STATISTICAL DECISION THEORY APPLIED TO THE FOCAL MECHANISMS OF PERUVIAN EARTHQUAKES

Donald E. Wagner, B.S., M.S.

A Digest of a Dissertation Presented to the Faculty of the Graduate School of Saint Louis University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

1972

DIGEST

A statistical decision theory was developed to determine earthquake focal mechanisms for nine shallow, four intermediate, and five deep focus events which occurred in northwestern South America. The theory combines the independent body wave measurements of P-wave first motions, S-wave polarization angles, and dominant P-wave amplitudes from long-period WWSSN stations.

Nodal plane solutions were calculated in the following manner: Observed P-wave polarities were plotted on a stereographic projection and a trial solution was chosen which minimized the number of quadrant inconsistencies for a theoretical double-couple source. Next, this graphical solution was perturbed in azimuth and/or dip until a solution set of all possible pairs of orthogonal nodal planes which differed by at least one degree and which allowed no further inconsistencies was generated. Finally, the observations of P amplitudes and S polarization angles were combined to statistically choose a solution from the set of orthogonal nodal planes.

To combine the P amplitudes and S polarization angles, a linear cost function formalism was developed. At each station, the residual between the measured and theoretical S polarization angle and the measured and theoretical P amplitude was computed for all the pairs of nodal planes in the solution set. This residual or quantitative error was then converted to a dollars-andcents value through a cost coefficient. That is, a residual of X degrees in the polarization angle was assigned a value of Y dollars. Large residuals were assigned higher values than smaller ones. Because the P and S residuals were both converted to a common metric (i.e., value), it was possible to combine them via a single linear cost function. Therefore, the optimum nodal plane solution was chosen as that solution which minimized the linear cost function.

The above procedure was applied to determine the focal mechanisms of eighteen Peruvian earthquakes. These mechanisms were categorized according to focal depth. The five deep inland events on the Peru-Brazil, Peru-Bolivia border demonstrate near-vertical principal pressure axes. In central Peru and Ecuador four intermediate depth events indicate a clustering of principal tension axes dipping at 45°. Moreover, these tension axes plunge in a NE to SE direction perpendicular to the Peruvian Trench. Nine shallow focus events display a wide range of solutions. In the Peruvian Trench, four earthquakes are found to have horizontal principal axes which strike perpendicular to the trench axis, while one earthquake yields a thrust fault mechanism. Two events in Ecuador and Colombia reveal a strike-slip mechanism with a possible slip axis perpendicular to the trench. Finally, two events in north central Peru show horizontal principal pressure axes.

These solutions are accounted for by the following model: An oceanic lithosphere approximately 70 km thick is dipping under the South American continent at the Peruvian Trench. To the east of the trench is a continental lithosphere. The oceanic lithosphere acts as a stress guide which changes the direction of principal stresses within the slab such that they align parallel to the dip of the descending lithospheric plate. Earthquakes occur in response to the state of stress within the slab which is in turn characterized by the principal stresses. Therefore, the four intermediate depth events with tension axes parallel to the plate indicate the lithosphere is in extension. This is interpreted as the gravitational sinking of an unstable oceanic lithosphere into the underlying asthenosphere. On the other hand, the five deep events with vertical pressure axes demonstrate that the lithosphere is in compression.below 550 kilometers. We interpret this as a segment of lithosphere which has possibly separated from the intermediate depth lithosphere and whose downward motion is now being retarded by the surrounding mantle. Finally, the nine shallow focus events illustrate a wide range of tectonic activity. Their focal mechanism solutions indicate possible thrusting of the oceanic lithosphere under the continental lithosphere, transform faults perpendicular to the Peruvian Trench axis, and mechanical instabilities related to the bending of an oceanic lithospheric plate.