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VII.4 An application of long-period waveform inversion to shallow sources under the Tibetan Plateau

In previous semiannual summaries we have reported on the development of long-period waveform inversion methods. We have now applied these methods to analyze shallow focus sources under the Tibetan Plateau. The purpose of this work was threefold:

1) To compare the performance of different methods for determining source parameters and location, and for determining travel time and amplitude residuals
2) To test current hypotheses concerning recent tectonics of Tibet, as implied by the principal stress pattern and the source depths
3) To determine station residuals and compare these residuals to those for deep events.

The methods we have applied include a centroid-moment tensor method comparable to the one described by Dziewonski and Woodhouse (1983), and a correlation method as described by Doornbos (1985). Both methods require the calculation of Green's functions in a realistic earth model; we have used a WKBJ method for mixed paths, and we have modified PREM by incorporating in the source region a crustal model for Tibet, and under the receivers an appropriate continental model. The principal differences between the methods concern the nature of the inversion procedure (linearized versus non-linear inversion) and the optimization criterion (least-squares error versus maximum correlation). On the basis of analysis of GDSN data with P and SH waveforms from seven events in Tibet, we conclude that the non-linear correlation method leads to more stable results. There are several reasons for this: (1) the correlation method is less sensitive to the initial value for source location. This is an important point since the standard focal depth value (33 km) used by NEIS for most of these events is significantly more than the values obtained in this work

(<10 km). (2) The correlation method explicitly accounts for travel time anomalies and is robust with respect to amplitude anomalies at the different stations. An example of a result by the correlation method is given in Fig. VII.4.1. The fault plane solution in this figure illustrates that faulting is consistent with east-west extensional tectonics. This was in fact found for all events as summarized in Fig. VII.4.2, and it supports one of the competing theories which have been proposed for this region. The fact that all focal depth values obtained by the correlation method are less than 10 km is moreover consistent with a relatively hot crust (c.f. Chen and Molnar, 1983). In the previously reported analysis of deep events it was found that the travel time residuals of S are surprisingly large; there was both a base line effect and a trend with epicentral distance. It is of interest to compare this result to the travel time residuals for the shallow focus events analyzed here. These residuals are plotted in Fig. VII.4.3; a correction for finite source duration has been applied here. To interpret the P residuals, note that the origin times given by NEIS involve the J-B velocity model and focal depths which are usually taken to be 33 km. Travel time effects due to systematic error in focal depth and due to the difference between the J-B model and the modified PREM model used here amount to about -3.5 s. This explains the P residuals in Fig. VII.4.3, as expected.

The S residuals would have to be correspondingly corrected by adding + 3.5 s. The corrected S residuals at the larger epicentral distances are then slightly negative, but on average the residuals are small. This contrasts with the large positive S residuals for deep events. It suggests the need for modifications of the PREM model involving both the upper and lower mantle.

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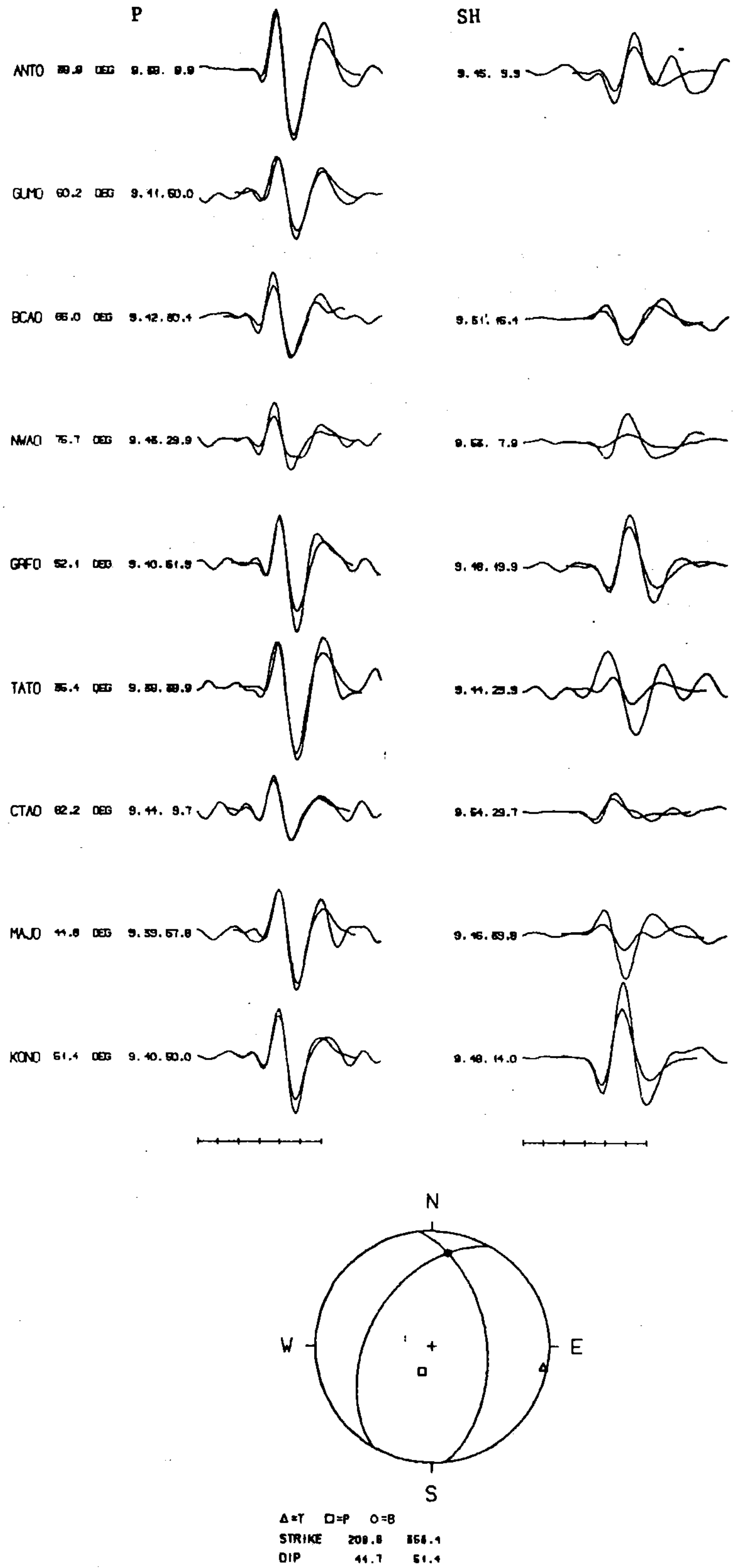

Fig. VII.4.1 Source analysis for one of the events in this study. Observed and synthetic waveforms at GDSN stations, together with the double-couple approximation to the moment tensor solution, in equal area projection of the lower focal hemisphere. The centroid depth is 5 km. The time axis is in 10 s intervals.

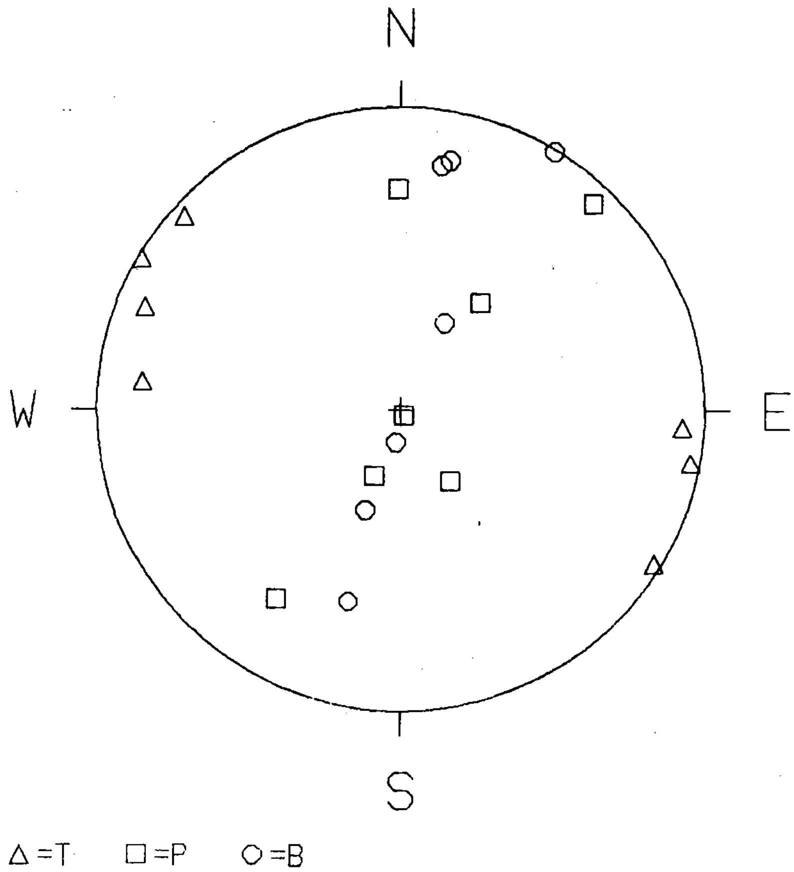

Fig. VII.4.2 Principal axis of 7 shallow sources under the Tibetan Plateau, in equal area projection of the lower focal hemisphere.

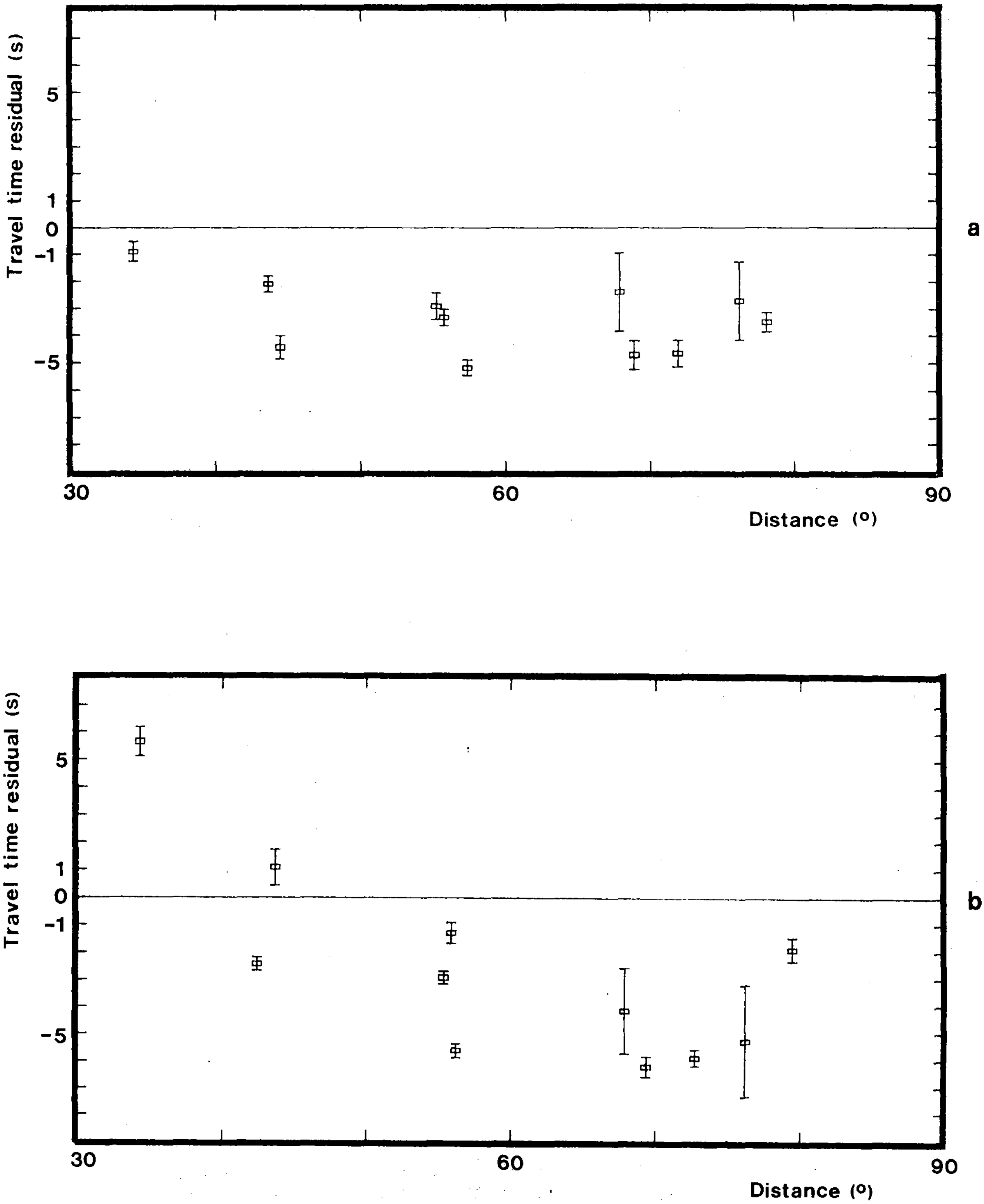

Fig. VII.4.3 Travel time residuals versus distance for P (a) and SH (b). The residuals are defined as observed minus predicted. Each station is positioned at the average distance from the events which were recorded.