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RS78 – Block Ore and Waste

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POLYMET MINING CORP.

POLYMET

RS78

REPORT ON MINE BLOCK MODEL

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SUMMARY

This report summarizes the data support and steps involved in creation of the PolyMet block model, used to estimate resources and reserves, and to generate deposit geochemical data for water quality predictions.

INTRODUCTION

For a mineral deposit to become an ore body an integral part of the evaluation is the creation of a model (generally digital) which allows the estimation and assessment of grade (quantities of metal or other elements), and therefore value. This model must also quantify the confidence in the predictability of that grade at all locations within the deposit. This confidence categorization is derived from a consideration of a number of factors including geology, continuity of the mineralization, mining method, known grade values (i.e., drill hole samples), and the distances from known samples to the block being estimated. As a measure of predictability, this goes well beyond geologic confidence and is the foundation of the resource and reserve categories needed for project financing.

PolyMet operates under Canadian National Instrument 43-101, which is a standard for reporting on mineral development projects. This standard references the Canadian Institute of Mining (CIM) “Estimation of Minerals Resources and Mineral Reserves, Best Practice Guidelines” (2003). Under this guidance, deposits (or parts of deposits) are classed as resource or reserves. A resource is a mineral deposit that has a <u>reasonable chance</u> of being mined at a profit, a reserve is a resource that has been assessed to the “bankable feasibility” stage and is <u>shown</u> to be minable at a profit. The definitions of resources are further broken down to Measured, Indicated, and Inferred, based on their statistical and geologic confidence. PolyMet also uses a fourth category, “in-fill”, to be sure that the entire model has a value at each block based on available information. Reserves may be either Proven or Probable. Measured Resources may be classified as Proven Reserves and Indicated Resources may be classified as Probable Reserves if they meet economic and technical criteria determined by the Feasibility Study. (see Table 1)

The resource and reserve categories for a particular deposit are dynamic over time as geologic interpretation or assay data densities change (i.e., using information from further exploration or development drilling or from changes in the geologic understanding of the deposit). Nor are they strictly fixed by the above guidelines, which leave the final decisions up to the “Qualified Person” (or Persons) responsible for the estimation.

Table 1. Showing relation between Resource and Reserve

	Higher ← Statistical and Geological Confidence in Grade Values → Lower			
Resources	Measured	Indicated	Inferred	In-fill
Reserves	Proven	Probable	Not recognized as reserve	Not recognized as reserve
PolyMet Modelling Confidence Category	1	2	3	4

Block modelling is the defacto standard method of resource estimation for most metal mines, particularly open-pit mines. This is due in large part to the fact that sophisticated pit optimization software requires a block model as input. *Pit optimization* is the process of defining a pit shell (i.e., an imaginary hole in the ground without regard to roads and some other design factors) that encompasses the greatest net present value of ore. *Pit design* is the process of establishing roads, sumps, and scheduling of the extraction of the ore in a safe fashion that matches the tonnage and grade required by the plant to produce a final product. This design work is done to best fit the optimized pit shell. See Figure 1 for a view of an economic pit shell derived from optimization software, and the resulting pit design needed to extract the ore in a safe and efficient manner.

Other less used or older resource estimation methods include polygonal-manual, gridded seam models and triangulation.

A block model is best described as a three dimensional array of regularly spaced data points. By virtue of the spacing between these data points, each point represents a specific volume of rock. This volume of rock is the "block". This data array is populated from drill hole data to represent the chemistry (or other quantitative properties) of the ore deposit and from a geologic model to represent the lithology. This allows prediction of the grade at any point. Because the density of the rock is known (either averaged or modelled) block tonnage can also be calculated. In simple terms, this modelling is the 3-D version of the 2-D gridding and contouring done in many software programs (i.e., Surfer, ArcView).

MODELLING PROCESS STEPS

The entire block modelling process for grade is a method of translating or modelling irregularly spaced drill hole based assay data to a regular 3-D array of data points. However, this is not a purely mathematical process carried out in a vacuum, but must be done in the context of what is known of regional and local geology so that the model is a reasonable representation of the geology and geochemistry of the deposit.

The general process of populating a block model follows a sequence of:

$ Collection and verification of drill data. This includes qualitative (primarily lithologic and mineralogic information obtained by geological logging of the drill core); quantitative (assays, density, rock strength, percent of sample recovered and other information); and spatial data such as drill collar location, angle of drill hole, and azimuth. In PolyMet's case all historical data was re-compiled and verified in 2004 with data generated since then undergoing rigorous quality control prior to inclusion in the database. Figures 2 and 3 show the top of the Virginia Formation and all drill holes, colored by geologic unit and sampling respectively.

$ Use of lithologic and structural geology data to construct a digital geologic model. This can be done directly in the computer or by digitizing hand drawn cross-sections (PolyMet's model was done in the computer with extensive reference to paper sections). To be valid, this digital model needs to honor as much definitive data as possible, such as surface topography, depth to bedrock, outcrop location, and drill hole intercept points to well defined horizons or contacts.

The geologic model of the deposit is created by generating a series of surfaces representing the tops of geologic units. These unit tops include the boundaries between units, and also include the ledge (top of bedrock) surface. These surfaces are based on cross-sections at one-hundred foot spacing across the deposit. Cross-sections are parallel to the geometry of the block model. See Figures 4 and 5 for examples of these 3-D surfaces.

$ Compositing of quantitative data. Drill hole data is generally recorded in intervals measured downwards from the top of the hole. Very often different types of data will be measured on different intervals. For instance, rock type changes may be measured in irregular intervals from inches to many feet, or major lithologic units may be intervals hundreds of feet in length (i.e., reflecting the true nature of the geology) whereas assay or geotechnical information may be measured in regular (five or ten foot) intervals. Compositing of drill hole data is the process of applying a weighted average of these data into discrete and regular intervals. Often, the composites at the edge of the geologic units will have their length adjusted so that they do not cross geologic boundaries. Composites are not used (forced to null) if their "support", or amount of actual sample within the interval, does not exceed a certain percentage of the composite length. It is also important to note the difference between a zero value and a null value. Zeros are used in calculation; nulls are treated as if the data point did not exist.

$ Variography. This is the geostatistical evaluation of the data to quantify two important variables in the modelling process: 1) spatial continuity-the safe distance that assays can be projected in order to realistically represent a model of the grades in the rock mass, in other words, "what is the meaningful sample spacing"? and 2) isotropy / anisotropy, which determines if the continuity of mineralization is the same in all directions, or whether it is longer in one direction (eg along strike) than another (eg down dip). These are important variables that have a direct input into evaluating the adequacy of the drilling density and also the next steps of the modelling process.

The variography compares pairs of samples at larger and larger distances and graphs this variation against distance which will, at some point, define the distance beyond which the grades cannot be accurately projected. These numbers may not be directly used, but are an important consideration in the overall estimation.

$ Selection of Search Ellipse. The information from the variography is used in determining the optimum size and shape of the "search ellipse". During the grade estimation process each block is assigned data from the nearby drill hole composites. The search ellipse is the distance along a set of X, Y, and Z axis' within which samples can be used in estimation. The center of the ellipse is the centroid of the block being estimated. The distance is directly related to data confidence in that direction. The ellipse axis' may be tilted to conform with geologic parameters (i.e., dipping rock units or structural zones).

If the data were fully isotropic, the search ellipse would be a sphere; if the data are anisotropic, the search ellipse may be longer in the direction of the strongest continuity and shorter in the direction of the least continuity. See Figure 6 for an image of a search ellipse.

$ Creation and Assessment of Domains. As part of the process described above, it is necessary to assess the geologic continuity of mineralization for estimation purposes. In particular, it is important to assess whether or not the mineralization follows clear geologic controls (i.e., unit boundaries or structure), is independent of these controls, or some combination of the above. A number of separate geological / geochemical domains were defined for purpose of deposit modeling at NorthMet. Firstly, two mineralized domains were defined, Domains 1 & 6. Domain 1 is the main zone of mineralization and occurs mainly in Unit 1 though may extend into the base of Unit 2. Domain 6, the Magenta Zone, occurs higher in the Duluth Complex in Units 4 – 6 and cross-cuts the upper units in the west half of the deposit. Secondly, the dominantly unmineralized domains were defined. These consist of the Virginia Formation and the unmineralized portions of Units 1, and 2 through 7.

$ Geologic coding of block model. Geologic unit is assigned to the block model by selecting all blocks between two surfaces. For example, all blocks between the top of Unit 1 and top of the Virginia Formation are coded as Unit 1. At the boundaries, the unit coding of the block is assigned based on the percentage of the block lying on one side or the other of the bounding surface. Once all blocks are given a geologic attribute, that attribute can be used to determine which blocks in the model the estimation routines are acting upon. See Figure 7 for a cross-section of the geology at NorthMet, and Figure 8 for the same image with the block model superimposed on the geology.

$ Interpolation of values into model. During the interpolation process, a subset of blocks is chosen for estimation, then the software sequentially finds the centroid of a block, and using criteria such as number of holes and number of composites within the search ellipse distance, assigns a value (essentially a 3-D weighted average) to that block based on surrounding samples. If the criteria cannot be met for number of holes or number of samples within the search radius, the block will be passed over by the first interpolation run. Once all blocks in the model have been done for a set search radius, the radius is expanded and the routine is run again, filling in some, but not all blocks with a value. Blocks already assigned a value are ignored in subsequent passes.
For the PolyMet model, with 5 domains, each domain has a separate interpolation run

resulting in 4 categories of confidence that generally correspond to Measured, Indicated, Inferred, and “in-fill”. The “in-fill” category is used to ensure that each block in the model has been assigned a grade value though these grades are not used to report resources. Each domain thus requires four estimation passes for each the six valuable elements (Cu, Ni, Co, Pt, Pd, & Au) as well as for elements of process and environmental significance (eg S, As, Cd, Mo, etc).

See Figure 9 for a cross-section at NorthMet with confidence blocks superimposed on geology, and Figure 10 for a section with Net Metals Value (NMV) superimposed on the geology.

USE OF BLOCK MODEL

Once the model is populated with grade and other data, it is generally output to other software for pit optimization and mine design. This requires some assumptions about metals prices, grade or value cut-offs, and mining costs. The blocks are assigned a value based on metals price. The optimization software “virtually” mines the deposit from the top downwards-those blocks above cut-off being classed as ore, those below cut-off as waste. This is done through many iterations and the highest value scenario is then investigated for practicality as a mine design.

Once a pit is designed, the blocks within the pit can be assessed by grade, the measured and indicted resource blocks within the pit may be classified as proven and probable reserves. Data can be output to other programs for assessment. Figure 11 shows 3-D Top of Virginia Formation, 20 year pits, Unit 1 blocks above cut-off grade, and the Magenta Zone (a zone of continuous mineralization in the upper units) as a transparent solid.

NORTHMET BLOCK MODEL PARAMETERS

The PolyMet block model parallels the deposit geometry, striking N56.06°E, with block size of 100 ft. by 100 ft. by 20 ft. high, there are 202 columns, 60 rows, and 56 levels (678,720 blocks). The current model stops at 500 ft. above sea level (about 1,100 ft. from surface). The overall model limits extend well beyond the expected mining area in all directions.

The 20-year pit shell includes about 41,000 blocks. Of these: 25% are in the measured category, 45% are in the indicated category, 18% are inferred, and the rest in-fill. The conversion to reserve can change these categories a small amount due to economic considerations.

Besides geochemical data, there are attributes stored in the block model for parameters such as geologic unit, density, year expected to be mined, distance to sample, ID of closest drill hole, number of samples used in interpolation, confidence ranking, and NMV.

Drill hole assay data (mostly five and ten foot samples) were composited to 10 foot samples along the drill hole (length weighted averages). The composited values as were used for estimation.

The metals expected to be produced at NorthMet (Cu, Ni, Co, Pt, Pd, and Au) were given values of close to zero where data was absent (based on examination of drill hole data for particular units). Where analyses returned results below detection limit a value of one-half the detection limit was used. This is normal practice to ensure conservatism in the resource evaluation. No copper, nickel, or cobalt values were below detection limits and hence no factoring was used in populating the model for these elements.

For the elements with potential effects on water discharge quality (S, Ag, As, Ba, Be, Cd, Cr, Mn, Mo, Pb, Sb, Zn) all values reported as less than detection limit were replaced with the detection limit value, then, all "not sampled" drill core intervals were assigned the average of the that data set. This is a conservative method in that it tends to raise the average value for compositing.

Each element was analyzed for spatial relations within each of the domains (variography) using the composited value. From that analysis, modeling geometry was established for interpolation of values into the block model.

The overall size of the search ellipse is related to the confidence ranking (measured, indicated, inferred, in-fill).

BLOCK MODEL DATA AND RAW DRILLING DATA

There are two data sets on rocks within the deposit - drill core and the block model. It is important to recognize that the process of going from irregularly spaced drill hole data to composites, and ultimately to a derived block model, tends to smooth out the grades. The highest values will be lowered and the lowest values will be raised. This makes sense because all samples are smaller than blocks-and block values are representative of the average of many samples-the average block value will always be lower than the highest composited drill core values. Table 2 shows how average and highest values for copper decrease in the process of going from raw data, to composites, to the block model.

Table 2. Comparison of raw data, composites, and block data. Note that this represents raw, composited and block model data within the 20-year pit. Because the pit is created after the block model there can be block data with higher values than the composites—the high-grade part of the pit was influenced by data from outside the pit, hence to higher maximum value for copper

	Min % Cu	Max % Cu	Avg % Cu
Raw drill hole data	0.001	4.89	0.20
10 foot composites	0.0013	2.2	0.183
Block model data	0.005	2.9	0.134

The NorthMet drill core data set consists of 310 drill holes divided into a total of 30,638 multi-element assay intervals. Each analyzed interval is also classified by geological unit and rock type. The drill core data set provides information (a measurement) only about the specific points in the pit that were drilled.

The block model was generated from the (composited) drill core data set using accepted geostatistical principles and knowledge of the geology of the deposit. Within the planned 20-year pit there are over 41,000 blocks (or parts of blocks) providing information (a prediction) at any point in the pit. The values in many of these blocks are derived from data points outside the pit. The resolution of the block model is the size of the blocks (100ft x 100ft x 20ft).

Each block has chemistry values (%S, %Cu, %Ni, ppm Co, ppb Pt, ppb Pd, ppb Au, ppm Ag, ppm As, ppm Zn, ppm Cd, ppm Pb, ppm Ba, ppm Be, ppm Cd, ppm Cr, ppm Mn, Pb, ppm Sb), tons and year mined. Each block is identified as "ore", "lean ore" or "waste rock" based on NMV. Each waste rock block is assigned a waste category based on sulfur content and copper / sulfur ratio.

BLOCK DATA USED FOR MINE PIT WATER CHEMISTRY

Pit water quality modeling requires input data on rocks that make up the surface of the pit wall, organized by elevation. The mine pit walls are divided into 60 ft vertical zones with the tops and bottoms of the zones corresponding to block midpoints. Each zone consists of the top half of a layer of blocks, two complete layers of blocks and the bottom half of a layer of blocks. The blocks that contact the pit shell within each zone are identified as edge blocks. Some edge blocks may contact wall and floor; some may only contact the shell across a very small area. The average of the chemistry values for the edge blocks in each zone is calculated. The planar (i.e., area looking down) area of each zone is calculated. This area is distributed to each Category of waste rock in a zone by multiplying the percent of the edge blocks in each Category in each zone by the total planar area for that zone. The result is a data set with area and chemistry by Category for the pit walls and floor in each elevation zone. This exercise is repeated for pit shells representing 1, 5, 10, 15 and 20-year pits. Figures 12 and 13 show the blocks touching the pit, and those that touch or are above the pit (note that the pit wall intersects the plane of the section at an oblique angle and that blocks that appear to not be touching the surface are touching in the third dimension.

The average chemistry of edge blocks and number of edge blocks in each zone and Category is also calculated for pit walls and floors that are in multiple pits to enable aging effects to be included in water quality predictions. For example, the 10-year pit includes some edge blocks that are also included in the 1 and 5 year pits and some edge blocks that are only in the 10-year pit. The square feet per block factor for each combination of pit and zone used to distribute total planar area can be used to estimate area based on the number of blocks.

BLOCK DATA USED FOR STOCKPILE CHEMISTRY

Stockpile drainage water quality modeling requires input data on rocks that are placed in each stockpile organized by year. The mining schedule shows what year each block of material will be moved. The Category of the block determines which stockpile each of the waste rock blocks will be placed in.

Chemistry of the rock placed in each stockpile each year is calculated as the average of the chemistry values of all of the blocks added to that stockpile during that year.

The total tons added to each stockpile each year is calculated as the sum of the tons all of the blocks added to that stockpile during that year.

ORE VERSUS WASTE CALCULATIONS

Blocks are sorted into ore versus waste categories based on the following steps and the different categories may have different handling requirements:

- Ore: greater than a target NMV. Because metal prices are set low in the modeling to provide a conservative economic model, the block NMVs may go higher during mining (i.e. lean ore could become ore).

- Lean ore, Category 4: NMV that may allow processing in future, sulfur content greater than 0.6. Because metal prices are set low in the modeling to provide a conservative economic model, the block NMVs may go higher during mining (i.e. lean ore could become ore and waste rock could become lean ore).

- Lean ore, Category 3: NMV that may allow processing in future, sulfur content less than or equal to 0.6. Because metal prices are set low in the modeling to provide a conservative economic model, the block NMVs may go higher during mining (i.e. lean ore could become ore and waste rock could become lean ore).

- Waste rock, Category 4: All of the Virginia Formation, large sedimentary inclusions, and all Duluth Complex waste rock with greater than 0.6% sulfur.

- Waste rock, Category 3: Duluth Complex waste rock only, with less than or equal to 0.6% sulfur and greater than 0.31% sulfur, or sulfur greater than 0.12% if the copper / sulfur ratio is more than 0.3.

- Waste rock, Category 1 / 2: Duluth Complex waste rock only, with less than or equal to 0.12% sulfur, and less than or equal 0.31% sulfur if copper / sulfur ratio is less than or equal to 0.3.

WASTE CATEGORIZATION SAMPLE COMPARISONS

Samples for waste characterization were selected from NorthMet drill core in 2005 based on knowledge at that time of the expected categorization of rock. Because sulfur is the main factor in determining rock disposition it is worth comparing these categorizations and their effect.

Table 3 below shows the sulfur values for raw drill core from the PolyMet database, values for the samples used in humidity cell tests, and the values for rock stockpiles defined by the results of these tests. Testing focused on the material with the widest range of compositions, hence the lower percentage of testing in the lowest sulfur rocks. It is important to note that the humidity cell test results are used in conjunction with extensive testing from MDNR and samples chosen are well grounded in the overall geology of the deposit. The data match is surprisingly good.

Table 3. Comparison of sulfur values in different data sets related to waste rock category. Note that drill data is not composited, i.e., not length weighted.

		Cat 1 / 2	Cat 3	Cat 3 Lean Ore	Cat 4	Cat 4 Lean Ore
Stockpiles	% of Rock	83.00	3.74	10.52	2.26	0.48
	Min % S	0.01	0.13	0.03	0.16	0.61
	Avg % S	0.08	0.22	0.23	2.37	0.88
	Max % S	0.31	0.60	0.60	4.75	3.19
Humidity Cell tests	Number of samples	49	12	7	13	8
	Min % S	0.02	0.14	0.15	0.68	0.75
	Avg % S	0.08	0.37	0.28	2.09	1.60
	Max % S	0.25	0.55	0.59	5.68	4.46
Drill core database	Number of samples	12,848	1,518	2,831	2,056	408
	% of Samples	65	8	14	10	2
	Min % S	0.01	0.13	0.01	0.01	0.61
	Avg % S	0.07	0.29	0.22	1.69	1.32
	Max % S	0.31	0.60	0.60	8.29	7.93

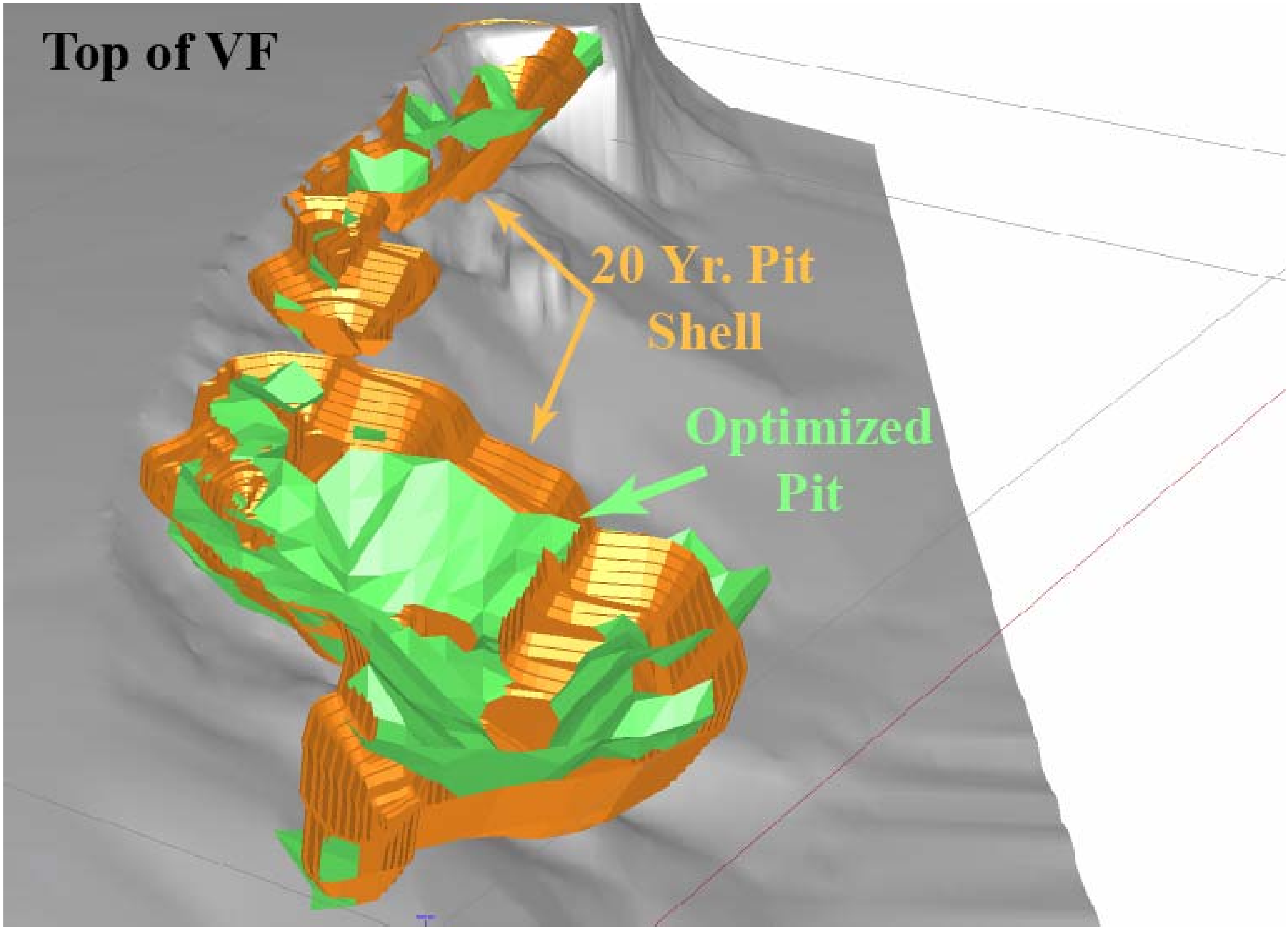

Figure 1: Gray = top of Virginia Formation, Green = Optimized pit shell, Tan / Orange = twenty year pit design built around that optimized shell, view looking ENE

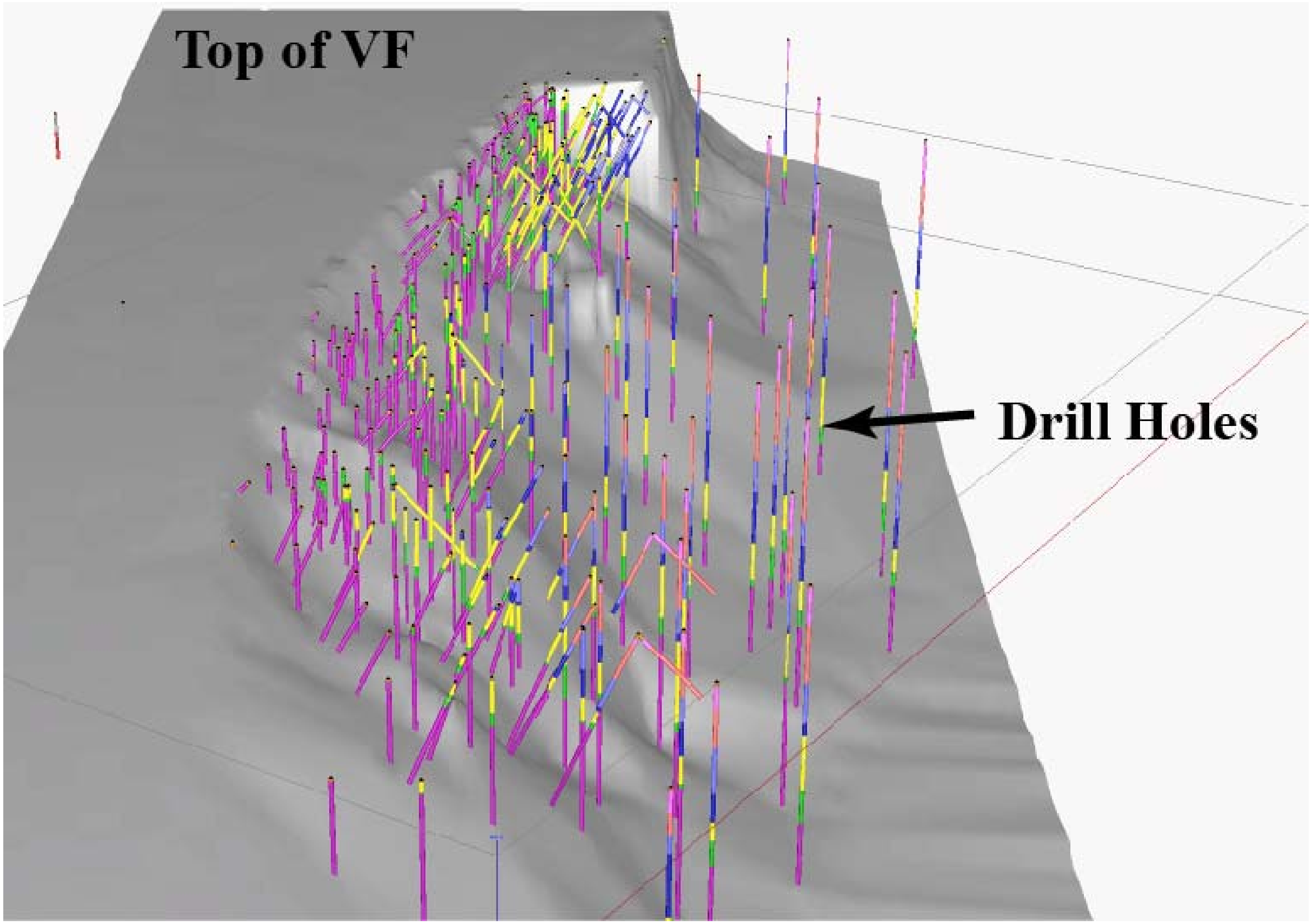

Figure 2: Top of Virginia Formation (gray), and drill hole coded by geologic unit, from bottom up, magenta = Unit 1, green = Unit 2, yellow = Unit 3, dark blue = Unit 4, light blue = Unit 5, pinkish-orange = Unit 6, light magenta = Unit 7. View is to ENE

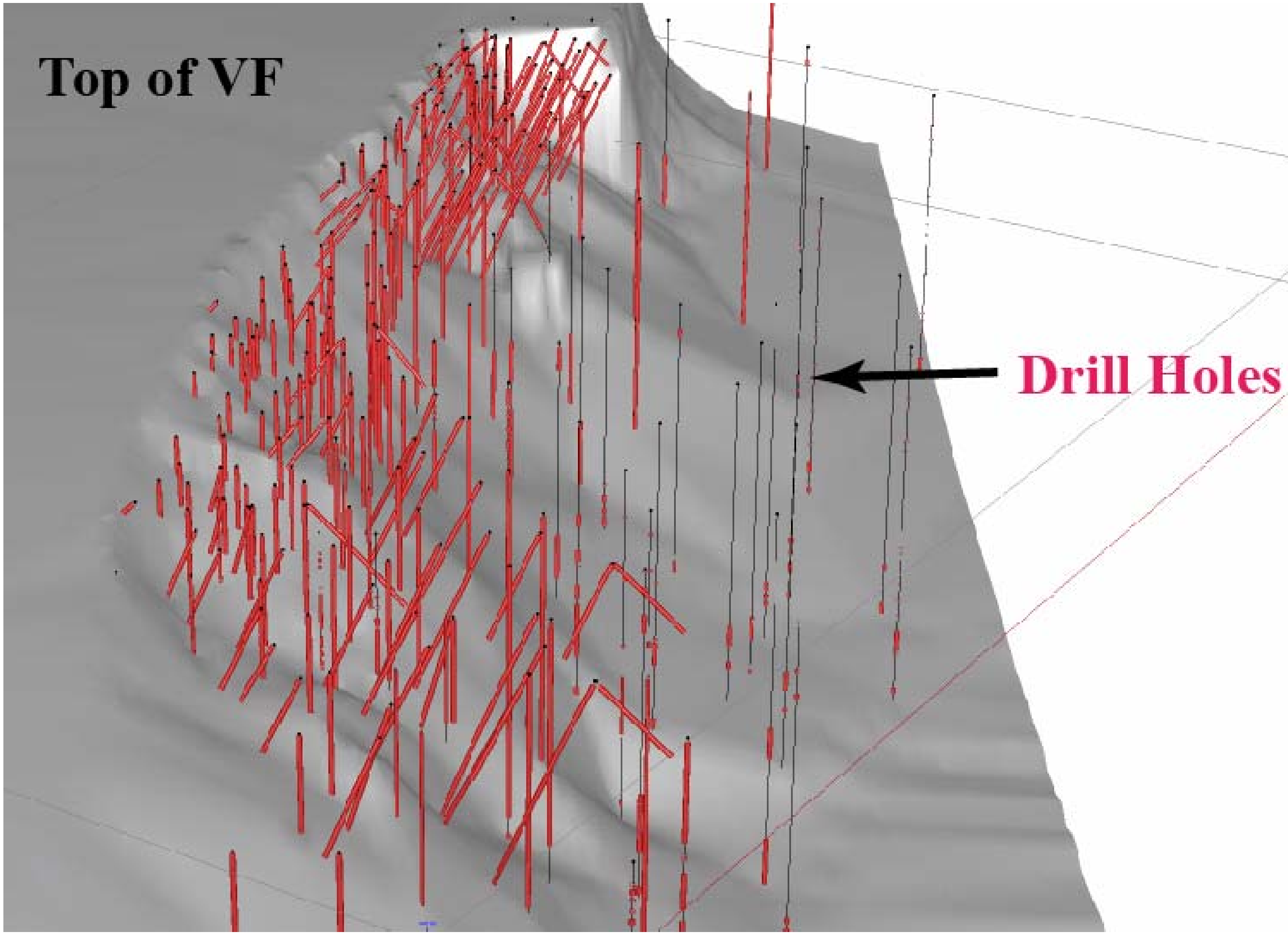

Figure 3: Top of Virginia Formation (gray), and drill hole coded by sampling. Red drill hole trace = sampled. View is to ENE

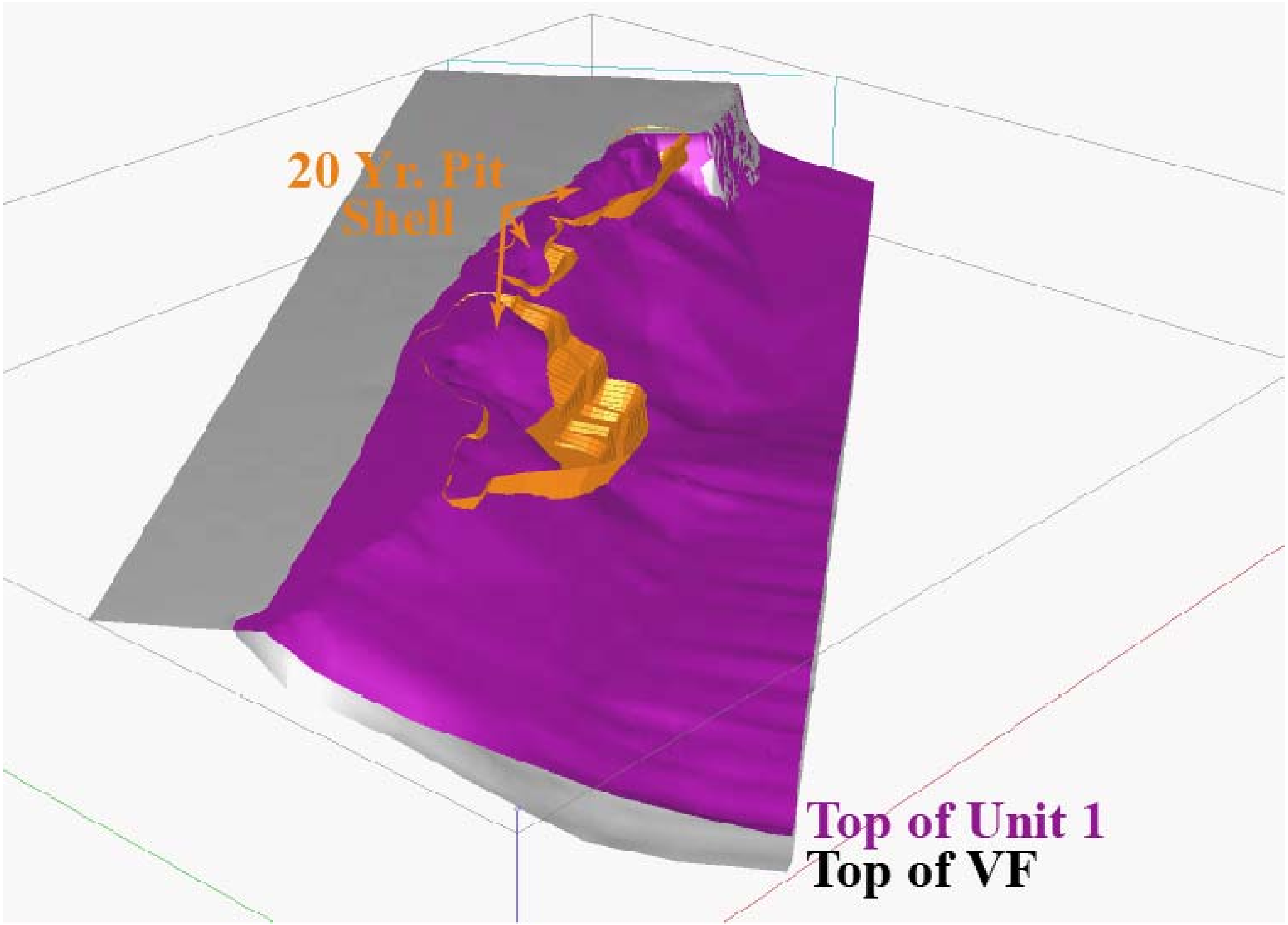

Figure 4: Example of model surfaces**,** Virginia Formation, Unit 1, and 20 year pit**.**

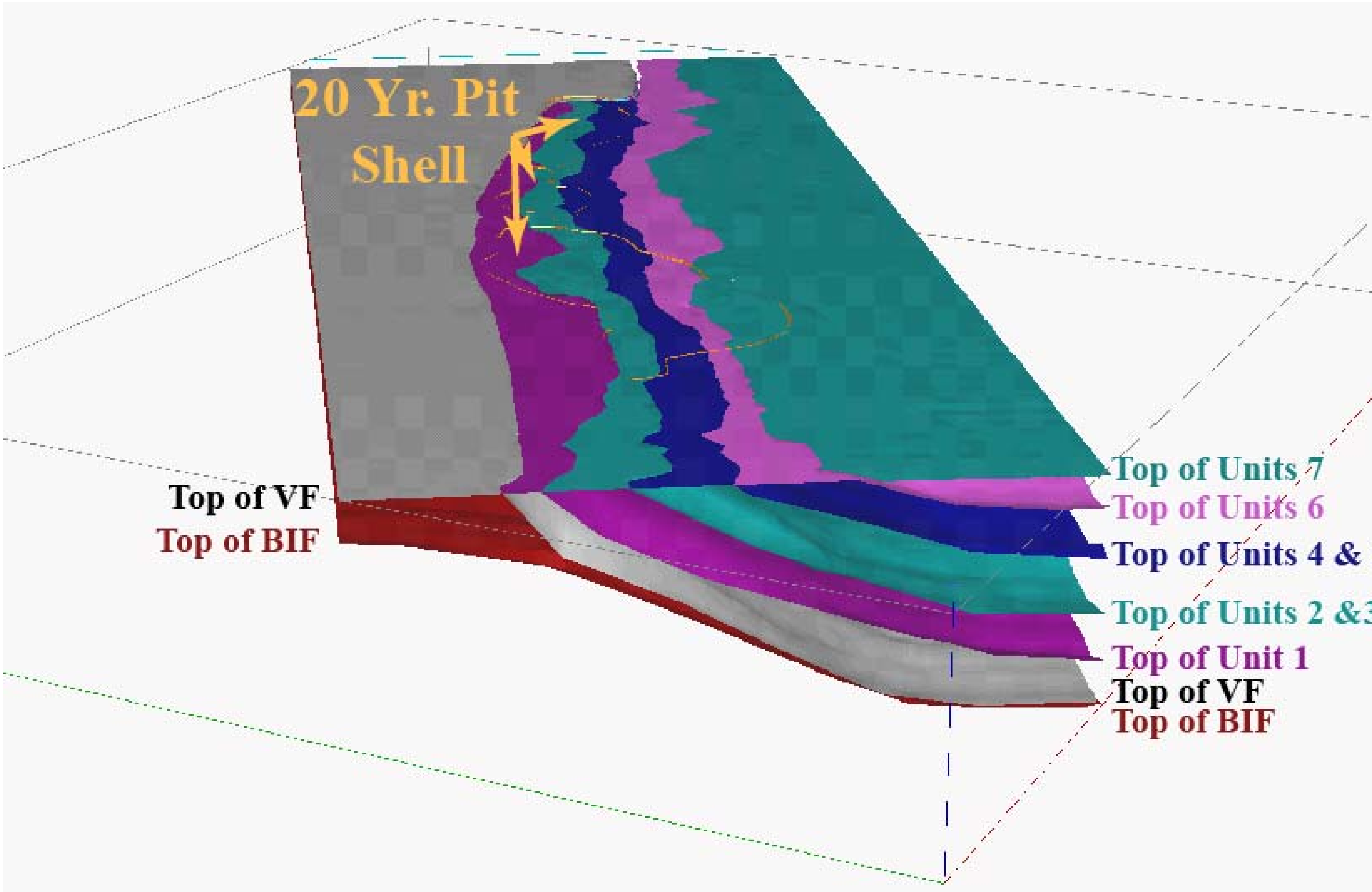

Figure 5: Example of modeled surfaces-all geology

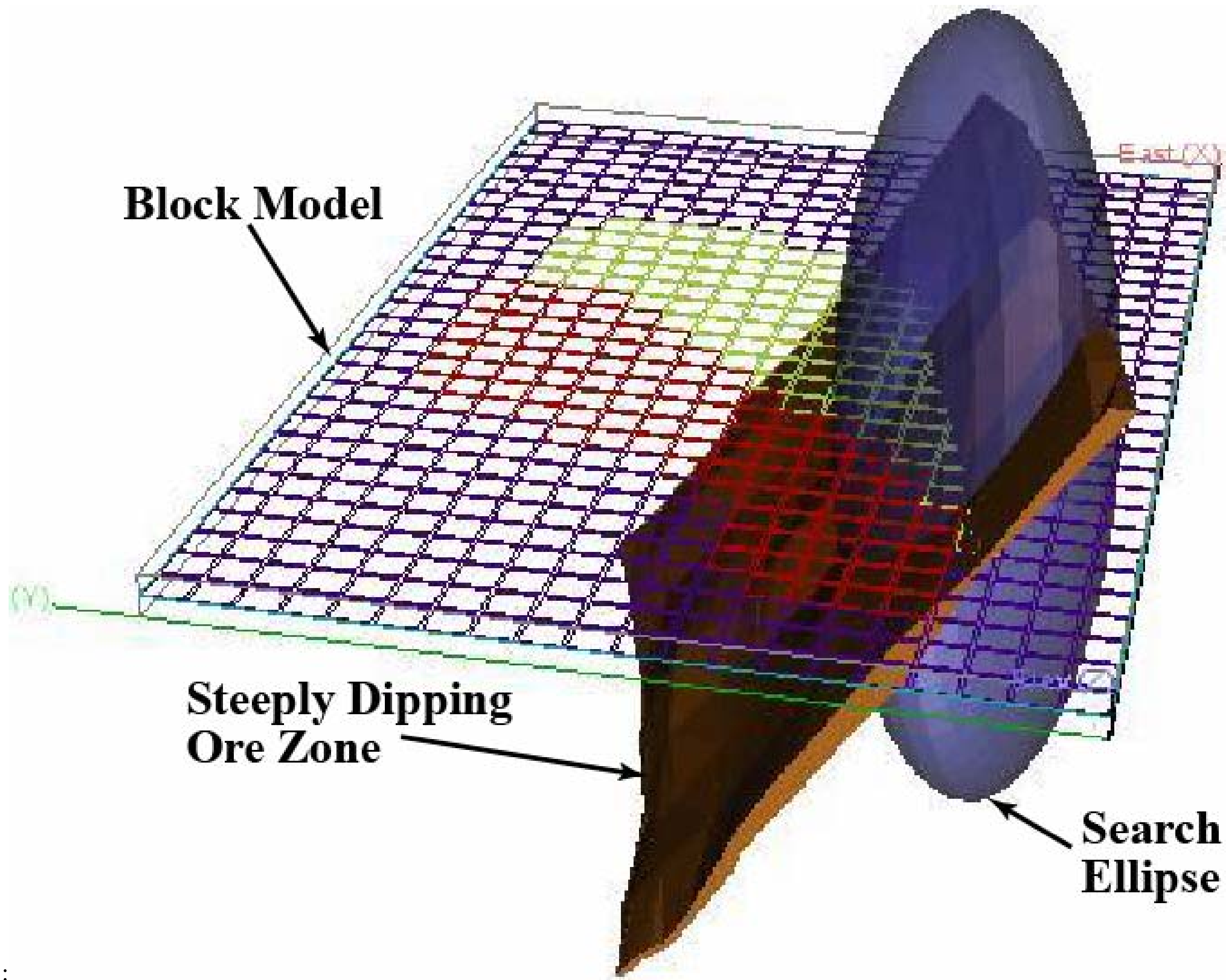

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Figure 6 Example of search ellipse and a relation to project geometry (not from NorthMet)

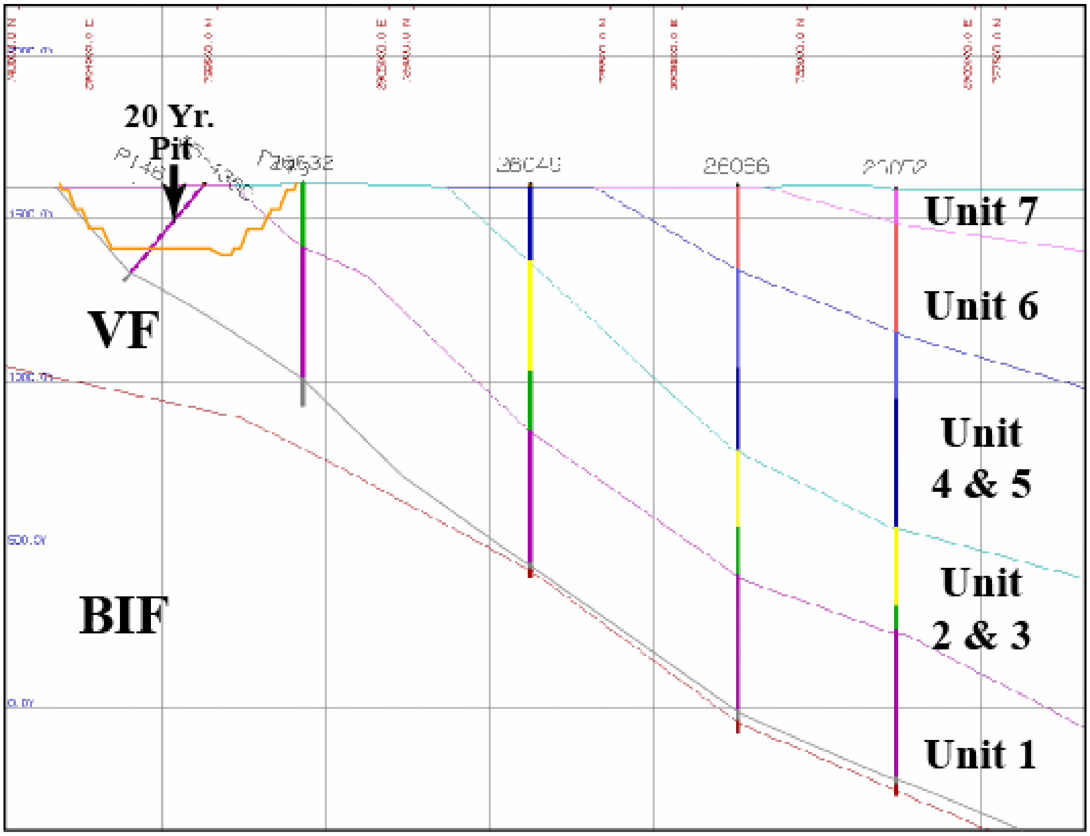

Figure 7: NorthMet geological cross-section-view to ENE. Note twenty year pit.

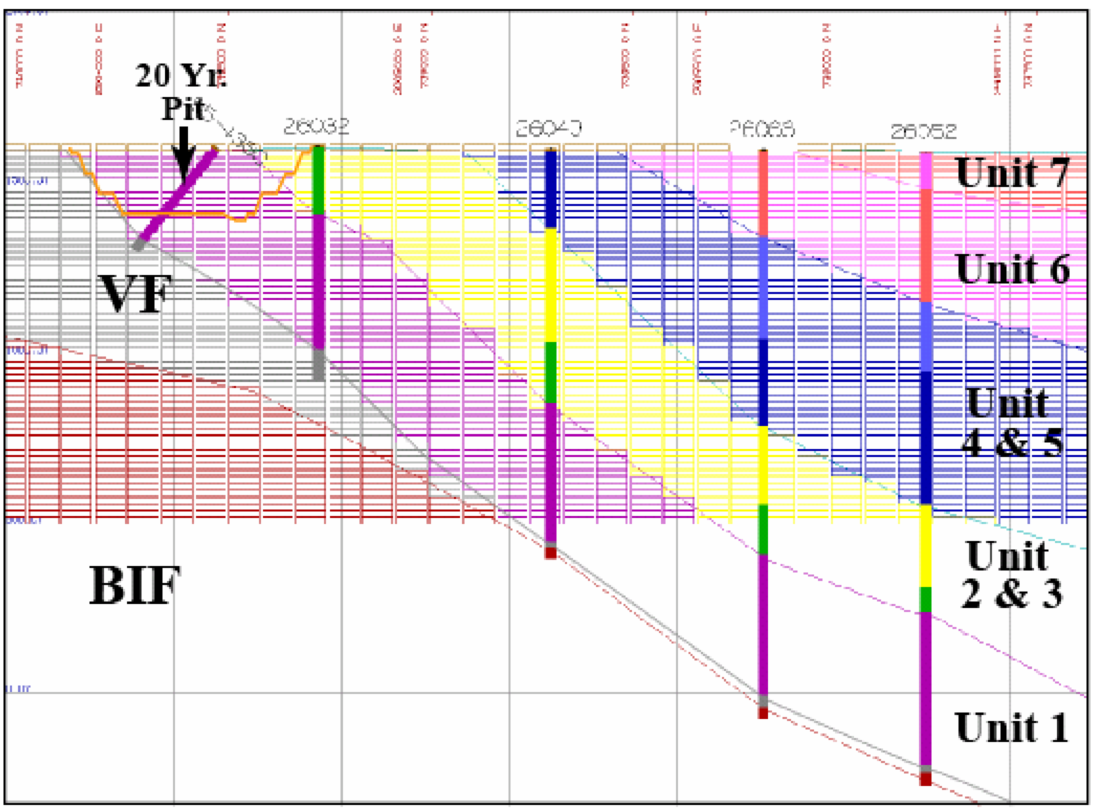

Figure 8: NorthMet geological cross-section-view to ENE, showing Unit block model. Note twenty year pit.

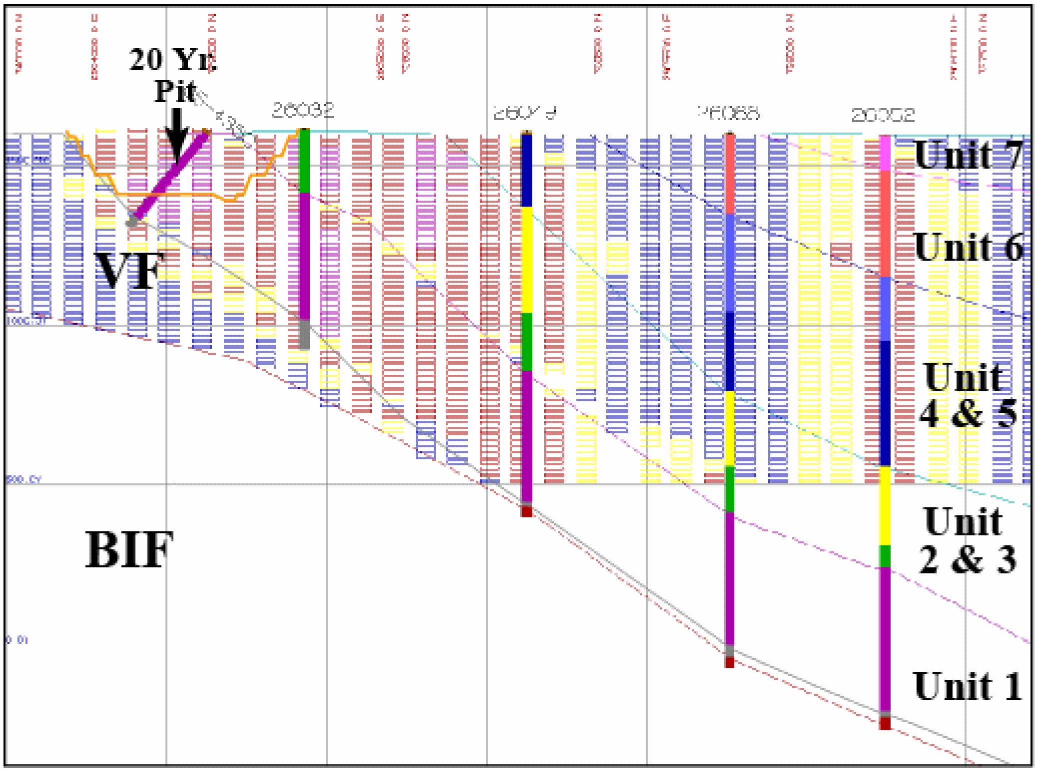

Figure 9: NorthMet block model resource categories superimposed on geologic section. Magenta = Measured, red = indicated, yellow = inferred, blue = in-fill. Note twenty year pit.

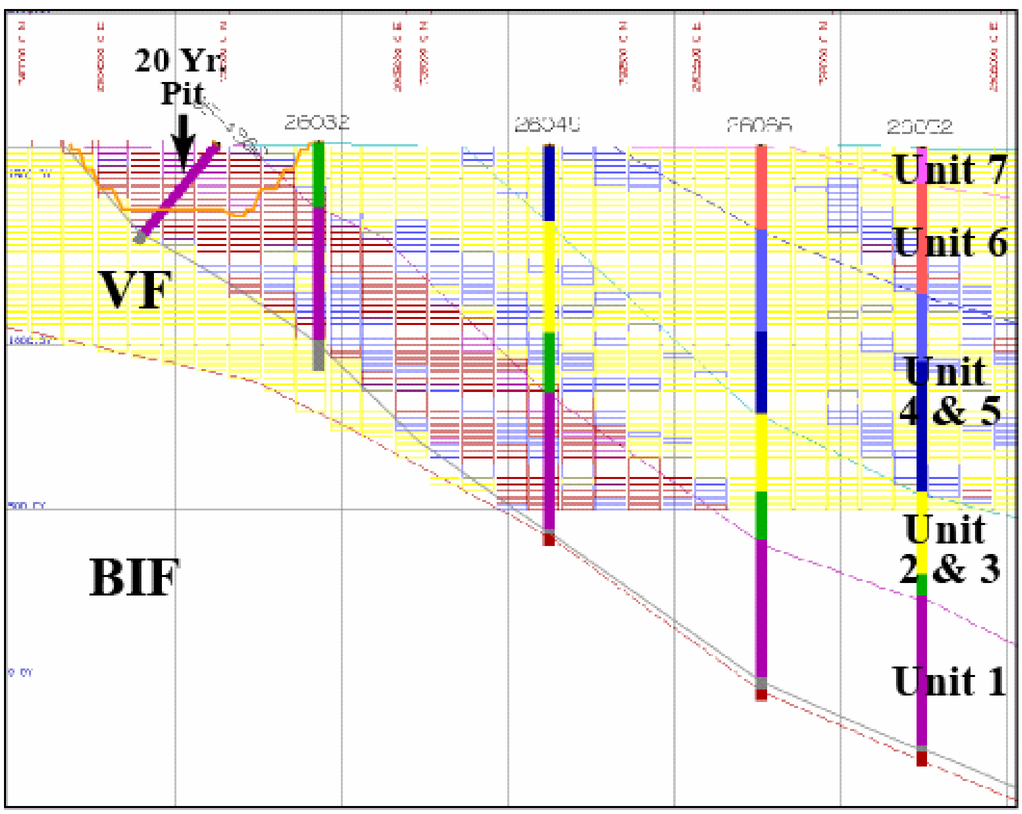

Figure 10: NorthMet grade categories superimposed on geologic section. Magenta and red = "ore", blue = "lean ore", yellow = "waste rock". Note twenty year pit

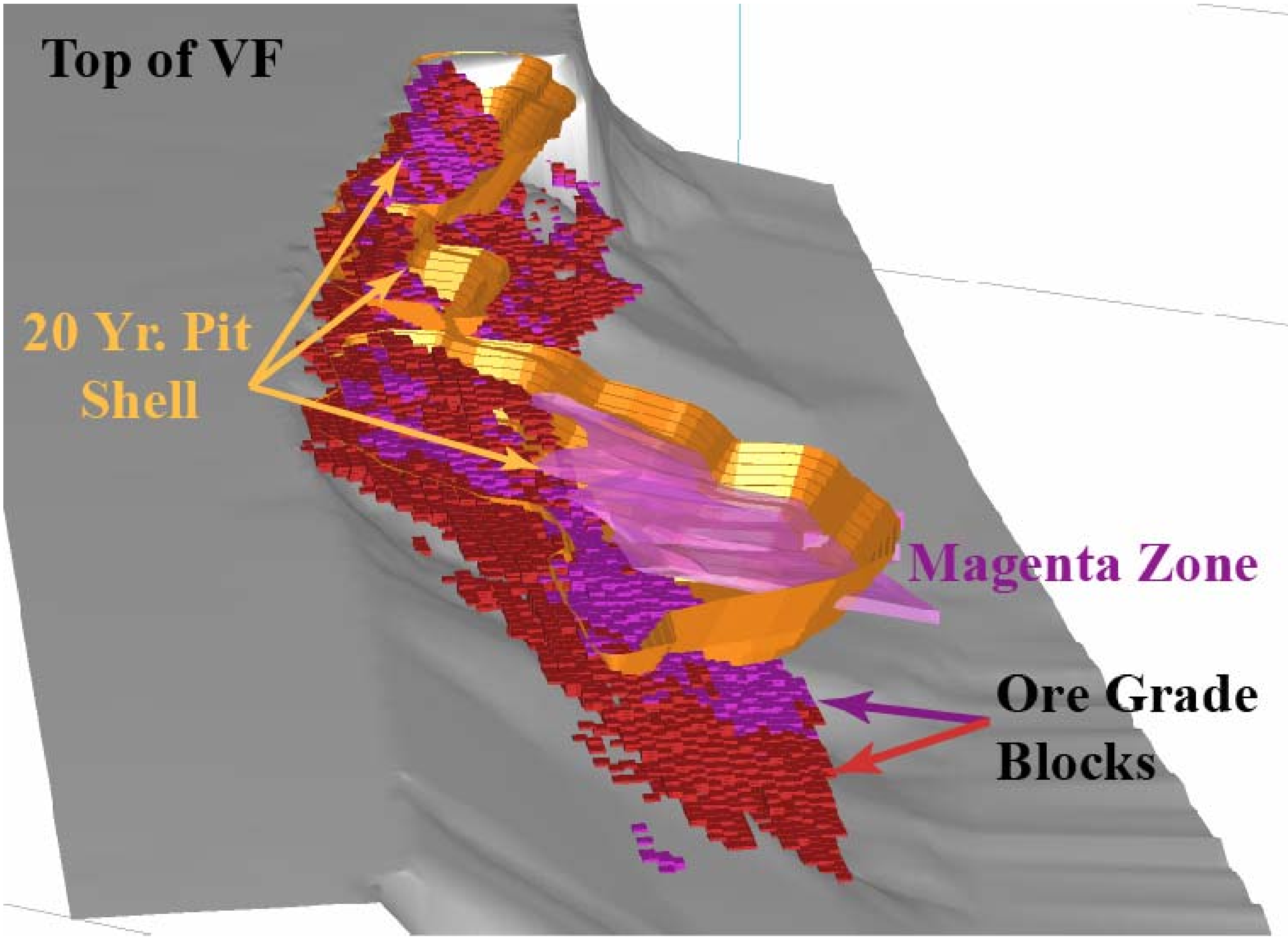

Figure 11: Top of Virginia Formation, Unit 1 blocks of “ore” grade, Twenty year pit, and Magenta Zone “solid”, view to ENE

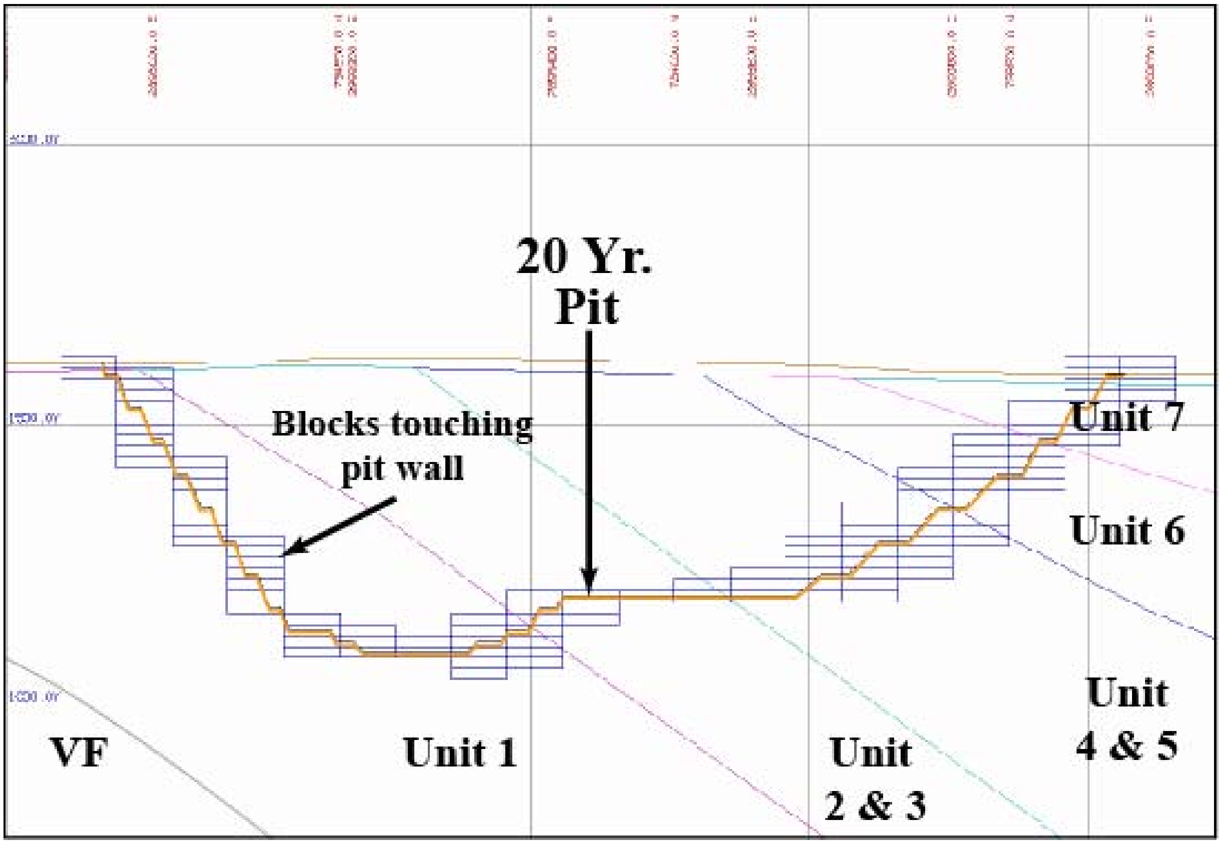

Figure 12: Cross-section showing blocks touching twenty year pit Note that blocks appearing to not touch pit are touching in the third dimension as pit intersects plane of cross-section at oblique angle.

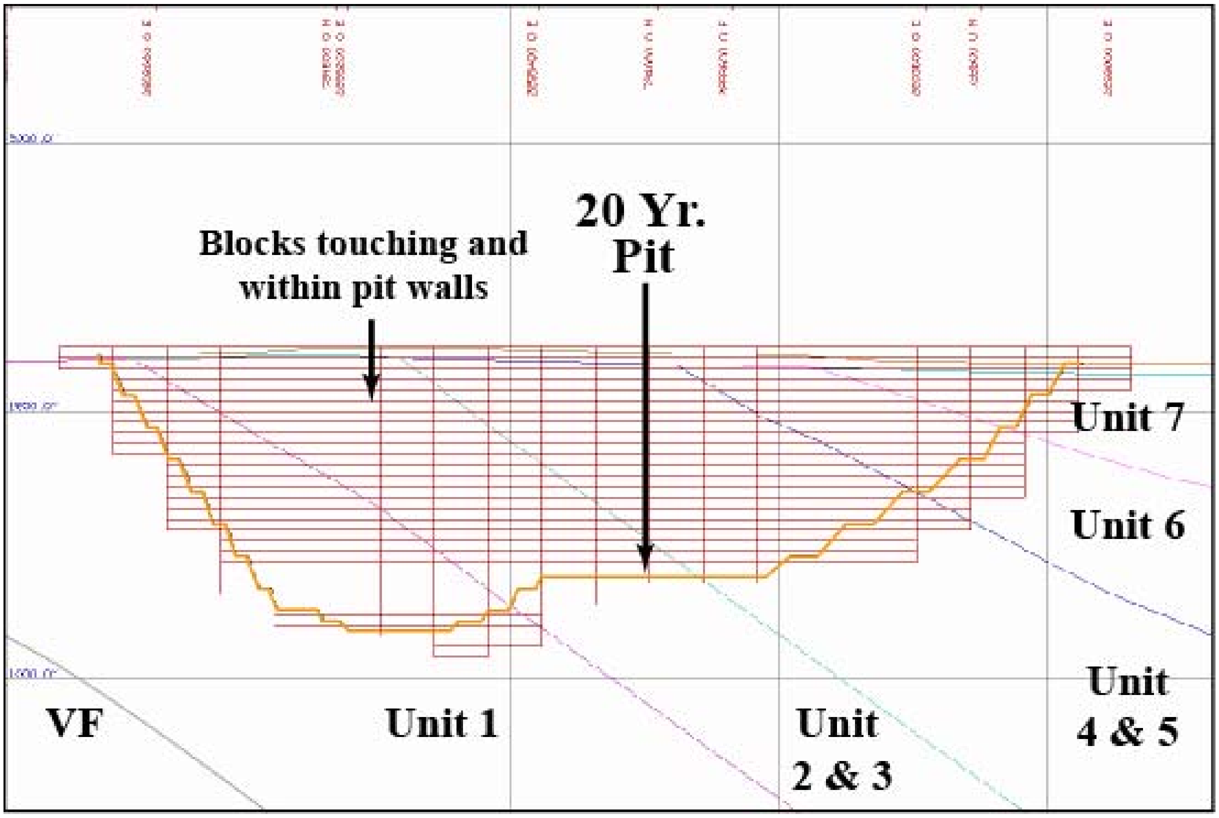

Figure 13: Cross-section showing blocks touching and within twenty year pit.