DIGITAL MODELING OF HEAVY MINERAL PLACER DEPOSITS FOR DEFINING OF PROSPECTS OF FURTHER DEPOSIT DEVELOPMENT

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Digital modeling

Digital modeling is the way to explore real phenomena, processes, devices, systems, and others., based on the study of mathematical models (mathematical descriptions) with the help of a digital computer
(by Great Soviet Encyclopedia).

The object can be described in various ways.
Therefore the choice of the type of model is very important - it will depend on how comfortable the model will be implemented and how well it will perform its functions.

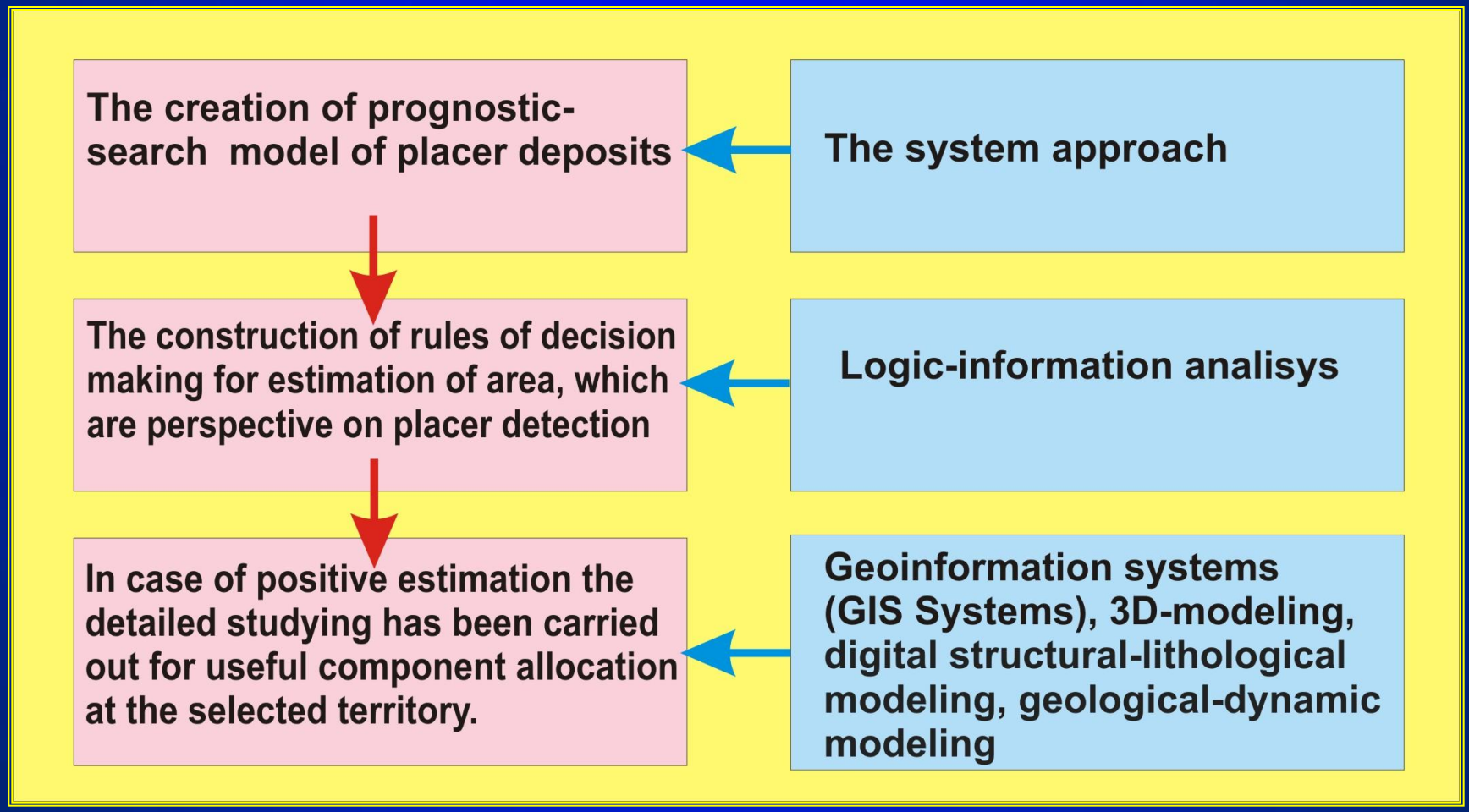
Why do we study placer deposits?

- The exraction of placer gold is conducted in Russia already almost 200 years and till now it is about 50 tons annually.
- Now placer deposits give about 30 % of world extraction of gold, about 50 % of tin, 70 % of titan, 95 % of zirconium; also placer deposits play the big role to extraction of diamonds, especially jeweller.
- By expert estimations of Russian scientists Bykhovsky and Tigunov by 2015-2020 years annually it will be required for Russia not less than 600 thousand tons of ilmenite and up to 100 thousand tons of zirconium concentrates.
- Monacite placer deposits can become a basis of thorium power (Rikhvanov, 2010).

The problem of deposit forecasting

- It can be considered as the problem of pattern recognition.
- While the forecasting problem solution there are prime the creation of prognostic-search models of placer deposits and the construction of rules of decision-making for estimation of area, which are perspective on placer detection.
- In case of positive estimation the detailed studying has been carried out for useful component allocation at the selected territory.
- As examples of the application of various methods of digital modeling, the gold placer objects of Southeast part of the Aldan shield (Russia), titanium-zirconium deposit Centralnoe (Tambov region, Russia), titanium deposit Zlobichskoe (Ukraine) are considered in this report.

Methods for forecasting problem solution



The System Approach

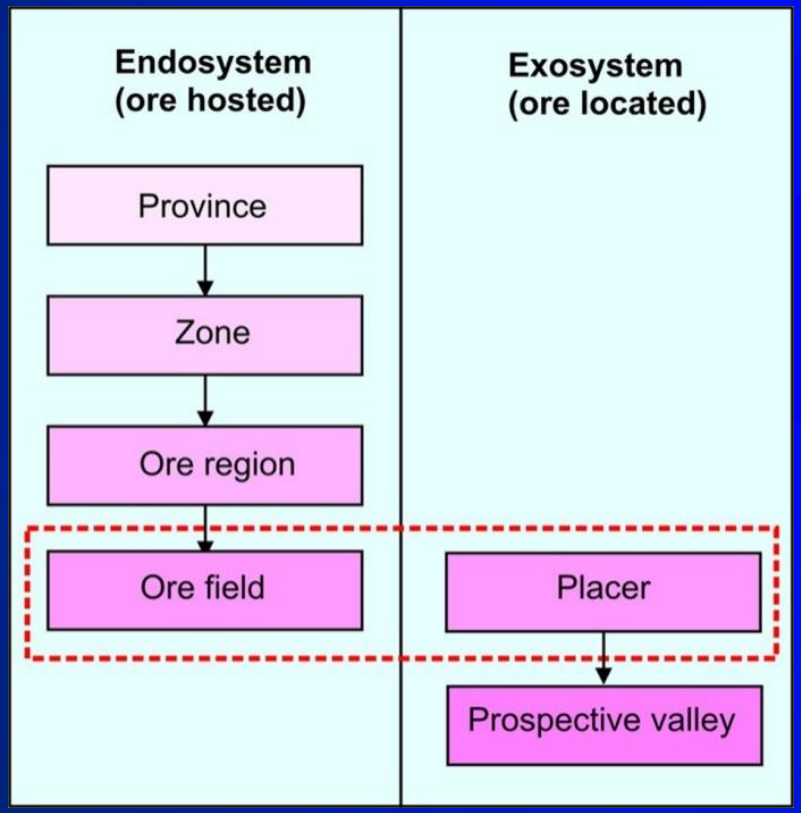


Fig. 1. Metallogenic taxa for placer objects

The features of created multifactor multitag models (MMM) for search and estimation of ore placer deposits, first of all, are caused by specificity of the researched object - gold placer deposit grew out of durable evolution of ore deposit (occurrence), while exogenous processe activity. Therefore it was necessary to accept the originally division of all tags and criteria on the membership into two systems (Fig. 1):

- endosystem (ore hosted) represents a set of criteria and the tags, routed on revealing of potential ore objects - provinces, zones, ore regions, ore fields;

- exosystem (ore placer located) is put in according to that level, where influence exogenous processes starts to play an appreciable role (field level).

Methodology of the Investigation

Methodology of the investigation included the following:

- 1) compiling of a table containing all potentially informative tags;
- 2) forming the database – coding the sites based on the principle of presence or absence of the analyzed tags;
- 3) choosing of the standard sites and compiling of the training populations;
- 4) mathematical processing of data using various algorithms and pattern recognition programs, accounting the frequency and/or character of correlation of the tags;
- 5) compiling of mathematical models of the determined classes from the most informative tags selected and calculation of their weights based on logic-information analysis;
- 6) checking the stability of the compiled models on the independent control populations;
- 7) forming the knowledge base for the computer expert system.

Logic-Information analysis

For allocation of a system of tags, informative for the description of objects of group Ak (where Ak - one of M of studied groups) and separable them from objects of other groups, will be used a following function:

$$\Delta Pjk = pjk1 - pjk0$$

where: pjk1 - probability that the value of tag j falls in the interval - indicator [ajk, bjk] of tag j for objects of group Ak and does not fall in this interval on objects of other groups; pjk0 - probability that the value of tag j does not fall in the interval - indicator [ajk, bjk] of tag j for objects of group Ak and falls in this interval on objects of other groups.

As dividing weight of tag j for allocation of objects of group Ak with the help of an interval of the indicator the function will be used:

$$P_{jk} = \frac{\Delta P_{jk}}{\sum_{j=1}^{N} \left| \Delta P_{jk} \right|},$$

For function evaluation of a fitting of object of research x, described in a system N of tags x=(x1,x2,…,xN), to one of studied groups of objects the following formula is offered:

$$\varphi_k(X) = \sum_{\substack{j=1 \\ P_{jk}>0}}^{N} P_{jk} \cdot x_j - \sum_{\substack{j=1 \\ P_{jk}<0}}^{N} P_{jk} \cdot (1 - x_j),$$

$$X = (x_1, x_2, \ldots, x_N) \qquad 0 \le \varphi_k(X) \le 1$$

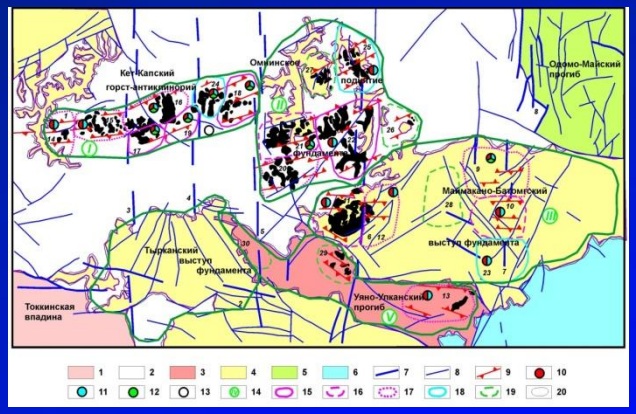
N - number of tags; k - number isolated groups; j - number of tag; pjk - information weight of tag (degree of importance of tag j for object identification ofgroup Ak facilities).
The similar functions can be constructed for any lengths of combinations of informative tags, using them as compound tag and thus complicating reduced above function.

The tags j, having positive value of dividing weight pjk, are interpreted as favourable for reference to group Ak. The tags j, having negative value of dividing weight pjk, are interpreted as unfavorable for reference to group Ak.

The closer function $\varphi_k(X)$ to "1", the object *X* is closer to group Ak.

If for all values k= 1, 2,…, M $\varphi_k(X)$ are close to "0", it proves a dissimilarity of object with given groups and fitting to other group (not participating in the analysis).

In outcome for each examined object we have set of factors describing a degree of its looking alike to each of given groups.



The allocation scheme of gold-bearing ore placer objects of different rank of the southeast part of the Aldan Shield , Russia (scale 1:2 000 000)

N of tag	Tags, informative for perspective area (placer ore field) outlining	Tag weights
	Basis, age	
15	Enninsk suite Rocks	0.05
	Ore	
187	Ore breccia zones (separate zones)	0.05
212	Pyrite zones	0.05
216	Bearing strata - R-V-terrigenous sedimentation	0.05
224	Sulphide quantity in ore up to 5%	0.058
227	Mineral types of ores - pyrite	0.058
230	Mineral types of ores - chalcopyrite	0.058
	Morphostrusture	
248	Moderate (1000-1300 m) raisings of ore field morphostrusture	0.054
249	Rather weak (800-1000 m) raisings of ore field morphostrusture	0.058
276	Radical figure of hydronetwork	0.058
	Substrat, age	
281	Development of linear decomposition residual soil	0.05
	Structure of valleys	
333	Alluvium thickness in waterway of I-II order 5-6 m	0.05
335	V-shaped type of valleys of I-II order	0.046
354	Halos and streams of schlich gold in river valleys of I-II order	0.058

While logic-information analysis the tags receive the quantitative estimation of degree of their importance for the selection of perspective areas.

N of tag	Tags, informative for unperspective area outlining	Tag weights
	Ore	
168	Low temperature hydrotermalite in the form of individual thin veinlet	-0.05
	Morphostrusture	
231	Block system did not differentiate	-0.058
	Geomorphological description of field	
263	Valley quantity less than 20	-0.04
	Structure of valleys	
332	In valleys of I-II order the multimode thickness of loose sedimentation is 2-3 m	-0.046
334	Gold absence in bed alluvium	-0.058

Results are represented numerically, suitable for their automated usage for the creation of the knowledge base of the predicting expert system ASTRA.

Identification

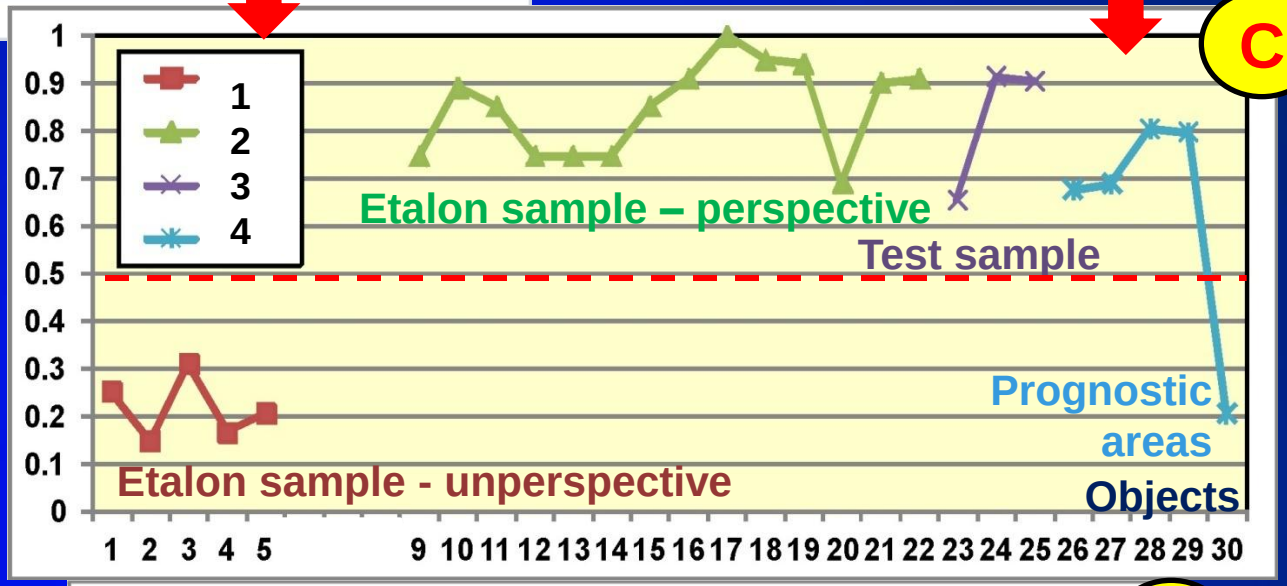
1	Etalon sample	Unperspective area (not placer ore field)
2	Etalon sample	Perspective area (placer ore field)
3	Test sample	
4	Prognostic area	

A

B

N	N of tag in database	Tag weights
1	15	0.05
2	168	-0.05
3	187	0.05
4	212	0.05
5	216	0.05
6	224	0.058
7	227	0.058
8	230	0.058
9	231	-0.058
10	248	0.054
11	249	0.058
12	263	-0.04
13	276	0.058
14	281	0.05
15	332	-0.046
16	333	0.05
17	334	-0.058
18	335	0.046
19	354	0.058

C



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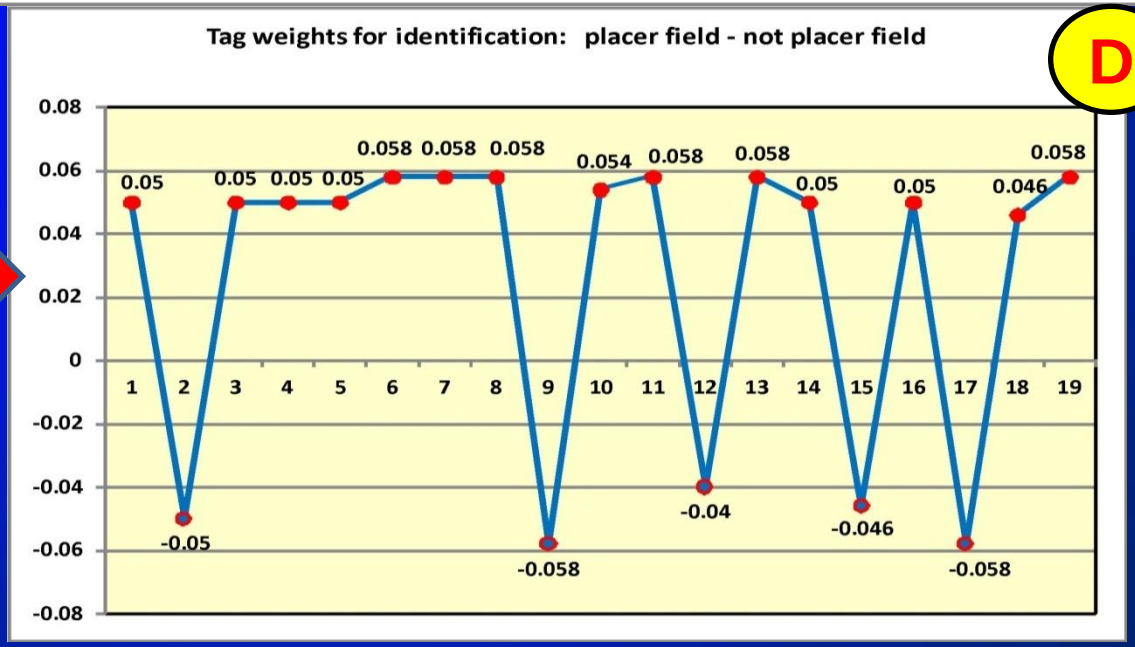
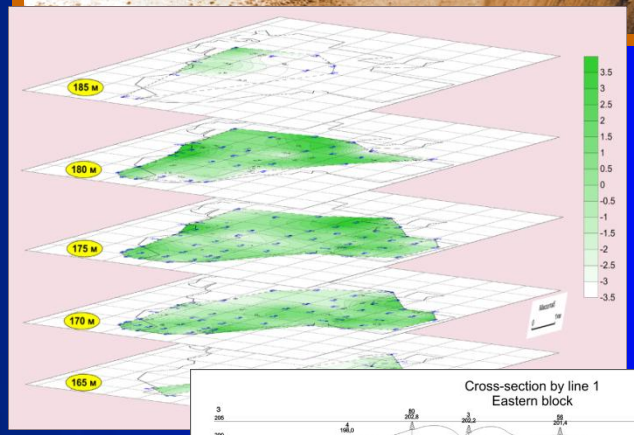
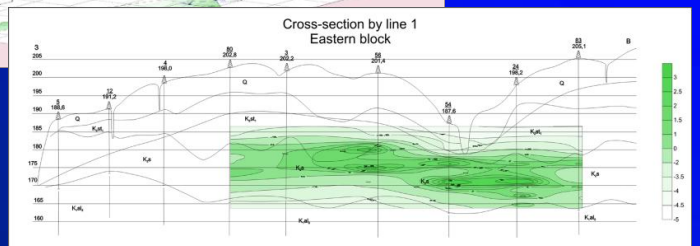
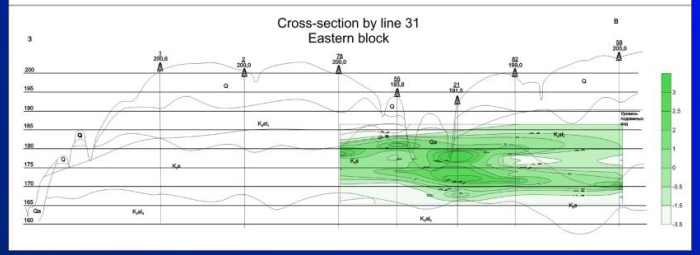








To develop the *structural-lithologic models* the procedure of their construction includes such important tasks as:

- development of a hierarchical structure of the object,

the allocation of structural elements;

- the setting of lithological (including ore) filling of the structural elements;

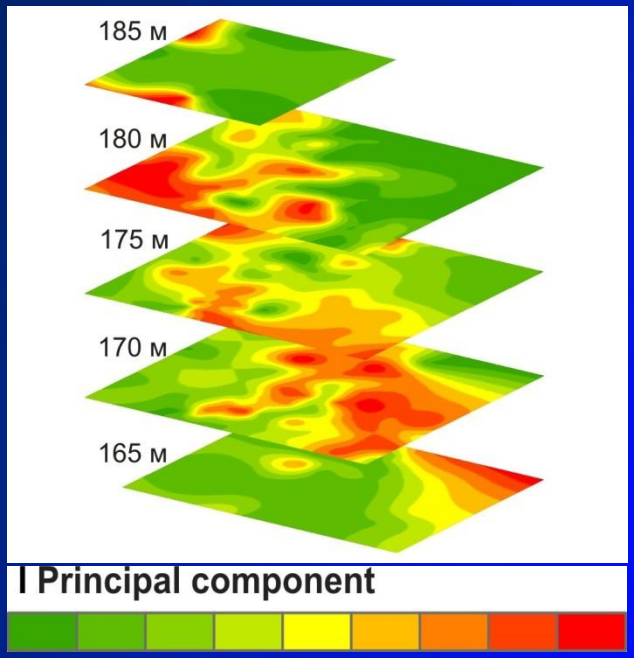
- development of two-dimensional layout of the model;

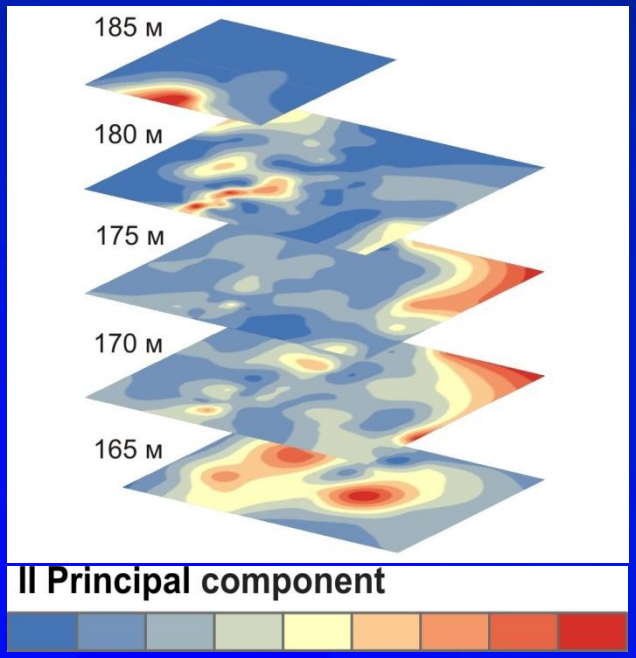
- development of digital three-dimensional model, its verification;

-model usage (derivatization, etc.).

For modeling the software ***ArcGIS*** and ***Geomapping*** was used.

2-D and 3-D-modeling allows to visualize the available geological information and to present the spatial location of placer productive layers.



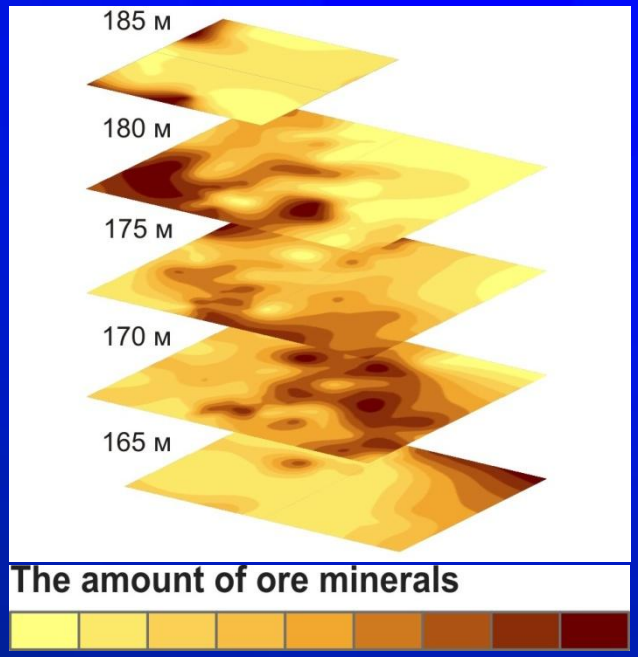


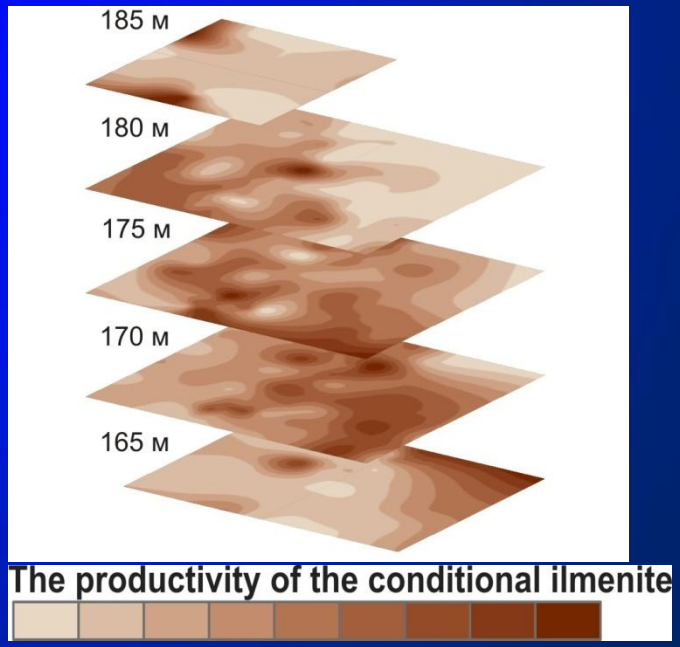
Space distribution of Principal components

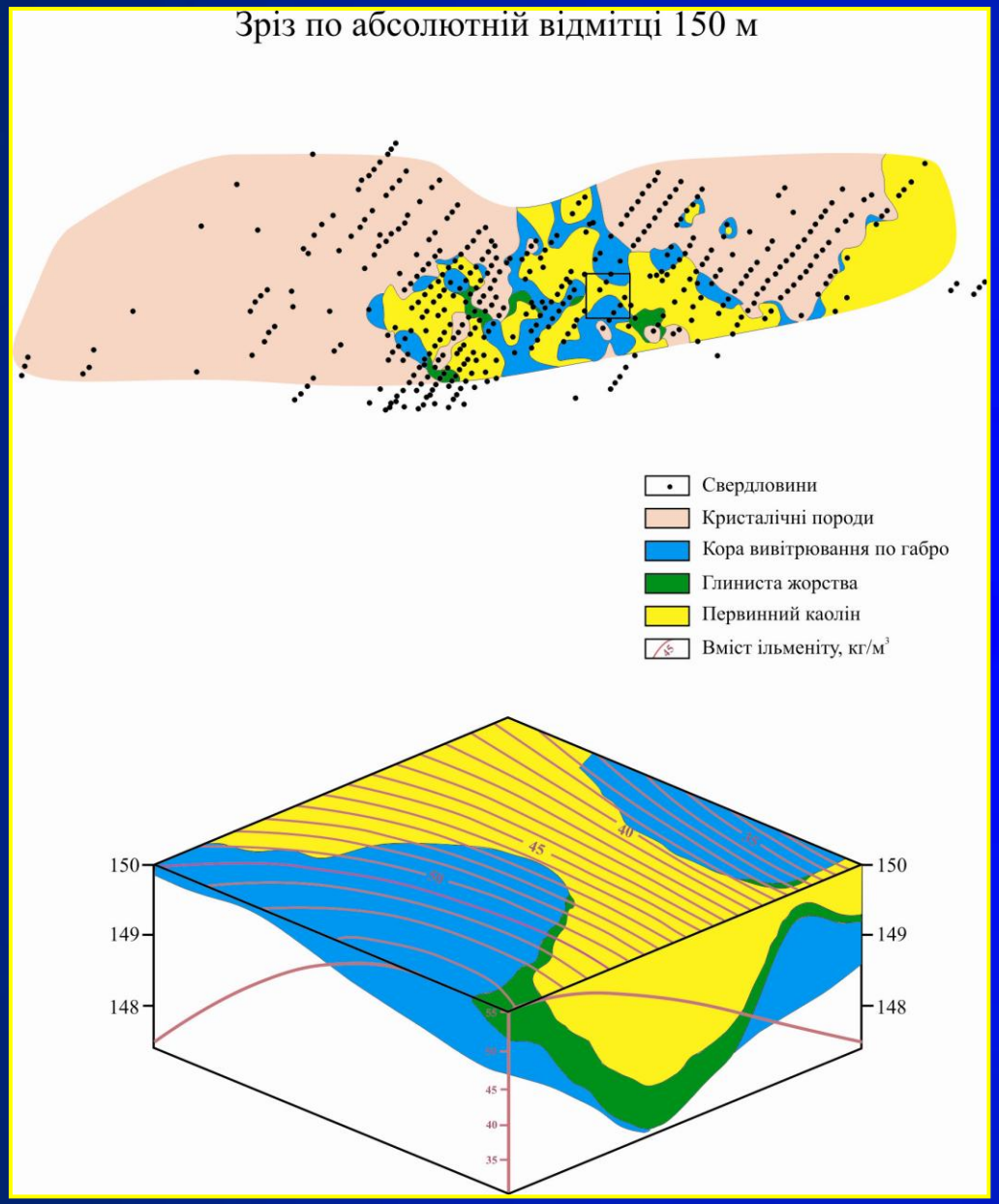
They indicate the main trend of mineral association variability.

Space distribution of ore minerals and productivity

Titanium-zirconium deposit Centralnoe (Tambov region, Russia)



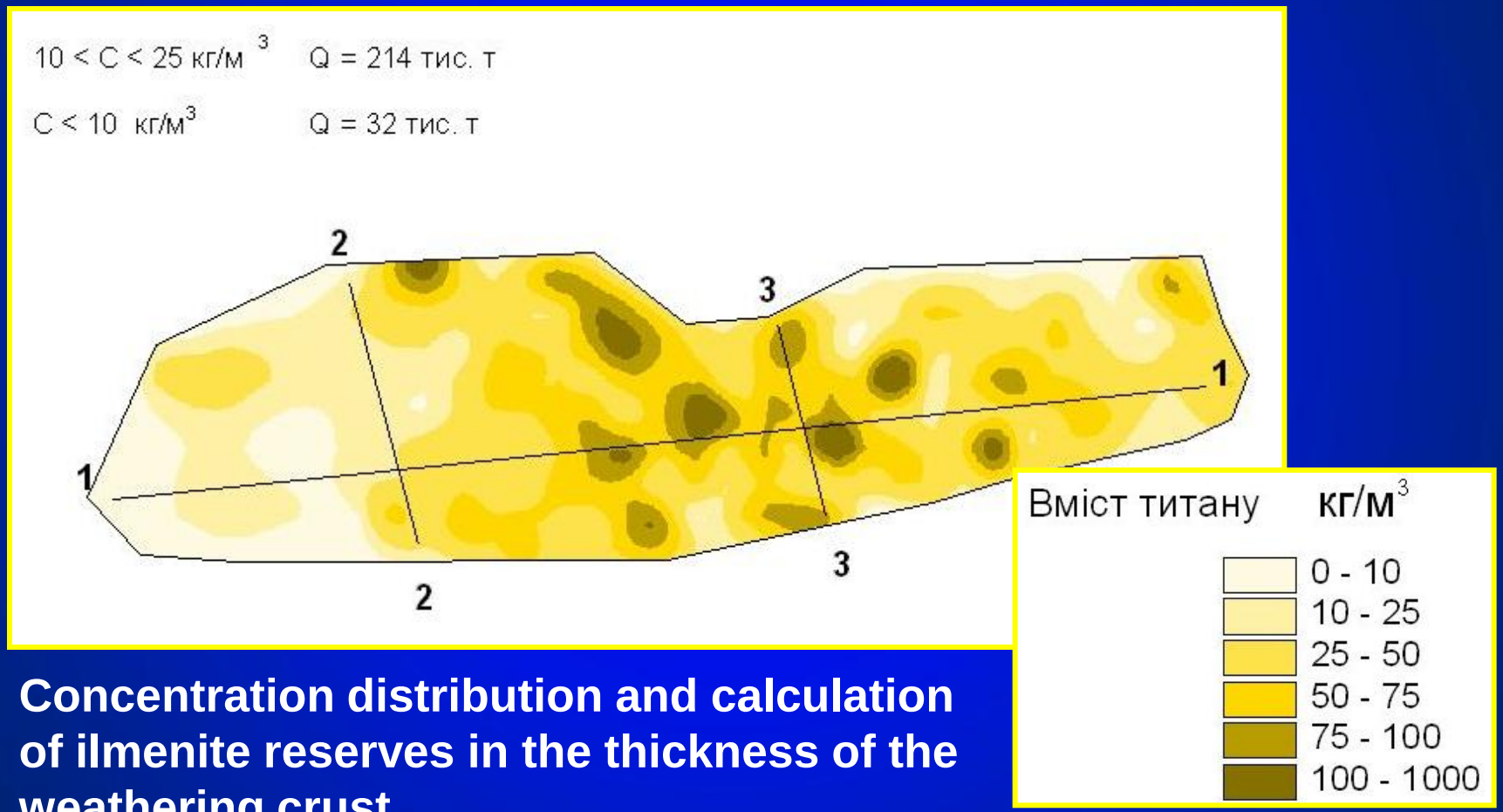




The structural-lithological model of ilmenite deposit (Zlobitskoe, Ukraine)

The model presents together lithological elements and the spatial distribution of useful components

Visualization of digital model of ilmenite deposit (Zlobitskoe, Ukraine)



Concentration distribution and calculation of ilmenite reserves in the thickness of the weathering crust

CONCENTRATION OF HEAVY MINERALS in accumulative zone of coastal deposits

$$C(X) = C(X'')((X_{max} - X)/(X_{max} - X''))^{(1-Br)}$$

where:

X – distance from beginning of lateral coastal flow;

C(X) – concentration of heavy minerals in point X;

X" – beginning of accumulative zone;

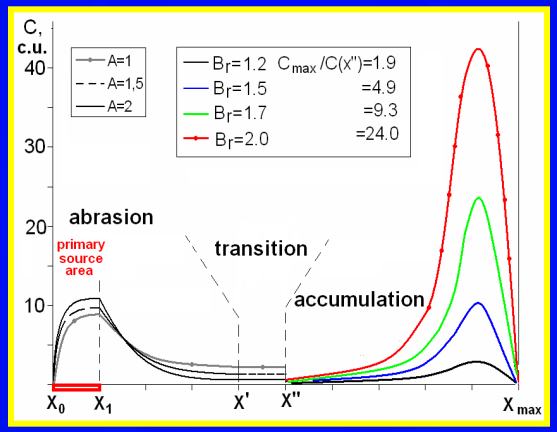
Xmax – end of accumulative zone;

Br = Ur/ U

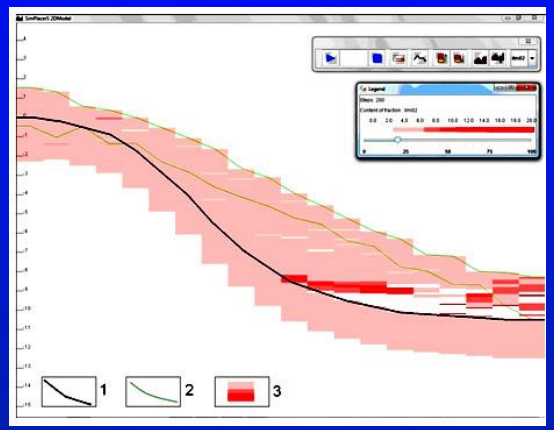
Ur – hydraulic size (fall velocity) of heavy minerals;

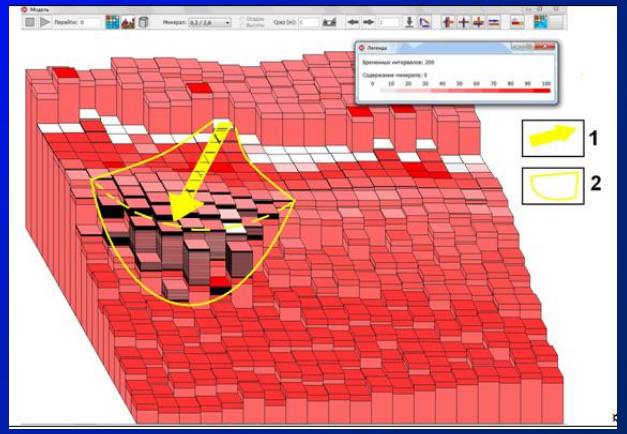
U – hydraulic size of light minerals (quartz).

A – the coefficient of intensity of material arrival in abrasion zone



The result may be considered as retrospective-static modeling.





Conclusion

- For receiving of models for placer fields of various productivity, the logic-information modeling was carried out. Results are represented numerically, allowing its automated usage for creation of the knowledge base of the forecasting expert system.
- Digital models of different kinds allow to carry out the integrated analysis of heavy mineral placer deposits.
- 3-d models greatly clarify the structure of the spatial variability of the technological properties of ore sand and ore concentrates.
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Thank you for attention!

Gold nuggets