COMPUTING & ENERGY FRONTIERS

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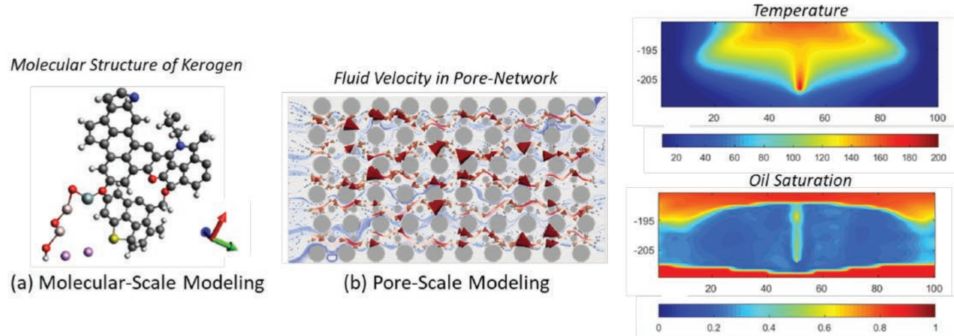
Dr. Kyung Jae Lee leads the Modeling and Simulation of Porous Media research group that conducts research with applications in petroleum engineering and subsurface energy and environmental systems. Dr. Lee is a reviewer for several peer-reviewed journals and has also extensively published her research. Her research interests include numerical and theoretical research on fluid transport and heat flow in porous/fractured media, modeling of unconventional hydrocarbon reservoirs (oil shale, shale gas, methane hydrates, heavy oil, bitumen), forward simulation and inverse modeling of diverse processes applied in subsurface energy sytems (chemical/thermal enhanced recovery, in-situ upgrading, cyclic stimulation, hydraulic fracturing CO_2 sequestration, CO_2 push-pull). Select highlights of research addressed in Dr. Lee's laboratory are listed below.

MULTI-SCALE MODELING AND CHARACTERIZATION OF UNCONVENTIONAL RESERVOIRS

Modeling and characterization of unconventional reservoirs involves complexity, and multi-scale approaches need to be taken for thorough understanding and description of these systems. Dr. Lee and her group apply upscaling techniques throughout molecular-pore-interwell-reservoir scales for more realistic simulation of unconventional reservoirs. They also apply inverse modeling coupled with forward simulation to augument characterization capacity. The Figures below illustrate select examples of Dr. Lee's multi-scale modeling and characterization.



(a) Molecular-Scale Modeling (b) Pore-Scale Modeling (c) Reservoir-Scale Modeling

SIMULATION OF REACTIVE THERMAL RECOVERY FOR OIL SHALE, BITUMEN, AND SHALE GAS

In-situ heating processes such as electrical heating and hot fluid injection are applied to thermally decompose organic matter called kerogen in oil shale reservoirs. Dr. Lee and her group provide optimized scenarios with high productivity and energy efficiency and minimized environmental impact. For instance, hot fluid of steam or water-solvent mixture is injected to mobilize viscous heavy oil in oil shale and heavy oil (bitumen) reservoirs. Additionally, thermal processes are applied along with hydraulic fracturing for thermal desorption of gas in shale gas reservoirs. Each process is scientifically complex, and its numerical simulation involves highly non-linear equations that need to be solved. Dr. Lee and her group apply advanced numerical methods and machine learning technologies to solve the equations with high numerical accuracy while preserving computational efficiency as illustrated in the Figure below. Inserts (a)-(e) show temperature distributions in an oil shale reservoir where electrical heating is applied, and inserts (f)-(j) show volume fraction of kerogen distributions.

Publications

1. Lee, K. (2020). Characterization of kerogen content and activation energy of decomposition using machine learning technologies in combination with numerical simulations of formation heating. Journal of Petroleum Science and Engineering. https://doi.org/10.1016/j.petrol.2019.106860

2. Reagan, M.T., Moridis, G.J., Keen, N.D., Lee, K. et al. (2019). Transport and fate of natural gas and brine escaping from a hydrocarbon reservoir through a failed deepwater well in the oceanic subsurface of the Gulf of Mexico. Transport in Porous Media, 127(2), 459-480.

3 Anyenya, G.A., Braun, R.J., Lee, K. et al. (2018). Design and dispatch optimization of a solid-oxide fuel cell assembly for unconventional oil and gas production. Optimization and Engineering, 19(4), 1037-1081.

4. Jung, Y., Doughty, C., Borgia, A., Lee, K. et al. (2018). Pressure transient analysis during CO_2 push-pull tests into faults for EGS characterization. Geothermics, 75, 180-191.
Lee, K., Finterle, S., & Moridis, G.J. (2018). Analyzing the impact of reaction models on the production of hydrocarbons from thermally up-graded oil shales. Journal of Petroleum Science and Engineering, 168:448-464.

5. Lee, K., Finterle, S., & Moridis, G.J. (2018). Estimating the reaction parameters of oil shale pyrolysis and oil shale grade using temperature transient analysis and inverse modeling. Journal of Petroleum Science and Engineering, 165, 765-776.

6. Lee, K., Oldenberg, C.M., Doughty, C. et al. (2018). Simulations of carbon dioxide push-pull into a conjugate fault system modeled after Dixie Valley-Sensitivity analysis of significant parameters and uncertainity prediction by data-worth analysis. Geothermics, 74, 121-134.

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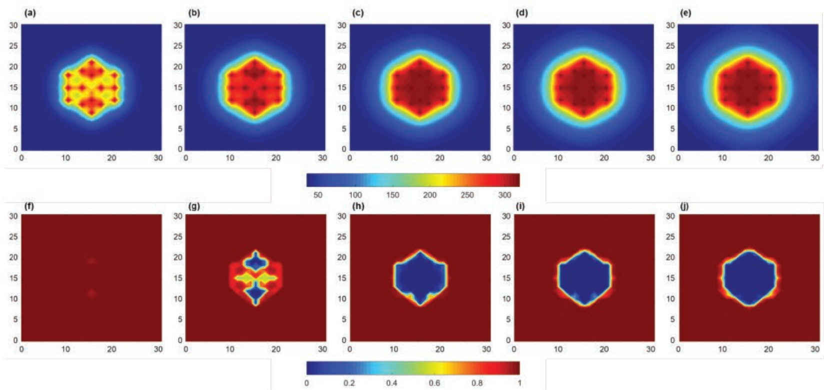
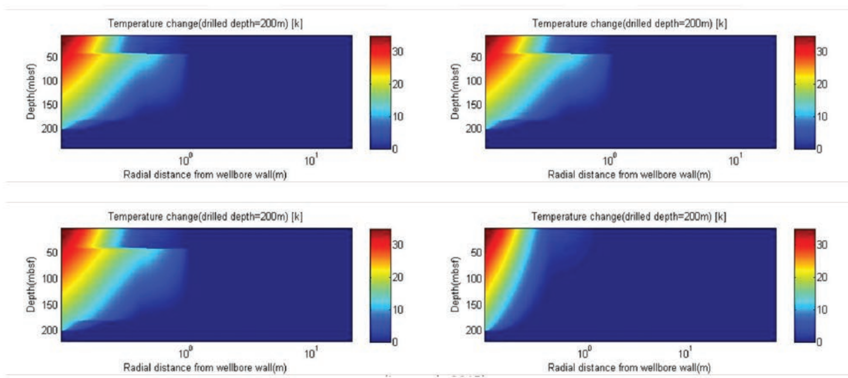


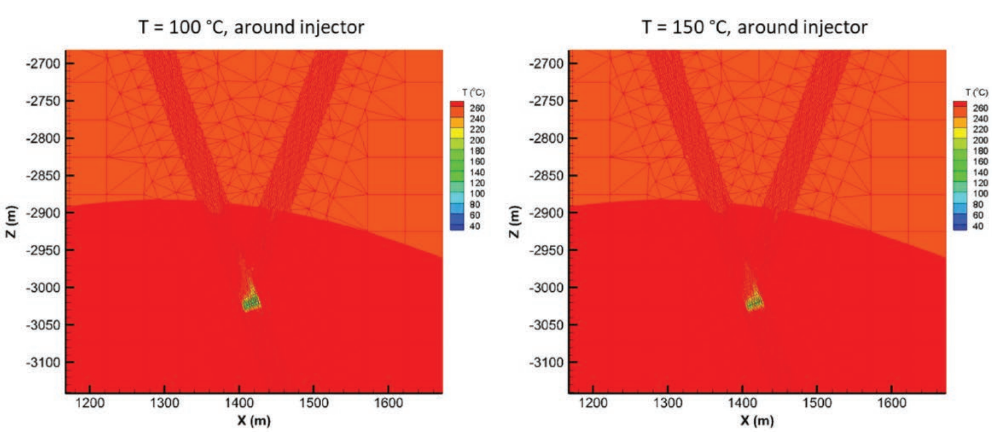
REAL-TIME MODELING OF DRILLING HAZARD IN HYDRATE ZONES

Hydrate bearing formations occur in permafrost regions or sediments under seabed. It is necessary to prevent excessive dissociation of hydrate for wellbore and formation stability while drilling and production. Dr. Lee and her group conduct real-time modeling of in-situ pressure and temperature while considering hydrate kinetics to quantify the hydrate dissociation-induced hazard as illustrated in the Figure below for temperature distributions of different types of hydrate formations.



MODELING GEOTHERMAL SYSTEMS

Modeling of geothermal system includes complexity induced by high pressure and high temperature. Dr. Lee and her group model diverse processes for exploration and exploitation of geothermal reservoirs, involving geochemistry to minimize the impact of hydrogen sulfide. They apply advanced techniques of gridding to describe fractures and faults, which are often present in geothermal reservoirs. Modeling scenarios of geothermal systems using Dr. Lee's advanced gridding techniques is illustrated in the Figure below.



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