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BASIC PRINCIPLES OF DEVELOPMENT AND USE A DIGITAL GEOMODEL FOR DESIGN THE OPEN PIT IN THE EXAMPLE OF QUARTZ AND SANDY CLAY DEPOSIT "BOŠNJANE" - SERBIA

Abstract

Based on the results of geological explorations carried out in the area of quartz sand and sandy clay deposit Bošnjane, a geomodel was developed using a software package Minex 5.2.3. geomodel, which was the basis for the calculation of reserves and design of the open pit in the deposit of quartz sand and sandy clay, in the specified software package.
Keywords: *geomodel, Minex 5.2.3, optimization, mine design*

INTRODUCTION

Calculation of reserves by MINEX 5.2.3 software package, starts with making three-dimensional geomodel. Interpretation of deposit and development the three-dimensional geomodel is caused by the entry of data from several files (Excel) on exploration drill holes.

Based on data obtained from exploratory works, database is formed that consists of four files: *Collars cls. Fail; Quality cls.;Lithology cls. Fail;Seam prn. Fail.*

Data from drill holes are entered into database entries in a properly way in a form of defined intervals, with the field in addition to the others *"from"* and *"to"*, i.e. defined intervals, in which the samples are analyzed.

Data from the exploratory drill holes are properly processed in the software Minex by mathematical and geostatistical methods (method of inverse distances of various degree), to determine the lawfulness of content in deposit.

Calculation of reserves is done by any method of polygons.

Block model can be refreshed in terms of entering the new data.

GEOLOGICAL STRUCTURE AND DESCRIPTION OF DEPOSIT

The deposit of quartz sand and sandy clay "Bošnjane" is situated, by sky way, about 7 km northeast of Paraćin and about 5 km south of the village of Popovac and Cement Factory "Holcim", in the village of Bošnjane.

A wider area of the deposit Bošnjane covers the eastern part of the leaf Paraćin with the signature L34-07 and the western part of the leaf Boljevac, with the signature L34-08, OGK, 1:100 000 [2].

Geological structure of the quartz sand and sandy clay deposit "Bošnjane" includes

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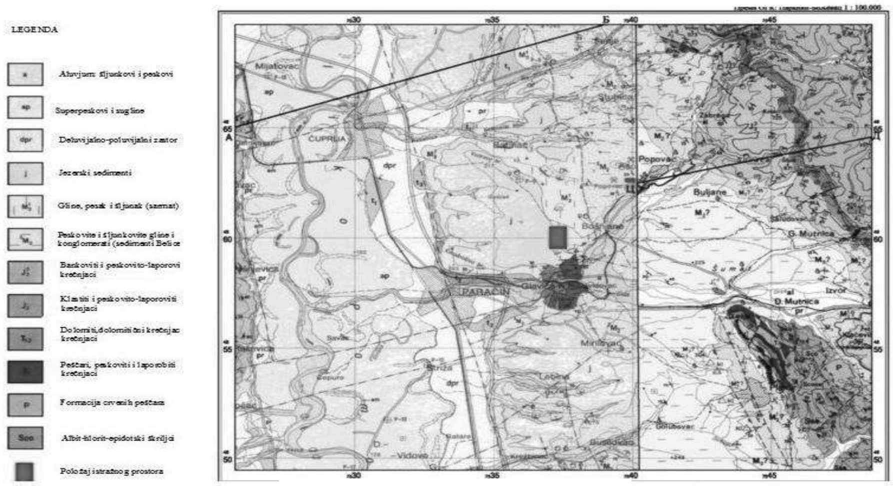
the freshwater sediments of the Middle Miocene and Miocene-Pliocene. In the Middle Miocene, during Helvet, on older Miocene and often pretertial formations, the clastic sediments were deposited discordantly as well as the sediments of lake facies as the result of older Styrian phase (Figure 1).

In these freshwater sediments, according to the lithological composition, the following can be separated: Middle Miocene facies of red clay sandstones, clay marls and tuffs, then Middle Miocene of marls, and Miocene-Pliocene facies of freshwater limestones, marls, clays, sand and gravel.

GEOLOGICAL MAP
OF THE SURROUNDING AREA OF THE QUARTZ SAND AND SANDY CLAY DEPOSIT - BOSNJANJE - POPOVAC NEAR PARACIN
1:100 000



GEOLOGICAL PROFILE C-D
1:50 000

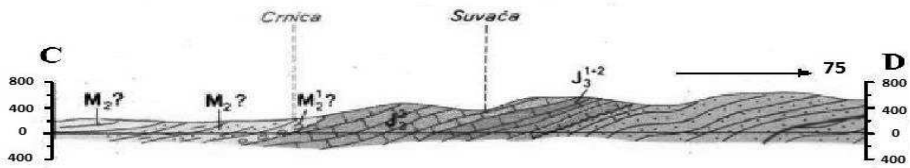


Figure 1 *Geological structure of surrounding area Bošnjane-Popovac near Paraćin*

The layers of clay and sand are horizontal to slightly inclined towards the SW. Previous explorations cover a portion of sandstone series, where it was determined that the roof of series consists of sandy clay that by the quality satisfies their use in the cement industry. The thickness of individual layers varies so there are unequal stratification. Overlying clays, due to this reason, are treated as the other useful resources. The average thickness of the overlying clay layer is about 10 m.

In the eastern and northeastern, also partly in the central part of clay deposit it has low thickness of up to 1 m, or a layer of clay is completely wedged, while in the western part of the deposit, the thickness of clay layer reaches 35 m. It has been concluded by previous explorations that, under a layer of clay, there is a series, built of: sands, sandy clays, clayey sand and gravels, gray and brown clays. In a series of sand itself, thin lentoid interlayers of sandy clay and very clayey sands appear. The thickness of these interlayers is from 10 cm to 50 cm. Thickness of contoured productive series of sands, which satisfies in terms of quality the requirements of its application in the cement industry, is about 18 m. Below this series, most often, there is a series of very clayey sands, or more rarely, sandy clay. Below this series, a series of basal Miocene sediments lies. The floor of this series consists of basal sediments of the Miocene series, built of red sandy clay, basal conglomerate and red sandstone. The lowest layers of this series lie over titonic limestone [2].

The deposit of quartz sand and sandy clay Bošnjane is of layered-lentoid form. Direction of expanding the deposit is NNW-SSE. It is seenaccording to ther direction of deposit expanding that it is approximately 600 m, and 300 m wide (direction E-W).

EXPLORATORY WORKS

Explorations in the area of the deposit Bošnjane, in order to ensure the quality reserves of quartz sand and sandy clay for use in the cement industry, were conducted into two separate time periods, i.e. from 1963 to 1965, and 2010. On the deposit of quartz sand and sandy clay Bošnjane, eight exploratory wells were drilled and total of 24 drill holes,i.e. in total 2,406 m of drilling. During the exploration of quartz sand and sandy clay deposit Bošnjane, the same methodology was more and less applied: the deposit was explored by vertical sections. The deposit of quartz sand and sandy clay Bošnjane was explored making 8 exploration wells and exploratory drilling from the surface (24 vertical drill holes). Common geological works followed (specifically included) the exploration drilling such as they were preceded by the project, performed at the same time (geological monitoring and directing of exploratory drilling, mapping and sampling) and resumed after them (making reports and studies) [2].

Geological works

Geological works in exploration the quartz sand and sandy clay deposit Bošnjane, related mainly to the surface geological mapping, monitoring, routing and geological mapping of exploratory wells and exploratory drill holes, their sampling and interpretation of the obtained results, and preparation of geological maps and development of cross-sections (profile) of deposit, countouring of deposit, calculation the reserves of mineral raw materials, etc. Geological work could include also the design of all exploratory works, preparation of reports and studies, and synthesis of data from which were made the geological profiles (sections) and geological maps. Samples were taken from exploratory drill holes, which were analyzed in the laboratories: Holcim Ltd. Popovac (chemical testing, technological testing), Mining and Metallurgy Institute Bor (geomechanical testing). Hydrogeological testing was carried out by the Geological Institute of Belgrade.

Exploratory wells

In the area of the deposit of quartz sand and sandy clay Bošnjane, eight wells, depth up to 20 m, were done. Two wells on the east, in the lowest part of the field were used for determining the hydrogeological characteristics of the field, while 6 wells (BI, B-II, B-III, B-IV, B-V and B-VI), in a square network of 100 × 100 m, ewere used for exploration the site in depth. Total length of wells is 123.4 m. Wells were discovered quartz sands of satisfactory quality, with SiO_2 content higher than 68%, which was the basic condition of its application in the cement industry.

Exploratory deep drilling

In the area of the depositof quartz sand and sandy clay Bošnjane, the exploratory drilling was done during 2010. Total of 24 drill holes were drilled with total drilling length of 862.6 m. Quartz sand of satisfactory quality for its use in the cement industry was drilled with 17 drill holes), while 7 were negative, so that the results of sampling these wells are excluded from calculations.

DEVELOPMENT OF GEOMODEL AND DESIGN OF OPEN PITS WERE DONE BY THE SOFTWARE PACKAGE MINEX 5.2.3.

Calculation of reserves by MINEX 5.2.3 software package, starts with development a three-dimensional geomodel [9]. Interpretation of deposit and development of three-dimensional geomodel is caused by the entry of data from several files (Excel) on exploratory drill holes [2]. The files contain for each drill hole: the name of drill hole, data on elevation, coordinates, data on lithological members in geological columns of drill holes (which are relevant to the assessment of position of layers in separated geological environments), as well as data on the results of chemical analyses of individual samples SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, SO_3 and loss on ignition.

Before starting a development of 3D model of deposit of quartz sand and sandy clay Bošnjane, it was necessary to create a database from which to access the development of model. All necessary data were obtained in the exploration process (exploratory drill holes and wells), as well as performed laboratory analyses (spatial position of each exploratory work is represented by X, Y, Z coordinates, the final depth of each exploratory work, lithological members were determined in the process of mapping the core drilling and quality data obtained by laboratory analyses). The database is comprised of 4 basic files:

- Collars cls. Fail – contains all data on spatial position of drillh holes;
- Quality cls. Fail – contains all data related to the quality;
- Lithology cls. Fail – contains all data on lithology;
- Seam prn. Fail - contains all data about the position of layers of sandy clay and quartz sand in every exploratory work. [12]

Within the contour of deposit, two different lithological members are clearly separated: a layer of clay and a layer of quartz sand. Due to this reason, each of these layers is modeled as a separate layer, which has a separate code letter. For each drill hole, a description of isolated rock types, i.e. geological column of drill hole, is given and then data were entered on characteristics of each separateed lithological type, necessary for further processing the block model of the deposit. In addition to the above-mentioned data, data were also entered on the fiedl topography. Data on topography were obtained from the Investor (Holcim Serbia doo Popovac). Figure 2 presents a graphical three-dimensional display of entered data from the database of software package MINEX 5.2.3. [8]

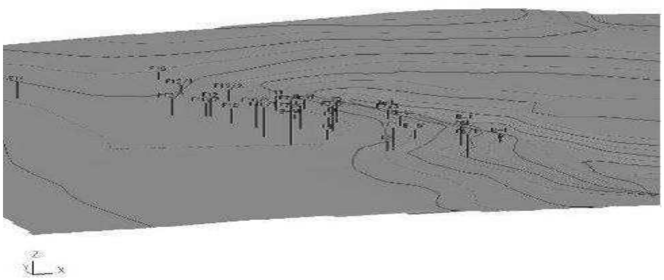


Figure 2 *3D view of topography and drill hole relationship (software package MINEX 5.2.3)*

All layers are modeled using the general method of modeling. In the process of interpolation of the missing data layers are used from minimum of 3 and a maximum of four neighboring drill holes, and radiusof exploration is limited to 250 m. While the weighting values used the general formula for weighting. After creating these layers, it was approached to their mutual spatial correlation and creating 3D models of deposit (Figure 3).

For each vertical section (profile) and horizontal section (floor), the reference surfaces and space were defined that, infront and back, covers a certain area. This type of interpretation eliminated the possibility of existence the "empty" spaces within the block model of deposit. The appearance of modeled layers by the software package MINEX 5.2.3 is shown in Figures 3 and 4. [11]

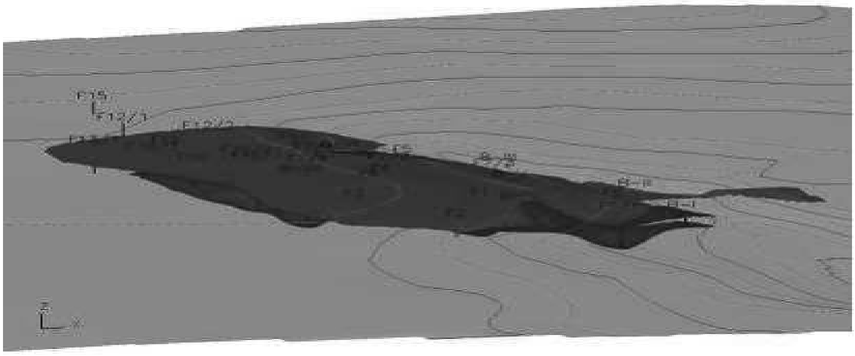


Figure 3 *3D view of layers with topography (software package MINEX 5.2.3)*

a) Gray shows topography; b)Red shows a layer of quartz sand (P1); c) Blue shows a layer of sandy clay (G).

Figure 4 *2D view a part of cross-section through the deposit of quartz sand and sandy clay Bošnjane (software package MINEX 5.2.3)*

a) Gray shows topography; b) Red shows a layer of quartz sand (P1); c) Blue shows a layer of sandy clay (G).

Any other data necessary for calculation of reserves, the program takes from the previously created database as well as created geological model of layers [7]. On such created model of the deposit it was possible to calculate the geological reserves both for each layer separately and deposit as a whole. [13]

SPATIAL LIMITATION OF OPEN PIT AND WASTE DUMP WITH GEOMETRY AND STABILITY ANALYSES

Construction of the open pit was done on the basis of certified balance reserves. Selection the optimal final pit contour was made using the licensed program Minex 5.2.3, which is used for optimization and analysis of open pits. [5] Optimization was done using the Pit Optimiser tool, which is based on the Lerches and Grossman algorithm, i.e.. procedure for determining the optimal open pit like the one with the highest value for the corresponding set of costs and factors of return. [6] The input parameters for optimization the deposit "Bošnjane" are:

1. Topography;
2. Geomodel of the deposit;
3. Volume mass of sand, clay and waste rosk;
4. Utilization of the excavation and preparation;
5. Unit value of a tone of sand and clay;
6. Medium and minimum SiO_2 content in the deposit;
7. Final slope angle of open pit;
8. Minimum final width of level plane;
9. Direct costs of mining the waste rock, sand and clay.

Angle of final pit slope is determined by the licensed software GEOSTUDIO 2007 or its tool Slope/W, which is specialized for methods of limit equilibrium. The default maximum open pit depth is determined based on the spatial position of sand and clay, as well as topography. The general angle of the final pit slope directly depends on the angle of slope of leveles and final width of level planes. It is assumed on the basis of the deposit geomodel that for a representative profile the ratio of clay and sand thickness is 1:1.5. [3]

According to these conditions, the assumed angle of the final pit slope is 24.3°. Minimum width of the final level plane enough for works on recultivation, is adopted at 4 m. Direct costs of mining the waste, sand and clay cover the costs of legislative normative material, human labor and current maintenance of all phases of work (mining, loading at the pit and dumps of sand and clay, transport, extra works at the opemn pit and dump, drainage) plus the costs of PPE equipment, NTO, administration and contingency costs. The results of optimization are shown in Figures 5 and 6.

Kop	Jalovina, t	Pesak, t	Glina, t	Iskopina, t	Kr	P/G	Vek rada	Jalovina, t/god	Pesak, t/god	Glina, t/god	Trošak, $	Dobit, $	NPV, $	Fp	DV, $
1	101 234	1 669 060	1 432 276	3 202 570	0.03	1.17	27.8	3 639	60 000	51 488	14 929 840	23 889 106	8 959 266	0.07056	632 156
2	101 506	1 698 708	1 433 281	3 233 495	0.03	1.19	28.3	3 585	60 000	50 625	15 076 926	24 171 159	9 094 233	0.06731	612 160
3	106 605	1 928 144	1 616 129	3 650 878	0.03	1.19	32.1	3 317	60 000	50 291	17 039 713	27 373 309	10 333 595	0.04675	483 134
4	110 279	2 091 034	1 788 937	3 990 250	0.03	1.17	34.9	3 164	60 000	51 332	18 633 835	29 897 053	11 263 218	0.03609	406 541
5	112 639	2 175 656	1 921 739	4 210 034	0.03	1.13	36.3	3 106	60 000	52 998	19 663 857	31 458 697	11 794 841	0.03155	372 181
6	113 895	2 239 338	2 023 966	4 377 199	0.03	1.11	37.3	3 052	60 000	54 229	20 448 244	32 647 227	12 198 983	0.02852	347 899
7	115 290	2 286 677	2 124 660	4 526 627	0.03	1.08	38.1	3 025	60 000	55 749	21 147 774	33 674 578	12 526 804	0.02645	331 369
8	115 970	2 328 106	2 209 098	4 653 174	0.03	1.05	38.8	2 989	60 000	56 933	21 741 314	34 552 213	12 810 900	0.02477	317 300
9	116 208	2 356 294	2 277 707	4 750 209	0.03	1.03	39.3	2 959	60 000	57 999	22 196 568	35 214 323	13 017 754	0.02368	308 305
10	116 437	2 386 328	2 328 084	4 830 849	0.02	1.03	39.8	2 928	60 000	58 536	22 575 603	35 787 465	13 211 862	0.02258	298 324
11	116 622	2 400 562	2 371 651	4 888 835	0.02	1.01	40.0	2 915	60 000	59 277	22 847 272	36 173 759	13 326 487	0.02208	294 185
12	116 779	2 412 022	2 407 887	4 936 688	0.02	1.00	40.2	2 905	60 000	59 897	23 071 424	36 491 523	13 420 099	0.02168	290 907
13	116 937	2 426 961	2 434 492	4 978 390	0.02	1.00	40.4	2 891	60 000	60 186	23 267 294	36 785 616	13 518 322	0.02117	286 164
14	117 067	2 435 000	2 468 174	5 020 241	0.02	0.99	40.6	2 885	60 000	60 817	23 463 117	37 056 637	13 593 520	0.02090	284 105
15	117 187	2 449 641	2 501 996	5 068 824	0.02	0.98	40.8	2 870	60 000	61 282	23 691 113	37 389 978	13 698 865	0.02042	279 725
16	117 293	2 459 135	2 544 273	5 120 701	0.02	0.97	41.0	2 862	60 000	62 077	23 933 903	37 724 603	13 790 700	0.02011	277 385
17	117 419	2 465 821	2 564 192	5 147 432	0.02	0.96	41.1	2 857	60 000	62 394	24 059 075	37 902 878	13 843 803	0.01990	275 511
18	117 549	2 468 537	2 591 316	5 177 402	0.02	0.95	41.1	2 857	60 000	62 984	24 198 885	38 086 124	13 887 239	0.01982	275 186
19	117 671	2 473 105	2 620 084	5 210 860	0.02	0.94	41.2	2 855	60 000	63 566	24 355 190	38 296 195	13 941 005	0.01967	274 254
20	117 745	2 475 508	2 652 137	5 245 390	0.02	0.93	41.3	2 854	60 000	64 281	24 516 336	38 505 226	13 988 890	0.01960	274 148
21	117 871	2 478 815	2 691 898	5 288 584	0.02	0.92	41.3	2 853	60 000	65 158	24 717 887	38 767 563	14 049 676	0.01949	273 896
22	117 959	2 479 794	2 726 014	5 323 767	0.02	0.91	41.3	2 854	60 000	65 957	24 881 888	38 975 340	14 093 452	0.01946	274 323
23	118 044	2 480 049	2 753 750	5 351 843	0.02	0.90	41.3	2 856	60 000	66 622	25 012 670	39 139 223	14 126 552	0.01946	274 856
24	118 044	2 480 467	2 753 750	5 352 261	0.02	0.90	41.3	2 855	60 000	66 610	25 014 668	39 143 117	14 128 449	0.01944	274 710
25	118 044	2 781 094	2 753 750	5 652 888	0.02	1.01	46.4	2 547	60 000	59 410	26 451 064	41 943 758	15 492 694	0.01206	186 858
OPT	116 528	2 213 236	2 172 835	4 502 599	0.03	1.02	36.9	3 159	60 000	58 905	21 024 894	33 270 925	12 246 031	0.02973	364 026

Figure 5 *Analytical presentation of optimizxation results*

The obtained contours which are the optimization result have no levels. As a guide for construction the open pit, which comprises the balance reserves, the contour 8 was selected, whose discounted value is at the end of the service period, which includes only the direct costs of excavation. This contour has 2,328,106 t of sand and 2,209,098 t of clay. The ratio of sand/clay is 1.05 and the overburden coefficient is 0.03 [4].

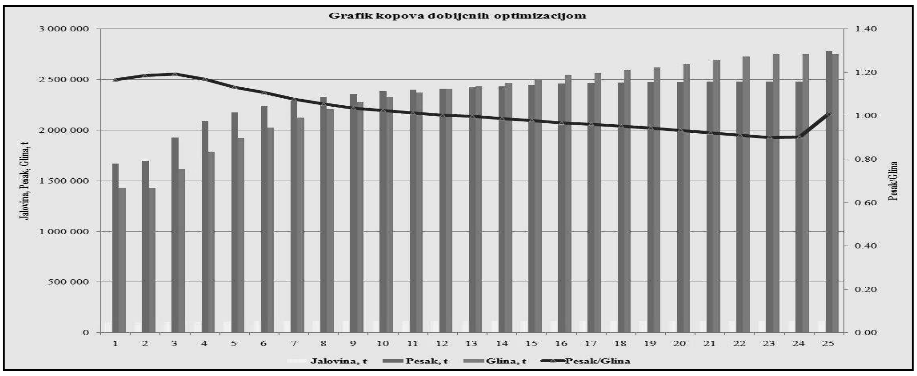


Figure 6 *Graphical presentation of optimization results*

By designed web of the final open pit, total excavation of 2,507,633 t of sand 1,941,416 t of clay was predicted. The ratio of sand/clay is 1.29, and the coefficient of overburden is 0.03. The final view of the open pit is shown in Figure 7.

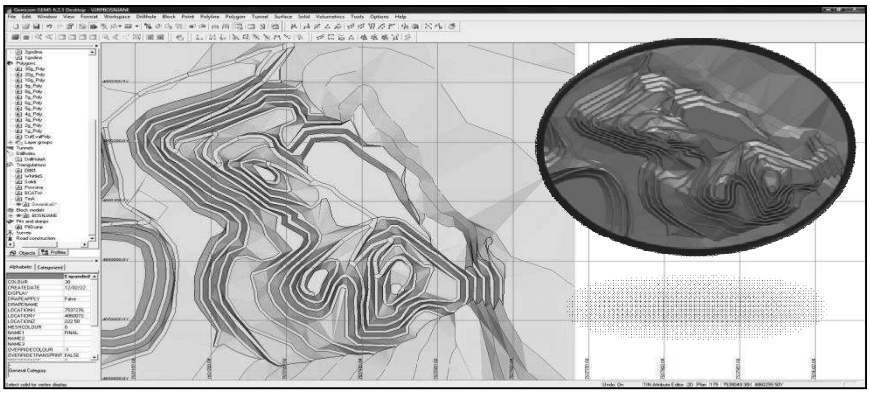


Figure 7 *View of the final open pit outline*

Construction of the clay and waste dump

A dump of the surface humus waste will be located on the northwest side of the open pit. This dump will be removed after works on recultivation, as it will be used as a borrow pit of humus in recultivation after the completitionb of operation. Waste dump has 3 levels, height 5 m. The lowest level od dump is E250/245 m, and the highest E260/255 m. View of waste dump is shown in Figure 8.

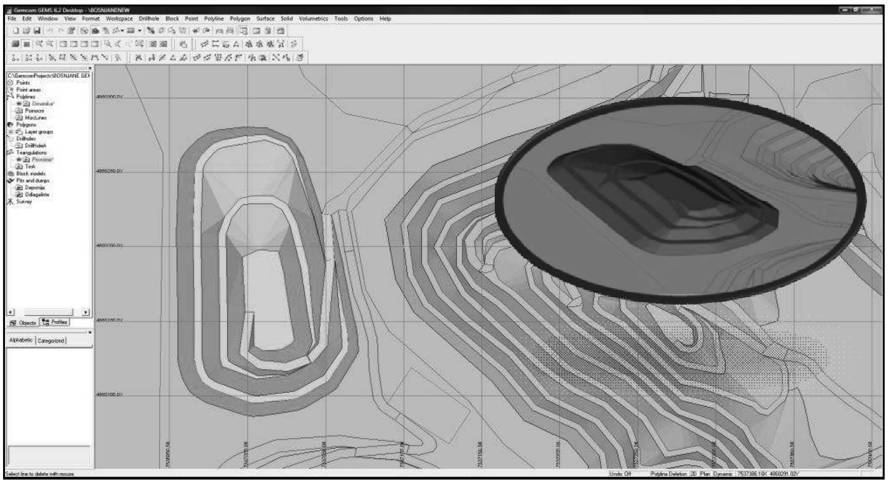


Figure 8 *Final view of waste dump*

Temporary clay dump is located on the west side of the open pit. This dump will be removed after the completion of operation as it will be used later in technological process of cement production. The required capacity of clay dump is determined by the amount of clay that is mined and not go directly into the technological process.

Clay dump has 3 levels, height 5 m. The lowest level od dump is E250/245 m, and the highest E260/255 m. Mutual position of the open pit, waste dump and clay dump is shown in Figure 10.

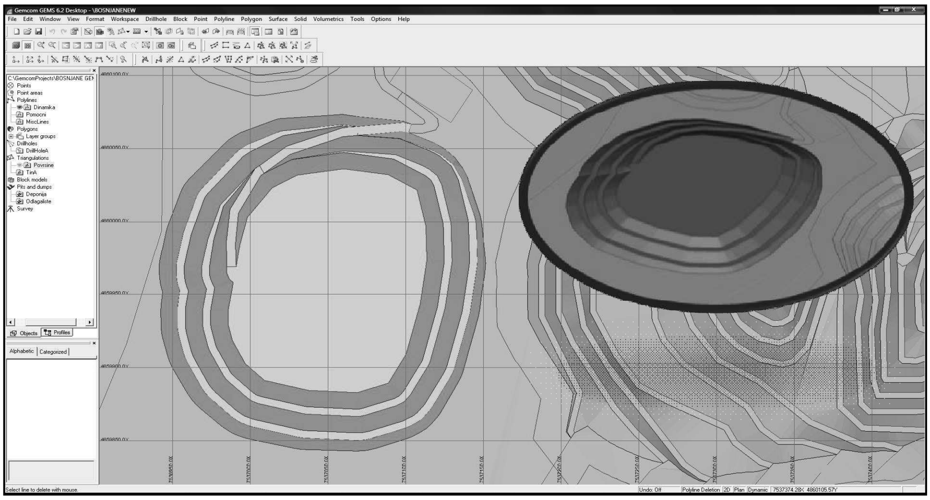


Figure 9 *Final view of clay dump*

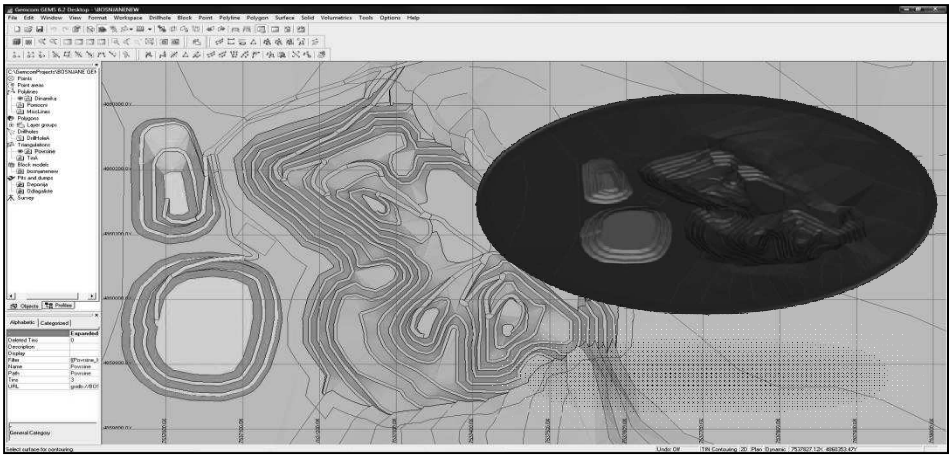


Figure 10 *Mutual position of the open pit, waste dump and clay dump*

CONCLUSION

Calculation of reserves, optimization of deposit as well as other mining designs are performed with the help of various software packages. One of the software packages used in geology, for development a geo-model, which calculates reserves and further mine design, is the program Minex 5.2.3, made in Australia in the company Surpac Minex Group Pty Ltd, which is applied in the Mining and Metallurgy Institute Bor. Development of a geomodel is done on the basis of data on the geological structure of deposits and results of geological explorations.

Optimization is done by explored and tested technical and economic parameters. An important factor in the use of the program Minex 5.2.3 is the ability to change and comparing several variants of input parameters, especially when it comes to the calculation of reserves and optimization. Using the computer technique and the appropriate software program packages, the time of preparation the project documentation and different calculations is shortened, compared to the conventional design. Using this program, the design is significantly improved in terms of time and quality due to the accurate analysis in order to select the best solutions. The application of this and similar programs has become a necessity and standard in geology and mining.

Determining the optimal open pit contour is a necessary step in design of surface mining, which is characterized by complexity and analysis of a large number of possible solutions that meet technical - technological given conditions, but mutually differ according to the economic effect. Determining the optimal open pit outline and its economic effect effect is important for balancing the reserves of mineral resources and geologic-economic evaluation of deposits of mineral resources. It is therefore necessary that the different solutions undergo the techno-economic analysis of individual variants and adopt a solution that would be optimal for the given conditions.

REFERENCES

[1] Minex manual, Surpac Minex Group Pty Ltd, 2007;

[2] Maksimović M., Marinković V., Elaborate on Mine Reserves of Quartz Sand and Sandy Clay as Raw Material for Cement Insutry in the Deposit Bošnjane - Popovac near Paraćin, 30.09.2011, MMI Bor, 2011;

[3] Rajković R. et all., Feasibility Study on Mining the Quartz Sand Bošnjane, Book 1 Text, MMI Bor, 2012;

[4] Main Mining Desing on Mining the Quartz Sand Bošnjane, Book 1, basic Concept, Department Minex and Gemcom, MMI Bor, 2012;

[5] R. Rajković, D. Kržanović, M. Mikić, V. Marinković: Construction of Ash and Slag Dump on the Thermal Power Plant Gacko With Software Gemcom 6.2 and Minex 5.2; Mining 2013 Plans For Development and Improvent Of Mining; Veliko Gradište, Srebrno Jezero, 2013., pp. 177-182;

[6] M. Ignjatović, R. Rajković, S. Ignjatović, L. Đurđevac Ignjatović, L. Kričak, R. Pantović: Determination of Optimal Contours of Open Pit Mine During Oil Shale Exploitation by Minex 5.2.3. Program; Journal of Process Management - New Technologies International, Vol 1, No.2, 2013;

[7] R. Rajković, D. Kržanović, V. Marinković: Determination of Balance Reserves in The Calcite Deposit "Kaona" and Determination of Optimum Open Pit Mine Contour Using Minex 5.2.3 Program; Mining Engineering 3/2011; pp. 19-24;

[8] R. Rajković, V. Marinković, R. Lekovski: Digital 3D Terrain Model; Mining Engineering 3/2011; pp. 33-40;

[9] D. Kržanović, R. Rajković, V. Marinković: Optimal Contour Selection of Open Pit in the Northwestern Part of Coal Deposit Potrlica – Pljevlja Using Software Package Minex 5.2.3; 3. International Symposium Energy Mining 2010;

[10] V. Marinković, R. Rajković, D. Kržanović, G. Pačkovski, D. Mitić: 2D and 3D Models, Similarity and Diferences, Copper 34 (1/2009) 2009;

[11] V. Marinković, M. Maksimović, R. Rajković; Fault Modelling Of Seams Using The Computer Programme Minex; 40th International October Conference On Mining And Metallurgy IOCMM 2008; Sokobanja, Serbia, 05 – 08 October 2008;

[12] V. Marinković, R. Rajković, M. Mikić; Calculation of Geological Reserves of the Coal Deposit by the Use of Computer Program Minex; First International Symposium Mining Energetic 07; Vrnjačka Banja, Serbia, 21 -24. November 2007.

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OSNOVNI PRINCIPI IZRADE I KORIŠĆENJA DIGITALNOG GEOMODELA KOD PROJEKTOVANJA POVRŠINSKOG KOPA NA PRIMERU LEŽIŠTA KVARCNOG PESKA I PESKOVITE GLINE „BOŠNJANE“,SRBIJA

Izvod

Na osnovu rezultata izvršenih geoloških istraživanja na prostoru ležišta kvarcnog peska i peskovite gline Bošnjane, urađen je programskim paketom Minex 5.2.3. geomodel, koji je bio osnova za proračun rezervi i projektovanje površinskog kopa na ležištu kvarcnog peska i peskovite gline, u navedenom programskom paketu.

***Ključne reči**: geomodel, Minex 5.2.3, optimizacuja i projektovanje kopa*

UVOD

Proračun rezervi programskim paketom MINEX 5.2.3, započinje izradom trodimenzionalnog geomodela. Interpretacija ležišta i izrada trodimenzionalnog geomodela uslovljena je unosom podataka iz nekoliko datoteka (Excel) o istražnim bušotinama.

Na osnovu podataka dobijenih iz istražnih radova formira se baza podataka koja se sastoji iz četri datoteke: *Collars cls. Fail; Quality cls.; Lithology cls. Fail; Seam prn. Fail.*

Podaci iz bušotina se u bazu unose na odgovarajući način u formi definisanih intervala, sa poljima pored ostalih „*from*“ i „*to*“, tj. definisanim intervalima u kojima su probe analizirane

Podaci iz istražnih bušotina se na odgovarajući način u softweru Minex obrađuju, matematičkim i geostatističkim metodama (metodama inverznih distanci različitog stepena), kako bi se utvrdila zakonomernost sadržaja u ležištu.

Proračun rezervi se vrši nekom od metoda poligona.

Blok model se može osvežiti u smislu unošenja novih podataka.

GEOLOŠKA GRAĐA I OPIS LEŽIŠTA

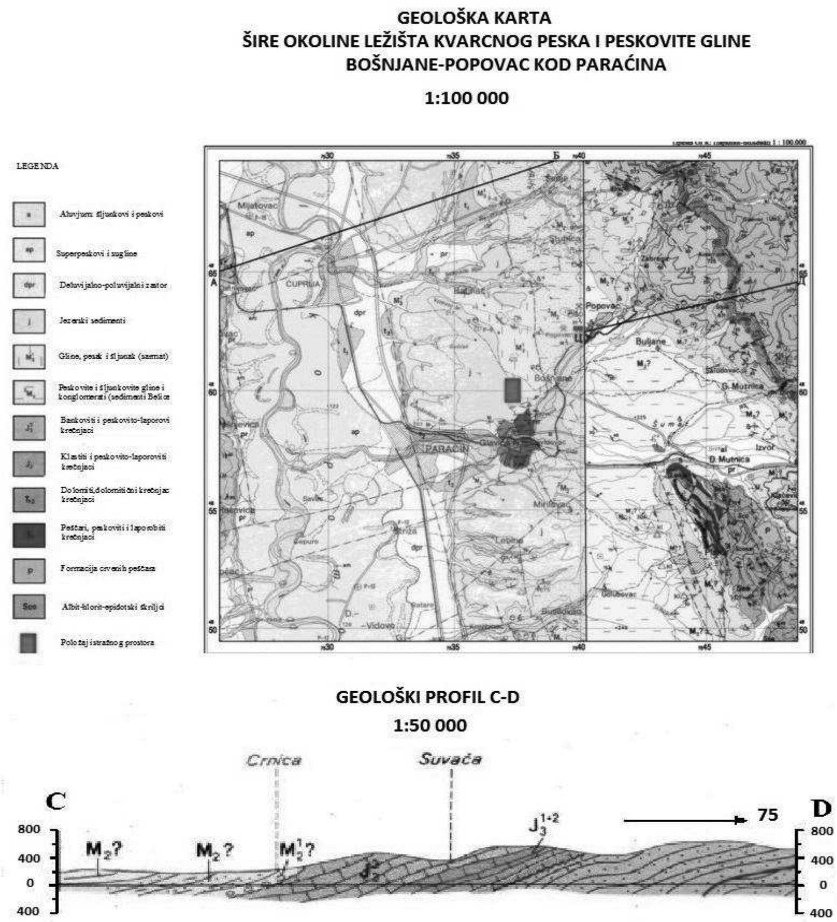
Ležište kvarcnog peska i peskovite gline „Bošnjane“, nalazi se, vazdušnom linijom, na oko 7 km severoistočno od Paraćina i na oko 5 km južno od mesta Popovac i fabrike cementa „HOLCIM“, u ataru sela Bošnjane.

Šira okolina ležišta Bošnjane obuhvata istočni deo lista Paraćin sa signaturom L34-07 i zapadni deo lista Boljevac, sa signaturom L34-08, OGK, razmere 1:100.000. [2]

U geološkoj građi ležišta kvarcnog peska i peskovite gline Bošnjane učestvuju slatko-

* *Holcim (Srbija) d.o.o. Popovac kod Paraćina*
** *Tehnički fakultet u Boru Univerzitet u Beogradu*
*** *Institut za rudarstvo i metalurgiju Bor, miroslava.maksimovic@irmbor.co.rs*

vodni sedimenti srednjeg miocena i miocen-pliocena. U srednjem miocenu su tokom helveta, diskordantno, na starijim miocenskim, a često i pretercijarnim formacijama kao posledica starije štajerske faze, taloženi klastični sedimenti, zatim i sedimenti jezerskih facija. (slika 1) U ovim slatkovodnim sedimentima se, prema litološkom sastavu mogu izdvojiti: *srednje-miocenska facija crvenih glinovitih peščara, glinovitih laporaca i tufa, zatim srednje miocenska facija laporaca, i miocensko-pliocenska facija slatkovodnih krečnjaka, laporaca, glina, peskova i šljunkova.*



Sl. 1. *Geološka građa šire okoline ležišta Bošnjane-Popovac kod Paraćina*

Slojevi gline i peska su horizontalni do blago nagnuti u pravcu JZ. Dosadašnjim istraživanjima obuhvaćen je jedan deo peščarske serije, pri čemu je utvrđeno da povlatu serije čine peskovite gline koje po kvalitetu zadovoljavaju njihovu upotrebu u cementnoj industriji. Debljina pojedinih slojeva varira tako da imamo neujednačenu slojevitost. Povlatne gline, iz tog razloga se, tretiraju kao druga korisna sirovina. Prosečna debljina sloja povlatnih glina je oko 10 m. U istočnom i severoistočnom, delom i u centralnom delu ležišta glina ili ima malu debljinu, do 1 m, ili sloj gline potpuno isklinjava, dok u zapadnom delu ležišta, debljina sloja gline dostiže i 35 m. Dosadašnjim istraživanjima konstantovano je da se, ispod sloja gline nalazi se serija izgrađena od: peskova, peskovitih glina, zaglinjenih peskova i šljunka, sivih i mrkih glina. U samoj seriji peska se pojavljuju tanki sočivasti proslojci peskovite gline i jako zaglinjenih peskova. Debljina ovih proslojaka je od 10 cm do 50 cm.

Debljina okonturene produktivne serije peskova, koja zadovoljava u pogledu kvaliteta, zahteve njegove primene u cementnoj industriji iznosi oko 18 m. Ispod ove serije, najčešće se, nalazi serija jako zaglinjenih peskova, ili ređe, peskovite gline. Ispod ove serije leži serija bazalnih sedimenata miocena. Podinu ove serije čine bazalni sedimenti miocenske serije, izgra-đeni su od crvenih peskovitih glina, bazalnih konglomerata i crvenih peščara. Najniži slojevi ove serije leže preko titonskih krečnjaka. [2]

ISTRAŽNI RADOVI

Istraživanja u području ležišta Bošnjane, sa ciljem da se obezbede kvalitetne rezerve kvarcnog peska i peskovite gline za primenu u cementnoj industriji, vršena su u dva vremenski razdvojena perioda, odnosno od 1963. do 1965., i 2010. godine. Na ležištu kvarcnog peska i peskovite gline Bošnjane, urađeno je 8 istražnih bunara i izbušene su ukupno 24 istražne bušotine, odnosno ukupno 2.406 m bušenja. Tokom istraživanja ležišta kvarcnog peska i peskovite gline Bošnjane, primenjivana je manje-više ista metodika: ležište je istraženo po verticalnim presecima. Ležište kvarcnog peska i peskovite gline Bošnjane istraženo je izradom 8 istražnih bunara i istražnim bušenjem sa površine terena (24 vertikalne bušotine). Uobičajeni geološki radovi pratili su (preciznije obuhvatali) istražno bušenje, tako što su im predhodili (projekat), izvođeni istovremeno (geološko praćenje i usmeravanje istražnog bušenja, kartiranje i oprobavanje) i nastavljani posle njih (izrada izveštaja i elaborata). [2]

Geološki radovi

Geološki radovi pri istraživanju ležišta kvarcnog peska i peskovite gline Bošnjane, odnose se uglavnom na geološko kartiranje površine terena, praćenje, usmeravanje i geološko kartiranje istražnih bunara i istražnih bušotina, njihovo oprobavanje i interpretaciju dobijenih rezultata, te izradu geoloških karata i izradu preseka (profila) ležišta, okonturivanje ležišta, proračun rezervi mineralne sirovine itd. U geološke radove treba ubrojiti i projektovanje svih istražnih radova, izradu izveštaja i elaborata, te sintezu podataka na osnovu kojih su urađeni geološki profili (preseci) i geološke karte. Iz istražnih bušotina uzete su probe, koje su analizirane u laboratorijama: Holcima d.o.o. Popovac (hemijska ispitivanja, tehnološka ispitivanja), Instituta za rudarstvo i metalurgiju Bor (geomehanička ispitivanja). Hidrogeološka ispitivanja je izveo Geološki Institut Beograd.

Istražni bunari

Na prostoru ležišta kvarcnog peska i peskovite gline Bošnjane, urađeno je 8 bunara dubine do 20 metara. Sa dva bunara, na istočnom, najnižem delu terena, utvrđene su hidrogeološke karakteristike terena, dok je sa 6 bunara (B-I, B-II, B-III, B-IV B-V B-VI), u kvadratnoj mreži 100×100 m, istraženo nalazište po dubini. Ukupna dužina izrađenih bunara iznosi 123,4m. Bunarima su otkriveni kvarcni peskovi zadovoljavajućeg kvaliteta, sa sadržajem SiO_2 većim od 68%, što je bio osnovni uslov njegove primene u cementnoj industriji.

Istražno dubinsko bušenje

Na području ležišta kvarcnog peska i peskovite gline Bošnjane istražno bušenje rađeno je u toku 2010. godine. Ukupno su izbušene 24 bušotine, ukupne dužine bušenja od 862,6 m. Kvarcni pesak zadovoljavajućeg kvaliteta za njegovu primenu u cementnoj industriji, nabušen je sa 17 bušotina,), dok su 7 negativne, tako da su rezultati oprobavanja tih bušotina isključeni iz proračuna.

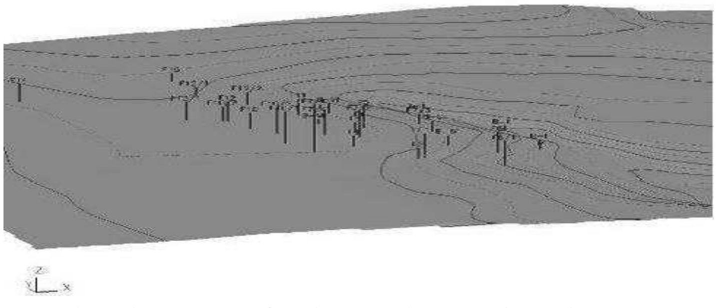
IZRADA GEOMODELA I PROJEKTOVANJE POVRŠINSKIH KOPOVA PROGRAMSKIM PAKETOM MINEX 5.2.3.

Proračun rezervi programskim paketom MINEX 5.2.3, započinje izradom trodimenzionalnog geomodela [9]. Interpretacija ležišta i izrada trodimenzionalnog geomodela uslovljena je unosom podataka iz nekoliko datoteka (Excel) o istražnim bušotinama. [2] Datoteke sadrže za svaku bušotinu: ime bušotine, podatke o koti, koordinatama, podatke o litološkim članovima u geološkim stubovima bušotina (koji su relevantni za procenu pozicije slojeva u izdvojenim geološkim sredinama), kao i podatke o rezultatima hemijskih analiza pojedinačnih proba SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, SO_3 i gubitak žarenjem.

Pre početka izrade *3D* modela ležišta kvarcnog peska i peskovite gline Bošnjane, bilo je potrebno formirati bazu podataka na osnovu kojih bi se pristupilo izradi modela. Do svih potrebnih podataka se došlo u procesu istraživanja (istražne bušotine, istražni bunari), kao i izvršenih laboratorijskih analiza (prostorni položaj svakog istražnog rada predstavljen X, Y, Z koordinatom, konačna dubina svakog istražnog rada, litološki članovi određeni u procesu kartiranja jezgra bušotine i podaci o kvalitetu dobijeni laboratorijskim analizama). Baza podataka se sastoji iz 4 osnovna fajla:

- *Collars cls. Fail - sadrži sve podatke o prostornom položaju bušotina;*
- *Quality cls. Fail - sadrži sve podatke vezane za kvalitet;*
- *Lithology cls. Fail - sadrži sve podatke o litologiji;*
- *Seam prn. Fail - sadrži podatke o položaju slojeva peskovite gline i kvarcnog peska, u svakom istražnom radu.* [12]

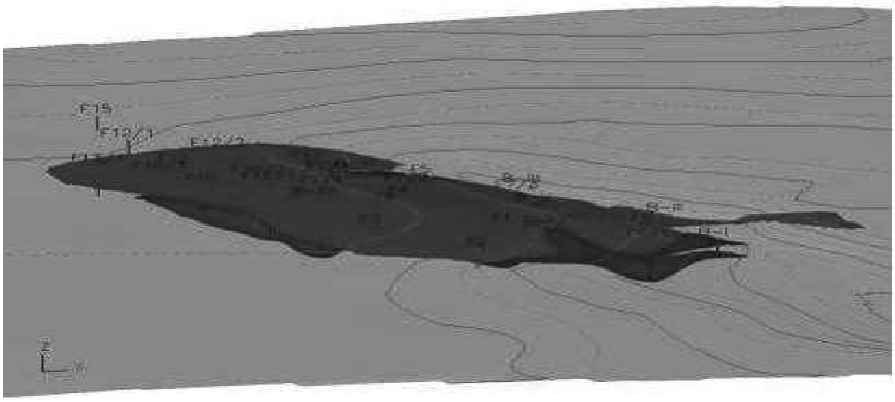
Ležište kvarcnog peska i peskovite gline Bošnjane je slojevito-sočivastog oblika. Pravac pružanja ležišta je SSZ-JJI. Po pružanju ležište se može pratiti oko 600 m, dok je široko oko 300 m (pravac I-Z). U okviru konture ležišta jasno se izdvajaju dva litološki različita člana, sloj gline i sloj kvarcnog peska. Iz tog razloga svaki od ovih slojeva modelovan je kao zaseban sloj, koji nosi posebnu slovnu oznaku. Za svaku bušotinu dat je opis izdvojenih tipova stena, odnosno geološki stub bušotine, a zatim su uneti podaci o karakteristikama svakog izdvojenog litološkog tipa, neophodni za dalju obradu blok-modela ležišta. Osim napred navedenih podataka, uneti su i podaci o topografiji terena. Podaci o topografiji preuzeti su od Investitora (HOLCIM Srbija d.o.o. Popovac). Na slici 2. dat je grafički, trodimenzionalni prikaz unetih podataka, iz baze programskog paketa MINEX 5.2.3.[8]



Sl. 2. *3D prikaz odnosa topografije i bušotina (programskim paketom MINEX 5.2.3)*

Svi slojevi su modelovani primenom opšteg metoda modelovanja. U procesu interpolacije nedostajućih slojeva korišćeni su podaci iz minimum 3, a maksimum 4 susedne bušotine, a radijus pretrage je ograničen na 250 m. Dok je za ponderisanje vrednosti korišćena opšta formula za ponderisanje. Nakon kreiranja ovih slojeva, pristupilo se njihovoj međusobnoj prostornoj korelaciji i izradi *3D* modela ležišta (slika 3).

Za svaki vertikalni presek (profil) i horizontalni presek (etažu), definisane su referentne površine i prostor, koji ispred i iza, zahvata određeni prostor. Ovakvim načinom interpretacije eliminisana je mogućnost postojanja "praznih" prostora unutar blok-modela ležišta. Izgled modeliranih slojeva programskim paketom MINEX 5.2.3 je prikazan slikama 3 i 4. [11]



Sl. 3. *3D prikaz slojeva sa topografijom (programskim paketom MINEX 5.2.3)*

a) Sivom bojom je prikazana topografija; b) Crvenom bojom je prikazan sloj kvarcnog peska (P1); c) Plavom bojom je prikazan sloj peskovite gline (G).

Sl. 4. *2D prikaz dela poprečnog preseka kroz ležište kvarcnog peska i peskovite gline Bošnjane (programskim paketom MINEX 5.2.3)*

a) Sivom bojom je prikazana topografija; b) Crvenom bojom je prikazan sloj kvarcnog peska (P1); c) Plavom bojom je prikazan sloj peskovite gline (G).

Sve ostale podatke potrebne za proračun rezervi, program preuzima iz predhodno kreiranih baza podataka, kao i izrađenog geološkog modela slojeva [7]. Na tako kreiranom modelu ležišta bilo je moguće proračunati geološke rezerve, kako za svaki sloj ponaosob, tako i za ležište u celosti. [13]

PROSTORNO OGRANIČENJE POVRŠINSKOG KOPA I ODLAGALIŠTA SA GEOMETRIJOM I ANALIZAMA STABILNOSTI

Konstrukcija površinskog kopa izvršena je na bazi overenih bilansnih rezervi. Izbor optimalne završne konture kopa izvršen je pomoću licenciranog programa Minex 5.2.3„ koji služi za optimizaciju i analizu površinskih kopova. [5] Optimizacija je izvršena alatom Pit Optimiser, koji se bazira na Lerches and Grossman algoritmu, tj. postupku za određivanje optimalnog kopa kao onog sa najvećom vrednošću za odgovarajući set troškova i faktora povraćaja. [6] Ulazni parametri za optimizaciju ležišta „Bošnjane“ su:

1. topografija,
2. geomodel ležišta,
3. zapreminska masa peska, gline i jalovine,
4. iskorišćenje na otkopavanju i pripremi,
5. jedinična vrednost tone peska i gline,
6. srednji i minimalni sadržaj S_iO_2 u ležištu,
7. ugao završne kosine kopa,
8. mimimalna završna širina etažne ravni,
9. direktni troškovi otkopavanja jalovine, peska i gline.

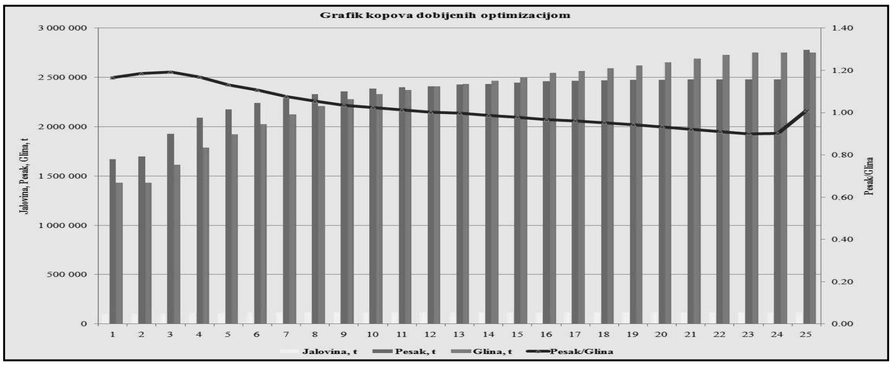
Ugao završne kosine kopa određen je licenciranim softverom GeoStudio 2007, odnosno njegovim alatom Slope/W koji je specijalizovan za metode granične ravnoteže. Pretpostavljena maksimalna dubina kopa određena je na osnovu prostornog položaja peska i gline, kao i topografije terena. Generalni ugao završne kosine kopa direktno zavisi od ugla kosine etaža i završne širine etažnih ravni. Pretpostavljeno je na osnovu geomodela ležišta da je za reprezentativni profil odnos moćnosti gline i peska 1:1,5. [3]

Prema ovim uslovima pretpostavljeni ugao završne kosine kopa iznosi 24,3°. Minimalna završna širina etažne ravni dovoljna za radove na rekultivaciji, usvojena je na 4 m. Direktni troškovi otkopavanja jalovine, peska i gline obuhvataju troškove normativnog materijala, ljudskog rada, i tekućeg održavanja za sve faze rada (kopanje, utovar na kopu i deponijama peska i gline, transport, pomoćni radovi na kopu i odlagalištu, odvodnjavanje) uvećane za troškove HTZ opreme, NTO, administracije i nepredviđene troškove. Rezultati optimizacije prikazani su na slikama 5 i 6.

Kop	Jalovina, t	Pesak, t	Glina, t	Iskopina, t	Kr	P/G	Vek rada	Jalovina, t/god	Pesak, t/god	Glina, t/god	Trošak, $	Dobit, $	NPV, $	Fp	DV, $
1	101 234	1 669 060	1 432 276	3 202 570	0.03	1.17	27.8	3 639	60 000	51 488	14 929 840	23 889 106	8 959 266	0.07056	632 156
2	101 506	1 698 708	1 433 281	3 233 495	0.03	1.19	28.3	3 585	60 000	50 625	15 076 926	24 171 159	9 094 233	0.06731	612 160
3	106 605	1 928 144	1 616 129	3 650 878	0.03	1.19	32.1	3 317	60 000	50 291	17 039 713	27 373 309	10 333 595	0.04675	483 134
4	110 279	2 091 034	1 788 937	3 990 250	0.03	1.17	34.9	3 164	60 000	51 332	18 633 835	29 897 053	11 263 218	0.03609	406 541
5	112 639	2 175 656	1 921 739	4 210 034	0.03	1.13	36.3	3 106	60 000	52 998	19 663 857	31 458 697	11 794 841	0.03155	372 181
6	113 895	2 239 338	2 023 966	4 377 199	0.03	1.11	37.3	3 052	60 000	54 229	20 448 244	32 647 227	12 198 983	0.02852	347 899
7	115 290	2 286 677	2 124 660	4 526 627	0.03	1.08	38.1	3 025	60 000	55 749	21 147 774	33 674 578	12 526 804	0.02645	331 369
8	115 970	2 328 106	2 209 098	4 653 174	0.03	1.05	38.8	2 989	60 000	56 933	21 741 314	34 552 213	12 810 900	0.02477	317 300
9	116 208	2 356 294	2 277 707	4 750 209	0.03	1.03	39.3	2 959	60 000	57 999	22 196 568	35 214 323	13 017 754	0.02368	308 305
10	116 437	2 386 328	2 328 084	4 830 849	0.02	1.03	39.8	2 928	60 000	58 536	22 575 603	35 787 465	13 211 862	0.02258	298 324
11	116 622	2 400 562	2 371 651	4 888 835	0.02	1.01	40.0	2 915	60 000	59 277	22 847 272	36 173 759	13 326 487	0.02208	294 185
12	116 779	2 412 022	2 407 887	4 936 688	0.02	1.00	40.2	2 905	60 000	59 897	23 071 424	36 491 523	13 420 099	0.02168	290 907
13	116 937	2 426 961	2 434 492	4 978 390	0.02	1.00	40.4	2 891	60 000	60 186	23 267 294	36 785 616	13 518 322	0.02117	286 164
14	117 067	2 435 000	2 468 174	5 020 241	0.02	0.99	40.6	2 885	60 000	60 817	23 463 117	37 056 637	13 593 520	0.02090	284 105
15	117 187	2 449 641	2 501 996	5 068 824	0.02	0.98	40.8	2 870	60 000	61 282	23 691 113	37 389 978	13 698 865	0.02042	279 725
16	117 293	2 459 135	2 544 273	5 120 701	0.02	0.97	41.0	2 862	60 000	62 077	23 933 903	37 724 603	13 790 700	0.02011	277 385
17	117 419	2 465 821	2 564 192	5 147 432	0.02	0.96	41.1	2 857	60 000	62 394	24 059 075	37 902 878	13 843 803	0.01990	275 511
18	117 549	2 468 537	2 591 316	5 177 402	0.02	0.95	41.1	2 857	60 000	62 984	24 198 885	38 086 124	13 887 239	0.01982	275 186
19	117 671	2 473 105	2 620 084	5 210 860	0.02	0.94	41.2	2 855	60 000	63 566	24 355 190	38 296 195	13 941 005	0.01967	274 254
20	117 745	2 475 508	2 652 137	5 245 390	0.02	0.93	41.3	2 854	60 000	64 281	24 516 336	38 505 226	13 988 890	0.01960	274 148
21	117 871	2 478 815	2 691 898	5 288 584	0.02	0.92	41.3	2 853	60 000	65 158	24 717 887	38 767 563	14 049 676	0.01949	273 896
22	117 959	2 479 794	2 726 014	5 323 767	0.02	0.91	41.3	2 854	60 000	65 957	24 881 888	38 975 340	14 093 452	0.01946	274 323
23	118 044	2 480 049	2 753 750	5 351 843	0.02	0.90	41.3	2 856	60 000	66 622	25 012 670	39 139 223	14 126 552	0.01946	274 856
24	118 044	2 480 467	2 753 750	5 352 261	0.02	0.90	41.3	2 855	60 000	66 610	25 014 668	39 143 117	14 128 449	0.01944	274 710
25	118 044	2 781 094	2 753 750	5 652 888	0.02	1.01	46.4	2 547	60 000	59 410	26 451 064	41 943 758	15 492 694	0.01206	186 858
OPT	116 528	2 213 236	2 172 835	4 502 599	0.03	1.02	36.9	3 159	60 000	58 905	21 024 894	33 270 925	12 246 031	0.02973	364 026

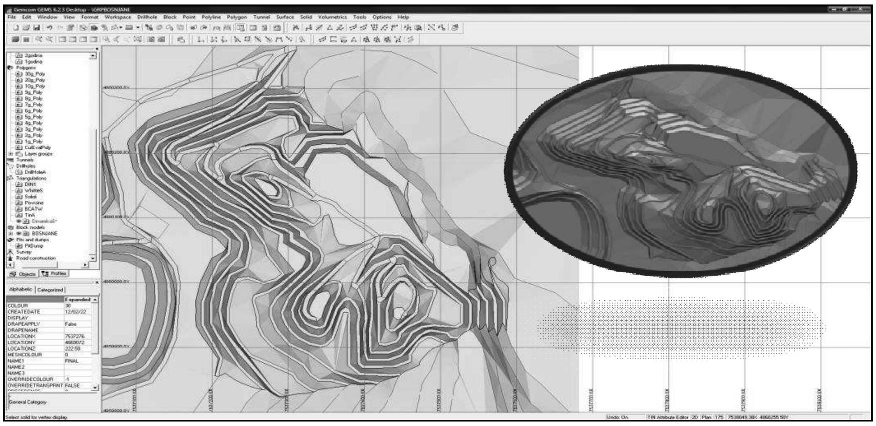
Sl. 5. *Analitički prikaz rezultata optimizacije*

Dobijene konture koje su rezultat optimizacije, nemaju etaže. Kao vodilja za konstrukciju kopa koji obuhvata bilansne rezerve izabrana je kontura 8, čija diskontovana vrednost na kraju perioda eksploatacije, koja obuhvata samo direktne troškove otkopavanja,. Ova kontura ima 2.328.106 t peska i 2.209.098 t gline. Odnos pesak/glina iznosi 1,05 a koeficijent raskrivke 0,03[4].



Sl. 6. *Grafički prikaz rezultata optimizacije*

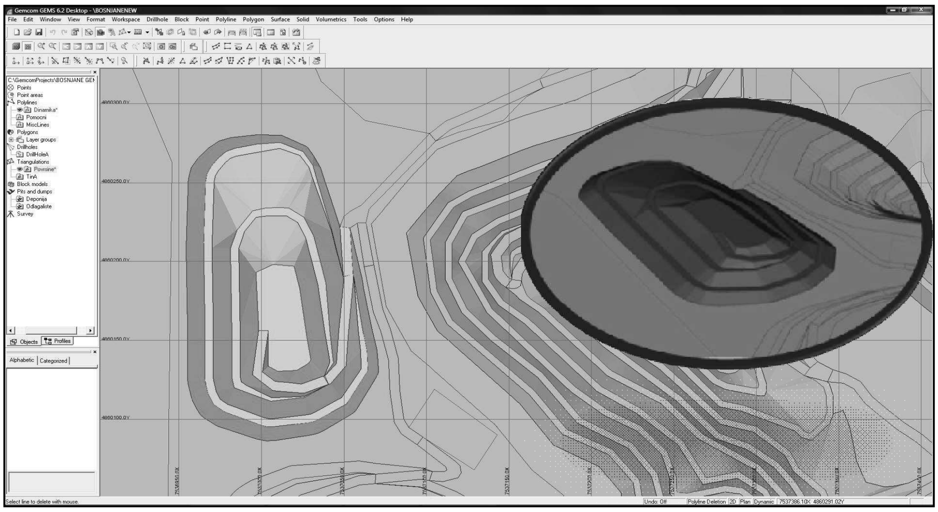
Projektovanim zahvatom završnog kopa ukupno je predviđeno otkopavanje 2.507.633 t peska i 1.941.416 t gline. Odnos pesak/glina iznosi 1,29, a koeficijent raskrivke 0,03. Izgled završnog kopa prikazan je na slici 7.



Sl. 7. *Izgled završne konture kopa*

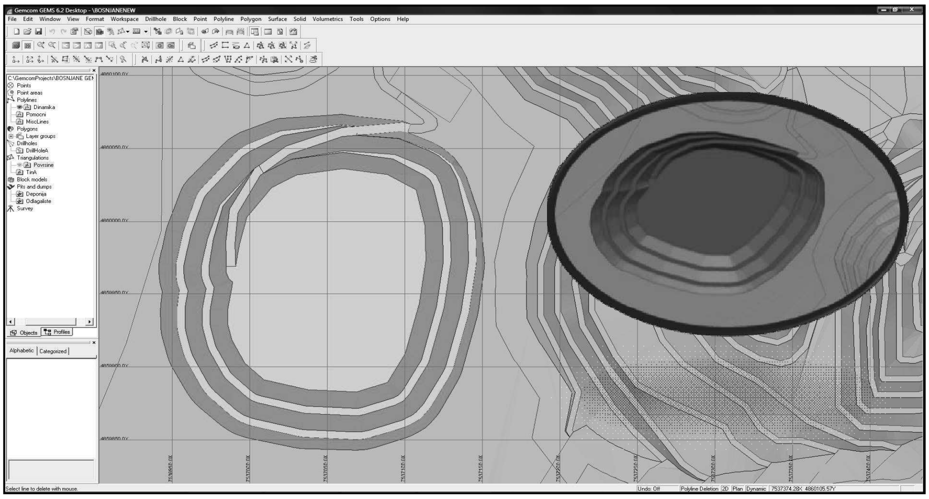
Konstrukcija deponije gline i odlagališta jalovine

Odlagalište površinske humusne jalovine biće locirano sa severozapadne strane kopa. Ovo jalovište će biti uklonjeno nakon radova na rekultivaciji, jer će se iskoristiti kao pozajmište humusa pri rekultivaciji po završetku eksploatacije. Odlagalište jalovine ima 3 etaže visine 5 m. Najniža etaža odlagališta je E250/245 m, a najviša E260/255 m. Izgled odlagališta jalovine prikazan je na slici 8.

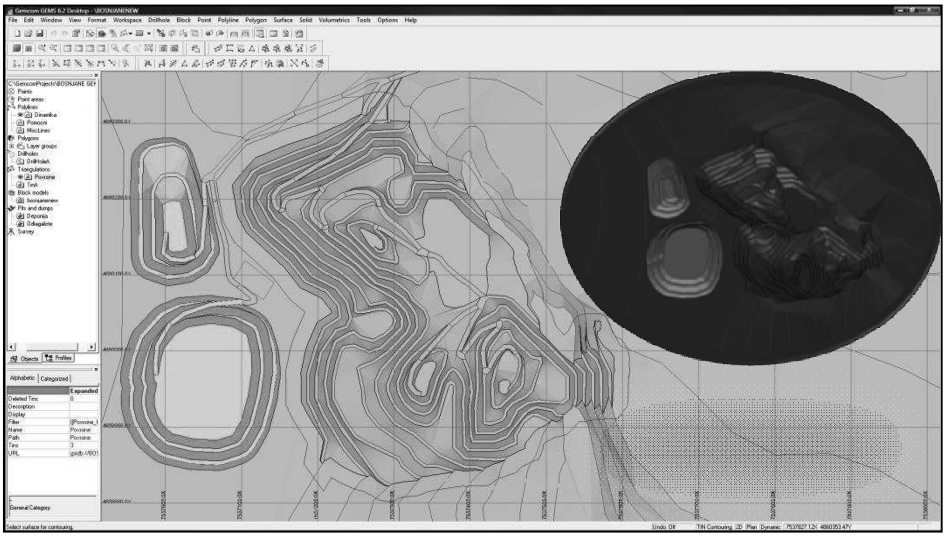


Sl. 8. *Konačni izgled odlagališta jalovine*

Privremena deponija gline locirana sa zapadne strane kopa. Ova deponija će biti uklonjena nakon završetka eksploatacije, jer će se odložena glina naknadno upotrebiti za tehnološki proces dobijanja cementa. Potrebni kapacitet deponije gline je uslovljen količinom gline koja se otkopava a ne ide odmah u tehnološki proces. Deponija gline ima 3 etaže visine 5 m. Najniža etaža deponije je E250/245 m, a najviša E260/255 m. Izgled deponije gline prikazan je na slici 9. Međusobni položaj kopa, odlagališta jalovine i deponije gline prikazan je na slici 10.



Sl. 9. *Konačni izgled deponije gline*



Sl. 10. *Međusobni položaj kopa, odlagališta jalovine i deponije gline*

ZAKLJUČAK

Proračun rezervi, optimizacija ležišta, kao i druga rudarska projektovanja, obavljaju uz pomoć različitih programskih paketa. Jedan od programskih paketa koji se koriste u geologiji, za izradu geomodela na kome se vrši proračun rezervi i dalja rudarska projektovanja, je program Minex 5.2.3, proizveden u Australiji u firmi Surpac Minex Group Pty Ltd, koji se primenjuje u Institutu za rudarstvo i metalurgiju Bor. Izrada geomodela vrši se na osnovu podataka o geološkoj građi ležišta i rezultata geoloških istraživanja. Optimizacija se vrši prema istraženim i ispitanim tehničkim i ekonomskim parametrima. Važan činilac upotrebe programa Minex 5.2.3 je mogućnost promene i upoređivanja više varijanti ulaznih parametara, pogotovu kada se radi o proračunu rezervi i optimizaciji. Primenom računarske tehnike i odgovarajućih programskih paketa skraćuje se vreme izrade projektne dokumentacije i različitih proračuna, u odnosu na klasično projektovanje. Upotrebom ovog programa projektovanje je znatno poboljšano sa aspekta vremena i kvaliteta usled mogućnosti brze analize u cilju odabira najboljih rešenja. Primena ovog i sličnih programa postala je neminovnost i standard, u geologiji i rudarstvu. Određivanje optimalne konture površinskog kopa je neophodan korak pri projektovanju u površinskoj eksploataciji, koji se karakteriše složenošću i analizom velikog broja mogućih rešenja koja odgovaraju tehničko - tehnološkim zadatim uslovima, ali se međusobno razlikuju prema ekonomskom efektu. Određivanje optimalne konture kopa, i njen ekononski efekat, je značajno za bilansiranje rezervi mineralne sirovine, i geološko-ekonomsku ocenu ležišta mineralne sirovine. Zato je potrebno da se različita rešenja podvrgnu tehno - ekonomskoj analizi pojedinih varijanti i usvoji rešenje koje će biti optimalno za date uslove.

LITERATURA

[1] Minex manual, Surpac Minex Group Pty Ltd, 2007 god

[2] Maksimović M., Marinković V., Elaborat o rezervama kvarcnog peska i peskovite gline kao sirovine za cementnu industriju, u ležištu Bošnjane-Popovac kod Paraćina, 30.09.2011, IRM Bor, 2011

[3] Rajković R. i saradnici „Studija izvodljivosti eksploatacije kvarcnog peska Bošnjane“, knjiga 1 tekst, IRM Bor, 2012

[4] Glavni rudarski projekat eksploatacije kvarcnog peska Bošnjane, knjiga 1 Osnovna koncepcija, Odeljenje Minex i Gemcom, IRM Bor, 2012

[5] R. Rajković, D. Kržanović, M. Mikić, V. Marinković: Construction of ash and slag dump on the thermal power plant Gacko with software Gemcom 6.2 and Minex 5.2; Mining 2013 Plans for development and improvent of mining; Veliko Gradište, Srebrno jezero 28-31 may 2013, pp. 177-182;

[6] M. Ignjatović, R. Rajković, S. Ignjatović, L. Đurđevac Ignjatović, L. Kričak, R. Pantović: Determination of optimal contours of open pit mine during oil shale exploitation by Minex 5.2.3. program; Journal of Process Management - New Technologies International, Vol 1, No 2, 2013, pp. 1-9;

[7] R. Rajković, D. Kržanović, V. Marinković: Određivanje bilansnih ležišta kalcita „Kaona“ i optimalne konture površinskog kopa programom Minex 5.2.3, Rudarski radovi 3/2011, str. 13-18;

[8] R. Rajković, V. Marinković, R. Lekovski: Digitalni 3D model terena, Rudarski radovi 3/2011, str. 25-32;

[9] D. Kržanović, R. Rajković, V. Marinković: Optimal contour selection of open pit in the northwestern part of coal deposit Potrlica – Pljevlja using software package Minex 5.2.3; 3. International symposium Energy Mining 2010, pp. 216-220;

[10] V. Marinković, R. Rajković, D. Kržanović, G. Pačkovski, D. Mitić: 2D i 3D modeli, sličnosti i razlike, Bakar 34 1/2009;

[11] V. Marinković, M. Maksimović, R. Rajković; Fault modelling of seams using the computer programme Minex; 40th International October Conference on Mining and Metallurgy IOCMM 2008, Sokobanja, Serbia, 05-08 October 2008, pp. 145-152;

[12] V. Marinković, R. Rajković, M. Mikić; Calculation of Geological Reserves of the Coal Deposit by the Use of Computer Program Minex; First International Symposium Mining Energetic 07, Vrnjačka Banja, Serbia, 21 - 24. November 2007, pp. 207-211;