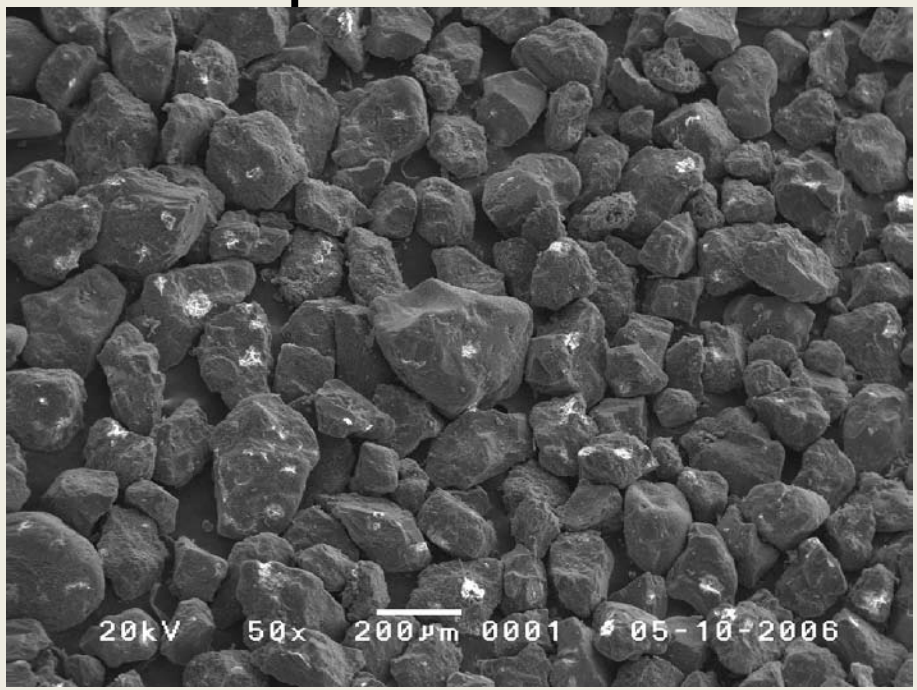
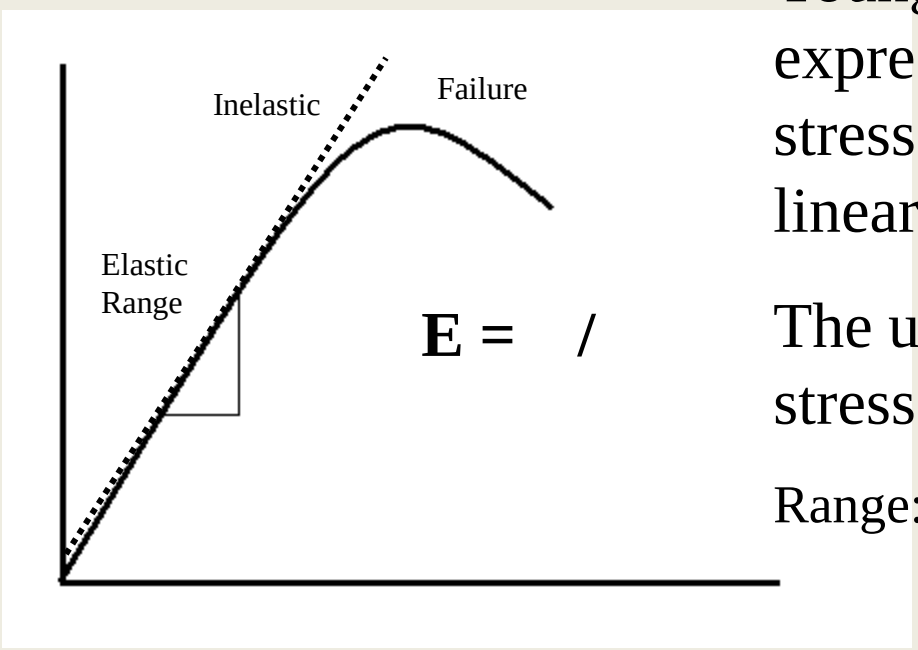
Sand Control – Rock Failure

- Why? – A bit of Mechanics on rock failure
- How? – Some choices that depend on the rock
- What is moving?
  - Sand grains?
  - Fines?



Young's Modulus, E

- Young's Modulus is a material's stiffness or resistance to being compressed or extended. When the stress overcomes the sand strength, it will fail.



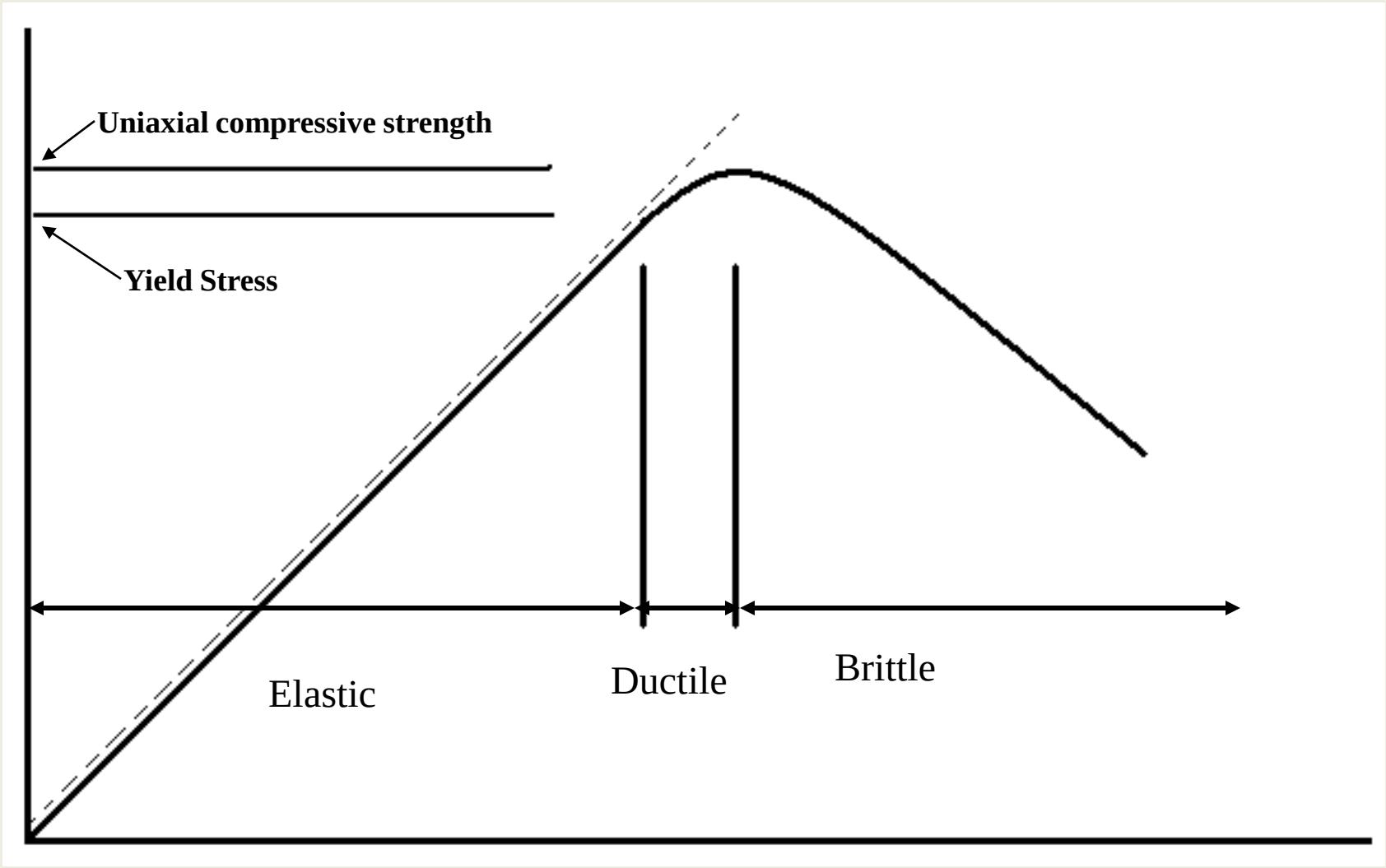
Young's Modulus, E, is expressed as the slope of the stress-strain curve in the linearly elastic region.

The units are the same as the stress unit – psi, or mpa.

Range: 0.1 to 3 x10^6 for rocks

Now, what does that mean?

Rock Stressed to Failure – Stages of Behavior



Some examples of rock properties:

Note that Young's modulus, Poisson's ratio and rock compressibility are not necessarily related.

There are also other factors that influence a rock's strength: phase changes, overburden changes, acids, gasses, etc.

Lithology	Minimum Horizontal Stress	Young's Modulus	Poisson's Ratio	Compressibility
Shale	2949	134045	0.394	4.95E-06
Shale	3035	138086	0.409	5.16E-06
Shale	2869	88222.6	0.366	6.80E-06
Sand	2909	158262	0.371	7.55E-06
Sand	2865	92243.8	0.363	7.38E-06
Sand	2870	186185	0.36	7.99E-06
Sand	2815	115461	0.349	8.29E-06
Sand	2863	87948.8	0.366	7.29E-06
Sand	2949	152106	0.379	7.40E-06
Sand	2829	97216.3	0.358	7.03E-06
Sand	2925	160602	0.383	6.38E-06
Shale	2969	89810.1	0.387	6.59E-06
Sand	2919	283327	0.367	8.90E-06
Sand	2942	116803	0.375	7.65E-06
Sand	2964	82282.8	0.381	7.23E-06
Sand	2947	175266	0.373	7.94E-06
Sand	2967	335912	0.375	8.81E-06
Sand	2979	115191	0.38	7.49E-06
Shale	3352	85311.5	0.45	4.36E-06

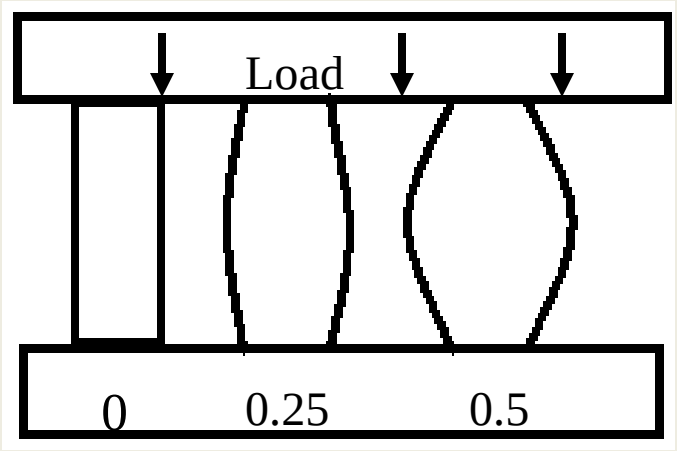
Poisson's Ratio – Just throwing in a definition or two……

- Ratio of the strain in the lateral direction to the strain in the axial direction. Will the rock creep or brittle fracture? Why?

$$= - \frac{\text{lateral}}{\text{axial}}$$

Unit: non dimensional

Range: 0 to 0.5



For materials with the same Young's Modulus, E.

How will the rock change during production?
How do shock loads from start-up affect the rock?

Another definition - Biot's Constant. Less Useful.

- Effectiveness of pore pressure in offsetting the applied stress.

$$= 1 - (C_m / C_{dry})$$

Where:

C_m = matrix compressibility

C_{dry} = dry rock compressibility

Sources of Downhole Stress

Relatively Constant

- Overburden (weight of the sediments above the pay) – dos change with depletion.
- Horizontal Stress – Poisson's ratio effects (in an ideal world)
- Salt movement
- Rock movement
- Tectonic movement
- Deviation effects
- Azimuth effects
- Radial stresses
- Axial stresses (in pipe)

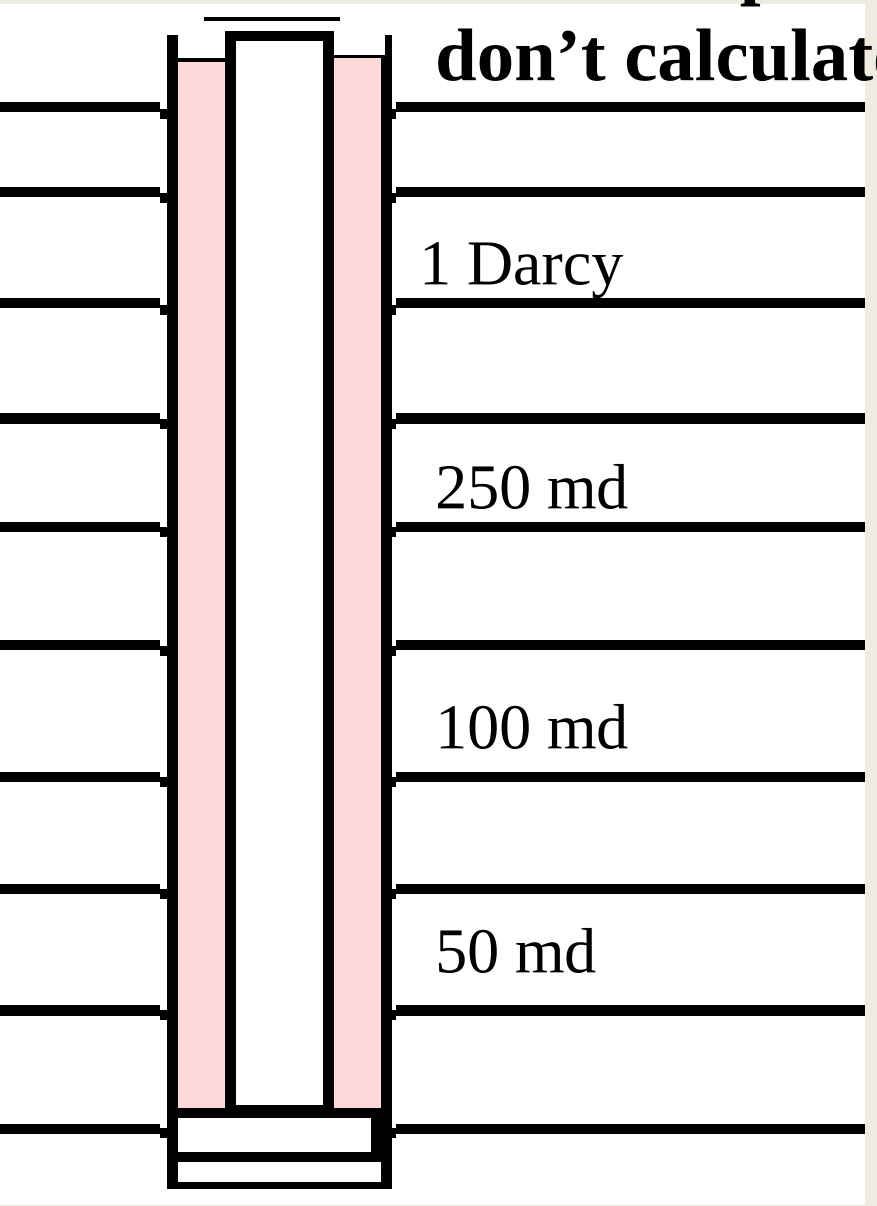
Changes

- Pore pressure
- Frac pressure
- Lubricated fluids
- Acids, soaps, solvents
- Shock loads
- Reversing loads (U-tube forces)
- Explosive loading from perforating
- High drawdown levels

Pore Pressure

- Load supporting element
  - Highest at initial production – directly offsets overburden and confining stresses.
  - Lowest at depletion – formation must withstand more overburden.
- Effective stress is that part of the overburden stress that must be supported by the rock matrix.

Flux as a production limit? Yes, but measure, don't calculate it.



Real world example:

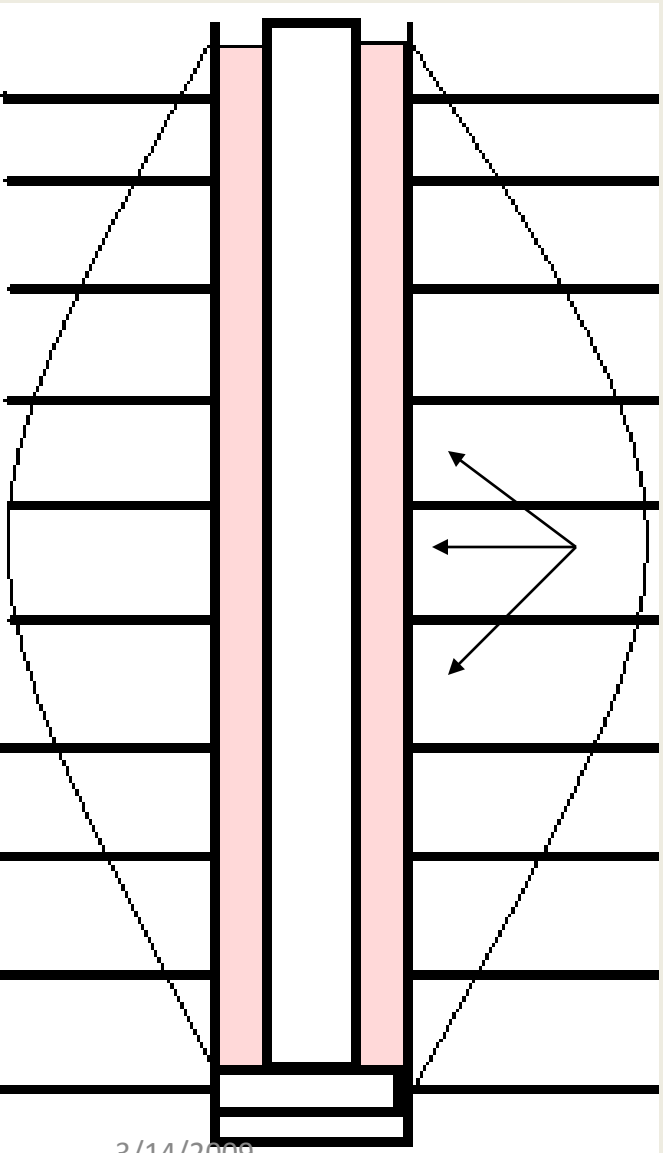
20,000 bpd, 100 ft screen,

calculated flux = 200 bpd/ft

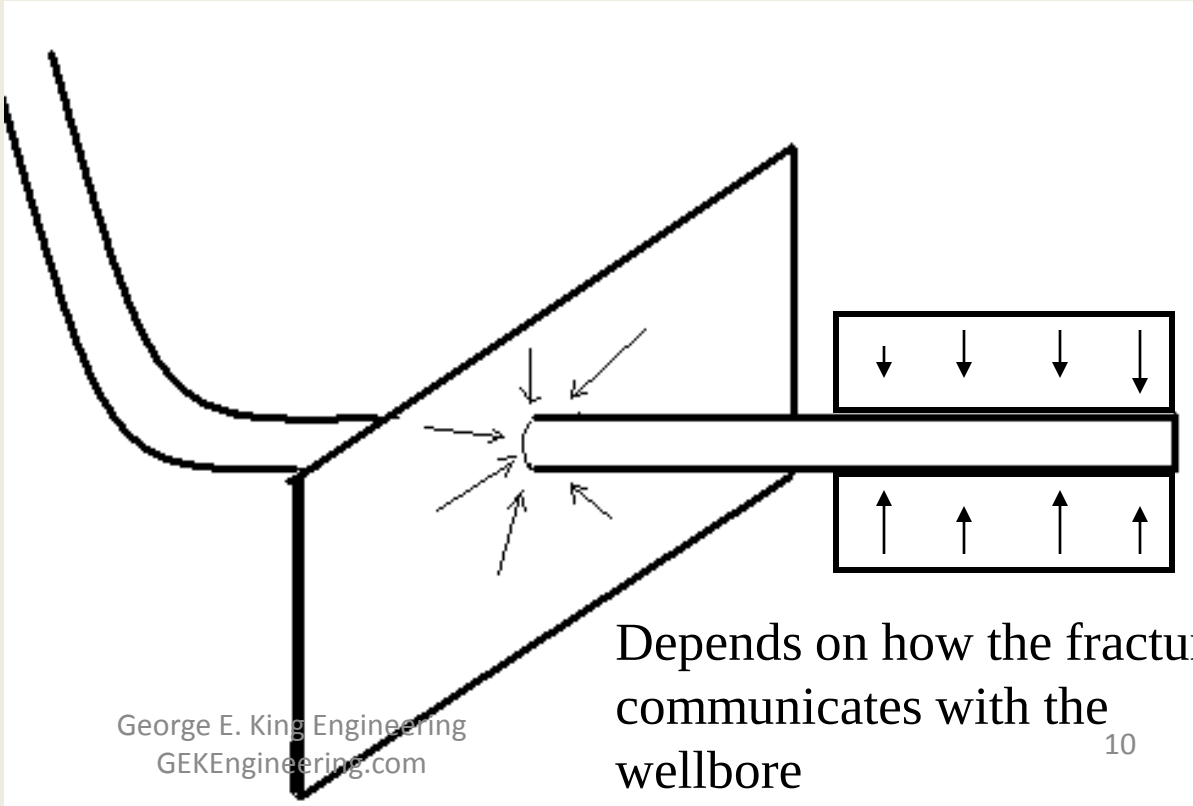
PLT measured flux = 700 bpd/ft in one zone – the high perm streak.

Localized hotspots from layered flow can destroy screens if the flow contains fines. Damage from clean liquid flow? – much less likely!

Fracturing may help link layers and avoid “hot spots” near the wellbore.



Does it work the same in horizontal wells?



Depends on how the fracture communicates with the wellbore

What affects strength/movement the most?

- Phase change, particularly water moving into the pore spaces.
  - Creates drop in relative perm to oil and gas.
  - May weaken the grain-to-grain cementation in clay cemented rocks.
  - Can liberate particles, silts and fines.
- Stress increases near depletion.
- High drag forces at start of production.

What is weak, what is strong?

- Again, conditions dictate the outcome
- Some ideas:
  - Rocks below about 1000 psi to 2500 psi may need active sand control. Can it support a cavity?
  - Rocks with strength up to 5000 psi or more may need carefully treatment to prevent sanding or breakdown of rock structure.

- Sonic travel time – some generalizations from experience:
  - <50 sec is strong formation
  - >50 sec to 90 sec is a transition area – moderately consolidated? – but subject to change?
  - >90 sec to <120 sec is a weak formation
  - >120 sec is near unconsolidated formation
- Porosity
  - <20% usually stronger formation
  - 20 to 30% - gray area
  - >30% - unconsolidated

What does it all mean to rock strength?

- Rock strength may or may not be constant over its life – depends on conditions.
- Care is needed in weaker rocks when:
  - Water comes in (coning, edge entry, leaks, floods…)
  - Starting-up (and shutting-down)
  - When acidizing or treating with solvents
  - Attaining very high drawdowns
  - At very high underbalance w/ perforating
  - Near the end of the well's life (increasing depletion causes increased overburden).