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RESERVES ESTIMATION OF A MARBLE QUARRY USING QUALITY INDICATORS

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INTRODUCTION

- The reserves estimation procedure discussed in this paper concerns the Platanotopos quarry of Iktinos Hellas SA
- Similar procedures are applied to the other quarries of the company.
- Specialised mine planning software (Maptek Vulcan Quarry Modeller) was used in all estimation and reporting stages.
- Data was provided by Iktinos Hellas SA personnel, including samples quality characterisation.
- A technical report was issued on behalf of Iktinos Hellas SA

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LOCATION

MARBLE QUALITY CLASSIFICATION

- Marble quarry reserves are based on marble quality categories, almost unique for each quarry/deposit considered.
- These categories represent visual and physical aspects of marble such as colour, texture and fractures.
- Classification of marble to one of the categories is performed by experienced personnel and is based on samples much smaller in area than the blocks of marble which are potentially exploited.

APPLICATION OF MINE PLANNING SOFTWARE

- The use of standard estimation and modelling software tools in estimating marble quarry reserves poses a number of challenges.
- The available information is mostly qualitative leading to further complications in the application of geomathematical estimation methods.
- The estimation of marble reserves described in this paper is based on interpolating quality indicator values from drillhole and quarry face samples to blocks in three dimensions.

PRODUCTION DETAILS

- Given the geological, mineralogical, and climate characteristics and the quarrying equipment of the quarry, production is scheduled for 7000-10000m^3 per annum (life of the quarry is estimated at 15 years).
- Marbles extracted are known as Golden Spider and are characterised as fine grain white dolomitic marble with spider net red-yellow fractures, filled with iron oxides and hydroxides.
- They present very good physical and mechanical properties and can take very fine polishing.

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GOLDEN SPIDER

QUALITY CHARACTERISATION – COLOUR, TEXTURE, AND DEFECTS

- Quality grading of Golden Spider marble is initially based on colour and in the following categories: G - Golden, Y - Yellow, R - Red.
- Grading based on spider texture is in one of 4 categories as described in the following table.
- Grading based on defects also leads to 4 categories.
- Combinations of all categories produces the final product classification.

QUALITY CHARACTERISATION – COLOUR, TEXTURE, AND DEFECTS

1	Classic Spider, even net, clear background (classic type)
2	Relatively even spider with local strong concentrations (logs), or unclearly constructed net (fuzzy spider) or uneven zones of dense/coarse net, (standard type)
3	Dense spider, or many continuous brown lines, (heavy type).
4	Absence of spider, many white parts or with minimum net, (white type)

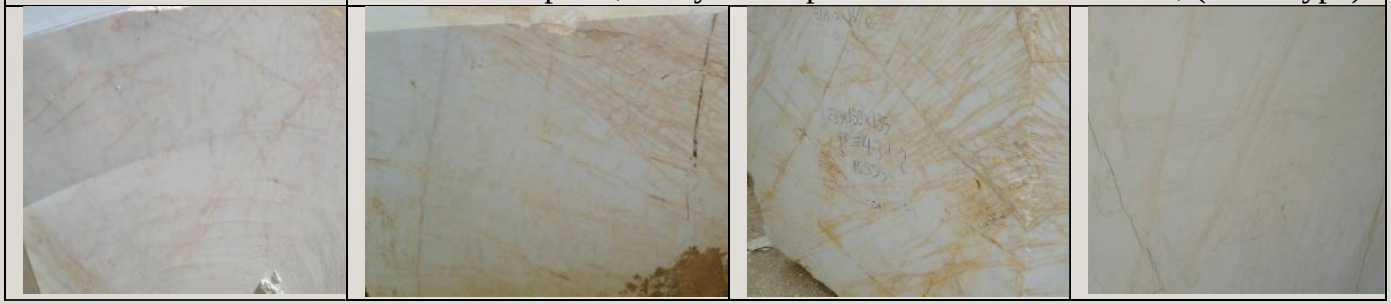
1	Solid volume with no evident defects or defects to less than 10% of each slab which is handled with a -3% or -6% discount
2	One or two defects up to 20-25% of each slab
3	Defects up to 30-35% of each slab
4	Defects up to 50% of each slab

Rectangular (Length >180, Height > 120)	1 - No defects	2 - Defects 25-35% of each slab	3 - Defects 25-35% of each slab	4 - Defects 35-50% of each slab
Classic type 1	1-1=A1	1-2=A2	1-3=AB	1-4=B
Standard type 2	2-1=A2	2-2=AB	2-3=B	2-4=BB
Heavy type 3	3-1=AB	3-2=B	3-3=BB	3-4=BB
White type 4	4-1=B	4-2=BB	4-3=BB	4-3=BB

QUALITY CHARACTERISATION – COLOUR AND TEXTURE EXAMPLES

1	Classic Spider, even net, clear background (classic type)
	
2	Relatively even spider with local strong concentrations (logs), or unclearly constructed net (fuzzy spider) or uneven zones of dense/coarse net, (standard type)
	

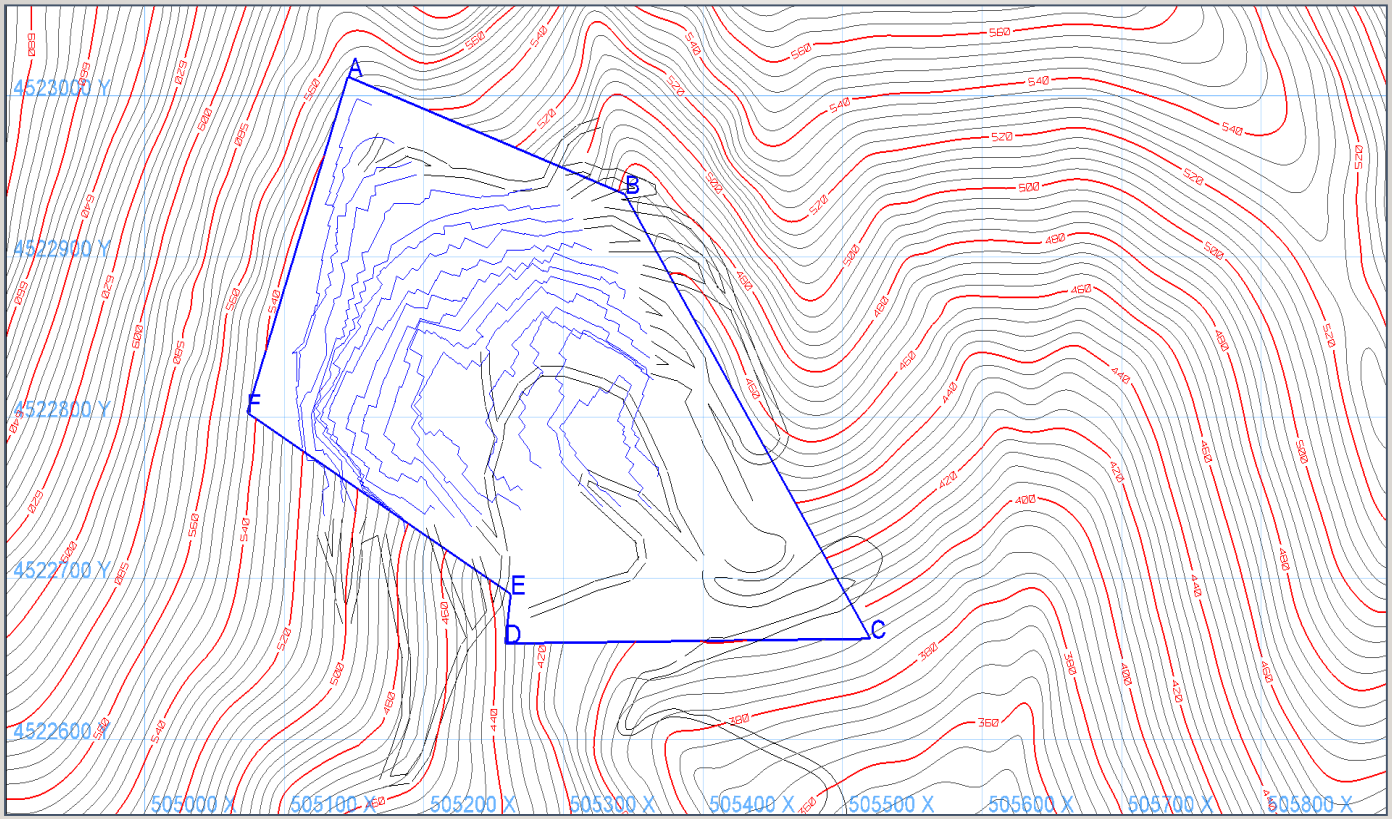
QUALITY CHARACTERISATION – COLOUR AND TEXTURE EXAMPLES

3	Dense spider, or many continuous brown lines, (heavy type).
	
4	Absence of spider, many white parts or with minimum net, (white type)
	

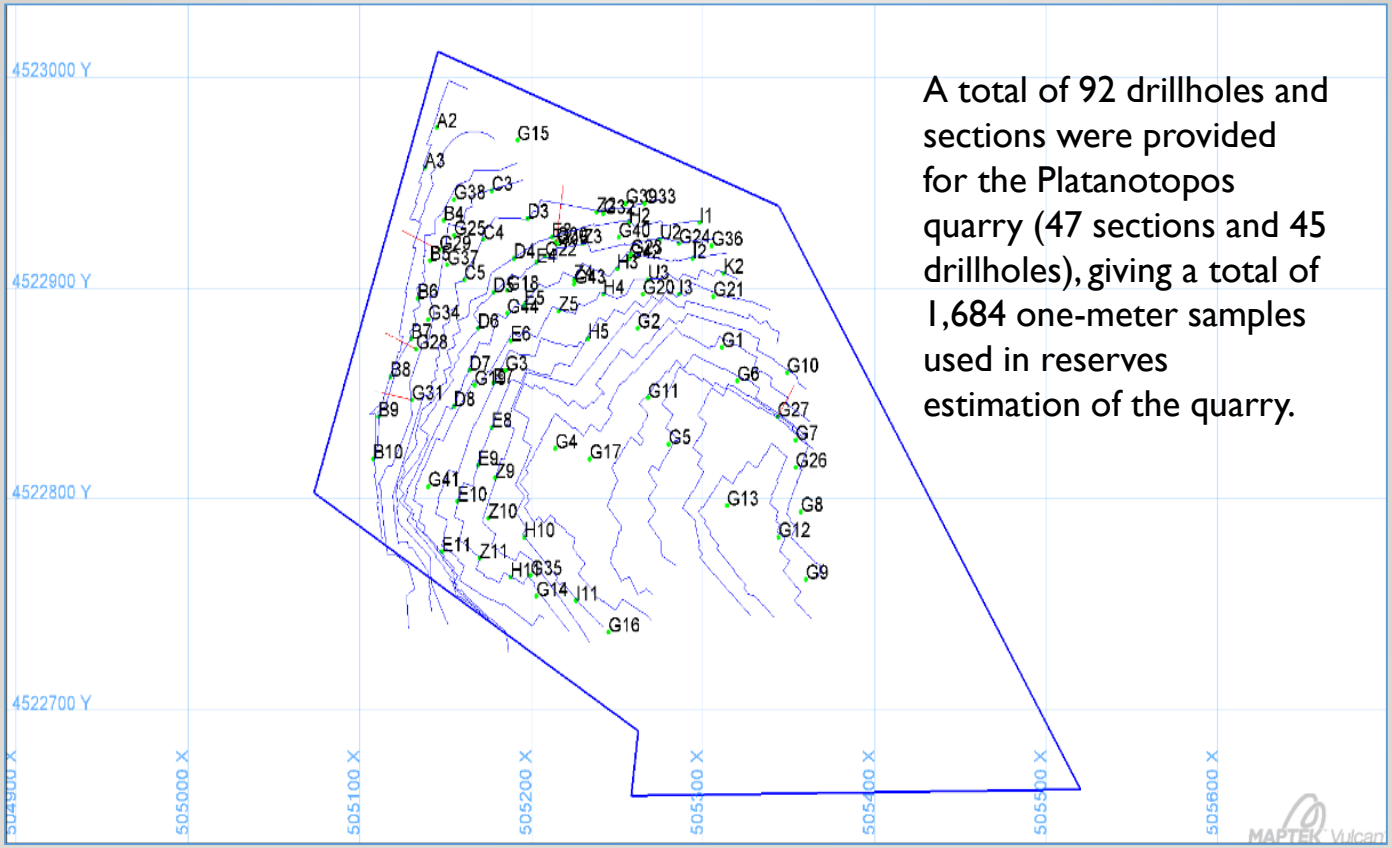
RESERVES ESTIMATION DATA

- Data included the original as well as the current topography of the quarry area based on the quarrying activities up to the date of the study.
- It also included diamond drillhole samples and sections on quarry faces, which were analysed per meter as to marble quality characteristics.
- Topographical data were provided in AutoCAD™ (DWG, DXF) file format and were imported to Maptek Vulcan Quarry Modeller software and stored to appropriate layers.
- Drillhole data were provided in Microsoft Excel™ file format and were imported to specialised samples databases in Maptek Vulcan Quarry Modeller.

TOPOGRAPHICAL DATA



DRILLHOLE AND QUARRY FACE DATA



A total of 92 drillholes and sections were provided for the Platanotopos quarry (47 sections and 45 drillholes), giving a total of 1,684 one-meter samples used in reserves estimation of the quarry.

QUARRY VOLUMETRIC MODEL

- The estimated volume of the final excavation was designed per bench (level) starting from the existing quarry morphology.
- The design of each of the 16 benches was modelled as a solid triangulation which was used in reserves estimation.
- These solids were visually checked and validated using triangulation topology checks (self-crossing, opening, inconsistencies) to ensure that they can be used for valid volumetric calculations.

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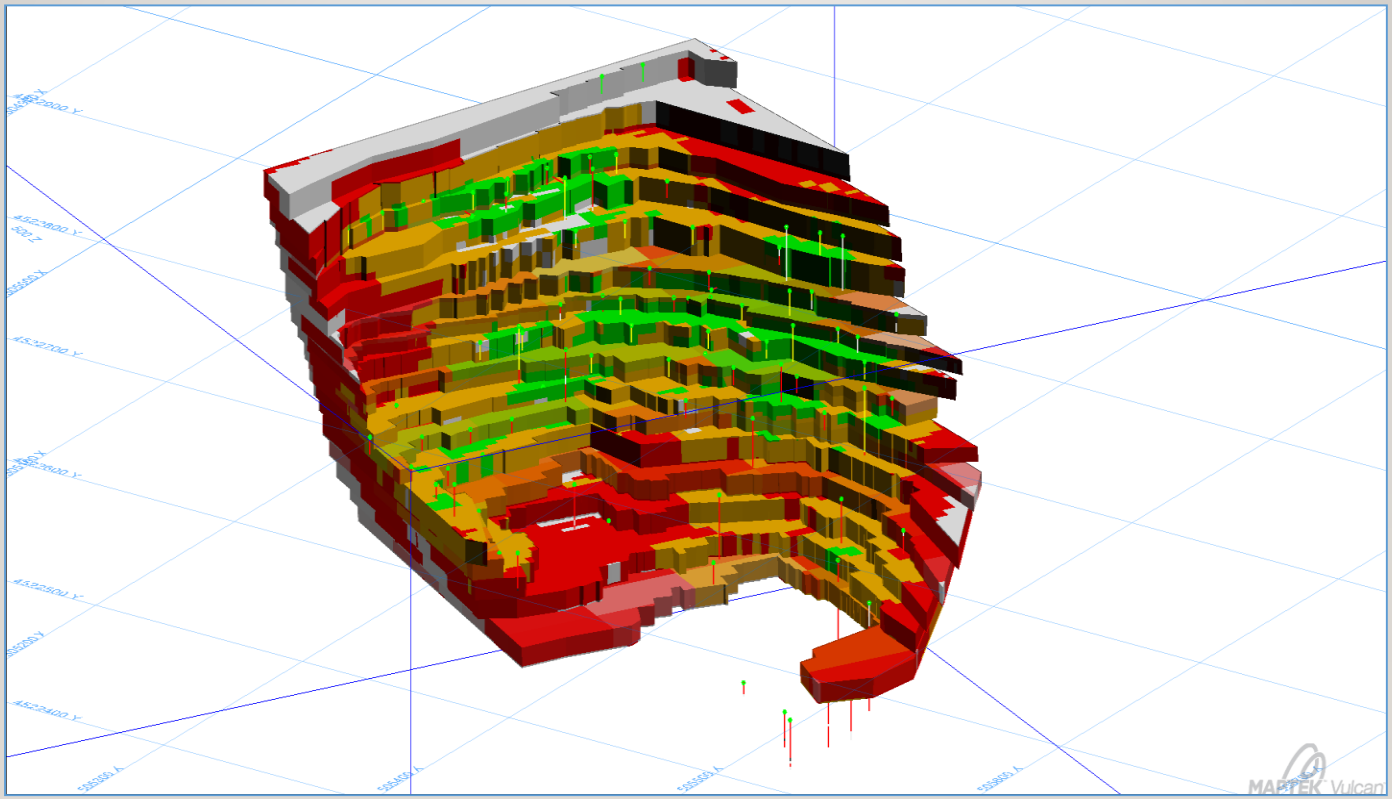
QUARRY VOLUMETRIC MODEL



SAMPLES DATABASE PROCESSING

- All samples were classified for lithology, colour, texture, fractures and defects.
- Fields were added to represent the membership of each sample to one of the final product categories (A1, A2, AB, B, BB and W).
- These received a value of 0 or 1 depending on the following logic:

Condition	Field	Equation
LITHO == "SPIDER" AND SPTYP == 1 AND BACKRO == 1	A1_PR	1
LITHO == "SPIDER" AND ((SPTYP + BACKRO) == 3) AND A1_PR == 0	A2_PR	1
LITHO == "SPIDER" AND SPTYP == 2 AND BACKRO == 2 AND (A1_PR + A2_PR == 0)	AB_PR	1
LITHO == "SPIDER" AND (SPTYP == 3 OR SPTYP == 4) AND BACKRO == 1 AND (A1_PR + A2_PR + AB_PR == 0)	B_PR	1
LITHO == "SPIDER" AND BACKRO < 4 AND SPTYP < 5 AND (A1_PR + A2_PR + AB_PR + B_PR == 0)	BB_PR	1
	W_PR	1 - A1_PR - A2_PR - AB_PR - B_PR - BB_PR

SAMPLES DATABASE PROCESSING - EXAMPLE

DHID	FROM	TO	LITHO	COLOUR	SPTYP	BACKRO	SYNOXH	A1_PR	A2_PR	AB_PR	B_PR	BB_PR	W_PR
G11	0	1	SPIDER	RED	2	3	2	0	0	0	0	1	0
G11	1	2	SPIDER	RED	2	1	1	0	1	0	0	0	0
G11	2	3	SPIDER	RED	1	1	1	1	0	0	0	0	0
G11	3	4	SPIDER	RED	1	1	2	1	0	0	0	0	0
G11	4	5	SPIDER	RED	1	2	1	0	1	0	0	0	0
G11	5	6	SP+GN	RED	1	2	3	0	0	0	0	0	1
G11	6	7	SPIDER	RED	1	2	3	0	1	0	0	0	0
G11	7	8	SPIDER	RED	1	2	2	0	1	0	0	0	0
G11	8	9	SPIDER	RED	1	2	1	0	1	0	0	0	0
G11	9	10	SPIDER	RED	1	1	1	1	0	0	0	0	0
G11	10	11	SPIDER	RED	1	2	3	0	1	0	0	0	0
G11	11	12	SPIDER	RED	1	2	2	0	1	0	0	0	0
G11	12	13	SPIDER	RED	1	2	1	0	1	0	0	0	0
G11	13	14	SPIDER	RED	1	1	2	1	0	0	0	0	0
G11	14	15	SPIDER	RED	1	1	2	1	0	0	0	0	0
G11	15	16	SPIDER	RED	1	3	2	0	0	0	0	1	0
G11	16	17	SPIDER	RED	1	2	2	0	1	0	0	0	0
G11	17	18	SPIDER	RED	1	1	1	1	0	0	0	0	0
G11	18	19	SPIDER	RED	1	1	2	1	0	0	0	0	0
G11	19	20	SPIDER	RED	1	3	1	0	0	0	0	1	0
G11	20	21	SPIDER	RED	1	2	2	0	1	0	0	0	0
G11	21	22	SPIDER	RED	1	1	2	1	0	0	0	0	0
G11	22	23	SPIDER	RED	1	2	3	0	1	0	0	0	0
G11	23	24	SPIDER	RED	4	3	3	0	0	0	0	1	0
G11	24	25	GNEUSIOS	BL	5	5	4	0	0	0	0	0	1

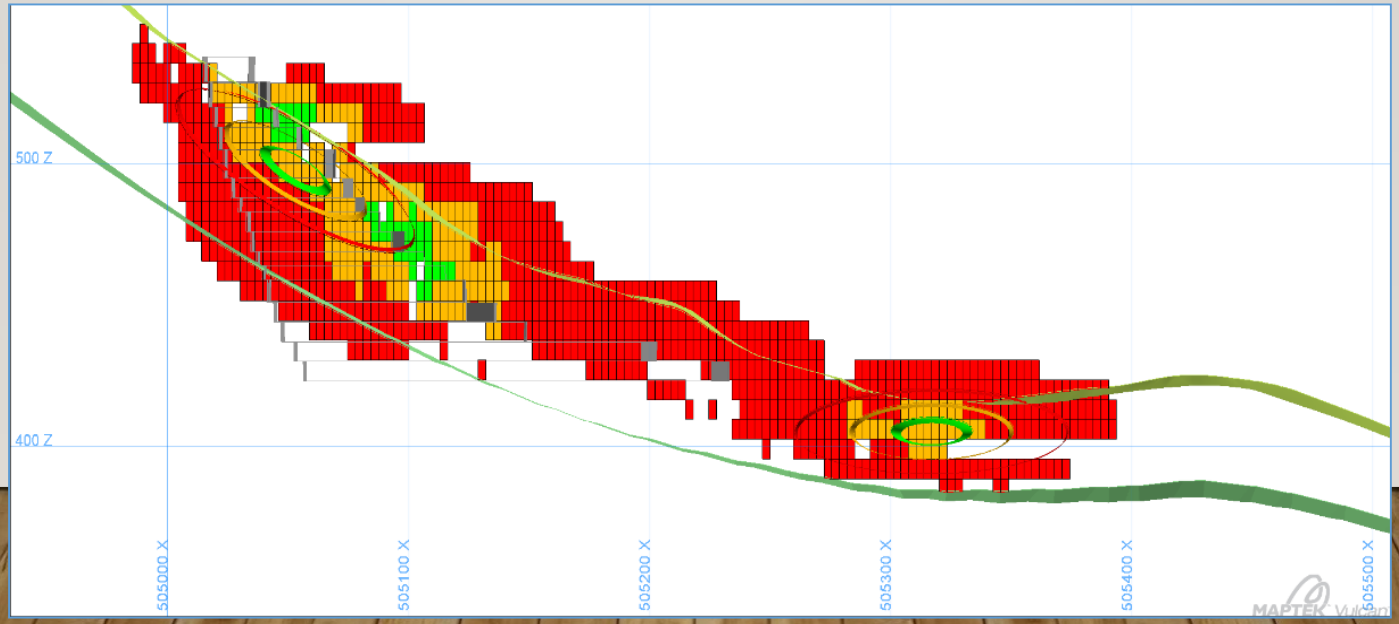
QUALITIES ESTIMATION

- Interpolation of quality class field values was performed using the inverse distance squared method as implemented by Maptek Vulcan Quarry Modeller software on the basis of a block model.
- The estimated volume was divided in blocks of the same size.
- Block dimensions were configured based on the marble volumes that are extracted separately at the given quarry.
- In each block, the percentage of each marble quality was estimated.
- Samples are selected around each block using search ellipsoids which are oriented according to the geological features of the particular deposit.

Origin	X	505,460
	Y	4,522,340
	Z	290.5
Model size	X	582
	Y	728
	Z	350
Block size	X	6
	Y	2.8
	Z	7
Orientation	X-axis azimuth	28
	X-axis rotation around Y-axis	0
	Y-axis rotation around X-axis	0
Block count		1,261,000

UNFOLDING

- Block estimation in Platanotopos quarry was different to the other quarries as the ellipsoids had different orientation in each block due to the folding of the deposit.
- Thus, a special function of the software was used before estimation that calculates the appropriate ellipsoid orientation for each block, taking in to account reference surfaces that define folding.



FROM RESOURCES TO RESERVES

	Measured (Proved) Reserves	Indicated (Probable) Reserves	Inferred In-Pit Resources	SYNOXH
Major Axis (m)	15	30	50	50
Semi-major Axis (m)	15	30	50	50
Minor Axis (m)	5	10	15	10
Azimuth	Variable	Variable	Variable	330
Plunge	Variable	Variable	Variable	0
Dip	Variable	Variable	Variable	70
Minimum Number of Samples	8	8	4	4
Maximum Number of Samples	20	20	20	20
Maximum Samples per Drillhole	4	4	4	4
Blocks estimated	1342	9754	26259	37355

- The modifying factors for converting marble resources to reserves include the limitation of resources inside a technicallly feasible excavation as designed by the company's personnel (mining and legal factors), inside the exploitation license limits (legal, environmental and governmental factors).
- Classification based on the three categories of mineral resources was performed during three stages of block estimation, using ellipsoids of different dimensions and different sample count requirements

RESULTS

		Measured (Proved) Reserves (m^3)			Indicated (Probable) Reserves (m^3)			Inferred In-Pit Resources (m^3)				
Bench	Elevation	A	AB	B	A	AB	B	A	AB	B	Waste	Total
P11	423	296	227	242	2,753	8,229	14,236	4,443	18,843	27,146	130,896	207,312
P10	430	140	128	337	3,942	7,863	12,088	7,094	19,414	41,562	92,659	185,228
P09	437	43	68	51	3,402	11,166	16,313	5,460	21,649	39,272	68,859	166,283
P08	444	28	156	708	2,078	13,171	25,174	4,088	16,381	34,392	59,047	155,222
P07	451	204	1,993	4,101	2,590	12,393	36,991	4,506	11,370	32,786	59,560	166,494
P06	459	336	1,548	4,253	2,444	7,987	24,850	2,485	5,618	12,518	31,392	93,432
P05	464	600	1,718	5,871	2,405	7,263	25,625	2,194	5,335	12,740	26,246	89,998
P04	469	722	2,351	9,020	2,116	7,906	30,162	2,530	6,826	18,035	30,793	110,460
P03	476	771	2,019	8,445	1,059	5,642	28,002	1,554	7,095	20,281	26,147	101,015
P02	483	398	1,031	4,824	465	2,732	18,544	573	5,367	16,006	18,327	68,267
P01	488	227	644	5,839	443	2,927	22,082	277	5,568	23,672	25,995	87,676
P00	495	1	826	5,230	358	2,691	28,704	177	5,356	29,298	38,795	111,435
P-01	505	165	818	3,063	343	2,376	20,618	104	3,624	18,147	22,949	72,207
P-02	513	118	253	2,536	298	2,012	11,791	134	2,634	17,007	14,016	50,801
P-03	520	17	19	192	198	1,022	14,530	82	1,034	10,987	20,008	48,090
P-04	529				-	22	1,240	89	139	8,449	18,125	28,063
Total		4,068	13,801	54,713	24,894	95,402	330,951	35,790	136,251	362,299	683,814	1,741,983

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THANK YOU FOR YOUR ATTENTION