

Recent earthquakes in Denmark are felt over as large areas as earthquakes of similar magnitudes in the Fennoscandian Shield and East European Platform

PETER H. VOSS, SØREN GREGERSEN, TRINE DAHL-JENSEN & TINE B. LARSEN



Voss, P.H., Gregersen, S., Dahl-Jensen, T. & Larsen, T.B. 2017. Recent earthquakes in Denmark are felt over as large areas as earthquakes of similar magnitudes in the Fennoscandian Shield and East European Platform. © 2017 by Bulletin of the Geological Society of Denmark, Vol. 65, pp. 125–134. ISSN 2245-7070. (www.2dgf.dk/publikationer/bulletin). <https://doi.org/10.37570/bgds-2017-65-08>

Received 22 March 2017
Accepted in revised form
19 May 2017
Published online
31 October 2017

For magnitude estimation of historical, pre-instrumental earthquakes it is useful to estimate felt areas for several intensities. From several macroseismic surveys it has been observed that an old shield such as the Fennoscandian Shield has especially large felt areas compared to California where the magnitude formula was developed. However, the newest Danish observations of felt areas and associated digitally determined magnitudes presented in this study show that the subsurface of Denmark has a response to shaking which is similar to that of the Fennoscandian Shield. This study covers the period 1996–2012 and includes an analysis of the macroseismic surveys of all felt earthquakes. Eight of these earthquakes provided new information on intensity areas in Denmark. An aim for the future is to use the felt areas of old earthquakes in Denmark for improved estimations of their magnitudes.

Keywords: Earthquakes in Denmark, macroseismic intensity, seismicity.

Peter H. Voss [pv@geus.dk], Søren Gregersen [sg@geus.dk], Trine Dahl-Jensen [tdj@geus.dk], Tine B. Larsen [tbl@geus.dk], Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark.

The most important information on the size of a modern earthquake comprises computations of magnitude and preferably also of moment, using the digital recordings from modern seismographs. But it is still important to obtain regional coverage of intensity from as many observers around the earthquake as possible. This gives added information on the influence of the regional geology as well as parallel information to historical, non-instrumental information. This is important because earthquakes in a region such as Denmark occur rarely, so that judgment of recurrence times for the purpose of evaluating earthquake hazards is highly dependent on a long history.

Båth (1956) was the first to introduce a size measure for earthquakes in Scandinavia, which through several elaborations and extensions has developed into the basis for the Scandinavian magnitude calculations (Båth *et al.* 1976; Wahlström 1978; Geodetic Institute 1983). This scaling is based on amplitude measurements on seismographs. The Danish scale (Geodetic Institute 1983) is copied from Sweden (Wahlström 1978) with the argument that the Lg waves on which

it is based propagate as well in Denmark as in Sweden (e.g. Gregersen 1984). Follow-up efforts have been applied to correlate the intensity observations by people feeling the earthquake to those of size/magnitude. This, naturally, has interest for historical earthquakes for which no instrument data is available. This has been done for Sweden and Finland (Wahlström & Ahjos 1982) and presented as the Baltic Shield, i.e. not including Denmark. For modern as well as historical earthquake magnitudes in Sweden further work has been done by e.g. Kulhanek & Wahlström (1996). In Denmark, the Swedish scaling has occasionally been used informally to derive a rough magnitude estimate from observations of felt areas of a certain intensity (intensity areas). No specific investigation has been performed until now.

The aim of this paper is to compare the intensity areas of earthquakes felt in Denmark with intensity areas of earthquakes felt in neighbouring Scandinavian countries in order to estimate the differences. Such differences will play an important role in the evaluation of the size of earthquakes in Denmark that

occurred in pre-instrumental time, as they are only described by felt intensities as established for the Baltic Shield in Scandinavia.

Data displays and areas

The location of earthquakes in Denmark is determined using the available data from the four Danish seismographs supplemented by data from neighbouring networks mainly in Sweden and Norway. Depending on the available seismographs at the time, and the location of an earthquake, the epicentre uncertainty ranges from app. 5 to 25 km, and the depth is normally located with an uncertainty of around 10 km.

For every earthquake felt since the beginning of the earthquake monitoring in Denmark in 1927, we have collected intensity information, also called felt area information. Until recently, this was done via letters and telephone, but today it is done via the Geological Survey of Denmark and Greenland (GEUS) home page (<http://www.geus.dk/>). A form with questions on how an observer has felt the shaking is filled out. This covers human reactions such as worry, fear and running out of the house, as well as physical effects such as creaking of roof constructions and rattling of glasses in cupboards. The form continues for more intense shaking to falling objects, swinging lamps or developments of cracks in walls. Fortunately, the larger intensities with real destruction have not been seen in Denmark. Any special observations in connection with the earthquake are encouraged to be included in the form. The felt earthquakes include

only a small part of all the earthquakes that occurred in the same period in the same area. Before 1927 individual researchers collected intensity information after significant earthquakes, see Lehmann (1956). For the period 1996–2012 the GEUS earthquake database contains 11 earthquakes felt in Denmark and 58 non-felt earthquakes in the area 54°N–58°N, 07°E–14°E (approximately the area shown in Fig. 5), many located in the southern part of Sweden such as the 2008-12-16 earthquake. The only other earthquakes located outside this area and felt in Denmark are two earthquakes in Kaliningrad that are described below. The largest earthquake located in Denmark and not felt occurred in northern Jylland (57.34°N, 10.28°E) on 2009-06-08 at 03:54 UTC with a magnitude of 2.6.

Upon receiving the felt observations a seismologist classifies these into intensity classes 1 to 12, following an international agreement for Europe (Grünthal *et al.* 1998; a rough overview is given in Appendix 1) and the intensity values are plotted on a map. The example in Fig. 1 shows that the intensity values are larger in certain areas than in others, with some irregularities. Thus some generalisation is necessary to describe the intensity field. In Fig. 1 only one curve is drafted around the felt area, with observations of intensities 3 and 4 lumped together because there was no agreement on a separation between intensity areas 3 and 4. This emphasises the subjectiveness of the map production. An attempt with about 10 colleagues estimating areas for one earthquake resulted in a rather large variation. The emphasis in the present study has been on homogeneity of procedure.

All earthquakes/shakings for which Danish intensity maps are available for the period 1996–2012 (since the last similar reporting by Gregersen *et al.* 1998) are

Table 1. Parameters for earthquakes felt in Denmark 1996 – 2012, including the major and minor elliptical half-axes in kilometres determined for macroseismic intensity 3 (Int3) and 4 (Int4) areas for the eight earthquakes plotted in Fig. 7 and the Kaliningrad earthquake SEP 21st 2004.

Date	Time	Latitude	Longitude	Depth	Magnitude	Int3 Major	Int3 Minor	Int4 Major	Int4 Minor
1996-12-17	18:15	55.574	12.879	13.4	2.7	n.d.	n.d.	n.d.	n.d.
1997-12-04	22:03	56.911	7.690	8.50	3.4	n.d.	n.d.	n.d.	n.d.
1998-07-08	23:14	57.203	8.423	15.0	3.4	46	46	39	39
2001-06-02	00:44	56.801	7.803	59.3	3.5	39	39	36	36
2001-10-21	00:31	56.733	7.661	29.1	3.4	68	53	66	46
2001-11-06	18:05	55.677	11.701	19.7	2.8	29	15	25	14
2003-07-10	05:05	56.745	9.283	11.4	2.7	n.d.	n.d.	n.d.	n.d.
2004-02-23	08:38	55.516	12.184	36.3	2.9	30	17	27	13
2004-09-21	13:32	54.820	19.960	10.0	5.2	808	425	356	187
2008-12-16	05:20	55.500	13.600	9.00	4.8	235	160	168	108
2010-02-19	21:09	56.874	7.581	38.7	4.3	129	68	n.d.	n.d.
2012-08-06	02:57	56.600	11.948	22.1	4.1	105	100	n.d.	n.d.

n.d.: not determinable.

displayed in Figs 1–6 and listed in Table 1. Similar to previous earthquake investigations (Lehmann 1956; Gregersen *et al.* 1998), we find most of the felt earthquakes in north-western Jylland, and fewer in Sjælland. Those felt in north-western Jylland are all located off the coast. Irrespective of which intensity is counted (Table 1), the felt areas are broadly the same as those of the previous studies.

A general observation is that there is a large influence on the observations from local geology: loose gravel versus solid sediment or bedrock. This is seen on several of the curve systems of Figs 1–6, and it has been elaborated for the Holbæk earthquake of 2001-11-06 (Fig. 3) by Larsen *et al.* (2008). For that earthquake the observations that reached GEUS were all from locations east of the earthquake. This emphasises that it is important to actively collect information via different means. As it stands, we are in doubt about

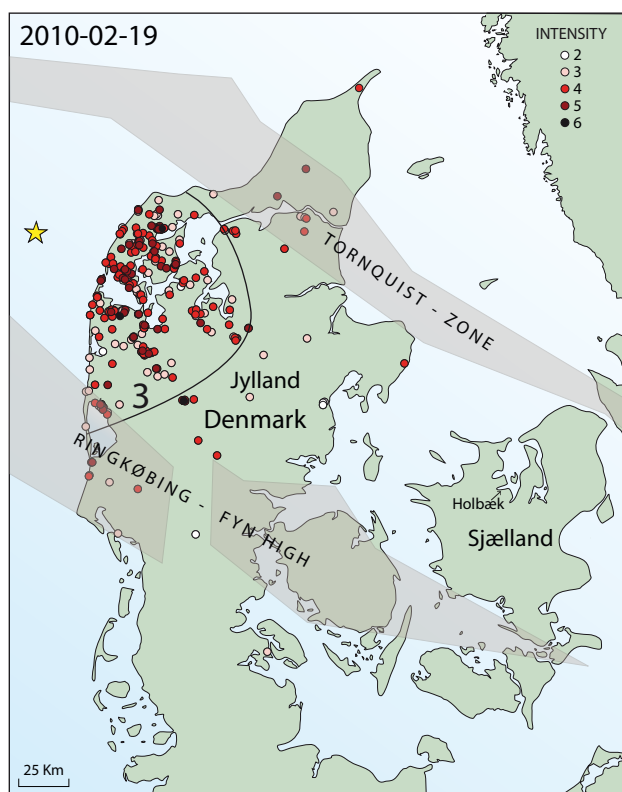


Fig. 1. Map with intensity data collected after the earthquake on 2010-02-19. Curves describing the generalised intensity field are sketched by hand to parallel the procedure historically used for old data. Star shows epicentre location and circles show addresses from where macroseismic reports have been collected. Intensity scale is given in upper right corner. Earthquake date is given in upper left corner. The location of the two major geological features the Tornquist Zone and the Ringkøbing–Fyn High are shown. The size of the area is roughly calculated assuming that the shape of the generalised area is elliptic and centred on the epicentre. Magnitude 4.3.

how much population density, and/or mass media coverage influences this result. This is in addition to the geological correlations, that the earthquake was felt the most in areas with relatively shallow chalk and less than 25 m of loose Quaternary sediment. The possible influence on this one-sided tendency by the earthquake source directionality cannot be evaluated.

A few of the events are observed at so few points that it is meaningless to attribute curves to the intensity picture. Even if a coincident signal has been observed on seismograph recordings, it may be doubted whether the shaking on 2003-07-10 (Fig. 3) should be called an earthquake. However, it is not a reported explosion and must have a natural source. As that natural source is very small, it could be a collapse event in the well-consolidated limestone in the area above a salt diapir. Another event with few observations, 1996-12-17 (Fig. 2) in the Øresund region between Denmark and Sweden, is by the present authors considered to be an earthquake of which the shaking was drowned by big city noise.

Beside observations of earthquakes in Denmark, two earthquakes in more distant areas have been felt in Denmark in the period since the last reporting. One is rather far from Denmark, namely the large Kaliningrad earthquake of 2004-09-21 (Gregersen *et al.* 2007) (Fig. 4). The other occurred in southern Sweden on 2008-12-16 (Voss *et al.* 2009). The felt area picture is shown in Fig. 5.

Area computation for an earthquake such as the one of Fig. 1 requires an assumption concerning the sea-covered area. The assumption in the present investigation is that the landward observations have a mirror picture around the epicentre, which is included in the area calculation.

The field of each intensity is not far from circular, but we have chosen to approximate the felt areas by ellipses. We note ratios of ellipse axes between 1 and approximately 2. The directions of the longest axes are influenced by population density, local noise sources (traffic, weather and sea waves), terrain forms, and regional and local geology. A special effect noted in Fig. 4 is that the felt area for the Kaliningrad earthquake in 2004 is delimited by the significant crustal change in the Tornquist Zone (Gregersen *et al.* 2006, 2007).

Correlation of magnitudes and felt areas

For modern earthquakes size, i.e. moment, energy and magnitude, can be measured via instruments if the recorded data has sufficient quality. If the data quality is low (due to e.g. low signal to noise ratio, few re-

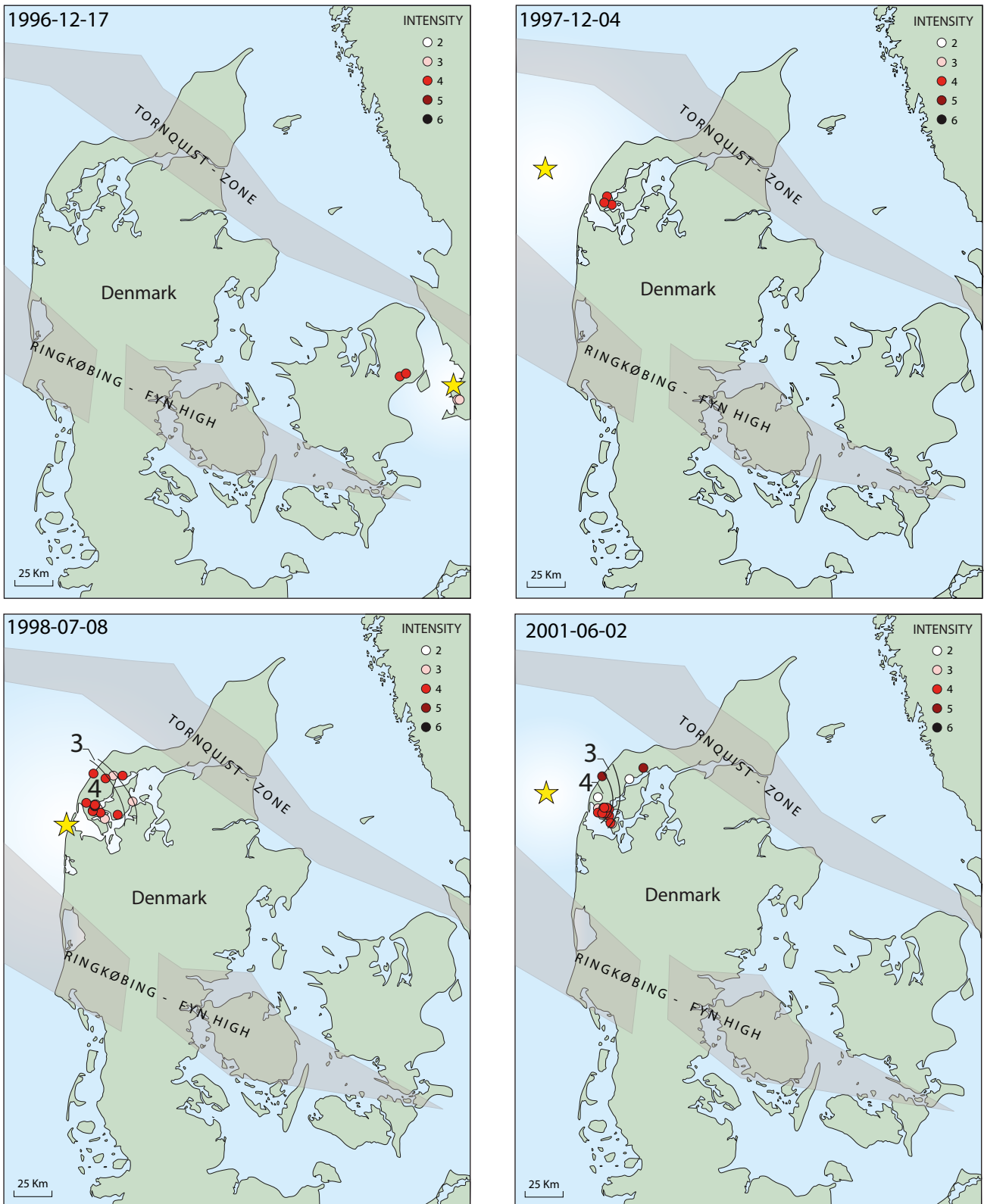


Fig. 2. Four different intensity maps with varied external influence: Upper left: few observations because of big city noise. The other three: noise from the sea but not from cultural activities, cutoff of pattern by the sea. Magnitudes are 2.7, 3.4, 3.4 and 3.5, for the earthquakes on 1996-12-17, 1997-12-04, 1998-07-08 and 2001-06-02, respectively. Yellow stars are the epicentres.

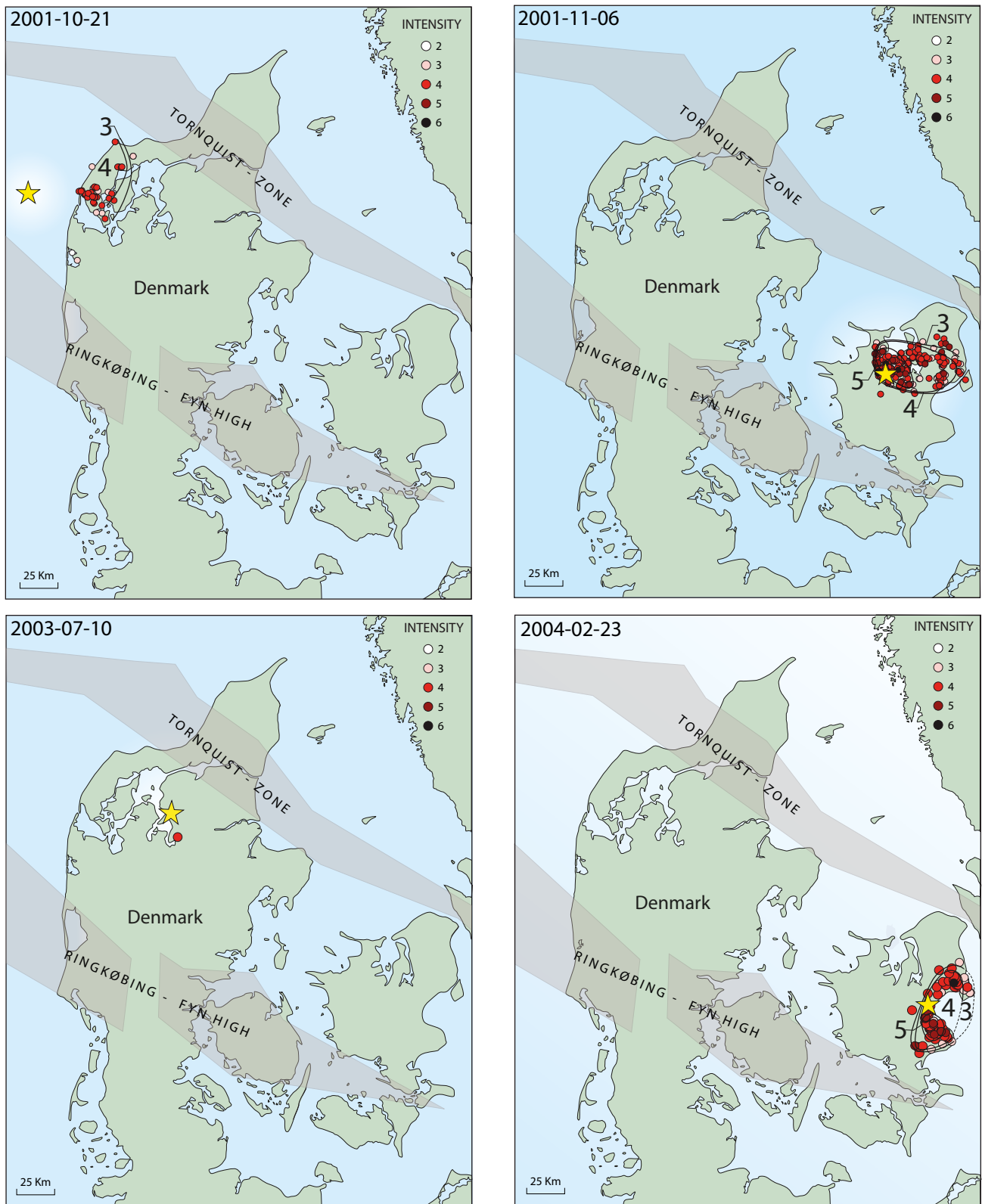


Fig. 3. Four different intensity maps with varied external influence: Upper left: noise from the sea but not from cultural activities, cutoff of pattern by the sea. Upper right: dense population toward the east, but also shallower consolidated sediment and more cultural noise toward the east. Lower left: only one observation, suspicion that the event is a collapse of a cave in the sediments. Lower right: population density largest along the coast. Magnitudes are 3.4, 2.8, 2.7 and 2.9, for the earthquakes on 2001-10-21, 2001-11-06, 2003-07-10 and 2004-02-23, respectively. Yellow stars are the epicentres.

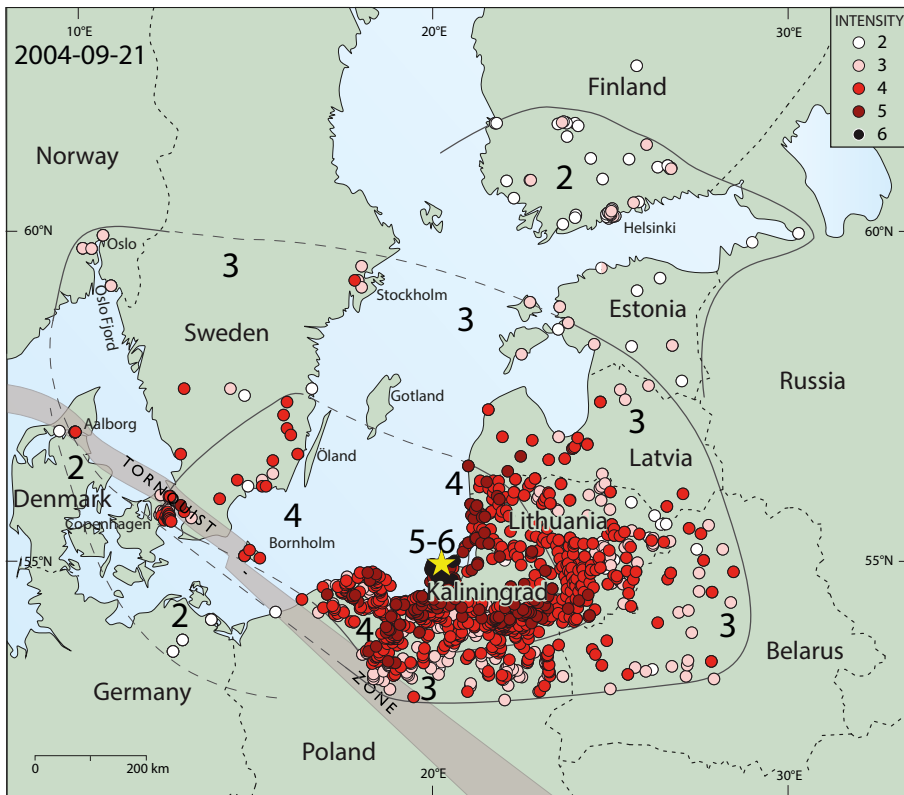


Fig. 4. Intensity map for the larger of the two Kaliningrad earthquakes, 2004-09-21. Curves describing the generalised intensity field are sketched by hand to parallel the procedure historically used for old data. The size of the area is roughly calculated by assuming the shape of the generalised area is elliptic and centred on the epicentre. Magnitude 5.2. (Gregersen *et al.* 2007).

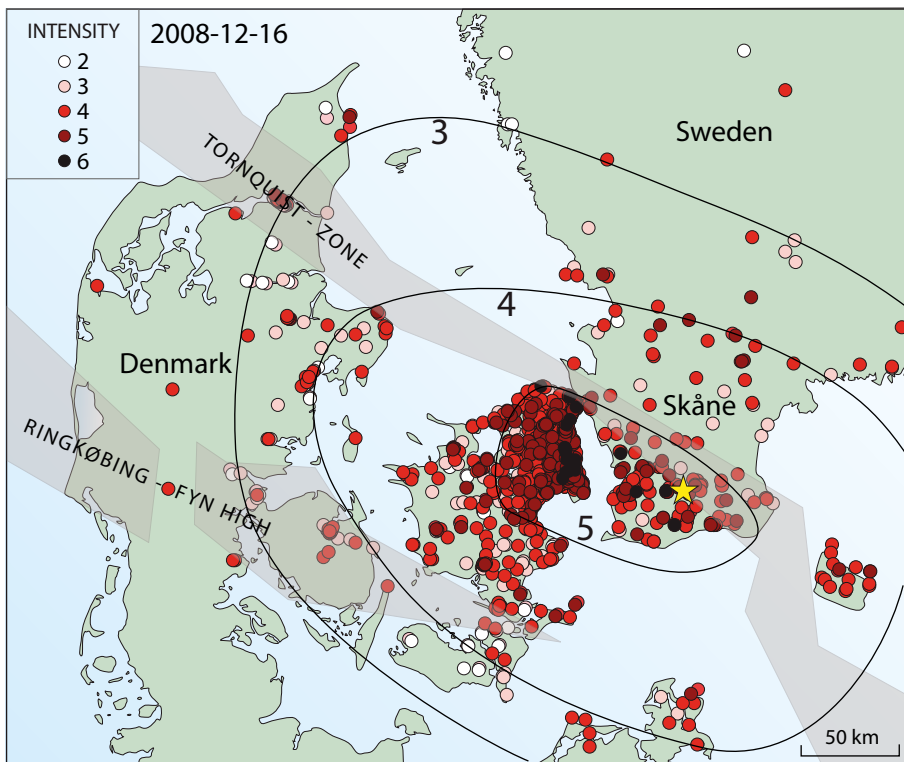


Fig. 5. The Skåne earthquake. The overwhelming reporting by more than 3.000 persons is caused by the timing, many people being at rest early in the morning, and the large population density of the area around and north of Copenhagen (Voss *et al.* 2009). In contrast, an area with very sparse population is found just north of the intensity 5 area in Sweden. The earthquake was located in the Tornquist Zone (yellow star) and the vigorous shaking is evident in the Tornquist Zone and the adjacent area of the Polish–Danish Basin in northern Sjælland. The elongation of the felt area is along the basin axis NW–SE. Magnitude 4.8.

ording stations, large distance to recording stations) only magnitude and energy can be estimated. And as mentioned above, we can evaluate intensity areas as an equivalent to historical earthquake information (e.g. with data from Arvidsson *et al.* 1991 or Kulhanek & Wahlström 1996 or Gregersen *et al.* 1998). An almost linear relationship is found when graphs are made of logarithm of area as a function of magnitude (Fig. 7), and the relation is valid for intensity value 3 as well as 4. We have tested our colleagues' area judgment by asking many seismologists about a specific map data set, the intensities of the 2010-02-19 earthquake seen in Fig. 1. The estimates showed an area spread of around a factor 2. When we interpret the illustrated areas, we treat the numbers with an uncertainty of a little less than 0.3 ($\log 2$).

The local magnitudes used are those based on Båth's (1956) original work as elaborated by Wahlström (1978) for earthquakes in Fennoscandia. The magnitude formula is applied to earthquakes in the Danish area with the argument from experience that there is only negligible difference in the magnitude of a given earthquake calculated in Sweden and in Denmark, despite the significant crustal/lithospheric

boundary, the Tornquist Zone (Geodetic Institute 1983; Gregersen 1984, 2006). The present paper substantiates this general experience.

Discussion

Fig. 7 confirms that the felt areas of intensities 3 and 4 for earthquakes in Denmark are as large as those of the Fennoscandian Shield for comparable magnitudes. The new data from Denmark (Dnew) show the same correlation as the generalised data set KaDS, which represents the two Kaliningrad earthquakes of 2004, the previous Danish observations and available data from Swedish maps published by Kulhanek & Wahlström (1996). We illustrate with a few representative samples that the KaDS points are in the high end of the spread of areas. The samples are average values from the UK and samples from Norway and the Norwegian shelf. For the UK the felt areas are in general smaller, those from Norway are in parts similar but in parts with very high variation (see intensity 4 around magnitude 4), and for the Norwegian shelf the felt areas are comparable.

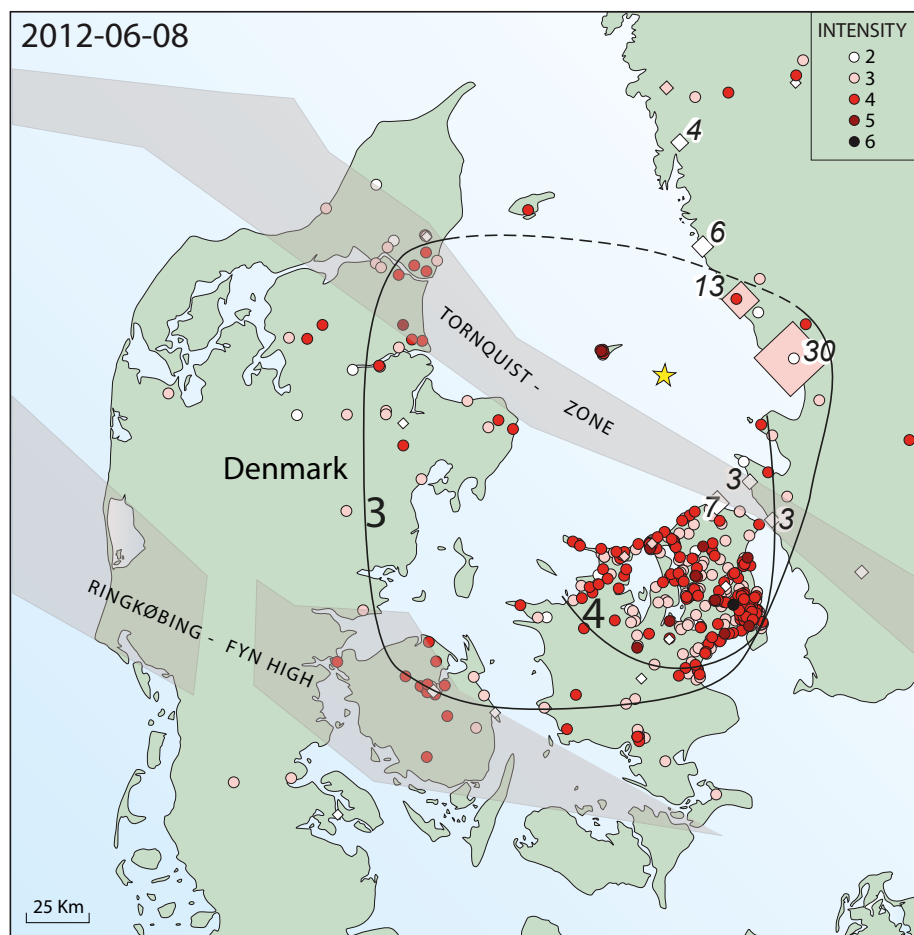


Fig. 6. Most recent Kattégat earthquake. The location (yellow star) is within a known cloud of earthquake activity (Gregersen *et al.* 1996, 1998) where many faults have been mapped. The Tornquist Zone shown here is based on the EUGENO-S (1988) project, and the earthquake is outside the zone. In the alternative Tornquist Zone definition of Gregersen & Holm (2011), it is within the edge of the zone. The felt area is most developed in the Danish sediment basin, and less in the bedrock area of Sweden. Macroseismic reports from cities in Sweden are shown by diamonds with the number of reports. Magnitude 4.1.

The Danish earthquakes take place in the broad edge zone of the Fennoscandian Shield around the Tornquist Zone, where previous investigations of disturbance of 1–4 Hz seismic waves have been conducted with variable results. The first investigations were on Lg waves of dominating frequency close to 1 Hz, which are used for magnitude evaluations. They indicated no influence of the Tornquist Zone

(e.g. Gregersen 1984; Kennett *et al.* 1985). Kvaerna & Mykkeltveit (1985) confirmed this for 1 Hz Lg waves, but when they investigated higher frequencies around 4 Hz they did see an influence. Schweitzer (1995) confirmed influence of the Tornquist Zone on propagation of Pg and Pn waves of frequencies 2½ to 4 Hz. Attempts at tomographic mapping of Lg attenuation in recent student theses (Bømler 2009; Rosing 2011) did not get beyond indications of influence. In future studies, it may be worthwhile to look for the distinguishing capability of the intensity patterns of frequencies of 3 to 5 Hz.

Most of the available intensity areas are so small that they do not overlap the Tornquist Zone. On both sides of the zone, the propagation effectiveness of the intensity-bearing waves (S and Lg) is close to that for the shield as seen in Fig. 7. However, for those two of the areas presented here that do cross the Tornquist Zone, there is some effect. For the Kaliningrad earthquake (Fig. 4) this has already been noted by Gregersen *et al.* (2007); the felt shaking reported in the Copenhagen area is likely due to a high population density in tall buildings, which is known to bias macroseismic surveys. For the Skåne earthquake (Fig. 5), we cannot distinguish between two effects: the possible influence of the Tornquist Zone and the sparse population density in the bedrock areas just north of the Tornquist Zone in southern Sweden. For the 2012 Kattegat earthquake (Fig. 6) an even more important factor that causes geographic differences is a different emphasis on collecting this intensity data in Sweden and Denmark.

For each new earthquake in the region, additional data become available on the geodynamics and its connection to crustal and lithospheric differences, and the basis for evaluation of magnitudes becomes larger and firmer. From the data presented here it would seem that the Tornquist Zone does disturb intensity patterns when the source is far away from it, and not when the source is in or close to it.

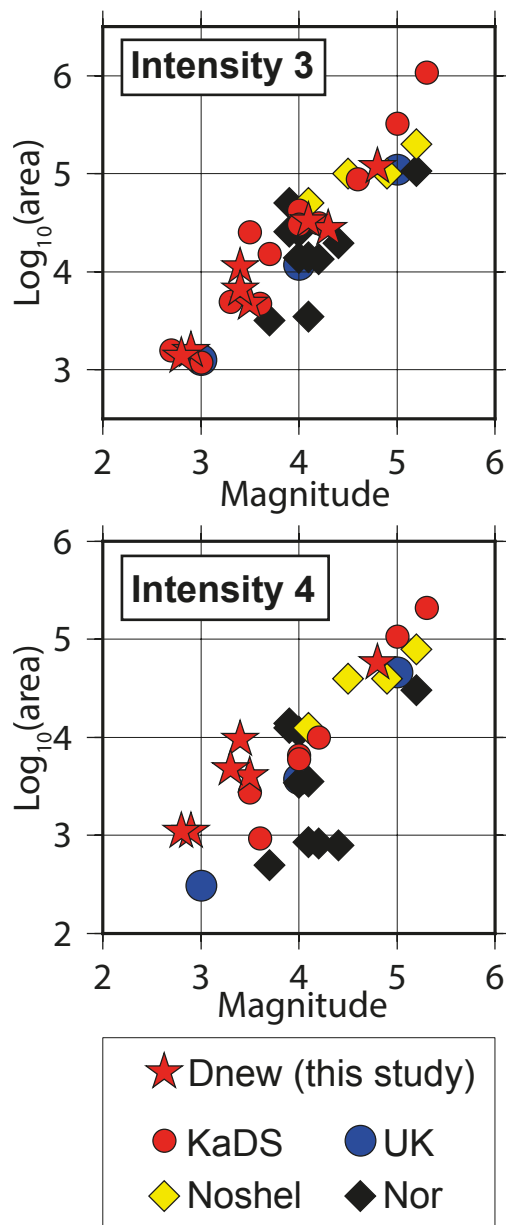


Fig. 7. Intensity areas as a function of magnitude for intensities 3 and 4 (Grünthal *et al.* 1998; Musson & Cecić 2002) in the investigated region. KaDS stands for Kaliningrad, Denmark, Sweden. A few comparisons are made with neighbouring regions Norway (Nor), Norwegian Shelf (Noshel), and the UK. Dnew are new Danish data points since the previous intensity map presentation (Gregersen *et al.* 1998).

Conclusion

The intensity areas we have estimated after analysing the macroseismic surveys of the eight recent earthquakes show that they follow the pattern of earlier earthquakes. We find that the intensity areas are as large as those in the Fennoscandian Shield and the East European Platform for similar magnitudes. The consistency of the determined intensity areas of this study and of previous data will improve the accuracy of determining the magnitude of pre-instrumental earthquakes.

Acknowledgements

The authors wish to thank the thousands of persons who filled out a macroseismic questionnaire following the earthquakes. H.P. Rasmussen and Eva Melskens provided valuable technical assistance.

References

- Arvidsson, R., Gregersen, S., Kulhanek, O. & Wahlström, R. 1991: Recent Kattegat earthquakes – evidence of intraplate tectonics in southern Scandinavia. *Physics of the Earth and Planetary Interiors* 67, 275–287.
- Bømler, M. 2009: Tomographic mapping of Lg surface wave attenuation in northern Europe. Master's thesis, University of Copenhagen, 112 pp.
- Båth, M. 1956: An earthquake catalogue for Fennoscandia for the years 1891–1950. *Geological Survey of Sweden Yearbook* 50, no. 1, 56 pp.
- Båth, M., Kulhanek O., Van Eck, T. & Wahlström, R. 1976: Engineering analysis of ground motion in Sweden. Report no. 5-76, Seismological Institute, Uppsala University, Sweden, 37 pp.
- EUGENOS Working Group 1988: Crustal structure and tectonic evolution of the transition between the Baltic Shield and the North German Caledonides (the EUGENOS Project). *Tectonophysics* 150, 253–348.
- Geodetic Institute 1983: The local seismograph network in Denmark 1979–1982. Geodetic Institute, Seismology Department, Charlottenlund, 54 pp. [In Danish]
- Graversen, O. & Holm, P.M. 2011: Bornholm–Skåne region's tectonic development. *Geoviden* no. 2011/1. Geocenter Denmark, Copenhagen, 20 pp. [in Danish]
- Gregersen, S. 1984: Lg-wave propagation and crustal structure differences near Denmark and the North Sea. *Geophysical Journal of the Royal Astronomical Society* 79, 217–234.
- Gregersen, S. 2006: Intraplate earthquakes in Scandinavia and Greenland. Neotectonics or postglacial uplift. *Journal of the Indian Geophysical Union* 10, 25–30.
- Gregersen, S., Leth, J., Lind, G. & Lykke-Andersen, H. 1996: Earthquake activity and its relationship with geologically recent motion in Denmark. *Tectonophysics* 257, 265–273.
- Gregersen, S., Hjelme, J. & Hjortenberg, E. 1998: Earthquakes in Denmark. *Bulletin of the Geological Society of Denmark* 44, 115–127.
- Gregersen, S., Voss, P., Shomali, Z.H., Grad, M., Roberts, R.G. & the Tor Working Group 2006: Physical differences in the deep lithosphere of northern and central Europe. In: Gee, D.G. & Stephenson, R.A. (eds), *European Lithosphere Dynamics*. Geological Society of London, Memoir 32, 313–322.
- Gregersen, S., Wiejacz, P., Dębski, W., Domanski, B., Assinovsky, B., Guterch, B., Mäntyniemi, P., Nikulin, G., Pacesa, A., Puura, V., Aronov, A.G., Aronova, T.I., Grünthal, G., Husebye, E.S. & Sliupa, S. 2007: The exceptional earthquakes in Kaliningrad District, Russia on September 21, 2004. *Physics of the Earth and Planetary Interiors* 164, 63–74.
- Grünthal, G., Musson, R.M.W., Schwarz J. & Stucchi, M. 1998: *European Macroseismic Scale 1998. EMS-98*. Centre Européen de Géodynamique et de Séismologie, Musée National d'Histoire Naturelle, Luxembourg, 101 pp.
- Kennett, B.L.N., Gregersen, S., Mykkeltveit, S. & Newmark, R. 1985: Mapping of crustal heterogeneity in the North Sea Basin via the propagation of Lg-waves. *Geophysical Journal of the Royal Astronomical Society* 83, 299–306.
- Kulhanek, O. & Wahlström, R. 1996: Macroseismic observations in Sweden 1991–1995. Research paper C829, 24. Geological Survey of Sweden, Uppsala, 24 pp.
- Kvaerna, T. & Mykkeltveit, S. 1985: Propagation characteristics of regional phases recorded at NORSAR. In: Loughran, L.B. (ed), *NORSAR Scientific Report 1-85/86*, 21–29.
- Larsen, T.B., Gregersen, S., Voss, P.H., Bidstrup, T., & Orozova-Bekkevold, V. 2008: The earthquake that shook central Sjælland, Denmark, November 6, 2001. *Bulletin of the Geological Society of Denmark* 56, 1–11.
- Lehmann, I. 1956: Danish earthquakes. *Bulletin of Geological Society of Denmark* 13, 88–103. [in Danish]
- Musson, R.M.W. & Cecić, I. 2002: Intensity and Intensity Scales. In: Bormann, P. (ed.), *IASPEI New Manual of Seismological Observatory Practice*. DOI: 10.2312/GFZ.NMSOP-2_ch12, 1–41.
- Rosing, A. 2011: Tomographic inversion of Lg surface waves in northern Europe. Master's thesis, University of Copenhagen, 89 pp.
- Schweitzer, J. 1995: Blockage of regional seismic waves by the Teisseyre-Tornquist Zone. *Geophysical Journal International* 123, 260–276.
- Voss, P., Larsen, T.B., Ottemöller, L. & Gregersen, S. 2009: Earthquake in southern Sweden wakes up Denmark on 16 December 2008. *Geological Survey of Denmark and Greenland Bulletin* 17, 9–12.
- Wahlström, R. 1978: Magnitude-scaling of earthquakes in Fennoscandia. Seismological Institute, University of Uppsala, Report no. 3-78, 20 pp.
- Wahlström, R. & Ahjos, T. 1982: Determination of local magnitude and calibration of magnitude scales for earthquakes in the Baltic Shield. Seismological Department, University of Uppsala, Report no. 1-82, 39 pp.

Appendix

The European Macroseismic Scale 1998 (Grunthal *et al.* 1998; Musson & Cčić 2002) is the basis for evaluating seismic intensity in European countries. Unlike earthquake magnitude, which indicates the energy a quake expends, EMS98 intensity denotes how strongly an earthquake affects a specific place. The European Macroseismic Scale has 12 divisions, as follows:

1. Not felt: Not felt, even under the most favorable circumstances.

2. Scarcely felt: Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.

3. Weak: The vibration is weak and is felt indoors by a few people. People at rest feel a swaying or light trembling.

4. Largely observed: The earthquake is felt indoors by many people, outdoors by very few. A few people are awakened. The level of vibration is not frightening. Windows, doors and dishes rattle. Hanging objects swing.

5. Strong: The earthquake is felt indoors by most, outdoors by few. Many sleeping people awake. A few run outdoors. Buildings tremble throughout. Hanging objects swing considerably. China and glasses clatter together. The vibration is strong. Topheavy objects topple over. Doors and windows swing open or shut.

6. Slightly damaging: Felt by most indoors and by many outdoors. Many people in buildings are frightened and run outdoors. Small objects fall. Slight damage to many ordinary buildings; for example fine cracks in plaster, and small pieces of plaster fall.

7. Damaging: Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many ordinary buildings suffer moderate damage: small cracks in walls; partial collapse of chimneys.

8. Heavily damaging: Furniture may be overturned. Many ordinary buildings suffer damage: chimneys fall; large cracks appear in walls and a few buildings may partially collapse.

9. Destructive: Monuments and columns fall or are twisted. Many ordinary buildings partially collapse and a few collapse completely.

10. Very destructive: Many ordinary buildings collapse.

11. Devastating: Most ordinary buildings collapse.

12. Completely devastating: Practically all structures above and below ground are heavily damaged or destroyed.