RockWorks Fracture Modeling

2/8/22

The ***Borehole Manager / Fractures Solid Modeling*** program has been re-designed (Figure 1) and significantly enhanced as described below. These changes apply to geotechnical (tunneling and roadcuts), environmental (contaminant migration pathways), hydrothermal (steam vents), mining (breccia pipes and hydrothermal venting), and petroleum (hydrofracking) applications.

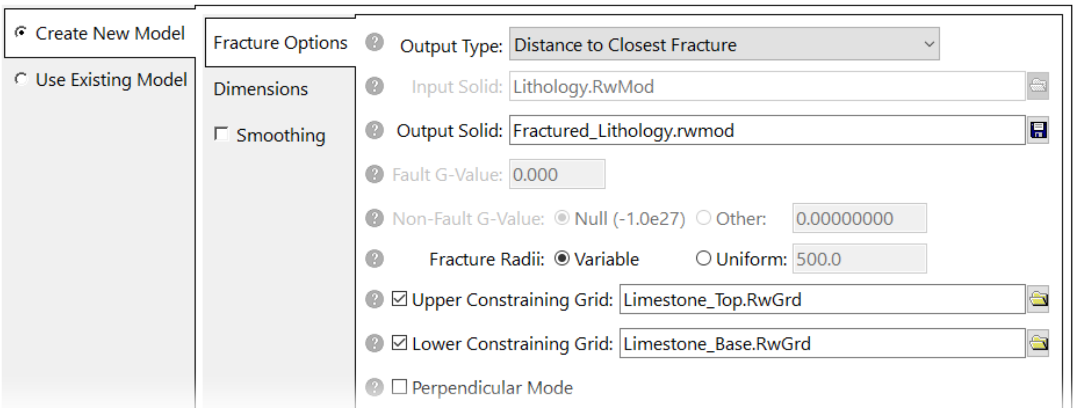

Figure 1

The ***Output Type*** pull-down menu (Figure 2) provides for six different types of operations;

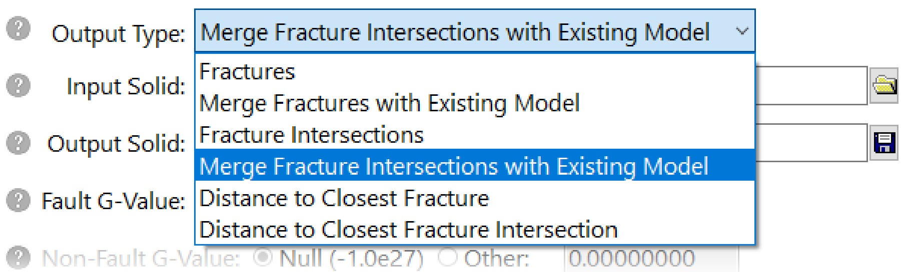

Figure 2

1. Output Type = Fractures

When using this option, voxels that are intersected by a fracture will be assigned a G-Value based on the specified ***Fault G-value*** while all other voxels will be assigned to a value specified by the ***Non-Fault G-Value*** (Figure 3). Please note that aperture attributes within the ***Borehole Manager / Fractures Table*** are not used in this program. Instead, the fracture modeling within this program identifies a voxel as fractured if it is intersected by a fracture plane.

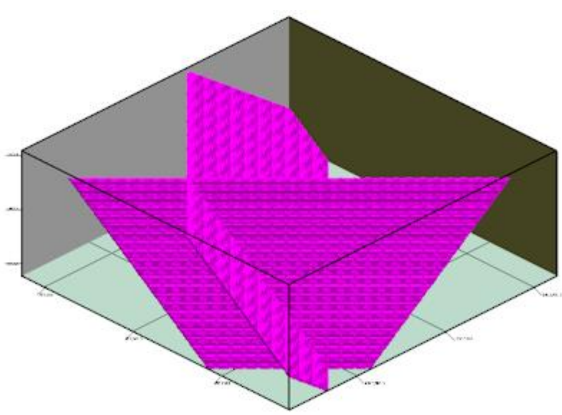

Figure 3

2. Output Type = Merge Fractures with Existing Model

This option will overwrite the voxels within the specified ***Input Solid*** that are intersected by a fracture with the value specified for the ***Fault G-Value***. This provides a means for adding karst voids, gouge, etc. based on a G-Value assigned within the Lithology or Stratigraphy Types tables. In the example below (Figure 4), a stratigraphic unit titled "*Void*" with a G-Value of zero and a color of black was added to the ***Stratigraphy Types*** table. The ***Fault G-Value*** within this menu was set to zero such that it replaces any fractured values within the *Void* rock type.

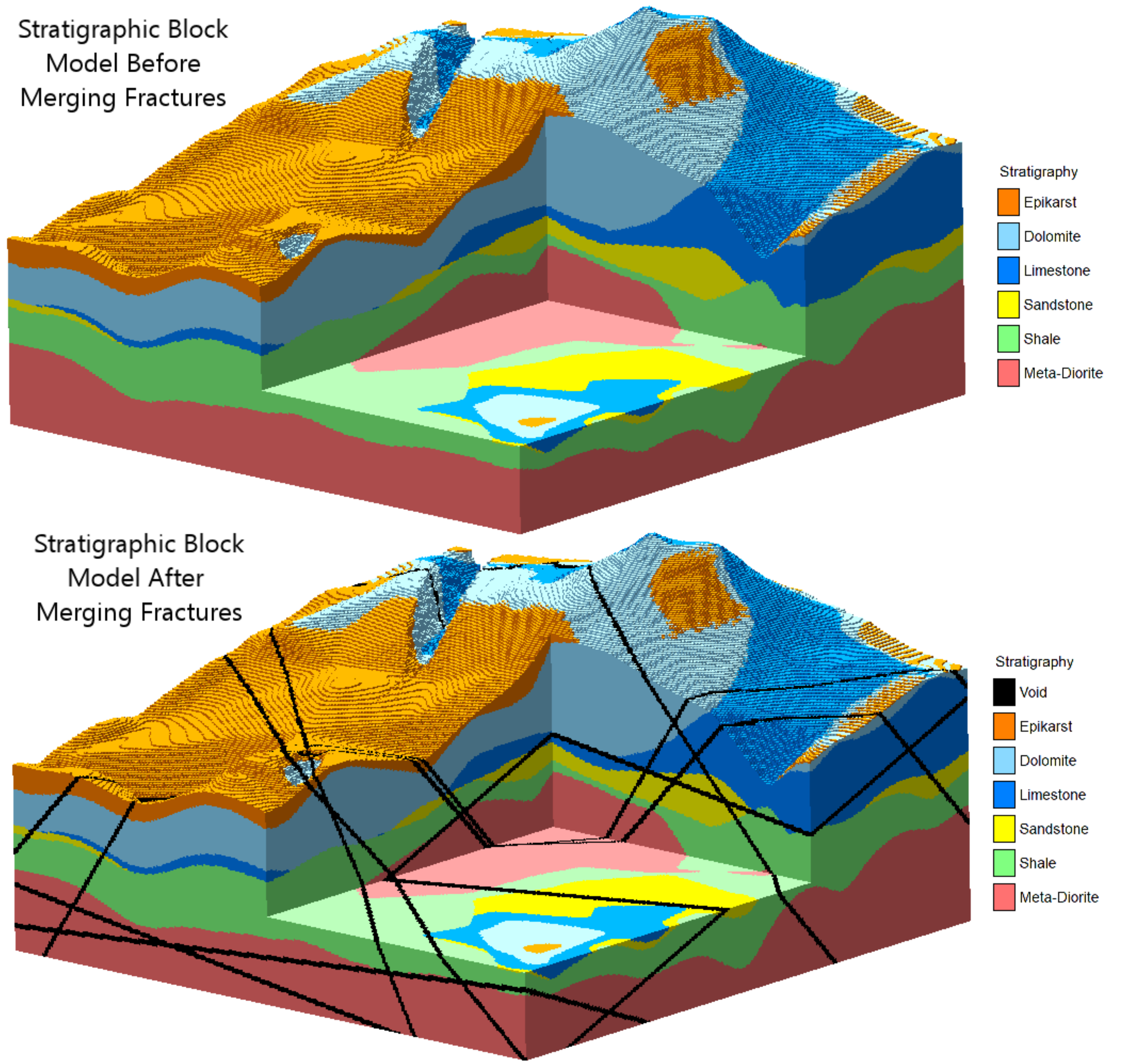

Figure 4

Previous version of RockWorks used fracture models, in conjunction with the ***ModOps / Solid / Merge*** program to add fracture information to other solid models (e.g., lithology, stratigraphy), however, this new option provides a significantly easier solution.

3. Output Type = Fracture Intersections

When using this option, voxels that are intersected by a fracture intersection (a line) will be assigned a G-Value based on the specified ***Fault G-value*** while all other voxels will be assigned to a value specified by the ***Non-Fault G-Value*** *(*Figure 5*)*. Given that fracture intersections often represent area of structural weakness, these models may be useful for identifying possible breccia and kimberlite pipes, hydrothermal steam vents, etc,

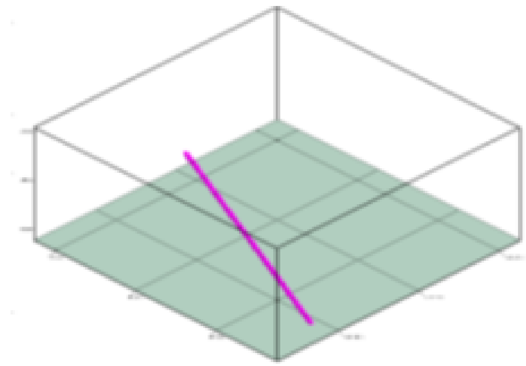

Figure 5

4. Merge Fracture Intersections with Existing Model

This option will overwrite the voxels within the specified ***Input Solid*** that are intersected by a fracture intersection with the value specified for the ***Fault G-Value***. This provides a means for adding karst voids, gouge, etc. based on a G-Value assigned within the Lithology or Stratigraphy Types tables.

5. Output Type = Distance to Closest Fracture

These models are used to visualize and quantify the degree of fracturing within a project site.

Conversely, the distance-to-fracture models may be filtered (via the ***ModOps / Solid / Range Filter*** program) to identify unfractured areas. Example applications include optimizing dimension stone quarrying (e.g., Indiana Limestone), siting nuclear waste repositories, and subway tunnel routing.

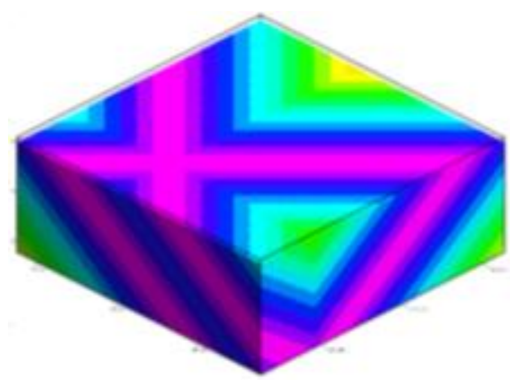

Figure 6

6. Output Type = Distance to Closest Fracture Intersection

Distance-to-Closest Fracture Intersection models (Figure 7) are commonly used to identify zones of maximum structural incoherence that may provide pathways or conduits for the movement of groundwater (e.g., karst), contaminants, hydrothermal fluids (e.g., breccia pipes), steam vents (e.g., geothermal), and molten rock (e.g., kimberlites).

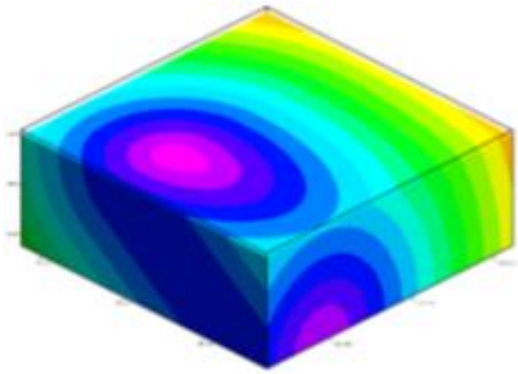

Figure 7

Fracture Radii

When used in conjunction with borehole fracture data (Figure 8), the ***Fracture Radii – Variable*** setting will define the radius of each fracture based on the associated radius within the borehole ***Fractures*** data table (Figure 9). When used in conjunction with the RockWorks ***Datasheet***, the radius for each fracture is defined within a specified ***Datasheet*** column.

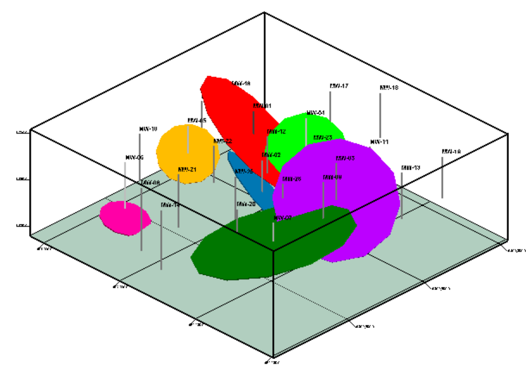

Figure 8

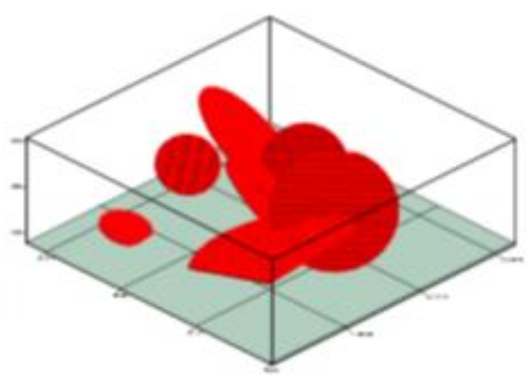

Figure 9

The ***Fracture Radii – Uniform*** setting will define the radius of all fractures based on a user-defined value (Figure 10). Note that this setting can be larger than the project size to define fractures that transect the project.

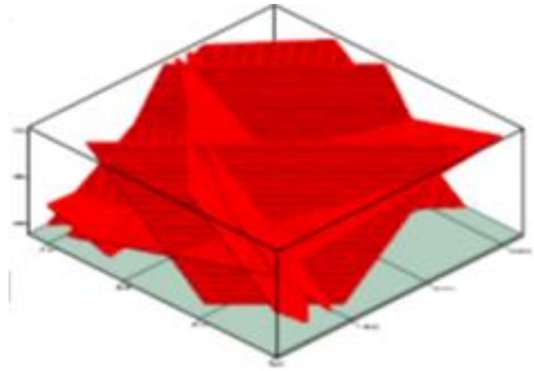

Figure 10

Although extending fractures to transect the project area creates an undecipherable mess (Figure 10), creating a ***Distance-to-Fracture Intersection*** model will provide a readily comprehensible and very important model in terms of fluid flow (Figure 11).

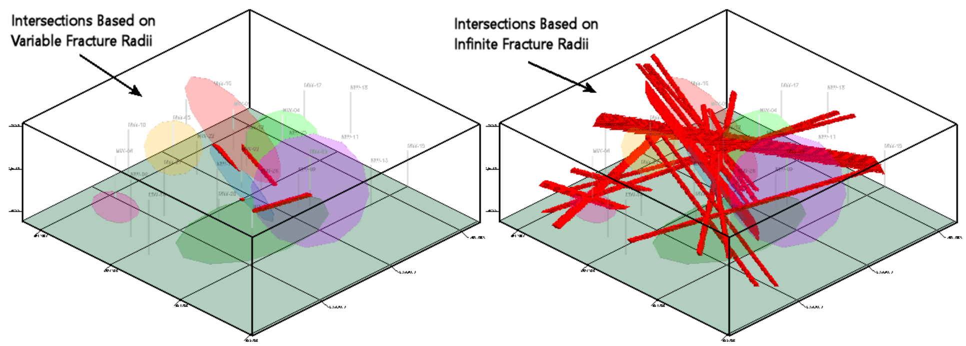

Figure 11

Perpendicular Mode

Enabling the ***Perpendicular Mode*** option will force the program to disregard the fracture azimuth and inclination data. Instead, all fractures will be assumed to be perpendicular to the log axis (Figure 12). This capability has been added primarily for downhole seismic and radar surveys in which the fracture radius represents the distance to an object (e.g., pilings) and the aperture represents the height of the object.

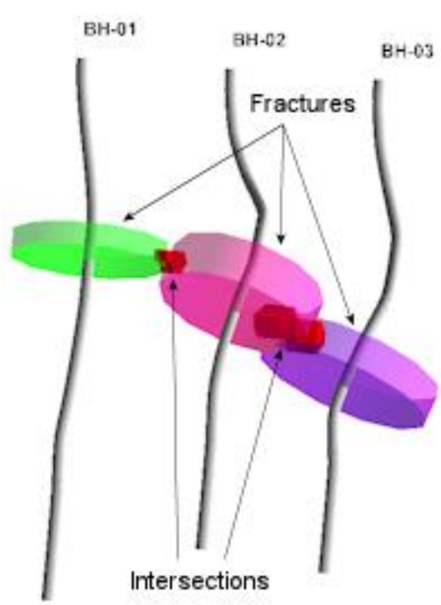

Figure 12

Constraining Grids

The ***Constraining Grids*** provide a means to restrict the fracture modeling below, above, or in-between existing grid models (surfaces). For example, if the borehole fractures are confined to a limestone unit overlain by sand and underlain by unfractured clay, it would make sense to limit the fracture model based on a surface that represents the top of the limestone and a surface that represents the base of the limestone (Figure 13).

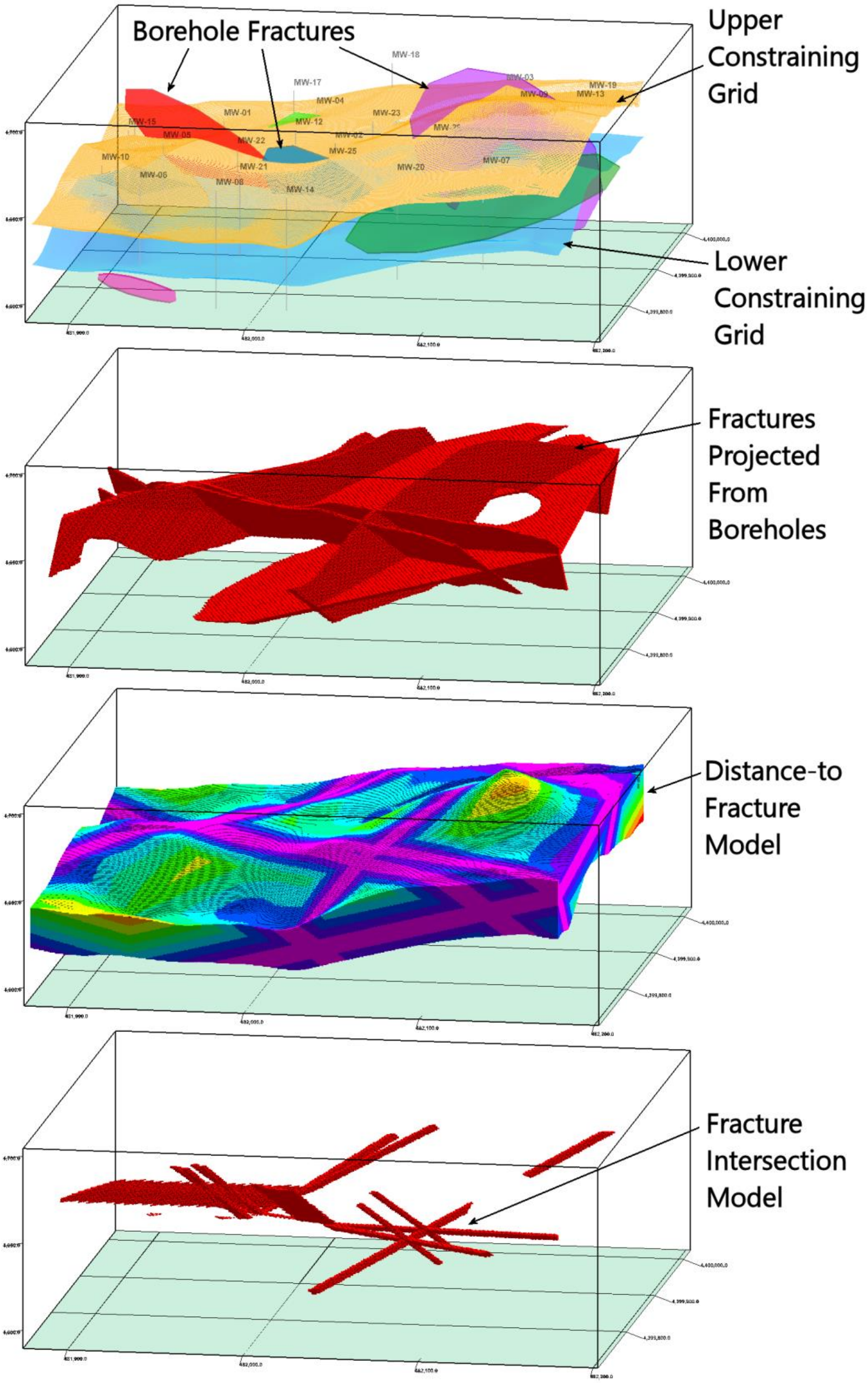

Figure 13

Using the Constraining Grids to Independently Model Stratigraphic Units

When dealing with stratigraphic units that have unique fracture fabrics unrelated to overlying and underlying formations (Reed & Arvidson, 1978) this process can be applied separately for each unit, or group of units that share the same jointing.

In the example shown below (Figure 15), the fractures were independently modeled for the following units;

- Epikarst & Dolomite
- Limestone
- Sandstone & Shale
- Meta-Diorite

The aforementioned iterations are best accomplished by using the RockWorks Playlist (Figure 14).

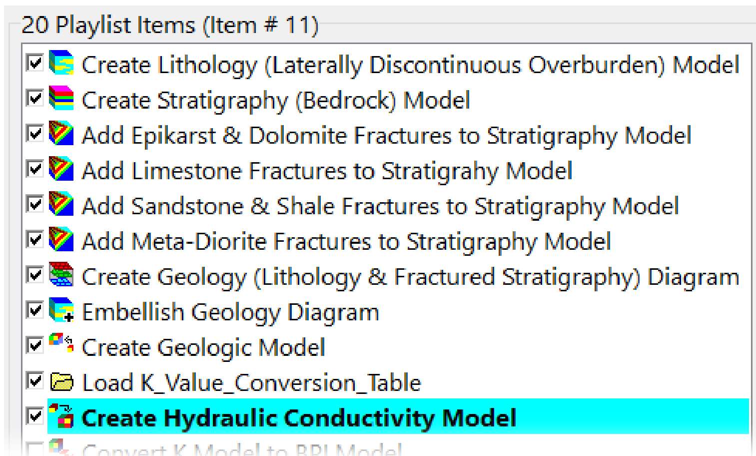

Figure 14

In this example, an initial stratigraphy block model was created. The ***Merge Fractures with Existing Model*** option was then used to replace all of the voxels between the top of the epikarst and the base of the dolomite with fracture nodes between these two surfaces. The output model was then successively filtered to replace all of the voxels between the top and base of the limestone, the top of the sandstone and the base of the shale, and all of the voxels below the meta-diorite. Notice how the fractures (shown in black within Figure 15.) terminate at the stratigraphic contacts.

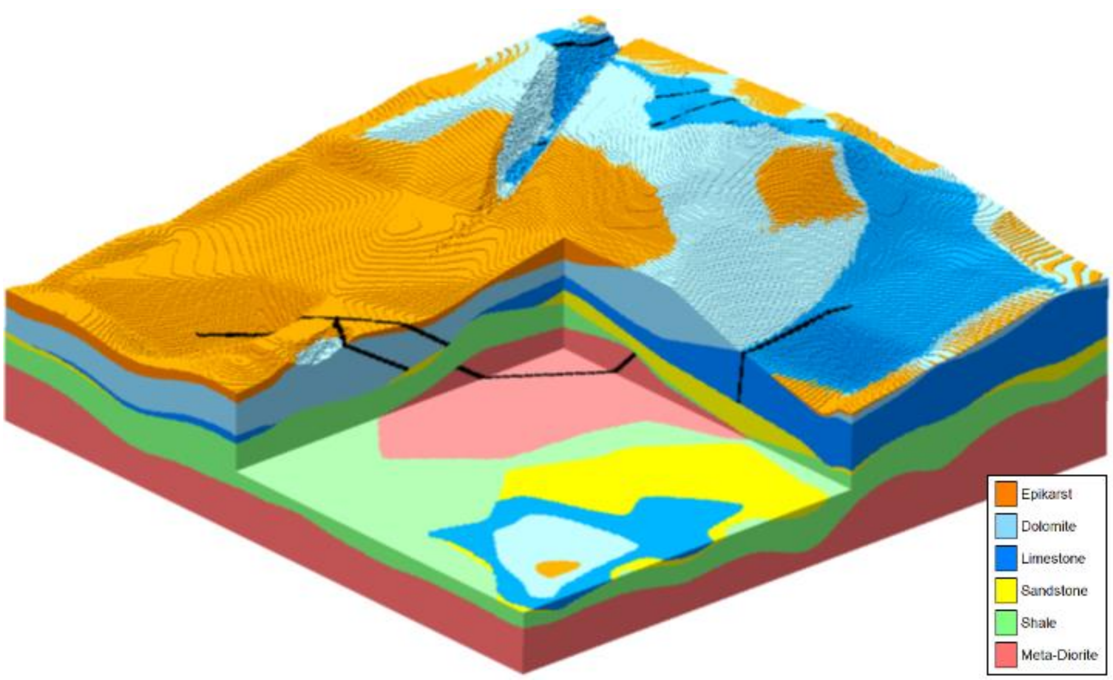

Figure 15.

In this study, the fractured bedrock stratigraphy (epikarst, dolomite, limestone, sandstone, shale, and meta-diorite) was overlain, in places, by unconsolidated laterally discontinuous and unfractured overburden described by USCS (Unified Soil Classification System) codes. Given that the overburden is unfractured, the two data sets (bedrock and overburden) were modeled separately. The bedrock contacts were modeled with a gridding technique (kriging) while the overburden was interpolated with a block-modeling method called "lateral blending". The two models were merged into a single model (Figure 16) for subsequent conversion to a hydraulic conductivity model.

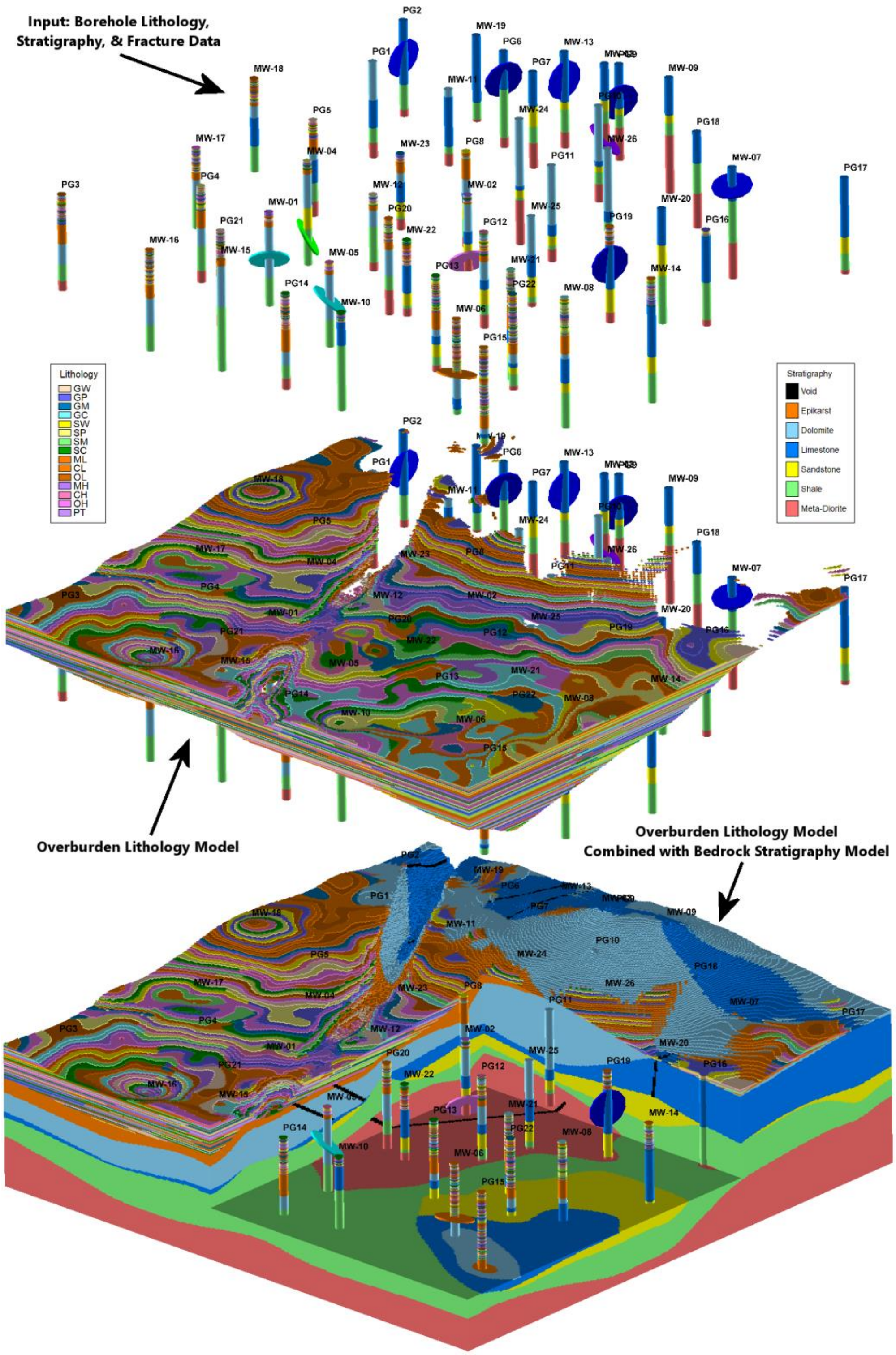

Figure 16

References: Reed, J.P. and Arvidson, R.E., 1978, Structural control of drainage nets in a portion of eastern Missouri, American Geophysical Union Midwest Meeting, abs.