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Mid-European seismic attenuation anomaly

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ABSTRACT

Macroseismic studies of various historical earthquakes with epicenters in the Eastern Alps region have shown a significant elongation of isoseismals in the North-West direction. Such an anomalous attenuation of seismic waves in Central Europe is investigated on the basis of instrumental records of two moderate-size earthquakes in the Vienna Basin, which occurred in September and October 2013. It has been found that for both earthquakes the peak amplitudes of both velocity and acceleration are considerably higher to the North-West of the epicenters compared to the other directions. The peak ground velocity amplitudes at comparable epicentral distances but different azimuths may vary by as much as one order of magnitude. The inspection of individual seismograms suggests that the phenomenon is associated mainly with the propagation of S waves. Significant differences in frequency content of the seismic waves radiated to different azimuths are also demonstrated. The maximum predominant frequency was not observed at stations closest to the epicenters but about 250 km away, in the Bohemian Massif. The possible causes of these observations are briefly discussed on the basis of an elementary data analysis but further research and in-depth analysis is required to elucidate the causes of these phenomena.

1. Introduction

From historical findings, earthquakes with epicenters in the Eastern Alps seem to display a strong azimuthal dependence of their amplitude attenuation with distance. The distribution of macroseismic observations of the East Alpine earthquakes felt in Bohemia and Moravia on July 25, 1927 (Supplementary Fig. S1), October 8, 1927, November 8, 1938 and September 18, 1939 was studied by Zátopek (1948), who reported that the "macroseismic field asymmetrically elongated in pear-shape to the NNW reaches as far as Dresden". That study was based on an extensive collection of 2966 reports from the territories of Bohemia and Moravia related to four strong earthquakes with epicentral intensities greater than 7 MCS. The results of this early study were later confirmed by Procházková and Kárník (1978) and Procházková (1993), who report an asymmetric shape of isoseismals, significantly extended in the North-West (NW) direction for the earthquake of April 16, 1972 (see Fig. 1). These findings suggest that macroseismic intensities of East Alpine earthquakes decay more slowly towards Bohemia in a systematic manner. The intensities reflect the spatial distribution of earthquake impacts in a given region and contain some degree of subjectivity. We can also speculate that ground motion amplitudes may display a corresponding asymmetry in their spatial distribution. In this study we call this phenomenon the mid-European attenuation anomaly. Confirmation of this anomaly with instrumental data is the main subject of this paper. Seismograms recorded by modern seismic stations in this region give us an opportunity to study this phenomenon in greater detail than isoseismal mapping. We used the recent moderate-size (M_L 4.2) earthquakes at Ebreichsdorf, situated in the Eastern Alps region, which occurred on September 20, 2013 (hereinafter Event 1) and on October 2, 2013 (hereinafter Event 2). These two events are located within the Vienna Basin Fault System, one of the most seismically active regions of Austria (Tary et al., 2016). The Vienna Basin separates the Eastern Alps from the Western Carpathians and lies in the northeastern extension of the active Mur-Mürz-Fault between the Bohemian Massive and the Pannonian Basin. Both events are nearly co-located (47.9318° N, 16.4230° W for Event 1, and 47.9315° N, 16.42229° W for Event 2; Apoloner et al., 2015) in the part of the basin adjoining the Eastern Alps. The depth of both events is about 10.5 km. We collected seismograms from seismic stations distributed across the region within 400 km of the epicenters in order to study spatial distribution and azimuthal dependence

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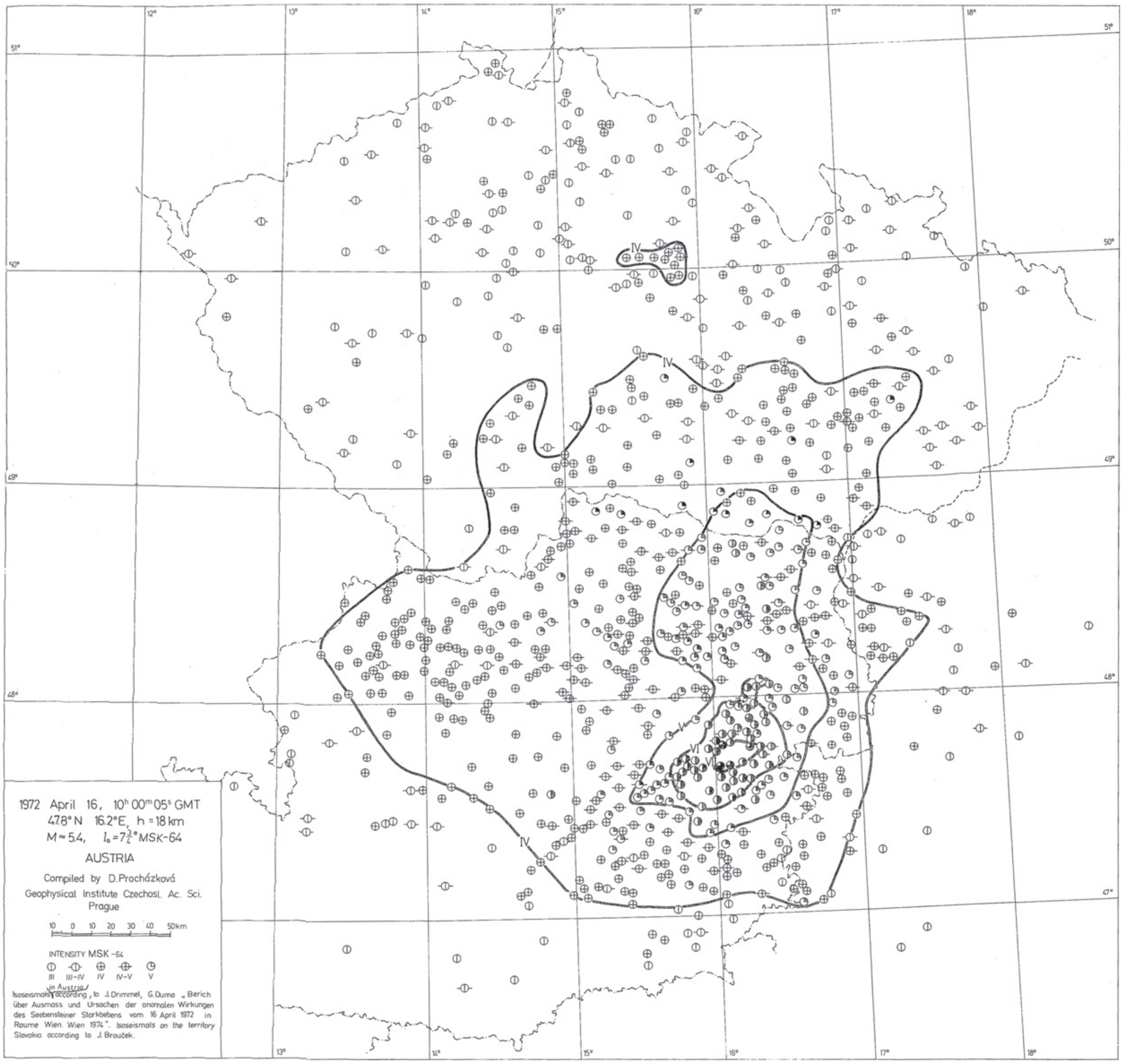

Fig. 1. The isoseismal map of the earthquake of April 16, 1972, 10:00:05 UTC at 47.8° N and 16.2° E, as compiled by D. Procházková..
Source: Reprinted from Plate 132, Procházková and Kárník (1978)

of amplitude decay with distance. Results for both events are compared in order to probe the stability of this phenomenon. The East-Alpine earthquake region represents one of the most important focal zones for seismic hazard of the Czech nuclear power plants Dukovany and Temelín, and the Slovakian power plants Jaslovské Bohunice and Mochovce. The effect of the azimuthal dependence of the amplitude decay (attenuation) should be considered in the revision of Probabilistic Seismic Hazard Assessment (PSHA) for those plants and other structures.

The aim of this paper is to confirm the attenuation anomaly, previously deduced from macroseismic data, but here based on instrumental data using exact quantities characterizing the ground motion (peak ground motion amplitudes). Further, we investigate the spectral characteristics of the seismograms, specifically the frequency content. Let us clarify that hereafter we use the term 'attenuation' in its general sense as a gradual decrease of amplitudes of seismic waves with distance without having in mind anelastic properties of the structure through which the seismic waves propagate, which would be described in terms of the seismic quality factor Q. The nature of the attenuation anomaly is discussed from a phenomenological point of view. A more detailed explanation of the anomaly, including modeling and geological interpretation, is the subject of a subsequent study.

2. Seismic data

In this study, we analyze seismic three-component records of the two earthquakes from 963 channels at 229 stations in 11 countries: the Czech Republic, Poland, Slovakia, Hungary, Serbia, Montenegro, Croatia, Slovenia, Italy, Austria, and Germany. The stations are distributed inside a circle with the radius of about 400 km from both epicenters.

The seismic mechanisms of the two M_L 4.2 earthquakes are similar. They are of the double-couple type characterized by the strike, dip, and rake 62° /73° /31° for Event 1 and 63° /79° /5° for Event 2