FORGE 3D Resistivity Model

Milestone 4.1 for FORGE Project 3-2535 : Joint Electromagnetic/Seismic/INSAR Imaging of Spatial-Temporal Fracture Growth and Estimation of Physical Fracture Properties During EGS Resource Development

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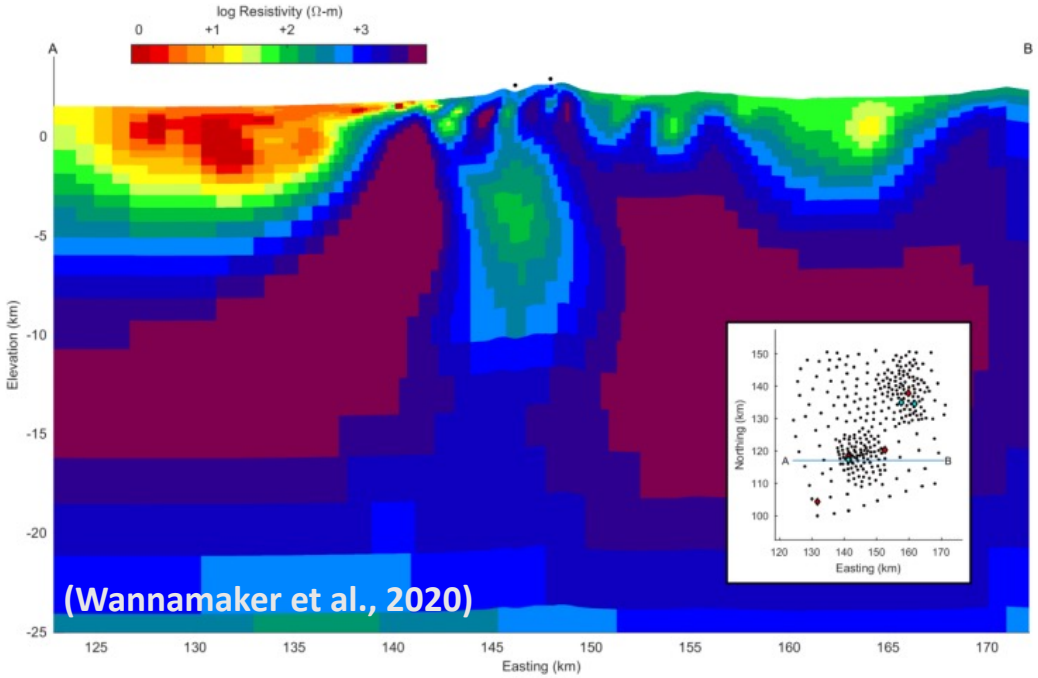
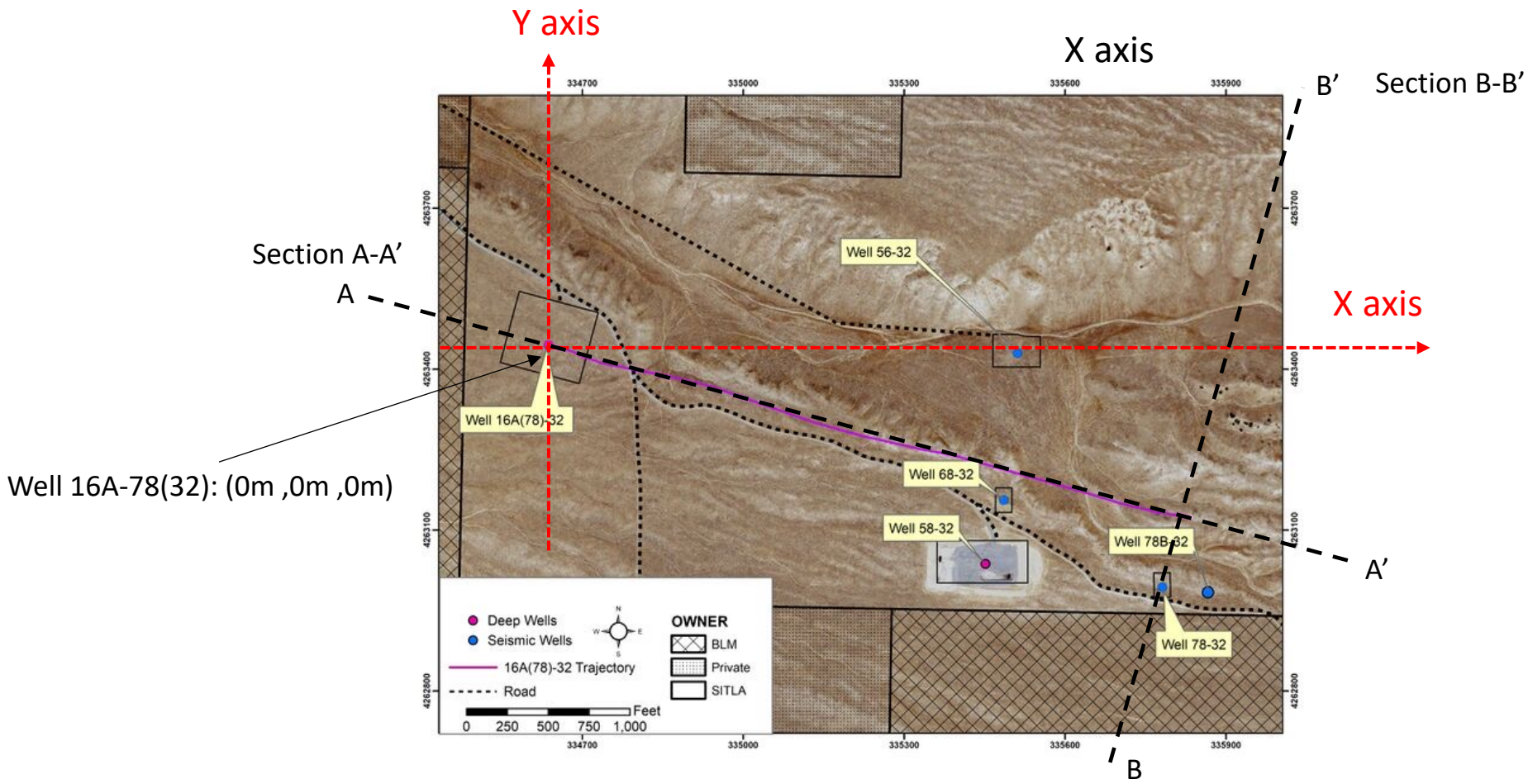
Introduction to Baseline Electrical Resistivity Model at FORGE



Section view of 3D MT inversion at the FORGE site

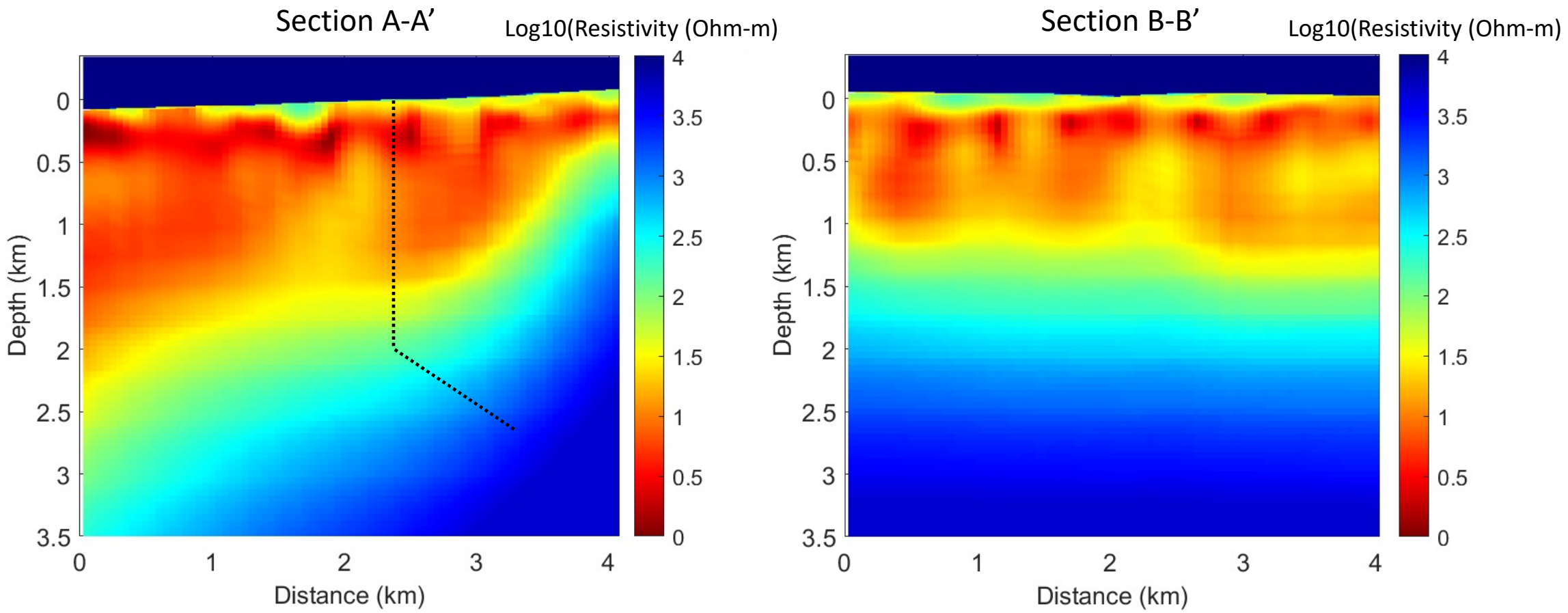
- Magnetotelluric (MT) data were acquired at 122 sites over the FORGE site.
- The MT data were inverted using a 3D MT inversion algorithm (Kordy et al., 2016)
- To discretize the large-scale topography existing in the FORGE site, the MT resistivity model was built on deformed hexahedral meshes.
- LBNL's in-house controlled-source electromagnetic modeling codes define an input Earth model using regular rectangular grids.
- The 3D MT inversion model was converted to a regular grid model using a linear interpolation scheme.
- 50m uniform grids were used in the x- and y-direction and 10m grids in z-direction.

New Coordinate System of 3D Electrical Resistivity Model in Regular Grids



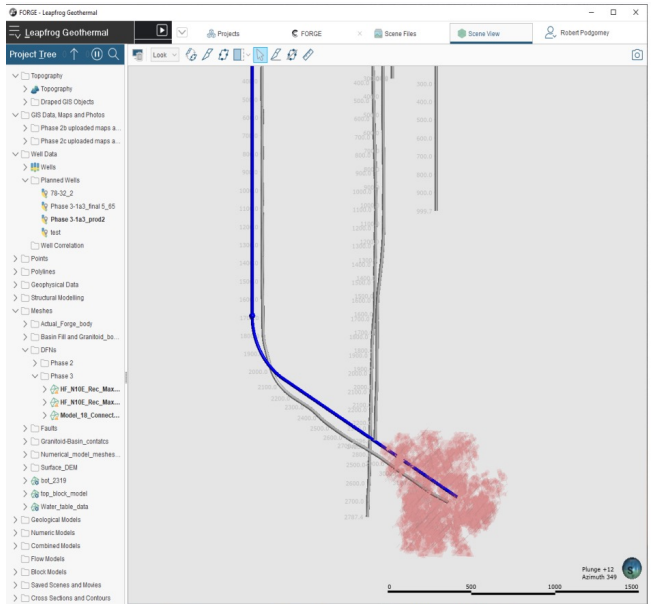
A central part of the model is mapped onto fine rectangular meshes (81*81*241) in the new coordinate system:
X: -2000 to 2000 m (50m cell size)
Y: -2000 to 2000 m (50m cell size)
Z: -350 to 3600m (10~50m cell size)
Larger cell sizes are used beyond the central part of the model.

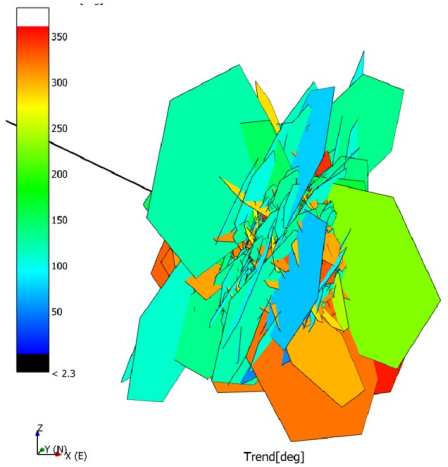
Central Portion of 3D Electrical Resistivity Model: before stimulation



Electrical Resistivity of Stimulated Zone

(From Modeling and Simulation for Utah FORGE:
2021 Summary and Plans for 2022, Podgorney)





- *The volume: 400m (width) x 600m (height) x 300m (length)
- Effective medium theories for earth media with fluid-filled fractures (Berryman and Hoversten, 2013, Geophysical Prospecting) are used for estimating electrical resistivity of the stimulated zone.
- The overall 1% porosity of the stimulated zone is distributed into the three directions (well direction: x axis)
  - XY directed fractures: 28%
  - XZ directed fractures: 32%
  - YZ directed fractures: 40%
- Other conditions: 430 F° at the target depth; 400 ppm of NaCl solution
- The resulting electrical resistivity tensor is

```
rho =

  301.9157         0         0
         0  269.8153         0
         0         0  256.2110
```

- If the fracture planes are aligned only in the YZ plane, the tensor would be

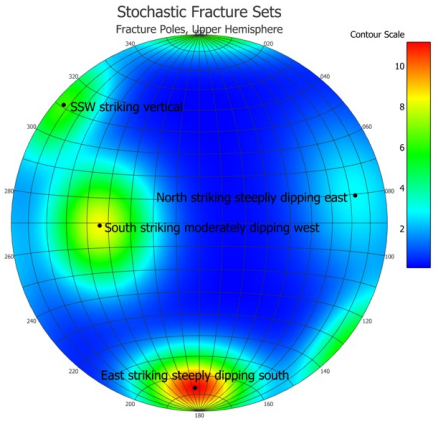
```
rho =

   1.0e+03 *

    2.9700         0         0
         0    0.1895         0
         0         0    0.1895
```

What orientations might be expected?

FOUR STOCHASTIC FRACTURE SETS

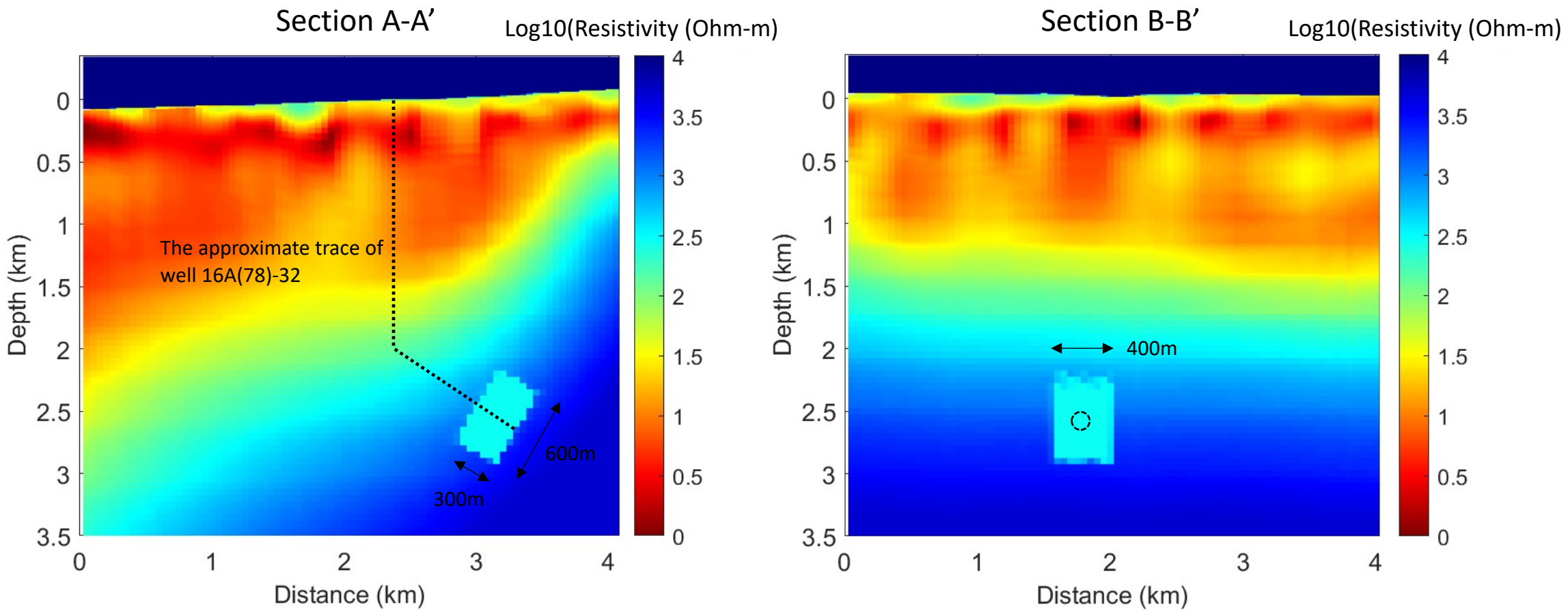
Discrete stochastic fractures provided in the previous DFNs have radius values in the 10-150 m range and have only **four constant orientations** corresponding with the mean set values shown in the table below

Set Description	Orientation		Intensity	
	Mean Trend/Plunge [deg]	Mean Strike/Dip [deg]	P_{32} [1/m]	[%]
South striking moderately dipping west	88.5/46	178.5/44	0.42	36.1%
East striking steeply dipping south	1.5/13.5	91.5/76.5	0.35	30.1%
North striking steeply dipping east	260/17	350/73	0.20	17.2%
SSW striking vertical	131/5	221/85	0.19	16.6%
			1.15	**100.0%**



(personal communication with Aleta Finnila)

Central Portion of 3D Electrical Resistivity Model: after stimulation



- The electrical resistivity of the stimulated zone (300m-by-400m-by-600m):
  - 256-302 Ohm-m (1% porosity; 430 F° at the target depth; 400 ppm of NaCl solution)
  - Effective medium theories for earth media with fluid-filled fractures (Berryman and Hoversten, 2013, Geophysical Prospecting) used.