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AMPLITUDE SPECTRA OF SEISMOGRAMS RECORDED AT EQUAL EPICENTRAL DISTANCES FROM BLAST IN NW BOHEMIA

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ABSTRACT
Two experimental blasts were recorded at equal distances of approximately 43 km and various back-azimuths from 115° to 265° using a net of 14 field seismic stations situated in the western part of the Bohemian Massif. These records are used for study of the frequency contents of seismic waves generated by surface source. Some of the measuring sites were located on rocky subsoil, others on subsurface layers of various thicknesses. The Fourier spectra of P-wave group were found to be very different from site to site, even if their mutual distances were only several km. No clear relation between the frequency of the spectral maxima for vertical and horizontal components and the type of subsoil were found. This documents a complex structure of the region in the uppermost part of the crust. Not only local subsoil, but the whole path between source and receiver should be taken into account to explain the measured spectra.

KEYWORDS: Bohemian Massif, refraction method, amplitude spectra, local geologic structure

INTRODUCTION

Within the CELEBRATION 2000 seismic refraction experiment (Guterch et al., 2001, 2003), a special local experiment, hereinafter called the SEMICIRCLE, was carried out. It was targeted to azimuthal variations of seismic waves propagation. Two special blasts, OTRA and OTRB, near the village of Otročín in western Bohemia were recorded along a semicircle profile at 14 seismic stations of the same type at nearly equal epicentral distances of about 43 km. The back-azimuths were from 115° to 265°.

Málek et al. (2001) studied the travel times of P-waves along the semicircle, and found significant variations from 7.25 s to 7.72 s. The present paper deals with differences in the frequency content of the seismograms. As the S-wave group is not clear on all seismograms, we have studied only the spectra of the P-wave group.

1. EXPERIMENT SEMICIRCLE

The SEMICIRCLE experiment was performed in the seismoactive region of West Bohemia in the western part of the Eger Rift. Preliminary information on the project has already been described in Málek et al. (2001). Two shots were fired on June 26, 2000 at 00h 15m 00s UTC (OTRA – shot point No. 29050) and 00h 45m 00s UTC (OTRB – 29051). The geographic coordinates and distances of the blasts and stations are given in Tab. 1. The same charges of explosive (210 kg of EXPLOSIT 5) and equal technology were used in both blasts. Each blast was carried out in three boreholes 30 m deep in the field with flat topography. These three boreholes formed the equilateral triangle with sides of about 5 m and the explosive was fired all at once. Therefore, the radiation pattern can be supposed to be isotropic. The distance between shots OTRA and OTRB was about 50 m.

The stations labelled K01 - K14 were deployed along the semicircle (Fig. 1). The seismograms from station K01 were disturbed and therefore only data from K02 – K14 are considered. At all measuring sites, the REFTEC stations with the L28 sensors (Mark Product) were used. They are three-component sensors with a natural frequency of 4.5 Hz, damping constant D=0.7 and electromagnetic constant B=30.4 Vs/m. Their amplitude-frequency characteristic is shown in Fig. 2. The low frequencies, up to 4.5 Hz are strongly suppressed by the sensor response, and the characteristic is almost flat between 10 and 50 Hz. The sampling frequency was 250 Hz for all channels. The sensors were buried into shallow holes (about 50 cm) and oriented to NS and EW directions according to compass.

The local geological conditions beneath the stations (in the uppermost several hundreds of meters) were very different. K01 was situated on low-grade metamorphic rocks of the Ordovician age. K02 and

Table 1 Coordinates and distances of the shots and stations during the SEMICIRCLE experiment.

Site	Latitude WGS-84	Longitude WGS-84	Altitude (m)	Back-azimuth (°)	Distance from OTRA (km)	Distance from OTRB (km)
OTRA	50.02097	12.90894	679	-	-	0.048
OTRB	50.02130	12.90850	680	-	0.048	-
K02	50.19157	12.37399	570	116.6	42.715	42.671
K03	50.23091	12.41272	512	123.5	42.478	42.431
K04	50.30100	12.50296	624	137.2	42.564	42.516
K05	50.35824	12.61979	850	151.3	42.824	42.777
K06	50.37634	12.68390	790	158.0	42.670	42.623
K07	50.39238	12.75560	840	165.2	42.738	42.695
K08	50.40320	12.83491	983	172.9	42.843	42.803
K09	50.39974	13.01559	989	190.2	42.814	42.783
K10	50.37489	13.13955	388	202.6	42.672	42.650
K11	50.32140	13.27872	340	218.2	42.598	42.589
K12	50.27247	13.36219	286	229.0	42.803	42.803
K13	50.16349	13.46300	340	248.1	42.699	42.715
K14	50.06628	13.50164	572	263.1	43.753	42.780

K03 were located at the NW border of the Cheb basin, which covers muskovitic granite of the Smrčiny pluton. K04 was placed on metamorphic rocks analogical to Freubach beds. K05 and K06 were situated on muscovite metagranite. K07 was placed on the 250-300 m thick layer of phylite. K08 was situated on low-grade metamorphic rocks. K09 was placed on the 300 m thick layer of mica schist which is underlain by metagranite. K10 was situated on the layer of pyroclastic rock of high porosity, 50-70 m thick. K11 was placed at the NE margin of the Doupov stratovolcano; pyroclastic and tufitic rocks compose the uppermost 150-m thick layer. K12 was situated at the E margin of the Doupov stratovolcano where Neogene clays and sand with pyroclastic and tufitic relics compose approximately 100 m thick layer. K13 is placed on a thick layer of permo-carboniferous sediments composed predominantly of sandstones and claystones. K14 is located in the area of the Čistá granitoid massif where the weathered layer is up to 50 m thick.

2. SPECTRAL AMPLITUDES OF THE P-PHASE

The recorded Z, NS and EW components were recalculated to components Z (upward), R (radial) and T (tangential). At most cases, the P-onsets are clear, with a high signal-to-noise ratio. On the other hand, the ends of the P-wave group are very uncertain. Undoubtedly, these properties are due to many reflected and converted waves that come at the beginning of seismograms, just after the refracted P-wave onset. For evaluating of the P-wave spectra, the first 1 second of the seismogram is used. The cosine window of a length of 0.1 s is applied on both sides of the selected part (so the total length of 1.2 s from each seismogram is used).

The repeatability of experiment can be illustrated by comparing of the seismograms from explosions OTRA and OTRB. As an example, the seismograms recorded at site K12 are shown in Fig. 3a. This site was chosen as it has exactly the same distance from both blasts. The seismograms are very similar but some differences are clearly visible. The amplitudes for OTRB are slightly higher. This is probably due to technological details during blasting, which can affect the amount of energy converted to seismic waves. Some peaks in the seismogram are slightly shifted and have different shape; for example, some single peaks for one blast are split into two peaks for the other blast. Figure 3b shows the corresponding spectra, where the differences are even bigger. The shape of spectra is very similar for lower frequencies up to 16 Hz, but the amplitudes for OTRB are higher. The main peak occurs at the same frequency of 13 Hz for both shots (for OTRB this peak is 1.5 times higher). In the frequency range from 16 to 28 Hz, the spectra are less similar than for low frequencies. The individual peaks can be correlated here, but they are slightly shifted (up to 0.5 Hz). For frequencies higher than 28 Hz the spectra are not correlated. The wavelength for these high frequencies is comparable with the distance between the shots (50 m). For instance, assuming the P-wave velocity near the surface to be 3.5 km/s, the wavelength is 125 m for 28 Hz and 70 m for 50 Hz. To obtain more stable data, mean values of both corresponding spectra are used hereafter.

The obtained amplitude spectra for 13 localities are shown in Fig. 4. The average spectra from all localities were also computed, and they are shown in the first section of Fig. 4. All three components (Z, R, T) of all spectra are shown in the same scale.

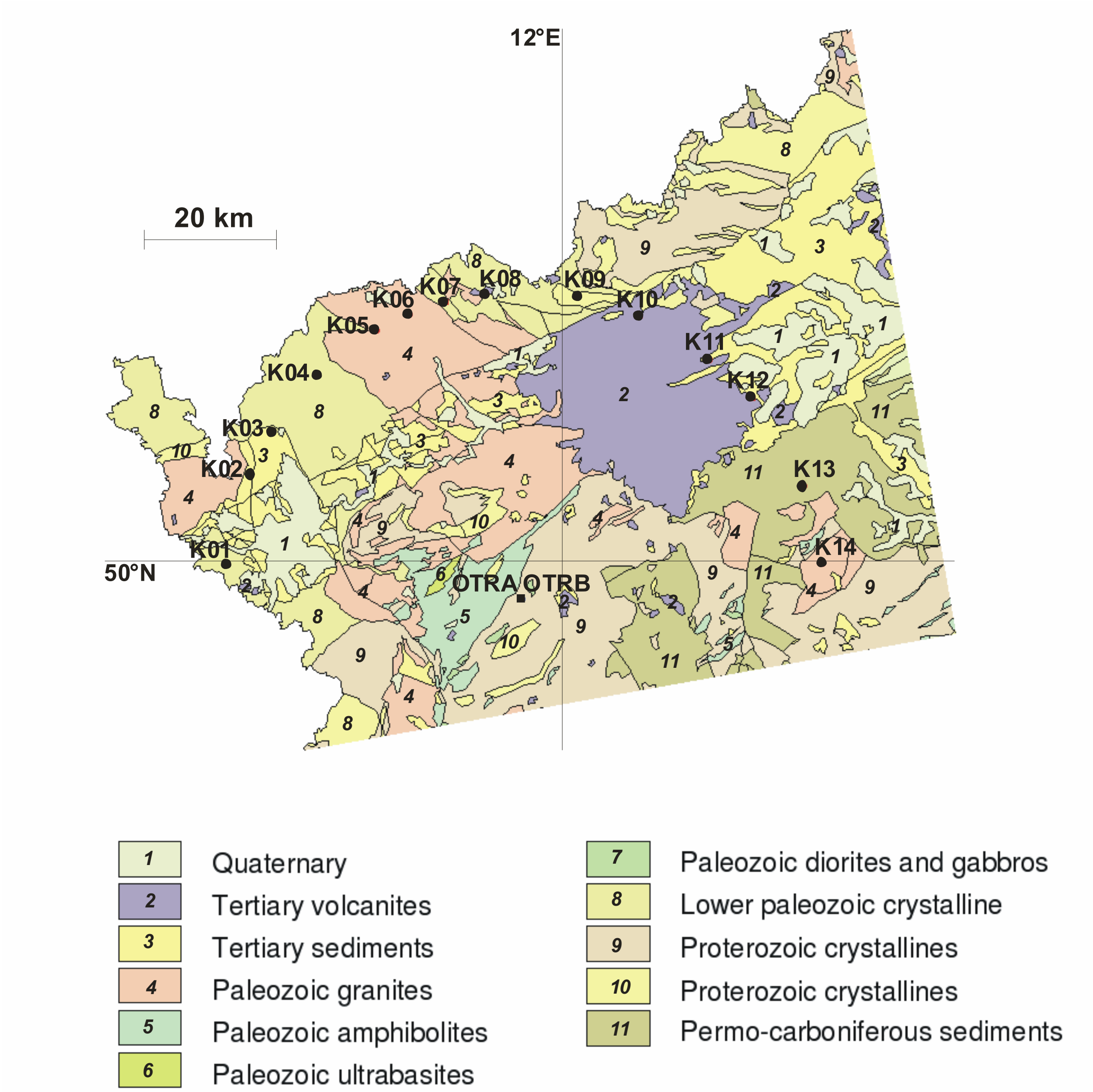

Fig. 1 Map of the SEMICIRCLE experiment: square – blasts OTRA and OTRB, circles – stations K01 – K14.

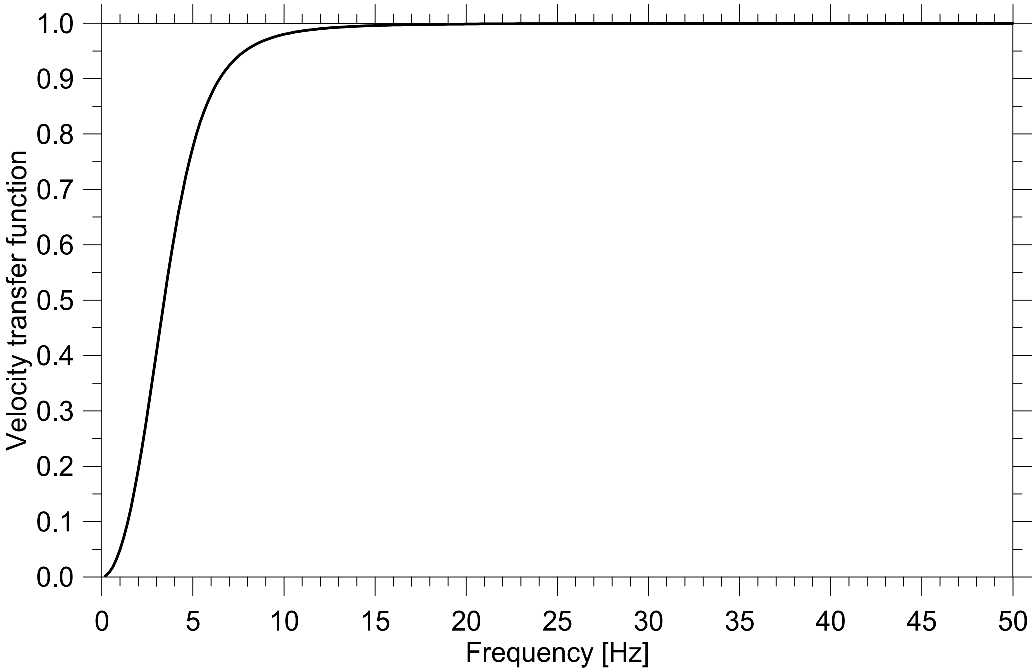

Fig. 2 Amplitude-frequency characteristics of the REFTEC seismic station with the L28 sensors.

3. DISCUSSION

Many authors have reported strong resonance effects on seismograms from earthquakes, if the seismic station was situated on sedimentary layers (e.g., Correigh, 1996). However, seismograms from surface blasts, considered in the present paper, display more complicated properties. For instance, K04 is situated on hard rock, but a strong resonance on the Z-component was observed. Different resonance effects can even be observed at close stations with similar local geological structure, see stations K05 and K06, which are situated on the same type of metagranite, and which are only 5 km apart from each other. While the spectra at K05 are similar for all components with the main peak at 7.5 Hz, the spectra of horizontal components at K06 have a strong resonance at 14 Hz, exceeding four times the value on the Z-component. Moreover, different spectral components predominate at the individual stations: The Z-component predominates at K02, K03, K04 and K07, both horizontal components (R and T) at K06 and K09, or the R component only at K10 and K11. These complicated spectral properties probably indicate that the frequency content from surface sources is strongly influenced not only by the station subsoil layer (down to first hundreds of meters), but by the shallow geological structure along the whole path between source and station. Namely, in case of surface sources, the main part of seismic energy propagates in shallow subsurface layers (down to a depth of a few kilometres). These layers are much more heterogeneous and anisotropic than deeper structures; see also Málek et al. (2004). Hence, the situation is much more complicated than in case of local earthquakes, where the seismic waves propagate more vertically, and the incidence angle is usually small.

Average spectra show that the prevailing frequency (for velocity) is about 15 Hz for the horizontal components, but 20 Hz for the Z component. Again significant differences for the different components are present. The Z component is much stronger than the horizontal ones in the range from 19 to 24 Hz. This is probably caused by strong resonances of the Z component in this frequency range at several stations (K03, K04, K13). As P-waves should be theoretically observed only on the Z and R components in laterally homogeneous media, large differences were expected between R and T components. However, the difference is clear only in a low frequency part of the spectrum, up to 16 Hz. This is the evidence that the subsurface structure cannot be regarded as laterally homogeneous, when talking about details which affect the high frequency part of the spectrum.

4. CONCLUSION

The wave field, generated by explosions in NW Bohemia and recorded at an equal distance from the source but at various azimuths, displays significant differences in spectral domain. These differences cannot be explained only by the resonance of the local geological structure beneath stations, but they are

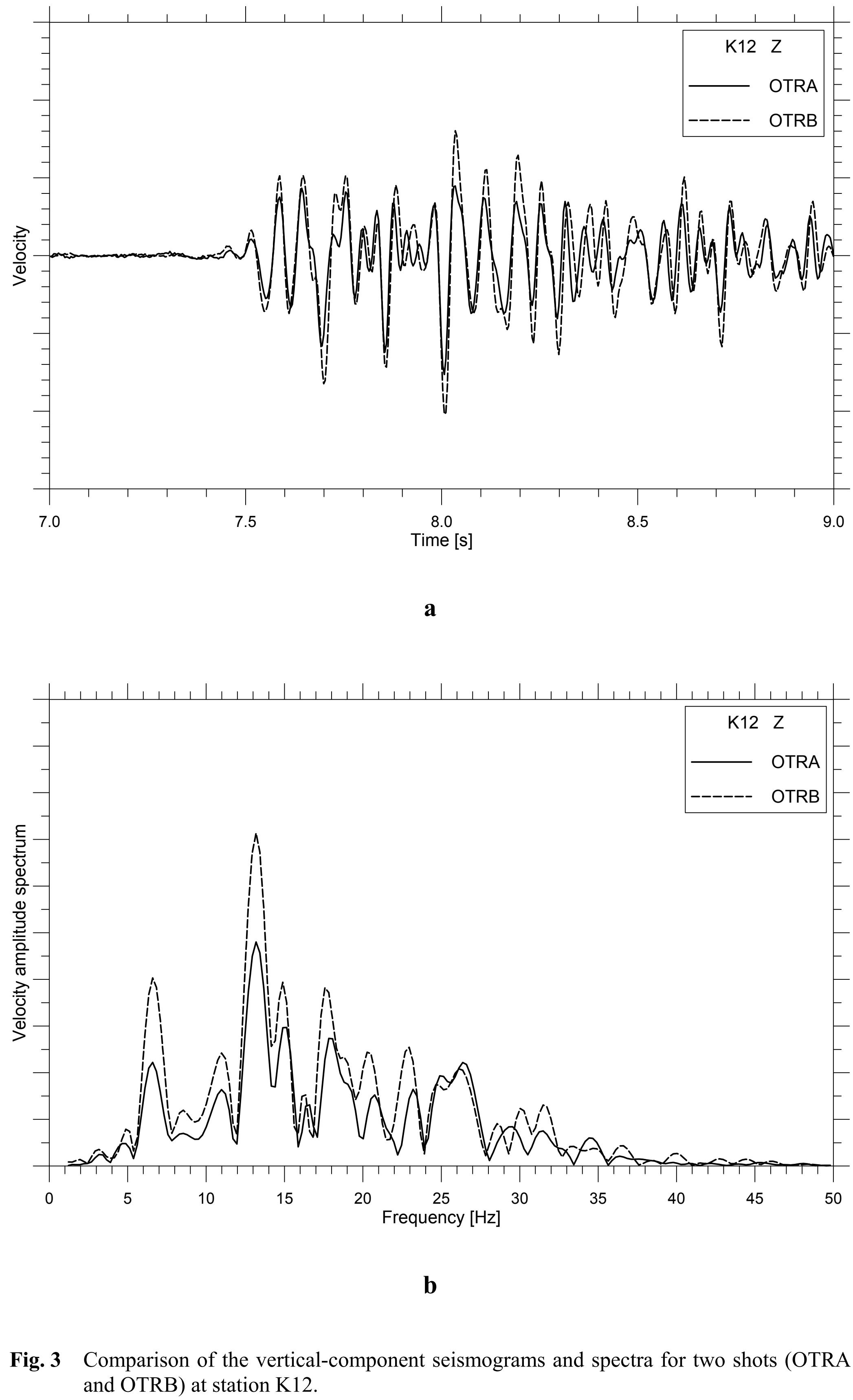

Fig. 3 Comparison of the vertical-component seismograms and spectra for two shots (OTRA and OTRB) at station K12.

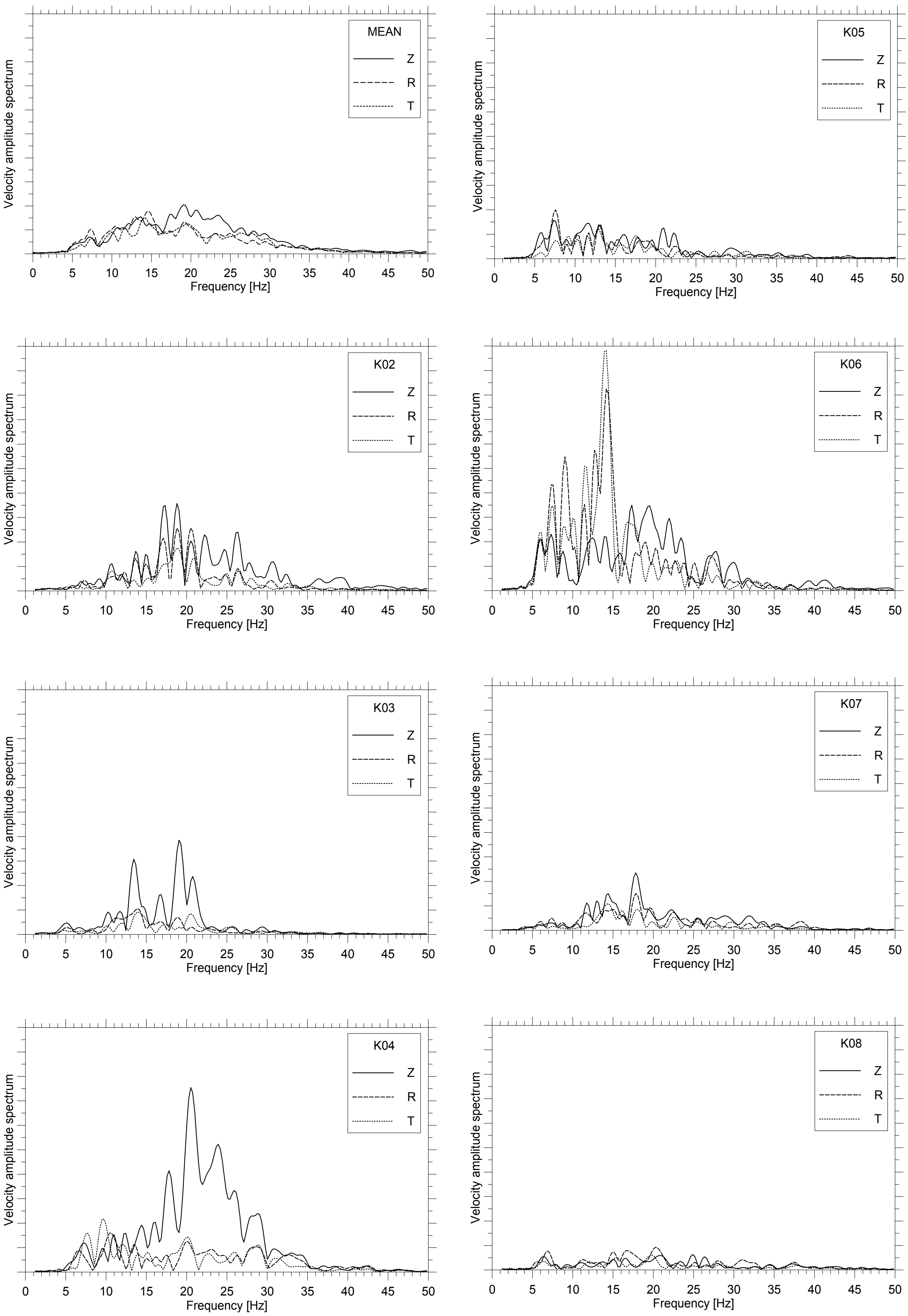

Fig. 4 Velocity amplitude spectra of the three components (Z, R, T) at the stations K02-K14. In the first section, the mean spectrum for all stations is shown. The scales in all frames are equal.

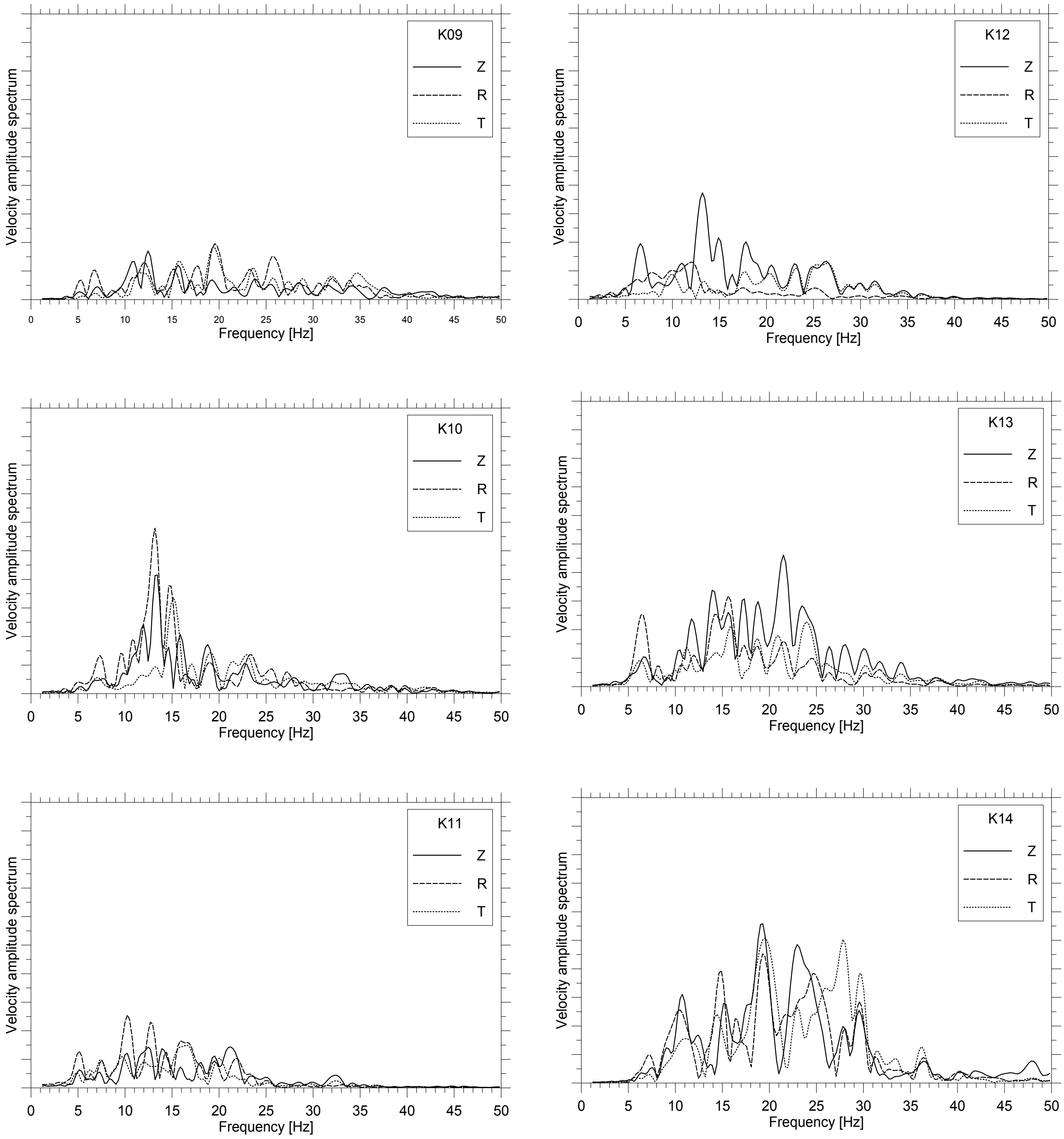

Fig. 4 continued

caused by strong heterogeneity of the subsurface structure along the whole path from source to station. The observed seismograms confirm a complex geological structure in the region.

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