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Influence of elastic effects on lower mantle shear attenuation measurements

3D mapping of attenuation has the potential to provide new constraints on the Earth's interior…

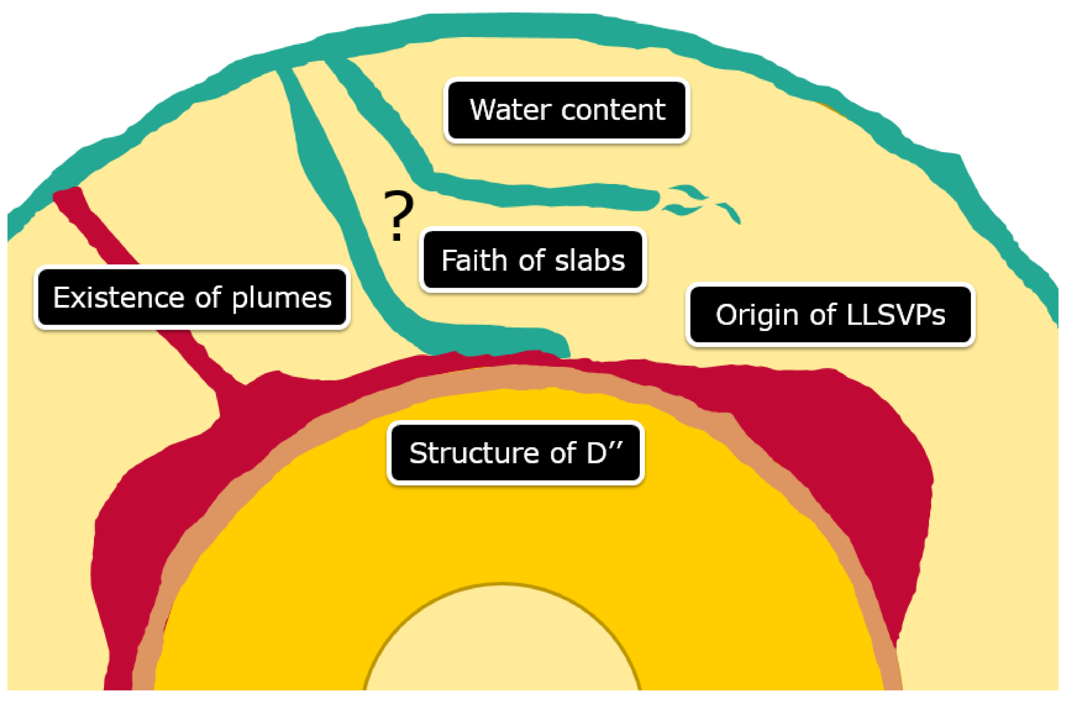

Figure 1: **Schematic overview of big questions on the structure governing Earth's mantle, that attenuation measurements could put new constraints on. (not to scale)**

Physical properties associated with the structure and composition of the Earth affect both elastic and anelastic features of seismic waves. Although 3D mapping of seismic velocities has progressed significantly in the last decades, attenuation properties remain unresolved due to challenges in distinguishing the effects of elastic scattering and intrinsic energy loss.

Attenuation and seismic velocity have opposite responses to several seismic parameters [1][2][3][4]

Reliable attenuation measurements can put new constraints on the Earth's structure

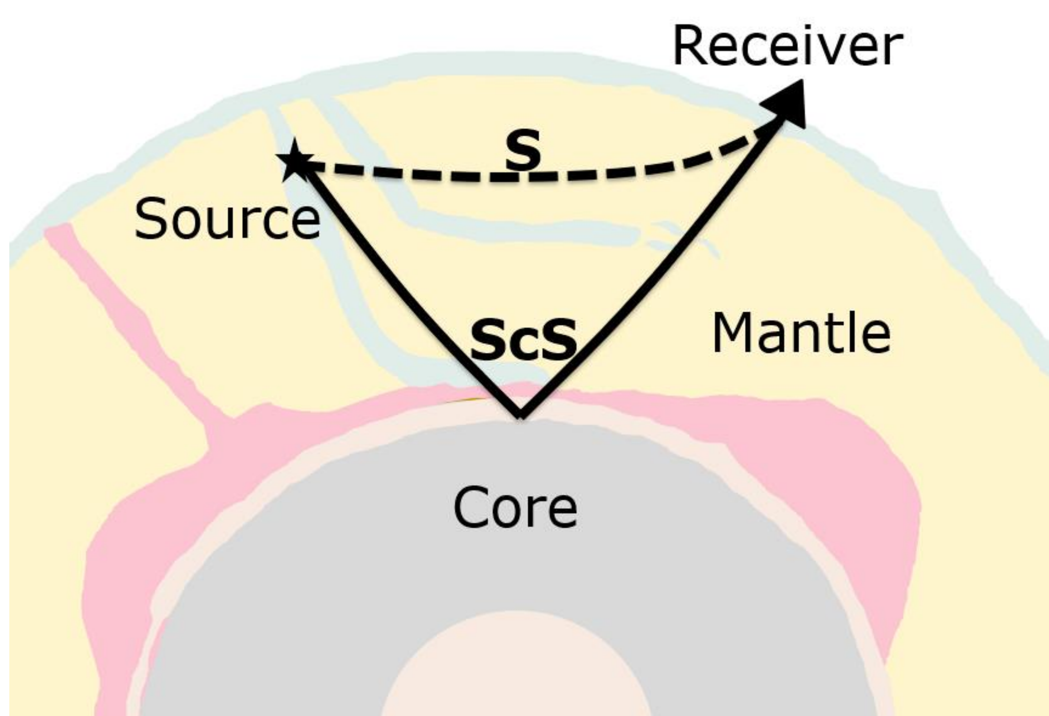

Figure 2: **Paths of the S and ScS seismic phases through the Earth. We can estimate shear attenuation by comparing the phases using methods explained below.**

… and can be measured from seismic body waves as t via instantaneous frequency matching…*

Q and t*

Intrinsic shear attenuation is expressed through quality factor Q_μ: the relative loss of energy in a cycle. t^* is a measure for the total attenuation accumulated along the path.

$$\frac{1}{Q_\mu} = \frac{\Delta E}{2\pi E}, \qquad t^* = \int \frac{ds}{Q V_s}$$

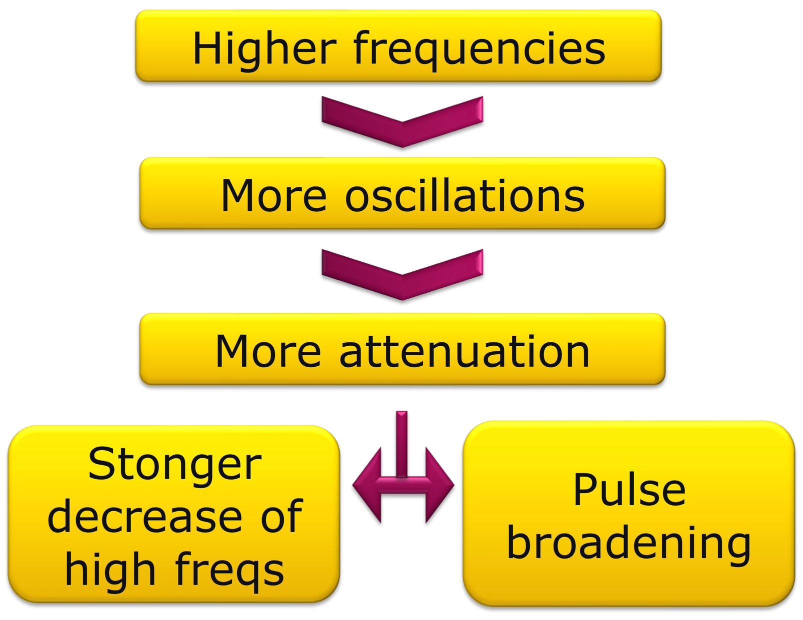

Figure 3: **Higher frequencies are more attenuated, so the dominant frequency decreases.**

Instantaneous frequency

The weighted average instantaneous frequency can be obtained from complex trace analysis. A value for t* is obtained by attenuating one phase with respect to another until their instantaneous frequencies *f(t)* at the peak of the envelope *a(t)* match (Figure 4).

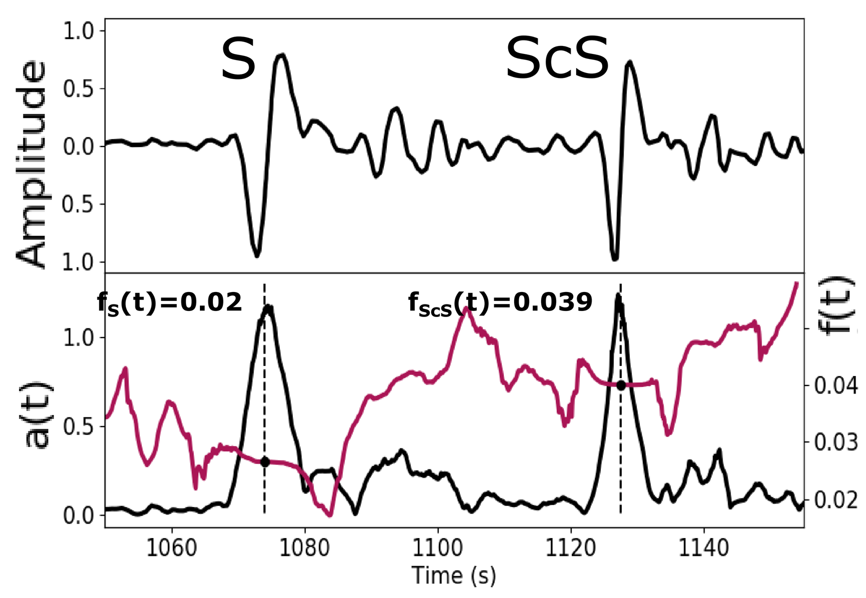

Figure 4: **A t* of -2.7 s is necessary to attenuate the instantaneous frequency of ScS from 0.039 to 0.026 Hz.** Reproduced from [5]

1D profile of Q_μ

The value of Q_μ in the lower mantle remains unknown.

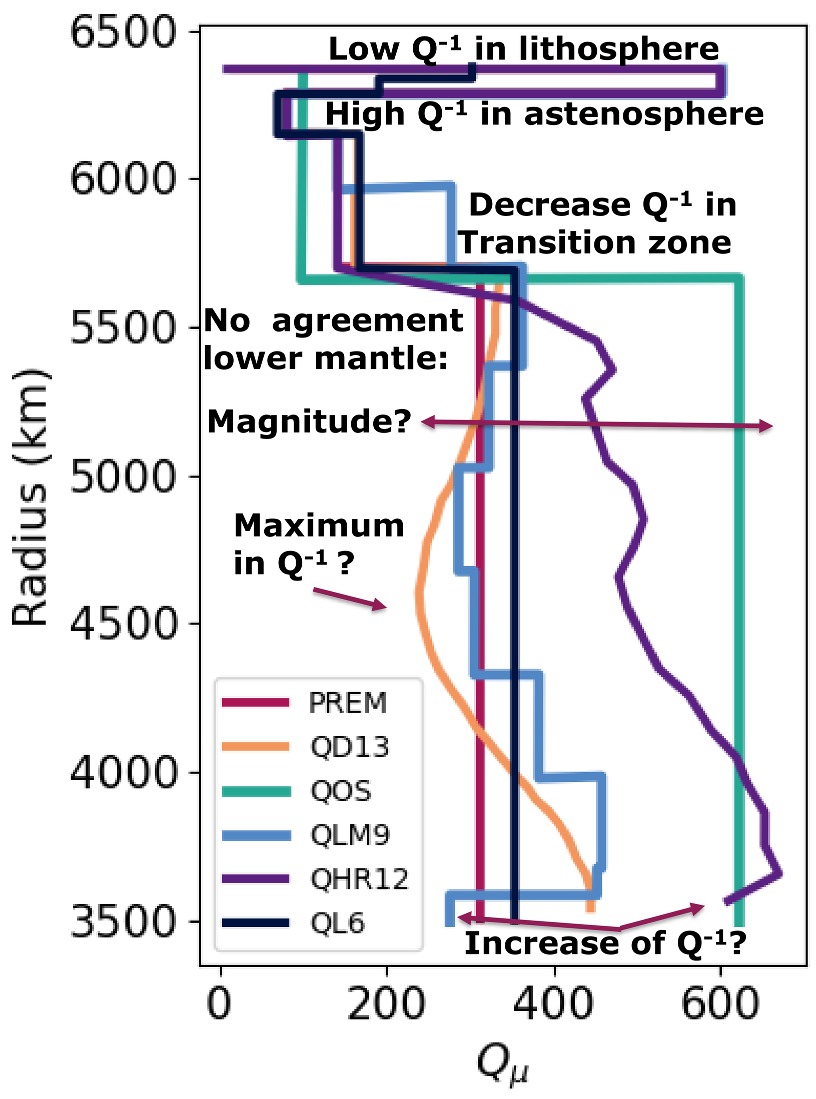

Figure 5: **Overview of body-wave-based radial models of Q_μ.** [6][7][8][9][10][11]

Sign of t*

The value of dt^*_{ScS-S} as a function of epicentral distance gives information about the value of Q_μ as a function of depth.

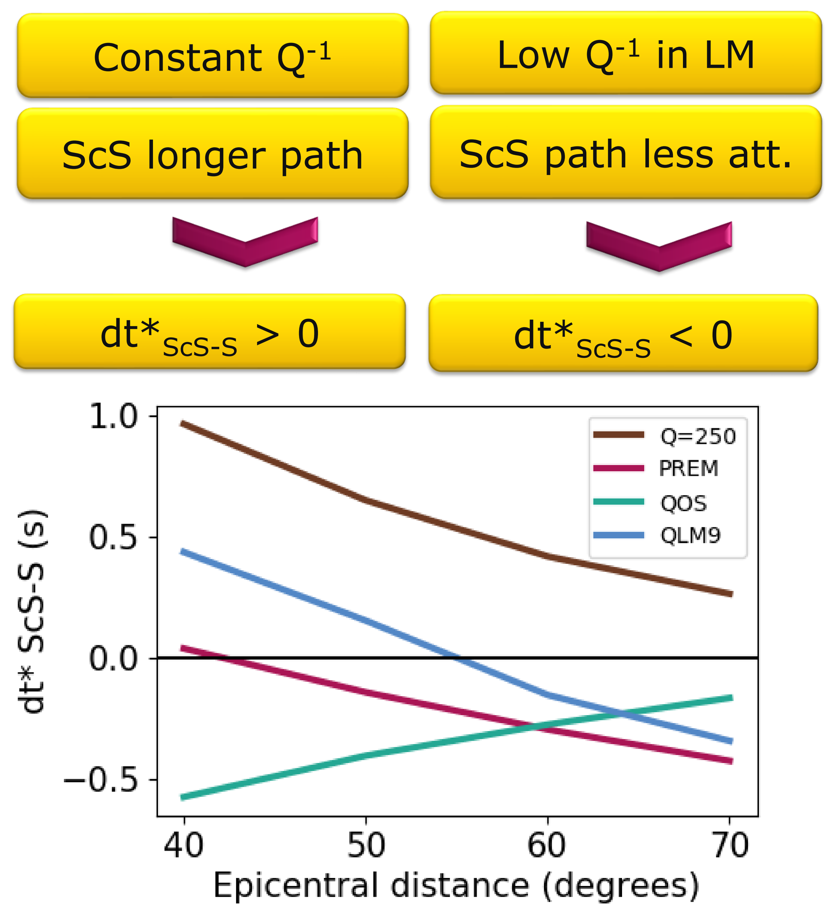

Figure 6: **The more negative dt^*_{ScS-S}, the more attenuating the S path compared to the deeper ScS path. Calculated using $t^* = \int \frac{ds}{QV_s}$.**

… but before interpreting results, we have to study the influence of elastic effects on t.*

Elastic effects versus intrinsic attenuation

Elastic effects in the mantle can reproduce observations otherwise interpreted as attenuation[12]. We study the influence of 3D elastic heterogeneities on attenuation using SPECFEM3D[13] synthetic waveform modelling and real data. This will put a benchmark on the extent to which elastic effects can be misinterpreted as attenuation.

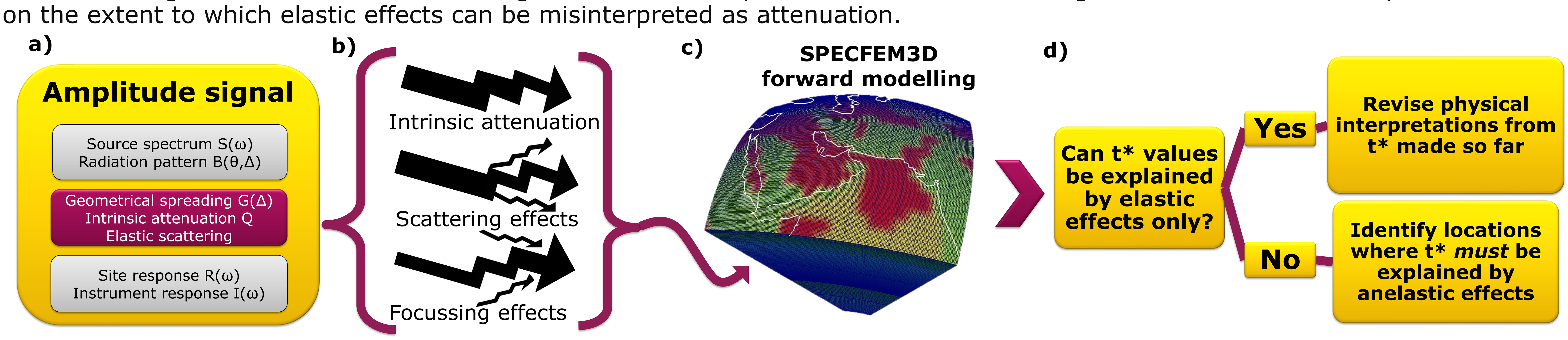

Figure 7: **(a) The amplitude spectrum of a seismic phase depends on properties of the source, medium and receiver. By studying phases within one seismogram, most terms cancel, except the contributions of elastic and anelastic effects in the medium (b). By forward modeling these effects (c)** [13] **, we will understand to which extent elastic effects may contribute to t* (d).**

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