SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 808 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 79 NR 2

OTA KULHÁNEK AND RUTGER WAHLSTRÖM

MACROSEISMIC OBSERVATIONS IN SWEDEN 1980–1983

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ISBN 91-7158-332-7
ISSN 0082-0024

Kartorna godkända ur sekretessynpunkt för spridning.
Statens lantmäteriverk 1985-05-06.

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Fotosats: ORD & FORM AB
Tryck: Offsetcenter AB, Uppsala 1985

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ABSTRACT

Kulhánek, Ota, and Wahlström, Rutger, 1985: Macroseismic observations in Sweden 1980–1983. Sveriges geologiska undersökning, Ser. C, No. 808, pp. 1–28, Uppsala 1985.

Macroseismic data from 32 events (20 earthquakes and a swarm-like sequence comprising 12 shocks) felt in Sweden during the time period 1980–1983 were collected and analyzed. Maximum felt intensities are determined for all earthquakes considered. Isoseismal maps and focal depths are given in 12 and 13 cases, respectively. The average difference between instrumental and macroseismic magnitudes is 0.2. To assure the homogeneity of interpretation, present intensity evaluations have been cross-checked with those made for the period 1977–1979.

INTRODUCTION

During the period from 1980 to 1983, there were 32 instrumentally recorded earthquakes, located within Swedish territory, which were reported felt by residents in the respective epicentral areas. These events provide opportunity for macroseismic investigations. Due to the lack of teleseismic data and strong-motion records, such investigations are extremely useful, e.g., when estimating the depth of rupture and local ground acceleration.

In Sweden, the long-term time average of events gives approximately three earthquakes annually which were reported felt. In this respect, the number of felt events during the period under review is above the "norm", even when 12 events near Hedemora, which constitute a swarmlike phenomenon, are disregarded. This is most likely due to a change in the routine of collecting macroseismic information rather than to an increase of seismicity. Generally speaking, prior to 1980, we relied upon letters of inquiry to postmasters of selected postal districts, whereas more recently, we introduced a procedure of publishing short inquiries in local newspapers. It seems that this method not only well complements the standard routine but sometimes also provides information on events which otherwise would pass unnoticed macroseismically.

The main objective of the present undertaking is to summarize and interpret available macroseismic data collected at the Seismological Department, Uppsala. Information has been extracted from mailed questionnaires, letters to the department, telephone calls and newspaper articles. For events of special interest, namely for those of February 13, 1981, September 26, 1982, and September 29, 1983, direct interviews were carried out by department staff members. The latter approach proved to be clearly superior.

All intensities given in the present paper refer to the modified Mercalli Scale, labeled MM, 1956, as described by Willmore (1979). For most practical purposes, intensity estimates made in terms of the MM, 1956 scale and of the more recent MSK, 1964 scale (Willmore 1979) are essentially the same. Sometimes, effects covering two or even three intensity degrees were reported from the same

locality, usually from population centres. If this is the case, the intensity given here is that corresponding to the maximum effect observed. To assure the homogeneity of interpretation, present evaluations have been cross-checked with those covering the period from 1977 to 1979 (Kulhánek and Wahlström 1981).

To determine the focal depth by making use of macroseismic data a number of formulae are at hand (Kulhánek and Wahlström 1981). In the present work, we employ the so-called Blake-Shebalin formula (see, e.g., Kárník 1969, pp. 28–32)

$$I_0 - I_n = k \log_{10} (D_n/h) \tag{1}$$

where I_0=maximum intensity, I_n=intensity of degree n, k=coefficient of attenuation, h=focal depth, $D_n^2 = h^2 + r_n^2$ and r_n=radius of equivalent circular area limited by intensity I_n. For the shallow, i.e. crustal, earthquakes within the Baltic Shield, a value of k=4 is recommended (Korhonen and Ahjos 1979). Introducing parameters associated with the level of perceptibility, equation (1) becomes

$$I_0 - I_p = k \log_{10} \frac{\sqrt{r_p^2 + h^2}}{h} \tag{2}$$

where I_p=intensity at level of perceptibility and r_p=radius of equivalent circular area of perceptibility. According to Korhonen and Ahjos (1979), I_p=2.5 is a relevant value for the Baltic Shield.

Data on maximum intensity and radius of perceptibility are also used for determination of macroseismic magnitude, M_M(UPP), from the formula of Wahlström and Ahjos (1982)

$$M_M(\mathrm{UPP}) = 0.38(\pm 0.25) + 1.14(\pm 0.18) \log r_p + 0.23(\pm 0.07) I_0 \tag{3}$$

For given macroseismic intensities and a frequency band of 2–10 Hz, ranges of likely peak ground accelerations are presented, e.g. in Willmore (1979). Formulae for approximate peak accelerations, within a limited interval of MM, 1956 intensities, have also been suggested by Trifunac and Brady (1975) among others. Estimated acceleration values given in the following chapter refer to the horizontal ground motion and should be considered as approximations only.

Instrumentally determined source parameters for the earthquakes are listed in Table 1, except for the Hedemora sequence which is presented in Table 2. Epicentral locations together with the recording sites of the current Swedish Seismograph Station Network (SSSN) are shown in Fig. 1. Macroseismic parameters are summarized in Table 3.

Besides the events which have been instrumentally recorded and felt, there are many recorded earthquakes which have not been macroseismically observed, as well as many felt events which have neither been recorded, nor can be identified as non-earthquake events. A list of the latter category is given in Table 4.

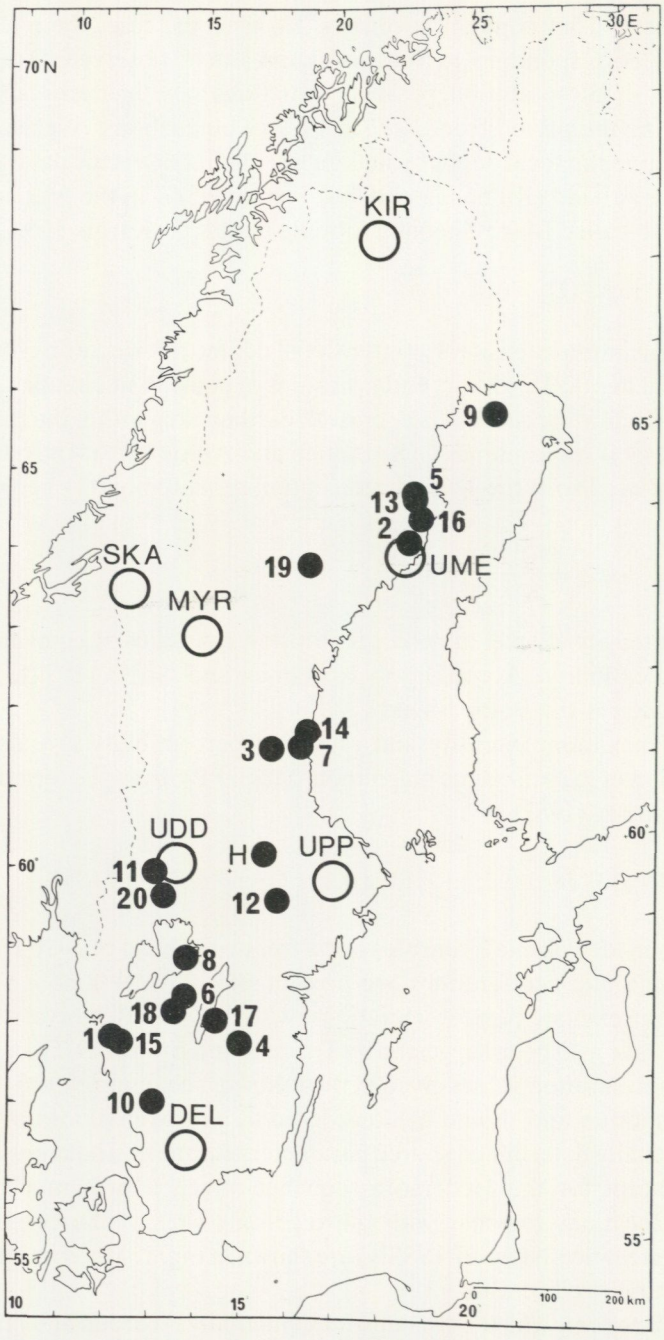

Fig. 1. Swedish Seismograph Station Network, SSSN, (open circles) and instrumental epicentres of earthquakes felt in Sweden, 1980–1983 (solid circles). Earthquake numbers are those used in Table 1; H is Hedemora sequence. The seismograph station at Skalstugan (SKA) was moved to Myrviken (MYR) in 1981.

TABLE 1. Instrumentally determined parameters of earthquakes felt in Sweden, 1980–1983[1)]

Event number	Date	Epicentral[2)] coordinates °N °E	Origin[2)] time GMT	Instrumental magnitude M_L(UPP)[3)]	Province
1	Apr. 11, 1980	57.9 12.1	04 19 11	2.7	Västergötland-Bohuslän
2	Jul. 25, 1980	64.0 20.4	21 45 12	2.3	Västerbotten
3	Aug. 19, 1980	61.5 16.2	01 13 17	2.2	Hälsingland
4	Aug. 26, 1980	57.8 15.2	03 15 46	2.1	Östergötland-Småland
5	Sep. 13, 1980	64.6 20.7	07 59 57	2.6	Västerbotten
6	Nov. 25, 1980	58.4 13.8	02 39 52	2.6	Västergötland
7	Dec. 17, 1980	61.5 17.0	18 19 24		Hälsingland
8	Feb. 13, 1981	58.9 13.9	06 39 11	3.3	Västergötland
9	May 22, 1981	65.5 23.4	03 42 30	2.9	Off coast of Norrbotten
10	Nov. 11, 1981	57.1 13.1	02 48 52	2.9	Halland-Småland-Västergötland
11	Mar. 15, 1982	60.0 13.1	13 57 11		Värmland
12	Sep. 26, 1982	59.6 16.2	13 40 18	2.3	Västmanland
13	Oct. 8, 1982	64.5 20.7	05 28 56	2.9	Västerbotten
14	Apr. 1, 1983	61.7 17.2	02 50 34	2.1	Hälsingland
15	Apr. 15, 1983	57.8 12.3	23 46 56	2.0	Västergötland
16	Jun. 18, 1983	64.3 20.8	12 43 44	3.0	Västerbotten
17	Jul. 12, 1983	58.1 14.6	19 04 30	2.8	Småland-Östergötland
18	Sep. 24, 1983	58.2 13.6	02 08 21	2.0	Västergötland
19	Sep. 29, 1983	63.8 17.5	05 03 25	4.1	Ångermanland
20	Oct. 3, 1983	59.7 13.3	09 50 41	2.2	Värmland

1) Events of the Hedemora sequence are given in Table 2.

2) Locations and origin times are according to Seismological bulletin, Uppsala, published monthly.

3) Starting with July 1981, the M_L(UPP)-scale has replaced the old M_L-scale in the bulletin. Magnitudes in this table are consistently given on the M_L(UPP)-scale and may thus sometimes differ from those in the bulletin for the period January 1980 - June 1981.

TABLE 2. Felt earthquakes in the Hedemora sequence, 1981, 60.2°N, 15.9°E [1)]

Date	Origin time GMT
Jan. 30	23 48 43
Feb. 14	21 27 26
Feb. 20	18 31 22
Feb. 20	18 51 48
Feb. 20	19 02 38
Feb. 20	19 59 22
Feb. 24	03 12 11
Feb. 26	17 43 42
Feb. 26	17 43 53
Mar. 07	00 39 40
Mar. 15	15 46 45
Mar. 15	20 39 42

1) All events were too small to be rated according to the M_L(UPP)-scale. Maximum intensities were ≤ III.

MACROSEISMIC DATA AND ANALYSIS

In the following paragraphs, we briefly describe available macroseismic data associated with the 20 earthquakes listed in Table 1. Also the Hedemora sequence (Table 2) is shortly described. For each individual event, we provide an estimate of the maximum intensity and a list of localities where the earthquake was felt. Whenever collected data permit, radius of perceptibility, focal depth, peak ground acceleration and macroseismic magnitude are also determined. Obtained results are summarized in Table 3. For events with a reasonable amount of observations, isoseismal charts are presented in Figs. 2–13. The classification of earthquake size in the text below relates to instrumental magnitude, M_L(UPP) (Wahlström and Ahjos 1982): weak <2.5, medium-size 2.5–2.9 and strong ≥3.0.

APRIL 11, 1980, NÖDINGE, PROVINCE OF VÄSTERGÖTLAND

A medium-size earthquake was felt on the morning of April 11, 1980, in western Västergötland, southern Bohuslän and northern Halland. The earthquake was

TABLE 3. Derived macroseismic parameters of earthquakes felt in Sweden, 1980–1983[1)]

Event number	Location	Maximum felt intensity MM, 1956	Radius[2)] km	Focal depth km	Macroseismic magnitude M_M(UPP)[3)]
1	Nödinge	IV	25 10(IV)	11	2.9
2	Sävar	V	-	<5	-
3	Lillbo	III	-	-	-
4	Österbymo	III-IV	-	-	-
5	Medle	IV	14	7	2.6
6	Skövde	IV	17 9(IV)	8	2.7
7	Enånger	IV	-	<5	-
8	Otterbäcken	IV-V[4)]	25	8	3.0
9		IV	-	-	-
10	Kinnared	IV	20 9(IV)	9	2.8
11	Lysvik	III-IV	-	-	-
12	Hallstahammar	IV-V	5	2	2.2
13	Burträsk	IV	-	-	-
14	Hudiksvall	IV	9(IV)	-	2.4
15	Floda	III	-	-	-
16	Flarken	IV	19 7(IV)	8	2.8
17	Gränna	IV	24 10(IV)	11	2.9
18	Falköping	IV	8 3(IV)	4	2.3
19	Solberg[5)]	V	167 122(IV) 7(V)	41	4.1
20	Ransäter	IV	13	6	2.6

1) Events of the Hedemora sequence are not included.

2) Radius of equivalent circular area of perceptibility is presented. Whenever possible, radii corresponding to intensities IV and V are also listed.

3) Computed according to eq. (3).

4) Estimated value (not observed). For details see the text.

5) It follows from the isoseismal map in Fig. 12 that the available areas, i.e. landward portions, of perceptibility and of intensity IV are about 80% and 90% of the total areas, respectively. Proper corrections have been applied when deriving the corresponding radii.

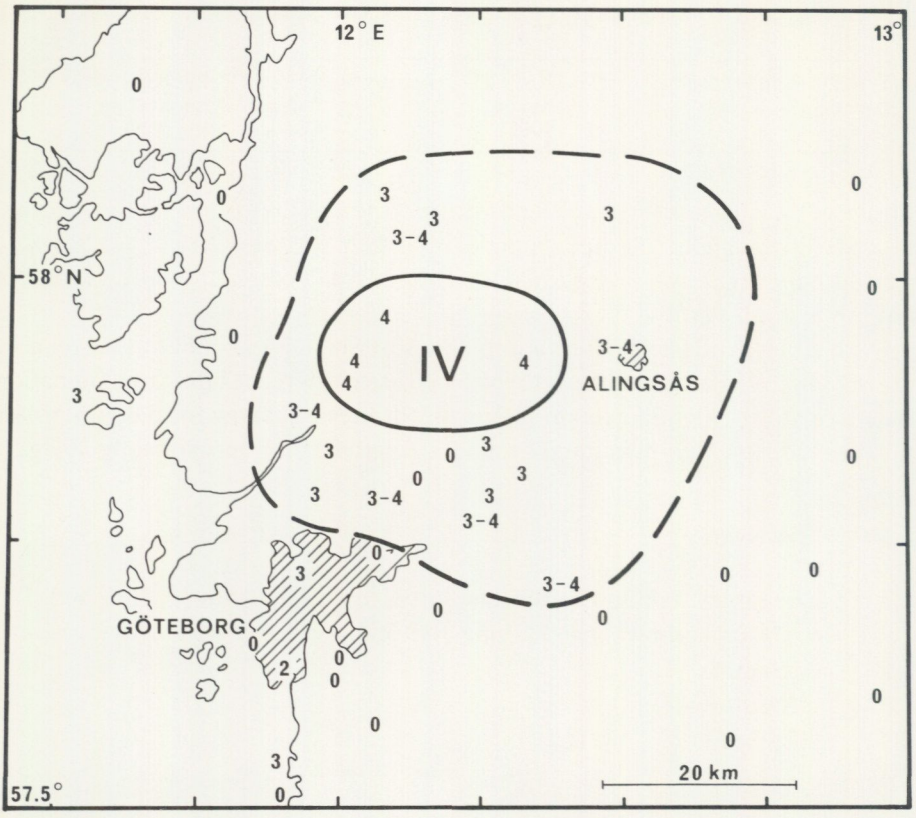

Fig. 2. Intensity distribution (MM, 1956) of the Nödinge earthquake of April 11, 1980 (heavy line). The dashed line limits the area of perceptibility. Zero means not felt.

felt in (alphabetical order) Alingsås, Älvängen, Angered, Askim, Floda, Göteborg, Gråbo, Hindås, Hisings Kärra, Kullavik, Kungälv, Lerum, Lilla Edet, Lödöse, Lysekil, Marstrand, Nödinge, Nol, Nygård, Sjövik, Sollebrunn, Stenkullen and Surte. The maximum intensity, IV, was felt in Älvängen, Nödinge, Nol and Sjövik. The vibration was like that due to the passing of a heavily loaded truck or to near-by blasting. Windows, doors and dishes rattled; at several places people thought that their furnaces had exploded. Within the epicentral area, many sleeping people awoke. In Älvängen and Sjövik, two household pets (cat, dog) became uneasy. There were many reports on audible effects similar to a thunder or an explosion.

The area of perceptibility of 1920 km^2 and the intensity distribution, displayed in Fig. 2, provide a focal depth estimate of 11 km. The peak ground acceleration, derived from the maximum felt intensity, is approximately 1–2% g.

JULY 25, 1980, SÄVAR, PROVINCE OF VÄSTERBOTTEN

In the late hours (local time) of July 25, 1980, a weak earthquake with rather strong macroseismic effects took place in eastern Västerbotten. Reports with positive answers were received from Bullmark (IV), Gravmark (V) and Sävar (V). At the two latter localities, many people awoke; at Gravmark people were frightened and ran outdoors. Windows, doors and dishes rattled, and buildings trembled throughout. People thought that their furnaces had exploded; one parked motorcycle was overturned. A fissure in the basement of one house in Sävar was observed.

With so few collected observations the isoseismal map could not be reliably drawn. On the other hand, the rather limited area of perceptibility in combination with a relatively high maximum intensity indicates a shallow focal depth of less than, say, 5 km. The maximum ground acceleration is approximately 3% g.

AUGUST 19, 1980, LILLBO, PROVINCE OF HÄLSINGLAND

On the morning of August 19, 1980, a weak earthquake was felt in Långhed (III) and Lillbo (III) in southwestern Hälsingland. Weak vibrations were felt by people at rest in houses; here and there people awoke. Sounds similar to a distant thunder, of duration 5–10 s, were reported.

AUGUST 26, 1980, ÖSTERBYMO, PROVINCE OF ÖSTERGÖTLAND

A weak earthquake was felt in Aneby (III), Österbymo (III) and Sund (III–IV) on August 26, 1980, within neighbouring areas of Östergötland and Småland. Two shocks, several minutes apart, were felt, the second one weaker. Windows, cupboards and floors shook slightly. Vibrations were felt by people at rest in houses. In Österbymo and Sund, household pets (dogs) showed unusual behaviour before the earthquake. Audible effects, of duration from a few seconds to 2–4 minutes, were reported from several localities.

SEPTEMBER 13, 1980, MEDLE, PROVINCE OF VÄSTERBOTTEN

A moderate-size earthquake shook an area of eastern Västerbotten on September 13, 1980. Felt effects were reported from Gråberg (IV), Järvtjärn (III), Klutmark (III), Medle (III), Ragvaldsträsk (III) and Skellefteå (IV). The vibration was described like that due to the passing of a heavy truck. At Gråberg, buildings trembled throughout, lamps swung and several people were frightened.

The area of perceptibility of 660 km^2, displayed in Fig. 3, together with the maximum observed intensity, IV, provide a focal depth of 7 km.

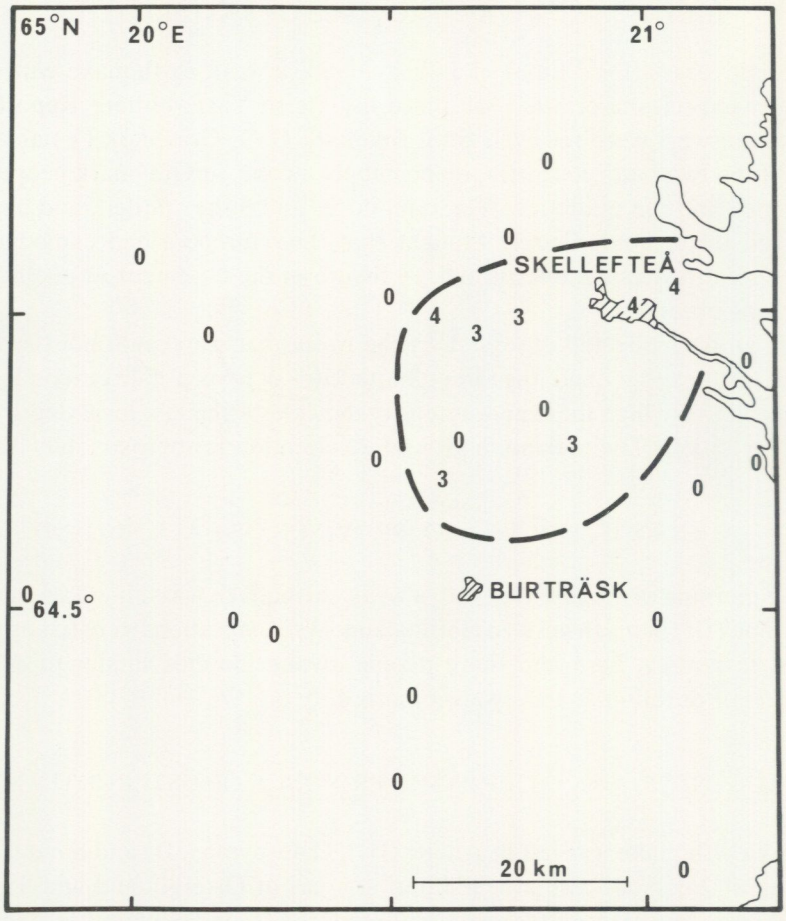

Fig. 3. Intensity distribution of the Medle earthquake of September 13, 1980. Conventions as for Fig. 2.

NOVEMBER 25, 1980, SKÖVDE, PROVINCE OF VÄSTERGÖTLAND

A medium-size earthquake took place in central Västergötland on the morning of November 25, 1980. Questionnaires with positive answers were received from Broddetorp (III–IV), Frösve (III), Igelstorp (IV), Lerdala (IV), Skövde (IV), Skultorp (III), Tibro (IV), Timmersdala (II), Ulvåker (IV) and Väring (III). Here and there people awoke; windows, doors and dishes rattled, and furniture began to shake. Vibration like the passing of a heavy truck was reported. In Skultorp, a guinea-pig became uneasy. Audible effects of a duration of up to two minutes were reported from several localities.

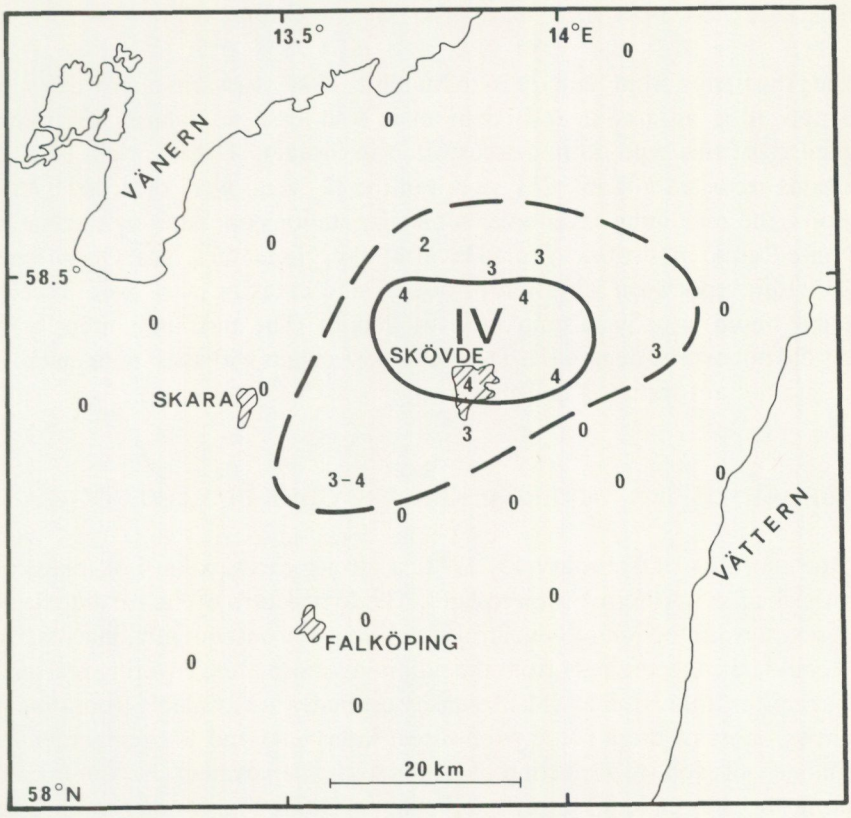

Fig. 4. Intensity distribution of the Skövde earthquake of November 25, 1980. Conventions as for Fig. 2.

The distribution of observed intensities and the area of perceptibility of 930 km^2 are depicted in Fig. 4. The available macroseismic data yield a focal depth of 8 km.

DECEMBER 17, 1980, ENÅNGER, PROVINCE OF HÄLSINGLAND

Two weak shocks were intensively felt on the evening of December 17, 1980, within a limited area of coastal central Hälsingland around Enånger. Reports were received from Oppänge (IV) and Tosätter (IV), where people described a vibration like that due to a near-by explosion; walls and floors trembled. People thought that their furnaces had exploded and some were frightened.

Lacking more observations, the isoseismals are not drawn. However, the small area of perceptibility and the maximum felt intensity, IV, suggest a rather shallow hypocentre, probably not deeper than 5 km.

JANUARY 30–MARCH 15, 1981, HEDEMORA, PROVINCE OF DALARNA

During the period from January 30 to March 15, 1981, a swarm of 12 weak shocks was noticed in an area near Hedemora in southeastern Dalarna. Earthquake sequences of this type do not occur often in Sweden. Dates, origin times and locations are listed in Table 2. Five out of the 12 events were recorded by SSSN stations, the remaining seven events only by stations operated by the National Defense Research Institute. From Davidshyttan, Hedemora, Nås, Olshyttan and Prästhyttan reports on vibration of houses and creaking walls were received. Audible booms usually accompanied the shaking. The maximum intensity most likely did not exceed degree III. The Hedemora events with their poor macroseismic data are not included in Table 3.

FEBRUARY 13, 1981, OTTERBÄCKEN, PROVINCE OF VÄSTERGÖTLAND

On the morning of February 13, 1981, a strong earthquake took place near Otterbäcken in northern Västergötland. The hypocentre of the earthquake was located a few km off shore beneath Lake Vänern. Consequently, macroseismic data could be collected only from the adjoining shore area, covering reasonably well azimuths from NNE to SSE. Intensity estimates are available from some 130 localities; most of them come from direct interviews and the remainder from telephone calls and by inspection of letters to the department. Except for a fine crack in the plaster in a hall of one house in Gullspång, no damage has been reported. Within the disturbed area, buildings are properly built brick or wooden houses. The foundation materials consist mainly of solid rock, and to lesser extent of clay, gravel or moraines. During the earthquake, macroseismic area residents felt heavy shaking indoors which lasted for several seconds, in some cases up to about one minute. From many places audible sounds similar to those of a distant thunder, blasting or heavy traffic were reported. The duration of these sounds varied between several seconds and several minutes. At three localities, household pets (dogs, cats) became uneasy during the earthquake. Several interviews revealed that the sensation of vibration was comparable to or even more intensive than that due to the April 11, 1973 earthquake of magnitude $M_L(UPP)=3.9$ from this area.

The maximum intensity was observed at Otterbäcken and northwards, where it reached the degree IV. Spatial distributions of intensities III and IV together with the area of perceptibility are depicted in Fig. 5. As can be seen in the figure, the observed macroseismic field is rather complex with a number of exceptional pockets of higher intensities as well as of unforeseen reports "not felt". Isolated reports of felt intensities were not encircled by corresponding isoseismals. Due to the location beneath Lake Vänern, the epicentral intensity of the Otterbäcken

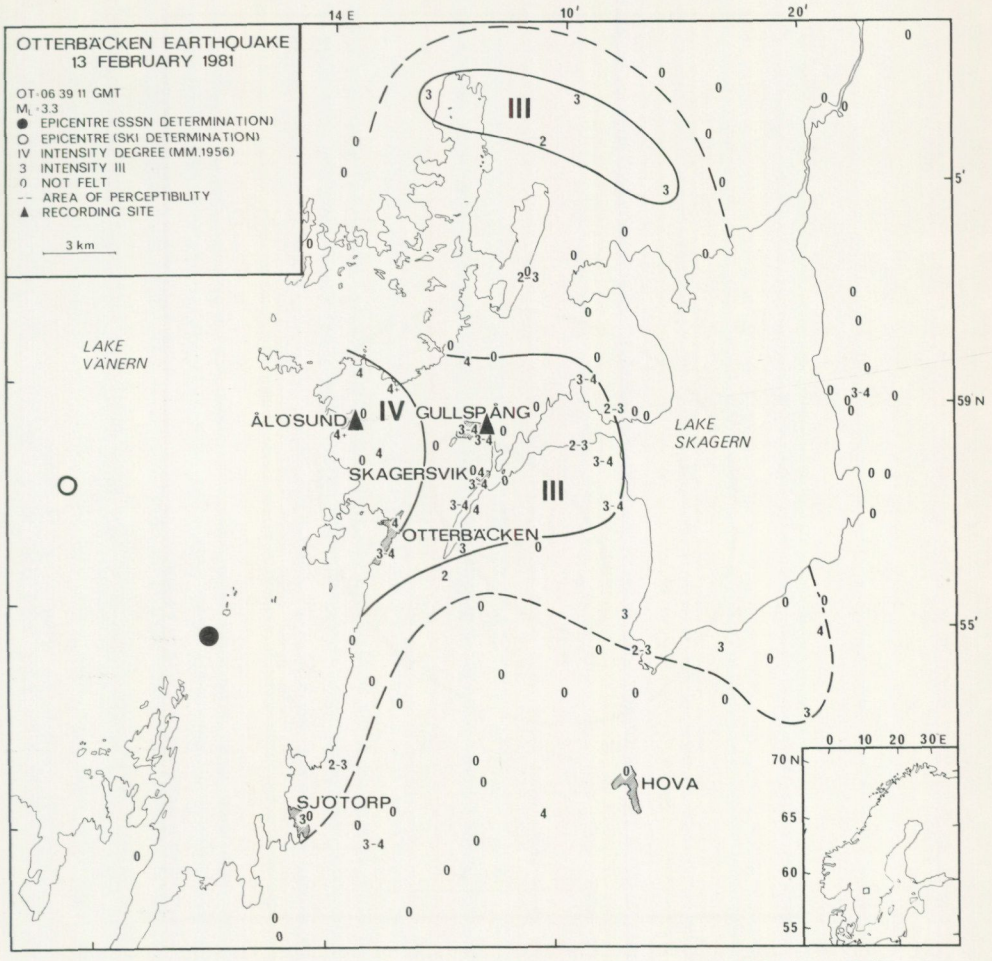

Fig. 5. Intensity distribution of the Otterbäcken earthquake of February 13, 1981 (from Kulhánek *et al.* 1981).

earthquake can only be approximated. It follows from Fig. 5 that the radius of perceptibility most likely falls between 20 and 30 km. The effect of a rather shallow focal depth, providing a smaller radius of perceptibility, is clearly demonstrated by macroseismic observations. The epicentral intensity should lie approximately between the degree IV (maximum intensity felt during the present earthquake) and V–VI (maximum intensity felt in Sweden during the last 30 years). We assume a value of IV–V to be a reasonable approximation of the otherwise inaccessible intensity I_0. Employing macroseismic parameters $I_0=4.5$ and $r_p=25$ km, we obtain a focal depth of 8 km. For more details on this particular event the reader is referred to Kulhánek et al. (1981, 1983).

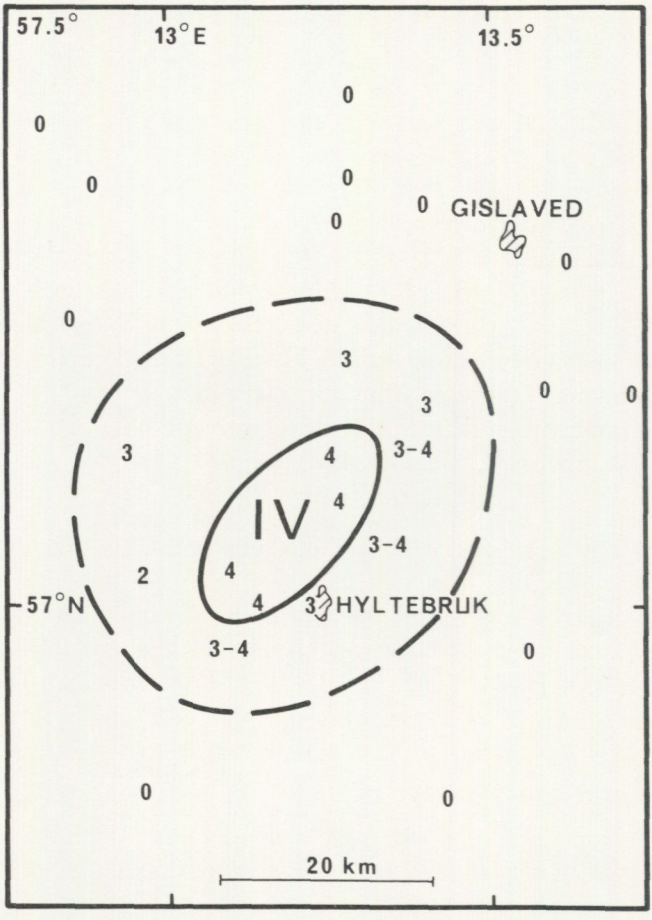

Fig. 6. Intensity distribution of the Kinnared earthquake of November 11, 1981. Conventions as for Fig. 2.

MAY 22, 1981, OFF COAST OF PROVINCE OF NORRBOTTEN

On the morning of May 22, 1981, a moderate-size earthquake was felt in Båtskärsnäs (IV), Hindersön (IV), Karlsborg (IV) and Storön (III), within the coastal region of Norrbotten. At several places, windows rattled and people thought that their furnaces had exploded. The instrumental epicentre was located about 30 km off shore. Due to missing information from seaward directions, it is not possible to draw the isoseismals.

NOVEMBER 11, 1981, KINNARED, PROVINCE OF HALLAND

A moderate-size earthqake which was felt in neighbouring areas of Halland, Småland and Västergötland occurred on the morning of November 11, 1981. Reports with positive answers were received from 12 localities, namely from Ätran (III), Broaryd (IV), Brännögård (IV), Burseryd (III), Drängsered (II), Hyltebruk (III), Kinnared (IV), Landeryd (IV), Långaryd (III–IV), Skeppshult (III–IV), Smålandsstenar (III) and Torup (III–IV). Generally speaking, felt effects were less intensive than those associated with the September 5, 1977 event of magnitude $M_L(UPP)=3.4$ from the same area. Windows and doors rattled, and weak vibrations of houses were noticed. Here and there sleeping people awoke. Audible booms were reported from many localities.

Collected intensity estimates, the area of perceptibility of 1210 km^2 and the distribution of intensity IV, are displayed in Fig. 6.

MARCH 15, 1982, LYSVIK, PROVINCE OF VÄRMLAND

A weak earthquake was felt in the afternoon of March 15, 1982, in central Värmland. The maximum intensity was III–IV in Bäckalund, Pörtberget, Pörtet, and S. Skoga, while in Ivarsbjörke, Lysvik, Munkfors, Råda and Ransbysäter the intensity was III. Weak vibrations of floors and houses, and sounds similar to a distant thunder, were reported from most of the above localities. The available data do not permit an isoseismal map to be drawn.

SEPTEMBER 26, 1982, HALLSTAHAMMAR, PROVINCE OF VÄSTMANLAND

A weak earthquake was felt on September 26, 1982, in central Västmanland. Intensity estimates at 18 localities were obtained from direct interviews: Forsta (III), Furberga (IV–V), Gränby (III), Grömsta (III), Gymninge (III), Hallstahammar (II), Hässle (II–III), Herrskogen (III), Klemetsbo (IV), Kolbäck (II), Lisjö (III), Norrhamra (III–IV), Olvsta (III), Prästgården (III–IV), Sandsta (III–IV), Vallhall (III), Viby (IV) and Ytterskälby (IV–V). The maximum intensity was reported from Furberga, where people thought that their furnaces had exploded.

The observed macroseismic field together with the area of perceptibility of 80 km^2 are displayed in Fig. 7. As follows from the figure, the intensity distribution is quite irregular and in spite of the relatively large number of interviews carried out, we were neither able to draw any isoseismals, nor could we locate the macroseismic epicentre. An unusually shallow focal depth of about 2 km is clearly demonstrated by the small area of perceptibility and relatively high maximum felt intensity. The peak ground acceleration lies within the range of 1 to 3% g.

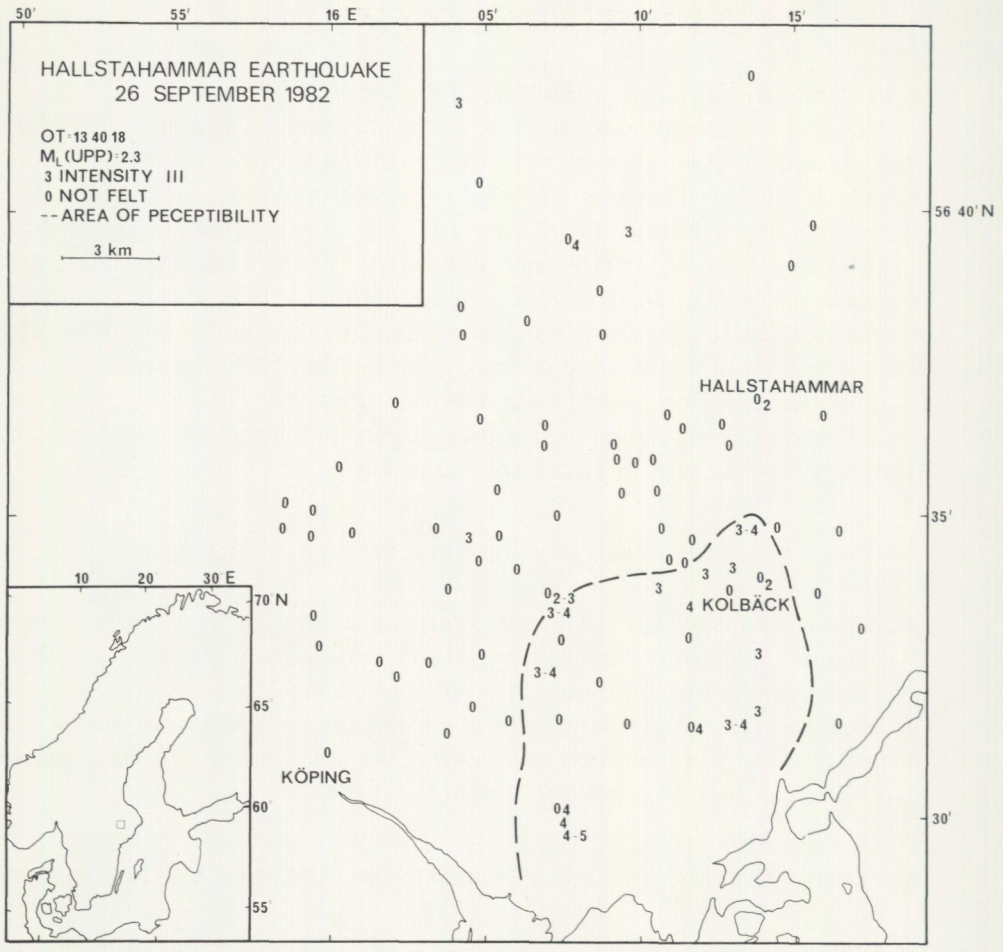

Fig. 7. Intensity distribution of the Hallstahammar earthquake of September 26, 1982.

OCTOBER 8, 1982, BURTRÄSK, PROVINCE OF VÄSTERBOTTEN

A moderate-size earthquake took place on the morning of October 8, 1982, in eastern Västerbotten. Maximum intensity, IV, was felt in Skråmträsk. Reports came also from Boliden (II), Burträsk (III–IV) and Bygdsiljum (III–IV). Many sleeping people awoke, houses vibrated lightly and at one locality furniture moved. The sensation of vibration was comparable to that of near-by blasting.

APRIL 1, 1983, HUDIKSVALL, PROVINCE OF HÄLSINGLAND

On the morning of April 1, 1983, a weak earthquake was felt within a limited area around Hudiksvall in coastal central Hälsingland. Reports about felt effects were

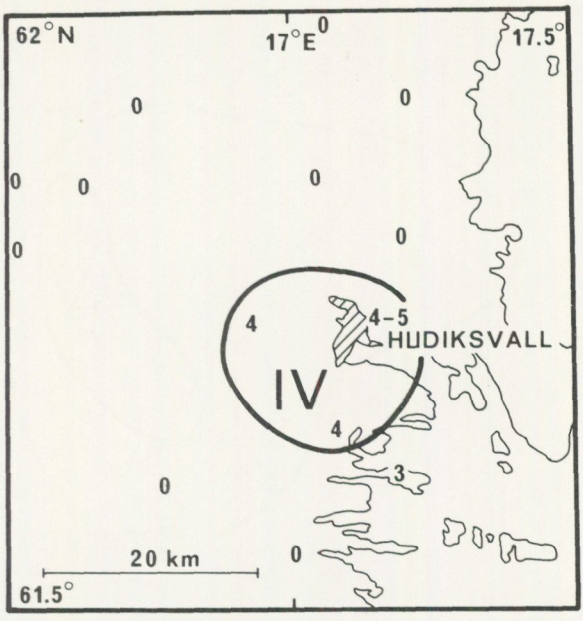

Fig. 8. Intensity distribution of the Hudiksvall earthquake of April 1, 1983. Conventions as for Fig. 2.

received from Forsa (IV), Hudiksvall (IV–V), Iggesund (IV) and Mössön (III). In the epicentral area, many people awoke; one person became frightened and ran outdoors. Windows and doors rattled, pictures swung out of place and furniture began to shake. From Hudiksvall, we received one report on unusual behaviour of a dog shortly before the earthquake. At several localities, sounds similar to a thunder were noticed.

Collected macroseismic observations are displayed in Fig. 8 together with the area of intensity IV.

APRIL 15, 1983, FLODA, PROVINCE OF VÄSTERGÖTLAND

On the early morning of April 16, 1983 (local time; April 15, GMT), a weak earthquake occurred in soutwestern Västergötland. The event was felt only in Floda (III), where one sleeping person on the upper floor awoke and furniture began to shake. Audible effects were also reported.

JUNE 18, 1983, FLARKEN, PROVINCE OF VÄSTERBOTTEN

On the afternoon of June 18, 1983, a strong earthquake shook the area of central eastern Västerbotten. Positive answers to our questionnaires were received from

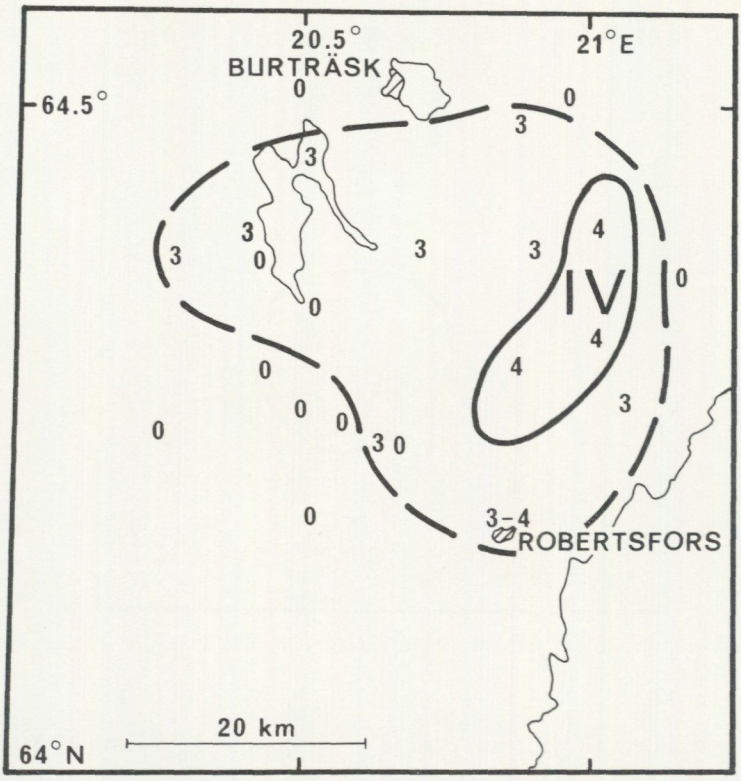

Fig. 9. Intensity distribution of the Flarken earthquake of June 18, 1983. Conventions as for Fig. 2.

12 localities, namely from Ånäset (III), Bjurfors (III), Bursiljum (III), Estermark (IV), Flarken (IV), Kålaboda (III), Kvarnbyn (III), Lidsjön (III), Robertsfors (III–IV), Stenfors (III), Västbyn (III) and Vebomark (IV). The event was felt indoors by many people and outdoors by a few at rest. Windows, doors and dishes rattled, taps vibrated, buildings trembled.

The estimated intensity degrees are depicted in Fig. 9 together with the area of perceptibility of 1080 km^2 and the area limited by intensity IV.

JULY 12, 1983, GRÄNNA, PROVINCE OF SMÅLAND

A moderate-size earthquake was felt on the evening of July 12, 1983, within the neighbouring areas of Småland and Östergötland. Reports with positive answers were received from Adelöv (IV), Aneby (III–IV), Aranäs (IV), Barkarp (III), Brandstorp (III), Brötjemark (III–IV), Frinnaryd (IV), Gripenberg (III), Hakarp (III), Hult (III), Järsnäs (III–IV), Kaxholmen (III), Marbäck (III), Ödeshög (II), Örserum (III), Sundhult (III–IV), Svartemålen (IV), Tranås (IV),

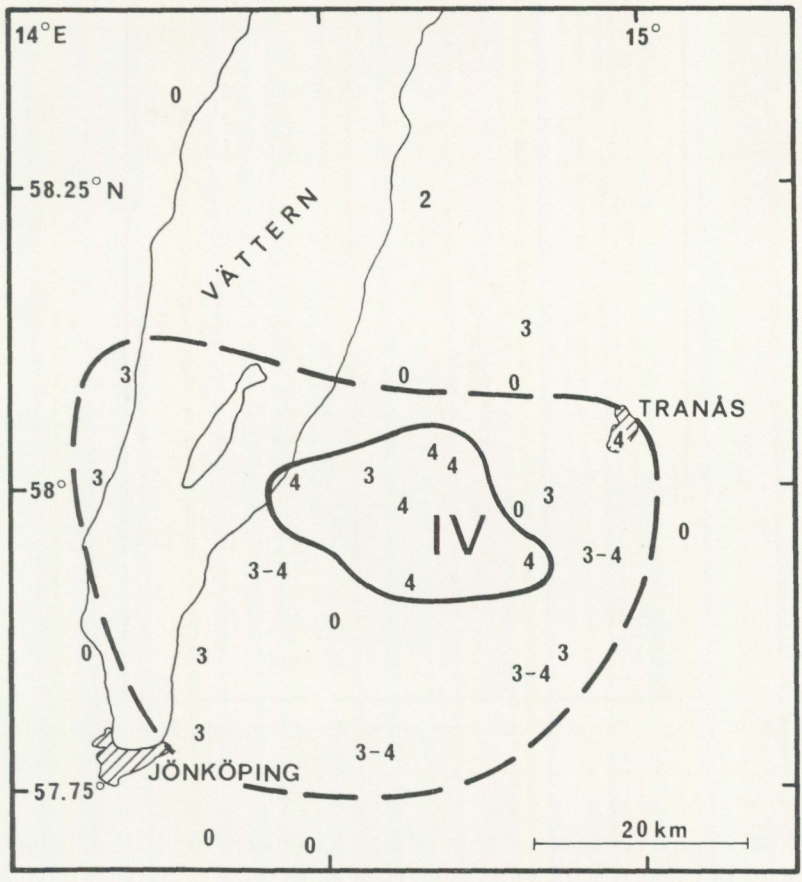

Fig. 10. Intensity distribution of the Gränna earthquake of July 12, 1983. Conventions as for Fig. 2.

Vallstorp (IV) and Vireda (IV). The earthquake was felt indoors as well as outdoors by many people. The vibration, which lasted for several seconds, was like that due to the passing of a heavily loaded truck or to near-by blasting. Doors, dishes and heating units rattled, and furniture shook. At one place, a hall-clock was overturned and at another place the shock was noticed in a standing car. Short (~2 s) audible effects were reported from several localities.

Interpretations of collected macroseismic data are summarized in Fig. 10. The shock was perceptible within an area of 1810 km^2.

SEPTEMBER 24, 1983, FALKÖPING, PROVINCE OF VÄSTERGÖTLAND

On the early morning of September 24, 1983, a weak earthquake was noticed within the area surrounding Falköping in central Västergötland. Positive obser-

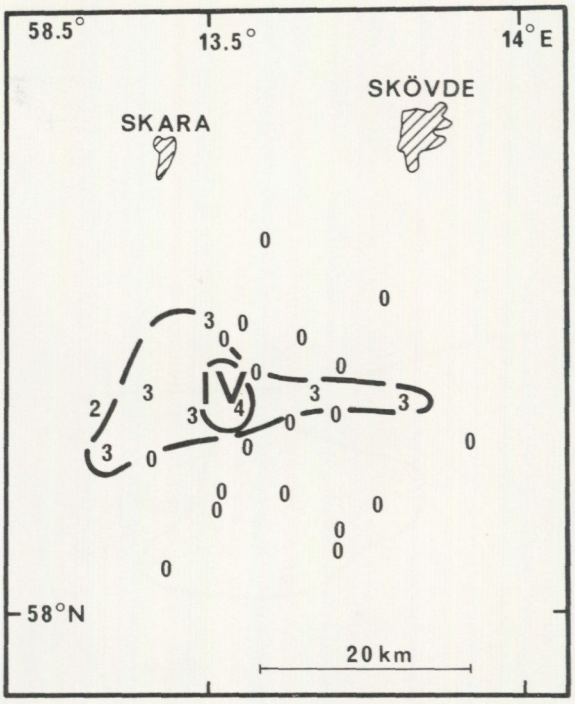

Fig. 11. Intensity distribution of the Falköping earthquake of September 24, 1983. Conventions as for Fig. 2.

vations were received from residents of nine localities: Åsle (III), Dimbo (III), Falköping (IV), Floby (III), Gökhem (III), Gudhem (III), Marka (III), Odensberg (II) and Ugglum (III). Here and there people awoke, windows rattled, several bottles were overturned, open doors slammed, furniture vibrated and floors creaked. Audible booms with a duration of 10 to 25 s were noticed.

Collected observations are presented in Fig. 11, where the distribution of intensity degree IV and the area of perceptibility are also displayed. The relatively small area of perceptibility of 180 km^2 provides a rather shallow focal depth of 4 km.

SEPTEMBER 29, 1983, SOLBERG, PROVINCE OF ÅNGERMANLAND

A study of the Solberg earthquake, the largest in Sweden since 1909, carried out within two weeks following the quake, shows that the main shock affected an area comprising major parts of Lappland, Västerbotten, Ångermanland, Medelpad and Jämtland. We used all relevant information from several hundreds of interviews with residents in the epicentral area, letters of inquiry to post and school

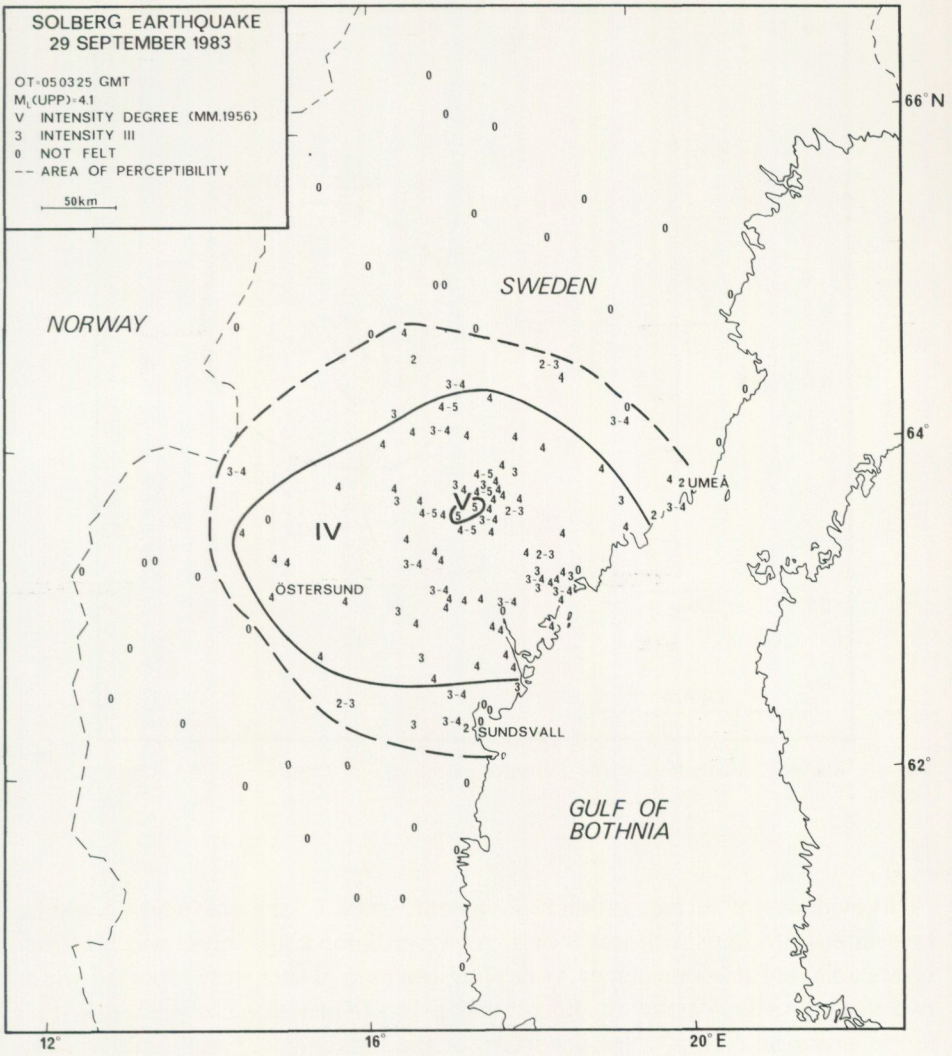

Fig. 12. Intensity distribution of the Solberg earthquake of September 29, 1983.

officials, newspaper articles and letters from the population. The data were supplemented by a number of telephone calls. Intensity assessments are available from 156 localities in central northern Sweden. The earthquake was not felt in the adjacent coastal area of Finland (T. Ahjos, personal communication).

The macroseismic epicentre, I_0=V, was located to the Sunnersta–Kläppsjö area indicating a reasonable proximity to the instrumental location. No reports that would suggest a VI-level were received. The collected data define intensity contours of V, IV and the perceptibility threshold reasonably well on the landward portion of the affected area (about 70.000 km^2, see Fig. 12).

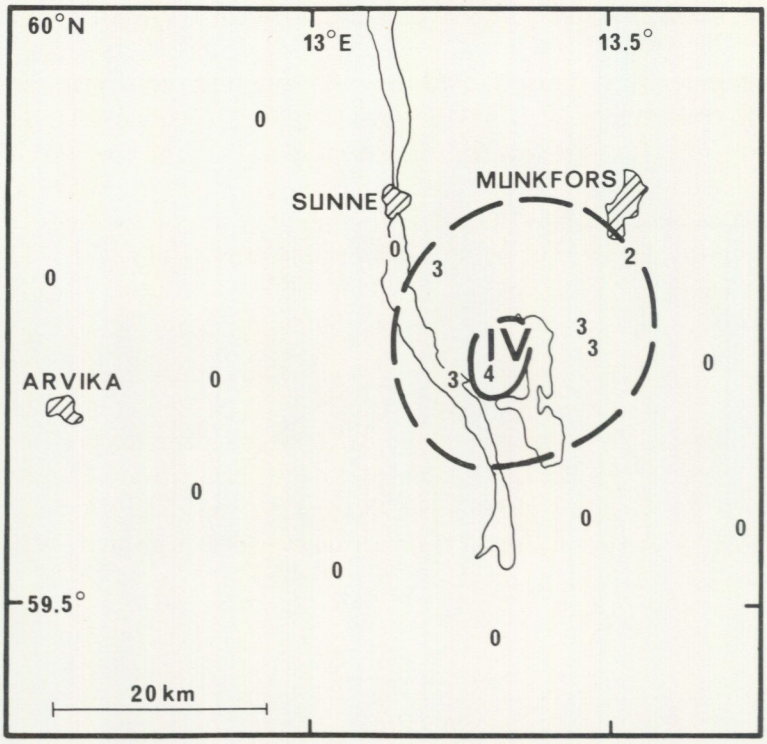

Fig. 13. Intensity distribution of the Ransäter earthquake of October 3, 1983. Conventions as for Fig. 2.

No evidence of surface ground movement, soil cracking etc. which could be associated with the shock was found. As to our knowledge, there was no structural damage. From one place (Åsele) fine cracks in plaster were reported and at two places (Åsele, Västby) the fall of small pieces of plaster was observed. Within the macroseismic area, a large portion of the buildings are well-built wooden structures or, to a lesser extent, ordinary brick houses. The sensation of vibration lasted from one second to several tens of seconds; at a few localities two shocks, several seconds apart, were felt (possibly arriving P- and S-waves, respectively). In a number of cases, local residents reported audible booms similar to a distant thunder or a blast. From about 15 localities, we received reports on anomalous animal behavior. Some of the animal reactions could have been premonitory.

The focal depth of about 40 km derived from macroseismic data locates the event close to the Moho-discontinuity, which is quite unusual for Swedish earthquakes. The maximum ground acceleration is about 3% g. More detailed information on this earthquake is available at the Seismological Department, Uppsala.

OCTOBER 3, 1983, RANSÄTER, PROVINCE OF VÄRMLAND

On the morning of October 3, 1983, a weak earthquake took place in central Värmland. The event was felt in Bäckängen (III), Geijersgården (III), Gunnerud (III), Munkfors (II), Ransäter (III) and Skacksjön (IV). The sensation of vibration was like that due to near-by blasting; windows, dishes and flowerpots rattled, and floors creaked. Audible booms were noticed at several localities.

The intensity distribution and the area of perceptibility of about 570 km^2 are shown in Fig. 13.

JANUARY 4, 1983, ENONTEKIÖ, FINLAND

On January 4, 1983, a strong earthquake, $M_L(UPP)=3.3$, was felt in Karesuando, Swedish Lapland, and the surrounding area. The epicentre was located in Finland, north of Enontekiö at 68.6°N, 22.9°E, and thus the event is not included in Tables 1 and 3. An evaluation of the macroseismic data is given by Ahjos *et al.* 1984.

FELT EVENTS, POSSIBLY EARTHQUAKES

Reports to the Seismological Department, Uppsala, about suspected Swedish earthquakes felt by people are checked on corresponding seismic records. Events which have been felt but not recorded are listed in Table 4. No definite judgement can be made about the nature of the events; several may have an aseismic origin. Identified non-earthquake events, e.g., sonic booms, chemical explosions and frost cracks, are not included in the table, nor are rockbursts in mines.

DISCUSSION

More reliable and complete macroseismic information is achieved in cases where direct interviews have been performed, as is clearly demonstrated by comparison of corresponding isoseismal charts (Figures 5, 7 and 12) with those of the other events (Figures 2, 3, 4, 6, 8, 9, 10, 11 and 13).

It is striking how well magnitudes computed from different sets of data – instrumental and macroseismic – resemble one another (cf Tables 1 and 3). For the 12 events for which magnitudes could be computed in both ways, the average difference $\overline{M_L(UPP) - M_M(UPP)}$ is 0.2 with standard deviation 0.2. This is a good

TABLE 4. Felt not recorded events possibly earthquakes, 1980–1983.

Date	Approximate time Local time (h)	Locality and Province
1980-01-16	16	Handen, Södermanland
02-21	11	Jörn, Västerbotten
03-09	15[1)]	Piteå, Norrbotten
03-18	22	Örsundsbro, Uppland
03-18	22	Alsike, Uppland
03-28	09[1)]	Gripenberg, Småland
04-07	04	Lidingö, Uppland
04-10	18	Lindome, Västergötland
04-11	04	Göteborg, Västergötland
04-12	21	Svanesund, Bohuslän
04-14	08	Arlanda, Uppland
04-22	14	Örebro, Närke
06-01	01	Bergsjö, Hälsingland
06-02	08[1)]	Malsta, Uppland
06-11	11	Onsala, Halland
07-20	15	Vagnhärad, Södermanland
07-29	09	Gnarp, Hälsingland
07-31	20	Laholm-Halmstad, Halland
09-14	09	Värmdö, Uppland
10-21	10	Löparö, Uppland
10-22	11	Norrtälje-Stockholm, Uppland
11-06	08[1)]	Bureå-Skelleftehamn, Västerbotten
11-19	15	Ljungby, Småland
12-03	04	Skövde, Västergötland
12-03	13	Smedjebacken, Dalarna
12-29	04	Hofors, Gästrikland
1981-01-20	13[1)]	Kode, Bohuslän
01-20	19	Billdal, Västergötland
02-05	02	Åkersberga, Uppland
03-03	14	Handen, Södermanland
04-22	16	Rödå, Västerbotten
05-20	10	Edsbyn-Alfta, Hälsingland
05-22	12	Lisö, Södermanland
05-23	07	Jukkasjärvi-Tuolluvaara, Lappland

TABLE 4 (cont.).

Date	Approximate time Local time (h)	Locality and Province
1981-06-09	01	Gustavsberg, Uppland
08-26	18	Luleå, Norrbotten
09-23	22	Sundsvall, Medelpad
09-29	14	Mariefred, Södermanland
10-25	00	Folkärna, Dalarna
10-27	14	Kramfors, Ångermanland
12-08	14	Kramfors-Mjällom, Angermanland
1982-02-08	19	Löparö, Uppland
02-26	08	Kramfors-Härnösand, Ångermanland
04-29	21	Brunflo, Jämtland[2)]
05-05	20	Brunflo, Jämtland[2)]
06-03	17	Brunflo, Jämtland[2)]
07-29	23	Emmaboda, Småland
08-02	23	Markitta, Lappland
11-04	09[1)]	Lidingö, Uppland
11-18	12	Lappträsk, Norrbotten
12-14	21	Skråmträsk, Västerbotten
1983-01-27	02	Svartlå, Norrbotten
02-04	09	Torsås, Småland
02-07	11	Väddö, Uppland
05-19	12[1)]	Timrå, Medelpad
06-12	23	Örsundsbro, Uppland
08-15	18	Sollentuna, Uppland
10-12	14	Falköping-Floby, Västergötland
10-24	03	Falköping, Västergötland
11-16	14	Huddinge, Södermanland
11-17	11	Kalmar, Småland
11-17	16	Fliseryd, Småland

1) Additional events have been felt during the same or following days.

2) Recorded at Myrviken(MYR). Near-surface event, probably explosion.

support of the idea behind the M_M(UPP) concept, namely to make feasible a relevant comparison of sizes of small, only instrumentally recorded shocks with pre-instrumental earthquakes. Since the same data, I_0 and r_p, are used for computation of macroseismic magnitude and focal depth, the magnitude agreement can also be interpreted as a reliability of focal depth estimates.

REFERENCES

AHJOS, T., POLKONEN, E., FRANSSILA, M., MUSTILA, L., and RAIME, M., 1984: Earthquakes in northern Europe recorded by the Finnish seismic network in 1983. – Inst. Seismol., Univ. Helsinki, Report S-9, 27 pp.

KÁRNÍK, V., 1969: Seismicity of the European Area. Part I. – D. Riedel, 364 pp.

KORHONEN, H., and AHJOS, T., 1979: A contribution to the macroseismic investigations of earthquakes felt in Finland. – Inst. Seismol., Univ. Helsinki, Report S-4, 21 pp.

KULHÁNEK, O., VAN ECK, T., JOHN, N., MEYER, K., and WAHLSTRÖM, R., 1981: The Otterbäcken, Sweden, earthquake of February 13, 1981. – Seismol. Sect., Uppsala, Tech. Report, 42 pp.

– 1983: Spectra of the earthquake sequence February–March, 1981, in south-central Sweden. – Tectonophysics, 93: 337–350.

KULHÁNEK, O., AND WAHLSTRÖM, R., 1981: Macroseismic observations in Sweden 1977–1979. – Sveriges geol. und., C 776, 13 pp.

SEISMOLOGICAL BULLETINS. – Seismol. Dept., Uppsala.

TRIFUNAC, M. D., and BRADY, A. G., 1975: On the correlation of seismic intensity scales with the peaks of recorded strong ground motion. – Bull. Seismol. Soc. Am., 65: 139–165.

WAHLSTRÖM, R., and AHJOS, T., 1984: Determination of local magnitude and calibration of magnitude scales for earthquakes in the Baltic Shield. – Annales Geoph., 2: 553–558.

WILLMORE, P. L., (Editor) 1979: Manual of Seismological Observatory Practice. – World Data Center A for Solid Earth Geophysics, Report SE-20.

PRISKLASS B
Distribution
Liber Distribution
162 89 STOCKHOLM
Tel. 08-739 91 30

Fotosats: ORD & FORM AB
Tryck: Offsetcenter AB, Uppsala 1985

ISBN 91-7158-332-7
ISSN 0082-0024