ANALYSIS OF AFTERSHOCKS OF THE JUNE 10, 1975 NEMURO-OKI EARTHQUAKE

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INTRODUCTION:

Tsunami earthquakes are a small group of earthquakes known to have produced anomalously large tsunamis relative to their seismic magnitudes. The June 10, 1975 Nemuro-Oki earthquake, which occurred in the subduction zone of the Kurile Island Trench northeast of Japan (M_S = 7.0, T_O = 13:47:12.5, 42:97°N, 147.17°E) is one such tsunami earthquake. Previous studies of this mainshock have shown it to have an unusually long rupture time of approximately 40 seconds (Kroeger et al., 1987; Fukao, 1979). One explanation for both the long rupture process and the large tsunami generation may be rupture in the low rigidity sediments of the accretionary wedge. However, it is difficult to determine the depth of the mainshock due to its complex rupture. Analysis of its aftershocks with their shorter, simpler time functions may be helpful in determining the fault mechanism of the main earthquake.

The purpose of this study was to model the first motion P- and SH-wave seismograms of the aftershocks to determine their depths in order to better understand the fault geometry of the mainshock. We wanted to see if the aftershocks occurred at depths in the oceanic crust or in the accretionary wedge. We expected to find aftershocks with a short source time function of less than 5 seconds, which is normal for earthquakes of their magnitudes. The aftershocks we modeled were the June 13 (M_S = 6.4, T_O = 18:08:11.7, 43.5°N, 147.7°E), June 14 (M_S = 6.1, T_O = 18:38:10, 43.5°N, 147.9°E), and June 22, 1975 (M_S = 6.1, T_O = 22:44:10, 43.2°N, 147.1°E) aftershocks.

METHODS:

We gathered WWSSN seismogram microfiche records from stations with distances between 30° and 102° away from the source. Two short sections of the first motions of the P- and SH-wave seismograms were printed and digitized for use in the modeling. From these records, we were able to determine the first motion of the P-waves which enabled us to locate the nodal planes giving a well controlled strike and an estimate of the dip of the fault. We synthetically modeled P- and SH-waves from the stations using synthesizer software written for the Macintosh by Glenn C. Kroeger at Trinity University.

Waveforms are the result of a series of rays which include the sum of all direct rays as well as wave phases which reflect off of geologic boundaries near the source, such as the ocean floor, the ocean surface, and the Moho boundary. The depth of the earthquake controls relative arrival time of these rays, and the fault geometry controls the relative pulse amplitudes. Waveforms are also controlled by their source time function which models the duration of the earthquake rupture process.

A layered model of the crustal structure, having layer boundaries with velocity changes at 5, 9, 11, and 17 km, was constructed based on assumed geometry of the accretionary wedge, the Kurile Island Trench, and refraction profiles of the area off the east coast of Hokkaido near the epicenter (Asano et al., 1980). Figure 1 is a cross section of the trench showing our layered model and the velocity structure from the refraction survey. By entering different strike, dip, depth, and time function variables, the computer mathematically synthesized seismic waves which we compared with our digitized seismogram data. Altering the combination of these variables enabled us to come up with a best fit waveform for as many seismic stations as possible.

RESULTS:

After analyzing our P-wave data, we found that all modeled depths were shallow (Table I). A few stations located close to the nodal plane, such as col, bks, and pmg, were key in determining the depth. The best fit modeled P-wave forms for recorded stations are illustrated in Figures 2, 3, and 4. Modeling SH-waves confirmed the fault parameters and time functions of the P-waves, but they suggested a slightly greater depth of 8-9 km, which were still located well within the accretionary wedge.

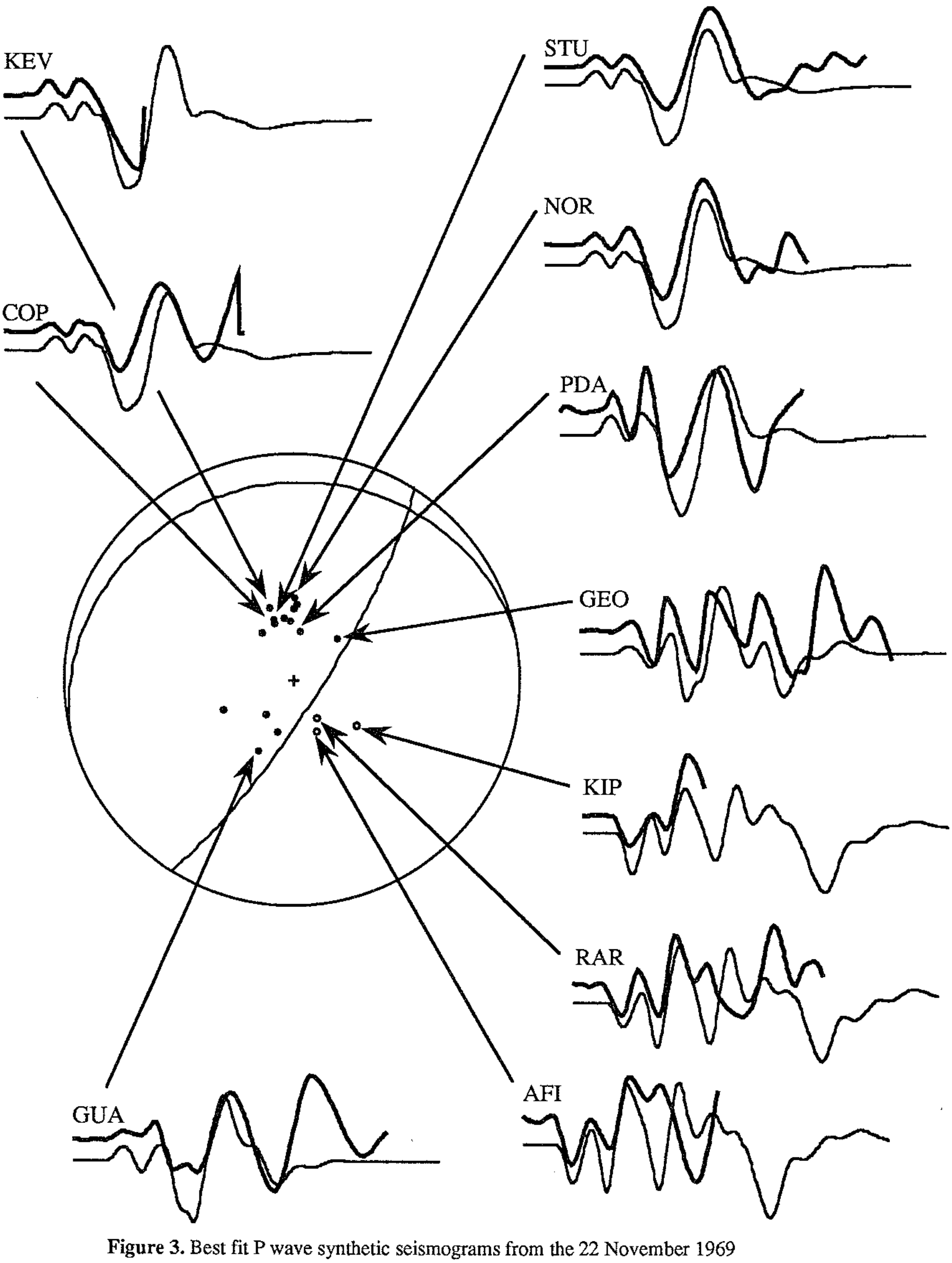

Figure 3. Best fit P wave synthetic seismograms from the 22 November 1969 earthquake. The heavy trace is the observed seismogram as digitized.

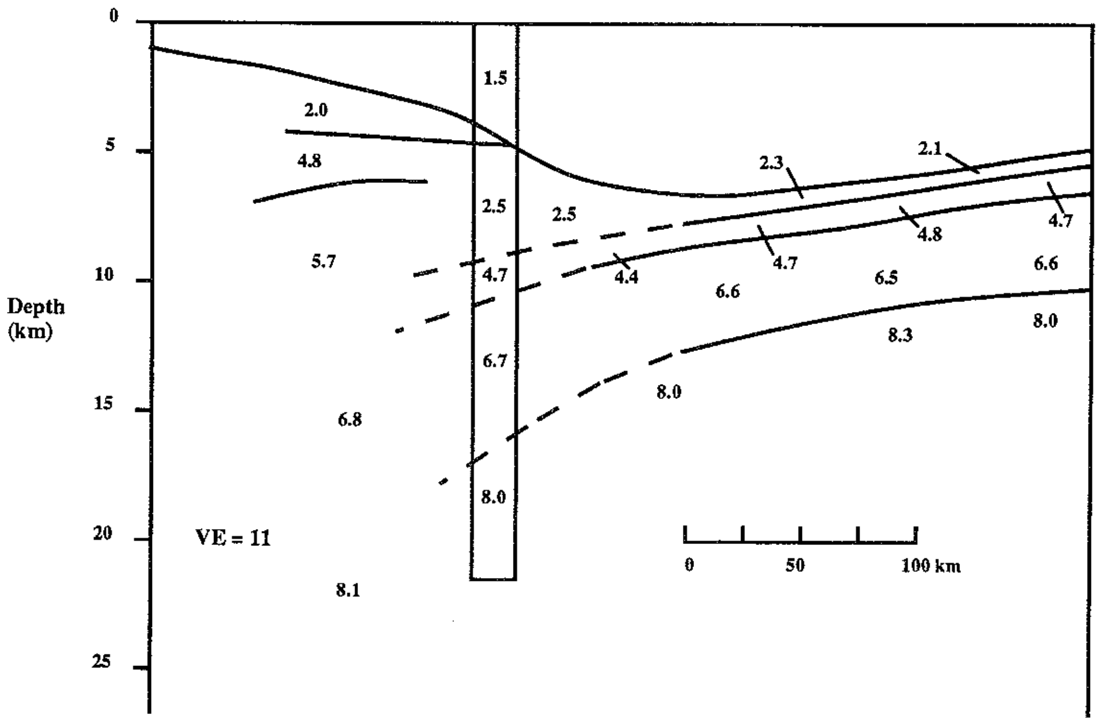

Figure 1. Velocity model for the Kurile trench derived from refraction seismic surveys conducted offshore of Hokkaido (after *Asano et. al.*, 1980). The zone with P velocities of approximately 6.5 km/sec represents the subducting oceanic crust. The lower velocity layers above the crust represent the accretionary wedge. The vertical column depicts the layered structure used in our modeling.

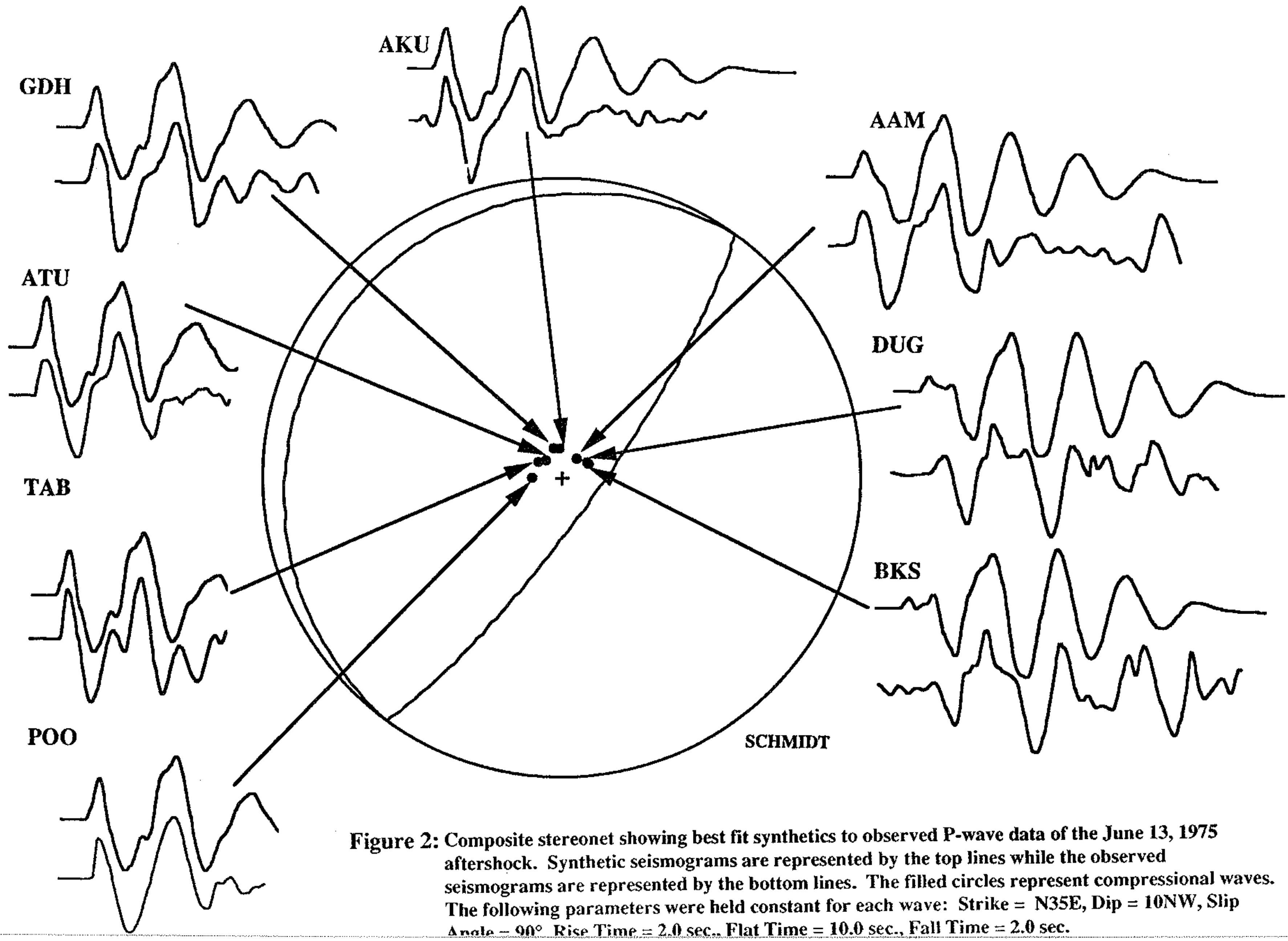

Figure 2: Composite stereonet showing best fit synthetics to observed P-wave data of the June 13, 1975 aftershock. Synthetic seismograms are represented by the top lines while the observed seismograms are represented by the bottom lines. The filled circles represent compressional waves. The following parameters were held constant for each wave: Strike = N35E, Dip = 10NW, Slip Angle = 90°, Rise Time = 2.0 sec., Flat Time = 10.0 sec., Fall Time = 2.0 sec.

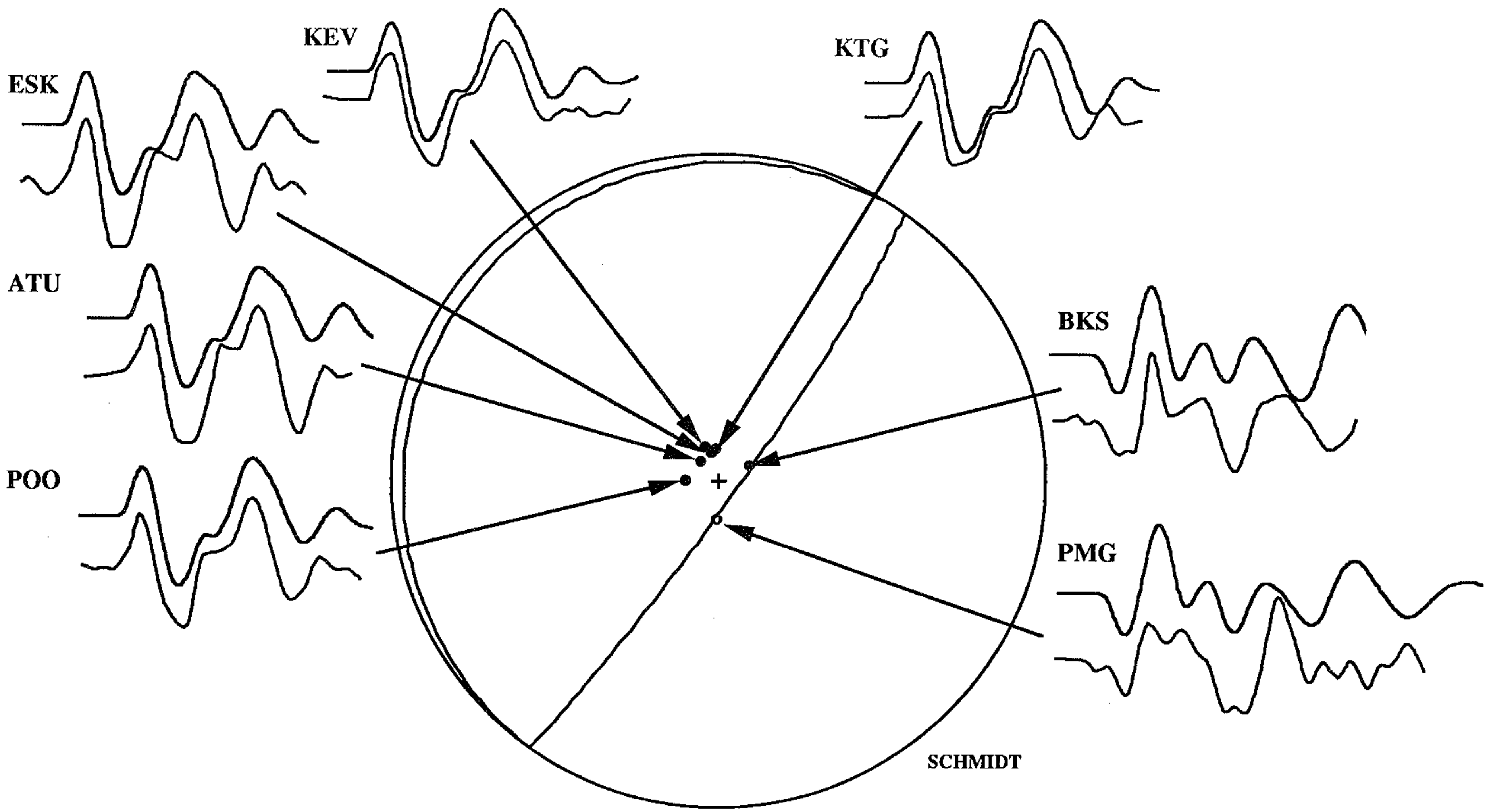

Figure 3: Composite stereonet showing best fit synthetics to observed P-wave data of the June 14, 1975 aftershock. Synthetic seismograms are represented by the top lines while the observed seismograms are represented by the bottom lines. The filled circles represent compressional waves while the open circle represents a dilatational wave. The following parameters were held constant for each wave: Strike = N35E, Dip = 5NW, Slip Angle = 90°, Rise Time = 2.0 sec., Flat Time = 10.0 sec., Fall Time = 2.0 sec.

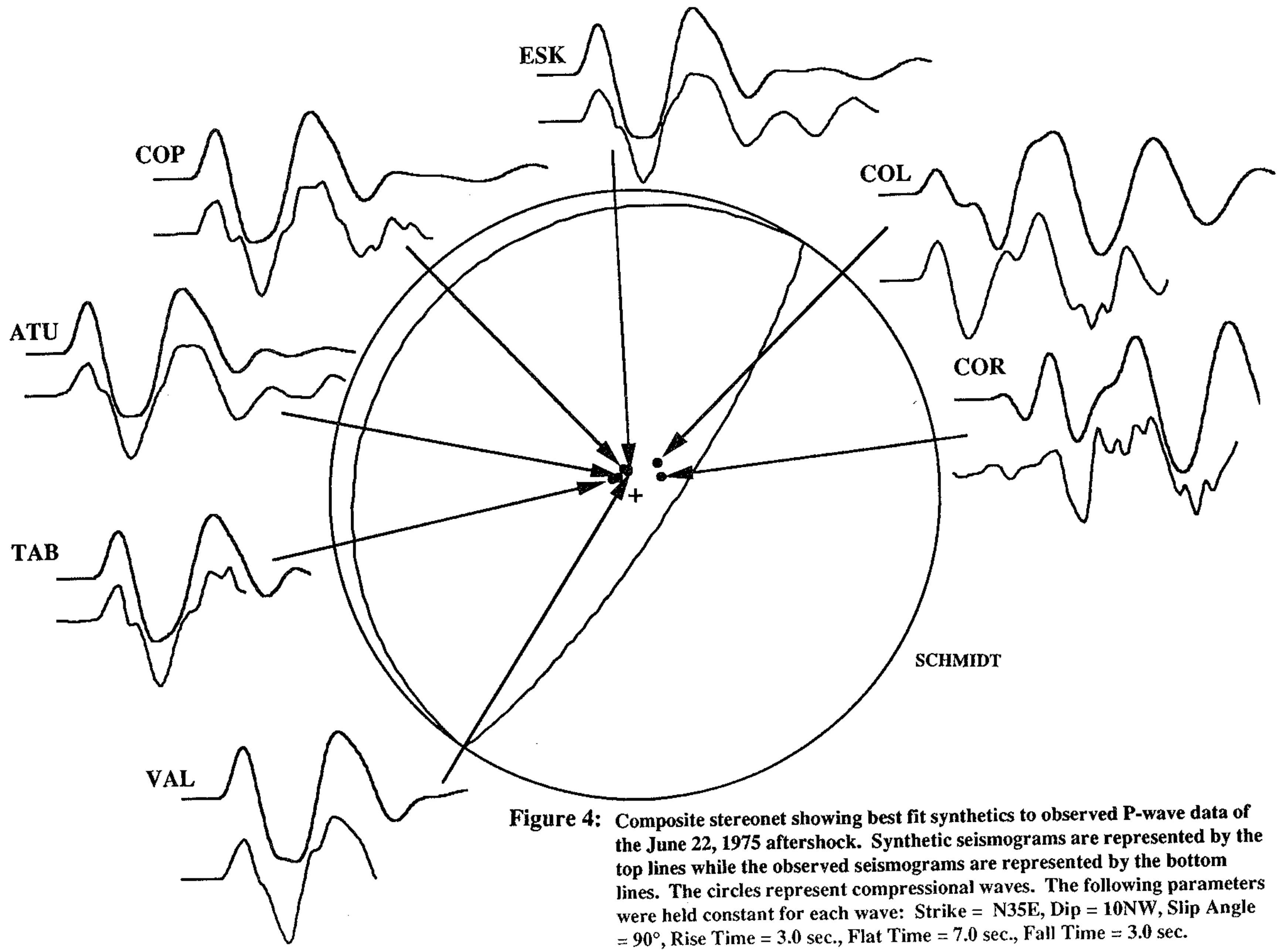

Figure 4: Composite stereonet showing best fit synthetics to observed P-wave data of the June 22, 1975 aftershock. Synthetic seismograms are represented by the top lines while the observed seismograms are represented by the bottom lines. The circles represent compressional waves. The following parameters were held constant for each wave: Strike = N35E, Dip = 10NW, Slip Angle = 90°, Rise Time = 3.0 sec., Flat Time = 7.0 sec., Fall Time = 3.0 sec.

Table I: Synthetic P-wave parameters for the June 13, June 14, and June 22, 1975 aftershocks.

Aftershock:	**June 13, 1975**	**June 14, 1975**	**June 22, 1975**
Fault Plane:	N35E, 10NW	N35E, 5NW	N35E, 10NW
Slip Angle (°):	90.0	90.0	90.0
Depth (km):	6.0	8.0	8.0
Source Time Function:			
Rise time (sec):	2.0	2.0	3.0
Flat Time (sec):	10.0	10.0	7.0
Fall Time (sec):	2.0	2.0	2.0
Total (sec):	14.0	14.0	12.0

DISCUSSION:

Seismic moment is a product of the fault area, fault slip, and rigidity of the surrounding material (Stein et al., 1980). For earthquakes smaller than magnitude (M_S) 7.5, the seismic moment has an approximately linear relationship to the surface wave magnitude. Thus, by knowing the earthquake's magnitude, we can estimate the relationship between the rigidity and the movement along the fault plane. For example, if the rigidity is low, then the amount of slip would be relatively large. In this subduction zone setting, the rigidity is strongly controlled by depth.

Our analyses of the aftershocks reveals shallow depths, ranging from 6.0 - 8.0 km or 1-3 km under the ocean floor. This indicates placement of the foci of the aftershocks in the accretionary wedge as opposed to the more rigid oceanic crust. From the depths of the aftershocks, we infer that the mainshock also occurred at similar depths in the accretionary wedge. Our depths combined with the long source time function of the mainshock from previous studies suggest a large displacement which accounts for the ability of the shock to produce a large tsunami relative to its seismic moment.

REFERENCES CITED:

Asano, S., P. Yamada, K. Suyehiro, P. Yoshii, Y. Misawa, and S. Iizuka. 1980. Crustal structure in a profile off the Pacific Coast of Northeastern Japan by the refraction method with ocean bottom seismometers. *Journal of P-hysics of the Earth*. 29: 267-281.

Fukao, Y. 1979. Tsunami earthquakes and subduction processes near deep-sea trenches. *Journal of Geophysical Research*. 84: 2303-2314.

Kroeger, G. C., K. Shimazaki, and R. J. Geller. 1987. Source process of the June 10, 1975 Nemuro-Oki tsunami earthquake. *Eos Transactions*. 68: 1352.

Stein, S. and G. C. Kroeger. 1980. Estimating earthquake source parameters from seismological data. *Solid Earth Geophysics and Geotechnology*, edited by S. Nemat-Nasser, American Society of Mechanical Engineers, NY.

A SOURCE MECHANISM FOR THE 7 APRIL 1958 HUSLIA, ALASKA EARTHQUAKE

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INTRODUCTION

On April 7, 1958, at 15:30:40 (UT) a magnitude 7.3 earthquake shook Huslia, Alaska. Extensive sand flows, surface collapses, and ice cracking occurred in an area of approximately 400 square miles. The event was followed by four aftershocks with magnitudes above 6.0 over the next five weeks.

Despite its large magnitude, little work has been done on the main shock. This study is the first attempt at using modern techniques to determine the depth, fault geometry, and source time function of the earthquake.

DATA ACQUISITION AND PROCESSING

Because the Huslia earthquake occurred prior to the establishment of the World Wide Standardized Seismograph Network (WWSSN), the data set for the Huslia earthquake required requesting records from individual observatories. These records began trickling in to Trinity in October. By mid-January records from nine observatories had been received.

Since these seismograms were made prior to the standardization of instruments, each seismograph had unique characteristics. These must be known in order to include the instrument's response when creating a synthetic seismogram. Not all records were received with instrument characteristics. In addition, observatories were experimenting with their instrument responses; some of the seismographs were too sensitive, recording the earthquake off-scale. Also, many records have been destroyed or preserved in a useless fashion. For example, a Belgian observatory responded to our request for seismograms by saying they had transferred all records to 16mm film, thereby rendering them unusable for scientific study.

After receiving the seismograms and determining the instrument responses, the traces had to be digitized into the computer. This required tracing the peaks and troughs of the records using a digitizing table at Trinity.

Originally this study was to encompass the four aftershocks of the Huslia earthquake. However, few observatories sent both aftershock and main event records. The records of the aftershocks which were received appeared to be too small to be of value.

GEOLOGIC SETTING

Located at 65.75°N 155.75°W (Davis, 1960), the Huslia earthquake represents a rare event in the Koyukuk Basin south of the Brooks Range and north of the Ruby Geanticline (fig. 1). While there is a thrust fault in the Brooks Range and a strike slip fault in the Ruby Geanticline, there are no known fault traces near the focus of the Huslia earthquake. Using the fault geometry of the Huslia event in conjunction with other studies may provide a clue as to the stress field between the two known faults.

The Basin is composed of a volcanic arc assemblage consisting of Middle Jurassic to Early Cretaceous igneous rock (Patton and Box, 1989). The terrain near Huslia consists of sand dunes covering alluvial deposits from the meandering Koyukuk River (Davis, 1960).

FIRST MOTION ANALYSIS

Ritsema (1962) used the polarity of the first P wave arrivals to determine the strike and dip of one of the nodal planes as N 58°E, 64°SE. He could not completely constrain the second nodal plane using the first arrivals, but concluded that it must lie between N 8°W, 50°W and N 70°W, 38°NE. Because the damage zone trends N 70°E (Davis, 1960), Ritsema concluded that the fault plane must have a strike of N 70°E. Furthermore, because the second nodal plane must be perpendicular to the first, a fault with a strike of N 70°E must have a dip of 26°NW.

However, Ritsema used a crustal P velocity of 7.72 km/s. Analysis of data from earthquakes north of Fairbanks indicate a crustal P wave velocity of 6.1 km/s (Cady, 1989). A new focal mechanism was created using this new velocity with Ritsema's polarity determinations (fig. 2). This plot suggests a strike and dip of N 54°E, 70°SE for one of the nodal planes and a range between N 46°W, 64°NE and N 26°W, 63°SW for the other nodal plane. Furthermore, the trend of the damage zone does not define a second nodal plane along N 70°E. Body wave analysis indicates this is primarily a thrust fault. Therefore both nodal planes will have approximately the same strike. One nodal plane is constrained along N 54°E, which is close to the N 70°E suggested by the damage zone.