МАКЕДОНСКО ГЕОЛОШКО ДРУШТВО И УНИВЕРЗИТЕТ "ГОЦЕ ДЕЛЧЕВ"-ШТИП

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INTERPOLATION AND EXTRAPOLATION MODELS OF GOLD DISTRIBUTION IN THE WATER-CATCHMENT BASINS OF STRUMA AND MESTA RIVERS BASED ON PAN-CONCENTRATED STREAM-SEDIMENT SAMPLES

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Abstract

The paper represents interpolation and extrapolation double Fourier series models of gold distribution in Bulgaria and Republic of Macedonia. The data are 34 405 pan-concentrated stream-sediment samples taken at a density of 2.7 samples/km² within the water-catchment basins of Struma and Mesta rivers in the Bulgarian territory comprising Pernik, Kyustendil and Blagoevgrad administrative districts. The minerals, which correlate positively and negatively with gold, and those which do not correlate are determined. The frequency of gold in the taken stream-sediment samples is assumed to be a probability for discovering/finding of gold in the area studied and contour maps of probability for discovering of gold are compiled using double Fourier series. The interpolation double Fourier series model shows that the probability distribution for discovering of gold has a stripe pattern as the highest probabilities are concentrated in three stripes named after the towns falling into the stripes as follows: Trun-Radomir-Dren, Treklyano-Kyustendil and Yakoruda-Goce Delchev. All known gold deposits, occurrences and indications fall into these stripes, which points to a good effectiveness of the model applied. The extrapolation double Fourier series model is applied for the territory of Republic of Macedonia. The grid of the model is a square one of 35 km² in area for each square. The parameters of the model are verified statistically and it is ascertained that the model is consistent with the data. The major harmonics of probability distribution of gold having indexes (2,2) includes 35% of gold and points to gold prospects in Northeastern and Southwestern Macedonia. Other harmonics of probability distribution of gold having indexes (3,2) concentrates 18% of gold and allows us to prognosticate gold deposits in Central Macedonia. The stripe pattern of gold distribution in Western Bulgaria and in Macedonia is attributed to a pronounced anomaly of Moho boundary in Central Balkan Peninsula.

Key words: gold, probability maps for discovering of gold, stream-sediment samples, Bulgaria, Republic of Macedonia

INTRODUCTION

The purpose of present study is to point regularities of gold distribution in the water-catchment basins of Struma and Mesta rivers comprising the territories of Pernik, Kyustendil and Blagoevgrad administrative districts in Bulgaria. These districts border with the territory of Republic of Macedonia, which allows us to make extrapolation model of gold distribution in the territory of Republic of Macedonia. The study presented herein is based on pan-concentrated stream-sediment samples and has a preliminary character. We hope it could help for future joint works of geologists from Bulgaria and Republic of Macedonia. In the present paper an attempt for synthesis of the pan-concentrated stream-sediment surveys carried out in a 50-year period (S. Tonev, 1947 - first pan-concentrated stream-sediment survey in the region of the town of Trun, unpublished data) is made thus presenting the labour of hundreds Bulgarian prospectors. The results of stream-sediment surveys are useful for metallogenic prognoses (Dimitrov et al., 1996; Georgiev, Vitov, 2007; Vitov, 1996) and are a layer of the metallogenic maps (Dimitrov et al., 1994). They also correspond to the results from geophysical (Boykova, 2005) and geochemical (Vitov, Yamakov, 1995) studies.

METHOD

The minerals are natural chemical compounds of definite composition, structure and properties (Kostov, 1973). Topographical mineralogy studies regularities of formation and distribution of minerals and mineral associations in geological systems of different scale and structural levels. The main method of topomineralogical study is mineralogical mapping as the oldest and most elaborated one is the stream-sediment surveying (Yushkin, 1982). Stream-sediment samples are a concentrate of heavy minerals taken from alluvial sediments (natural concentrate, Kiryazova, Iliev, 1974).
Stream-sediment data in known papers, monographs (Ozerov, 1959; Kiryazova, Iliev, 1974), guides (Ickson, 1953) and geological reports (National Geofund) are addressed to sampling points (presence of minerals and their concentrations) and are interpreted as points of halos of mechanical dispersion (an area of Earth surface on which a definite mineral or minerals is/are distributed). At work at big scale the stream-sediment indicative map is labour-consuming and not informative, what requires a modification of form of presentation by tapes (Bakalov, 1977; Sochneva, Prokopchuk, 1976) or by maps of equal concentrations (Aizenshstadt, Roseeva, 1984). For detailed stream-sediment dividing and compiling of prognoses for prospecting for mineral resources it is assumed that the mineral composition of stream-sediment samples is a combination of mineral composition of many recovering each other halos of mechanical dispersion from the water-catchment basin of the sampling point (Vitov, 1992; Vitov, 1994). It is followed from this that the mappable area in the stream-sediment surveying is the water-catchment basin of the sampling point. When we have a lot of samples and draw up the water-catchment basins of all sampling points the water-catchment basin of the explored territory falls into many elementary areas named feeding areas. The mineral composition of a sample at this presentation of stream-sediment data is a result of mixing of minerals from different sources in different quantities. The data from stream-sediment surveying are formalized with numbers of taken samples; table with number of samples containing each mineral found; table with data for the samples: number of geological report, number of sample, next number of sample along the river current, mineral composition of each sample with concentrations of the containing minerals, outline of the feeding area. If an ore mineral is found in a given sample, the feeding area of this sample attains first-order significance (first-order prognosis) for prospecting for ore body, while the feeding province (the rest part of the water-catchment basin of the sampling point) has secondary importance (second-order prognosis). The concentration of a given mineral as well as the prospectivity of a given territory designate by colouring and rastering. At work at bigger scale (1:100 000 and bigger, Vitov, 2005) the explored territory divides into equal in size squares and the ratio of the number of samples containing a given mineral to the number of all taken samples calculates for each square. This ratio is the frequency of occurrence and has a sense of probability of finding/discovering of a given mineral in a given square with a confidence interval calculated by the formulae of Vuchev (1969). The information formalized in this way allows one to calculate the enough number of samples for attaining an acceptable accuracy as well as the enough number of samples needed for finding of a given mineral in one sample at least (Corn and Corn, 1977). In this sense the probability of finding/discovering of a given mineral could be referred to the whole explored territory independently of its outline, and the needed and enough number of samples to prospect for a given mineral could be planned as well as one could compare two or more territories in respect to their prospectivity for a given mineral resource. 

The multitudes of recovering each other halos of mechanical dispersion of different age and origin form a continuous plain of probabilities for finding of a given mineral as the calculated probabilities are an average assessment of the probability referred to the geometric centre of the squares. Data of coordinates and probability values of the centers of squares are used for drawing up contour maps (of equal probabilities) by a chosen method (triangle method, cartographic programs, etc). The anomalies of this probability mineralogical field could be interpreted as areas of destruction of ore bodies or areas of accumulation of a given source mineral (placer deposit). The continuity of mineralogical field allows one to compile a mathematical model of mineral distribution in the explored territory as a sum of even and uneven functions, in particular by decomposition of the "signal" in double Fourier series (Davis, 1977) but a problem there is: the stream-sediment maps are drawn up at different scales by different authors and cover different requirements. In some cases the quality of pan-concentrating and misses in the mineral identification of the samples has an impact on the quality of stream-sediment maps. As a result of these circumstances the assembly map for some minerals contains numerous blanks and artificial contrasts in next areas. The compiled double Fourier series models (Davis, 1977) in these cases are not preservative and need some corrections of the model parameters to be done using a coefficient equal to the ratio between the sum of probabilities according to the data and
the sum of probabilities according to the model for the same squares. For an evaluation of the corrected model a correlation coefficient between the probabilities calculated from the data (by squares) and the calculated probabilities from the model should be obtained as well as analysis of the differences between the real probabilities and model ones should be made. When the model is representative at chosen critical range, the coefficient of linear correlation is statistically significant and the residuals have Normal (Gauss) distribution. The presentation of data on probability of finding of minerals in double Fourier series arranged by amplitude, phase and length of wave (vectors) allows the probability for discovering of a given mineral in areas without stream-sediment sampling (interpolation) and in areas outside the sampled area (extrapolation) to be calculated. Vector diagram of the model points to preferable directions and periodicities in the distribution of minerals. These periodicities originate from the property of Earth crust to destroys into blocks accordingly to the depth of interaction – the Earth crust–scaled faults have intervals of about 40-70 km; the shallow faults have intervals of about 1-4 km, whereas the intervals between the cracks in the rocks are about meters and centimeters. The decomposition of the probability data on different minerals in double Fourier series shows quick decreasing – the first several members of the row comprise 60-90% of the total sum of probabilities, which points to predominantly tectonic reasons for the particular distribution of minerals. The separation of dominant members of the double Fourier series in a separate layer allows one to evaluate the distribution of a given mineral in per cent in a definite field of tectonic stress (metallogenic epoch). Having in mind that every next tectonic cycle redistribute the matter, concentrated in a definite pattern in the previous cycles, it follows that we have the most intensive concentrations in the youngest processes, while the older processes participates with smaller share in the total concentrating. This peculiarity allows us to separate halos of dispersion of one tectono-magmatic cycle as well as to trace out the evolution in the development of Earth crust in a given area. The mineral associations divided from stream-sediment samples are a product of mixing of minerals from different sources in different quantities. As we have calculated the probability of presence/absence of a given mineral in a given sample (from the basic statistics) so after multiplication of these probabilities we will have the probability for realization of a concrete mineral composition. The absolute value of logarithm of this probability becomes informational significance of the sample (Yushkin, 1977) and represents its mineral diversity. The samples having high value are combination of minerals, which are rarely met because of their low stability under supergene conditions or are product of specific ore-forming process. They appear indicator of close nearness to the source of ore minerals. Conversely – samples having low value comprise stable, often met minerals, which form the mineralogical background of the sampled area and point to a remoteness of the source. Mineral anomalies having high values are indicators of ore zones under erosion, while these ones of low values are areas of accumulation and formation of placer deposits. Double Fourier series by this parameter point to areas of expected ore regions, knots and zones. The correlation between the samples is investigated applying Bernoulli test (Tonkov, 1984) for evaluation of the observed cases of simultaneously occurring minerals. Multiplying the probability for discovering of the first mineral by the probability for discovering of the second mineral we obtain the probability for simultaneous findings of both if they are randomly met together in the samples. This probability is enough for estimation of the sum of probabilities for all possible cases and for evaluation of the position of observed number of simultaneous findings. At very small sum of probability (in our case probability smaller than 0.001) it is assumed that the minerals are negative indicators: the appearance of one mineral points to the absence of other mineral in the sample. Conversely – at probability bigger than 0.999 it is assumed that the minerals are mutually connected and the finding of one mineral supposes that the other mineral also presents in the sample. At small probabilities for discovering of a given mineral as well in the cases of constancy of the product of number of samples by the probability for discovering of minerals the border case of the distribution of Bernoulli, the distribution of Poisson, is applicable. The result of this study is represented by a circular diagram “every versus every” and by a graph of expected relations between the minerals at chosen critical range. The sense of these relations is
phomenological but very often functional explanations could be made – stable mineral associations of ore minerals; minerals of their transformation in the zone of supergenesis; zonality of ore deposits; associations of ore minerals and rock-forming minerals; similar behavior during hydrodynamical transport in the rivers (density; size and shape of mineral grains). When we analyze a given mineral we investigate the group of minerals which correlate with it as a sub-multiplicity. The relations revealed and the graph of relations point to a definite minerogenesis and expected medium of ore formation.

DATA

The studied territory of 12 700 km² includes the water-catchment basins of Struma and Mesta rivers within the Bulgarian territory. It is sampled with 34 405 pan-concentrated stream-sediment samples with a density of 2.7 samples/km². The unsampled area is about 2 600 km². The stream-sediment surveys were carried out by map sheets at 1:25 000 scale (10x10 km) as the results are saved in geological reports as maps and as data base (number of geological report, map sheet, number of sample, number of next sample, mineral composition and concentrations of minerals) in the National Geofund (Vitov, 1995; Vitov, 2001). The data in the National Geofund are accessible and are used according to Ordinance of Ministry Council №253/20.09.2004 (Darjaven vestnik No 58/2004). For the present study the whole territory is divided into 1 027 squares each of about 12 km² in area.

RESULTS

Interpolation prognosis for prospecting for gold deposits

In Pernik, Kyustendil and Blagoevgrad administrative regions 34 405 pan-concentrated stream-sediment samples were taken and 63 minerals were found in them, which realize 581 significant correlations (Poisson test, \( \alpha < 0.001 \)). 36 minerals found have an equal or greater frequency of occurrence in this area in comparison with the country, what points to abundance of outcrops of ore bodies. The samples containing cinnabar, columbite, scheelite, barite, minerals of lead and titanium as well as zircon, xenotime and apatite predominate. Gold has a frequency close to the average one for the country. Minerals which correlate with gold are minerals of base metals deposits, products of their alteration, and rock-forming minerals (Table 1). The relations between them are result of superimposing in time of many processes of redistribution of gold in the studied area (fig. 1). Each line on the circular diagram points to a statistically significant relation in both ends in presence of gold in the samples. The presence of low-temperature (cinnabar), middle-temperature (galena) and high-temperature minerals (scheelite) in correlation with gold point to polygenetic character of gold mineralizations. On the other side, the relationship scheelite-cinnabar is an indicator of significant presence of fluorine in the hydrothermal solutions. Minerals which do not correlate with gold are ilmenite and titanite pointing to non-prospective for gold of rocks containing these minerals (Table 2).

Table 1. Minerals which correlate with gold (found in 3,301 stream-sediment samples from 34,405 taken ones, \( \alpha < 0.001 \)).

<table>
<thead>
<tr>
<th>Mineral</th>
<th>m</th>
<th>a</th>
<th>( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cinnabar</td>
<td>574</td>
<td>153</td>
<td>55.07</td>
</tr>
<tr>
<td>2. Galena</td>
<td>1818</td>
<td>438</td>
<td>174.43</td>
</tr>
<tr>
<td>3. Cerussite</td>
<td>608</td>
<td>184</td>
<td>58.33</td>
</tr>
<tr>
<td>4. Anglesite</td>
<td>93</td>
<td>32</td>
<td>8.92</td>
</tr>
<tr>
<td>5. Vanadinite</td>
<td>27</td>
<td>9</td>
<td>2.59</td>
</tr>
<tr>
<td>6. Wulfenite</td>
<td>404</td>
<td>108</td>
<td>38.76</td>
</tr>
<tr>
<td>7. Pyromorphite</td>
<td>523</td>
<td>158</td>
<td>50.18</td>
</tr>
<tr>
<td>8. Massicot</td>
<td>87</td>
<td>38</td>
<td>8.35</td>
</tr>
<tr>
<td>9. Lead</td>
<td>706</td>
<td>208</td>
<td>67.74</td>
</tr>
<tr>
<td>10. Cuprite</td>
<td>36</td>
<td>17</td>
<td>3.45</td>
</tr>
<tr>
<td>11. Copper</td>
<td>32</td>
<td>14</td>
<td>3.07</td>
</tr>
<tr>
<td>12. Bismutite</td>
<td>3071</td>
<td>383</td>
<td>294.65</td>
</tr>
<tr>
<td>13. Arsenopyrite</td>
<td>259</td>
<td>82</td>
<td>24.85</td>
</tr>
<tr>
<td>14. Scheelite</td>
<td>8459</td>
<td>1108</td>
<td>811.60</td>
</tr>
<tr>
<td>15. Barite</td>
<td>7286</td>
<td>1175</td>
<td>699.06</td>
</tr>
<tr>
<td>16. Cassiterite</td>
<td>75</td>
<td>32</td>
<td>7.20</td>
</tr>
<tr>
<td>17. Wolframite</td>
<td>159</td>
<td>45</td>
<td>15.25</td>
</tr>
<tr>
<td>18. Molybdenite</td>
<td>159</td>
<td>32</td>
<td>15.25</td>
</tr>
<tr>
<td>19. Pyrolusite</td>
<td>181</td>
<td>50</td>
<td>17.37</td>
</tr>
<tr>
<td>20. Pyrite</td>
<td>5035</td>
<td>683</td>
<td>483.00</td>
</tr>
<tr>
<td>21. Marcasite</td>
<td>419</td>
<td>110</td>
<td>40.20</td>
</tr>
<tr>
<td>22. Martite</td>
<td>357</td>
<td>58</td>
<td>34.25</td>
</tr>
<tr>
<td>23. Rutile</td>
<td>9444</td>
<td>1005</td>
<td>906.10</td>
</tr>
<tr>
<td>24. Lecoexene</td>
<td>1309</td>
<td>335</td>
<td>125.59</td>
</tr>
<tr>
<td>25. Anatase</td>
<td>2398</td>
<td>369</td>
<td>230.08</td>
</tr>
<tr>
<td>26. Monazite</td>
<td>10145</td>
<td>1076</td>
<td>973.36</td>
</tr>
<tr>
<td>27. Xenotime</td>
<td>2381</td>
<td>289</td>
<td>228.45</td>
</tr>
<tr>
<td>28. Zircon</td>
<td>9791</td>
<td>1158</td>
<td>939.49</td>
</tr>
<tr>
<td>29. Garnet</td>
<td>876</td>
<td>117</td>
<td>84.05</td>
</tr>
<tr>
<td>30. Epidote</td>
<td>320</td>
<td>61</td>
<td>30.70</td>
</tr>
<tr>
<td>31. Corundum</td>
<td>599</td>
<td>96</td>
<td>57.47</td>
</tr>
</tbody>
</table>
m - number of pan-concentrated stream-sediment samples containing the respective mineral, a - observed number of pan-concentrated stream-sediment samples with simultaneous finding of gold and the respective mineral, λ - expected number of pan-concentrated stream-sediment samples if both minerals (gold and the respective mineral) are independent.

Table 2. Minerals, which do not correlate with gold (α≤0.001).

<table>
<thead>
<tr>
<th>Мінерал</th>
<th>М</th>
<th>a</th>
<th>λ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Иліменіте</td>
<td>7024</td>
<td>535</td>
</tr>
<tr>
<td>2</td>
<td>Тітаніте</td>
<td>10221</td>
<td>862</td>
</tr>
</tbody>
</table>

Fig. 2. Parameters of interpolation double Fourier series model of gold probability in the watercatchment basins of Struma and Mesta rivers.

The drawn up contour map of probability for finding of gold in the stream-sediment samples (Fig. 3 - top) shows pronounced anomalies in three stripes named after the towns, which fall into the different stripes as follows: Trun-Radomir-Dren; Treklyano-Kyustendil and Yako-ruda-Goce Delchev. The known gold deposits, occurrences and indications in the studied area are surrounded by halos of mechanical dispersion of gold but there are many halos without known sources of gold. Such anomalies of probability for finding of gold are observed in Osogovo base metals region, the region of the village of Teshevo, and in Ograzhden Mountain. To analyze these peculiarities an interpolation double Fourier series model of the probability for discovering of gold is compiled (Davis, 1977) (fig.2-bottom). The characteristics of model (statistically significant linear correlation between the model and the data; residuals of the difference between the model and data having average value equal to zero and Normal distribution) allow us to assume that gold is regularly distributed.

Fig. 3. Contour probability map for discovering of gold in the water-catchment basins of Struma and Mesta rivers (top) and the most pronounced Fourier harmonics of gold probability distribution (bottom).
Double Fourier series modeling shows that 35% of gold is arranged in a stripe of 135° in strike and transversely (fig. 3 - bottom). All known deposits, occurrences and indications of gold fall into the prognosticated areas.

Extrapolation prognosis for prospecting for gold deposits within the territory of Republic of Macedonia

To prognosticate the gold distribution in Republic of Macedonia an extrapolation double Fourier series model based on data of gold distribution in the Pernik, Kyustendil and Blagoevgrad administrative districts is compiled (fig. 4, 5). The model operates with squares of about 35 km² in area as gold is “found” in 309 squares.

The model has significant linear correlation and Normal distribution of the residuals, which allows us to accept it as effective one. The effectiveness of the model is shown also after putting of the known gold deposits, occurrences and indications after Maznikov, 1997 - unpublished data and Bogoevskij, 1995 on the map of probability for discovering of gold in the stream-sediment samples and their consistence with the model distribution (fig. 5 - top).

Two systems of stripes of northwest-southeast direction are revealed. The first system having indexes (2,2) comprises the distribution of 35% of gold from the samples and is a prognosis for discovering of gold deposits in Northeastern and in Southwestern Macedonia (fig. 5-middle). The second system (3,2) comprises 18% of gold and is a prognosis for gold deposits in Central Macedonia (fig. 5-bottom). The rest harmonics have smaller intensity and are not considered herein.

![Image](image_url)

Fig. 4. Parameters of the extrapolation double Fourier series model of probability distribution of gold within the territory of Republic of Macedonia.

![Image](image_url)

Fig. 5. Probability distribution of gold within the territory of Republic of Macedonia: double Fourier series model (top) and patterns of the most pronounced harmonics of the model: 2,2 in the middle and 3,2 in the bottom. Metallogenic dividing after Bogoevskij (1995).

DISSCUSSION

Summarizations of data from the Osogovo region (Mankov et al., 1972), and from Kyustendil, Pernik and Blagoevgrad administrative districts (Vitov, 2005, 2006, 2007) showed the effectiveness of the methodologies presented in this paper and the fitness of data for mineralogical dividing and pointing to prospects for mineral prospecting. The stream-sediment surveying of the area under study has good parameters for the chosen map scale. The ascertained sampling density of 2.7 stream-sediment samples/km² is acceptable for prospecting works (Ickson,
1953). On the other side, the increasing of sampling density near known ore regions, deposits and occurrences deform in some degree the real frequencies of minerals in the studied area. Considering that the knowing of minerals and mineral associations in the stream-sediment samples is fundamental for learning of mineral diversity it is follows that a new pan-concentrated stream-sediment survey should be designed and carried out in volume of about 40 000 stream-sediment samples with full mineral investigation. The mineral diversity of stream-sediment samples correlating with presence of gold shown in Table 1 as well as the circular diagram of correlations between minerals show the presence of low-temperature, middle- and high-temperature minerals, products of their transformation, and rock-forming minerals, all connected in complex system of relations, which are results of long-term geological history of the area studied. Diagrams of such design are suitable for determination of indirect mineral indicators. The water-catchment basins of Struma and Mesta rivers within the Bulgarian territory lay in the Kraishtidi structural zone and its neighbouring areas. Not discussing herein its structure-tectonic belonging it is ascertained that the probability for discovering of gold has highest values in the Trun-Radomir-Dren, Treklyano-Kyustendil-Vlahina planina and Yakoruda-Goce Delchev stripes as 34% of gold is arranged in two parallel stripes of 135° in strike and transverse smaller stripes of 45° in strike (fig. 3). The extrapolation model—a prognosis for gold deposits in Republic of Macedonia, based on pan-concentrated stream-sediment samples from the water-catchment basins of Struma and Mesta rivers within Bulgaria (fig. 4, 5) shows a consistency between the data and the model as the model do not “discover” the gold deposits and occurrences in Southeastern Macedonia. A possible explanation of this fact is genetic and spatial peculiarities of these gold mineralizations different from those of the mineralizations in Kraishtides. An important result from Fourier modeling is the fact that when we use the same data but with different size of the grid (12 km² for the water-catchment basins of Struma and Mesta rivers and 35 km² for the aforesaid area plus the territory of Republic of Macedonia) the model without losing its consistency shows a presence of second system of gold distribution (3,2), which is an indication for older plan of tectono-magmatic distribution of gold at thinner Earth crust (smaller interval between the gold stripes) and other plan of tectonic stress. A possible explanation of this regularity is the anomaly of Moho boundary in the area studied— the stripes of gold coincide with a sharp change in the thickness of Earth crust (fig. 6). It could be supposed that due to the steep incline of the continental crust fragment in the area studied the thermal fluxes from the mantle and probably the released fluids have been focused in the steepest zones and formed mineralizations, magmatic bodies and products of interaction with the host rocks.

Fig. 6. Location of the studied area (in grey) on the map of Earth crust thickness (Boykova, 1999).

The strike of revealed gold distribution within the Western Bulgaria correspond to zones of Late Alpine activity (Batandjiev, 1989) and to fragments of Thracia ore network (Dragov et al., 1976). The ascertained regional regularities of gold distribution hold for the whole Bulgarian territory (Vitov, Georgiev, 1997) and probably correspond to similar stripes and processes in Dinarides (Serafimovski et al., 1995).

CONCLUSION
Gold in the pan-concentrated stream-sediment samples taken in the studied area is concentrated in stripes of 135° in strike (Trun-Radomir-Dren-Yakoruda-Goce Delchev-Dospat and Treklyano-Kyustendil-Vlahina planina and southeastern) and transverse stripes of 45° in strike, which are consistent with the morphology of Moho boundary there. In the intersections of both systems of stripes all known ore regions (Osogovo and Trun ones) and gold prospects (Dren, Treklyano, Yakoruda and Goce Delchev ones) are localized. Presence of gold mineralizations along the boundary of Republic of Macedonia with Albania as well as in Central Macedonia is prognosticated.
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INTRODUCTION

The purpose of present study is to point regularities of gold distribution in the water-catchment basins of Struma and Mesta rivers comprising the territories of Pernik, Kyustendil and Blagoevgrad administrative districts in Bulgaria. These districts border with the territory of Republic of Macedonia, which allows us to make extrapolation model of gold distribution in the territory of Republic of Macedonia. The study presented herein is based on pan-concentrated stream-sediment samples and has a preliminary character. We hope it could help for future joint works of geologists from Bulgaria and Republic of Macedonia. In the present paper an attempt for synthesis of the pan-concentrated stream-sediment surveys carried out in a 50-year period (S. Tones, 1947 - first pan-concentrated stream-sediment survey in the region of the town of Tran, unpublished data) is made thus presenting the labour of hundreds Bulgarian prospectors. The results of stream-sediment surveys are useful for metallogenic prognoses (Dimitrov et al., 1996; Georgiev, Vitov, 2007; Vitov, 1996) and are a layer of the metallicum maps (Dimitrov et al., 1994). They also correspond to the results from geophysical (Boykova, 2005) and geochemical (Vitov, Yamanov, 1995) studies.

METHODS

The method of determining gold distribution in the water catchment basins is based on the interpolation models of gold distribution, their extrapolation and computer-aided analysis of different categories of gold enrichment in the territory of Republic of Macedonia. The method consists of the following stages: 1) the determination of gold distribution models for points in the form of maps with different scales; 2) the selection of the most adequate interpolation models for the territory of Republic of Macedonia; 3) the computer-aided analysis of the distribution of gold in the territory of Republic of Macedonia on the basis of the selected interpolation models. The method is based on the work of S. Tones, 1947 - first pan-concentrated stream-sediment survey in the region of the town of Tran, unpublished data.

RESULTS

The results of the method described are presented in the following figures (Fig. 1, 2, 3). The probability distribution of gold shows the model for discovering gold (Fig. 3a) and the most prominent characteristics of the Fourier model (Fig. 3b). The map shows the distribution of gold in the territory of Republic of Macedonia (Fig. 2a). The computer-aided analysis of the distribution of gold in the territory of Republic of Macedonia on the basis of the selected interpolation models shows the model for discovering gold (Fig. 3a) and the most prominent characteristics of the Fourier model (Fig. 3b).

Table 1. Mineral which contains with gold

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Concentration</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Silver</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Copper</td>
<td>25%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Fig. 1: a) Location of the studied region; b) Topographical map; c) Geological map; d) Mineral resources (red figures) and sites of stream-sediment pan-concentrated samples; e) Density of sampling.

Fig. 2: a) Location and concentration of gold-containing stream-sediment pan-concentrated samples; b) Gold concentrations (red figures) and map of the equal frequencies; c) Two-series Fourier model of the probability for discovering gold; d) The most pronounced characteristics of the Fourier model.

Fig. 3: Probability distribution of gold within the territory of Republic of Macedonia: a) Map of the equal gold frequencies; b) Double Fourier series model; c) Pattern of the (2,2) harmonics of the model; d) Pattern of the (3,2) harmonics of the model. Metallogenic dividing after Bogoslovskiy (1995).

REFERENCES


Fig. 1: a) Location of the studied region; b) Topographical map; c) Geological map; d) Mineral resources (red figures) and sites of stream-sediment pan-concentrated samples; e) Density of sampling.
Fig. 2: a) Location and concentration of gold-containing stream-sediment pan-concentrated samples; b) Gold mineralizations (red figures) and map of the equal frequencies; c) Two-series Fourier model of the probability for discovering of gold; d) The most pronounced charmonics of the Fourier model.
Fig. 3. Probability distribution of gold within the territory of Republic of Macedonia: a) Map of the equal gold frequencies; b) Double Fourier series model; c) Pattern of the (2,2) harmonics of the model; d) Pattern of the (3,2) harmonics of the model. Metallogenic dividing after Bogoevskj (1995).