Intelligent Fracture Creation for Shale Gas Development

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Shale gas modeling is complex

- Shale gas appears in a large number of small fractures that are not naturally interconnected and are difficult to recover gas from.
- Natural and hydraulically induced fractures are created to connect shale gas reservoirs to make recovery of shale gas economically viable.
- *More complex than conventional reservoirs*.

Discrete fracture model (DFM)

- Each fracture represented individually and explicitly:
  - requires unstructured gridding of the fracturematrix system using 3D (Delaunay) triangulation
  - transmissibility evaluation between each pair of adjacent cells.
- Nearwell effects are modeled in detail by refining the unstructured 3D grid to the point where we fully resolve stimulated fractures.
- Very large models require an upscaling process, such as a multiple subregion procedure to allow fast computations.

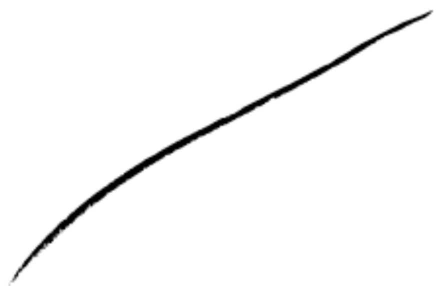
Complex geometries

- Common in shale gas reservoir simulation.
- Horizontal wells and multistage hydraulic fracturing provide difficulties leading to only
  - single well simulations or
  - simple decline curve analysis.
- *More accurate reservoir simulation is key to better field management*.

Advanced simulation techniques

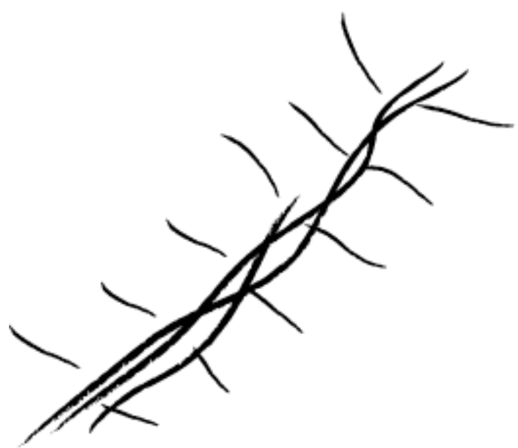
- Critical to reservoir management and sources of information to companies that develop and operate shale reservoirs.
- In the past, much of the simulation development has been aimed at a working field, not at creating a working field.
- *We show how a dynamic data-driven application system (DDDAS) approach can significantly enhance the creation of a fracture shale gas field.*

Different crack formulations



Simple Fracture

Complex Fracture



Complex Fracture
With Fissure Opening

Complex Fracture
Network

Model formulation

- DFM:
  - Each fracture is its own geometric entity.
  - DFM *was* difficult to use due to a lack of accurate information to describe a fractured reservoir.
  - The computational cost *was* prohibitive.
    - *With the ready access of relatively inexpensive fast, parallel computers, computational cost is no longer a barrier*.
    - Peta-, exa-, zetta-, …, *darema*-scale candidate.

DFM formulation of interest

- Studied since 1970's for
  - finite element, finite difference, and finite volume methods.
  - Cartesian and unstructured grids.
- For us,
  - unstructured grid, finite volumes most accurate.
  - a connection list to represent unstructured grids in two and three dimensions with multiphase flow.
  - local grid refinement in both fractures and matrix.

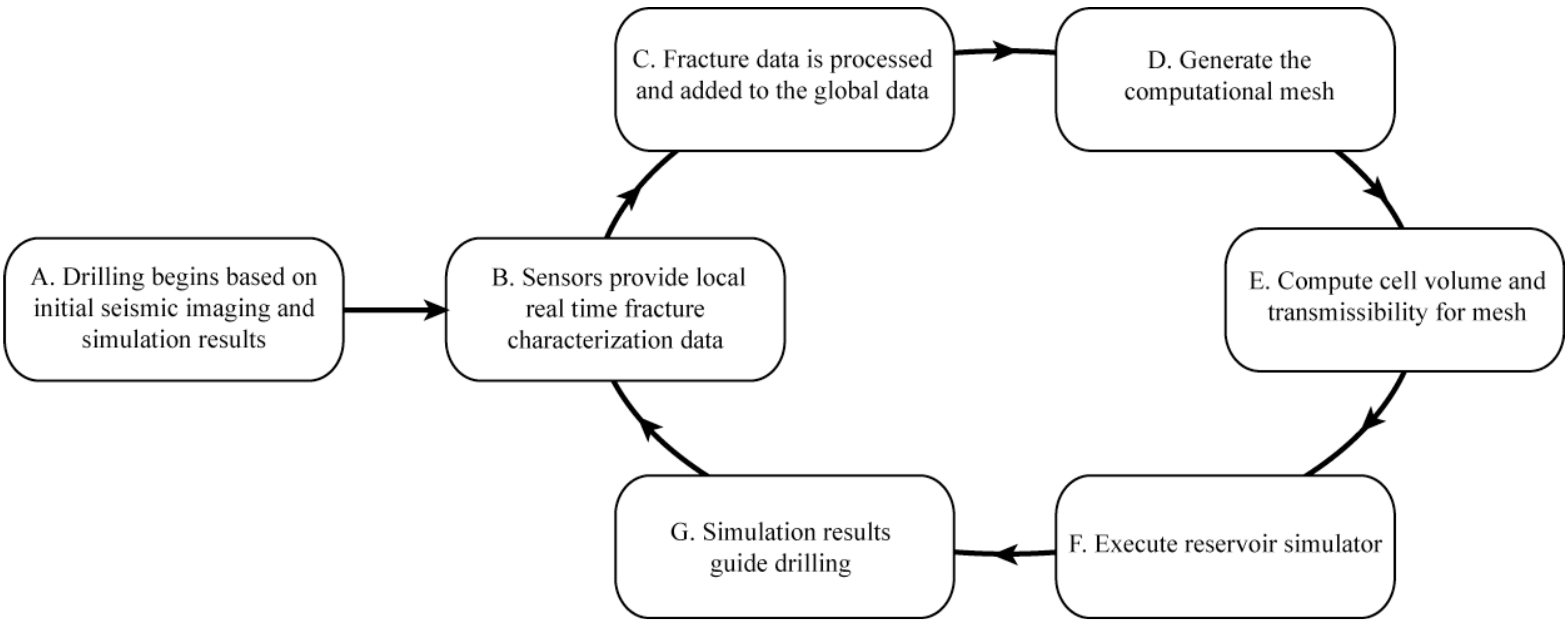
Upscaling

- The multiple subregion (MSR) method is used to upscale the problems to construct attractive coarse grid problems to solve instead of fine grid ones.
- By using local subregions, the upscaled model is in a dual-porosity form.
  - Matrix rock and fractures can then exchange fluid locally in parallel with large scale flow through the fracture network.
  - A connection list including all internal and interblock transmissibilities can be created that is suitable for direct input into a reservoir simulator.

Upscaling procedure

- Three steps:
  - The coarse scale equations may be different than the fine scale ones. Hence, the upscaled parameters must be computed explicitly.
  - A local or global domain must be chosen for the upscaled parameters.
  - The boundary conditions have to be determined and post processing is applied when computing the upscaled parameters.

DDDAS workflow



Visualization and timing

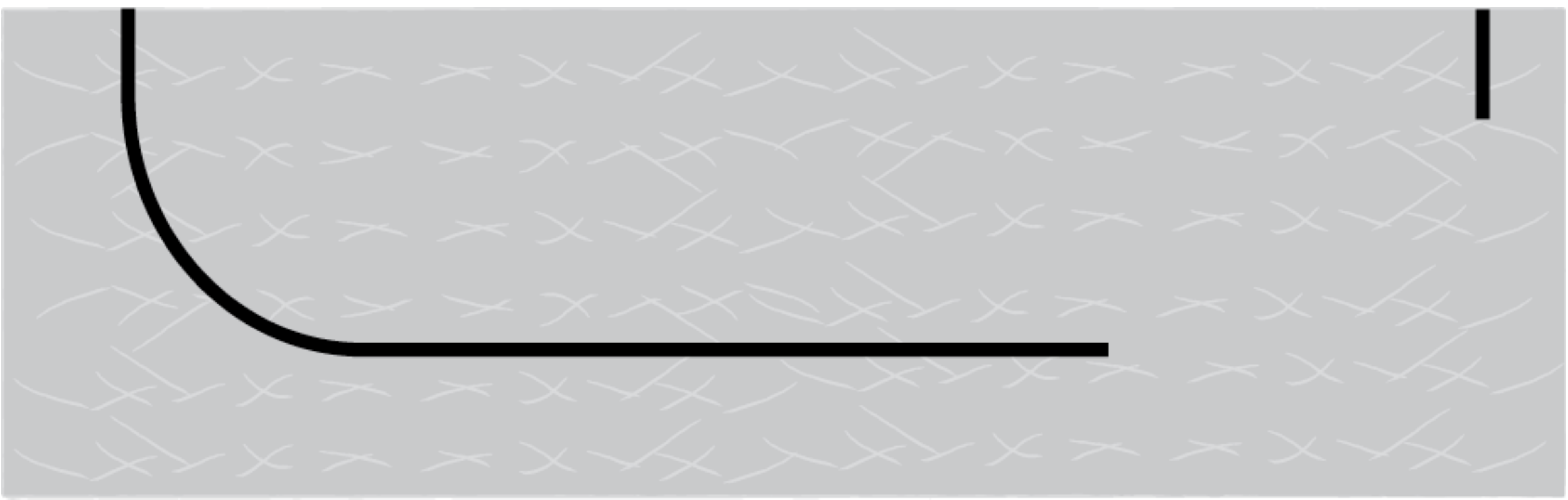
- Visualization not in workflow, but
  - Critical in steps A, C, D, F, and G.
- Complete cycle takes
  - Many months for standard collection and assimilation.
  - Tedious manual intervention in step C can be done in background while other parts done automatically.

Microseismic imaging

- Can show new fractures very quickly.
- Adding to map is much cheaper than a complete seismic image processing.
- Should be added in Steps B-D quickly. Integrating the data into the overall seismic image is
  - nontrivial,
  - not automatic, and
  - there have been few advances in automatically doing this step.

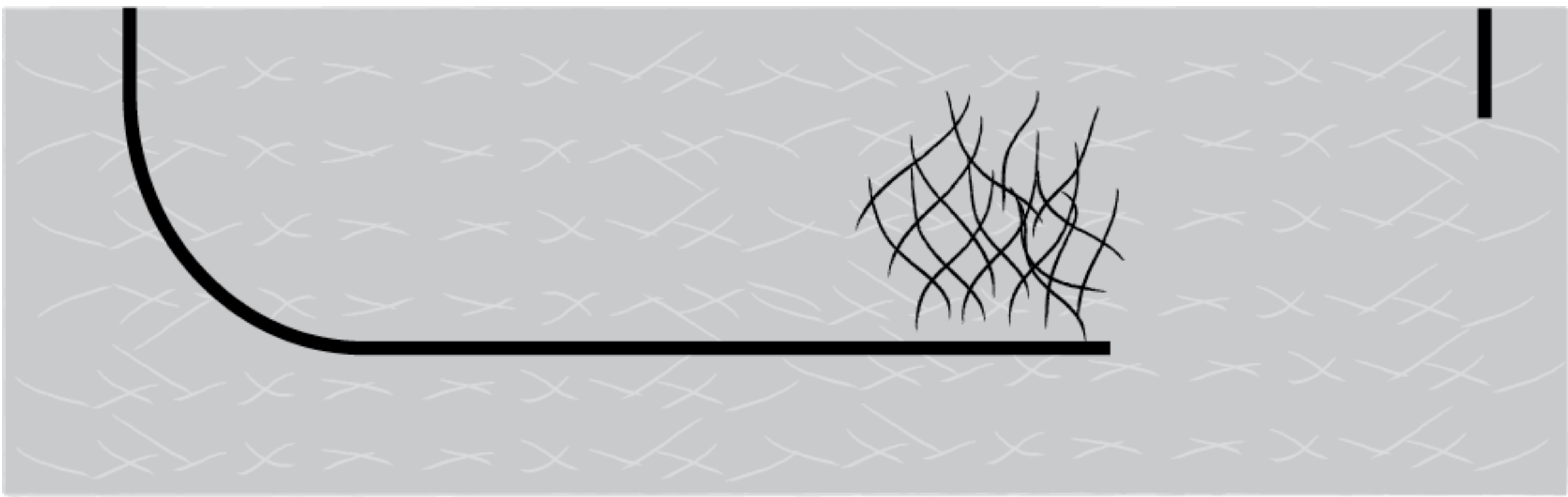
Example

- (a) Initial configuration with the horizontal well, the vertical well with microseismic sensors, and natural fractures



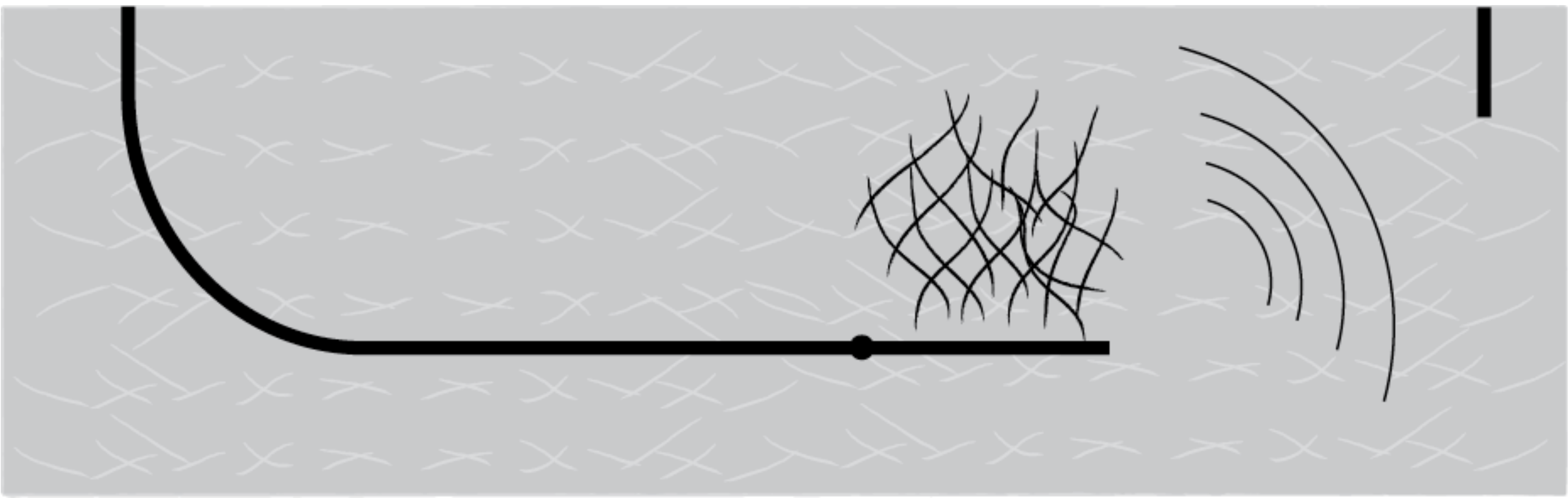
Example

- (b) Fractures after the first hydraulic fracturing process completed at far end of horizontal well



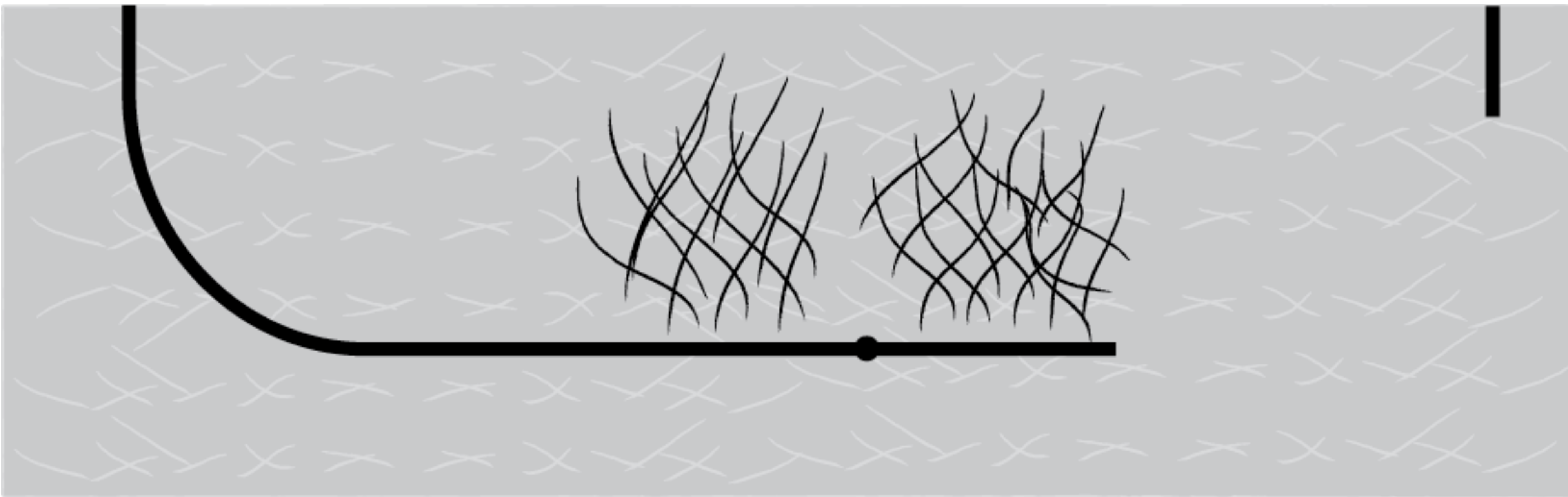
Example

- (c) Microseismic imaging to the vertical well with a plug in place in the horizontal well



Example

- (d) Fractures after the first hydraulic fracturing process completed at far end of horizontal well



Conclusions

- We outlined a DDDAS for network fractured shale gas reservoir creation that should work well with an established reservoir model and simulation.
- A systematic workflow for a DDDAS that models shale gas reservoirs with complex fractures in fine scale (DFM) and coarse scale (MSR).
  - Ideally this methodology will be implemented for a real shale gas development project where the natural and hydraulic fracture network is mapped through borehole imaging logs, microseismic imaging, and other characterization approaches.