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Macroseismology in Finland from the 1730s to the 2000s. Part 2: From an Obligation of the Learned Elite to Citizen Science

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Abstract

The present article is the second part of a snapshot of macroseismology in Finland from the 1730s to the 2000s. In the 1730s, more numerous and informative earthquake reports began to appear. The article begins with an outline of the connection between academia and macroseismology. The focus is on the dissemination of macroseismic questionnaires and their respondents. The standard practice in Finland is to conduct macroseismic surveys remotely. Postal services were widely used to disseminate questionnaires in the areas affected by earthquakes. The newspaper press has frequently been utilized in the surveys. Since the latter half of the 1800s, telephones and telegraphs made instant communication possible. Macroseismic field surveys have sometimes been conducted after important local earthquakes to interview eyewitnesses and to disseminate questionnaires on the spot.

The group of earthquake reporters that stands out throughout the centuries is the clergy. Its leading position waned only in the 1900s. Finns became more literate, acquiring their writing skills during the 1800s. The occupational groups of the respondents became more versatile in the 1900s, reflecting the evolution of macroseismology into a genuine citizen science.

Macroseismic reporting mirrors the development of society throughout the centuries. In particular, new technologies have an immediate effect on the surveys.

Keywords: Earthquake, history, macroseismology, questionnaire, Finland

1 Introduction

Macroseismology is the branch of seismology that collects and evaluates non-instrumental data on earthquakes, that is, their effects on people, objects, buildings and nature. After an earthquake is felt in some region, the data are usually collected by means of questionnaires. Field surveys complement the questionnaires in the case of a destructive earthquake.

Seismic intensity values are estimated on the basis of the collected data. Intensities are integers that summarize the strength of earthquake effects in different places – the bigger the integer, the more severe the consequences. Macroseismic earthquake parameters (at least the earthquake size and location) are determined using intensity data. Earthquake loss modelling and historical earthquake analyses employ seismic intensities. Local attenuation properties can be studied using macroseismic intensity data. Intensities are also effective in earthquake early warning and communicating earthquake hazard and risk to the general public and the media. In the modern era of digital seis-

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mology, the resurgence in macroseismology tells us of its essential contribution to seismicity and seismic-hazard analyses.

In a low-seismicity region, the macroseismic data for even a weak earthquake might be more valuable and useful for the study of seismicity than the data for a stronger event in a high-seismicity region. It pays to extract as much information of earthquakes as possible in regions where they are not very frequent. In particular, full attention should be paid to large earthquakes that occur far more seldom than small ones. Pre-instrumental magnitudes can be improved by calibrating them against instrumental magnitudes for which the corresponding areas of perceptibility are known.

This article is the second part of a snapshot of macroseismology in Finland from the 1730s to the 2000s. In the 1730s, more numerous and informative earthquake reports began to appear. The designing of macroseismic questionnaires from the year 1882 until the beginning of the 2000s was the most extensive topic covered in the first part (*Mäntyniemi*, 2017). Attention was also given to the newspaper press due to its importance as a means of communication. This part begins with the contributions of academia to macroseismology in the country (section 2). The main focus is on the dissemination of macroseismic questionnaires and their respondents. Standard practices of macroseismic surveys are reconstructed using available information (section 3). The respondents, those persons who wrote down earthquake observations, are described in section 4. Technological innovations affecting the history of macroseismology are discussed in section 5.

2 Contributions of academia to macroseismology

Learned societies had a major role in promoting macroseismology in Finland in its infancy (*Mäntyniemi*, 2017). This section points out some highlights of the academic contribution to its development. Networks of scholars are created and maintained in academia as well as the learned societies, and individual scholars are typically involved in many activities.

During the Swedish era until 1808, the *Regia Academia Aboensis* in Turku (Swedish *Åbo*; Fig. 1) was the only institution of higher education on Finnish territory; it was renamed the Imperial University of Turku after 1809 and was later moved to Helsinki and renamed once more in 1828. The clergy and civil servants were all educated there. Meteorology became very fashionable in the mid-1700s, and future clergymen were guided in the practice of observing the weather. Understanding weather phenomena was considered necessary to avoid the repeated loss of crops due to frost. Earthquake observations were occasionally written down and published together with weather statistics or included in the parish histories prepared by the vicars.

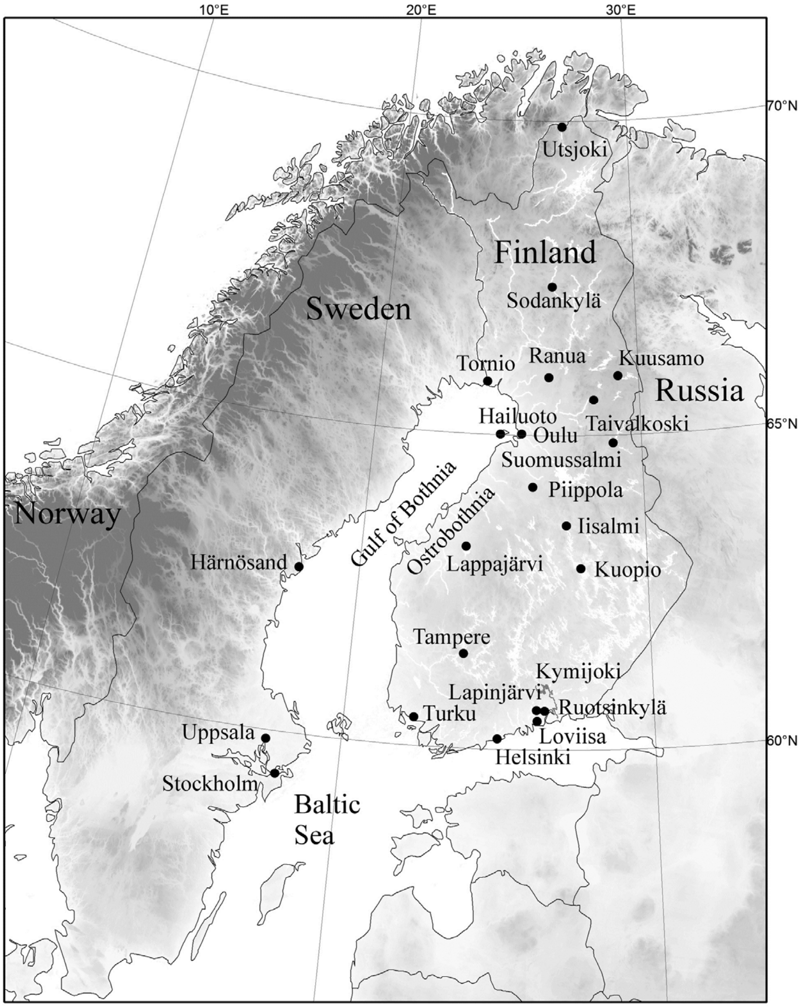
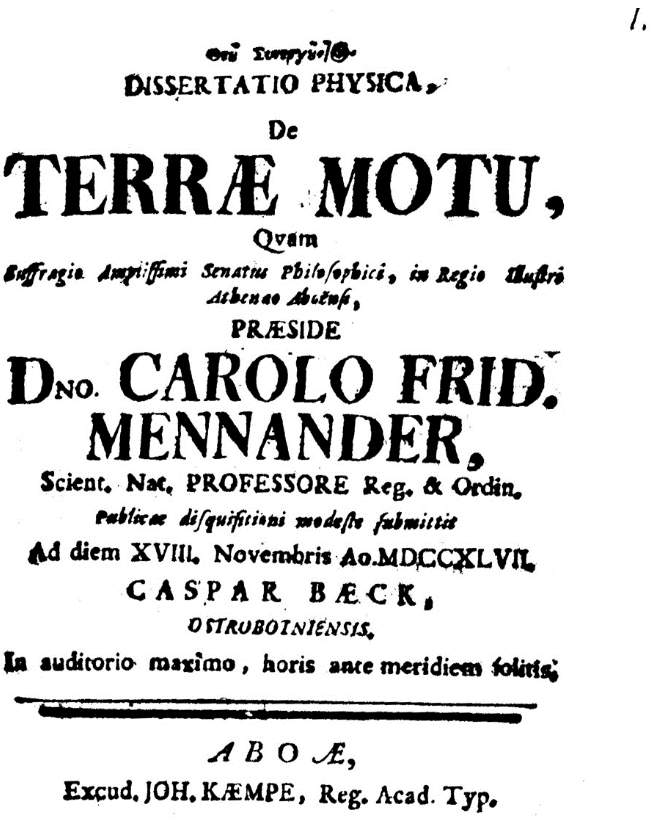


Fig. 1. Location of northern European places mentioned in the text. Thin lines denote present-day national borders.

A dissertation on earthquakes in 1747 included observations of ground tremors made in Ostrobothnia in the 1730s (Fig. 2). It was conducted on the initiative of Professor Carl Fredrik Mennander (1712–1786), who was keen to promote studies on the province. His interest in science is attributed to botanist, physician and zoologist Carl von Linné (1707–1778), who tutored him privately in Turku and later at Uppsala University. Carl von Linné was the most internationally acclaimed Swedish scientist at that time, aside from the astronomer-physicist Anders Celsius (1701–1744). In addition, dissertations focusing on the history and geography of a given municipality sometimes included first-hand remarks on earthquakes.

During the Russian era, 1809–1917, the Imperial Alexander University of Finland in Helsinki was instrumental in research and scholarship in the Grand Duchy of Finland from 1828 to 1917. Adolf Moberg (1813–1895) served as a professor of physics there from 1849 to 1875 and as the rector of the university from 1872 to 1875. He extracted earthquake notifications from the observations collected by the Finnish Society of Sciences and Letters (*A. Moberg*, 1855). His son Karl Adolf Moberg (1840–1901) was the first director of the Geological Commission, established in 1885 (predecessor of the Geological Survey of Finland). Karl Adolf Moberg wanted the Geological Commission to systematically collect information on earthquake occurrences in Finland, because similar work had been undertaken in neighbouring Sweden and Norway. Johan Evert Rosberg (1864–1932) worked as an established professor of geography from 1912 to 1929. During his career the university was renamed, after Finland's independence from Russia, to the University of Helsinki. Rosberg was responsible for the collection of macroseismic observations for the Geographical Society of Finland until the end of 1925. He was succeeded by Henrik Renqvist (1883–1953) (*Rehn*, 1926), who was also in charge of the seismological station of the University of Helsinki until 1937 (*Vesanen*, 1952). He was the first person to obtain the title of docent of geophysics at the University of Helsinki (in 1926). His other positions involving geophysics and geodesy were external to the university (*Blomstedt et al.*, 1977).

Geophysics became an independent discipline at the University of Helsinki in 1947, and the Department of Geophysics was founded in 1966 (*Simojoki*, 1992). The University of Oulu was established in 1958, and seismological studies, including both instruments and macroseismology, were commenced at the Geophysical section of the Department of Physics there.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DISSERTATIO PHYSICA,

De

TERRÆ MOTU,

Quam

Suffragio Amplissimi Senatus Philosophici, in Regio Illustri Athenaeo Aboënsi,

PRÆSIDE

DNO. CAROLO FRID. MENNANDER,

Scient. Nat. PROFESSORE Reg. & Ordin.

Publicae disquisitioni modeste submittit

Ad diem XVIII. Novembris Ao.MDCCXLVII.

CASPAR BÆCK,

OSTROBOTNIENSIS.

In auditorio maximo, horis ante meridiem solitis;

ABOÆ,

Excud. JOH. KÆMPE, Reg. Acad. Typ.

Fig. 2. The front cover of a dissertation on earthquakes prepared at the *Regia Academia Aboensis* in 1747.

3 *Macroseismic surveys in Finland*

The standard practice in Finland is to conduct macroseismic surveys remotely, but very little has been written about how they have actually been carried out. It has been a topic of accumulating tacit knowledge rather than written instructions. Published studies and administrative compilations sometimes include comments on the dissemination of printed questionnaires. In the fortuitous cases, the returned questionnaires contain the address of the recipient and respondent. The absence of detailed reporting on macroseismic surveys is not unlike many other countries. General guidelines for macroseismic observatory practice began to appear in the 2000s (*Musson*, 2002; *Musson and Cecić*, 2002; *Cecić and Musson*, 2004).

3.1 *Conducting macroseismic surveys remotely*

A new earthquake is the impulse for macroseismic action, but seismologists first have to learn about it. In the pre-instrumental era, the surveys involved very long distances: many important earthquakes occurred in northern Finland, whereas the persons responsible for data collection lived far away in Helsinki. Since the latter part of the 1800s, they could obtain information via telegrams and telephone. Newspapers were an important means of communication. For example, the earthquake in Kuusamo on the afternoon of 18 August 1926 made headlines in the newspapers the following day. The first batch of questionnaires was transported to the affected area on a train from Helsinki on the morning of 20 August (*Renqvist*, 1926).

The Mainka seismographs installed in Helsinki in 1924 recorded earthquakes at teleseismic distances and were of little practical value for detecting local seismic events. In the beginning, the absence of a seismogram recording gave rise to misinterpretations. For example, the earthquake of 22 April 1926 in south-western Finland was first taken to be an explosion, and was confirmed to be an earthquake only a few days later (newspaper *Uudenkaupungin Sanomat*, 24 & 27 April 1926).

A fully instrumental era began in Finland in 1971. When local earthquakes are recorded by instruments, and the location and magnitude are subsequently determined using seismograms, seismologists can infer an approximate area of perceptibility shortly after the occurrence. No magnitude thresholds have been set for macroseismic surveys in Finland; any earthquake in the proximity of population centres may be interesting. If the network of seismic stations is not very dense, earthquakes felt by people are not always recorded instrumentally. The initiative on a survey may come from the observers themselves.

3.1.1 *Looking out for respondents*

Musson (2002) discerned four basic types of persons, who may fill in a macroseismic questionnaire. The *public official*, for example the police force or town mayors, and *volunteers*, such as school teachers, are expected to have knowledge of the experiences of the entire community. No networks of permanent correspondents have been arranged in Finland for macroseismic surveys, but respondents are individual citizens who have to be found in the affected area time and again. *Musson* (2002) classified these respondents as *the unselected individual* and *the randomly selected individual*. The former means that the questionnaires are sent to specified locations where someone is asked to distribute them to clients, colleagues, or to the general public. For example, *Korhonen and Saviaro* (1977) acknowledged the local dairy cooperatives and school teachers for their help in distributing macroseismic questionnaires after the earthquakes felt in northern Finland in 1974.

The approach includes having questionnaires printed in local or national newspapers. For example, after the earthquake of 5 November 1898 local time, felt widely in northern Finland, the director of Geological Commission, Karl Adolf Moberg, had the questionnaire published in the national Swedish-language newspaper *Hufvudstadsbladet* on 8 November. After the Ranua earthquakes of 24 December 1956, the director of the Sodankylä Geophysical Observatory, Eero Kataja, had the questionnaire published in the northern newspapers *Kaleva*, *Lapin Kansa*, *Pohjois-Suomi* and *Pohjolan Sanomat* on 28 December. The dissemination method is practical, but may bias the results in favour of positive responses.

Karl Adolf Moberg distributed questionnaires to many vicarages in the affected area. One was delivered to Piippola from Helsinki on 18 November 1898 and reached its destination in three days (Fig. 3a). The reply was mailed the following day (Fig. 3b). Henrik Renqvist made use of occupational registers and telephone catalogues to find addresses of local residents in the affected areas after the Kuusamo earthquake of 1926 (*Renqvist*, 1926). In the Kuusamo area bordering Russia (formerly the Soviet Union), border guards are potential respondents and were targeted, for example, after the February 1960 earthquakes studied by *A. Kataja* (1961). This approach can at least be called *the selected individual*, because random selection procedures were infrequently employed. Sometimes only addresses, such as those of schools and railway stations, could be found. The advantage was that also contiguous communes as well as remote corners of the affected areas were covered.

Henrik Renqvist seems to have followed this routine throughout his macroseismic service from 1926 to 1946. As the director of the Hydrological office in the 1930s, he could also utilize its register of water-level observers. A few days after Renqvist's retirement in May 1946 newspapers reported on felt earth-shaking in central Finland. Renqvist sent a postcard to the director of the seismological station, Eijo Vesanen, urging him to launch a macroseismic survey on the occurrence (Fig. 4). Vesanen should use telephone catalogues and lists of primary schools to find addresses of recipients in the affected area and disseminate plenty of questionnaires in the contiguous communes as well. (It was later discovered that the event was of non-seismic origin.) The postcard also reveals that Mrs Nisula was knowledgeable about the questionnaires and could be asked for help. Macroseismology, as well as other disciplines, has benefitted from assistants, whose identities may later pass into oblivion.

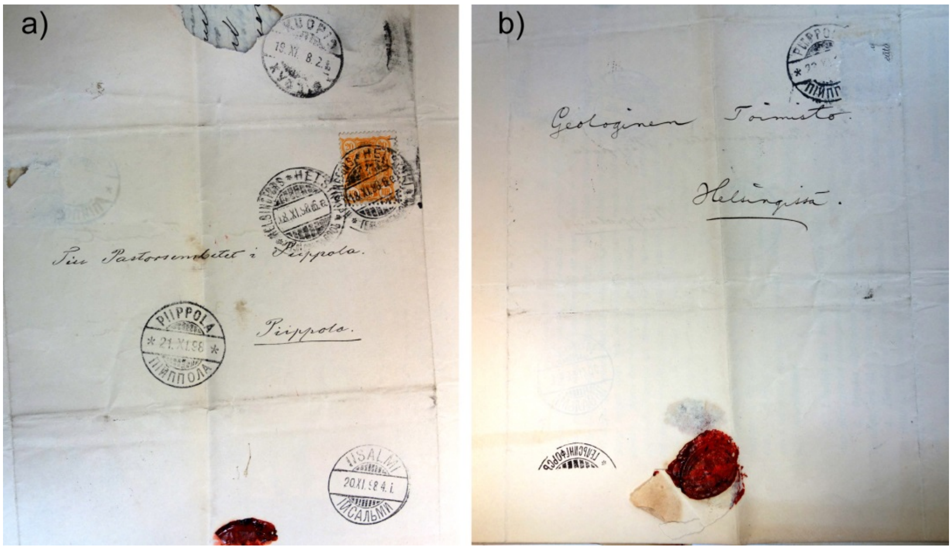

Fig. 3. Correspondence after the earthquake of 5 November 1898 local time a) from the Geological Commission to the vicarage in Piippola via Kuopio and Iisalmi, b) from Piippola to the Geological Commission in Helsinki.

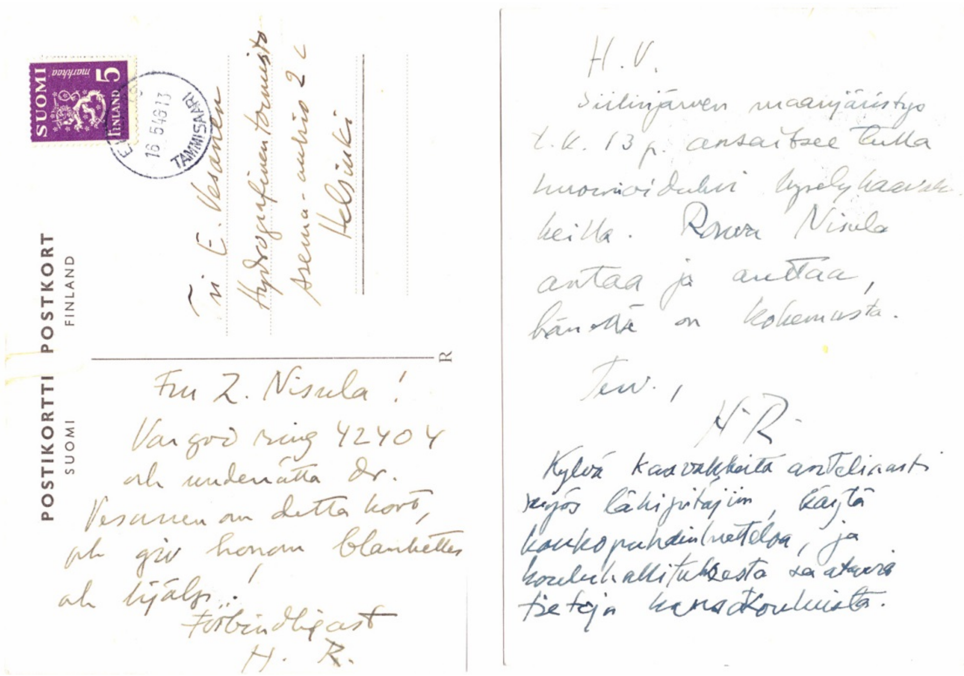

Fig. 4. Postcard mailed by Henrik Renqvist to the Hydrological office in Helsinki on 16 May 1946. Mrs Nisula should contact Eijo Vesanen and give him macroseismic questionnaires. Renqvist advices Vesanen to launch a macroseismic survey following the ground shaking felt in central Finland three days earlier. Vesanen should use telephone catalogues and lists of primary schools to find addresses of recipients in the affected area. (It was later discovered that the event was of non-seismic origin.)

Questionnaires have rarely been filled in at interviews and distributed to respondents during field trips (section 3.2). Field trips increase the cost of the survey, but certainly improve the results. Observations have frequently been obtained over the telephone. Using the telephone systematically would be time-consuming to seismologists, however. In practice, macroseismic questionnaires were typically distributed using various approaches and media to collect data on one and the same earthquake. The questionnaire has been both printed in newspapers and mailed to residents in the affected area. A combination of mail and telephone has been rather common (e.g. *A. Kataja*, 1967). Requests made on the radio or TV can enhance the efficiency of the survey. Henrik Renqvist's lecture on the central Finland earthquakes, broadcast via radio on 18 November 1931, prompted several persons to write down their observations (newspaper *Helsingin Sanomat*, 18 November 1931; *Mäntyniemi*, 2004).

Also the respondents learned the procedure: over the years, several persons have acted multiple times as earthquake reporters, in particular in northern Finland. In Kuusamo, the earthquakes were conscientiously reported by the local press, and residents learned to report to the Sodankylä Geophysical Observatory when new earthquakes occurred (*Airi Kataja*, letter of 23 July 2014). Volunteers have occasionally collected additional data. For example, forester Einar Reuter made house-to-house inquires in Taivalkoski in the autumn of 1926 and returned 21 questionnaires.

3.1.2 On the response rates of the surveys

Obviously, not all questionnaires disseminated by seismologists were ever sent back. In August 1926, about 200 questionnaires were distributed, and about 120 of them were returned (*Renqvist*, 1926). However, this macroseismic survey continued later in the autumn. In November 1931, about 2000 questionnaires were distributed, and 1100 were returned (*Karjalainen*, 1936). In February 1960, over 300 questionnaires were distributed, and over 30% of them were returned (*Kataja*, 1961). In 1979, a total of 2120 questionnaires were distributed by mail and during the field trip, and 46% were returned (*Ahjos*, 1980).

The Internet questionnaire resembles an appeal for earthquake observations published in a newspaper or disseminating questionnaires at public places. It has potential for a large response, but is strongly biased in favour of positive responses. The response rate is no longer relevant. The success of Internet data collection is defined by the number of responses per earthquake and the scope of their geographical distribution. It is not self-evident to judge how reliable the area of perceptibility is in the absence of negative responses. The unprecedented speed is an obvious advantage: hundreds of responses can be obtained within the first 24 hours following an earthquake. For example, close to 900 responses were obtained after an earthquake in southern Finland on 19 March 2011 (M_L2.6), but they may also be attributed to the densely populated area. Dissemination of information after new earthquakes remains important also in the Internet era.

3.2 Field trips

Macroseismic field surveys are not routinely conducted in Finland, because local earthquakes seldom have permanent effects on the built-up environment or nature. Fire inspection officers conducted a rare survey of earthquake damage in Tornio after the earthquake of 5 November 1898 local time, because of the concern that the tremors had damaged masonry stoves and chimneys, posing a fire hazard (*Mäntyniemi*, 2007). Seismologists have occasionally interviewed eyewitnesses and distributed questionnaires during field trips. The known field trips are listed in chronological order below.

a) 1751/1752

In the winter of 1751−1752, recurrent earth shakings and underground roars were noticed in the village of Ruotsinkylä in southern Finland. The first occurrence is dated 27 October 1751 according to the Julian calendar. The development of events is known on the basis of a letter to the Royal Swedish Academy of Sciences (*Östberg*, 1752). By request of the Academy, the vicar of Loviisa, David Starck, inquired into the matter and confirmed the reports truthful. This case can be regarded as an early field study: an appointed person inspected the site of interest to observe earthquake effects there.

b) 1931

Dr Henrik Renqvist and Tauno Karjalainen, a student of natural sciences, conducted a field trip after the earthquake felt widely in central Finland on the early morning of 16 November 1931 and its largest aftershock on the evening of the same day. They left Helsinki on 20 November (newspaper *Sisä-Suomi,* 24 November 1931), and visited several localities during the six-day trip (*Karjalainen*, 1936). Every now and then they stopped the car, made telephone calls in the area and interviewed eyewitnesses. Renqvist and Karjalainen also distributed questionnaires; at that time, the Geographical Society of Finland was responsible for macroseismology. In addition, the postal services were used for distributing questionnaires with the help of newspaper editors in the affected area. The questionnaires filled in at interviews can be discerned from the other original questionnaires because of missing postmarks and an identical handwriting. Figure 5 shows the localities of the interviews (reproduced from *Mäntyniemi*, 2004).

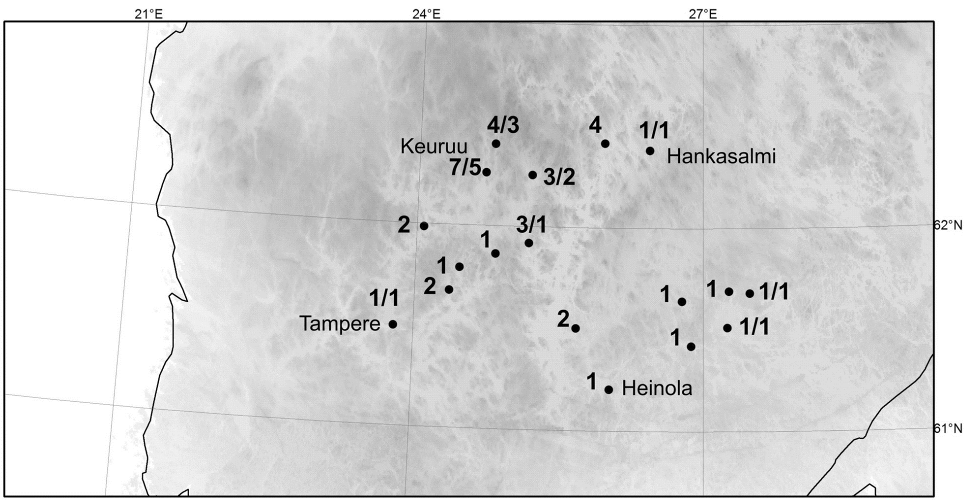

Fig. 5. The numbers of questionnaires obtained at interviews during the field trip of Henrik Renqvist and Tauno Karjalainen in November 1931. The dots denote localities in central Finland. The first number refers to the main shock of 16 November, the second one after the slash to the largest aftershock the same day. Reproduced from *Mäntyniemi* (2004).

c) 1952

Earthquakes were noticed in Lapinjärvi and adjacent areas in southern Finland in August 1951, and the seismic activity intensified in February and continued until April the following year. The events were accompanied by sounds resembling thunder and rumbling. On 13 March 1952, Dr Allan Sirén and MSc Nils Koroleff travelled to Lapinjärvi to interview local residents (newspaper *Helsingin Sanomat*, 15 March 1952). A school building served as the headquarters of the survey. At least 100 questionnaires were filled in. The visit was somewhat ill-timed, however, in so far as there were no seismic events during it, but the strongest earthquake so far occurred on 18 March after the researchers had already left (*HS*, 19 March 1952). The field trip was conducted at the expense of the Geophysical Society of Finland (*Uusi Suomi*, 14 March 1952).

d) 1953

On the evening of 22 November 1953, many inhabitants in Kuusamo noticed a roaring and rumbling that here and there appeared to come from the sky. They were concerned about the origin of the phenomena and contacted the local border-guard station. The Finnish Border Guard launched an investigation into the matter. First lieutenant N. Enkkelä and Lieutenant V. Taskinen visited many villages in the area between 23 and 25 November and interviewed eyewitnesses. The observations had been simultaneous, as far as could be judged, the rumbling quite loud, awakening residents at some places and making windowpanes rattle, sometimes a tremor had been felt. The weather was calm. It was concluded that the phenomenon was of natural origin. A lesser earthquake not close to the ground surface is a plausible explanation for the somewhat obscure observations. The examination record prepared on the basis of the interviews is a remarkable document of a macroseismic survey carried out by non-seismologists.

e) 1969

After the earthquake of 23 May 1969 in Ranua, northern Finland, three field trips were carried out to collect information about the felt effects (*Talvitie et al.*, 1974). Questionnaires of the University of Oulu were in use, and they were mainly filled in during the trips. Hand-written notes dated 25 June and 2 July have survived, but the date of the third field trip is unknown.

f) 1979

An earthquake was felt in Lappajärvi and contiguous communes in the province of Ostrobothnia on the evening of 17 February 1979, rather intensively at some places. The instrumental magnitude was assessed at M_L3.8. BSc Tellervo Hyvönen and librarian Annikki Lipponen travelled widely in the affected area between 21 and 26 February, aiming at visiting up to 70 municipalities (newspaper *Vaasa*, 23 February 1979; field-trip logbook). They also took photos of the sustained non-structural damages (Fig. 6). They distributed 1579 questionnaires at schools, among other places. Postal services were used to deliver 541 questionnaires to the affected areas.

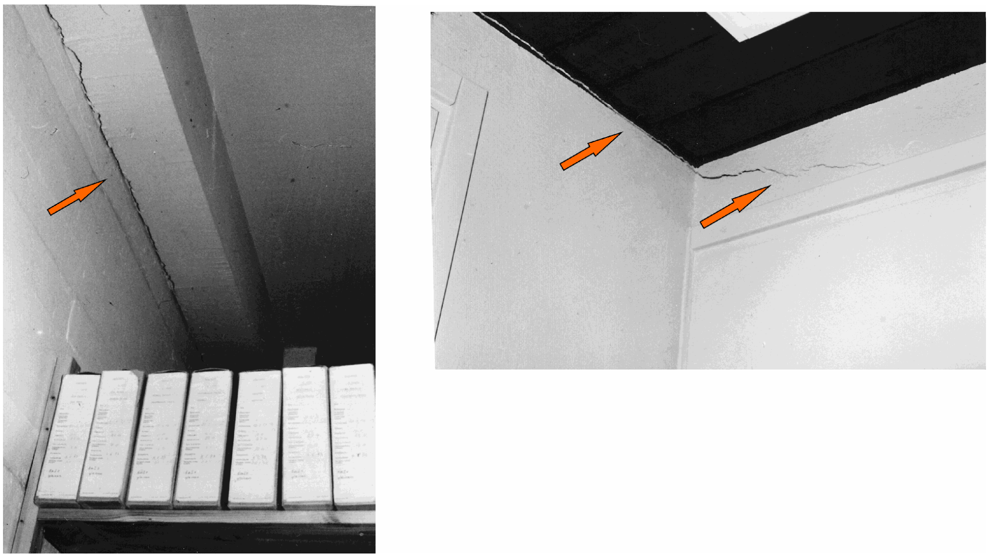

Fig. 6. Cracks in ceilings and walls, caused by the Lappajärvi earthquake of 17 February 1979 (M_L3.8). Photos by Tellervo Hyvönen and Annikki Lipponen.

4 Respondents

Macroseismology investigates written documents testifying to the effects of earthquakes in different times and places. Identifying the authors helps in judging how reliable the documentation is. Original documentation is typically preferred to copies, and eyewitnesses and experts have the highest priority as authors. This section discusses the authors of earthquake reports and respondents of the macroseismic surveys in the Finnish territory.

4.1 Vicars as earthquake reporters

A wealthy Englishman, Arthur de Capell Brooke, made a journey to Sweden and Norway in the summer of 1820. His travel book includes the comment that the clergy in the north “seem to be naturally and more particularly led” to natural history (*Brooke*, 1823, p. 312). This was a shrewd observation. The significance of vicarages in the Swedish era (“*prästgårdskulturen*”) is seen in the history of macroseismology quite clearly. Prior to the introduction of macroseismic questionnaires, earthquake reports were frequently prepared by the clergy. During the first few decades of questionnaires, the vicars continued to be an important target group; their position waned gradually in the 1900s.

Vicars were obliged to attend to the annual bookkeeping of the parishes. The law on the church enacted in 1686 by the Swedish parliament (*Riksdagen*) provided that rare incidents should be included. The requirement benefitted seismology in the following century, when the Statistical Office (*Tabellverket*, a predecessor of Statistics Sweden) was established in 1749. The first version of a questionnaire format was introduced shortly thereafter, and included an item for unusual natural phenomena.

Vicars had access to parish archives and were often familiar with local oral tradition. Many of them prepared a history of the parish in writing and included recollections and notifications of earthquakes. Not all phenomena reported were of local or regional origin. Vicar of Loviisa, David Starck (1729–1778), described water disturbances in the river Kymijoki, southern Finland, on 1 November 1755 (*Starck*, 1885). Similar observations were made also in the western part of the Kingdom of Sweden (*KVAH*, 1755; *Sidenbladh*, 1909) and all over Europe as a consequence of the Great Lisbon earthquake.

In Utsjoki, northernmost Finland, vicar Henrik Wegelius (1735–1791) made meteorological observations after the fashion of the mid-1700s. His description of local ground shaking was published together with his weather report of 1758 by the Academy (*Wegelius*, 1759). His successor David Erik Högman (about 1733–1781) reported ground tremor in Utsjoki on 25 December 1772 (*Sidenbladh*, 1909). Also Erik Johan Frosterus (1773–1847), vicar of Hailuoto, was a diligent observer of the weather. His manuscript mentions an earthquake felt on the island in 1757 (*Renqvist*, 1930, p. 15). Other clergymen can be identified among the respondents. Also newspaper reports can be attributed to them. For example, water disturbances in the river Kymijoki were described in the newspaper *Inrikes Tidningar* on 25 October 1762. The wording is identical to the text that was later published in a book (*Starck*, 1885). The domestic press was a forum where the description of the natural phenomenon of 1755 could be printed.

The 1700s marked a great era in Swedish science. It was not the specialized, highly technical science of today, but the growing importance of direct observation benefitted seismology. A landmark was the establishment of the Royal Swedish Academy of Sciences in 1739. A diverse range of natural scientific topics was published in its *Proceedings*, contributed to by a network of scholars. A frequent correspondent in the town of Härnösand on the Gulf of Bothnia was Nils Gissler (1715–1771), whose interests comprised meteorology, astronomy and seismology. He was the first physician of much of northern Sweden (*Dahl*, 1946). His kind of natural scientists with medical skills constituted a growing group of the well-read.

4.2 Towards citizen science

In the Finnish territory, the learned elite communicated in Swedish, whereas most laypeople spoke Finnish dialects. It has been estimated that the educated constituted some 3% of Finns in the early 1800s (*Leino-Kaukiainen*, 2007). Another gap to be bridged was that, on average, laypeople learned to read much earlier than they learned to write. General reading skills went back a long way: the law on the church enacted in 1686 by the Swedish parliament had urged the clergy to promote literacy in the parishes.

About 5% of the rural male population could write in the 1830s (*Tommila*, 1988a, p. 32). The means to learn to write were not standard until the Primary School Decree in 1866 advocated more uniform education. From the mid-1800s onwards, the press was an important forum for the self-taught (*Stark*, 2013). Also earthquake notifications can be found in the Finnish-language press since that time. For example, the newspaper *Oulun Wiikko-Sanomia*, issued on 25 June 1859, included a letter from Suomussalmi, reporting mainly on weather and farming, but also some unusual rumbling of the ground. About 60% of the rural correspondents at that time were clergymen, schoolmasters and writers; about 40% were literate peasants. The proportion of peasants increased in the 1860s (*Tommila*, 1988b, p. 202).

The urban and affluent had command of writing earlier than the rural poor, and men earlier than women. Literacy rates were assessed along with the census of 1880. In Helsinki, about 65% of Finns over the age of 10 could read and write, in Tampere about 47%, but in the countryside the corresponding figure was below 10% (*Leino-Kaukiainen*, 2007). At the turn of the 1900s, the literacy rates started to increase quite fast.

Respondents to macroseismic surveys tell us about improving literacy. After the earthquake of 5 November 1898 (local time), felt observations were obtained from northern Finland on 29 questionnaires of the Geological Commission. Close to 69% of them were filled in by clergymen, and 27.6% of the respondents used Swedish (*K.A. Moberg*, 1861, 1898). The numbers of questionnaires could not increase without the involvement of a wider range of occupations. A total of 144 questionnaires were collected after the earthquake that was felt in south-western Finland on 22 April 1926. The respondent cannot be identified in 19 cases; among the remaining 125, the four largest occupational groups are farmers (23.2%), clergymen (20.8%), teachers (15.2%) and merchants (5.6%) (Fig. 7a). About 8.8% of the respondents were women. Close to 7.6% of the questionnaires were returned from the Swedish-speaking archipelago. These respondents were occupied in shipping.

Four months later a rather strong earthquake occurred in Kuusamo, north-eastern Finland. The macroseismic survey was prolonged because, after the first earthquake on 18 August 1926, a second earthquake occurred in October, and observations of the first quake continued to be reported as well. A total of 246 questionnaires exist; excluding letters and interviews, 225 remain. The clergymen constituted the largest group of the respondents (17.8%), foresters and forest wardens the second largest (16.9%), crofters the third (13.8%) and the military (mainly of the Border Guard) the fourth largest group (5.8%) (Fig. 7b). Of those who wrote their name in full, 2.7% were women.

In 1931, questionnaires were filled in central Finland. Some 1266 questionnaires testify to the main shock on the morning of 16 November. There were 435 primary school teachers among the respondents, 56% of them women and 31% men; the rest used initials only. The range of occupations was wide, including a prison warden and ferry boaters. Many water-level observers working for the Hydrological office participated in the survey.

The occupation of the respondent was not requested on the questionnaires designed in the 1960s and later. In the Internet era, respondents sometimes prefer to remain anonymous or give their first name only.

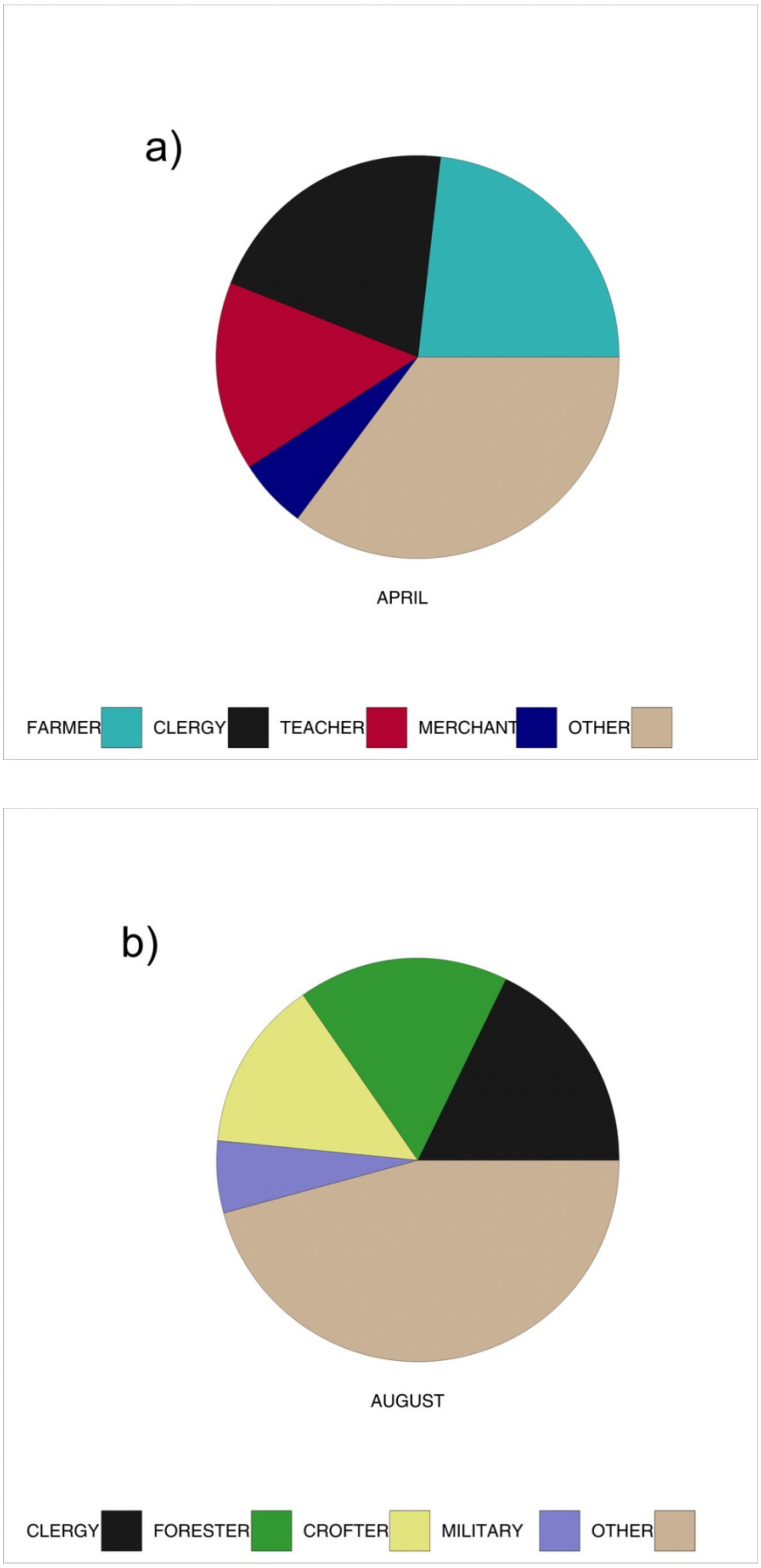

Fig. 7. The four largest occupational groups of the respondents who filled in a macroseismic questionnaire after the earthquake of a) 22 April 1926 in south-western Finland and b) 18 August 1926 in north-eastern Finland.

5 Discussion

The present review focused on the time span from the 1730s to the 2000s. Reports of earthquakes as natural phenomena were written down and systematically collected in the Finnish territory throughout this time, although detailed scientific knowledge developed slowly. The causes of earthquakes were not understood until plate tectonics became generally accepted as the fundamental paradigm of solid-Earth geoscience in the 1960s. Observations remain usable after centuries, even though the possible accompanying speculation of the earthquake theory is outdated. Effects of the Lisbon earthquake of 1 November 1755 were noticed up to northern Europe (*KVAH*, 1755; *Starck*, 1885). The vastness of the calamity led to biblical interpretations (e.g. *Hedberg*, 1757), but Swedish newspapers, such as *Stockholms Post-Tidningar*, continued to report the aftershocks as a matter of routine in the foreign news section and the supplement in the following years (e.g. 31 March 1757, 16 January & 6 March 1758, 31 March 1760).

The available technologies shaped the creation and circulation of written earthquake reports. Newspaper press was based on the printing technology developed in the 1400s. The numbers of publications could multiply in comparison with handwritten notes. A constraint on the number and size of newspapers was the price of paper; using textile rags as raw material was expensive. An ordinary newspaper size was four pages in the Kingdom of Sweden in the 1700s. The technical problems in using wood were resolved by the 1870s, so mechanical wood-pulp could be produced at a lower cost (*Gustafsson and Rydén*, 2010).

Technological innovations affected the speed of news circulation. Regular postal services in the Swedish realm date back to the 1640s. Mail delivery was slow in bad weather conditions, when ships could not cross the sea between Finland and the western Kingdom of Sweden. Telegraph cable networks started to make instant communication possible during the latter part of the 1800s. Telephones were in use and helpful when collecting earthquake observations.

An accurate assessment of time is vital to historical earthquake analyses, in order to judge which observations were coincident and belonged to one and the same earthquake. It can be quite a complicated puzzle because of possible mistakes and different calendars. In the Kingdom of Sweden, the shift from the Julian to the Gregorian calendar was multiphase in the mid-1700s. Railways started to be built in the mid-1800s and made a more precise recording of time necessary. However, it lasted long before everybody had easy access to a reliable standard time. The first generations of Finnish questionnaires inquired whether the respondent's clock was keeping time (see the Appendix of the first part). The time signal started to be broadcast over radio in Finland in 1926.

The first generations of Finnish questionnaires were printed at printing houses. The date and location of interest were left blank and were written in ink when a new earthquake had occurred. Stamping pads increased the speed of questionnaire preparation. Copy machines made it fast and practical to produce large numbers of questionnaires for a given earthquake. The Internet questionnaire made redundant the printing of questionnaires and return envelopes.

Modern technologies are literally in the hands of the people, as smart phones provide opportunities to empower citizen seismology (*Bossu et al.*, 2017). New ways of communication such as social media have been created (*Earle et al.*, 2017). There are exciting opportunities available for macroseismology, but it may also have to compete with different sorts of entertainment. Macroseismology will thrive only if observers of the shaking ground continue to send large numbers of reliable, informative and clear reports.

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