goCad to Finite Element Model Using LaGriT

Case Study of Community
Block Model and Landers/Hector Mine

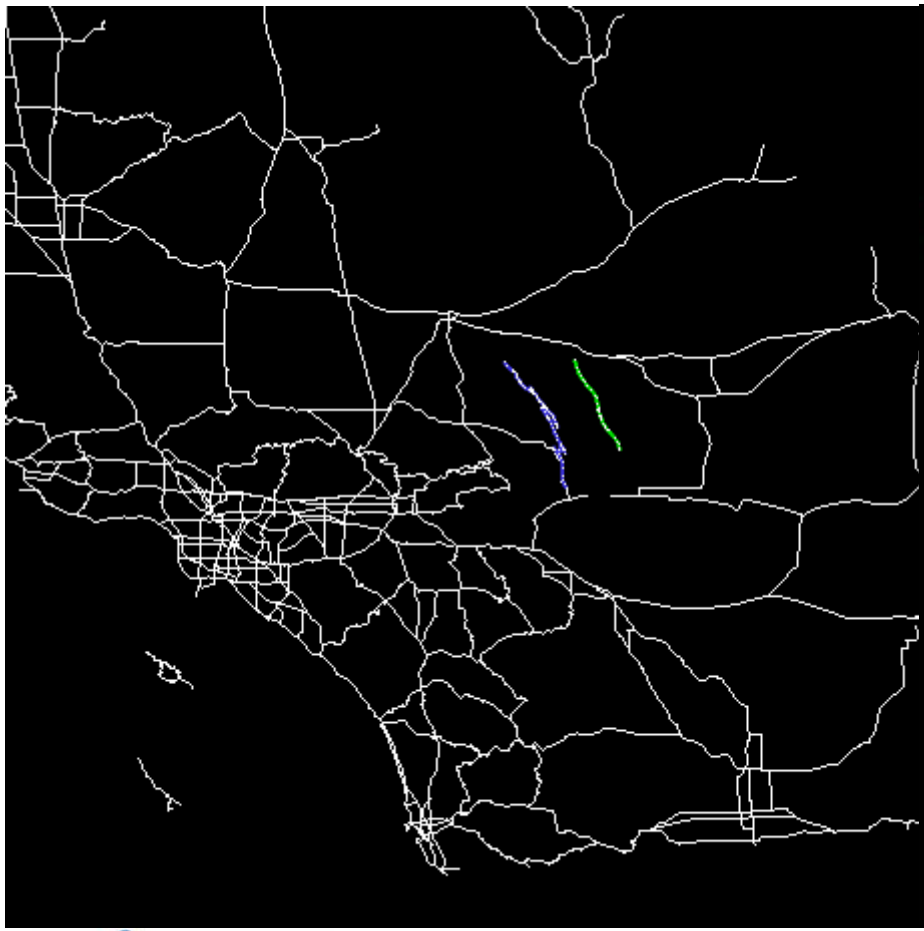
Carl Gable

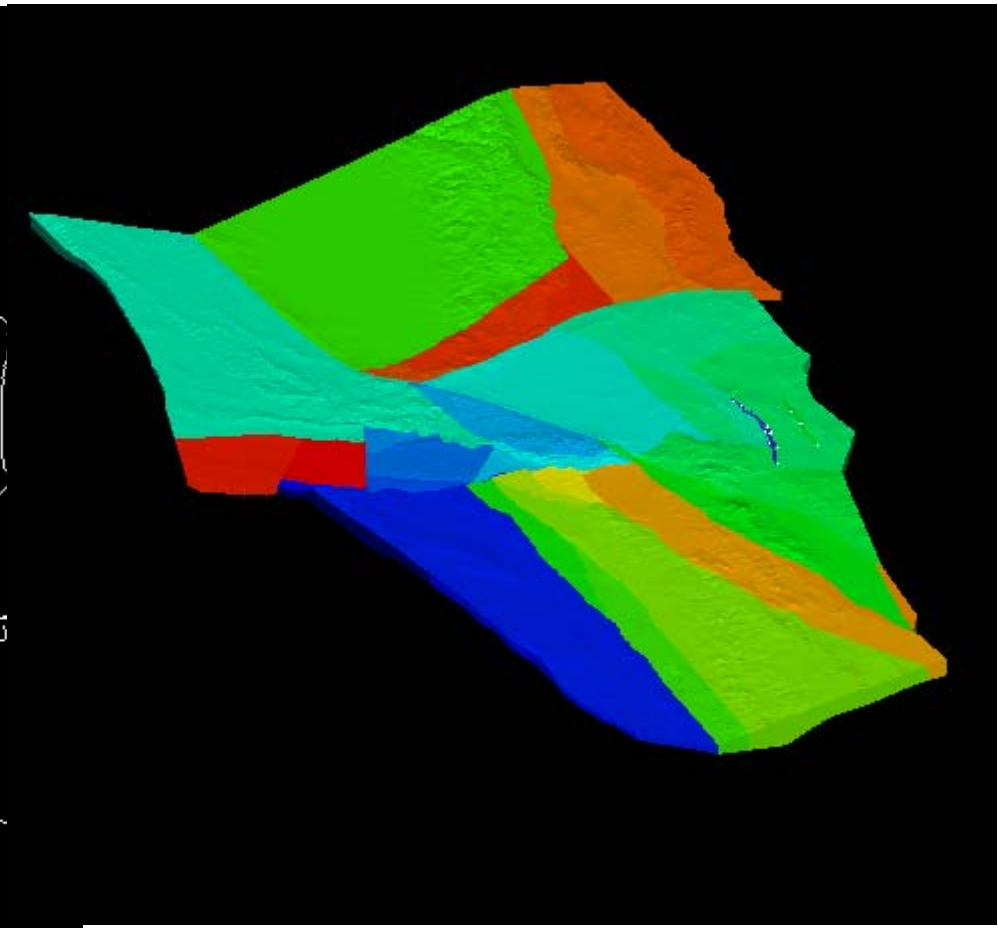
Los Alamos National Laboratory

Goals: Build 3D FE Mesh of Landers/Hector Mine Fault Zone

- Preliminary mesh for benchmark and testing.
- Keep mesh small enough (element count).
- High resolution (5X10**2 m) near faults.
- Low resolution (5x10**4 m) far from faults.
- Gradual variation in mesh resolution.
- Grid quality sufficient for stable and accurate computations.

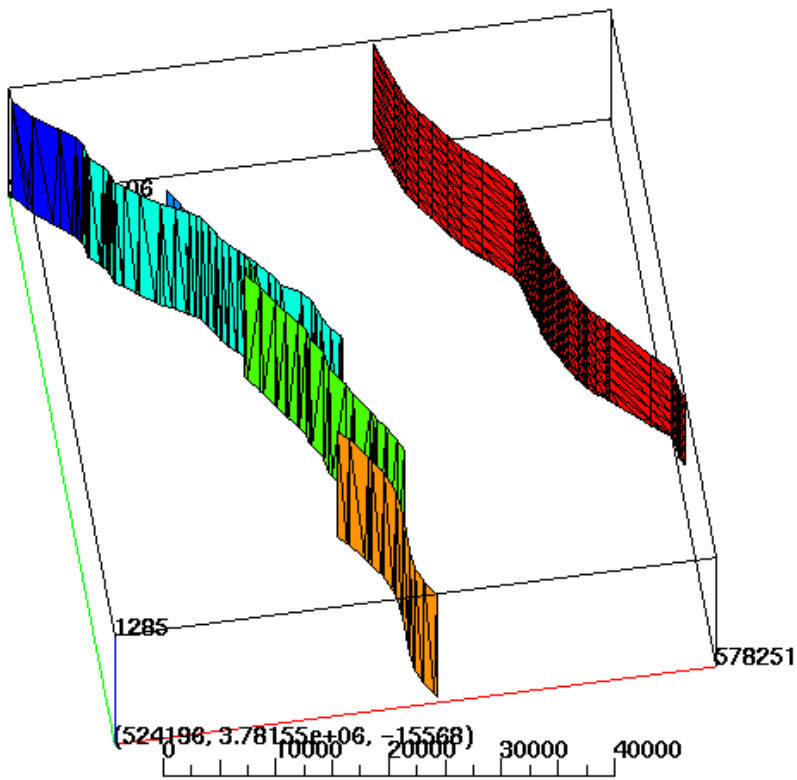
Landers/Hector Mine Faults



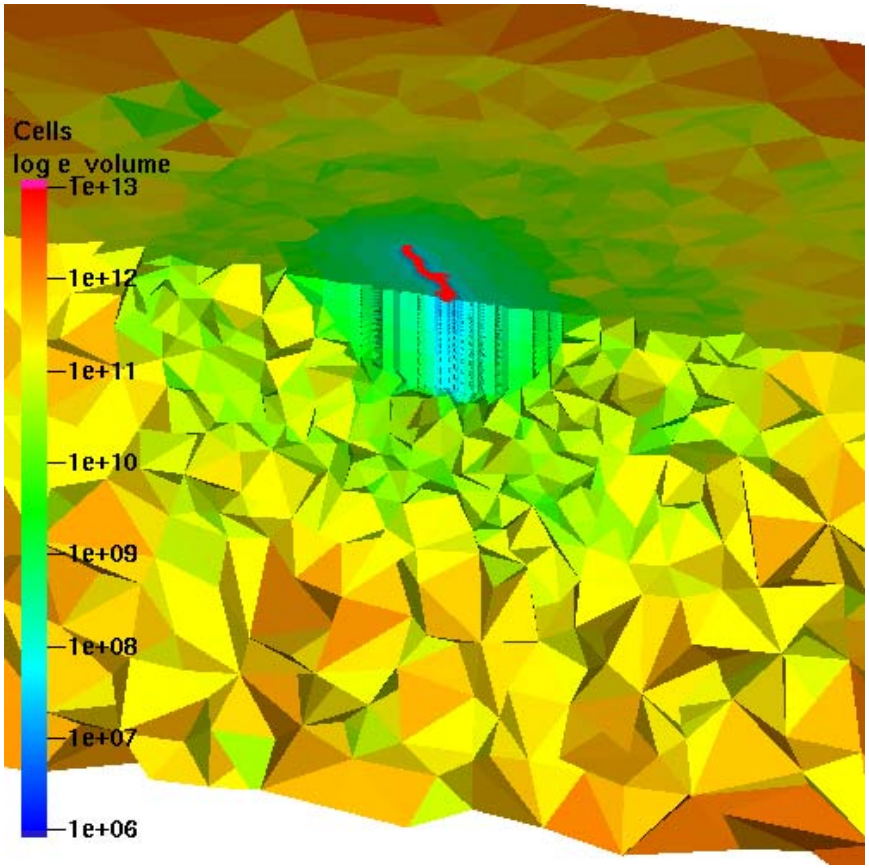


Community Fault Model (CFM) Input

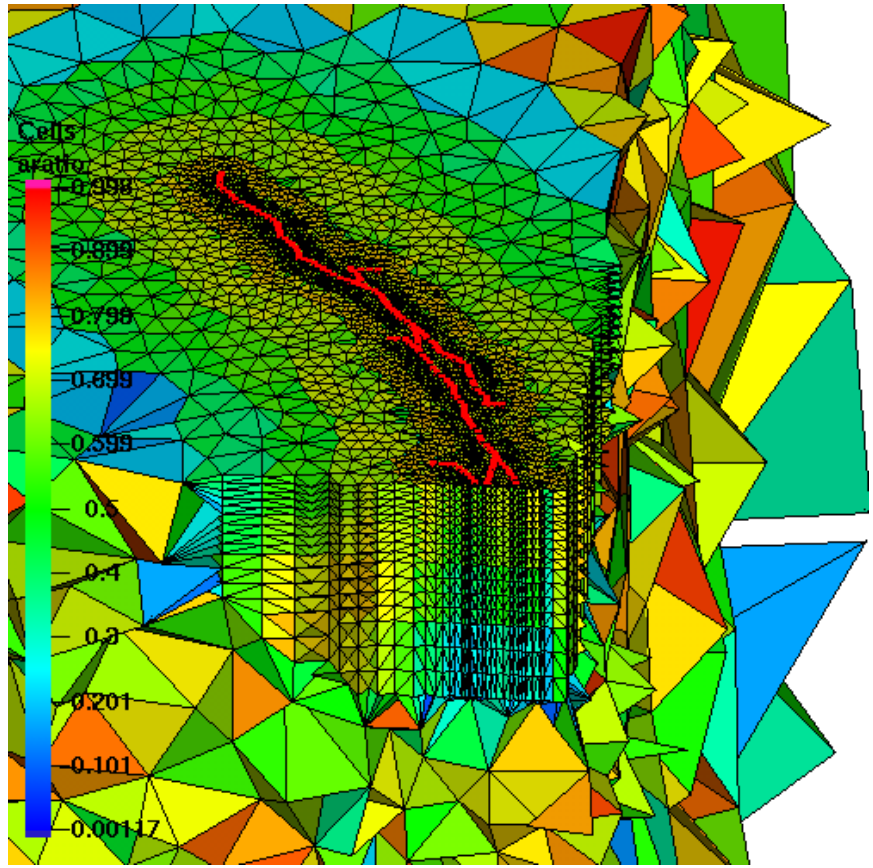
- Vertical fault surfaces from CFM.
- goCad Tsurf format files
- Hector Mine is a single vertical fault surface.
- Landers is a set of 7 segments with splays.
- Faults cover area apx 50km square.



Where we are heading with this…

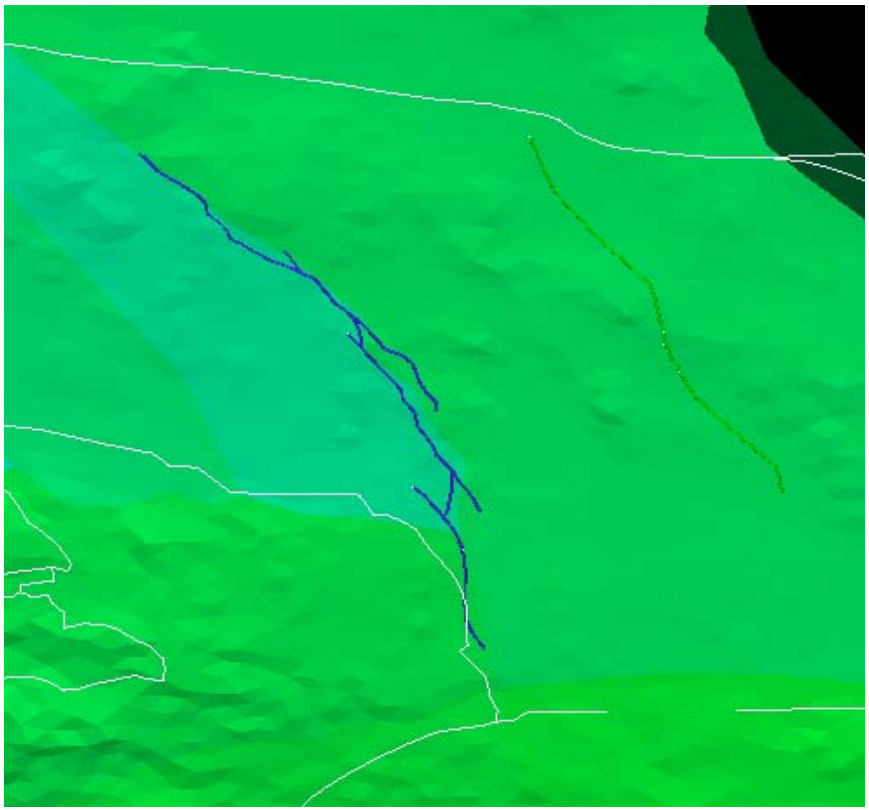


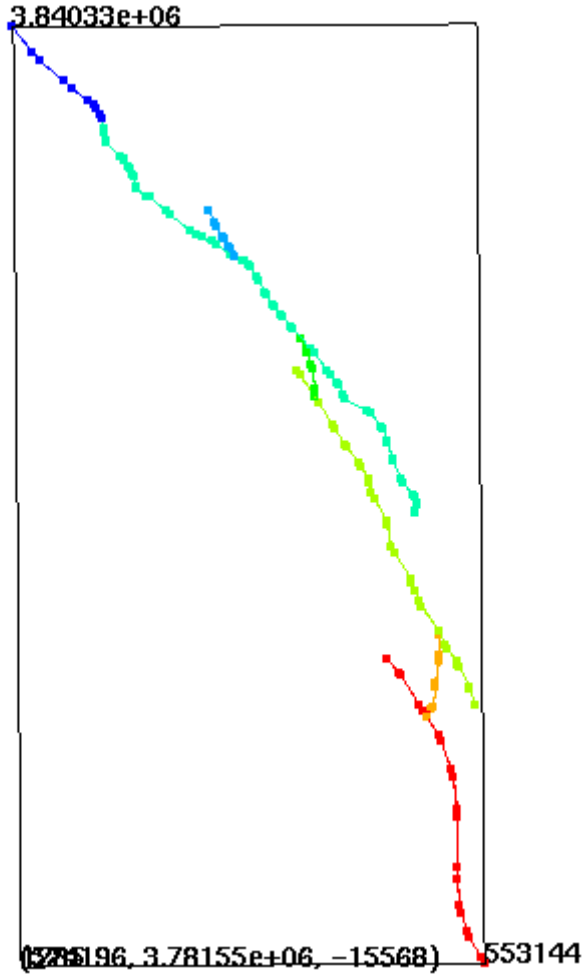
3D Tet mesh, log(Element Volume)



3D Test mesh, Aspect Ratio

Landers/Hector Mine Faults

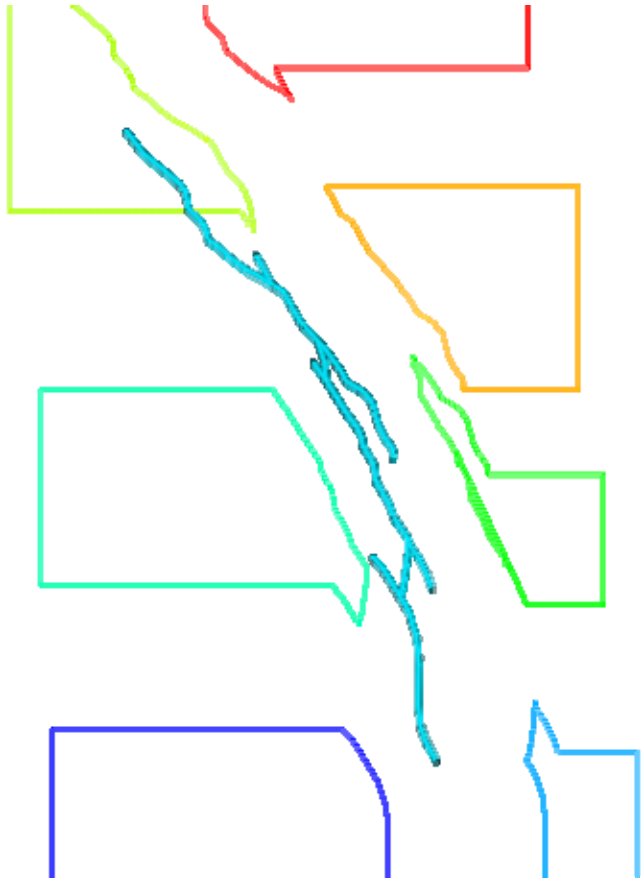




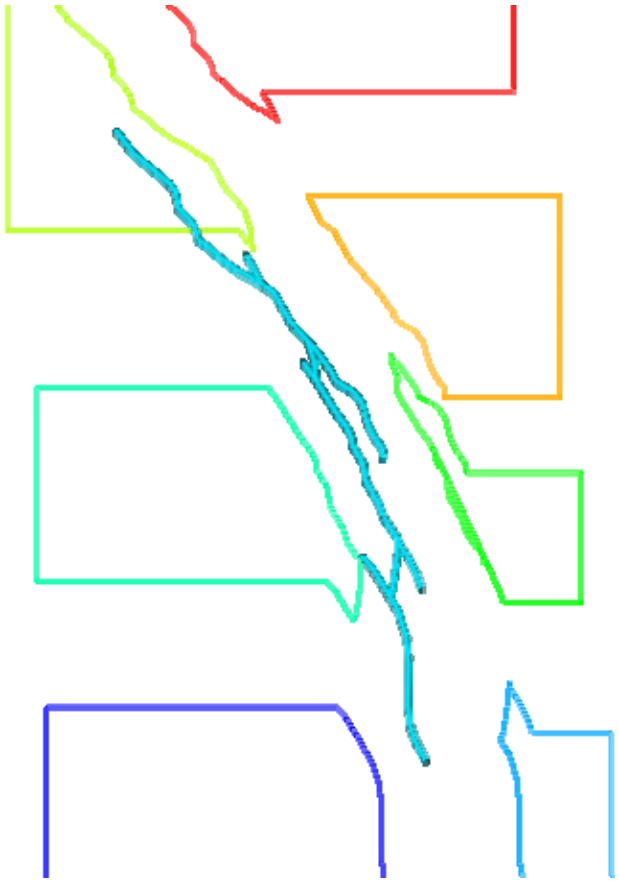
Strategy For Building Mesh

- Build 2D triangle template that follows fault trace.
- Grade triangles from small near faults to large away from faults.
- Special Considerations
  - Fault trace is defined by a set of piecewise linear surfaces (triangles) or in 2D, a set of piecewise linear line segments.
  - Line segments have branches
  - No closed curves to define geometry
- Build a set of coincident oriented polygons to define geometry.

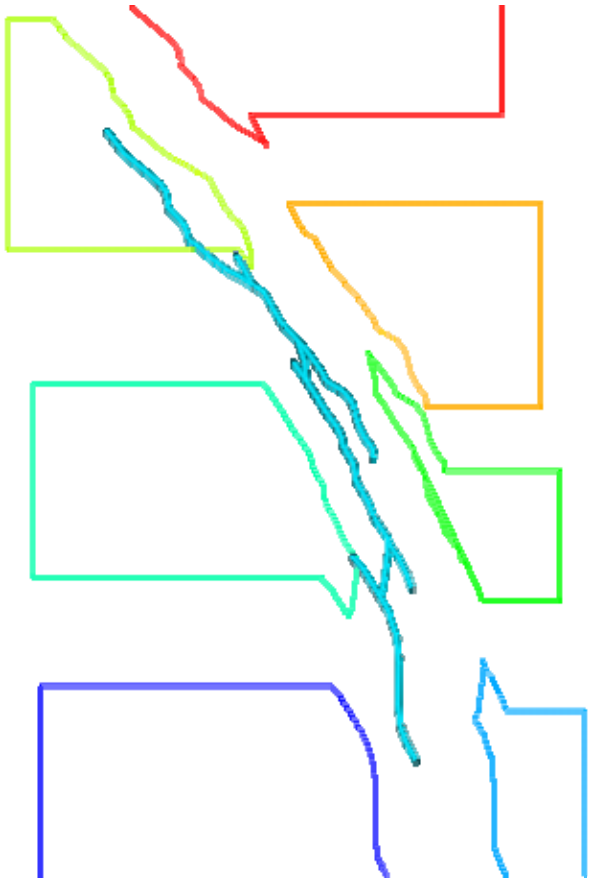
Create Closed Polygons From Fault Trace



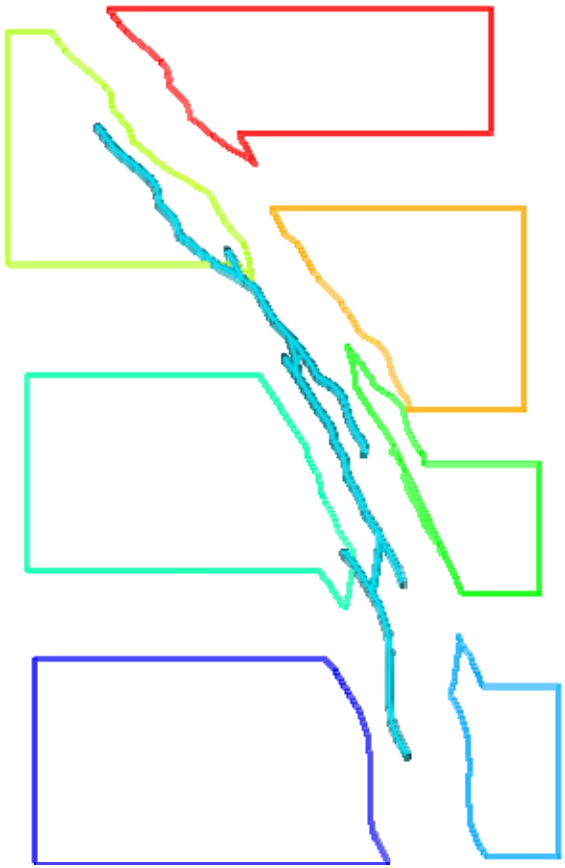
Create Closed Polygons From Fault Trace



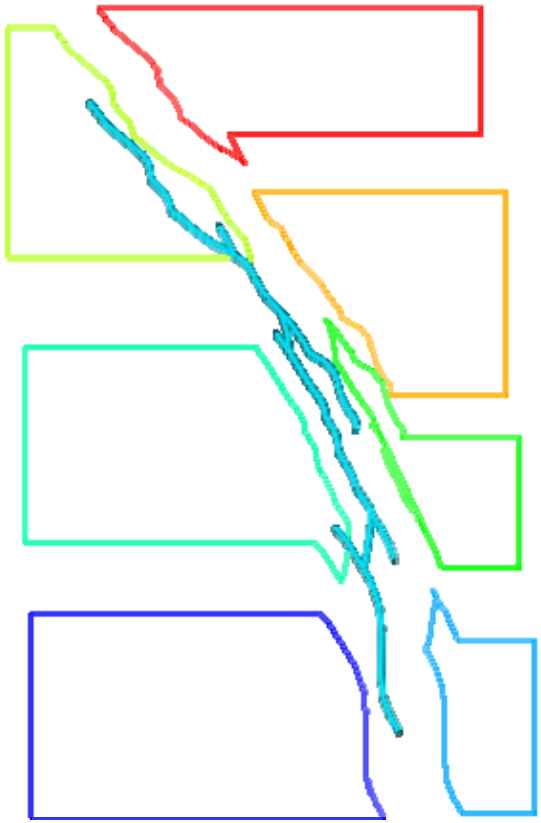
Create Closed Polygons From Fault Trace



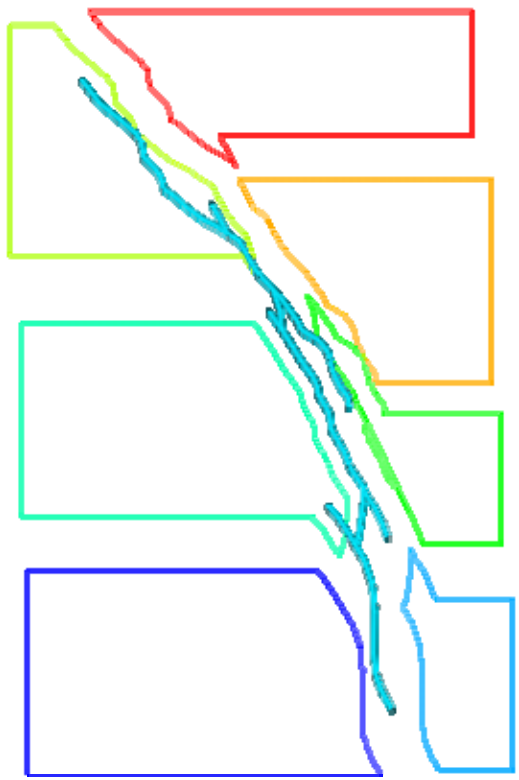
Create Closed Polygons From Fault Trace



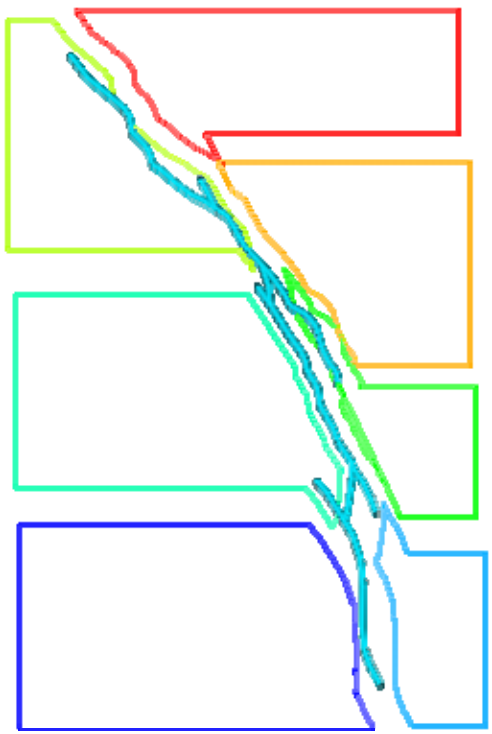
Create Closed Polygons From Fault Trace



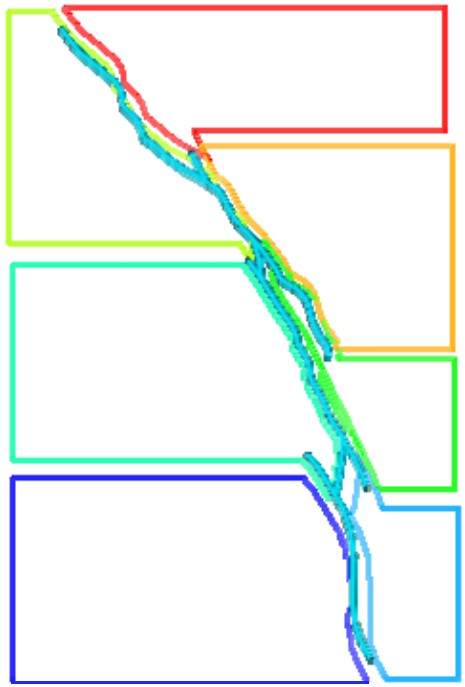
Create Closed Polygons From Fault Trace



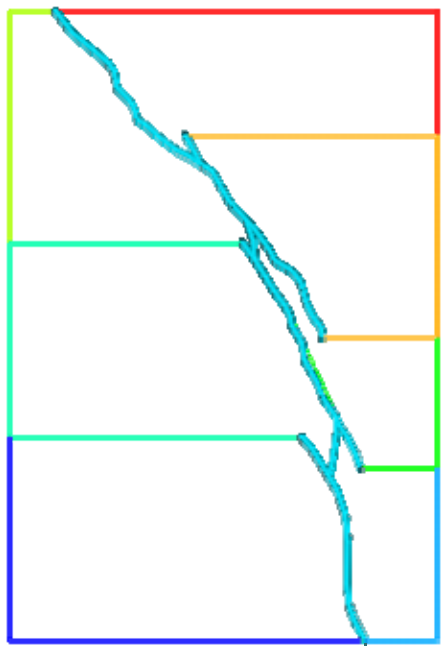
Create Closed Polygons From Fault Trace



Create Closed Polygons From Fault Trace

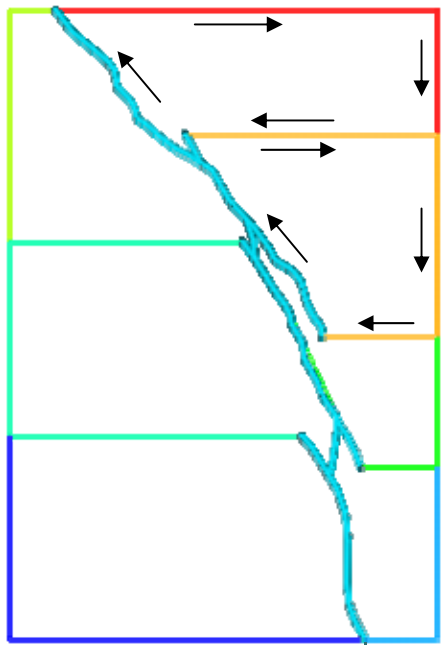


Create Closed Polygons From Fault Trace



Polygons Must Have The Same Orientation

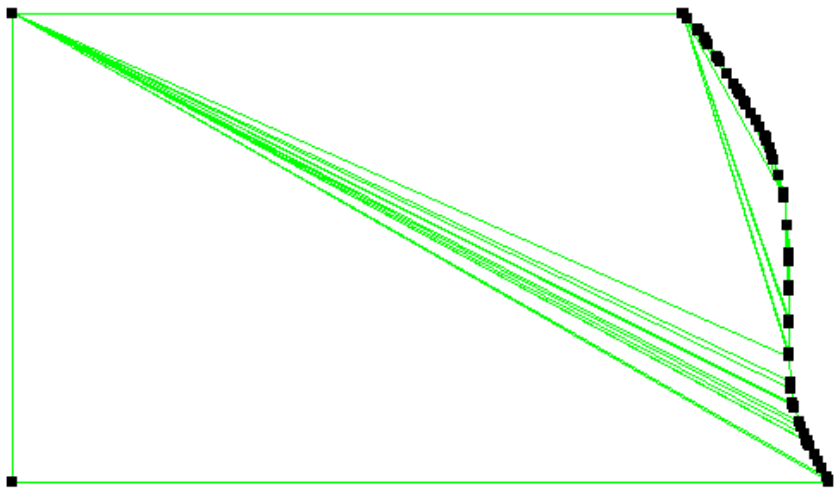
All polygons have the same clockwise orientation.



Triangulate 2D Polygon

```
voronoi% more poly_07l.inp
        78          0           0           0           0
001   5.471813437500E+05  3.800555343750E+06  0.00E+00
002   5.472268951425E+05  3.800505715423E+06  0.00E+00
003   5.473801750125E+05  3.800338692370E+06  0.00E+00
…

read/avs/poly_07l.inp/cmo
cmo/create/cmot///triplane
copypts/cmot cmo
cmo select cmot
triangulate
dump / avs2 / tri_07l.inp / cmot / 1 1 0 0
finish
```

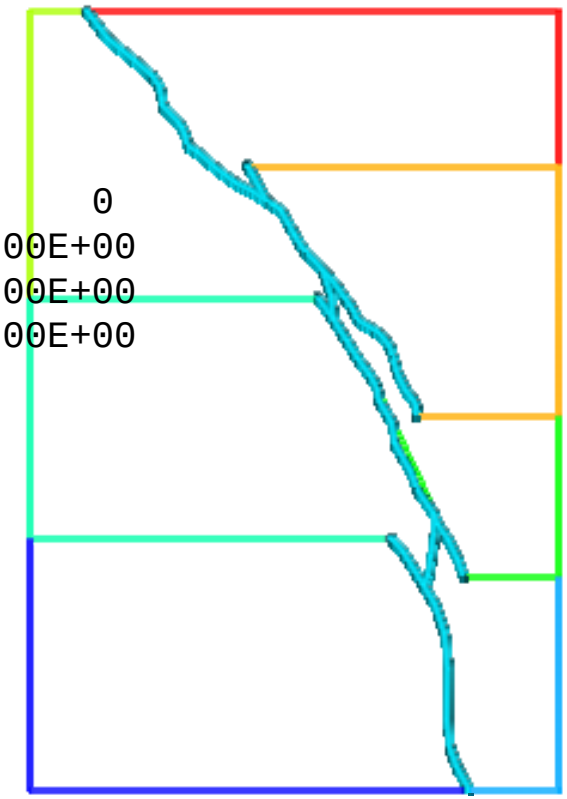


Triangulate 2D Polygons

- Triangulate polygons without point addition.

```
voronoi% more poly_07l.inp
        78          0           0           0           0
001   5.471813437500E+05  3.800555343750E+06  0.00E+00
002   5.472268951425E+05  3.800505715423E+06  0.00E+00
003   5.473801750125E+05  3.800338692370E+06  0.00E+00
…

read/avs/poly_07l.inp/cmo
cmo/create/cmot///triplane
copypts/cmot cmo
cmo select cmot
triangulate
dump / avs2 / tri_07l.inp / cmot / 1 1 0 0
finish
```

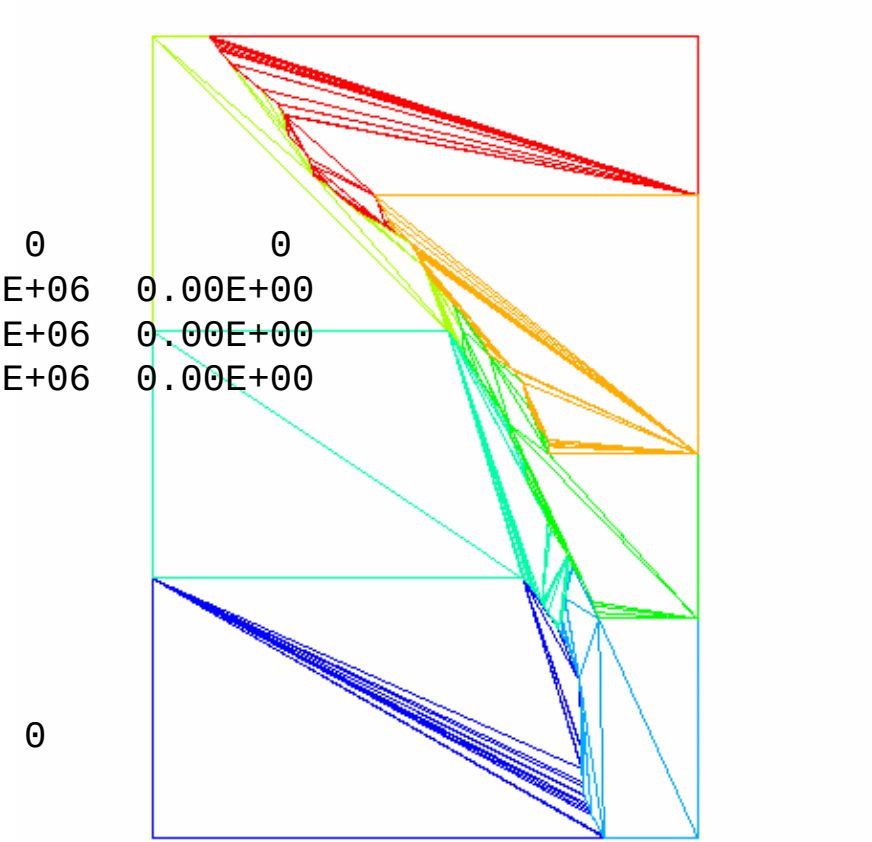


Triangulate 2D Polygons

- Triangulate polygons without point addition.

```
voronoi% more poly_07l.inp
        78          0           0           0           0
001   5.471813437500E+05  3.800555343750E+06  0.00E+00
002   5.472268951425E+05  3.800505715423E+06  0.00E+00
003   5.473801750125E+05  3.800338692370E+06  0.00E+00
…

read/avs/poly_07l.inp/cmo
cmo/create/cmot///triplane
copypts/cmot cmo
cmo select cmot
triangulate
dump / avs2 / tri_07l.inp / cmot / 1 1 0 0
finish
```

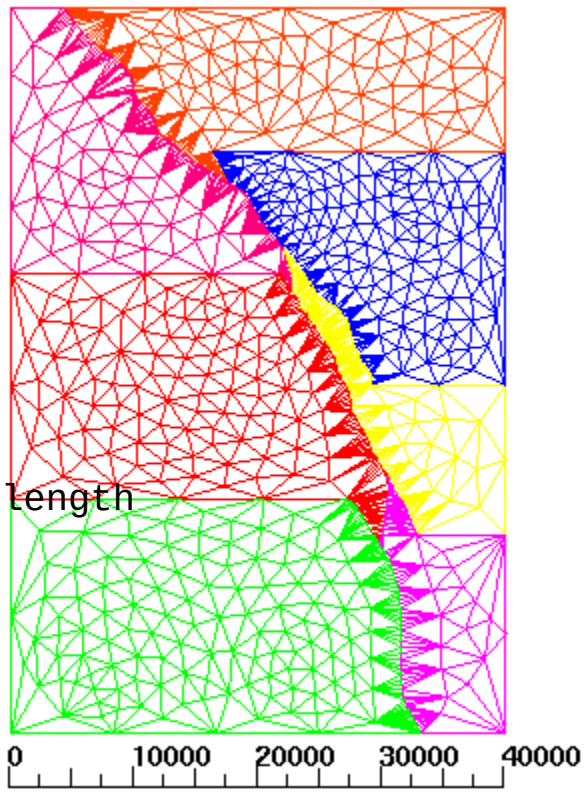


Merge Triangulations, Refine, Smooth

```
read / avs / tri_07l.inp / cmo7l
(Etc…)
read / avs / tri_01r.inp / cmo1r
addmesh / append / cmoall / cmo7l cmo7r
(Etc…)
addmesh / append / cmoall / cmoall cmo1r
cmo / select / cmoall
filter / 1 0 0
rmpoint / compress
dump / gmv / merge_6_triangulations.gmv / cmoall
dump / avs / merge_6_triangulations.inp / cmoall
massage / 10000. / 1.0 / 0.1 / 1 0 0 / strictmergelength
recon 0
smooth / position / esug / 1 0 0
recon 0
smooth / position / esug / 1 0 0
dump / gmv / triangles_10000.gmv / cmoall
```

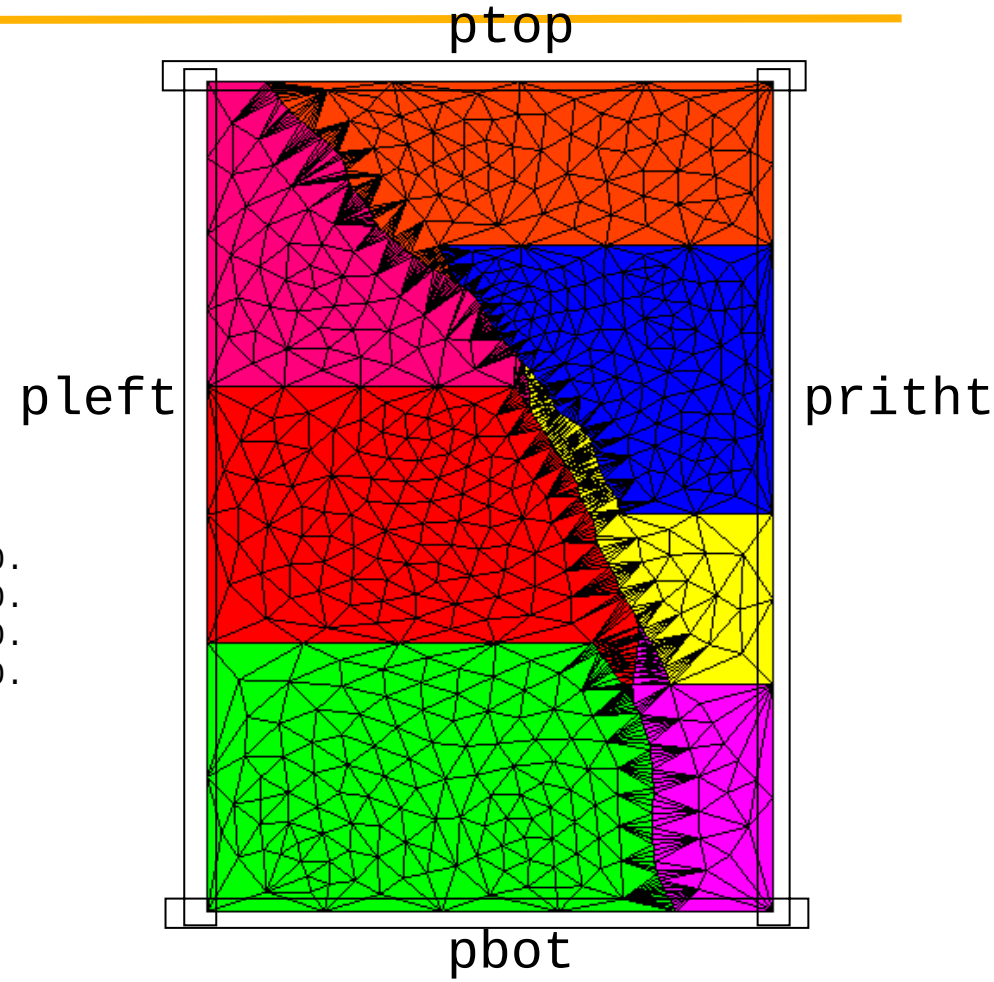
Merge Triangulations, Refine, Smooth

```
read / avs / tri_07l.inp / cmo7l
(Etc…)
read / avs / tri_01r.inp / cmo1r
addmesh / append / cmoall / cmo7l cmo7r
(Etc…)
addmesh / append / cmoall / cmoall cmo1r
cmo / select / cmoall
filter / 1 0 0
rmpoint / compress
dump / gmv / merge_6_triangulations.gmv / cmoall
dump / avs / merge_6_triangulations.inp / cmoall
massage / 10000. / 1.0 / 0.1 / 1 0 0 / strictmergelength
recon 0
smooth / position / esug / 1 0 0
recon 0
smooth / position / esug / 1 0 0
dump / gmv / triangles_10000.gmv / cmoall
```



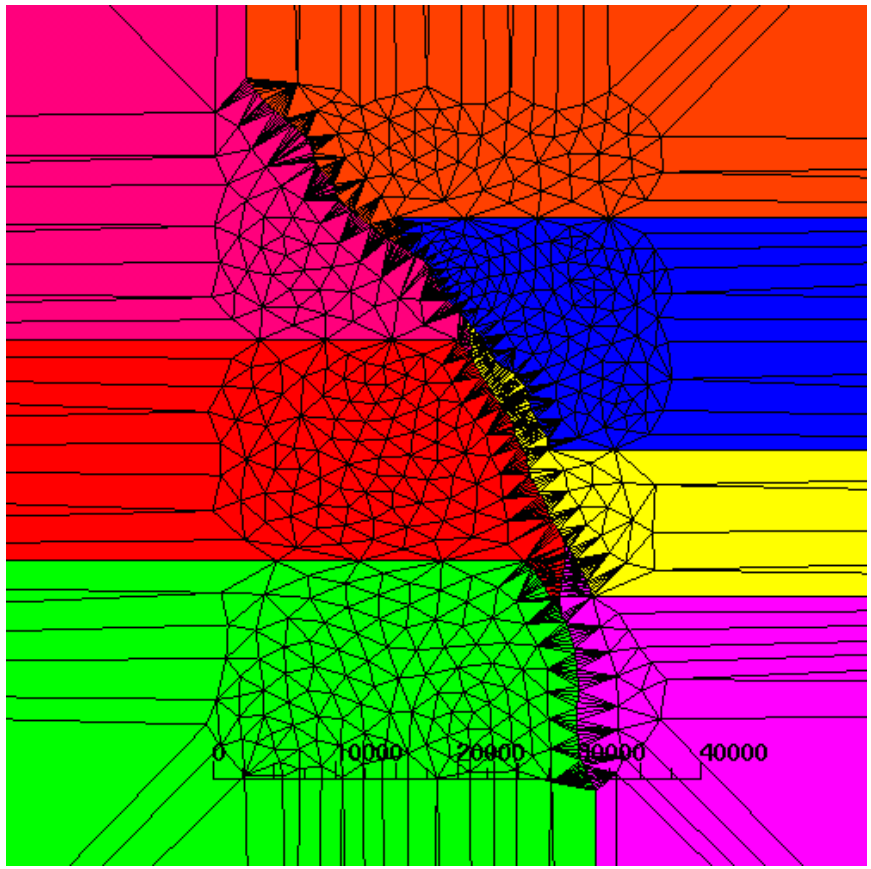
Expand Triangulation 50x50km to 350x350km

```
pset / pleft / geom / xyz / 1 0 0 &
   5.19999E+05 0.0  -1000.0 &
   5.20111E+05 1.e7  1000.0
pset / pright / geom / xyz / 1 0 0 &
   5.59999E+05 0.0   -1000.0 &
   5.60001E+05 1.e7   1000.0
pset / ptop / geom / xyz / 1 0 0 &
   0.0   3.84030E+06  -1000.0 &
   1.e7  3.84034E+06   1000.0
pset / pbot / geom / xyz / 1 0 0 &
   0.0   3.78150E+06  -1000.0 &
   1.e7  3.78157E+06   1000.0
trans/pset get pleft /0.0 0.0 0.0/-150000. 0. 0.
trans/pset get pright/0.0 0.0 0.0/ 150000. 0. 0.
trans/pset get ptop  /0.0 0.0 0.0/0.  150000. 0.
trans/pset get pbot  /0.0 0.0 0.0/0. -150000. 0.
dump / gmv / tmp_expand.gmv / cmoall
```



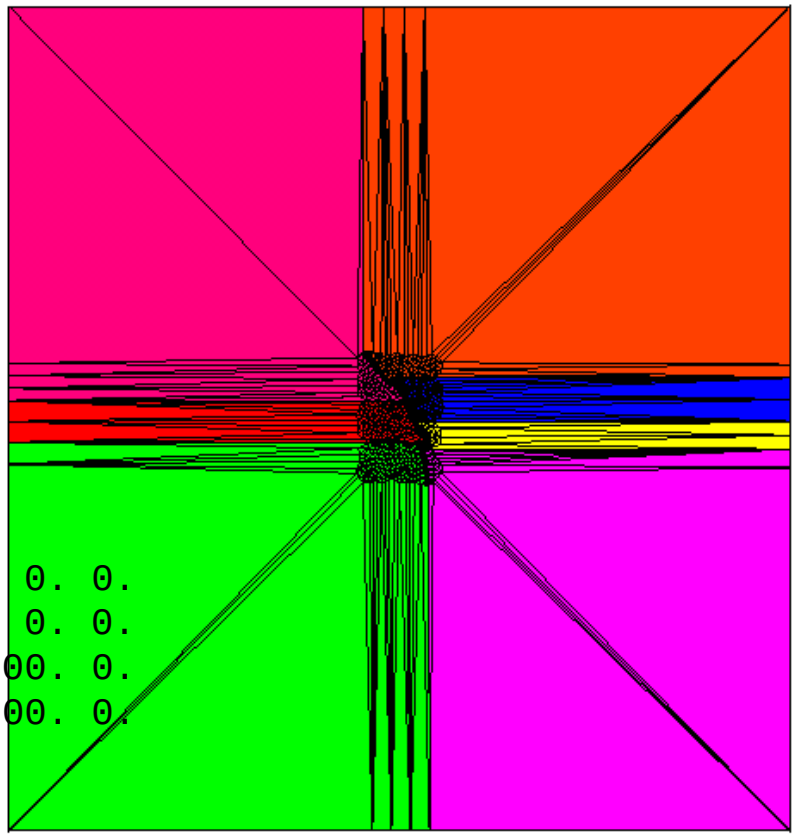
Expand Triangulation 50x50km to 350x350km

```
pset / pleft / geom / xyz / 1 0 0 &
   5.19999E+05 0.0  -1000.0 &
   5.20111E+05 1.e7  1000.0
pset / pright / geom / xyz / 1 0 0 &
   5.59999E+05 0.0   -1000.0 &
   5.60001E+05 1.e7   1000.0
pset / ptop / geom / xyz / 1 0 0 &
   0.0   3.84030E+06  -1000.0 &
   1.e7  3.84034E+06   1000.0
pset / pbot / geom / xyz / 1 0 0 &
   0.0   3.78150E+06  -1000.0 &
   1.e7  3.78157E+06   1000.0
trans/pset get pleft /0.0 0.0 0.0/-150000. 0. 0.
trans/pset get pright/0.0 0.0 0.0/ 150000. 0. 0.
trans/pset get ptop  /0.0 0.0 0.0/0.  150000. 0.
trans/pset get pbot  /0.0 0.0 0.0/0. -150000. 0.
dump / gmv / tmp_expand.gmv / cmoall
```

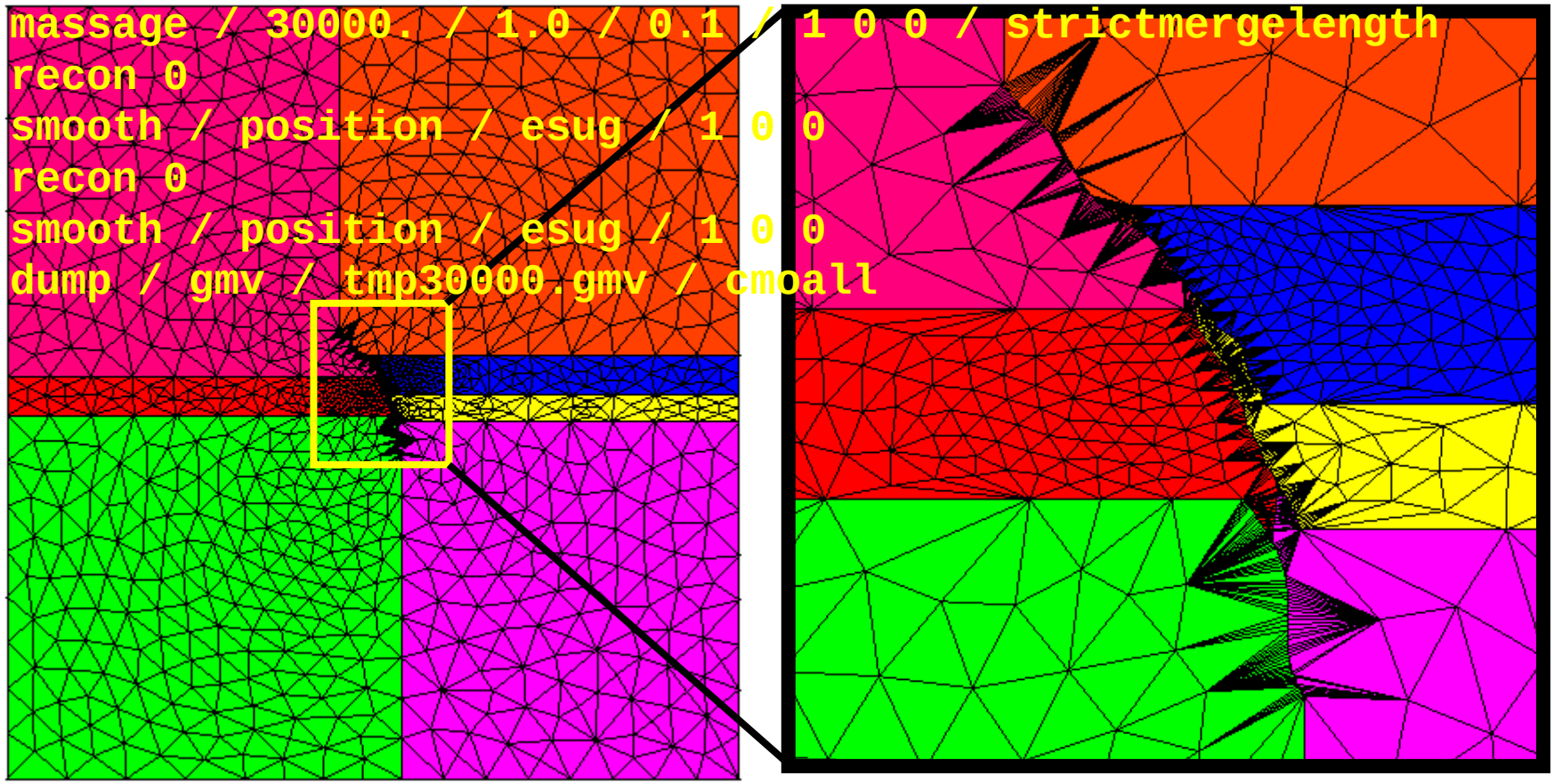


Expand Triangulation 50x50km to 350x350km

```
pset / pleft / geom / xyz / 1 0 0 &
   5.19999E+05 0.0  -1000.0 &
   5.20111E+05 1.e7  1000.0
pset / pright / geom / xyz / 1 0 0 &
   5.59999E+05 0.0   -1000.0 &
   5.60001E+05 1.e7   1000.0
pset / ptop / geom / xyz / 1 0 0 &
   0.0   3.84030E+06  -1000.0 &
   1.e7  3.84034E+06   1000.0
pset / pbot / geom / xyz / 1 0 0 &
   0.0   3.78150E+06  -1000.0 &
   1.e7  3.78157E+06   1000.0
trans/pset get pleft /0.0 0.0 0.0/-150000. 0. 0.
trans/pset get pright/0.0 0.0 0.0/ 150000. 0. 0.
trans/pset get ptop  /0.0 0.0 0.0/0.  150000. 0.
trans/pset get pbot  /0.0 0.0 0.0/0. -150000. 0.
dump / gmv / tmp_expand.gmv / cmoall
```

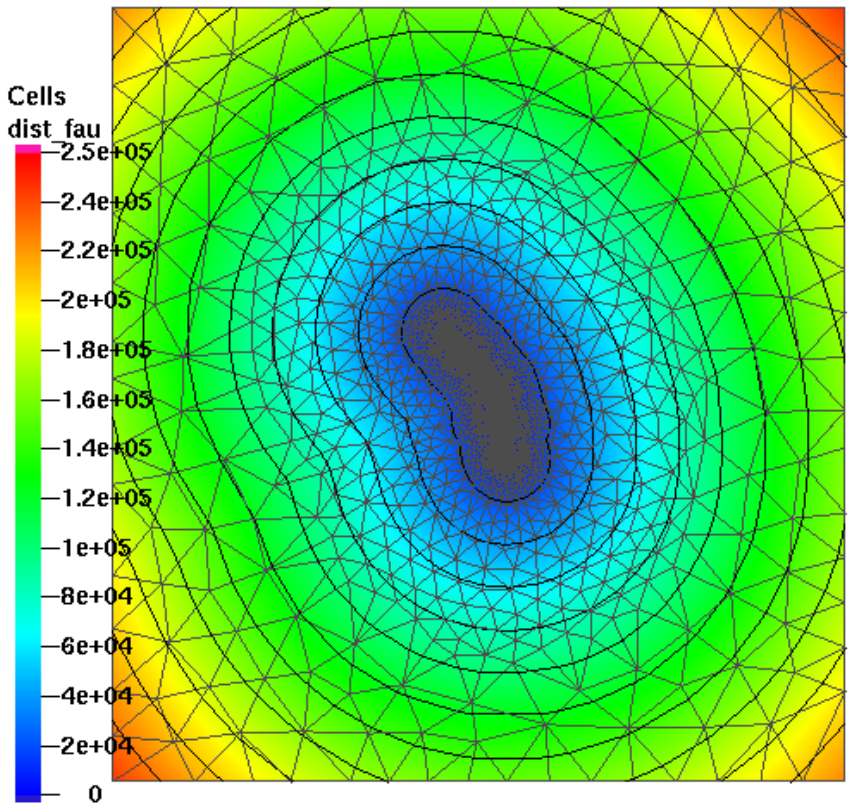


Refine and Smooth Expanded Area



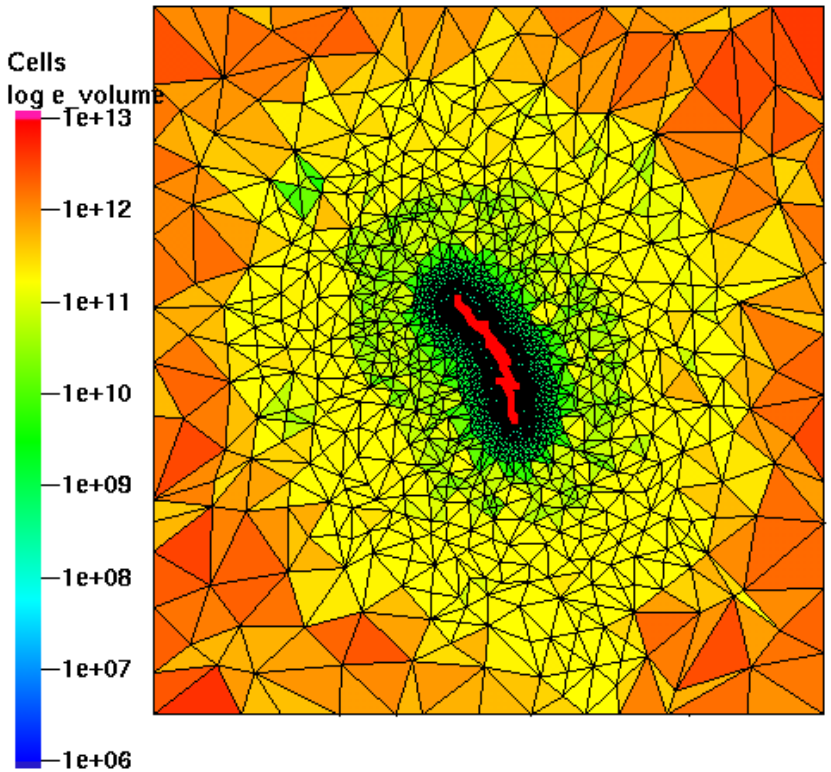
Final 2D Trianulation: Landers

- Final 2D triangulation
- Apx 500m near the fault
- Apx 50km far from the fault

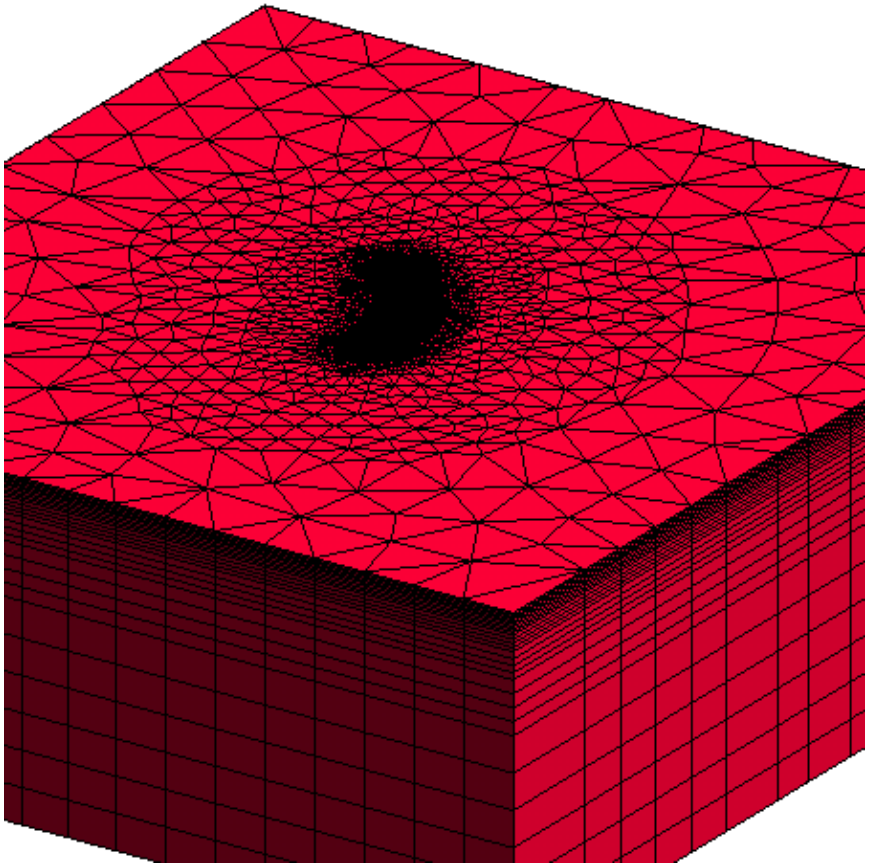


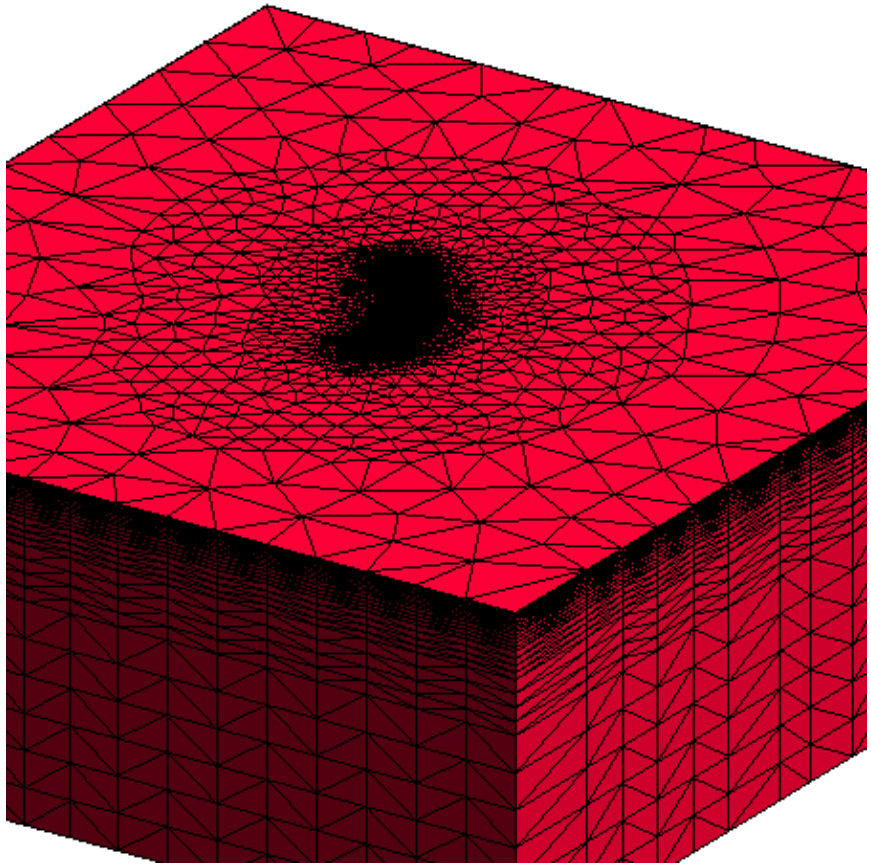
Final 2D Trianulation: Landers

- Final 2D triangulation
- Apx 500m near the fault
- Apx 50km far from the fault

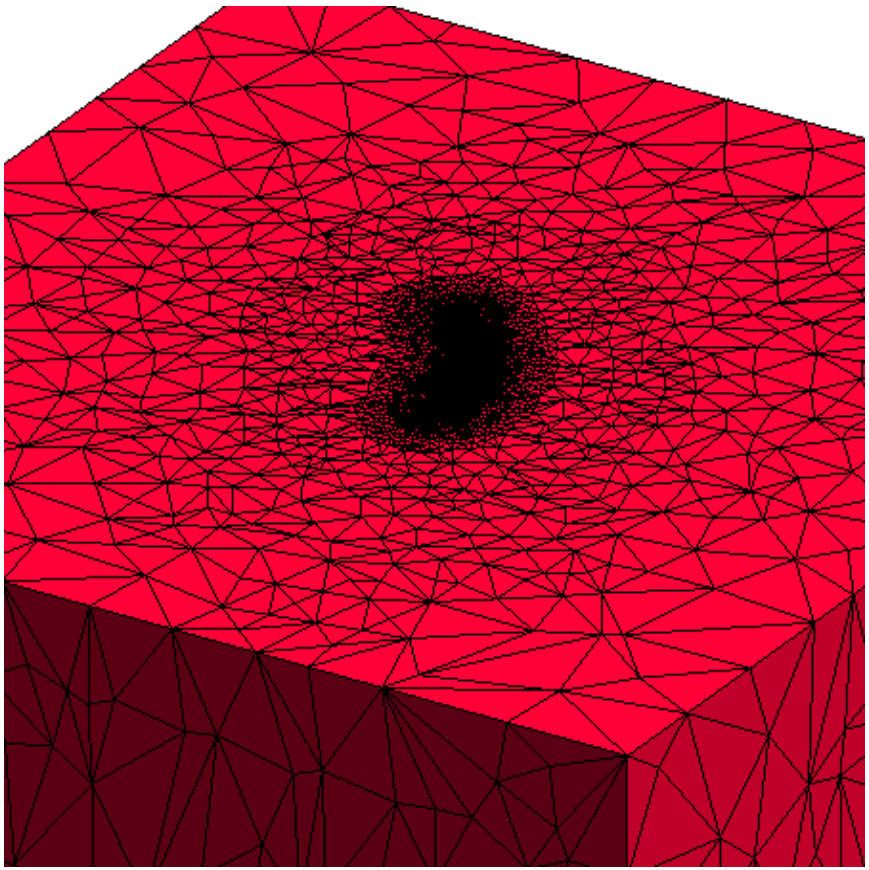


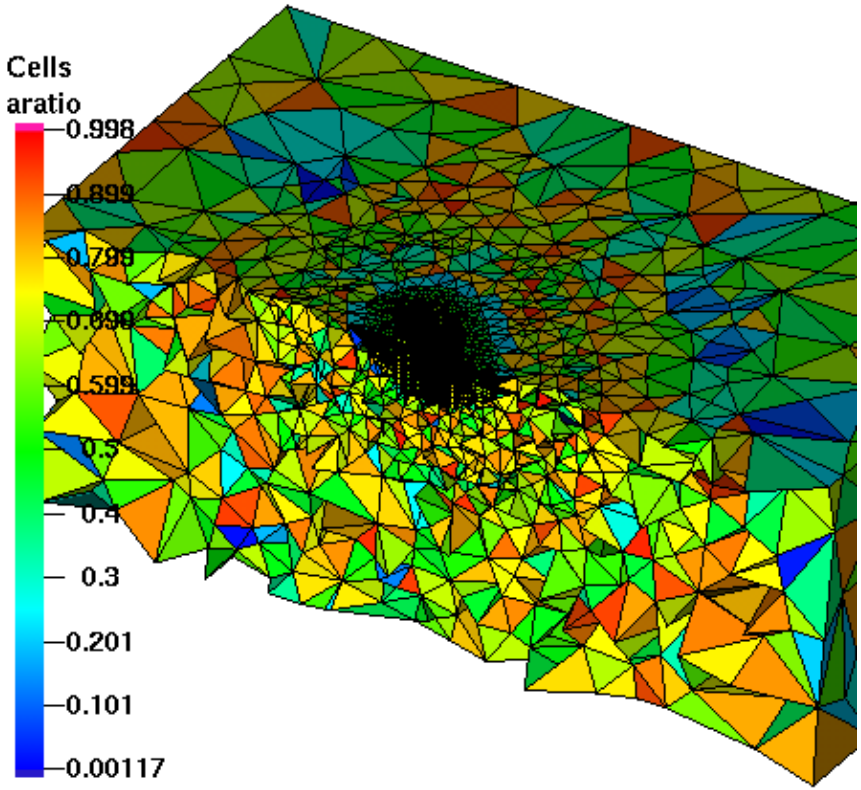
Stack Triangles -> Prisms, Prisms->Tets



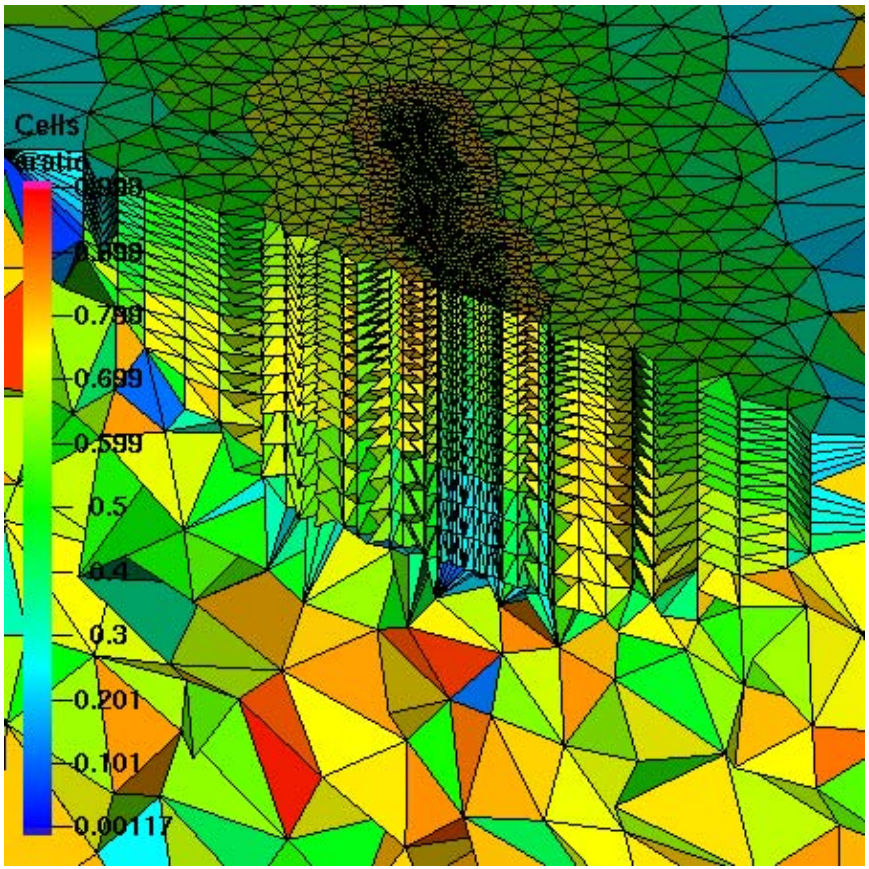


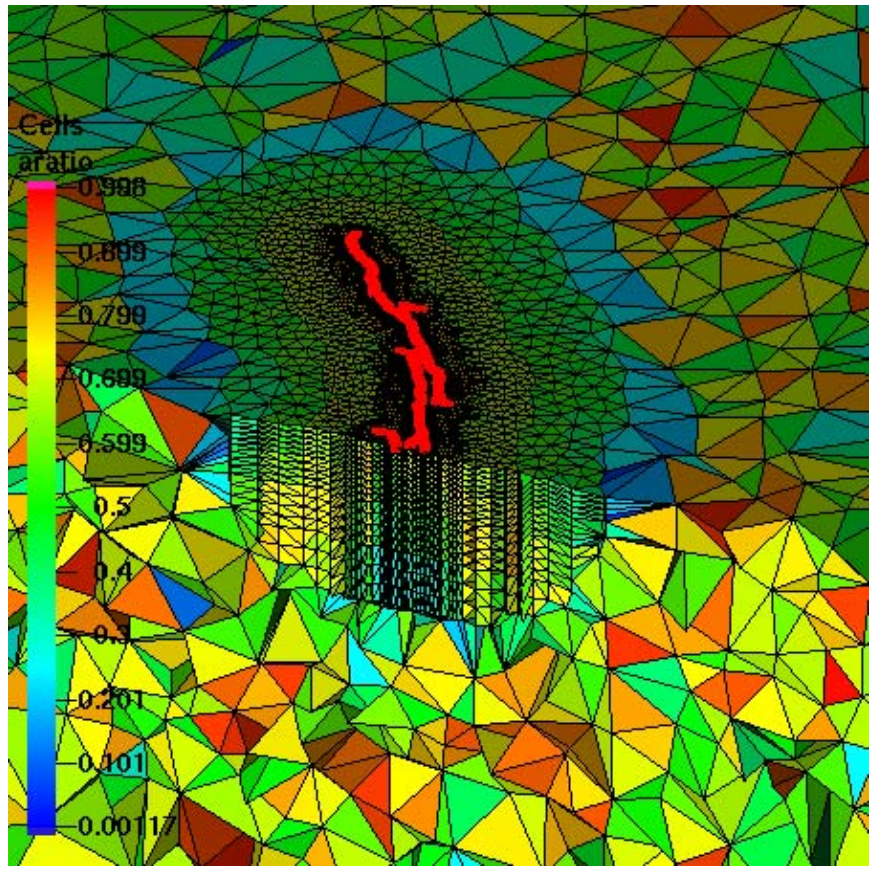
Smooth, Refine, Derefine Tets



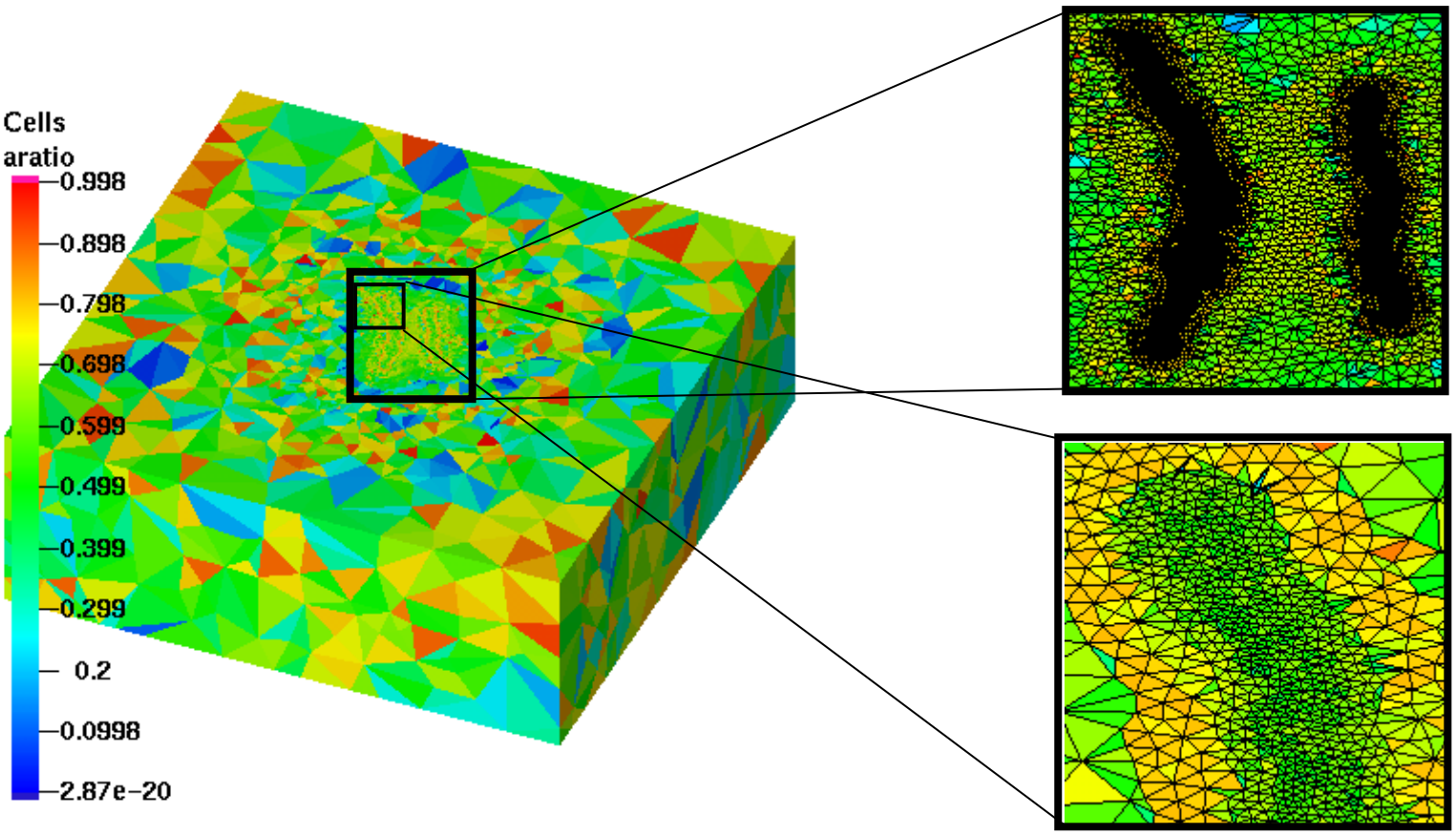


Landers, Final Tet Mesh, Aspect Ratio





Landers and Hector Mine Faults



Landers/Hector Mine, Cut Away View