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VI.3 Automated Arrival Time Determination for Local and Regional P and S Waves

Microearthquake arrays quite often have a detectability down to zero or below in local magnitude (cf. Section VI.6). This means that even for intermediately active areas the number of recorded earthquakes may be substantial, quite often many thousand in a single year. The routine work connected to the analysis of such data may therefore be substantial, with large potential gains if the procedure can be automated.

Our approach to the problem has been to compute signal envelopes following a procedure outlined by Levshin et al (1972). After an initial inverse Fourier transform a bandpass filter is applied (in frequency domain), and the envelope is computed as the absolute value of a complex function where the real part is the output of the filter and the imaginary part is its Hilbert Transform. The time of computation is speeded up significantly by a folding procedure by which the sampling rate of the initial Fourier transform is reduced n times, the effect on the envelope being to avoid oversampling and to introduce smoothing.

Given the envelopes covering a certain time interval for each trace, the next step is to detect signal arrivals. This is done by computing STA/LTA ratios, where we initially have used window lengths of 0.2 and 1.67 sec, respectively (30 Hz sampling rate). This is followed by an iterative detection procedure in which the following parameters have been used, and where a detection is declared if P out of Q values of STA/LTA exceed the given threshold:

Iteration	Threshold	P/Q
1	1.55	5/9
2	2.00	3/5
3	3.50	2/4

These parameter values have been chosen for the following reasons:

In iteration 1, the threshold is low in order to be sensitive to first arrivals, and P and Q are large in order to avoid spike detections. Also, in this iteration it usually takes a long time to leave detection state, and until then a new detection cannot be declared. This means that only very strong and late second arrivals can be picked up, illustrated by the bottom event in Fig. VI.3.1. We see that all the S arrivals for this event are correctly determined, and note especially that we have been able to avoid the large secondary P arrival for Channel 5.

Iterations 2 and 3 are only entered if for a given channel only one detection has been declared in previous iterations. In this case we start the search following detection 1. This means a higher sensitivity for events with short S-P times, which is the case for the two top events in Fig. VI.3.1. Some of the S phases there are determined in the second, and some in the third iteration. For Event 1 one of the S phases is incorrectly determined (Ch. 6) and one is not found (Ch. 3). For Event 2 one S is possibly wrong (Ch. 3), one S has not been found (Ch. 7), and since P is not seen on Ch. 6 the S phase has been called P by the automatic procedure.

It is of course necessary that a procedure like this is followed by manual control and editing. However, provided that data files with the appropriate format are established in the automatic analysis for each event, the editing time can be very short compared to a manual analysis from scratch. A procedure like that is under establishment for our data from the Stiegler's Gorge Seismic Network, and we plan to use it also for data from the microearthquake network now under establishment in Southern Norway. So far, the procedure has not been tested on a larger number of events, and it is quite likely that this will lead to changes in the parameter values given above, maybe also to the procedure as such.

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References

Levshin, A.L., V.F. Pisarenko and G.A. Pogrebinsky, 1972: On a frequency-time analysis of oscillations. Ann. Geophys., 28, 211-218.

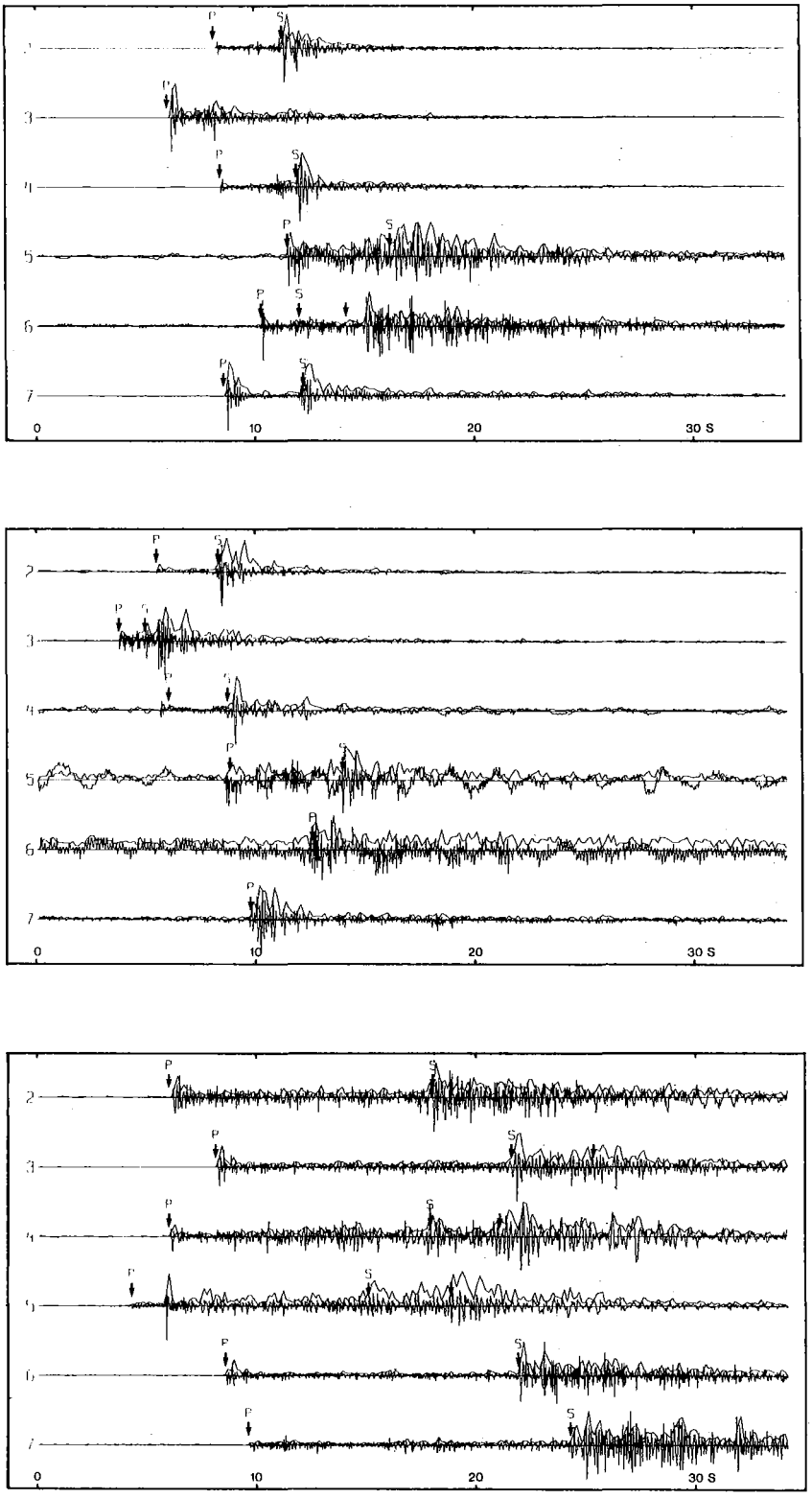

Fig. VI.3.1 Automatically determined P and S waves for three local events recorded at the Stiegler's Gorge Seismic Network. The data traces are unfiltered while the plotted envelopes are based on data filtered between 2 and 8 Hz.