ATTENUATION OF LG WAVES IN THE EASTERN TIBETAN PLATEAU

Jiakang Xie

Lamont-Doherty Earth Observatory of Columbia University

Sponsored by The Defense Threat Reduction Agency

Contract No. DSWA01-98-1-0006

ABSTRACT

In the past year I have been processing a large amount of regional/teleseismic data from various broadband seismic stations in eastern Eurasia. Fourier spectra of Pn, Lg and Pg waves were computed for many events and paths to study path attenuations. Among the data collected and processed are Lg spectra collected from the 1991-1992 Tibetan Plateau Passive Experiment. Using these spectra and a standard two-station method that virtually eliminates source and site effects, I obtain a model of $Q_0 = (126 \pm 9)$ and $\eta = (0.37 + -0.02)$ in a frequency range between 0.2 and 3.6 Hz, where Q_0 and η are Lg Q at 1 Hz and its power-law frequency dependence, respectively. The estimated Q_0 value is among the lowest ever reported for continental areas; it qualitatively supports the observation by McNamara *et al.* (1996) that Lg can not be observed inside the plateau beyond about 700 km, a limiting distance that is much shorter than those in the other low Q_0 (~ 200) regions, such as Iran and the western U.S.

Quantitatively, the estimated Q_0 value is lower by a factor of 3 than the values of 366 estimated by McNamara *et al.* (1996), who used data from the same experiment. Since there are several differences in the data processing and inversion procedures used in this and the previous studies, I investigated the effects of these differences on the Q estimates. I conclude that the most probable cause of the discrepancy is in the different inverse methods used. This is so because the previous inversion allowed the source and site terms to be free parameters solved for. Since 20 events, 8 stations and 5 frequency bands were used, the unknown source and station terms should be more than 100. In this study only two free parameters (Q_0 and η) are solved for, thus avoiding the instability caused by parameter trade-offs.

This research suggests that the previously observed Lg blockage for paths crossing the northern boundary of the plateau may be partially or entirely caused by the abnormal low Lg Q. Further research on lateral and depth variations of crustal Q in and around the Tibetan Plateau is highly recommended.

KEY WORDS: Lg Q, Tibetan Plateau, Lg blockage, Central Asia.

OBJECTIVE

The primary objective of this research is to quantify path attenuation of regional waves in continental areas, such as Eurasia, by developing digital tomographic Q maps. The proposed research include (a) various improvements of the methods for measuring path-variable Q_0 and η (Q at 1 Hz and its power-law frequency dependence, respectively) using regional wave spectra, (b) applications the improved methods to regional waves paths in Eurasia to measure Q_0, η, and (c) to input the measured Q values to a computerized tomographic algorithm, to obtain laterally varying Q maps for Lg and other regional waves.

This research provides important input to the world-wide monitoring of nuclear explosions. The tomographic Q maps can be used for the calculation of source spectral characteristics of any future seismic event to infer the nature and size of the event. These Q maps can also be used for estimating the detection

Report Documentation Page			*Form Approved OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.			
1. REPORT DATE **16 MAR 03**	2. REPORT TYPE **Unknown**		3. DATES COVERED **2 Oct 2001 - 5 Oct 2001**
4. TITLE AND SUBTITLE **Attenuation Of LG Waves In The Eastern Tibetan Plateau**			5a. CONTRACT NUMBER **DSWA01-98-1-0006**
			5b. GRANT NUMBER
			5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Jiakang Xie**			5d. PROJECT NUMBER
			5e. TASK NUMBER
			5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Lamont-Doherty Earth Observatory of Columbia University**			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **Defense Threat Reduction Agency**			10. SPONSOR/MONITOR’S ACRONYM(S)
			11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**			
13. SUPPLEMENTARY NOTES			

14. ABSTRACT

In the past year I have been processing a large amount of regional/teleseismic data from various broadband seismic stations in eastern Eurasia. Fourier spectra of Pn, Lg and Pg waves were computed for many events and paths to study path attenuations. Among the data collected and processed are Lg spectra collected from the 1991-1992 Tibetan Plateau Passive Experiment. Using these spectra and a standard two-station method that virtually eliminates source and site effects, I obtain a model of Q0 = (126 ± 9) and h= (0. 37 + -0. 02) in a frequency range between 0.2 and 3.6 Hz, where Q0 and hare Lg Q at 1 Hz and its power-law frequency dependence, respectively. The estimated Q0 value is among the lowest ever reported for continental areas; it qualitatively supports the observation by McNamara et al. (1996) that Lg can not be observed inside the plateau beyond about 700 km, a limiting distance that is much shorter than those in the other low Q0 (~ 200) regions, such as Iran and the western U.S. Quantitatively, the estimated Q0 value is lower by a factor of 3 than the values of 366 estimated by McNamara et al. (1996), who used data from the same experiment. Since there are several differences in the data processing and inversion procedures used in this and the previous studies, I investigated the effects of these differences on the Q estimates. I conclude that the most probable cause of the discrepancy is in the different inverse methods used. This is so because the previous inversion allowed the source and site terms to be free parameters solved for. Since 20 events, 8 stations and 5 frequency bands were used, the unknown source and station terms should be more than 100. In this study only two free parameters (Q0 and h) are solved for, thus avoiding the instability caused by parameter trade-offs. This research suggests that the previously observed Lg blockage for paths crossing the northern boundary of the plateau may be partially or entirely caused by the abnormal low Lg Q. Further research on lateral and depth variations of crustal Q in and around the Tibetan Plateau is highly recommended.

15. SUBJECT TERMS **Lg Q, Tibetan Plateau, Lg blockage, Central Asia.**					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

threshold of the existing seismic stations located within the area studied.

RESEARCH ACCOMPLISHED

Over the past I have continued data collection and inversion for Lg Q in Eurasia. In this paper I report analysis of a data set that consists of Lg spectra from 11 broadband PASSCAL seismic stations deployed during the 1991-1992, passive Tibetan Plateau experiment (McNamara et al., 1996). In an effort to invert for source spectra, I found that the data required that the Lg Q in eastern Tibet be re-measured.

A robust, two-station method is used. Ideally the method uses stacked spectral ratios (SSR, see equations (10)-(17) of Xie and Mitchell, 1990) that are calculated using two-station pairs that are aligned to the same event-to-station azimuths. In practice the SSRs are obtained by requiring that, the differences between the azimuths from the same events to the two stations are smaller than a preset maximum allowable value, $(\delta\theta)_{\max}$. The choice of $(\delta\theta)_{\max}$ is less restrictive for the Lg than for many other phases, since the Lg contains a minimal source radiation pattern in 3D structures. In this study two different values of $(\delta\theta)_{\max}$ of 30° and 12° are used. These values result in 37 and 22 two-station pairs from the data set, respectively. SSRs are formed and used to fit $Q_{Lg}(f)$ models. Figure 1 shows the path coverage by the two sets of SSRs, and Figure 2 shows the SSRs and the fit of the $Q_{Lg}(f)$ models. SSRs obtained with $(\delta\theta)_{\max} = 30°$ are fitted by

$$Q_{Lg}(f) = (126 \pm 9) f^{(0.37 \pm 0.02)} \qquad 0.2 Hz \leq f \leq 3.6 Hz \ .$$

SSRs obtained with a $(\delta\theta)_{\max}$ of 12° are very similar to those with a $(\delta\theta)_{\max}$ of 30° (Figure 2), and are fitted by a $Q_{Lg}(f)$ with Q_0 of (134 ± 10) and η of (0.32 ± 0.02), respectively. These values are virtually the same as those in equation (1), but are theoretically more subject to random errors and bias owing to a smaller dataset. $Q_{Lg}(f)$ in equation (1) is therefore my preferred model. This model is in agreement with the short limiting distance of about 700 km for Lg observation in the study area reported by McNamara et al (1996), and the recent Q_0 estimates by Fan and Lay (2001).

Xie (2001) discussed in detail about several possible reasons why the Q model in this paper differs from a previous one, and concluded that the most likely cause is a parameter trade-off in certain inverse schemes.

CONCLUSIONS AND RECOMMENDATIONS

The Q_0 value of about 126, estimated for the eastern Tibetan plateau in this study, is among the lowest ever documented for any continental areas. An implication of this low value is that the well-known "blockage" of Lg for paths crossing the boundaries of the plateau (e.g., Ruzaikin et al., 1977; Ni & Barazangi, 1983) may be largely, or even entirely, attributed to the low Q_0 values in the plateau (see Figure 3 for a detailed discussion). Another implication of the low Q_0 is that the crust in Tibet may be characterized by higher-than-normal temperature and fluid content, which are responsible for the low Q_0 values. These are in line with the electral conductivity measurements, and suggests that Lg Q should vary laterally, sometimes drastically, in the Tibetan plateau.

Future research should be directed to analyzing more seismic data from recent seismic experiments in the plateau, to resolve details of the lateral variations of $Q_{Lg}(f)$ in the plateau.

REFERENCES

Fan, G.W. and T. Lay, (2001), Characteristics of Lg attenuation in the Tibetan Plateau, J. Geophys. Res., submitted.

Kennett, B.L.N., (1986), Lg waves and structural boundaries, Bull. Seism. Soc. Am., 76, 1133-1141.

McNamara, D.T., T. J. Owens and W.R. Walter (1996), Propagation characteristics of Lg across the Tibetan Plateau, Bull. Seismol. Soc. Am., 86, 457-469.

Ni, J. & Barazangi, M. (1983), High-frequency seismic wave propagation beneath the Indian shield, Himalayan arc, Tibetan plateau and surrounding regions: high uppermost mantle velocities and efficient Sn propagation beneath Tibet, Geophys. J. R. Astr. Soc, 72, 665-689.

Ruzaikin, A.I., Nersesov, I.L., Khalturin, V.I. & Molnar, P. (1977), Propagation of Lg and lateral variation in crustal structure in Asia, J. Geophys. Res., 82, 307-316.

Xie, J. and B.J. Mitchell (1990), Attenuation of multiphase surface waves in the Basin and Range Province, part I: Lg and Lg coda, Geophys. J. Int., 102, 121-137.

Xie, J. (2001), Lg Q in the Eastern Tibetan Plateau, Bull. Seism. Soc. Am., submitted.

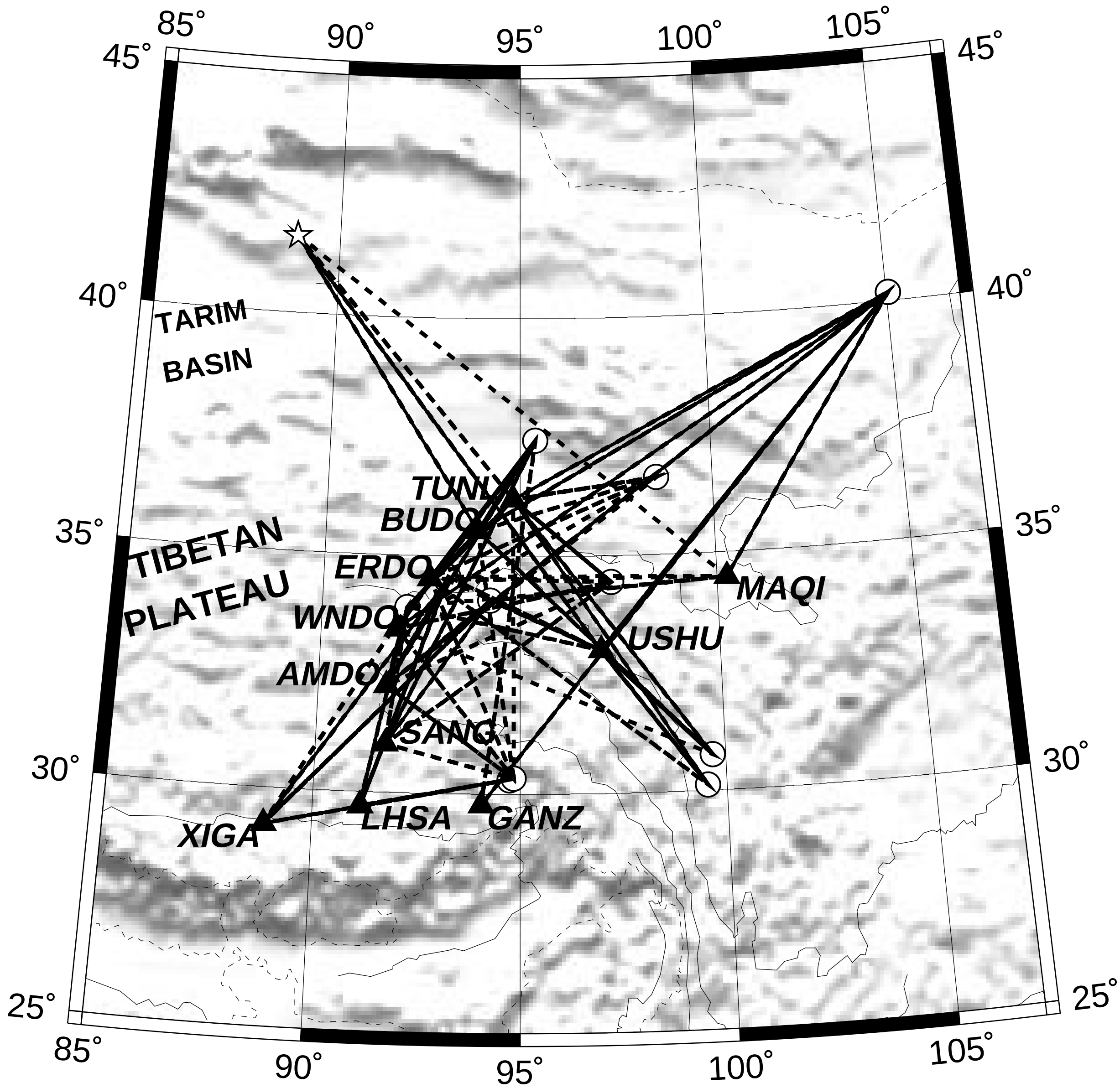

Figure 1. Locations of the PASSCAL stations deployed during the 1991-1992, passive Tibetan Plateau experiment (solid triangles), earthquakes (open circles) and explosion (star) used in this study. Solid paths are those satisfying a $(\delta\theta)_{max}$ (the maximum allowable difference between the event-to-station azimuths of two stations; see text) of 12° when two-station pairs are selected. Dashed paths are those satisfying a $(\delta\theta)_{max}$ of 30°. More information of the stations and events can be found in McNamara *et al.* (1996).

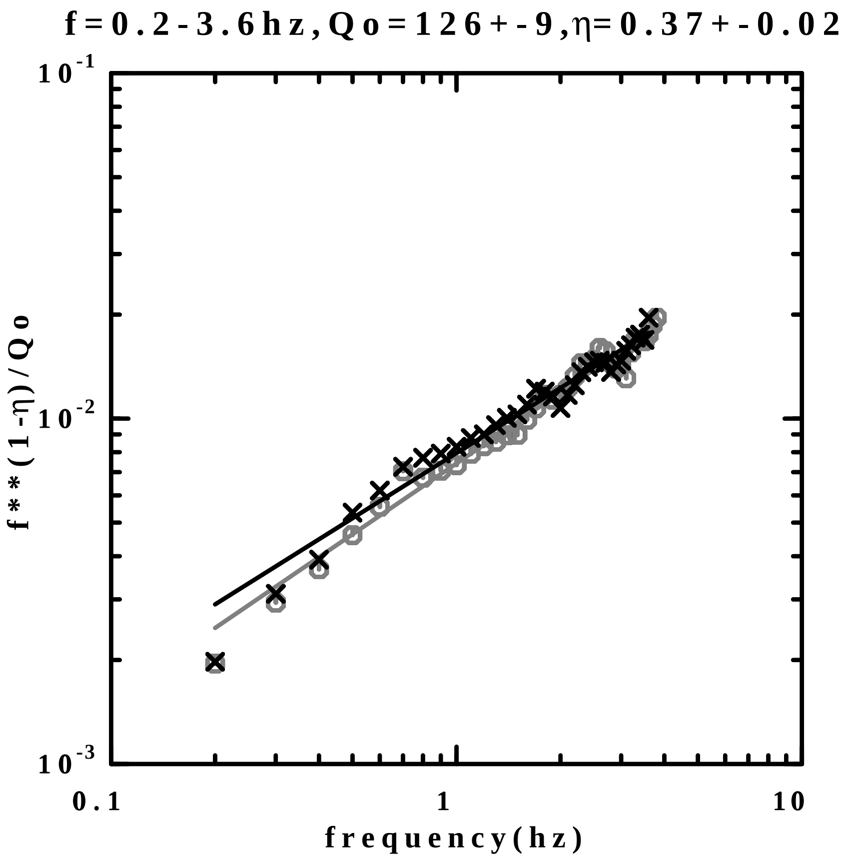

Figure 2. Stacked spectral ratios (SSRs) from many two-station pairs plotted in Figure 1, and the fit of best Q models (straight lines). Black and gray symbols are SSRs obtained using a $(\delta\theta)_{max}$ of 30° and 12°, respectively. The Q models from fitting both sets of SSRs are similar. The Q model written on the top of the panel is from fitting the black symbols.

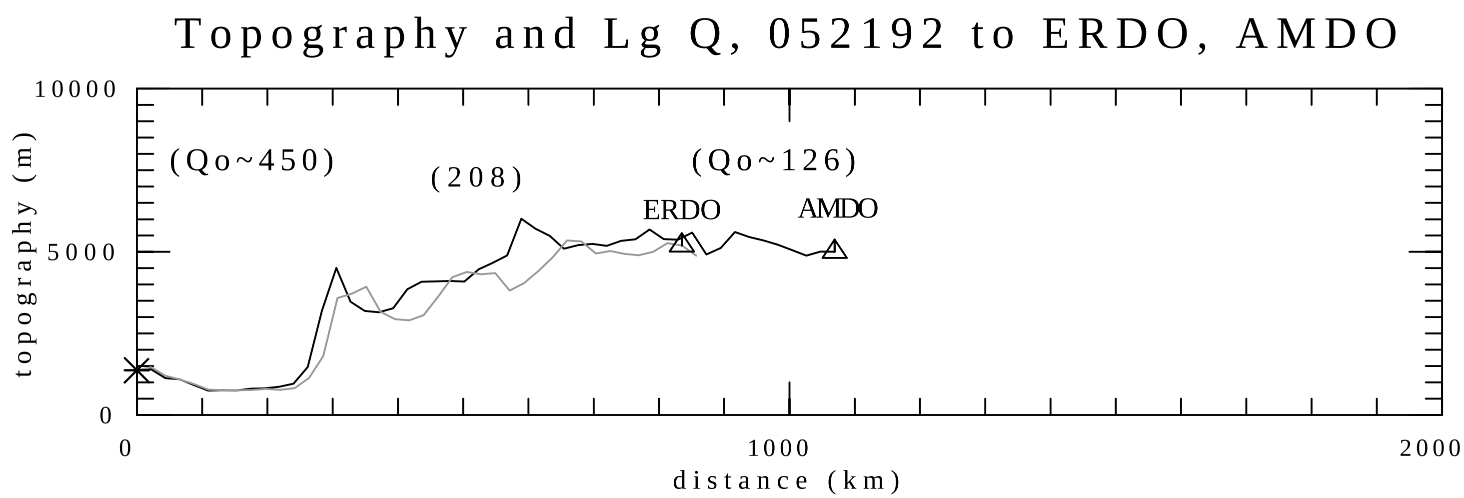

Figure 3. Figure showing a scenario for the Lg blockage across the northern boundary of the Tibetan Plateau. Plotted are topographic profiles from the 052192 Lop Nor explosion (asterisk; also see star in Figure 1) to stations ERDO (curve in gray), and AMDO (curve in black). The observed Lg amplitudes show a partial blockage at ERDO, and complete blockage at AMDO. The numbers in parentheses are Lg Q_0 values. The left segments of the profiles are in the Tarim Basin where Q_0 should be about 450 or higher from previous works. Between stations ERDO and AMDO, Q_0 should be close to 126 (this study). Using these Q_0 values and the spectral amplitude in the expected Lg window at AMDO, I estimate that Q_0 between the topographic boundary and station ERDO is 208 or lower. This means a low average Q_0 value in the plateau of between 126 and 208 is capable to block Lg at AMDO. Therefore, a strong scattering at the topographic boundary is not required. This is consistent with the simulation of, e.g., Kennett (1986), who shows that the scattering is unlikely to fully account for the blockage.