The Effect of Compressibility and Boundaries on Displacement Stability

Aura N. Araque and Larry W. Lake
Hildebrand Department of Petroleum and Geosystems Engineering

The Mobility Ratio

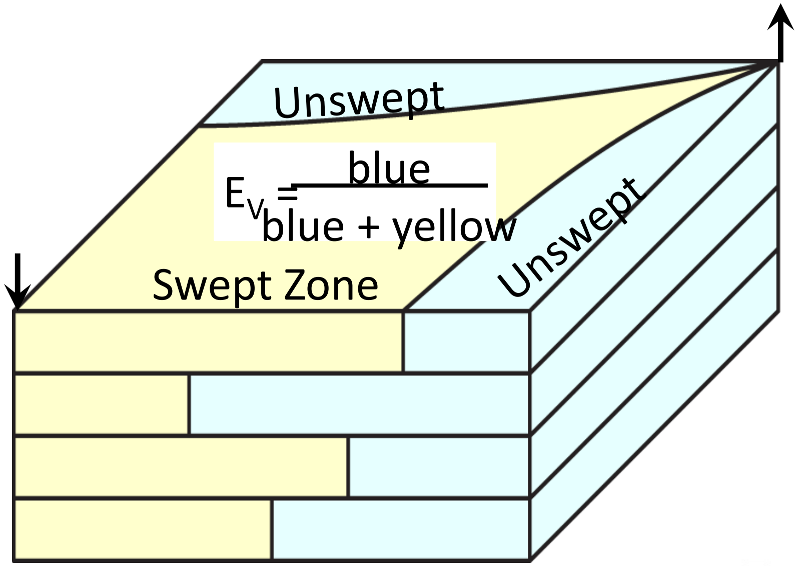
Definition $$M = \frac{\text{Mobility displacing fluid}}{\text{Mobility displaced fluid}}$$

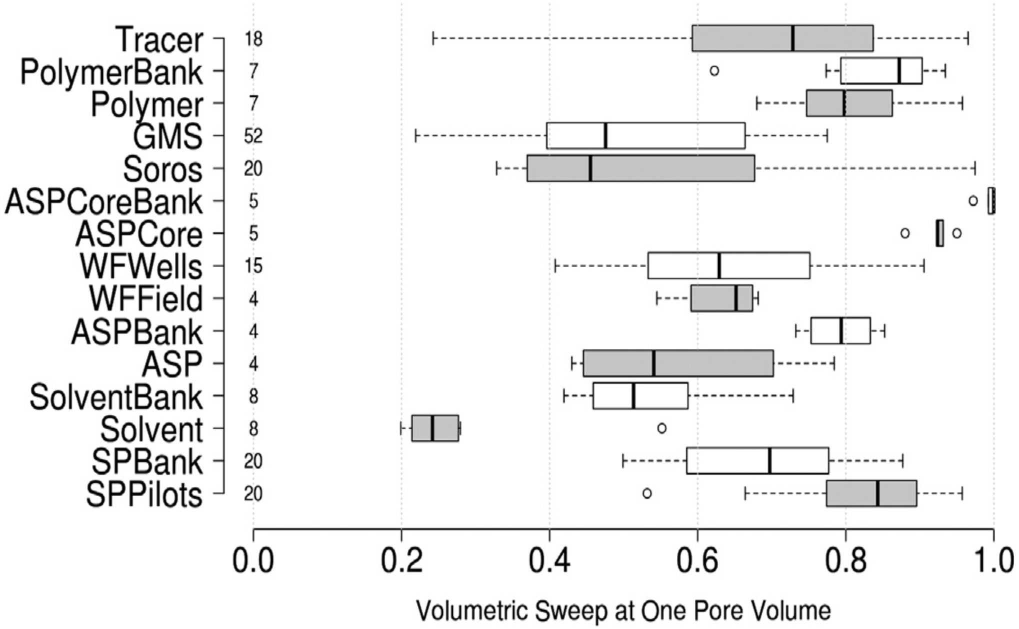
$$M = \frac{\left(\text{Relative perm./viscosity}\right)_{\text{displacing}}}{\left(\text{Relative perm./viscosity}\right)_{\text{displaced}}}$$

$$M = \begin{cases} 0.5 - 10 & \text{Light oil waterflood} \\ 10 - 20 & CO_2 \text{ flood} \\ 20 - 50 & \text{Methane flood} \end{cases}$$

No compressibility in this definition

Volumetric Sweep Efficiency Field Scale…

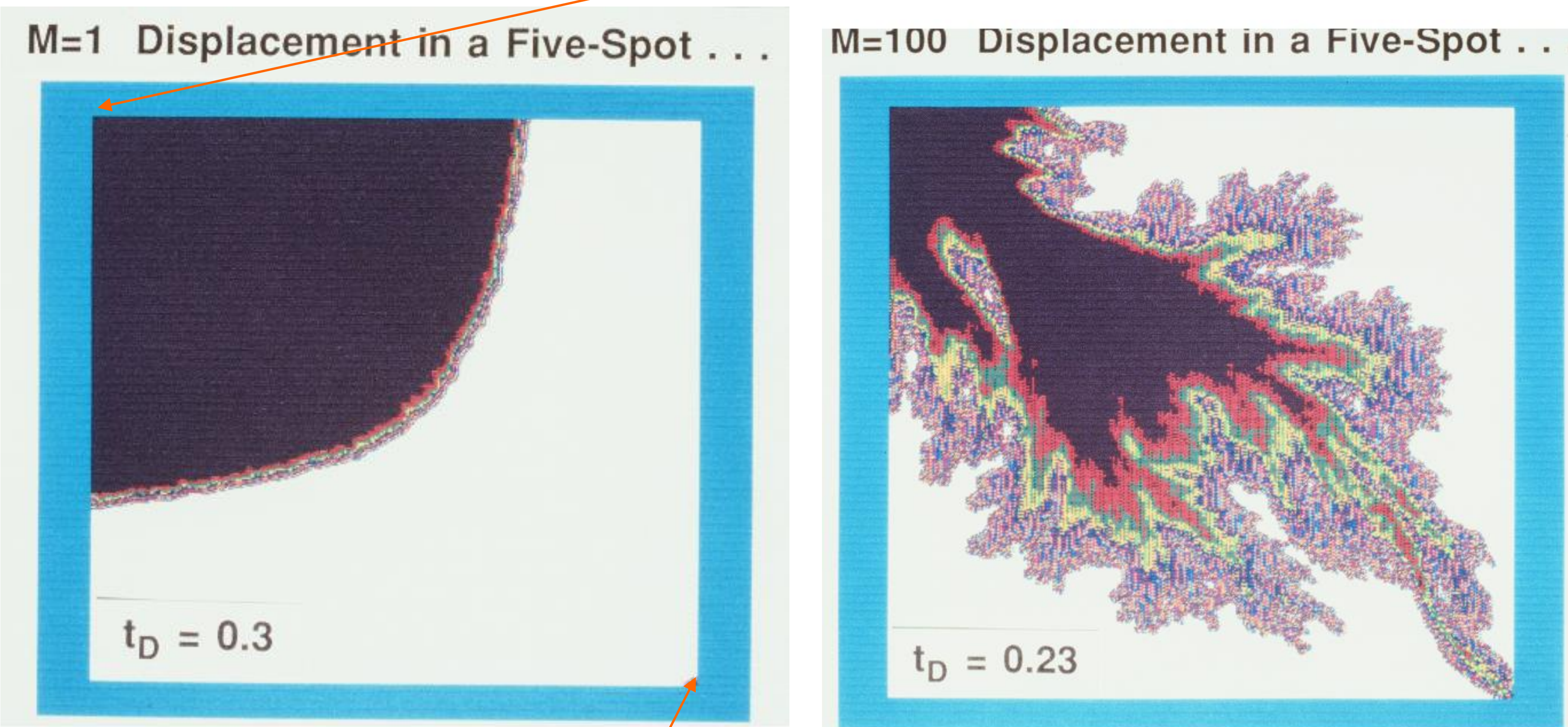




Simulated

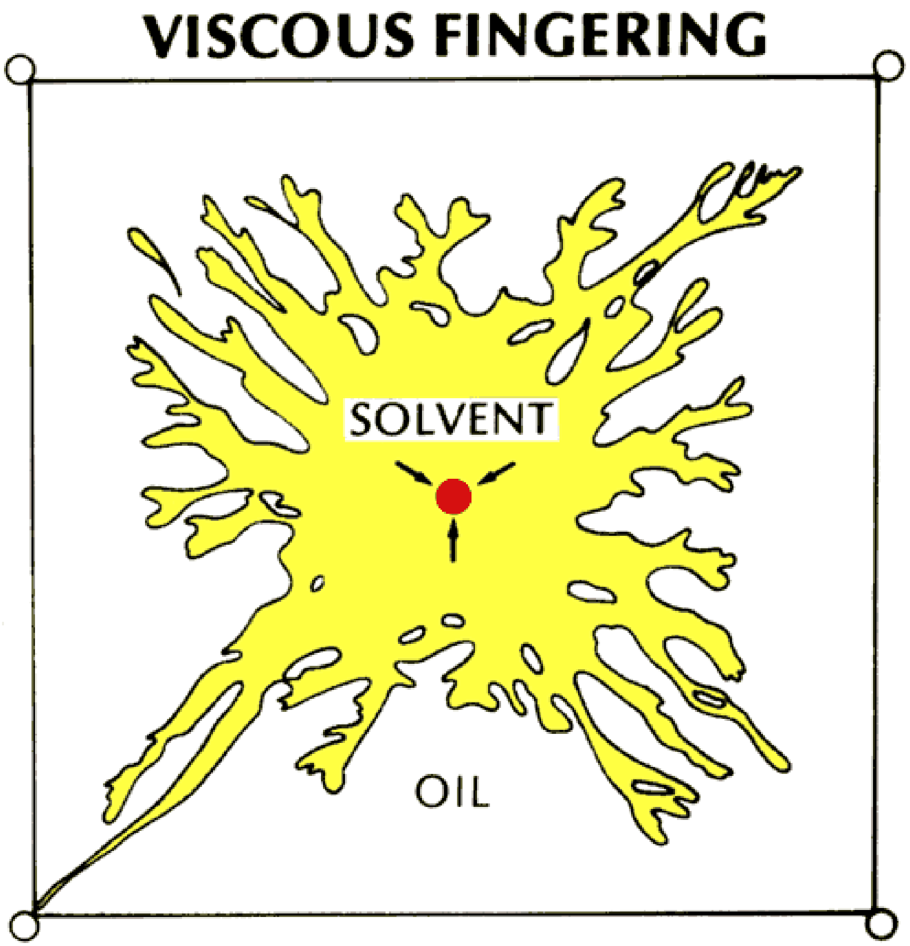
Incompressible fluids (Simulation results from previous work)

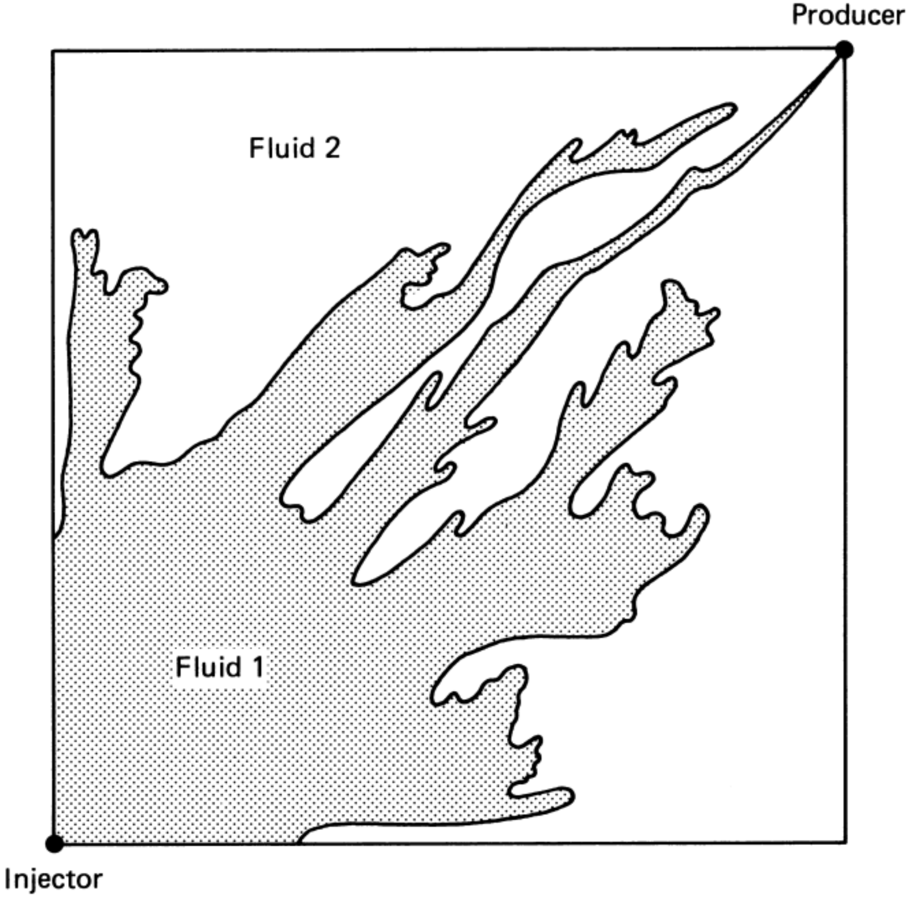
Injector



Producer

Experimental
Left Hele Shaw; Right M=17





which appear equally possible. Experiments in which various fluids were forced into a narrow Hele-Shaw cell showed that single fingers can be produced, and that unless the flow is very slow λ = (width of finger)/(width of channel) is close to $\frac{1}{2}$, so that behind the tips of the advancing fingers the widths of the two columns of fluid are equal. When $\lambda = \frac{1}{2}$ the calculated form of the fingers is very close to that which is registered photographically in the Hele-Shaw cell, but at very slow speeds where the measured value of λ increased from $\frac{1}{2}$ to the limit 1·0 as the speed decreased to zero, there were considerable differences. Assuming that these might be due to surface tension, experiments were made in which a fluid of small viscosity, air or water, displaced a much more viscous oil. It is to be expected in that case that λ would be a function of $\mu U/T$ only, where μ is the viscosity, U the speed of advance and T the interfacial tension. This was verified using air as the less viscous fluid penetrating two oils of viscosities 0·30 and 4·5 poises.

1. The stability of the interface between two fluids in a porous medium

---

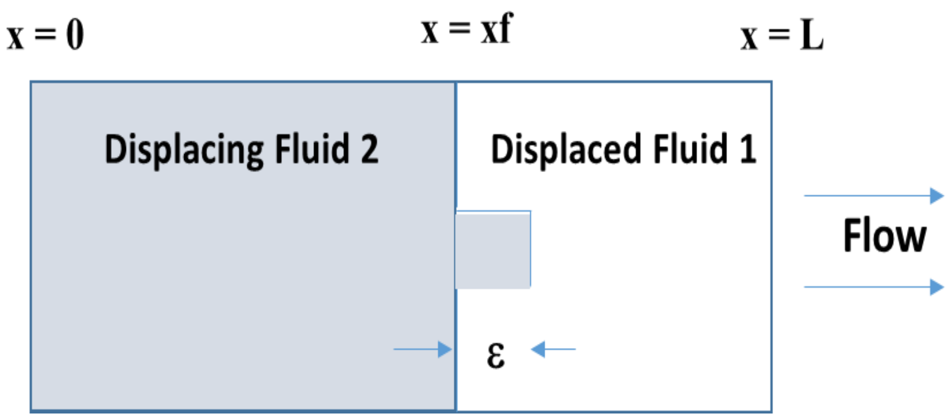
Channelling in packed columns

S. Hill, M.A., F. Inst. P., F.S.S.
Tate & Lyle Research Laboratory, Keston, Kent

(Received August 1952)

Chemical Engineering Science

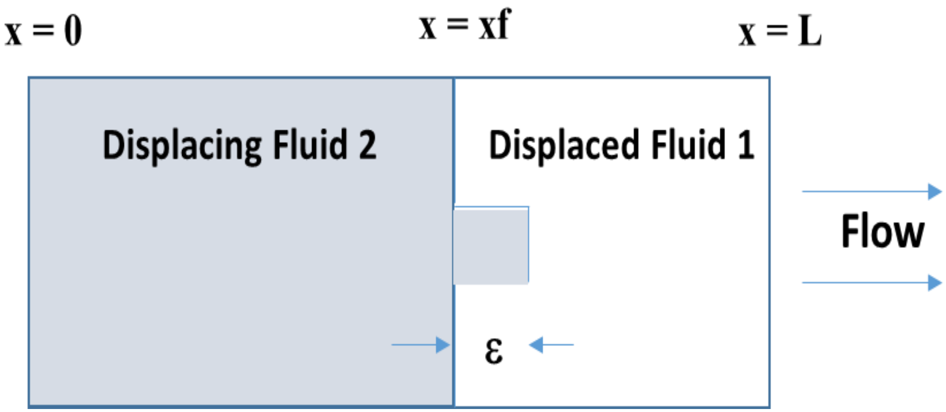
ST Instability



$$\dot{\varepsilon} \sim \begin{cases} < 0 & \text{dies out} \\ = 0 & \text{neutral} \\ > 0 & \text{grows} \end{cases}$$

$$M \sim \begin{cases} < 1 & \text{stable} \\ = 0 & \text{neutral} \\ > 1 & \text{unstable} \end{cases} \qquad u_{upstream} \sim \begin{cases} < u_{down} & \text{unstable} \\ = u_{down} & \text{neutral} \\ > u_{down} & \text{stable} \end{cases}$$

ST Instability



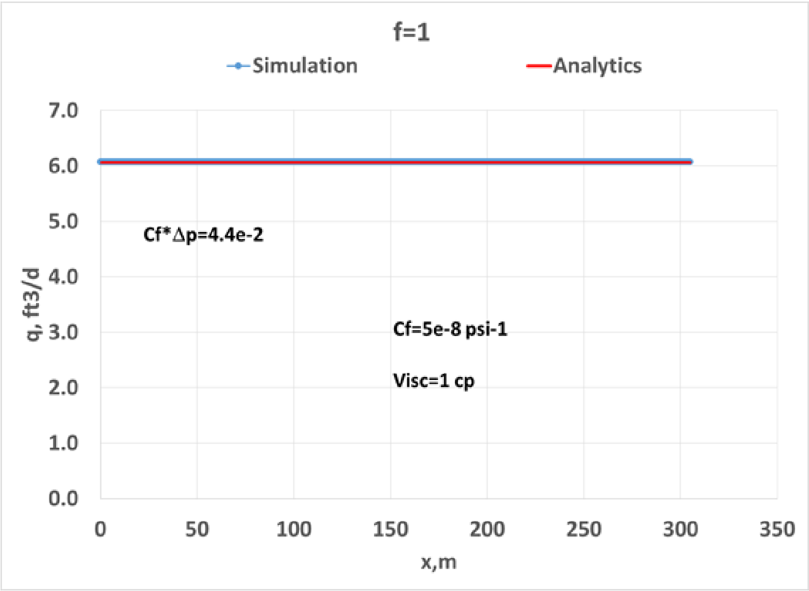
$$u_{upstream} \sim \begin{cases} < u_{down} & \text{unstable} \\ = u_{down} & \text{neutral} \\ > u_{down} & \text{stable} \end{cases}$$

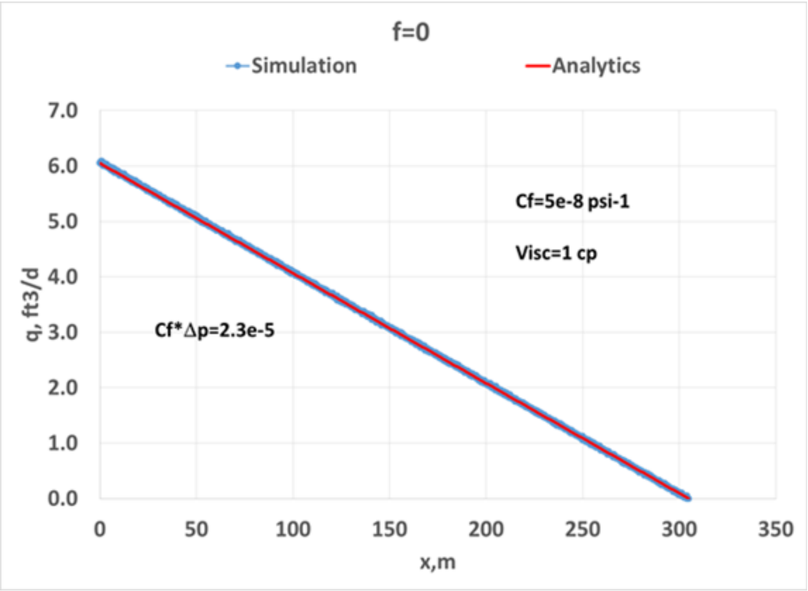
$$f = \frac{(\rho u)_{outlet}}{(\rho u)_{intlet}} = \begin{cases} 0 & \text{sealed (SSS)} \\ 0 < f < 1 & \text{partially sealed} \\ 1 & \text{transparent (SS)} \end{cases}$$

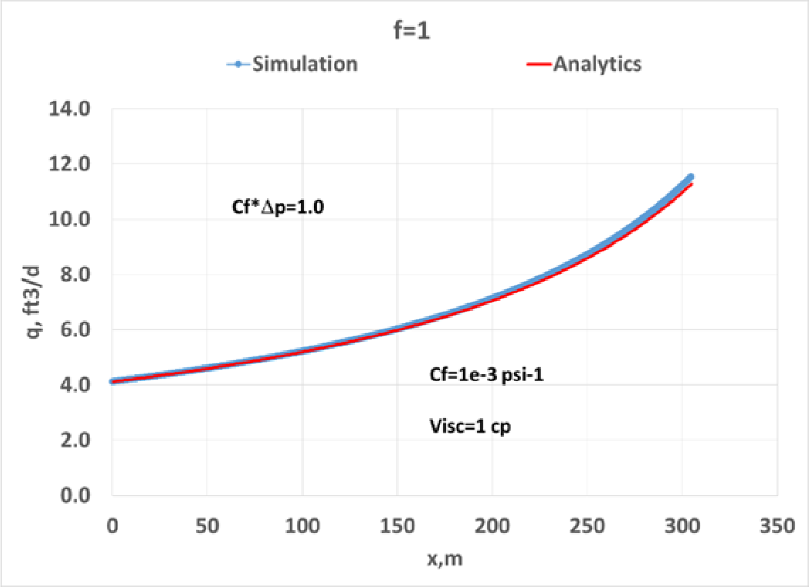
Velocity Profiles

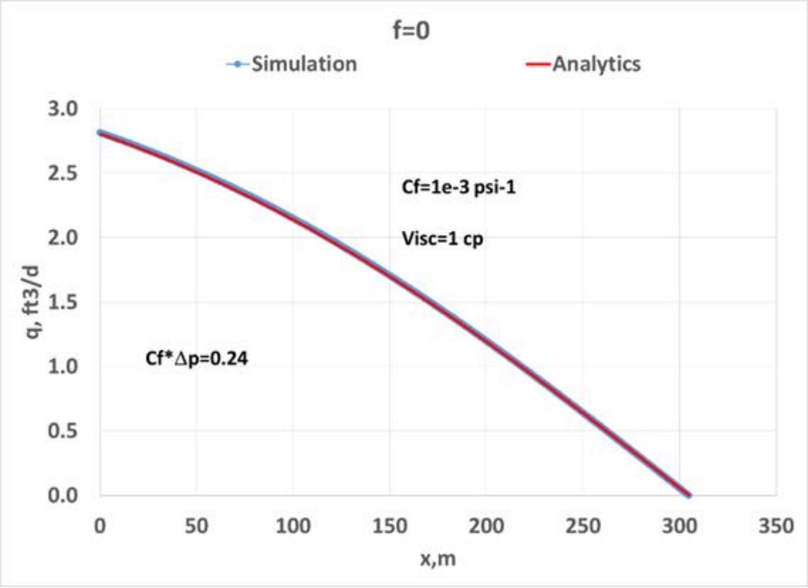
Transparent Boundary

Sealed Boundary

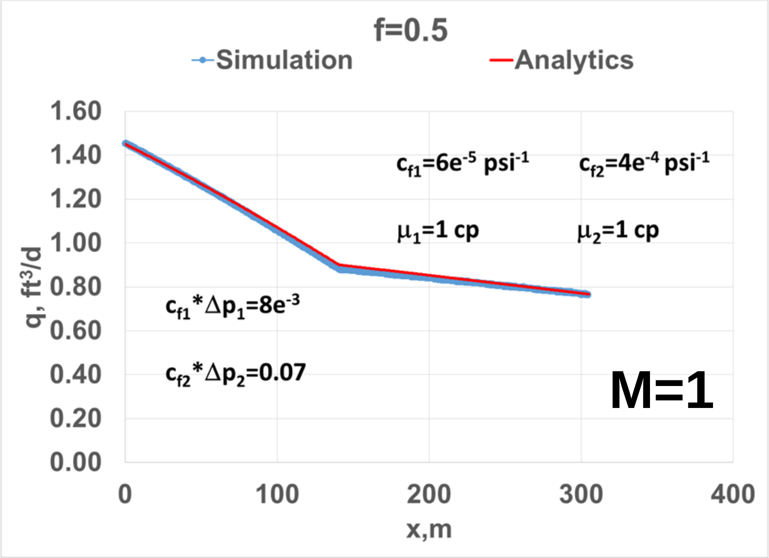


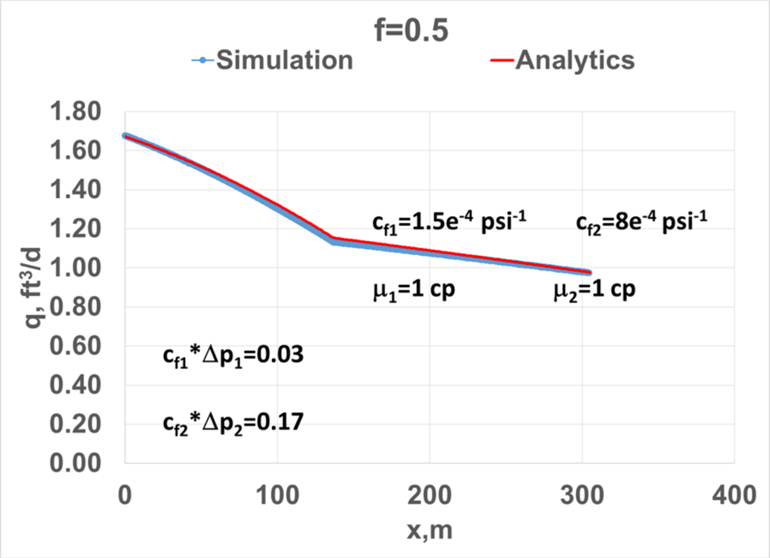


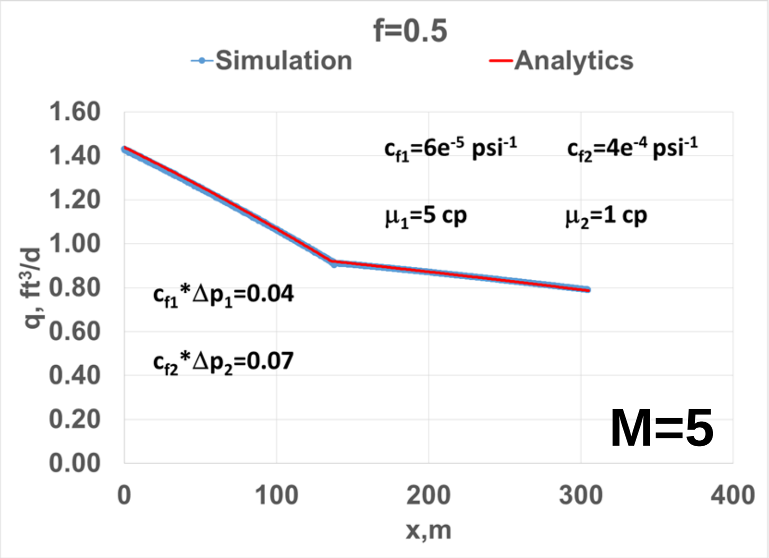


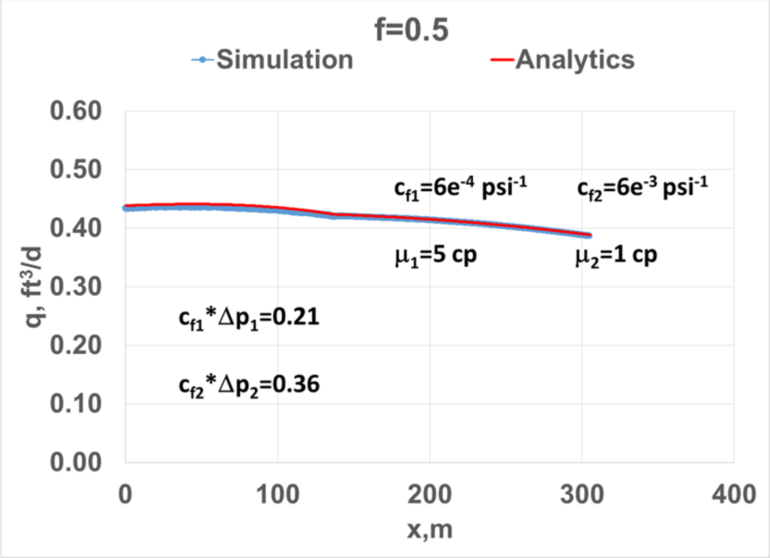


Velocity Profiles, partially sealed









CENTER FOR PETROLEUM & CPGE GEOSYSTEMS ENGINEERING

TEXAS The University of Texas at Austin

Conclusions

- **Derived an analytic solution for ST instability in compressibility flow**
- **Behavior of fluid velocity is equivalent to perturbation analysis**
- **Increasing velocity toward external boundary leads to ST instability**
- **Compressibility always destabilizes**
- **Partially sealed external boundary stabilizes flow**
- **Sweep efficiency in CO_2 storage (no producers) should be greater than for CO_2 -EOR**
- **Commercial simulators do not work well in the high compressibility limit**

The Effect of Compressibility and Boundaries on Displacement Stability

Aura N. Araque and Larry W. Lake
Hildebrand Department of Petroleum and Geosystems Engineering