Operational Procedures of Agencies Contributing to the ISC

Seismological Observatory Berggießhübel

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5.2 Seismological Observatory Berggießhübel

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The Seismological Observatory Berggießhübel was founded by the Freiberg University of Mining and Technology (TU Bergakademie Freiberg) in 1957 as an initiative of the project "International Geophysical Year". The Observatory belongs to the Institute for Geophysics and Geoinformatics and is situated about 60 km south-east of Freiberg at the edge of the Saxonian Ore Mountains (Fig. 5.16). The remoteness of the location and the underground installation of measurement devices within an old mine provides excellent conditions for seismological measurements, which have been done continuously since 1966.

5.2.1 History

The idea to establish a seismic station close to Freiberg mines came along after the 1st International Seismological Conference in Strasbourg in 1901, but for political reasons it took a while to set up a seismic station. The first who took action at the beginning of the 1950's was Prof. Wolfgang Buchheim, director of the Institute for Theoretical Physics and Geophysics of Bergakademie Freiberg and a former student of Werner von Heissenberg. He looked for an alternative, quieter site for seismological measurements in the environment of noisy Freiberg town and found it in Berggießhübel, where the instruments could be installed within a tunnel of an abandoned mine. Based on the intention to measure a broad spectrum of Earth's oscillations, the observatory was established as a so-called "Earth tide station" first. A seismic test recording was set up on 1st May 1960, just 22 days before the strongest earthquake ever recorded by seismographs occurred with a magnitude of Mw 9.5 in Chile. This was good timing and a stroke of luck because this strong event showed that the amplification of the horizontal components (Fig. 5.17) was very low (only ten times real ground motion) while the vertical component was completely locked and station operators would have waited, unsuccessfully, for a long time for any visible deflection of the seismic record.

The continuous seismic record began in October 1966, two years after the International Seismological Centre (ISC) was established. Equipped with 3-component short and long periodic seismometers, seismic station Berggießhübel was integrated under code BRG into the World-Wide Standard Seismographic

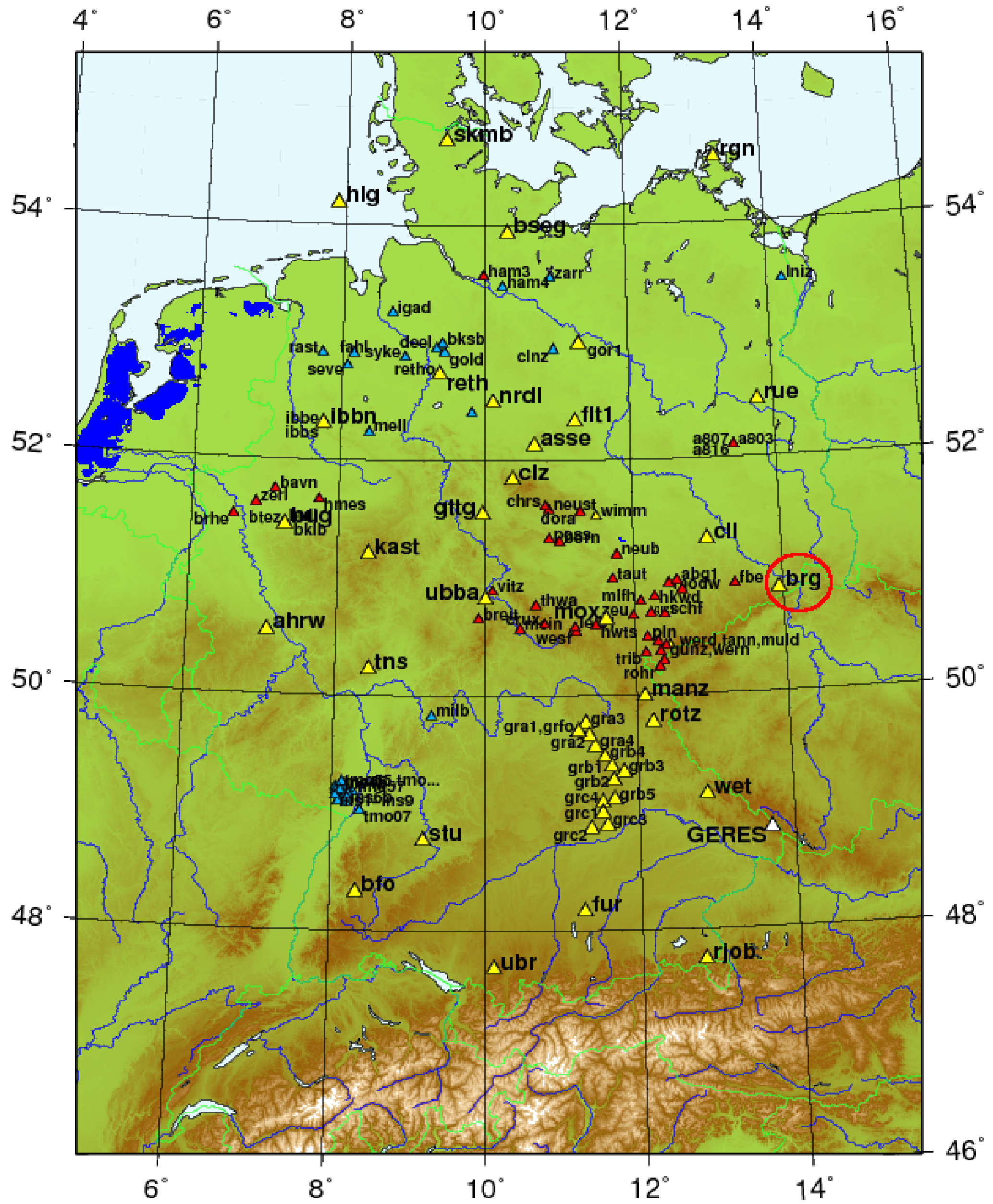

Figure 5.16: *GRSN (German Regional Seismic Network) seismic station network with station BRG (red circle). Yellow triangles are GRSN stations and GRF array, red triangles are stations from institutions other than Federal Institute for Geosciences and Natural Resources (BGR) and blue triangles are temporary BGR deployments. © BGR (http://www.bgr.bund.de/EN/Themen/Seismologie/Seismologie/Seismometer_Stationen/Stationsnetze/d_stationsnetz_node.html)*

Network WWSSN. From 1974 the observatory BRG began to send seismo reports to the ISC and became a consistent data contributor.

In 1993 the observatory was equipped with a Streckeisen triaxial broadband seismometer of type STS-2 (Fig. 5.18) with digital data acquisition. Via the German Regional Seismic Network GRSN seismic station BRG was also integrated into the Global Digital Seismographic Network GDSN. In 2001 a LaCoste earth tide gravimeter of type G 701 and an in-house made tiltmeter were set up to extend measurements to low frequencies.

A short description of the development of the observatory is given below.

1951	First visit to the abandoned mine in Berggießhübel and planning of installation of a seismic station.
1953	First tide measurements with horizontal pendulums.
1957	Establishment of the observatory building and reconstruction of mining tunnel with vaults. In September 1957 official opening of the Observatory as "Earth tides station" under the umbrella of the Institute for Theoretical Physics and Geophysics of the TU Bergakademie Freiberg.
1960	Beginning of continuous earth tide and geomagnetic measurements. First seismic test measurements.
1964	First gravimetric measurements.
1966	Beginning of continuous seismic measurements with 3-component short- and long-period seismometer and permanent analogue drum recording.
1970	Takeover of the observatory by the Central Institute for Physics of the Earth ZIPE in Potsdam.
1974	Beginning of routine interpretation of seismic records and exchange of seismological data with data centres (ISC, NEIS, WDC-B (Moscow)).
1980-82	Operation of a seismic array for monitoring of induced seismicity in the environment of a nearby reservoir.
1981-92	Transmission of vertical short-periodic components of the seismic record for digital archiving to ZIPE in Potsdam.
1992	Takeover of the observatory by the German Research Center for Geosciences GFZ in Potsdam.
1993	Permanent installation of broadband seismometer STS-2 with digital data acquisition, transfer and archiving at the national data centre for German Regional Seismic Network GRSN in Hanover. Temporary installation of 3 gravimeters for device adjustment.
1994	Repatriation of the observatory into the hands of the Institute for Geophysics within TU Bergakademie Freiberg.
2001	Installation of a LaCoste gravimeter G 701 and home made tiltmeter.

5.2.2 Present Observatory Status

The observatory site includes a station building (Fig. 5.19) with office and facilities for the staff (Fig. 5.20) and a 200 m long mining tunnel system (Figs. 5.21 and 5.22) with vaults, that host measurement devices

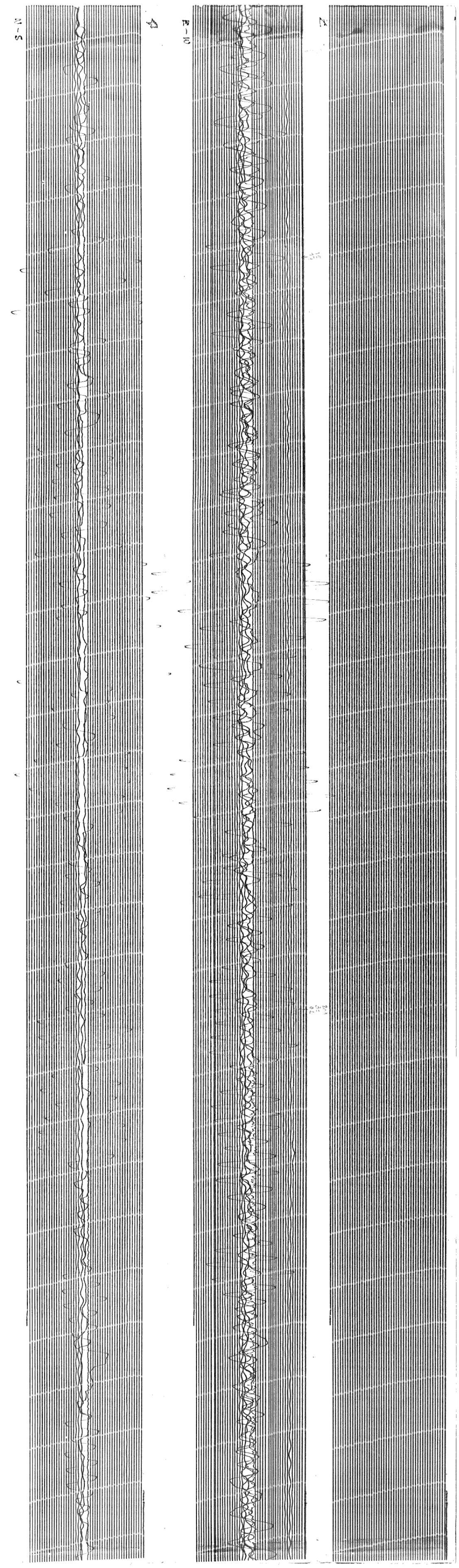

Figure 5.17: *Record on BRG of the M 9.5 1960 Chile event, the strongest earthquake ever recorded by seismographs. Left: N-S component, middle:, E-W component, and right: Z component, which unfortunately was locked.*

Figure 5.18: *STS-2 seismometer and Quantera data logger.*

(Fig. 5.18) and a collection of historical instruments (Figs. 5.23 and 5.24). The tunnel system is air conditioned. The broadband triaxial seismometer STS-2 as well as the gravimeter G 701 are installed in an isolated measurement chamber in a depth of 36 meters and coupled with the hard bedrock directly. The annual seismic noise spectra of station BRG is given in comparison to High and Low Noise Models for 2016 in Figure 5.25 showing that the noise level at the BRG site is at the lower end.

Digital data acquisition of the broadband seismometer is carried out by a 24 bit Quanterra digitizer, which generates data in miniSEED format. The time signal is provided by a GPS receiver. Data exchange is organized using a SEEDlink server that works as a ring buffer and can hold data on site for up to half a year.

Waveform data is transmitted online to the data centre of the GRSN, hosted by the Federal Institute for Geosciences and Natural Resources (BGR) in Hanover. Digital waveform data is stored and archived at this site and can be requested within suitable formats via the following website:

`http://www.bgr.bund.de/DE/Themen/Erdbeben-Gefaehrdungsanalysen/Seismologie/Seismologie/Datenzentrum/waveform_request/waveform_request_node.html`

The archiving of seismic drum records from 1966 to 1995 was taken out of the observatory to TU Bergakademie Freiberg (Fig. 5.26). Seismogram copies can be requested via email (brg@geophysik.tu-freiberg.de).

Data acquisition and storage of SG G 701 accelerometer data is done offline with a sampling frequency of 1 sample per minute. Data archiving is organized by an internal format on site.

Figure 5.19: *Observatory building.*

Figure 5.20: *Observatory office with seismologist Anja Zeibig.*

Figure 5.21: *Entry to mining tunnel.*

Figure 5.22: *Mining tunnel.*

Figure 5.23: *Reconstruction of the Bina vertical pendulum seismoscope.*

Figure 5.24: *Historical instruments including Kirnos and SSJ-1,2 seismometers.*

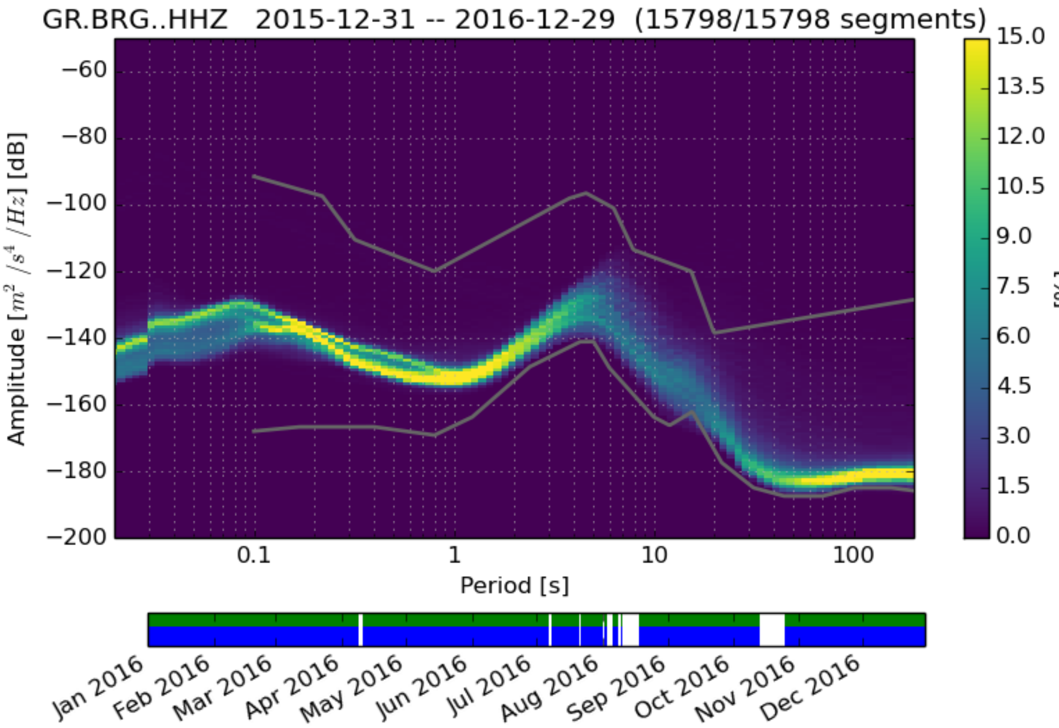

Figure 5.25: *Power spectral density of noise for station BRG, determined over one year period for 2016. Upper grey line is High Noise Model, lower grey line is Low Noise Model. White areas in time line below represent time periods with no data. © K.Stammler, BGR.*

Figure 5.26: *Archive of drum records.*

5.2.3 Data Analysis

For seismic waveform analysis the software packages Seismic Handler SH (*Stammler*, 1993) and Seis89 (*Baumbach*, 1990) are used. Data analysis is done in the tradition of observatory practice and must provide data for the monitoring of local, regional and global seismicity simultaneously. For that purpose, digital data of STS-2 broadband seismometer are processed by high pass (1 Hz), low pass (10 Hz) and bandpass filtering (0.588 Hz – 2.5 Hz) to simulate streams, equivalent to the WWSSN short- and long-period characteristics. The high pass and bandpass streams are processed by a STA/LTA detector to detect both crustal phases of local seismic events as well as body wave phases of teleseismic events. Phase and amplitude picking is done manually. Therefore, accuracy of onset time determination is limited by the sampling frequency and can be picked up to hundredths of seconds at the best. Figure 5.27 shows an example for the data analysis with Seismic Handler. For determination of amplitudes an Auto Peak procedure within Seismic Handler is mostly used and values are given to a tenth of nanometers. For seismic reports amplitude values are rounded and are given with three decimal place accuracy.

For event and phase type determination in routine station analysis data is compared with the hypocenter determination results of the local seismic network SXNET and the European data center EMSC. Because seismic station BRG is integrated into the real time information and seismic event notification services of both seismic monitoring systems, an appropriate association of event and phase type of the station records can be done. The local seismic network SXNET was set up in 2001 to monitor the local seismicity in Saxony. The seismic waveform data of the local network is processed using SeisComP (`http://www.seiscomp3.org`), a seismological software developed for data acquisition, processing, distribution and interactive analysis by the GEOFON Program (`http://geofon.gfz-potsdam.de`) at Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences. For detecting regional and teleseismic earthquakes at station BRG, a review of event data provided by the European data centre EMSC is used to ensure a proper phase association. Based on sophisticated manual routine analysis observatory BRG can provide the ISC with most accurate and relevant data of extensively exploited waveform data. As a result, observatory BRG is one of the leading single stations data providers for ISC with regard to teleseismic and secondary phase arrivals as well as amplitudes and period data for determination of magnitudes. Statistical investigations of the last ten years reveal that 7000 to 11000 seismic events are recorded by observatory BRG every year. Detected events colour coded by different event types are shown for the last 10 years in Figure 5.28. Figure 5.29 shows the percentage of each event type for 2016 in more detail. Nearly one third of the 7288 events are earthquakes, whereof 1495 (20%) are recorded from distances greater than 1000 km and 961 (13%) from distances less than 1000 km. 1138 events (16%) are associated with mining induced seismic events, mainly from Lubin Copper mine in Poland. Because station BRG is situated in a very dense region of explosion sites, nearly half of the detected events (3433, or 47%) are explosions. The rest (less than 3%) are unassociated detections.

The station's capability for detecting small magnitude events in relation to epicentral distance is shown in Figure 5.30 where all events in the ISC database for 2013, that had been recorded at station BRG, are plotted with magnitude Mw versus epicentral distance. According to the figure, from about 3 to 10 degrees epicentral distance the lowest detectable magnitude increases from ∼Mw 3.3 to ∼Mw 4. From epicentral distance of 10 to about 25 degrees the lowest magnitude threshold increases to ∼Mw 4.5 with a few smaller magnitude events around 20 degree distance. From epicentral distance 25 degrees

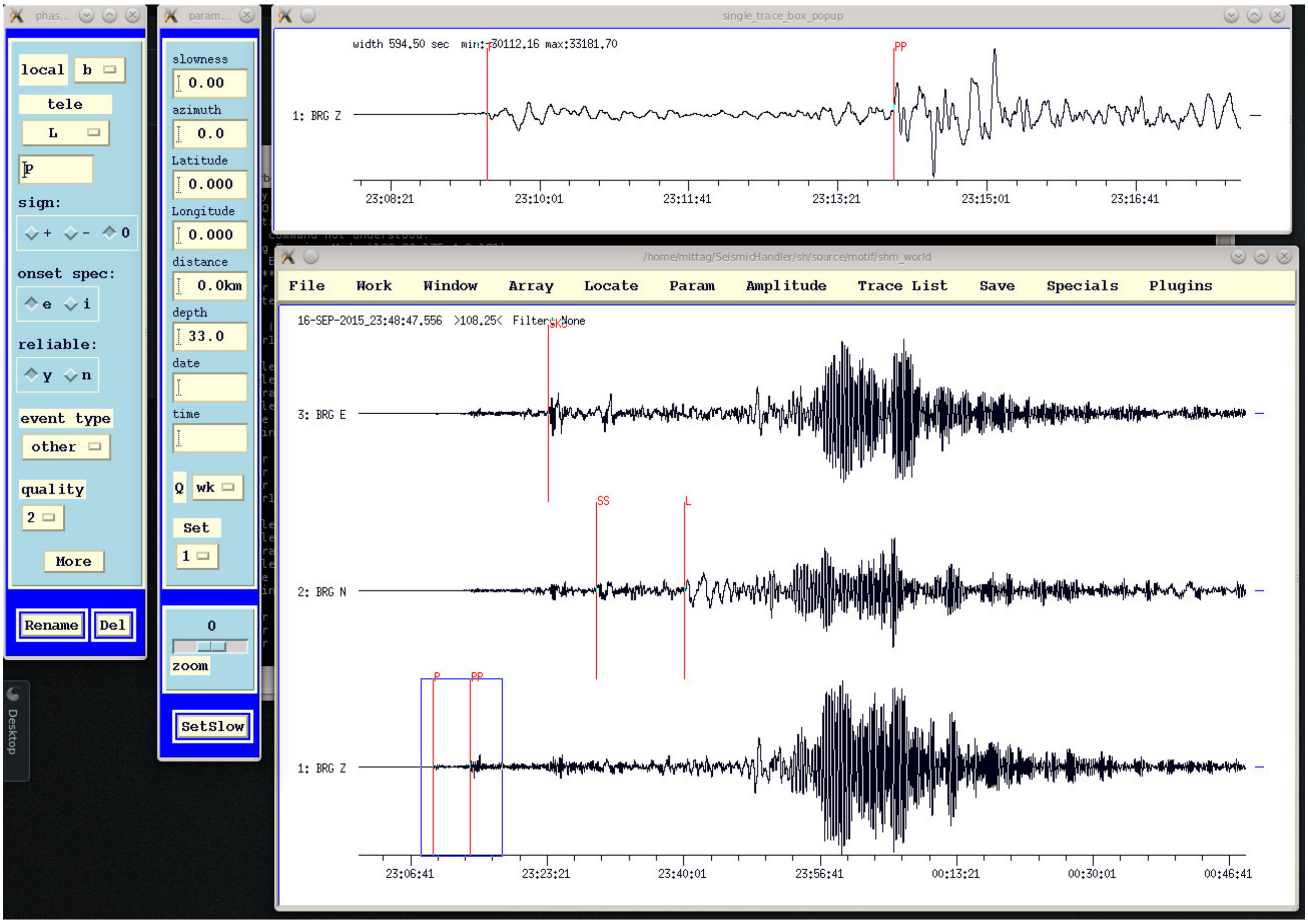

Figure 5.27: *Example for data analysis with Seismic Handler for the Mw 8.2 Illapel earthquake in Chile on 16*th *September 2016.*

onwards the lower magnitude limit shows a slight increase up to magnitudes of ∼Mw 5. For epicentral distances ranging around 80 degrees, that cover the Kuril Islands earthquake region, also smaller events with magnitude ∼Mw 4 are detected by BRG. From the linear part of cumulative magnitude-frequency distribution of all events (Fig. 5.31) recorded at station BRG in 2013 the Gutenberg-Richter-Relation can be determined to $\lg N = -0.91\, Mw + 7.61$. Furthermore, a magnitude threshold of Mw∼5.2 for complete detection of global seismicity can be derived for BRG and other single stations located in Central Europe, which have similar recording conditions to BRG.

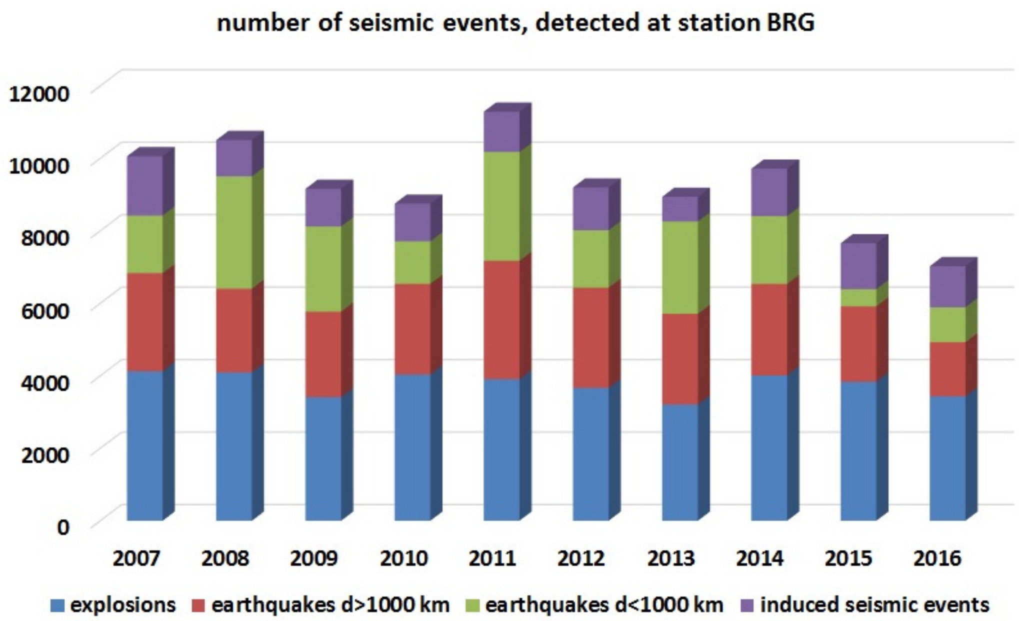

Figure 5.28: *Annual number of seismic events detected at station BRG.*

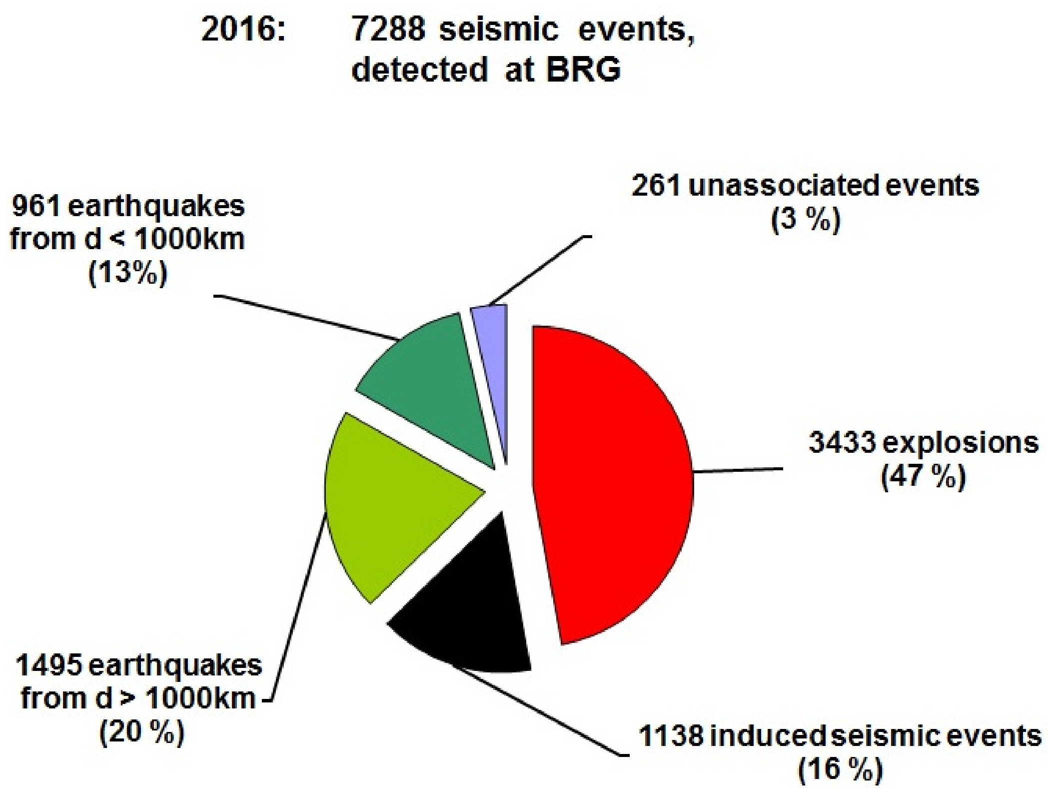

Figure 5.29: *Percentages of seismic event types detected at station BRG in 2016.*

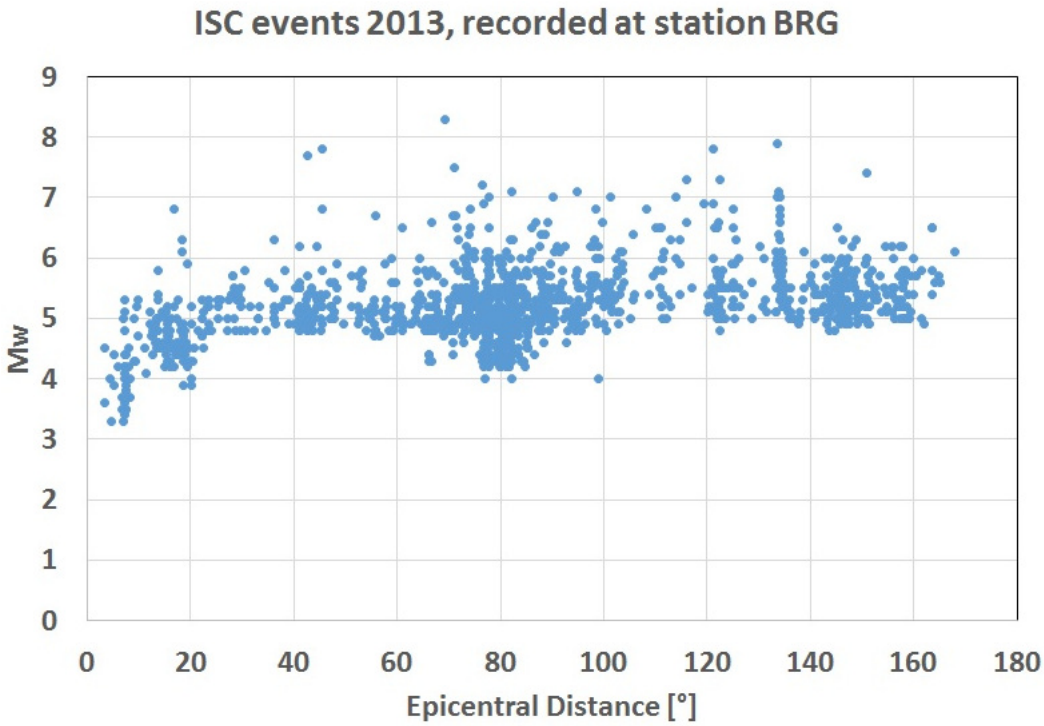

Figure 5.30: *ISC events in 2013, recorded at station BRG according to ISC bulletin.*

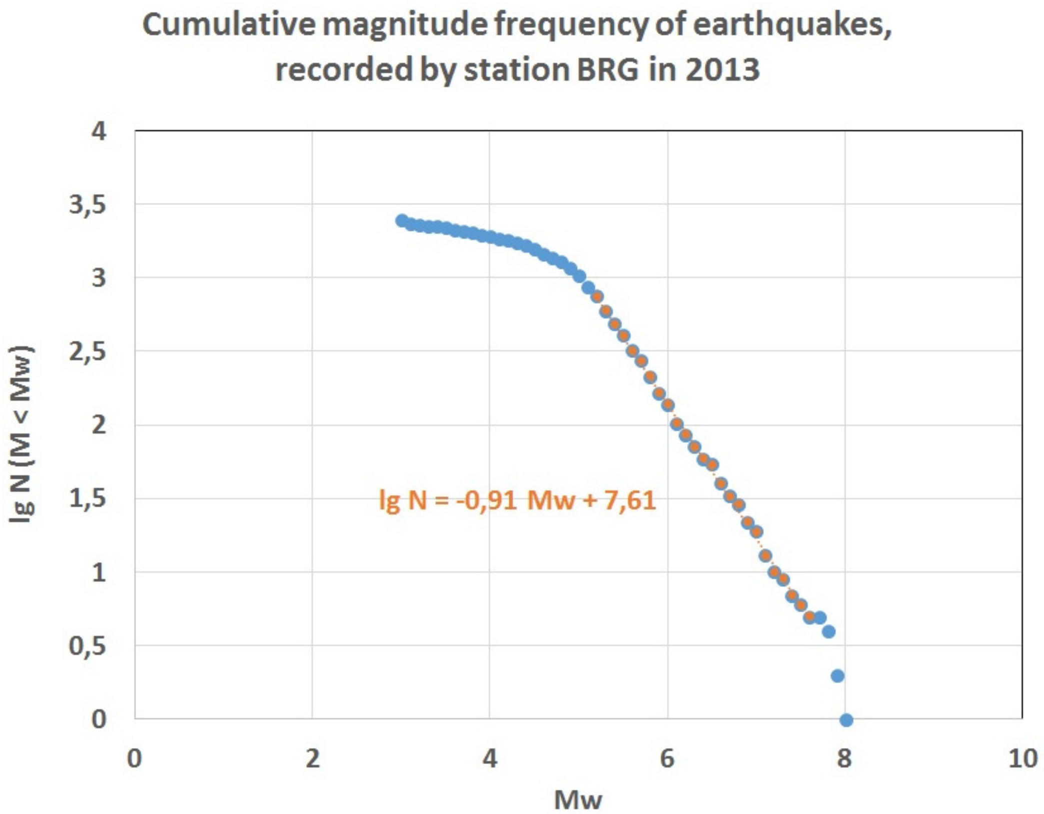

Figure 5.31: *Cumulative magnitude frequency of earthquakes, recorded at station BRG in 2013 according to ISC bulletin.*

5.2.4 References

Baumbach, M. (1992), SEIS89 – A PC application for interactive seismogram analysis and processing. *XXII General Assembly European Seismological Commission*, Barcelona, 17-22 September 1990.

Stammler, K. (1993), Seismic Handler – Programmable multichannel data handler for interactive and automatic processing of seismological analyses, *Computers & Geosciences*, *19*(2), 135–140, http://www.seismic-handler.org, DOI:10.1016/0098-3004(93)90110-Q.