Influence of Q_s factor over complex Geological Formation – A case study of Ohchigata Fault Zone at Japan

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An attempt has been made to estimate the frequency dependent Qs value and its lateral variation over Ohchigata fault zone and the surrounding area in Ishikawa Pref. using the double spectral ratio method (Izutani (2000), Izutani and Ikegaya (2003)) and the strong motion records obtained by the borehole sensors of the KiK-Net.

- The Qs value determined in the central part that includes the Ohchigata fault zone is apparently lower in comparison with the northern and the southern parts of the surrounding area.

Source, path and site effects

Source effects

↓

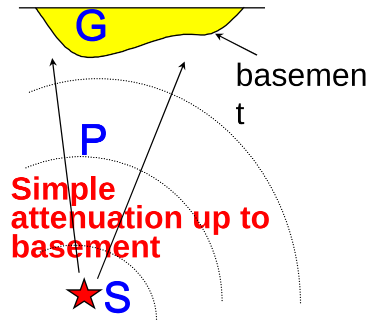
Path effects

↓

Site effects

output ↓

Ground motion

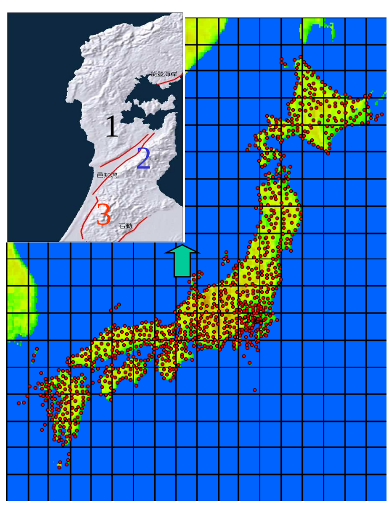


Observed Spectra

$$O(\omega) = S(\omega).G(\omega).P(\omega)$$

$$O_{ij}(f) = S_i(f)G_j(f)R_{ij}^{-1}\exp(-\pi f R_{ij} / Q_S(f)V_S)$$

Iwata and Irikura (1988)



-A 44km length SW-NE tending Graven of Active fault with three segments

1.Bijou-san active segment
Strike:N50^{0}E;Dip:30^{0}N;length18km;
0.5m/1000year

2.Sekidon-san active segment
Strike:N40^{0}E;Dip:20^{0}E;length:30km;
1.5m/1000 y

3.Nodera active segment
Strike:N20^{0}E;Dip:45^{0}E; length:17km
0.0m/1000year

(source:Active Fault Data base of Japan; Active Fault Research Center; National Institute of Advanced Science & Technology)

Theory used (Double Spectral Ratio Method)

$$\frac{O_{12}\cdot O_{21}}{O_{11}\cdot O_{22}}=\frac{(S_1\cdot P_{12}\cdot G_2)\cdot(S_2\cdot P_{21}\cdot G_1)}{(S_1\cdot P_{11}\cdot G_1)\cdot(S_2\cdot P_{22}\cdot G_2)}=\frac{P_{12}\cdot P_{21}}{P_{11}\cdot P_{22}}$$

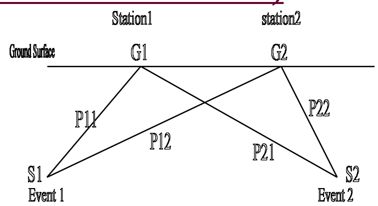


Figure 1 Configuration of two events (earthquakes) and two stations and the ray-paths

$$P_{ij}(f)=\frac{1}{R_{ij}}e^{-\pi f t_{ij}^*}\quad\text{.........(1)}$$

$$t^*_{ij}=\int_{path}\frac{dR_{ij}}{V_S Q_S}\quad\text{.......... .....(2)}$$

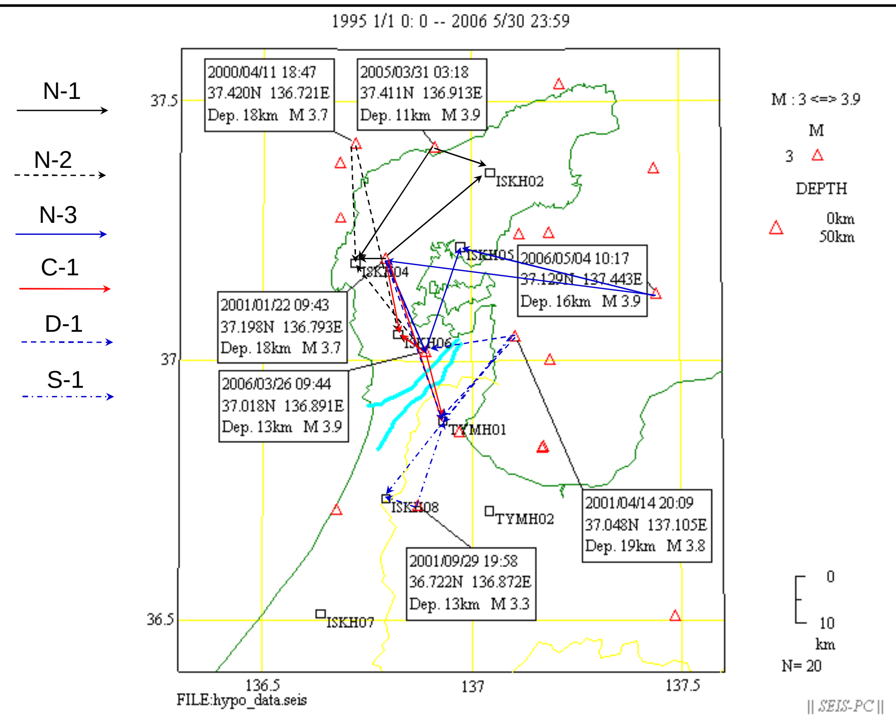
$$\frac{O_{12}O_{21}}{O_{11}O_{22}}=\frac{R_{11}R_{22}}{R_{12}R_{21}}e^{\pi f\Delta t^*}\quad\text{.......... (3)}$$

$$\Delta t^*(f)=t^*_{12}+t^*_{21}-t^*_{11}-t^*_{22}$$

$$Q_S(f)=\frac{\Delta R}{V_S\Delta t^*(f)}$$

$$\Delta R=R_{12}+R_{21}-R_{11}-R_{22}$$

Izutani et.al 2003



Data Used in Analysis

The accelerograms due to the events listed in Table 1 recoded by the borehole sensors at the stations in Table2 that belong to KiK-NET (NIED) are used in analysis. The configuration of the station's and event's pairs (group) is shown in Figure 2. Location of the events are referred from JMA seismic catalog and that of stations from KiK-NET home page.

Data Processing

1) Average Vs is obtained by the regression analysis of the travel time – hypocentral distance relation. As shown in Figure 3, Vs=3.5 Km/sec is obtained and used in analysis.

2) Considering on the necessity to extract the ballistic body waves and the corner frequency of the used events (M<4), the duration of the time window for FFT equal to 1.0 sec. is chosen.

3) Fast Fourier Transform is calculated for the time window from S onset of the accelerograms, then O_{11}, O_{12},O_{21}, O_{22} of 6 groups (Figure 2)by vector sum of three components with smoothing by moving average in the frequency domain, then Δt^* and Q^{-1} as shown in Figure 4.

4) The influence of the time window length is checked for N-1 and C-1 groups (Figure 5). The influence appears in the frequency range lower than about 2Hz for C-1.

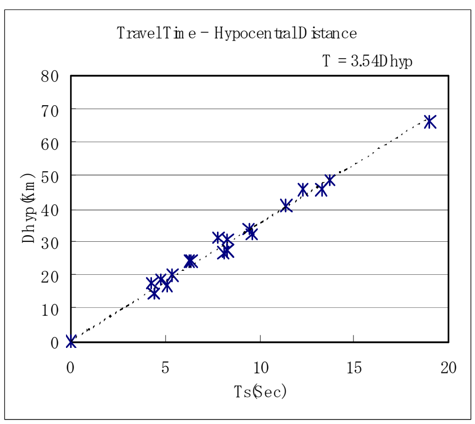


Figure 3 Estimation of Vs from the travel time vs the hypocentral distance.
Vs=3.5Km/sec is used for analysis

Table 1. Events list (origin time, epicenter, focal depth and magnitude).

Event	Date	Time	Latitude(^{0}N)	Longitude(^{0}E)	Depth(km)	Magnitude
1	2000/04/11	18:47:41.0	37.422	136.708	20.0	3.9
2	2001/01/22	09:43:26.8	37.198	136.793	17.6	3.8
3	2001/04/14	20:09:16.6	37.045	137.102	18.0	3.6
4	2001/09/29	19:58:36.9	37.722	136.872	13.0	3.3
5	2006/03/26	09:44:20.9	37.014	136.893	13.0	3.9
6	2005/03/31	03:18:38.7	37.411	136.913	11.3	3.9
7	2006/05/04	10:17:29.2	37.129	137.443	16.0	3.9

Table 2. List of observation stations.

Station Code	Latitude(^{0}N)	Longitude(^{0}E)	Station Name
ISKH02	37.3617	137.0442	Yanagida
ISKH04	37.1872	136.7206	Togi
ISKH05	37.2194	136.9725	Anamizu
ISKH06	37.0503	136.8236	Shika
ISKH08	36.7350	136.7936	Tsubata
TYMH01	36.8836	136.9306	Himi

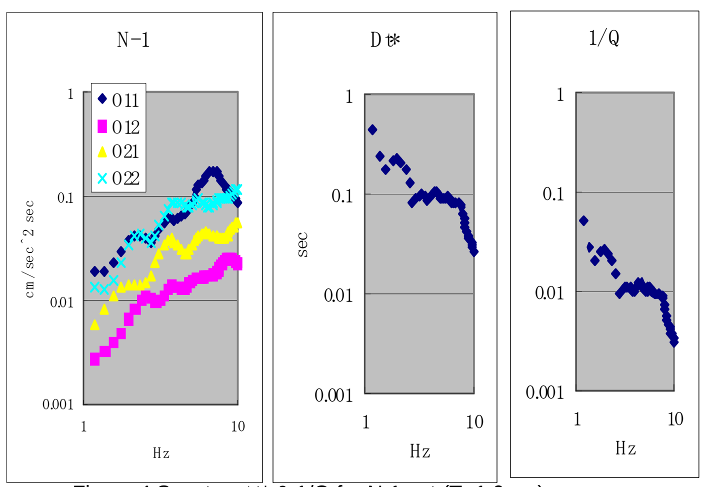


Figure 4 Spectra, Δt* & 1/Q for N-1 set (T=1.0sec).

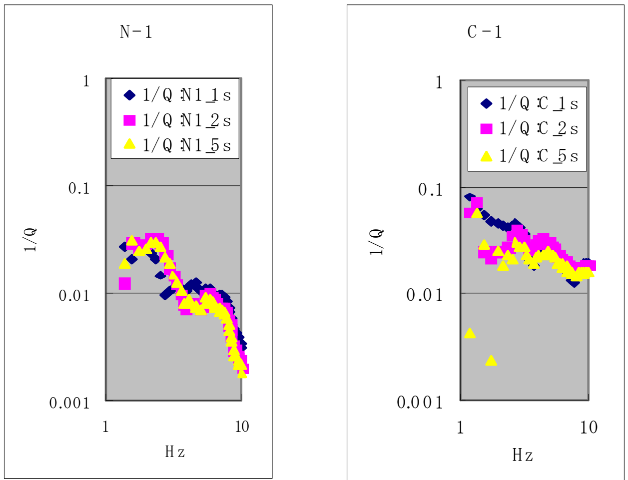


Figure 5 Influence of Time Window Length T on 1/Q for N-1 set & S-1 set. T=1.0 sec is used for analysis.

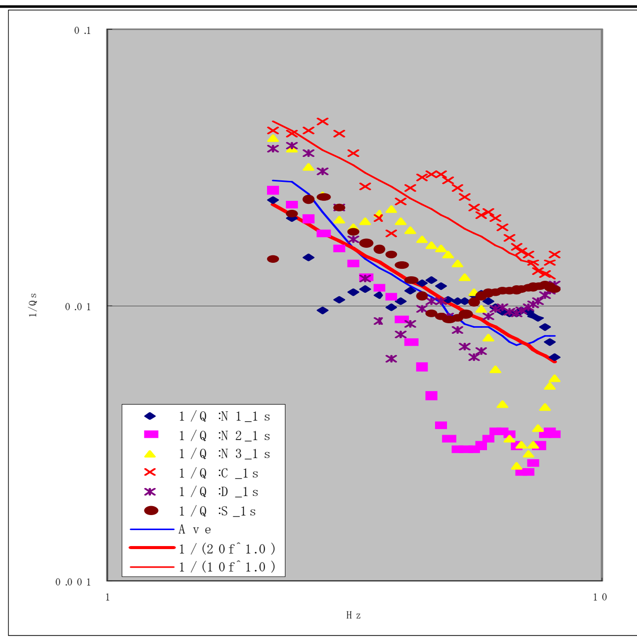


Figure 6 1/Qs obtained for 6 groups. “Ave” means average of all observed curves except C-1.

Result and Interpretation

- The 1/Qs curves obtained for 6 groups are shown in Figure 6. C-1 group shows considerably higher Qs^{-1} values than others. The average of all groups except C-1 (thin blue curve) shows a good fit with Qs=20f (thick red line), whereas C-1 curve (red x) suggests Qs=10f (thin red line) or lower.
- Qs=20f means Qs=20 at 1Hz that is very low for the crust in comparison with the existent result in Japan.
- Izutani (2000) has obtained Qs value at 1Hz approximately 20 and interpreted it by their paths under Kirishima Volcano.
- Uetake and Kudo (2005) obtained similar small values of Qs by spectral inversion and also double spectral ratio.

- They interpreted that these small values represent only shallower part of the crust than the depth of the events used.
- They also mentioned about the trade-off relation between geometrical spreading effect and the attenuation plus scattering and about the possibility of influence of lateral heterogeneity.

In the present studied region, high attenuation part under volcano can not be expected. All the events used in analysis are shallower than 20 Km and the values obtained represent only the shallow part of the crust. The influence of heterogeneity in the crust can be expected. Continuation of Ohchigata fault zone into the crust is a suspect.

• The Qs value less than 10 at 1Hz suggested by the result for C-1 is so small that we can not consider it as the true value of Qs as a material property of the crust even for anomalous part.

• Figure 2 shows two stations and one event located at northerner part than Ochigata fault zone and one event at southerner part. Then, the lateral or/and spatial variation of Qs have to be taken into account.

• The interesting thing is that D-1 having one event and one station at both side of Ochigata fault zone does not show such small Qs value. These configurations can be a keyword to solve the enigma given in this study.

If an anomalous part exists at only shallow part of the crust under Ochigata fault zone and the ray path from the event 2006/03/26/09:44 to TYMH01 passes under it whereas the path from the event 2001/01/22/09:43 to ISKH06 passes through it, the result of C-1 can be explained qualitatively (Figure 7). The following equation derived from Eqs. (4), (5) and (7) supports this idea.

$$Q_s^{-1} = \frac{\overline{V}_s}{\pi f \Delta R} \cdot \ln\left(\frac{P_{11} P_{22}}{P_{12} P_{21}} \cdot \frac{R_{11} R_{22}}{R_{12} R_{21}} \right)$$

However, it is not possible to deny the following influences that are remained un-checked.

- The influence of the radiation pattern can not be evaluated due to lack of information of the focal mechanism for the events used that are smaller than magnitude 3.9.
- That of the hypocenter location error and that of deviation of ray paths from the strait lines between the events and the stations are neither considered. Therefore, figure 7 is just a speculation.

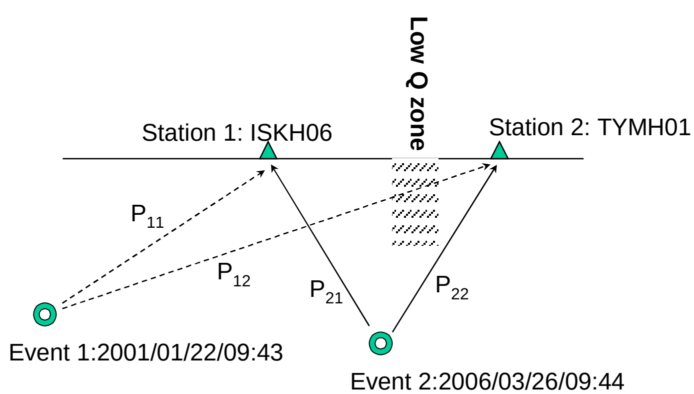
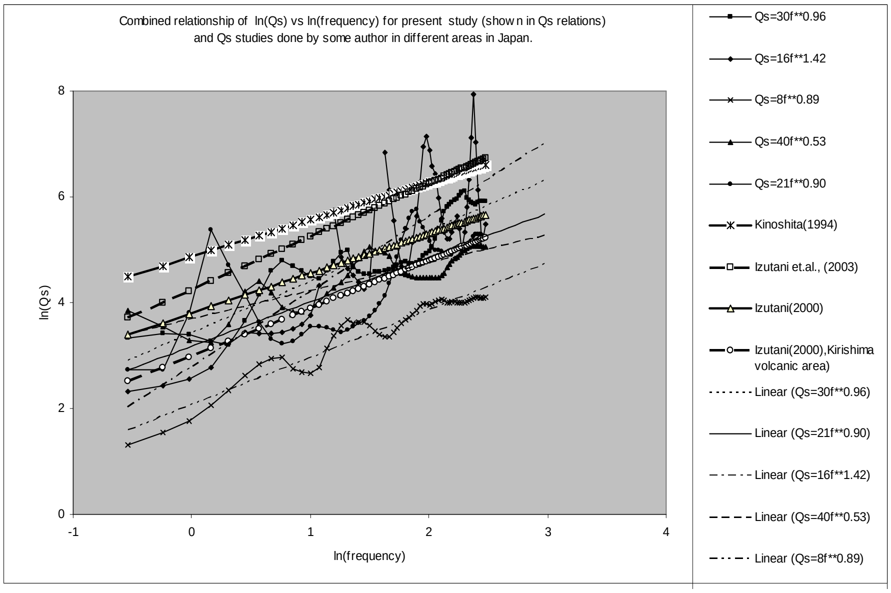


Figure 7 Schematic configuration that can explain the anomalous result of C-1, only quantitatively.

Combined output results of the present study and some work done by other authors in different parts of Japan



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Thank You