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CODA Q OF LOCAL EARTHQUAKES OBSERVED ON THE SOUTHEAST TIBETAN PLATEAU — COMPARISON WITH LÜTZOW-HOLM BAY REGION, EAST ANTARCTICA —

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Abstract: Coda Q of local earthquakes observed at Bomi, southeast Tibetan plateau was evaluated using a single scattering model and compared with that in the Lützow-Holm Bay region, East Antarctica. The results obtained are: (1) Q^{-1} for short lapse time (SLT) from 5 to 50 s shows large dependence on frequency; (2) Q^{-1} for SLT in the Tibetan plateau region is larger than that in the Lützow-Holm Bay region; (3) Q^{-1} for long lapse time from 80 to 160 s in the Tibetan region is nearly the same as that in the Lützow-Holm Bay region. Although there is a need for discussion of coda excitation modeling, all these features are consistent with the general relation between coda Q and regional tectonic activities.

1. Introduction

Seismic coda of local earthquakes is considered as superposition of back-scattered S waves from various inhomogeneities, such as faults, cracks and irregular distribution of seismic velocity and density in the lithosphere (*e.g.* AKI and CHOUET, 1975). Its excitation reflects scattering and attenuation properties over a wide area encompassed by the waves. The decay rate of coda, coda Q, is though to be an indicator of the regional tectonic condition: the regional variation of coda Q has been discussed in relation to tectonic activity and its development (JIN and AKI, 1988; JIN *et al*., 1985; SINGH and HERRMANN, 1983). Generally, the higher the tectonic activity, the larger the attenuation of coda is in the shallow lithosphere.

Recently seismic records observed at Bomi, southwest Tibetan plateau, have become available (AKAMATSU, 1994). The Tibetan plateau is considered to have been raised by the collision of continental plates (MOLNAR and TAPPONNIER, 1975). The Himalaya continues upheaval and the seismic activity is the highest in the continental regions. The crust is found to be very thick (60–70 km) and complicated (ZENG *et al*., 1993). Therefore, it is very interesting to compare the coda Q in the Tibetan region with those in other regions from the viewpoint discussing the relation between coda Q and tectonic activity. Here, we report the characteristics of coda Q observed at Bomi, southeast Tibetan plateau, and compare them with those of the Lützow-Holm Bay region, East Antarctica.

2. Geological Setting and Seismic Activity around Bomi

Figure 1 shows the location of Bomi. Bomi is located on the River Polung Zanbo, a branch of the River Yarlung Zanbo (Brahmaputra), running from ESE to WNW between the mountain ranges of Nianquintanggula (highest peak, 6115 m) and Gangrigabu (6585 m). Rock formations are mainly argillacious rock, phylite and limestone of the Carboniferous and Permian periods with granite formed in the Triassic and Jurassic periods. Huge fracture systems with WNW-ESE strike are developed.

Figure 2 shows the epicentral distribution of shallow earthquakes with $M \geq 4.5$ in southeast Asia from 1964 through 1992. It is seen from the figure that in the continental region most of epicenters are concentrated on the Tibetan plateau, which shows tectonically high activity in this area. In Fig. 3 is shown the frequency distribution of earthquake magnitude around Bomi (AKAMATSU, 1993), from 1981 to 1990; here R is the epicentral distance from Bomi. There occurred 10 events with $M \geq 6.0$ within 1000 km from Bomi, and 58 events with $M \geq 5.0$ within 500 km.

During the ten years from 1983 through 1992, 172 events with $M \geq 6.0$ occurred in and around Japan and 201 events with $M \geq 5.0$ in southwest Japan (JAPAN METEOROLOGICAL AGENCY, 1983–1992). In Antarctica, however, only 13 intraplate earthquakes of $M \geq 4.3$ were detected during the 17 years from 1963 through 1979 (TANI and KAWASAKI, 1984). Therefore, the seismic activity in the southeast Tibetan region appears rather lower than that in southwest Japan and much higher than that in the Lützow-Holm Bay region.

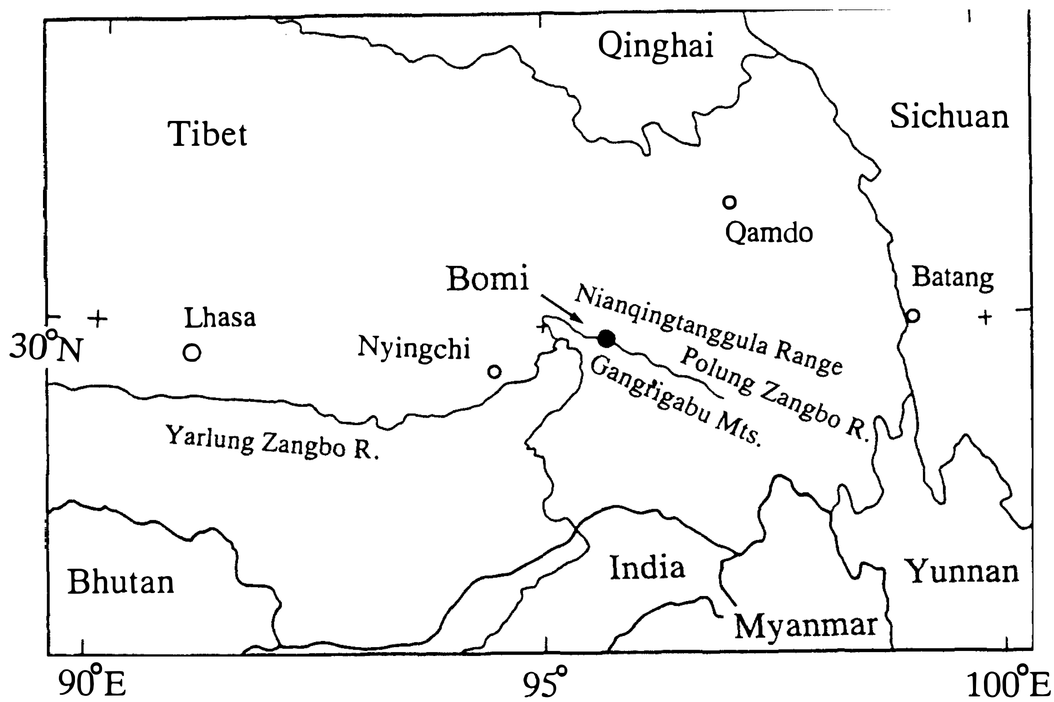

Fig. 1. Location of Bomi, southeastern Tibet.

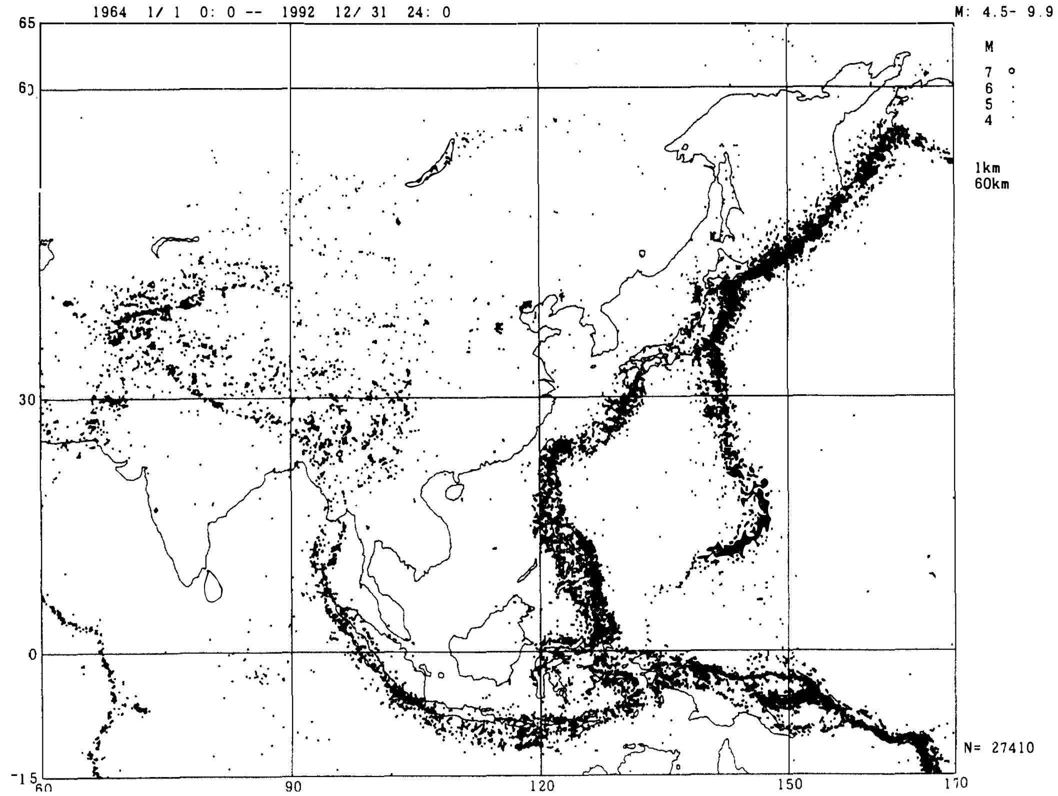

Fig. 2. *Epicentral distribution of shallow earthquakes ($H \leq 60$ km) with $M \geq 4.5$ in southeast Asia during the period from 1964 through 1992 (National Committee of Seismology and Physics of the Earth's Interior, 1993).*

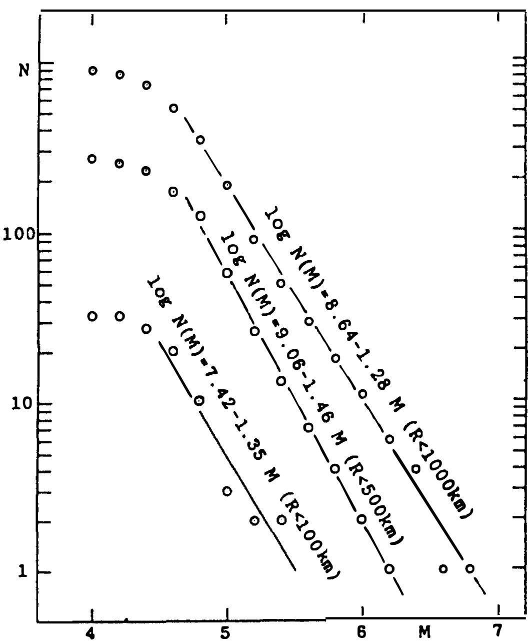

Fig. 3. *Frequency distribution of earthquake magnitude around Bomi from 1981 to 1990. R is the epicentral distance from Bomi.*

3. Seismic Observation at Bomi

Bomi town is on the River Polung Zangbo between mountain ranges. The observation site was located at the foot of the northern range (29°51′.6 N, 95°46′.6 E). Its altitude is about 2700 m. The observation system (Fig. 4) was composed of a 3-component velocity seismometer with a natural period of 1 s and an analog magnetic recorder with ordinary event-trigger equipment (threshold level $=2.0\times10^{-6}$ m/s). The velocity response is flat in the frequency range from 1 to 30 Hz. For the vertical component, high and low amplification channels were available. During the observation period of 101 days from July 20 to November 6, 1992, 89 tectonic earthquakes were recorded.

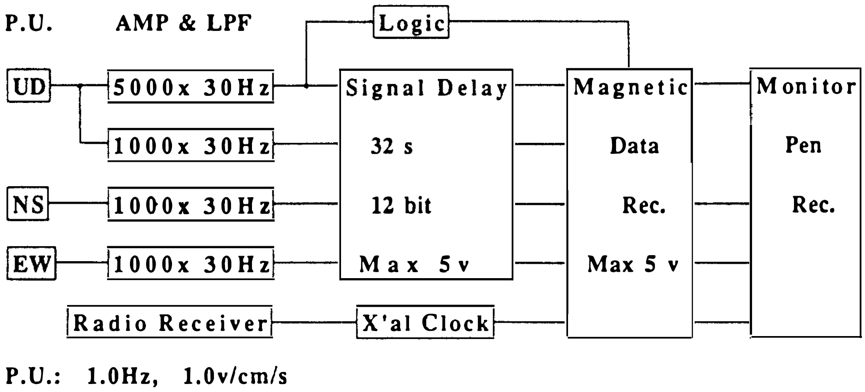

Fig. 4. Seismic observation system at Bomi, southeastern Tibet.

4. Coda Analysis

Assuming single scattering of S waves based on the Born approximation, the bandpass-filtered coda amplitude, $A(f, t)$, can be written:

$$A(f,t)=\sqrt{\frac{V_S}{2}}\sqrt{g(\pi)}S(f)\frac{1}{V_S\cdot t}e^{-\pi f t/Q(f)}, \quad (1)$$

(AKI and CHOUET, 1975), where f is the center frequency of the bandpass filter, t is lapse time measured from source origin time, V_S is S wave velocity, g is the backward scattering coefficient, S is the source spectrum of S waves, and Q is the quality factor. In this formula, the term, $1/V_S\cdot t$, represents the geometrical spreading factor for S wave. Assuming spatial stationarity of g, Q can be estimated by the least square method to the logarithmic RMS amplitude. The center frequencies of the bandpass filter used are 1, 2, 4, 8, 16 and 24 Hz. Analyzing intervals are from 2 times t_{S-0} (travel time of direct S wave) to the time when the S/N ratio falls below 3. We analyzed 48 vertical records (high and low amplification channels) from 31 local events. Figure 5 shows an example of bandpass-filtered seismograms and least square fitting to logarithmic RMS amplitude. Table 1 list the results thus obtained for the frequency band of 8 Hz. M in the table is the duration magnitude proposed by TSUMURA (1967).

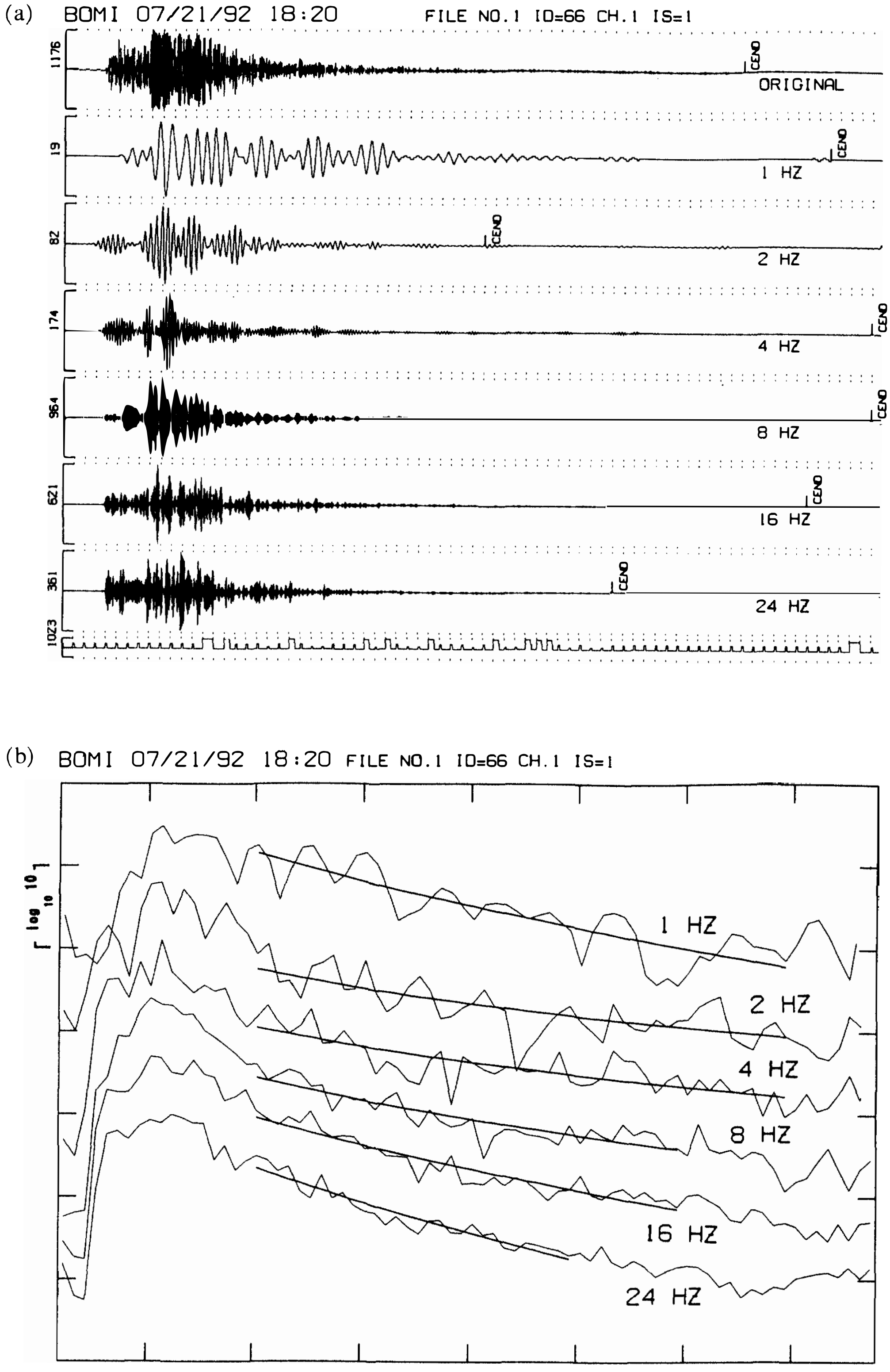

Fig. 5. An example of bandpass-filtered seismograms (a) and least square fitting to logarithmic RMS amplitude (b). RMS amplitude is obtained with 1 s moving time window.

Table 1. Coda Q of 8 Hz in the southeast Tibetan region.

No.	Date M D Y	Time HM	CH	*M*	T_{s-p} s	2^*T_{s-o} s	Interval s	$100/Q$
1	11/02/92	1634	H	2.3	1.0	4.8	5- 15	0.1008
2	09/24/92	1913	L	2.3	1.1	5.3	5- 25	0.2357
	09/24/92	1913	H	2.3	1.1	5.3	5- 25	0.2793*
3	10/22/92	0053	H	2.0	1.3	6.2	7- 25	0.2152*
4	10/22/92	0429	H	2.1	1.3	6.2	7- 30	0.2523*
5	10/21/92	1939	H	1.5	1.4	6.7	7- 25	0.0947*
6	10/14/92	0525	H	1.7	1.5	7.2	7- 25	0.2709*
7	09/07/92	1852	H	2.2	2.3	11.0	12- 30	0.0864*
8	08/22/92	1455	H	2.4	2.6	12.5	15- 40	0.1623*
9	08/31/92	0231	H	1.8	2.6	12.5	15- 35	0.1504*
10	08/24/92	1133	H	2.0	2.7	13.0	13- 30	0.1341
11	09/18/92	1724	H	2.1	2.7	13.0	13- 30	0.2360
12	08/22/92	0506	H	2.1	2.8	13.4	15- 35	0.2307*
13	10/23/92	2242	H	1.9	2.8	13.4	15- 40	0.1854*
14	08/25/92	1229	H	2.1	3.3	15.8	15- 35	0.1733*
15	10/06/92	1305	H	3.2	3.8	18.2	20- 50	0.1504*
16	07/21/92	1820	L	3.2	3.9	18.7	20- 60	0.0920*
	07/21/92	1820	H	3.2	3.9	18.7	25- 70	0.0748
17	08/08/92	1236	L	3.1	4.9	23.5	25- 45	0.2059
	08/03/92	1236	H	3.1	4.9	23.5	25- 50	0.1434*
18	08/11/92	0901	H	3.1	5.2	25.0	25- 45	0.1696*
19	09/14/92	0914	H	3.0	9.3	44.6	45- 60	−0.1281
20	10/23/92	2123	H	3.1	10.2	49.0	50- 75	0.0484
21	08/11/92	2211	H	2.6	11.5	55.2	55- 75	0.1790
22	08/22/92	2235	H	3.0	11.7	56.2	50- 80	0.0554
23	10/01/92	1925	H	3.1	11.7	56.2	55- 75	0.1359
24	09/25/92	0859	L	3.8	11.9	57.1	55- 75	0.1481
	09/25/92	0859	H	3.8	11.9	57.1	55- 75	0.1457
25	08/23/92	0328	H	3.1	12.0	57.6	60- 75	0.1875
26	08/26/92	2352	L	3.8	12.4	59.5	60- 95	0.1552
	08/26/92	2352	H	3.8	12.4	59.5	60-100	0.1898
27	10/28/92	0953	H	4.0	12.7	61.0	60-100	0.0690
28	11/02/92	0607	H	2.8	13.0	62.4	60- 80	0.1432
29	08/23/92	0132	L	4.0	14.2	68.2	60- 80	0.2169
	08/23/92	0132	H	4.0	14.2	68.2	60- 85	0.1622
30	10/05/92	0433	H	4.3	16.7	80.2	80-130	0.0977⁼
31	09/08/92	2330	L	4.4	19.0	91.2	100-160	0.0915
	09/08/92	2330	H	4.4	19.0	91.2	100-160	0.0940⁼
32	08/29/92	1453	L	4.3	20.6	98.9	100-140	0.0533
	08/29/92	1453	H	4.3	20.6	98.9	100-140	0.0646⁼
33	08/31/92	1906	H	3.5	20.6	98.9	95-120	0.0398⁼

M: Duration magnitude, H and L: channels of high and low gain, respectively, T_{s-p}: *S-P* time, T_{s-o}: travel time of direct *S* wave, Interval: analyzing time interval measured from source origin time. * and ⁼ represent the events used for calculation of mean Q^{-1} for SLT and LLT shown in Table 2, respectively.

5. Coda Q in Southeast Tibetan Region

Figure 6 shows an example of the dependence of Q^{-1} on analyzing intervals. Q^{-1} totally decreases with time. This is a commonly observed feature and is considered that, the coda waves of larger lapse time traverse the deeper part of the lithosphere where the inhomogeneity is believed to be relatively small. The difference in Q^{-1} between events is expected to reflect that, coda waves from each event cover their respective regions characterized by different attenuation and scattering properties. When the analyzing intervals are short, however, coda Q is largely affected by the fluctuation property of scattering waves. This phenomenon is considered to be attributable partly to the amplitude fluctuation of wave field (CHERNOV, 1960) and mainly to inhomogeneous distribution of scatterers. Therefore, we calculated the mean values of coda Q for a given lapse time, T, under the following conditions: (1) the analyzing interval, TL, is sufficiently long; TL for 1, 2, 4, 8, 16 and 24 Hz is longer than about 30, 25, 20, 20, 15 and 15 s, respectively, and (2) the starting time of the analyzing interval, TS, is nearly the same for each event; $T-TS \leqq 20$ s. As a result, the number of analyzed seismograms varied with f and T. Table 2 and Fig. 7 show Q^{-1} for $T=20$ s (short lapse time, SLT; 5–50 s) and 100 s (long lapse time LLT; 80–160 s). In Fig. 7, Q^{-1} of the Lützow-Holm Bay region for short lapse time (10–50 s) and long lapse time (150–210 s) are also shown for comparison.

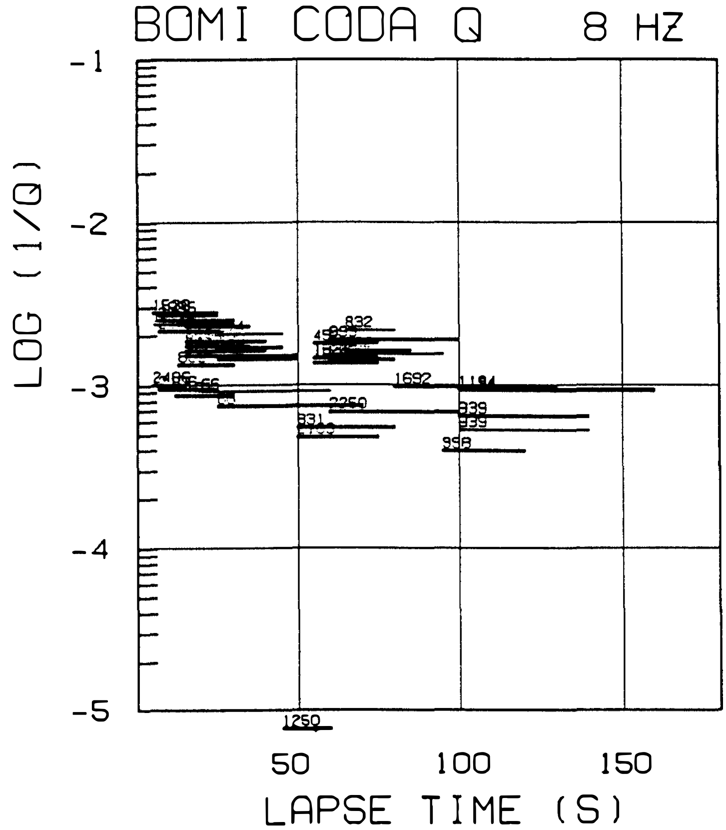

Fig. 6. Dependence of Q^{-1} on lapse time for 8 Hz band.

Table 2. Mean Q^{-1} in the southeast Tibetan region for short and long lapse times.

Band	$T=20$ s		$T=100$ s	
	N	Q^{-1}	N	Q^{-1}
1 Hz	5	0.006059 ± 0.007618	4	0.003329 ± 0.001570
2 Hz	6	0.003122 ± 0.004493	4	0.002868 ± 0.002733
4 Hz	13	0.003292 ± 0.002873	4	0.001295 ± 0.000225
8 Hz	15	0.001771 ± 0.000602	4	0.000740 ± 0.000236
16 Hz	17	0.001061 ± 0.000387	4	0.000422 ± 0.000064
24 Hz	17	0.000745 ± 0.000159	4	0.000204 ± 0.000151

N : Amount of data analyzed.

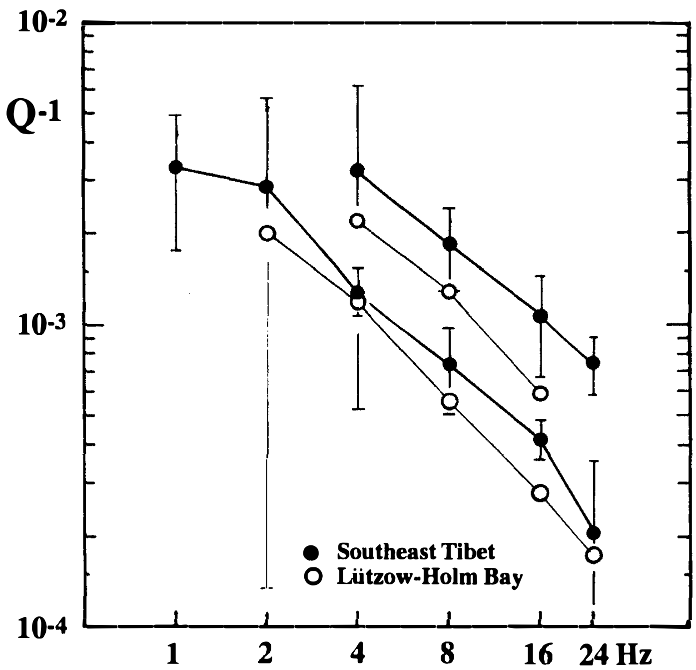

Fig. 7. Q^{-1} in the southeast Tibetan region for short lapse time (SLT) and long lapse time (LLT). Q^{-1} in the Lützow-Holm Bay region, East Antarctica is also shown for comparison.

6. Comparison of Coda Q between Southeast Tibetan Region and Lützow-Holm Bay Region

Taking S wave velocity into account, Q^{-1} for SLT and LLT may mainly reflect the attenuation and scattering properties of the crust and the upper mantle, respectively.

Many observations show that Q^{-1} in the crust and the uppermost mantle in the lower frequency range varies extensively depending on regional tectonic activity. Namely, Q^{-1} at about 1 Hz in active regions is higher than that in stable regions, while the difference in Q^{-1} in the higher frequency range of 20–30 Hz is not so large. Consequently, the dependence of Q^{-1} on frequency is large in a tectonically active region (see Fig. 6 of JIN *et al*., 1985). As seen in Fig. 7, Q^{-1} for SLT decreases rapidly with increase of frequency ($Q^{-1}=0.01 f^{-0.81}$). This seems to reflect the characteristics of high tectonic activity in the Tibetan region as expected from the general tendency of coda Q.

In East Antarctica, Q^{-1} for short lapse time is lower than that of Tibet in all frequency bands. Contrary to the general relation between coda Q and tectonic activity, and to the extremely low activity in the shield area, the dependence of Q^{-1} on frequency is large ($Q^{-1}=0.008\,f^{-0.90}$). This apparently large frequency dependence is due to the fact that Q^{-1} in the higher frequency range in East Antarctica is very small, as discussed by AKAMATSU (1991a, b).

In Fig. 7, Q^{-1} values for LLT in Tibet are mean values of 80–160 s, and Q^{-1} values of long lapse time in East Antarctica are those of 150–210 s. Although there is differences in analyzing intervals and the crustal thickness between these areas, Q^{-1} values in Tibet and East Antarctica are considered to be nearly the same. Therefore, according to the assumption of single scattering, the attenuation and scattering properties in the upper mantle resemble each other between these areas.

The above discussion was based on the single scattering assumption. For a long lapse time range, however, the effect of multiple scattering plays an important role in coda generation (GAO *et al*., 1983). In particular, as the crust of the Tibetan plateau with large Q^{-1} is thick (60–70 km), the coda waves of LLT may be affected to a considerable extent by the multiple scattering. Q^{-1} for long lapse time range should be studied with appropriate multiple scattering modeling. Therefore, the direct comparison of the attenuation and scattering properties for the upper mantle between Tibet and East Antarctica is open to discussion.

7. Conclusions

Coda Q for the southeast Tibetan region was studied using a single scattering model, and compared with coda Q for the Lützow-Holm Bay region, East Antarctica. The following results were obtained:

(1) Q^{-1} decreases with increase of lapse time measured from source origin time, suggesting relatively weak inhomogeneities in the deeper part of the lithosphere.

(2) Q^{-1} for short lapse time from 5 to 50 s shows large dependence on frequency, which is consistent with the general tendency of coda Q observed in tectonically active regions.

(3) Q^{-1} for short lapse time is larger than that in the Lützow-Holm Bay region, showing the difference in tectonic activity between Tibet and East Antarctica.

(4) Q^{-1} for long lapse time from 80 to 160 s is nearly the same as that in the Lützow-Holm Bay region. Although the coda waves of long lapse time are affected by multiple scattering, the single scattering modeling suggests nearly the same attenuation and scattering properties of the upper mantle in the two regions.

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