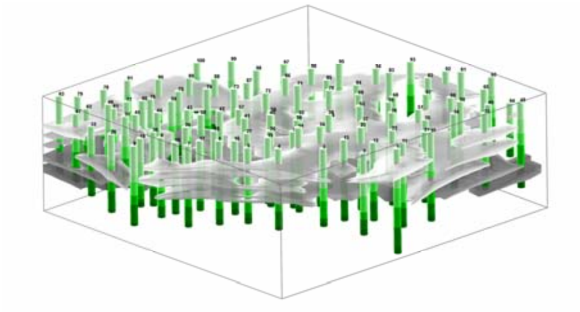
Modeling a Multi-Seam Coal Reserve using RockWorks



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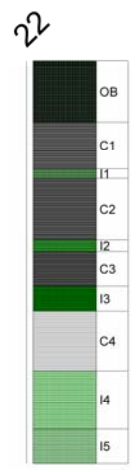
Introduction



This Case Study documents the modeling and visualization of a Multi-Seam Coal Reserve.

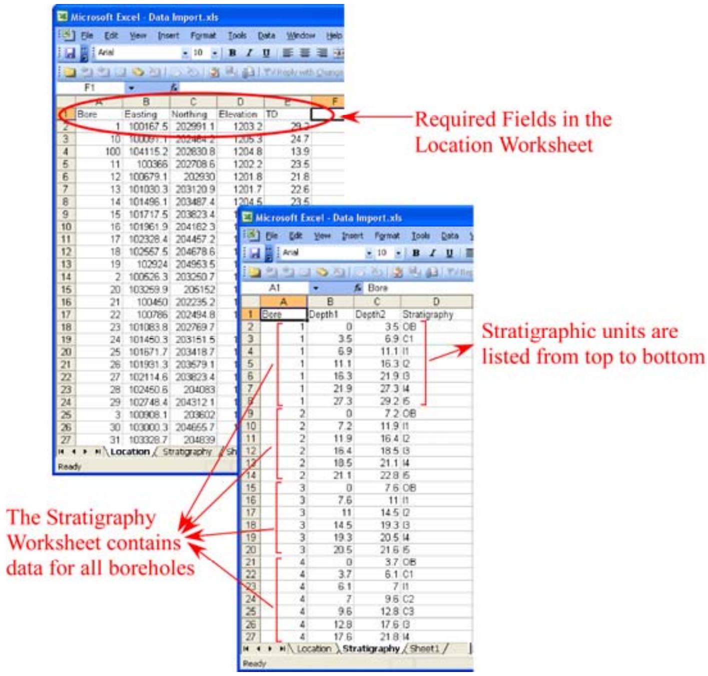
The coal layers and surrounding sediments have been broken up into eleven different stratigraphic layers. The top OB unit is Overburden material above the first Coal layer, C1. Units C1 through C5 are coal layers. Units I1 through I5 are interbed units.

The RockWorks Borehole Manager is the best place to store and work with downhole information. Data was entered into an Excel workbook and was then imported into the RockWorks Borehole Manager.

Step 1: Enter the Data into Excel

The Excel workbook contains two worksheets: one stores general Location information for each borehole, and one stores depth to top and depth to base information for the Stratigraphic layers that appear in each borehole.

The Location worksheet contains five required fields: Borehole Name or ID, Easting, Northing, Elevation at the top of the hole, and Total Depth of the hole. The Stratigraphy worksheet contains a column listing the Borehole Name or ID (this corresponds to the Bore column in the Location Worksheet), Depth to Top of Interval, Depth to Base of Interval, and Stratigraphic Unit. The data for each borehole should be listed in order from top to bottom and borehole data is listed one after another in the worksheet.

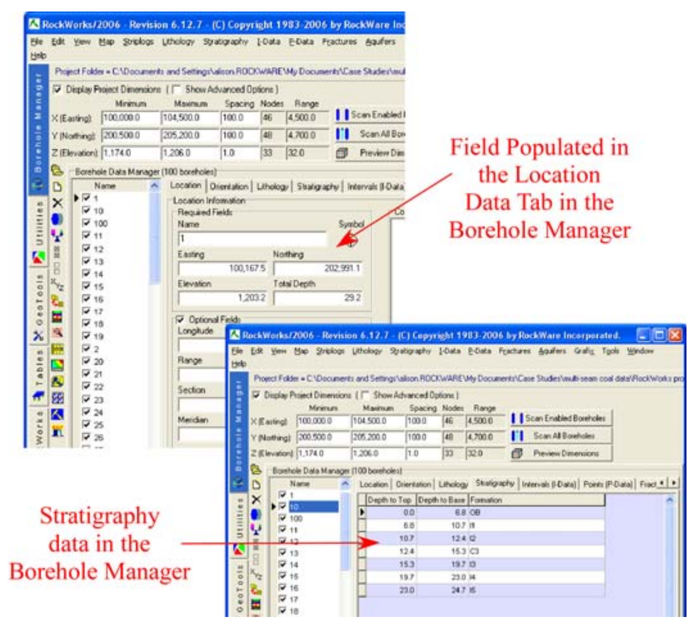


Step 2: Importing the Data into the Borehole Manager

The RockWorks Borehole Manager is the best place to store and work with downhole information.

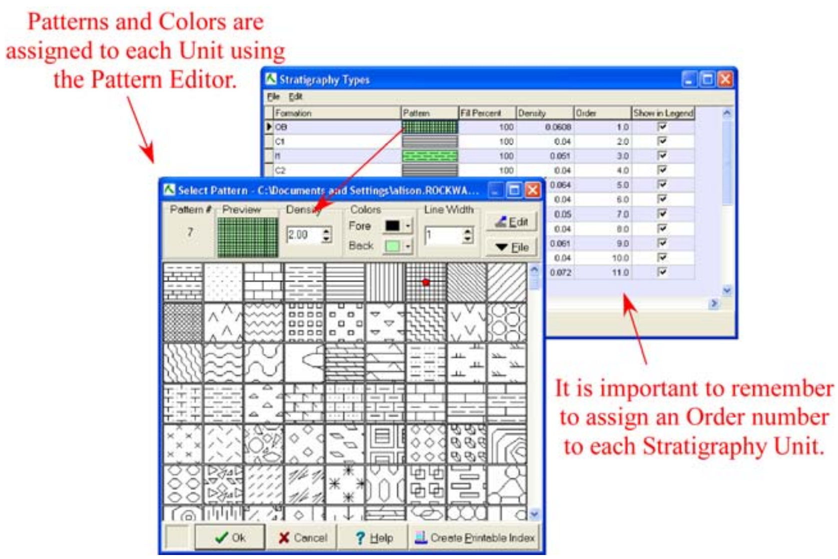
You can import the Worksheet referenced in Step 1 into the Borehole Manager using the File / Import / Excel menu item.

The program will populate the Location and Stratigraphy datatabs. After the import is complete, the program will prompt you to set your project dimensions. You can have the program scan the location information for each borehole by clicking on the Scan All Boreholes button. The program will automatically assign Minimum and Maximum Eastings and Northings for your area, as well as top and base elevations.



The program will also populate the Stratigraphy Types Table. The user will need to add patterns and colors to the Stratigraphy Types Table. Other fields that should be populated in the Stratigraphy Types Table include:

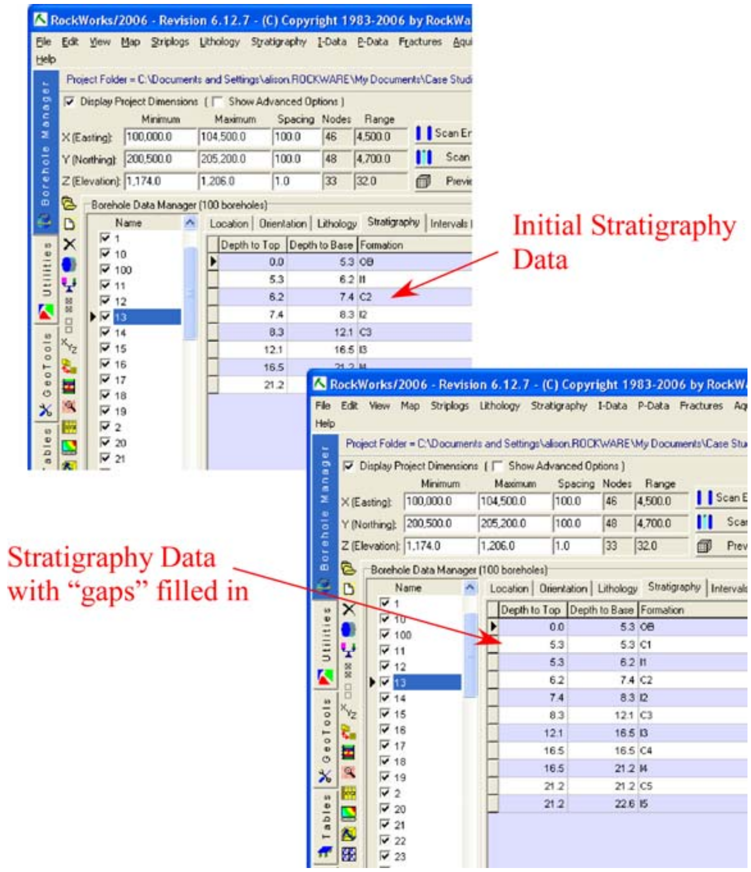
- Fill Percent – Governs what column percent will be filled with pattern in strip log diagrams such as cross-sections and profiles.
- Density - A density per cubic unit (for computing mass).
- Order – The order in which these units exist from top to bottom. The order field is very important because the program references this order when creating Stratigraphy Models.
- Show in Legend – This check-box allows the user to specify whether the unit will appear in Legends created by RockWorks.



If you do not want to use Excel as a tool for data import, you can also hand enter your data directly into the RockWorks database. There are also tools available for importing data from ASCII files, LogPlot DAT files, and several other industry data formats.

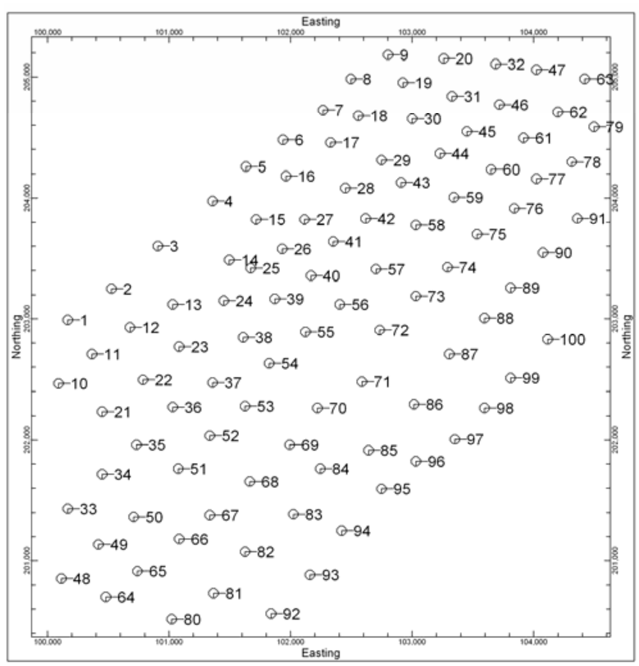
Step 3: Filling Stratigraphic Data Gaps

When logging units and picking tops, missing Stratigraphic units are normally not referenced in the data. However, when creating Stratigraphy models in RockWorks, it is useful to list missing units as existing, but with a thickness of 0. You can have the program automatically fill in missing units by choosing the Stratigraphy / Fill in missing Stratigraphy menu item.



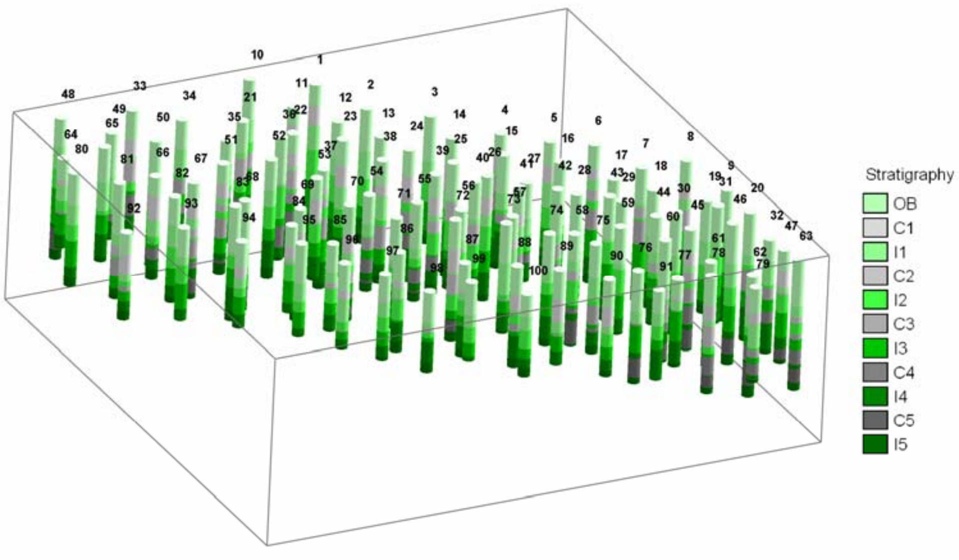
Step 4: Create a Borehole Location Map

Once the data is entered, use the Borehole Manager Map / Borehole Locations to create simple site map. This can be saved as a RockPlot2D image for later use.



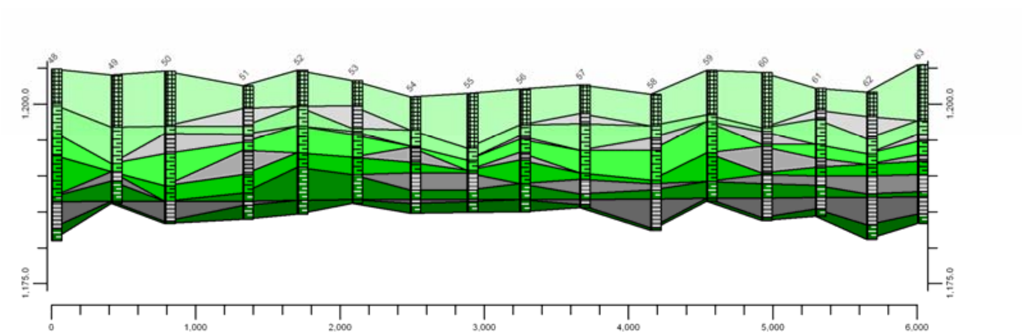
Step 5: Display Observed Data in 3D Striplogs

In addition to creating the borehole location map, above, you can create a 3D view of your input data (locations and stratigraphic intervals) using the Striplogs / Multi-Log 3-D utility. The following diagram shows the borehole logs, with titles and stratigraphy colors, displayed in the RockPlot3D window.



Step 6: Create a 2D Hole to Hole Cross Section

A series of hole-to-hole cross sections can be created using the Stratigraphy / Section / Straight-Line tool. The example below shows a section traversing a southwest to northeast slice of the study area. Stratigraphy logs with titles are included with colors-only correlation panels. Note that simple linear correlations are drawn to the existing data.

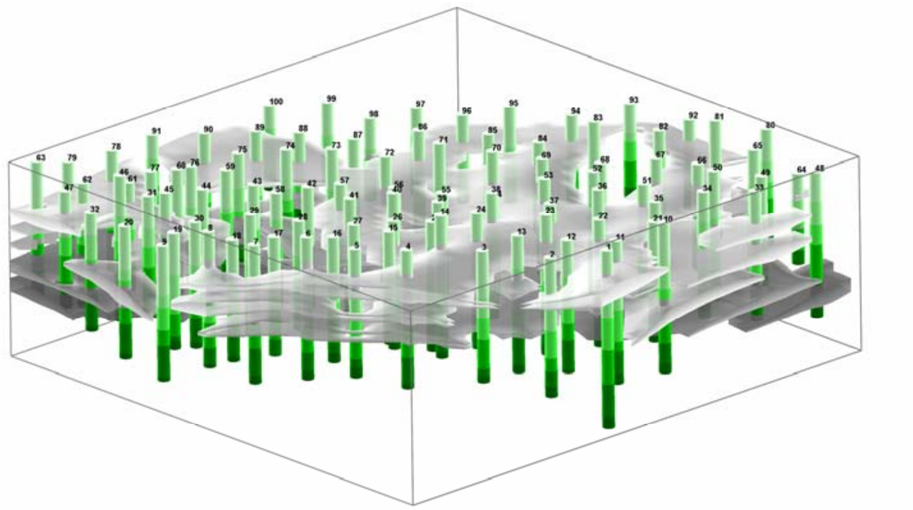


Note the discontinuous coal layers (gray) and interbed layers (green) which are pinched out because of the zero-thickness method of data entry.

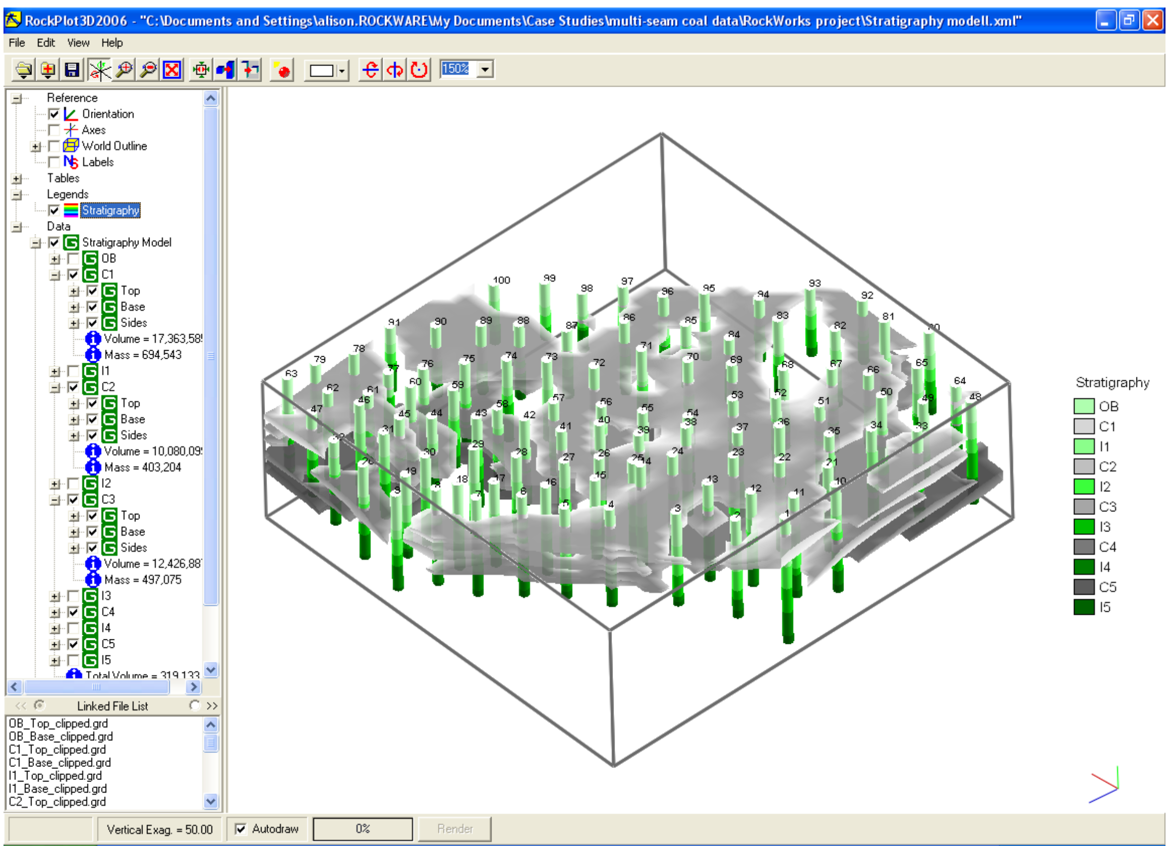
Step 7: Create a 3D Stratigraphic Model

The next step is to create a stratigraphic block model by modeling the units and stacking them from the bottom up. The diagram below illustrates a stratigraphic model, displayed in the RockPlot3D window. The 3D logs, from Step 5, have been appended to the model for reference. Individual units can be turned on and off. Many visualization options are available (lighting, zoom, rotations, colors, filtering, etc.).

The model below was created using the Kriging algorithm. All grid cells that were not within 5% of the diagonal distance across the project were set to null values so that areas where boreholes are not present are rendered transparent. In the image below, any coal layers that were less than 0.5 feet thick were also rendered transparent.

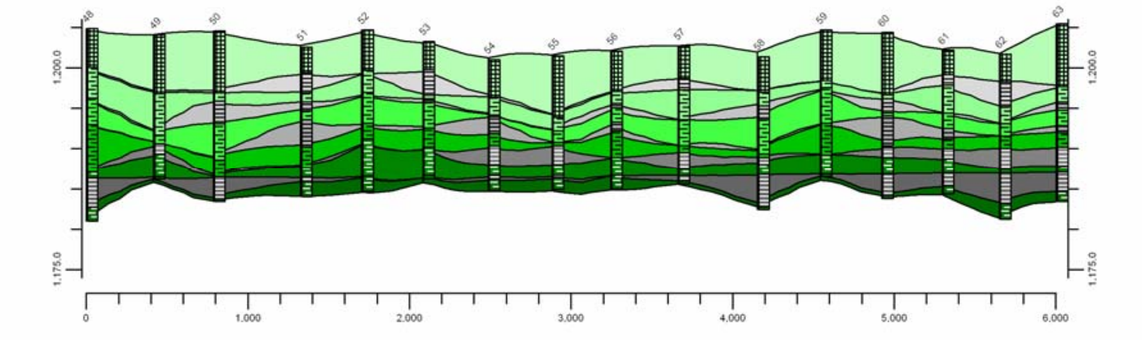


Note that volumes and mass are calculated for each layer. Volumes are computed automatically based on the cubic units of the X, Y, and depth units. Mass is computed based on the "density" setting, per cubic unit, in the Stratigraphy Types Table (Step 2).



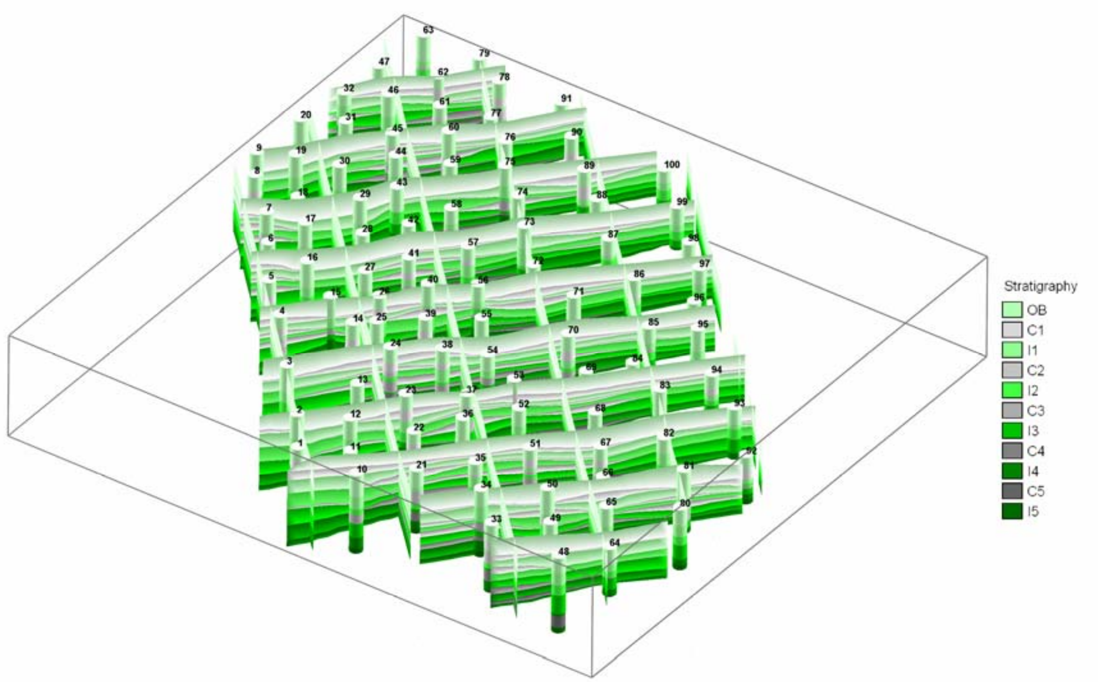
Step 8: Create a Projected Cross Section

Now that your Stratigraphy model has been generated, you can create 2D and 3D diagrams slicing through the gridded layers. The image below shows a modeled stratigraphic section following the same section line used to create the cross-section in Step 6.



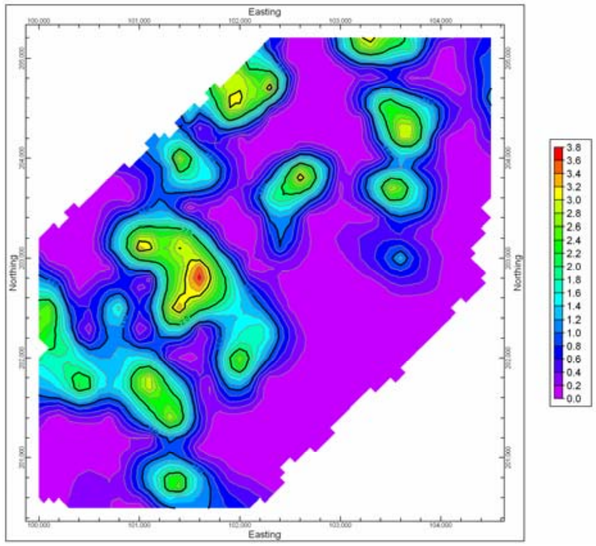
Step 9: Create a Fence Diagram

Next, a projected fence diagram is created. Fence panels can be selected interactively, read from a list of endpoints, or automatically selected. Note how discontinuous most of the units are.



Step 10: Creating an Isopach Map

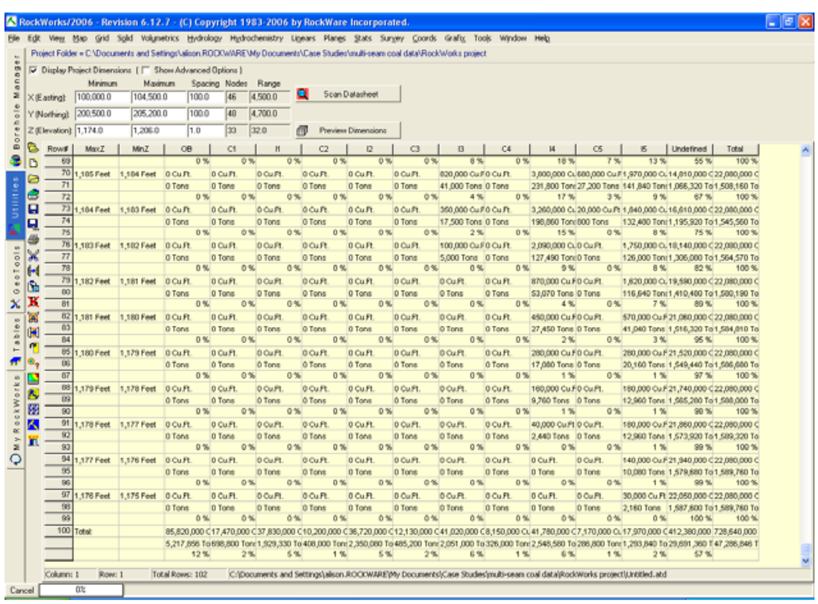
The Stratigraphy menu contains tools for display of 2D or 3D isopach maps of individual units, or of multiple, adjacent units. The contour map below was created for the C3 coal unit.



Step 11: Create a Volume Report

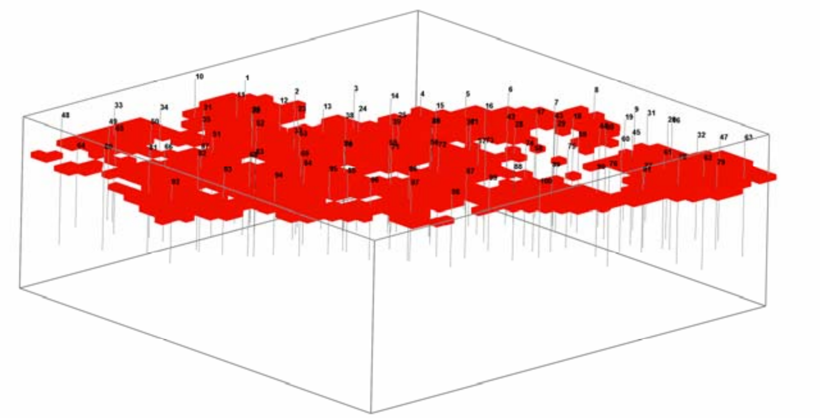
Although the volumes and masses of each unit are displayed in the RockPlot3D window, it's also helpful to generate a volume report.

When a Stratigraphy model is created, the user has the option of converting it to a 3D solid model. This is stored in a file separate from the grid files that are used to display the model in RockPlot3D. We can now run this model through the Stratigraphy / Volumetrics tool to generate a report of volume or mass, by elevation interval, with totals for each unit. This report is displayed in the RockWorks Utilities datasheet. This particular example shows 1-foot elevation intervals, but the stratigraphic solid can be stored at any interval. This report can be stored as a tab-delimited ASCII file using the File / Save option.

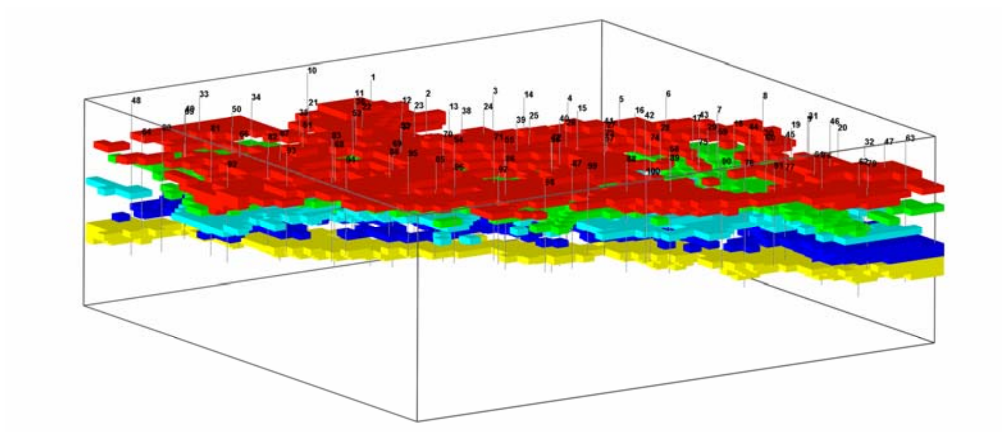


Step 12: Advanced Visualization and Volume Computation of Multiple Coal Layers

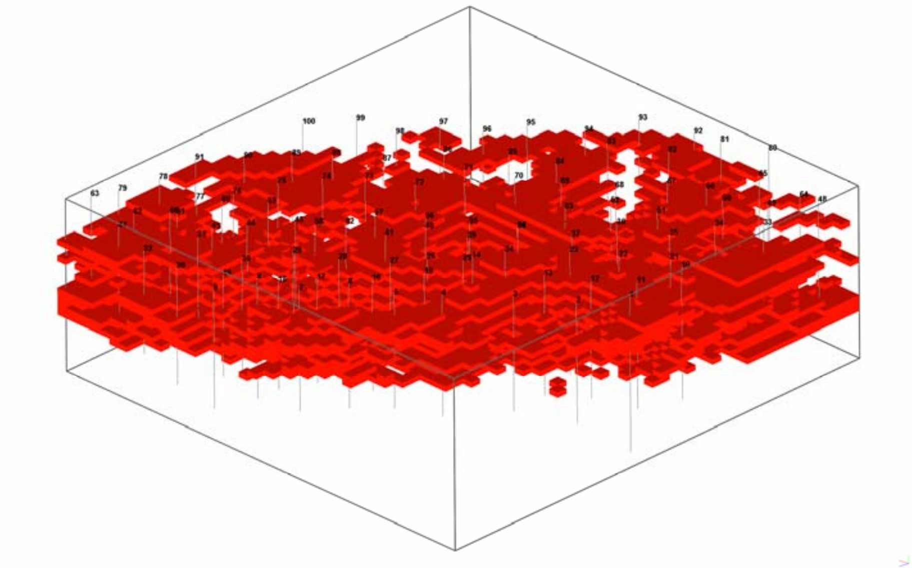
A further step can be to create a series of Boolean solid models, containing only 0's and 1's for "false" and "true", each model created for a different coal layer. Each coal layer would need to be filtered independently, using the RockWorks Utilities' Solid / Boolean Ops / Boolean Conversion tool. For the C1 layer, for example, the minimum and maximum thresholds would be set to 2 and 2 (to filter for its "order" values of "2"). The output model would look like the image below when displayed in RockPlot3D (3D stick logs have been appended).



Appending additional layers assigned different colors (C2-Boolean in blue and C3-Boolean in green,etc.), we see the following image.

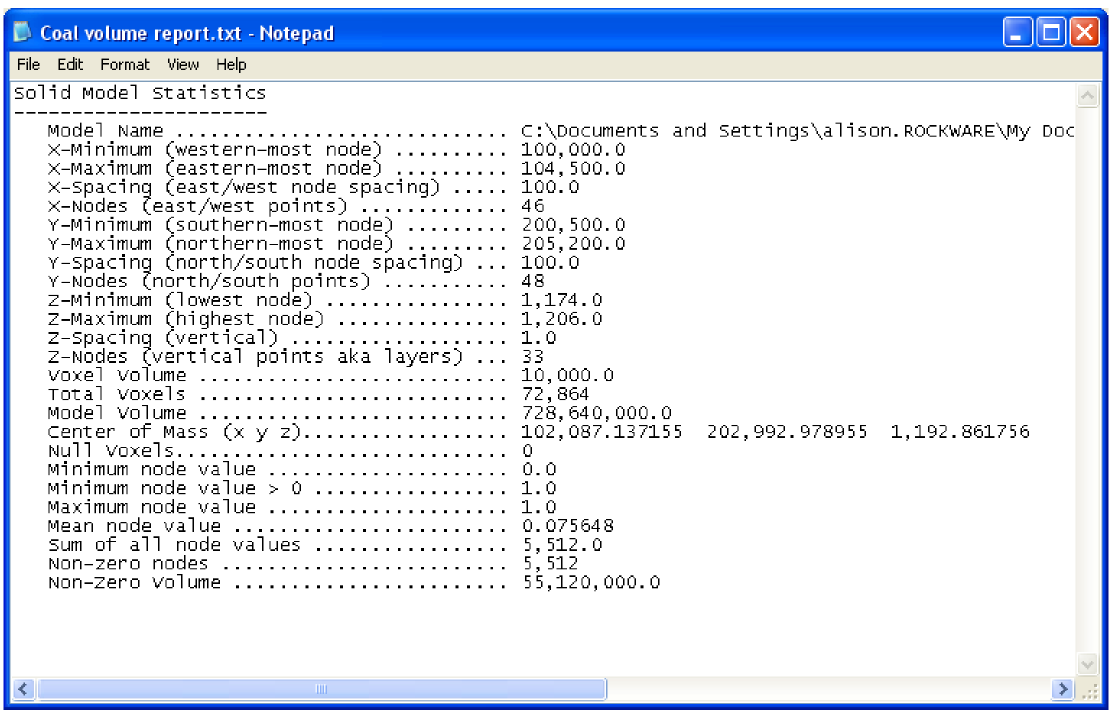


Finally, the Boolean models for all areas in which you are interested can be combined back into a single "all-coal" Boolean model using the Geological Utilities / Solid / Math / Model & Model option. The additions are done individually, so that C1 Boolean + C2 Boolean = C1-C2 Boolean. C1-C2 Boolean + C3 Boolean = C1-C2-C3 Boolean, and so on. The final model (C1-C2-C3-C4-C5 Boolean) is shown below, with all coal layers displayed in red.



Remember ... we're adding Boolean models (in which 1 = coal and 0 = not-coal) on a voxel-by-voxel basis. Therefore, any voxel within the C1-C2-C3-C4-C5 Boolean file that contains coal for any of the five seams will be defined by a node value of 1.

This resulting solid Boolean model can be run through the RockWorks Utilities' Solid →Statistics → Report option to determine total non-zero volume, for all coal layers. The "non-zero" volume is the computation to use because this Boolean model only contains 1's (for coal) and 0's (for not-coal).



Coal volume report.txt - Notepad

File Edit Format View Help

```
Solid Model Statistics
----------------------
   Model Name ............................ C:\Documents and Settings\alison.ROCKWARE\My Doc
   X-Minimum (western-most node) ......... 100,000.0
   X-Maximum (eastern-most node) ......... 104,500.0
   X-Spacing (east/west node spacing) ..... 100.0
   X-Nodes (east/west points) ............ 46
   Y-Minimum (southern-most node) ......... 200,500.0
   Y-Maximum (northern-most node) ......... 205,200.0
   Y-Spacing (north/south node spacing) ... 100.0
   Y-Nodes (north/south points) ........... 48
   Z-Minimum (lowest node) ................ 1,174.0
   Z-Maximum (highest node) ............... 1,206.0
   Z-Spacing (vertical) ................... 1.0
   Z-Nodes (vertical points aka layers) ... 33
   Voxel Volume ........................... 10,000.0
   Total Voxels ........................... 72,864
   Model Volume ........................... 728,640,000.0
   Center of Mass (x y z).................. 102,087.137155   202,992.978955   1,192.861756
   Null Voxels............................. 0
   Minimum node value ..................... 0.0
   Minimum node value > 0 ................. 1.0
   Maximum node value ..................... 1.0
   Mean node value ........................ 0.075648
   Sum of all node values ................. 5,512.0
   Non-zero nodes ......................... 5,512
   Non-zero Volume ........................ 55,120,000.0
```