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ANNUAL REPORT

OPERATION OF A TELEMETERED SEISMIC NETWORK ON THE ALASKA PENINSULA

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ABSTRACT

A large aperture network of eleven short period seismic stations is being operated on the Alaska Peninsula and several offshore islands to acquire data for the study of the seismotectonics of a part of the Alaska-Aleutian arc-trench structure. The system operated satisfactorily during the past year and continued to provide seismic coverage at a low magnitude threshold level ($M_L = 2.0$). An event detection system, developed under this contract over the past years, has been field installed and is undergoing fine tuning.

Focal mechanism studies of intermediate depths Benioff zone earthquakes were continued. Like a previous, smaller set, these mechanisms show predominantly down-dip extension, indicating gravitational sinking of the subducting lithosphere.

Analysis of the combined data from our network and a temporary array of Ocean Bottom Seismometers, deployed under a related study, indicate that epicenters of earthquakes in the continental shelf area off Kodiak Island are shifted landward by about 15 km with respect to the epicenters determined from the combined data set.

Clusters of shallow seismic activity associated with certain Alaska Peninsula volcanoes, observed over the past years, had previously been interpreted as related to shallow magmatic-geothermal reservoirs. Volcanologic-petrologic field studies conducted last year show that volcanic centers associated with such swarms do indeed have surface manifestations of hydrothermal activity.

INTRODUCTION

In June 1973 the Geophysical Institute of the University of Alaska began a cooperative program with Lamont-Doherty Geological Observatory of Columbia University (LDGO) to study the seismotectonics of the eastern Aleutian-Alaska Peninsula arc structure. The Geophysical Institute's part of the program called initially for the gradual installation and operation of large-aperture seismic network on the Alaska Peninsula and the southern offshore area between the Semidi Islands and the western coast of Kodiak Island.

After a period of buildup that was plagued with technical and logistic difficulties, we are now operating a eleven-station, short-period seismic network in the area. The network overlaps with one operated by us under contract with the National Oceanographic and Atmospheric Adminstration (NOAA) on Kodiak Island and the lower Cook Inlet. That contract also provides the major logistic support for the maintenance of the system described here. To the west, the combined NOAA-DOE system merges with LDGO's seismic network. To the northeast, it overlaps with a network operated by the United States Geological Survey (USGS) in the eastern Gulf of Alaska. These networks taken together cover a 1,000-km portion of the Aleutian-Alaska arc system, a subduction complex with associated features: deep sea trench, shallow thrust zone with high potential for large tsunamigenic earthquakes, Benioff seismic zone, and an overlying chain of andesitic volcanoes.

OPERATION AND MAINTENANCE OF THE ALASKA PENINSULA SEISMIC NETWORK

We have made few changes in the layout and technical design of the system. In connection with the above mentioned NOAA program, we have installed 3 new seismic stations on the northern margin of Bristol Bay (stations BR1, BR2 and BR3 in Figure 1) and one station on the flanks of Aniakchack volcano (station ANI in Figure 1). These stations were installed in order to obtain seismic hazards data for the Bristol Bay region. In terms of the objectives of this project, the Bristol Bay stations will provide a better coverage of events occurring in the deeper portion of the Benioff zone, events that fall outside the Alaska Peninsula network proper. The station on Aniakchack provides an additional station on the Alaska Peninsula and permits us to monitor an active volcano. Besides the routine servicing and maintenance of the network, the major technical activities were associated with the installation and troubleshooting of the seismic event detection system. This system, together with a new, satellite-linked time standard, was installed in November, 1980. The recording system is controlled by a microprocessor which scans all incoming data, buffers it and starts a digital magnetic tape recorder only in the case of a seismic event. Arrival times of the seismic waves, associated with a particular event, are stored in the memory of the microcomputer. Daily tests, bearing the status of each seismic station and of the recording and timing systems, are also performed by the system and retained in the memory. At certain time intervals, the system is addressed via long distance telephone call from the Geophysical Institute and arrival times and station status reports printed out in Fairbanks. This permits us to retain a certain knowledge about the system which is operating essentially unattended. Recording tapes are changed once a week and sent to Fairbanks by mail. Some problems still do exist with the unattended operation of the system. One is that of sudden short-term loss of signal flow on our VHF radio

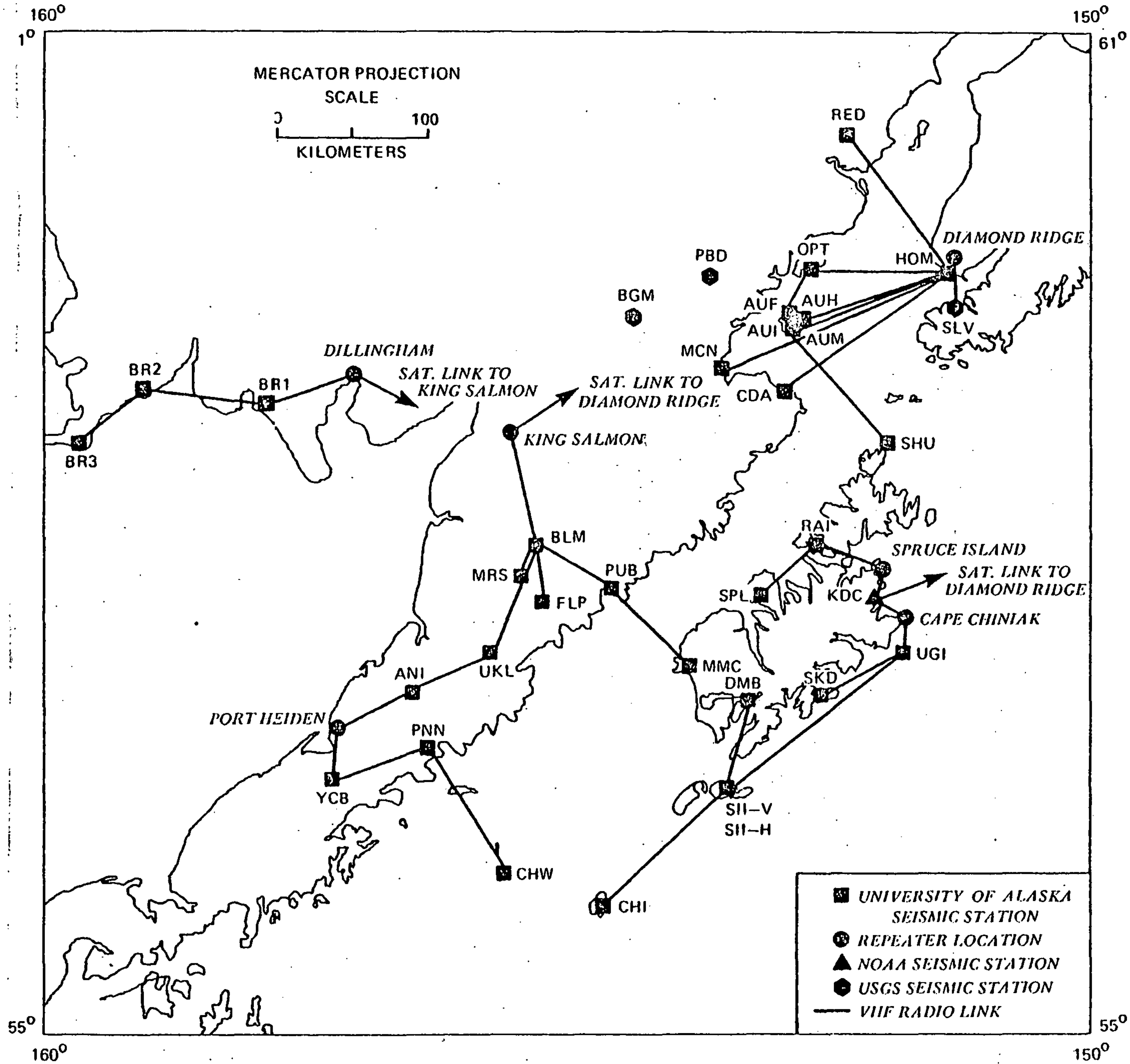

Figure 1. University of Alaska seismic network. All stations telemetering into King Salmon and CHI constitute the "Alaska Peninsula seismic network."

links during periods of adverse weather conditions. These outages (lasting from a few minutes to several hours) cause noise bursts on several incoming signal lines and are interpreted as seismic events by the microprocessor. During periods of high frequency of these bursts, the recording tape fills up quickly, requiring tape change within a few days. Tape playback then also becomes very time consuming. We are presently modifying the software to distinguish between such noise bursts and real events. We have also had problems with the purchased tape control unit that required tape changes before a full record was written. Because of these problems, we have retained the film recording system at Homer and the leased telephone circuit between King Salmon and that site. We are confident that the remaining problems with the detection system can be resolved within a few months.

Otherwise, the system has been performing satisfactory and no major changes appear warranted.

DATA ANALYSIS

Earthquake Catalogue:

Hypocentral parameters derived from the network data are being continually compiled in an earthquake catalogue of the study area. Figures 2 through 4 are sample epicenter maps for the time period, January through December 1980.

No unusual patterns of seismicity occurred during the report period. The Benioff zone constitutes the most significant seismotectonic feature of the area. The shallow, less than 50 km deep, thrust portion continues to be most active beneath and offshore of the southwestern part of Kodiak Island, while the steeper dipping, deeper portion is seismically most active beneath the northern lower Cook Inlet volcanoes.

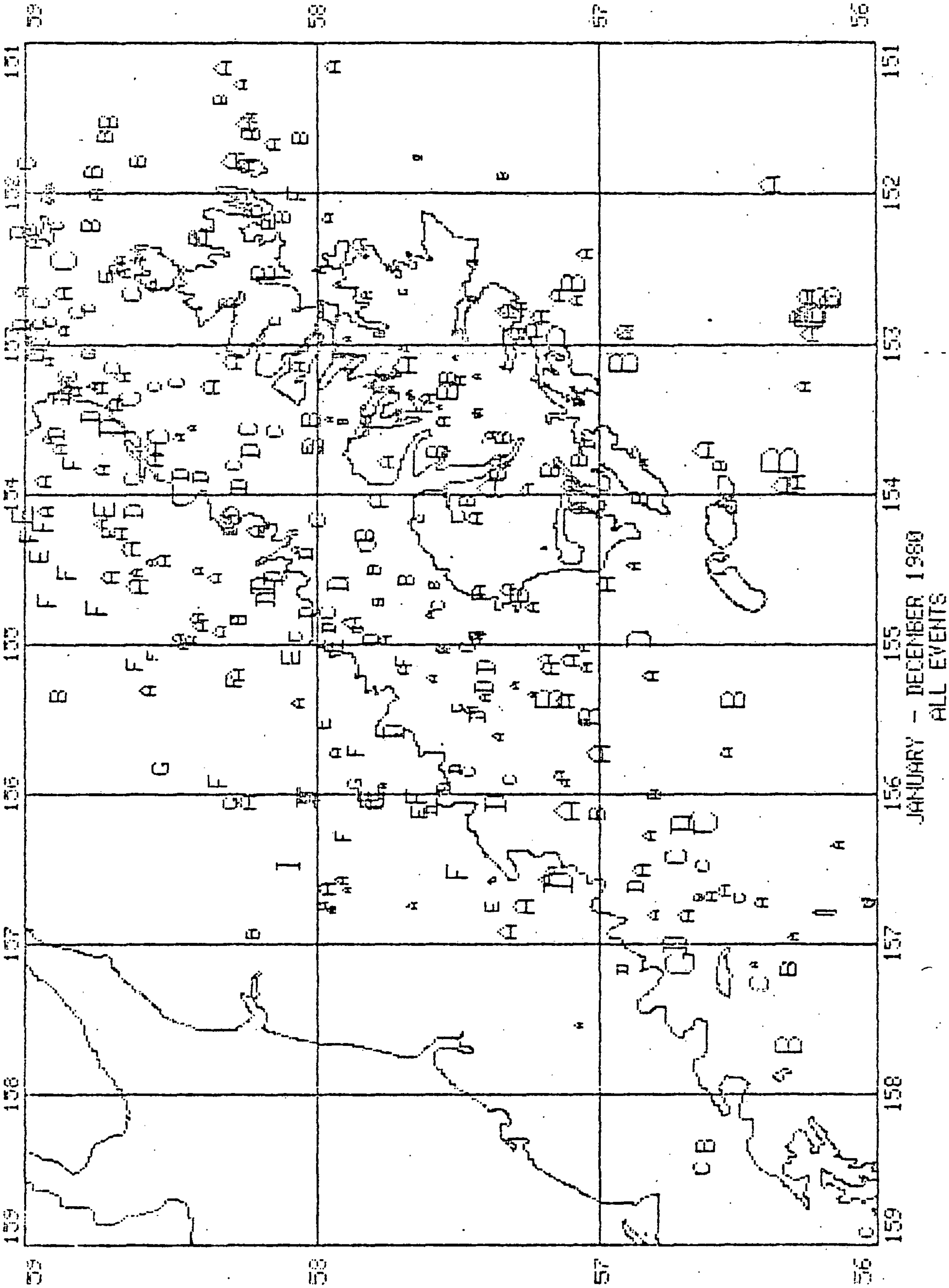

Figure 2. Epicenter map (all locatable events) for Kodiak-Alaska Peninsula area, January-December 1980. The letter code indicates dopth of the event in 25-km intervals (A: 0-25 km, etc.). The size of the letter is proportional to the magnitude, the size of the numbers used for the geographic coordinates corresponding to $M_L = 2.0$.

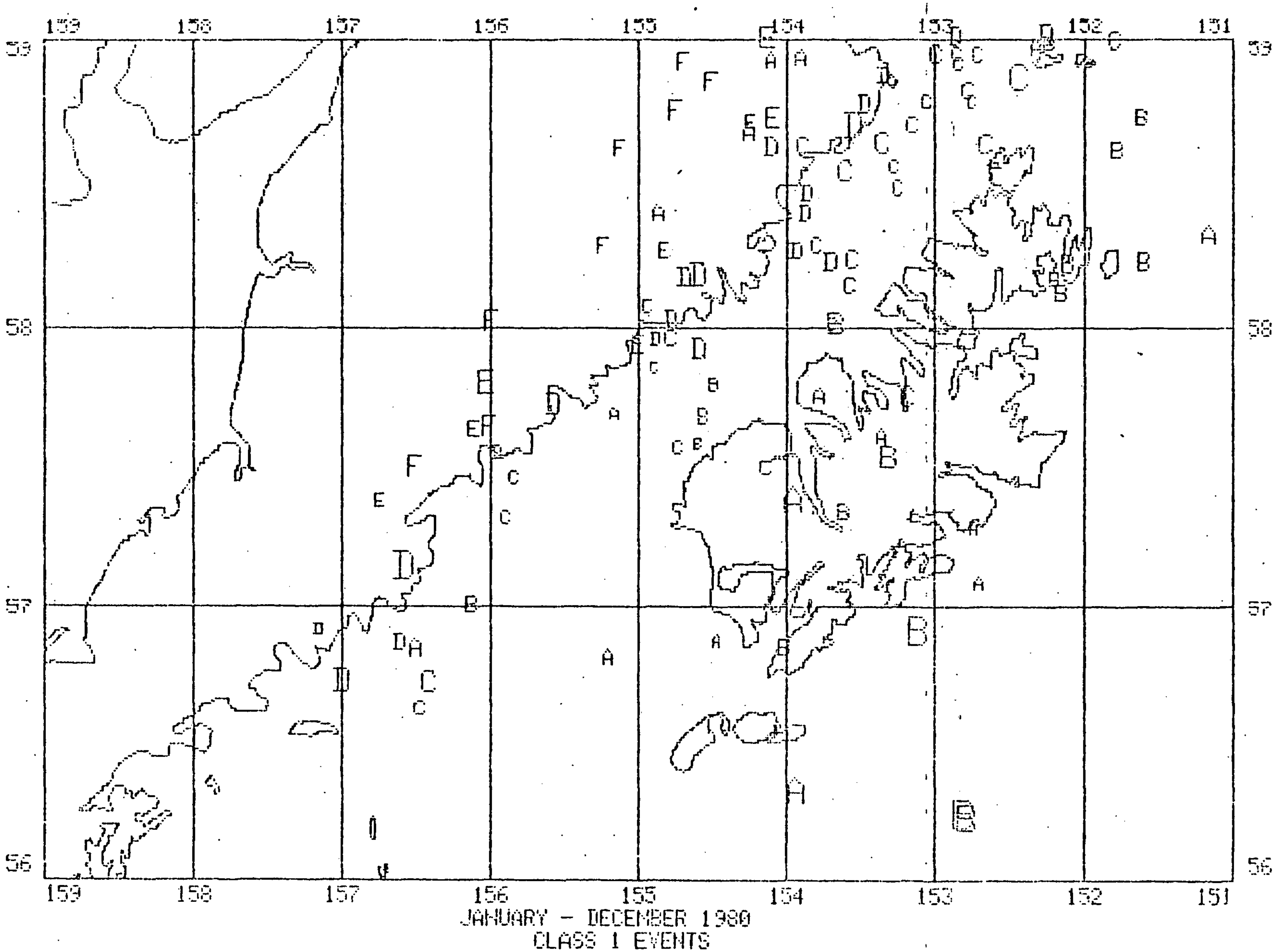

Figure 3. Epicenter map (best located events only) for Kodiak-Alaska Peninsula area, January-December 1980. Symbols as in Figure 2.

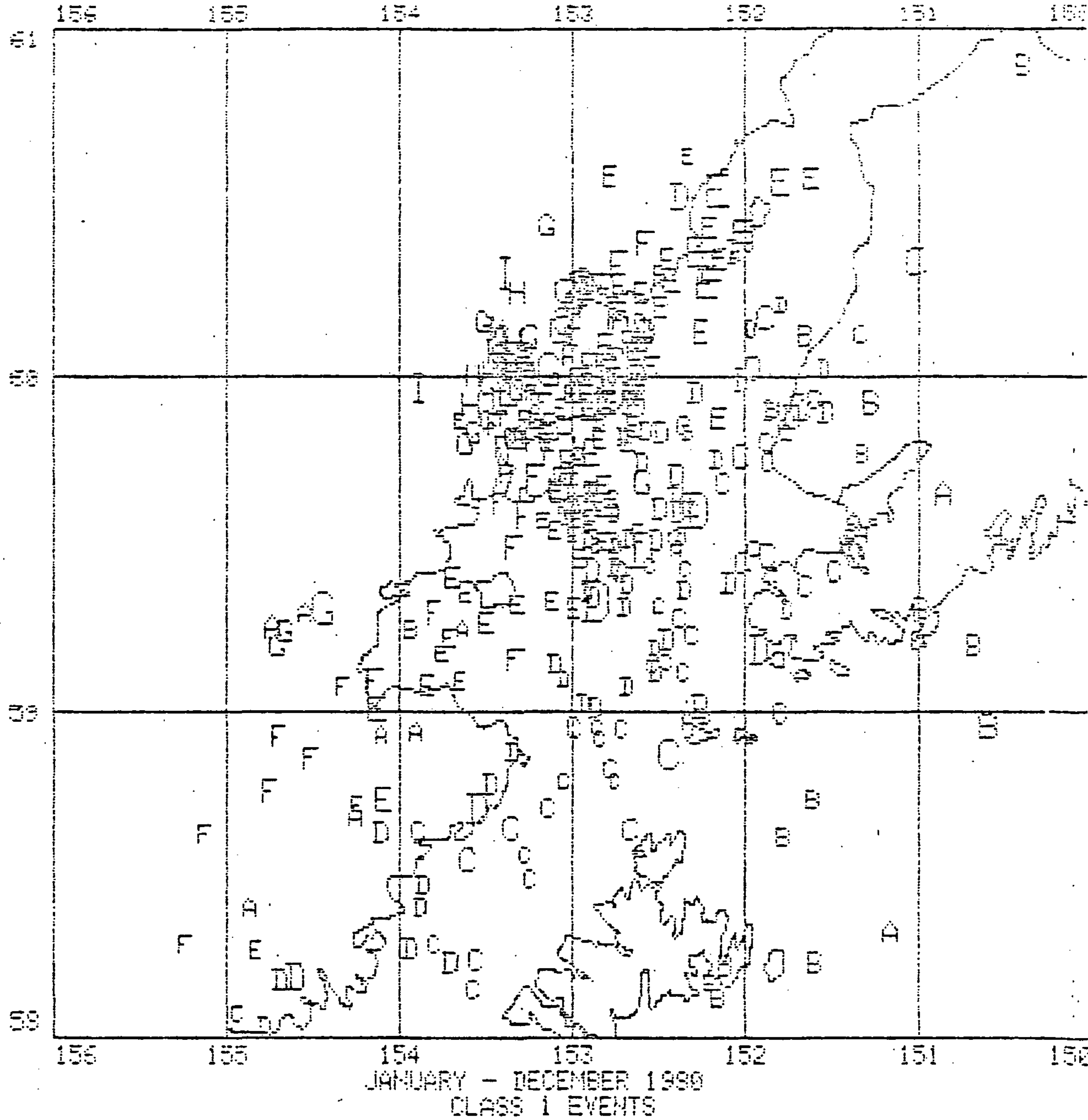

Figure 4. Epicenter map (best located events only) for Lower Cook Inlet area, January-December 1980. Symbols as in Figure 2.

Seismicity to the southwest of Kodiak Island continues, for the second year in a row, at apparently higher levels than had been observed in the earlier years of the network operations. However, many of these events, lying outside the network proper, are poorly constrained, so the precise delineation of the active zones of this eastern portion of the Shumagin seismic gap will require the combined data set from both the LDGO and our networks. We continue to observe clusters of shallow (less then 10 km) seismic activity in association with certain volcanic centers. Such activity, in particular beneath Mt. Douglas, Kaguyak Crater, Kukak Volcano, Snowy Mtn., Trident, Mt. Mageik and Mt. Martin, had been suggested (Pulpan and Kienle, 1979) to be the result of hydro-fracturing in active shallow magmatic-geothermal reservoirs beneath these volcanoes. A petrologic-volcanologic field investigation of many Alaska Peninsula volcanic last summer centers revealed that all centers which associate with shallow seismic swarms do indeed have surface manifestations of hydrothermal activity such as active fumaroles.

Focal Mechanism Studies:

The study of the focal mechanisms of some 20 lower Cook Inlet earthquakes is just being completed. The purpose of this study is to infer the fault motion at the hypocentral region associated with the earthquake and the orientation of the stress system that caused the dislocation. All events studied originate from the deeper portion of the Benioff zone covering a depth range from approximately 80 km to 160 km. The largest events are roughly of magnitude 5, so that only regional seismic data could be used. Figures 5 through 8 are samples of the preliminary solutions derived. The majority of events appear to be

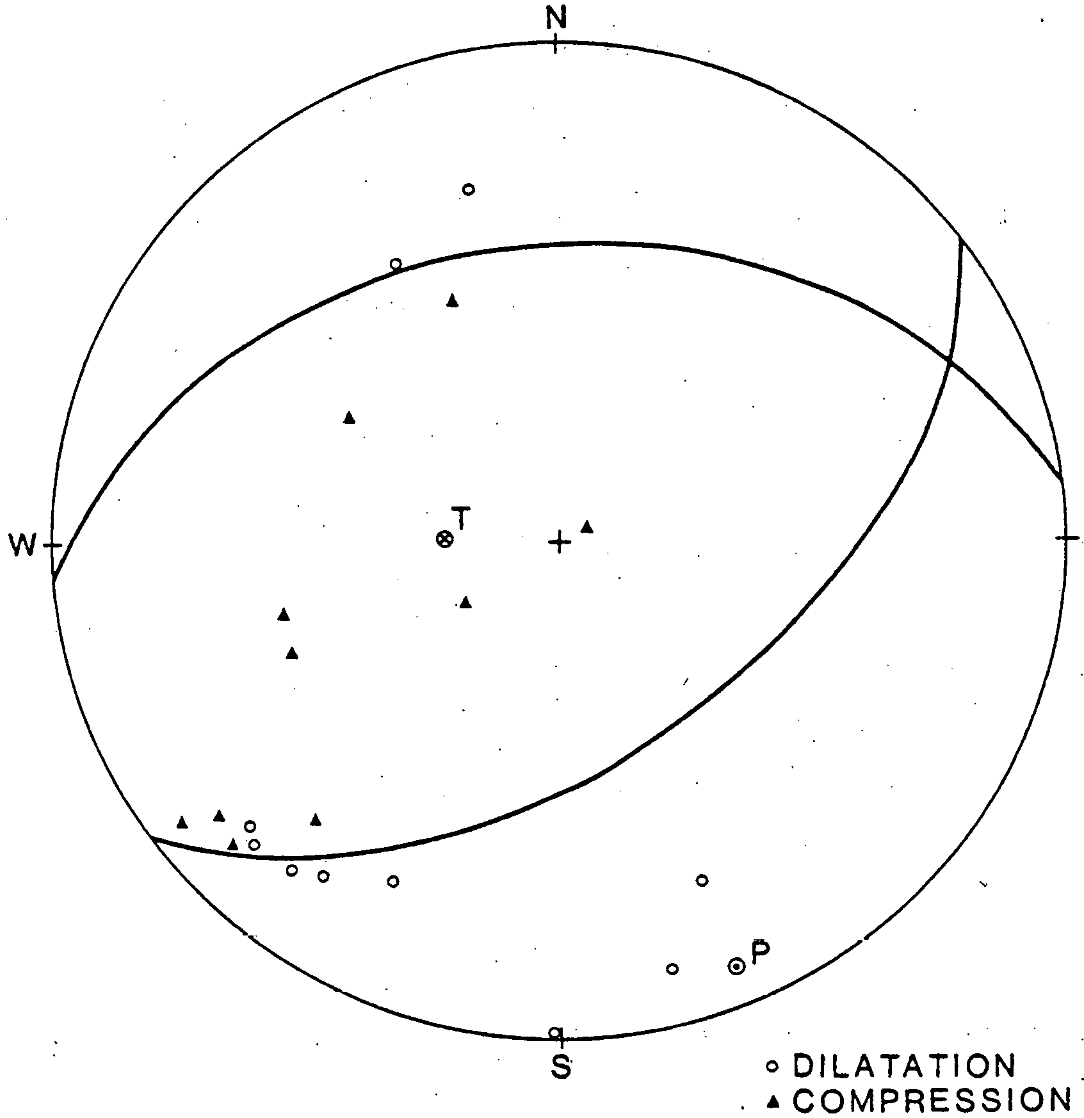

Figure 5. First motion fault plane solution for the earthquake of April 16, 1979 (59.146N, 154.026W, h = 152 km). Shown is the lower focal hemisphere. P and T denote the pressure and tension axes, respectively).

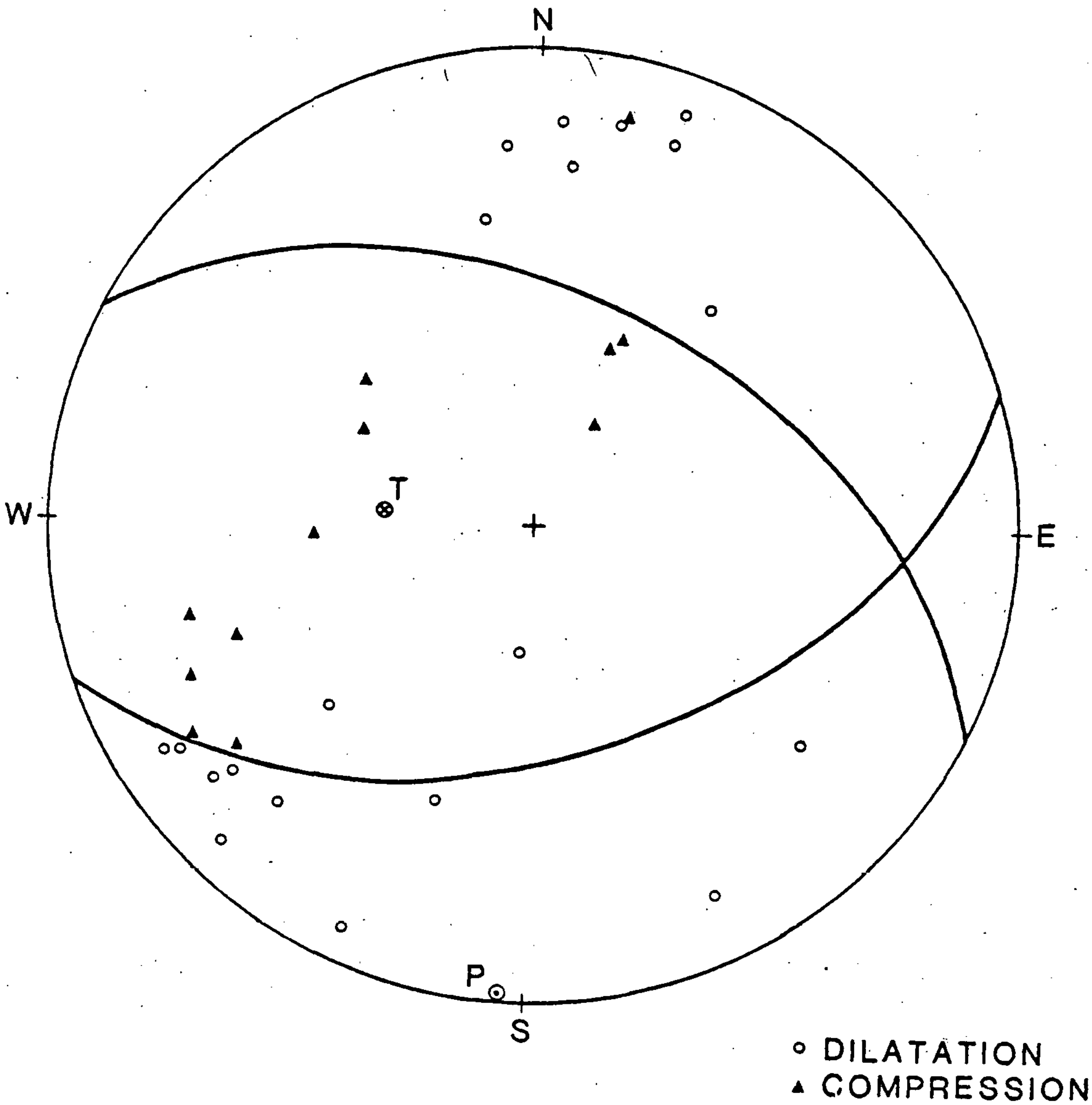

Figure 6. First motion fault plane solution for earthquake of January 25, 1979 (59.997N, 152.840W, h = 129 km). Symbols as in Figure 5.

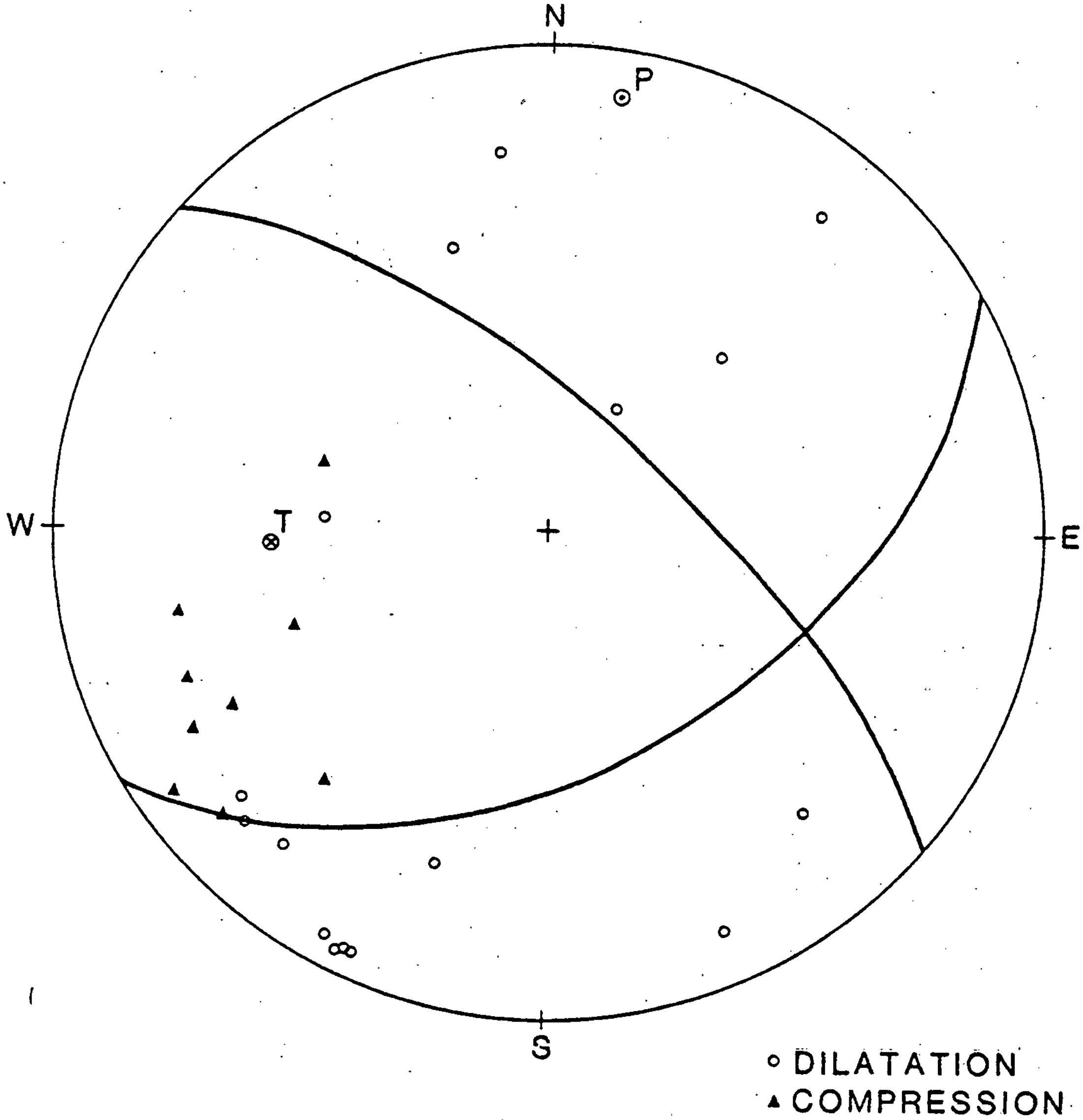

Figure 7. Fault plane solution for earthquake of March 07, 1979 (59.698N, 153.050W, h = 119 km). Symbols as in Figure 5.

associated with a stress system where the axis of least compressive stress is approximately aligned with the dip direction of the subducting lithospheric slab, compatible with the hypothesis that it is sinking gravitationally. This situation was also indicated by a previous, although much smaller set of solutions. All solutions so far have been derived on the basis of seismic velocity structure that varies with depth only. The subducting lithosphere, however, introduces a velocity structure that varies in more than one dimension. A more realistic first motion distribution is obtained by using three-dimensional seismic ray tracing techniques. We shall investigate selected events on that basis.

Hypocenter Relocation:

The satisfactory performance of the regional seismic network over the past years has provided us with an earthquake catalogue of the area that contains a large number of well recorded events. Hypocentral parameters of these events provide a good picture of the seismic source zones and seismotectonic features of the area and our understanding of their relation to other features and aspects of the arc system. For a better understanding of some problems, the ability to locate more precisely earthquake hypocenters is required. Such problems are, for example, the relationship between the morphological details of the Benioff zone and the alignment and offsets of the volcanic centers above it; the precise extent and orientation of aftershocks zones of larger earthquakes in connection with strong ground motion studies, and the precise determination of seismic source zones for seismic risk studies. We have, therefore, begun an integrated effort in this direction. A number of important preliminary tasks have been completed during the report period. The basic problem of location accuracy is related to the inhomogeneities of the earth's crust and upper mantle. Thus, one of our efforts is directed towards a better determination of the crustal and upper mantle seismic velocity structure. To this end, we have completed a catalogue of reread arrival times of high quality from both local and teleseismic events. These data will serve as the fundamental input to the travel time inversion analysis. We have also compiled a catalogue of teleseismically-located events of the study area and classified these events according to location quality based upon regional station control, azimuthal control and the consistency of depth phases. This catalogue will serve as a basis for relocation of our events by Master Event and Joint Hypocenter Determination techniques. We have also performed a detailed study of location accuracy of events occurring in the zone of high seismic activity off Kodiak Island. During two 3-month periods in 1978 and 1979, our landbased system was complimented by an array of eleven Ocean Bottom Seismometers (OBS) deployed by the University of Texas. In the Kodiak area, 19 events were detected by both networks, independently. All events could be located by the land network alone, albeit some rather poorly, because of their small magnitude, while some could not be located by the OBS system alone. Table 1 indicates the shift in epicenters as a consequence of incorporating readings from the OBS system. In general, the events are shifted away from the landbased network, towards the south. The average dislocation is about 15 km. After completion, this study will allow us to incorporate station adjustments in the routine location of offshore events.

Event	Land System Locations		Land and OBS System Locations		Shift (Km)
	Latitude (°N)	Longitude (°W)	Latitude (°N)	Longitude (°W)	
1	57.226	151.680	57.301	151.222	25
2	55.948	153.042	56.047	153.312	19
3	55.973	153.121	56.041	153.267	12
4	56.150	152.304	56.209	152.452	11
5	55.861	153.349	55.593	153.778	40
6	56.178	152.333	56.293	152.532	12
7	56.457	152.301	56.403	152.266	6
8	56.841	150.801	56.914	150.975	13
9	56.007	153.118	56.058	153.224	6
10	57.280	150.721	57.160	151.100	26
11	56.150	152.593	55.976	152.651	4

Table 1. Preliminary locations of Kodiak shelf events determined by land system and combined land-OBS system.

Research Papers:

Abstracts of two papers to be given at the 1981 AGU meeting were sumbitted. Both papers resulted in part from the work under this contract and include the principal investigator as co-author. The text of one abstract is given in Appendix 1. The second is entitled: Earthquake Activity at the Continental Shelf, Alaska, Determined by Land and Ocean Bottom Seismograph Networks, by Jeff Lawton, Cliff Frohlich, Hans Pulpan and Gary V. Latham.

REFERENCE

Pulpan, H. and J. Kienle, Western Gulf of Alaska Seismic Risk, Proc. Offshore Technology Conference, 2209-2219, 1979.

APPENDIX 1

VOLCANIC CENTERS IN THE KATMAI AREA, ALASKA

by

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In the Katmai area of the northern Alaska Peninsula identification of volcanic centers is difficult because of the extensive cover of glacial ice. Results of our reconnaissance study combined with the work of others in the region now give a clear picture of the distribution of volcanic centers in the Katmai area. Volcanic centers are associated with Mt. Douglas, Fourpeaked Mtn., Kaguyak Crater, Devils Desk, Kukak Volcano, Mt. Stellar/Mt. Denison, Snowy Mtn., Mt. Katmai, Novarupta, Mt. Griggs, Mt. Trident, Mt. Mageik, Mt. Martin and Kejulik Mtns. Active fumarole activity is currently associated with Douglas, Kaguyak, Kukak, Snowy, Katmai, Novarupta, Griggs, Trident, Mageik and Martin. Clusters of shallow (less than 10 km deep) earthquake swarms have been located over the past 5 years beneath the volcanoes Mt. Douglas, Kaguyak Crater, Kukak Volcano, Snowy Mtn., Trident, Mt. Mageik and Mt. Martin. This seismicity is apparently related to active magmatic-geothermal reservoirs beneath these volcanoes. Both Mt. Griggs and Katmai have active fumaroles, but no unusual seismic activity has yet been detected beneath these volcanoes. Two pyroxine andesite is the most common lithology in these volcanic centers except at Kaguyak Crater where dacite is the dominant bulk composition and at Novarupta where rhyolite is the most abundant rock type.