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The 6 May 1976 Friuli earthquake: re-evaluating and consolidating transnational macroseismic data

A. Tertulliani[1], I. Cecić[2], R. Meurers[3], I. Sović[4], D. Kaiser[5], G. Grünthal[6], J. Pazdírková[7], C. Sira[8], B. Guterch[9], R. Kysel[10], T. Camelbeeck[11], T. Lecocq[11] and G. Szanyi[12]

[1] *Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy*

[2] *Agencija RS za okolje, Ljubljana, Slovenia*

[3] *Zentralanstalt für Meteorologie und Geodynamik, Vienna, Austria*

[4] *Geofizički odsjek Prirodoslovno-matematičkog fakulteta Sveučilišta, Zagreb, Croatia*

[5] *Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Germany*

[6] *Helmholtz Centre, GFZ German Research Centre for Geosciences, Potsdam, Germany*

[7] *Ústav fyziky Země, Brno, Czech Republic*

[8] *Le Bureau Central Sismologique Français, Strasbourg, France*

[9] *Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland*

[10] *Comenius University and Earth Science Institute of the Slovak Academy of Sciences, Bratislava, Slovakia*

[11] *Seismology-Gravimetry, Royal Observatory, Brussels, Belgium*

[12] *MTA CSFK GGI Kövesligethy Radó Szeizmológiai Obszervatórium, Budapest, Hungary*

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ABSTRACT The aim of this paper is to propose the creation, in terms of European Macroseismic Scale (EMS-98), of the entire macroseismic field of the 6 May 1976 Friuli earthquake. Only forty odd years have passed, and nothwithstanding that there is a huge quantity of existing data, it was still disturbing to find that much of the original data are missing and probably lost forever. Efforts have, therefore, been made to find additional and still unknown primary data. For the majority of the collected national data sets, a re-evaluation was, then, possible. This study presents the comprehensive macroseismic data set for 14 European countries. It is, to our knowledge, one of the largest European data sets, consisting of 3423 intensity data points. The earthquake was felt from Rome to the Baltic Sea, and from Belgium to Warsaw. The maximum intensity 10 EMS-98 was reached in eight localities in Friuli (Italy). Compared to previous studies, the I_{max} values have changed from country to country, in some cases being lowered due to methodological differences, but in the case of three among the most hit countries, I_{max} is now higher than in the previous studies, mainly due to the new data.

Key words: 1976 Friuli earthquake, macroseismic intensity.

1. Introduction

On 6 May 1976, 20:00 GMT, an earthquake of M_w 6.4 (Rovida *et al.*, 2016) devastated towns

and villages in Friuli (northern Italy) and adjacent regions, over an area about 1800 km^2, taking almost 1000 lives (among other reports Briseghella *et al.*, 1976; Di Cecca and Grimaz, 2009; Slejko, 2018). Many small towns and villages were almost completely destroyed, such as Gemona, Venzone, and Osoppo in Italy, or Podbela and Breginj in Yugoslavia (today Slovenia), with the loss of a huge architectural and monumental heritage. The damage area included many Italian, Austrian, and Slovenian towns and villages. The earthquake was felt in the whole of northern-central Italy, and in almost all of central Europe up to the Baltic Sea (Kárník *et al.*, 1978). The epicentral intensity was estimated as IX-X or X Medvedev-Sponheuer-Kárník (MSK) or Mercalli-Cancani-Sieberg (MCS), according to different studies (e.g. Gasparini, 1976; Giorgetti, 1976; Molin, 1994; Boschi *et al.*, 1995). On 11 and 15 September 1976, two strong aftershocks with respective magnitudes M_w 5.6 and 5.9 (Rovida *et al.*, 2016) contributed to worsen the damage and halt the first restoration work. The sequence was considered concluded after the 16 September 1977 aftershock (M_L 5.4) and its tail-end of aftershocks (Suhadolc, 1982).

The 6 May event and the following seismic sequence have been the subject of many and various studies, including investigating the seismogenic source (e.g. Caputo, 1976; Finetti *et al.,* 1979; Cipar, 1981; De Natale *et al.*, 1987; Slejko *et al.*, 1999; Aoudia *et al.*, 2000; Pondrelli *et al.*, 2001; Galadini *et al.*, 2005; Burrato *et al.*, 2008; Cheloni *et al.*, 2012; Moratto *et al.*, 2012), the ground motion characteristics (Rovelli *et al.*, 1991; Zollo *et al.*, 1997, and others), stress modelling and geodetic inversion (Bencini *et al.*, 1982; Briole *et al.*, 1986; Perniola *et al.*, 2004, and others). A widely accepted model is a 18×11 km^2 reverse fault, WNW-ESE oriented (Aoudia *et al.*, 2000) while, among the proposed hypocentre locations there are still some differences in the literature (Costa *et al.*, 2009; Slejko, 2018).

Although it was one of the earthquakes that provoked a very large resonance in Europe, a thorough cross-border macroseismic study of the 1976 Friuli earthquake does not yet exist. However, Kárník *et al.* (1978) published a joint isoseismal map of the event by combining, more or less, the contributions of the European countries within the shaken area in the form of their national isoseismals (Fig. 1). Other papers dealing with macroseismic data of the 1976 Friuli earthquake were, in general, confined to a national level (e.g. Gasparini, 1976; Giorgetti, 1976; Mayer-Rosa *et al.*, 1976; Milošević, 1977; Schmedes and Leydecker, 1978; Drimmel *et al.*, 1979; Sikošek *et al.*, 1979). Noteworthy in this respect are the report by Ambraseys (1976) and the monumental collection of data on damage to historical buildings by Briseghella *et al.* (1976). The MSK-64 scale (Medvedev *et al.*, 1967) was preferentially used to estimate the intensity values, even if in some cases, especially in Italy, the MCS scale was chosen using a translation of its German original by Sieberg (1932).

So far, the task to re-evaluate and consolidate the huge amount of macroseismic information on the Friuli earthquake was considered too large to undertake. Issues and questions in producing standardized transnational macroseismic data have already been described by Tertulliani *et al.* (1999). Moreover, the 1970s was a period of important instrumental developments, within which macroseismology was pushed into the background. Later, in the 1980s and 1990s, with the increasing demands for realistic probabilistic seismic hazard assessments, reliable earthquake catalogues were needed based on, among others, detailed basic macroseismic material. Additionally, with upcoming seismic risk studies, more and more intensity based load parameters were required. All these developments led to a general revival of macroseismology.

The aim of this work was to create a new macroseismic map of the 6 May 1976 Friuli

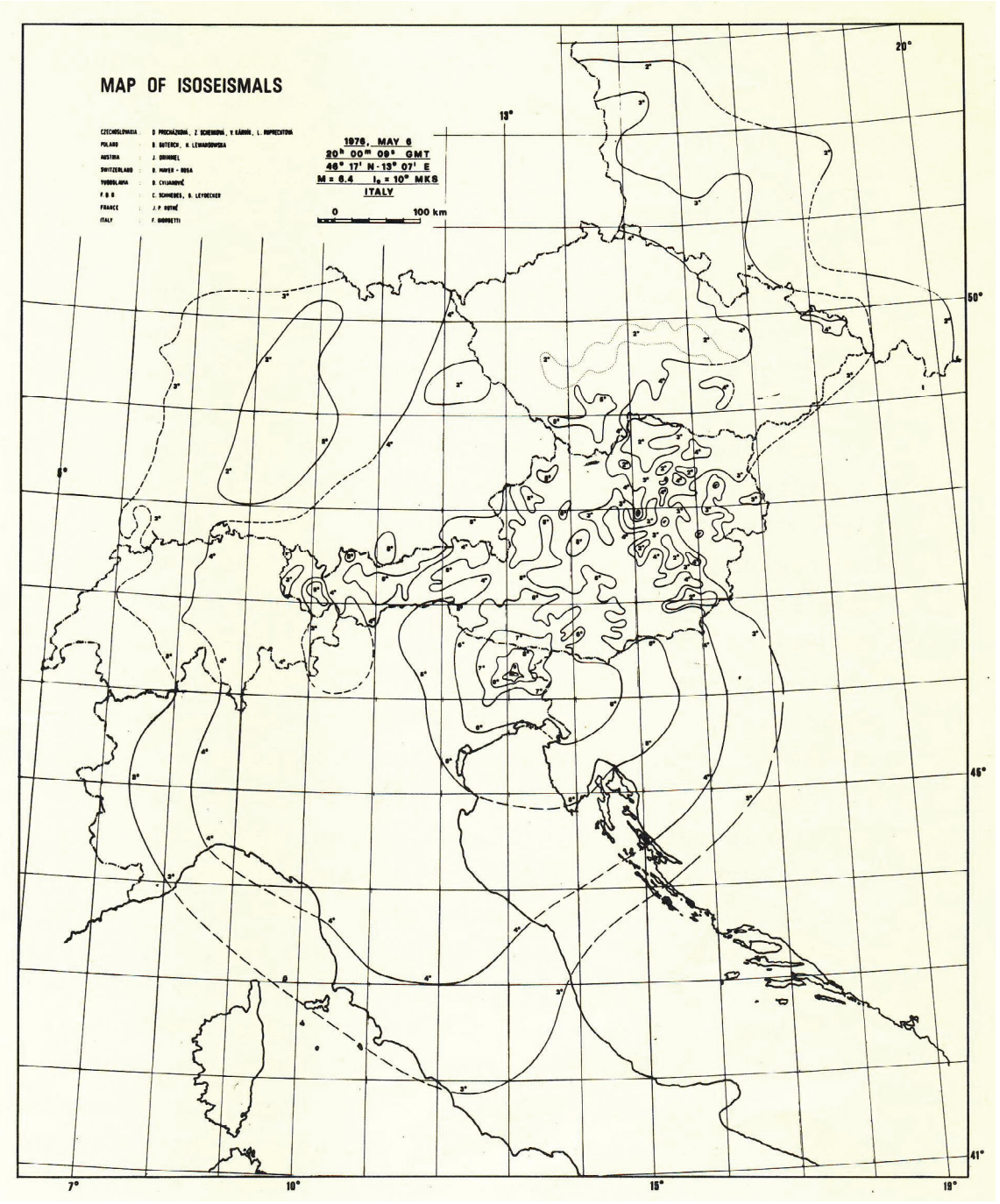


Fig. 1 - Multinational isoseismal map of 6 May 1976 Friuli earthquake, compiled by Kárník *et al.* (1978).

earthquake, by applying the EMS-98 scale (Grünthal *et al.*, 1998) on the abundant intensity data set available from a considerable number of European countries. This enables specifying and unifying the intensity assignments with the bonus of overcoming discontinuities in the course of isoseismals at national borders as they occurred in the respective joint isoseismal map of the 1970s.

2. State of the art about 40 years ago

The 6 May 1976 earthquake had an impact on many countries. Italy and the neighbouring Slovenia (at that time part of Yugoslavia) and Austria suffered major effects, while in other countries, situated further away from the epicentre, the earthquake was barely felt by people. In the following chapters, we describe how the macroseismic approach on the earthquake was managed in each of the countries involved, and which kind of data are available so far.

In order to make the differentiation visually easier, we have chosen to use Roman numerals for the intensity values taken from older studies and Arabic numerals for the new study.

2.1. Italy

The Friuli region (NE Italy) sustained the main and worst effects of the earthquake, with widespread destruction. The earthquake hit a traditional and old building stock, often poorly maintained (Santulin *et al.,* 2018). In the words of Ambraseys (1976) describing the local situation: "*More than three-quarters of the houses in the region are of very old construction. Their walls consist of a coarse, short-bedded, badly-laid rubble masonry sometimes mixed with bricks and with great thicknesses of lime or clay mortar joints, concealed by plaster or rough cast.*"

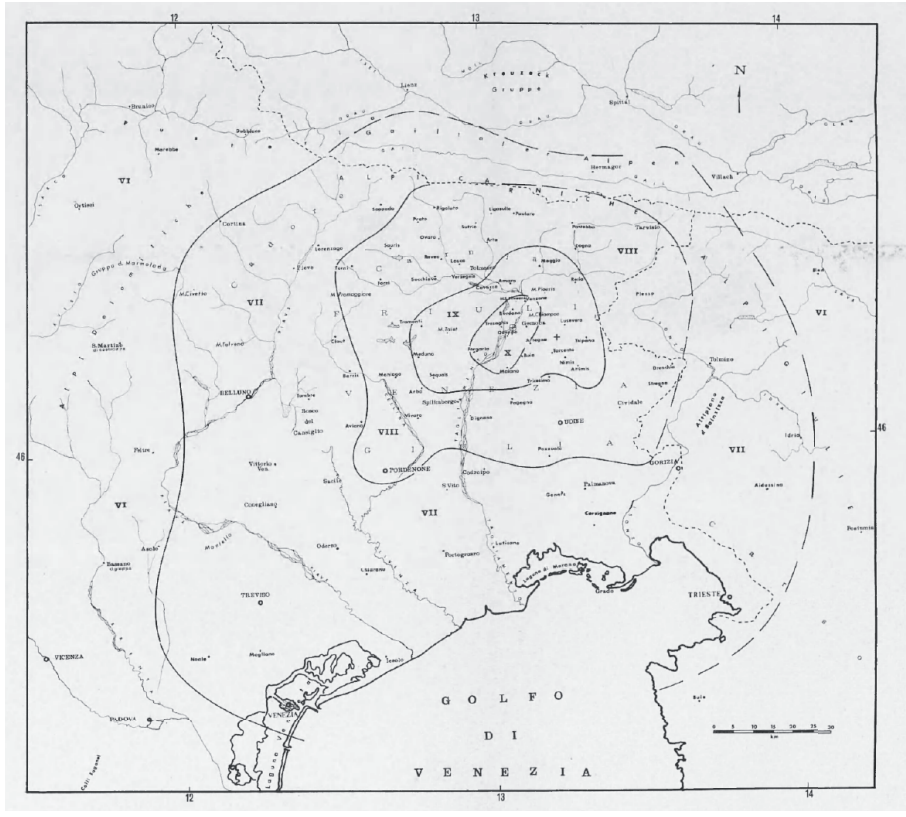
The main and earliest sources of the macroseismic intensity data for the Italian side of the earthquake are Gasparini (1976) and Giorgetti (1976), who both used direct field surveys data, the questionnaires of the Genio Civile Regionale of Friuli Venezia Giulia, and the macroseismic questionnaire forms collected at that time by the Central Bureau of Agrarian Ecology (UCEA - Ufficio Centrale di Ecologia Agraria) in Rome. Both Gasparini (1976) and Giorgetti (1976) did not publish any descriptions of effects, but only the isoseismal maps; Gasparini (1976) used the MCS scale (Fig. 2a) and Giorgetti (1976) used MSK (Fig. 2b).

Other important coeval sources of information are the cited report of Ambraseys (1976) who, on behalf of UNESCO, prepared a thorough report with descriptions of earthquake effects in approximately 600 localities, and the report by Briseghella *et al.* (1976) on the damage to historical buildings.

Later, Molin (1994) made a synthesis of the above-cited works and some other sources, providing a final list of 772 localities with MCS intensities, without descriptions. His work, in particular, is the reference source of the Parametric Catalogue of Italian Earthquakes [CPTI15: Rovida *et al.* (2016)], the most recent macroseismic intensity data set of the Friuli earthquake. The other important collection of macroseismic data for Italian earthquakes is the Catalogue of Strong Earthquakes in Italy [CFTI04: Guidoboni *et al.* (2007)], which used a variety of different sources, including press reports and newspaper articles, providing concise descriptions for each locality. These two catalogues display a different number of intensity data points (IDPs; CFTI04: 528 IDPs, 450 with $I \geq$ VI MCS; while CPTI15 displays: 770 IDPs, 651 with $I \geq$ VI MCS), and acknowledge different sources. Different maximum intensity (I_{max}) values are also published: X MCS for five localities by CFTI04 and IX-X MCS for sixteen localities by CPTI15.

2.2. Slovenia

Previously, macroseismic data for Slovenia was evaluated twice, in 1976 by Ribarič (1976b), and then in 2002 by Cecić (2002).



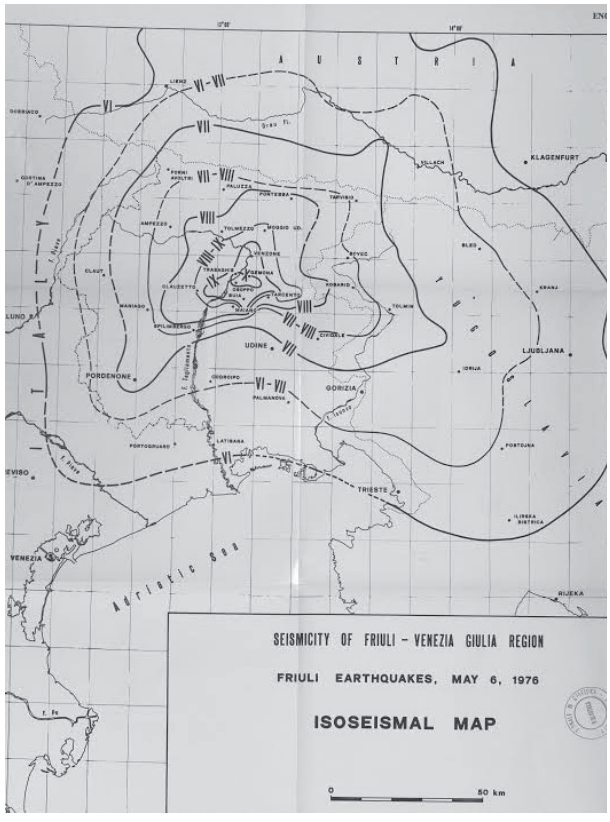


Fig. 2 - Isoseismal map for Italy: a) compiled by Gasparini (1976); b) compiled by Giorgetti (1976).

In Slovenia, the earthquake caused a great deal of damage in its westernmost part, called Breginjski kot. One person died and 31 were wounded (Informacija, 1976). There were not many reinforced-concrete houses; the majority of buildings in the most hit villages were of low vulnerability class (A or B), mostly made of stone with wooden floors and lime mortar. The poor quality of buildings was owing to the fact that some localities were destroyed in both World Wars and rebuilt using available local material and very little funds.

The majority of buildings in Breginjski kot had damage categorized as degree 3 and 4. One of the reasons was also local geology, and the short distance from the epicentre played its part. There were also some seismogeological effects (7 m long cracks on the banks of river Bela).

In all, there were 10552 buildings damaged in the 1976 earthquakes in Slovenia, 6336 among them in the municipality of Tolmin. Out of those, 5532 buildings in the municipality of Tolmin were damaged on 6 May 1976. The area of damage went as far as Ljubljana, in the city centre alone there were 31 damaged houses.

After the 6 May earthquake, seismologists and civil engineers from Yugoslavia visited the epicentral region and investigated the earthquake effects in the most heavily hit villages and small towns. Vladimir Ribarič (Slovenian seismologist and the head of seismology at that time) used questionnaire data for Slovenia, as well as his notes from the field. He most likely combined his field notes with those made by other experts (D. Cvijanović, M. Feigl, M. Krstanović, B. Metović, V. Mihajlov, S. Nedeljković, D. Prosen, B. Sikošek, V. Tešić). The questionnaires are today in the archives of Agencija RS za okolje (ARSO, Slovenian Environment Agency), the field data are collected in some unpublished reports and letters (e.g. Feigel, 1976; Hržič, 1976; Ribarič, 1976a, 1976b) or published in several papers, the most important ones being Sikošek *et al.* (1979), and Ribarič (1980).

The scales used in the publications were both MCS and MSK-64. In some cases two intensities were published for each locality, one for 6 May and the other for the cumulative effects including the earthquake on 15 September and all events in between.

The data for all the Yugoslav republics (at that time each republic had its own seismological survey) were compiled by Croatian seismologist Dragutin Cvijanović (Fig. 3) and included in Milošević (1977). This was the Yugoslav input for the map prepared by Kárník and his team (Kárník *et al.*, no date). The map shows both intensities and isoseismals for Slovenia and Croatia, with I_{max} VIII MCS in Breginj (Bergogna) for Slovenia and V-VI MCS in Motovun, Pazin, and Rijeka for Croatia (see paragraph on Croatia below). The intensities ranked from VIII to II MSK-64. The isoseismals VII, IV and III match well with Austrian ones, while for isoseismals VI and V a significant shift was visible on the state border.

In 1994, there was an attempt to begin re-evaluating intensities in Austria and Slovenia, led by Rolf Gutdeutsch from Vienna University (Gutdeutsch, 1994), but it was too time-consuming, as it assumed that all the questionnaires will be translated and exchanged, so it was never finished.

In 2002, a brief preliminary estimate of the EMS-98 intensities in Slovenia was made (Cecić, 2002), using only the selection of those considered to be most reliable.

2.3. Austria

The earthquake was felt almost all over the country; heavy damage was reported from more than thirty places in Carinthia, close to the Italian border. The intensity assessment in 1976 was

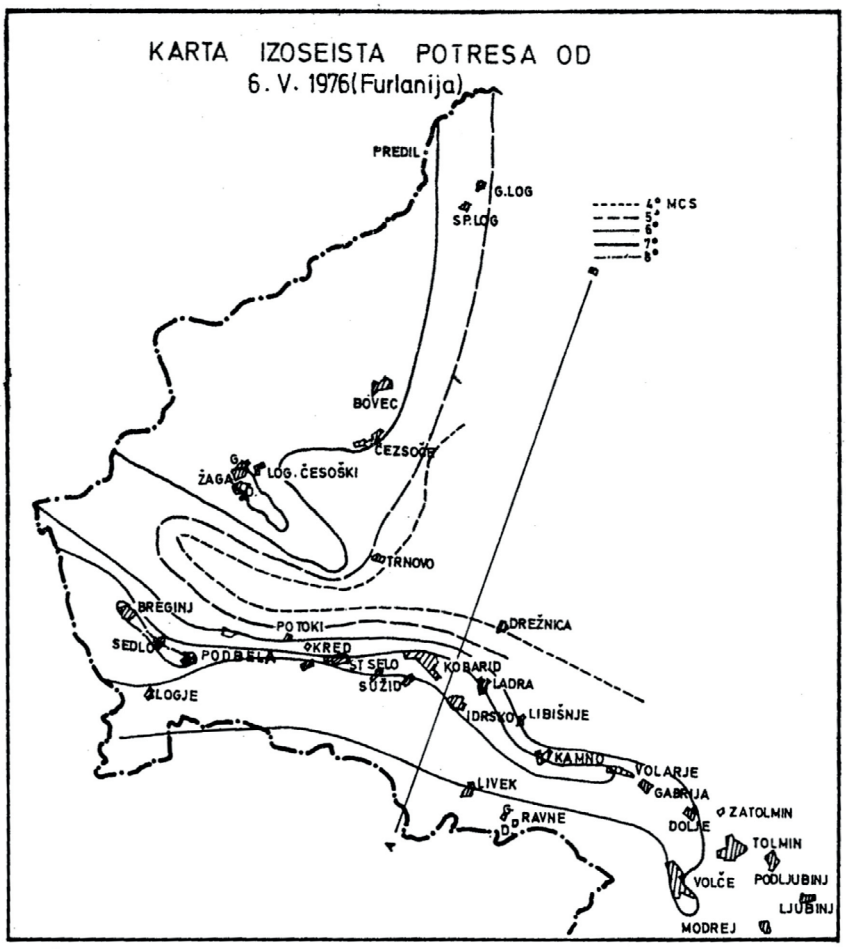


Fig. 3 - Isoseismal map for Slovenia, compiled by Ribarič (Sikošek *et al.*, 1979).

carried out by the seismological staff of the Zentralanstalt für Meteorologie und Geodynamik (Central Institute for Meteorology and Geodynamics: ZAMG) in Vienna. A summary, as well as the macroseismic results, were published by Drimmel *et al.* (1979). The MSK-64 scale was used, as was the standard practice in the 1970s. The highest local intensity was VII-VIII MSK-64 and it was assigned to seven places in the south of Carinthia. Additionally, there were 16 places with intensity VII MSK-64. The damage area ($I \geq$ VI MSK-64) covered the middle and western part of Carinthia and the eastern part of eastern Tyrol.

The isoseismal map published by Drimmel *et al.* (1979) presents very short-wavelength features as it was plotted in high spatial resolution (Fig. 4). Therefore it did not match with the isoseismals of the neighbouring countries. The inhomogeneous intensity distribution could be explained by the complexity of the geology in Austria or again simply due to insufficient information about the actual strength of shaking (e.g. only single reports from a place, contradictory descriptions). Some isolated data might have been over-interpreted when drawing the isoseismals.

After the earthquake, the Austrian Earthquake Service at ZAMG sent questionnaires to hundreds of police stations and other public authorities throughout Austria, providing a fairly high density of macroseismic information, distributed well all over the country. The questionnaires are stored in the archive of the ZAMG in Vienna.

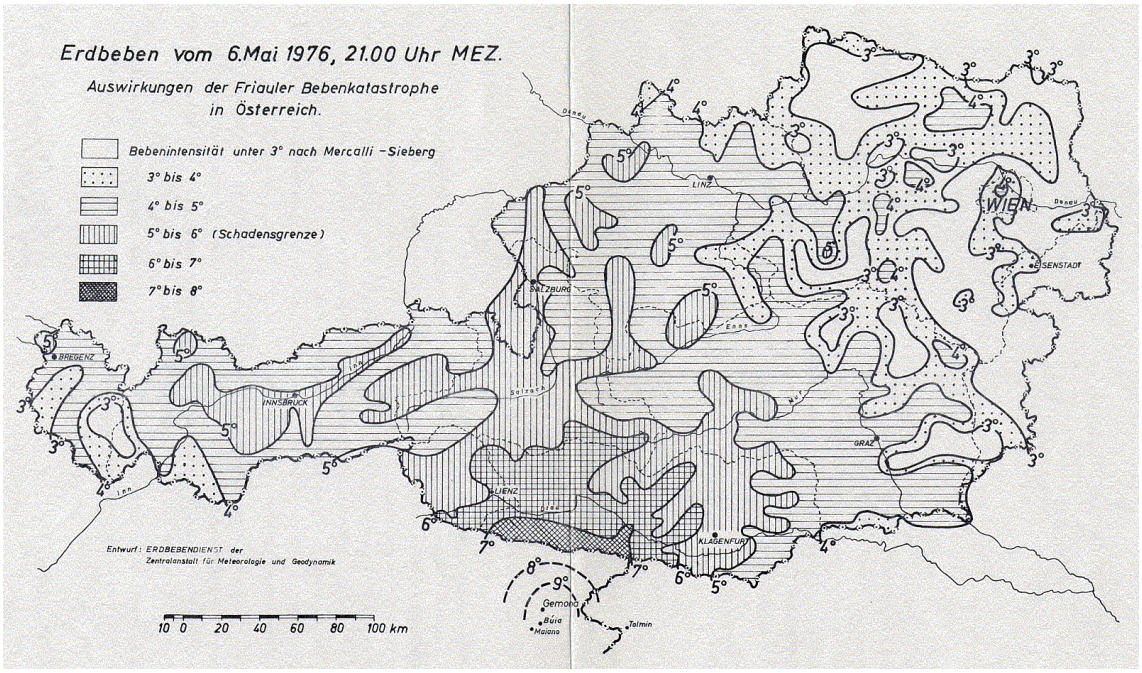


Fig. 4 - Isoseismal map for Austria, compiled by Drimmel (1979).

2.4. Croatia

The Friuli earthquake on 6 May 1976 was felt in the western part of former Yugoslavia. In Croatia, the earthquake was especially strong in its westernmost part, Istria, where houses were damaged and some of them even collapsed.

The archive of the Geophysical Institute in Zagreb contains very few data about this event, only 18 questionnaires, in spite of the evident damage. There are no records of the number of questionnaires sent, no original isoseismal map, and no list of intensities; there are no records of any field investigation. Two different isoseismal maps (Fig. 5) with data from Croatia were published (Milošević, 1977; Kárník *et al.*, 1978), but there are no originals in the Geophysical Institute archive, so it is presumed that the original isoseismal map was either lost or handed over to the civil defence authorities.

2.5. Germany

The Friuli main shock was also felt in large parts of Germany, which was at that time divided in two countries. In both parts, macroseismic studies have been treated rather differently and without any possibility of interaction. The approaches differed in particular concerning the 1976 Friuli earthquake. Therefore, the respective studies in both parts of Germany are addressed here in separate sub-chapters.

2.5.1. Former Federal Republic of Germany

The macroseismic survey of the Friuli earthquake in former West Germany was severely hampered by a general strike of the printing industry in May 1976, at the very time of the earthquake and over the following days. As the main evaluators of the macroseismic survey

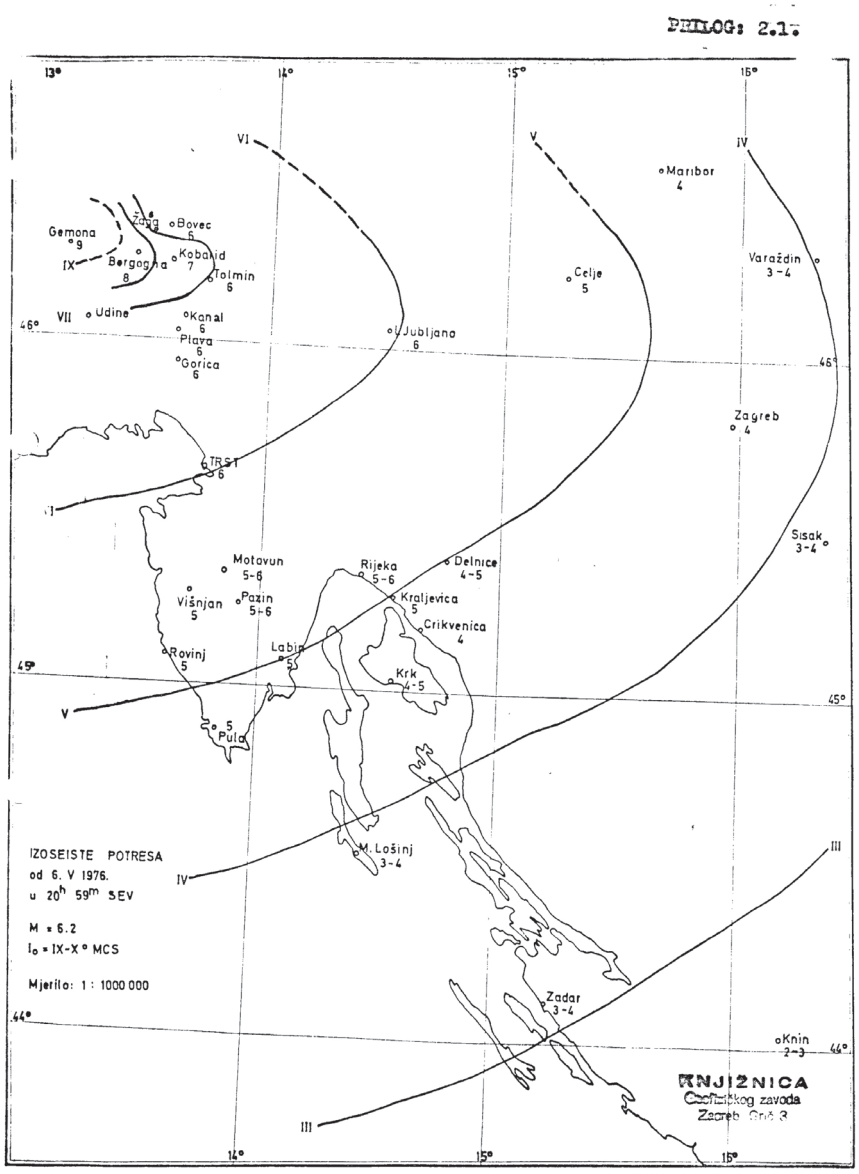


Fig. 5 - Isoseismal map for part of former Yugoslavia (today Slovenia and Croatia), compiled by Cvijanović (Milošević, 1977).

Schmedes and Leydecker (1978) state "at the time of the earthquake only few newspapers were available for some days due to a strike". The collection of macroseismic data remained incomplete. Macroseismic investigations were carried out by several institutions.

The Geophysikalisches Observatorium der Universität Ludwig-Maximilians-München in Fürstenfeldbruck (Geophysical Observatory of Munich University) collected 108 letters and reports from the population in Bavaria, which were sent by people following announcements on the regional television and radio. Most letters date from the first 2 days following the earthquake and give detailed descriptions, some of them with maps drawn by hand or even an artistic painting. Macroseismic questionnaires had not been distributed in Bavaria.

The Seismologisches Zentralobservatorium (Central Seismological Observatory: SZGRF) in Erlangen collected 11 questionnaires and 6 newspaper articles from Franconia, mostly the region of Nürnberg and Regensburg.

Questionnaires had been sent by Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources: BGR) in Hannover to residents north of Hannover with the help of a local newspaper. 37 questionnaires from the northern part of Lower Saxony, mostly from the town of Nienburg/Weser, were returned to BGR. They typically report hanging lamps swinging from side to side for a few minutes while the people were watching television. In addition, there is a report summarizing observations in Hannover and the surrounding area, especially messages to the police. It has been reported from Hannover that residents left a high-rise building in panic.

Erdbebenstation Bensberg (BNS) of Geologisches Institut der Universität zu Köln (Bensberg Earthquake Station of Cologne University) produced a list of observations from 16 towns in north Rhine-Westphalia (Nordrhein-Westfalen) with intensities (all of them long period effects of intensity II MSK-64), compiled by Ludwig Ahorner. This list was used in part or condensed by Schmedes and Leydecker (1978).

The Landeserdbebendienst (State earthquake service) of Baden-Württemberg decided not to conduct a macroseismic survey. Thus there is almost no macroseismic data available from south-western Germany.

Today, the original macroseismic material, letters, reports, questionnaires, newspaper articles, and a few notes by the compilers Eberhard Schmedes and Günther Leydecker, are archived partly at the Geophysical Observatory Fürstenfeldbruck and partly at the Federal Institute for Geosciences and Natural Resources (BGR) in Hannover.

Intensities were assessed using MSK-64 scale and a macroseismic intensity map for West Germany was published by Schmedes and Leydecker (1978) showing IDPs and isoseismals for intensities V, IV-V, and IV MSK-64.

2.5.2. Former German Democratic Republic

The 1976 Friuli main shock, which was felt widely by the population at least as far north as Berlin, became a seismological key event for the former German Democratic Republic (GDR), since it triggered a re-organization of seismological work in the country. A telemetered seismic network was established at the Central Institute of Physics of the Earth (ZIPE) in Potsdam immediately after the earthquake with a 24/7 seismic service and, among others, a working group on engineering seismology (Grünthal, 2018). One of the tasks of this new working group was to perform macroseismic studies. Spontaneously, a number of postcards and letters, where people described their macroseismic observations, were sent to the ZIPE. However, the activities for macroseismic inquiries or for publishing press releases to motivate people to submit their observations were prohibited by state authorities. In December 1976, permission was gained, with stringent statutory requirements however, which again delayed the inquiries. All this is described in more detail in Grünthal (2018).

Despite the difficulties and the huge delay of about nine months, positive replies from 205 localities were received, often including detailed descriptions of felt effects. There were no indications that people were limited with regard to recalling what they had felt such a long time before. The intensities were assigned at that time according to the MSK-64 scale (e.g. in Medvedev *et al.*, 1967) with the maximum observed intensity IV in the south-easternmost part of the country.

2.6. Czech Republic

Strong seismic shaking is rather infrequent in Czech Republic, therefore macroseismic effects caused by the Friuli 1976 earthquake caught people's attention. The Geophysical Institute of Czechoslovak

Academy of Sciences (CAS) in Prague, received a great number of spontaneous macroseismic reports immediately after the strongest event on 6 May. In the following days, a team of seismologists, led by Vít Kárník, organized a systematic collection of macroseismic observations. Macroseismic questionnaires were also sent to localities from where no observations had been reported before, in order to have positive or negative information from each 10×10 km area. In total, 2841 reports from 566 localities were obtained, 2567 reports from 460 localities were positive (I>1). 896 positive observations were reported from Prague. The collected data were classified uniformly according to the MSK-64 scale. The correction -0.5° was used for observations from the 5th and higher floors. Data processing and the results, as well as the information of the respective geological structures, were described in detail in two papers by Kárník *et al.* (1980a, 1980b). Original data - questionnaires and letters - are stored in the macroseismic archive of the Institute of Geophysics of the CAS in Prague.

2.7. France

Shaking from this destructive earthquake in Italy was felt in eastern France, over 600 km away. The French Central Seismological Office (BCSF) distributed a macroseismic questionnaire, based on the MSK-64 intensity scale, to communes of 4 departments located in north-eastern France. They received 260 replies; 248 among them contained sufficient information for BCSF to estimate 248 IDPs.

The BCSF questionnaire of 1976 was less precise than the one used today for EMS-98 estimation. It included 30 questions grouped into 13 sections, most of which requested free-form answers. One question described the intensity degrees and asked respondents to choose the one they felt most appropriate. I_{max} had been estimated at V (MSK) in the city of Hettenschlag in southern Alsace.

2.8. Poland

The earthquake of 6 May 1976 was felt in south-western Poland: in was particularly strong in the Sudetes, bordered in the SW by the Bohemian Massif, and in the Sudetic Foreland.

Macroseismic data have mainly been derived from macroseismic questionnaires published immediately after the earthquake in local as well as in national Polish newspapers. Feedback came from 89 localities. The vast majority of intensity data points were estimated on the basis of single or a few responses. About a hundred reports were sent from Wrocław, the biggest town of the region. IDPs, estimated initially in the MSK-64 scale by Guterch and Lewandowska-Marciniak (1976), were included by Kárník *et al.* (1978) in the map of isoseismals of the main Friuli earthquake.

Unfortunately, the macroseismic questionnaires have not been stored.

2.9. Slovakia

In June 1976, the Geophysical Institute of the Slovak Academy of Sciences (GPI SAS) received more than 60 questionnaires, letters and postcards from two localities, most of them from the capital Bratislava. No damage was reported. The Institute also organized a systematic collection of macroseismic observations for the territory of Slovakia, at that time part of Czechoslovakia. For this purpose, GPI SAS sent the questionnaires to the 5 municipalities near the Slovak - Austrian border and to one municipality in the Czech Republic (Břeclav). The institute also published the request to send the macroseismic reports in the national and regional newspapers. The questionnaires from Břeclav were subsequently sent to the Geophysical Institute of the Czechoslovak Academy of

Sciences in Prague and the questionnaires for the capital Bratislava were vice versa sent from Prague to Bratislava for further investigation. This was due to the fact that Czechoslovakia was a federal state with two geophysical institutes in Prague and Bratislava, responsible for the macroseismic investigation in different parts of Czechoslovakia. These two institutes operated autonomously with their own version of macroseismic questionnaire. This meant that there was no single version of the questionnaire for the territory of Czechoslovakia in two language versions, Czech and Slovak, as would be expected, but the structure of the questionnaires was different.

The questionnaires were evaluated in the MCS scale and the results were published in the Bulletin of the Slovak Seismographic Stations of 1976. No correction was made for the observations from the upper floors. This was a rather different approach to the one in the Czech part of Czechoslovakia, where the macroseismic intensity for the Friuli 1976 earthquake was evaluated in MSK-64 scale (Kárník *et al.*, 1980a). However, there is an IDP for Bratislava in both scales: 3 MCS and 3-4 MSK-64. It is unclear whether at that time the special re-evaluation of questionnaires for Bratislava in MSK-64 scale was done, as the number of questionnaires for Bratislava in the Kárník *et al.* (1980a) study does not match the number of original data sources kept in the macroseismic archive of the Earth Science Institute of the Slovak Academy of Sciences.

2.10. Belgium

The earthquake was felt in most of the medium to large-scale cities in Belgium. The Royal Observatory of Belgium (ROB) scientists filled macroseismic questionnaires with the information obtained from phone calls they received from 32 localities in Belgium. An additional study to the one obtained at the ROB from firefighters at the time of the earthquake was compiled by Camelbeeck (1983): it allows marking 6 localities where the event was felt only in high levels of multi-storey buildings. Some minor damage to the ceiling and wall plaster to a very limited extent, without more details, was mentioned in the official questionnaires from Brussels, Chapelle-lez-Herlaimont, Houdeng-Goegnies, Liège and Paturages. The questionnaire for Brussels grouped the responses from different communes, some of which reported effects only in high-rise buildings. Although no questionnaires were received from Antwerp or Oostende, the press mentioned them together with Brussels and Mons where people residing in high-rise buildings panicked.

2.11. Hungary

The archives of the Kövesligethy Radó Seismological Observatory of the Hungarian Academy of Sciences were searched in 2016 and no macroseismic data for 1976 earthquake were found, although Vit Kárník mentioned that the earthquake was felt in Hungary. No information is preserved about the possible origin of this information.

3. Data collection and the new data set

In the following chapter, we set out to show how macroseismic information has been retrieved and reconsidered for assessing EMS-98 intensities. Taking into account that the data we intended to re-evaluate derived from non-uniform procedures, by using different scales, and collected with different scopes, we adopted some constraints to adhere, as far as possible, to the guidelines of the EMS-98.

3.1. Italy

The Italian data set is mostly related to the epicentral area, so our choice was to revise the accounts of all the localities that were cited in the two aforementioned catalogues (CPTI15 and CFTI04) with the intensity higher than, or equal to, V-VI MCS. These two catalogues acknowledged almost all the available sources, included Gasparini (1976) and Giorgetti (1976), whose original accounts, unfortunately, we did not recover. Fig. 6a shows one of only a few preserved Italian questionnaires. Therefore, the revision of the Italian data set started from all other available coeval sources, with the addition of some new data from the newspapers and some scientific papers and reports.

We assumed that the building stock of the localities hit by the 1976 earthquake was represented by vulnerability classes A, B, and C of the EMS-98, and that these classes may reasonably be identified with the corresponding A, B, and C of the MSK scale, which was used in some cases by previous authors. In fact, it is correct to assert that in the 1976 earthquake area, there were no buildings with moderate-to-high earthquake-resistant design (types D and E in the EMS-98 classification).

The localities with V-VI MCS intensities were reassessed as 5 EMS-98, consistent with very light and rare damage. In case of monumental sites or very small settlements, cited in the catalogues as IDP, the codes D (damage) or HD (high damage) have been assigned. It was discovered that 60 localities from Molin (1994), with $I \geq$ VI MCS (including localities assessed as D), were not surveyed by Ambraseys (1976) or Briseghella *et al.* (1976). All those localities are not supported by documents, which have probably been lost, so we kept the MCS intensity value assessed by Molin (1994).

IDPs with intensity lower or equal to V were not reassessed, but acknowledged as quoted in the catalogues, following the conclusions of Musson *et al.* (2010). The data for some small boroughs have been estimated together with the data from the closest municipality or the main settlement.

The research of new accounts and information brought to light five previously unknown localities for the data sets. In total, the Italian data set counts 772 IDPs, with I_{max} assessed as 10 EMS-98 in the localities of Forgaria del Friuli, Borgo Jouf, Micottis, Isola di Montenars, Musi (Lusevera), Osoppo, Piovega, and Villuzza. Eleven localities suffered effects of the 9-10 EMS-98.

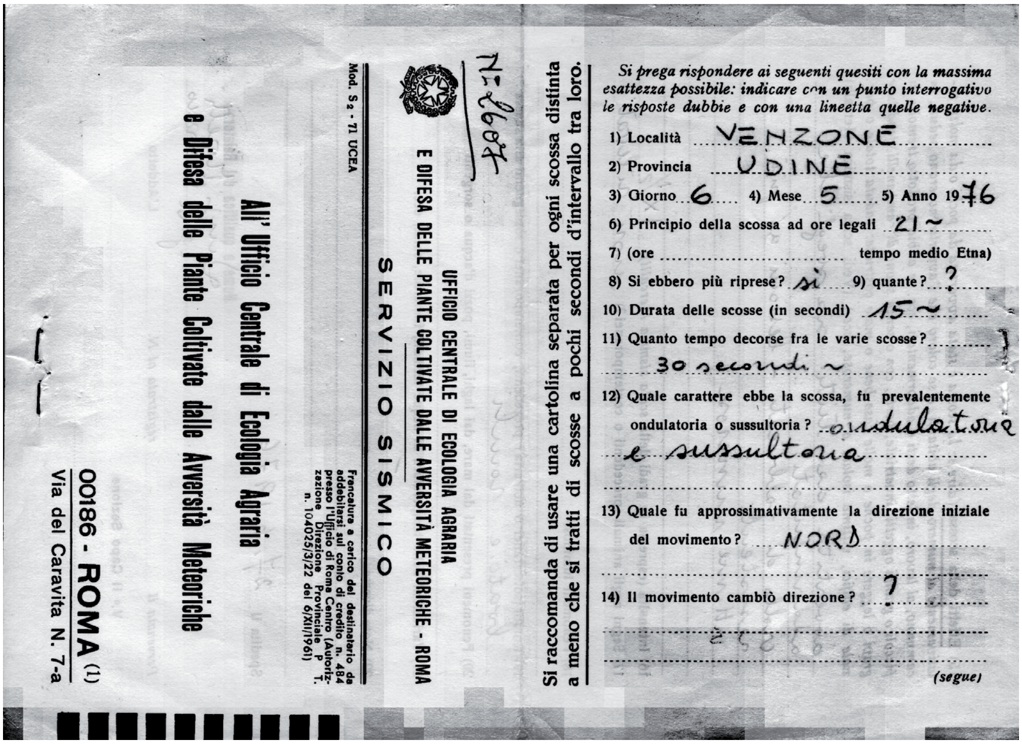
A more in-depth but time-consuming activity to retrieve new information about far-field localities could be performed, through a scrutiny of local newspapers.

3.2. Slovenia

The main seismological source of the macroseismic information in Slovenia is the collection of questionnaires (Fig. 6b). The macroseismic archive of ARSO in Ljubljana has questionnaires describing the effects of Friuli earthquake in 82 localities in Slovenia. They were sent by the Astronomsko-geofizikalni inštitut (Astronomical and Geophysical Observatory) in Ljubljana to permanent observers.

The macroseismic archive also holds several newspapers from 1976. Beside the Slovenian papers, there are some from other Yugoslav republics as well. The main newspapers sent their journalists to the most damaged area in Slovenia and published reports with details that were useful for intensity estimation. Intensities for 7 localities were estimated using the newspapers as the main primary source.

There are several letters and short notes about the phone calls kept in the archive. It was possible to evaluate intensity for 4 IDPs using those.


Si prega rispondere ai seguenti quesiti con la massima esattezza possibile: indicare con un punto interrogativo le risposte dubbie e con una lineetta quelle negative.

1) Località VENZONE
2) Provincia UDINE
3) Giorno 6 4) Mese 5 5) Anno 1976
6) Principio della scossa ad ore legali 21 ~
7) (ore .... tempo medio Etna)
8) Si ebbero più riprese? sì 9) quante? ?
10) Durata delle scosse (in secondi) 15 ~
11) Quanto tempo decorse fra le varie scosse? 30 secondi ~
12) Quale carattere ebbe la scossa, fu prevalentemente ondulatoria o sussultoria? ondulatoria e sussultoria
13) Quale fu approssimativamente la direzione iniziale del movimento? NORD
14) Il movimento cambiò direzione? ?

(segue)

Si raccomanda di usare una cartolina separata per ogni scossa distinta a meno che si tratti di scosse a pochi secondi d'intervallo tra loro.

UFFICIO CENTRALE DI ECOLOGIA AGRARIA E DIFESA DELLE PIANTE COLTIVATE DALLE AVVERSITÀ METEORICHE - ROMA

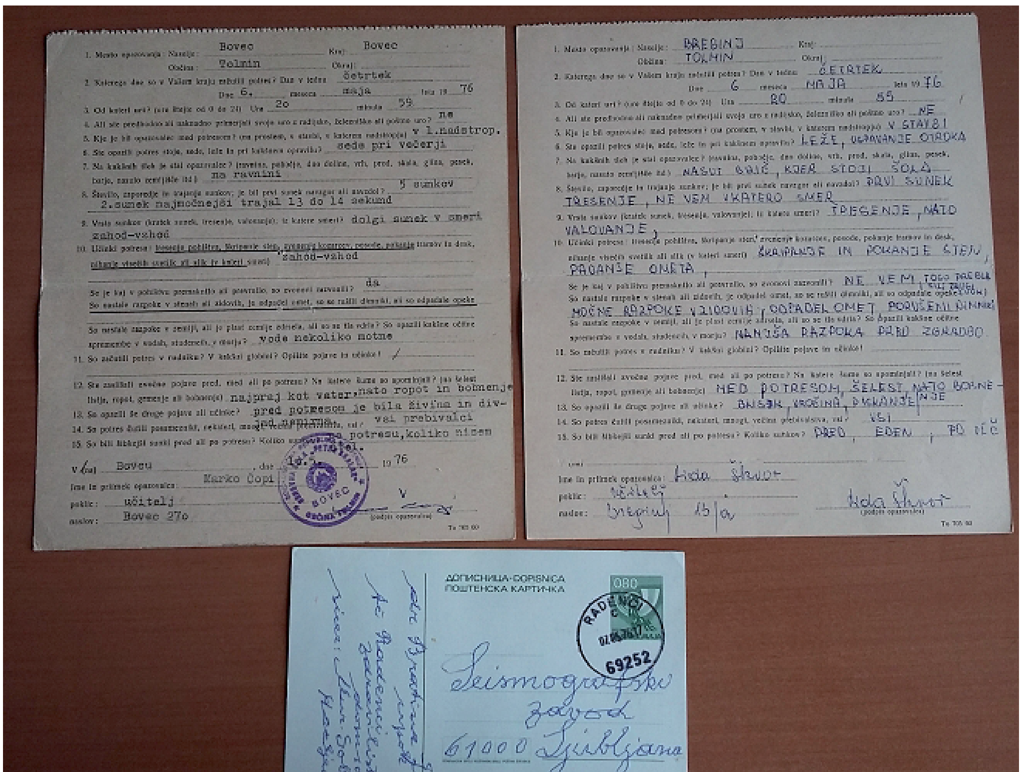
SERVIZIO SISMICO

Mod. Sz - 71 UCEA

All'Ufficio Centrale di Ecologia Agraria e Difesa delle Piante Coltivate dalle Avversità Meteoriche

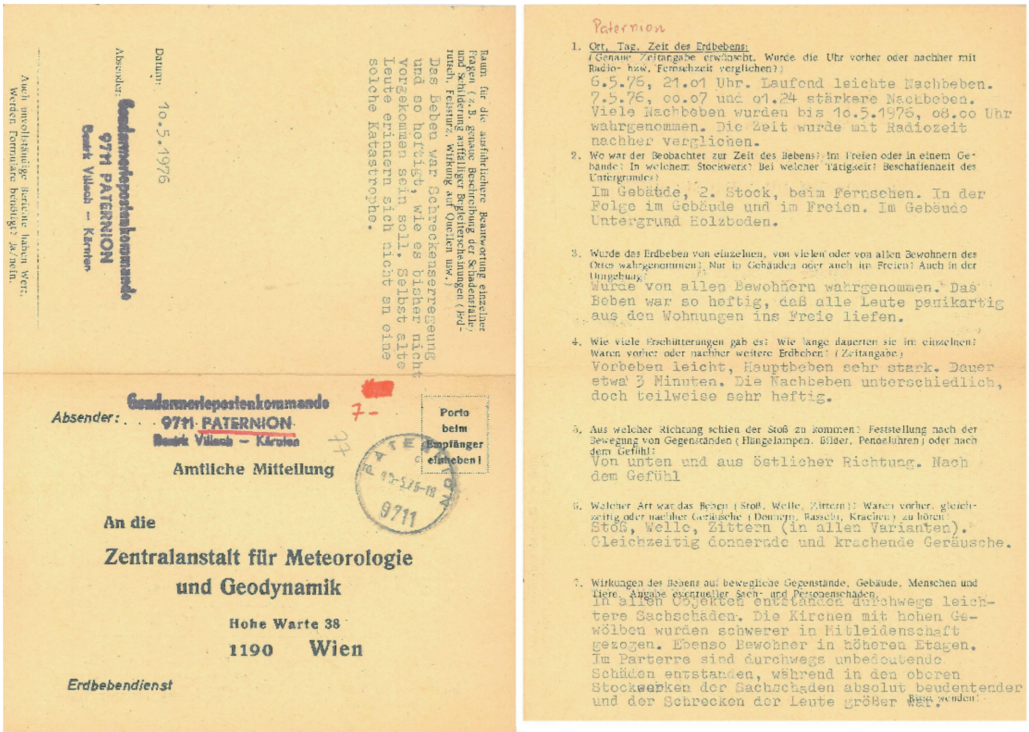
00186 - ROMA (1)
Via del Caravita N. 7-a

a



b

Fig. 6 - Questionnaires: a) from Venzone, Italy (Macroseismic Archive INGV); b) a postcard from Slovenia (Macroseismic Archive ARSO); c) from Paternion, Austria (Archive ZAMG); d) from Rijeka, Croatia.


Raum für die ausführliche Beantwortung einzelner Fragen (z.B. genaue Beschreibung der Schadenfälle; und Schilderung auffälliger Begleiterscheinungen (Felsrutsch, Felssturz, Wirkung auf Quellen usw.)
Das Beben war Schreckenserregung und so heftig, wie es bisher nicht vorgekommen sein soll. Selbst alte Leute erinnern sich nicht an eine solche Katastrophe.

Datum: 10.5.1976

Absender: Gendarmeriepostenkommando 9711 PATERNION Bezirk Villach – Kärnten

Auch unvollständige Berichte haben Wert. Werden Formulare benötigt? Ja/nein.

Absender: Gendarmeriepostenkommando 9711 PATERNION Bezirk Villach – Kärnten

Porto beim Empfänger einheben!

Amtliche Mitteilung

An die

Zentralanstalt für Meteorologie und Geodynamik

Hohe Warte 38

1190 Wien

Erdbebendienst

Paternion

1. Ort, Tag, Zeit des Erdbebens:
(Genaue Zeitangabe erwünscht. Wurde die Uhr vorher oder nachher mit Radio- bzw. Fernsehzeit verglichen?)
6.5.76, 21.01 Uhr. Laufend leichte Nachbeben. 7.5.76, 00.07 und 01.24 stärkere Nachbeben. Viele Nachbeben wurden bis 10.5.1976, 08.00 Uhr wahrgenommen. Die Zeit wurde mit Radiozeit nachher verglichen.

2. Wo war der Beobachter zur Zeit des Bebens? Im Freien oder in einem Gebäude? In welchem Stockwerk? Bei welcher Tätigkeit? Beschaffenheit des Untergrundes?
Im Gebäude, 2. Stock, beim Fernsehen. In der Folge im Gebäude und im Freien. Im Gebäude Untergrund Holzboden.

3. Wurde das Erdbeben von einzelnen, von vielen oder von allen Bewohnern des Ortes wahrgenommen? Nur in Gebäuden oder auch im Freien? Auch in der Umgebung?
Wurde von allen Bewohnern wahrgenommen. Das Beben war so heftig, daß alle Leute panikartig aus den Wohnungen ins Freie liefen.

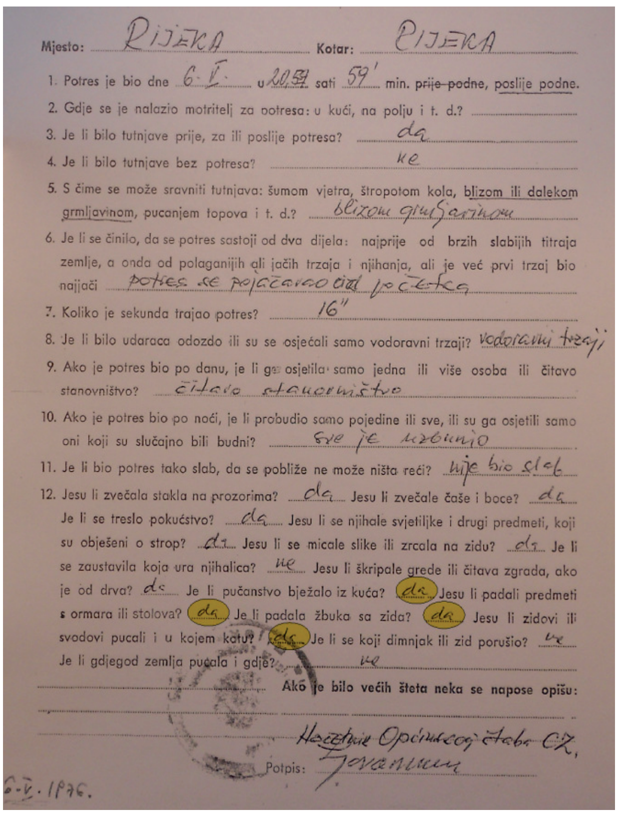
4. Wie viele Erschütterungen gab es? Wie lange dauerten sie im einzelnen? Waren vorher oder nachher weitere Erdbeben? (Zeitangabe)
Vorbeben leicht, Hauptbeben sehr stark. Dauer etwa 3 Minuten. Die Nachbeben unterschiedlich, doch teilweise sehr heftig.

5. Aus welcher Richtung schien der Stoß zu kommen? Feststellung nach der Bewegung von Gegenständen (Hängelampen, Bilder, Pendeluhren) oder nach dem Gefühl?
Von unten und aus östlicher Richtung. Nach dem Gefühl

6. Welcher Art war das Beben (Stoß, Welle, Zittern)? Waren vorher, gleichzeitig oder nachher Geräusche (Donnern, Rasseln, Krachen) zu hören?
Stoß, Welle, Zittern (in allen Varianten). Gleichzeitig donnernde und krachende Geräusche.

7. Wirkungen des Bebens auf bewegliche Gegenstände, Gebäude, Menschen und Tiere. Angabe eventueller Sach- und Personenschäden.
In allen Objekten entstanden durchwegs leichtere Sachschäden. Die Kirchen mit hohen Gewölben wurden schwerer in Mitleidenschaft gezogen. Ebenso Bewohner in höheren Etagen. Im Parterre sind durchwegs unbedeutende Schäden entstanden, während in den oberen Stockwerken der Sachschaden absolut beudentender und der Schrecken der Leute größer war.
Bitte wenden!

c


Mjesto: RIJEKA Kotar: RIJEKA

1. Potres je bio dne 6. V. u 20.59 sati 59' min. ~~prije podne~~, poslije podne.
2. Gdje se je nalazio motritelj za potresa: u kući, na polju i t. d.?
3. Je li bilo tutnjave prije, za ili poslije potresa? da
4. Je li bilo tutnjave bez potresa? ne
5. S čime se može sravniti tutnjava: šumom vjetra, štropotom kola, blizom ili dalekom grmljavinom, pucanjem topova i t. d.? blizom grmljavinom
6. Je li se činilo, da se potres sastoji od dva dijela: najprije od brzih slabijih titraja zemlje, a onda od polaganijih ali jačih trzaja i njihanja, ali je već prvi trzaj bio najjači potres se pojačavao od početka
7. Koliko je sekunda trajao potres? 16"
8. Je li bilo udaraca odozdo ili su se osjećali samo vodoravni trzaji? vodoravni trzaji
9. Ako je potres bio po danu, je li ga osjetila samo jedna ili više osoba ili čitavo stanovništvo? čitavo stanovništvo
10. Ako je potres bio po noći, je li probudio samo pojedine ili sve, ili su ga osjetili samo oni koji su slučajno bili budni? sve je probudio
11. Je li bio potres tako slab, da se pobliže ne može ništa reći? nije bio slab
12. Jesu li zvečala stakla na prozorima? da Jesu li zvečale čaše i boce? da Je li se treslo pokućstvo? da Jesu li se njihale svjetiljke i drugi predmeti, koji su obješeni o strop? da Jesu li se micale slike ili zrcala na zidu? da Je li se zaustavila koja ura njihalica? ne Jesu li škripale grede ili čitava zgrada, ako je od drva? da Je li pučanstvo bježalo iz kuća? da Jesu li padali predmeti s ormara ili stolova? da Je li padala žbuka sa zida? da Jesu li zidovi ili svodovi pucali i u kojem katu? da Je li se koji dimnjak ili zid porušio? ne Je li gdjegod zemlja pucala i gdje? ne

Ako je bilo većih šteta neka se napose opišu:

Potpis:

6.V.1976.

d

Fig. 6 - continued.

We tried to collect as much of the photographic evidence as possible. In order to do so, we visited the archives of the newspaper house Delo and the Information and Documentary Centre for Heritage (INDOK Center za dediščino) of the Ministry of Culture. In the latter, hundreds of photographs, taken mainly in May and June 1976, were found, as well as the official reports (Informacija, 1976) that were published in Tolmin in the period May-October 1976. The information found in the INDOK Centre enabled us to assess intensity for 29 localities.

We have also used the official reports on damage, collected by civil engineers. As it was not possible to obtain original field notes made by the commissions for damage evaluation, we had to deal with the classifications and percentages they produced, although slightly different from EMS-98. Unfortunately, there are no detailed instructions on how the evaluation was performed, and the original data are most probably lost. The reports were the primary source for 146 IDPs.

A circular mail was sent to the colleagues in ARSO, asking them to recall the circumstances they were in when they felt the earthquake. Several answers were received, mostly for different parts of Ljubljana, but two of them were for localities that were previously without intensity data.

The intensities for 32 localities were assessed using the data from different published seismological papers, and for 2 localities the sources were the web pages of villages.

In the end, the new study has produced a list of 304 localities, 4 of which being isolated buildings in high mountains; therefore there are 300 IDPs for Slovenia.

Beside the degrees of EMS-98 scale, three descriptions for intensity are used: D, F, and T, for damage, felt and sound, respectively. D was used when no specifications of damage were given, but only the information that there was some damage on the locality, or in case that we only had information on damage for monumental buildings (e.g. a church or a castle). Symbol T indicates that in this particular case there was a speleologist who heard the earthquake while inside a cave.

For some cases when the earthquake was felt in an isolated building, the intensity was evaluated as well, just for information; in these cases the coordinates of the locality are not included in the intensity file, as EMS-98 intensity should not be evaluated for single buildings.

According to this study, I_{max} in Slovenia is 8-9 EMS-98, in the Podbela village close to the Italian border (Cecić, 2016).

3.3. Austria

Written reports (questionnaires) by the Austrian population are the main source of macroseismic data (Fig. 6c). For this study each single report was re-evaluated, and the macroseismic intensity based on EMS-98 was assigned to each place. Most of the reports originate from public authorities, e.g. police stations, schools and municipalities, and therefore they often give a summary for the whole community. Additionally, there are official form sheets for damage reports. They were sent to ZAMG by the municipalities and provide information about the damage grades, the building classes and the relative frequency of damage.

Information from telephone-protocols and telexes, today's narrations from witnesses, who still remember their experience (this data was collected mainly by phone calls in 2016 and 2017), a documentation of earthquake damage by Litscher and Strobl (1977) on behalf of the Kärntner Elektrizitäts-AG (KELAG, electricity supplier of Carinthia) and minutes of a local council meeting in Arnoldstein, kindly provided by the municipal office of Arnoldstein, were also useful to support the assessment. Many newspapers reported the effects of the earthquake in Austria and were used to improve the accuracy of the intensity.

It is important to point out that the average EMS-98 intensities obtained by this study are lower than the previous MSK-64 values. This is partly due to the slightly different evaluation criteria of EMS-98 as compared to the earlier intensity scales. One of the most significant reasons for the discrepancies is the handling of slight damage reports. A single report about small damage is no longer considered representative for the whole village or town area and does not automatically indicate intensity 6. The same is true if, for example, major damage was reported for only one building, while almost all the others were undamaged: referring to EMS-98 intensity should not be assigned to a single building or street. Another problem concerning damage is simply a matter of expression. So-called "cracks in walls" could possibly mean only cracks in the plasterwork and therefore indicate lower intensity. This misunderstanding is often observed in macroseismic evaluation also today. It was assumed that the EMS-98 building classes A, B, and C basically correspond to the building classes used in the previous MSK-64 evaluation.

Today, the reports from upper storeys are taken into account to a much less extent than in former times. This applies especially to reports from towns with a large number of high buildings. In fact, recent macroseismic evaluation in Austria generally shows that intensity increases when reported from the 2nd or higher storey. Also, feeling frightened is very subjective and should not be weighted too strongly, when it is only reported from a few people in a locality. Information about **'**running outdoors' or **'**losing balance' was treated carefully in that respect as well.

At 57% of all locations in Austria the intensity was reduced by 0.5 degrees after re-evaluation; at 9% localities the intensity values were reduced by 1 degree, while about 33% of the evaluations remained unchanged. The differences are spread all over the country with slightly larger reduction in the high intensity area.

The long duration of shaking due to the high magnitude and long-distance effects characterized this strong earthquake. Geological conditions clearly play an important role in amplifying the vibrations, as can be seen, for example, in the Inn Valley and the Rhine Valley.

Strong swinging and wave motion were reported very often (hanging objects swung for a very long time) also from places that were far from the epicentre. This fact intensifies the observer's uneasiness although they are already outside of the damage area. In a couple of places, mainly in Carinthia, the local people were highly agitated and displayed behaviour similar to panic, but there was less or even no damage.

The majority of the written reports originate from police stations and municipalities. A big advantage is that they often report the perception of the whole population of a location. Therefore statistical statements like "most of the people felt it" are possible and can readily be used for intensity assignment. Knowing the frequency of a particular phenomenon makes it easier to assess the correct intensity. The reports from official authorities are generally more objective and less emotional than reports from individuals. Nevertheless, some problems can occur. A mixture of personal and general observations might be reported in one form and is hard to distinguish. In several cases, contradictory information was provided by two different official statements, e.g. concerning the frequency and degree of damage. In those cases the more reliable report was the preferred choice. According to the EMS-98, individual striking reports were considered as outliers and, therefore, disregarded.

The intensity in Austria decreased much faster towards the eastern part than to the west. In Vienna, strong perceptions were only reported from higher storeys, therefore the intensity was assigned as 3 EMS-98 or 3-4 EMS-98, depending on the district. As usual, the intensity assignment

in large cities was not as easy as in the countryside. Surprisingly, not many reports from Vienna were available: 76 documented telephone calls - some of them gave useful information - and less than 20 written reports. It is possible that some reports were lost over the last decades.

When an intensity assignment was not possible due to insufficient information, the intensity was set to "felt", which means unknown intensity. Certainly there are some places, mainly in the east and NE of the country, where the earthquake was not felt. Nevertheless, the "not felt" category was not added to the data set, because no thorough study was performed to clarify this. Hence, one can hardly be sure that anybody felt the earthquake in a particular place.

As the result of this study, the Austrian data set includes EMS-98 intensities for 1008 localities, with an I_{max} assessed as 7 EMS-98. The re-evaluation brought a decrease of the intensities by 0.5 degrees on average.

3.4. Croatia

Due to the small number of questionnaires (Fig. 6d), the additional data from contemporary newspapers were used for the new study. Four contemporary newspapers were searched: two local (Glas Istre for Istrian region, Novi list for Rijeka region), one regional (Slobodna Dalmacija, covering mainly Dalmatia) and one national newspaper (Večernji list). Newspaper articles were often tainted by auto-censorship because of the coming tourist season, so the reports on the earthquake were formulated carefully. Using information from these sources, intensities for 6 new localities were assessed. For an additional two localities, intensities were assessed using combined information from questionnaires and newspapers.

All the intensities were assessed according to EMS-98 and MSK-78 (Medvedev, 1978), as the MSK scale has been used in Croatia since 1984 and there is a large macroseismic archive with MSK IDPs. There were no numerical differences between the EMS-98 and MSK-78 intensities.

Intensities were assessed for 24 IDPs, 22 of them in Croatia and two in Bosnia and Herzegovina. Eighteen of them were assessed on the basis of questionnaires, and the rest were assessed using the data from contemporary newspapers. In two cases newspaper data was used as the additional data.

The earthquake effects were strongest in the Istrian towns Buje and Pazin, with intensity 7 EMS-98, where the houses were heavily damaged. The walls were cracked, chimneys collapsed and even some old houses were completely destroyed.

Intensity 6 EMS-98 was assessed for Rijeka, Rovinj and Pula. The buildings suffered slight to moderate damage, cracks in walls and the fall of plaster. Most people were frightened and ran outside.

It is interesting to note that miners at work in the Labin coal mine did not feel this earthquake at the depth of a several hundred metres owing to the machine noise.

3.5. Germany

3.5.1. Former Federal Republic of Germany

All localities and original MSK-64 intensities are tabulated from the map published by Schmedes and Leydecker (1978) and compared with the macroseismic material from the archives. For most of the localities the original intensities are verified and left unchanged.

In several localities, the reassessed EMS-98 intensities are lowered by half a degree mainly because of the small number of existing reports.

For some of the localities on the map no original information could be found and the intensities could only be verified partially using handwritten notes by the original compilers. In the publication by Schmedes and Leydecker (1978), telephone calls to police stations and geophysical observatories are mentioned as sources, but today no written records have been found in the archives. The intensities in these locations range from 2 to 4 EMS-98 and in these cases we assume MSK = EMS (Musson *et al.*, 2010).

On the other hand, from the analysis of the material, 36 IDPs are added, mostly in Bavaria. Three previously unconsidered questionnaires were discovered by chance in March 2018 in the archive of the earthquake service of Baden-Württemberg in Freiburg im Breisgau. The total number of IDPs is 110 in West Germany as compared to 74 IDPs on the map by Schmedes and Leydecker (1978).

Altogether, for the reasons stated in the section 2.5, the macroseismic data set in West Germany is sparse and the data not well distributed. For many places there are only few reports. The uncertainty of these intensities is probably ±1 degree in most cases. Half degrees always indicate an uncertainty range.

From the available reports, we assume that in most parts of Germany to the northwest of Bavaria long-period effects lasting up to a few minutes were observed leading to intensity 2 EMS-98.

3.5.2. Former German Democratic Republic

For this study the EMS-98 has been applied. The basic difference between the original and the new assignment of intensities is that previously several intensities of III-IV MSK-64 were re-determined with intensity 3 EMS-98. Such assignments, following the guidelines for applying the EMS-98, fit better with the relative frequency of those observations, for the respective intensities; i.e. formerly, such frequencies were not considered very rigorously which led to the former somewhat higher intensity values. Differences in intensity assignment between the original and new ones are in no cases larger than half a degree, which is indeed minor. The area shaken with intensity 3 EMS-98 encompasses Berlin (about 700 km away from the epicentre) and continues in an easterly direction towards the Polish territory. West of Berlin, this area extends SW-wards up to Thuringia. The only agglomeration of localities, where intensity 4 EMS-98 has been observed, is concentrated in the south-easternmost part of the region; i.e. in the area of Zittau in the triple junction with Poland and former Czechoslovakia. Surprisingly, the earthquake was even felt to the north and mostly NE of Berlin with intensities of 2-3 EMS-98, in the majority of cases up to locations at or near the Baltic Sea coast; i.e. at a distance of almost 900 km from the focal area. Macroseismic observations in high rise apartment buildings were disregarded, as it was recommended later in the EMS-98 to discount at least observations from the fifth floor and above.

The earthquake was not felt in localities near the summit line of the central Erzgebirge; i.e. very close to former Czechoslovakia. These not-felt data in those 20 localities are the result of personal inquiries by Grünthal in the field. Moreover, many questionnaires, mostly from the periphery of the macroseismically shaken area, have been received with negative information; i.e. that the earthquake was not felt. Nonetheless, the experience tells us that information from questionnaires

stating the event was not felt in a specific locality must be handled with care. There were observed cases where spontaneous letters had just described respective observations from such localities. Therefore, it was decided to refrain from including negative information in general.

In all, there are 225 IDP for this part of the shaken area, which includes the 20 well justified not-felt IDP. Concerning more information on details of the macroseismic study of the part of Germany presented here, reference is made to Grünthal (2018).

3.6. Bosnia and Herzegovina

Snježana Cvijić-Amulić from Federal Hydrometeorological Institute in Banja Luka, reported that there are no macroseismic data for the Friuli earthquake in their archives and that the earthquake was not felt in the territory of Bosnia and Herzegovina (Cvijić-Amulić, 2016). The new study has not been performed. However, the research by I. Sović (this study, chapter on Croatia) shows that there are two IDPs for localities Bihać and Sarajevo, with I_{max} 4-5 EMS-98 in Bihać.

3.7. Czech Republic

Reports with intensity IV MSK-64 and higher have now been re-evaluated. New EMS-98 intensity values are in many cases 0.5 - 1.0 degree lower then MSK-64 ones, mostly because of a small number of reports from the IDP. Some original intensities of V or V-VI MSK-64 were based on not new damage, but reactivated hair-line cracks that had previously been repaired (originally caused by different mechanisms to earthquakes - settlement problems etc.). The highest intensity was originally classified as VI MSK-64 in one village. The estimation was made on the basis of one isolated report of a damaged room ceiling. Nevertheless, after questioning the author of the original report it turned out that the report had only mentioned the plaster fallen from the ceiling; no shaking or trembling had been observed in this location that time. Intensity of this IDP was reassessed as 4 EMS-98.

More IDPs and higher intensities (up to 4-5 EMS-98) occurred in the western half of the Czech territory almost independently of the distance from the focus. A relative increase in the number of observations and in the level of intensity was observed in the young sedimentary basins of Plzeň, Chomutov, České Budějovice, Kladno and Ostrava. No reports were obtained from the easternmost part of the Czech Republic along the border with Slovakia.

3.8. France

BCSF has re-evaluated the original questionnaires using the EMS-98 criteria to produce updated intensity estimates. As the Friuli earthquake did not damage any buildings in France, except for rare cracks in a few ancient houses (vulnerability A, in Artzenheim and Huningue), the lack of vulnerability information in the 1976 questionnaires had no effect on the recalculated intensity values. These EMS-98 estimates included 6% of intensity 4, 23% of intensity 3, 10% of intensity 2 and 61% of intensity 1 (not felt).

Shaking from the Friuli event was amplified by the sediments located in the Fossé Rhénan basin, leading to intensity 4 EMS-98 estimates for 15 municipalities located in the Alsace plain. The maximum EMS-98 intensity is estimated at 4-5 in Artzenheim in the south of Alsace, but this estimation is of uncertain quality. Perceived effects were rare in the Vosges massif and weak on the Lorraine plateau (Thionville 630 km of epicentre, Nancy 595 km).

3.9. Poland

Unfortunately, the macroseismic questionnaires have not been stored. Reassessment of IDPs was done assuming that (according to Grünthal *et al.*, 1998) in principle values of intensities in both scales are the same for $I<5$ and secondly, that the EMS-98 scale suggests preferably integer values and prefers underestimated to overestimated values. Thus, intensities assessed at II-III and III-IV in the MSK-64 scale became, respectively, 2 and 3 in the EMS-98 scale.

The data for this study were supplemented by some IDPs omitted in papers by Guterch and Lewandowska-Marciniak (1976), and Kárník *et al.* (1978). The final list consists of 86 IDPs in both MSK-64 and EMS-98 with I_{max} 4 EMS-98 in two localities (Lubań and Lwówek Śląski).

3.10. Switzerland

Macroseismic data for Switzerland were supplied by Donat Fäh, ETH. The file consists of 153 IDPs with I_{max} IV MSK-64. The new study was not performed. We have accepted that MSK = EMS (Musson *et al.,* 2010).

3.11. Slovakia

The contemporary Slovak macroseismic questionnaire in MCS was compared with the current Slovak macroseismic questionnaire in EMS-98. Questions with similar meaning for both intensity scales were marked. A good match between the structure of questions and answers was found, so the contemporary MCS questionnaires were used for IDPs re-evaluation in terms of EMS-98. All MCS questionnaires were processed with the recent technique used in Slovakia to evaluate the macroseismic effects in EMS-98 scale (Labák and Kováčová, 2002). The information from the contemporary regional newspaper "Večerník" were used secondarily to identify the parts of Bratislava where the macroseismic effects were felt.

Two separate investigations for Bratislava were performed: all questionnaires (reports) regardless of the floor of observation and reports only up to the fifth floor. Because of a lack of sufficient data for a more detailed investigation, only one IDP for the capital Bratislava was obtained. Therefore, no IDPs for the Bratislava city districts are available.

The collection of macroseismic data was organized in 5 localities, and the institute in Bratislava received negative reports from the local municipal administration of Záhorská Ves and Veľké Leváre. These negative reports were not mentioned in the previous study (Kárník *et al.*, 1980a). The IDP for Kúty remains the same for MCS and EMS-98 scales; however the IDP for Bratislava is now half a degree higher in EMS-98 compared to MCS scale. The inclusion of observations only up to the fifth floor does not change the IDP value in EMS-98. The new value 3-4 EMS-98 for Bratislava corresponds to the value in MSK-64 scale (Kárník *et al.*, 1980a) and is the new I_{max} value for the territory of Slovakia.

3.12. Belgium

In this re-evaluation work, macroseismic observations in high-rise apartment buildings were disregarded, as recommended in the EMS-98. For the 27 other localities, we estimate the intensity to be 2 EMS-98.

3.13. Hungary

The archives of the Kövesligethy Radó Seismological Observatory of the Hungarian Academy of Sciences were searched in 2016 and no macroseismic data for 1976 earthquake were found. A further search for macroseismic data was performed and it was found out that the earthquake effect was described by several contemporary county and national newspapers using almost exactly the same words. The texts (e.g. in the Hungarian newspaper Népszabadság, Vol. XXXIV, Number 108, 8 May 1976, page 1) say: "The north-Italian earthquake remained almost unnoticed in our country, news of swinging chandeliers and clattering china were received only from Szombathely; damage has not occurred anywhere." Therefore the intensity file for Hungary consists of 1 IDP with I_{max} felt.

3.14. Serbia

According to Branko Dragičević, Seismological Survey of Serbia in Belgrade, the earthquake was not felt in Serbia; in the macroseismic archives of the Survey there is only a handwritten list of the intensities for some localities in Slovenia (Dragičević, 2016). Some contemporary Serbian newspapers stored in the macroseismic archive of ARSO were also checked, but they published only the reports from the damaged area in Slovenia.

4. Discussion and conclusions

In 2016, we began considering the feasibility to re-evaluate all the macroseismic data for the Friuli mainshock. In the beginning, the idea was to do the re-evaluation only for high intensity countries, but an increasing number of countries were coming in with their data, checking and re-checking their data sets. In September 2016, at the General Assembly of European Seismological Commission in Trieste, Italy, we were then able to present a first draft of the map (Cecić *et al.*, 2016). Since then, more data has been added and more countries joined in the effort to produce an as complete data set as possible.

Several problems have been encountered on the way, starting from the disturbing discovery that the Italian questionnaires were lost or no longer available, to the fact that many other documents were lost over the past 40 years. Fortunately, a number of colleagues that were personally involved and active in times of the Friuli earthquake are still with us, so we have used their knowledge and memory to decipher some of the puzzles we found in our macroseismic archives.

This study presents the intensity data set for 13 European countries (as of 2018, as in 1976 there were 10 countries): Austria, Belgium, Bosnia and Herzegovina, Croatia, Czech Republic, France, Germany, Hungary, Italy, Poland, Slovakia, Slovenia and Switzerland. In addition, there is information that the earthquake was not felt in Serbia (but no IDPs). It is, to our knowledge, one of the largest European data sets, consisting of 3423 IDPs (Electronic Supplement and Figs. 7 and 8). The earthquake was felt, from Rome in the south to the Baltic Sea in the north, and from western Belgium in the west to Warsaw, Poland, in the east. The maximum intensity 10 EMS-98 was reached in eight localities in Friuli, Italy (Electronic Supplement). The lowest I_{max} (in a particular country) was reached in Hungary, where the earthquake was felt in one locality (Szombathely). From the map (Fig. 7), a different density of data points becomes obvious. This depends on the different kind of data collection at the time of the earthquake and if such data were

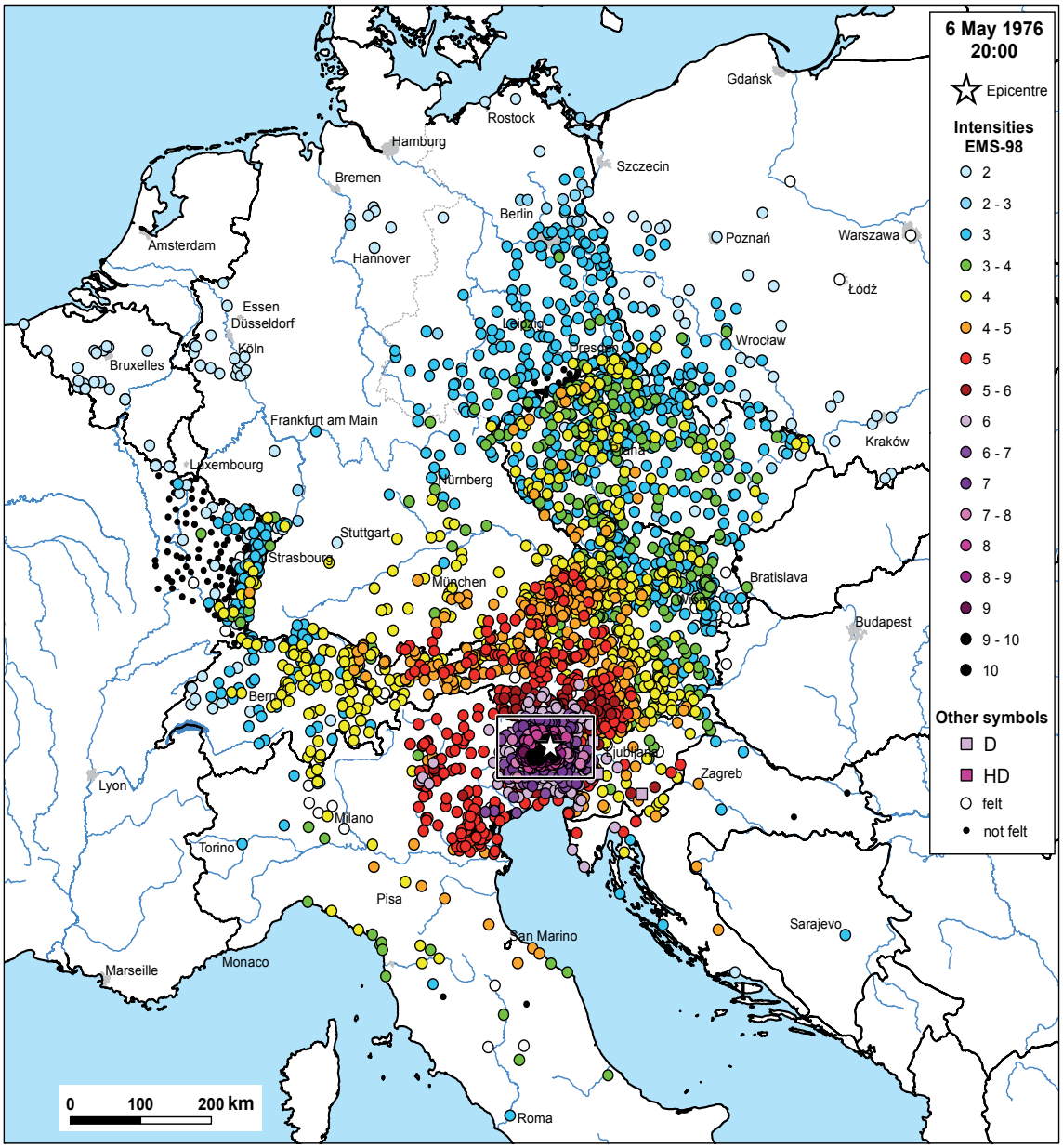


Fig. 7 - Map of the intensity points realized with the new data set in EMS-98.

preserved. Differences in data density are so pronounced in some parts that state boundaries can be traced. It is very noticeable that parts of the study area show a high density of IDPs, while in others there is only very sparse data coverage. Striking differences also occur in the periphery of the felt area. In some parts, the outer border of the felt area can be described sufficiently well, like in Belgium, northern Germany and in Poland.

Compared to the previous studies, the I_{max} values have changed from country to country, in some cases being lowered due to methodological differences, but in case of three of the most hit

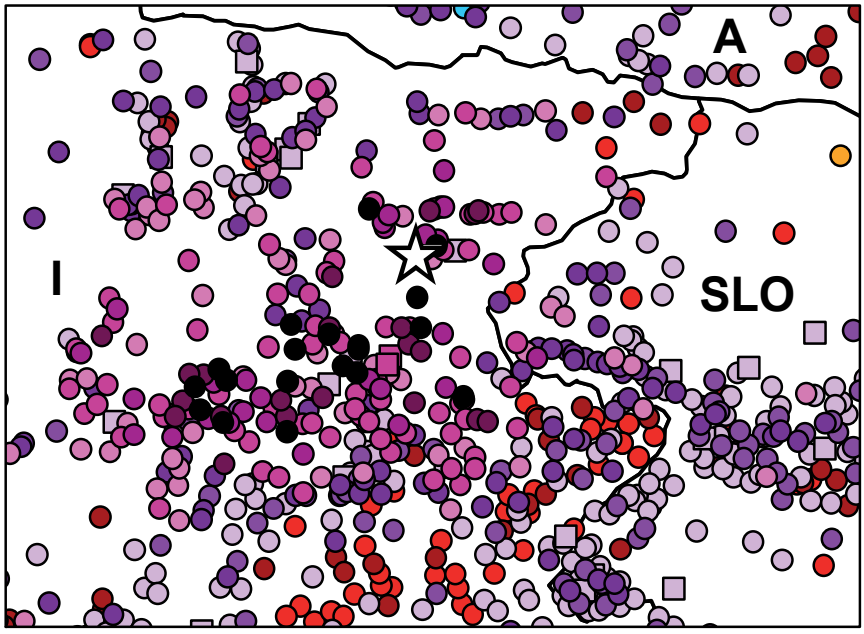


Fig. 8 - Focus on the epicentral area of the new map. See the legend in Fig. 7.

countries (Italy, Slovenia and Croatia), I_{max} is now higher than in the previous studies, mainly due to the introduction of new data (Table 1).

The task of producing the intensity map of an earthquake that was felt in the best part of Europe is indeed huge; however, this is just a beginning of dealing with this long and complicated earthquake sequence, as there are numerous aftershocks to be dealt with yet. Nevertheless, the

Table 1 - The overview of the macroseimic data for the 6 May 1976 earthquake in 15 European countries. IDP = intensity data point; before = studies prior to 2016 have been considered.

Country		N. IDPs before	N. IDPs now	I_{max} before	I_{max} EMS-98
Italy	I	772	770	IX-X MCS	10
Slovenia	SLO	52	304	VIII MSK-64	8-9
Austria	A	934	1008	VII-VIII MSK-64	7
Croatia	HR	17	22	V-VI MSK-64	7
Germany W. Germany(BGR) E. Germany (GDR)	 D-W D-E	 74 225	 110 225	V MSK-64	5
Bosnia-Herzegovina	BH	0	2	NF	4-5
Czech Republic	CZ	458	458	VI MSK-64	4-5
France	F	248	248	V MSK-64	4-5
Poland	PL	86	86	IV MSK-64	4
Switzerland	CH	153	153	IV MSK-64	4
Slovakia	SK	2	4	III-IV MCS	3-4
Belgium	B	32	32	F	2
Hungary	H	1	1	F	F
Serbia	S	0	0	NF	NF
Total IDPs		3054	3423		

study shows that it is possible to establish excellent international cooperation in macroseismology, and combine efforts in implementing the same methodology in order to achieve a joint goal.

We close this paper with a curious, but interesting observation about this earthquake: an amateur astronomer, making observations in his garden somewhere in the south of England on the night of the earthquake, noticed the image of a distant star he was looking at through his telescope quiver for a moment. He later discovered that this occurred exactly at the reported time of the Friuli earthquake (Roger Musson, personal communication).

Supplementary material related to this article is available online at the BGTA website www3.inogs.it/bgta.

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Corresponding author: Andrea Tertulliani
Istituto Nazionale di Geofisica e Vulcanologia
Via di Vigna Murata, Rome, Italy
Phone: +39 06 51860219; e-mail: andrea.tertulliani@ingv.it