



GeoModeller GFX (Geophysics)

## Variable Density

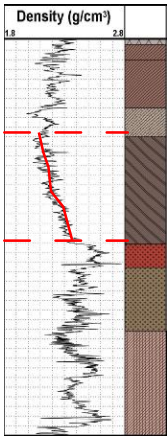





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## Variable Density

The density of basin sediments may vary as a function of depth (below surface)

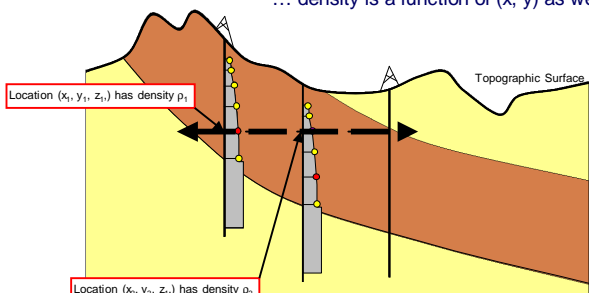


- However, variable density is not simply some variation of density as a function of 'z'
- Typically it is also a function of (x, y) ... due to topography

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## Variable Density

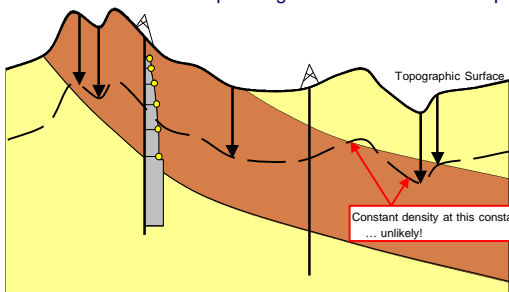


The density at  $(x_1, y_1, z_1)$  differs from  $(x_2, y_2, z_1)$   
... density is a function of (x, y) as well as 'z'

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## Variable Density

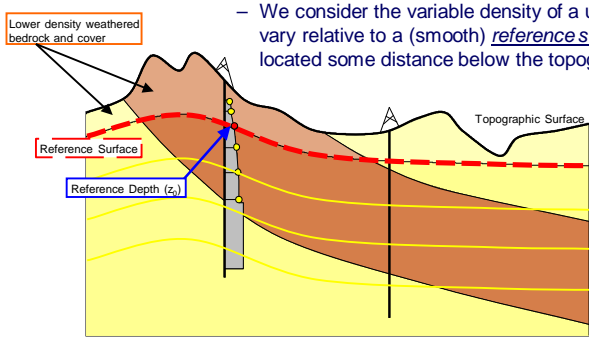
- Density variations at depth do not reflect the sharp changes that we observe in topography



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## Variable Density

- We consider the variable density of a unit to vary relative to a (smooth) reference surface located some distance below the topography



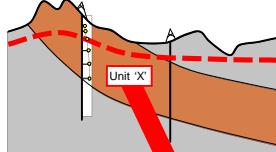
The reference surface could be a smoothed version of the topography, displaced to an appropriate depth

## How do we record the 3D variation of the density of a formation?



### Variable Density – Density Voxel



- We use a *voxel* to record the 3D variation of density of a given geology formation
- For a specific lithology unit (UnitX) ...
  - The recorded data values are the *density of UnitX* at each voxel-centroid location (x, y, z)
  - A value for density of UnitX is recorded *throughout the whole* of the voxel volume
  - One of the *property fields* of the voxel stores the density data for UnitX



### Variable Density – Density Voxel

- A density voxel must be *spatially identical* to the lithology voxel used in GeoModeller forward modelling or inversion
  - same overall size, dimension, position and voxel size and number of voxels
- Thus – in inversion – whenever any voxel of the lithology model is assigned to be the lithology 'UnitX', the correct density value for that (x, y, z) location can be read from the corresponding voxel of the (UnitX) density property of the density voxel
- If several formations have variable density, the density data for each lithology must be recorded in separate property fields of the density voxel



## How do we create a density voxel?

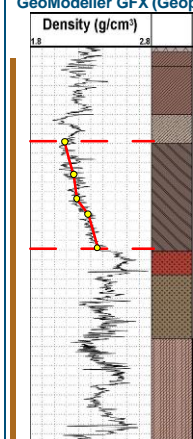


## Create a Density Voxel?

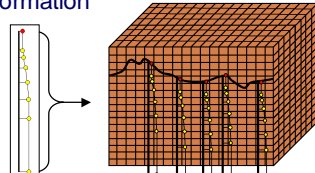
- Some organisations will already have datasets that describe the 3D variation of density for specific formations – typically derived from density logs, 3D seismic interpretation and velocity analysis
  - These need to be written out to a voxel of appropriate dimension – and can then be directly used in GeoModeller forward modelling and inversion
- Alternatively ... use CreateDepthFunction



## CreateDepthFunction



- Typically our knowledge of variable density is derived from a density log in a drillhole ... from which we would choose a set of (depth, density) pairs ...
- CreateDepthFunction references these (depth, density) data to the topographic surface ... to generate a density voxel for a specific formation

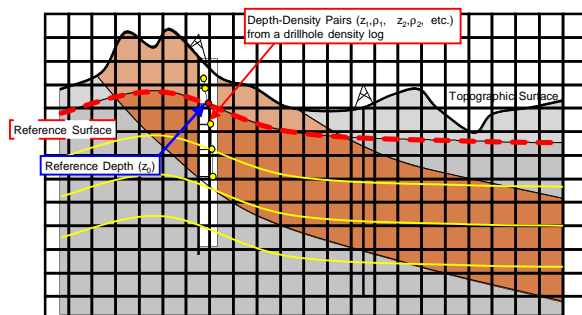


## CreateDepthFunction - Details

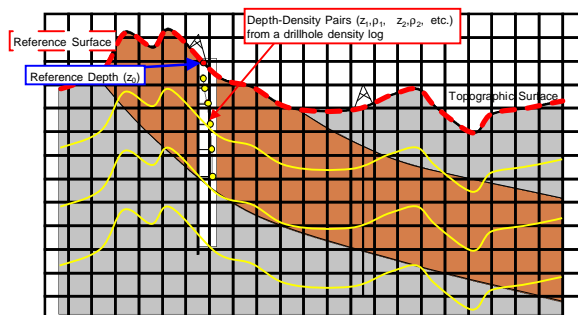
- The CreateDepthFunction operation uses a list of two or more (depth,density) pairs to generate a piece-wise linear spline function
- Reference Surface is the topography
- Reference Depth is 0m
- For each 'column' of voxels, the spline function is 'referenced to' the Reference Surface (i.e. topography) at that column location (x, y), and density values are interpolated at the required elevations of each voxel-centroid
- The (depth,density) pairs can be in any order (they will be sorted by depth prior to splining). Where voxels extend above or below the limits of the supplied (depth, density) data pairs, the top or bottom supplied density value is used



## CreateDepthFunction - Ideal



## CreateDepthFunction - Current



## CreateDepthFunction - Command

- The arguments to the CreateDepthFunction command are ...
  - F(d1,v1,...,di,vi,...) - a list of depth-density pairs
  - <Output Voxel> - the name of the output voxel
  - <Output Field> - a name for the density property field

### CreateDepthFunction Command ...

```
call %DoTask%%CaseXML% CreateDepthFunction F(200,2.5,1000,4.9)^
%ToResultsDIR%%Case%DensityDepth_BigCubeFormation.vo BigCubeDensity
```



## CreateDepthFunction - Workaround

- To generate a density voxel for the ideal case
  - Generate a grid of your preferred Reference Surface (e.g. smooth a topography grid, and subtract, say, 50m)
  - Create a temporary GeoModeller Project using this surface as 'the topography'
  - Using this Project, create an inversion Case
  - Revise the 'depths' of the (depth, density) pairs such that density at 'true 50m' temporarily corresponds to 'adjusted 0m' i.e. the 'adjusted topography'
  - Use the CreateDepthFunction to generate the required density voxel (and delete all temp. files!)



## How do we use a density voxel?



## Variable Density: SetLaw Density

- A variation to the CaseControl SetLaw command is used to assign a specified field of a specified voxel to supply density values for a particular formation
- The density voxel must match the Case voxel in terms of voxel size and voxel extents
- The voxel may be generated via the CreateDepthFunction, or can be generated by third-party software

### CaseControl SetLaw Command ...

```
call %DoTask% %CaseXML% CaseControl SetLaw ^
Tertiary Density Normal(2.67,0.01,100,XYZ,%Case%\DepthDensity_Tertiary.vo,TertiaryDensity)" ^
Palaeozoic Density Normal(2.55,0.01,100) ^
Basement Density Normal(2.65,0.01,100)
```



## Variable Density: SetLaw (Detail)

```
Tertiary Density Normal(2.67,0.01,100,XYZ,%Case%\DepthDensity_Tertiary.vo,TertiaryDensity)" ^
```

Note the "" and (). Warning – no spaces within the ()

Tertiary	Name of the geology formation
Density	Keyword – this SetLaw command sets the density property
Normal	Keyword – in this case specifying a 'normal' density distribution
2.67	Mean density value – not used – but you must enter a number here
0.01	Standard deviation of the (normal) density distribution
100	Percentage of formation with this density value
XYZ	Keyword, signifying that (mean) density to be read from a voxel
%Case%\DepthDensity_Tertiary.vo	Name of the density voxel
TertiaryDensity)	Name of property field (of the voxel) containing formation density
^	The 'continuation character' for Windows 'command scripts'

