

第 41 期：如何采用微地震数据建立页岩气水力压裂模型

编写人：郑伶俐

第 29 期讲述了如何采用 GEM 软件来模拟页岩气的理论模型以及水力压裂模型，本期将主要讲解如何用 Builder 前处理软件建立基于微地震解释数据的水力压裂模型。

在体积压裂中可采用微地震数据确定裂缝形状和尺寸，采用 Builder 建立裂缝模型。裂缝加密方法采用 LS-LR-DK 网格加密（即对数分布-局部加密-双渗模型 **Logarithmically Spaced, Locally Refined, Dual-Permeability Model**），该方法能够在不失计算精确度的条件下减少加密网格数，并且能够快速建立裂缝网格。

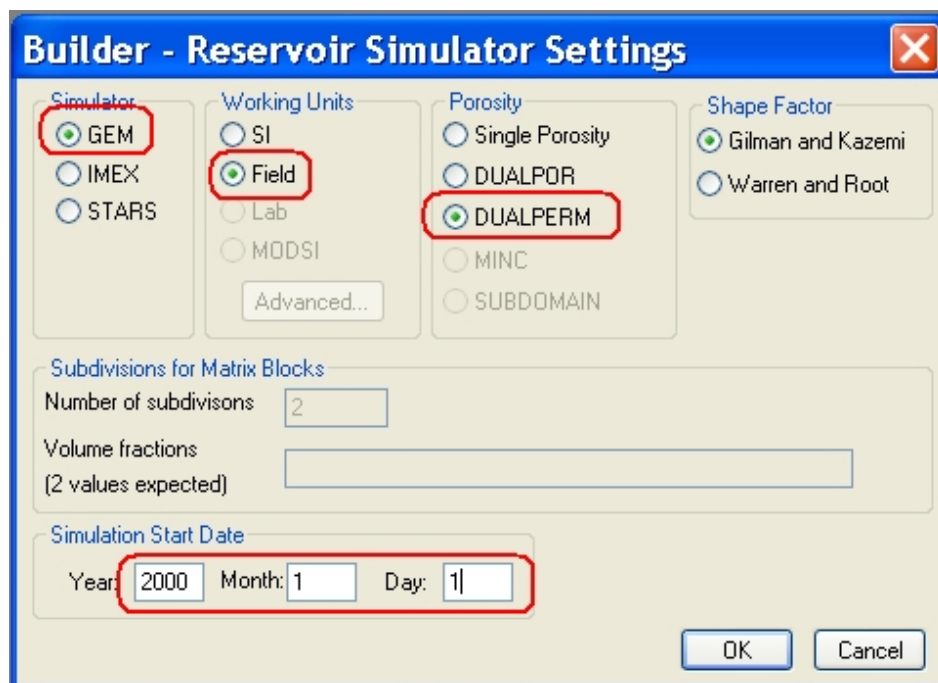
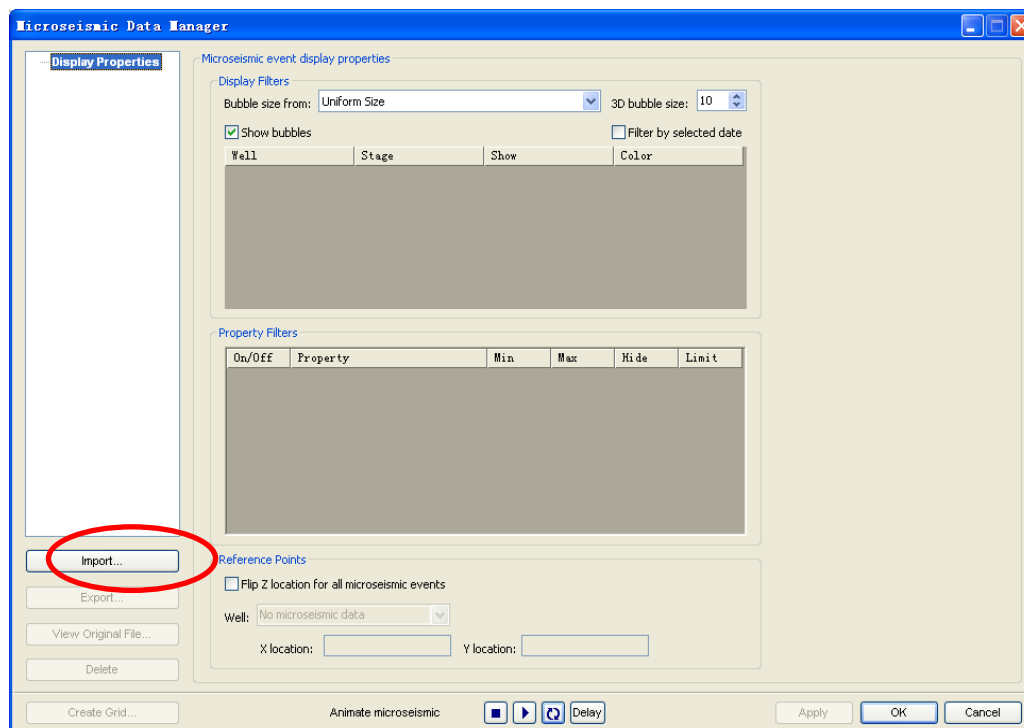
微地震检测技术的基本应用方法是：通过在井中或地面布置检波器，排列接收生产活动所产生或诱导的微小地震事件，并通过对这些事件的反演求取微地震源位置等参数，最后通过这些参数对生产活动进行监控和指导。以下为如何采用微地震数据建立页岩气裂缝模型的操作流程。

本期讲义还包含两个数据文件：微地震数据文件 **MS_Data.csv** 以及讲义所生成的模型文件 **shale gas modeling.dat**。

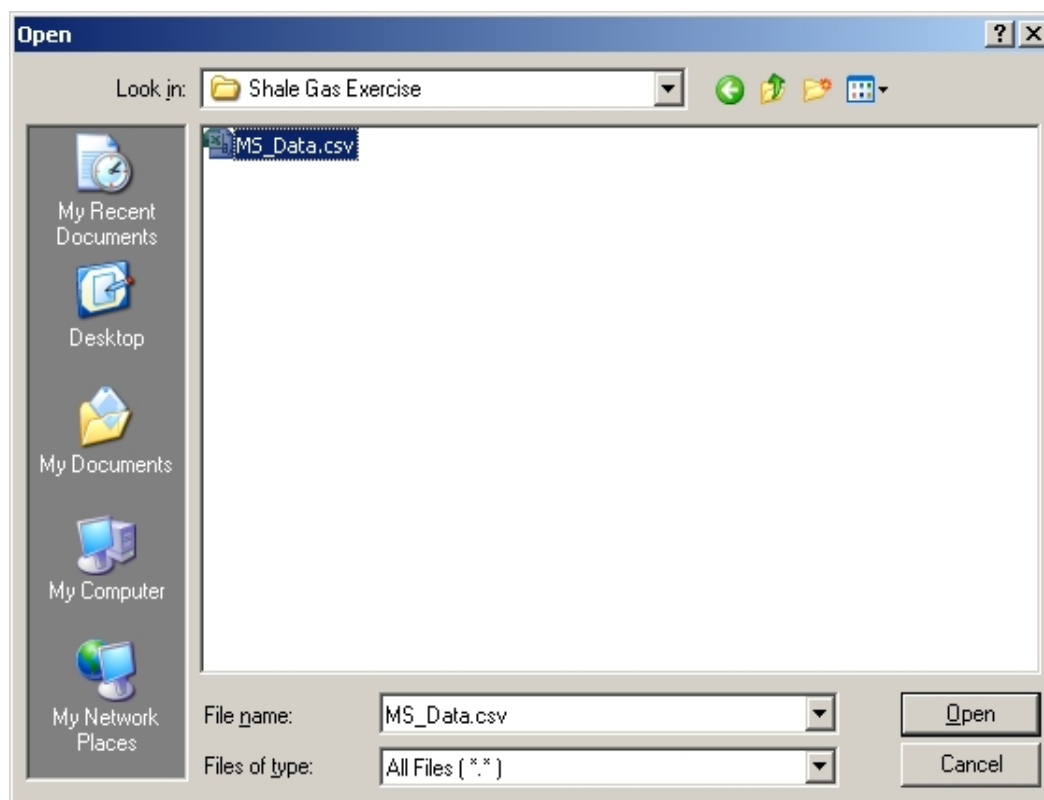
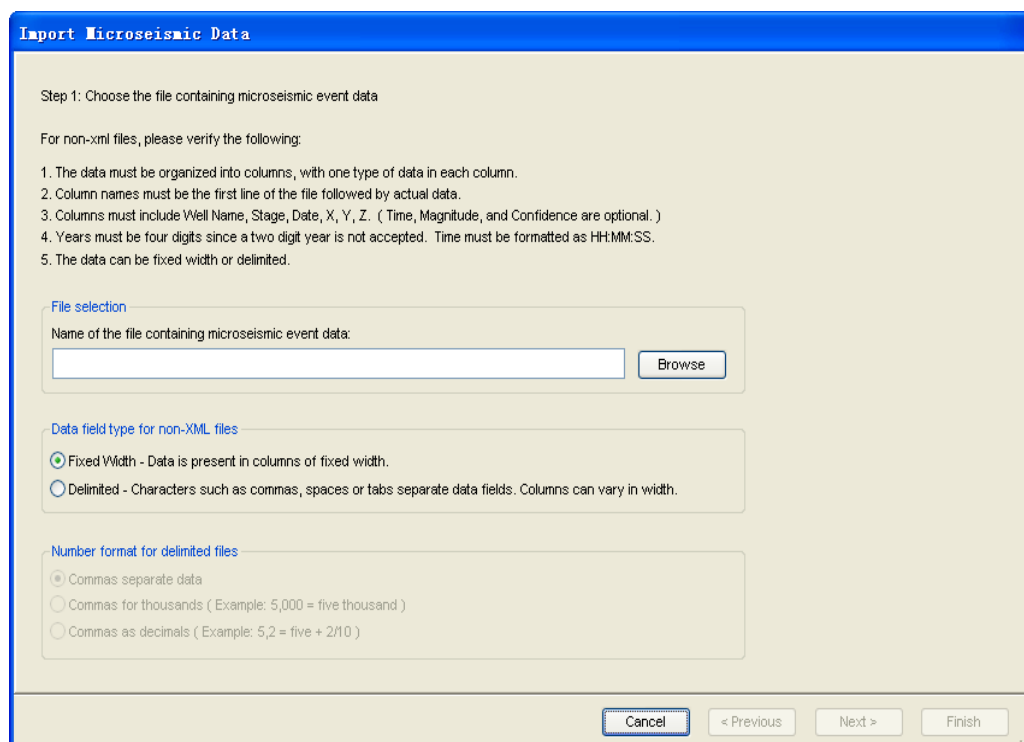
本讲义操作须在 Builder 2010.10 版或更高版本实现。

1. 打开 Builder

选择 **GEM** 模拟器, **Field Units**, **DUALPERM**, **Gilman and Kazemi** 形状因子, 模拟开始时间 **2000-01-01**, 点击 **ok**。

2. 在 **Builder** 界面, 点击 **Tools**, 选择 **Microseismic Data Manager...** 点击 **import** 按钮。

3. 点击 **Browse** 按钮，导入准备好的微地震数据文件 **MS_Data.csv**。



4. 选择 **Delimited** 数据类型，选择默认的 **comma** 选项。

Import Microseismic Data

Step 1: Choose the file containing microseismic event data

For non-xml files, please verify the following:

1. The data must be organized into columns, with one type of data in each column.
2. Column names must be the first line of the file followed by actual data.
3. Columns must include Well Name, Stage, Date, X, Y, Z. (Time, Magnitude, and Confidence are optional.)
4. Years must be four digits since a two digit year is not accepted. Time must be formatted as HH:MM:SS.
5. The data can be fixed width or delimited.

File selection

Name of the file containing microseismic event data:

D:\Training\Shale Gas Exercise\MS_Data.csv Browse

Data field type for non-XML files

☐ Fixed Width - Data is present in columns of fixed width.

☒ Delimited - Characters such as commas, spaces or tabs separate data fields. Columns can vary in width.

Number format for delimited files

☒ Commas separate data

☐ Commas for thousands (Example: 5,000 = five thousand)

☐ Commas as decimals (Example: 5.2 = five + 2/10)

Cancel < Previous Next > Finish

5. 选择 **NEXT** 按钮，到如下界面。确保选项都空着，然后点击 **NEXT**。文件格式第一列为井名，之后分别为井段，年月日，时间，定位点坐标(x,y,z)，地震事件震级(能量大小)，发生该事件破坏力矩张量大小，定位可信度(精确度)。

Import Microseismic Data

Step 2: Choose delimiters

☐ Tab ☐ Space ☒ Comma ☐ Semicolon

☐ Treat consecutive separators as one

1	2	3	4	5	6	7	8	9	10
Well Name	Stage	Date	Time	X-Coordinate	Y-Coordinate	Z-Coordinate	Magnitude	Moment	Confidence
Well-1	1	1/1/2000	0:00:00	709.06	1065.79	3567.35	3.903244889	69.05461795	1
	1	1/1/2000	0:00:00	1028.73	1022.49	3594.85	5.691061886	39.14183277	15.2783783
	1	1/1/2000	0:00:00	914.85	938.65	3602.52	6.498236201	14.50730783	10.36485481
	1	1/1/2000	0:00:00	942.42	997.54	3583.92	7.701849836	12.57124798	14.90463761
	1	1/1/2000	0:00:00	1073.57	930.45	3595.65	5.772529376	40.97732443	9.78712601
	1	1/1/2000	0:00:00	1030.88	994.59	3597.01	8.560672178	26.37244379	16.07510104
	1	1/1/2000	0:00:00	944.49	988.23	3592.71	1.420293327	19.92042164	15.08564906
	1	1/1/2000	0:00:00	953.47	1037.47	3569.99	6.364141561	18.06130213	13.79077536
	1	1/1/2000	0:00:00	1007.25	889.24	3557.77	5.257368508	26.88777444	9.16921714
	1	1/1/2000	0:00:00	1019.96	1015.41	3599.12	9.436515666	23.07678762	16.26345816
	1	1/1/2000	0:00:00	1064.05	860.27	3582.77	3.970913493	28.12917853	4.97391439
	1	1/1/2000	0:00:00	993.07	1024.28	3590.67	2.450733394	40.20214139	16.81176618
	1	1/1/2000	0:00:00	1008.15	945.67	3598.67	4.907186446	15.88482054	14.92251502
	1	1/1/2000	0:00:00	945.13	941.64	3594.1	4.18778913	10.23881404	12.96136679
	1	1/1/2000	0:00:00	922.51	918.16	3562.05	7.553059382	22.56247241	9.44867514
	1	1/1/2000	0:00:00	948.58	952.39	3597.14	0.608501763	61.88646976	13.91015848
	1	1/1/2000	0:00:00	998.12	974.02	3571.28	4.777371886	30.91486165	17.5302932

Cancel < Previous Next > Finish

6. 根据需要使用数据格式，时间的格式为“**Month Day Year**”，最后三列数据标识成“**Include Column**”。

Import Microseismic Data

Step 3: Choose column details and date format
Well Name, Stage, Date, X-Coordinate, Y-Coordinate and Z-Coordinate must be selected.
Valid date delimiters include forward slash (/), dash (-), dot (.), and a space.

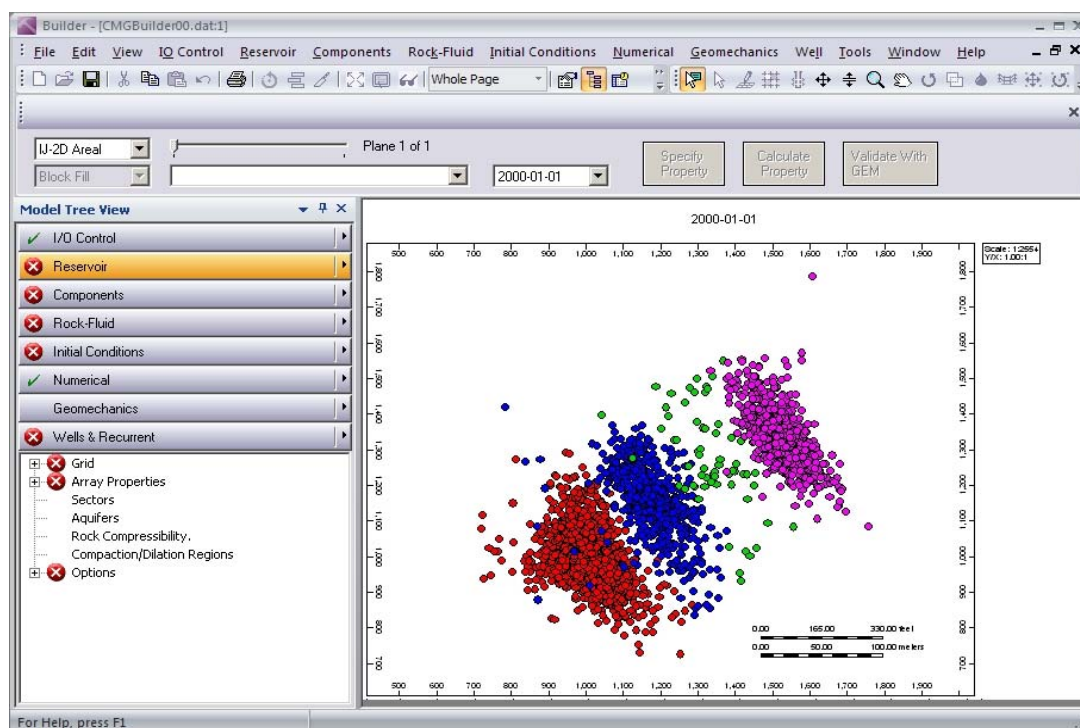
Date format: **Month Day Year**

Well Name	Stage	Date	Time	X-Coordinate	Y-Coordinate	Z-Coordinate	Include Column	Include Column	Include Column
Well-1	1	1/1/2000	0:00:00	709.06	1065.79	3567.35	3.903244889	69.05461795	1
2	1	1/1/2000	0:00:00	1028.73	1022.49	3594.85	5.691061886	39.14183277	15.2783783
3	1	1/1/2000	0:00:00	914.85	938.65	3602.52	6.498236201	14.50730783	10.36485481
4	1	1/1/2000	0:00:00	942.42	997.54	3583.92	7.701849836	12.57124798	14.90463761
5	1	1/1/2000	0:00:00	1073.57	930.45	3595.65	5.772529376	40.97732443	9.78712601
6	1	1/1/2000	0:00:00	1030.88	994.59	3597.01	8.560672178	26.37244379	16.07510104
7	1	1/1/2000	0:00:00	944.49	988.23	3592.71	1.420293327	19.92042164	15.08564906
8	1	1/1/2000	0:00:00	953.47	1037.47	3569.99	6.364141561	18.06130213	13.79077536
9	1	1/1/2000	0:00:00	1007.25	889.24	3557.77	5.257368508	26.88777444	9.16921714
10	1	1/1/2000	0:00:00	1019.96	1015.41	3599.12	9.436515666	23.07678762	16.26345816
11	1	1/1/2000	0:00:00	1064.05	860.27	3582.77	3.970913493	28.12917853	4.97391439
12	1	1/1/2000	0:00:00	993.07	1024.28	3590.67	2.450733394	40.20214139	16.81176618
13	1	1/1/2000	0:00:00	1008.15	945.67	3598.67	4.907186446	15.88482054	14.92251502
14	1	1/1/2000	0:00:00	945.13	941.64	3594.1	4.18778913	10.23881404	12.96136679
15	1	1/1/2000	0:00:00	922.51	918.16	3562.05	7.553059382	22.56247241	9.44867514
16	1	1/1/2000	0:00:00	948.58	952.39	3597.14	0.608501763	61.88646976	13.91015848

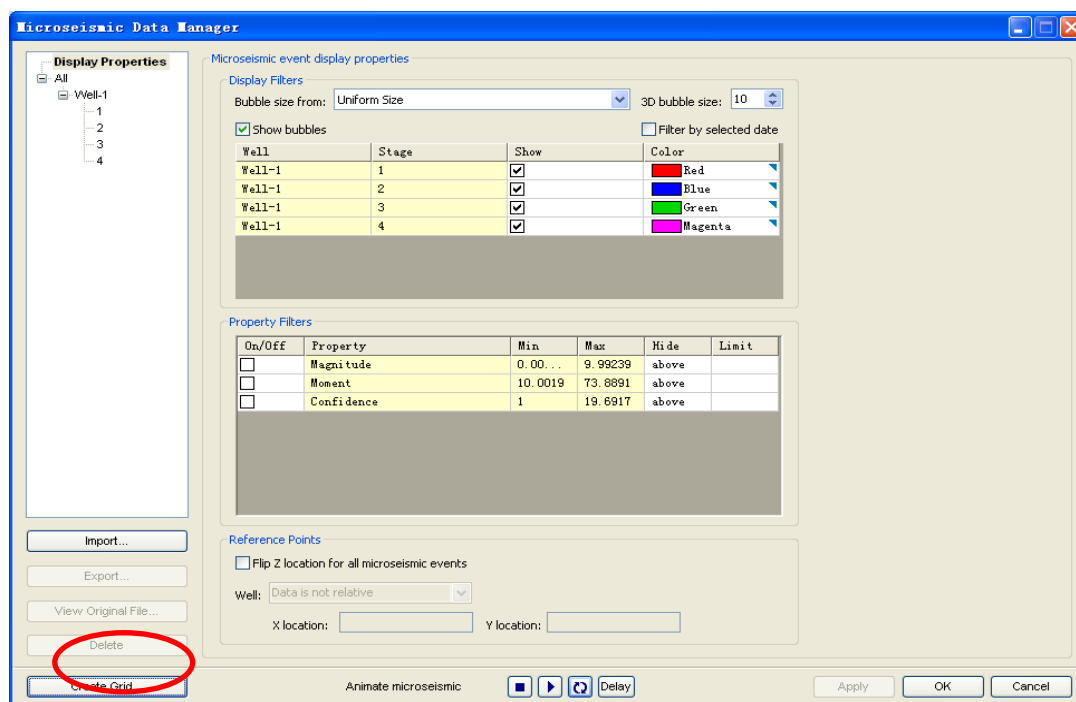
☐ Event coordinates are relative to a reference point ☐ Flip Z location for all microseismic events

Cancel < Previous Next > Finish

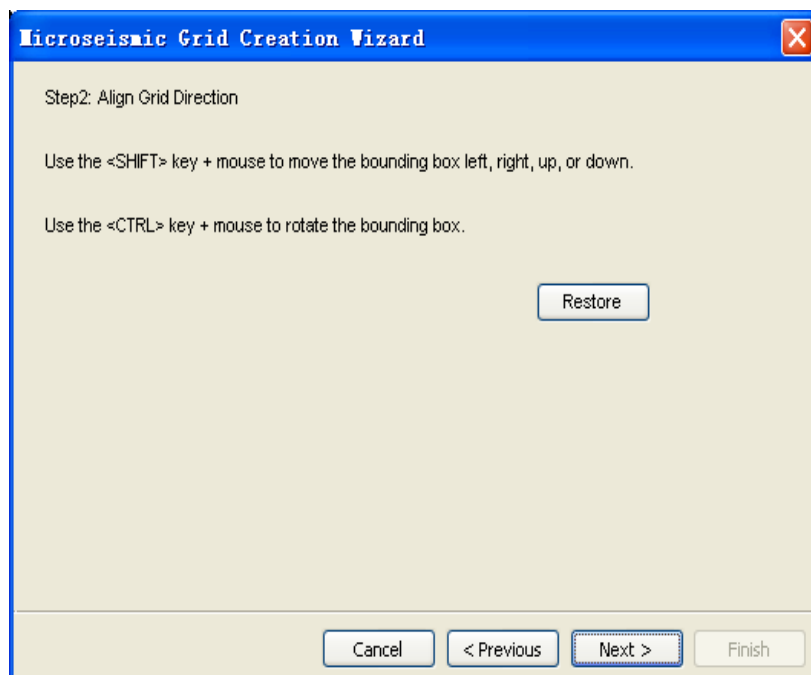
7. 点击 **Next** 按钮，一切就绪之后选择 **Finish** 按钮。在 **Builder** 界面，四段水力压裂裂缝的微地震数据已经导入。

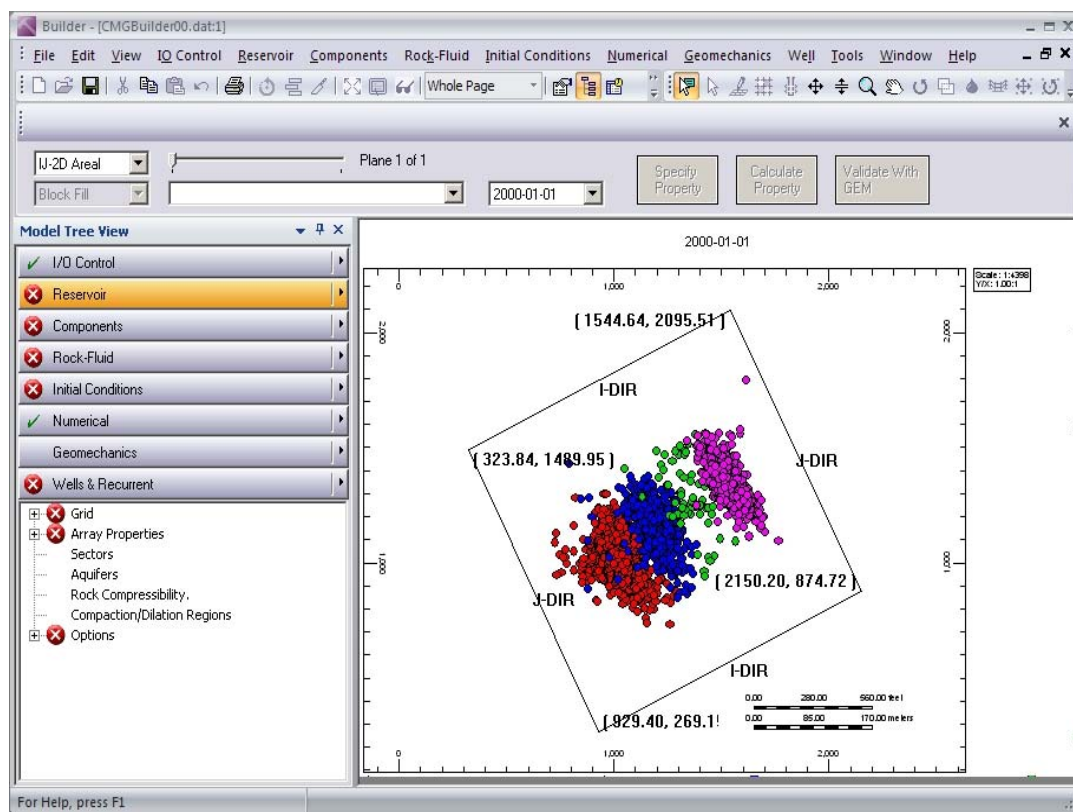


8. 下一步生成网格。在 **Microseismic Data Manager** 界面，点击 **Create Grid** 按钮。

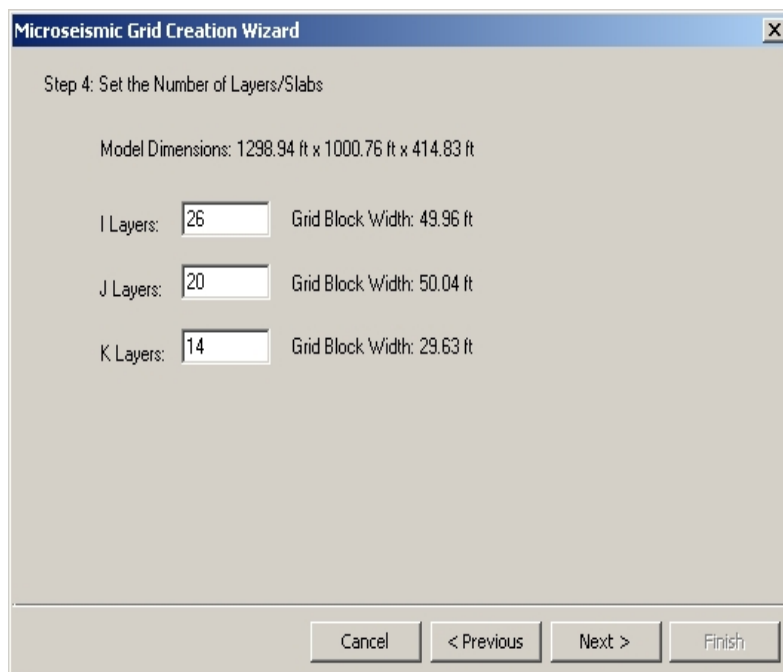


9. 点击 NEXT 到如下界面。选择网格与水力压裂裂缝平行。若不平行，可用鼠标加<SHIFT>或<CTRL>键进行移动和旋转。





10. 选择 **Next** 按钮，按下图输入 **IJK** 各方向的网格数。



Microseismic Grid Creation Wizard

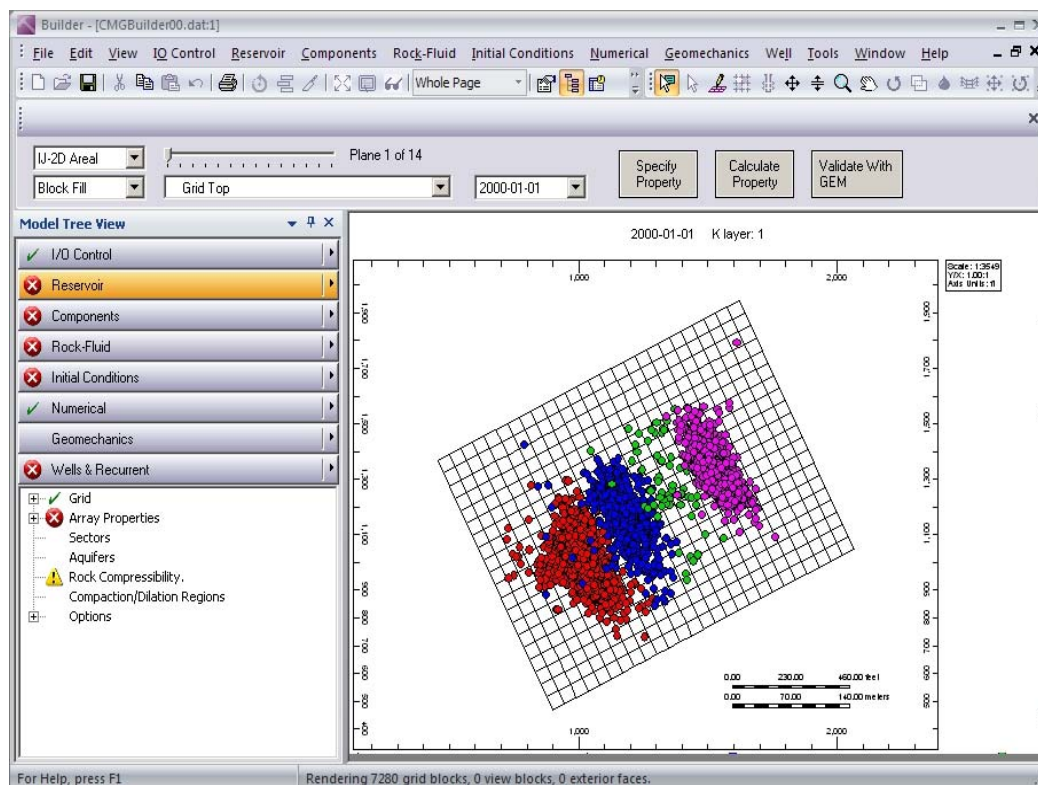
Step 4: Set the Number of Layers/Slabs

Model Dimensions: 1298.94 ft x 1000.76 ft x 414.83 ft

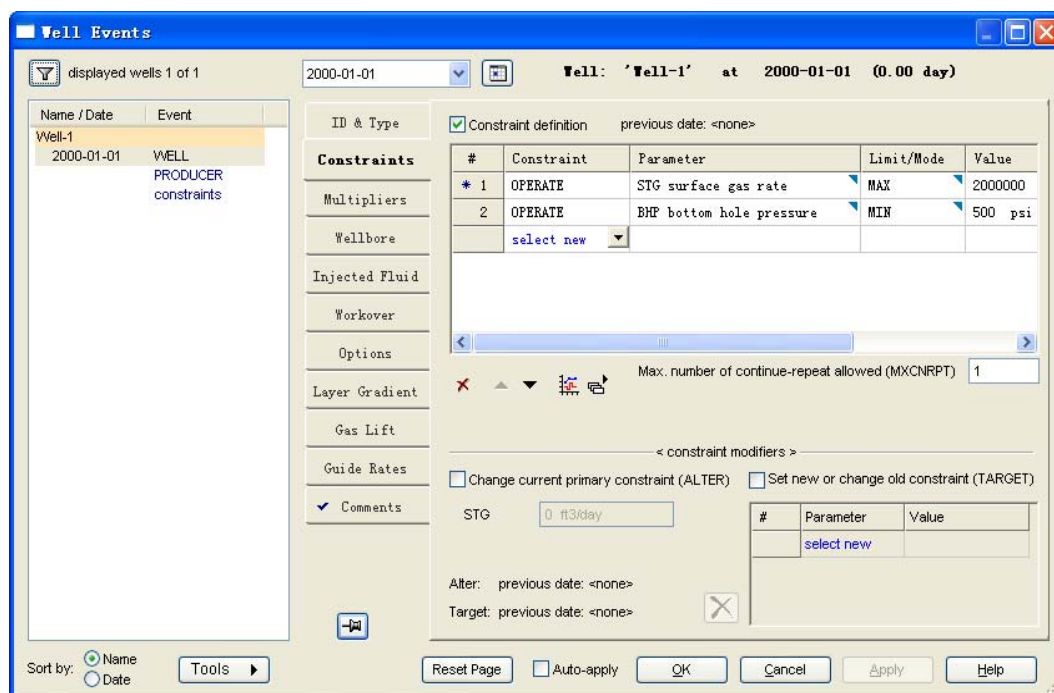
I Layers:	<input type="text" value="26"/>	Grid Block Width: 49.96 ft
J Layers:	<input type="text" value="20"/>	Grid Block Width: 50.04 ft
K Layers:	<input type="text" value="14"/>	Grid Block Width: 29.63 ft

Cancel < Previous Next > Finish

11. 点击 **Next**，然后点击 **Finish**。生成网格。



12. 在 **Builder** 中打开,对井进行定义。点击 **WELL-New Well**,选择井类型为“**producer**”，定义井的约束条件，**STG surface gas rate, MAX, 2E06 scf/d, CONT REPEAT; BHP bottom hole pressure, MIN, 500 psi, CONT REPEAT**。



Well Events

displayed wells 1 of 1

2000-01-01

Well: 'Well-1' at 2000-01-01 (0.00 day)

#	Constraint	Parameter	Limit/Mode	Value
1	OPERATE	STG surface gas rate	MAX	2000000
2	OPERATE	BHP bottom hole pressure	MIN	500 psi

select new

Max. number of continue-repeat allowed (MXCNRP) 1

< constraint modifiers >

☐ Change current primary constraint (ALTER) ☐ Set new or change old constraint (TARGET)

STG 0 ft3/day

Alter: previous date: <none>

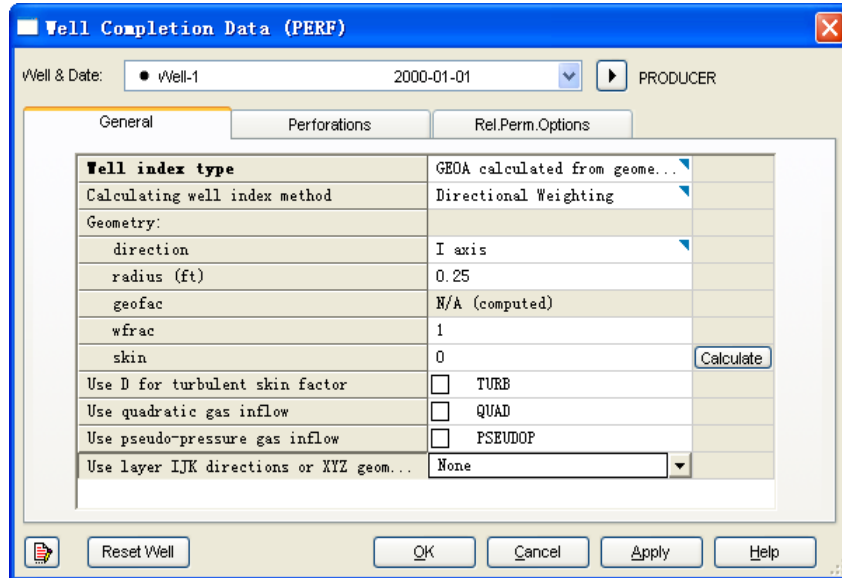
Target: previous date: <none>

Sort by: ☒ Name ☐ Date

Tools

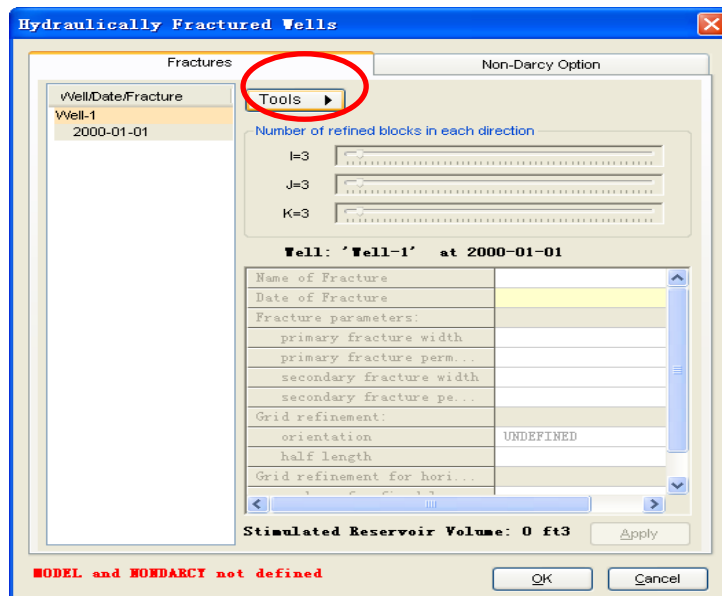
Reset Page ☐ Auto-apply OK Cancel Apply Help

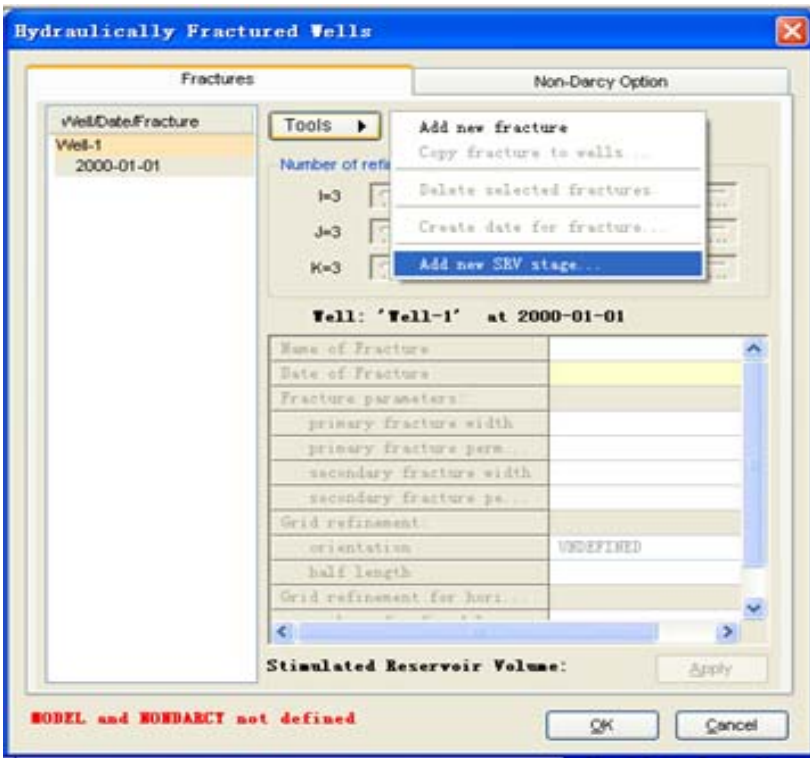
13. 对 **well-1** 进行完井设置。点击 **Well -> Well Completion (PERF)**，点击 **Completion - Add New**，选择时间点为 **2000-1-1**，然后 **OK**。在 **General** 界面，讲默认的网格方向改成 **I axis**。“Use layer IJK directions or XYZ geometric data”选择 **None**。



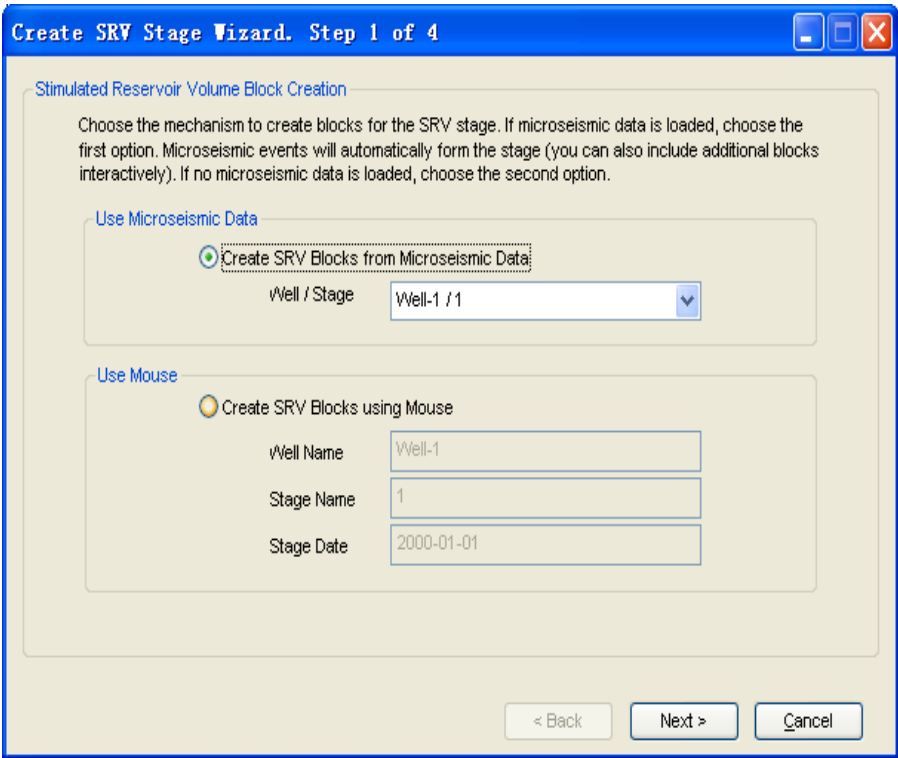
到**Perforations**界面。采用鼠标对**5 11 6** 到**20 11 6**网格进行射孔操作。

14. 添加一段模拟时间。从**2000-01-01**，到**2005-01-01**。在**2005-01-01**处设置**STOP**。
15. 打开菜单 **Tools**，选择 **Microseismic Data Manager**，选择 **Import** 按钮，点击 **Browse** 打开上期的微地震数据文件，点击 **Next** 然后 **Finish**。点击 **OK** 退出 **Microseismic Data Manager** 界面。
16. 回到 **Well** 菜单，选择 **Hydraulically Fractured Wells**。选择时间 **2000-01-01**，点击 **Tools**，选择 **Add New SRV Stage**。





17. 在体积压裂向导界面（**Create SRV Blocks from Microseismic Data**）， 点击 **Next**。添加第一段体积压裂数据。



18. 填写裂缝属性，见下图。分别为裂缝的宽度、渗透率。然后点击 Next。

Create SRV Stage Wizard. Step 2 of 4

Fracture Properties

Primary fracture width	0.001 ft
Primary fracture permeability	1.000e+004 md
Secondary fracture width	
Secondary fracture permeability	
Grid cell width for primary fracture model	2.00000 ft

Number of refined blocks in each direction

The number of refined blocks in the I and J directions cannot be less than three.

I=7

J=7

K=1

< Back Next > Cancel

19. 下一步用于筛选微地震数据，直接点击 Next。

20. 选择 **Select Perforation(s) for Fracture Source** 按钮，选择 4 个射孔数据然后点击 OK。

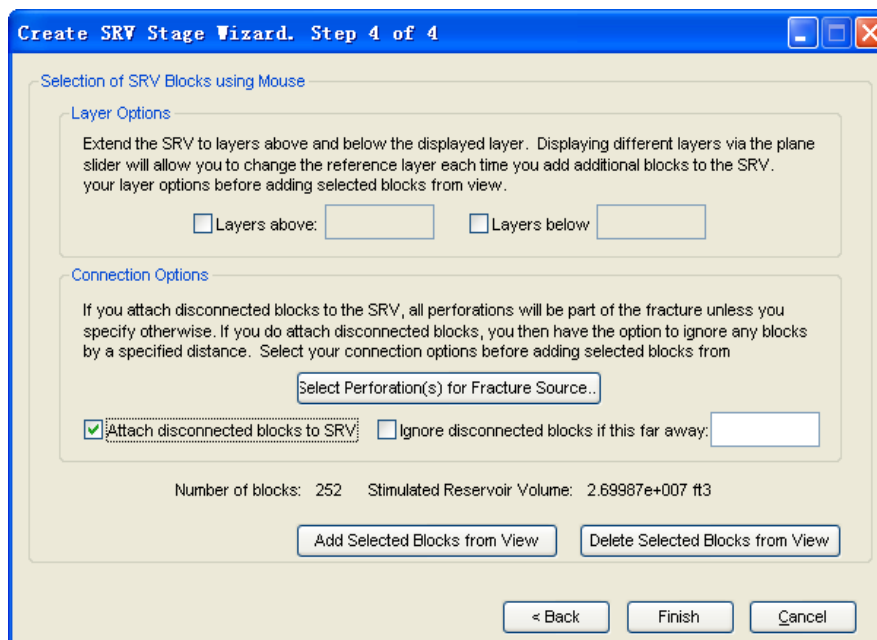
Select Perforation(s)

Well: Well-1

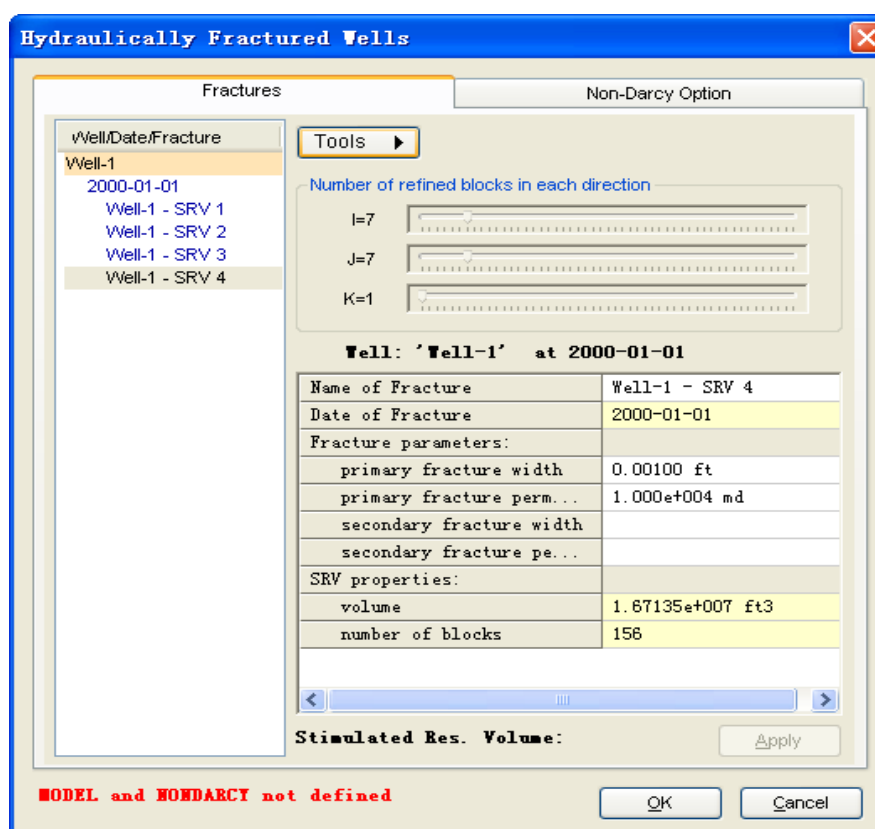
In...	User Block Address
<input checked="" type="checkbox"/>	5 11 6
<input checked="" type="checkbox"/>	6 11 6
<input checked="" type="checkbox"/>	7 11 6
<input checked="" type="checkbox"/>	8 11 6
<input type="checkbox"/>	9 11 6
<input type="checkbox"/>	10 11 6
<input type="checkbox"/>	11 11 6
<input type="checkbox"/>	12 11 6
<input type="checkbox"/>	13 11 6
<input type="checkbox"/>	14 11 6
<input type="checkbox"/>	15 11 6
<input type="checkbox"/>	16 11 6
<input type="checkbox"/>	17 11 6

Select All Clear All

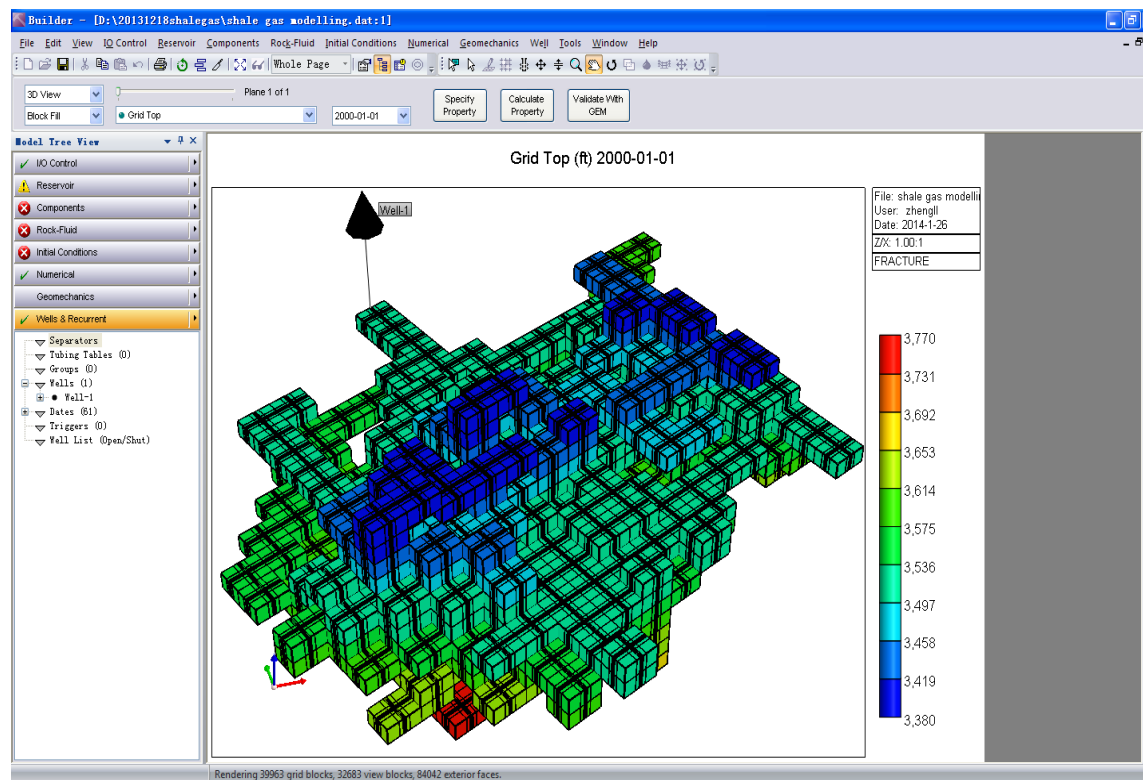
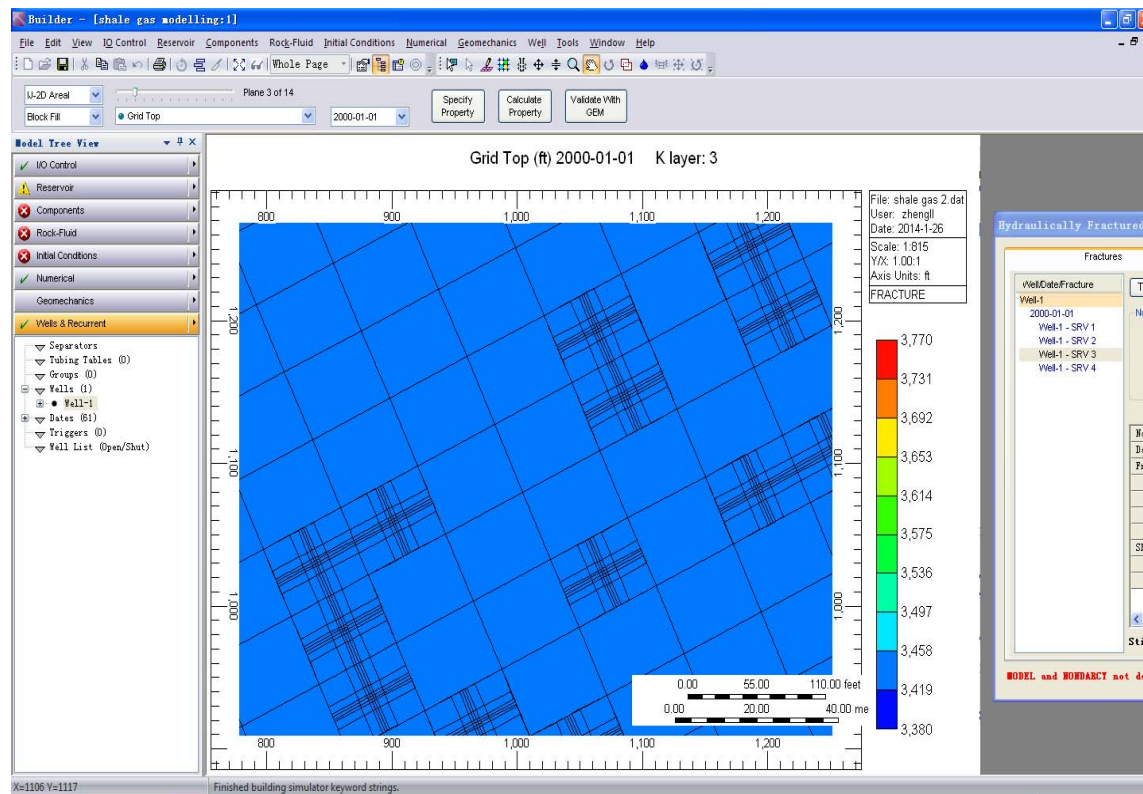
OK Cancel

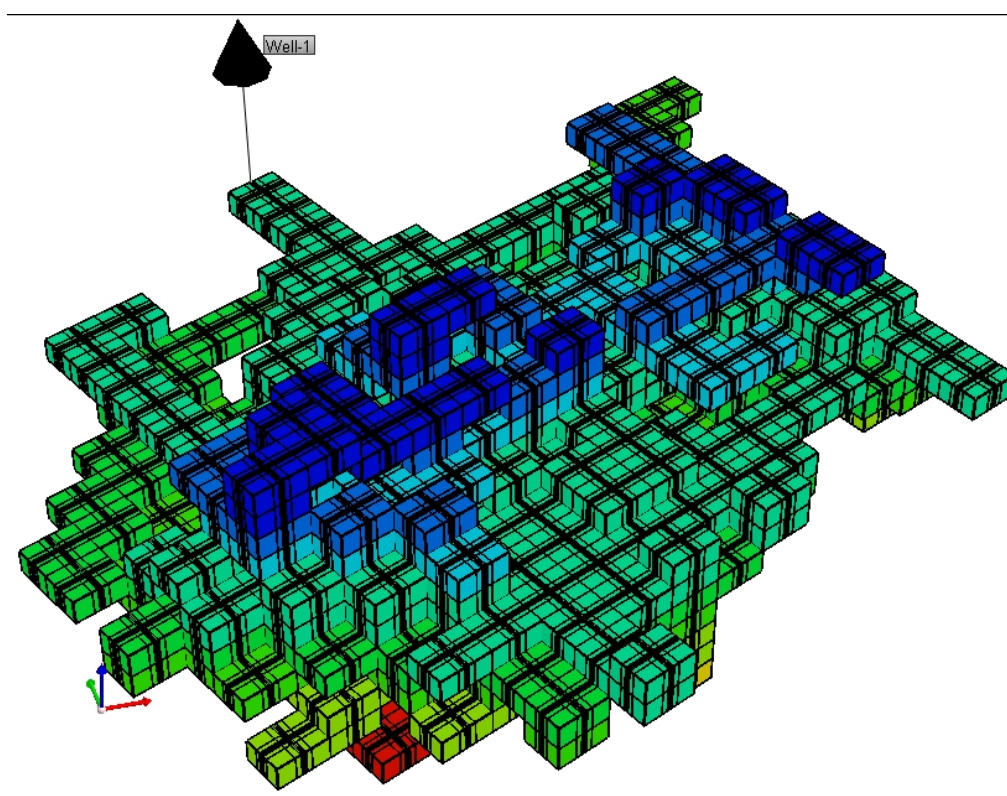
21. 选择 **Attach disconnected blocks to SRV** 然后 **Finish**。

22. 重复 13-18 步采用同样的方法定义其他三段体积压裂裂缝。



23. 完成之后的体积压裂平面网格加密示意图，裂缝三维图如下。





24. 生成的模型文件为 shale gas modelling.dat。