

Elastic Rock Properties

1. Derive the expression for the bulk modulus $K = \frac{3\lambda+2\mu}{3}$, using Hooke's law $\sigma_{ij} = \lambda\delta_{ij} \sum_k \epsilon_{kk} + 2\mu\epsilon_{ij}$ for an isotropic elastic medium.
2. The online database of physical rock properties of the Canadian Government showed until recently the following entries:

Rock	v (20MPa) [km/s]	v (100MPa) [km/s]	v (200MPa) [km/s]	v (400MPa) [km/s]	v (600MPa) [km/s]	ρ (0.1MPa) [g/cm ³]	Composition
marble1 (v_P)	6.37	6.88	6.93	7.01	7.05	2.75	95.9% Ca, 3.6% Opx, 0.5% Mus
marble2 (v_P)	5.89	6.39	6.46	6.53	6.56	2.73	95.9% Ca, 3.6% Opx, 0.5% Mus
amphibolite1 (v_P)	6.43	6.63	6.68	6.72	6.76	3.22	71%Hb,15.5%Plag,12.5%Ep,1%Cpx
amphibolite1 (v_S)	3.78	3.94	3.98	4.02	4.03	3.22	71%Hb,15.5%Plag,12.5%Ep,1%Cpx
amphibolite2 (v_P)	7.21	7.44	7.48	7.53	7.56	3.20	71%Hb,15.5%Plag,12.5%Ep,1%Cpx
amphibolite2 (v_S)	4.13	4.20	4.25	4.30	4.32	3.20	71%Hb,15.5%Plag,12.5%Ep,1%Cpx

The shown seismic velocities v_P and v_S of some rocks were measured at different ambient pressure conditions of 20 MPa, 100 MPa, 200 MPa, 400 MPa, and 600 MPa.

Compare the above velocities with the velocities obtainable from the Voigt-Reuss-Hill averages of the elastic moduli of the related mineral constituents (determined at 0.1 MPa):

mineral	K [MPa]	μ [MPa]
calcite (ca)	73.31	31.97
clinopyroxene (cpx)	112.93	67.09
epidote (ep)	106.15	61.20
amphibole (hb)	87.14	43.15
muskovit (mus)	58.18	35.36
orthopyroxene (opx)	103.46	74.72
plagioclase (plag)	70.68	33.56