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Digitizing and three-dimensional model establishment for Ereen gold ore deposit in Mandal Soum, Selenge province, Mongolia

The Mineral Mathematical Model Software and Micromine Software from abroad for digitization analysis were used to study some of the mines in Ereen gold mine in Mandal Soum, Selenge province, Mongolia. This study dealt with: primitive database construction, sample statistical analysis, lithology modelling, variation function, grade modelling, etc. Finally,a three-dimensional space model of ore bodies was established, on the basis of this mineral mathematical model.These results of digitization research enormously make the mine production management become more convenient, and have provided the scientific basis for mine prospecting project design, mining engineering design and economic evaluation.

Keywords: *Ereen deposit, digitization, three-dimensional model.*

1. Introduction

The Ereen property is located in north-central Mongolia approximately 42 km to SW from the centre of Mandal soum, Selenge Province and 140 km to NNW of Ulaanbaatar, capital of Mongolia. The Dzüünharaa, one of the largest stations on the Trans-Mongolian Railway is located 35km to the north. The main towns in the area are served by good infrastructure including power, water and communications. it is the detailed location in north-central Mongolia. There are two main access rates to the Ereen site; by paved road from Ulaanbaatar to Bornüür (110km) and then approximately 50km on dirt road to the site, or 136km to the north of Ulaanbaatar to Boroo gold mine's improved earth road, and then approximately 30km by unpaved road to the site.

2. Geology of the region and deposit

Ereen deposit is located near to the principal gold deposit in the district, Gatsuurt mine, developed by Centerra Gold Corporation. The Sujigtei fault separates Devonian rhyolites (which host Ereen) in the west from Palaeozoic granites in the east. Therefore, certain Gatsuurt ore controlling features could be similar to Ereen ore-controlling factors. Stratigraphic section of the Ereen area is consecutively represented by Cambrian-Ordovician Kharaa group formation, Ordovician-Silurian Undur formation, Silurian Mandal group formation, Devonian Uaan Undur formation, Jurassic-Cretacious Ajnai white fracture formation, lower Cretacious Shariin Gol formation, Quaternary Holocene sedimentary formation. Plutonic rocks are spread moderately in the project area. From the previous research the following groups of plutonic rocks were identified on the basis of the geologic-structural location, stratigraphy deposition and border relation towards each other, petrography, and petrochemical characteristics.

1. Medium late Ordovician Boroo river formation
2. Late Ordovician Ikh Tashir formation
3. Medium Devonian rock formation
4. Permian Guadeloupian small Khentii formation
5. Early Triassic Tukhum formation

3. Mine geology

Gold grades vary from trace to 409g/t along the strike and depth extension of the vein. Better grades (from 14g/t to 363.4g/t) of Au were distributed in the middle and deeper parts of the vein, with near-surface grades (down to 40m) considered uneconomic. The average gold grades were 18-23g/t in different blocks.

Ore minerals are pyrite, arsenopyrite, tetrahedrite, chalcopyrite, sphalerite, galena, scheelite, malachite, azurite, limonite and free gold. Free native gold is associated with quartz, galena and arsenopyrite. The average size of visible Au was reported to be of 1mm.

Vein 2 is located in the north-east part of the deposit, strikes north-east and dips gently (12º) to the north-west. It has a strike length of 200m and an average thickness of 0.4m. Trenching was undertaken between 1959 and 1960 and showed the average thickness of the vein to be of 1m on surface and is surrounded by a 7m wide silicified halo. Gold grade varies from 0.5g/t to 2.7g/t on the surface.

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Fig.1 Project location in North-Central Mongolia

4. Resources and reserves

Digital modelling database for Ereen deposit area was established. Modelling was based on MICROMINE version 10.1 software.

4.1 Data and analyses

Based on the available materials, as of the transfer of the database 44 boreholes were drilled in the area amounting to 1093.45 m of drilling and 6146 m of intervals, sampled for gold. No other data on drilling were submitted.

The results of drilling analyses were obtained statistically and were reviewed for presence of anomalous high contents that can have a negative impact upon the estimation of contents.

Outstanding gold grades are not observed.

The results of diagram analysis show the absence of anomalous high gold grades (outstanding grades) and identify a true cut-off grade of 0.3 g/t. Within the framework of the current economic requirements to the quality of mineral raw materials it can be deemed well substantiated .

4.2 Interpretation

At the time when resource estimation was undertaken no sufficient information on the geology of this deposit was available. Also, the database does not contain any data on lithology codes. Therefore, it is difficult to interpret the genetic type of such prospect, its morphology and to take into account any critical deposit elements, genetic mineralization control and general continuity.

The main conclusion supported by the results of the analysis performed was estimation of that the mineralization does not have any distinct geological control, i.e. does not have geological limits, which could have been used for interpretation of the mineralization. Thus, the interpretation of the mineralization was based only on the analytical borehole data. The interpretation was conducted in the interactive mode for all existing sections. The sections extended from north-west to south-east. Each section was visualized using MICROMINE Visex. Boreholes trajectories with sampling data coloured according to the grade values were projected on the sections. Composite intervals with a nominal value of 0.3 g/t were established to support the interpretation and they were visualized together with the actual values of sampling intervals. Thus, the minimum grade of composite intervals was 0.3 g/t, the minimum length of composite intervals comprised 3 meters. The acceptable thickness of waste rock intervals included in the estimation comprised 3 meters. In addition, short intervals with high grades were taken into account in the interpretation.

All interpreted strings were associated with the respective sampling or composite intervals, i.e. the interpretation was conducted in a 3D environment. Internal dilution was included where its total thickness was less than 3 meters and its grade did not dilute the total average grade lower than the established cut-off grades. Interim sections were interpreted using wireframe models designed between main sections. Wireframe sections were associated with the existing sampling intervals. If a mineralized body did not extend to the neighbouring drill section it was projected on the half a distance to the next section and was discontinued. In addition, the general direction of the strike and dip of the body sustained. Fig.4 selects interpretation from cross-sections #7, #8 and #8.

4.3 Wireframe modelling

Interpreted strings were used to design a 3D closed wireframe model for gold mineralized bodies. Wireframe models with a gold grade of 0.3 g/t were designed for the mineralized zone. A digital topographic model (DTM) was designed using topographic survey data (Figs.5 and 6).

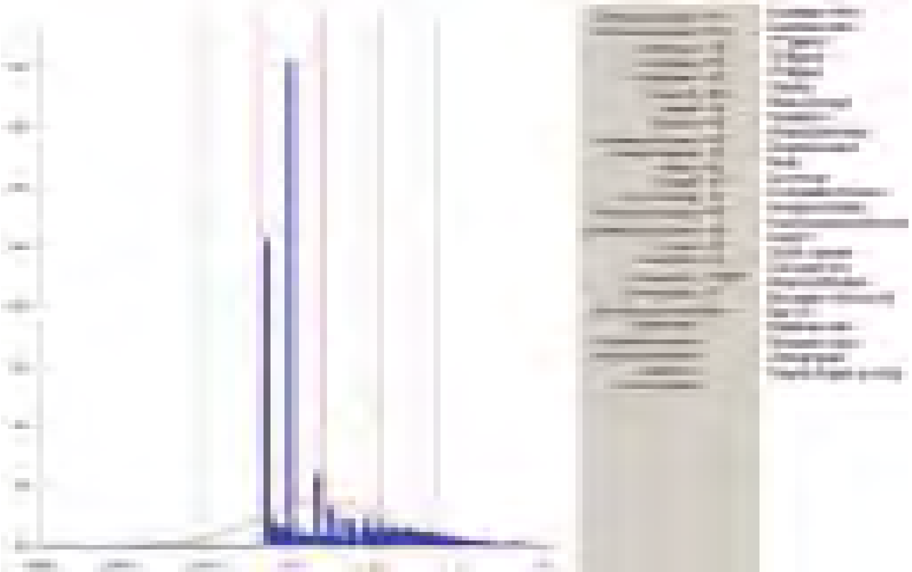

Fig.2 Logarithmic histogram distribution of gold

Fig.3 Gold distribution probability diagram

Table 1: Consolidated statistics on Au grades

Normal statistics	Logarithmic statistics
Minimum : 0.000	Number of points : 5983
Maximum : 10.460	Ln average : -3.78815
Number of points : 6146	Geometric mean : 0.023
Amount : 898.830	Ln dispersion : 2.63604
Average : 0.146	Ln standard deviation : 1.62359
Dispersion : 0.28905	Sichel V : 2.63560
Standard deviation : 0.53764	Sichel's gamma : 3.73520
Rel. st. deviation : 3.676	Sichel estimation function : 0.08456

4.4 Selection of samples and establishing composite intervals

The selection of borehole data is a standard procedure designed to ensure the use of correct samples for classical statistical and geostatistical analyses, as well as for grade interpretation procedures. Given this objective, closed wireframe models were used to take and encode borehole samples. Samples were taken and encoded separately for mineralized bodies and waste rock. Then classical statistical analysis was repeated for those samples which were taken within the limits of the respective mineralized bodies. Outstanding grades were not diluted in the initial samples due to the absence of outstanding grades in the analysis of the gold distribution probability diagram (Fig.7 and Table 2).

The most samples were taken within the limits of interpreted mineralized bodies and analyzed with a sampling length of 1 meter. Therefore the length of 1 meter was selected for designing composite interval.

It should be noted that only one sample is identified to have an outstanding value (over 10 g/t), therefore its impact on the whole sample massif within the ore wireframes can be disregarded.

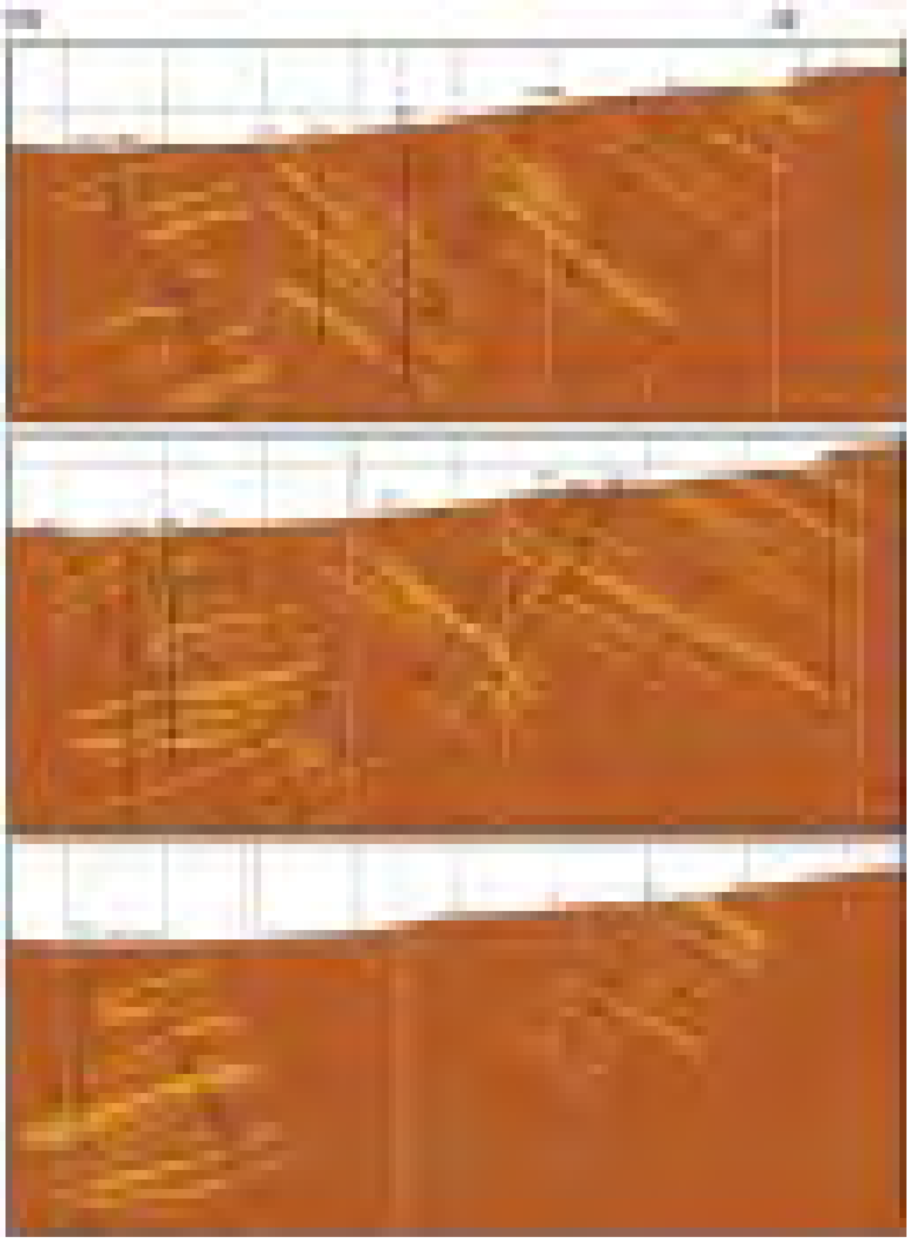

Fig.4 Selected sectional interpretation of ore-bearing zones (cross-section #7, 8 and 9)

4.5 Geostatistical analysis and block modelling

Geostatistical analysis of samples within the limits of ore body wireframes was not conducted due to limited number of samples for estimation of distribution of a useful component and reserves by Kriging method. Apparently, a large scope of analytical data and data on the geology of the deposit is required.

The block model was designed at several stages. Empty block models were designed by filling 3D wireframe models with blocks of the established size. Then block models were limited by a topographic surface (TS), i.e. all blocks above the topographic surface were deleted from model files.

The initial model was designed using 50×50×10 m mother blocks, and then mother blocks were divided into sub-blocks where necessary. The minimum size of a sub-block comprised

Table 2: Statistics of Au dispersion in the wireframe mineralized zone

Normal statistics	Logarithmic statistics
Minimum : 0.005	Number of points : 685
Maximum : 10.460	Ln mean : -0.99781
Number of points : 685	Geometric mean : 0.369
Amount : 632.402	Ln dispersion : 2.65461
Mean : 0.923	Ln standard deviation : 1.62930
Dispersion : 1.66852	Sichel V : 2.65073
Standard deviation : 1.29171	Sichel's gamma : 3.74361
Rel. St. deviation : 1.399	Sichel estimation function : 1.38022

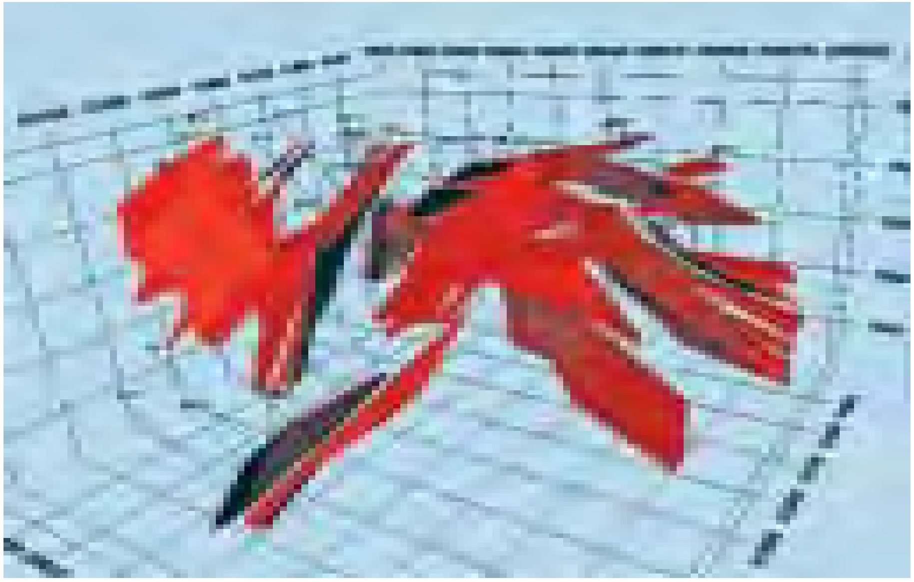

Fig.5 3D ore deposit wireframe model

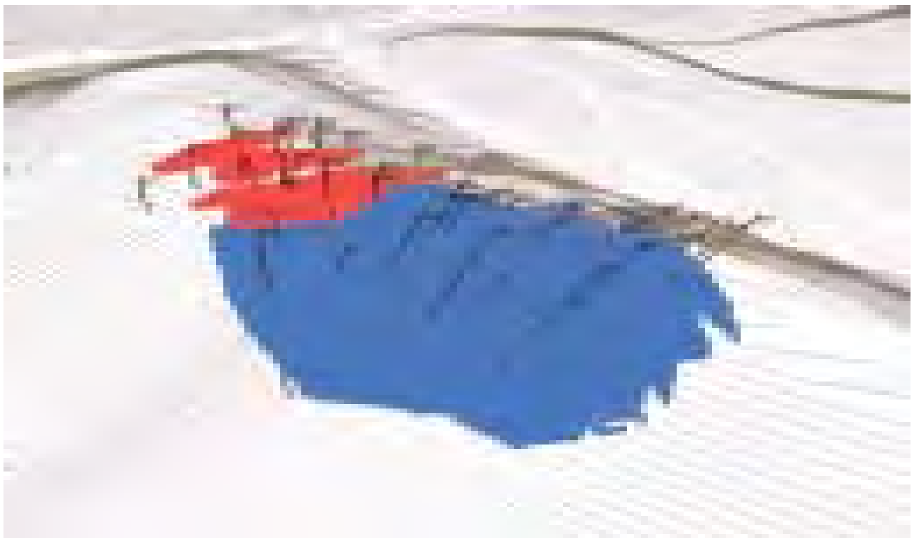

Fig.6 Digital surface model

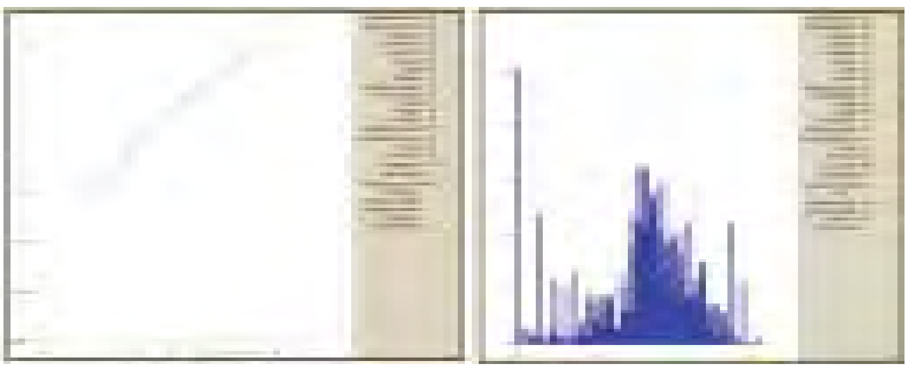

Fig.7 Logarithmic histogram distribution of gold in the mineralized zone wireframe

5×5×1 m. The size of mother blocks was selected based on the density of the exploration grid, at the same time given the required detailed distribution estimation at this stage. The minimum size of subblocks (5×5×1 m) was selected given the required support for identifying the boundaries of mineralized bodies (Table 3).

4.6 Content interpolation

Using IDW method (inverse distance weighing), gold grades were interpolated into an empty block model limited by the surface. IDW method with a degree of two was used as a basic estimation method as Kriging method could not be used at this stage.

Grades were interpolated without dilution (reduction) of outstanding grades.

The block model with interpolated grades was repeated several times. Initial grades were interpolated using search radiuses equal to two thirds of impact zones in all directions. Then full search radius interpretation was conducted. In the third final round a double and greater search radiuses were used.

For interpolation "mother block estimation method" was used, i.e. all sub-blocks within one mother block were attributed one and at the same grade. Search radiuses were defined based on the parameters of the exploration pattern, elements of body wireframe deposition and degree of even distribution of a useful component. The first search radiuses were selected to constitute two thirds of search ellipse impact zone along the strike, dip and across the dip (thickness) of bodies. Those model blocks that were not attributed grades after the first interpolation of grades were used for the second full search radiuses interpolation. If block models were not attributed grades after two first interpolations, they were used for subsequent interpolations, where a search radius was increased by two times in the respective directions. To increase the reliability of estimation during interpolation of model blocks based on search radiuses not exceeding full semi-variogram impact zones, a restriction to estimate a block as minimum by three sample and not less than two boreholes were applied. The strategy for grade interpolation is detailed in Tables 4 and 5 and Figs.5-8, and the block model is shown as Fig.9.

Blocks were interpolated using only composite intervals limited by the wireframe.

4.7 Classification of resources and estimation

The strategy for classification of resources was based on the Australian Code System (Code AusIMM JORC). Resources are classified as measured, indicated and inferred according to the degree of assurance in resources based on the available geological data and their spatial position. The obtained classification of resources is based on the anisotropic search distances, number and types of used samples and accuracy of the interpretation of ore deposits. Search distance for measured resources was established on the basis of the variogram range constituting two thirds of the search radius in three directions. The search distance for measured resources corresponded to full radiuses. The other resources of the deposit, the search radius that exceeded the double value of zone impact on three axes were classified as inferred. The report on the Ereen deposit resources is based on the gold grades estimated by IDW method in the block model spatially limited by the ore body envelope. The cut-off grades were applied to the values of the useful component in model blocks, which in their turn were attributed contents from sample values without reducing outstanding grades. Ore density for estimating resources was accepted to be of 2.7 t/m^3. Table 6 shows the part summary of resources for Ereen deposit.

Table 3: Block model characteristics

Axes	Extension, m		Block size (m)	Maximum sub-blocking (m)	Number of mother blocks
	Minimum	Maximum			
East	612410	613360	50	5	20
North	5385894	5386844	50	5	20
Height	1100	1630	10	1	54

Table 4: Content interpolation parameters

Interpolation method	IDW method (inverse distance weighing)		
Interpolation no.	1	2	3
Search radius	Less or equal to 2/3 of variogram impact zones	Less or equal to full variogram impact zones	Equal to 2 or more variogram impact zones
Minimum number of samples	3	2	1
Maximum number of samples	16	12	8
Minimum number of workings	2	2	1

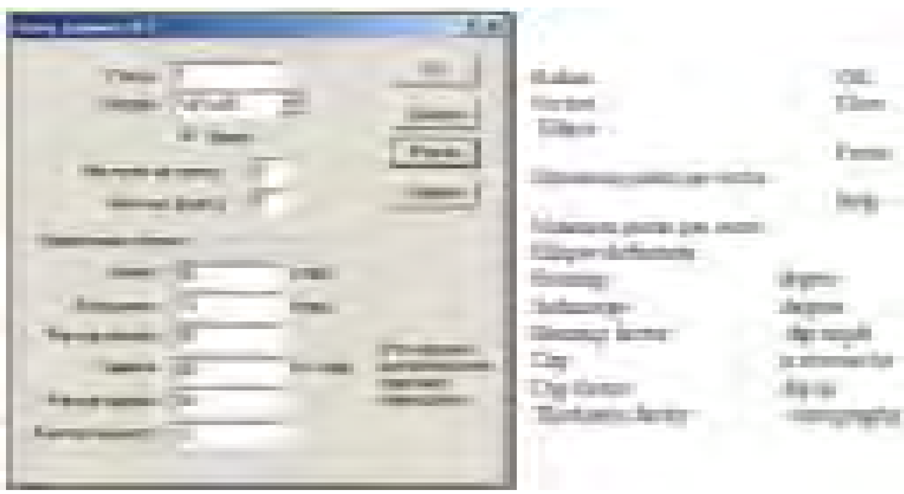

Fig.8 Search ellipse parameters

Table 5: IDW interpretation model parameters

Search pass	Range axis 1m	Range axis 2m	Range axis 3m	Min. no. of composites	Max. no. of composites	Max. per quadrant
Pass 1	33	33	6.6	3	16	4
Pass 2	50	50	10	2	12	3
Pass 3	$\geq$100	$\geq$100	$\geq$20	1	8	2

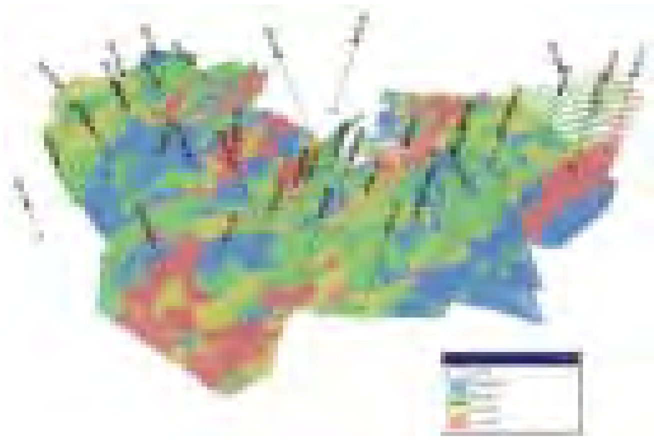

Fig.9 Interpreted content block model

5. Conclusion

Preliminary total resources of the deposit (measured, indicated and inferred) with a gold cut-off grade of 1 g/t comprise 9804038 tonnes @ 1.73 g/t, totalling to 16,941.40 kilograms or 526,936.83 ounces, however using more optimistic cut-off grade of 0.5 g/t total resources can be significantly increased to 24,067.10 kilograms or 748,571.04 ounces of gold. It is recommended that in the purpose of upgrading inferred resources to indicated and measured, additional follow up drilling programme should be initiated which also can help with better understanding of shape and size of deposit, consequently to build a more clear 3D model with appropriate resource estimation.

The new model can be helpful to define the design proposed open pit mine and resources/reserves should be accordingly estimated to this model.

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MINING ASSESSMENT OF EREEN GOLD ORE IN MANDAL SOUM, SELENGE PROVINCE MONGOLIA

(Continued from page 598)

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