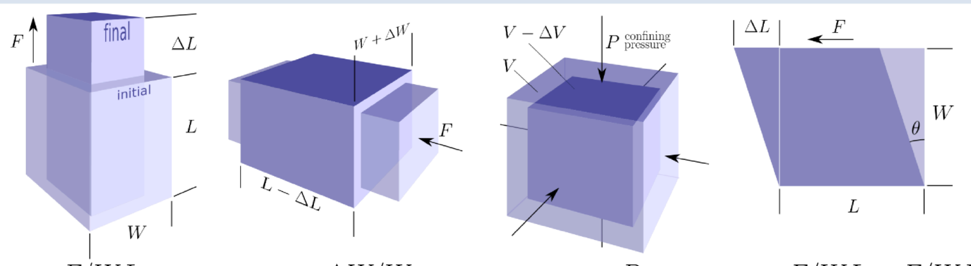
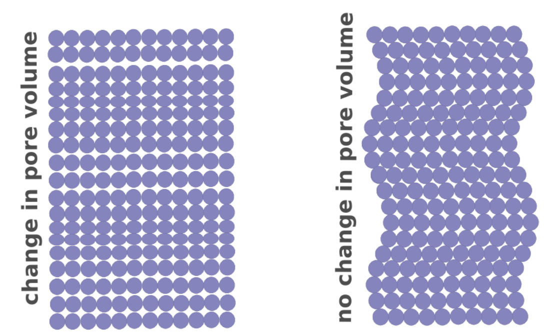
Elastic parameters	E Young's modulus [kg·m⁻¹s⁻²]	ν Poisson's ratio [dimensionless] aka σ	K bulk modulus [kg·m⁻¹s⁻²] aka volumetric modulus	μ shear modulus [kg·m⁻¹s⁻²] aka rigidity, G	λ 1st Lamé parameter [kg·m⁻¹s⁻²] aka incompressibility	V_P P-wave velocity [m/s] aka compressional vel	V_S S-wave velocity [m/s] aka shear velocity	Γ V_P:V_S ratio [dimensionless]
Engineers... (E,ν)			$\frac{E}{3(1-2\nu)}$	$\frac{E}{2(1+\nu)}$	$\frac{E\nu}{(1+\nu)(1-2\nu)}$	$\sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}}$	$\sqrt{\frac{E}{2\rho(1+\nu)}}$	$\sqrt{\frac{1-\nu}{\frac{1}{2}-\nu}}$
Fluid substitution... (K,μ)	$\frac{9K\mu}{3K+\mu}$	$\frac{3K-2\mu}{2(3K+\mu)}$			$K-\frac{2}{3}\mu$	$\sqrt{\frac{K+\frac{4}{3}\mu}{\rho}}$	$\sqrt{\frac{\mu}{\rho}}$	$\sqrt{\frac{K+\frac{4}{3}\mu}{\mu}}$
Rock physicists... (μ,λ)	$\frac{\mu(3\lambda+2\mu)}{\lambda+\mu}$	$\frac{\lambda}{2(\lambda+\mu)}$	$\lambda+\frac{2}{3}\mu$			$\sqrt{\frac{\lambda+2\mu}{\rho}}$	$\sqrt{\frac{\mu}{\rho}}$	$\sqrt{\frac{\lambda+2\mu}{\mu}}$
Geophysicists... (V_P,V_S)	$\rho V_S^2\frac{(3V_P^2-4V_S^2)}{V_P^2-V_S^2}$	$\frac{V_P^2-2V_S^2}{2(V_P^2-V_S^2)}$	$\rho\left(V_P^2-\frac{4}{3}V_S^2\right)$	ρV_S^2	$\rho\left(V_P^2-2V_S^2\right)$			$\frac{V_P}{V_S}$



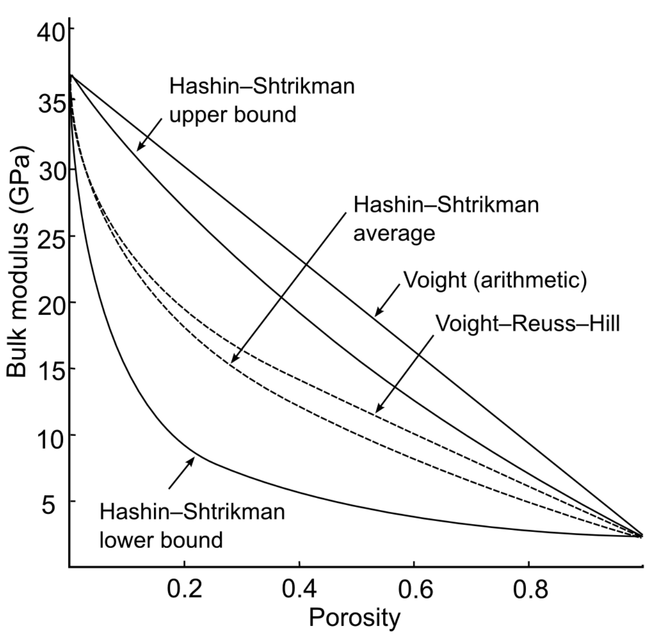
$E = \frac{F/WL}{\Delta L/L}$ = longitudinal stress / longitudinal strain; $\nu = \frac{\Delta W/W}{\Delta L/L}$ = transverse strain / longitudinal strain; $K = \frac{P}{\Delta V/V}$ = volume stress / volume strain; $\mu = \frac{F/WL}{\tan\theta} = \frac{F/WL}{\Delta L/L}$ = shear stress / shear strain

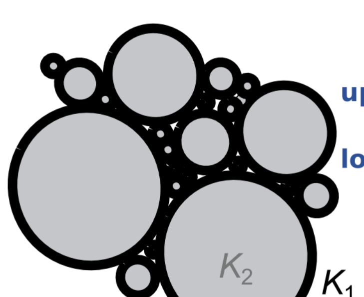


	Density [kg/m³]	[GPa]	[dimensionless]	[GPa]	[GPa]	[GPa]	[m/s]	[m/s]	[dimensionless]
Quartz	2650	95	0.07	37	44	8	6008	4075	1.47
Feldspar (mean)	2620	40	0.32	37.5	15	28	4685	2393	1.96
Plagioclase	2630	70	0.35	76	26	59	6487	3144	2.06
Calcite	2710	84	0.32	77	32	56	6645	3436	1.93
Dolomite	2870	117	0.30	95	45	65	7349	3960	1.86
Anhydrite	2980	72	0.23	45	29	26	5299	3120	1.70
Siderite	3960	135	0.32	124	51	90	6963	3589	1.94
Pyrite	4930	305	0.15	147	132	59	8094	5174	1.56
Sandstone, 10 p.u.	2500	32-105	~0.05-0.10	15-18	7-24	1-3	2500-4500	1725-3103	~1.45-1.5
Limestone, 10 p.u.	2540	97-280	~0.33	37-71	9-26	18-53	3800-6500	1900-3250	~2.0
Shale, 5 p.u.	2500	20-160	~0.27	16-36	2-19	3-24	1800-5000	1000-2777	~1.8
Water (brine)	1030	0	0.5	2.3	0	2.3	1507	0	undefined
Oil (40 API)	830	0	0.5	1.6	0	1.6	1226	0	undefined

Hashin–Shtrikman

Upper and lower bounds





upper bound when $K_1 > K_2$
lower bound when $K_1 < K_2$

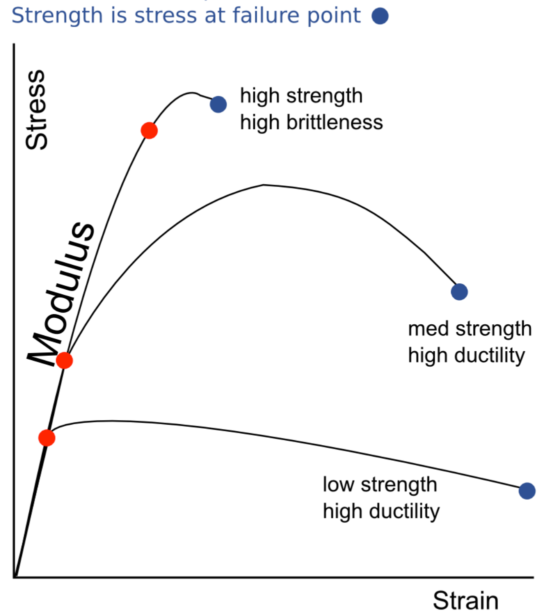
$$K^{HS\pm} = K_1 + \frac{f_2}{(K_2-K_1)^{-1} + f_1(K_1+\frac{4}{3}\mu_1)^{-1}}$$

$$\mu^{HS\pm} = \mu_1 + \frac{f_2}{(\mu_2-\mu_1)^{-1} + \frac{2f_1(K_1+2\mu_1)}{5\mu_1(K_1+\frac{4}{3}\mu_1)}}$$

Get upper bound and lower bounds by switching indices
upper: $K_1 = K_1$, $K_2 = K_2$ lower: $K_1 = K_2$, $K_2 = K_1$
f_1 and f_2 is volume fraction of constituent 1 and 2.

Strength and brittleness

Modulus is the slope below the elastic limit
Strength is stress at failure point



Bulk density $\rho = (1-\phi)\rho_S + \phi\rho_F$

ρ_S density of the solid, ρ_F density of the fluid, ϕ is porosity

Fluid modulus $\frac{1}{K_f(P,T)} = \sum_i \frac{S_i}{K_i(P,T)}$

for a mixture of fluids with fractions S_i, fluid bulk moduli depend on temperature T & pressure P

Gassmann's equation

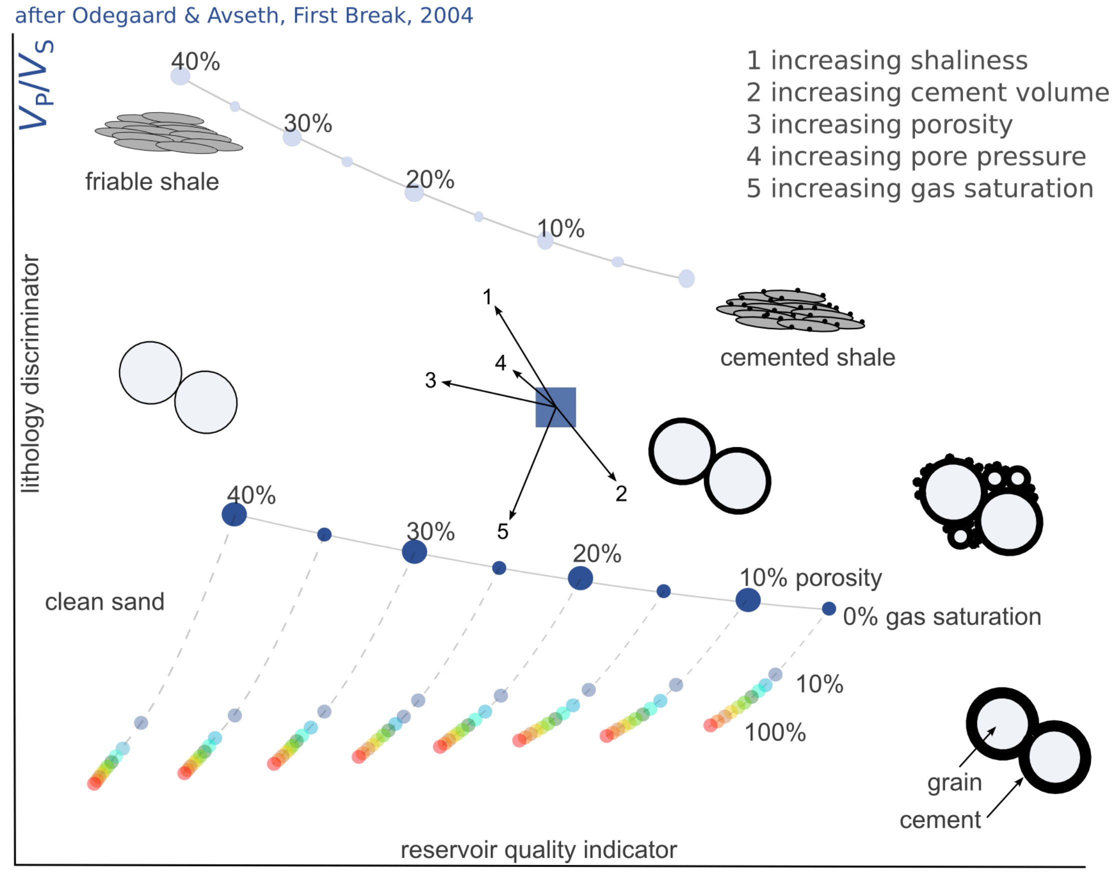
Fluid substitution

$$K_{eff} = K_{dry} + \frac{\left(1-\frac{K_{dry}}{K_{min}}\right)^2}{\frac{1-\frac{K_{dry}}{K_{min}}-\phi}{K_{min}} + \frac{\phi}{K_f}}$$

$$K_{dry} = \frac{1+\left(K_{eff}\left(\frac{\phi-1}{K_{min}}\right)-\frac{\phi}{K_f}\right)}{\frac{1-\frac{K_{eff}}{K_{min}}+\phi}{K_{min}} - \frac{\phi}{K_f}}$$

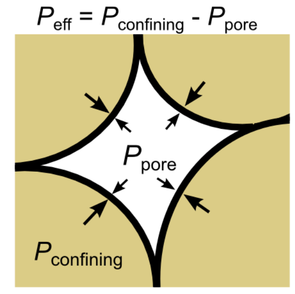
V_P/V_S P-impedance template

Conceptual trends for siliciclastic lithologies at constant confining pressures
after Odegaard & Avseth, First Break, 2004

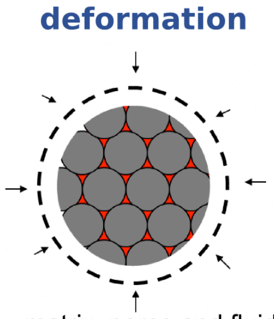


P-impedance: ρV_P

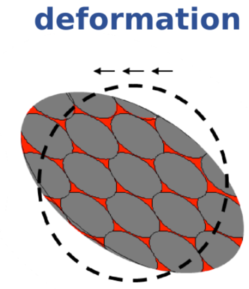
Effective pressure



Volumetric deformation



Shear deformation



ROCK PHYSICS cheatsheet v 3.0