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The Ore Deposit 3D Modelling, New Effective Solution in the Optimization of Geological and Mining Works

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Abstract: Despite its small area, Albania is rich in mineral deposits. One of these is Kçira's copper ore deposit located about 12 km west of Puka. The core tools for developing and mining in local or regional-scale 3D common earth models for the purpose of targeting new ore or specific geologic relationships are now here. It is now incumbent on the industry, with its wealth of knowledge of specific ore forming processes, its rich archive of 3D data sets, and with a definite need to find deeper ore, to capitalize on this new technology to achieve its expected goals, enhancing the mineral targeting process and ultimately increasing mineral wealth. The emerging geo-modelling softwares for automating the model construction process, are leaving the experts free time to interpret and test exploration criteria. Due to the rapid technological change it is easier to process data and create a 3D model of the mineral body, update in real time, also increasing the accuracy of calculating the quantity of metals in the mineral resource. This article treats the 3D modelling of the copper ore using the Maping and General mining software. This method of modelling ore bodies reduces the time and cost for research and exploitation by facilitating the work of geologists, institutions and companies on their respective functions. Geological modelling is a complex sub-discipline of geology which integrates structural geology, sedimentology, paleo climatology, metallogeny, diagenesis etc. The model that we obtain for this mineral deposit (based on implicit and explicit methods) is important because it allows us to calculate and represent accurately the amount of copper metal, in-citu and mining resources.

Keywords: 3D Modelling, Copper, Exploration, Implicit, Puka

1. Introduction

A geological 3D modeling is a spatial representation of the distribution of sediments, rocks and metals in a portion the earth's crust based on geophysical and geological data available. The model was traditionally presented by 2D cross-sections, but with today technology capability is displayed as a very sophisticated and dynamic 3D virtual model. Depending on the requirements of a project a wide range of commercially available digital tools for the purposes of geological 3D-modelling exist, which can differ extremely concerning costs, performance and user-friendliness etc. In recent years in response to growing demand for minerals and the difficulties of finding new deposits, innovative technologies have been developed to help geologists for exploration, among them mention new technique as *implicit method*.

But considerable uncertainties are associated with the model set-up and parameterization, and all hydrothermal flow models, including the geological model, should therefore be validated carefully from experienced geologists and using specific application.

The mineral potential of a region selected from an exploration company is assessed based on the geological evaluation and modelling of data collected. This process consists of several successive phases and the implementation of each phase depends on the positive results obtained before. Mineral deposits exploration aim is finding a mineral resource and the process involves a consideration money and time expenses. Before we conduct any work for a mineral we must know very well the geological aspect of the region under study, based on the data we have for it, collecting new data (mainly by drilling and surface structural geology) and a deep knowledge of several inter disciplinary factors.

These large investments ask geologists to make predictions for unknown mineral deposits beneath the surface of the earth. Exploration and mining of mineral deposits is probably one of the most risky financial enterprises based on the complexity of nature and the fact that the mineral resource are becoming quite sparsely.

Despite the fact that a region can have the geological premises for mineral potential, its value cannot be determined until the evidence is obtained and treated rigorously that enables the evaluation of the mineral content in 3 dimensions.

This paper is a modest contribution on evaluation the geological data for the Kçira ore mineralization by creating a 3 dimensional model on copper metal by the Mapping software and General mining programs using traditional explicit method and most advanced the implicit inter - extrapolation method.

2. Short Description of the Geology of the Area

The studied area is located about 12 km to the west of the town of Puka, in Albania. Kçira ore deposit region overlaps two topographic maps 1:25 000 with the nomenclature K-34-064-D-c and K-34-076-B-a, (Figure 1).

The mining area has hilly morphological characteristics with, an average height at about 620m, ranging between, 390m and 704.2m, at Maja Lepurit (Figure 1, 4).

The hydrographic network is represented by a main stream, the Gomsiqe river, which crosses the area from east to west and the Gomsiqe e vogel creek from north to south.

2.1. Hydrological Conditions

Based on hydro geological studies the Kçira ore deposit can be divided into two parts, where the eastern part has a dense water grid, while in the western part water has negligible values or is absent.

The existence of numerous cracks on the rock formation cause the groundwater to be present uniformly throughout the eastern side at a dip of 50-60 m from the surface.

The groundwater originates only from atmospheric precipitation directly from the soil surface. Taking into account the hypsometric position of the ore deposit, as well as the geological background with small cracks which are feed only from atmospheric precipitation, it is concluded that hydrological conditions of the mining area are simple.

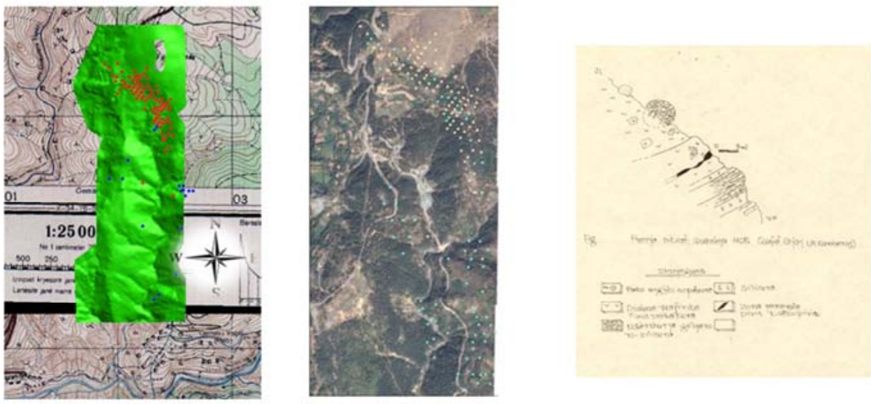


Figure 1. *Topographic map and location of dholes completed; right a typical outcrop.*

The region is characterized by a mountain continental climate with cool summers and harsh winters. Minimal temperature is -15°C and maximal is 32°C.

The region of Kçira has a complicated geological construction conditioned by the diversity of rocks and the development of powerful thrust tectonics. It is located on the front of Mirdita tectonic zone (Figure 2). The Kçira ore mineralization is located in the Kçira's gabbro massive, consisting mainly of altered normal leukokrate and a length of 40 km.

2.2. Main Rock Types

a) Gabbro - is the most widespread rock type in the region represented by leukokrate. These kinds of gabbro are encountered throughout the cross section of the Kçira's massif.
b) Gabbro diabases -which are constantly encountered in the area, are a structural variety of normal gabbro mentioned above. They are characterized by the gabbro ophiolite composition.
c) Gabbronorites -are found in loose form on the surface in the northern and southern part of the area. These are known alongside plagioclases and of pyroxene.
d) Olivine gabbros - are distinguished by the presence of olivine in addition to basic plagioclases and pyroxenes.

2.3. Mineral Composition of Ore Types

Regarding the mineral composition we distinguish these 3 types of ore mineralization:

1. The copper chlorine-sulphide type, is found at the northern part and is represented by ore veins in 10-140m stretch. From the microscopic study of this type the following metallic mineral composition are present:
   (1) chalcopyrite 15.2%

(2) pyrite 0.11%,
(3) iron hydroxides up to 0.04%

2. The quartz sulphur type is located at the southern part. From the macroscopic description of the drilling samples the main metallic minerals are: chalcopyrite, azurite, iron hydroxides.
3. The simple type of copper sulphide is represented by veins that fill the cracks of almost fresh gabbros. It has a mineral composition of chalcopyrite, pyrite and iron hydroxides.

2.4. Tectonics of Study Area

The area characterized by local and regional tectonic faults. The Kçira region is part of the tectonic zone of Mirdita (Figure 2, 3).

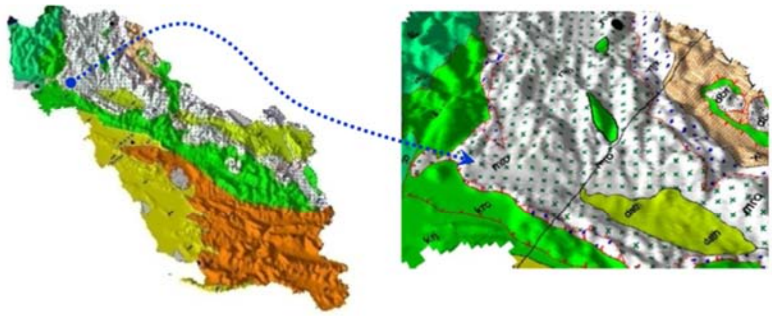


Figure 2. *3D display the Albanian tectonic zones (left) and on the right location of Kçira ore deposit on the Mirdita's ophiolitic zone (R. Kamberaj 2005).*

3. Methodology

Three are main steps to build a 3D model:

a) First step is preprocessing and preparation of basic data, Here are included collecting data as: drilling results, historical cross section, existing different maps, geophysical data, properties of rocks and other followed by data controlling, validation, homogenization and transform to a importable data format.
b) Second step is build up the geological 3D model using special software which prerequisites import data and further data controlling, 3D surface model and 3D body model.
c) Third step is further utilization of geological 3D model; export, build specific model (e.g. different Cu cut off grade), export model.

The methodology used is a combination of two programs, Maping software and General mining program (both methods; explicit and implicit), using data from the drilling completed in the area (S. Gjoni, A. Tershana, R. Kamberaj *"Mbi rezultatet e punimeve gjeologjike te kerkim zbulimit ne vendburimit Kcire dhe llogarijta e rezervave. Puke, 1981"* and all the other geological information for this region.

These programs were used for the different purposes during prospecting, exploration and mining process. At first stage of exploration the mapping software program were used for the digitalization the geological map (scale 1: 2000) of Kçira ore deposit with all its respective layers such as topography, hydrographic, etc. These layers were exported in the general mining program by reconciling any discrepancy. General mining software were used to generate copper block model (5x 5m) based on explicit method and also generating all possible and practical domains on mineralization based on implicit method. Implicit method, as much quicker method, helped to focus more on options of modelling, generating enough 3D model copper cut off contents as 0.2, 0.3, 0.5, 0.7, 1, 2, 3% Cu (Figure 7).

General mining software was used to generate the 3D model based on four main tables (Collar, Survey, Litology, Assay). The data used on these tables were taken from the data of the 88 drillings carried out in the area [S. Gjoni etc, 1988]. The above mentioned tables are:

Table 1. *Collar.*

Dhole	North	East	Rl	Total depth (m)
1	yy53310.850	xx02031.430	619.48	105.2
4	yy53221.150	xx02121.500	627.62	103.6
6	yy52950.360	xx02311.760	620.24	100.3

Collar table represents for each drill hole, east, west and rl coordinates (Pulkovo 1942, GK, Z4) and total depth in m.

Table 2. *Assay.*

Dhole	Sample	From	To	Rp(m)	Cu(%)	Co(%)	S(%)	Zn(%)
1	2592	81.4	88.2	0.80	0.11	0.02		_
1	2598	38.5	39	0.50	0.22	0.006		_
1	2525	12.1	13.1	1.00	1.61	0.0025	104	_

The assay table presents the results (in%) of the analysis of elements such as Cu, S, Co, Zn, etc for each sample taken successively on each drill hole.

Table 3. *Lithology.*

Dhole	From	To	Code	recover m	Chlorite	Chalcopyrite	Pyrite
1	0	1	DEV	1			
1	1	11	GAB	10			S
1	11	14	ZON	3.4	K		

Litho table represents for each interval main litho code and respective weathering logged by field geologists.

Table 4. *Survey.*

Dhole	East	North	Rl	Sdepth	Azimuth(°)	Dip angle(°)
1	xx53310.850	yy02031.430	619.48	105.2	35	-80
4	xx53221.150	yy02121.500	627.62	103.6	35	-80
6	xx52950.360	yy02311.760	620.24	100.3	35	-80

Each drill hole is surveyed for inclination measuring azimuth and dip angle.

Drilling azimuth is 215° degree south west (aiming to cross-intersect mineral zone) and the dip from -70 to -90° (most drill holes are completed at angle -80°). Drilling process has intersected all thickness of the mineralized zone. The average depth of drilling has been 100-140m.

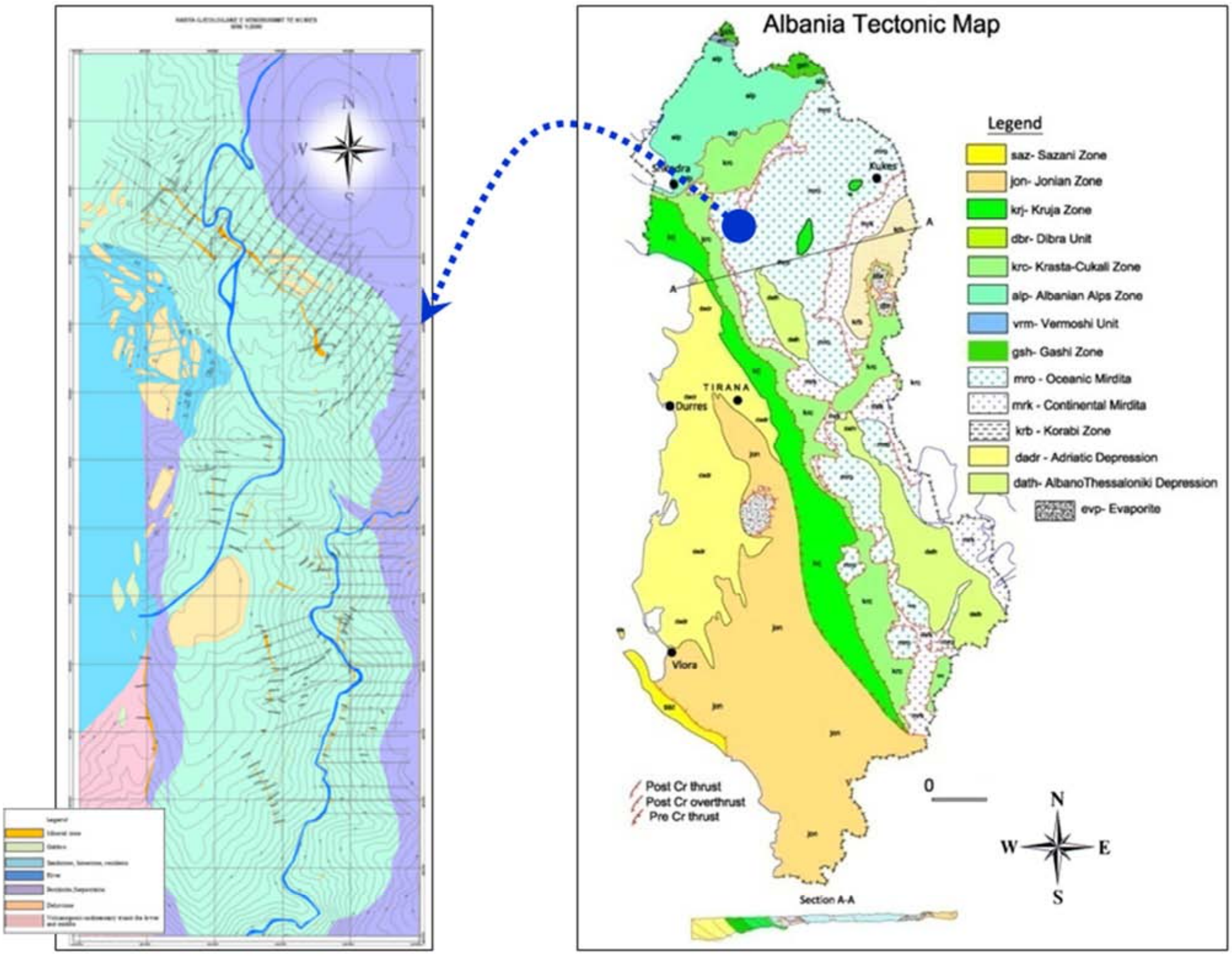


Figure 3. *Geological map, scale 1:2000 on the left and 2D display of tectonic zones of Albania (R. Kamberaj 2005).*

After building each table, evaluating and cleaning free for any error and discrepancy all tables are combined in one single unique data base for the 3D modelling in General mining program.

4. Results

Following graphics show the drill holes completed on the Kçira deposit, giving a clear idea of the number of drillings, their RL and density.

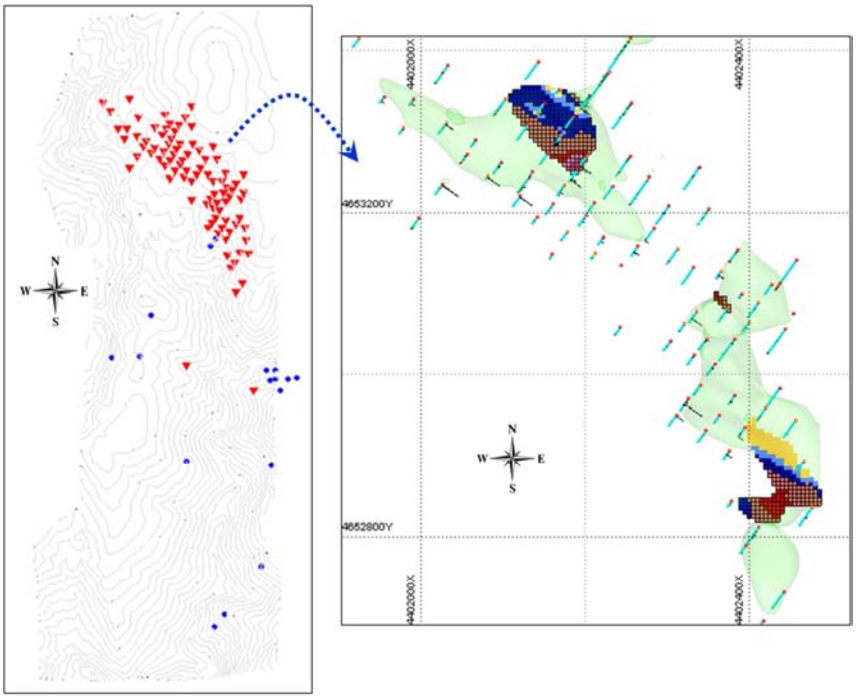


Figure 4. *Drill hole (left) completed at Kçira copper deposits, drill holes on blue colour are completed after 1988 (N. Pjetri, 2011), they are not included on database and on the right 0.1% Cu domain and copper blocks.*

Figure 5 shows the 3D model of the copper ore body (0.1% Cu implicit model on red colour) seen from below. It also shows the drillings log represented by litho codes. Historical cross section 9-9 is shown on blue.

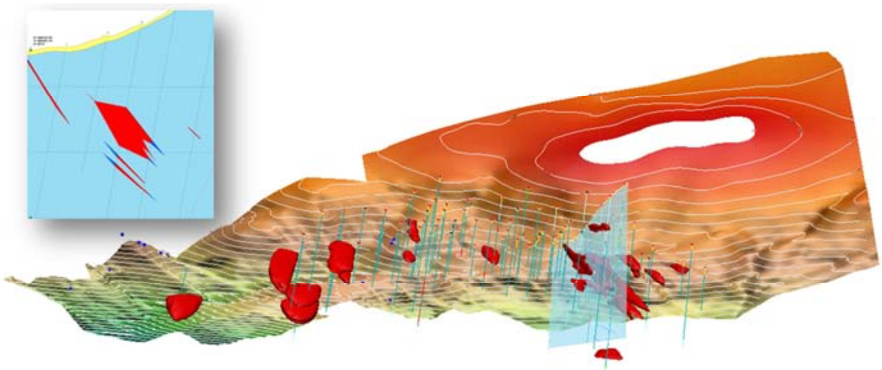


Figure 5. *Implicit Cu 0.1% model seen from below and a historical cross section superposed on the 3D ore body model.*

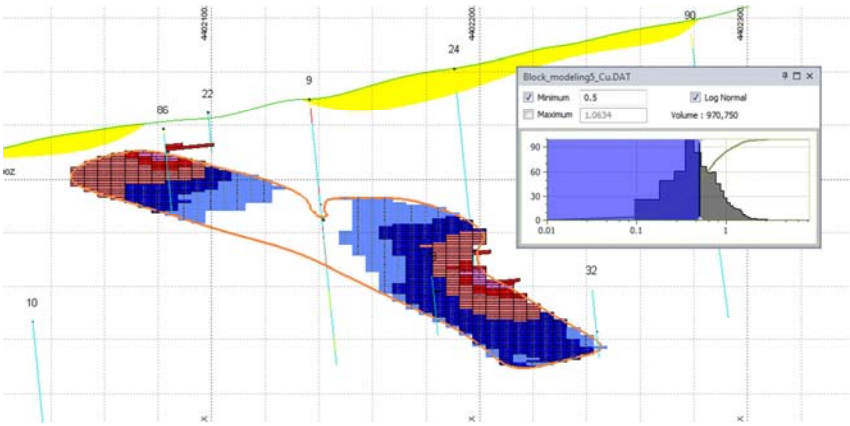
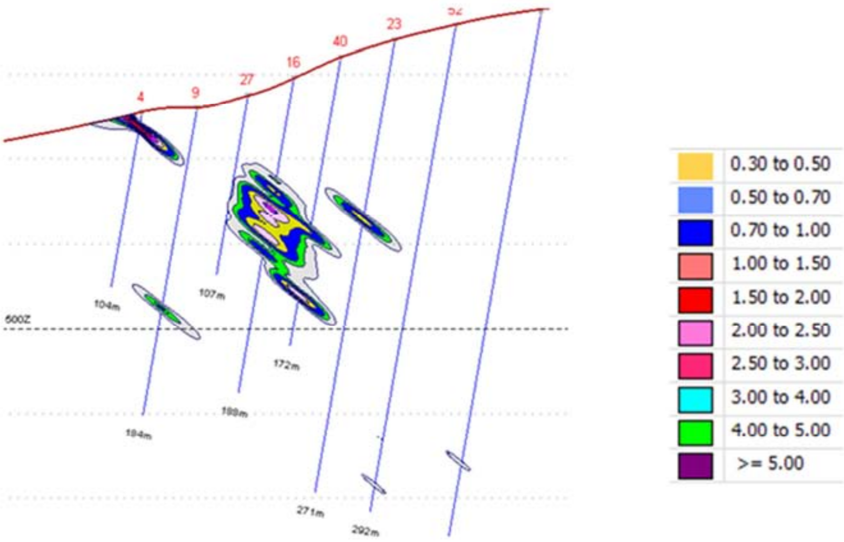
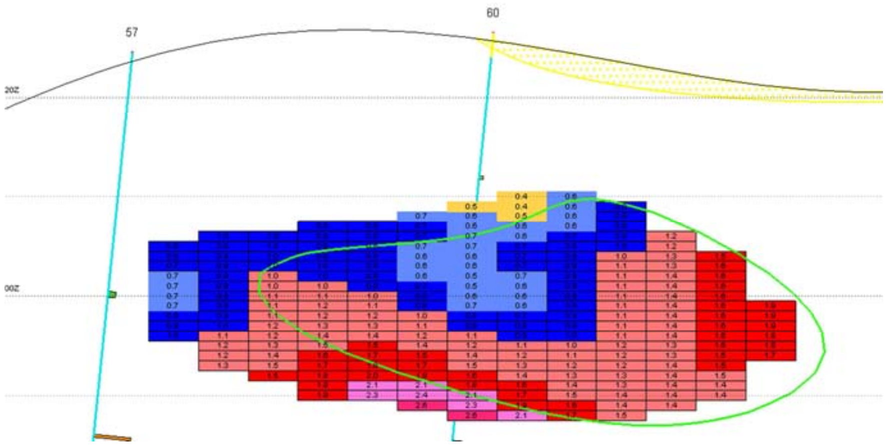


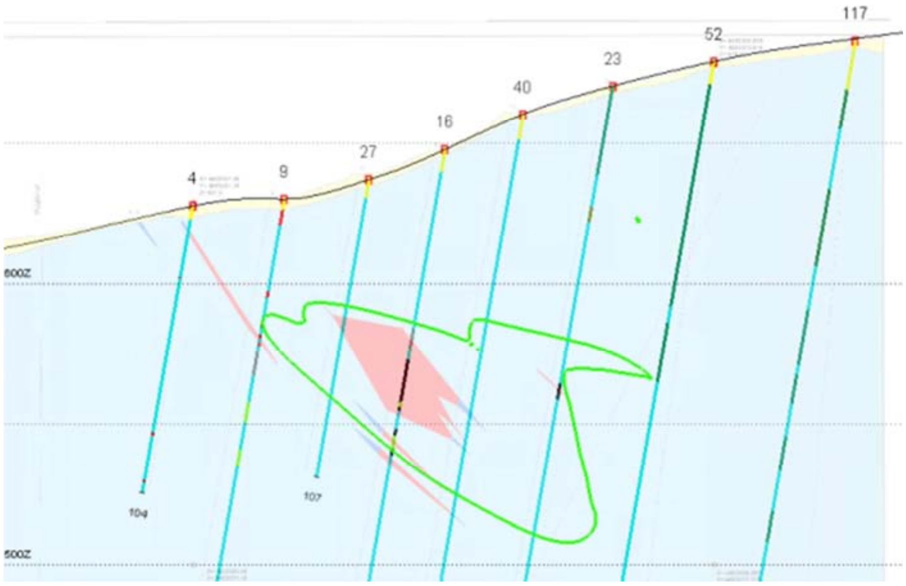
Figure 6. *Cross section (at 215^0) ore body blocks with different copper grade inside implicit domain 0.1% Cu.*


4
9
27
16
40
23
52
104m
107m
172m
188m
184m
271m
292m
600Z
0.30 to 0.50
0.50 to 0.70
0.70 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
2.50 to 3.00
3.00 to 4.00
4.00 to 5.00
>= 5.00

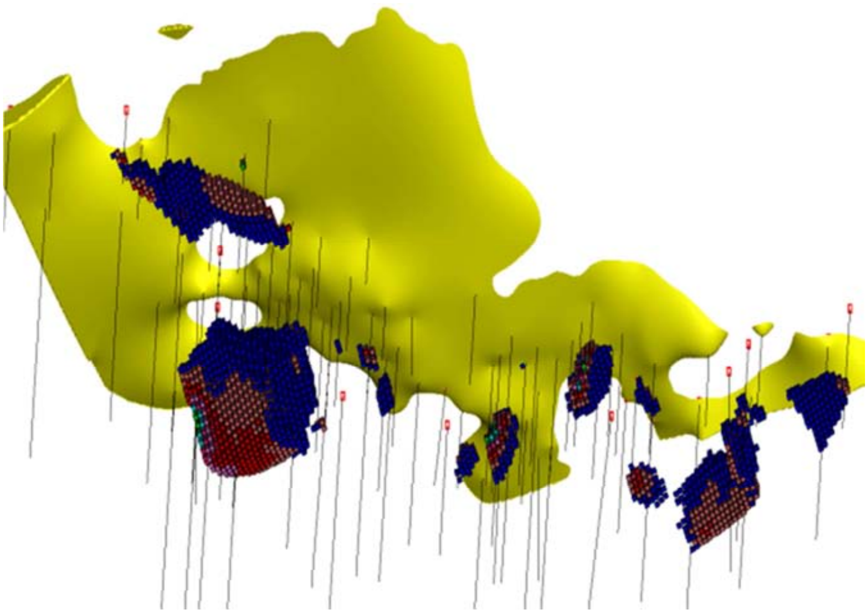
(a)


57
60

(b)


117
52
23
40
16
27
9
4
104
107
600Z
500Z

(c)



(d)

Figure 7. *a) All Cu grades (implicit model) in cross section, b) Compare implicit (green line) and explicit model cross section, c) Cross section, compare implicit method and historical interpretation of ore model, d) 3D display Cu block model (explicit) under diluvium model (implicit).*

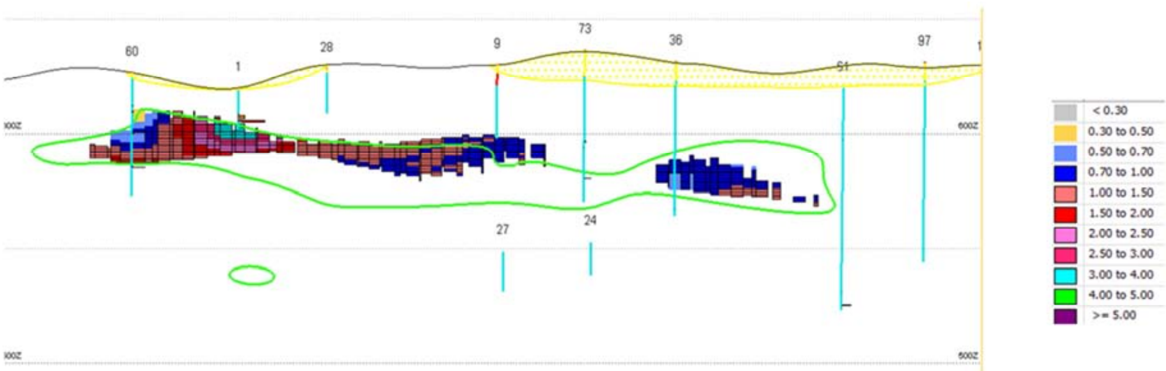
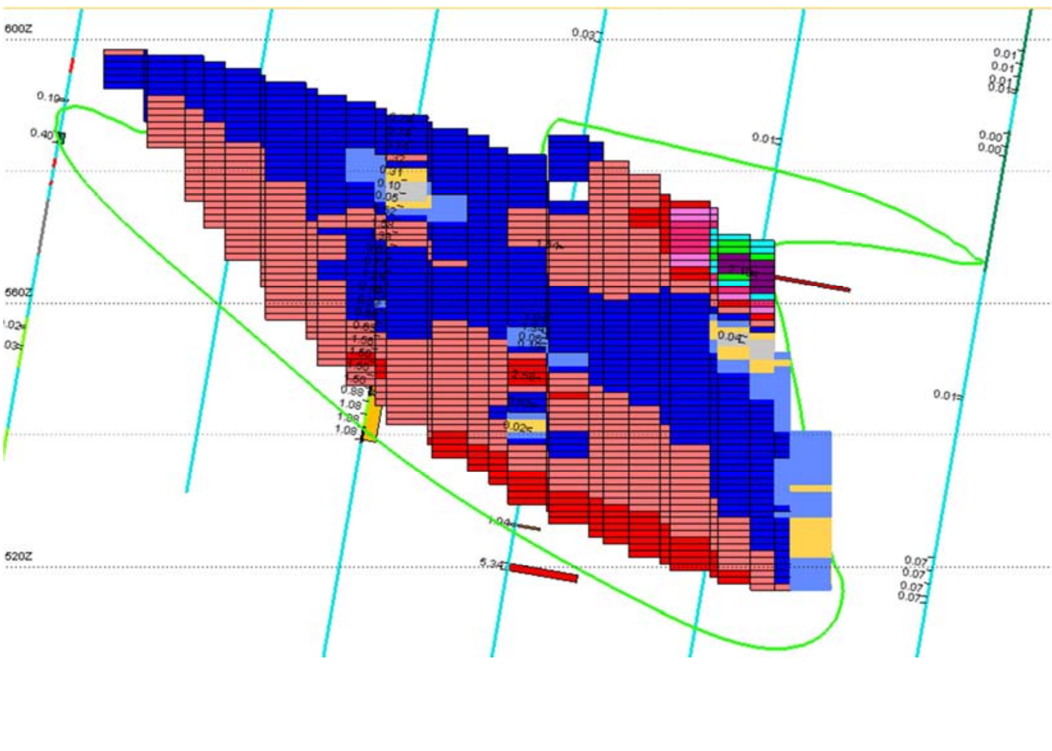


Figure 8. *Longitudinal section, Cu domain generated by implicit method section (green line) and explicit Cu block model.*



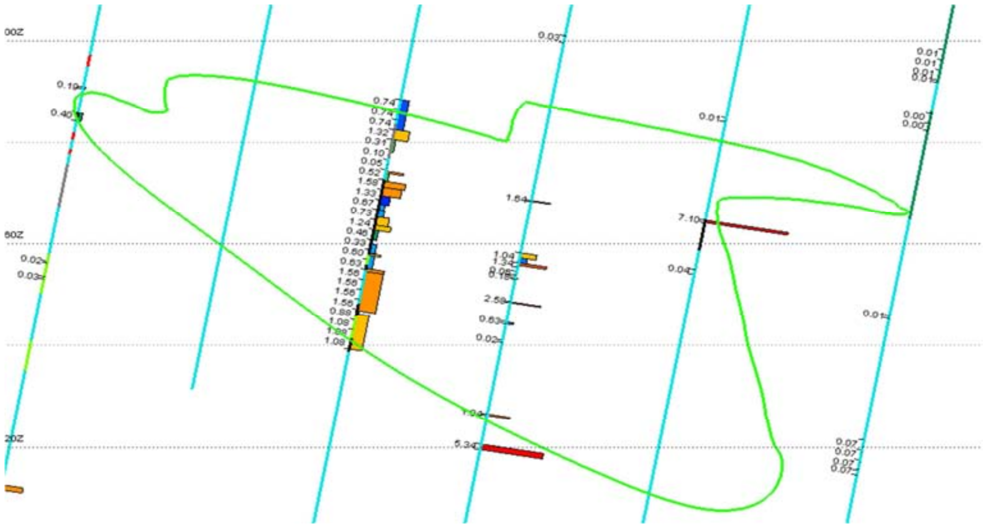


Figure 9. *Drilling results from assay table, Cu block model (explicit method), and the mineral domain generated by implicit method (green contour) superposed on a cross section.*

5. Conclusions

Mineral exploration is evolving into a more rigorous quantitative science. The ore deposit 3D modelling provides support for this activity through an environment in which a rich and diverse set of exploration-related observations can be analyzed and interpreted.

The Kçira copper ore deposit is located in the gabbros massif of Kçira, Puke, which is located east of the ultrabasic rocks and west of volcanogenic-sedimentary. The gabbroic massif of Kçira has a prolonged irregular shape and tectonic borders with the surrounding rocks. The petrographic composition of this gabbro massif is mainly leukokrates gabbros and to a lesser extent gabbroic diabases, gabbronorites etc.

The study of the geological model shows that copper content of 0.7-1% prevails. Model has generated all practical domains of Cu grades. Kçira region shows interest for further research of mineralization, in gabbroic rocks, ultrabasic, and in volcanogenic sedimentary rocks of T_{1-2} (Early-Middle Triassic). Exploration for copper mineralization should continue mainly in areas where gabbroic rocks are present. Exploration for new sulphur mineralization should focus on shear zones, tectonic cracks with a near longitudinal main direction along gabbroic rocks themselves, peridotite gabbros contacts and especially in areas of development of sulphide mineralization, quartz-sulphide and quartz. Combining both method of inter and extrapolation for building 3D ore model has improved understanding and minimising error on geological interpretation. Some of advantages of using implicit method of ore and geological 3D modelling are:

Implicit models are easy to keep up-to-date with the latest data. Implicit method can be evaluated anywhere in 3D space, on surface and off surface of the object and is independent of the locations of experimental data. The raw interpolation of assay data yields important grade. Drawing can be done using control points and poyline contours or any contact points that are extracted from drill hole database. Implicit modelling allows several alternative hypothetical models to be produced from the data, quickly and easily, which means that a range of geological interpretations can be continually tested.

Inter and extrapolation are inherent and consequently can be applied to the incomplete meshes to fill holes and closing objects. Because less effort is involved in creating a model, more time is available to spend on understanding the geology and studying more complex details such as faulting, stratigraphic sequences, trends and veins. The wire frame generated are smoothed and can be created at any desire resolution therefore very useful for geological modeling.

The implicit method allows more reliable geological interpretation and millions of points can be processed in matter of seconds, 3D models are saved as continuous factions therefore can be generated at any desired resolution. Geological risk is reduced when modelling is done implicitly and it is easy to change your mind when modelling implicitly.

References

[1] Apel M (2006): From 3D geomodelling systems towards 3D geoscience information systems: Data model, query functionality, and data management. – Computers & Geosciences 32(2): 222–229.

[2] Artimo A, Makinen J, Berg RC, Abert CC, Salonen VP (2003): Three-dimensional geologic modeling and visualization of the Virttaankangas aquifer, southwestern Finland. – Hydrogeology Journal 11(3): 378–386.

[3] Barnett PJ, Sharpe DR, Russell HAJ, Brennand TA, Gorrell G, Kenny F, Pugin A (1998): On the origin of the Oak Ridges Moraine. – Canadian Journal of Earth Sciences 35(10): 1152–1167.

[4] Bowler, J., 2002, Ministerial inquiry into Greenf elds Exploration in Western Australia: Western Australia Department of Industry and Resources, 146 p.

[5] Calcagno, P., Chilès, J., Courrioux, G., Guillen, A., 2008. Geological modeling from field data and geological knowledge: Part I. Modeling method coupling 3D potential-field interpolation and geological rules.

[6] Chambers H, Brown AL (2003): 3-D visualization continues to advance integrated interpretation environment. – First Break, May 2003, http://www.lgc.com/resources/technicalreview04/ 3dvisualizationcontinues.pdf.

[7] Chilès, J. P., Aug, C., Guillen, A., and Lees, T., 2004, Modelling the geometry of geological units and its uncertainty in 3D from structural data: The potential f eld method: Australasian Institute of Mining and Metallurgy, Orebody Modelling and Strategic Mine Planning [abs.]: Uncertainty and Risk Management, Perth, WA, November 22–24, 2004, Proceedings, p. 313–320.

[8] Codd, E. F. A relational model of data for large shared data banks, Comm. ACM 9 (1970), No. 9, pp 377-387.

[9] De Kemp, E. A., 2006, 3-D Interpretive Mapping: An Extension of GIS Tech-nologies for the Geoscientist: Harris, J. R. ed., GIS for the Earth Sci-ences, Geological Association of Canada Special Publication, v. 44, p. 591–612.

[10] Fallara, F., Legault, M., Rabeau, O., 2006.3-D integrated geological modelling in the Abitibi sub province (Québec, Canada): techniques and applications Exploration and Mining Geology, 15 (2) (2006).

[11] Goleby, B. R., Korsch, R. J., Fomin, T., Bell, B., Nicoll, M. G., Drummond, B. J., and Owen, A. J., 2002, Preliminary 3-D geological model of the Kalgoorlie region, Yilgarn Craton, Western Australia, based on deep seismic-ref ection and potential-f eld data: Australian Journal of Earth Sciences, v. 49(6), p. 917–933.

[12] Gjoni, S., Tershana, A., 1988. Geological Report with the reserves calculation of copper deposit in the region of Kçira.

[13] Henriksen HJ, Troldborg L, Nyegaard P, Sonnenborg TO, Refsgaard JC, Madsen B (2003): Methodology for construction, calibration and validation of a national hydrological model for Denmark. – Journal of Hydrology 280(1–4): 52–71.

[14] Hojberg AL, Refsgaard JC (2005): Model uncertainty – parameter uncertainty versus conceptual models. – Water Science and Technology 52(6): 177–186.

[15] Houlding. S. W., 1994 3D Geoscience Modeling-computer Techniques for Geological Characterization Springer–Verlag, Berlin, Germany (1994).

[16] James, P. Reed. Volumetric Analysis & Three-Dimensional Visualization of Industrial Mineral Deposits

[17] Jeffery, K. G. & Gill, E. M. The design philosophy of the G-EXEC system'. Computers and Geosciences 2 (1976) No.3, pp 347-349.

[18] Journel, A. G., and Kyriakidis, P. C., 2004, Evaluation of mineral reservers: A simulation approach: London, Oxford University Press, 216 p.

[19] Kassenaar D, Holysh S, Gerber R (2003): An integrated 3D Hydrostratigraphic Interpretation Methodology for Complex Aquifer Systems. – In: Poeter, Zheng, Hill and Doherty (eds.): Proceedings, MODFLOW and More, understanding through modelling, Colorado School of Mines, Golden CO, September 16–19, 2003, p. 661–665.

[20] Mallet, J. L., 2002, Geomodeling, Oxford University Press, 599 p.

[21] Pjetri, N. 2011. Relacion mbi punime gjeologjike te kryera ne Kçire, (material i pa botuar), Nd, Gjeologjike Puke

[22] Rasmussen ES (2004b): Stratigraphy and depositional evolution of the uppermost Oligocene – Miocene succession in Denmark. – Geological Society of Denmark, Bulletin 51: 89–109.

[23] Refsgaard JC,Henriksen HJ (2004): Modelling guidelines – terminology and guiding principles. – Advances in Water Resources 27(1): 71–82.

[24] Shepard, D., 1968. A two-dimensional interpolation function for irregularly spaced data. In: Proceedings of the 23rd National Conference ACM, New York, NY, pp. 517-523

[25] Sprague, K., Kemp, E., Wong, W., McGaughey, J., Perron, G., Barrie, T., 2006. Spatial targeting using queries in a 3-D GIS environment with application to mineral exploration, Computers and Geosciences, 32 (3) (2006).

[26] Wang, G., Chen, J., Du, Y., 2007. Three-dimensional localization prediction of deposit and mineralization environment quantitative assessment: a case study of porphyry copper deposits in Sanjiang region, China. In: Proceedings of IAMG, 07 Geomathematics and GIS Analysis of Resources, Environment and Hazards, Beijing, China, pp. 102-105.

[27] Woodall, R., and Duncan, I. J., 1993, The third dimension: A geoscience challenge for the 21st century: Australian Institute of Mining and Metallurgy, Parkville, Victoria, Australia (AUS), 39–40 p.

[28] Zanchi, A., Francescac, S., Stefano, Z., Simone,S., Graziano. G., 2009. 3D reconstruction of complex geological bodies: examples from the Alps, Computers and Geosciences, 35 (2009).