Chapter 4
Seismicity of Polish Part of the Western Carpathians in the Light of Recent Data

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Abstract This chapter presents our up-to-date knowledge on seismicity of the Polish part of the Western Carpathians. It also gives a list of seismic sites and description of measurement procedures applied in the discussed region thus far. We mainly focus on seismicity of the Podhale region, the Pieniny Klippen Belt and the Beskids. At the moment there are 5 seismic stations in the Podhale region, which record the permanent weak seismic activity at the level of $0.5 \leq M_L \leq 2.3$. In this paper we estimated the completeness of catalogs and the distribution of magnitude exceedance probability for events in the Podhale region.

Keywords Seismicity · Western Carpathians · Podhale · Seismic network · Catalog completeness · Probability distribution

4.1 Introduction

The Carpathians are part of the Alpine Mediterranean Belt. The seismicity of the Carpathians is mainly observed in the Vrancea zone in Romania. Three strong earthquakes, with magnitudes larger than 6.5, occurred there in the last 30 years, and earthquakes with magnitudes of 5 occur almost every year (Zsíros 2003). Another seismic area in the Carpathians is the Pannonian Basin. Magnitude 6 earthquakes occur once in about 100 years, while magnitude 5 events occur every 20 years on the average (Tóth et al. 2008).

The Western Carpathians region is the northwesternmost part of the Carpathian mountain chain. It is located mostly on the territory of Slovakia and Poland, and

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partly in the Czech Republic, Hungary and Austria. The Western Carpathians have a significant seismicity. Epicenters of earthquakes, that occurred manly on the territory of Slovakia, have been documented in the Labák and Brouček's (1996) catalog since the year 1034. The most seismically active in the Western Carpathians are the regions of Žilina, Dobrá Voda (the best spatially defined focal zone), Malé Karpaty Mts, Central Slovakia, Komárno and Slanské Vrchy Mts (Slovakia). The three largest earthquakes were those of 5 June 1443 in Central Slovakia, 28 June 1763 in Komárno and 9 January 1906 in Dobrá Voda, all with epicentral intensity $I_o = 8–9$ (MKS) (Kováč et al. 2002). Earthquakes from Žilina have been known since the XVII century, where the strongest event was that of 16 November 1613 with $I_o = 8$ (Labák and Brouček 1996), causing damage to buildings in Bratislava. Another felt earthquake in this region was that of 15 January 1858 with epicentral intensity of about 8 (EMS) (Zsíros 2005).

The Western Carpathians are divided into three subprovinces: Outer, Central and Inner. The territory of Poland covers in part the Outer and Central Western Carpathians, and also in part the Outer Eastern Carpathians. In the area of Poland, the Western Carpathians region is the most seismically active region of the country, as known since the XVIII century. The strongest events occurred on 11 March 1717, 23 March 1935 and 30 November 2004 in the Podhale area (Laska 1902; Pagaczewski 1972; Guterch 2009). Their epicetral intensity was 7.

The instrumental seismic measurements have been carried out in Poland since the beginning of the last century. The recent data cover permanent digital measurements by the Polish Seismological Network (PLSN) and measurements by mobile seismic monitoring stations. Since 2008, the Institute of Geophysics, Polish Academy of Sciences (IGF PAS) has begun seismic measurement campaign focused on the observation of local seismicity and neotectonic recognition of the Western Carpathians. The recording of permanent seismicity made it possible to verify the completeness of the catalogs and determine the seismic hazard parameters of the Podhale region in the Central Western Carpathians.

4.2 Seismic Measurements in Poland

On the territory of the present-day Poland, seismic measurements have been conducted since the beginning of XX century. The first seismological observatory in this area was established by Professor M.P. Rudzki at the Jagiellonian University in Cracow (KRA) in 1903. It was equipped with two horizontal seismographs of Bosch-Omori type. Its high-quality data over the period 1903–1916 are still used in the world literature. Another seismological observatory with long tradition was the Silesian Geophysical Observatory at Racibórz (RAC), which started working in 1928, established (in then German town Ratibor) and directed by Professor Karl Mainka, inventor of the MAINKA seismographs. Since 1953 the station RAC, managed by the IGF PAS, has been continuing its work. There was also the "Erdbebenwarte Breslau-Krietern" station in Wrocław (BRE) (then German city

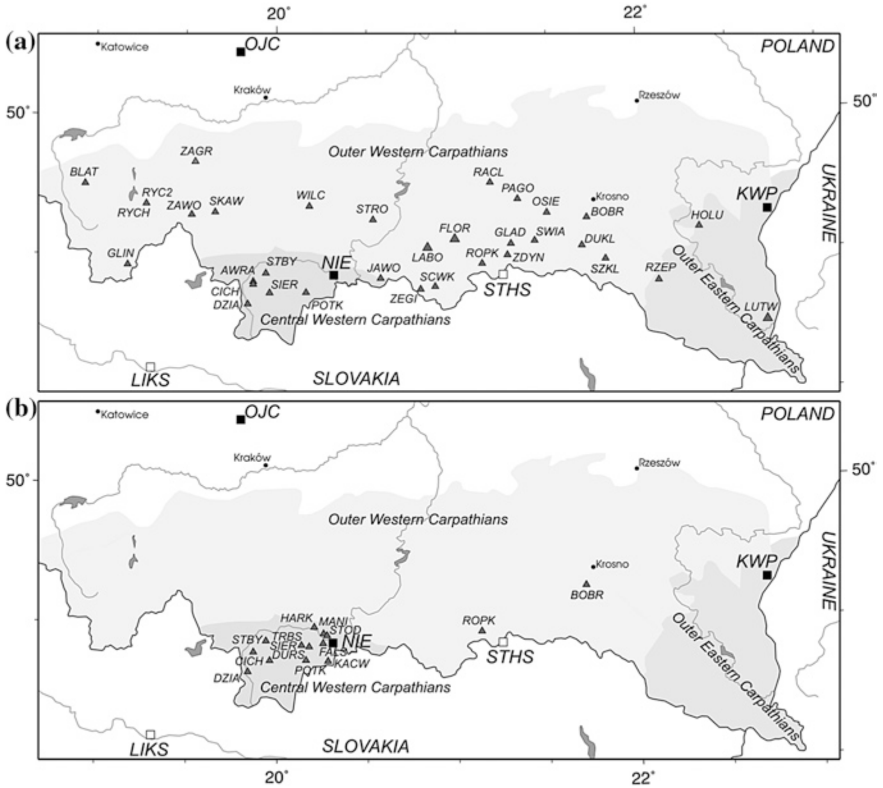

Fig. 4.1 Location of seismic stations in the Polish part of the Western Carpathians: **a** MSHTP project: 2008–2012, **b** PGMP-I project: from 2013. *Triangles*—temporary seismic network, *squares*—National Seismic Networks (*black*—Polish, *white*—Slovakian)

Breslau), established in 1909, operative (with some breaks) until the Second World War. We should also mention the Seismological Station in at the Polytechnic in Lwów (now Lviv in the Ukraine), established as early as 1901 (for more information about the history of seismology in Poland see, e.g., Maj and Teisseyre 2014).

Since 1953, the seismic measurements on the territory of Poland have been managed by the Institute of Geophysics PAS; until the 1990s these were analog recordings. Digital recording of seismic signal started in fact in 1988. The Polish Seismological Network (PLSN) consists of 7 broadband and 2 short-period stations. The seismic data are exchanged online with foreign institutions and seismological centers.

Local seismicity in the Western Carpathians in southern Poland is monitored mainly by seismic stations Niedzica (NIE), Ojców (OJC) and Kalwaria Pacławska (KWP) (Fig. 4.1). The NIE was established in the mid-1960s on the historical castle in Niedzica. The seismic noise was related to human activity in the castle. The station was moved in 1994 to a new location on a mountain top about 2 km away from the dam on the river Dunajec, and started operating as a short-period digital station. Despite the proximity of the power plant, the recording conditions at NIE were remarkably good; however, the triggered mode of recording limited the detection of small events. In September 2005 there started a continuous recording of 20 sps (samples per second) data, whereas 100 sps data were still recorded in triggered mode. In 2013 it started continuous 100 sps data recording. In April 2009, seismometers SM-3 were replaced by the broadband seismometers STS-2. Station OJC was put up in 1990 and it is the best Polish station in terms of noise conditions. It has been working all the time as a digital station. It has been using different equipment, but since August 1999 the broadband seismometer STS-2 has been applied. The seismic station KWP was put up in June 1999 in cooperation with GEOFON Network of the GeoForschungsZentrum Potsdam (Germany). It has been equipped with the broadband seismometers STS-2 and performed continuous data recording, initially at a rate of 20 sps and from May 2010 at a rate of 100 sps. In addition, the seismic monitoring is supported by Slovak seismic stations LIKS (Likavka) and STHS (Stebnická Huta).

In 2008–2012, the project *Monitoring of Seismic Hazard of Territory of Poland* (MSHTP) was launched by the IGP PAS (Trojanowski et al. 2012). The goal of the project was to complement PLSN with temporary mobile seismic network to record natural seismic events in chosen regions of Poland. The stations' sites were determined after detailed analysis of historical seismic activity. The MSHTP project administered 24 seismic stations over a period of 5 years in two stages (Trojanowski et al. 2015). In the first stage of the project, since mid-2008 to mid-2010, the measurements were made in southern Poland, with special attention to the Western Carpathians. The recording was made in 33 sites. In the second stage, since mid-2010 to the end of 2012, seismic monitoring was made in central and southern Poland, while the Western Carpathians region was only monitored by the five stations: CICH, DZIA, SIER, STBY, and POTK (Fig. 4.1a, b).

The seismic network in Podhale continued working after the end of the MSHTP project. These measurements have been run by the IGP PAS within the *Permanent Geodynamical Monitoring of Poland—stage I* (PGMP-I) project. The period of realization of the PGMP-I project is 2013–2015. Seismic monitoring consists of 20 mobile stations in Poland, 14 being located in the Western Carpathians. The location of stations in the Western Carpathians and duration of their operation in the framework of MSHTP and PGMP-I projects is shown in Fig. 4.1a, b and Appendices A and B.

4.3 Seismicity of the Western Carpathians in Poland

4.3.1 Outer Western Carpathians—Carpathians Foothills and Beskids

The oldest historical earthquake in the Outer Western Carpathians, with epicentral intensity $I_o = 4$, was located in the Carpathians Foothills in 1857 (Guterch 2009).

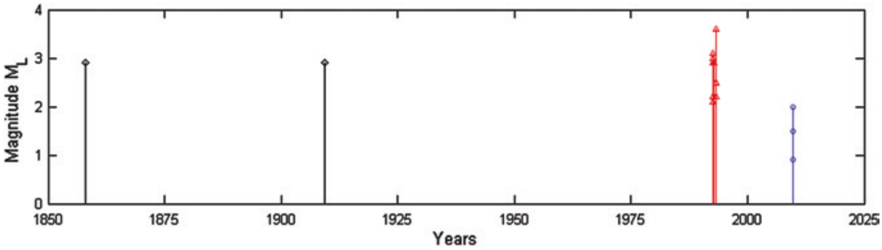

Fig. 4.2 Time sequence of earthquakes around Krynica. *Diamonds*—historical earthquakes, *triangles*—earthquakes recorded instrumentally by the PLSN, *circles*—earthquakes recorded by the MSHTP project

The Western Beskids is the region in which the historical seismic activity is poorly documented and can be confirmed only by one earthquake of 06.05.1909 with $I_o = 4$. In the years 1992–1993, a series of shocks took place near Krynica (Figs. 4.2 and 4.4). The magnitudes of main earthquakes were $M_L = 3.6$ (29.06.1992) and $M_L = 4.0$ (01.03.1993) (Guterch 2009). For the stronger event, small construction damages were reported near the epicenter. Each of these events was accompanied by weaker foreshocks and aftershocks (Guterch et al. 2000; Guterch 2009). Seismic activity of the Krynica region was confirmed during the MSHTP project. Three earthquakes were registered. Two events occurred on 4 September 2009: the first with $M_L = 0.9$ and the other with $M_L = 1.5$. The strongest one, of 23 October 2009, had $M_L = 2.0$.

Seismological bulletins of Institute of Geophysics PAS exhibit in the period 2001–2002 [see Draber et al. 2003b, 2004) a series earthquakes of local magnitude about 2 on the border of the Western Beskids and the Pieniny Klippen Belt (Figs. 4.3 and 4.4). During the PGMP-I project, four events were registered in this region. The first and strongest event ($M_L = 2.8$) was on 01.04.2014 and was felt by some Szczawnica inhabitants. Later the same day, another event ($M_L = 1.8$) was registered, which was followed by two weaker earthquakes in next few days.

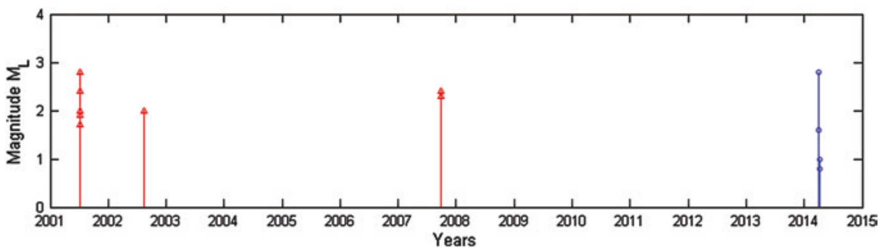

Fig. 4.3 Time sequence of earthquakes in the area between Szczawnica and Grybów. *Triangles*—earthquakes recorded instrumentally by the PLSN, *circles*—earthquakes recorded by the PGMP-I project

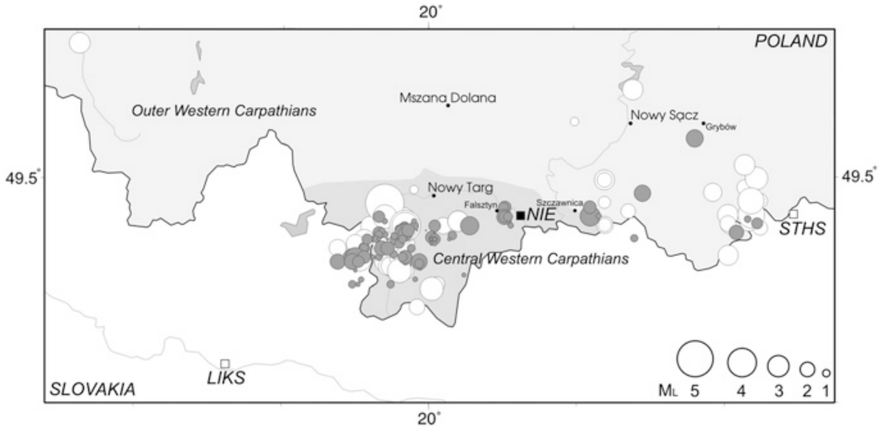

Fig. 4.4 Earthquakes in the Carpathians in Poland over the period from 1716 to 2007 (*white circles*) and recent events from 2008 to 2014 (*gray circles*)

The region of Central Beskids is very poorly explored. The reports on its seismicity are of weak reliability (Pagaczewski 1972). However, between 24 and 27 September 2007, seismic stations in Poland and Slovakia registered series of weak events in the neighborhood of Grybów town. On 24 and 25 September 2007 there were 13 events and on 27 September 2007 other two weak events which were recorded by STHS only. No felt reports have been known. Locations were only possible for the two most intense events from area of Grybów (Wiejacz et al. 2008): $M_w = 2.3$ at 16:27 on 25.09.2007, and $M_w = 2.6$ at 21:32 on 25.09.2007 (Fig. 4.4). There were no seismic events registrations from this area during the MSHTP and the PGMP-I projects. However, due to a widespread area of station sites, the detection threshold was at the level of $M_L = 1.5$.

4.3.2 Central Western Carpathians—Podhale and Pieniny Klippen Belt

Podhale is a relatively well examined seismic region in the Western Carpathians, where historical events of epicentral intensity I_o in the range of 6–7 are known since the XVIII century (Table 4.1). The strongest instrumentally recorded shock in Podhale took place on 30 November 2004 ($M_L = 4.3$) in the Orava–Nowy Targ Basin (Guterch 2005). After the main shock, a series of aftershocks, which lasted for almost one year, took place. Because of the lack of seismic stations in this area, focal parameters could be calculated only for shocks of magnitudes greater than 2.0. Other historical earthquakes in the region are also known: $I_o = 7$ on 23 March 1935 and on 11 March 1717, and weaker events that were instrumentally recorded since the late 1980s (Table 4.1).

Table 4.1 Historical events in the Podhale region (mainshocks, Guterch 2014)

Date	Longitude [°N]	Latitude[°E]	Epicentral intensity I_o	Magnitude M_L
1716	19.90	49.40	6	3.9
1717.03.11	19.90	49.40	7	4.4
1935.03.23	19.85	49.45	7	4.4
1942.03	19.90	49.40	4–5	3.0
1966.03.17	19.90	49.30	4–5	2.8

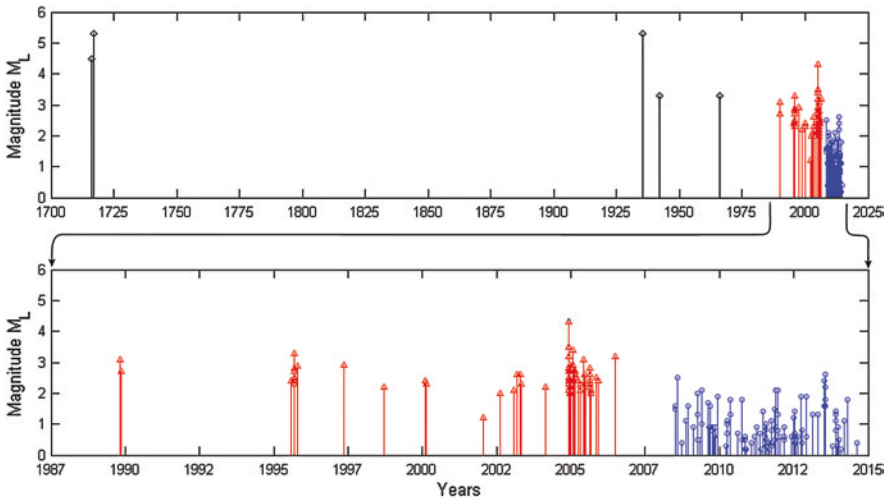

Fig. 4.5 Time sequence of all earthquakes in the Podhale region. *Diamonds*—historical earthquakes, *triangles*—earthquakes recorded instrumentally by the PLSN, *circles*—earthquakes recorded by the MSHTP and the PGMP-I projects

Podhale is the only region in Poland which shows constant natural seismic activity. During the MSHTP and the PMGP-I projects, between July 2008 and May 2014, about 150 earthquakes were registered in Podhale, 100 of them being located (Fig. 4.4). Moreover, in the area of Czorsztyńskie Lake, in November and December 2011, swarm events were registered in the Pieniny Klippen Belt area. Epicenters were localized in the Pieniny Klippen Belt near Falsztyn village, about 2 km from the Seismological Observatory NIE, where seismic activity has not been known so far.

The seismic monitoring network in Podhale registers, on the average, a natural seismic earthquake of $0.5 < M_L < 2.3$ once a month. These are weak events, at the level of noise. Figure 4.5 presents time sequence of all earthquakes in Podhale since 1700 until May 2014.

4.4 Distribution of Magnitudes in Podhale, Western Carpathians

Podhale is the only region in Poland in which a sufficient number of seismic events was recorded and the historical seismicity was documented in order to determine the probability of occurrence of shocks. To this end, it was necessary to use all the available information on the events in Podhale in various times. We can specify three different catalogs of seismic events in the Podhale region, including:

i. Historical events noticed up to the 1970s. The catalog includes only extreme events (Guterch 2014).
ii. Events recorded instrumentally by the PLSN from the late 1980s.
iii. Events recorded by seismic network in Podhale from the mid-2008 to the first three months of 2014.

The historical catalog includes 5 events noticed in the period 1716–1966 (Table 4.1).

The catalogs of instrumentally recorded events have different magnitude completeness thresholds. In order to determine the magnitude distribution, it was necessary to define the magnitude completeness threshold of these catalogs.

4.4.1 Completeness of Catalogs

Magnitude of completeness (M_C) of earthquake catalogs is the lowest magnitude at which all the earthquakes are detected in selected space and time volume. The completeness of catalogs can be estimated based on shape of Frequency-Magnitude Distribution (FMD) of detected events in the selected region as well as by other techniques (Mignan and Woessner 2012). The following methods were applied: Maximum Curvature (MAXC) method (Wyss et al. 1999; Wiemer and Wyss 2000), Entire Magnitude Range (EMR) method (Woessner and Wiemer 2005) and the *b*-value stability (MBS) method (Cao and Gao 2002).

The Maximum Curvature method estimates M_C as the point of the maximum curvature by computing the maximum value of the first derivative of the frequency-magnitude distribution. In practice, this matches the group of magnitudes with the highest frequency of events in the FMD. This technique requires fewer events than other techniques to reach a stable result, however it underestimates sometimes the M_C value (Wiemer and Wyss 2000; Woessner and Wiemer 2005).

The EMR technique estimates M_C using the entire magnitude range with events below the M_C. Woessner and Wiemer (2005) proposed a model consisting of two parts: the Gutenberg-Richter law for the complete part, and the cumulative normal distribution for the incomplete part of the FMD. They tested the lognormal and Weibull distributions as well.

Cao and Gao (2002) estimated Mc using the stability of the *b*-value of Gutenberg-Richter (Gutenberg and Richter 1944) model as a function of cut-off magnitude M_{Co}, named MBS by Woessner and Wiemer (2005). The M_C is defined as the magnitude for which the changes in b-value (Δb) are smaller than 0.03. It is based on the assumption that the estimated value of b increases for $M_{Co} < M_C$ and remains constant for $M_{Co} > M_C$. This method does not produce good results in case of high variability of the FMD. Woessner and Wiemer (2005) used the b-value uncertainty δb according to Shi and Bolt's (1982) criterion:

$$\delta b = 2.3b^2\sqrt{\frac{\sum_{i=1}^{N}(M_i - \langle M\rangle)^2}{N(N-1)}},$$

where $\langle M\rangle$ is the mean magnitude and N is the number of events. In case of events in the Podhale region, the variability of the FMD is rather high, because of a small number of events.

In the years 1989–2007, seismic stations in Poland recorded 75 earthquakes (Draber et al. 1998, 2001, 2002, 2003a,b, 2004; Guterch 2006, 2007, 2009). After removing aftershocks of the event on November 30, 2004, there remain 50 events. They are shown in Fig. 4.6. To determine M_C the MAXC, EMR and MBS methods were applied. M_C values calculated by different methods and minimum recorded magnitude (M_{min}) are presented in Table 4.2. Basing on Table 4.2 and the FMD (Fig. 4.7a) we can assume that the catalog of events recorded instrumentally by the PLSN is complete from magnitude 2.4.

In the years 2008–2014, more than 100 seismic events with magnitude M_L from 0.2 to 2.4 was detected and localized in the Podhale region (Fig. 4.8). The best detection of small events is inside the network of seismic stations and outside it is worse. On the basis of values of M_C presented in Table 4.2, spatial distribution of magnitude of the recorded events (Fig. 4.8) and the shape of the FMD (Fig. 4.7b), it was assumed that the catalog of events is complete from magnitude 0.8.

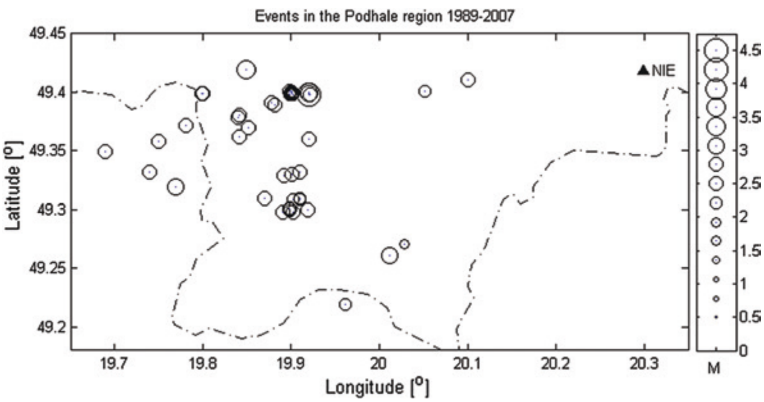

Fig. 4.6 Main seismic events in Podhale recorded in the years 1989–2007

Tab. 4.2 Magnitudes of completeness (M_C) of two catalogs of events (periods 1989–2007 and 2008–2014) estimated by various methods

Technique	M_C	
	1989–2007	2008–2014
MAXC	2.4	0.6
EMR	2.4	0.8
MBS	1.4	0.3
M_{min}	1.2	0.2

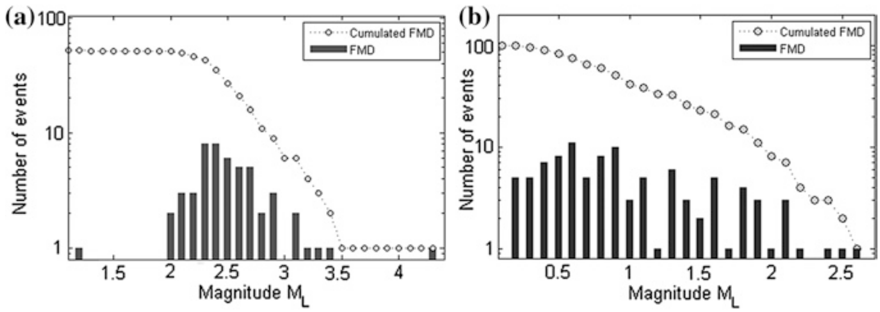

Fig. 4.7 The frequency-magnitude distribution (FMD) of events recoded in the Podhale region in the period 1989–2007 (**a**) and 2008–2014 (**b**)

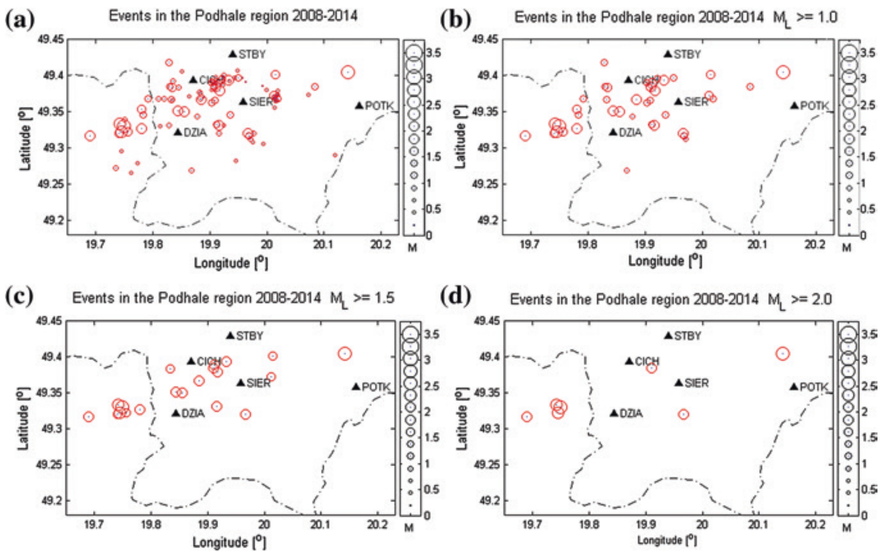

Fig. 4.8 Seismic events in Podhale in the period 2008–2014 for different cut-off magnitudes: **a** all events, **b** $M_L \geq 1.0$, **c** $M_L \geq 1.5$, and **d** $M_L \geq 2.0$

4.4.2 The Magnitude Exceedance Probability in the Podhale Region

The probability distribution of magnitude in the Podhale was calculated on the basis of estimation of earthquake hazard parameters from incomplete data catalogs

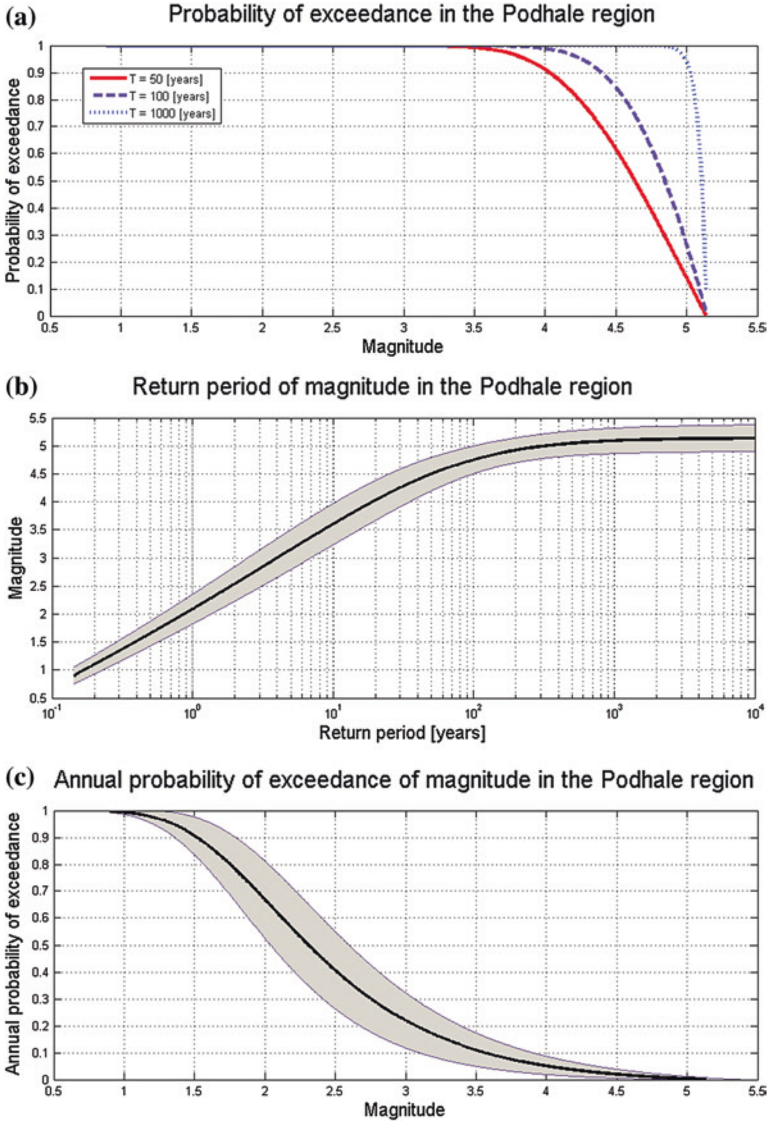

Fig. 4.9 The distributions of magnitudes in the Podhale region: **a** probability of exceeding the magnitude within the period of: 50 years—*solid line* (*red*), 100 years—*dashed line* (*purple*), 1,000 years—*dotted line* (*blue*); **b** return period versus magnitude; **c** annual probability of exceedance of magnitude; *gray* color in **b** and **c** indicates the range of uncertainty

(Kijko and Sellevoll 1989, 1992). We used three seismicity catalogs of Podhale: historical, catalog for 1989–2007, and catalog for 2008–2014. The maximum regional magnitude in the Podhale region was determined by Kijko-Selevoll-Bayes method (Kijko and Singh 2011). Calculations were made by HA2 program shared by the author, Prof. A. Kijko (Kijko 2010). The magnitude probability distribution parameters were:

$$\begin{array}{ll} \boldsymbol{\beta} = 1.76 \pm 0.18 & (\boldsymbol{b} = 0.77 \pm 0.08) \\ \boldsymbol{\lambda} = 9.795 \pm 2.457 & (\text{for}\, \boldsymbol{m_{min}} = 0.90;\ \boldsymbol{a} = 1.67 \pm 0.11) \\ \boldsymbol{m_{max}} = 5.11 \pm 0.51 & (\text{for}\, \boldsymbol{m_{max\,obs}} = 5.00 \pm 0.50) \end{array}$$

The distributions of magnitudes in the Podhale region is presented in Fig. 4.9. The probabilities of exceeding a magnitude within a defined period of time (50, 100, 500 years) are shown in Fig. 4.9a. The probability of exceeding the magnitude 5 is greater than 0.1 even for the shortest period (50 years). The return period of the particular magnitude is shown in Fig. 4.9b. Annual probability of exceeding the magnitude is presented in Fig. 4.9c. Probability of occurrence of events of $M_L = 1.5$ in one year is bigger than 0.9.

4.5 Conclusions

The Western Carpathians area had been monitored by the seismic station in Niedzica and additionally by stations of Slovak Seismological Network since 1960. However, the increase in detections of events in Podhale coincides with the expansion of PLSN, which began in the late 1980s, as well as the start of digital seismic measurements. This enabled the creation of complete catalog of seismic events with magnitude above 2.4 in this period. In the years 2008–2014, the mobile seismic monitoring of the Western Carpathians was carried out. Data from the seismic networks in the region significantly increased the amount of information on seismicity. The seismic network PLSN, as well as a temporary networks in the MSHTP and PGMP-I projects allowed for moving from macroseismic analysis in the region to registration of microevents.

The constant tectonic seismic activity in the Central Western Carpathians was detected in the area of Podhale. On the average, one shock a month was recorded in this region. Occasional events appeared in the Outer Western Carpathians as well. Basing on recent data we can conclude that they are grouped in two areas: around Krynica town and between Szczawnica and Grybów towns.

Owing to the monitoring of Podhale it was possible to create a complete catalog starting with magnitude of 0.8. This rendered us a possibility of attempting an evaluation of magnitude distribution. However, the duration of recording in the Podhale region was too short to get a sufficient number of strong events. Therefore, for estimating the magnitude distribution we had to use both the data from historic earthquake catalogs and those from catalogs of events recorded by PLSN. The magnitude distributions obtained are important from the engineering point of view, since it follows from them that the probability of the occurrence of an magnitude 5 event within 50 years is greater than 0.1, which should be accounted for, e.g., when buildings are designed.

However, to make a full assessment of seismic hazard of the Podhale region, a long-term continuation of measurements is indispensable, since no stronger events have been recorded in the period examined thus far. First of all, there is a lack of records of stronger ground motion amplitudes for estimating the Ground Motion Prediction Equations (GMPE). It is also advisable to further develop the network of seismic stations. This will enable determining the focal mechanism of the events in Podhale, and getting a better insight into the neotectonics of the area.

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Appendixes

Appendix A: List of seismic stations in the Western Carpathians—*Monitoring of Seismic Hazard on the Territory of Poland* project (in alphabetical order)

No.	Station code	Place	Registration period	Latitude [°N]	Longitude [°E]
1	AWRA	Ciche	2008.06.17–2008.08.10	49.40	19.87
2	BLAT	Błatnia	2009.05.06–2009.10.02	49.75	18.94
3	BOBR	Bóbrka	2008.09.09–2010.05.19	49.62	21.71
4	CICH	Ciche	2008.08.11–2012.12.31	49.39	19.87
5	DUKL	Dukla	2008.06.19–2008.08.06	49.52	21.68
6	DZIA	Dzianisz	2010.10.27–2012.12.31	49.32	19.84
7	FLOR	Florynka	2008.06.18–2008.09.04	49.55	20.98
8	GLAD	Gładyszów	2009.10.26–2010.01.09	49.53	21.29
9	GLIN	Glinka	2009.09.17–2010.04.14	49.46	19.18
10	HOLU	Hołuczków	2008.07.17–2010.06.08	49.58	22.33
11	JAWO	Jaworki-Biała Woda	2008.06.18–2008.07.20	49.41	20.57
12	LABO	Łabowa	2008.09.10–2010.05.19	49.52	20.83
13	LUTW	Lutowiska	2008.07.18–2010.05.31	49.24	22.69
14	OSIE	Osiek Jasielski	2008.06.19–2008.09.03	49.64	21.49
15	PAGO	Pagorzyna	2008.09.09–2010.05.27	49.69	21.33
16	POTK	Potok	2010.10.26–2012.12.31	49.36	20.16
17	RACL	Racławice	2008.08.07–2008.08.30	49.75	21.18

(continued)

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18	ROPK	Ropki	2008.08.09–2010.06.01	49.46	21.13
19	RYCH	Rychwałdek	2008.11.01–2009.05.05	49.68	19.28
20	RYC2	Rychwałdek	2009.05.05–2010.05.17	49.68	19.28
21	RZEP	Rzepedź	2008.07.19–2010.05.31	49.39	22.10
22	SCWK	Szczawnik	2008.08.09–2008.10.29	49.38	20.87
23	SIER	Sierockie	2008.08.11–2012.12.31	49.36	19.96
24	SKAW	Skawica	2008.07.20–2010.05.12	49.65	19.66
25	STBY	Stare Bystre	2008.07.20–2012.12.31	49.43	19.94
26	STRO	Stronie	2008.09.13–2010.06.01	49.62	20.53
27	SWIA	Światkowa Wielka	2008.08.08–2008.09.04	49.54	21.42
28	SZKL	Szklary	2008.08.07–2010.05.31	49.47	21.81
29	WILC	Wilczyce	2008.08.11–2010.05.31	49.67	20.18
30	ZAGR	Zagórze	2008.07.21–2010.06.16	49.83	19.55
31	ZAWO	Zawoja	2008.06.17–2008.07.20	49.64	19.53
32	ZDYN	Zdynia	2009.09.30–2009.10.26	49.49	21.27
33	ZEGI	Żegiestów	2008.10.29–2010.05.31	49.37	20.79

Appendix B: List of seismic stations in the Western Carpathians—*Permanent Geodynamical Monitoring of Poland—stage I* project (in alphabetical order)

No.	Station code	Place	Registration from	Latitude [°N]	Longitude [°E]
1	BOBR	Bóbrka	2013.11.20	49.62	21.71
2	CICH	Ciche	2013.08.27	49.39	19.87
3	DURS	Dursztyn	2013.08.27	49.41	20.19
4	DZIA	Dzianisz	2013.08.27	49.32	19.84
5	FALS	Falsztyn	2013.08.27	49.42	20.28
6	HARK	Harklowa	2013.08.27	49.48	20.18
7	KACW	Kacwin	2013.08.27	49.36	20.30
8	MANI	Maniowy	2013.08.27	49.45	20.28
9	POTK	Potok	2013.08.27	49.36	20.16
10	ROPK	Ropki	2013.11.19	49.46	20.16
11	SIER	Sierockie	2013.08.27	49.36	19.96
12	STBY	Stare Bystre	2013.08.27	49.43	19.94
13	STOD	Kluszkowce	2013.08.27	49.44	20.29
14	TRBS	Trybsz	2013.08.27	49.42	20.12

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