Results of Geochemical Data Analysis of Homestake Elastic Wave Speeds

Levi Walls

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Assumptions:

- Data is assumption-free; e.g. :
  - Temperature does not affect mineral data;
  - Pressure does not affect mineral data;
  - Does not consider porosity of rock;
  - Does not consider fracturing of rock, etc.
- Results are from a purely mineralogical dependence

Methodology

- Main assumption: elastic wave speeds through materials is an additive quantity Using the geochemical data [1] in addition to wave speeds through the pertinent minerals [2] :
- Estimate hardness ($\bar{H}_M$) of each site using a normalized weighted average; i.e.

$$\bar{V}_M = \sum_{i \in S} w_i (V_M)_i \qquad (1)$$

where S spans the sample space consisting of the pertinent minerals in each table, w_i is the percent mineral composition, and $(V_M)_i$ is the wave speed of each constituent mineral [2]

Wave Speed Model Based on Mineral Hardness

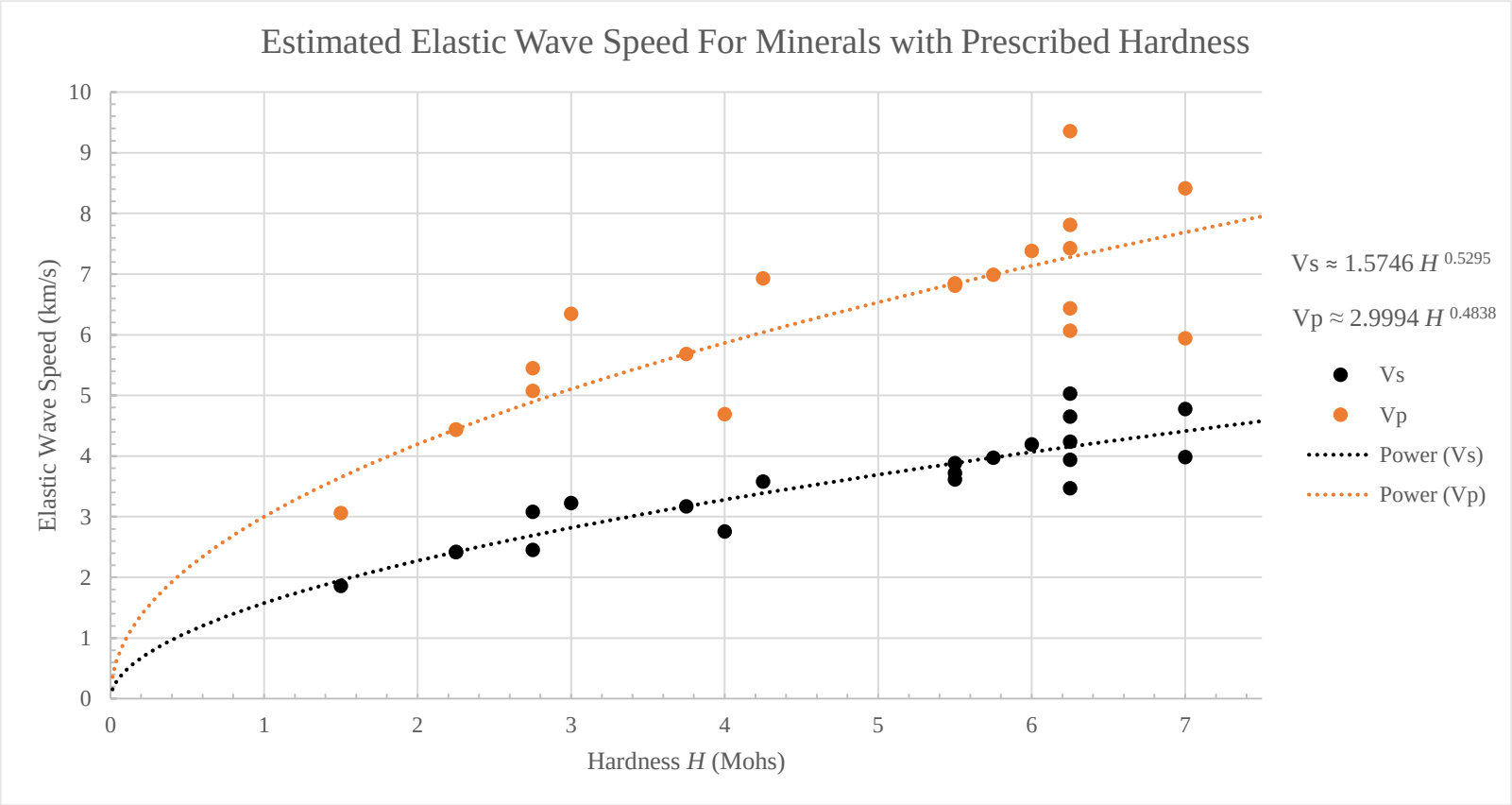

Fig. 1:
There were several minerals for which I did not have wave speeds.

Models are based on the hardness of minerals, values which I do have.

It was narrowed down to a power model (shown) or linear—Linear might have been more realistic at lower *H* values, but it does not really matter in the domain of interest.

Results: Poorman Formation

Table 1

Rock Type	P-Wave Speed (km/s)	Error (+/-)	S-Wave Speed (km/s)	Error (+/-)	Location
HPS	6.780	0.168	3.710	0.167	3800 level, Yates Shaft area
HPS	6.714	0.157	3.680	0.156	4100 level, Yates Shaft area
HPS	6.692	0.155	3.684	0.153	4850 level, Yates Shaft area
CS	5.741	0.080	3.186	0.092	7700 level, No. 6 Winze
HBCS	6.174	0.114	3.261	0.187	4100 level, Yates Shaft area
GQSP	6.014	0.104	3.774	0.084	8000 level, 21 Ledge
GQSP	5.416	0.142	3.272	0.103	8000 level, 19 Ledge
GQSP	5.549	0.141	3.055	0.126	4850 level, 15 Ledge
SCQP	5.646	0.153	3.365	0.127	4100 level, Ross Shaft area
SCQP	5.621	0.228	3.281	0.174	4850 level, 4 Winze area
SCQP	5.550	0.172	3.267	0.135	6800 level, near Main Ledge
BQCP	5.354	0.108	3.013	0.235	4850 level, 15 Ledge
BQCP	5.177	0.109	2.846	0.232	7700 level, 6 Shaft area

Results: Homestake Formation

Table 2

Rock Type	P-Wave Speed (km/s)	Error (+/-)	S-Wave Speed (km/s)	Error (+/-)	Location
GDS	6.090	0.120	3.342	0.174	4550 level, Main Ledge
GDS	6.336	0.113	3.761	0.114	4550 level, 9 Ledge
GDS	6.572	0.156	3.745	0.157	6800 level, 21 Ledge
GDS	5.681	0.108	3.130	0.118	6800 level, 21 Ledge
GDS (ore)	7.163	0.113	4.044	0.099	7200 level, 9 Ledge
GDS	6.645	0.150	3.764	0.153	8300 level, Pierce Structure (Main Ledge)
SDP (ore)	6.401	0.144	3.433	0.145	800 level, 7 Ledge
SDP	6.330	0.122	3.483	0.127	1700 level, 7 Ledge
SDP (ore)	5.613	0.115	3.011	0.115	6650 level, 9 Ledge
SDP	6.149	0.125	3.375	0.125	5750 level, 17 Ledge
SDP	5.874	0.096	3.332	0.096	5900 level, 17 Ledge
SDP (ore)	5.809	0.095	3.300	0.096	6800 level, 21 Ledge
CQS	5.755	0.075	3.350	0.086	800 level, 7 Ledge
CQS	5.087	0.125	2.886	0.125	5600 level, 11 Ledge
CQS	5.678	0.100	3.210	0.100	6950 level, 21 Ledge

Results: Ellison Formation

Table 3

Rock Type	P-Wave Speed (km/s)	Error (+/-)	S-Wave Speed (km/s)	Error (+/-)	Location
Quartzite	5.813	0.061	3.799	0.053	4550 level, 11 Ledge
Quartzite	5.942	0.064	3.982	0.056	6500 level, Main Ledge
Quartzite	5.916	0.065	3.935	0.054	6800 level, 9 Ledge
QMS	5.798	0.090	3.568	0.105	5900 level, 13 Ledge
SQP	5.746	0.313	3.435	0.231	2600 level, east of Yates Shaft
SQP	5.522	0.244	3.225	0.196	6800 level, Main Ledge
SQP	5.430	0.338	3.086	0.256	6800 level, 13 Ledge
SQP	5.643	0.180	3.423	0.139	6800 level, 15 Ledge
BQP	5.502	0.101	3.204	0.193	2600 level, east of Yates Shaft
BQP	5.386	0.093	3.062	0.144	6500 level, Main Ledge
BQP	5.922	0.093	3.413	0.190	6800 level, 9 Ledge
Amphibolite	6.683	0.150	3.635	0.150	Drill hole north of Lead, S. Dak.

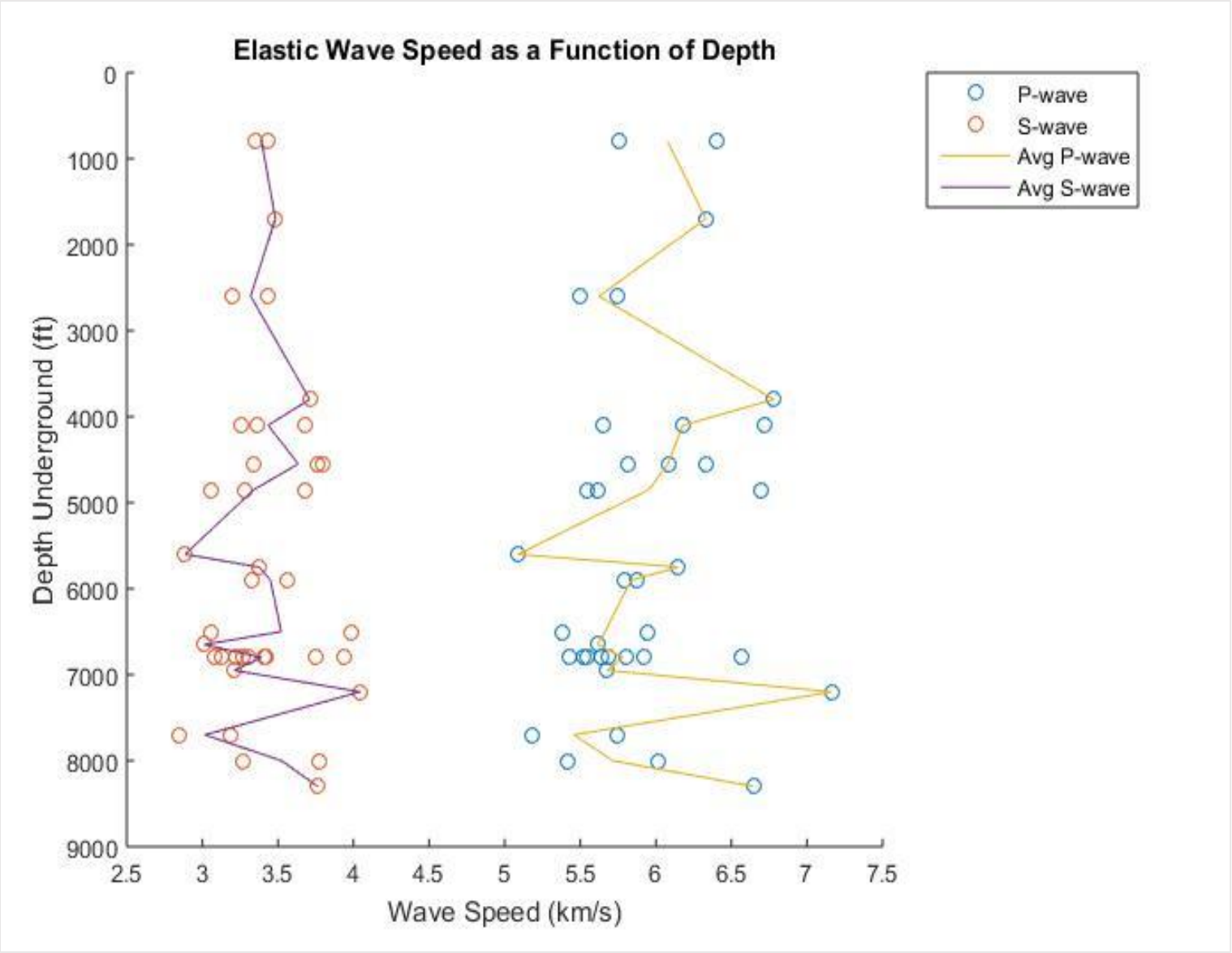

Fig. 2:

Plot of P- and S-wave velocities with respect to depth (and no other spatial coordinate).

Plotting over depth only introduces data points of different wave speed occurring at the same depth.

Thus, for such data points, I found the average wave speed and plotted it with the single data points as a solid line.

Future

- Compare with Gary and student's measurements of 2000 S-wave speeds.
  - Used in conjunction, we could determine the effects of fracturing and others of seismological importance have on the Homestake environment.
- Compare with work of Victor and Daniel
  - Maybe find a velocity model specific to Homestake
  - Determine ray paths of seismic wave

Appendix: Mineralogical Wave Speeds

Mineral	Hardness (on Mohs scale)	Error (+/-)	P-wave velocity (km/s)	Error (+/-)	Trend_Power	S-wave velocity (km/s)	Error (+/-)	Trend_Power
Quartz	7.00	-	5.942	0.064	7.689	3.982	0.056	4.412
Hornblende	5.50	0.50	6.810	0.198	6.843	3.720	0.198	3.883
Biotite	2.75	0.25	5.074	0.187	4.893	2.453	0.417	2.690
Sericite/Muscovite	2.75	0.25	5.450	0.481	4.893	3.080	0.354	2.690
*Mg-chlorite aka Clinochlore	2.25	0.25	4.440	0.198	4.440	2.419	0.198	2.419
˚Intermediate Plagioclase	6.25	0.25	6.438	0.216	7.279	3.473	0.181	4.155
Rutile	6.25	0.25	9.357	0.274	7.279	4.653	0.474	4.155
Graphite	1.50	0.50	3.060	0.198	3.649	1.860	0.198	1.952
Siderite	4.25	0.25	6.930	0.198	6.040	3.580	0.198	3.388
Ankerite	3.75	0.25	5.685	0.198	5.685	3.170	0.198	3.170
Calcite	3.00	-	6.347	0.211	5.103	3.227	0.089	2.817
Pyrrhotite	4.00	0.50	4.690	0.198	5.866	2.760	0.198	3.281
Pyrite	6.25	0.25	7.812	0.152	7.279	5.032	0.071	4.155
*Grunerite	5.50	0.50	6.843	0.198	6.843	3.883	0.198	3.883
˚Na-amphibole	5.50	0.50	6.843	0.198	6.843	3.615	0.198	3.883
*Fe-chlorite aka Chamosite	2.25	0.25	4.440	0.198	4.440	2.419	0.198	2.419
*Garnet	7.00	0.50	8.415	0.194	7.689	4.776	0.131	4.412
Albite	6.25	0.25	6.070	0.198	7.279	3.940	0.198	4.155
Arsenopyrite	5.75	0.25	6.991	0.198	6.991	3.976	0.198	3.976
Epidote/Clinozoisite	6.25	0.25	7.430	0.198	7.279	4.240	0.198	4.155
Magnetite	6.00	0.5	7.385	0.007	7.137	4.195	0.007	4.066

Table 4:
Wave speeds for different rock-composing minerals of Homestake.

Note: The values in red have come from use of wave speed model based on hardness of each mineral (cf. Slides 4 and 11).

Error Calculation

- Errors were not given in [2]
- For sample spaces with ≥ 2 minerals [2]:

  The error was calculated as the standard deviation of the wave speeds for that particular mineral
- For sample spaces with 1 mineral [2]:

  The error was calculated to be the average of the errors calculated above.

Resources

[1] Caddey, S., & Geological Survey. (1992). *The Homestake Gold Mine : An Early Proterozoic Iron-formation-hosted Gold Deposit, Lawrence County, South Dakota*. Print.

[2] Mineralogical wave speed data retrieved from: http://petrowiki.org/Isotropic_elastic_properties_of_minerals