Earthquake-triggered landslides in Norway, and a reassessment of the 1819 Lurøy earthquake

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Jordskjelv som utløser massebevegelser i Norge og stabilitetsanalyse av Preikestolen med seismisk last

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Masteroppgave i Geovitenskap

Institutt for Geovitenskap

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Focus Section: Historical Earthquake Data and Research

A Reappraisal of the Lurøy, Norway, Earthquake of 31 August 1819

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Abstract

Archives and libraries were visited to find previously unknown documents testifying to the Lurøy, Norway, earthquake of 31 August 1819 in northernmost continental Europe. The focus here is on Sweden, Finland, and Russia, which are important for determining the area of perceptibility east of Norway. The new written sources include 12 notes or entries in original archived documents, six contemporary newspaper reports, and two recollections written down years later. The original documentation uncovered is contributory to establishing the authenticity of the observations in Finland and Sweden. The dates of the original documentation allow tracing of the dissemination of eyewitness accounts in writing from the inner area of perceptibility southward to the larger documentation and population centers. New sources of information include weather reports of the Royal Swedish Academy of Sciences, minutes of its meetings, and correspondence sent to the Senate in Finland. The minutes of meetings of the Academy indicate that ample data were collected in the Swedish province of Västerbotten. We found no original Russian documentation but uncovered national newspapers that are more reliable than the previously used Parisian newspaper.

To increase transparency, we provide the first list of macroseismic data points (MDPs) including the respective documentation that testify to the Lurøy earthquake. A macroseismic intensity was assigned to a locality, using the European Macroseismic Scale of 1998, when adequate information was available. Accounting for the uncertainty of intensity assessment, the magnitude was estimated as moment magnitude $M = 5.9 \pm 0.2$, reconfirming the ranking as the largest onshore or nearshore earthquake in the historical seismicity record of Fennoscandia. In addition to the reappraisal of the 31 August 1819 earthquake, a macroseismic map is provided for the earthquake of 17 February 1819, which was felt in northern Finland and Sweden. Some of its MDPs were previously associated with the Lurøy earthquake.

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Supplemental Material

Introduction

The seismic hazard analyses mandatory for critical constructions are a major reason behind the need for earthquake catalogs covering both the preinstrumental and instrumental eras, at plate boundaries and continental interiors alike. The preinstrumental seismicity record in northernmost continental Europe (Fennoscandia; Fig. 1) only spans a few centuries but is sufficient to demonstrate that earthquakes with larger areas of perceptibility have occurred in the past, although they have not occurred during the instrumental era.

This investigation focuses on the earthquake of 31 August 1819 in Norway. Its epicenter is estimated to have been near Lurøy, on the coast of Nordland, Norway (Fig. 1). Macroseismic maps have been published by Ambraseys (1985) and Muir Wood and Woo (1987). The latter map was republished by Muir Wood (1988) and will serve as the main macroseismic reference in this investigation. Ambraseys (1985) and Muir Wood (1988) made use of historical records, the contemporary press, seismological compilations, and travelers' accounts. Ambraseys (1985, p. 370) even sent an open letter to the Swedish press calling for unpublished information on the Lurøy earthquake but received a poor response. They estimated the maximum intensity to be 8 on the Medvedev–Sponheuer–Kárník (MSK) and modified Mercalli intensity (MMI) scales. They showed that the Lurøy earthquake had

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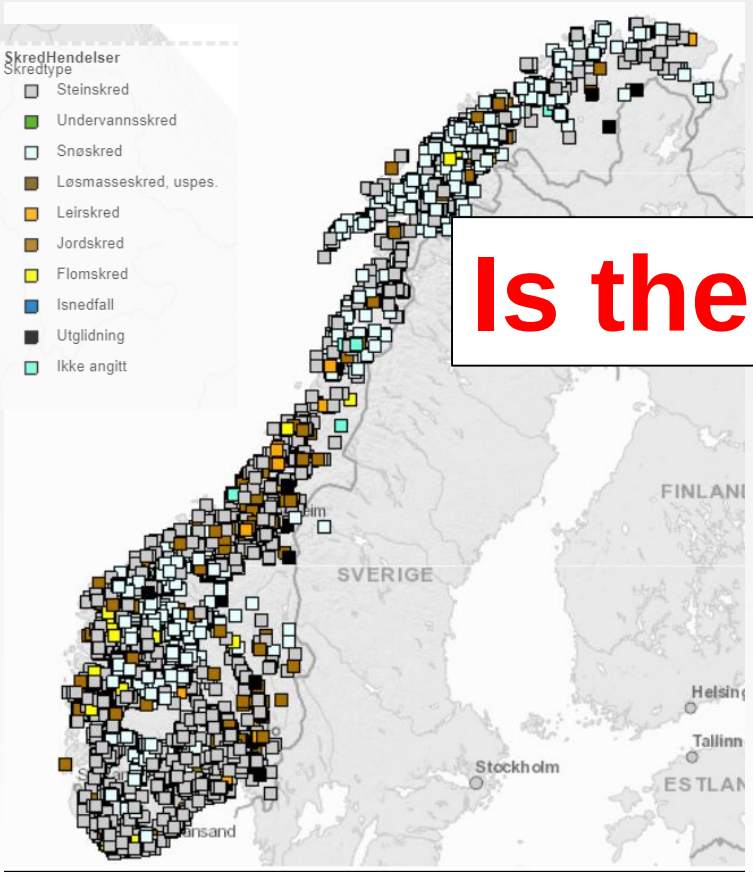
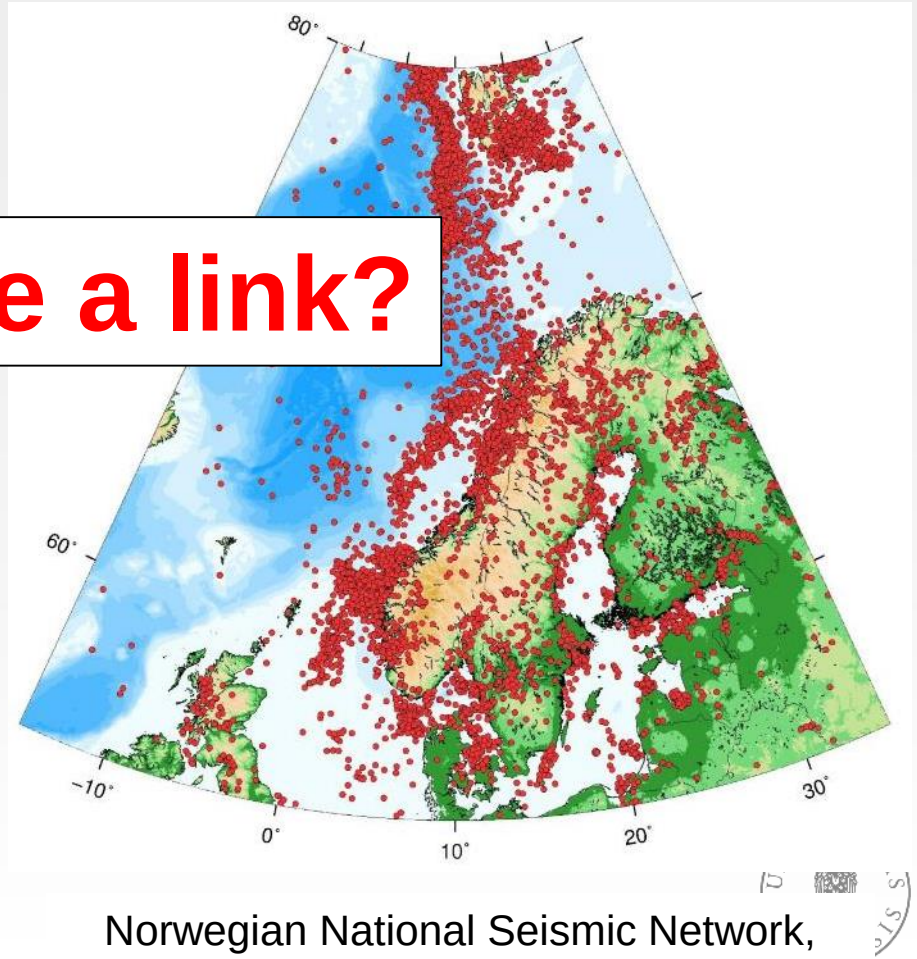
Norway, a land of slope failures.. and earthquakes



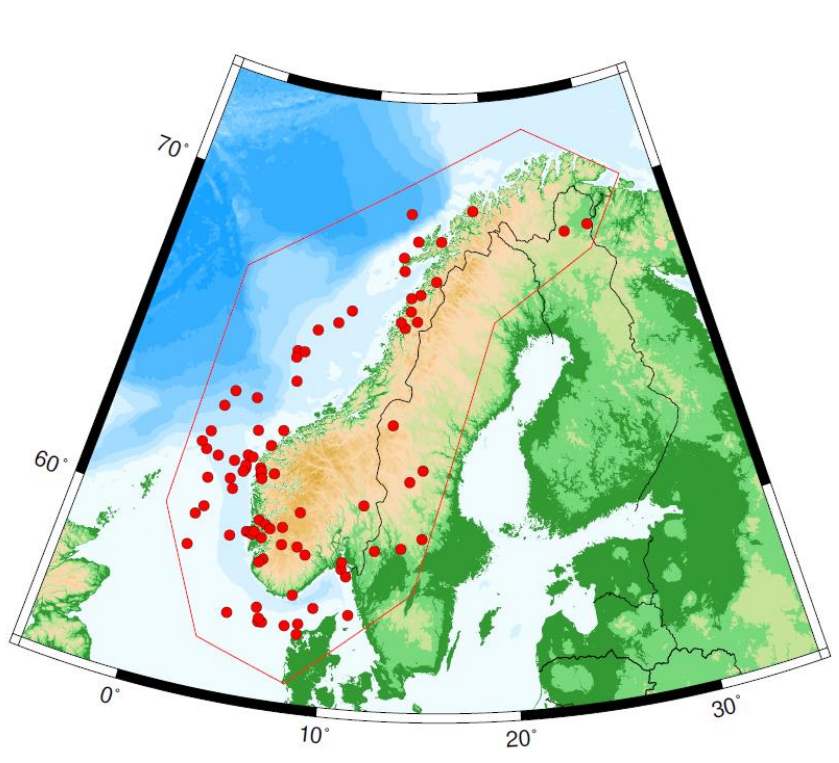
Is there a link?



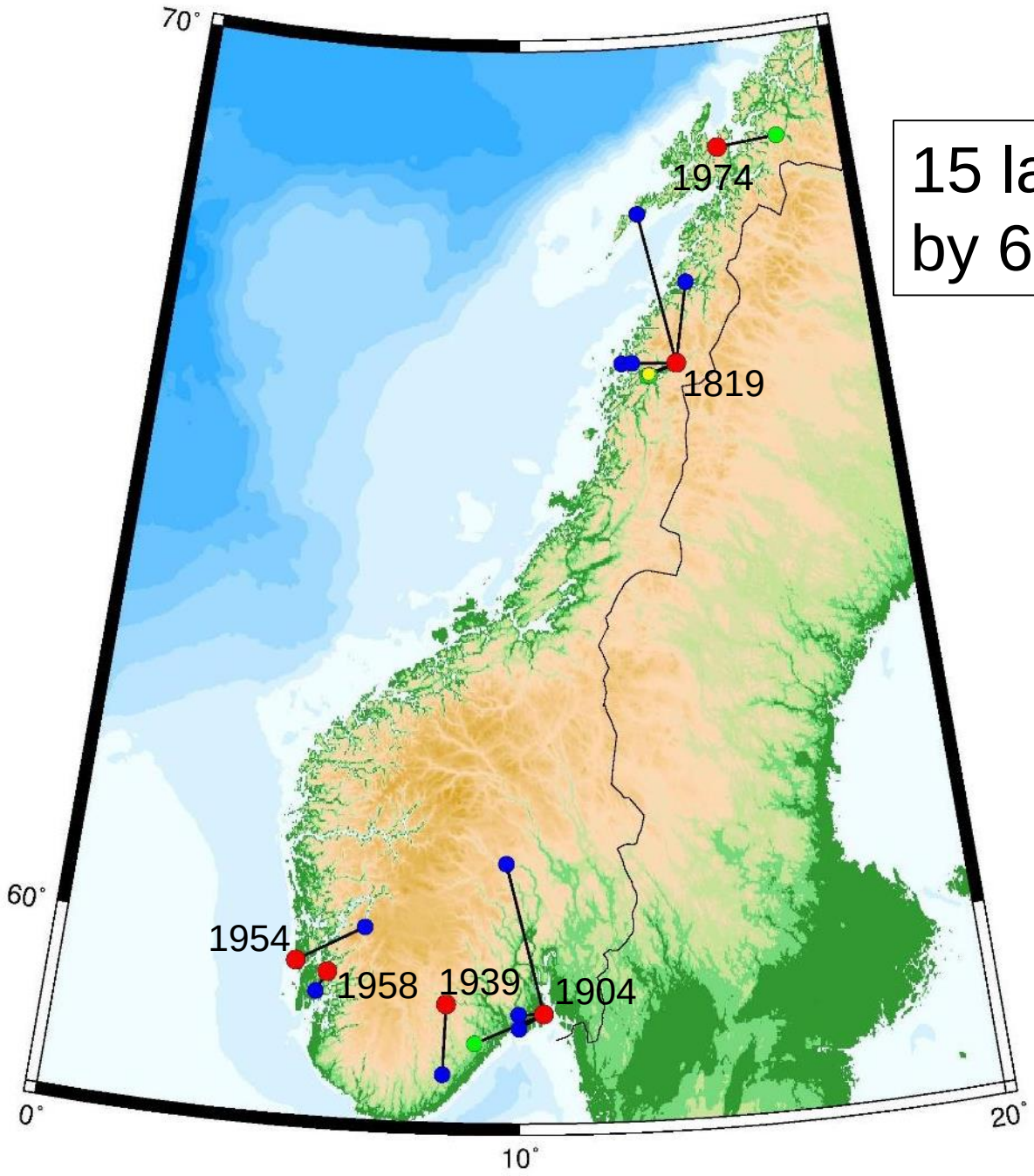
Landslides in Norway Sep 2018 – Sep 2020
www.skrednett.no

Norwegian National Seismic Network, 1970-2010

Earthquake-triggered landslides in Norway



- Mainland Norway
  1819-2019
  M≥4.5
  86 events
- skrednett.no
- Historical earthquake archive @UiB
- Digital earthquake database @UiB
- met.no rainfall statistics

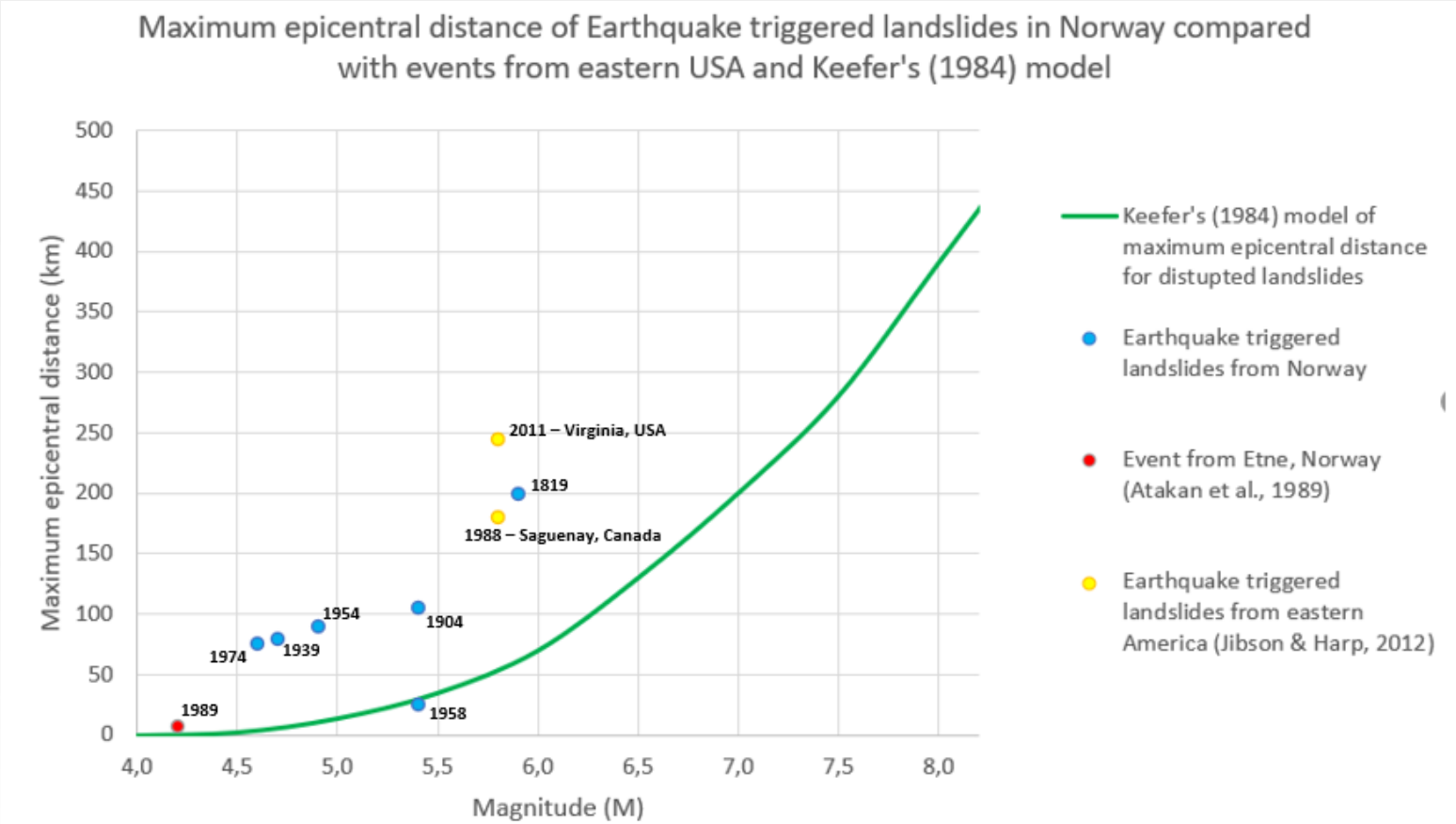


15 landslides triggered by 6 earthquakes

Blue: rockfall
Green: clay slide
Yellow: debris slide

Red:
earthquake location

Landslide distance limits



Summary, part 1

- 15 landslides triggered by 6 earthquakes since 1819
- Database is expected to be highly incomplete
- Most triggered failures are small
- Landslide distance limits for Norway are longer than those identified by Keefer (1984)

The 31. August 1819 Lurøy earthquake

- Largest historical event in Fennoscandia
- Triggered several rock falls and landslides
- Large waves were observed in the fjord
- Reports of people having difficulty standing

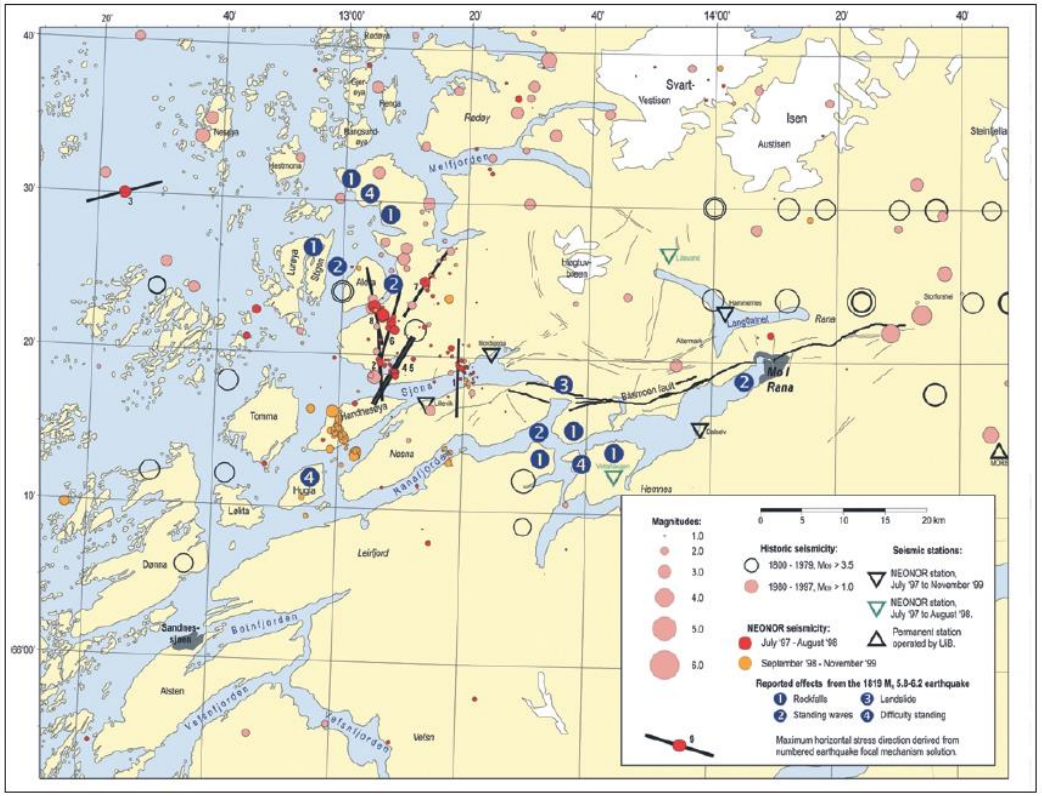
The 31. August 1819 Lurøy earthquake

Challenges:

- Sparse population, limited literacy
- Newspaper publishers are consentrated in major cities far away

- Husebye and Kebeasy (2004) proposed lowering magnitude to 5.1, which triggered a large debate.

The 31. August 1819 Lurøy earthquake



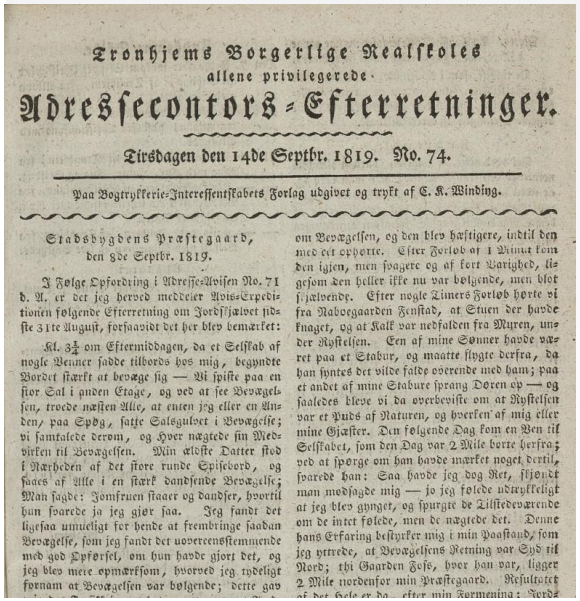
Bungum and Olesen, 2004, based on Muir Wood 1988

What did we do?

- Compile all available reports
- Include new data, not considered in earlier studies
- Re-assess intensities according to EMS98
- Present all available sources, incl. English translations
- Re-assess the magntiude

New data

- 12 notes or entries in original archived documents
- Six contemporary newspaper reports
- Three recollections written down years later



Trondhjems Borgerlige Realskoles
allene privilegerede.

Adressecontors-Efterretninger.

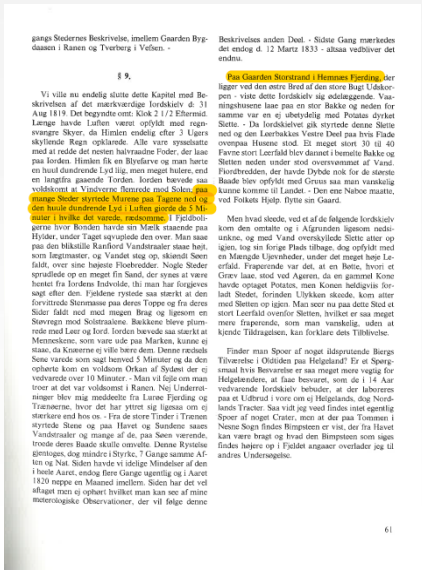
Tirsdagen den 14de Septbr. 1819. No. 74.

Paa Bogtrykkeries-Interessentskabets Forlag udgiver og trykt af C. K. Winding.

Stadsbygdens Præstegaard,
den 8de Septbr. 1819.

I Følge Opfordring i Adresse-Avisen No. 71 d. A. er det jeg herved meddeler Avis-Expeditionen følgende Efterretning om Jordskjælvet sidste 31te August, forsaavidt det her blev bemærket:

Kl. 3¼ om Eftermiddagen, da et Selskab af nogle Venner sadde tilbords hos mig, begyndte Bordet stærkt at bevæge sig — Vi spiste paa en stor Sal i anden Etage, og ved at see Bevægelsen, troede næsten Alle, at enten jeg eller en Anden, paa Spøg, satte Salsgulvet i Bevægelse; vi samtalede derom, og Hver nægtede sin Medvirken til Bevægelsen. Min elskte Datter stod i Nærheden af det store runde Spiseboord, og saaes af alle i en stærk dandsende Bevægelse; Man sagde: Jomfruen staaer og danser, hvortil hun svarede ja jeg gjør saa. Jeg fandt det ligesaa umueligt for hende at frembringe saadan Bevægelse, som jeg fandt det overeensstemmende med god Opførsel, om hun havde gjort det, og jeg blev mere opmærksom, hvorved jeg tydeligt fornam at Bevægelsen var bølgende; dette gav om Bevægelsen, og den blev hastigere, indtil den med et ophørte. Efter Forløb af 1 Minut kom den igjen, men svagere og af kort Varighed, ligesom den heller ikke nu var bølgende, men blot sjælvende. Efter nogle Timers Forløb hørte vi fra Nabogaarden Finstad, at Stuen der havde knaget, og at Kalk var nedfalden fra Muren, under Rystelsen. Een af mine Sønner havde været paa et Stabur, og maatte flygte derfra, da han syntes det vilde falde overende med ham; paa et andet af mine Stabure sprang Døren op — og saaledes bleve vi da overbeviste om at Rystelsen var et Puds af Naturen, og hverken af mig eller mine Gjæster. Den følgende Dag kom en Ven til Selskabet, som den Dag var 2 Mile borte herfra; ved at spørge om han havde mærket noget dertil, svarede han: Saa havde jeg dog Ret, skjønt man modsagde mig — jo jeg følede udrykkeligt at jeg blev gynget, og spurgte de Tilstedeværende om de intet følede, men de nægtede det. Denne hans Erfaring bestyrker mig i min Paastand, som jeg yttrede, at Bevægelsens Retning var Syd til Nord; thi Gaarden Foss, hvor han var, ligger 2 Mile nordenfor min Præstegaard. Resultatet



gangs Stedernes Beskrivelse, imellem Gaarden Bygdaasen i Ranen og Tverberg i Vefsen. -

§ 9.

Vi ville nu endelig slutte dette Kapitel med Beskrivelsen af det mærkværdige Jordskiælv d. 31 Aug 1819. Det begyndte omt: Klok 2 1/2 Eftermid. Længe havde Luften været opfyldt med regnsvangre Skyer. da Himlen endelig efter 3 Ugers skyllende Regn opklarede. Alle vare sysselsatte med at redde det nesten halvraadne Foder, der laae paa Jorden. Himlen fik en Blyefarve og man hørte en hul dundrende Lyd lig, men meget hulere, end en langtfra gaaende Torden. Jorden bævede saa voldskomt at Vindverne flenrede med Solen. paa mange Steder styrtede Marene paa Tagene ned og den hule dundrende Lyd i Luften gierde de 5 Minuter i hvilke det varede, raadsomme i Fjeldbolagerne hvor Bonden havde sin Mælk staaende paa Hylder, under Taget sqvuplede den over. Man saae paa den bikstille Rørdord Vandstraaler staae høit, som længmaster, og Vandet stog op, skiendt Seen faldt, over sine høieste Floebredder. Nogle Steder sprudlede op en meget fin Sand, der synes at være hentet fra Jordens Indvolde. thi man har forgiæves sagt efter den. Fjeldene rystede saa stærkt at den forvittrede Stormasse paa deres Toppe og fra deres Sider faldt ned med megen Brag og lignsom en Støvregn mod Solstraalene. Bækkene bleve plumrede med Leer og Iord. Iorden bævede saa stærkt at Mennesker. som vare ude paa Marken, kunne ej staae, da Knæerne ej ville bære dem. Denne raadsels Sene varede som sagt henved 5 Minuter og da den ophørte kom en voldsom Orkan af Sydøst der ej vedvarede over 10 Minuter. - Man vil følge em man troer at det var voldsomst i Ranen. Nej Underretninger blev mig meddelete fra Larøe Fjerding og Træneerne, hvor det har yttret sig ligesaa om ej stærkere end hos os. - Fra de store Tinder i Trienen styrtede Stene og paa Havet og Sandene saaes Vandstraaler og mange af de, paa Seen værende, troede deres Baade skulle omvelte. Denne Rystelse gientoges, dog mindre i Styrke, 7 Gange samme Aften og Nat. Siden havde vi ideilge Mindelser af den i heele Aaret, endog flere Gange ugentlig og i Aaret 1820 nappe en Maaned imellem. Siden har det vel aflagt men ej ophørt hvilket man kan see af mine meteorologiske Observationer, der vil følge denne Beskrivelses anden Deel. - Sidste Gang mærkedes det endog d. 12 Martz 1833 - altsaa vedhiver det endnu.

Paa Gaarden Storstrand i Hemnæs Fjerding, der ligger ved den østre Bred af den store Bugt Udskerpen - viste dette Jordskielv sig ødelæggende. Vaaningshusene laae paa en stor Bakke og neden for samme var en ej ubetydelig med Potates dyrket Slette. - Da Jordskielvet gik styrtede denne Slette ned og den Leerbakkes Vestre Deel paa hvis Flade overpaa Husene stod. Et meget stort 30 til 40 Favne stort Leerfald blev dannet i bemelte Bakke og Sletten neden under stod overswømmet af Vand. Floedbredden, der havde Dybde nok for de største Baade blev opfyldt med Gruus saa man vanskelig kunne komme til Landet. - Den ene Naboe maatte, ved Folkets Hjelp. flytte sin Gaard.

Men hvad skeede, ved et af de følgende Jordskielv kom den omtalte og i Afgrunden ligesom nedsunkne, og med Vand overskyllede Slette atter op igien, tog sin forige Plads tilbage, dog opfyldt med en Mængde Ujevnheder, under det meget høje Leerfald. Fraperende var det, at en Bøtte, hvori et Grav laae, stod ved Agøren, da en gammel Kone havde optaget Potates, men Konen heldigvis forladt Stedet, forinden Ulykken skeede, kom atter med Sletten op igien. Man seer nu paa dette Sted et stort Leerfald overfor Sletten, hvilket er saa meget mere fraperende, som man vanskelig, uden at kiende Tildragelsen, kan forklare dets Tilblivelse.

Finder man Spoer af noget idsprutende Biergs Tilværelse i Oldtiden paa Helgeland? Er et Spørgsmaal hvis Besvarelse er saa meget mere vegtig for Helgelændere, af faae besvaret, som de i 14 Aar vedvarende Jordskielv bebuder, at der laboreres paa et Udbrud i vore om ej Helgelands, dog Nordlands Tracter. Saa vidt jeg ved findes intet egentlig Spoer af noget Crater, men at der paa Tommen i Nesne Sogn findes Bimpsteen er vist, der fra Havet kan være bragt og hvad den Bimpsteen som tages findes højere op i Fjeldet angaaer overlader jeg til andres Undersøgelse.

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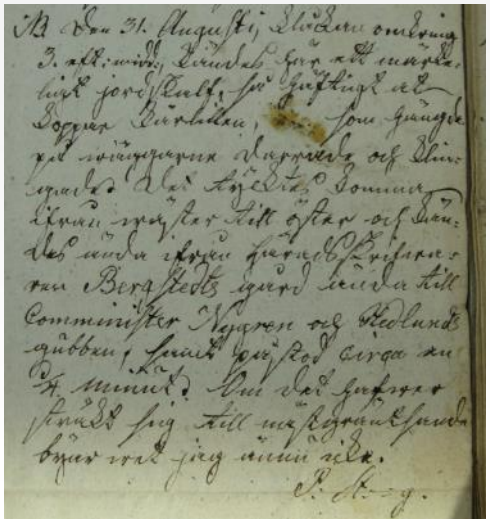

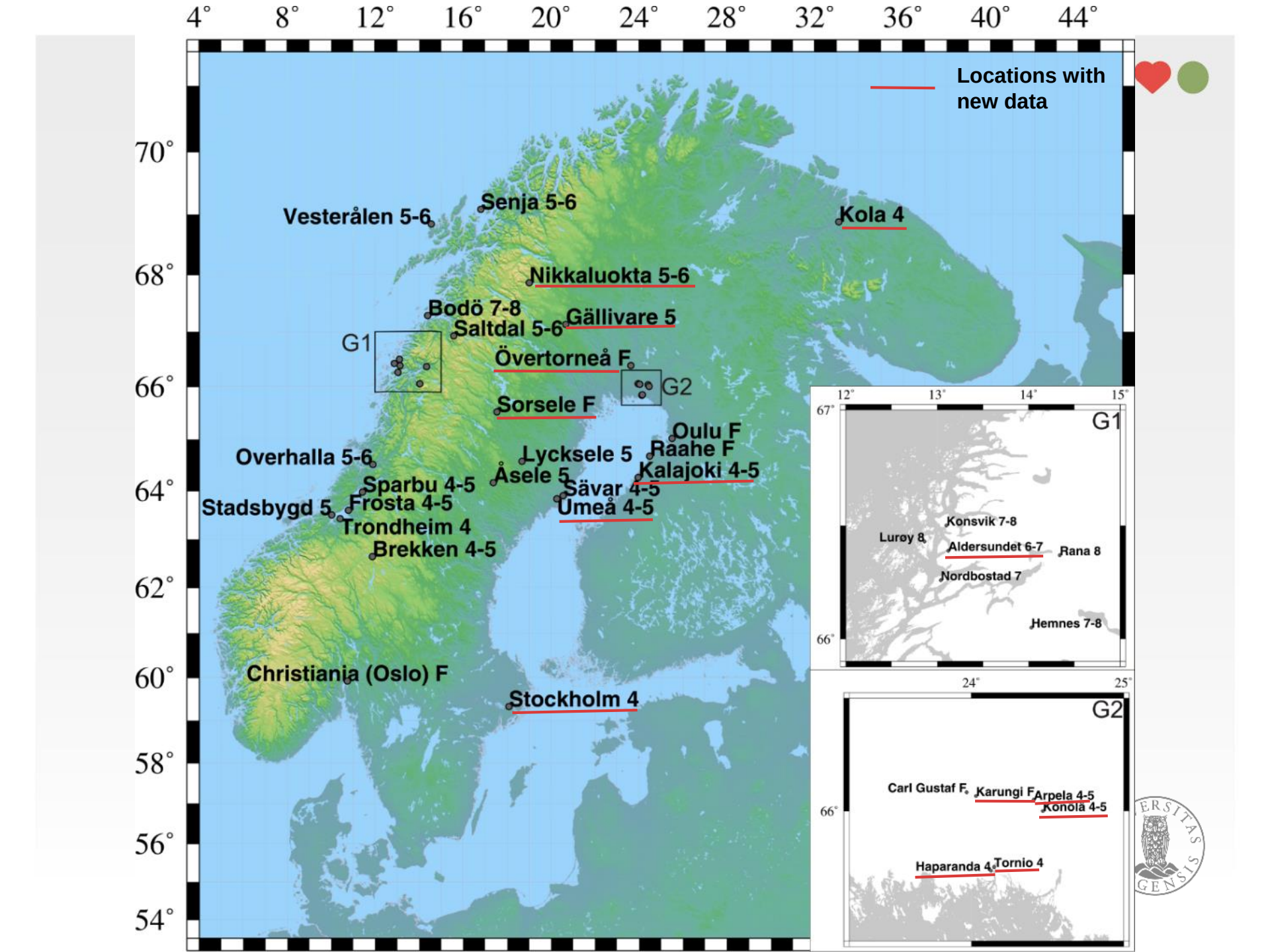
Locations with new data
Vesterålen 5-6
Senja 5-6
Kola 4
Nikkaluokta 5-6
Bodö 7-8
Saltdal 5-6
Gällivare 5
G1
Övertorneå F
G2
Sorsele F
Oulu F
Overhalla 5-6
Lycksele 5
Raahe F
Åsele 5
Kalajoki 4-5
Sparbu 4-5
Sävar 4-5
Stadsbygd 5
Frosta 4-5
Umeå 4-5
Trondheim 4
Brekken 4-5
Christiania (Oslo) F
Stockholm 4
G1
Konsvik 7-8
Lurøy 8
Aldersundet 6-7
Rana 8
Nordbostad 7
Hemnes 7-8
G2
Carl Gustaf F.
Karungi F.
Arpela 4-5
Konola 4-5
Haparanda 4
Tornio 4

Table of all reports

Karungi* (24.03,66.04) 502 km	**National Archives, Helsinki, Finland**: Senate documents sto, kd 98/166 1819: – *This earth shaking has according to accounts that tally with each other moved from the southwest to the northeast, because up along the River Tornio that runs in the south and north it was not felt further than Karungi 3 miles* [~33 km] *away, but on the side of the villages Arpela and Könölä the shaking was more discernible than around Tornio and Hapavanda.* *Tornio 10th September 1819* *J. Heickell*		F
Lyckesele (18.68,64.58) 338 km	**Newspaper** Inrikes Tidningar 24 Nov 1819: *On the same day and at the same time an earthquake was felt also in Lyckesele. The earth shook, houses creaked and groaned* [orig. husen brakade]*, roofs creaked, looms in rooms swung; the church tower and chimney stacks seemed to totter.*		5
Nikkaluokta* (19.01,67.85): Proxy for the location in the mountains; the Nikkaluokta Sámi group slaughter their reindeer there in early September 309 km	**Newspaper** Stockholms Posten 29 Dec 1819: *Lapp people, who at that time camped up in the mountains close to the Norwegian border, report how they experienced the same natural phenomenon and were astonished and amazed by it, and that pots and pans clattered together in their huts, and even the most insignificant shrubs visibly moved.*	The observations were made outdoors.	5-6
Övertorneå* (23.64,66.39) 479 km	**Swedish National Archives**, Royal Swedish Academy of Sciences, Meteorological observations 1690-1923, Meteorological observations in the territory of Sweden, SE/RA/420468/1/1a:57 County of Norrbotten, Meteorological observations in Haapakylä, Övre-Torneå by Johan Bortin, 1809-1822: 1819: *on the 31st of July* [sic] *an earthquake was felt through the whole region from the southeast to the southwest also in Lapland, or merely an earthshaking.*	possibly LT	F
Sävar (20.55,63.90) 456 km	**Newspaper** Inrikes Tidningar 22 Dec 1819: *an earthquake was felt at 3:15 p.m. in the village of Sävar and the municipality of Umeå, lasting for about 2 seconds and beginning with banging in junctions and walls, followed by a strong noise in the upper floors and attics of houses and then a shaking, so that many smaller gears on the walls began to move and the pile in the woodshed tipped over; the shaking was felt only in a given direction from the south to the north, in two, in the southern end of the village, east of the river in the same route at the homesteads on the west side of the river, but nothing was felt at the homesteads east of the river.*		4-5

Sorsele* (17.53,65.53) 234 km	**Regional State Archives in Härnösand, Sweden**; Sorsele church archives SE/HLA/ 1010185/KI:1 (1789-1841) Minutes of the meetings of the municipality council, meeting on 29 November 1819: *§ 4. Both Swedish and Lappish folk told to have felt of the ground shaking on 31 Aug*	An earthquake on 29 Aug is also mentioned (electronic supplement).	F
Stockholm* (18.78,59.33) 844 km	**Newspaper** Allmänna Journalen 11 Oct 1819: *One person reading a book (at 3 p.m.) laying on a sofa, whose position in the room was from the North to the South, felt like falling backwards and rose up hurriedly and felt a shaking, which also appeared in the opposite house. Since he heard no gunshot, and another person in his household, when immediately asked, had not observed anything, he took it to be a spell of dizziness.* **Newspaper** Inrikes Tidningar 24 Nov 1819: *In the capital many have observed this natural phenomenon. Two persons sitting in armchairs, with their backs toward the south, felt a shaking or swaying from the east to the west, which made the head swing from one side to the other. This did not continue a full minute, and one of the persons observed some kind of suspension between the shakings. The walls and doorframes were heard to creak; chandeliers hanging in the ceilings swung from the east to the west; a woman drinking coffee had to hold on to the table and saw coffee spill from the cup, etc. – Two persons living on the fourth floor of a house in Norrmalm* [central Stockholm] *felt an unusual jolt or shaking. A subdued noise followed from one such swinging of the house, so that a tea-tray hanging on the wall began to shake fully and a book hold on to the hand almost fell due to the abruptness of the jolt. The earthquake lasted for 30 to 40 seconds, and its direction seemed to be from the northwest to the southeast. It began with a vertical jolt and came to an end with a horizontal slump, which became quite noticeable because the tea tray mentioned above finally moved half a span* [7.2 cm] *on the wall ..... This earthquake was also felt on the third floor of the house we live in, but in the lower part of the house it was hardly noticeable. – In general the shaking was stronger in the upper floors than in the lower ones.* **Swedish National Archives**, Royal Swedish Academy of Sciences, Series Minutes, SE/SVAR/KVA-111010001/A/20 (1816-1820), Minutes of the meeting on 22nd September 1819:	Some of the academy members felt the earthquake 'in the countryside', which cannot be located.	4

Magnitude estimation

Based on area of perceptability of I=4 (A_4) (Muir Wood and Woo, 1987):

- $M_S = 0.90 + 0.81 \cdot \log A_4$
- $M_S = 1.57 + 0.63 \cdot \log A_4 + 0.0007 \cdot \mathrm{sqrt}(A_4)$

I=IV observations in Tornio (510 km) and Stockholm (850 km) correspond to

M=6.0±0.3

Magnitude estimation

Based on intensity prediction equation for ENA (Bakun et al., 2003):

$$MMI = 1.41 + 1.68 \cdot M - 0.00345 \times \Delta - 2.08 \cdot \log(\Delta)$$

Applying to the 29 Intensity-distance datapoints and averaging gives

M=5.9±0.2

Conclusions

- New reports of the 1819 earthquake help constraining the felt-area of the event
- It is quite certain that the event was felt at distant locations such as Stockholm and Kola
- It is confirmed that the event is the largest historical event in Fennoscandia with M=5.9±0.2

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