A STUDY OF EARTHQUAKE MAGNITUDES AND THEIR RELATION TO THE LAW OF SEISMIC SPECTRUM SCALING

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DIGEST

It is known that short-period body-wave magnitude, m_b, is not a reliable indicator of the strength of very large earthquakes. For these earthquakes the surface-wave magnitude, M_S, appears to be a more reliable index of the strength. A possible solution to the body-wave magnitude problem would be to determine the magnitude from the lower-frequency part of the P-wave spectrum, such as would be obtained from the amplitude of P as recorded by long-period seismographs. This P-wave magnitude is called m_B.

Predicted $m_b - M_S$, $m_B - M_S$ and $m_b - m_B$ curves were constructed from spectra obtained from some of the source models in current vogue; (Aki's ω^{-2}, A and B Models; Archambeau's $V_r/V_p = \frac{1}{2}$, $R_s/R_o = 2$ Model ; Berckhemer and Jacob's Model; and Brune's Partial Stress Drop Models $\epsilon = 0.1$ and 0.01). These models all predict a slope near 1 for the m_b versus M_S and m_B versus M_S curves at large magnitude. However, the different models predict widely varying values for the absolute difference between m_B and m_b; this difference is a function of the slope of the spectra at intermediate frequencies.

Magnitude data obtained using the first few cycles of P motion did not support the prediction of the models at high magnitude, that is both m_b—M_S and m_B—M_S plots of observed data flatten out at the high magnitude end, although this is not predicted by the mathematical models. However, as the seismograms were analyzed, it was noted that a high percentage of the larger earthquakes had later P phases which were consistently larger than the first arrival at all distances and azimuths. When these "multiple" earthquakes were identified, it was noted that they separated out (smaller m_b and m_B values) from the remaining shocks on the m_b—M_S and m_B—M_S plots and that the remaining earthquakes supported the predicted curves. Body-wave magnitudes, m_b and m_B , were recomputed from the amplitude and period of the later "main event" for "multiple" earthquakes. On m_b—M_S and m_B—M_S plots the "simple" and "multiple" earthquakes became compatible, the scatter in the plots was reduced, and the plots supported the predicted curves.

The observed absolute difference between m_b and m_B was found to be independent of the nature of the earthquake ("simple" or "multiple") and supported predicted results of only Aki's Model B and Brune's Partial Stress Drop models.

P-wave spectra were computed for earthquakes over an M_s range of 4.9 to 8.4. These spectra were characterized by two corner frequencies, a slope of -3 for the migration of the low frequency corner with increasing displacement amplitude, a slope of -3 for the migration of the high frequency corner below $M_S = 7.1$, and a vertical migration of the high frequency corner above $M_S = 7.1$.

Predicted $m_b - M_S$, $m_B - M_S$ and $m_b - m_B$ curves were constructed from the observed spectra. The $m_b - M_S$ and $m_B - M_S$ curves obtained from the observed spectra do not support the Hanks and Wyss (1972) assumption that the S-wave spectrum is shifted by an amount α/β to lower frequency with respect to the P-wave spectrum. The data support Savage's (1972) prediction that the spectra should be shifted the other way.

Conventional m_b is considered to be a questionable parameter for all shallow earthquakes of M_S greater than $5\frac{1}{2}$. Conventional m_b has little relation to the strength of earthquakes of M_S greater than $6\frac{1}{2}$. Conventional m_B fares somewhat better in maintaining a relation to the size of the earthquake (at least m_B increases when M_S increases) for about another order of magnitude.