Average intrinsic Q_s in the crust and uppermost 8 km of mantle in the Ganga Plains, Bihar

The attenuation properties of the media constitute basic elements governing the amplitude of seismic waves at various distances from an earthquake source. The overall attenuation is composed of several factors that include geometrical divergence, scattering due to inhomogeneities in the media and inelasticity.

Here, we estimate the average inelastic attenuation property for the shear waves in the crust and upper 8 km in mantle in the Ganga basin close to the Himalaya in Bihar. The parameter estimated is the frequency-independent quality factor Q_s, in the frequency band of 0.2–1.5 Hz. It characterizes losses due to internal friction in inelastic materials. This parameter is approximately independent of frequency in the seismic frequency band[1]. We note that it is the first estimate of its kind for this region, although estimates of coda-Q are available in the Himalaya[2].

We estimate the intrinsic attenuation quality factor Q_s for the Ganga basin region by making use of the teleseismic broad-band SH waveforms from the 1988 Nepal–India border earthquake (6.4 M_b). This earthquake took place in Bihar in Ganga basin. It has a depth of focus of 55 km. Figure 1 shows S wave mechanism and the waveforms at nine stations. The seismograms of the stations at KEV, COL, HIA, INU, GUM, CTA, CRZF, SLR and TOL have been used in the analysis. The spectral ratios of the $_s$SH and SH phases are the basis of estimating the average Q_s in the crust and a small portion of the uppermost mantle in the epicentral region. One of the advantages of using the SH wave is that there is no mode conversion at the layer interfaces and the estimate will correspond to the case of the shear waves only. The path travelled by the direct SH wave and the corresponding depth phase, i.e. $_s$SH from a shallow earthquake to a distant recording station is approximately the same. Therefore, the ratio of the spectra of the depth and the direct phases will have a slope that is proportional to the value of Q_s for the path difference of the $_s$SH phase in the epicentral region.

Let $A(f)$ be the spectral ratio of the surface reflected $_s$SH and the direct SH phases, then we have

$$\ln A(f) = -\pi f t / Q_s, \quad (1)$$

which is the equation of a straight line with $-\pi t/Q_s$ as its slope, from which Q_s can be determined.

The event was recorded by the IRIS-GSN and GEOSCOPE networks. Zhou *et al.*[3] obtained the SH displacement waveforms of this earthquake at nine stations. We have used these waveforms for this study. The waveform of the station COL has not been used for the present analysis as it does not show a clear depth phase.

A straight line is fitted in the least square sense to the spectral ratio versus frequency. The value of Q_s is estimated from the slope of the line by

$$Q_s = -\pi t/m, \quad (2)$$

where t is the two-way travel time of the depth phase from the source to the surface and m is the slope of the fitted line. The time here is for the slant paths corresponding to the epicentral distances of the respective stations. The velocity function was taken as per the model (Table 1) adopted by Zhou *et al.*[3] for the Ganga basin region. The smoother spectral ratios along with the least square fitted lines for the eight stations are shown in Figure 2. The values of the shear wave quality factor, Q_s, obtained range from 1140 to 1580 with an average value of 1310 ± 158. These values are rounded

Table 1. Velocity function taken for Ganga basin region (after Zhou *et al.*[3])

Thickness (km)	V_s (km/s)
4.0	2.4
43.0	3.97
Infinity	4.61

Table 2. Values of Q_s obtained using the teleseismic waveform recorded at eight stations

Station code	Q_s
KEV	1150
HIA	1580
CTA	1400
CRZF	1210
INU	1200
SLR	1400
GUM	1140
TOL	1400

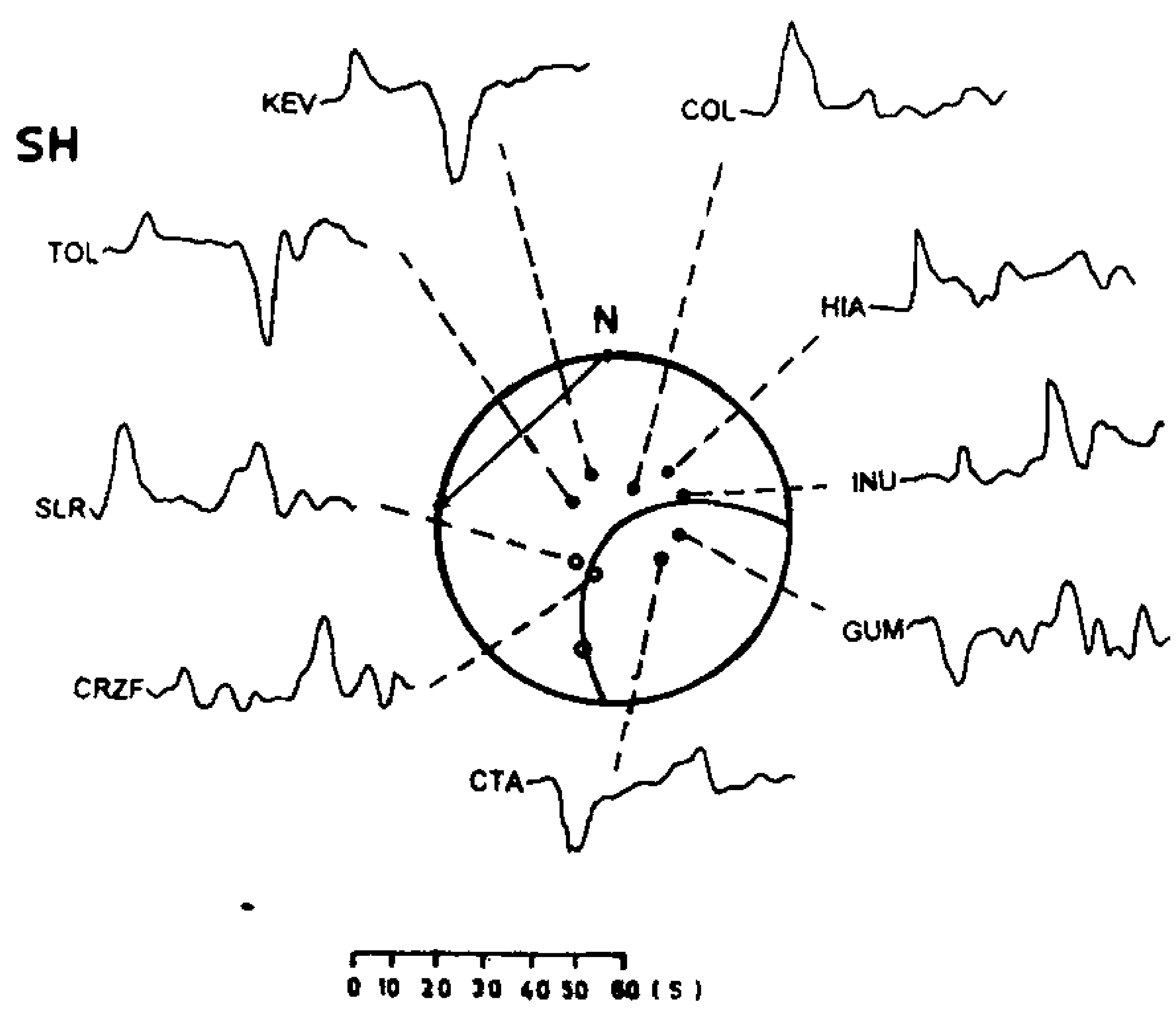
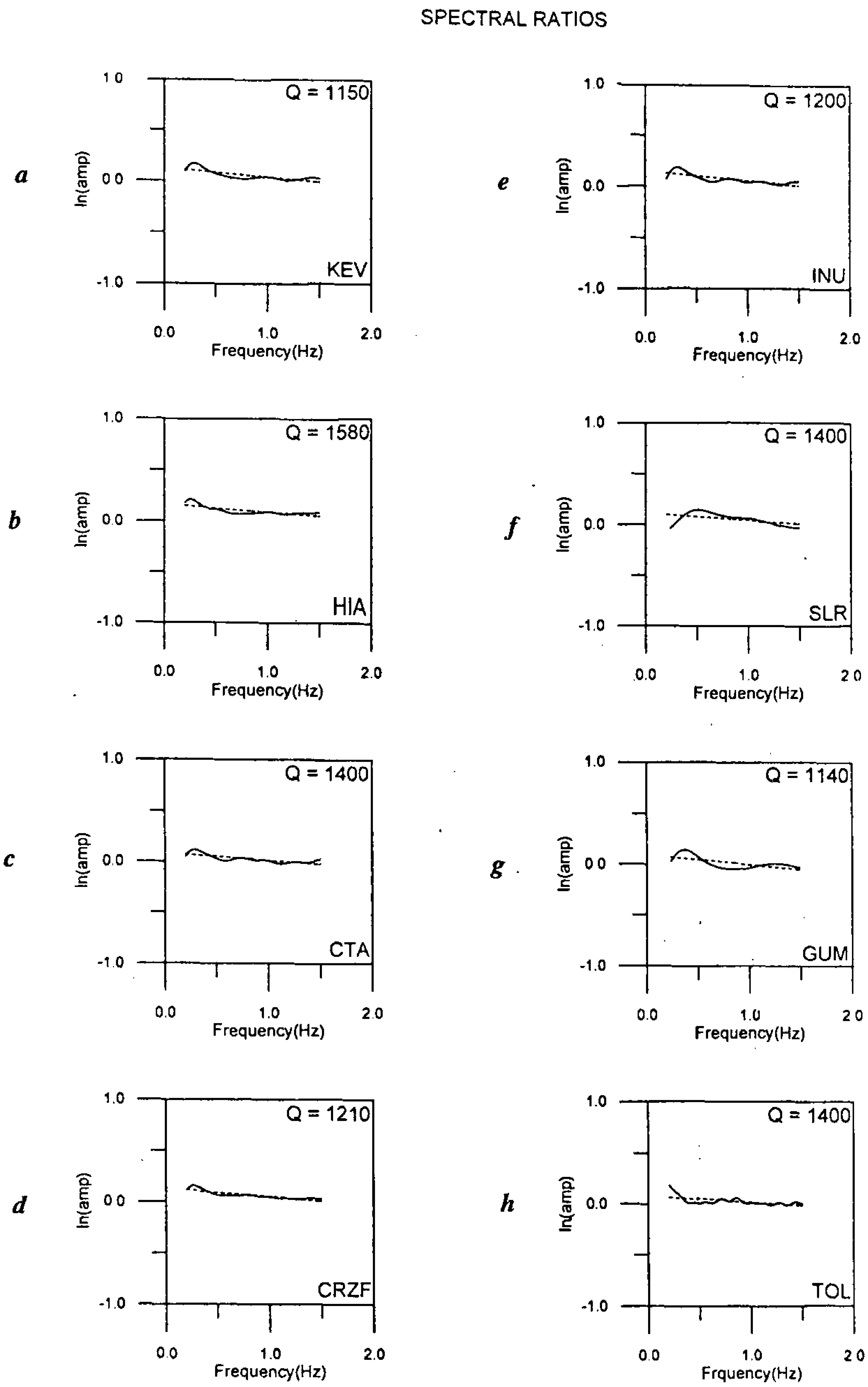


Figure 1. S wave mechanism of the 1988 Nepal–India border earthquake along with SH waveforms at nine stations (modified after Zhou *et al.*[3]).



ure 2. Observed smoothed spectral ratios along with fitted lines (dash lines) at stations: ⟨EV; ***b***, HIA; ***c***, CTA; ***d***, CRZF; ***e***, INU; ***f***, SLR; ***g***, GUM and ***h***, TOL.

to the nearest tens and are given in ɔle 2. We note the variations in the Q_s values obtained from different stations which may be due to lower signal-to-noise (S/N) ratios at some of the stations. The S/N ratio is good at SLR, CTA, TOL, KEV, fair at INU and poor at HIA, CRZF, GUM. These variations cannot arise due to propagation of the rupture as that effect will cancel out on taking the ratios. In general, the estimates are consistent.

In summary, the average value of the shear wave quality factor Q_S, has been determined for the crust and a small portion (8 km) of the underlying mantle in the Ganga basin in Bihar at a location close to the Himalaya using the spectral ratios of the direct and the surface reflected shear waves. This value is 1310 ± 158 which indicates an efficient wave propagation regime for the region. This value is expected to be closely representative of the Himalaya region as well. A consequence of the high Q_s in the region is that damaging levels of strong ground motions can occur at considerable distances from the earthquake sources.

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