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Macroseismic Effects of the Ebreichsdorf Earthquake of July 11, 2000 in Vienna

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Abstract

In the early hours of July 11, 2000 an earthquake occurred in the Vienna Basin, about 30 km south of the city center of Vienna, causing an epicentral intensity of “6”. It was the strongest event since 1972 in Austria. Near the epicenter some buildings suffered minor to moderate damage. The tremor was felt strongly throughout Lower Austria. The large number of reported observations, especially from the city of Vienna, allowed investigating the macroseismic effects in Vienna in greater detail. Although only 0.04% of the Vienna population reported their observations, detailed statements about the perceptibility could be made due to the high population density. As expected, the southern districts of the city were affected strongest because of the vicinity to the epicenter. This earthquake may serve as an example for the macroseismic effects of a future stronger earthquake in the Vienna Basin.

1. Introduction

The Vienna Basin together with the Inn valley (Tyrol) and the Mur-Mürz valley (Styria) is one of the main seismic active areas in Austria. During the 20th century 345 earthquakes in the Vienna Basin and adjacent areas in Styria could be felt, 17 earthquakes caused building damage. The latest event causing considerable damage happened on July 11 at 04:49:49 Central European Summer Time (CEST). The epicenter was located near Ebreichsdorf, Lower Austria. The epicenter intensity was assessed as “6” on the intensity scale “EMS-98”, the magnitude was 4.8 on the Richter scale. The ground shaking was felt strongly in most areas of eastern Austria and also in Vienna.

In this article we refer to the Macroseismic Intensity Scale (EMS-98; Grünthal, 1998; see appendix) to quantify the “strength” of an earthquake based on its effects on the surface. Nowadays mostly the logarithmic Richter magnitude scale characterizing the released energy at the hypocenter is used in literature and by the media. This magnitude can be used to estimate the effects of an earthquake before any reports of the population are available. The transfer of the data from the seismic station to the center in Vienna takes only a few seconds and a few seconds later the magnitude of an earthquake can be calculated. In contrast, the evaluation of macroseismic reports may last a few weeks, especially in the case of a stronger event. Therefore, the first estimate of the intensity of an earthquake in Austria is based on the magnitude and a focal depth estimate in combination with the intensity of the first incoming reports. Intensity and magnitude are published on the web-site of the Central Institute of Meteorology and Geodynamics (www.zamg.ac.at).

This paper concentrates on the macroseismic particularities only in the urban area of Vienna because the report density of other regions is comparable low. General information about the perceptibility in Lower Austria is shown in the isoseismal map which is discussed later.

2. Historic seismicity and recurrence statistics

It is well known, that before 1900 many damaging earthquakes occurred in the Vienna Basin and surroundings (Drimmel, 1980). Also in the 20th century several strong earthquakes led to major damage of buildings. The strongest and best known events are compiled in Tab.1. The effects within the epicenter and in Vienna are described e.g. by Hammerl and Lenhardt (1997). At the occasion of the earthquake in 1927, buildings were seriously damaged not only in the epicenter Schwadorf and surroundings, but also in Vienna where the fire brigade had to clean up collapsed chimneys and the phone communication broke down for half an hour (Conrad, 1928). In 1938 (epicenter in Ebreichsdorf) some factory chimneys collapsed even in the 10th district of Vienna (Mifka and Trapp, 1941). The epicenter of the earthquake in 1972, however, was close to Seebenstein, about 30 km to the south of Vienna, and thus the most distant event in this context. During the earthquake the church of Seebenstein suffered heavy damage and two old buildings collapsed in Guntramsdorf and in Schwarzau. In Wiener Neustadt the main road was impassable for some hours because chimneys and moldings thrown down had to be removed. In Vienna the fire brigade was alerted to remove collapsed chimneys and roof tiles. The balustrade of the university in Vienna toppled down along a length of 20 m, fortunately claiming no casualties (Drimmel and Duma, 1974).

For distinct regions logarithmic relations can be derived between magnitude or intensity and earthquake recurrence frequency (Gutenberg and Richter, 1944). These relations permit to estimate the average number of earthquakes occurrences in a time period and their expected effects. In this paper we compare the recurrence periods of Vienna and the Vienna Basin. No epicenters are known in the city area so far. Additionally, Vienna is situated at the margin of the Vienna Basin and the spatial extent of both areas disagrees. Due to these reasons different recurrence periods of local intensities (or “ground motions”) exist. The following numbers are based on the Austrian Earthquake Catalogue (ZAMG, 2001).

While in the Vienna Basin on an average five events are felt per year, in Vienna itself only every second year the corresponding effects of an earthquake from the Vienna Basin are witnessed. On average every 2-3 years an earthquake with intensity “5” occurs in the Vienna Basin, whereas in Vienna one has to wait 20-30 years.

Ground shaking associated with minor damage to buildings (intensity "6") is relatively seldom in Vienna whereas in the Vienna Basin this type of earthquake happens every ten years on average. The most recent event of intensity "7" happened in 1972 in Seebenstein. Such intensities can be observed in Vienna only at intervals of several 100 years. The last earthquake of such a local intensity in Vienna occurred in 1590 (Gutdeutsch et al., 1987). At that time numerous buildings and steeples were seriously damaged, and the collapse of a guest house in Vienna left several persons dead. The insurance company "Münchner Rückversicherung" estimated reconstruction expenses in the order of 10.000 million Euros would such an intensity affect Vienna today (Allmann and Smolka, 2000).

The most recent earthquake of intensity "8" occurred in 1927 in Schwadorf, southeast of Vienna. Larger earthquakes are unlikely in the Vienna Basin as tectonic constraints (crustal deformation rates) tend to limit the earthquake potential when compared with those areas with high plate movements. For performing long-term earthquake statistics, historical earthquakes (events before 1900) need to be investigated and included in the analysis. Based on experience of past investigations (Drimmel, 1981, Gutdeutsch et al., 1987, Eisinger et al., 1992, Gutdeutsch and Hammerl, 1996) a detailed study of historical sources in Lower Austria commenced in 2003.

3. The Ebreichsdorf earthquake of July 11, 2000

The main shock of the Ebreichsdorf earthquake happened on July 11 at 04:49:49 a.m. CEST. The epicenter was located about 3 km southeast of Ebreichsdorf (47.96°N, 16.40°E), Lower Austria, the magnitude was 4.8 on the Richter scale. More than 1000 macroseismic reports were received at the Central Institute of Meteorology and Geodynamics. Therefore a detailed macroseismic analysis and the estimation of the damage-area is possible. The epicenter intensity was assessed as "6" on the intensity scale "EMS-98". According to the well-known relation between magnitude, intensity and focal depth the hypocenter is estimated to be in approximately 10 km. A more accurate depth cannot be calculated owing to the scarcity of available seismic stations. The ground shaking was felt strongly in most areas of eastern Austria and also in Vienna. Accordingly, the media showed great interest.

The strongest aftershock occurred on the same day at 12:56:04 CEST with a magnitude of 4.5 (refer to Tab. 2). The macroseismic evaluation does not allow estimating a reliable focal depth for this event either due to the reasons given above. A few days later an inspection team of CTBTO installed a local seismic network in the epicentral area. Eighteen aftershocks have been recorded indicating focal depths ranging from 6 to 10 km (CTBTO, 2001), thus allocating the events to the underlying geological unit of the Bohemian Massif.

4. Tectonic setting

From the geological point of view the Vienna Basin constitutes a pull-apart basin at the eastern end of the Mur-Mürztal-fault (Gutdeutsch and Aric, 1987). Beginning at the Semmering the fault splits into a number of faults, of which the most western fault has been coined "Thermenlinie" by Suess (1873). The Ebreichsdorf earthquake

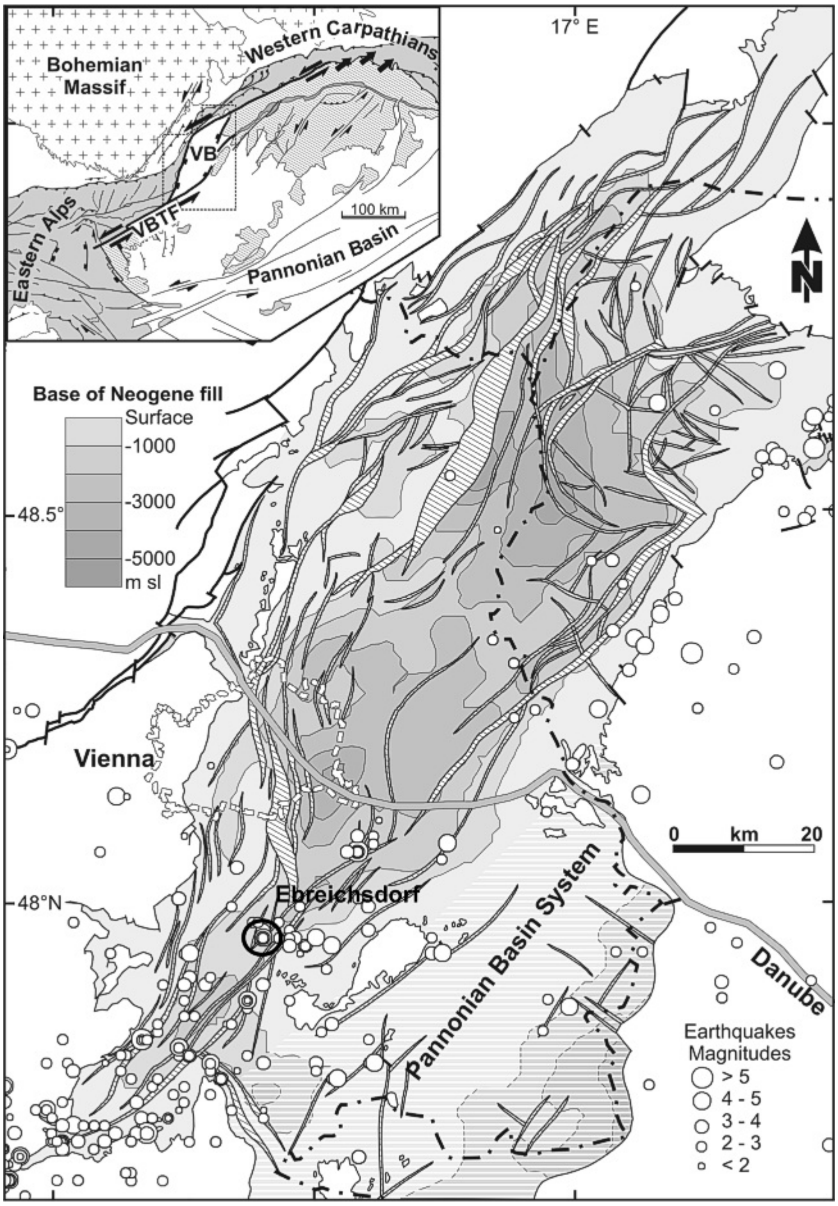

Figure 1: Structural setting and seismicity of the Vienna Basin. Modified after Hinsch et al. (2004). Inset: Main structural units in the Eastern Alpine - Carpathian region (modified after Decker, 1996), VB: Vienna basin, VBTF: Vienna Basin Transfer Fault. The main map shows the faulted pre-Neogene basement surface (modified from Kröll and Wessely, 1993) and earthquake epicenters (ZAMG, 2001).

occurred on a deep fault beneath the Vienna Basin situated in the middle of the basin, which connects the well-known seismic focuses of Schwadorf, Wiener Neustadt and Seebenstein/Pitten. Fig. 1 shows the tectonic setting including the seismicity of the Vienna Basin.

A fault plane solution of the main shock on July 11, 2000, at 04:49 CEST has been calculated by the Seismological Service of Austria (ZAMG) based on first motions of the recorded waveforms showing a N-S directed pressure axis (Fig. 2). One of the nodal planes corresponds to a vertical NE-SW oriented fault zone matching the fault tectonics near the epicenter (Fig. 1). Similar mechanisms were observed already for previous events in the Vienna Basin (Reinecker and Lenhardt, 1999). The largest aftershock a few hours later at 12:56 CEST exhibited the same mechanism. Both focal solutions were confirmed by the moment tensor inversion analysis carried out by the Swiss Seismological Service (SED, 2000).

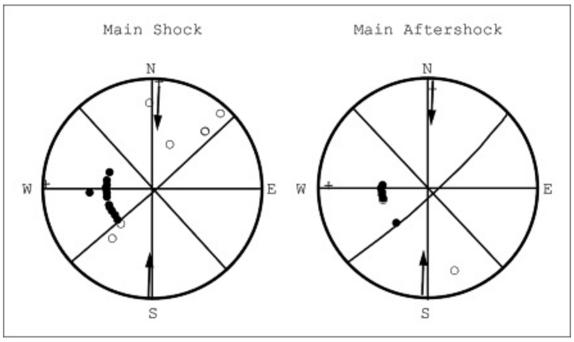

Figure 2: Focal planes based on first motions (left: main shock, right: largest aftershock) showing a N-S directed pressure axis.

5. Macroseismic effects

In the epicenter many buildings were damaged, in some cases considerably. The villages Ebreichsdorf, Trumau, Weigelsdorf, Unterwaltersdorf, Mitterndorf an der Fischa and Schranawand were especially affected. Walls and ceilings of many buildings were cracked and few chimneys were destroyed. In Trumau the primary school was closed because of danger of collapse and most of the ceilings had to be renewed. Another public building and a factory suffered structural damage. Even from distant towns (e.g. Eisenstadt, Traiskirchen, Gumpoldskirchen) large cracks in walls and damaged chimneys were reported. Slight damage was observed and reported from about 20 other places.

The isoseismal map is shown in Fig. 3. The "6 degree" isoseismal line defines the area from where damage reports were received. It extends elliptically from southeast to northwest. Also within the "5 degree" area some minor damage has been reported e.g. in Baden, Maria Enzersdorf, Mödling and Wien-Mauer, corresponding to the EMS-98, which states, that occasionally slight damage may occur within the "5 degree" contour line.

Date	Time (CET)	Epicenter	Epicentral intensity
October 8, 1927	19:49	Schwadorf	8
November 8, 1938	04:12	Ebreichsdorf	7
September 18, 1939	01:14	Puchberg	7
April 16, 1972	11:10	Seebenstein	7

Table 1: Strongest earthquakes in the Vienna Basin since 1900 (CET = Central European Time).

The "4 degree" isoseismal line is particularly asymmetric. Ground vibrations were felt especially in the north and north-west. This special kind of seismic wave propagation is typical for the Vienna Basin and well-known from previous strong events, and can be explained by two effects - the geology and the fault mechanism with its corresponding radiation pattern. Also in the neighboring countries Czech Republic, Slovakia and Hungary many persons perceived this earthquake (e.g. some reports from Prague have been assigned to a local intensity of "4"). The places and assigned intensities have been forwarded to the ZAMG by the Seismological Service of Prague and by the IPE in Brno in the Czech Republic as well as by the Seismological Service of Hungary.

Few aftershocks could be felt, too. As mentioned earlier, the by far strongest aftershock occurred the same day, July 11, 2000, at 12:56 CEST with a Richter magnitude of 4.5. The intensity in the epicenter was assigned to 5 degrees on the EMS-98. Ground vibrations were felt in wide areas of Lower Austria and Burgenland as well as in Vienna again. However, no damages were reported in these cases. All felt aftershocks are compiled in Tab. 2.

Not only due to the distinct perceptibility in the capital, the earthquake of July 11, 2000, caused great medial attention. Because of the high population density in the city area and the wide-spread

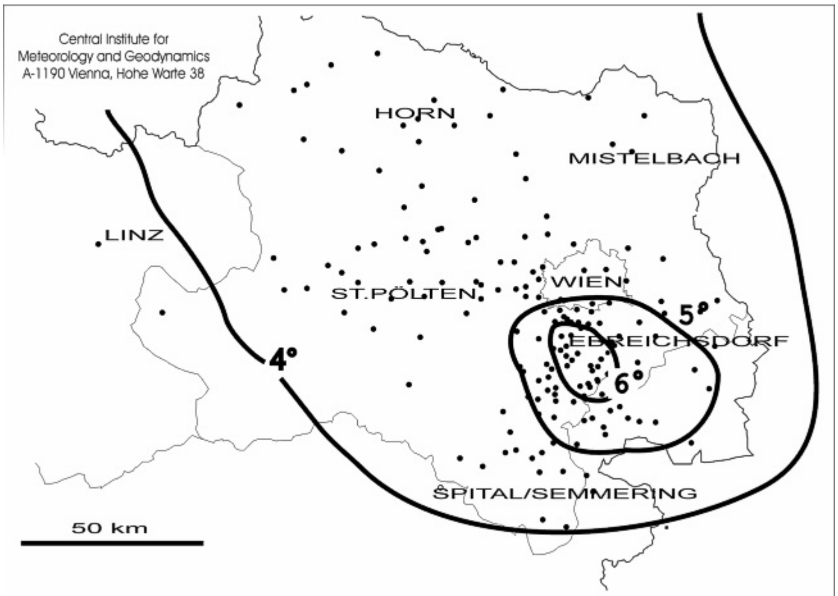

Figure 3: Isoseismal map of the earthquake on July 11, 2000. The contour lines of different intensities delimit areas of similar effects. The dots mark those localities from where "positive" reports were received.

Date	Time (CEST)	Magnitude	Epicentral intensity
2000 07 11	04:50	4.8	6
2000 07 11	08:47	3.0	3
2000 07 11	12:56	4.5	5
2000 07 12	02:23	2.1	3
2000 07 12	09:56	3.3	3-4
2000 07 12	23:20	3.4	4
2000 07 16	04:28	3.0	3

Table 2: Earthquakes with epicenter near Ebreichsdorf felt in July 2000 (CEST = Central European Summer Time).

ability to report observations via e-mail, some hundreds of reports could be gathered within the first few hours.

The assessment of the macroseismic intensity based on individual reports submitted by the public is difficult as the latter are often not sufficiently precise and informative. Therefore the Seismological Service offers the possibility to send reports using the ZAMG website, where a form can be completed on-line allowing the Seismological Service to assign intensities much more precise and effective.

The individual human perceptibility, human reaction and the ability to describe observations render a correct assessment difficult. In addition, many important data regarding the type of building constructions, story floor or the local situation remained often unknown. Due to this reason intensities of 3-4 and 4-5 respectively had to be assigned to many reports.

Damage has been reported even in the center of Vienna. Based on experience such reports must be treated carefully as often minor damage to buildings like plaster fissures or cracks in walls are attributed unjustified to an earthquake. In individual cases it happens, however, that existing damage caused by aging such as fissures due to drying up plaster, subsidence, reconstruction measures or traffic vibration can be aggravated by an earthquake. This applies especially to older buildings that dominate the inner districts of Vienna.

5.1. Influence of building height and number of floors

In a city like Vienna, with many old and multi-storey buildings, the influence of the building height has an important influence on vibrations. The oscillation characteristic of a construction and also the intensity enhancement depend on the building type and condition as well as on the frequency and amplitude of the vibration. Generally earthquakes are felt stronger on higher floors. Even in one- or double-storied buildings people report that the vibration is more perceptible on the upper than on the ground floor. Obviously, the ceiling height and the construction type of a building play an essential role, too. Often the number of floors does not even permit to estimate the total building height and the approximate elevation of a given floor above ground remains uncertain as sometimes - due to historical building tradition - intermediate floors exist (“Mezzanin”, “Hochparterre”).

In spite of those uncertainties all reports in Vienna were compared regarding the storey description. Although in many cases the floor could not be identified the tendency appears that especially in the inner districts of Vienna (1 - 4, 6, 8 and 9) as well as in the districts 11, 20, 21 and 22 most reports originated from the 3rd floor or above. This observation is probably due to the common type of building construction in the districts mentioned above. However, it supports the supposition that the earthquake was generally less perceptible at lower floors. Additionally, geophysical subsurface conditions seem to be important in many cases.

5.2. Report density

Based on the population data from December 31, 1999 (source: town council of Vienna) the report density for specific districts could be determined. Related to the total population of the district most reports were received for the districts 9, 1, 4, 19 and 18 (ranked with decreasing response). This ranking is followed by the districts 23, 7, 5 and 6 (more than 0.6 ‰). The lowest report density (0.13 ‰) was observed from districts 11 and 21 (Fig. 4).

6. Results

In total 592 reports from Vienna could be evaluated. 374 (63%) were received by mail (most of them by e-mail), 218 (37%) by phone call ('oral reports'). Generally the reports by phone are necessarily very short and thus often not precise enough.

Intensity “4” was assigned to most of the reports from Vienna (63.6%) whereas 23.4% of the reports indicated a local intensity of “4-5” and 4.7% corresponded to the highest local intensity of “5”. There are only few reports corresponding to a relative low intensity (0.5% for intensity “3” and 7.8% for “3-4”). Regarding this ratio there is almost no difference between written or phone reports.

Fig. 5 presents the number of reports for each intensity class in

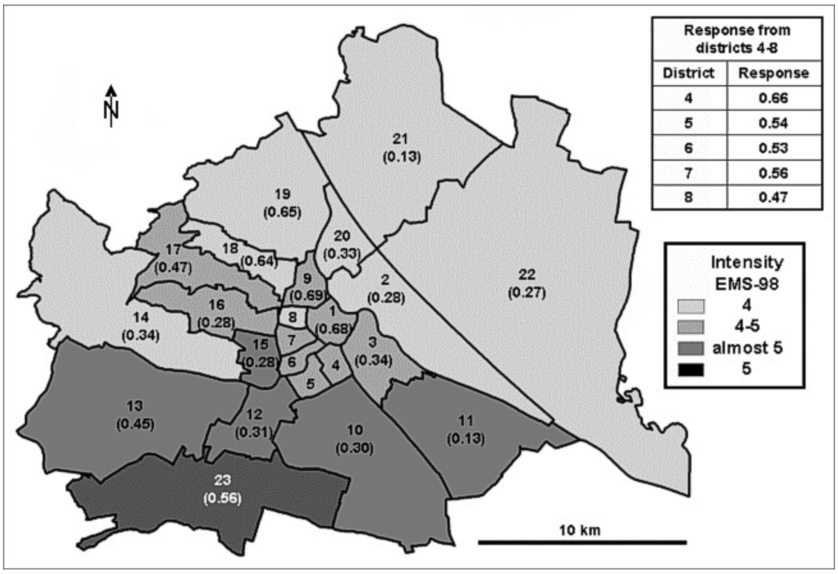

Figure 4: Intensity distribution in Vienna for the Ebreichsdorf earthquake on July 11, 2000 at 04:50 CEST. District numbers and the number of reports related to the district population [‰] are displayed.

Vienna (written reports in black, phone reports in dark grey). Most reports correspond to a local intensity of “4”, many to “4-5” and “3-4”, where a distinct assignment was impossible. In conclusion it can be stated that the majority of reports across the total area of Vienna corresponded to a local intensity “4”.

A detailed evaluation with regard to the different districts in Vienna shows some differences and peculiarities, however. The results are given in Tab. 3.

The earthquake was felt most strongly with an intensity up to “5” (EMS-98) in the most southern, and therefore nearest district from the epicenter - the 23rd district. Even slight damage to buildings was reported from there. Strongest vibrations were reported from the sub-districts Mauer, Liesing and Siebenhirten. Additionally two damage reports were received from Inzersdorf - from the southern border of Vienna. Most of the reports were gathered in Mauer and Atzgersdorf. An interesting fact is that reports from a new building complex in Alterlaa - with exclusively multi-storey towers - can be assigned to intensity “4” only. This may be due to the construction style.

Within the districts 10, 11, 12, 13 and 15 - all of these districts are situated in the south of Vienna - the local intensity achieved almost “5”. Sporadically slight damage was reported in these districts too. But because of the rareness of those damage reports in spite of the high population density the intensity was estimated lower than “5” for each of these districts. The special situation in the 11th district is worth mentioning: there are two oral damage reports, but all other observations correspond to intensity lower than “4” or at maximum “4”.

From the districts 1, 3, 4, 5, 6, 7, 9, 16 and 17 several reports are available corresponding to intensity “4-5”, but most reports correspond to “4” again. These districts include the inner part of Vienna with predominantly older buildings. In the 16th and 17th district the parts close to the “Gürtel” main road and those situated in outward direction can be distinguished. In the 16th district highest intensities were reported from the most western area (slope of Wilhelminenberg) and from the “Schmelz”-area, bordering to the 15th district where generally a higher intensity was reported from. In the 17th district the earthquake was felt most strongly in the vicinity of the “Gürtel”, although this finding is not statistically significant as only few reports were received from there.

Unambiguously intensity “4” can be assigned to the districts 2, 8, 14, 18, 19, 20, 21 and 22, i.e. the entire northern part of the city. In these districts the earthquake was felt most weakly. From the 19th district several written reports suggest a higher intensity, but based on the much more numerous oral reports the most representative intensity for this district was “4”.

Fig. 4 shows a map of Vienna and the distribution of the intensity assigned to each district. The separation into intensity “4”, “4-5”, “almost 5” and “5” has been chosen to express the small differences between the districts although such a fine scale resolution seems to be problematic. For that purpose the frequency distribution of the reports (see Tab. 3) has been considered, rejecting maximum intensity reports if received rarely in relation to the number of the most frequently reported intensity. Intensity variations within single districts are not displayed in this map.

Within the framework of a detailed study of the earthquake risk in Vienna (Duma, 1988) the following characteristic was found: Within an arched zone west and north-west of the city center systematically higher local intensities were observed from seismic events located in the southwest of the city. This zone contains the 'Gürtel' area including the districts 16, 17, 18 and 19, and particularly district 9. This observation was not made in the case of the Ebreichsdorf earthquake on July 11, 2000, however (Fig. 4). The reason may be that previous studies were dealing mainly with much stronger events with a higher content of low frequency ground vibrations.

6.1. Evaluation of the aftershock at 12:56

The strongest aftershock on July 11, 2000 at 12:56 CEST was also felt in wide areas of Vienna. Nevertheless only 120 reports were available, in most cases from people staying in higher floors where the vibrations were generally perceptible much better.

Most reports (52%) correspond to local intensity “3-4”, 43% to “3”, and only a small percentage (5%) to “4”.

The small amount of reports hampers to perform a statistical analysis or to distinguish between the districts. Nevertheless there seems to be a tendency that the event was mostly felt in the districts 23 and 13. There were no evident intensity variations in other parts of the city. It must be considered, that the foregoing main earthquake caused many people to be more alert on one hand but reluctant to report the event otherwise.

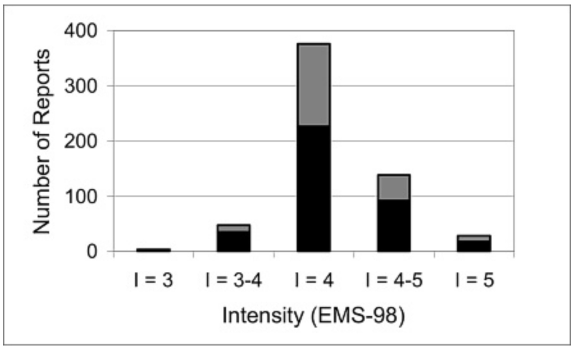

Figure 5: Number of reports from Vienna. (black: written reports, dark grey: oral reports)

6.2. Measurement of ground motion

The Seismological Service of Austria maintains a number of seismometers to evaluate earthquakes, to determine epicenter and magnitude and to estimate possible damage at the surface. The so-called strong-motion stations play an important role in this regard. Among others, two stations are located in the Vienna Basin (Schwadorf and Wiener Neustadt), and another five in Vienna itself (Duma et al., 1996) measuring the ground acceleration during an earthquake. The observed acceleration can be correlated with the official regulation for building constructions ÖNORM B 4015 (2002), soil constitution and with received damage reports.

On July 11, 2000 the maximum of horizontal acceleration (0.12 m/s^2) was observed at the station at Schloss Neuwaldegg, the only measuring site in Vienna located on rock (Fig. 6, showing the seismogram). The minimum was observed in district 22 close to the Danube (horizontal peak amplitude of 0.067 m/s^2).

The largest aftershock on July 11, 2000, at 12:56 CEST, that was felt also in Vienna, caused a maximal horizontal acceleration of 0.03 m/s^2 at

Schloss Neuwaldegg only. This is about ¼ of the main shock amplitude.

A maximum amplitude around 0.1 m/s² (as observed during the main earthquake) is usually associated with a local intensity of “4”. This corresponds well with the observed macroseismic intensity, although generally a local intensity can only roughly be assigned to ground accelerations, because frequency content, soil constitution and the duration of the earthquake play a dominant role. The four other seismic stations in Vienna recorded lower amplitudes, although they are slightly closer to the epicenter. This discrepancy can be explained by resonance effects due to local ground conditions and the frequency content of the incoming seismic waves. The station in Neuwaldegg is located on rock while the others are installed in buildings standing on quaternary sediments. The duration of ground motions is thus longer due to resonance while high frequent ground movements are absorbed in the sedimentary layer. Still, this leads to better perceptibility and observation of effects in general and consequently to higher intensities although the peak accelerations are actually smaller.

7. Conclusions

Earthquakes in the Vienna Basin are an expression of the prevailing pull-apart mechanism. The epicenter of the recent earthquake in Ebreichsdorf on July 11, 2000 is already known from seismic activity during the past. The mechanism was determined to be of sinistral strike-slip which took place along a NE-SW striking fault few kilometers below the Vienna Basin at a depth around 10 km in the underlying Bohemian Massif.

Numerous reports were received after the earthquake at the Central Institute of Meteorology and Geodynamics. Based on the responses from the public (0.04% of the population in Vienna), a detailed macroseismic investigation was conducted. The newly introduced possibility by the ZAMG to report the effects of an earthquake via internet is thought to assist in future to gather even more reports in a structured and effective manner.

The highest intensity in Vienna (degree 5) during the earthquake of Ebreichsdorf could be allocated to the 23rd district which is nearest to the epicenter. A local intensity close to “5” was assigned to the districts 10-13 and 15. The perceptibility was weakest in the northern districts of Vienna (intensity “4”) as expected. This tendency matches theoretical considerations based on the epicentral distance. Local anomalies in terms of higher than normal intensities due to the different geological situations could not be observed, probably because of the relative low intensity. A slightly higher intensity in the 15th district, the slope area of Wilhelminenberg in the 16th district and some areas within 17th district close to the “Gürtel” main road, as well as slightly lower intensity in Alterlaa (23rd district) were exceptions deviating from the general tendency, however.

Instrumental recordings in Vienna corresponded well with the intensity assignments, especially when taking into account the geology, which is responsible for wide scatters in documented intensity-ground motion relations.

District	Intensity				
	3	3-4	4	4-5	5
1			9	4	
2	1	5	18	1	
3		2	19	7	1
4		2	13	5	
5		2	19	8	
6		1	9	6	
7			13	4	
8		2	8	1	
9		1	19	8	
10		2	24	16	5
11		1	7		2
12		1	12	11	1
13		1	10	12	1
14		3	21	2	2
15		2	9	7	2
16		2	16	6	1
17		1	14	8	1
18		1	23	6	
19		1	35	6	2
20	2	3	17	4	
21		2	13	2	
22		4	30	3	
23		8	18	11	10

Table 3: Intensity distribution for the different districts of Vienna.

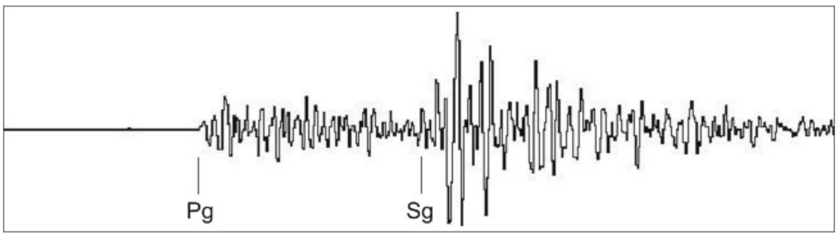

Figure 6: Record of the main shock of the event on July 11, 2000, 04:50 at the strong-motion station in Vienna-Neuwaldegg (vertical component). Pg- and Sg-arrivals are clearly visible as well as the increasing amplitude and period of the S-wave that transports the major part of the released energy and is used to determine the magnitude. The time interval between Pg- and Sg-arrival can be used to estimate the epicenter distance. In the present case the time difference amounted to 4 seconds, corresponding to a distance of about 32 km. Some inhabitants woke up when the P-wave arrived and noticed the S-wave-arrival few seconds later. Maximum amplitude in horizontal direction: 0.12 m/s².

The discussed earthquake was not the strongest, which occurred ever in the Vienna Basin. From the past, stronger seismic events are known from the earthquake catalogue (ZAMG, 2001). Local intensities in Vienna were already observed up to intensity "7", and thus the potential of damage in Vienna due to earthquakes in its vicinity remains relatively high. The Austrian Building Code ÖNORM B4015 (2002) considers these stronger earthquakes. However, some historical earthquakes have to be re-analyzed or even still to be found. Apart from instrumental methods the Seismological Service of Austria (ZAMG) continues to investigate such historical events to enhance the quality of estimating the earthquake hazard the population of Vienna is exposed to.

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Appendix

EMS intensity	Definition	Description of typical observed effects (abstract)
I	**Not felt**	Not felt.
II	**Scarcely felt**	Felt only by very few individual people at rest in houses.
III	**Weak**	Felt indoors by a few people. People at rest feel a swaying or light trembling.
IV	**Largely observed**	Felt indoors by many people, outdoors by very few. A few people are awakened. Windows, doors and dishes rattle.
V	**Strong**	Felt indoors by most, outdoors by few. Many sleeping people awake. A few are frightened. Buildings tremble throughout. Hanging objects swing considerably. Small objects are shifted Doors and windows swing open or shut.
VI	**Slightly damaging**	Many people are frightened and run outdoors. Some objects fall. Many houses suffer slight non-structural damage like hair-line cracks and fall of small pieces of plaster.
VII	**Damaging**	Most people are frightened andrun outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many well built ordinary buildings suffer moderate damage: small cracks in walls, fall of plaster, parts of chimneys fall down; older buildings may show large cracks in walls and failure of fill-in walls.
VIII	**Heavily damaging**	Many people find it difficult to stand. Many houses have large cracks in walls. A few well built ordinary buildings show serious failure of walls, while weak older structures may collapse.
IX	**Destructive**	General panic. Many weak constructions collapse. Even well built ordinary buildings show very heavy damage: serious failure of walls and partial structural failure.
X	**Very destructive**	Many ordinary well built buildings collapse.
XI	**Devastating**	Most ordinary well built buildings collapse, even some with good earthquake resistant design are destroyed.
XII	**Completely devastating**	Almost all buildings are destroyed.

Short form of the EMS-98 (Grünthal, 1998)

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