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Weaknesses in Bethe's Theory of Seismic Coupling

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MEMORANDUM

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SUBJECT: Weaknesses in Bethe's Theory of Seismic Coupling.

Quantitatively, Bethe's theory is in error by a large factor. It may also be qualitatively wrong. Several major weaknesses are outlined below:

1. Equation of state in the hydrodynamic region.

   Bethe uses an equation of state which approximates the initial shock Hugoniot. Since the shock changes entropy and the subsequent expansion is nearly isentropic, the adiabats and the Hugoniot do not coincide. Within approximately 75 feet of the Rainier explosion, Bethe's equation of state overestimates by about a factor of two the energy deposited as waste heat by the shock wave.

2. The fractured region.

   Bethe does not correctly treat the region between ~ 130' and ~ 250' (from Rainier) which is neither elastic nor plastic. The initial motion before the Tuff goes into tension (compressive stress due to overburden is exceeded) is approximately elastic. This transient elastic motion reduces the scalar radial momentum (proportional to the impulse subsequently applied to the elastic region). Thereafter, since no large scale tensile stresses can exist and the radial stress is compressive and non-zero, the stress-strain relation is very complicated. Even if the fractures are on a small scale relative to the shock radius, it is not correct to set the shear modulus to zero (i.e., make the stress a scalar) and use a fluid type equation of state (e.g., sand supports a weight).

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3. Elastic region.

Bethe assumes that when the peak shock pressure is less than ~.5 kb, the Tuff behaves elastically. Actually Tuff probably has no tensile strength on a large scale. Elastic behavior can occur only when the compressive stress due to the overburden is not exceeded. (Other rocks may possibly have some large scale tensile strength, but it is probably less than the stress due to 1000' of overburden.) The "strength" of materials depends upon stress rate, pressure, size of sample, and local stress concentrations.

4. Non-linear attenuation.

By the use of Fourier analysis to find the low frequency component Bethe implicitly assumes that attenuation is by a linear physical process. There is evidence that this process is non-linear. Energy may therefore be transferred from high to low frequencies.

The HE and nuclear experimental programs may be expected to produce some surprises.

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