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SEMIANNUAL TECHNICAL SUMMARY

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VII. SUMMARY OF TECHNICAL REPORTS/PAPERS PREPARED

VII.1 Source solutions from long-period waveform inversion

Seismic waveform inversion techniques are being applied to determine source parameters, and to determine the parameters describing earth structure. This requires (1) a suitable source parameterization, and (2) a suitable device to account for earth structure effects in waveform modelling. Moment tensor techniques offer a partial solution to the first problem since the source type need not be specified a priori, whereas model-dependent constraints can still be used in the inversion. A remaining problem is that a moment tensor method in practice involves a point source inversion technique, i.e., solutions are obtained with a reference to a point $(\underline{\xi}_0, \tau_0)$. In previous work aimed at the determination of source finiteness, a particular partorization of the moment tensor stress glut was used:

$$\dot{m}_{jk}(\underline{\xi}, \tau) = M_{jk}\ f(\underline{\xi}, \tau) \tag{1}$$

and the source finiteness is contained in $f(\underline{\xi}, \tau)$. However, the effect of source finiteness can usually be neglected in long-period waves from sources of up to moderate size. Alternatively, if the effect is known (or assumed), it can be directly included in the Green's functions. In these circumstances, a useful approximation to the far-field response is a sum of terms of the form

$$u_i(\underline{x}, t) = M_{jk}\ G_{j,k}{}^{i}(\underline{\xi}_0, \underline{x}, t-\tau_0-\delta\tau_i) \tag{2}$$

where $G_{j,k}{}^{i}$ is a modified Green's function, and the time delay $\delta\tau_i$ depends on the mislocation of the source. In practice, the use of an imperfect earth model in computing $G_{j,k}{}^{i}$ also leads to a time residual, so we can write

$$\delta\tau_i = \underline{\zeta}_i^T \underline{F}_{(1)} + d_i \qquad (3)$$

where $\underline{F}_{(1)}$ is the mislocation vector, $\underline{\zeta}_i$ is a slowness vector, and d_i is often called a station residual.

The straightforward approach to solve for $\delta\tau_i$ in equation (2) is by a correlation method, e.g., Ward (1983). In the iterative method we use, M_{jk} is estimated by a least squares inversion of the normalized records; this estimate is used in forming synthetics which are correlated with the observed waveforms to determine $\delta\tau_i$, etc. With shallow sources, where the observed records are modelled by a superposition of direct and depth phases, the correlation method should be applied for a range of depths.

Fig. VII.1.1 illustrates the applicaiton of this method to a deep event in the Fiji Islands region. Rather than showing the complete moment tensor, the equal area projection to the right shows only a double couple approximation. However, results on deviations from the double couple for 12 events are summarized in Fig. VII.1.2. Figs. VII.1.2a, b and c were obtained by slightly different inversion procedures, and the result in somewhat different deviations. Our presumably best solutions are in Fig. VII.1.2c, and we conclude that at this stage there is no compelling evidence for significant deviations from the double couple mechanism of these deep earthquakes (c.f. Giardini, 1984).

The method also leads to an estimate of the centroid time shift $\Delta\tau_0$ which is one of the components of the mislocation vector, and which is related to source finiteness. The centroid time shifts are shown in Fig. VII.1.3 together with the time difference between the short-period P onset and the long-period P correlation lag. The theoretical relation would be of the form

$$\delta\tau_o - b(M/\Delta\sigma)_{1/3} \qquad (4)$$

and for a circular fault with directivity coefficient d = 1.5 (Doornbos, 1984) and relevant P and S velocities: $b = 17.2\times10_{-9}$ where M is in dyne.cm and $\Delta\tau$ in bar. Comparison with the results in Fig. VII.1.3 then suggests that the data are consistent with a stress drop in the range 10-100 bar.

D.J. Doornbos

References

Doornbos, D.J. (1984). On the determination of radiated seismic energy and related source parameters, Bull. Seism. Soc. Am., 74, 395-415.

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Ward, S.N. (1983). Body wave inversion: Moment tensors and depths of oceanic intraplate bending earthquakes, J. Geophys. Res., 88, 9315-9330.

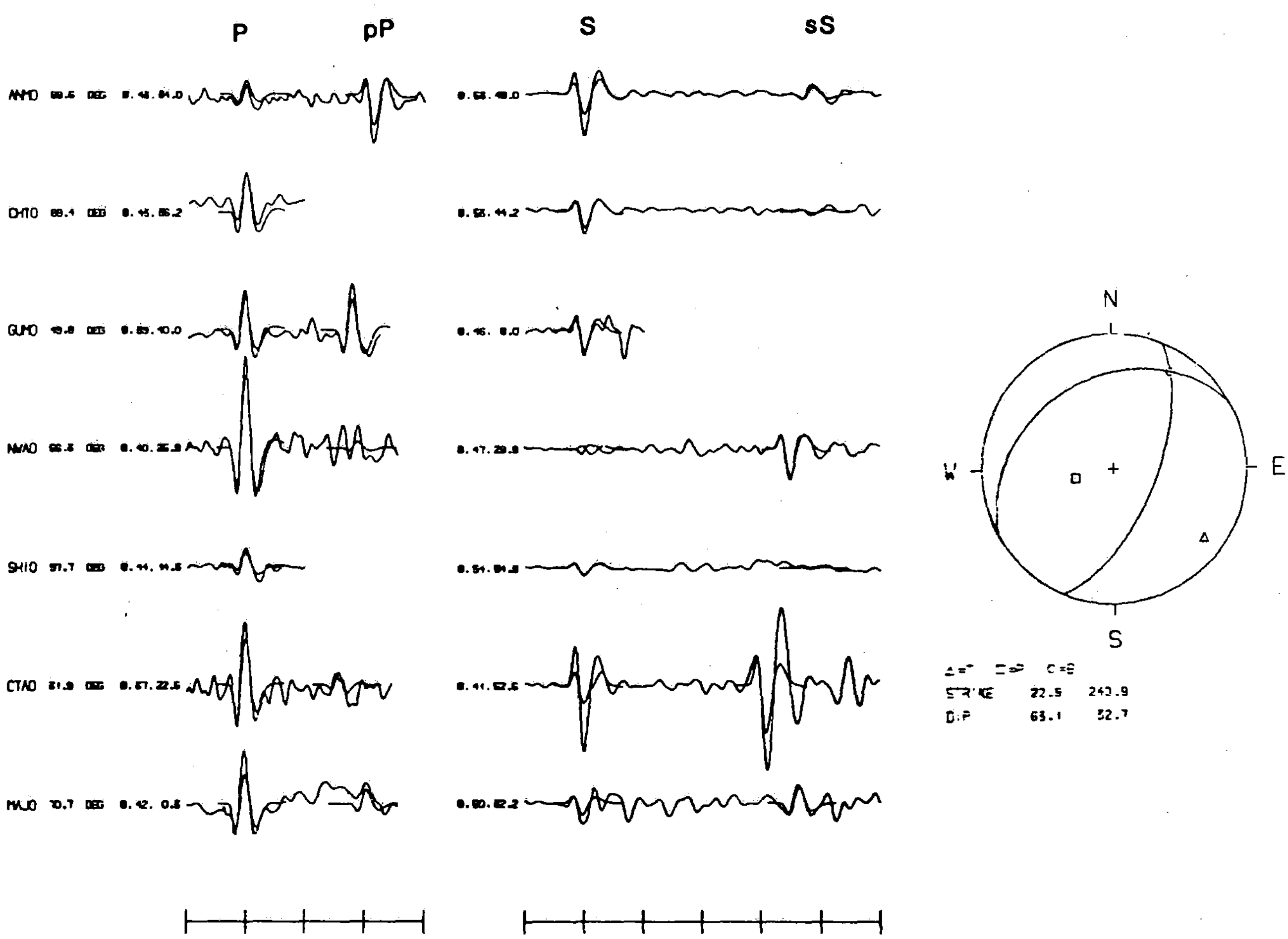

Fig. VII.1.1 Vertical and transverse component records from stations of the GDSN network, showing P, pP, SH and sSH from a deep m_b 5.6 event in the Fiji Islands region. Synthetic record sections for the moment tensor point source solution are plotted over the observed records. To the right, the equal area projection of a double couple approximation to the moment tensor.

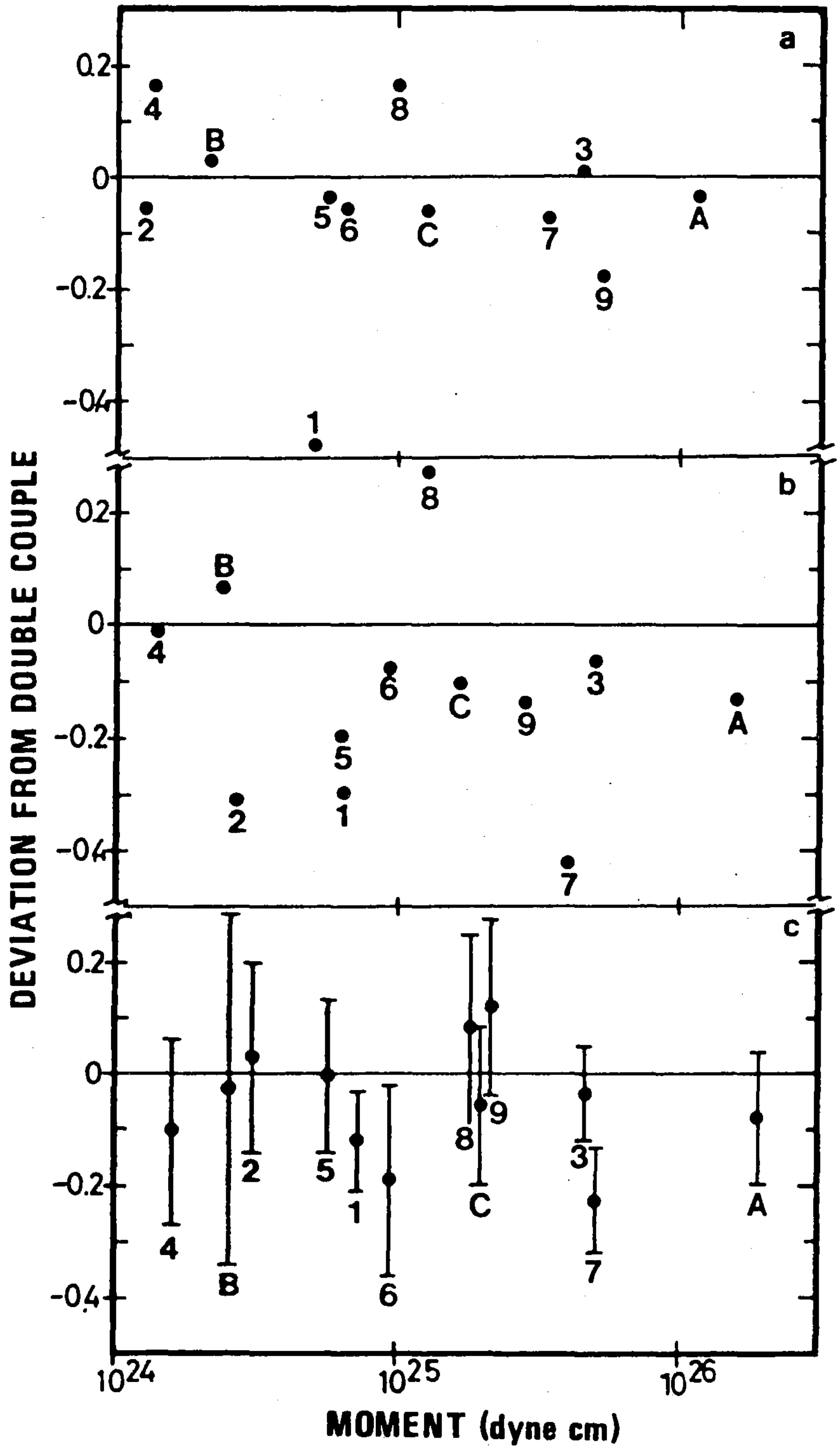

Fig. VII.1.2 Deviation from the double couple versus the seismic moment for 12 deep events in the Fiji Islands region. The deviation is given by $\lambda_3 | \lambda_1 |$ where $| \lambda_1 |$ and $| \lambda_3 |$ are the largest and smallest absolute eigenvalue of the moment tensor. A positive/negative deviation corresponds with λ_1 being the compressional/tensional eigenvalue. The results in a, b and c represent different moment tensor inversions but the best solutions, with standard deviations, are given in c.

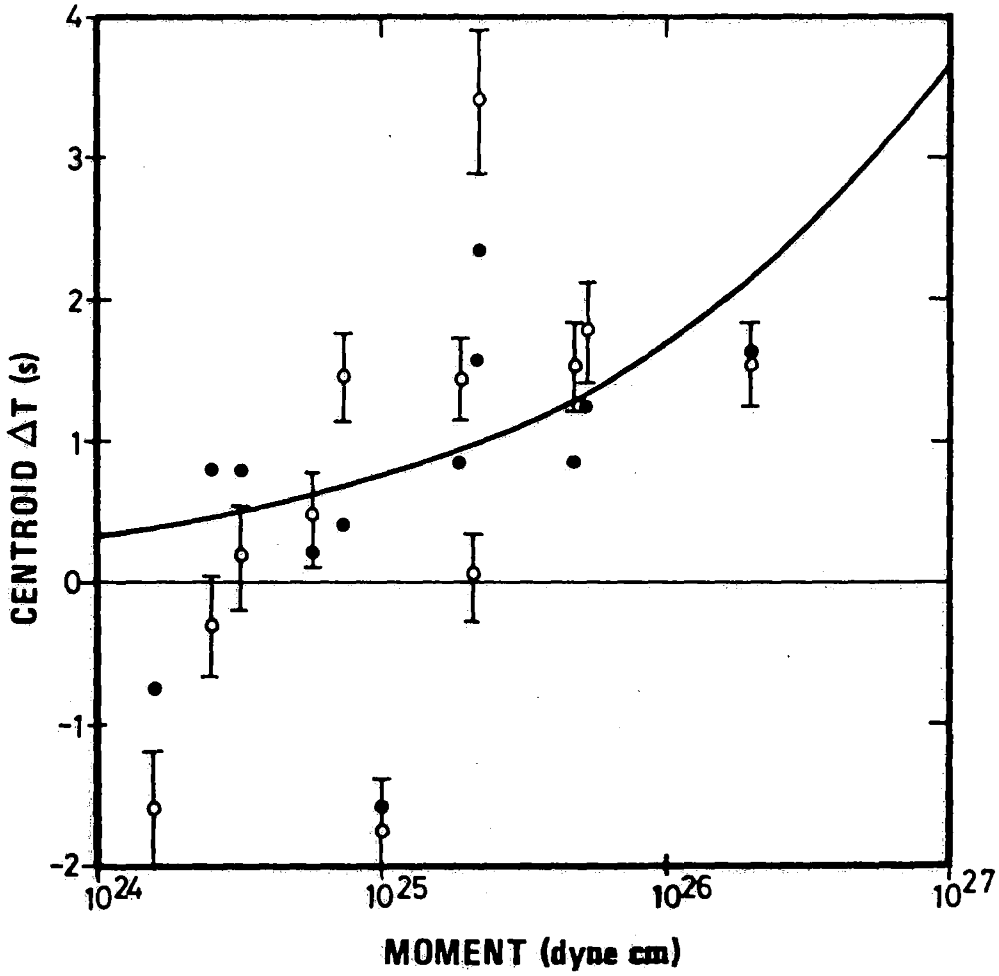

Fig. VII.1.3 O: Centroid time shift versus moment of the deep events referred to in Fig. VII.1.2. ●: Averaged difference between short-period P onset and long-period P correlation lag. The solid line is a theoretical relation of the form $\Delta\tau_o = c\ M_o^{1/3}$, with $c - 3.6\times10^{-9}$ s/(dyne.cm)$^{1/3}$.