Brown 981

Los Alamos

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memorandum

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SUBJECT: DYNAMIC MODULI FOR THE PHASE I SYSTEM CALCULATED FROM THE 1977 AND 1978 DRESSER ATLAS

Introduction

The 1977 and 1978 Dresser Atlas acoustic experiments provided a good measure of the P-wave velocity in the Phase 1 system (Fehler 1981). However, not enough good S-wave arrivals were present in any step to allow Fehler to calculate S-wave velocities using a velocity hyperbola. This is unfortunate because I need the S-wave velocity to calculate dynamic moduli from the seismic velocities. In this memo I describe a method for calculating the S-wave velocity without making a velocity hyperbola and I calculate S-wave velocities and dynamic moduli for the Phase 1 system in 1978.

Method

The 1977 and 1978 Dresser Atlas experiments were cross wellbore velocity logging experiments using a slightly modified Dresser Atlas acoustic logging tool as a source. The acoustic signals had a frequency of approximately 10 khz. The experiments are more completely described in Fehler (1981).

Since, from Mike Fehler's work we know the mean P-wave velocity for each step, all that is needed to calculate the mean S-wave velocity, is the mean ratio of the S- and P-wave velocities (Vs and Vp respectively). If Ts is the S-wave arrival time, Tp is the P-wave arrival time, and D is the source, receiver distance, the Vs = D/Ts and Vp = D/Tp and clearly Vp/Vs = Ts/Tp. So we can estimate the Vp/Vs ratio from the ratio of the arrival times without knowing the source receiver distance. This simplified the procedure greatly because the uncertainties in estimating the absolute depths of the two tools can introduce a 15% error in velocity measurements. I measured the S- and P-wave arrival times using special expanded playbacks. My measurement precision was better than .01 ms which corresponds to 5 mm in distance. My main problem was finding enough traces with clear S- and P-wave arrivals. These are quite common in the shallowest step (Step 1 8380' - 8570') so the mean Vp to Vs ratio here is based on 136 points. In the two lower steps S attenuation is higher and we only found 25 or 26 traces with clear S- and P-wave arrivals. Data showing typical S and P wave arrivals are shown in Fig. 1.

Results

In Table 1 I listed the S- and P-wave velocities from three steps in the 1978 Dresser Atlas acoustic experiment. In Table 2 I listed the resulting moduli. I also calculated moduli for Trice and Warren's (1977) laboratory velocity measurements on two GT-2 core samples (Table 3). Clearly in our highest step (Step 1) the moduli are very similar to the Trice and Warren's laboratory values for the 8581 sample. However these velocity measurements are not directly comparable because Trice and Warren's measurements were on dry laboratory samples using megahertz frequencies while the rocks in our Phase I reservoir are clearly saturated and the velocities are measured using a 10 khz source. The two lower steps (Step 5 and 7) that are actually in the heat transfer system, have lower P-wave velocities and higher P to S velocity ratios than either Step 1 or the laboratory valves. In these steps the bulk modulus and shear modules are 30% lower than in the undisturbed case and the Poisson's ratio is 30% higher.

We also found that the upper parts of Step 1 has a lower Vp/Vs ratio than the lower part of the step. The depth range from 8380' - 8479' has a mean Vp/Vs ratio of 1.67 while the depth range from 8479 - 8570' has a Vp/Vs ratio of 1.70. While these differences are small, they are significant at the 95% level of confidence. This change may correspond to the Gneiss-Granodioride contact. I also looked at the 1977 data in this step. The data was very similar to the 1978 data.

Reference

Fehler, M., "Changes in P Wave Velocity During Operation of a Hot Dry Rock Geothermal System, JGR, Vol. 86, pp. 2925-2978, 1981.

Trice, R. and R. Warren, "Preliminary Study on the Correlation of Acoustic Velocity and Permeability in Two Granodiorites from LASL Fenton Hill Deep Borehole GT-2, Near Valles Caldera, New Mexico", Los Alamos Scientific Laboratory Report LA-6851-MS, 1977.

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Table 1

Step	Depth Interval/Ft	Vp km/s	Vs km/s	Vp/Vs	Number of Measurements	Std. Dev.
1	8380'-8570'	5.89	3.49	1.69	136	.034
1a	8380'-8479'		3.53	1.67	58	.029
1b	8479'-8570'		3.46	1.70	78	.031
5	8700'-8802'	5.69	3.19	1.78	21	.086
7	8802'-8887'	5.52	2.92	1.89	25	.117

Table 2

Step	K Bulk Modulus G Pa	E Young's Modulus G Pa	λ Lame's Constant G Pa	μ Shear Modulus G Pa	ν Possion's Ratio
1	48.34	78.47	27.07	31.91	0.23
1a	47.36	79.64	25.60	32.65	0.22
1b	49.07	77.57	28.16	31.37	0.24
5	49.28	67.76	31.50	26.66	0.27
7	50.05	58.34	35.15	22.34	0.31

Table 3

Depth of Sample	Confin-ing Stress	Vp km/s	Vs km/s	Bulk Modulus G Pa	Young's Modulus G Pa	Lame's Const. G Pa	Shear Modulus G Pa	Poisson's Ratio
8581	495	5.95	3.50	49.96	79.30	28.56	32.10	0.24
9519	480	6.25	3.47	60.28	80.58	39.25	31.55	0.28

Fig 1