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Mechanics of wave propagation in fragmented geomaterials

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The Earth's crust has blocky or fragmented structure at different scales. Laboratory experiments and in-situ measurements reported in the literature show that the wave propagation in blocky media is characterised by the presence of unusually low frequencies in the spectrum and by low wave velocities (so-called pendulum-type waves). What was overlooked is that the fragments relatively free to move are at most held together by weak gouge. Mechanically, this implies two important phenomena. First, the large-scale stress-strain behaviour is highly non-linear and is characterised by considerably different moduli in tension and compression. In compression the resistance is controlled by contacts between the fragments and hence the corresponding moduli are determined by the deformation moduli of the fragments. In tension the moduli are determined by usually low stiffness of the gouge. We show that this leads to low wave velocities. Since in order for the wave to propagate through fragmented media, the wave lengths must be considerably larger than the dimensions of fragments, the low wave velocities only permit propagation of low frequency waves. Second, the fragments can have independent rotational degrees of freedom. Furthermore, rotations of fragments in the presence of compression (the prevalent state of stress in the Earth's crust) can exhibit the effect of negative stiffness. This changes the resonance spectrum of the fragmented medium leading to formation of low resonance frequencies. We propose simple models of these two phenomena, which can improve the understanding of the wave propagation and its utilisation for deciphering the Earth's crust structure.