ON THE NEAR FIELD EARTHQUAKE MOTION IN INTRAPLATE ENVIRONMENTS

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SUMMARY

The characteristics of intraplate earthquake ground motion were studied in Scandinavia through seismic records of the national and special purpose arrays. The recordings of small to medium size earthquakes were interpreted in terms of two source parameters: the seismic moment and the corner frequency. Comparison with California data indicates smaller source dimensions and larger stress drops. The comparison also indicates similar trends between Scandinavia and the Transverse Ranges in California and suggests that intraplate ground motion is represented in the California strong motion data set by events like the February 9, 1971 San Fernando earthquake.

INTRODUCTION

Statistical sets of strong ground motion parameters are obtained from high seismicity areas where the yield of strong motion records is high. In assessing seismic risk in low seismicity areas one is always faced with the question : how relevant for a site in a low seismicity environment are statistical correlations developed in high seismicity areas?

It is clear that there are differences in low level earthquake motion between high seismicity interplate and low seismicity intraplate environments. For example, attenuation of peak ground motion is slower in intraplate areas (Herrmann & Nuttli, 1975) with obvious implications in high probability design. For low probability design (e.g. nuclear installations) other parameters, like the focal depth and the characteristics of the seismic source become more important. It has been suggested, for example, that intraplate seismic sources are smaller and generate higher frequency motion (Nuttli & Herrmann, 1978). Differences in source characteristics cannot be studied on the basis of a single parameter, e.g. the magnitude of the earthquake. More parameters are necessary in order to account for the amount of dislocation and the size of the seismic source. Two parameter models have been suggested such as two different magnitudes (say M_b and M_s) or a seismic moment M_o and a corner frequency f_o. Both of the above two-parameter descriptions are generally possible for high as well as low seismicity areas, on the basis of far field data.

This presentation is concerned with near field earthquake motion: a two parameter model is employed in order to compare an intraplate area, namely Scandinavia, with an interplate area, namely California. The comparison is performed on a $\log M_o - \log f_o$ chart : on this chart every earthquake is represented by a point and an area is characterised by the locus of the corresponding points. Care was taken to determine the source parameter in a similar manner in order to have a valid comparison between the two areas.

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THE SET OF INTRAPLATE DATA

The earthquakes considered in the analysis are shown on Fig. 1 together with the national seismic networks and special arrays in operation in Scandinavia. The national seismic networks comprise short period instruments with response peaked at around 1Hz whereas in the special purpose arrays the instruments have a flat response for a wider range of frequencies (Fig.2). Event 1 on Fig. 1 is the 1904 Oslo earthquake; this event was recorded by many stations in Europe, and has been assigned an instrumental magnitude M_sN6.0 (Papastamatiou, 1977). However, only the Leipzig seismogram, recorded by a Wiechert instrument, was available and the interpretation of this event was based on this record alone. The characteristics of the Wiechert seismograph are compared to the corner frequencies of Scandinavian events on Fig. 2. The rest of the events were analysed on the basis of recordings by the national network in Sweden or the special arrays, operated by FOA and NORSAR.

The registrations were Fourier analysed and interpreted in terms of a flat low frequency asymptote Q_o and a corner frequency f_o on a log-log plot. An example of the interpretation is shown on Fig. 3. The spectra on this figure are average power spectra derived by NORSAR from 6 NAO registrations of event 14. The spectra represent separately the P and S phases of the earthquake and are contaminated by noise outside the frequency window 0.7 to 6Hz; for this particular event the noise introduces substantial uncertainty to the determination of both Q_o and f_o. The high frequency asymptote for this event is -3 whereas the ratio of the two corner frequencies is 1.68, in reasonable agreement with Minster's theoretical prediction (Minster, 1974) :

$$\frac{f_{o,p}}{f_{o,s}} = \left(\frac{V_p}{V_s}\right)^{2/3} = \left(\frac{6.5}{3.5}\right)^{2/3} = 1.5 \qquad \text{(Eq. 1)}$$

where V stands for the phase velocity of propagation and subscripts p and s for the P and S phase respectively.

COMPARISON WITH INTERPLATE DATA

The Scandinavian events are compared to Californian events on a $\log M_o$-$\log f_o$ plane on Fig. 4. The Scandinavian points on this figure were determined from the pairs Q_o, f_o described in the previous paragraph. The corresponding points on the $\log M_o$-$\log f_o$ plane were obtained from a predominantly shear phase following the method described in Hanks & Thatcher (1973), i.e. according to the formula:

$$M_o = 4\pi\rho V_s^3 \, Q_o \; R/0.85 \qquad \text{(Eq. 2)}$$

Where M_o = seismic moment

ρ = density

V_s = shear wave velocity

R = epicentral distance

As the slope of the high frequency asymptote was found, insensitive to distance from the epicentre, no correction was applied for inelastic (frequency dependent) attenuation. The accuracy of the determinations is indicated on Fig. 4 by the two pairs of linked points; these points correspond to determinations of the same event from two different arrays.

Four sets of data appear on Fig. 4:

1. Theoretical curves, following Brune's two-parameter model, (Brune, 1970) for constant stress drop 6.= 0.1, 1.0, 10.0 and 100.0 bars.

2. An average curve obtained from the analysis of Californian data by Trifunac (1976).

3. A subset of Californian data, namely events from the Transverse Ranges, from Hanks & Thatcher (1973).

4. The set of Scandinavian events with an average curve fitted to them. The October 25, 1976 earthquake is reproduced on the basis of the parameters determined by Slunga (1979); this earthquake was not considered in drawing the average curve for Scandinavia. The large moment event corresponds to the 1904 Oslo earthquake and is poorly determined from spectral analysis of a single record.

Comparison of the four different sets on Fig. 4 suggests that Scandinavian events are associated with larger stress drops and smaller size sources than Californian interplate earthquakes. However, the differences become smaller as the seismic moment increases. The large moment part of the Scandinavian curve is in agreement with the worldwide intraplate data presented by Kanamori & Anderson (1975). In this publication the authors commented on the common features of the San Fernando, 1971 earthquake and large intraplate events. That prompted the comparison of the Scandinavian data with events from the Transverse Ranges in California where the San Fernando earthquake belongs. The comparison shown on Fig. 4 confirms the similarity on a $\log M_o - \log f_o$ plane and for medium and small magnitude earthquakes.

DISCUSSION

Comparison of an intraplate with an interplate area points to similarities and differences in source mechanisms. The comparison shows that small intraplate events are associated with smaller size sources and larger stress drops; this indication is in agreement with the high frequency motion recorded in the epicentral area of small magnitude intraplate earthquakes, e.g. South Germany. The differences, however, become smaller for larger size events. For the largest events expected in intraplate environments worldwide data indicate stress drops in excess of 100 bars whereas the bulk of interplate events are associated with stress drops in the range 10 to 100 bars.

The simplified two-parameter source model is not adequate to predict ground motion in the near field of intraplate earthquakes on the basis of differences with interplate events. Increasing the number of source parameters, on the other hand, is not justified due to the scarcity of instrumental data from intraplate environments. With respect to the needs of engineering design a positive indication is provided by the similarity between events in Scandinavia and the Transverse Ranges in California. The similarity was found in comparing source mechanisms of the two regions and suggests that near field earthquake motion in intraplate environments is represented in the Californian strong motion data set. This representation becomes weak as one moves away from the source where differences in attenuation have been demonstrated between different seismic environments (Herrmann & Nuttli, 1975).

ACKNOWLEDGEMENTS

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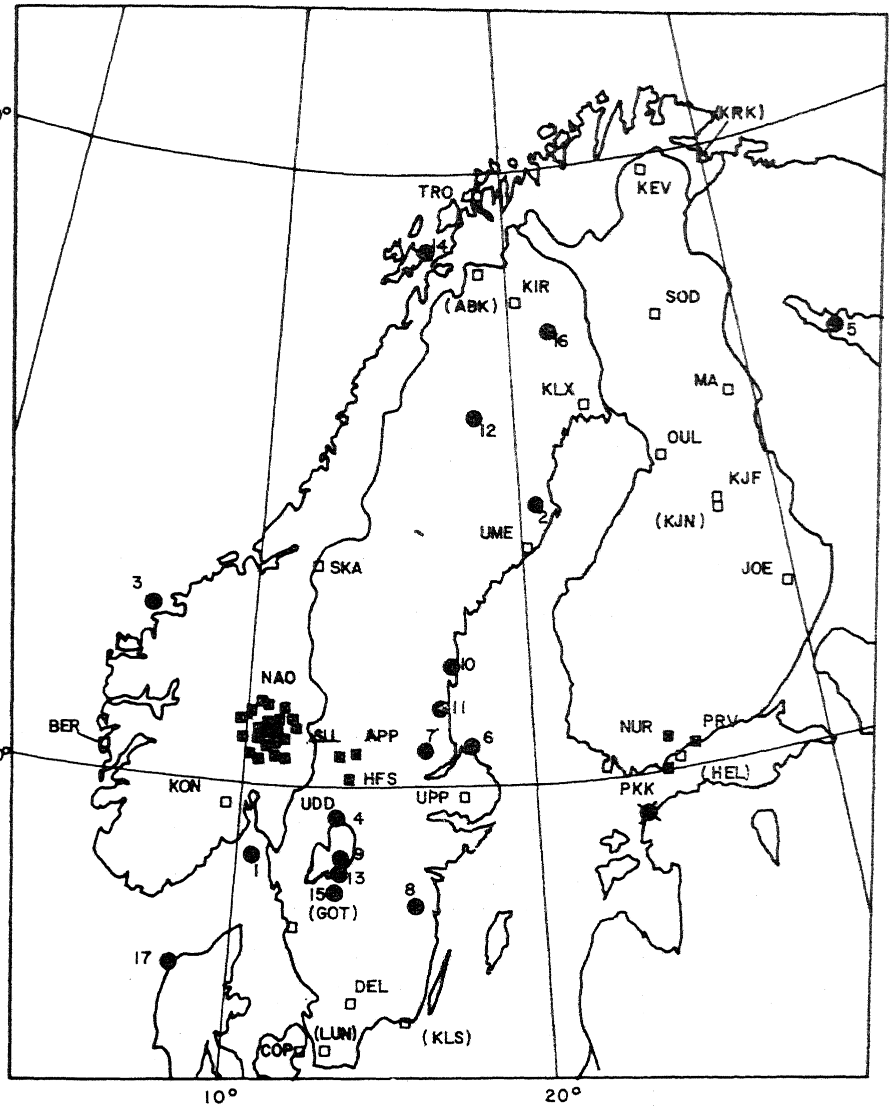

▫ NATIONAL SEISMIC NETWORKS

▪ SEISMIC ARRAYS

● EVENTS USED IN THE ANALYSIS

✱ OCTOBER 25, 1976 EARTHQUAKE

FIG. 1. SEISMIC STATIONS AND EARTHQUAKES CONSIDERED IN SCANDINAVIA

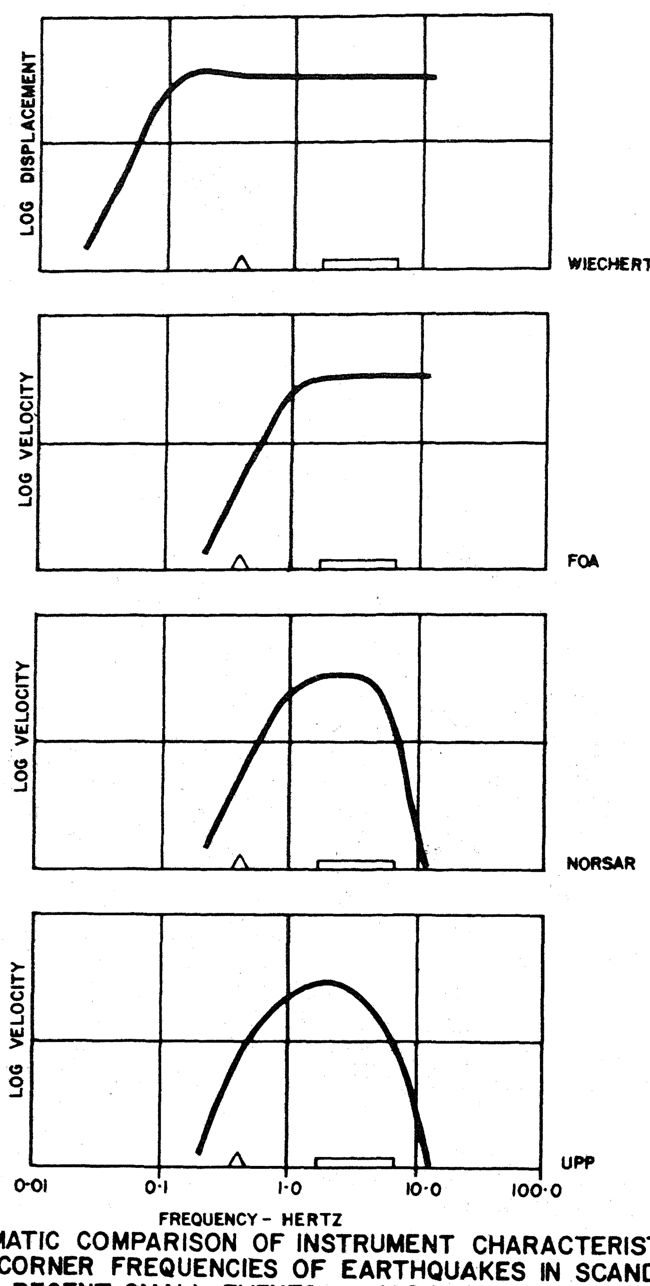

FIG. 2. SCHEMATIC COMPARISON OF INSTRUMENT CHARACTERISTICS WITH CORNER FREQUENCIES OF EARTHQUAKES IN SCANDINAVIA (▭ RECENT SMALL EVENTS, △ 1904, OSLO EARTHQUAKE)

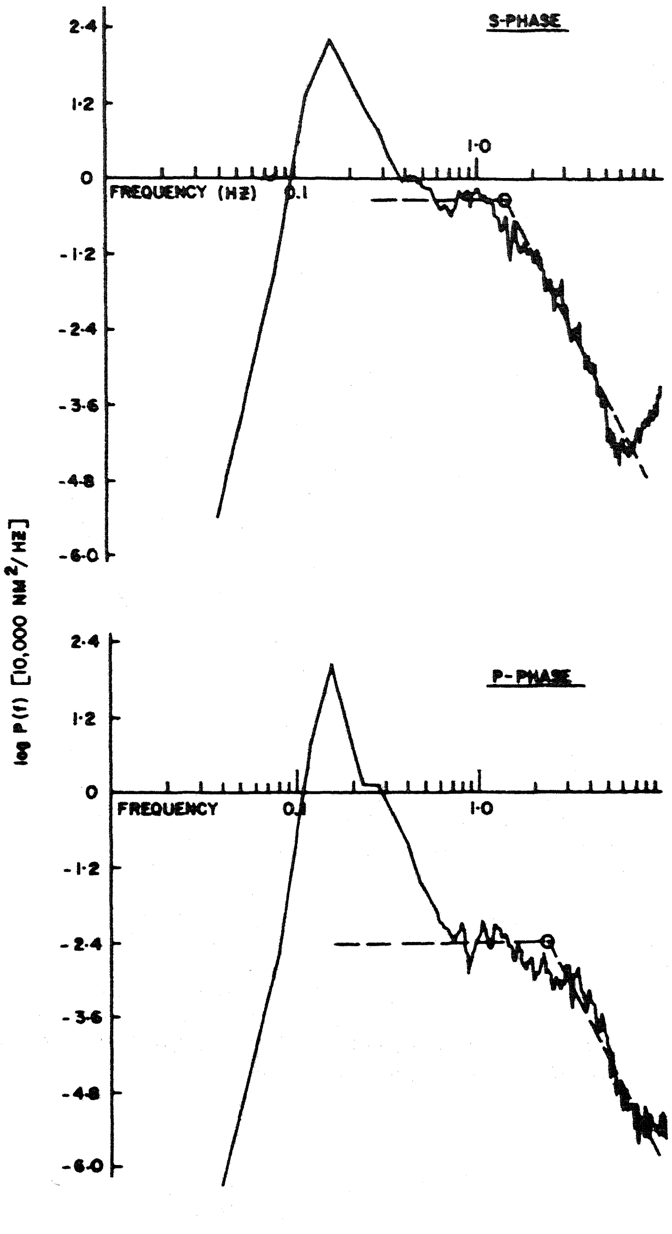

FIG. 3. POWER SPECTRA FOR EVENT 14

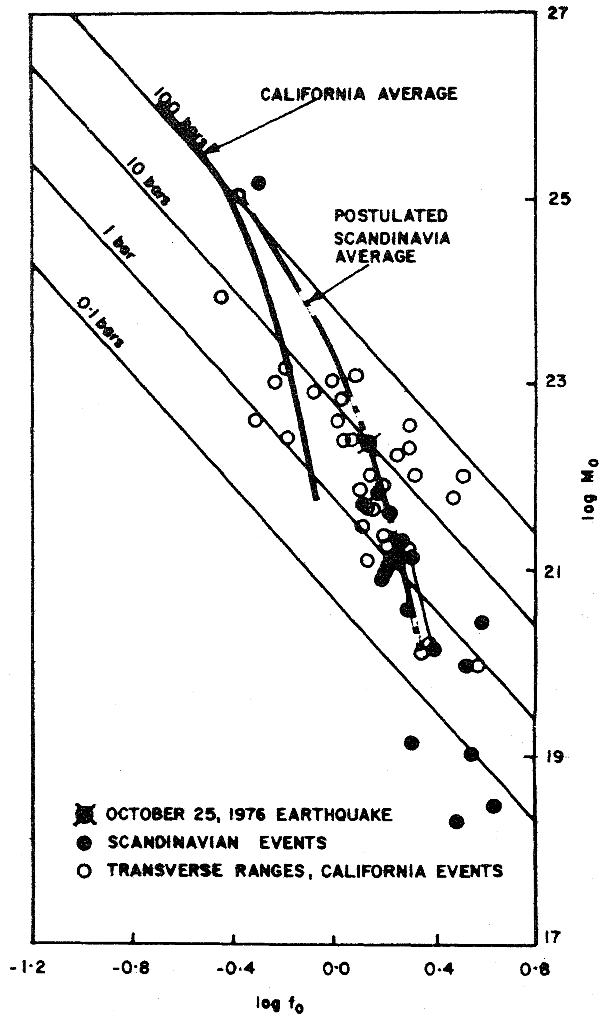

FIG. 4. TWO PARAMETER REPRESENTATION OF EARTHQUAKES IN SCANDINAVIA AND CALIFORNIA.