

TELESEISMIC MECHANISM OF THE MAY 2, 1983
COALINGA, CALIFORNIA, EARTHQUAKE FROM
LONG-PERIOD P-WAVES

by

Stephen H. Hartzell¹

Thomas H. Heaton²

ABSTRACT

Teleseismic, long-period P-waveforms are modeled to obtain estimates of the source parameters for the May 2, 1983 Coalinga earthquake. The best fitting focal mechanism is: strike = $297 \pm 5^\circ$, dip = $64 \pm 1^\circ$, rake = $70 \pm 10^\circ$. The moment is estimated to be $3.8 \pm 1.5 \times 10^{25}$ dyne-cm with a slip duration of 5 ± 1 sec. The depth is estimated at 12 ± 2 km.

¹Woodward-Clyde Consultants, P.O. Box 93245, Pasadena, CA 91109

²U.S. Geological Survey, California Institute of Technology,
Pasadena, CA 91125

ANALYSIS AND DISCUSSION

Long-period, vertical P-waves from WWSSN and Canadian stations in the distance range from 30° to 90° were collected for the Coalinga earthquake. The P-waves are shown in Figure 1 (boldface traces). These waveforms are modeled using the generalized ray technique (HelMBERGER and HARKRIDER, 1978). The crustal structure used in the modeling is given in Table 1. In choosing this velocity structure, the results of refraction surveys by the U.S. Geological Survey (WALTER and MOONEY, 1982) were used as guidelines. Because we are using a layered crustal model, the ray expansion needed in the generalized ray method is complicated. To ensure that the ray expansion contains all significant rays, the results were checked against a Haskell matrix code. The value of t^* is assumed to be 1.0.

The strike and dip of the north-easterly-dipping nodal plane (297° and 64° , respectively) are fairly well constrained by the downward first motion at PHC and by the nodal up first motions at ALE and WES. By fitting these key stations, the first motions at all the remaining stations are satisfied (for a thrust mechanism). Although there is some trade-off between the assumed velocity in the source region and the fault dip, reasonable perturbations in the assumed velocity structure results in variations in the dip angle of about a degree. Local first-motion data suggest a rake of near 90° (Eaton, 1983). However, the teleseismic P-waveforms, particularly those at MAT, SKH, and WES, appear incompatible with a rake of 90° or greater. These waveforms are better described by a rake of less than 90° . Figure 2 compares waveforms for different rakes. We have chosen a rake of 70° since it does not violate many of the local first motions and fits the teleseismic P-wave data well. However, the error bars are relatively large, about $\pm 10^\circ$. The corresponding conjugate nodal plane has a strike of $156 \pm 15^\circ$, a dip of $32 \pm 5^\circ$, and a rake of $125 \pm 10^\circ$. Since we approximate the source with a point source, we cannot choose between the conjugate planes based upon this analysis. A comparison of the synthetics for this mechanism with the data is shown in Figure 1. The best fitting average moment is 3.8×10^{25} dyne-cm. All the stations were used to obtain this value except LPA, which has an anomalously low amplitude. Amplitudes of the synthetics in Figures 1 and 2 are based on this moment. A very similar mechanism has been obtained by Kanamori (1983, this volume) from surface wave data.

The far-field source-time function used is a trapezoid (pictured in Figure 1) with a rise of 1 sec, a top of 1 sec, and a fall of 3 sec. A 5 sec total source duration is generally consistent with the duration of strong shaking recorded by the Pleasant Valley Pumping Plant Station 9.4 km from the epicenter (Maley et al., 1983). Long-period body waves are not particularly sensitive to the depth of the source. However, we can set some upper and lower bounds. Most of the P wave-forms in Figure 1 have a positive deflection about 15 sec after the first arrival. This phase is made up of crustal multiples of Moho reflections involving S to P conversions at the free surface, and gives some control on the depth.

The synthetics in Figures 1 and 2 are calculated for a depth of 12 km. The match between the synthetics and the data degrades for depths less than 10 km and greater than 14 km. There are of course trade-offs between these depths and the velocity structure.

Figure 3 shows teleseismic short-period P-waves. All the records are from WWSSN stations except ESK which is a special instrument with a response similar to WWSSN. The records are lined up on the first major upswing, which can be identified in each of the 8 seismograms. There is a fairly coherent low-amplitude arrival about two seconds ahead of this first major peak. There appears to be a two second low-amplitude initiation phase, suggesting less energetic faulting at the beginning of the rupture. This observation is consistent with initial low-level ground motions recorded on high-gain digital instruments in the Parkfield area (William Ellsworth, Menlo Park, personal communication). A similar feature in the teleseismic short-period P-waves for the 1979 Imperial Valley earthquake has been reported by Hartzell and Heaton (1983).

CONCLUSIONS

The mechanism of the 1983 Coalinga, California earthquake determined by modeling of teleseismic long-period P-waves is found to be strike = 297° , dip = 64° , rake = 70° , with a moment of 3.8×10^{25} dyne-cm. The depth is estimated at 12 km with a source-time-function duration of 5 sec. The emergent character of the teleseismic short-period P-waves suggests that the rupture started with a 2 sec interval of less energetic faulting.

ACKNOWLEDGMENTS

The authors are grateful to the operators of WWSSN stations who supplied records for this study. We thank Hiroo Kanamori for useful discussions and for reviewing the manuscript.

REFERENCES

- Eaton, J. P. (1983). Seismic setting, location and focal mechanism of the May 2, 1983, Coalinga earthquake, in Coalinga earthquake sequence commencing May 2, 1983, U.S. Geological Survey Open File Report 83-511.
- Hartzell, S. H. and T. H. Heaton (1983). Inversion of strong-ground motion and teleseismic waveform data for the fault rupture history of the 1979 Imperial Valley, California earthquake, Bull Seism. Soc. Am., December.
- HelMBERGER, D. V. and D. Harkrider (1978). Modeling earthquakes with generalized ray theory, in Modern Problems in Elastic Wave Propagation, J. Miklowitz and J. D. Achenback, Editors, John Wiley and Sons, New York.
- Kanamori, H. (1983). Mechanism of the 1983 Coalinga earthquake determined from long-period surface waves, CDMG Special Report, The 1983 Coalinga, California, earthquake.
- Maley, R., G. Brady, E. Etheredge, D. Johnson, P. Mork, J. Switzer (1983). Analog strong motion data and processed main event records, in Coalinga earthquake sequence commencing May 2, 1983, U.S. Geological Survey Open File Report 83-511.
- Walter, A. W. and W. D. Mooney (1982). Crustal structure of the Diablo and Gabilan ranges, central California: a reinterpretation of existing data, Bull. Seism. Soc. Am., 72, 1567-1590.

Table 1

Velocity Structure

α (km/sec)	β (km/sec)	ρ (gm/cm ³)	Th (km)
3.0	1.70	2.1	3.0
5.5	3.17	2.5	3.0
6.2	3.58	2.7	20.0
8.0	4.62	2.9	----

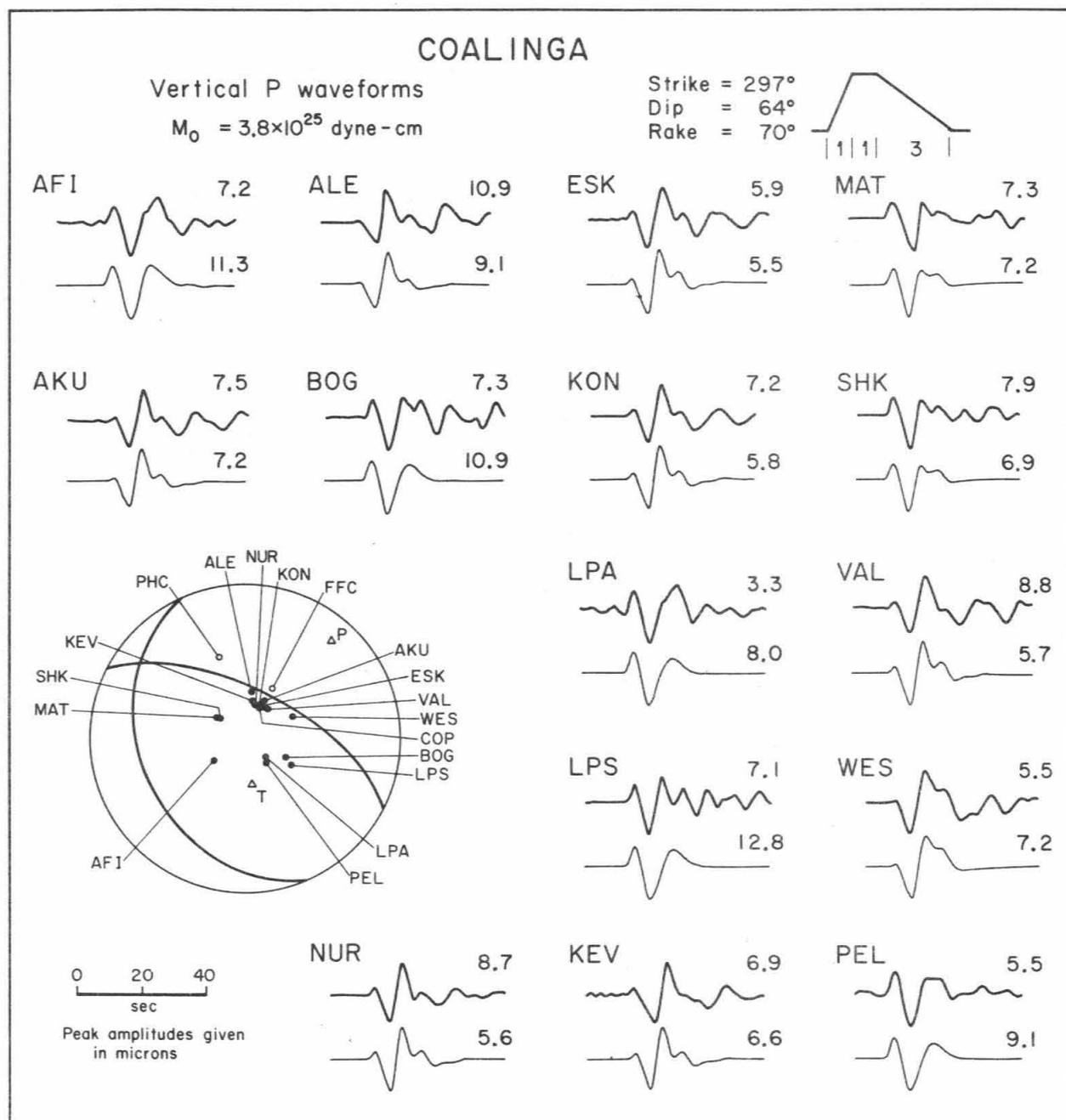


Figure 1. Comparison of observed, vertical, long-period, teleseismic P-waveforms (boldface traces) with generalized ray synthetics for the May 2, 1983 Coalinga earthquake. The focal mechanism is an equal area projection.

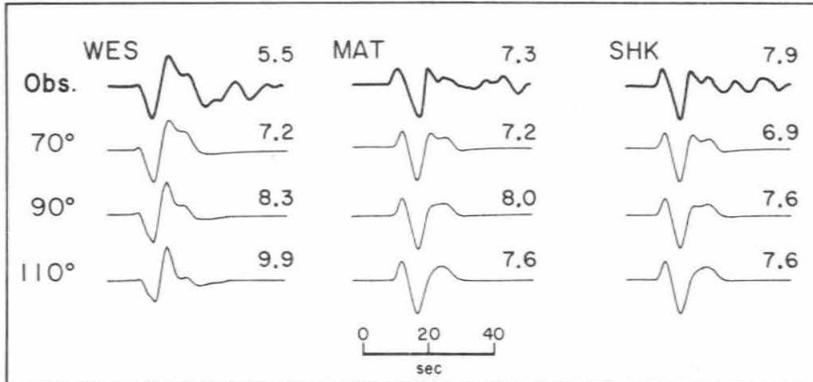


Figure 2. Comparison of P-waveforms for rakes of 70°, 90°, and 110°. Amplitudes are given in microns for a moment of 3.8×10^{25} dyne-cm.

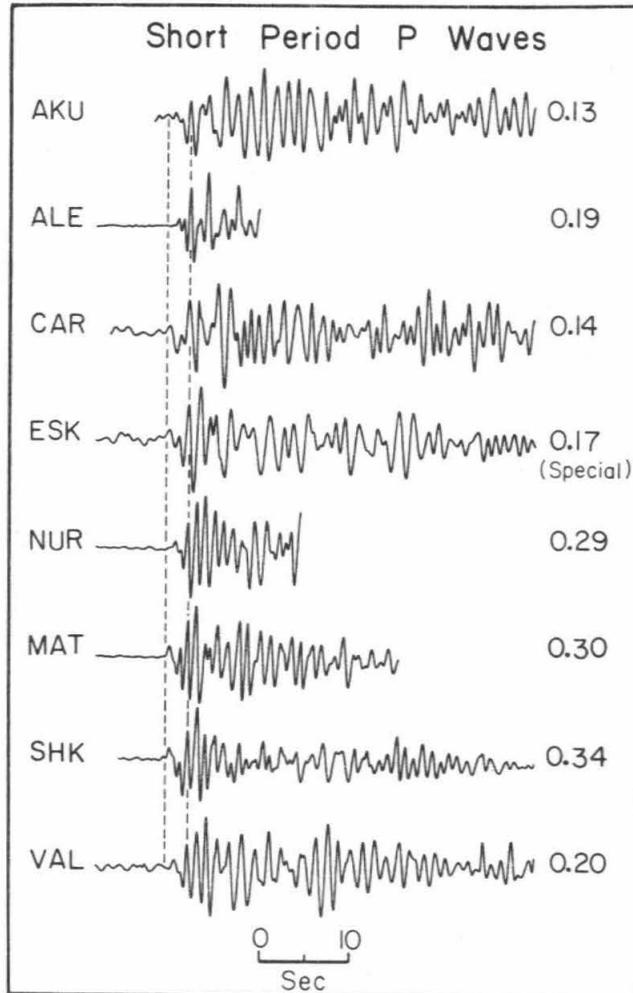


Figure 3. Short-period teleseismic P-waves. These data suggest a two second initiation phase of low-amplitude faulting. Amplitudes are given in microns.