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FINAL TECHNICAL SUMMARY

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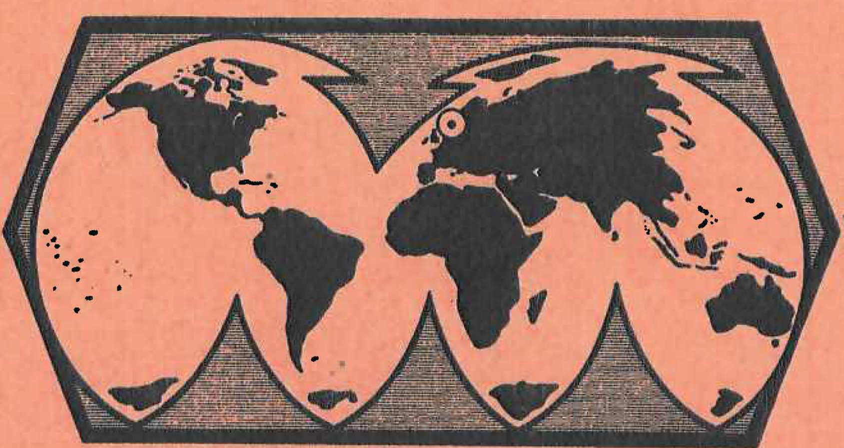

VI.7 Short-period Discrimination Using Multivariate Autoregressive Representation of P-waves

It is shown that seismic P-wave vector signals as recorded by selected NORSAR subarrays can be described by multivariate parametric models of autoregressive type. These are models having the form

$$\underline{X}(t) - A_1\underline{X}(t-1) - \ldots - A_p\underline{X}(t-p) = \underline{W}(t) \qquad (1)$$

where $\underline{X}(t)$ is the digitized short-period (SP) vector time series defined by the P-wave signal and $\underline{W}(t)$ is a white noise vector time series. The multivariate autoregressive analysis is undertaken for 83 presumed explosions and 72 earthquakes from Eurasia (see Figs. VI.7.1 and VI.7.2) using subarrays 01A, 02C and 04C. For each event a separate analysis of the main signal and of the coda has been carried through. Using the multivariate FPE criterion it is found that in most cases a reasonable statistical fit is obtained using a low order autoregressive model. The autoregressive parameters characterize the spectral density matrix of the P-wave signal and therefore form a convenient basis for constructing SP discriminants between earthquakes and explosions.

We decided to fit a second order model to each of the coda and signal series. This means that we have 2•2•3•3=36 purely autoregressive parameters from the matrices A_i and 2•6=12 parameters from the covariance matrices $K=E\{W(t)\ W(t)^T\}$ for the coda and signal residual series. The parameters of the K-matrices were replaced by one SP scaling parameter, namely, m_b. Thus we end up with a primary feature vector $\underline{Y}$ of dimension 37. This parameter vector was subsequently reduced to a 9-dimensional secondary feature vector using principal component analysis. Finally we used the classifier $S_1(\underline{Z})-S_2(\underline{Z})$ given in formula (3) of Tjøstheim (1977).

For matters of comparison we treated the m_b:M_s data and the a_{31}:a_{32} discriminant of Tjøstheim (1975) in a similar way. From Fig. VI.7.3 it is seen that the new multivariate autoregressive discriminant has a substantially larger discrimination potential than the parameters a_{31}, a_{32}.

The $a_{31}:a_{32}$ discriminant on the other hand is thought to be fairly representative for most SP discriminants proposed in the literature; compare Dahlman and Israelson (1977, p. 248). Moreover, a comparison with the $m_b:M_s$ data on Fig. VI.7.3 indicates that it may now be possible to construct purely SP discriminants which are comparable, if not superior, to the $m_b:M_s$ criterion.

O.A. Sandvin and D. Tjøstheim

References

Dahlman, O., and H. Israelson (1977): Monitoring Underground Nuclear Explosions, Elsevier, Amsterdam.

Tjøstheim, D. (1975): Autoregressive representation of seismic P-wave signals with an application to the problem of short-period discriminants, Geophys. J. R. Astr. Soc., 43, 269-291.

Tjøstheim, D. (1977): A pattern recognition approach to seismic discrimination. Part II: Classification, Semiannual Technical Summary, NORSAR Sci. Rep. No. 2-76/77, 61-63.

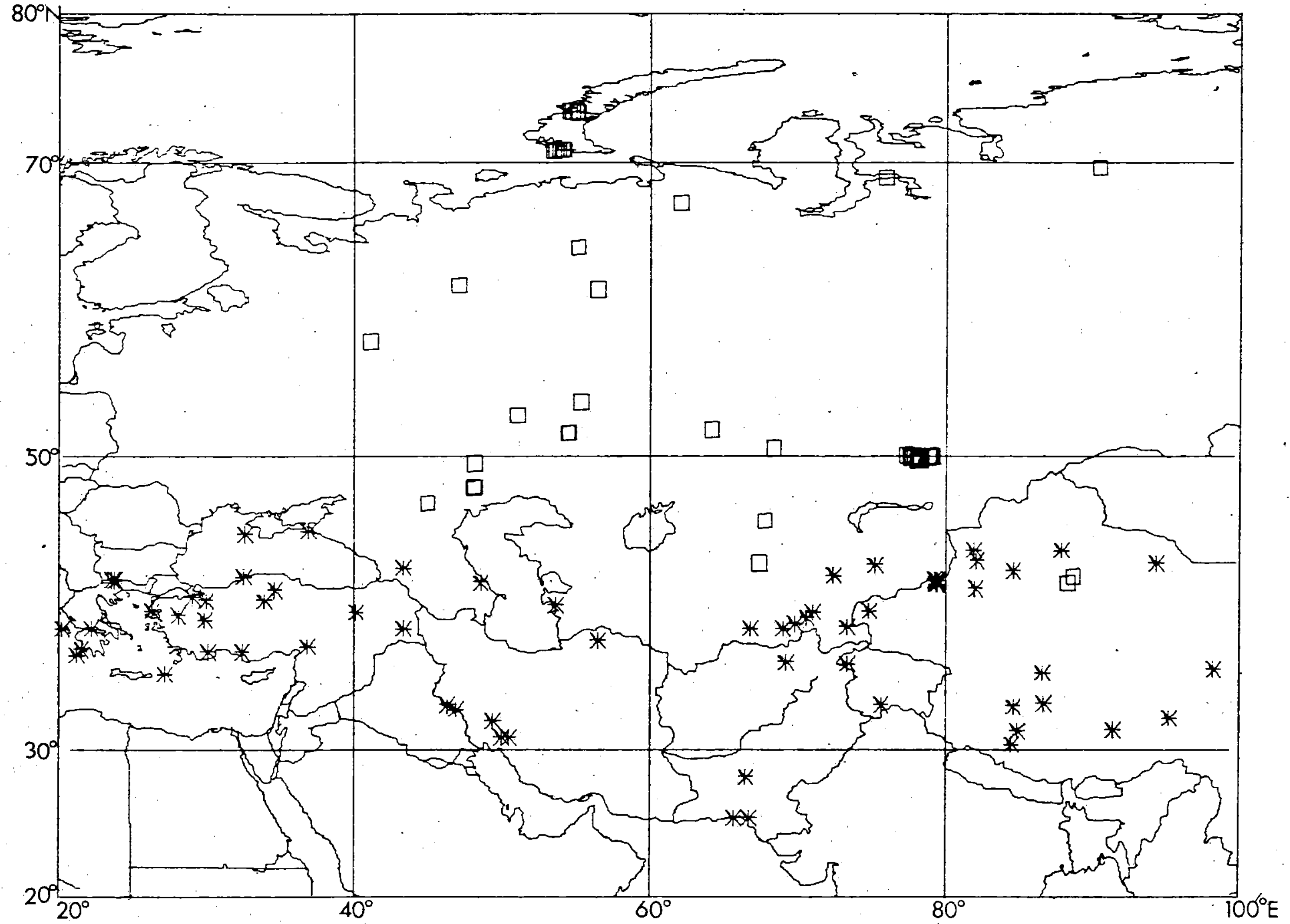

Fig. VI.7.1 The geographic distribution for the data set of 83 explosions and 72 earthquakes. Explosions are depicted by squares and earthquakes by stars in this figure as well as in figures VI.7.2 and VI.7.3.

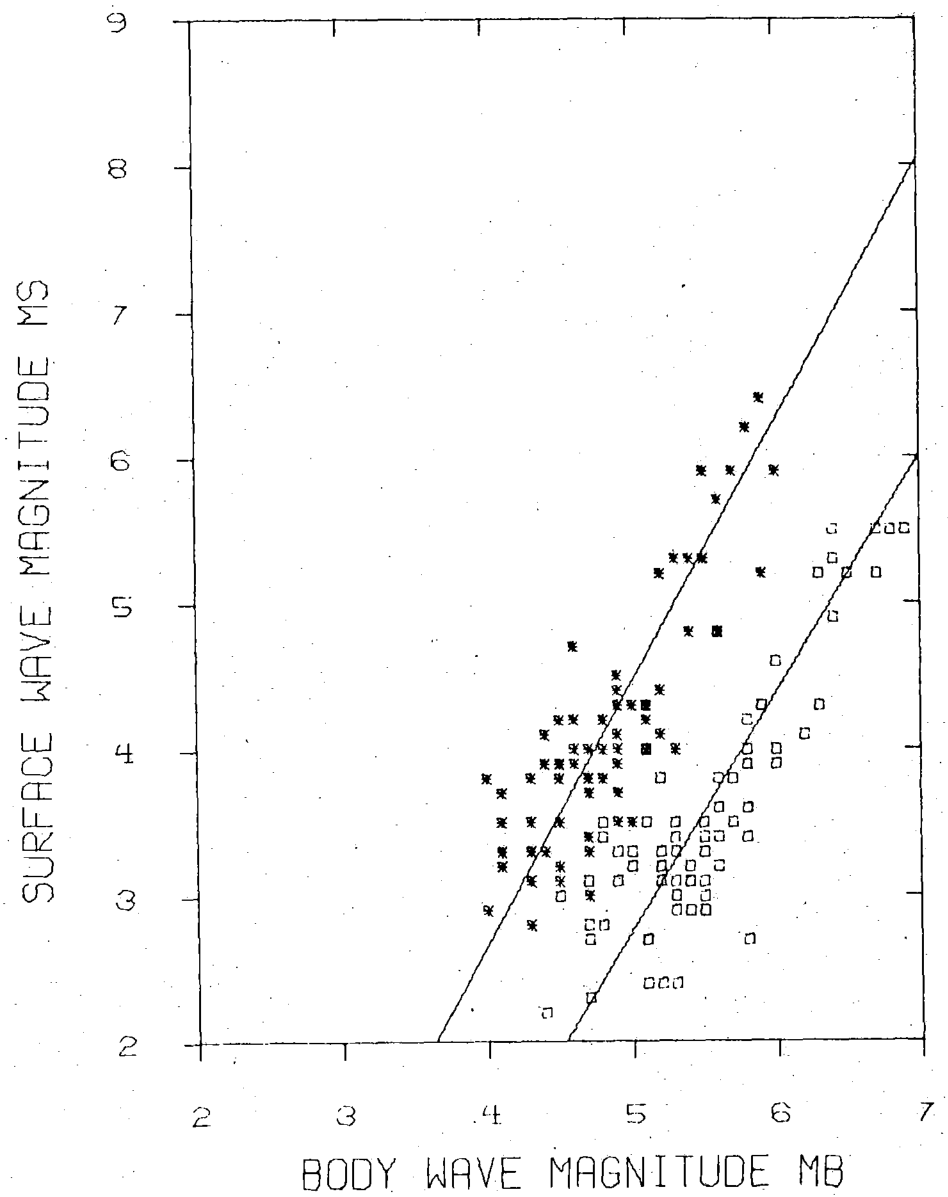

Fig. VI.7.2 $m_b:M_s$ diagram for the data set of 83 explosions and 72 earthquakes. PDE m_b and NORSAR M_s values have been used. Vertical component Rayleigh waves were not detected for 20 of the explosions. These events have been provided with an upper limit for a surface wave magnitude M_s by measuring the amplitude of the largest noise cycle within a time window of about 1 minute covering the expected arrival time of the 20 s Rayleigh wave component.

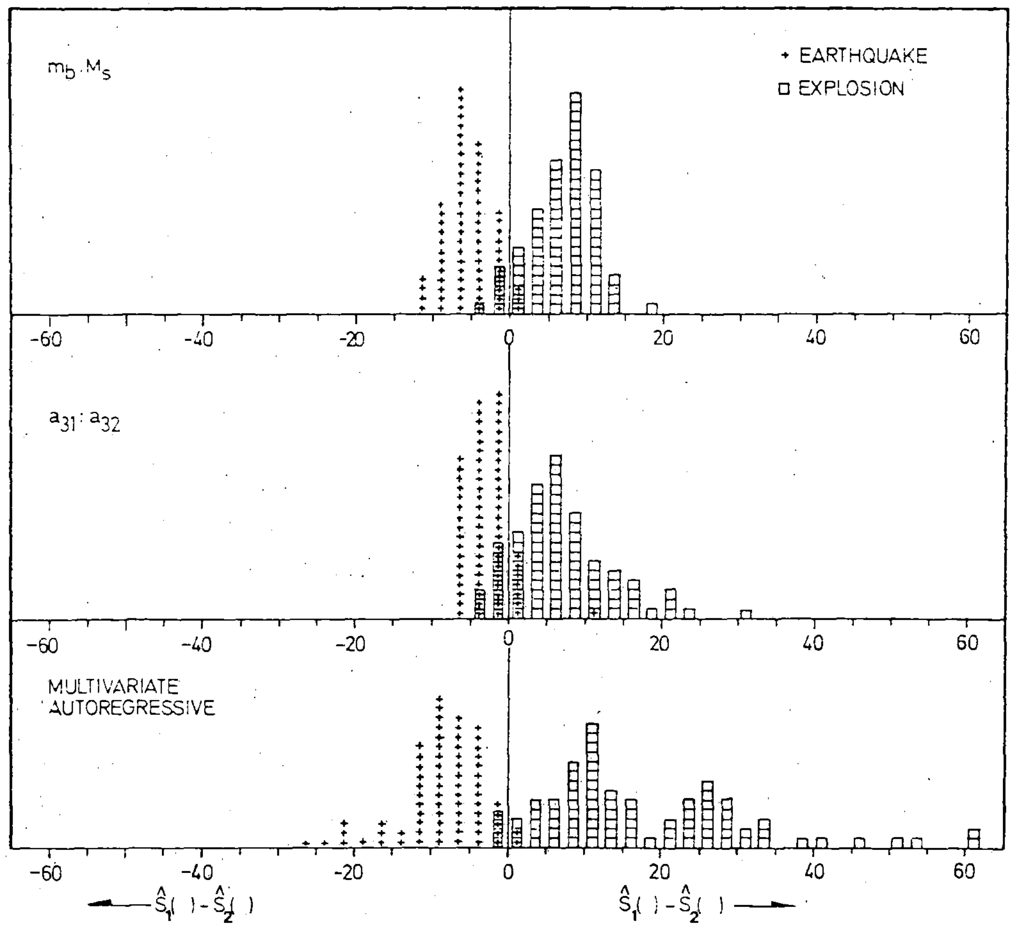

Fig. VI.7.3 Histogram of discrimination scores $\hat{S}_1(\ ) - \hat{S}_2(\ )$ as determined by formula (3) of Tjøstheim (1977). The decision rule is to declare an explosion if $\hat{S}_1(\ ) - \hat{S}_2(\ )$ is positive and an earthquake if this difference is negative.