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Observations of sPn From Swabian Alb Earthquakes at the GRF Array

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A number of the largest earthquakes from the Swabian Alb recorded at the Gräfenberg array have been examined (the geographic coordinates of the main station GRF are 49.69° N and 11.22° E; see Harjes and Seidl (1978) for a description of the array). The interest was concentrated at the time window between the first onset Pn and Pg. In Fig. 1 are shown GRF records proportional to ground displacement of five events which have indications for a second arrival between Pn and Pg. The parameters for these five events are given in Table 1. The amplitudes of Pg in Fig. 1 are clipped only for the plotting purpose. The seismograms in Fig. 1 are plotted in form of seismogram sections, as it is common in explosion seismology. Only for this purpose, the known epicenter of the large earthquake of September 3, 1978, is adopted for all earthquakes. The phase between Pn and Pg, labeled sPn, is clearly visible for the largest events, and it is getting weaker for smaller events. The magnitude 4.1 event at September 3, 1978, at 08:10 and a few more smaller events have also been examined without success, in order to detect this phase. The reason for that was an unfavorable signal to noise ratio. However, it seems possible that more sophisticated data processing methods lead to better results. The time difference sPn-Pn is about 2.6 s for the events 2 and 3, and it is about 1.0 s for the remaining three events. This variation of the sPn-Pn times rules out the possibility that structural effects have caused the phase labeled sPn. Another possibility is, that a second shock is responsible for this phase. In order to check the sPn hypothesis, theoretical seismograms have been computed using the buried source version of Fuchs' reflectivity method by Kind (1978) and Kind (1979). The ray path of Pn and sPn is demonstrated in Fig. 2. In Fig. 3 are shown sections of theoretical seismograms for several possible source orientations (Götz Schneider, personal communication). The used crustal model is a simplified version of model I by Aichele (1976), derived from explosion seismol-

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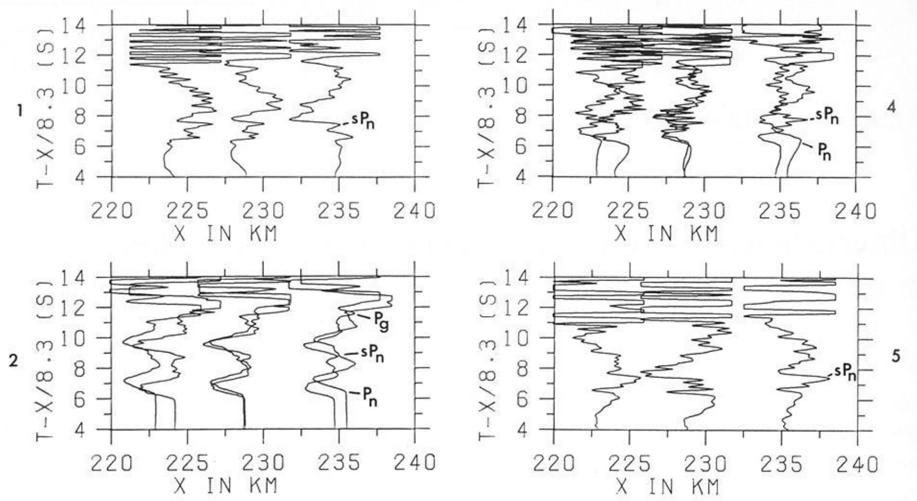

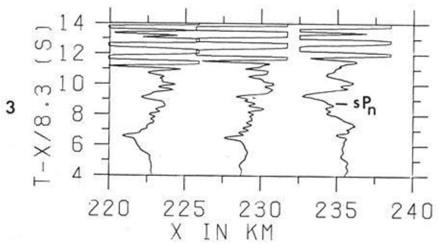

Fig. 1. Vertical displacement component observed at the GRF array for the five events listed in Table 1

Table 1

Event	Date	Pn time at GRF	Magnitude (GRF)	Filter	Subarray
1	16. January 1978	143147.7	4.6	HP	A
2	03. September 1978	050904.7	5.9	BB	A+B
3	03. September 1978	053452.5	4.3	HP	B
4	03. September 1978	100316.6	4.7	BB	A+B
5	19. September 1978	235421.4	4.1	HP	B

Parameters of the Swabian Alb events used. HP = simulated records of a 2 s displacement proportional seismometer, BB = broad band displacement proportional. The three stations 1, 2, and 3 of the subarrays A and B are used

ogy for an area about 70 km west of GRF. The observed Pg-Pn times are about 1 s larger than the ones taken from the theoretical section. Because this point is not relevant for the present purpose, it will not be pursued further. The time difference sPn-Pn in the theoretical Section 1 in Fig. 3 is about 1 s, very similar to the observed values for the events 1, 4, and 5. This leads to a focal depth of about 2.5 km. The source orientation is typical for Swabian Alb events (strike slip, strike of the fault plane N 15° E, dip 80° W). Theoretical

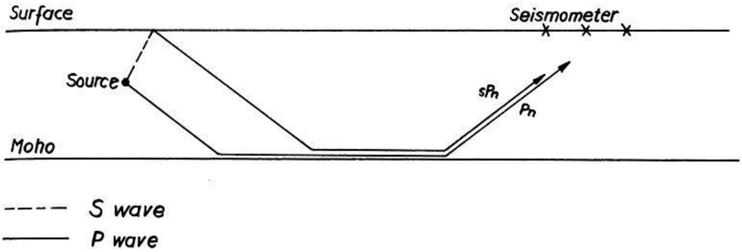

Fig. 2. Ray path of Pn and sPn

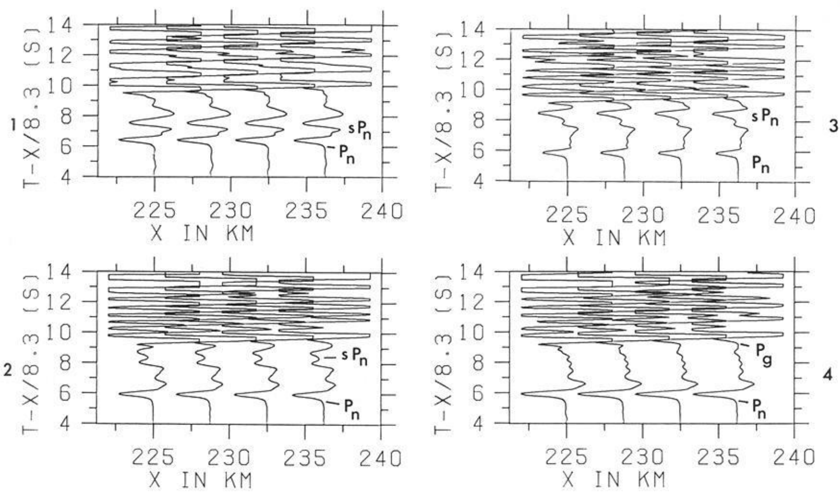

Fig. 3. Theoretical seismograms for comparison with the data shown in Fig. 1. Section 1: $h=2.5$, $\lambda=0$, $\delta=80$. Section 2: $h=6.5$, $\lambda=0$, $\delta=80$. Section 3: $h=6.5$, $\lambda=-10$, $\delta=80$. Section 4: $h=6.5$, $\lambda=0$, $\delta=60$. With h=source depth in km, λ=slip vector down negative in degrees, δ=dip of the fault plane to the west in degrees. The strike of the fault plane was N 15° E in all sections

seismograms for the same source orientation, but with a source depth of 6.5 km are plotted in section 2, Fig. 3. The amplitudes of sPn are clearly smaller than the amplitudes of Pn. There is another phase about 1 s in front of sPn. This is a phase very similar to sPn, but reflected from an assumed first order discontinuity between the sediments and the basement instead at the free surface. In Sect. 3, Fig. 3 has sPn about the same amplitudes, as it is observed. The phase about 1 s in front of sPn is very much reduced in its amplitudes. The first order discontinuity between sediments and basement was replaced by a gradient zone in this section. The dip of the fault was assumed 80° W, and the slip vector was assumed to have a dip of 10° down. The time difference sPn-Pn is about 2.6 s, like for the observed events 2 and 3. In Sect. 4, Fig. 3 are shown theoretical seismograms for another possible source orientation: pure strike slip and fault dip 60° W. However, in this section is no sPn visible. This source orientation can therefore probably be excluded, which narrows the error bounds of the fault plane solution. In conclusion it has been shown that the GRF records of some of the largest Swabian Alb earthquakes have a clear additional arrival between Pn and Pg. It can be said, that the inpretation of this arrival as sPn is at least for the large earthquake (event 2) in good agreement with focal parameters determined by traditional methods. For another earthquake (event 5) is the focal depth 4–5 km, according to a referee's comment, whereas 2.5 km result from the present study. This disagreement requires further studies of several kinds of data.

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