Oasis montaj Best Practice Guide

VOXI Earth Modelling - Creating Gradient Weighting Voxels

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Generate the Gradient Weighting constraint voxel models

Introduction

This document describes how to generate the set of constraint voxel models used in the Run an inversion using gradient weighting How-To Guide.

As part of the quantitative interpretation project of the Reid-Mahaffy [1] area, you may have applied parametric modelling along a few magnetic profiles to identify the geometry of the isolated dyke like body running NNW along the middle of the areas. These parameters then can be used through a set of math equations to generate the gradient weighting constraints.

For expediency, the constraint of this document is build on a single feature. One can extend this exercise and similarly incorporate the other geologic features.

In order to create the gradient voxel models, you will:

- Digitize the trace of the dyke on the geology map.
- Run parametric inversion (we used the *Oasis montaj* PotentQ extension) to get the geometric parameters for the dyke at a few locations.
- Use MS Excel to produce math equation coefficients.
- Create the constraint voxel model, using voxel math and the area mesh.
- Create the horizontal gradient voxel models using voxel filters.
- Convert the horizontal gradients to weight voxel models.

Voxel Model Preparation

The constraint voxel will be generated at the resolution and size of the voxel model resulting from the unconstrained inversion. To acquire its size and resolution, you will use the voxel model generated during the unconstrained inversion, thus the files required to generate the gradient voxel models are:

1. The padded voxel model mesh *Mesh_PADDED.geosoft.voxel* or output model of an earlier inversion: *Susceptibility_PADDED.geosoft.voxel*
2. The Reid Mahaffy database : *ReidMahaffy__DIG.gdb*
3. The surface geology map: *ReidMahaffy__geology.map*

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[1] The Reid-Mahaffy property in Ontario, Canada, has been designated by the as a test site and was flown by a number of airborne companies. The airborne Reid-Mahaffy magnetic data was flown in 1999 by Dighem as part of an airborne EM survey, commissioned by OGS, under the project number MRD-55

Digitize the trace of the dyke into a text file

The interpreted surface geology is displayed in *Figure 1*. The feature that makes the object of this guide is the Dyke indicated with the bold black trace running NNW across the map. Digitize this feature into an XYZ file, by calling *Map tools>CAD Tools>Digitize to XYZ File...*. Digitize three traces, one for each indicated segments.

The suggested parameters are:

Output file: *Dyke.xyz*,
Append or Overwrite: *Append*
Grid name: <Leave blank>
Significant Digits: *7*
Data prefix: <Leave blank>
Delimiter: <Leave blank>

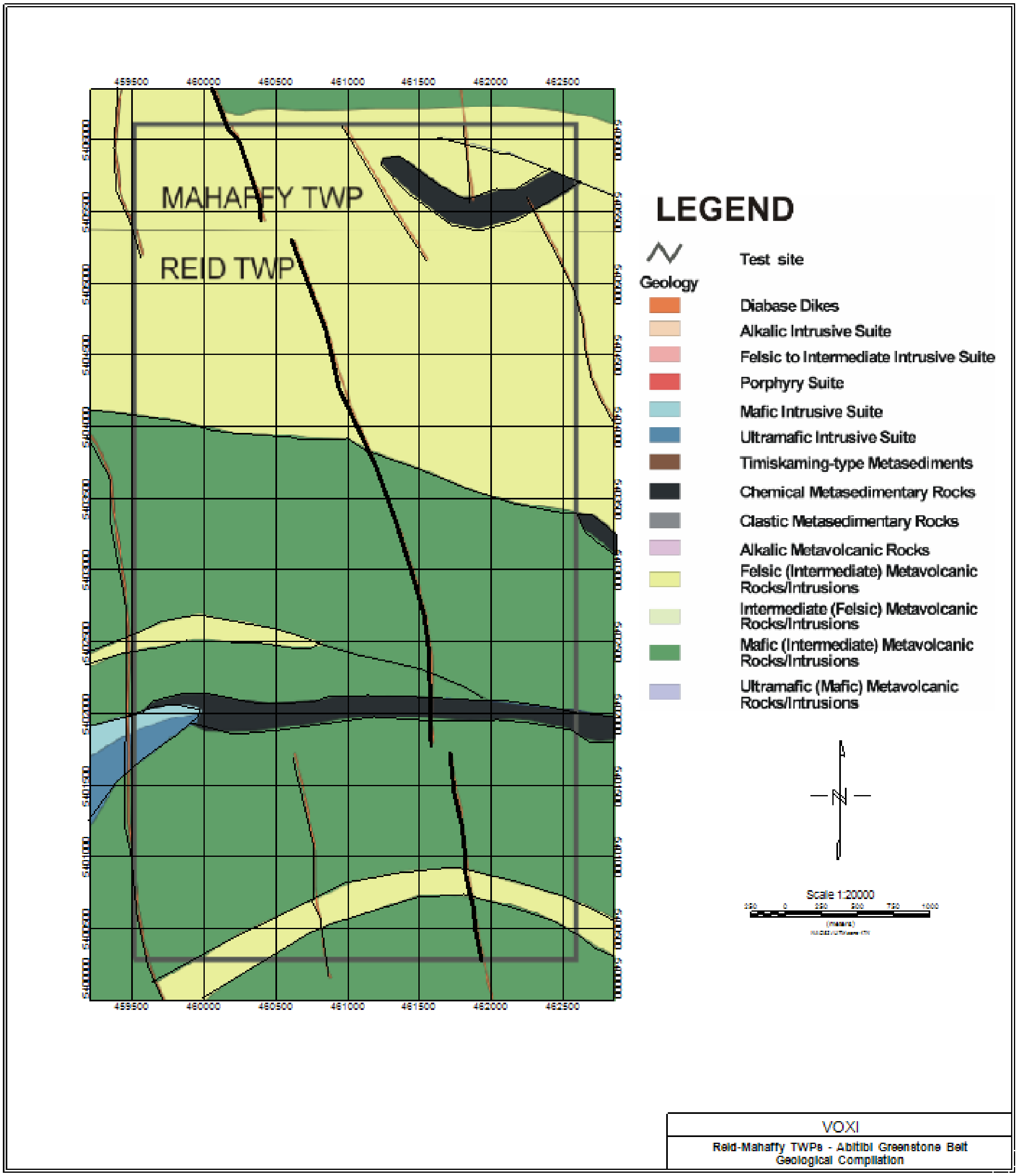


Figure 1: Reid-Mahaffy Geology map

Between digitizing exercises for each segment, edit the output file to add a line label.

```
Line 1
460035  5406369
460172  5406062
460232  5405993
460394  5405583
Line 2
460608  5405310
460838  5404703
460924  5404267
461325  5403362
461564  5402559
461581  5401756
Line 3
461693  5401747
461735  5401440
461787  5401243
461829  5400850
461940  5400252
461895  5400655
461944  5400297
```

Figure 2: Digitized dyke-like structure

You can import this file into a Geosoft database and plot the trace on the geology map to ensure that your digitized file closely follows the dyke-like structure.

Determine the average geometry of the dyke

Determine at a few locations, the depth, width, dip, and depth extent of the dyke-like feature. In producing this guide, we used the *Oasis montaj*'s PotentQ extension and ran 3 parametric inversions along survey profile segments. The data traces used for the inversions are indicated in red in *Figure 3*. The manner in which the geometric parameters are determined are out of scope of this guide and can be generated in a number of different ways. Another approach is to obtain this information from drillhole data.

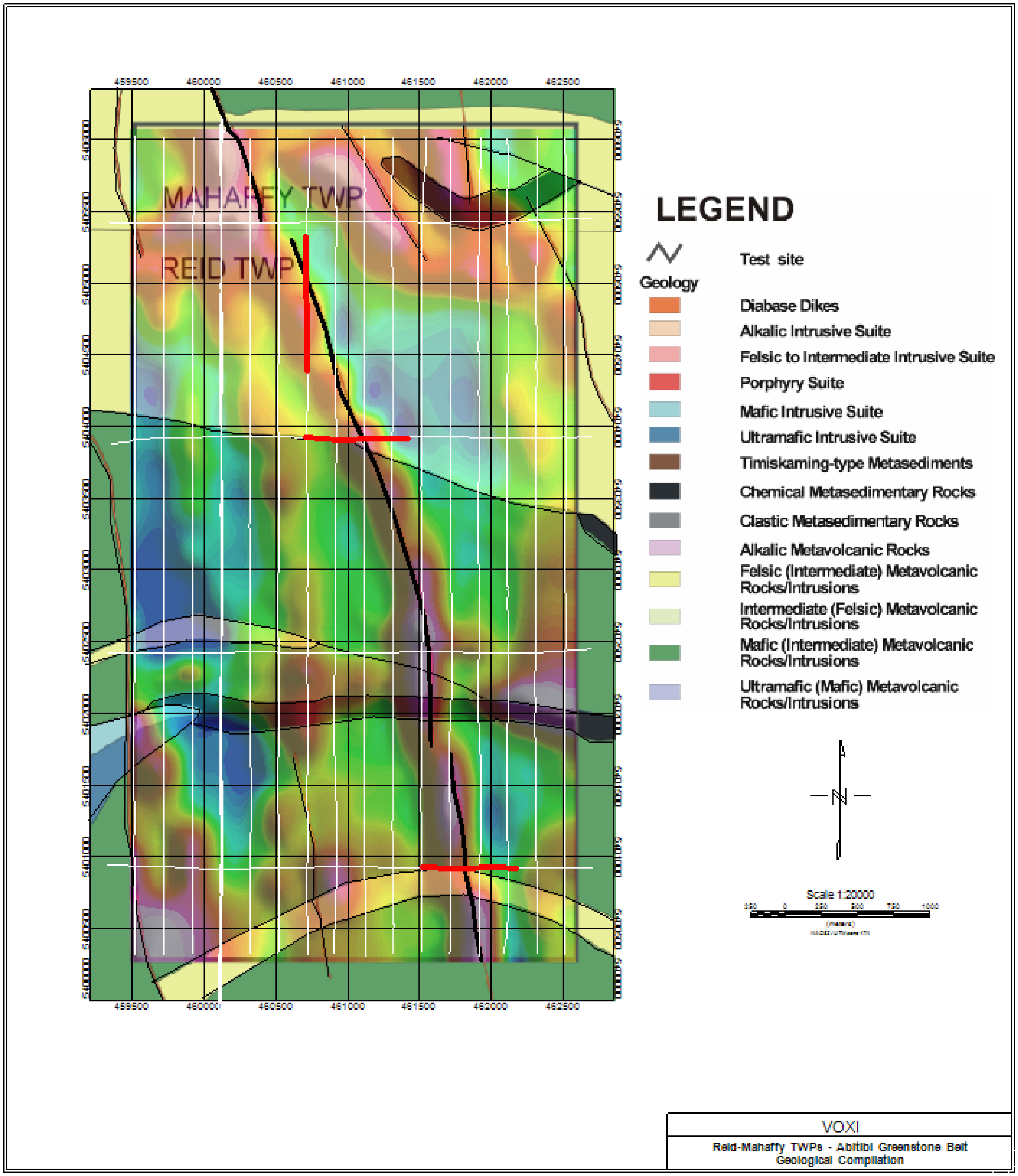


Figure 3: The mag data is superimposed semi-transparent on the geology map. The survey lines are depicted in white and the red traces indicate the profiles used to define the geometry of the dyke.

For the purpose of this demonstration, and in order to simplify the process, the results of the 3 inversions were averaged and rounded. The average dyke geometry is set to:

Depth : 50 m

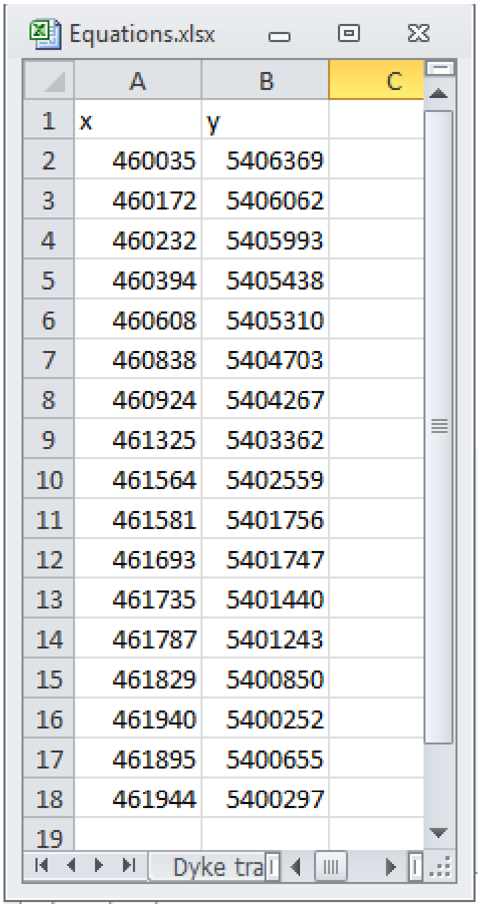
Width: 140 m

depth extent : 350 m

Slope : 38° west of the vertical (128° from the horizontal +ive X direction)

Build an excel file using the dyke geometry

Start by importing the x & y coordinates into an excel file as illustrated in *Figure 4*.



Equations.xlsx

	A	B	C
1	x	y	
2	460035	5406369	
3	460172	5406062	
4	460232	5405993	
5	460394	5405438	
6	460608	5405310	
7	460838	5404703	
8	460924	5404267	
9	461325	5403362	
10	461564	5402559	
11	461581	5401756	
12	461693	5401747	
13	461735	5401440	
14	461787	5401243	
15	461829	5400850	
16	461940	5400252	
17	461895	5400655	
18	461944	5400297	
19			

Dyke tra

Figure 4: Cut and paste the coordinates into an MS Excel file.

In order to be able to calculate at each surface cell the correct x & y coordinates of the dyke trace, calculate the A & B coefficients of the line equation:

y=A*x+B

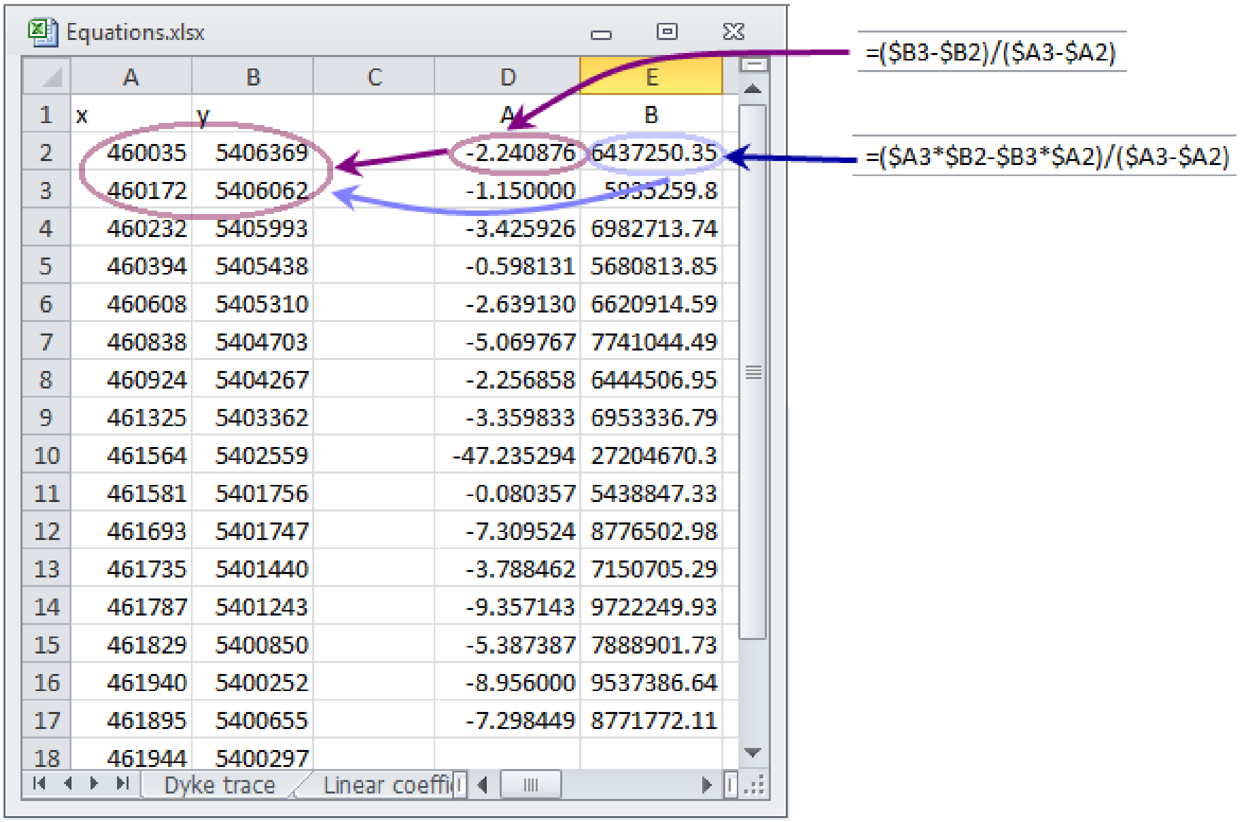
joining every 2 consecutive points of the trace of the dyke. You can easily accomplish this task in excel by entering the formulae:

A = (y2-y1)/(x2-x1)

B = (x2*y1-x1*y2)/(x2-x1)

In this exercise, in order to keep things simple and avoid dealing with exceptions, there are no points along the dyke trace that have the same X value.

This will generate the following A & B columns for each pair of x & y coordinates

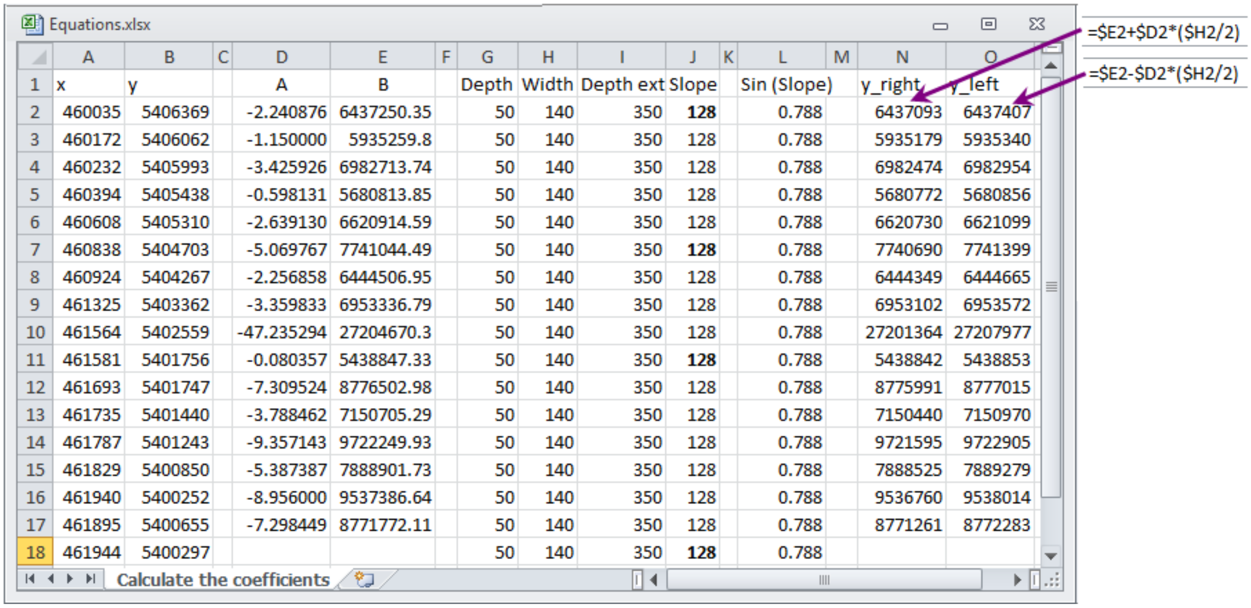


	A	B	C	D	E
1	x	y		A	B
2	460035	5406369		-2.240876	6437250.35
3	460172	5406062		-1.150000	5935259.8
4	460232	5405993		-3.425926	6982713.74
5	460394	5405438		-0.598131	5680813.85
6	460608	5405310		-2.639130	6620914.59
7	460838	5404703		-5.069767	7741044.49
8	460924	5404267		-2.256858	6444506.95
9	461325	5403362		-3.359833	6953336.79
10	461564	5402559		-47.235294	27204670.3
11	461581	5401756		-0.080357	5438847.33
12	461693	5401747		-7.309524	8776502.98
13	461735	5401440		-3.788462	7150705.29
14	461787	5401243		-9.357143	9722249.93
15	461829	5400850		-5.387387	7888901.73
16	461940	5400252		-8.956000	9537386.64
17	461895	5400655		-7.298449	8771772.11
18	461944	5400297			

Figure 5: Apply simple linear formula to calculate A & B for each pair of x & y coordinates

Add the average parameters of the dyke as separate columns. Then calculate the trace of the contacts of the dyke with the host rock on either side. Use a simple subtraction in Excel to generate these two columns.

To keep things simple, constant dyke parameters are used. However, if desired the actual calculated geometric parameters of the dyke can be used at the locations where they were calculated and a linear interpolation can be applied in between.



	A	B	D	E	G	H	I	J	L	N	O
1	x	y	A	B	Depth	Width	Depth ext	Slope	Sin (Slope)	y_right	y_left
2	460035	5406369	-2.240876	6437250.35	50	140	350	**128**	0.788	6437093	6437407
3	460172	5406062	-1.150000	5935259.8	50	140	350	128	0.788	5935179	5935340
4	460232	5405993	-3.425926	6982713.74	50	140	350	128	0.788	6982474	6982954
5	460394	5405438	-0.598131	5680813.85	50	140	350	128	0.788	5680772	5680856
6	460608	5405310	-2.639130	6620914.59	50	140	350	128	0.788	6620730	6621099
7	460838	5404703	-5.069767	7741044.49	50	140	350	**128**	0.788	7740690	7741399
8	460924	5404267	-2.256858	6444506.95	50	140	350	128	0.788	6444349	6444665
9	461325	5403362	-3.359833	6953336.79	50	140	350	128	0.788	6953102	6953572
10	461564	5402559	-47.235294	27204670.3	50	140	350	128	0.788	27201364	27207977
11	461581	5401756	-0.080357	5438847.33	50	140	350	**128**	0.788	5438842	5438853
12	461693	5401747	-7.309524	8776502.98	50	140	350	128	0.788	8775991	8777015
13	461735	5401440	-3.788462	7150705.29	50	140	350	128	0.788	7150440	7150970
14	461787	5401243	-9.357143	9722249.93	50	140	350	128	0.788	9721595	9722905
15	461829	5400850	-5.387387	7888901.73	50	140	350	128	0.788	7888525	7889279
16	461940	5400252	-8.956000	9537386.64	50	140	350	128	0.788	9536760	9538014
17	461895	5400655	-7.298449	8771772.11	50	140	350	128	0.788	8771261	8772283
18	461944	5400297			50	140	350	**128**	0.788		

Figure 6: All the values to generate the math equations are in the excel file. Linear math equations have been applied to columns titled ***A,B, Sin(Slope), y_right, Y_left.***

Create the voxel math equations

Use **Voxel Math** to generate the susceptibility voxel reference model that represents the dyke-like feature. This voxel will be set to 0 everywhere except at the voxel elements within the dyke, where it will be set to 0.02 SI - the average susceptibility of the dyke - which, in this case, is obtained through PotentQ inversion. The math expression file will have multiple equations. The first equation will simply consist of setting all the voxel elements to 0:

```
@V2=VI*0.0;
```

where

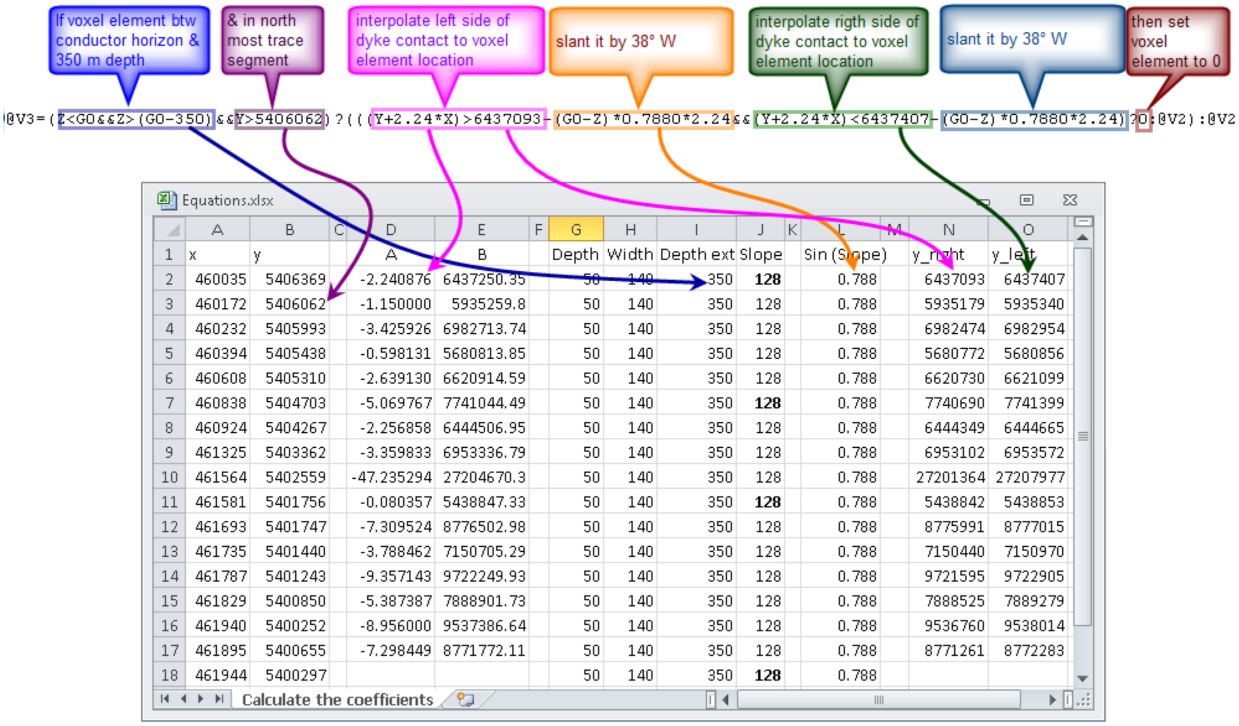
VI is the input voxel model. Set this to the output or the mesh of the unconstrained inversion.

@V2 is a voxel variable.

G0 is the grid representing the top of conductor depth.

V0 is the output voxel representing the susceptibility reference model of the dyke-like feature.

The next equation sets all voxel elements inside the dyke-like structure and vertically confined below the conductor horizon to a depth of 350 metres to 0.02 SI. This is done for each straight line segment defining the 2 sides of the dyke. The equation for the north-most segment of the dyke is explained in detail in the illustration below:



	x	y	A	B	Depth	Width	Depth ext	Slope	Sin (Slope)	y_right	y_left
2	460035	5406369	-2.240876	6437250.35	50	140	350	**128**	0.788	6437093	6437407
3	460172	5406062	-1.150000	5935259.8	50	140	350	128	0.788	5935179	5935340
4	460232	5405993	-3.425926	6982713.74	50	140	350	128	0.788	6982474	6982954
5	460394	5405438	-0.598131	5680813.85	50	140	350	128	0.788	5680772	5680856
6	460608	5405310	-2.639130	6620914.59	50	140	350	128	0.788	6620730	6621099
7	460838	5404703	-5.069767	7741044.49	50	140	350	**128**	0.788	7740690	7741399
8	460924	5404267	-2.256858	6444506.95	50	140	350	128	0.788	6444349	6444665
9	461325	5403362	-3.359833	6953336.79	50	140	350	128	0.788	6953102	6953572
10	461564	5402559	-47.235294	27204670.3	50	140	350	128	0.788	27201364	27207977
11	461581	5401756	-0.080357	5438847.33	50	140	350	**128**	0.788	5438842	5438853
12	461693	5401747	-7.309524	8776502.98	50	140	350	128	0.788	8775991	8777015
13	461735	5401440	-3.788462	7150705.29	50	140	350	128	0.788	7150440	7150970
14	461787	5401243	-9.357143	9722249.93	50	140	350	128	0.788	9721595	9722905
15	461829	5400850	-5.387387	7888901.73	50	140	350	128	0.788	7888525	7889279
16	461940	5400252	-8.956000	9537386.64	50	140	350	128	0.788	9536760	9538014
17	461895	5400655	-7.298449	8771772.11	50	140	350	128	0.788	8771261	8772283
18	461944	5400297			50	140	350	**128**	0.788		

Figure 7: Detailed explanation on how the formula for the geometry of dyke-like feature is built using the geometric parameters.

Similarly, generate an equation for each line segment along the trace of the dyke-like feature and define the input and output files as indicated below.

```
//VO=.\Slant_Gradientreferencemodel.geosoft_voxel
//GO=.\Depth3.grd(GRD)
//VI=.\Master_PADDED.geosoft_voxel
@V2=VI*0.0;
@V3=(Z<(GO)&&Z>(GO-350)&&Y>5406062)?(((Y+2.24*X)>6437093-(GO-Z)*0.7880*2.24&&(Y+2.24*X)<6437407-(GO-Z)*0.7880*2.24)?0.02:@V2):@V2;
@V4 =(Z<(GO)&&Z>(GO-350)&&Y<5406062&&Y>5405993)?(((Y+1.150*X)>5935179.0-(GO-Z)*0.7880*1.150&&(Y+1.150*X)<5935340.0-(GO-Z)  *0.7880*1.150)?0.02:@V3):@V3;
@V5 =(Z<(GO)&&Z>(GO-350)&&Y<5405993&&Y>5405438)?(((Y+3.425*X)>6982473.9-(GO-Z)*0.7880*3.425&&(Y+3.425*X)<6982953.5-(GO-Z)  *0.7880*3.425)?0.02:@V4):@V4;
@V6 =(Z<(GO)&&Z>(GO-350)&&Y<5405310&&Y>5404703)?(((Y+2.639*X)>6620729.8-(GO-Z)*0.7880*2.639&&(Y+2.639*X)<6621099.3-(GO-Z)  *0.7880*2.639)?0.02:@V5):@V5;
@V7 =(Z<(GO)&&Z>(GO-350)&&Y<5404703&&Y>5404267)?(((Y+5.069*X)>7740689.6-(GO-Z)*0.7880*5.069&&(Y+5.069*X)<7741399.3-(GO-Z)  *0.7880*5.069)?0.02:@V6):@V6;
@V8 =(Z<(GO)&&Z>(GO-350)&&Y<5404267&&Y>5403362)?(((Y+2.256*X)>6444348.9-(GO-Z)*0.7880*2.256&&(Y+2.256*X)<6444664.9-(GO-Z)  *0.7880*2.256)?0.02:@V7):@V7;
@V9 =(Z<(GO)&&Z>(GO-350)&&Y<5403362&&Y>5402559)?(((Y+3.359*X)>6953101.6-(GO-Z)*0.7880*3.359&&(Y+3.359*X)<6953571.9-(GO-Z)  *0.7880*3.359)?0.02:@V8):@V8;
@V10=(Z<(GO)&&Z>(GO-350)&&Y<5402559&&Y>5401756)?(((Y+47.23*X)>27201363.-(GO-Z)*0.7880*47.23&&(Y+47.23*X)<27207976.-(GO-Z)  *0.7880*47.23)?0.02:@V9):@V9;
@V11=(Z<(GO)&&Z>(GO-350)&&Y<5401747&&Y>5401440)?(((Y+7.309*X)>8775991.3-(GO-Z)*0.7880*7.309&&(Y+7.309*X)<8777014.6-(GO-Z)  *0.7880*7.309)?0.02:@V10):@V10;
@V12=(Z<(GO)&&Z>(GO-350)&&Y<5401440&&Y>5401243)?(((Y+3.788*X)>7150440.0-(GO-Z)*0.7880*3.788&&(Y+3.788*X)<7150970.4-(GO-Z)  *0.7880*3.788)?0.02:@V11):@V11;
@V13=(Z<(GO)&&Z>(GO-350)&&Y<5401243&&Y>5400850)?(((Y+9.357*X)>9721594.9-(GO-Z)*0.7880*9.357&&(Y+9.357*X)<9722904.9-(GO-Z)  *0.7880*9.357)?0.02:@V12):@V12;
@V14=(Z<(GO)&&Z>(GO-350)&&Y<5400850&&Y>5400252)?(((Y+5.387*X)>7888524.6-(GO-Z)*0.7880*5.387&&(Y+5.387*X)<7889278.8-(GO-Z)  *0.7880*5.387)?0.02:@V13):@V13;
@V15=(Z<(GO)&&Z>(GO-350)&&Y<5400252&&Y>5400655)?(((Y+8.956*X)>9536759.7-(GO-Z)*0.7880*8.956&&(Y+8.956*X)<9538013.5-(GO-Z)  *0.7880*8.956)?0.02:@V14):@V14;
VO  =(Z<(GO)&&Z>(GO-350)&&Y<5400655&&Y>5400297)?(((Y+7.298*X)>8771261.2-(GO-Z)*0.7880*7.298&&(Y+7.298*X)<8772283.0-(GO-Z)  *0.7880*7.298)?0.02:@V15):@V15;
```

Figure 8: The complete math equation file. One equation per dyke trace line segment. Note the breaks separating the 3 segments of the feature.

Run **Voxel math** from the *3D>Voxel Utilities* menu using the math equations constructed above and produce the gradient reference model.

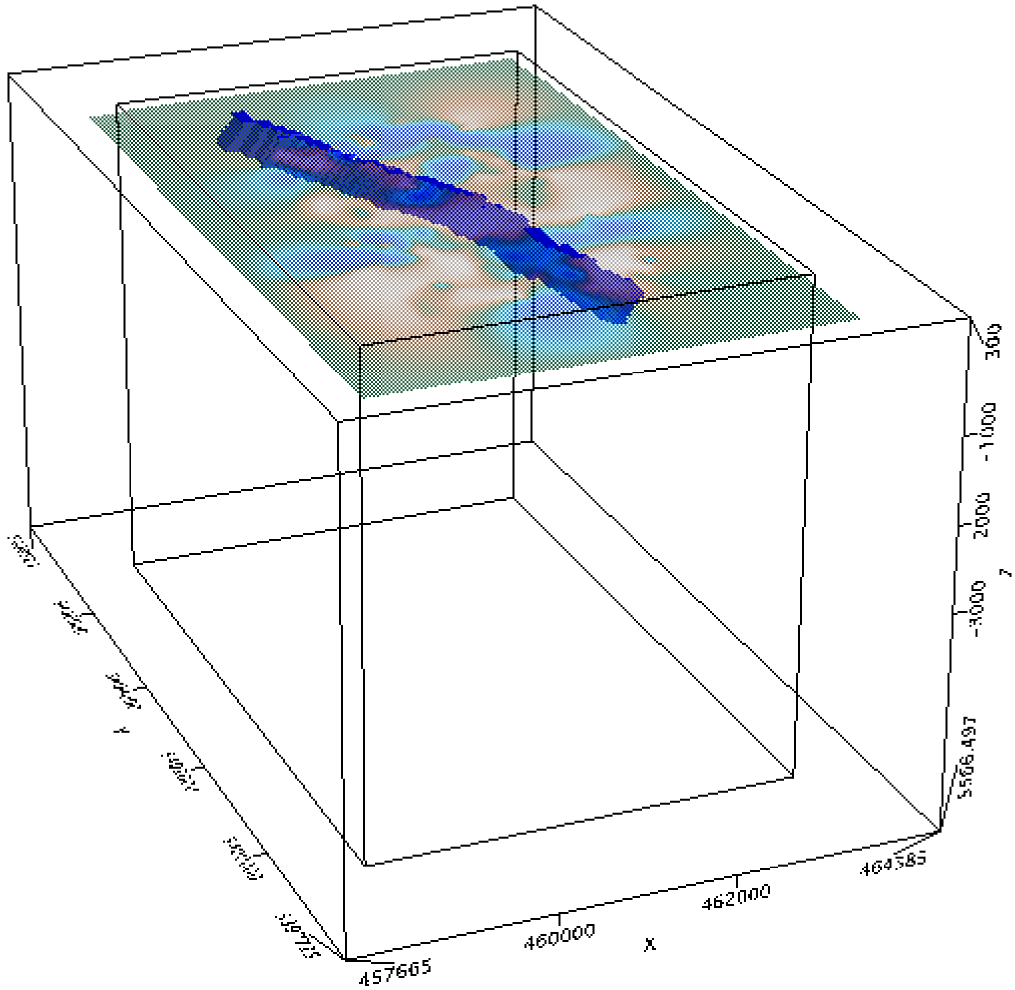


Figure 9 : The gradient reference model.

The next step is to generate the NS and EW gradient weights. These weights should have a value of 1 everywhere to allow for a smooth model, except at the contact between the dyke and the surrounding rock, where the voxel elements will be set to 0.0001 to indicate a sharp discontinuity.

This is done in 2 steps for each direction. First the gradient is calculated by applying a 3x3x3 gradient filter, then the normalized weight voxel model is calculated through the use of voxel math. These NS and WE gradient filters are :

```
/ X-weight
0 0 0 0 0 0 0 0 0
0 0 0 0 -.5 .5 0 0 0
0 0 0 0 0 0 0 0 0
```

and

```
/ Y-weight
0 0 0 0 0 0 0 0 0
```

```
0 0 0 0 -.5 0 0 .5 0

0 0 0 0 0 0 0 0 0
```

There is a slight difference between these filters and the standard ones provided with your Oasis montaj installation. Please take a moment to compare them. Then, generate your custom gradient filter files with the above content. Place these filters in c:\program files(x86)\geosoft\Oasis montaj\user\etc *so that you can easily locate them during future constraint inversions.*

To apply these filters, run **Filter a Voxel** from the *3D>Voxel utilities* menu. The suggested parameters are:

Input voxel: *Slant_GradientReferenceModel*,

Output voxel: *X-Gradient*

Filter: from file

File: <Navigate to the user\etc directory and select the newly created X-Weight file>

Number of passes : *1*

Dummy handling: *Interpolate*

The output of each of these filter processes will yield a voxel populated by 0's everywhere except at the contact where it is set to -0.01 or +0.01.

The last step is to apply a simple formula and substitute all the 0 elements with 1 and all the ±0.01 elements with 0.0001. This is done through applying the equation below in voxel math.

```
VO=(VI==abs(0.01))?0.0001:1;
```

The reference model, the EW gradient and the NS gradient weights are displayed below. These are the 3 voxel models that can be used concurrently to apply a gradient constraint on the Reid-Mahaffy magnetic data.

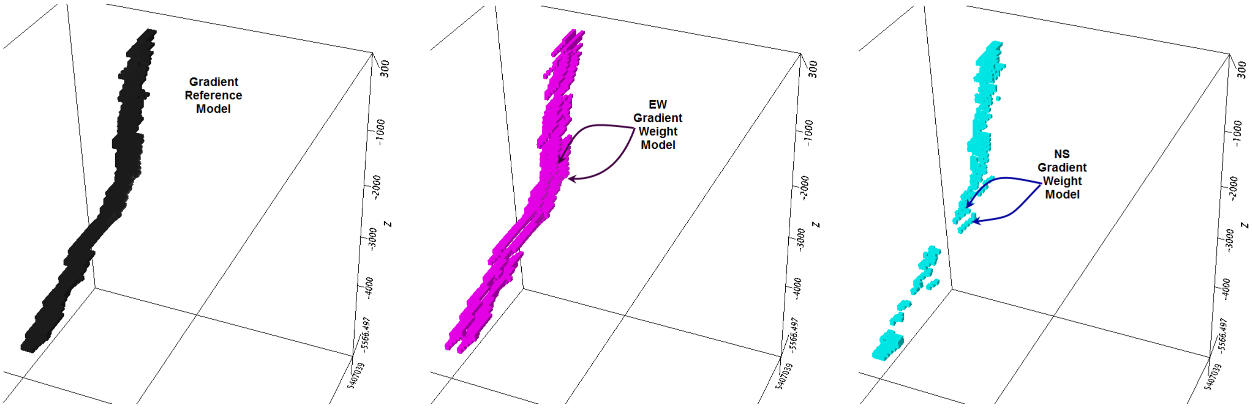


Figure 10: from left to right , the dyke with a susceptibility contrast of 0.02 SI, the EW gradient weight on the 2 sides of the dyke, and the NS gradient on the 2 sides of the dyke.