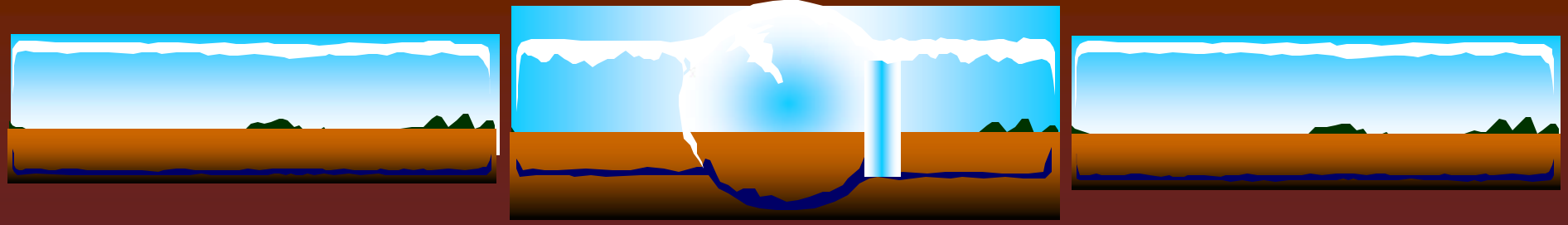

DOE's EGS Program Review

Geochemical Enhancement of Enhanced Geothermal System Reservoirs: An Integrated Field and Geochemical Approach

DE-FG36-04GO14292

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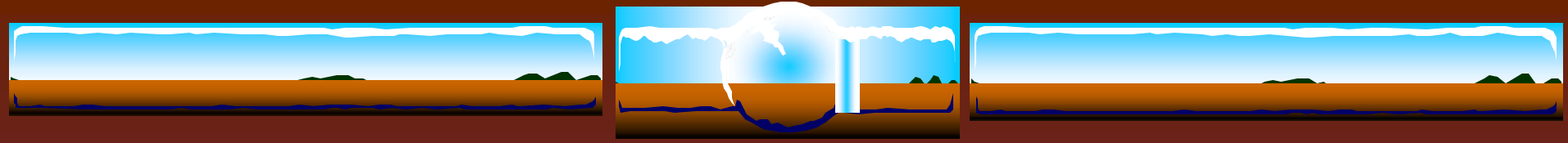


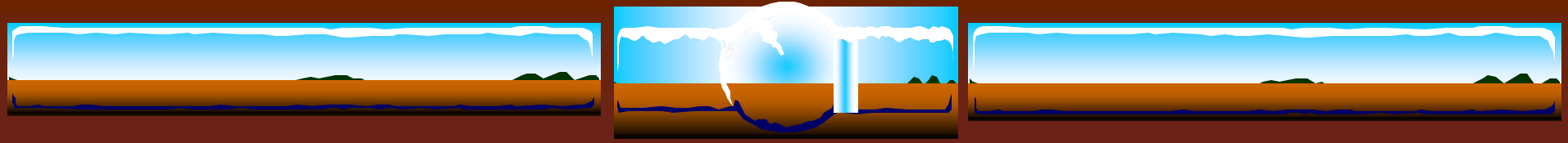
Collaborations

Cost-Sharing Partners

- **Calpine Corp.**
- **Coso Operating Co.**
- **University of Utah**

Collaborators

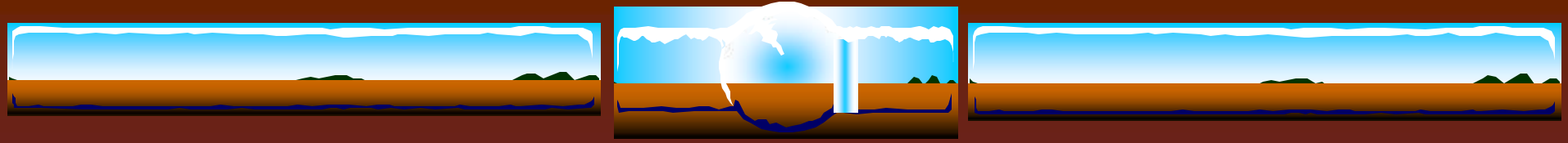
- **Mr. Brian Berard** – CalEnergy Operating Corp.
- **Dr. John Bowman** – U of Utah
- **Ms. Lorrie Dilley** – New Mexico Tech
- **Mr. Jeffrey Hulen** – EGI
- **Mr. Dennis Kaspereit** – CalEnergy Operating Corp.
- **Ms. Katie Kovac** – EGI
- **Mr. Jess McCulloch** – Coso Operating Co.
- **Dr. Jungho Park** – New Mexico Tech
- **Mr. Mitch Stark** – Calpine Corp.
- **Dr. Tianfu Xu** – Lawrence Berkeley National Lab



Project Objective

1. Determine the extent mineral deposition or dissolution related to injection affects reservoir permeabilities.
2. Develop injection strategies for mitigating and reversing the negative effects of fluid injection and natural fluid flow.
3. Characterize the geology of the Coso EGS well 46A-19RD and determine likely zones of failure.

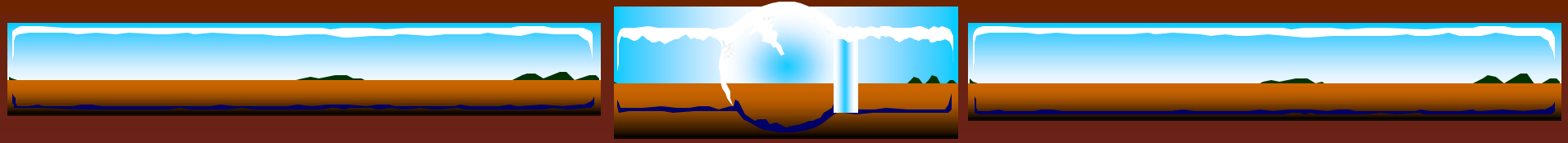
The Peer Review panel did not request any changes in the project. However, objective 3 was added at the request of DOE during the second year of the project in lieu of other proposed tasks.



EGS Problem

- Why is the project important to the EGS program?

  This project will lead to improved productivity and sustainability of EGS reservoirs. The techniques developed here will be applicable to any class of geothermal system (e.g. enhanced geothermal systems, binary systems-open or closed loop, dual flash or combined flash and binary systems)
- What technical issue does the project address?
  - Once an EGS reservoir is created, the fluid pathways must be maintained and extended in order to sustain production rates and reduce thermal drawdown. Mineral deposition, which will close fractures, is a consequence of injection. This project addresses the following technical issues:
    - What are the effects of water/rock interactions on reservoir permeability?
    - How significant are these effects?
    - How can the detrimental effects of mineral scaling due to injection or naturally circulating fluids be mitigated or reversed?
- How will the project help to achieve the overall program goals?
  - The project directly addresses the goals of decreasing the levelized cost of electricity, increasing the resource base, increasing the net power extracted per production well and increasing reservoir lifetime by increasing fracture permeability, fracture volume, and the effective fracture area.

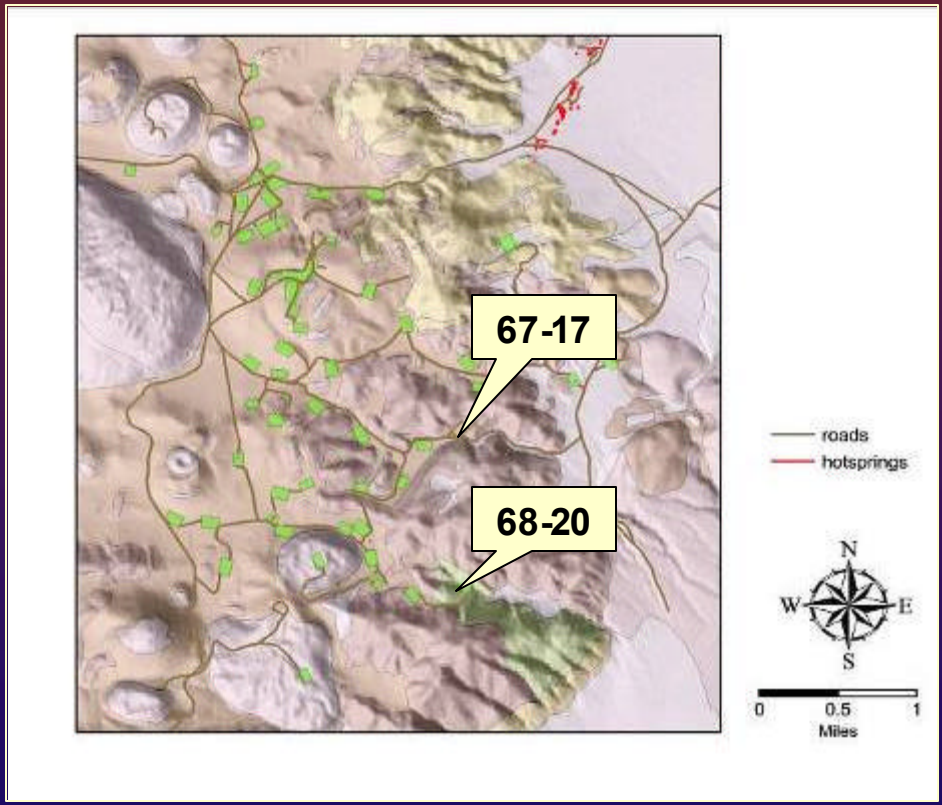


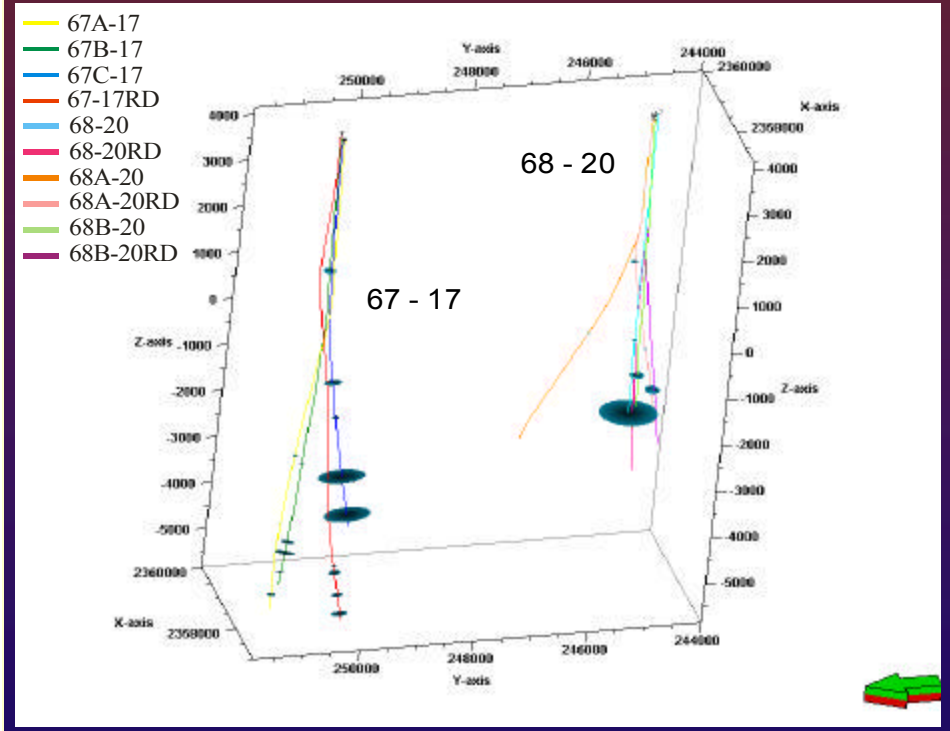
Background/Approach

1. Compare samples from original and redrilled injection wells to determine the mineralogic and geochemical effects of injection.
2. Use these observations to constrain numerical models of water-rock interactions in the near well bore environment and to predict the far field effects of injection.
3. Develop appropriate injection/mitigation strategies.
4. Conduct petrologic and mineralogic investigations of cuttings samples from Coso 46A-19RD to locate zones of potential failure (e.g. fossil fluid pathways, fault zones, breccias, dikes).

Results/Accomplishments

COSO INJECTION WELLS





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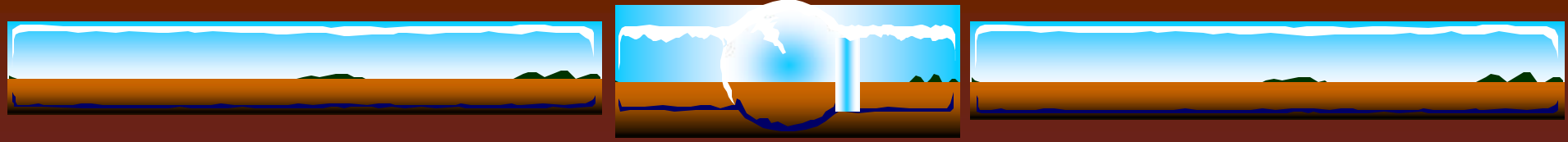
Results/Accomplishments

Amorphous Silica Scale: 68-20RD; 5600 ft

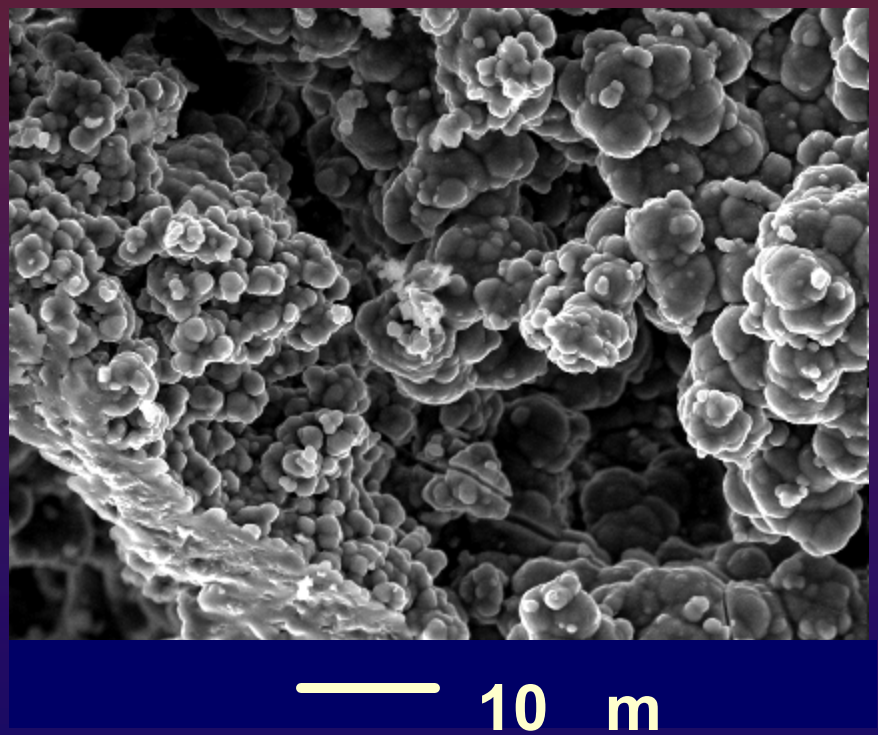
Well	Comp date
68-20	10/29/1987
68-20RD*	5/8/1992
68A-20	7/2/1988
68A-20RD	9/14/1988
68B-20	11/10/1988
68B-20RD*	1/26/1993

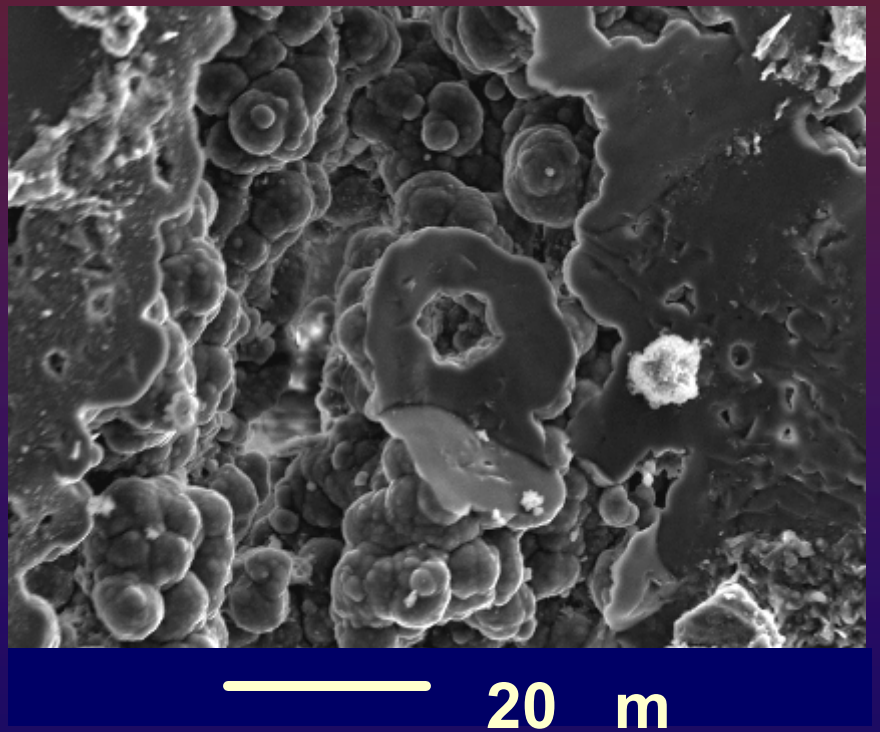
* Contains silica scale



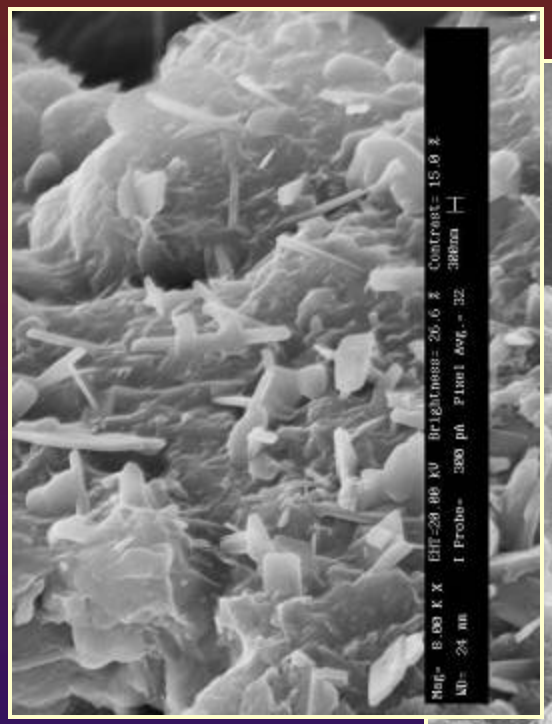
Results/Accomplishments

Identified causes of injection declines at Coso





Results/Accomplishments



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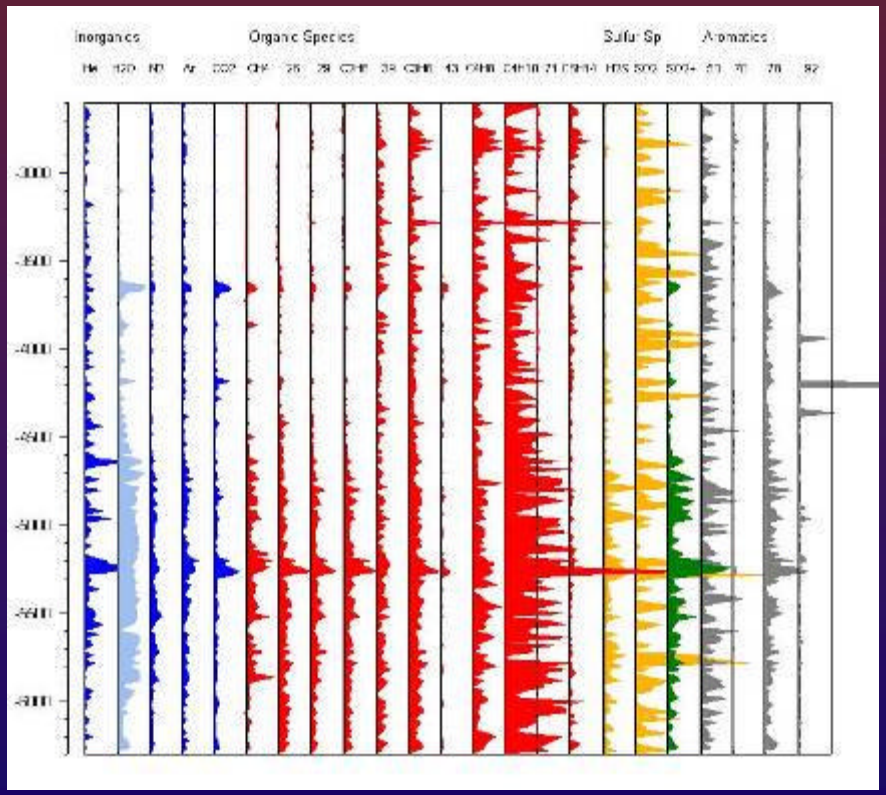
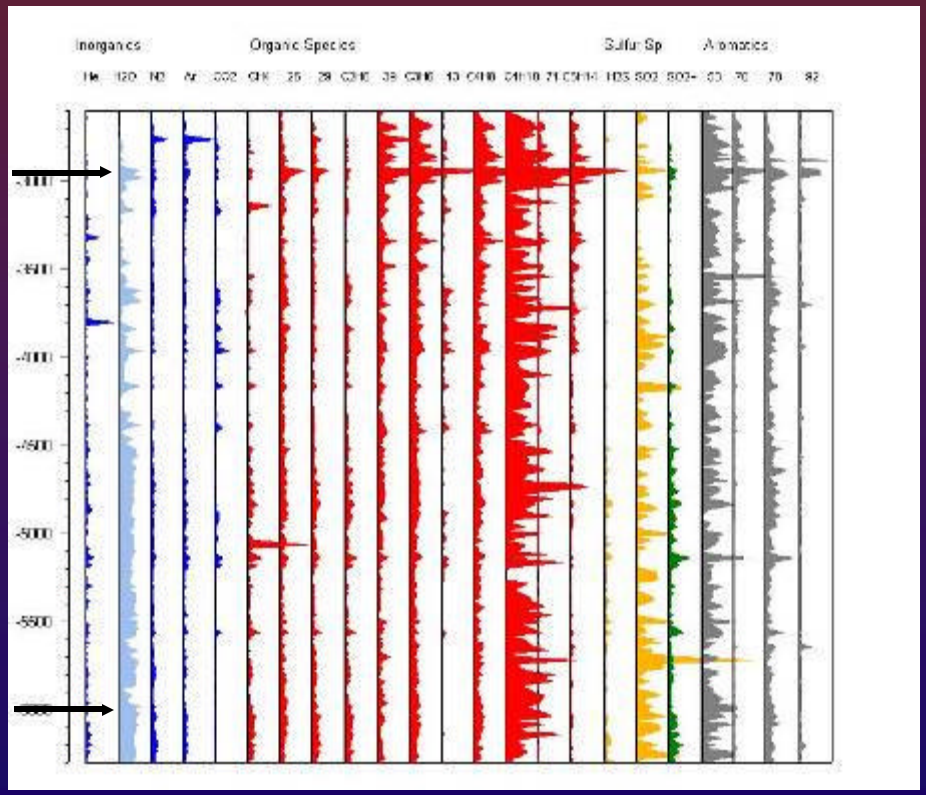
Results/Accomplishments

68-20



68-20RD



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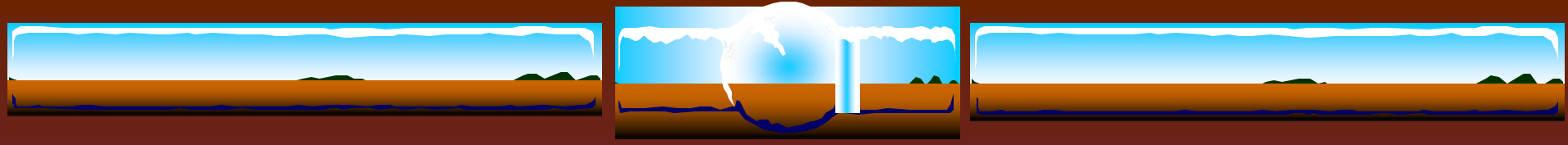
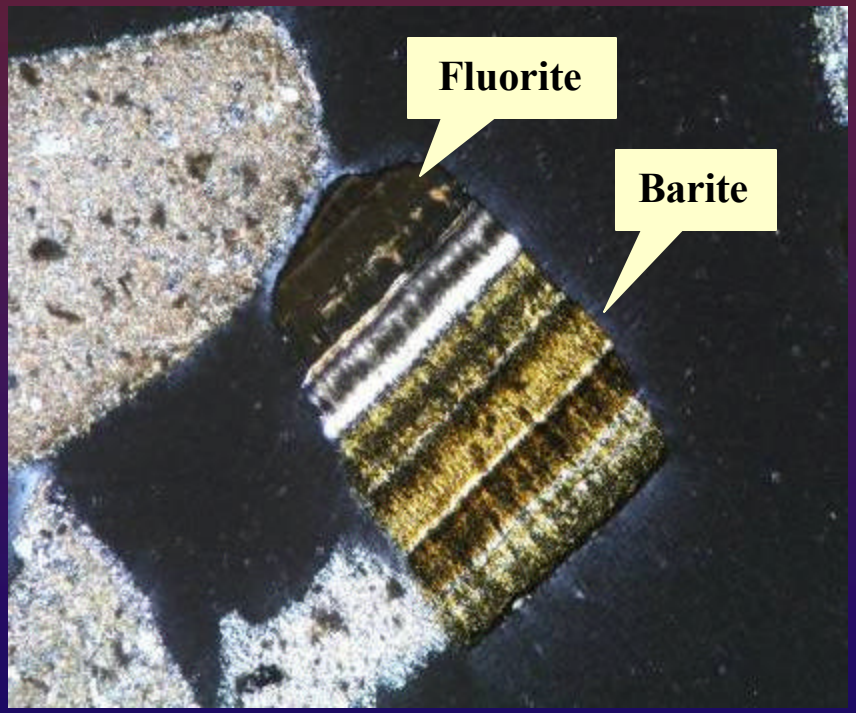
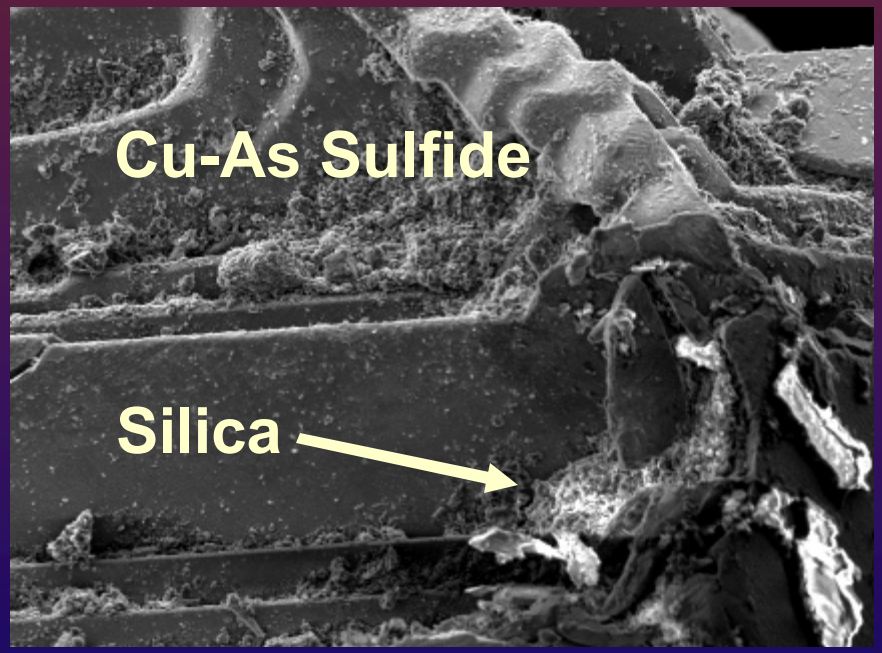


Results/Accomplishments

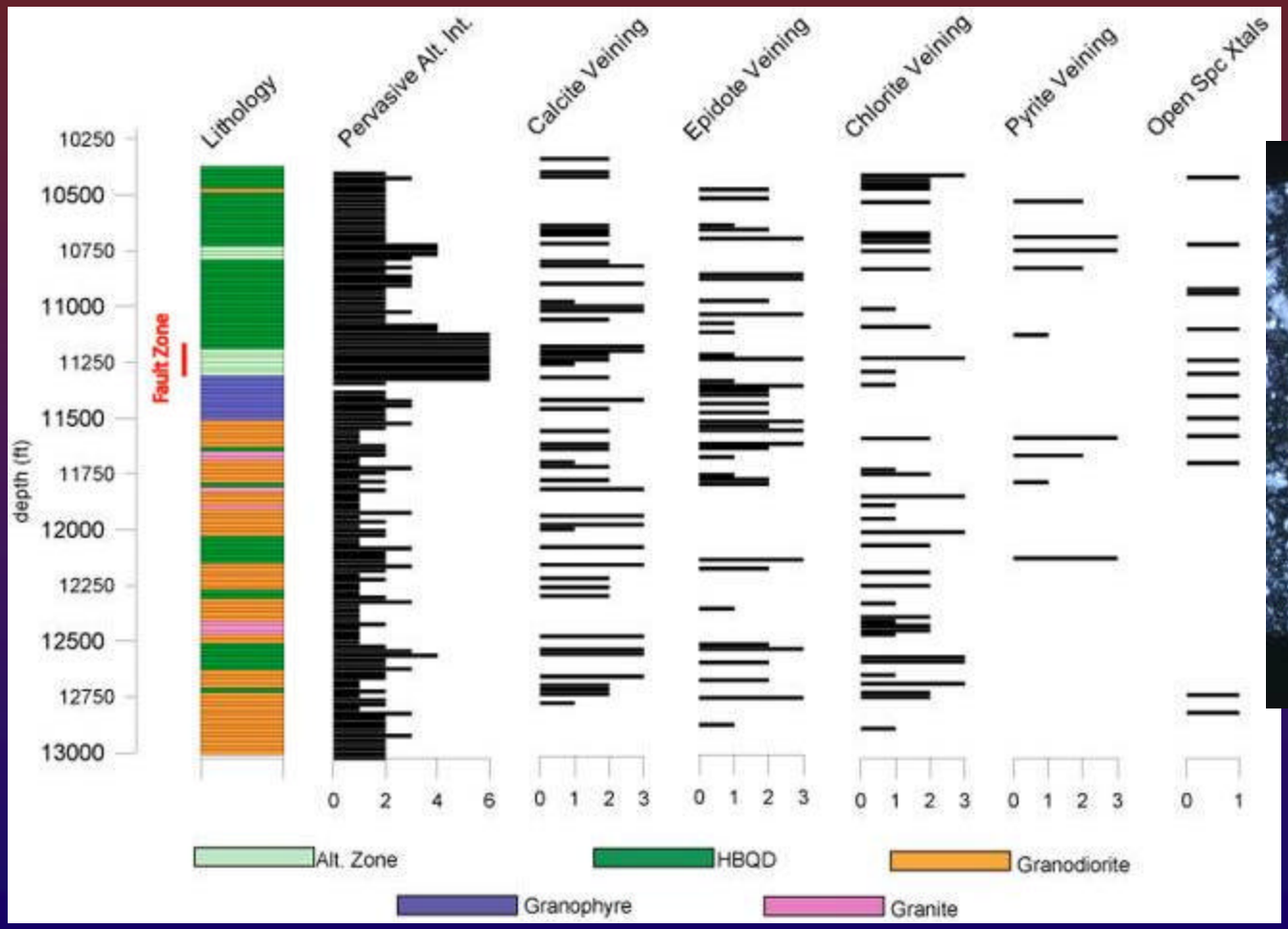
- Demonstrated that mineral scaling caused the loss of permeability in injection well Elmore IW-3 at the Salton Sea

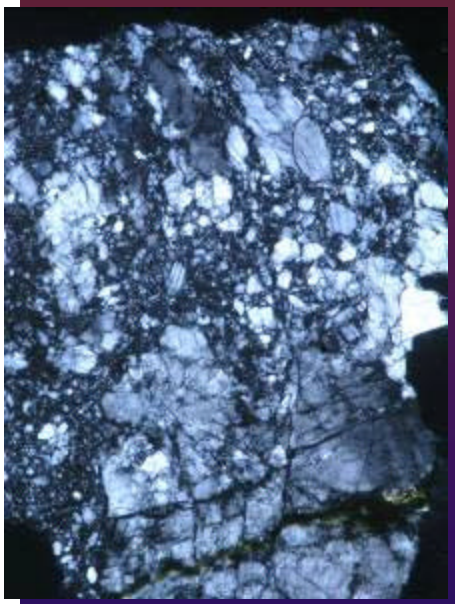




Results/Accomplishments

Lithologic and Alteration Log of Coso 46A-19RD





11,240 ft

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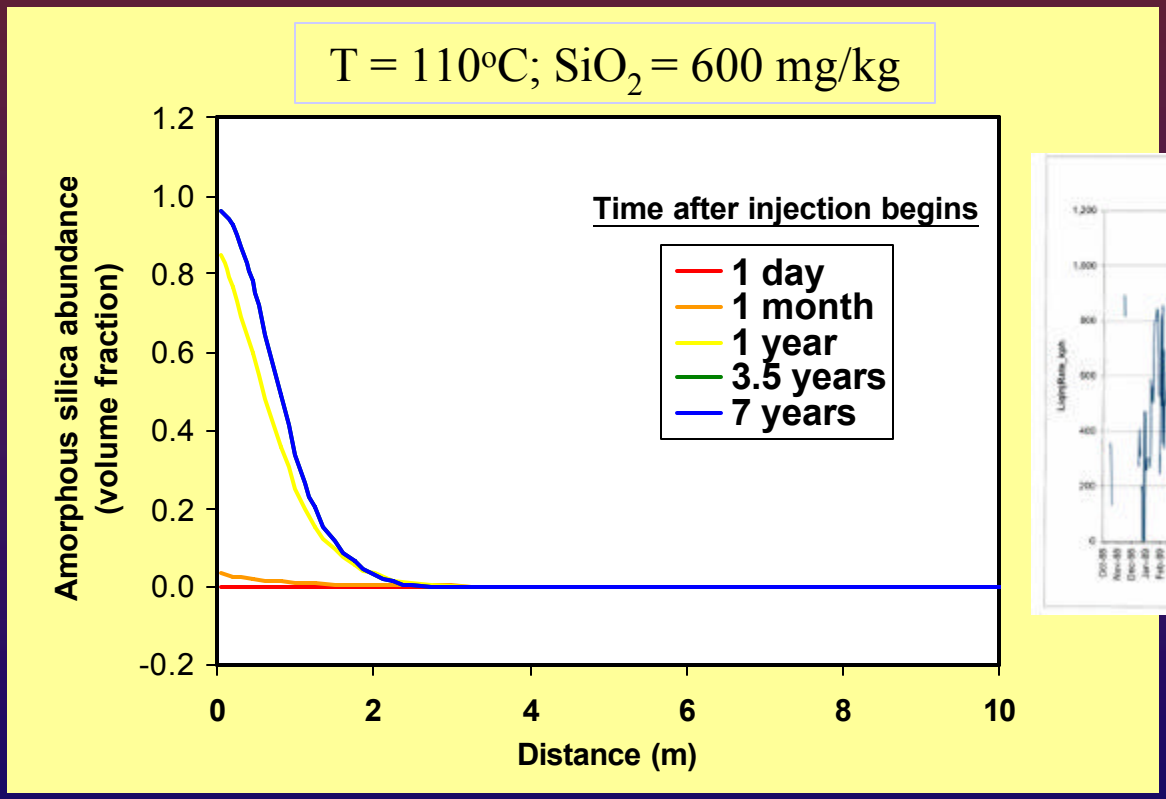
Kovac et al. 2006

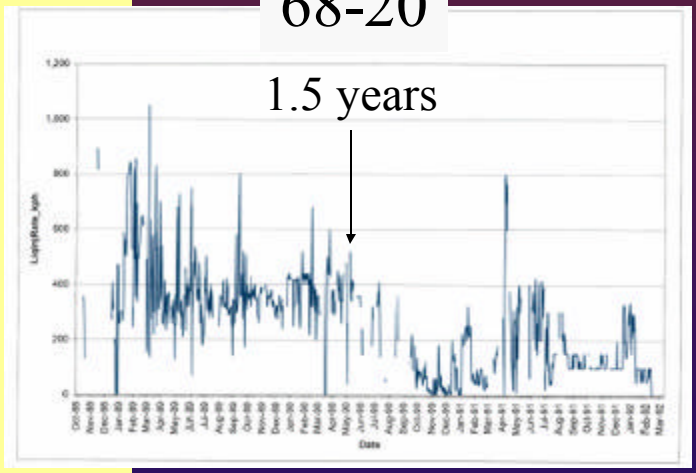
Results/Accomplishments

Numerical Simulations

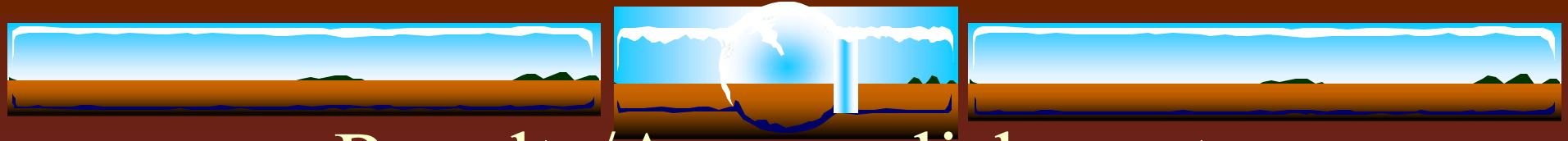
TOUGHREACT Model



68-20



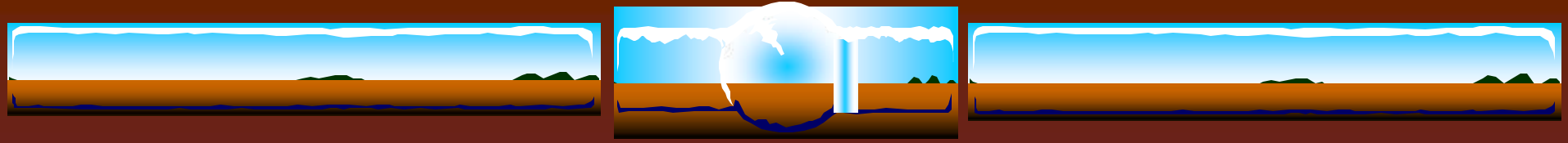
McLin et al., 2006



Results/Accomplishments

Impact and Significance of Results

1. Documented, for the first time, mineral deposition resulting from injection and its effect on reservoir permeability.
2. Identified portions of the reservoir around the injection well affected by the injection fluids but not containing scale deposits.
3. Numerically simulated the effects of mineral deposition on permeability due to injection of silica (Coso) and sulfate-rich (Salton Sea) waters. These simulations accurately predict the observed scale mineralogy and rapid permeability plugging of the formation near the well bore.
4. Identified intervals of potential failure in Coso 46A-19RD.
5. Although the work is directed toward EGS reservoirs, the results are applicable to all classes of geothermal systems.
6. 10 conference papers and abstracts (Transactions of the Geothermal Resources Council, Proceedings of the Stanford Engineering Conference, Geological Society of America, Goldschmidt Conference)

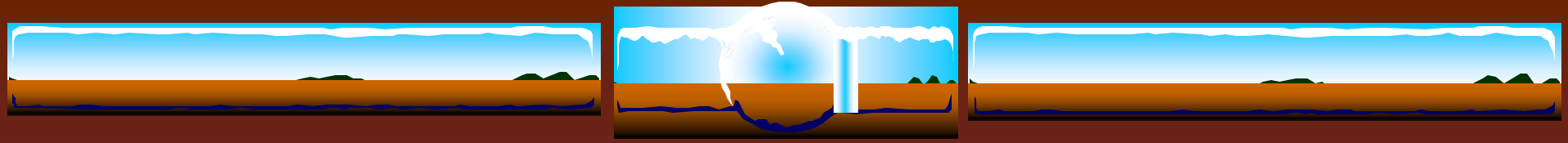


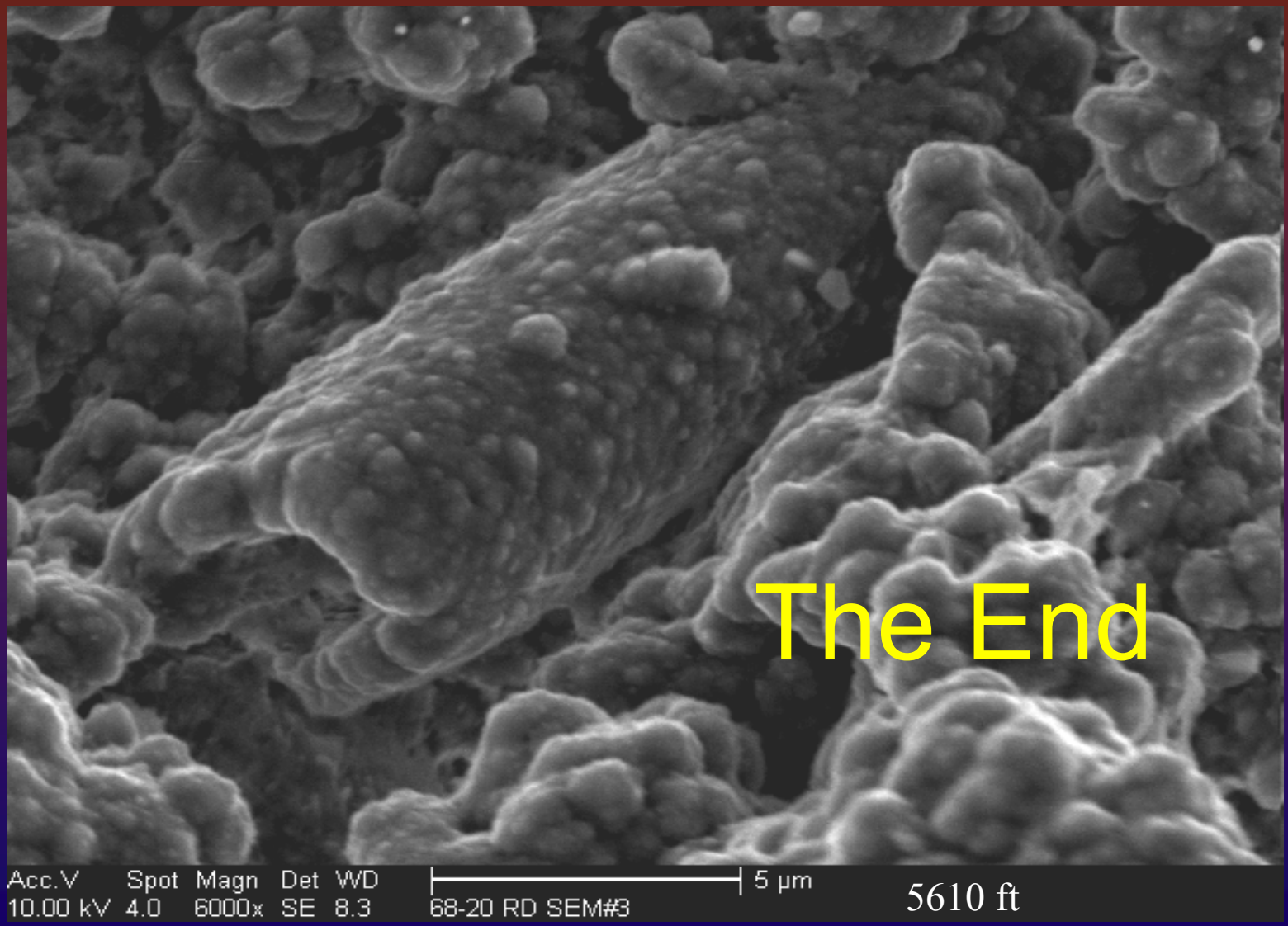
Conclusion

- We anticipate meeting the project's objectives.

The benefits to EGS technology include:

1. Demonstrated the role of mineral deposition as a cause of reservoir permeability loss around injection wells.
   - Documented scale mineralogy and its maturation
   - Characterized scale deposition with respect to distance from the injection well and time
   - Developed numerical simulations consistent with field observations
2. Improved injection strategies to enhance reservoir permeabilities
3. Development of a new method to trace injected fluids





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