

MODERN METHODS FOR THE CALCULATION OF STOCKS VOLUMES EXISTING IN SURFACE MINING EXPLOITATIONS

S. DOROBANTU^{1*}, Larisa FILIP¹, N. DIMA¹

¹University of Petrosani

*Corresponding author: silviu.dorobantu@yahoo.com

Abstract. *The work presented in this paper consists in taking photogrammetric images with the help of drones, realizing their mosaic and georeferencing the orthophotomap resulting in the national stereographic projection system 1970. The calculating methods of volumes of materials situated inside the surface mining exploitations, based on satellite measurements and programs specific calculations, are also presented. For these measurements, a Leica GNSS system, as well as a specialized software were used. These data were combined with the cloud of points resulting from the photogrammetric flight, thus obtaining a high accuracy on the calculated volumes. The purpose of this paper is to present a modern alternative to classical topography. This is much faster and more accurate in both accessible places and areas with unsafe conditions for the human factor. At the same time, this method offers the possibility of collecting much larger number of field details, compared to an ordinary measurer.*

Keywords: *volume calculation, mining, GPS, drone, UAV, 3D model*

INTRODUCTION

When the manner in which exploitation will be applied to a rock deposit is selected, depending on the shape, sizes and location in the ground, surrounding rocks and topography of the area, the following three situations are:

- Day extraction is **evident** for the entire mineral reserve from the deposit;
- The day extraction is **advantageous** only for a part of the reserves of the deposit, the rest being exploited through underground works;
- The day extraction is **excluded** because of the high depth of the deposit, and its exploitation will be done only through underground mining.

Deposits that can be fully exploited through day works can be found in the following forms:

- **stocks or large stocks** located above or below ground level, at a small depth below the slope;
- **a thick layer, or large packet layers**, located close to the surface, in a horizontal position or with a relatively constant inclination and equal or slightly different from the slope of the covering ground;
- **a medium or large thickness layer with variable inclination**, relatively close to the surface area.

For deposits which are in the form of loose layers, plugs, lenses or highly tectonic lugs and with medium or large inclination, as for the pleated deposits, the day exploitation is advantageously only partially, to a certain depth, the reserves at a greater depth being exploited by underground mining.

In addition to the geological conditions mentioned, in order to be exploited day works, a number of conditions still need to be met:

- **a favourable relief** of the area which can allow the normal development of the exploitation in the extraction, transport and storage of both the tailings and the useful mineral;
- **a favourable hydro-geological regime**, as poor as possible for surface water or

underground aquifers;

- covered layers are preferably made of **disaggregated rocks**, low cohesion rocks, or soft solid rocks;
- **the climate of the area need to be acceptable** to ensure working hours without excessive atmospheric events.

Useful mineral substances suitable for use in day exploitation:

- Solid mineral fuels (peat, lignite, brown coal, etc.);
- Metallic ores (iron, copper, zinc, gold, etc.);
- Non-metallic substances (kaolin, phosphates, clay, bentonite, sulphur, asbestos);
- Building materials (sand, gravel, marble, granite, etc.).

Problems related to mining excavation tracking are not an absolute novelty in the field. These have always required topographic measurements and calculations (FILIP ET AL., 2016), (LUPU - DIMA AND FILIP, 2012).

MATERIAL AND METHOD

✚ Horizontal sections method. Average height variant per step

In order to determine the excavated volume, the surfaces S1 at first and S2 at the end of the tread operation must be determined, as well as the difference in level between two surfaces.

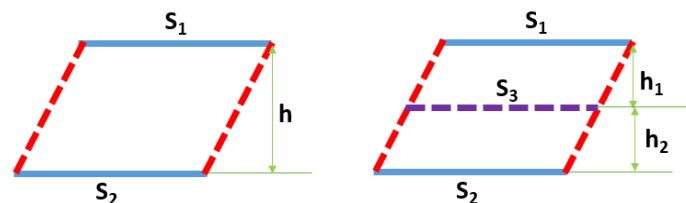


Figure 1 Horizontal sections method

In the case of a flat slope, the excavated volume is obtained by:

$$V = \frac{S_1 + S_2}{2} \cdot h \quad (1)$$

Where:

S1 = the surface of the superior section (at the beginning of the interval);

S2 = the surface of the inferior section (at the end of the interval);

h = the medium heights of the step.

If the inclination of the slopes varies, in addition to the two base sections S1 and S2, the third section S3 is measured at the level of slope change and the calculation formula will be:

$$V = \frac{S_1 + S_3}{2} \cdot h_1 + \frac{S_3 + S_2}{2} \cdot h_2 \quad (2)$$

Where: h1 and h2 represent the medium heights between the surfaces S1 and S3, S3 and S2.

The steps surfaces are determined by polar tachymetric observations on the contour of the surface (step), which are later related to topographical planes.

The value of the surface will be determined by the arithmetic mean of two plans, if the difference between them does not exceed $\pm 5\%$. The measurements of the different points on the step (Daltha apparatus 010) are also determined by tachymetric observations, the density of which must be at least 4 points at 25 m² (located at distances of less than 5 m between them).

The medium height as the difference between the average measurements on the two surfaces is also determined:

$$h_m = H_{mS_1} - H_{mS_2} \quad (3)$$

The method is applied on a small-scale, in open-pit mines (pits), in which the irregular contour gap is better approximated by horizontal sections at the step.

Vertical sections method

This method can be applied in two cases depending on the size of the day mining, the shape of the slopes, the required precision, etc.

Option 1: applies if the exploitation is done on portions. In these areas, cross-sections are drawn with the front line in the exploitation and with parallel lines between them. These are drawn on each profile, either in one base I-II (side of the step polygonation), with the equidistance “e” of 5, 10, 15 or 20 m or in two bases (the other on the side of the quarry – contour polygonation).

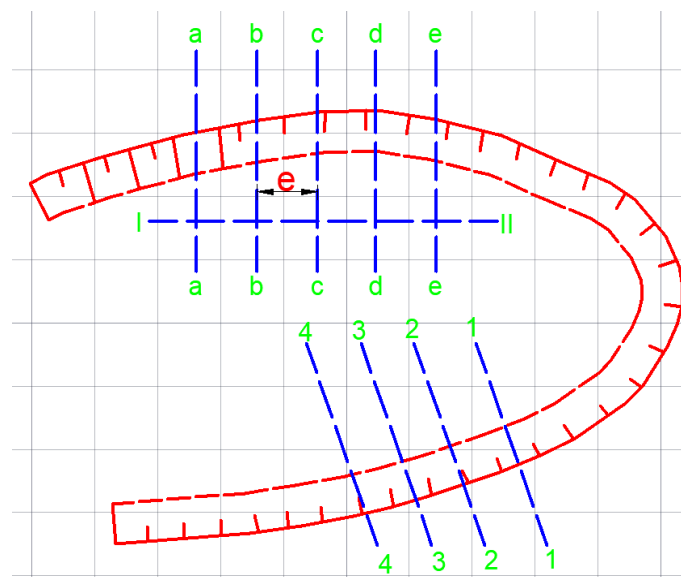


Figure 2 Vertical sections methods applied on portions

Each profile is raised by the tachymetric method using the autoreductor tachymeter and the profile lines are reported, thus obtaining the vertical sections concerned. In order to find out the size of the surface, the exploited surface B M V is decomposed into simple surfaces on which the base and the height of the triangle are plotted.

$$S_i = \frac{1}{2} \cdot h_i \cdot b_i \quad (4)$$

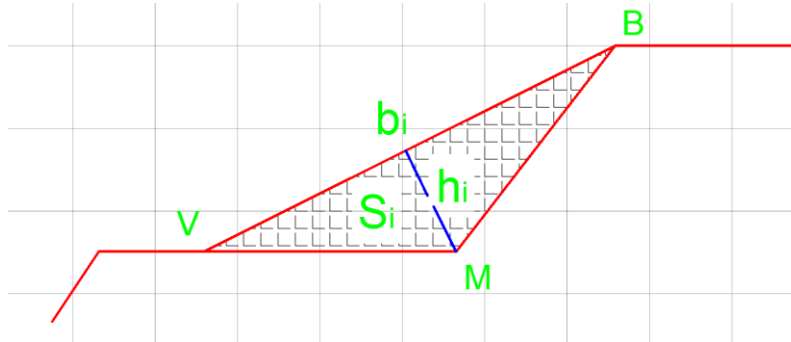


Figure 3 Section on the profile line

If the section after the profile line is more complicated, this can be determined by double planimetry. The volume between two lines will be:

$$V_i = \frac{S_i + S_{i+1}}{2} \cdot e \quad [\text{m}^3] \quad (5)$$

The volume excavated per step is given by the relation:

$$V = \left(\frac{S_1 + S_n}{2} + \sum_{i=2}^{n-1} S_i \right) \cdot e \quad [\text{m}^3] \quad (6)$$

Where:

S1 = the surface after the first profile line;

S_n = the surface after the last profile line;

S_i = the surface after the i profile line.

If the difference between successive surfaces exceeds 30%, the following relation is recommended:

$$V = \frac{e}{3} \sum_{i=1}^{n-1} \left(S_i + S_{i+1} + \sqrt{S_i S_{i+1}} \right) \quad (7)$$

Option 2: refers to the day exploitation, with a circular shape and which is realized inside the entire career and where the profile lines have been drawn.

The method of parallel vertical sections is suitable for elongated excavations with uniform and non-uniform slopes. For non-solid profiles, the volume will be:

$$V = \frac{1}{3} \left(S_1 \cdot e_1 + \frac{S_1 + S_2}{2} \cdot e_2 + \dots + \frac{S_{n-1} + S_n}{2} \cdot e_n + \frac{1}{3} S_n \cdot e_{n+1} \right) \quad (8)$$

It is important to notice that in the above figure and relation the longitudinal development of the quarry exceeds the profile line, aspect materialized by the introduction of the first and the last term in the relation.

For equidistant profiles, the volume will be:

$$V = \left(\frac{S_1 + S_n}{2} + \sum_{i=2}^{n-1} S_i \right) \cdot e \quad [\text{m}^3] \quad (9)$$

If the difference between successive surfaces exceeds 30%, the volume is calculated with the relation:

$$V = \frac{e}{3} \left(S_1 + S_n + 2 \sum_{i=2}^{n-1} S_i + \sum_{i=1}^{n-1} \sqrt{S_i S_{i+1}} \right) \quad [\text{m}^3] \quad (10)$$

The sizes of surfaces can be obtained from cross-sections either by the graphical process (decompositions into simple geometric figures) or through the mechanical process (planimetry with at least two determinations).

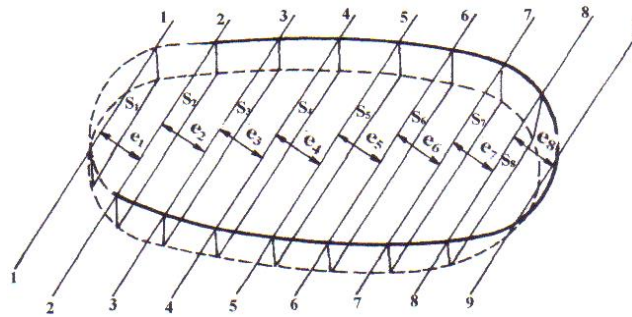


Figure 4 Profile lines

Networks method

This method applies to large-scale mining operations. It consists in drawing a well-established exploitation network, like a mesh, for which in addition to the planimetric position of the corners, the measures of these points are also determined. Square meshes are selected with the side 5, 10, 15, 20 m, depending on the degree of accuracy required. At a certain date (beginning of the quarter, trimester), the measurements of all square corners are determined:

- H1 a, H1 b H1 g
- H2 a, H2 b H2 g
-
- H7 a, H7 b H7 g

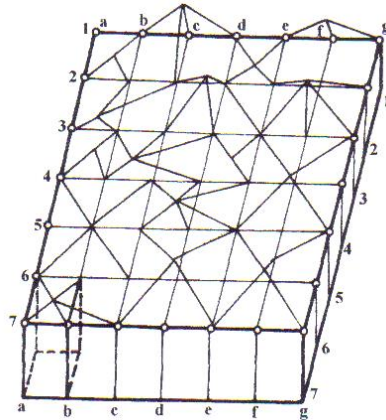


Figure 5 Mesh method

With the help of this method, the weighted average quotient of the quarry-bed (at the beginning of the quarter) is determined, taking into account the following coefficients:

$$P_c = \frac{1}{4}, \text{ for the corner points (1 a, 1 g; 7 a, 7 g);}$$

$$P_e = \frac{1}{2}, \text{ for the exterior sides points (1 b, 1 c, ..., 2 a, 2 g; 3 a, 3 g, 7 b; t c, ..., t f);}$$

$$P_m = 1, \text{ for the corner inside the mesh points (2 b, 2 c, ..., 2 f, 3 b, ..., 3 f, 6 b, ..., 6 f).}$$

The average measurements will be obtained using the relation:

$$H_{mp} = \frac{P_c \sum H_c + P_e \sum H_e + P_m \sum H_m}{n_c P_c + n_e P_e + n_m P_m} \quad (11)$$

$n_c = 4$, $n_e = 20$ and $n_m = 25$ – the number of interior and exterior corner points.

$$H_{mp}^i = \frac{\frac{1}{4}(H_{1a} + H_{1g} + H_{7a} + H_{7g}) + \frac{1}{2}(H_{1b} + H_{1e} + \dots + H_{7f}) + 1(H_{2b} + \dots + H_{6f})}{4 \cdot \frac{1}{4} + 20 \cdot \frac{1}{2} + 25 \cdot 1} \quad (12)$$

A similar procedure is applied to determine the average measurements for the end of the quarter: H_{mp}^s .

The exploited depth will result as a difference between the two values:

$$H = H_{mp}^i - H_{mp}^s \quad (13)$$

The volume obtained for a period of time is given by the relation:

$$V = N_p \cdot S_p (H_{mp}^i + H_{mp}^s) \quad [m^3] \quad (14)$$

where:

N_p = the number of squares; S_p = the surface of a square.

✚ Photogrammetric methods

Photogrammetry represents the science that deals with the determination in time and space of fixed, mobile or deformable objects and their photographic, graphic or numerical representation based on photographs (FILIP ET AL., 2016), (HERBEI ET AL., 2016).

Data for photogrammetry are collected by using drones or UAVs (Unmanned Aerial Vehicle - UAV). The drone or the pilotless plane (UAV) is an aerial device that is remotely controlled: based on a predefined flight plan / route or a remote control. These are equipped with sensors, GPS and have a high-resolution or infrared camera with which they record more photos. These can be georeferenced using the ground control points and ultimately a high-resolution orthophotomap. Also, with the help of specialized software, you get the digital model of the field or a “cloud of points”.

The applications of photogrammetry can be:

- topographical measurements and the realization of: ortophotomaps, digital terrain model, raster images (POPESCU ET AL., 2016);
- volumetric calculations (SMULEAC ET AL., 2012), (SMULEAC ET AL., 2017)
- the inspecting of power lines, gas, bridges, dams;
- the monitoring of national parks;
- the monitoring of forests;
- the monitoring of crops;
- the monitoring of archaeological sites.



Figure 6 The orthophotomap of the area studied with the help of UAV

RESULTS AND DISCUSSIONS

In order to carry out the work for the determination of the volumetric calculations, a topographic elevation was carried out using the WGS 1984 projection system, in order to draw up the situation plans according to the technical norms in force, coordinated which were later transformed with the TransDat4.0 program in stereographic coordinates 1970, and the level reference system being the BLACK SEA 1975 (HERBEI, 2013), (HERBEI AND ULAR, 2011).

The RTK kinematic method was which used in real time differential correction from the ROMPOS specialized service also helped in the finalization of this paper (GLONT AND FILIP, 2017).

The Leica 1200 GPS was also used to complete the work. The data processing was done with the help of the Leica Geo Office Combined software, after which, the calculated points were reported in AutoCAD to help draw the situational plan.

Surface calculation was performed from an analytical point of view

In this paper we used:

- Situational plan, scale 1:1000;
- Mapping plan in the area, scale 1: 2000, 1: 10000.

The permanent GNSS stations used for these measurements are the Resita and Moldova Noua Station.

The coordinate trans-calculation of the ETRS'89 reference system in the Stereo system'70 was realized with the TransDat 4.01 software produced by A.N.C.P.I. The set of transformation parameters link the reference system to the ETRS89 coordinate system (GRS80 ellipsoid) and the national reference system S-42 (Krasovski 1940 ellipsoid).

The ellipsoidal coordinates that can be transformed with the help of these programs are those obtained by connecting to the Class A national geodetic network (RGN), without necessarily staying triangulation points.

Thus, the precision of transformation of new points depends largely on the current situation of the number and arrangement of points with common coordinates on the national territory.

From a planimetric point of view (coordinates X and Y), the precision is met, all points were obtained with an accuracy of 2-4 cm, below the required value (5 cm on coordinates X and Y).

From the altimetric point of view, the measurements obtained using GPS measurements have also met the required value, being also in 3-5 cm.

The points resulting from their transformation with the help of the WGS 1984 system into the STEREOGRAPHIC reference system 1970, were reported in Autocad in order to merge the points and prepare the situational plans and to make the volumetric alloys for different heaps marked with V1, V2, V3, V4, V5, V6, V7, V8 and V9.

In order to realize topographical surveys, the following operations were carried out:

- Land Recognition;
- GPS (Global Positioning System) measurements using the RTK (Real Time Kinematic) kinematic method using the reference station from Resita and Moldova Noua;
- Downloading the instrument with Leica Geo Office Combined;
- Gross data processing;
- The use of the software TransDat 4.0 to transform the WGS'84 (World Geodetic System) into the 1970 Stereogram System;
- Data processing and volumetric calculations using specialized programs;

- The importing of points in Autocad with TopoLT;
- Joining the points and drafting the situational plan, as well as calculating the high surface area in square meters.

Coordinate system: this paper was drafted in the STEREOGRAPHIC Projection System 1970 and using the level reference system BLACK SEA 1975.

Volume calculated with specialized program:

- Terrain minimum measurement = 220.619m
- Terrain maximum measurement = 292,330m
- Base surface = 28930mp
- Volume = 379.972mc

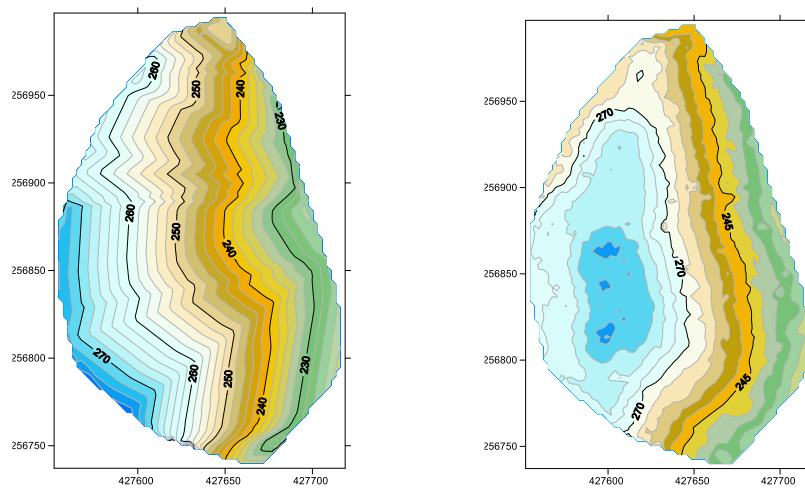


Figure 7 2D Model

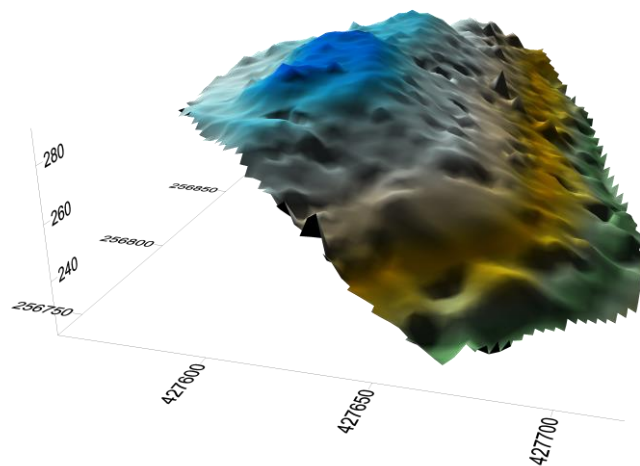


Figure 8 3D Model

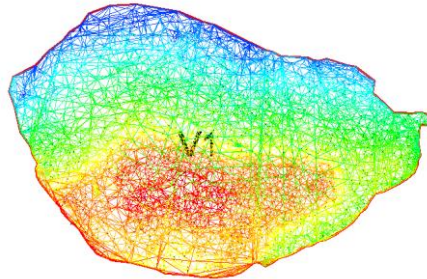


Figure 9 TIN Structure

CONCLUSIONS

The use of drones in topography is an addition to classical measurements using the total station or GPS, but adding more information to delivered products. Thus beneficiaries can be delivered the following: punctuation cloud, plane level plan, orthophotomap, digital model of DTM terrain, volumes etc. The advantage of using drones in topography is: high speed in obtaining results, realizing measurements in dangerous areas: swamps, very large stocks or dangerous materials, high accuracy.

BIBLIOGRAPHY

- FILIP, O. L., GLONȚ, D. C., & DIMA, N. (2016). Lidar by measurements monitor the movement of surfaces. *International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & mining Ecology Management*, 2, 391-396.
- FILIP, O. L., RISTACHE, A., & DIMA, N. (2016). Methods used to represent the mining objectives. *International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & mining Ecology Management*, 2, 427-433.
- GLONȚ, C. D., & FILIP, L. O. (2017). The alternative use of various measurement methods for surface movement tracking. *Annals of the University of Petrosani Mining Engineering*, 18.
- HERBEI, M. V., HERBEI, R., SMULEAC, L., & SALAGEAN, T. (2016). Using Remote Sensing Techniques in Environmental Management. *Bulletin UASVM series Agriculture*, 73,(2).
- HERBEI, M. V., POPESCU, C. A., BERTICI, R., SMULEAC, A., & POPESCU, G. (2016). Processing and Use of Satellite Images in Order to Extract Useful Information in Precision Agriculture. *Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca. Agriculture*, 73(2).
- HERBEI, M., HERBEI, R., DRAGOMIR, L., & SMULEAC, A. (2013). The analysis of cartographic projections used in Romania. *Research Journal of Agricultural Science*, 45(2), 127-136.
- LUPU-DIMA, L., & FILIP, L. (2012). Error propagation of the sizes measured in mine working. *Revista Minelor/Mining Revue*, 18(2).
- POPESCU, G., POPESCU, C. A., HERBEI, M., & SMULEAC, A. (2016). Measuring the parameters that influence the phenomenon of displacement and deformation of the ground at Mina Livezeni. *Research Journal of Agricultural Science*, 48(1).
- SMULEAC, A., HERBEI, M., & POPESCU, C. (2012). Creating the digital terrain model of the USAMVB area using modern technology. *Research Journal of Agricultural Science*, 44(3), 282-287.
- ȘMULEAC, A., NEMEȘ, I., CREȚAN, I. A., NEMEȘ, N. S., & ȘMULEAC, L. (2017, October). Comparative Study of the Volumetric Methods Calculation Using GNSS Measurements. In *IOP Conference Series: Materials Science and Engineering* (Vol. 245, No. 5, p. 052020). IOP Publishing.
- HERBEI, M., & ULAR, R. (2011). *Întocmirea și redactarea hărților și planurilor topografice*, ed. Dalami, Caransebeș. ISBN 978-973-1717-42-5.