Reflection seismic 1

script

Educational Material

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Publication date:
2001

Permanent link:
https://doi.org/10.3929/ethz-a-004363847

Seismic Velocities

Important for :

Conversion from traveltime to depth

Check of results by modelling

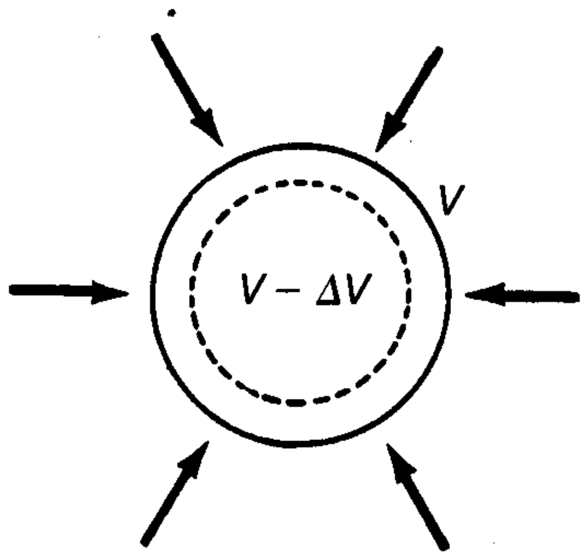
Imaging of the data (migration)

Classification and Filtering of Signal and Noise

Predictions of the Lithology

Aid for geological Interpretation

Bulk modulus



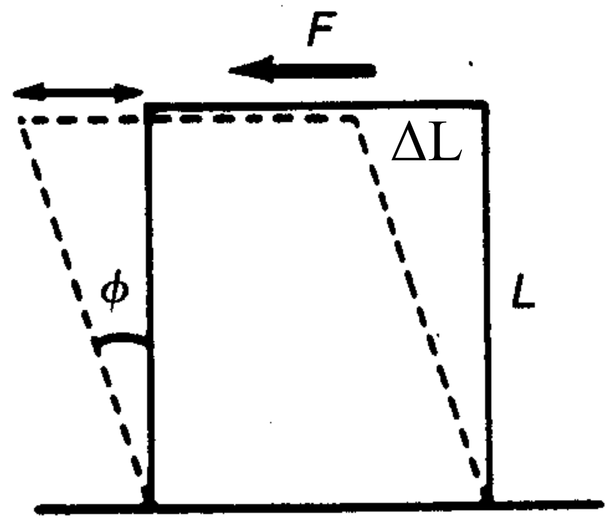
(d) Bulk contraction

$$K = \frac{\text{volume stress}}{\text{volume strain}} = \frac{P\text{(pressure)}}{\Delta V/V}$$

Bulk modulus: $$k = \frac{1}{\kappa} = \frac{\Delta P}{\Delta V / V}$$

κ = compressibility

Shear modulus



(c) Shear

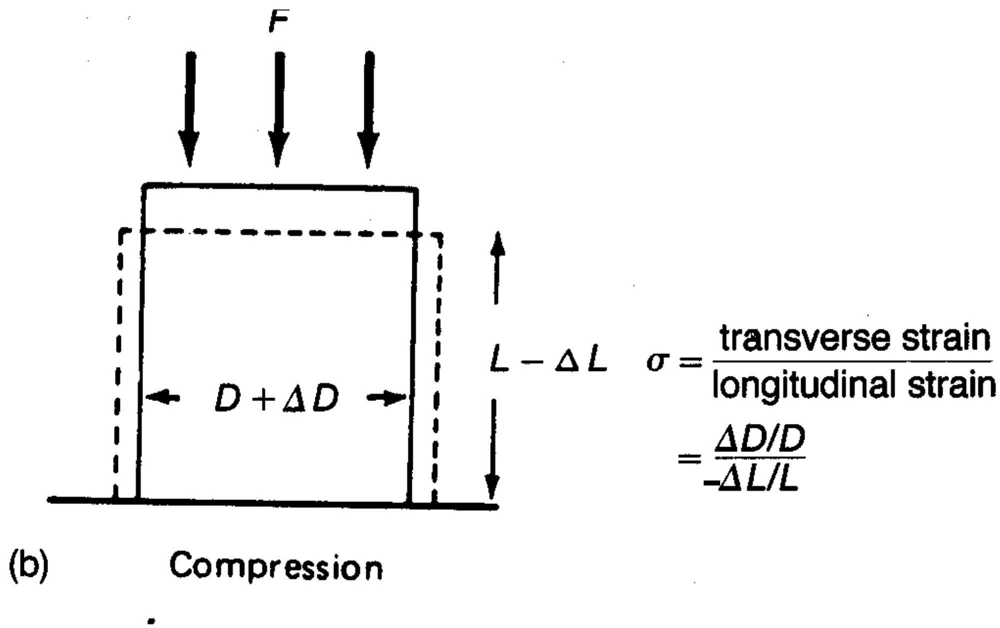
$$\mu = \frac{\text{shear stress}}{\text{shear strain}} = \frac{F/A}{\tan\phi} = \frac{F/A}{\Delta L/L}$$

Shear modulus: $$\mu = \frac{\tau}{\tan\theta}$$

τ is the shear stress

The shear modulus μ is zero for fluids and gaseous media

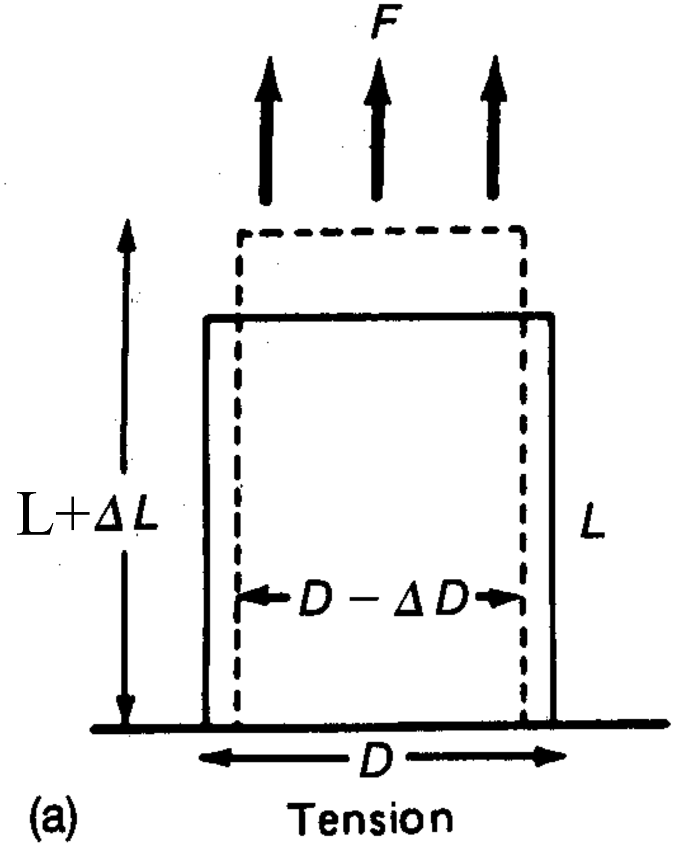
Poissons ratio



Poisson's ratio varies from 0 to ½.
Poisson's ratio has the value ½ for fluids

$$\sigma = \frac{3k - 2\mu}{2(3k + \mu)}$$

Young's modulus



$$E = \frac{\text{longitudinal stress}}{\text{longitudinal strain}} = \frac{F/A}{\Delta L/L}$$

$$E = \frac{9k\mu}{3k + \mu}$$

Seismic Velocities in a homogeneous medium

$$v_p = \sqrt{\frac{k + \frac{4\mu}{3}}{\rho}} = \sqrt{\frac{\lambda + 2\mu}{\rho}}$$

$$v_s = \sqrt{\frac{\mu}{\rho}}$$

μ = Shear modulus
k = Bulk modulus
ρ = mass density
λ = Lame's lambda constant

$$\lambda = k - \frac{2}{3}\mu$$

Ratio V_p and V_s

$$\frac{V_s}{V_p} = \sqrt{\frac{0.5 - \sigma}{1 - \sigma}}$$

$$\sigma = \frac{3k - 2\mu}{2(3k + \mu)}$$

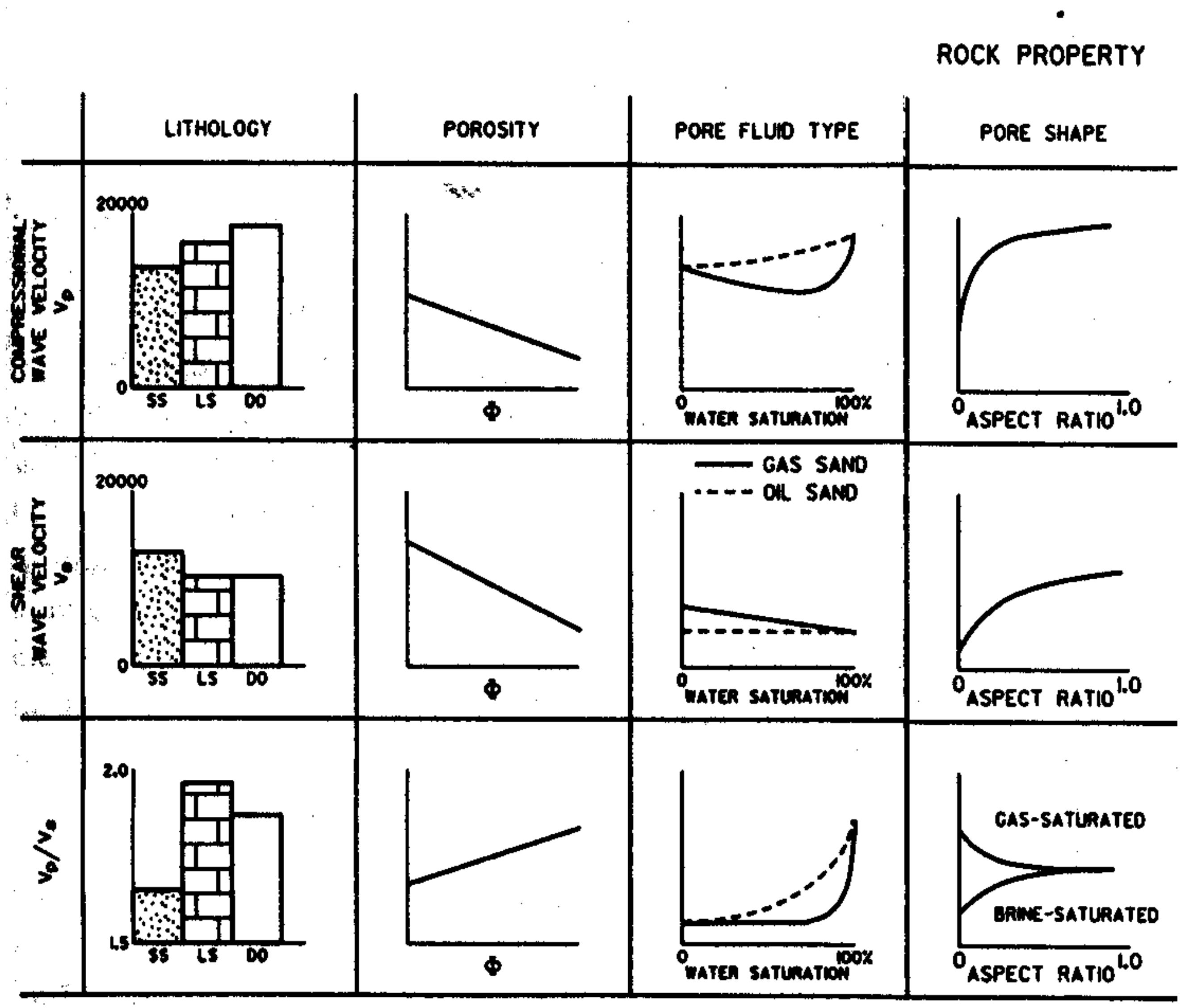
Seismic Velocity

ρ, μ and k depend on:

Matrix und Structure of the stone
Lithology
Porosity
Porefilling (Interstitial fluid)
Pressure (Depth)
Temperature
Degree of Compaction

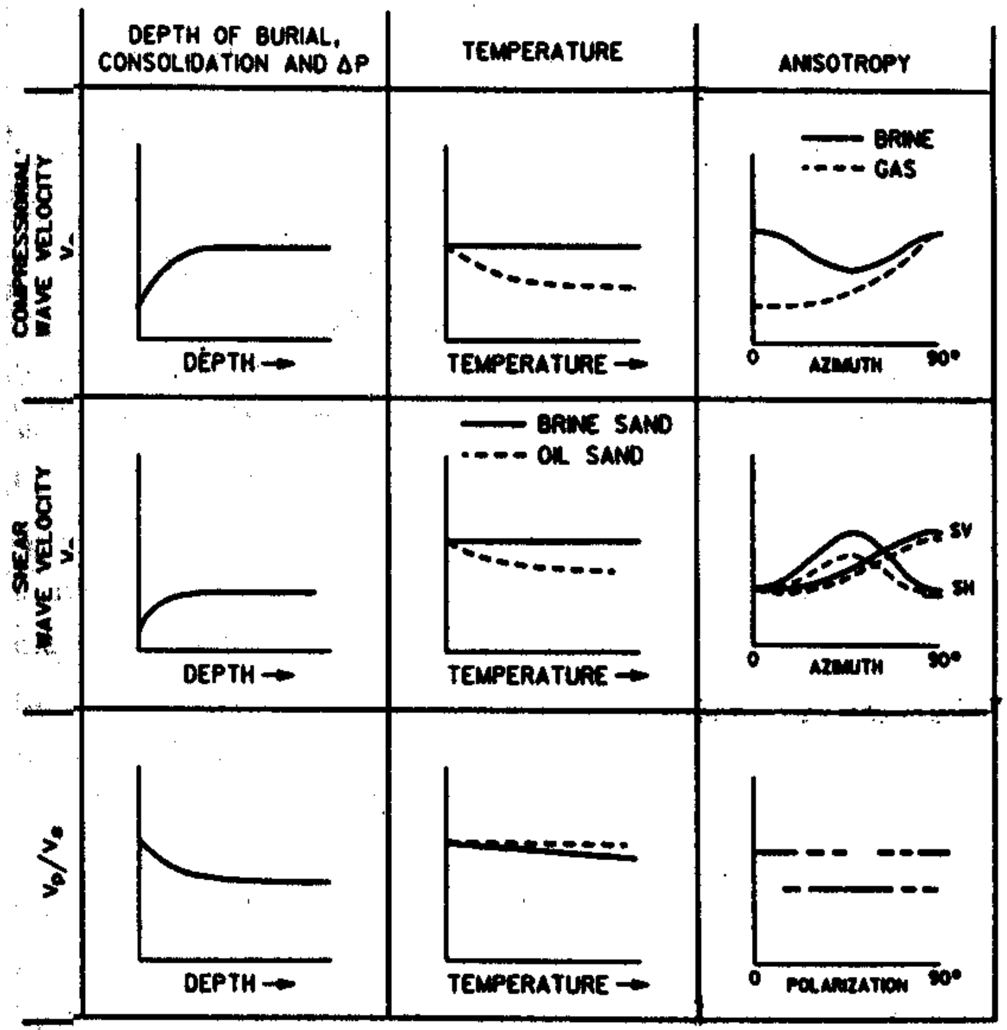
. . .

Seismic Velocity depending on rock properties



(Sheriff und Geldard, 1995)

ROCK PROPERTY



P-wave velocities v_p for different material in (km/s)

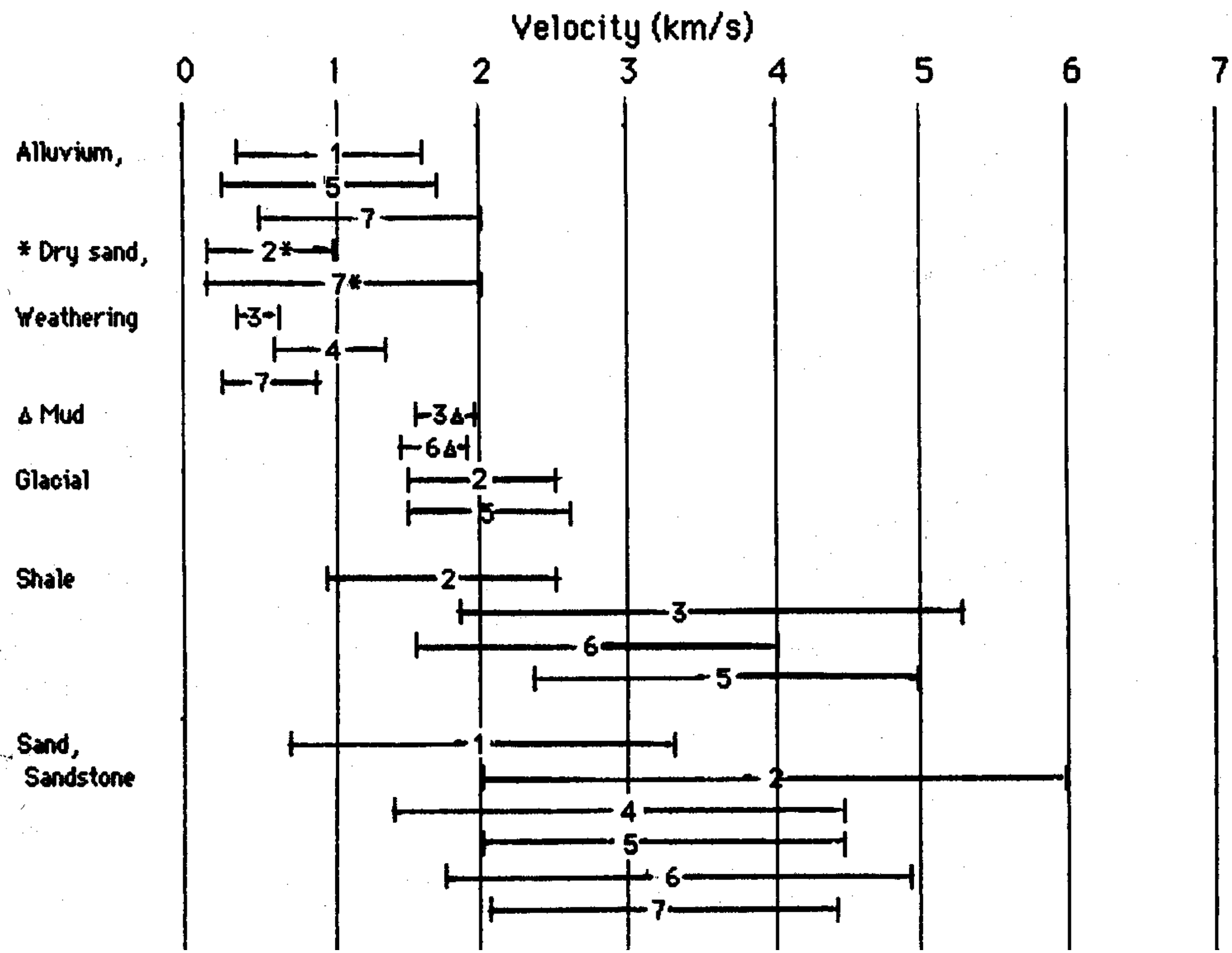
Unconsolidated Material	
Sand (dry)	0.2 - 1.0
Sand (water saturated)	1.5 - 2.0
Clay	1.0 - 2.5
Glacial till (water saturated)	1.5 - 2.5
Permafrost	3.5 - 4.0
Sedimentary rocks	
Sandstone	2.0 - 6.0
Tertiary sandstone	2.0 - 2.5
Pennant sadstone (Carboiferous)	4.0 - 4.5
Cambrian quartzite	5.5 - 6.0
Limestones	2.0 - 6.0
Cretaceous chalk	2.0 - 2.5
Jurassic oolites and bioclastic limstones	3.0 - 4.0
Carbiniferous limestone	5.0 - 5.5
Dolomites	2.5-6.5
Salt	4.5 - 5.0
Anhydrite	4.5 - 6.5
Gypsum	2.0 - 3.5

Kearey and Brooks, 1991

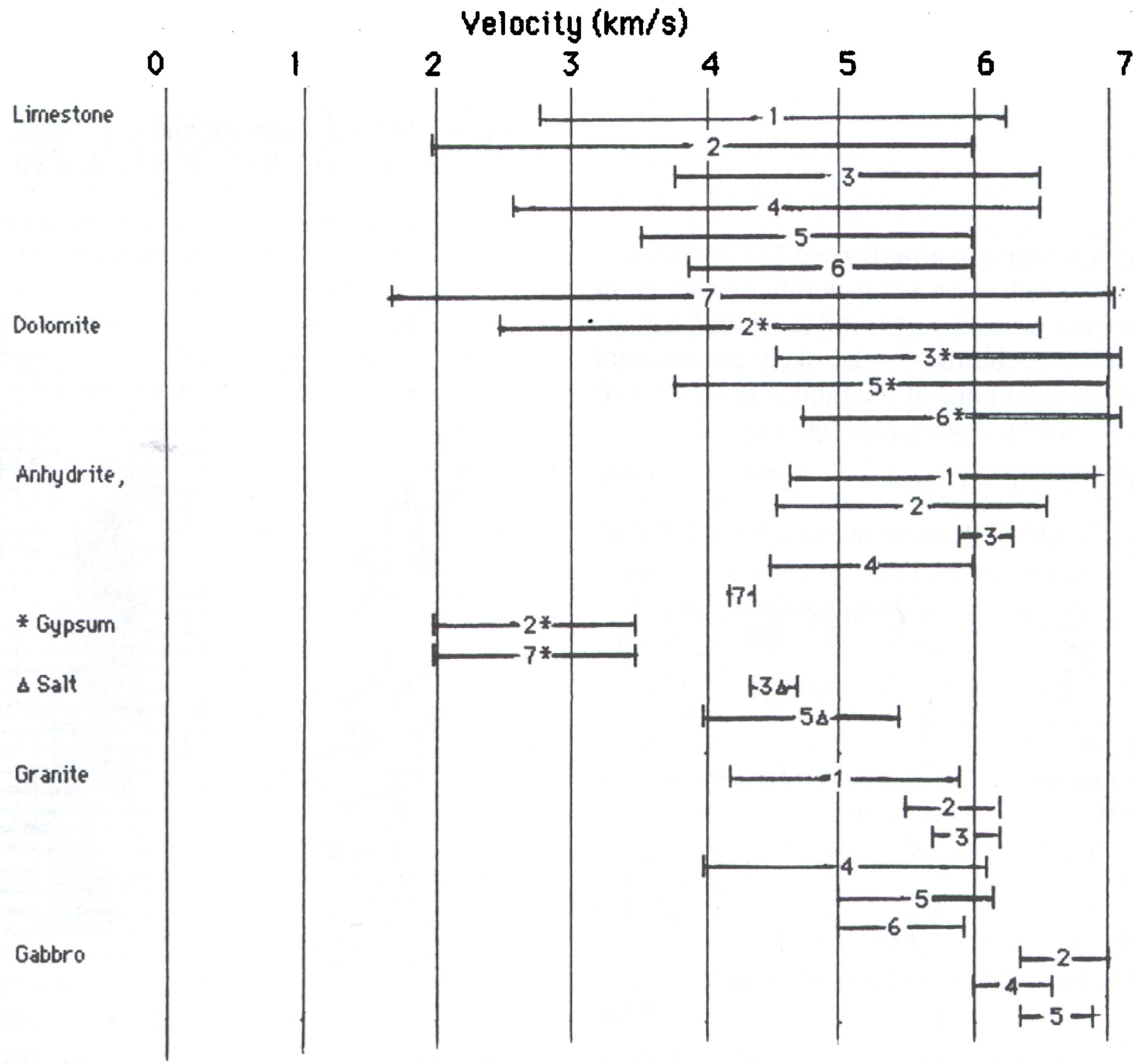
P-wave velocities v_p for different material in (km/s)

Igneous / Metamorphic rocks	
Granite	5.5 - 6.0
Gabbro	6.5 - 7.0
Ultramfic rocks	7.5 - 8.5
Serpentinite	5.5 - 6,5
Pore fluids	
Air	0.3
Water	1.4 - 1.5
Ice	3.4
Petroleum	1.3 - 1.4
Other materials	
Steel	6.1
Iron	5.8
Aluminium	6.6
Concrete	3.6

Kearey and Brooks, 1991



Velocity (km/s)
0
1
2
3
4
5
6
7
Alluvium,
1
5
7
* Dry sand,
2*
7*
Weathering
3
4
7
Δ Mud
3Δ
6Δ
Glacial
2
5
Shale
2
3
6
5
Sand,
Sandstone
1
2
4
5
6
7



Velocity (km/s)
0
1
2
3
4
5
6
7
Limestone
1
2
3
4
5
6
7
Dolomite
2*
3*
5*
6*
Anhydrite,
1
2
3
4
7
* Gypsum
2*
7*
Δ Salt
3Δ
5Δ
Granite
1
2
3
4
5
6
Gabbro
2
4
5

Interval-Velocity

$$V_I = \frac{Z_m - Z_n}{t_m - t_n}$$

Instantaneous Velocity

$$V_{inst} = \frac{dz}{dt}$$

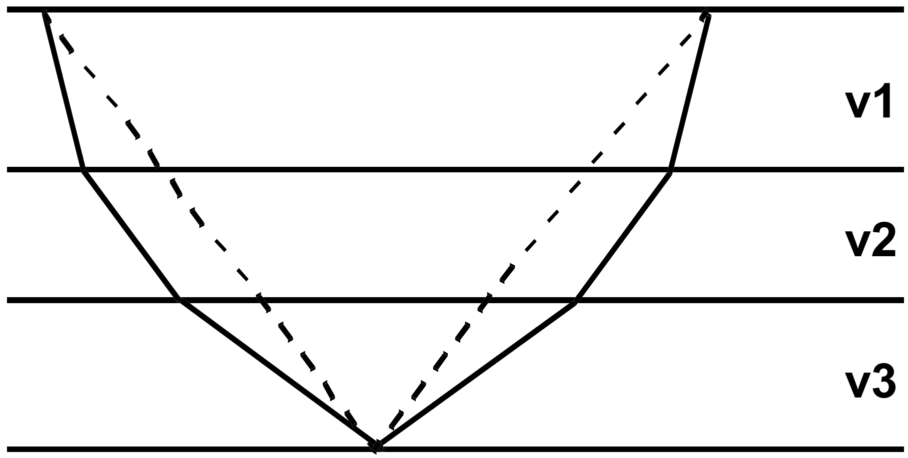
Average-Velocity

$$V_{av} = \frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} t_i} = \frac{\sum_{i=1}^{n} v_i \Delta t_i}{\sum_{i=1}^{n} t_i}$$

RMS-Velocity

$$V_{rms}^2 = \frac{\sum_{i=1}^{n} v_i^2 \Delta t_i}{\sum_{i=1}^{n} t_i}$$

Several horizontal layers



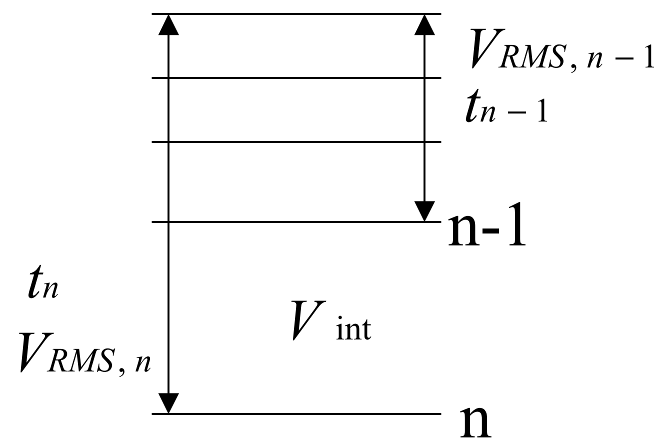
$$V_{rms}^2 = \frac{\sum_{i=1}^{n} v_i^2 \Delta t_i}{\sum_{i=1}^{n} t_i}$$

rms = root-mean-square

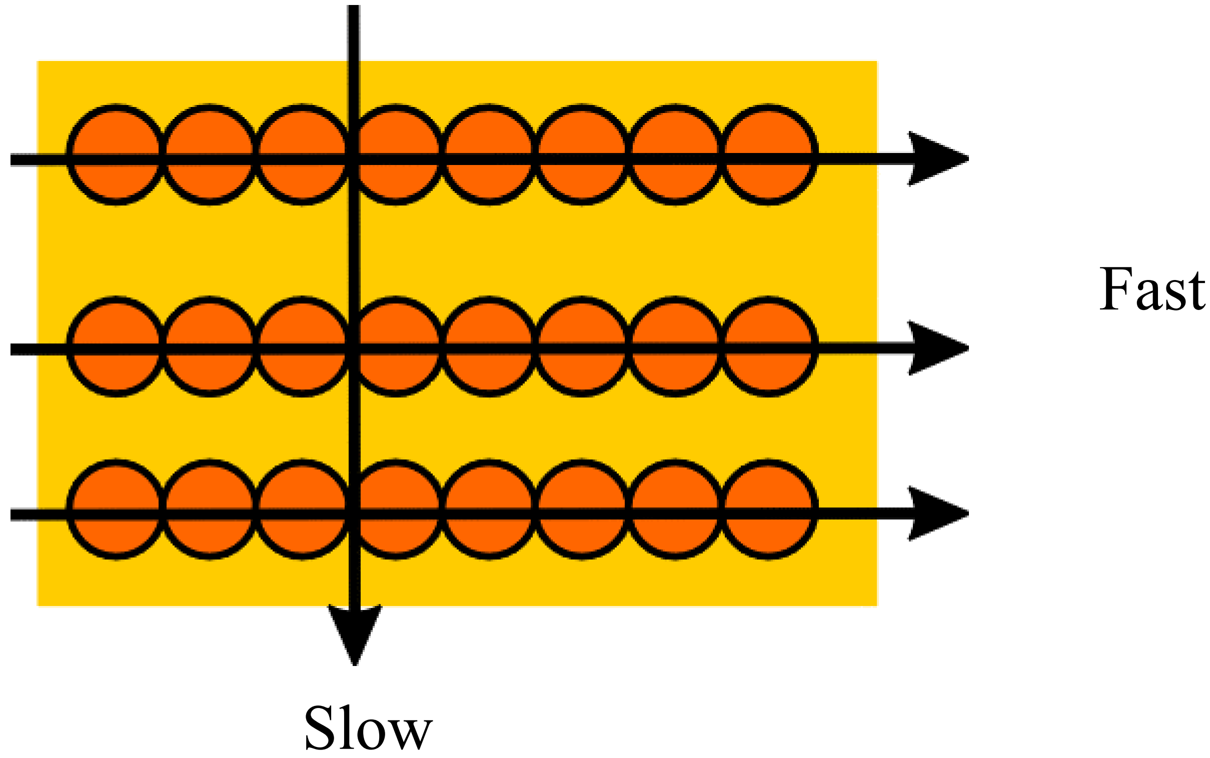
Dix' Formula

Conversion from v_{rms} in interval velocities

$$V_{int} = \sqrt{\left[\frac{(V_{RMS,n})^2 t_n - (V_{RMS,n-1})^2 t_{n-1}}{t_n - t_{n-1}}\right]}$$



Anisotropy



Anisotropy(seismic): Variation of seismic velocity depending on the direction in which it is measured.

Measurements of velocities

Laboratory measurements using probes

Borehole measurements

Refraction seismic

Analysis of Reflection hyperbolas