ESTIMATION OF SEISMIC ATTENUATION FROM VSP DATA

Xiao-Ping Li
University of Karlsruhe, Geophysical Institute, Hertzstr. 16, 76187 Karlsruhe, Germany

April 6, 1993

Introduction

The seismic attenuation was investigated in the KTB (German Continental Deep Drilling Program)-Oberpfalz in Eastern Bavaria using the Vertical Seismic Profile (VSP)-measurements, which have been completed during drilling operations of the KTB pilot hole down to 4000 m and main borehole down to 6013 m. Those large data sets allowed us to compute a complete profile of mean crustal attenuation. I report here only the results from analysing the two main measurements known as VSP3600 and VSP6000.

Depth-dependent attenuation

VSP3600 (figure 1) was recorded with a sampling rate of 0.5 ms in the pilot hole within the 85-3623 m depth interval using a dynamite source, and VSP6000 (figure 2) with a sampling rate of 2 ms in the main hole between 3000 and 6000 m using a vibrator source (sweep frequency 8-123 Hz). Both surveys were obtained with an offset of 200 m using three-component geophones and 12.5 m geophone spacing.

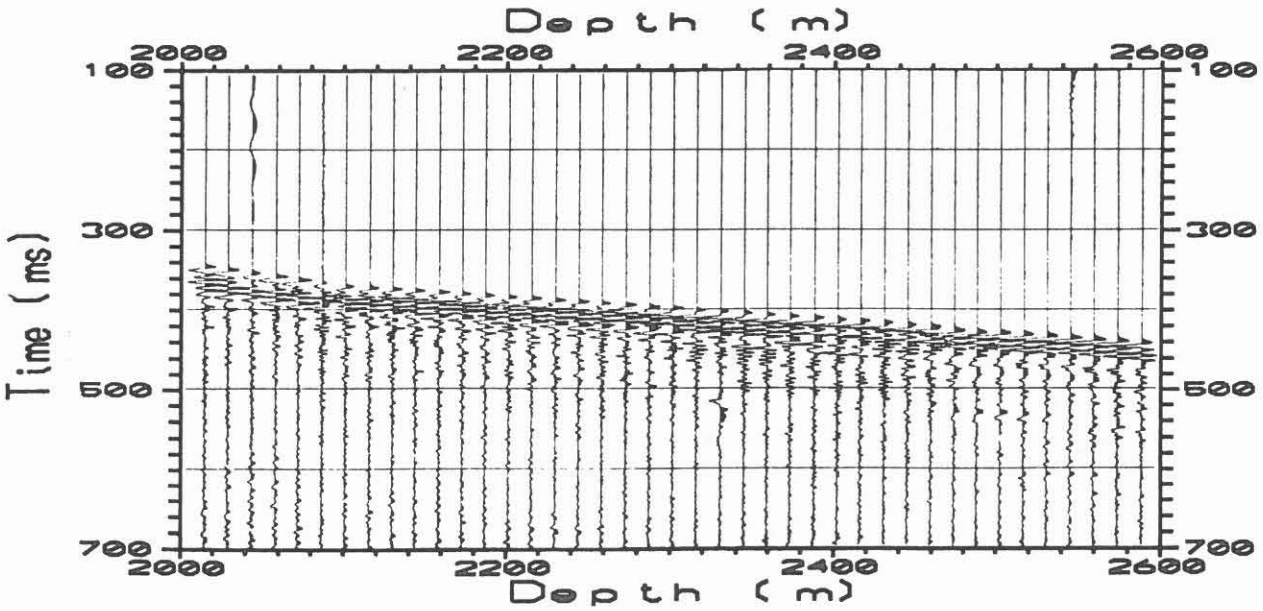

Figure 1: *Selected traces of VSP3600 (depth 2023-2598 m)*

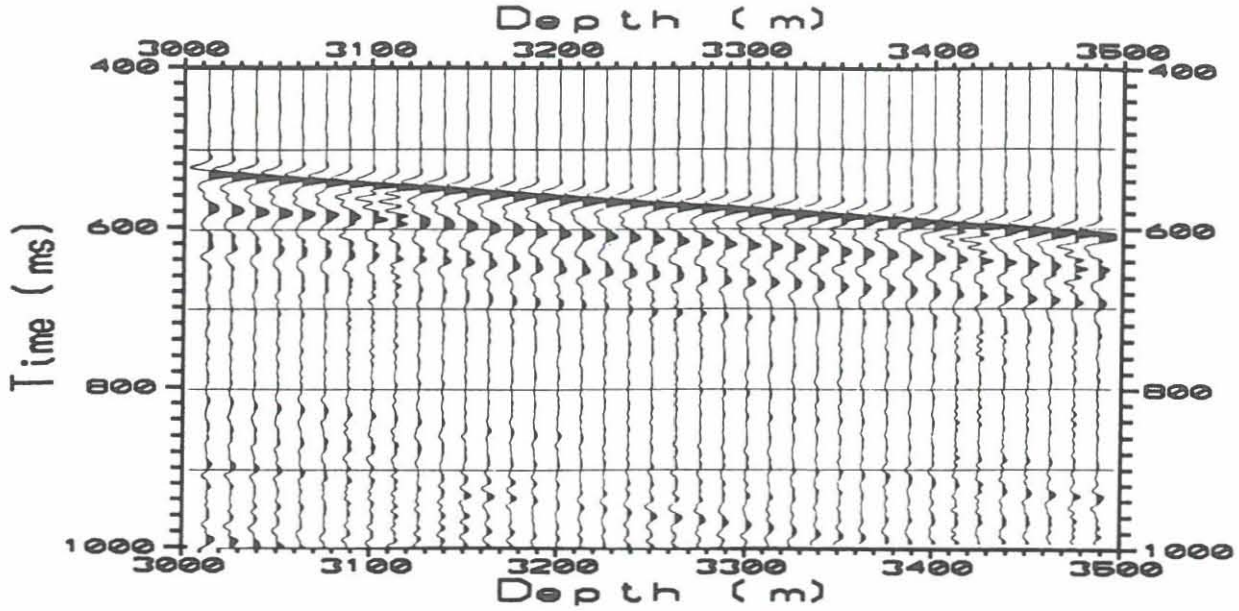

Figure 2: *Selected traces of VSP6000 (depth 3013-3488 m)*

A time window with 5 ms cosine taper was used to isolate the basic downhole wavelet (first arrival) from other interfering wavelets that may follow it, such as multiply scattered waves, which have longer travel time. The length of the time window was selected 60 ms for VSP3600 and 90 ms for VSP6000. The computation of attenuation coefficients is based on fitting a straight line to the logarithm of amplitude ratios computed for a fixed depth over the frequency range 30-150 Hz for VSP3600 and 10-80 Hz for VSP6000, where the quality factor Q was found to be constant (figure 4). Figure 3 shows a complete profile of attenuation coefficients down to 6000 m combined from the data of the pilot borehole with those of the main borehole. The transition between 3000 m and 3623 m depth of the two curves of attenuation seems to be well correlated. The attenuation profile decreases generally with depth. Measured values of attenuation vary in a range from less than 0.03 to 2.1 dB/λ (λ-wavelength), corresponding Q varies from 13 to 927. The values of Q are distributed mostly between 30 and 300. The strongest contrasts on the attenuation profile can be correlated with lithological boundaries and the strong scattered values of attenuation between 3000-4000m correspond to fracture zones (fluid systems).

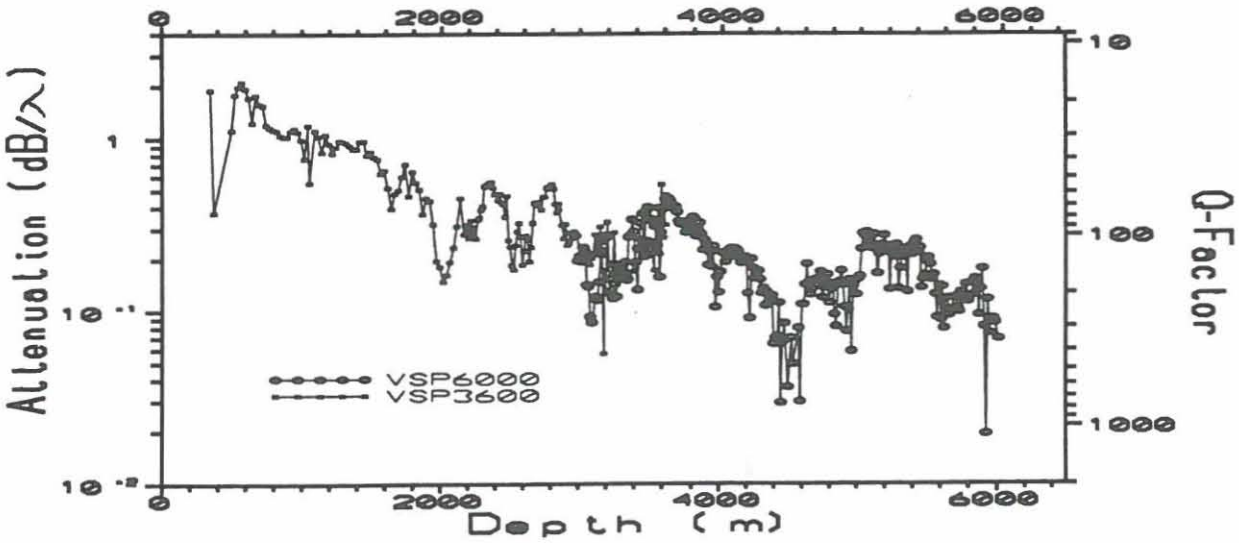

Figure 3: *Depth-dependent attenuation computed from VSP3600 and VSP6000*

Frequency-dependent attenuation

The maximum RMS (root mean square) amplitude ratio method was used to study the frequency dependence of mean Q. In this case the seismograms were bandpass filtered using a Gaussian filter (Dziewonski et al. 1969) at different central frequencies. Furthermore, RMS amplitudes were generated for the filtered outputs in each frequency band. The attenuation coefficients were measured by fitting a straight line to the logarithm of the maximum RMS amplitude ratio, which is a function of depth. The results from both VSPs show approximately the same trend (figure 4). The

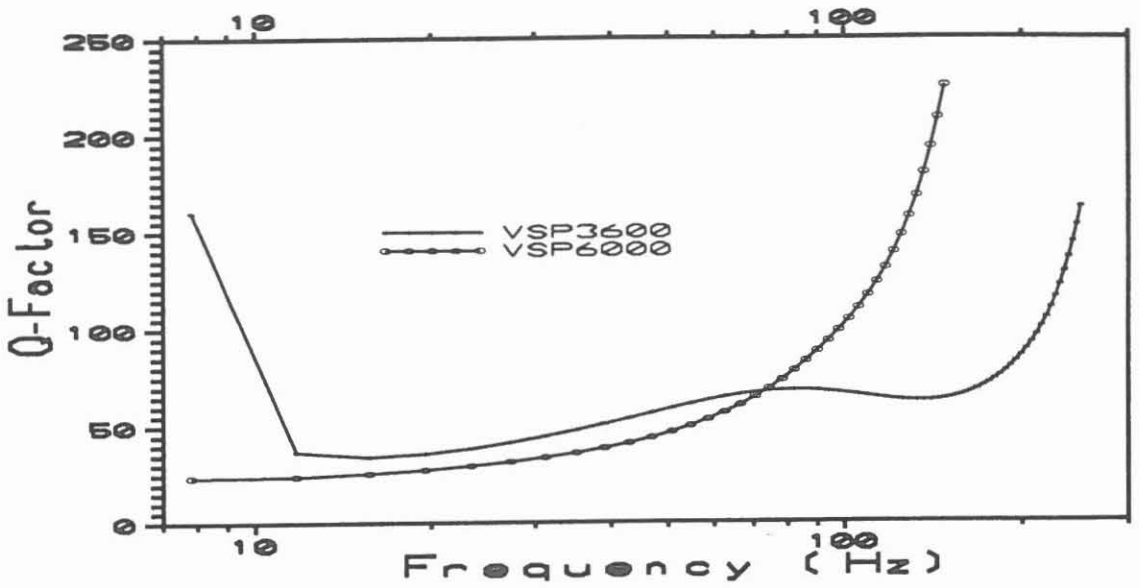

Figure 4: *Frequency-dependent attenuation*

mean Q does not depend strongly on the frequency if we consider the main frequencies of VSP3600 (140 Hz) and VSP6000 (40 Hz). Especially, some important observations can be obtained from the attenuation of VSP3600, i.e, seismic waves are more attenuated at low frequencies than at high frequencies. One can expect better identification of reflection events in this frequency range than at low frequency, and there will be different responses for the correlation of the reflection events in different frequency ranges, which have been made (Söllner et al., 1992) during the processing phase for KTB-VSPs with dynamite sources.

ACKNOWLEDGMENTS

This work was supported by the project of the 'Deutsche Forschungsgemeinschaft (DFG)', entitled 'The DFG-priority program of the KTB' under grant No. Hu 413/2-1. I thank the KTB-management for permission to use the VSP-data.

REFERENCES

Söllner, W., Lüschen, E., Li, X.-P., Hubral, P., Gut, T.W., and Widmaier, M. (1992): VSP - A link between seismic reflection profiling and lithology: in Dübraum, H.-J., Reichert, C., and Bram, K., Eds., KTB-Report 92-5: Niedersächsisches Landesamt für Bodenforschung.

Dziewonski, A., Bloch, S., and Landisman, M., (1969): A technique for the analysis of transient seismic signals: Bull. Seismol. Soc. Am., Vol.59, No.1, pp.427-444.