of a complex of geophysical fields – gravitational, magnetic, thermal, and others.

3.1.2. East African Rift

The objective of the work was to study the nature of the spatial interconnections between lineament networks and vein ore deposits. At the same time, various characteristics of the network were studied and compared in order to identify those deposits where these interconnections would be the closest. Space surveys were used as input materials for conducting the research.

During space image studying, it was found that concentration map of lineaments with "non-standard" azimuths reflects the spatial interconnection with known deposits much better than the concentration map of all lineaments (Fig. 6).

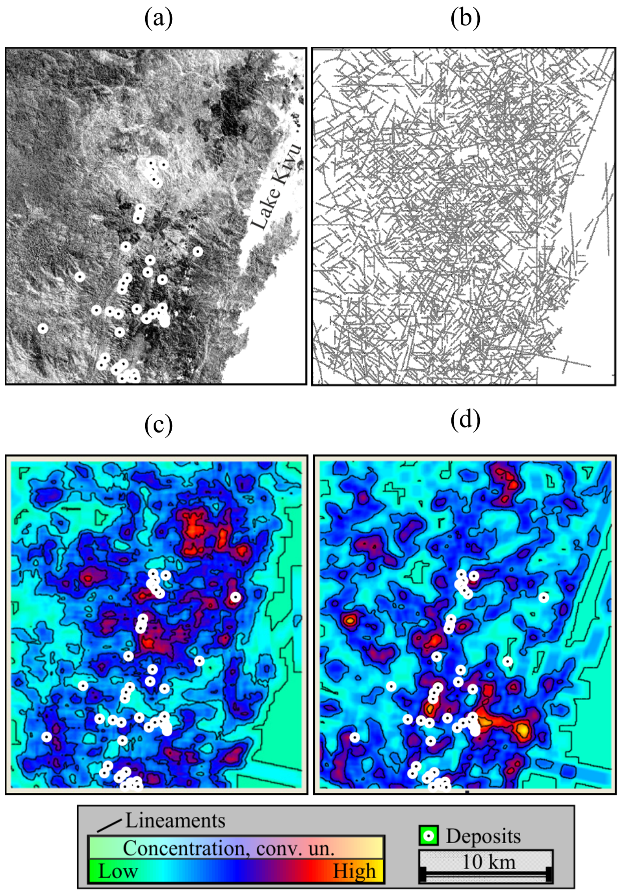

Figure 6. Landsat-8 satellite image, band 5 (a), known deposits (b), concentration maps of standard (c) and non-standard (d) azimuth lineaments

The study was carried out on an area of 2500 km^2 located in the Democratic Republic of the Congo, near Lake Kivu. The eastern and central parts of the site are located within the East African rift valley; the western part is the edge of the Congo Basin. The site is composed of rocks of Paleo- and Mesoproterozoic age, is interspersed with Neoproterozoic rocks and partially overlapped by Neogene sediments. Within the site, there are several dozens of tin, niobium, tantalum, tungsten, gold, iron, and tourmaline deposits. The greatest industrial value of the tin deposit is associated with cassiterite, as well as niobium-tantalum (coltan) ores, which are found both in alluvial sediments and in the Proterozoic primary vein pegmatites (Wit, Guillocheau, & Wit, 2015).

In the studied area, like on the most part of the earth's surface, lineaments of two orthogonal systems with azimuths of 0º/90º and 45º/135º degrees prevail. Thus, out of 3059 lineaments detected in the interactive mode, 2343 (77%) have azimuths in one of the ranges of 0 ± 11.25º, 90 ± 11.25º, 45 ± 11.25º, or 135.25 ± 11.25º. However, the concentration map of 716 (23%) lineaments that do not fall within the specified ranges, is much more informative. Thus, there are significantly fewer anomalous zones that do not correspond to known deposits, though the number of deposits associated with positive anomalies is almost invariable on both maps.

3.2. Mineral deposits localization forecast

The capabilities of RAPID GIS can be demonstrated using the example of searching for gold ore objects in the Republic of Uzbekistan, on a site located in the Jamansai Mountains (Fig. 6). On a site of 18 × 22 km in size, several dozens of ore occurrences and one gold deposit were known. The task was to identify areas promising for prospecting new gold objects.

The initial data were: high-resolution satellite imagery from the QuickBird 2 satellite with a spatial resolution of pan-chromatic band of 0.6 and 2.5 m multispectral (red, green, blue and near infrared) bands, materials of 6 geophysical fields survey in 1:25000 and 1: 50000 scales (Vz, ΔTa, Za, γ-field, isoresistivity field and the field of natural electric potentials), represented in the form of contour line maps. In addition, we used such geological and geochemical data: points of increased gold mineralization in ditches and wells, geological maps and schemes.

To solve the forecasting problem, a specially developed technology was used, oriented on establishing direct interconnections between the spatial regularities of objects and phenomena location, on the one hand, and the data structure describing them based on supervised classification procedures, on the other. The technology includes three main stages:

1) forming the space of descriptions (attributes), i.e. various transformations of initial materials, with subsequent evaluation of their informative value and selection of the most informative ones;

2) forming reference and control samples required to execute the supervised classification procedures;

3) forecasting based on territory ranking by its similarity to reference sample objects in the multidimensional description space.

During the first stage, features-descriptions were obtained, representing the lineament networks, circular structures, geophysical fields and geological data processing and analyzing results. In total, the stage yielded over 1000 different transformants, 18 of which were selected using special Data Mining procedures.

Particular attention was paid to reference sample forming, which is essential for reference classification, as a stage that significantly affects the forecasting efficiency (Busygin & Nikulin, 2015). The network nodes over the 20 known gold objects were used as reference points. Reference objects located in different geological conditions on the basis of a priori structural and petrographic representations were grouped into several classes. Then, objects clustering procedures were performed with a different number of initially defined classes (clusters) and a different structure of attribute space. 2 classes were formed after clustering results analysis. Irrelevant objects were removed from each class based on multidimensional scaling (Borg & Groenen, 2005), which made it possible to significantly increase the degree of compactness of class images in a multidimensional space. And 12 well-known gold objects formed a control sample, used later to assess the forecasting accuracy.

The ranking consisted in calculating several similarity measures for network nodes with respect to each of the two sample classes, with subsequent designing of a generalized map of a complex indicator of the territory prospectivity. The type I error calculated for the control sample was 8%, and the type II error was 16%.

The areas characterized by the highest similarity were chosen as promising on the constructed maps of similarity measures (Fig. 7).

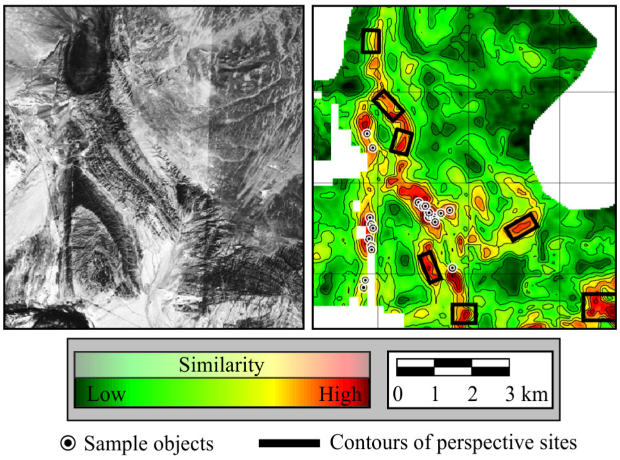

Figure 7. QuickBird-2 space image of the site (a) and a similarity measure map of the territory in relation to the reference classes (b) with promising sites

The total sites area was about 20 km^2 (5.1% of the territory). Further ground-based geological studies of the site confirmed high quality of forecasting and made it possible to identify several promising gold ore objects.

4. CONCLUSIONS

Only a few of the numerous examples of using RAPID GIS were treated above. The use of RAPID GIS for solving various geological problems allows to conclude that it is highly efficient, especially in difficult geological conditions when searching for deep-seated objects that are weakly manifested in external fields. The presence of a clear sequence of technological stages necessary to achieve high quality results, numerous feedbacks and a wide choice of tools implemented in the RAPID geographic information system make it possible to solve problems even in the most complex geological conditions. The system has a substantial potential for further development, associated primarily with the implementation of multi- and hyperspectral satellite images processing procedures, texture analysis of geo-images, as well as ring and arc structures of the Earth's surface.

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REFERENCES

Borg, I., & Groenen, P.J.F. (2005). *Modern multidimensional scaling: theory and applications*. Berlin, Germany: Springer. https://doi.org/10.18637/jss.v014.b04

Busygin, B.S., & Nikulin, S.L. (2015). Specialized geoinformation system RAPID: features, structure, tasks. In *14th EAGE International Conference on Geoinformatics – Theoretical and Applied Aspects, Geoinformatics 2015* (pp. 1-4). Kyiv, Ukraine: EarthDoc. https://doi.org/10.3997/2214-4609.201412353

Busygin, B.S., & Nikulin, S.L. (2016). The relationships between the lineaments in satellite images and earthquake epicenters within the Baikal Rift Zone. *Sovremennye Problemy Distantsionnogo Zondirovaniya Zemli iz Kosmosa*, *13*(4), 219-230. https://doi.org/10.21046/2070-7401-2016-13-15-219-230

Florinsky, I.V. (2008). Global lineaments: application of digital terrain modelling. *Advances in Digital Terrain Analysis (Lecture Notes in Geoinformation and Cartography)*, 365-382. https://doi.org/10.1007/978-3-540-77800-4_20

Kuttykadamov, M.E., Rysbekov, K.B., Milev, I., Ystykul, K.A., & Bektur, B.K. (2016). Geodetic monitoring methods of high-rise constructions deformations with modern technologies application. *Journal of Theoretical and Applied Information Technology*, *93*(1), 24-31.

Masoud, A., & Koike, K. (2017). Applicability of computeraided comprehensive tool (LINDA: LINeament Detection and Analysis) and shaded digital elevation model for characterizing and interpreting morphotectonic features from lineaments. *Computers & Geosciences*, (106), 89-100. https://doi.org/10.1016/j.cageo.2017.06.006

Pivnyak, G.G., Busygin, B.S., & Garkusha, I.N. (2010). Conceptual approach to the creation of the state system of monitoring and prediction of coal fires in the data space survey. *Geoinformatics 2010 – 9th International Conference on Geoinformatics: Theoretical and Applied Aspects*, A020.

Wit, M.J., Guillocheau, F., & Wit, M.C.J. (2015). *Geology and resource potential of the Congo Basin*. Heidelberg, Germany: Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29482-2

Witten, I., Frank, E., Hall, M., & Pal, C. (2017). *Data Mining: practical machine learning tools and techniques*. Amsterdam, Netherlands: Morgan Kaufmann Publishing.

Zakharov, V.N., Zverev, A.V., Zverev, A.T., Malinnikov, V.A., & Malinnikova, O.N. (2017). Application of automated lineament analysis of satellite images in modern geodynamics research: a case study. *Russian Journal of Earth Sciences*, *17*(3), 1-14. https://doi.org/10.2205/2017ES000599

РІШЕННЯ ЗАДАЧ НАДРОКОРИСТУВАННЯ В СЕРЕДОВИЩІ ГІС РАПІД

Б. Бусигін, С. Нікулін, К. Сергєєва

Мета. Рішення задач надрокористування на базі створеної геоінформаційної технології ГІС РАПІД.

Методика. Виявлення тісних просторових взаємозв'язків різноманітних характеристик мереж лінеаментів і епіцентрів землетрусів проводилося у 3 сейсмоактивних ділянках, розташованих в гірських районах Центральної Європи. Використовувалися цифрові моделі рельєфу (DEM), побудовані за зйомками зі супутника ASTER і дані по епіцентрах землетрусів. Дослідження характеру просторового взаємозв'язку мережі лінеаментів і жильних рудних об'єктів проводилися на території Демократичної Республіки Конго, в районі озера Ківу із використанням космічних зйомок. Дослідження пошуку та прогнозу золоторудних об'єктів виконувалися в Узбекистані на ділянці Джамансайскіх гір. Використовувалися високоточні космічні зйомки зі супутника QuickBird 2, зйомки геофізичних полів, геологічні та геохімічні дані.

Результати. Виявлено, що значна частина епіцентрів приурочена саме до ділянок підвищеної концентрації лінеаментів "нестандартних" азимутів, складаючи від 27 до 34% загального числа лінеаментів. Встановлено, що 59.6% епіцентрів знаходяться всередині 10% території ділянок, що володіють найвищими значеннями комплексних карт деформацій; 50% території з найвищими значеннями цих карт вміщають, в середньому, 89% усіх епіцентрів землетрусів. Визначено, що карти концентрації лінеаментів космознімків з "нестанартними" азимутами значно краще відображають просторовий взаємозв'язок з відомими родовищами у порівнянні з картою концентрації всіх лінеаментів. Встановлено, що сумарна площа перспективних ділянок золоторудних об'єктів склала близько 20 км^{2}.

Наукова новизна. Застосування ГІС РАПІД на ряді ділянок земної кори дозволило встановити нові закономірності, що зв'язують характеристики мережі лінеаментів фізичних полів і ландшафту з локалізацією рудних тіл та епіцентрів землетрусів.

Практична значимість. Розроблено нову технологію рішення прогнозних і пошукових геологічних завдань, яка може застосовуватися для вирішення широкого кола практичних задач, особливо у складних геологічних умовах при пошуках глибокозалягаючих об'єктів, що слабо виявляються в зовнішніх полях і ландшафті.

Ключові слова: *геоінформаційна система, Data Mining, родовища корисних копалин, землетруси, лінеаментний аналіз*

РЕШЕНИЕ ЗАДАЧ НЕДРОПОЛЬЗОВАНИЯ В СРЕДЕ ГИС РАПИД

Б. Бусыгин, С. Никулин, Е. Сергеева

Цель. Решения задач недропользования на базе созданной геоинформационной технологии ГИС РАПИД.

Методика. Выявление тесных пространственных взаимосвязей разнообразных характеристик сетей линеаментов и эпицентров землетрясений проводилось в 3 сейсмоактивных участках, расположенных в горных районах Центральной Европы. Использовались цифровые модели рельефа (DEM), построенные по съемкам со спутника ASTER, и данные об эпицентрах землетрясений. Исследования характера пространственной взаимосвязи сети линеаментов и жильных рудных объектов проводились на территории Демократической Республики Конго, в районе озера Киву с использованием космических съемок. Исследования поиска и прогноза золоторудных объектов выполнялись в Узбекистане на участке Джамансайских гор. Использовались высокоточные космические съемки со спутника QuickBird 2, съемки геофизических полей, геологические и геохимические данные.

Результаты. Выявлено, что значительная часть эпицентров приурочена именно к участкам повышенной концентрации линеаментов “нестандартных” азимутов, составляя от 27 до 34% общего числа линеаментов. Установлено, что 59.6% эпицентров находятся внутри 10% территории участков, обладающих наивысшими значениями комплексных карт деформаций; 50% территории с наивысшими значениями этих карт вмещают, в среднем, 89% всех эпицентров землетрясений. Определено, что карты концентрации линеаментов космоснимков с “нестанартными” азимутами значительно лучше отражают пространственную взаимосвязь с известными месторождениями по сравнению с картой концентрации всех линеаментов. Установлено, что суммарная площадь перспективных участков золоторудных объектов составила около 20 км^2.

Научная новизна. Применение ГИС РАПИД на ряде участков земной коры позволило установить новые закономерности, связывающие характеристики сети линеаментов физических полей и ландшафта с локализацией рудных тел и эпицентров землетрясений.

Практическая значимость. Разработана новая технология решения прогнозных и поисковых геологических задач, которая может применяться для решения широкого круга практических задач, особенно в сложных геологических условиях при поисках глубокозалегающих объектов, слабо проявляющихся во внешних полях и ландшафте.

Ключевые слова: *геоинформационная система, Data Mining, месторождения полезных ископаемых, землетрясения, линеаментный анализ*

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