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PetraSim Examples:

Five-Spot Geothermal Injection and Production using Polygonal Cells and Wells

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Five-Spot Geothermal Injection and Production using Polygonal Cells and Wells

We will repeat the previous example, but this time using a different mesh and wells to define the injection and production. Open the Five-Spot Geothermal Production and Injection model and save it to a new folder. This will preserve all the parameters not related to the mesh that we already defined in the previous model.

Add Wells

To add wells:

1. On the **Model** menu, click **Add Well…**
2. In the **Name** box, type *Inject*
3. In the **Ordered Well Coordinates** table, type these values:

X	Y	Z
0.0	0.0	310.0
0.0	0.0	0.0

4. Click **OK** to create the well
5. Repeat this for the production well. Use the name *Produce* and the following coordinates:

X	Y	Z
500.0	500.0	310.0
500.0	500.0	0.0

Create Mesh

To create a polygonal (Voronoi) mesh:

1. On the **Model** menu, click **Create Mesh**
2. For **Mesh Type**, select *Polygonal*
3. Click **OK** to create the mesh

Your mesh should be refined near the wells, Figure 1. When a new mesh is created, the previous cell-specific properties, names and sources/sink data, are erased.

Figure 1: Polygonal (Voronoi) mesh showing refinement near wells

Edit Well Flow Rates

To define the injection rate:

1. In the **Tree View**, right-click on the **Inject** well and click **Properties…**
2. On the **Flow** tab, in the **Injection** section, select the **Water/Steam** check box
3. In the **Rate** box, type *7.5*
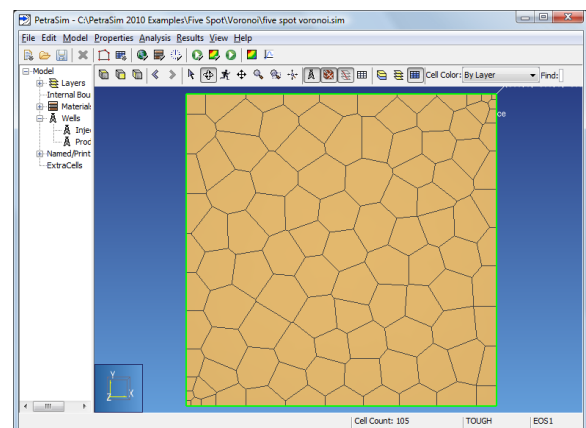4. In the **Enthalpy** box, type *50000* (corresponding to about 6 °C)

5. Click the **Print Options** tab
6. Click to select the **Print Time Dependent Flow and Generation Data** check box
7. Click **OK** to save changes and close the dialog

To define the production rate:

1. In the **Tree View**, right-click on the **Produce** well and click **Properties…**
2. On the **Flow** tab, in the **Production** section, select the **Mass Out** check box
3. In the **Rate** box, type *7.5*
4. Click the **Print Options** tab
5. Click to select the **Print Time Dependent Flow and Generation Data** check box
6. Click **OK** to save changes and close the dialog

Save and Run

The input is complete and you can run the simulation. Save your model and run the simulation:

1. On the **Analysis** menu, click **Run TOUGH2**

The solution will start and then Halt Prematurely. Click **OK** to close the **Error** dialog.
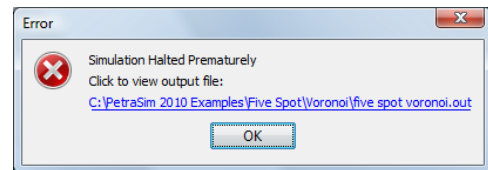
In the **Running TOUGH2** dialog, click on the **Graph** tab. This display will show how the time step increased and then became small before halting. Next click on the **Log** tab. This displays the error messages from the TOUGH2 output file. The critical message that will cause convergence failure is EOS CANNOT FIND PARAMETERS AT ELEMENT *   3*. Use the **Find** function and it will show that cell 3 is the cell that contains the production well.
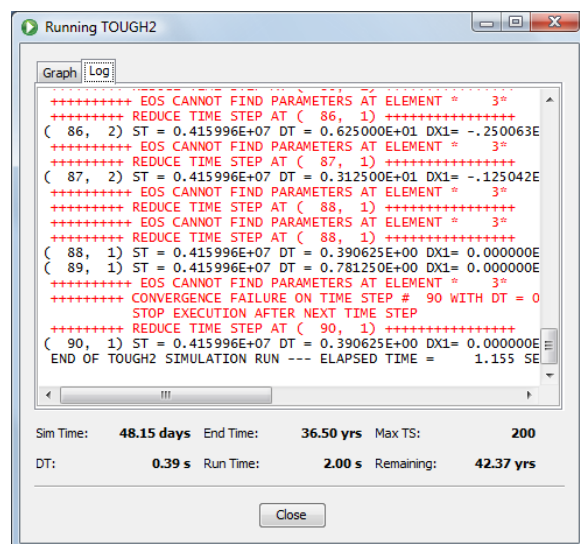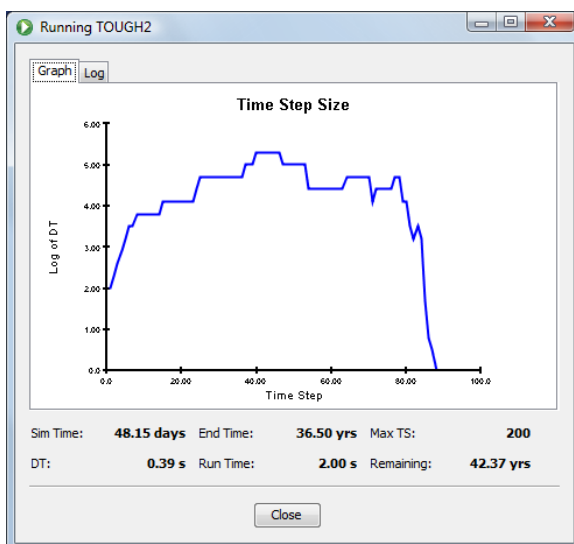
So, in the previous example we were able to run with injection and production, but in this example the solution failed. This provides a good example of the critical importance of physically meaningful

boundary conditions in TOUGH2 . Specifying a constant production rate is not a realistic boundary condition. In a real well, we cannot specify any desired production rate. In a real well, the production rate depends on the fluid conditions and material properties of the reservoir and the geometry and conditions of the production well. By specifying a fixed production rate, we have attempted to remove mass at a higher rate than physically possible. As shown below, the pressure in the production cell goes to zero and the equation of state is no longer valid.
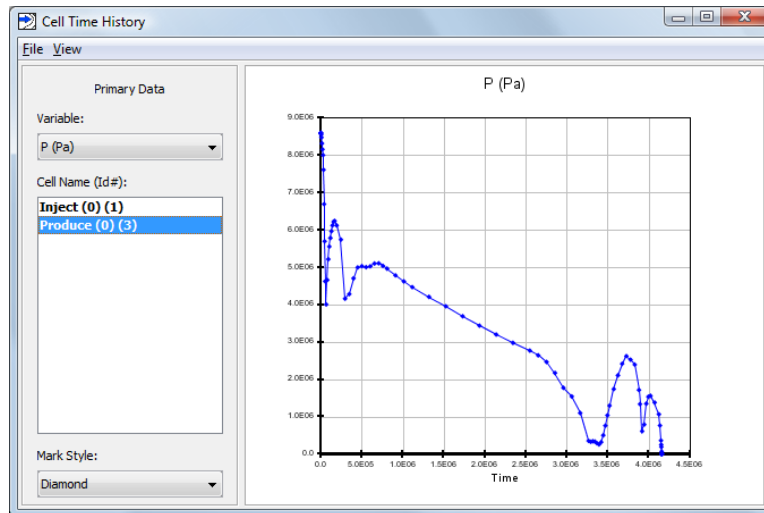
The reason the pressure goes to zero is that the production cell size in the polygonal model is smaller than in the uniform rectangular grid. We are trying to remove the same total flow rate from a smaller cell. Since the flow area to the well is smaller, this requires a greater pressure drop into the cell, lowering the pressure in the production cell until an unphysical state is reached in the model.

A better approximation of a real well can be made using the Productivity Index (see p.64 of the TOUGH2 user manual). Using the Productivity Index, the flow into the well is proportional to the pressure difference between the well and containing cell.

To define the production well using the Productivity Index:

1. In the **Tree View**, right-click on the **Produce** well and click **Properties…**
2. Click on the **Flow** tab
3. In the **Production** section, click to clear the **Mass Out** check box
4. In the **Production** section, click to select the **Well on Deliv** check box
5. In the **Productivity Index** box, type *2.0E-12* (based on calculation described in the TOUGH2 User Manual)
6. In the **Pressure** box, type *8.6E6* (the initial pressure in the model)
7. For **Gradient**, select *Well Model*
8. Click the **Print Options** tab
9. Click to select the **Print Time Dependent Flow and Generation Data** check box
10. Click **OK** to save changes and close the dialog

Save and Run with Well on Delivery Conditions

The input is complete and you can run the simulation. Save your model and run the simulation:

1. On the **Analysis** menu, click **Run TOUGH2**

The **Simulation Complete** dialog will notify you when the end time has been reached. Click **OK** to dismiss the notification and click **Close** to exit the **Running TOUGH2** dialog.

View 3D Results

To open the **3D Results** dialog:

1. On the **Results** menu, click **3D Results**

By default, the display will show isosurfaces corresponding to pressure for the first output step.

To show temperature isosurfaces for the last time step:

1. In the **Scalar** list, click **T**
2. In the **Time(s)** list, click the last entry (t = **1.15183E9**)

To show scalar data on a slice plane:

1. Click **Slice Planes...**
2. In the **Axis** list, click **Z**
3. In the **Coord** box, type *305*
4. Click **Close**

To remove isosurfaces and show only slice data:

1. Click to clear the **Show Isosurfaces** check box
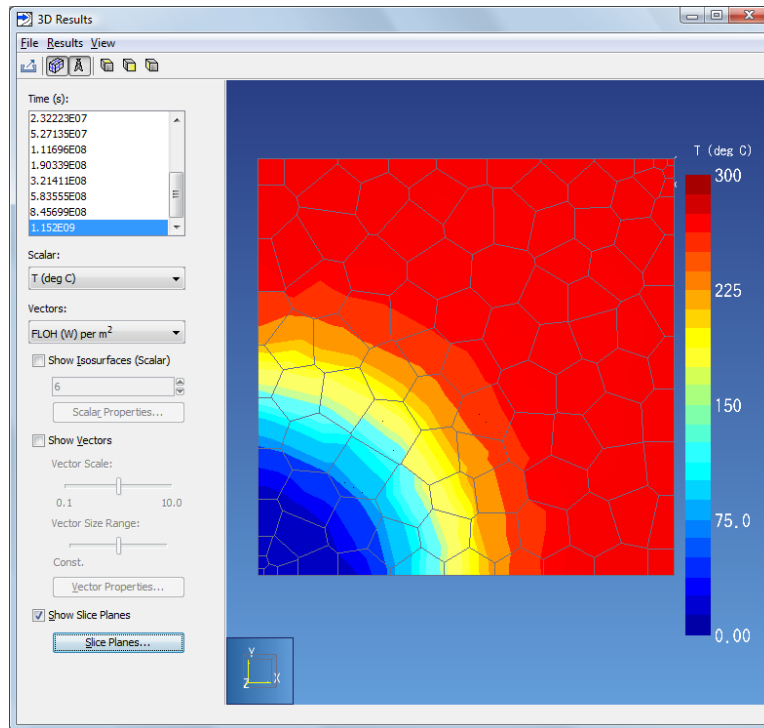
The resulting visualization is shown below:

Figure 2: Temperature contours at end of solution for analysis using Productivity Index and Voronoi cells

Comparing Figure 2 to the previous results shows that there is not a pressure and temperature drop at the production well when using the Productivity Index.

When finished, you can close the **3D Results** dialog.

View Time History Plots

To view time history plots:

1. On the PetraSim **Results** menu, click **Cell History Plots...**
2. In the **Variable** list, click **T (deg C)**
3. In the **Cell Name (Id#)** list, click **Inject (1)**

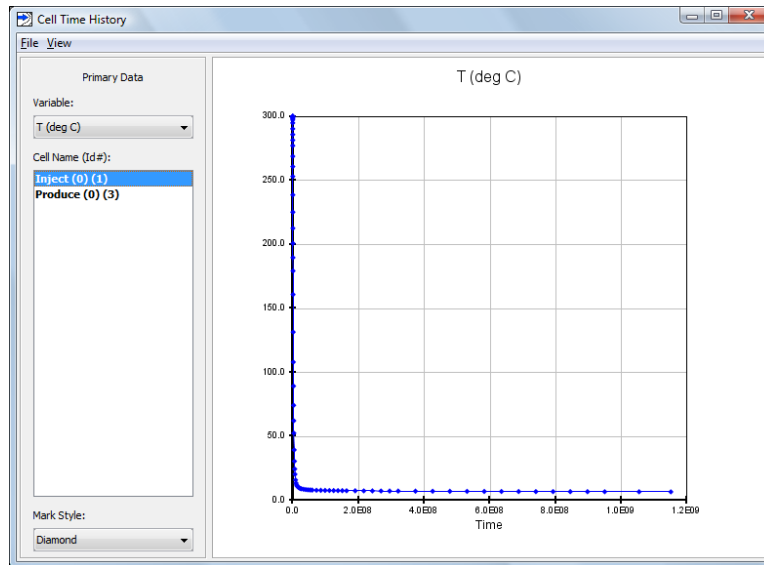The resulting plot is shown below.

Figure 3: Temperature history of injection cell using polygonal mesh

Comparing Figure 3 with the previous example, shows again the effect of the small cell near the injection well in the polygonal mesh. Because the cell that contains the injection well has a small volume in the polygonal mesh, it cools much more rapidly than the larger cell in the rectangular mesh.

When finished, you can close the **Cell History** dialog.

View Well Flow Time History Plots

The total flow from the well can be plotted by:

1. On the PetraSim **Results** menu, click **Well Plots...**
2. In the **Variable** list, click **Flow Rate (kg/s)**
3. In the **Well Name** list, click **Produce (1)**
4. On the **View** menu, click **Range**.
5. Click to clear **Auto Range**
6. In the **X-Max** box type *5.0E6*
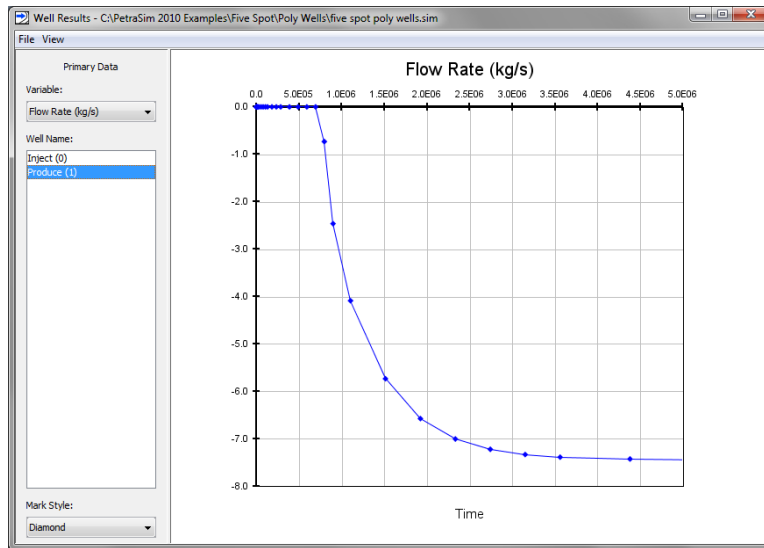7. Click **OK**

The resulting plot is shown below.

Figure 4: Flow at output well

Figure 4 shows how the production flow rate is initially zero, and then increases until it matches the injection flow. The initial two-phase state of the model that provides compressibility, so that although injection is constant, there is a time delay as the production increases to the steady state value.