POLISH POLAR RESEARCH	11	3—4	277—285	1990

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Seismicity of Spitsbergen Platform and its relation to geotectonics of the region

ABSTRACT: An analysis of seismic shocks from the Heer Land and the Nordaustlandet was made (shocks recorded by the *Hornsund* seismological station). Kinematic models and synthetic seismograms were constructed. A system of horizontal discontinuities located in the upper mantle was assumed. A good agreement between observational data from the seismograms and theoretical results was obtained.

Key words: Arctic, Spitsbergen, seismicity, geotectonics.

Introduction

The Barents Sea shelf is a young structural element of the Earth's crust of a platform character. Its regions nearby the continental slopes and areas densely traversed by faults are the sites of structural transformations responsible for considerable seismic activity. Earthquakes in the Svalbard region are to be interpreted as reactions — along local weakening zones — on regional stress field associated with the tectonics of lithospheric plates.

In the region of Spitsbergen there are three major zones of seismic activity (*see* Fig. 1). Two of these are located around the Heer Land and Nordaustlandet (Mitchell 1983, Bungum and Kristoffersen 1980, Chan and Michell 1985, Górski 1985). The seismicity of these two regions, densely intersected by faults (Ohta 1982) is related to structural transformations. Worth mentioning is the conformity in the location of displacement planes in earthquake foci models and general directions of faults in these regions (Bungum 1980; Chan and Mitchell 1985). The third seismically active zone is west of the continental slope. Earthquakes occuring there are associated with the rift zone of the so-called Knipovich ridge. Apart from these regions, some weak seismicity is observed in many places over Spitsbergen. Foci of these weak shocks are also located in the close vicinity of the *Hornsund* Station (Górski 1986).

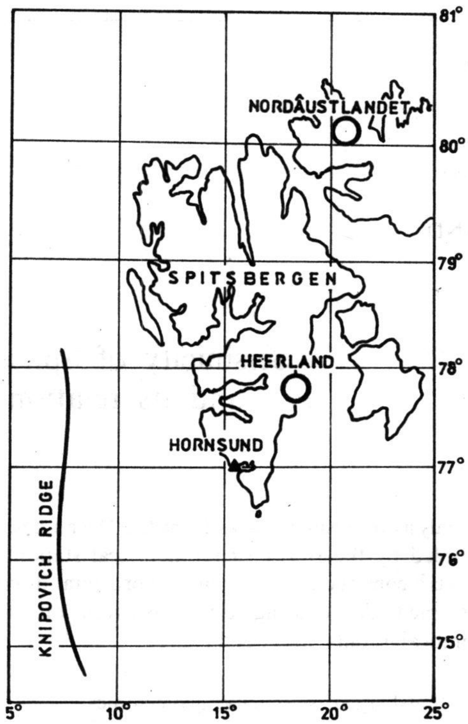

Fig. 1. Location of the Heer Land and Nordaustlandet seismic regions

Kinematic model of the Earth's crust

Data on the Earth's crust structure in the Spitsbergen region come from two Polish geophysical expeditions, in 1976 and 1978. This was the basic for the seismic model developed for the area (Guterch *et al.* 1982: Fig. 7.12). This model for the central part of Spitsbergen was applied to dynamical analysis made in the present work. The earthquakes with epicentres located in the Heer Land region, recorded at the *Hornsund* Station were analysed (Górski and Perchuć 1987). All the epicenters in question are located close to one another. The epicentral distance of all these earthquakes is nearly the same and amounts to some 110 km. The similarity of seismograms gives grounds for believing that all analysed earthquakes which were generated by a source in the Heer Land are of the same type. A detailed analysis was made for a group of P-waves. Four phases, P1-P4, associated with the crustal structure of central Spitsbergen, were separated (Fig. 2b). Using the seismic model mentioned above, a kinematic model (Fig. 3) was fitted so as to have proper time relations of interpreted phases P1-P4. Several models and travel-times associated with them have been calculated assuming different source depths at horizontal

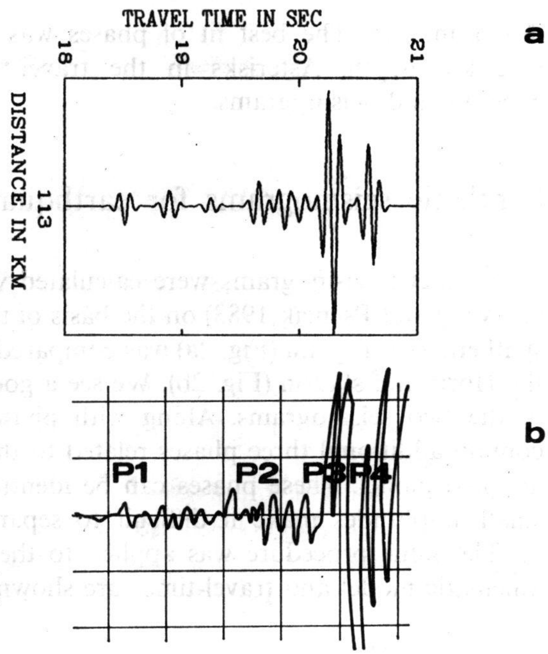

Fig. 2. Comparison of the seismogram recorded at the *Hornsund* Station (b) and the synthetic seismogram (a)

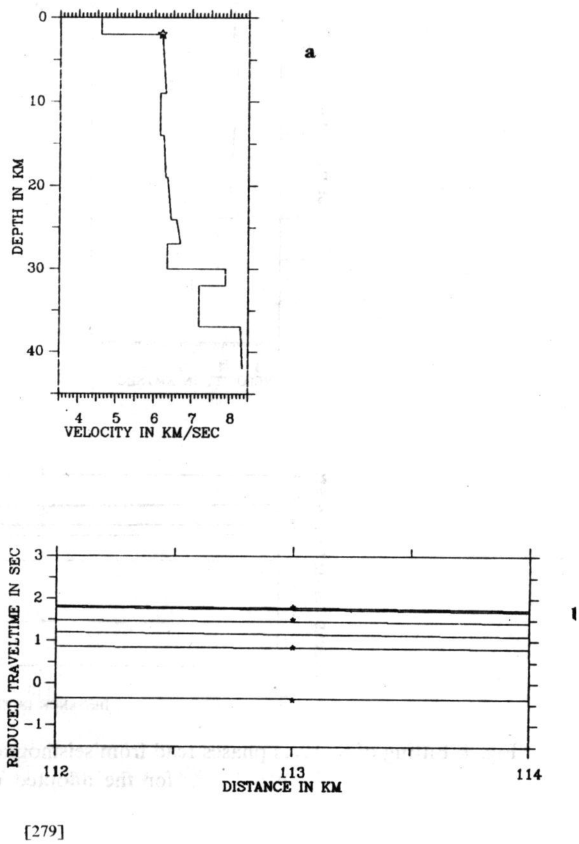

Fig. 3. Fitting of phases P1-P4 read from the seismogram (asterisks) to the travel-time (b) calculated for the adopted model (a)

discontinuities. The best fit of phases was obtained for a source placed at a 2 km depth. Asterisks in the travel-times mark phases P1-P4 from experimental seismograms.

Synthetic seismograms for earthquakes from Heer Land

Synthetic seismograms were calculated with the use of program SEIS 83 (Cerveny and Psencik 1983) on the basis of the kinematic model of Fig. 3. The synthetic seismogram (Fig. 2a) was compared with the seismogram recorded at the Hornsund station (Fig. 2b). We see a good time and amplitude agreement of the two seismograms. Along with phases P1-P4, synthetic seismograms contain additional three phases related to the respective discontinuities in the adopted model. These phases can be identified is some recordings, but their small amplitudes make it difficult to separate them.

The same procedure was applied to the group of S waves; the obtained kinematic model and travel-times are shown (Fig. 4). A synthetic seismogram

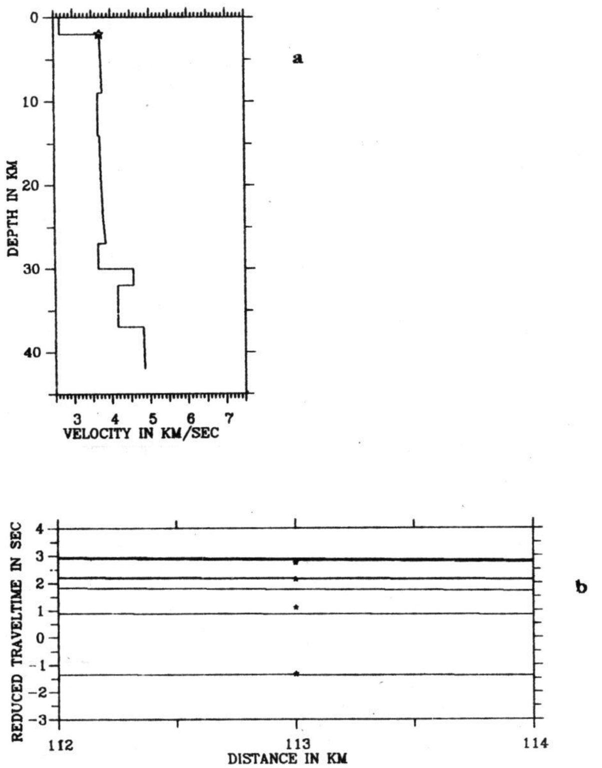

Fig. 4. Fitting of S waves phases read from seismogram (asterisks) to the travel-time (b) calculated for the adopted model (a)

was computed and compared with those recorded at the *Hornsund* Station (Fig. 5). The conformity of seismograms is good. Some differences in synthetic seismograms of the P-wave group (Fig. 2a, 5) are a consequence of the assumption of different periods of waves. The seismogram (Fig. 5) was calculated with the period corresponding to the S-wave group.

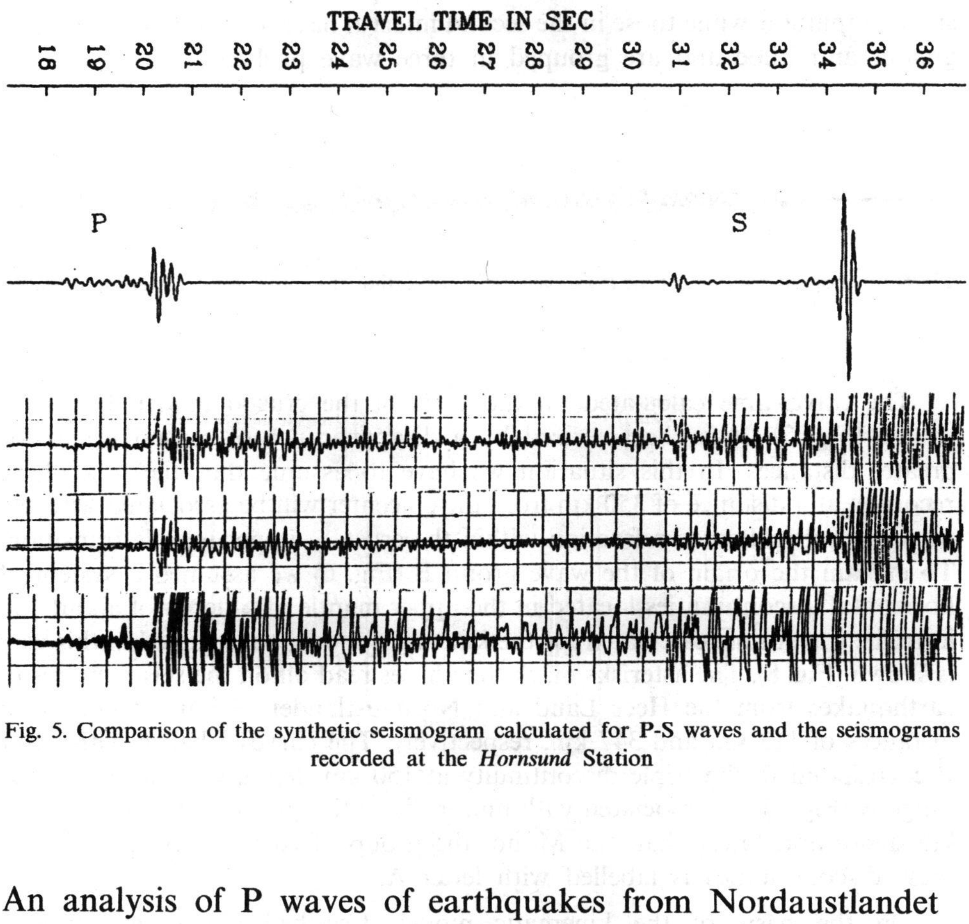

Fig. 5. Comparison of the synthetic seismogram calculated for P-S waves and the seismograms recorded at the *Hornsund* Station

An analysis of P waves of earthquakes from Nordaustlandet

A similar methodological procedure was applied to earthquakes from Nordaustlandet recorded at the *Hornsund* Station. The azimuth of the Nordaustlandet group of earthquakes determined from the *Hornsund* Station is by about 20 less than that of the Heer Land group. Thus, the seismic waves from Nordaustlandet earthquakes recorded at Hornsund run through the central part of Spitsbergen as well, and it seems reasonable, while analysing the course of these waves in the crust, to use the same model as that adopted for the Heer Land earthquakes (Fig. 3).

The Nordaustlandet group of earthquakes is about 350 km away of the *Hornsund* Station. A sample seismogram of an earthquake from this region recorded at Hornsund is shown (Fig. 6). The P and S waves are clearly singled out. Further analysis is made for the P wave group in the range of the first 12 seconds. In this group one can distinguish two characteristic intervals: the first one of 7—8 s duration (A) and the other of approximately 3 s duration (B). The oscillations recorded in the first interval have a period of 0.25 s and a relatively small amplitude, while those in the second interval have a period of 0.4 s, much greater amplitude and are grouped in three wave packets.

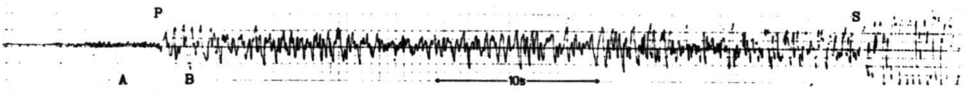

Fig. 6. Seismogram recorded at the *Hornsund* Station of aerthquake with epicenter in Nordaustlandet

The travel-time calculated on the basis of the crustal model (Fig. 3) is shown (Fig. 7). It is characterized by a disappearance of crustal waves for greater distances. In this situation we have to assume that the first phase recorded at a distance of 350 km from the epicenter will be associated with the wave packet related to refraction within the crust — upper mantle transition. To explain the origin of the wave group B (Fig. 6) we assumed a system of horizontal discontinuities located in the upper mantle at a depth of about 150 km. The travel-time calculated for the kinematic model constructed in this way is shown (Fig. 8). The asterisks mark the phases read off on the seismograms of earthquakes from the Heer Land and Nordaustlandet regions at epicentral distances of 113 km and 347 km, respectively. The curves labelled with letter B correspond to the triple discontinuity at 150 km depth. Oscillations in the range A (Fig. 6) are associated with minor discontinuities located above a 150 km depth and lower than the Moho; the group of curves corresponding to these discontinuities is labelled with letter A.

On the basis of the kinematic model described above, a synthetic seismogram was calculated and compared with seismograms recorded at Hornsund (Fig. 9). One sees a good time and amplitude conformity of the seismograms. The lack of frequency differentiation on the synthetic seismogram results from the fact that it was necessary to adopt the same frequency of oscillations for the whole seismogram, and at the same time to compute the seismogram with program SEIS 83.

Another possibility of interpretation of the seismogram (Fig. 6) is to assume multiple reflections within the crust. The analysis made for such reflections, however, has not yielded satisfactory results.

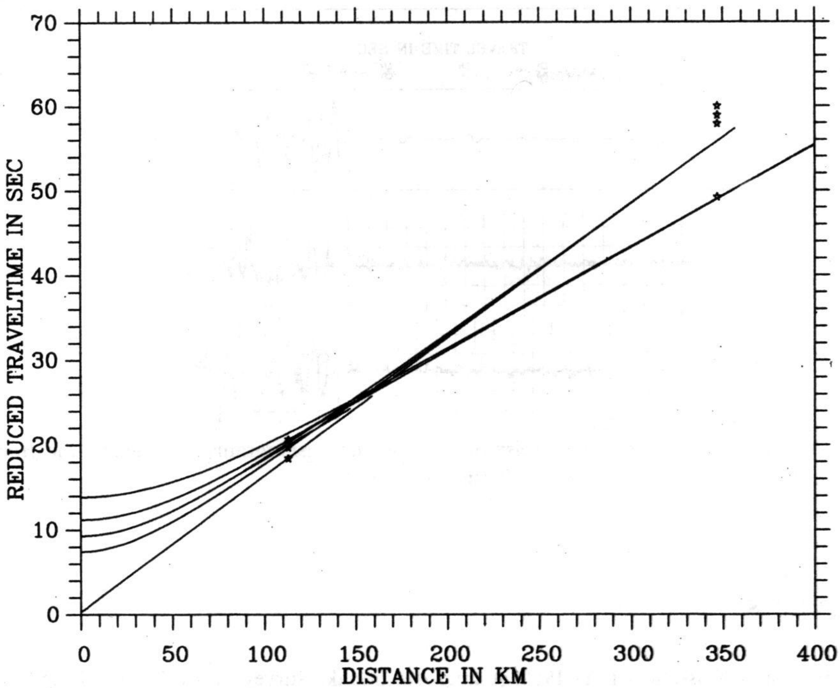

Fig. 7. The travel-time calculated for distance 0—400 km (crust model fig. 3, asterisks — phases read from the seismograms)

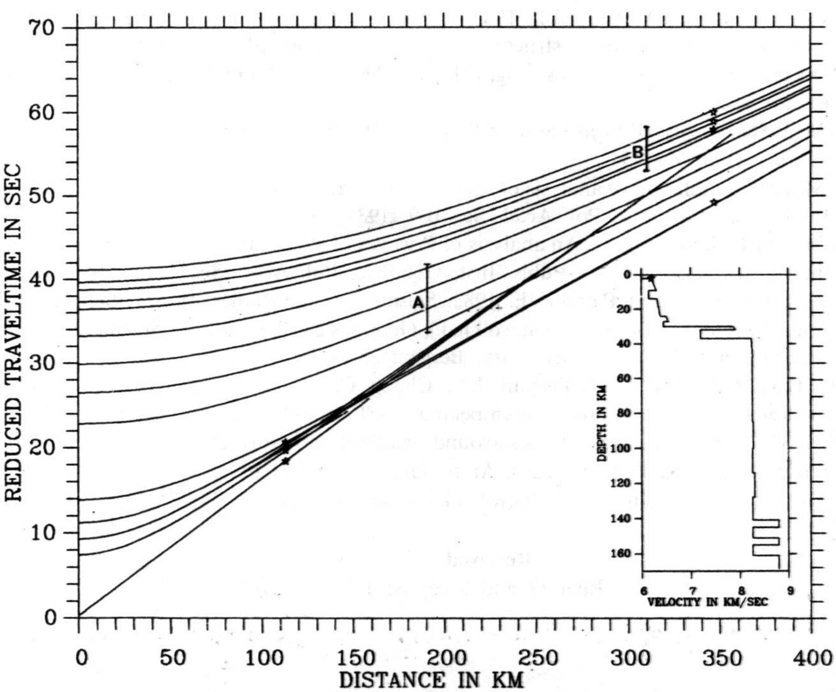

Fig. 8. The travel-time calculated for kinematic model with horizontal discontinuities at depth of 150 km (asterisks — phases read from the seismograms)

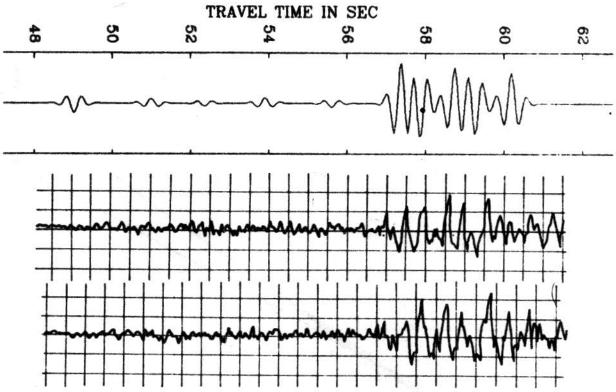

Fig. 9. Comparison of the synthetic seismogram and the seismograms recorded at the *Hornsund* Station (P waves)

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Received July 5, 1990
Revised and accepted July 20, 1990

Streszczenie

W pracy przeanalizowano wstrząsy sejsmiczne, pochodzące z obszaru Ziemi Heera i Ziemi Północno-Wschodniej, zarejestrowane na stacji *Hornsund* (fig. 1). Skonstruowano modele kinematyczne (fig. 3—4), a na ich podstawie sejsmogramy syntetyczne (fig. 2, 5). Przyjęto układ horyzontalnych nieciągłości w górnym płaszczu (fig. 8). Otrzymano dobrą zgodność pomiędzy danymi obserwacyjnymi i wynikami teoretycznymi (fig. 9).

Badania prowadzono w ramach CPBP 03.03.