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Original scientific paper

MODELING OF THE ILOVICA-ŠTUKA COPPER-GOLD DEPOSIT, MINERAL RESOURCE ESTIMATION AND CLASSIFICATION

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Abstract: The Ilovica-Štuka project's mineral resource estimation has been defined in accordance with the reporting requirements outlined in the 2012 edition of the "Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves" (the JORC Code). Statistical and grade continuity analyses were completed to characterize the mineralization and subsequently used to develop grade interpolation parameters for the deposit. Exploratory data analysis highlighted a number of statistically differentiated grade populations, which were interpreted to be controlled by the following: stockwork intensity, oxidation state, supergene leaching and enrichment. Wireframe models were used to isolate grade populations into domains for the purpose of sample selection and to constrain the grade interpolation. Grade estimation was completed using ordinary kriging. The search ellipsoid dimensions and orientations were chosen to reflect the continuity revealed by geostatistical studies and optimized using quantitative kriging neighbourhood analysis. The wireframe models were used within the sample selection and compositing routine and subsequently as a constraint to the grade estimation. In calculating dollar equivalent block values metal prices used are provided by Euromax management and are generated based on industry capacity analysis, global commodity consumption and economic growth trends. A Mineral Resource classification scheme consistent with the JORC guidelines (2012) was applied. The estimates are categorized in the Measured, Indicated and Inferred Mineral Resource categories, reported above a cut-off grade that defines the resource as potentially mineable by open pit mining methods. Resource grade/tonnage sensitivity graph were created based upon a range of dollar equivalent cut-offs for blocks within the resource pit shell.

Key words: the JORC Code – Australasian Code for Reporting of Exploration Results; mineral resources and ore reserves; EDA (Exploratory Data Analysis); wireframe models; domaining, block model; ordinary kriging; kriging neighbourhood analysis

INTRODUCTION

The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves ('the JORC Code') is a professional code of practice that sets minimum standards for public reporting of minerals exploration results, mineral resources and ore reserves. The JORC Code provides a mandatory system for the classification of minerals Exploration Results, Mineral Resources and Ore Reserves according to the levels of confidence in geological knowledge and technical and economic considerations in Public Reports. (https: //www.jorc.org/).

Mineral Resource Classification scheme consistent with JORC Code guidelines (2012) was used at the Ilovica-Štuka deposit. The estimates are categorized in the Measured and Indicated Mineral Resource categories, reported below a cut-off grade that defines the resource as potentially mineable by open pit mining methods.

GEOLOGICAL SETTING AND MINERALIZATION

Ilovica-Štuka is a porphyry copper-gold deposit, located in a northwest-southeast striking Cenozoic magmatic arc, that covers large areas of Central Romania, Serbia, Macedonia, Southern Bulgaria, Northern Greece and Eastern Turkey (Tomič, 1936; Stojanović, 1971; Westra, 2005; Schefer et al., 2011; Schmid et al., 2013) (Figure 1).

Fig. 1. Ilovica location and regional geological setting (from: Davies et al., 2016)

The Illovica porphyry system is about 1.5 km in diameter and is associated with a poorly exposed dacite-granodiorite plug, emplaced along the north-eastern border of the northwest-southeast elongate Strumitza graben (Rakičević et al, 2008; Sinclair, 2008). The exact location of the deposit is controlled by major north-south cross cutting faults and minor northwest-southeast faulting, parallel to the faulted border of the graben.

At surface, the Ilovica intrusive complex consists of a central dacitic breccia diatreme, approximately 1.3 km in diameter (Bird and Morris, 2012; Wheeler, 2015). The diatreme is intruded by at least one dacite and two granodiorite porphyry stocks that have generated several hydrothermal pulses, resulting in widespread multi-phase veining within a mineralized stockwork (Serafimovski, 1990; Janković et al., 1995; Tasev, 2003).

The Ilovica porphyry is centred on a hill of more than 400 metres (m) of absolute relief, surrounded at lower elevations by numerous small dykes and irregular bodies of dacitic tuff and breccias and intermediate volcanic rocks (Figure 2).

The Ilovica magmatic complex is emplaced into lower Palaeozoic granite. The granite is locally weakly foliated, coarsely porphyroblastic, and forms a roughly northwest-elongate body some 4 by 12 km in size, intruding Precambrian mica schist and gneiss. Portions of the main dacitic diatreme locally contain abundant xenoliths of basement granite near the lithological contact.

Alteration has not been studied in detail, but visual observations document the following zones:

Distal: Structurally-controlled silicification and silica or silica-alunitesulphide / iron oxide (FeOx) altered rocks (‘advanced argillic’), surrounded by narrow zones of clay alteration and bleaching, hosted in both fractured zones within basement granite, or within dykes of Cenozoic tuff-breccia. Such occurrences are present in zones of a few metres up to approximately 100 m in maximum dimension, and occur throughout the entire 8 km^2 altered area.

Proximal: Pervasive quartz-sericite-clay-iron oxide ('phyllic') alteration, which contains larger bodies of quartz-alunite alteration, hosted in both basement granite and Cenozoic magmatic rocks, very similar to those given by Lowell and Guillber, (1970).

Proximal stockwork: Quartz-pyrite / iron oxide alteration and intense clay-sericite alteration largely confined to Cenozoic dacitic breccia and dacite-granodiorite intrusive rocks.

Central: Quartz-magnetite-sulphide / iron oxide stockwork and dissemination, with matrix alteration of illite-sericite, chlorite ('intermediate argillic alteration) containing patches of residual secondary biotite and potassium feldspar, hosted in dacite-granodiorite porphyry, and minor andesite and latite-andesite porphyry dykes.

Supergene: Sulphide oxidation, leaching, and argillization, locally extending as much as 150 m below surface.

The main sulphide mineral at Ilovica is chalcopyrite, followed by pyrite and secondary copper sulphides such as chalcocite, covellite and bornite. molybdenite; galena and sphalerite are present in minor amounts, and occasional traces of sulphosalt minerals such as tetrahedrite-tennantite and tellurides of gold and silver are observed.

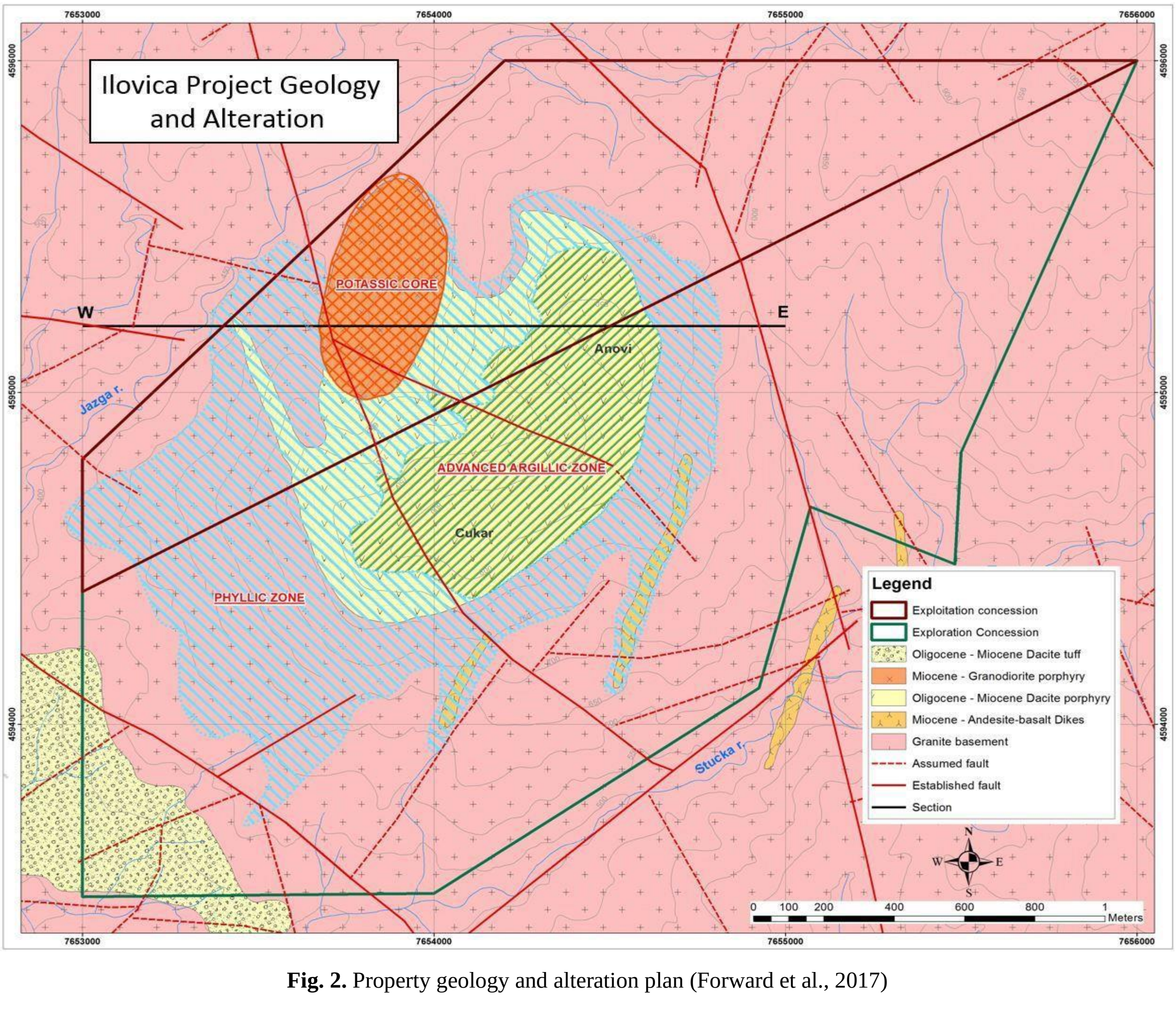

Fig. 2. Property geology and alteration plan (Forward et al., 2017)

High temperature oxide mineralization such as magnetite, dominates at depth, associated with pyrrhotite and chalcopyrrhotite in what is interpreted as the core of the system (Denkovski et al., 1993; Serafimovski and Tasev, 2011). A variety of iron hydroxide group minerals are largely developed within the oxidation and cementation zones. Very occasionally gold nuggets are observed at the base of the oxidation zone, which is quite similar to some other mineralizations in the Alpine-Balkan Carpathian-Dinaride geodynamic province (Heinrich and Neubauer, 2002).

EXPLORATION AND RESULTS

Geological mapping, rock chip sampling, soil geochemistry sampling, induced polarization (IP) / resistivity and magnetic geophysical surveys were completed between 2004 and 2015.

Mapping was completed on 1:2 000 and 1:5 000 scales and comprised observations with respect to petrology, style of alteration, and mineralization.

In total, three phases of soil sampling have been undertaken on the property, resulting in a total of 540 sampling points arranged on a 100 m by 100 m grid covering an area of circa 5 000 m^2 (Bird and Morris, 2012; Wheeler, 2015).

A total 163 holes have been drilled over 11 campaigns between 2004 and July 2016. Of the 163 holes, 43 were drilled for geotechnical investigation, 25 were drilled for hydrogeological investigation, and 95 were drilled for mineral resource determination (Tables 1 and 2). In total, 45,284.7 m have been drilled (Figures 3 and 4).

Table 1

Summary of DD drilling at Ilovica-Štuka

Drill hole type	Number of holes	Total meters
Exploration	70	30,661.0
Infill	22	6,036.5
Geotechnical	43	4,440.8
Hydrogeological	25	3,148.3
For metallurgical sample	3	998.1
Total	163	45,284.7

Table 2

Summary of drilling used for the Ilovica-Štuka mineral resource estimate:

Drill type	Number of holes	Total meters
Diamond drilling	90	5,309.5

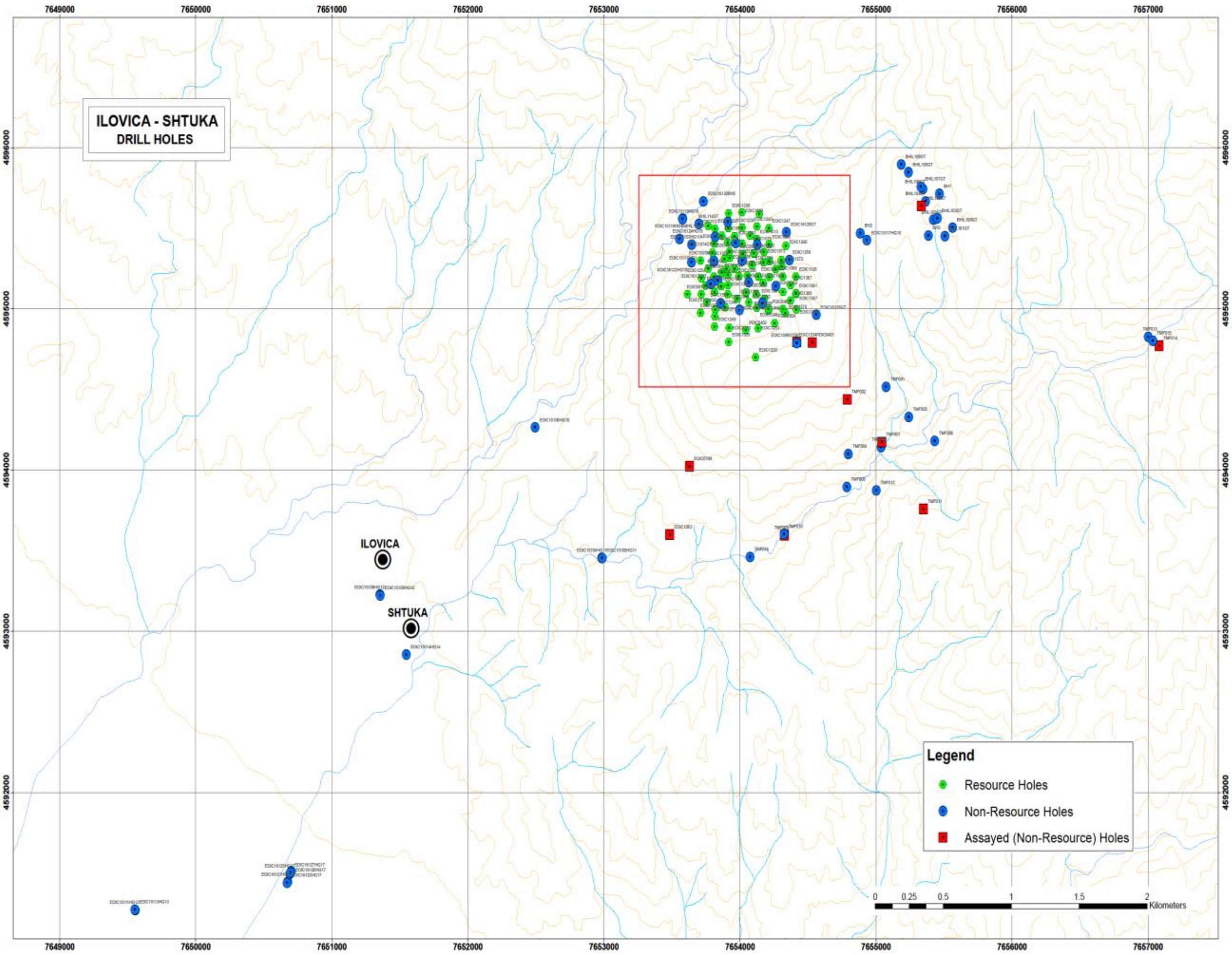

Fig. 3. Drill hole collar location plan

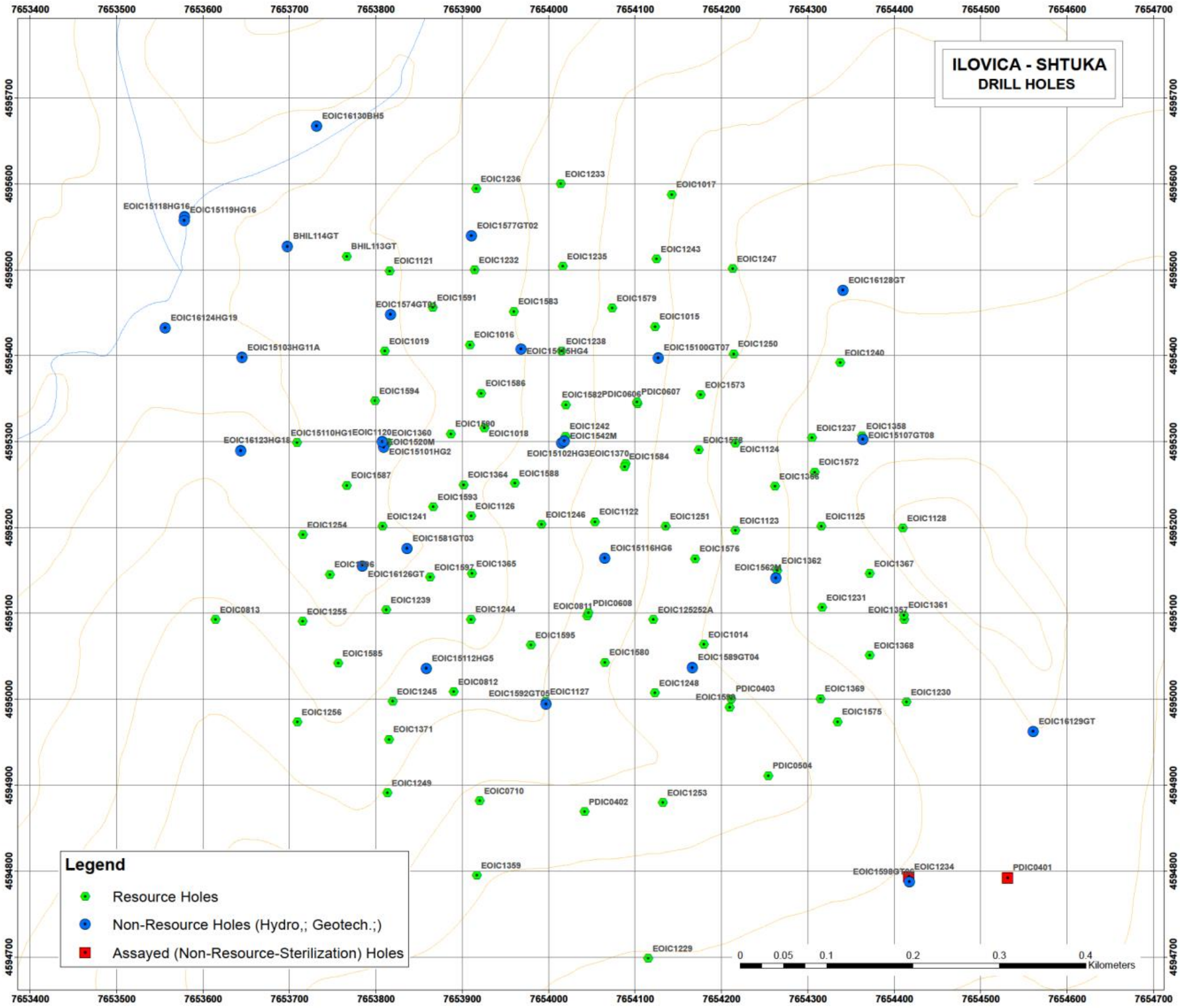

Fig. 4. Drill hole collar location plan on the deposit

The quality assurance/quality control (QA/QC) programme conducted by Euromax Resources was appropriate and meets industry standards. In Tetra Tech's opinion, the sample preparation and security procedures are acceptable and the data can be relied upon for resource estimation.

Mineral processing and metallurgical testing

The historical investigations have been conducted by two organizations: ITMNS in Belgrade, Serbia, and SGS, UK (SGS). This review covers only the most recent mineralogical and metallurgical testwork completed during Phase II (PII) (Pre-Feasibility Study (PFS) – by Tetra Tech) and Phase II Residual (PIIR) on the Ilovica Copper Gold project ore under the supervision of Euromax Resources and carried out by SGS (Lakefield, Canada, and Cornwall, UK). Metallurgical tests are reported from the Phase II (PII) samples. The work was undertaken on two drill holes which were used to generate an overall master composite (MC) sample. The PII work was extended as Phase II Residual (PIIR), using the PII MC and supplemented by two additional samples covering higher grade domains designated Hifgher (H) and a Transitional (T), the latter so named because of the presence of secondary sulphides such as chalcocite and bornite. The PIIR work was essentially to evaluate and confirm the results obtained from the PII work to the level of lock cycle test, especially in the higher grade material which is encountered in the early years of production. The Phase III (PIII) work has to date focussed on the comminution, with flotation work to optimize reagents and flotation variability work in order to assess recoveries in the early years (Prout and Grammatikopoulos, 2013).

Mineral resource estimates

The definition of Mineral Resource as outlined within the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves ('the JORC Code').

Wireframe models. A comprehensive set of lithological and alteration models have been developed for the deposit. The refined classification scheme for lithological and alteration units of the deposit was made. To build the 3D model, geological mapping of the deposit has been used together with borehole data and discontinuous/faults of the area (Figures 5, 6, 7 and 8).

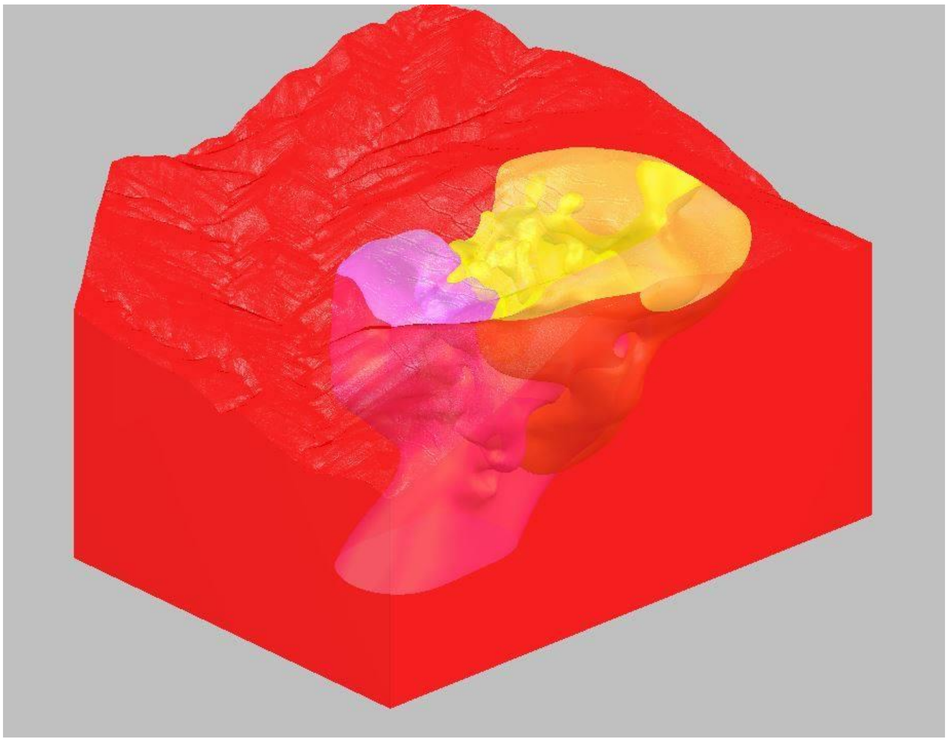

Fig. 5. Lithological model of the Ilovica-Štuka deposit

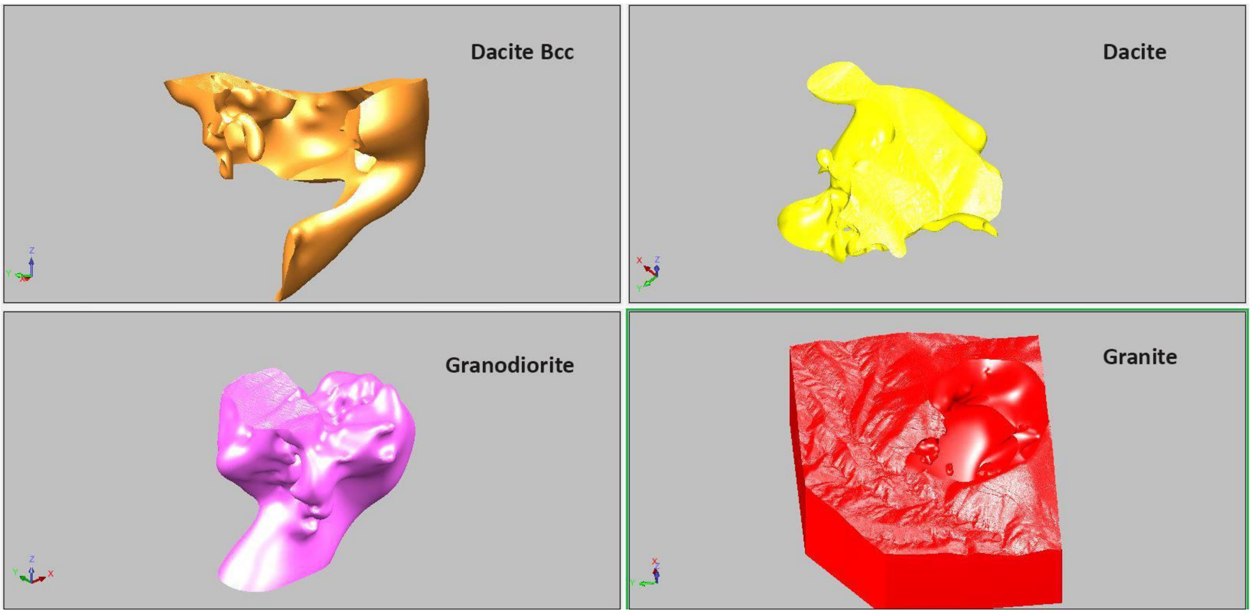

Fig. 6. Lithological units in the Ilovica-Štuka deposit

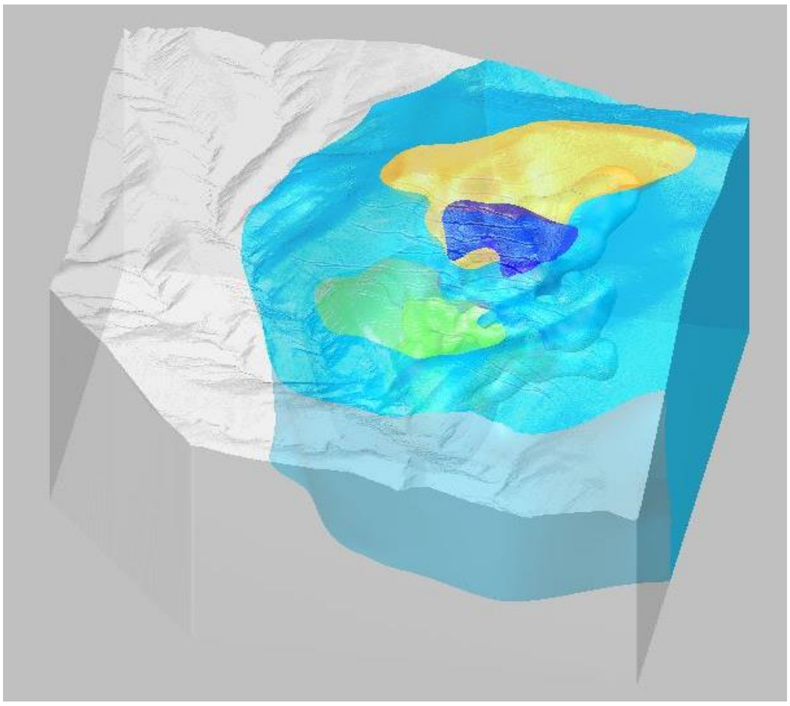

Fig. 7. Alteration model of the Ilovica-Štuka deposit

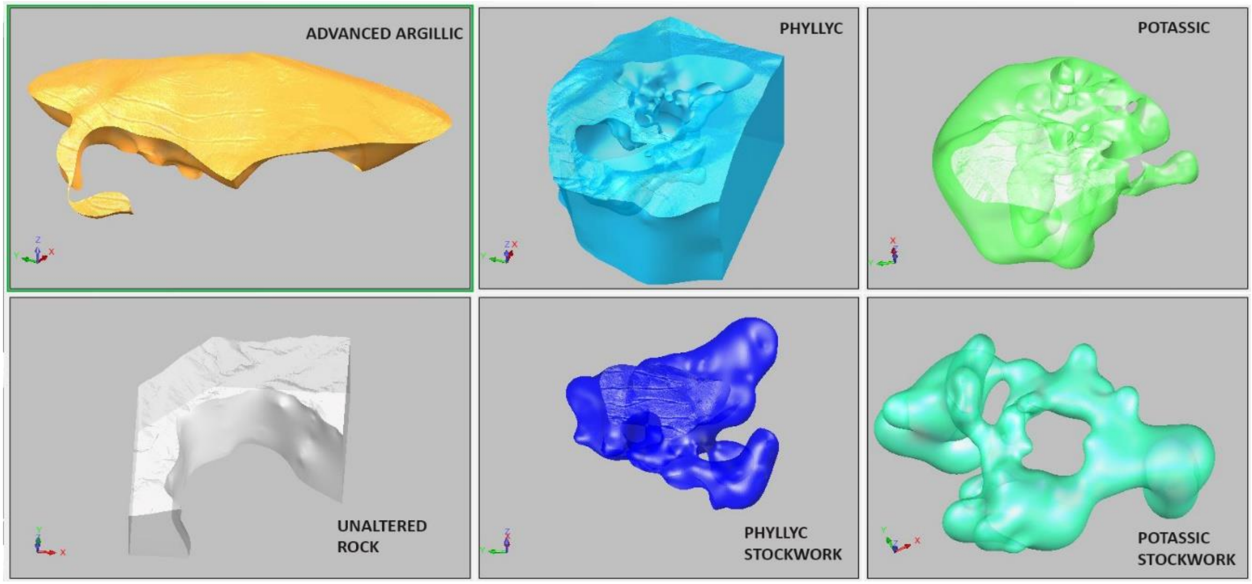

Fig. 8.. Alteration units in the Ilovica-Štuka deposit

A three-dimensional (3D) wireframe models defining the limit of mineralization was created for the deposit using implicit methods. Where the mineralization is still open laterally, the mineralization has been constrained by approximately 50 m distance constraint beyond the drill holes (the mineralization continue in depth and grades slightly decrease) (Figures 9 and 10).

The hypogene zone was defined on an in-situ copper equivalent basis (CuEq ≥ 0.15%), as follows:

$$\text{CuEq\%} = (\text{Cu \%} + (\text{Au g/t} \times [(1300\text{oz}))/(22.0462 \times 3.0/\text{lb} \times 31.0135\ \text{g/t})]$$

$$\text{CuEq} = \text{Cu\%} + (\text{Au g/t} \times 0.633779)$$

using: US$ 3.0/lb copper price (6614 US$ per tonne); US$ 1300/oz gold price.

The supergene zone was defined on an in-situ gold CuEq ≥ 0.15 g/t.

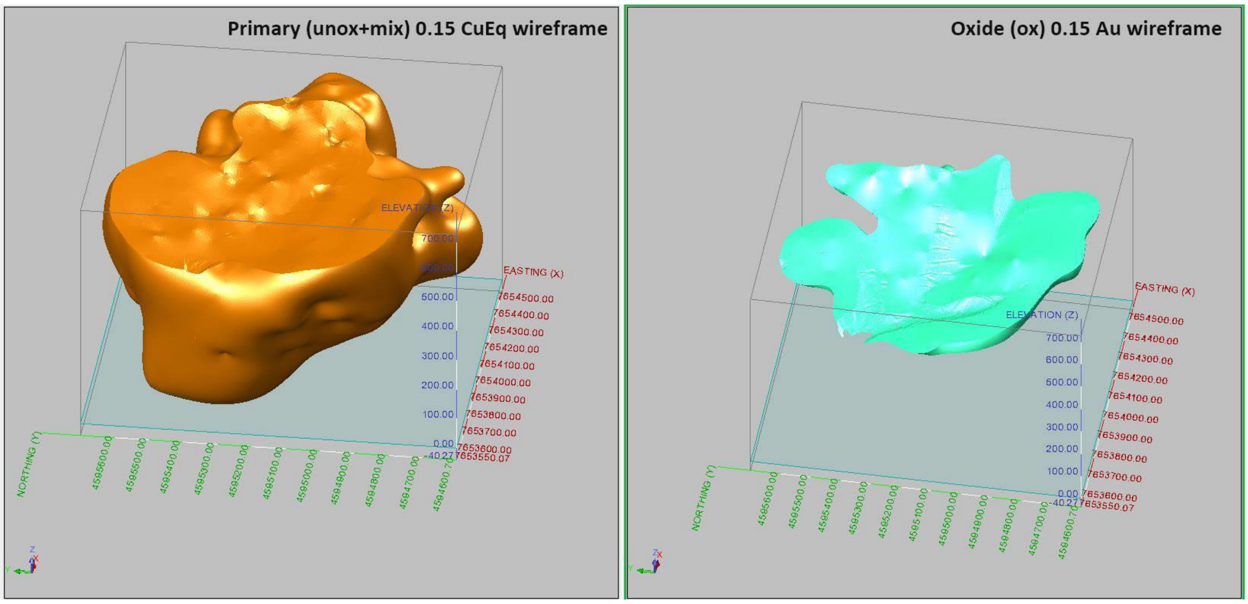

Fig. 9. Ore domains Ilovica-Štuka deposit

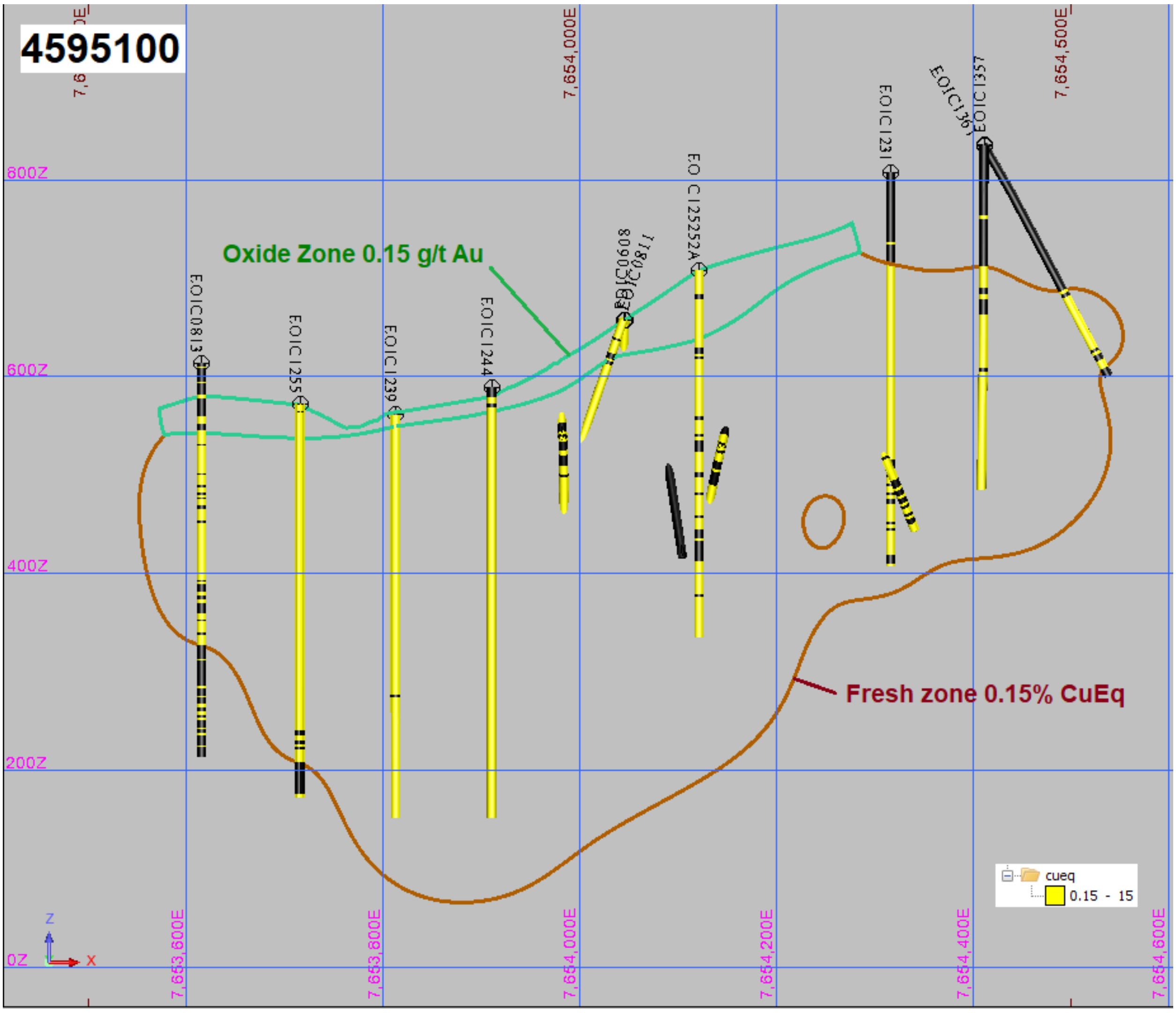

Fig. 10. Section – ore domains in the Ilovica-Štuka deposit

COMPOSITING

Lithology and alteration observations dictated sample interval selection for all drilling campaigns at Ilovica. A 3 m the best fit routine was utilized to produce composites within hard domain boundaries. The compositing was completed in Surpac.

POPULATION ANALYSIS AND DOMAINING

The box and whisker plot below demonstrates that the oxide material is depleted with respect to copper. This distribution is interpreted to be associated with leaching of copper from the oxide zone and supergene enrichment within the transitional zone. The gold distribution is not controlled by the oxidation state.

The log histograms below presented the distribution of the copper and gold grade populations (Figures 12 and 13).

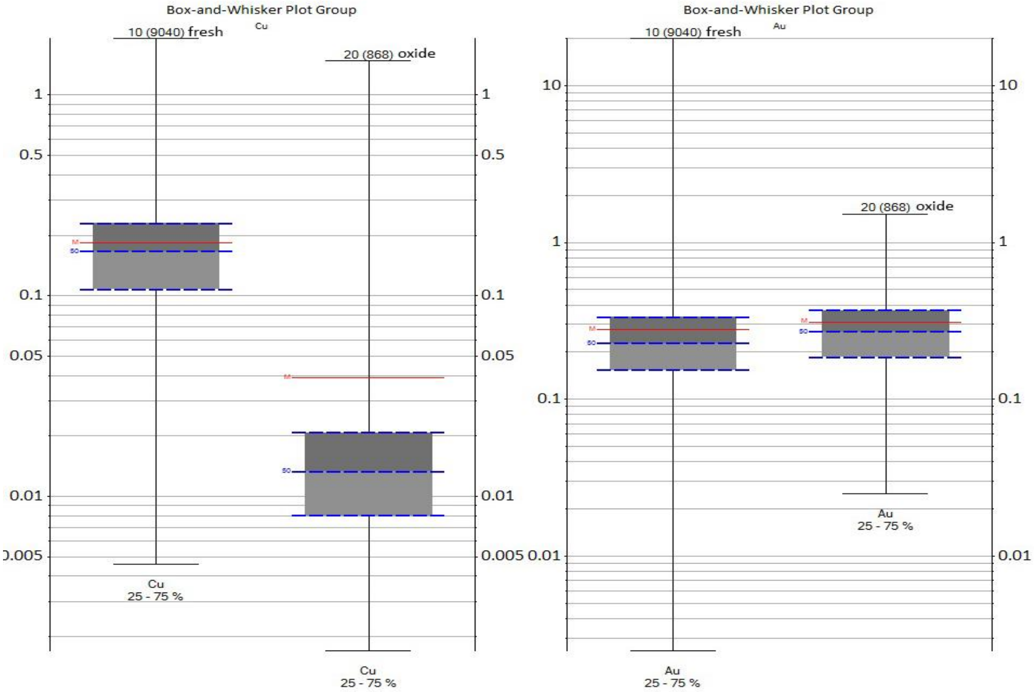

Fig. 11. Box and whisker plot of gold and copper – fresh and oxidation state

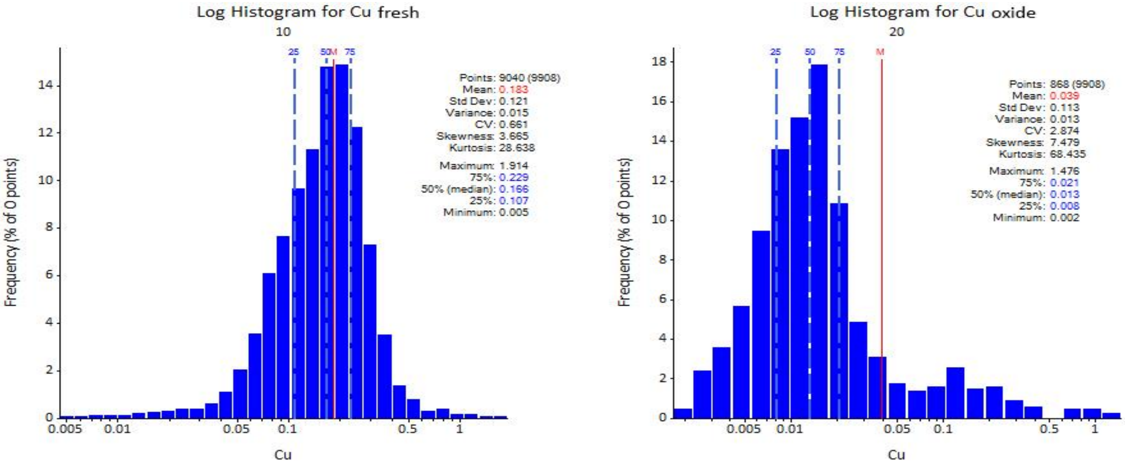

Fig. 12. Log histogram illustrating copper populations from composites within estimation domains 10 (fresh) and 20 (oxide)

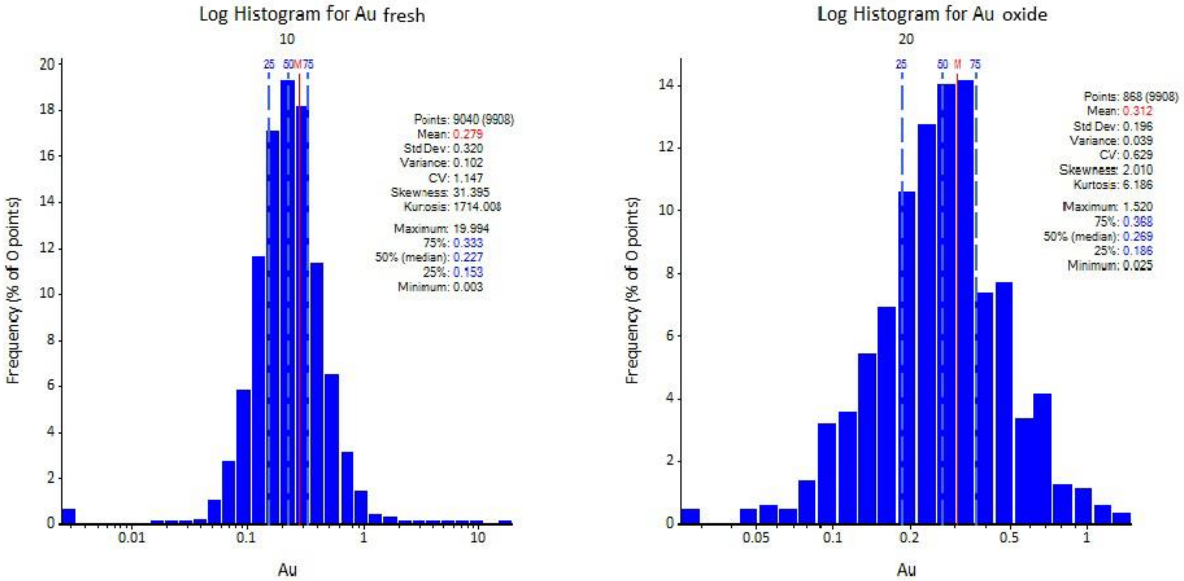

Fig. 13. Log histogram illustrating gold populations from composites within estimation domains 10 (fresh) and 20 (oxide)

Bulk Density

Euromax provided density results for 8282 samples. The samples included granite, granodiorite and dacite, and were taken from the oxide, transitional and fresh zones (Figures 14 and 15).

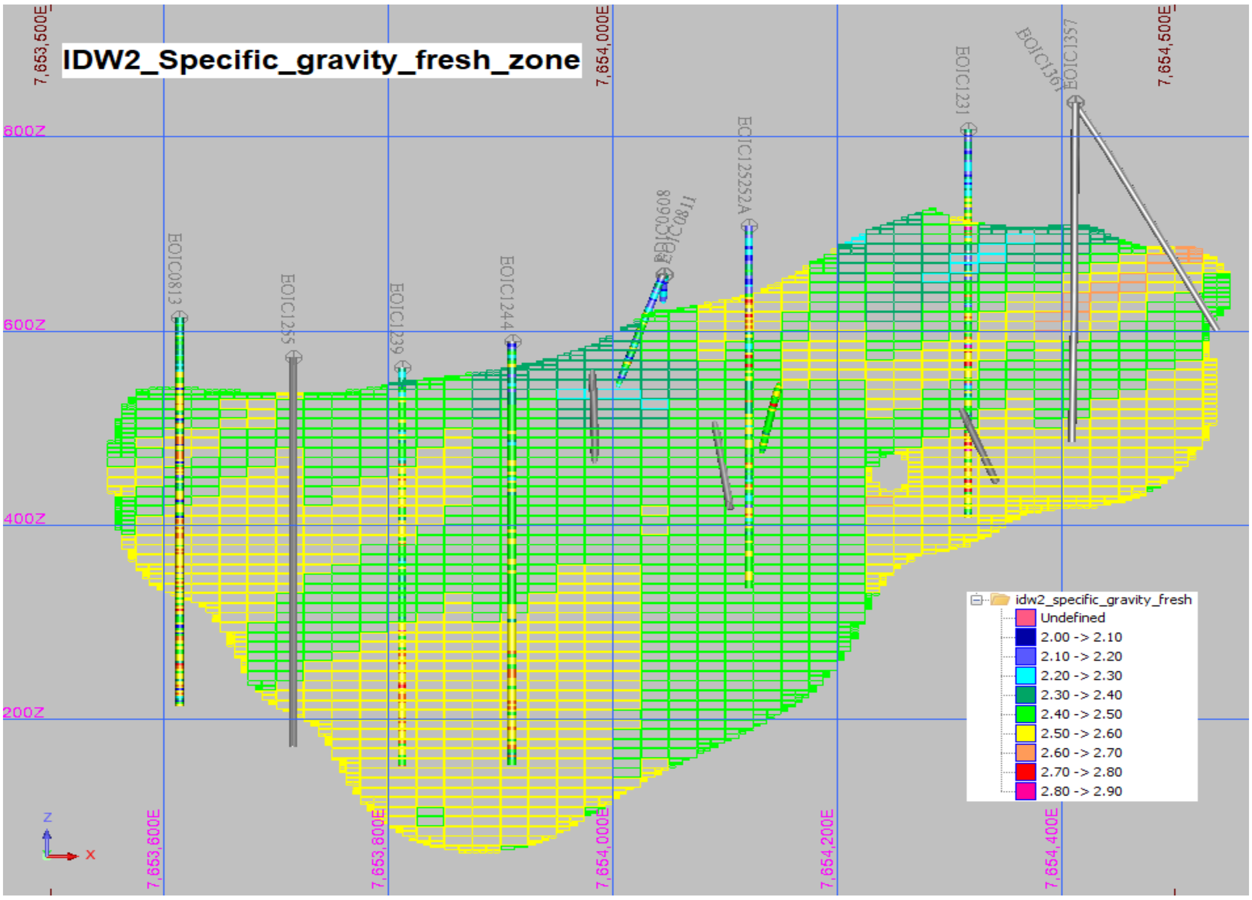

Fig. 14. The density values were estimated using an IDW2 method – domain 10 (fresh) in the Ilovica-Štuka deposit

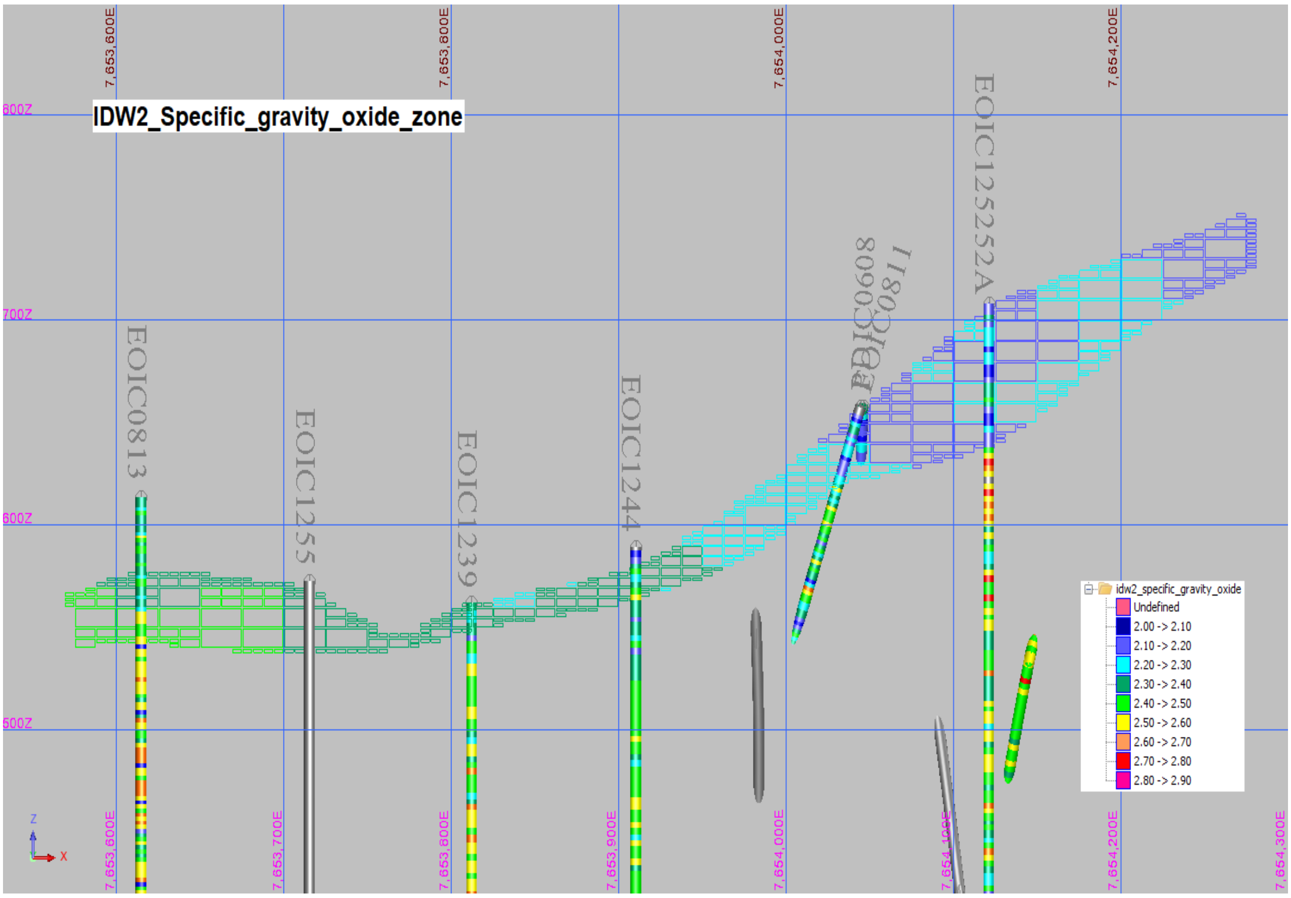

Fig. 15. The density values were estimated using an IDW2 method – domain 20 (oxide) Ilovica-Štuka deposit

The density values were estimated per gold estimation domains using an Inverse Distance Weighting method (Snowden, 1993; 1996; Parrish, 1997). The mean density for the rock types reported from the drill hole database are presented per oxide state and lithology in Table 3.

Table 3

Density values by oxide state

Oxide state	Density (t/m^3)
Oxide	2.26
Fresh	2.50

Variography

Experimental semi-variograms were produced in plan view initially, with the strike, dip and plunge established independently thereafter (Table 4). The nugget value has been established from a downhole variogram (Clark, 1982; Baafi and Schofield, 1996). The modelled variogram parameters establish the variogram structures to be utilized within the ordinary kriging estimation. Weak to moderate directional control has been established in the majority of the domains for both copper and gold (Figures 16, 17, 18).

Table 4

Variogram parameters used for the estimation

		Nugget	Sill	Range	Bearing	Plunge	Dip	Major/Semi	Major/Minor
Oxide (20)	Au	0.12	0.88	288	156.691	16.27	–11.792	1.047	6.261
Fresh+mix (10)	Cu	0.06	0.94	263	227.882	4.531	–64.916	1.056	1.201
	Au	0.12	0.88	243	226.781	3.828	–49.892	1.152	1.272
	CuEq	0.08	0.92	286	226.781	3.828	–49.892	1.336	1.395

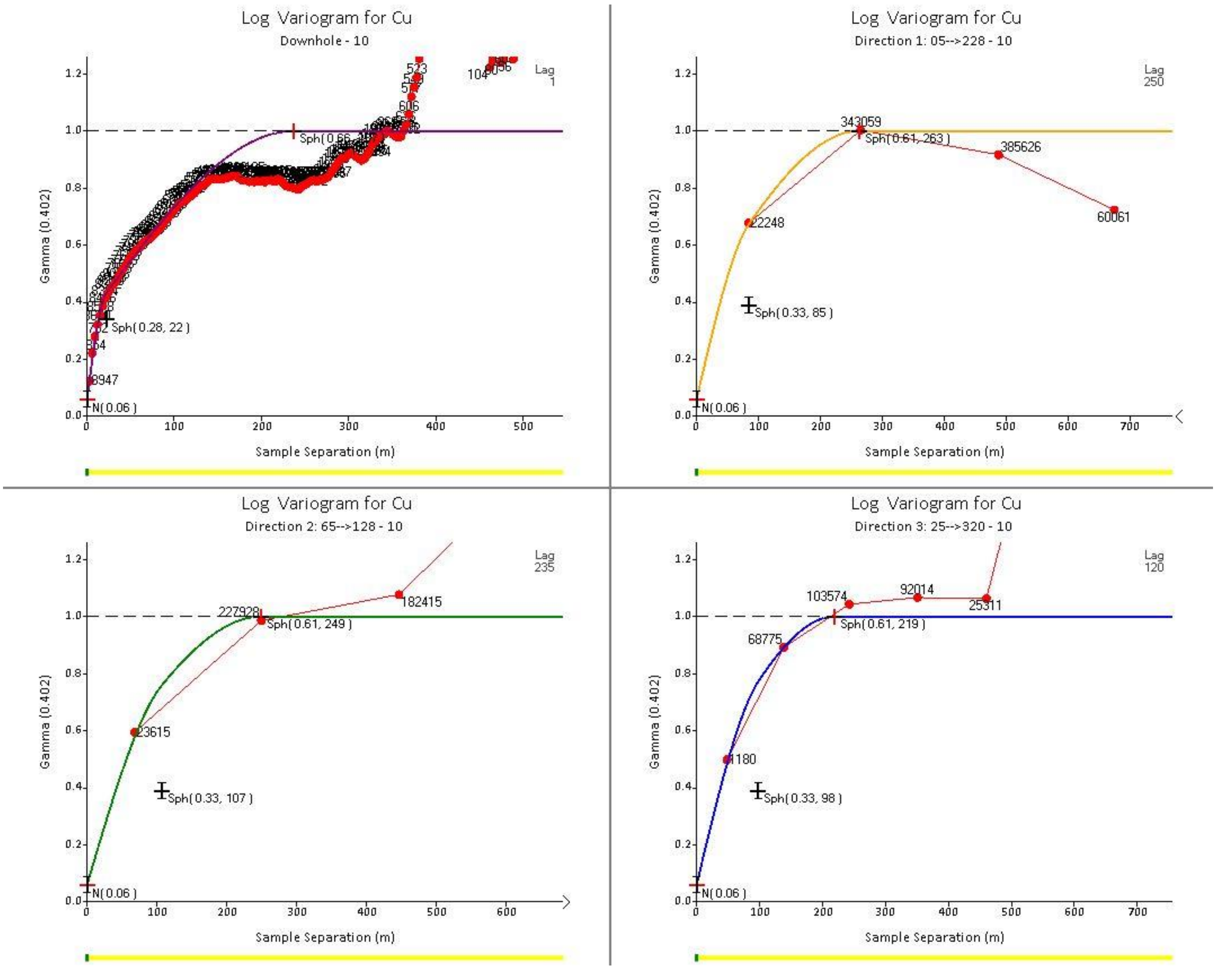

Fig. 16. Log variograms for copper – fresh

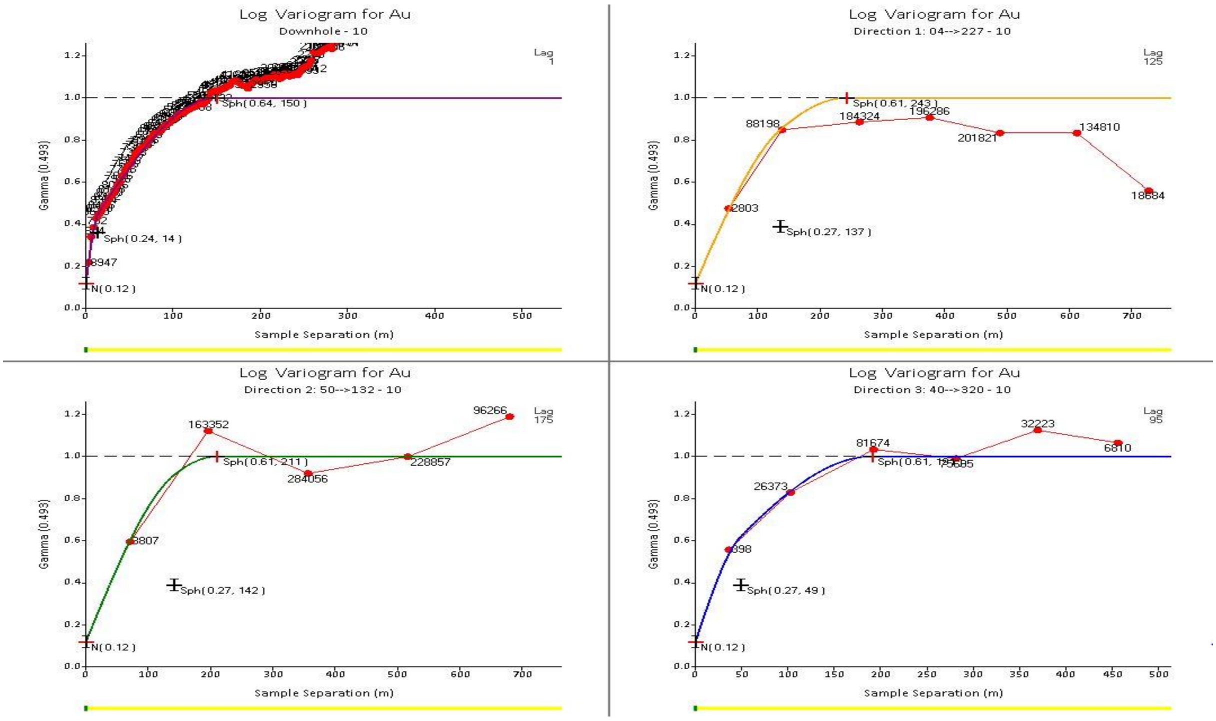

Fig. 17. Log variograms for gold – fresh

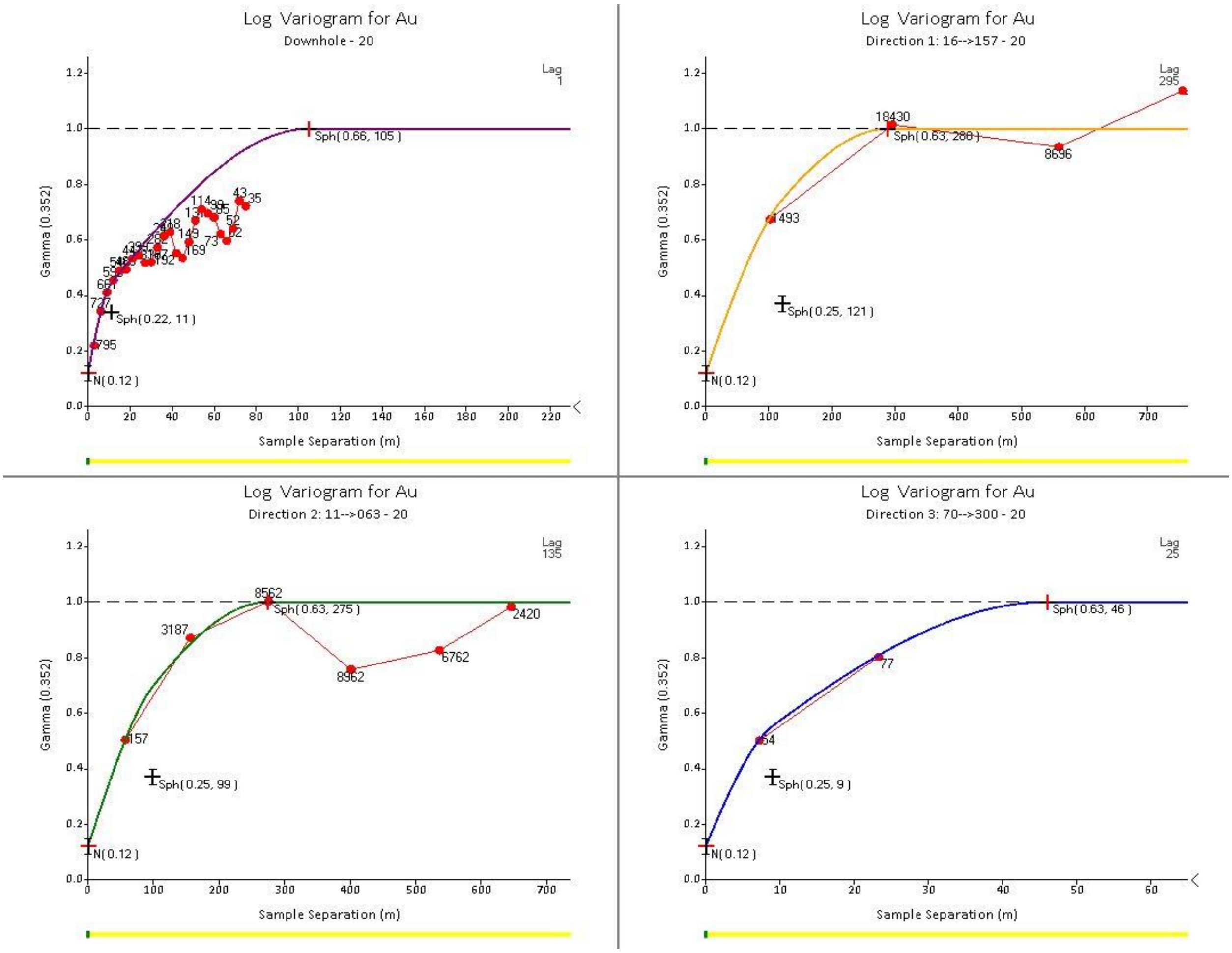

Fig. 18. Log variograms for gold – oxide

Resource block models

A single block model has been constructed in Surpac for the project. The block model parameters are given in the Table 5.

Sub-blocks were used to accurately differentiate domains within the block model. The block model volume for a given zone was found to match well with its corresponding wireframe (Tables 6 and 7).

Table 5

Block model parameters and extents

Measure	Y	X	Z
Minimum coordinates	4 594 500	7 653 000	–200
Maximum coordinates	4 596 500	7 655 000	1000
Parent BLOCK SIze (m)	25	25	10
Minimum block size (m)	6.25	6.25	2.5
Rotation (°)	0	0	0

Table 6

Comparison of block model and fresh wireframe volumes

Description	Unit	Volume
Mineralization wireframe	m^3	258 699 343
Block model	m^3	258 690 918
Difference	%	0.003

Table 7

Comparison of block model and oxide wireframe volumes

Description	Unit	Volume
Mineralization wireframe	m^3	20 237 017
Block model	m^3	20 247 852
Difference	%	0.053

Interpolation strategy

Grades were estimated using ordinary kriging, adopting a multi-pass methodology (Krige, 1981, 1996).

As previously described the estimation was controlled by two domains, defined by oxide state.

Quantitative kriging neighbourhood analysis was undertaken to optimize the block size, number of informing samples, discretization and search distances used in the estimation.

Quantitative measures of the kriging performance (e.g. slope of regression, kriging efficiency, kriging variance, block variance) were used to test the appropriateness and optimise the kriging parameters (Wellmer, 1998; CIM, 2010).

A summary of the estimation strategy is show in Tables 8 and 9.

Table 8

Variogram parameters

Domain	1st pass	Min samples	Max samples	2nd pass	Min samples	Max samples	3rd pass	Min samples	Max samples
Au_oxide (20)	60 m	8	35	110 m	8	26	288 m	6	12
Cu_fresh (10)	55 m	8	31	110 m	8	23	263 m	6	12
Au_fresh (10)	60 m	8	30	110 m	8	22	243 m	6	12
CuEq_fresh (10)	45 m	8	30	110 m	8	22	286 m	6	12

Table 9

Optimization kriging neighbourhood analyses

Domains		Block sizes	Samples (min–max)	Block discretization
Oxide (20)	Au	25 × 25 × 10	7 → 35	4 × 4 × 4
Fresh+mix (10)	Cu	25 × 25 × 10	6 → 31	4 × 4 × 4
	Au	25 × 25 × 10	6 → 30	4 × 4 × 4
	CuEq	25 × 25 × 10	6 → 30	4 × 4 × 4

Block model validation

Block model validation was completed using graphical and statistical methods, to confirm that the estimated block model grades appropriately reflect the local composite grades (Coombes, 1997, 2008; Coombes et al., 1998, 1999, 2000, 2005). Graphical analysis of the informing samples versus estimated block grades was undertaken using horizontal and vertical sections (selected vertical sections are presented in Figures 19 and 20).

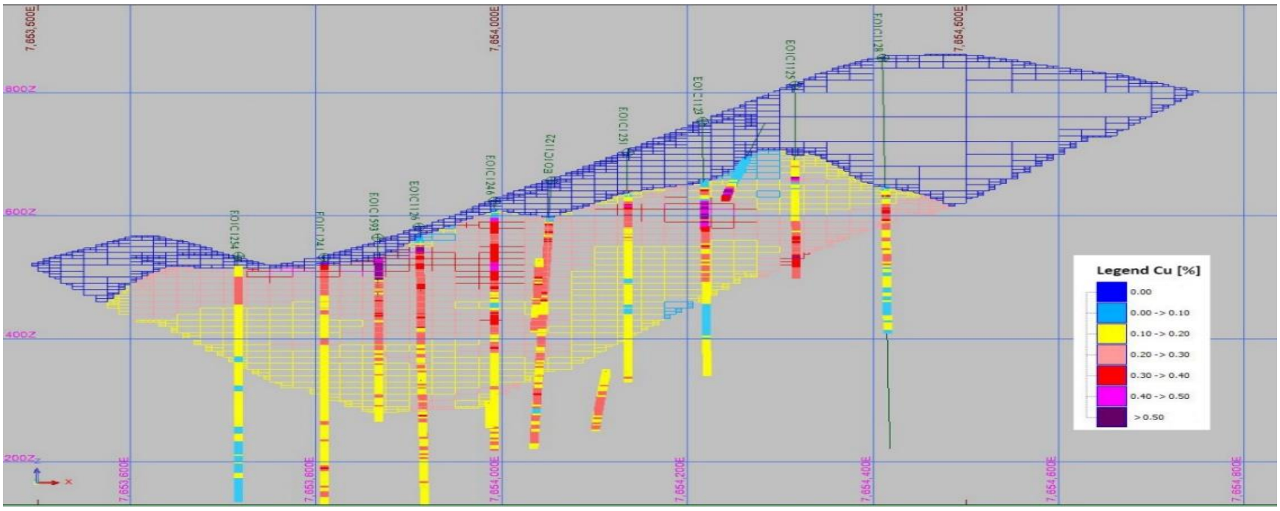

Fig. 19. East-west section through block model and local drill holes with copper grades presented in Ilovica-Štuka deposit

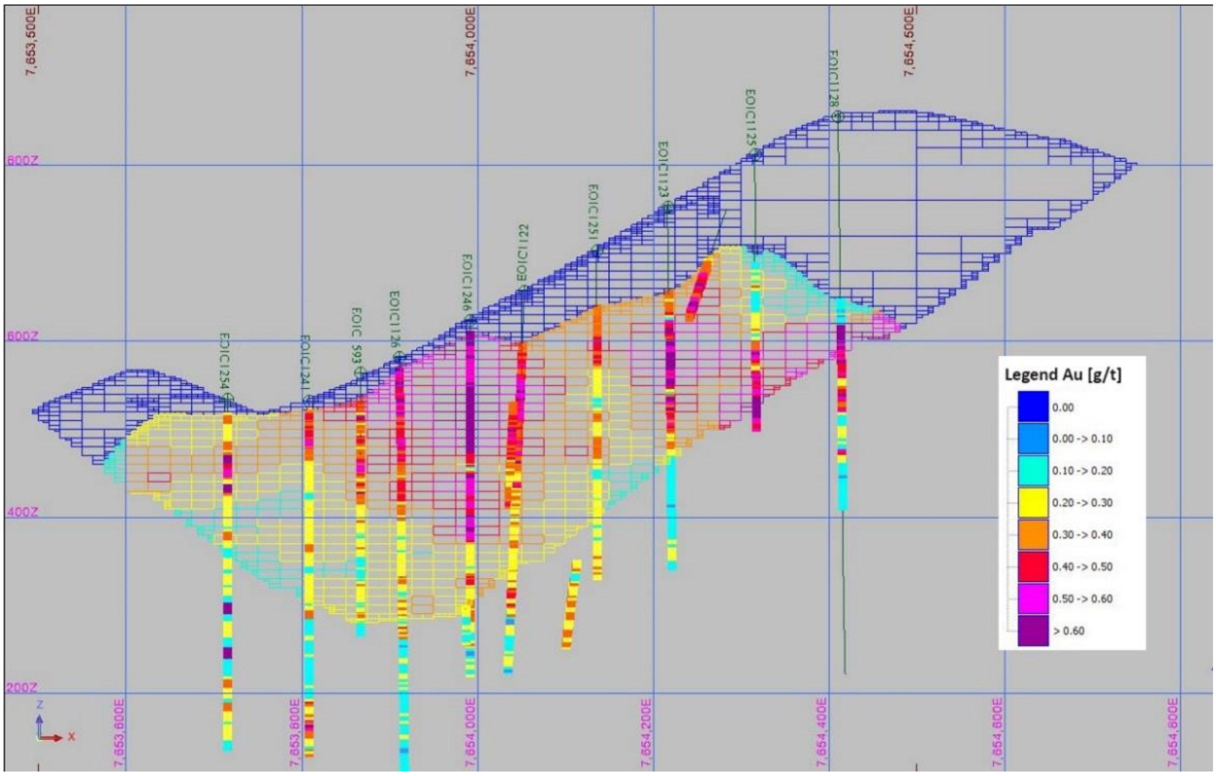

Fig. 20. East-west section through block model and local drill holes with gold grades presented in Ilovica–Štuka deposit

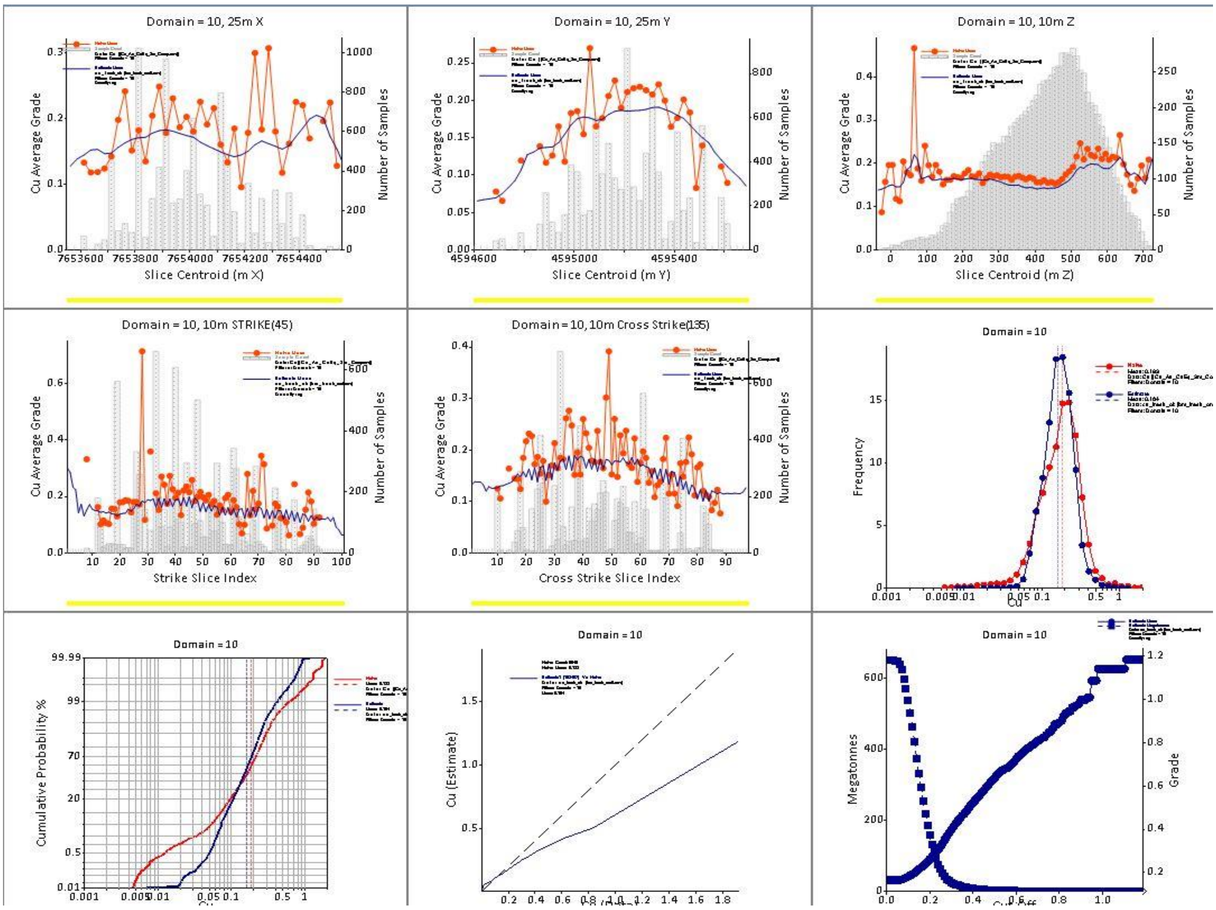

Fig. 21. Illustrates the correlation between the kriged copper grades and the informing composites

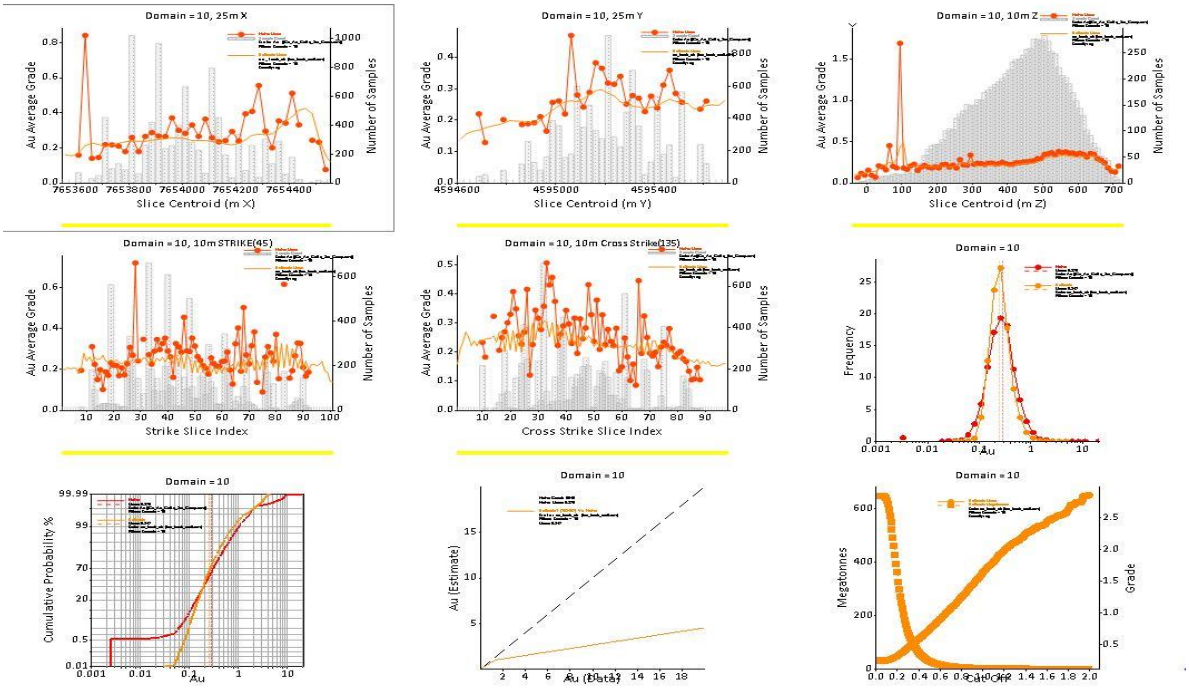

Fig. 22. Illustrates the correlation between the kriged gold grades and the informing composites

The plots illustrates a good correlation, with the composite trends being reflected in the block model. There is a reduction in variance shown in the block model.

A comparison was made between the overall estimated block grades and the entire informing composite populations for each domain and metal. This was undertaken through the use of a range of statistical measures.

A number of the measures indicate a reduction in variance. This is as a result of the change of support associated with the estimation process and the kriging interpolation. Overall, the statistics present excellent conformance.

DISCUSSION

The various comparators described in the foregoing subsections serve to illustrate that the block model estimate is robust and satisfactorily models the distribution and variability of the informing sample grades without undue bias or smoothing.

Mineral resource classification and tabulation

The model was classified according to the Australasian Code for the Reporting of Exploration Results, Mineral Resources and Ore Reserves (The JORC Code, 2012 Edition).

The resource classification at Ilovica considers the following criteria:

- Confidence in the sampling data and geological interpretation.
- Statistical analyses of distance at which grades are correlated:
  - – the data is sufficient to define only the longer range than the resource, it is classified as Inferred;
  - – the area of the resource that is covered by data closer spaced than the range that corresponds to two-thirds of the sill, it is classified as Indicated;
  - – the area of the resource that is covered by data closer spaced than the range that corresponds to one-half of the sill, is it classified as Measured.
- The data distribution (based upon graphical analysis and average distance to informing composites).
- Analysis of variogram parameters.
- Kriging efficiency.
- Slope of regression.

- To avoid over smoothing and the string effect, the restrict number of composites – five (5) from each drillhole for measured and indicated is used.

Note: 65 diluvium samples with 0.21 g/t avg. Au grades in oxide zone were taken into consideration for oxide mineral resource estimation

The block model was constrained based upon the variogram parameters analyses, kriging efficiency, slope of regression and average distance to informing composites. Whilst taking into account the confidence in the sampling and geological interpretation, along with the knowledge of the variogram parameters, three wireframe models were generated to define the Measured, Indicated and Inferred resources. The models reflected the trends in the classification parameters, whilst ensuring that the classification resulted in appropriately coherent units. Figure 23 presents the fresh and oxide ore body with adopted Resource classification. Figure 24 presents a west-east section illustrating the adopted Resource classification.

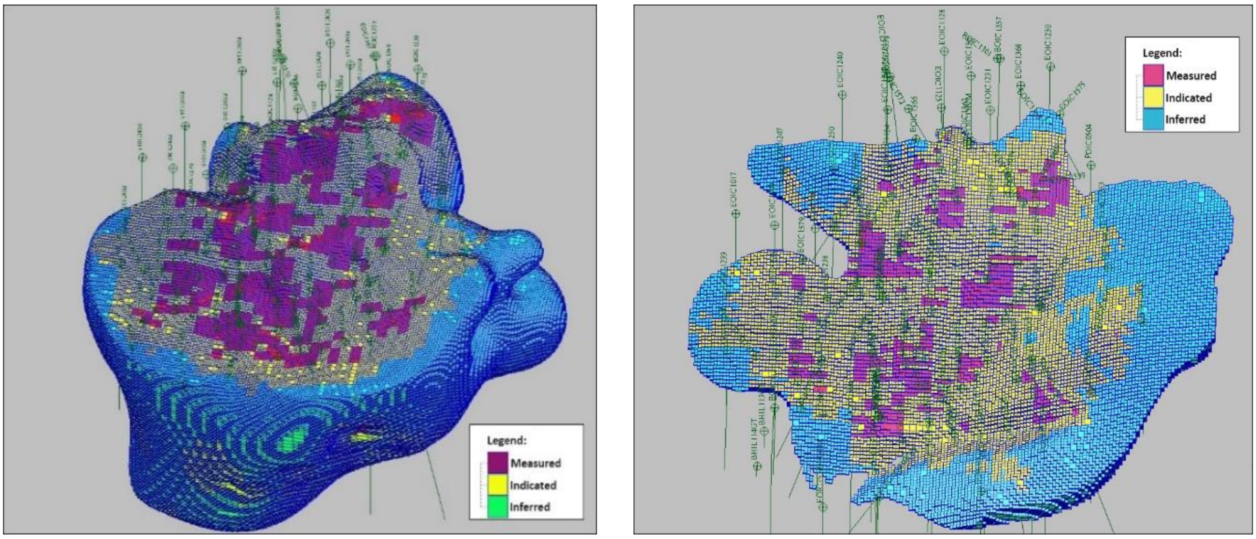

Fig. 23. Fresh and oxide ore body with adopted Resource classification, Ilovica – Štuka deposit

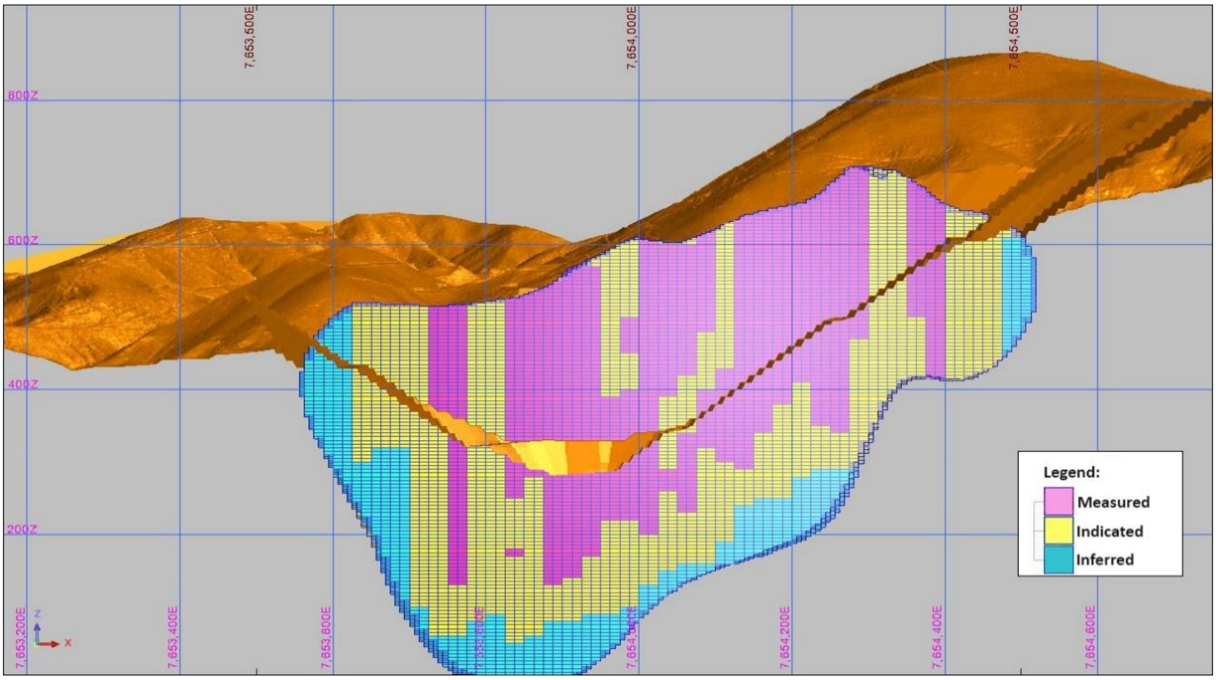

Fig. 24. West-east section illustrating the adopted Resource classification, Ilovica–Štuka deposit

In order to statistically validate the adopted classification, the weighted average block values within each classification domain were reported (see Tables 10 and 11).

Table 10

Statistical validation of classification – fresh

Classification	Distance at which grades are correlated	Average distance to informing composites (m)	Kriging efficiency	Slope of regression
Measured	≤ 1/2 sill range	40	82	97
Indicated	≤ 2/3 sill range	70	70	97
Inferred	≤ sill range	85	12	56

Table 11

Statistical validation of classification – oxide

Classification	Distance at which grades are correlated	Average distance to informing composites (m)	Kriging eficiency	Slope of regression
Measured	≤ 1/2 sill range	44	87	97
Indicated	≤ 2/3 sill range	77	81	100
Inferred	≤ sill range	110	45	78

Mineral resources

The mineral resource for fresh material is summarized in Tables 12 and 13.

Grams to Oz = 31.1

Tonnes to lb = 2204.62

The oxide mineral resources within the constraining pit shell are summarised within Tables 14 and 15.

Table 12

Measured and indicated fresh mineral resource based upon a dollar equivalent cut-off of US$ 10/t

Classification	Tonnage	Grade		Contained metal	
		Au (g/t)	Cu (%)	Au (koz)	Cu (klb)
Measured	82,846,100	0.343	0.228	914	416,429
Indicated	115,927,618	0.289	0.191	1,077	488,151
Total M & I	198,773,718	0.311	0.206	1,988	902,734

Notes: koz = kilotroy ounces; klb = kilopounds

Table 13

Inferred fresh mineral resource based upon a dollar equivalent cut-off of US$ 10/t

Classification	Tonnage	Grade		Contained metal	
		Au (g/t)	Cu (%)	Au (koz)	Cu (klb)
Inferred	12,300,911	0.216	0.183	85	49,627

Notes; koz = kilotroy ounces, klb = kilopounds

Table 14

Measured and indicated oxide mineral resource based upon a dollar equivalent cut-off of US$ 10/t

Classification	Tonnage	Grade	Contained metal
		Au (g/t)	Au (koz)
Measured	3,927,783	0.459	58
Indicated	7,348,085	0.417	99
Total M & I	11,275,868	0.432	157

Notes: koz = kilotroy ounces. klb = kilopounds

Table 15

Inferred oxide mineral resource based upon a dollar equivalent cut-off of US$ 10/t

Classification	Tonnage	Grade	Contained metal
		Au (g/t)	Au (koz)
Inferred	3,053,191	0.487	48

Notes: koz = kilotroy ounces, klb = kilopounds

Notes:

1. To define the blocks with reasonable prospects of economic extraction a dollar equivalent have been applied based upon the following calculation:

$$Dollar\ eq = (Au \times recovery \times price) + \\ + (Cu \times recovery \times price)$$

2. The following assumptions were adopted for the calculation of the dollar equivalent:

- Au recovery in oxide of 74%,
- Cu recovery in oxide of 0%,
- Au recovery in fresh 60.7%,
- Cu recovery in fresh 84.8%,
- forcast metal prices of of US$1300 /oz Au and US$ 3.00 /lb Cu.

3. Recoveries are based on those quoted by Trafigura/Geotechmin estimates.

4. Tonnages calculated interpolated density values.

5. Mineral resources that are not mineral reserves do not have demonstrated economic viability. The estimate of mineral resources may be materially affected by environmental, permitting, legal, title, taxation, socio-political, marketing, or other relevant issues.

In addition to the dollar cut-off, in order to ensure that the resource has reasonable prospects of economic extraction, the block model was constrained to a resource open pit design (derived from an optimized pit shell). The pit designs are based on an optimzed pit shell generated using Datamine's NPV Scheduler software package.

A dollar equivalent cut-off of US$10 was applied to blocks within the resource pit shell to define the mineral resource presented within Tables 16 and 17. Base case dollar equivalent cut-offs have been chosen based upon Processing and General and Administration (G&A) costs of 7.48 US$/t ore. The Mine operating cost estimate of 1.83 US$/t mined.

Grade tonnage sensitivity analysis

The block model has been reported at a range of dollar equivalent cut-offs, as presented in Table 16 and Table 17. It should be noted that the figures presented in Table 16 and Table 17 do not constitute a Mineral Resource statement. The figures are only presented to show the sensitivity of the block model estimates to the selection of cut-off grades.

Table 16

Grade tonnage sensitivity for fresh materials

Material	Dollar equivalent cut-off (US$)	Tonnage	Au (g/t)	Cu (%)
Fresh	8	224,572,531	0.297	0.198
	10	1,074,629	0.306	0.205
	12	86,503,213	0.321	0.217
	14	156,532,614	0.342	0.233

Table 17

Grade tonnage sensitivity for oxide materials

Material	Dollar equivalent cut-off (US$)	Tonnage	Au (g/t)
Oxide	8	22,809,693	0.387
	10	14,329,059	0.444
	12	8,455,735	0.507

It is noted that even with higher dollar equivalent cut-offs, the resource remains spatially coherent and relatively close to surface. (Table 18 and Figure 25). As can be seen from Table 18, this approach enables quick calculations of reserves taking into account a wide range of values for cut off grade (for example. 0.14% Cu – 0.22% Cu – 0.30% Cu; the most common ones), which of course results and with serious changes in the final amounts of calculated reserves that steeply decrease several times (e.g. from 564 Mt through 297 Mt to 116 Mt) with the increase in cut-off grade.

Table 18

Calculation of ore tonnages in accordance with different cut off grades, Ilovica-Štuka deposit

Cut off grade	Tonnage	Cueq_fresh_rep	Content (t)	Cu (%)	Au (g/t)
>0.01	647,167,666	0.233	1,509,041	0.163	0.246
>0.10	635,643,823	0.236	1,498,889	0.165	0.249
>0.12	609,971,564	0.241	1,470,264	0.169	0.254
>0.14	564,869,021	0.250	1,411,089	0.176	0.263
>0.16	499,214,226	0.263	1,312,279	0.184	0.277
>0.18	429,598,610	0.278	1,194,002	0.195	0.294
>0.20	363,747,918	0.294	1,068,820	0.206	0.311
>0.22	297,455,705	0.312	929,540	0.218	0.333
>0.24	237,266,060	0.334	791,345	0.231	0.359
>0.26	188,899,015	0.355	670,620	0.244	0.387
>0.28	147,591,226	0.379	559,255	0.258	0.418
>0.30	116,763,255	0.403	470,008	0.271	0.450
>0.32	91,897,592	0.428	392,949	0.283	0.488
>0.34	72,552,608	0.454	329,207	0.297	0.527
>0.36	57,892,660	0.480	277,985	0.311	0.565
>0.38	47,325,946	0.505	238,910	0.324	0.601
>0.40	38,788,844	0.530	205,666	0.337	0.638
>0.42	31,798,472	0.557	177,034	0.349	0.679
>0.44	26,986,602	0.579	156,381	0.360	0.715
>0.46	23,218,874	0.601	139,445	0.370	0.747
>0.48	19,966,240	0.622	124,167	0.379	0.782
>0.50	16,951,739	0.645	109,408	0.391	0.818
>0.52	14,336,640	0.670	96,064	0.402	0.857
>0.54	12,429,901	0.692	85,956	0.412	0.891
>0.56	10,672,373	0.715	76,295	0.423	0.928
>0.58	9,264,498	0.737	68,277	0.434	0.963
>0.60	7,934,304	0.762	60,444	0.444	1.004
Total	**647,167,663**	**0.233**	**1,509,041**	**0.164**	**0.246**

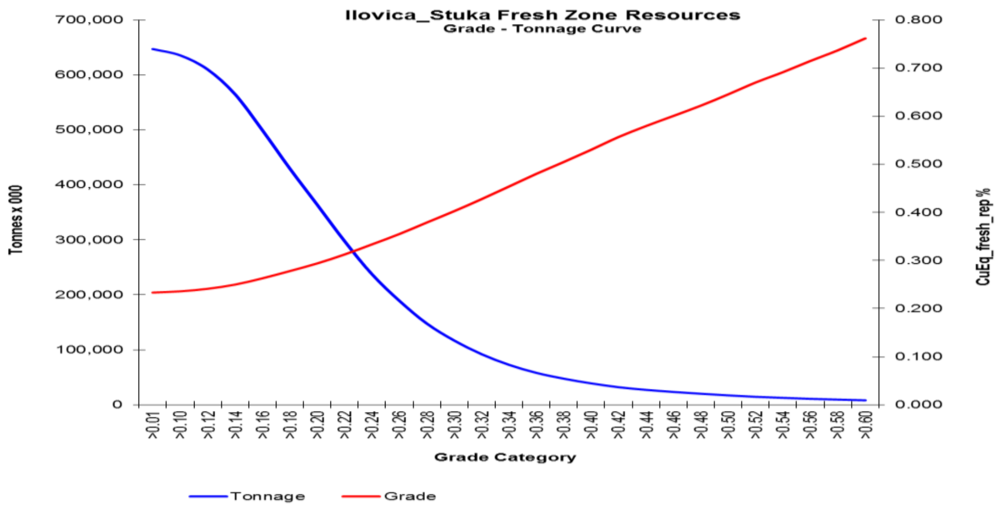

Fig. 25. Resource tonnage curve

CONCLUSIONS

- The mineral resource estimation for the Ilovica – Štuka project has been defined in accordance with the reporting requirements outlined in the 2012 edition of the "Australasian Code for Reporting of Exploration Results, Mineral Resources, and Ore Reserves" (the JORC Code).
- To characterize the mineralization, statistical and grade continuity analyses were completed, which were then used to develop grade interpolation parameters for the deposit.
- The results of exploratory data analysis revealed a number of statistically differentiated grade populations that were thought to be influenced by the following factors: stockwork intensity, oxidation state, supergene leaching, and enrichment.
- To isolate grade populations into domains for sample selection and to constrain grade interpolation, wireframe models were used.
- Ordinary kriging was used to estimate grades.
- The resource grade/tonnage sensitivity graph was created using a variety of dollar equivalent cut-offs for blocks within the resource pit shell.

REFERENCES

Baafi, E. Y. & Schofield, N. A. (Eds.) (1996): *Geostatistics Wollongong. Quantitative Geology and Geostatistics*. Kluwer Academic Publishers, Dordrecht.

Bird, S., Morris, R. (2012): *NI 43-101 Resource Estimate for Ilovitca Project, Macedonia*. Moose Mountain Technical Services, British Columbia, Canada.

Carter, S. (2008): *NI 43-101 Technical Report on the Copper Gold Resources on the llovitza Project, Macedonia*. Broad Oak Associates, Toronto, Canada.

Čifliganec, V. (1993): *Copper Mineralization in the Republic of Macedonia: Types and Distribution Patterns*, Univ. “Sv. Kiril i Metodij”, Skopje, Macedonia, 303 p.

CIM (2010): *Definition Standards for Mineral Resources and Mineral Reserves*. Prepared by the CIM Standing Committee on Reserve Definitions. Adopted by CIM Council on November 27, 2010.

Clark, I. (1982): *Practical Geostatistics*. Applied Science Publishers, London.

Coombes, J. (1997): Handy hints for variography. In: *AusIMM lronmaking Resources and Reserves Estimation*, pp. 127–130.

Coombes, J., Thomas, G., Gifford M., Jepsen L. (1998): Assessing the risk of incorrect prediction – A nickel/cobalt case study, *Aus IMM Mine to Mill Conference*, Proceedings. The Australian Institute of Mining and Metallurgy, Melbourne, pp. 63–68.

Coombes, J., Thomas, G., Glacken, I. (1999): Conditional simulation – A practitioner's performance analysis, *International Symposium on Geostatistical Simulation Modelling Conference*, Perth, Australia.

Coombes, J., Thomas. G., Glacken, I., Snowden, D. V. (2000): Conditional simulation – which method for mining? *Geostatistics Conference 2000*, Cape Town, South Africa.

Coombes, J., Standing, C., Lacourt, R., Rodrigues, R., Queinoz, C. (2005): Exposing uncertainty in schedules for proactive stockpile planning. *AuslMM Annual Conference – National Conference on lronmaking Resources and Reserves Estimation*, Proceedings, The Australian Institute of Mining and Metallurgy, Melbourne, pp. 263–270.

Coombes, J. (2008): *The Art and Science of Resource Estimation: A Practical Guide for Geologists and Engineers*, Subiaco, W. A. Coombes Capability.

Coombes, J. (2016): *I’D like to be OK with MIK, UC?:* A Critique of Mineral Resource Estimation Techniques; Coombes Capability.

Davies, R., Hope, R., Browner, H., David, D., Dippenaar, B., Zeitsman, P., Critcher, P., White, J., White, R., Digges La Touche, G. and Chamberlain, G. (2016): *Feasibility Study – Technical Report, Ilovica Gold-Copper Project, Southeast Macedonia*. Euromax Resources professional fund, 549 p.

Denkovki, G., Pop-Vasilev, V. Georgiev, D., Stojkov, Z. (1993): *Report for geological investigation on the primary gold in the Ilovica-Štuka, Strumičko*, Geoinstitut.

Forward, P., Ligovski, M., Davies, R. (2017): Resource modelling at the Ilovica-Štuka porphyry copper-gold deposit, Eastern Macedonia. *Geologica Macedonica*, **31** (1), pp. 21–40.

Georgiev, S., Peytcheva, I., Stefanova, E., Quadt, A., Marchev, M., Grozdev, V., Serafimovski, T. (2012): *Geochemistry and Geochronology of Ilovica Magmatic Rocks*. SE FYR Macedonia.

Harkovska, A., Yanev, Y., Marchev, P. (1989): General features of the Paleogene orogenic magmatism in Bulgaria. *Geologica Balcanica*, **19**, 1, 37–72.

Heinrich, C. A., Neubauer, F. (2002): Cu–Au–Pb–Zn–Ag metallogeny of the Alpine-Balkan-Carpathian-Dinaride geodynamic province. *Min. Dep*., **37**, 533–540.

Janković, S., Serafimovski, T., Aleksandrov, M. (1995): The Besna Kobila-Osogovo metallogenic zone. *Geologica Macedonica*, **9**, 1, pp. 39–50.

JORC Code 2012 Edition – *The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* (the ‘JORC Code’ or ‘the Code’).

Krige, D. G. (1981): *Lognormal-de Wijsian Geostatistics for Ore Evaluation*. South African Institute of Mining and Metallurgy, Johannesburg.

Krige, D. G. (1996): A practical analysis of the effects of spatial structure and of data available and accessed, on conditional biases in ordinary kriging. In: *Geostatistics Wollongong* (Eds: E. Y. Baafi and N. A. Schofield). Kluwer, pp. 799–810.

Lowell, J. D. and Guilber, J. M. (1970): Lateral and vertical alteration-mineralization zoning in porphyry ore deposits. *Economic Geology*, **65** (4), 373–408, DOI: 10.2113/gsecongeo.65.4.373.

Parrish, I. S. (1997): Geologist's Gordian knot: to cut or not cut. *Mining Engineering*, **49**. pp. 967–982.

Prout, S., Grammatikopoulos, T. (2013): *The mineralogical characteristics of a flotation tailings sample from the Ilovica copper-gold deposit*. SGS UK.

Rakičević, T., Kovaćević, M., Radović, N. (2008): *Interpreter of Geological Map of Macedonia, sheet Strumica, 1:100 000.*

Schefer, S., Cvetković, V., Fügenschuh, B., Kounov, A., Ovtcharova, M., Schaltegger, U., Schmid, S. M. (2011): Cenozoic granitoids in the Dinarides of southern Serbia: age of intrusion, isotope geochemistry, exhumation history and significance for the geodynamic evolution of the Balkan Peninsula, *Int. J. Earth Sci*., **100**, 1181–1206.

Schmid, S. M., Bernoulli, D., Fügenschuh, B., Kounov, A., Oberhänsli, R., Schefer, S., Van Hinsbergen, D., Ustaszewski, K. (2013): *Similarities and Differences between Alps-Carpathians, Dinarides-Hellenides and Anatolides-Taurides.– EGU*, **15**, 3525.

Serafimovski, T. (1990): *Metalogenija na zonata Lece-Halkidiki – Metallogeny of the Lece-Chalkidiki Zone*, Ph.D. thesis, Faculty of Mining and Geology, Štip, 390 p. [In Macedonian].

Serafimovski, T., Tasev G. (2011): *Report for ore-microscopic explorations of the samples at the Ilovica site – Strumica*. University "Goce Delčev" in Štip, Faculty of Natural and Technical Sciences.

Sinclair, W. D. (2008): *Interpreter of Geological Map of Macedonia, sheet Strumica,* Mineral Deposits of Canada Porphyry Deposits. Geological Survey of Canada (www.nrcan.gc.ca). 14 p.

Snowden, D. V. (1993): Improving predictions by studying reality, *Geostatistics for the Next Century*. Kluwer Academic Publishers, pp. 330–337.

Snowden, D. V. (1996): Practical interpretation of reserve classification guidelines, *Proc. 1996 Aus IMM Annual Conference – Diversity, the Key to Prosperity*, The Australasian Institute of Mining and Metallurgy, Melbourne, pp. 305–308.

Stojanović, M. (1971): *Completed annual report for regional geological exploration of the region of eastern Macedonia – locality Ilovica-Štuka*.

Stolić, N. (2011): Elaborate of calculation of geological reserves from the Ilovitsa deposit, Strumica, at 30.05.2011. Geologing for DOOEL Phelps Dodge Vardar, 120 p. (in Macedonian).

Tasev, G. (2003): *Polimetalnite mineralizacii povrzani so tercierniot magmatizam vo Republika Makedonija* [*The polymetallic mineralizations related with Tertiary magmatism in the Republic of Macedonia*] Master thesis, University "Sts. Cyril and Methodius", Faculty of Mining and Geology, Štip, 176 p. (in Macedonian).

Tomić, J., 1936: Lithological composition of the Ogražden. *Geological Annals. Balkan Peninsula,* knj. **XIII**, Belgrade, pp. 80–91.

Wellmer, F-W. (1998): Statistical evaluations, In: *Exploration for Mineral Deposits.* Springer-Verlag, Berlin.

Westra, G. (2005): Report prepared for Phelps Dodge Exploration Corporation.

Wheeler Amec Foster (2015): *Ilovica Gold-Copper Project*. Feasibility Study Technical Report.
S2233-0000-BA00-RPT-1000.

Резиме

МОДЕЛИРАЊЕ НА БАКАРНО-ЗЛАТОНОСНОТО НАОЃАЛИШТЕ ИЛОВИЦА-ШТУКА, ОЦЕНА НА РЕСУРСИТЕ И КЛАСИФИКАЦИЈА

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Клучни зборови: код ЈОРК – австралискоазиски код за приказ на истражувачките резултати, минерални ресурси и рудни резерви; ЕДА (анализа на истражни податоци); мрежни модели, домени, блок-модел; кригинг-метод; и анализа на соседни површини

Процената на минералните ресурси на проектот Иловица-Штука е дефинирана во согласност со барањата за известување наведени во изданието од 2012 година на „Австралазискиот кодекс за приказ на резултатите од истражување, минералните ресурси и рудните резерви“ (кодот JORC). Статистичките и анализите за континуитет на оцени беа извршени за да се карактеризира минерализацијата, а последователно се користеа за развивање параметри за интерполација на концентрациите во наоѓалиштето. Истражувачката анализа на податоци истакна голем број статистички диференцирани групи на концентрации, за кои се толкува дека се контролирани со следново: интензитетот на резервите, состојбата на оксидацијата, секундарното лужење и збогатување. Моделите на жична рамка беа користени за да се изолираат групите на концентрации во домени со цел да се избере примерок и да се ограничи интерполацијата на концентрациите. Процената на концентрациите беше реализирана со користење на обичен кригинг. За пребарување беа избрани елипсоидните димензии и ориентации за да го одразат континуитетот откриен со геостатистичките проучувања и беа оптимизирани со користење на квантитативна кригинг-анализа на блиски вредности. Моделите на жичната рамка беа користени рутински за избор и составување примероци и последователно за ограничување на процената на концентрациите. При пресметувањето на блок-вредностите врз еквивалент на долар, цените на

металите што се користат се обезбедени од менаџментот на Еуромакс и се генерирани врз основа на анализа на капацитетот на индустријата, глобалната потрошувачка на стоки и трендовите на економски раст. Применета е шема за класификација на минералните суровини во согласност со упатствата на JORC (2012). Проценитe се категоризирани во категориите *измерени, индицирани и заклучени* минерални суровини, одредени над граничната концентрација што ја дефинира минералната суровина како потенцијално експлоатабилна со методите на ископување од површински коп. Графикот за чувствителност на концентрацијата на минералната суровина/тонажата е создаден врз основа на граничната содржина на еквивалент долар за рудни блокови во рамките на копот.