SOURCE MECHANISM OF THE NOVEMBER 29, 1978, OAXACA, MEXICO EARTHQUAKE – A LARGE SIMPLE EVENT

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RESUMEN*

El reciente temblor de Oaxaca, México ($M_S = 7.8$) es de especial interés pues se localiza dentro de un tramo de quietud ("gap") sísmica determinado previamente. El evento generó ondas Rayleigh y Love múltiples de período largo (100-200 seg.), que fueron bien registradas por la red WWSSN. Estos datos, junto con datos del primer movimiento de las ondas P, fueron usados para restringir el mecanismo focal. Los resultados indican un mecanismo focal de tipo de falla inversa y oblicua consistente con la subducción de la placa de Cocos según una dirección noreste bajo México (buzamiento $\simeq 14^\circ$, rumbo $\simeq$ N90°W, deslizamiento $\simeq +54^\circ$); por lo tanto, este evento es ciertamente del tipo anticipado por Ohtake, Matumoto y Latham (1977).

A pesar de su gran tamaño, con momento sísmico $M_o \simeq 3.2 \times 10^{27}$ dinas-cm, las ondas internas indican una fuente extremadamente simple dentro del rango de períodos de los sismógrafos de período largo de la red WWSSN. Esto fue verificado calculando sismogramas sintéticos para la forma de las ondas internas; se utilizó una fuente elemental y el mecanismo mencionado. Este tipo de simplicidad de las ondas internas para temblores fuertes de tipo subducción ha sido observado en otras áreas, especialmente en las Islas Salomón (Lay y Kanamori, 1978) y por lo tanto constituye una característica importante del modo de liberación de la energía elástica a lo largo de algunas zonas de subducción.

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The Oaxaca, Mexico earthquake of 29 November 1978 ($M_S = 7.8$) is of special interest because it occurred within an identified seismic gap (Ohtake *et al.*, 1977). We have studied the body and surface waves generated by this event in order to constrain the source mechanism and determine rupture characteristics. We conclude that the event represents oblique thrust faulting on a plane which dips 14° to the north ($\phi = 270°$, $\delta = 14°$, $\lambda = +54°$); the earthquake is best modeled as a single simple event, suggesting smooth propagation of the rupture. These results, when combined with those of ongoing studies of other events along the Middle America Trench, should lead to a better understanding of the regional tectonics and associated earthquake phenomena.

To determine the mechanism of the Oaxaca earthquake, we began by plotting P-wave first motions read from all available stations. These data were sufficient only to constrain the steeply dipping, presumably auxiliary plane. Of special significance here was the nodal character of the arrival at station NNA. To fix the shallow fault plane we examined the radiation patterns of both Rayleigh and Love surface waves. The R_3 and G_3 arrivals recorded by the long-period instruments at several WW-SSN stations were digitized and filtered to remove energy outside of the 60-300 second period band. The arrivals were then normalized to a propagation distance of 360° + 90°, using the method described by Kanamori (1970). In Figure 1, the amplitudes of the resulting waveforms are plotted as a function of azimuth from the epicenter; the data are satisfied best by the synthetic radiation pattern (solid line) for a fault dipping 14° to the north, with a component of left-lateral slip on predominantly thrust motion ($\phi = 270°$, $\delta = 14°$, $\lambda = +54°$). Amplitudes of both the R_3- and G_3 curves yield a seismic moment $M_O = 3.2 \times 10^{27}$ dyne-cm.

This mechanism was used to compute synthetic body waves at four stations within $\Delta = 100°$ for which the P-wave arrivals were well-recorded. Waveforms from these long-period seismographs suggested a very simple source, thus synthetics were generated using only a single trapezoidal time function. The synthetic waveforms represent the superposition of the direct P and reflected pP and sP phases, based on a half-space model with Vp = 6.1 km/sec. We varied the source depth and the rise time and duration of the time function to obtain optimal fits between the synthetic and observed body waves. We found that a depth of 18 km, together with a broad time function (rise time = 4 sec, duration = 9 sec), produced waveforms in excellent agreement with the records of all four stations (Figure 2). The observed P-wave amplitudes indicate a body-wave moment of 1.5 – 2.0 x 10^{27} dyne-cm. Body wave simplicity of this nature has been observed for other subduction zone earthquakes of comparable seismic moment, notably in the Solomon Islands (Lay and Kanamori, 1979), and so represents an important characteristic of the strain release along some subducting plate margins.

Based on the results of aftershock studies by Singh *et al.* (1980), a rectangular fault geometry with dimensions 82 km by 65 km was employed to determine the average displacement on the fault and the stress drop. When projected onto the dipping fault plane, these dimensions produce a rupture area of 5500 km^2. Then, we obtain for displacement D and stress drop $\Delta\sigma$:

$$\overline{D} = \frac{M_O}{\mu S} = 1.2 \text{ meters}$$

$$\Delta\sigma = \frac{8}{3\pi}\,\mu\,\frac{\overline{D}}{w} = 8 \text{ bars}$$

where:

M_O = seismic moment
S = rupture area
w = fault width

using for the rigidity $\mu = 5.0 \times 10^{11}$ dynes/cm^2. Assuming the rupture to have propagated bilaterally at a velocity of about 2.5 km/sec for a duration of 9 sec, one obtains a rupture length of 45 km. This is significantly smaller than the dimensions indicated by the aftershock distribution, which suggests that the observed P-waves were generated only by a limited portion of the rupture surface; strain on the remaining area may have been relieved more slowly. This is perhaps the reason for the discrepancy between the surface and body wave moments.

In summary, then, the Oaxaca earthquake was caused by oblique thrust faulting on a fault plane dipping 14° to the north, consistent with subduction of the Cocos Plate beneath Mexico along the Middle America Trench. Body wave modeling indicates a simple single event, with the rupture propagating smoothly away from the epicenter. Preliminary analysis of seismograms for the 1965 $M_S = 7.7$ and the 1968 $M_S = 7.5$ earthquakes, which occurred on either side of the Oaxaca event, suggests that the simple rupture properties observed here are characteristic of large events in this region.

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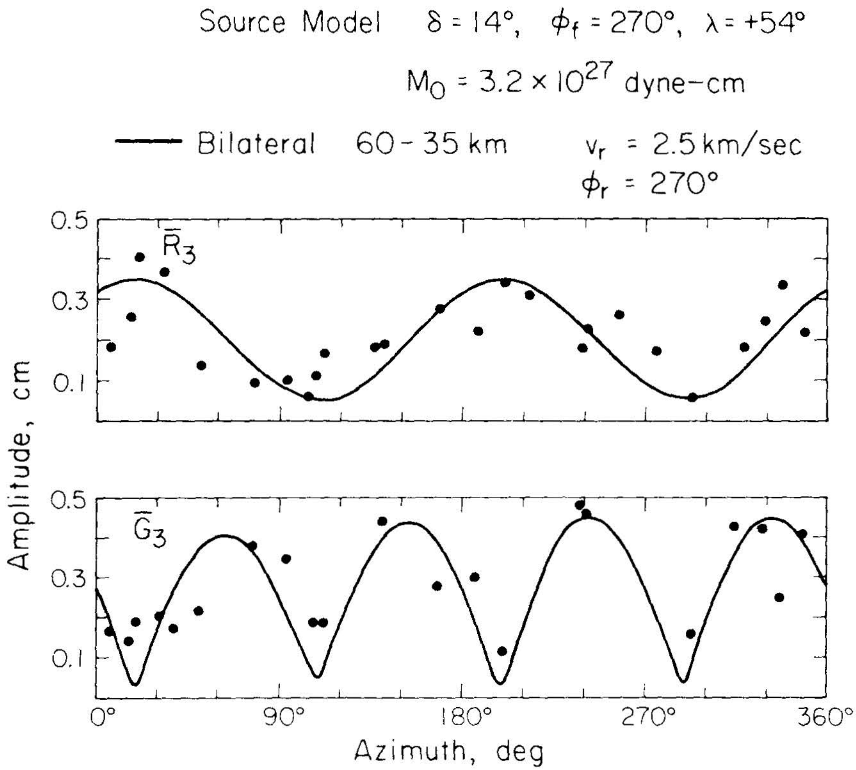

Figure 1. Radiation patterns for Rayleigh and Love waves. Data points show observed amplitudes of normalized R_3 and G_3 arrivals, as a function of station azimuth. Solid lines are the synthetic radiation patterns generated for the given source model.

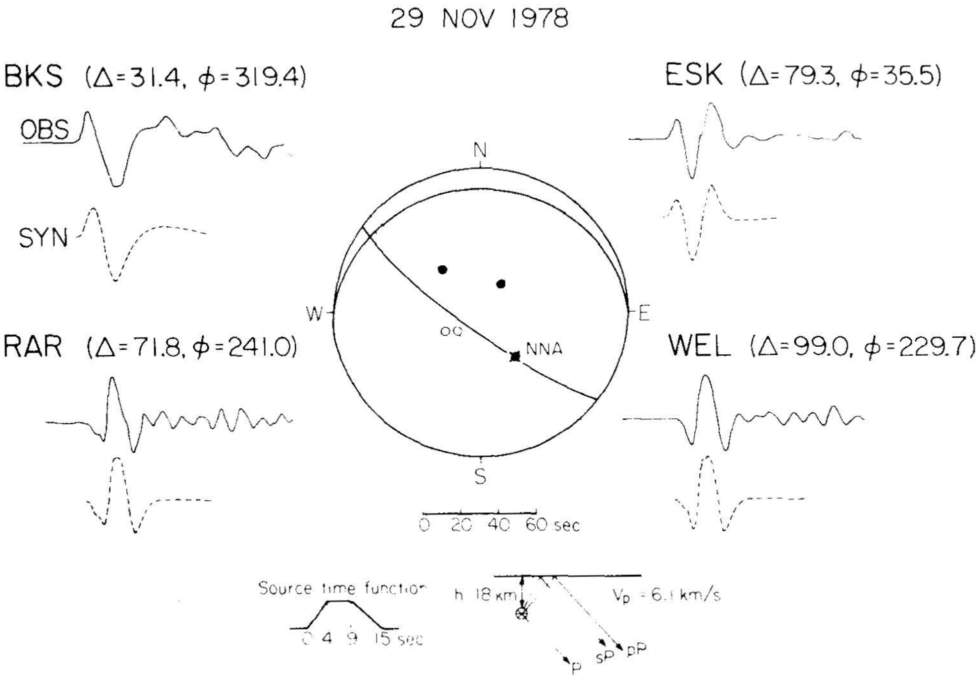

Figure 2. Observed and synthetic P-waves. The focal mechanism in the center of the figure is that determined from P-wave first motions and surface wave radiation patterns; only the nodal station NNA and those stations used for body wave modeling are located here. Observed P-waves are shown as solid lines, synthetics as broken lines. The synthetic waveforms were generated using the source geometry and time function shown. Records at ESK, RAR, and WEL are from standard 15-100 sec instruments; the BKS record is from an ultra-long period 100-300 sec instrument.

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