UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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EASTERN GULF OF ALASKA SEISMICITY:

ANNUAL REPORT TO THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

FOR APRIL 1, 1980, THROUGH MARCH 31, 1981

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by

Christopher D. Stephens, John C. Lahr, and John A. Rogers

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ANNUAL REPORT

Title:	Earthquake Activity and Ground Shaking in and along the Eastern Gulf of Alaska
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I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objective of this research is to collect and analyze data on earthquake activity in the northeast Gulf of Alaska (NEGOA) and adjacent onshore areas in order to develop a better regional seismotectonic model and more accurately assess the earthquake potential. This information is critical to the establishment of criteria for the safe development of oil and gas. Large ($M_S > 7$) historical earthquakes have occurred in and around the NEGOA, and recent studies suggest that the NEGOA is a likely site for a magnitude 8 or larger earthquake to occur within the next two or three decades. A great earthquake ($M_S > 8$) associated with low-angle oblique underthrusting of the sea floor beneath continental shelf could be accompanied by strong ground shaking throughout much of the eastern Gulf of Alaska, possibly from Cross Sound to Kayak Island (Page, 1975), and could trigger tsunamis, seiches, and submarine slumping, any of which could be hazardous to offshore and coastal structures (Meyers, 1976).

II. INTRODUCTION

A. General nature and scope of study

The purpose of this research is to investigate the earthquake potential in the NEGOA and adjacent onshore areas. This will be accomplished by assessing the historical seismic record as well as by collecting new and more detailed information on both the distribution of current seismicity and the nature of strong ground motion resulting from large earthquakes.

B. Specific objectives

1. Record the locations and magnitudes of all significant earthquakes within the NEGOA area.
2. Prepare focal mechanism solutions to aid in interpreting the tectonic processes active in the region.
3. Identify both offshore and onshore faults that are capable of generating earthquakes.
4. Assess the nature of strong ground shaking associated with large earthquakes in the NEGOA.
5. Compile and evaluate frequency versus magnitude relationships for seismic activity within and adjacent to the study areas.
6. Evaluate the observed seismicity in close cooperation with OCSEAP Research Units 16 and 251 towards development of an earthquake prediction capability in the NEGOA.

C. Relevance to the problem of petroleum development

It is crucial that the seismic potential in the NEGOA be carefully analyzed and that the results be incorporated into the plans for future petroleum development. This information should be considered in the selection of tracts for lease sales, in choosing the localities for oil pipelines land-based operations, and in setting minimum design specifications for both coastal and offshore structures.

III. CURRENT STATE OF KNOWLEDGE

The eastern Gulf of Alaska and the adjacent onshore areas are undergoing compressional deformation caused by north-northwestward migration of the Pacific plate with respect to the North American plate (Figure 1). Direct evidence for continued convergent motion comes from studies of large earthquakes along portions of the Pacific-North American plate boundary adjacent to the eastern Gulf of Alaska. The 1958 earthquake on the Fairweather fault in southeastern Alaska was accompanied by right-lateral slip of as much as 6.5 m (Tocher, 1960). The 1964 Alaska earthquake resulted from dip-slip motion of about 12 m (Hastie and Savage, 1970) on a fault plane dipping to the northwest beneath the continent from the Aleutian trench and extending from eastern Prince William Sound to southern Kodiak Island. Most recently, the 1979 St. Elias earthquake involved about 2 m (Hasegawa and others, 1980) of low-angle reverse faulting on a shallow, northwestward-dipping plane beneath the St. Elias mountains in southeastern Alaska and southwestern Yukon Territory. The plate boundary in the source region of the 1964 earthquake is relatively simple. To the east, however, approximately between the longitudes of Kayak Island and Cross Sound, the precise manner in which the convergent motion is accomodated is still the subject of investigation.

IV. STUDY AREA

This project is concerned with the seismicity within and adjacent to the eastern Gulf of Alaska continental shelf area. This is the southern coastal and adjacent continental shelf region of Alaska between Montague Island and Cross Sound.

V. METHODS AND RATIONALE OF DATA COLLECTION

The high-gain short-period seismograph stations installed along the eastern Gulf of Alaska under the Outer Continental Shelf Environmental Assessment Program as well as the other stations operated by the USGS in southern Alaska are shown in Figure 2. Single-component stations record the vertical component of the ground motion, while three-component stations have instruments to measure north-south and east-west motion as well. Data from these instruments are used to determine the parameters of earthquakes as small as magnitude 1. The parameters of interest are origin time, epicenter, depth, magnitude, and focal mechanism. These data are required to further our understanding of the regional tectonics, to identify faults, and to assess rates of seismic activity.

A network of strong motion instruments (Figure 3) is also operated. These devices are designed to trigger during large earthquakes and give high-quality records of large ground motions which are necessary for engineering design purposes.

VI. RESULTS

Over 5,400 earthquakes that occurred within the NEGOA region between October 1, 1979, and February 28, 1981, were located during the past year. Such an extensive data set is a valuable tool for identifying areas that are currently seismically active, for resolving tectonic processes and seismogenic structures, and for studying variations in spatial and temporal patterns of seismic activity. Maps showing the distribution of the earthquake epicenters for six successive quarters since October 1979 are shown in Figures 4 to 9.

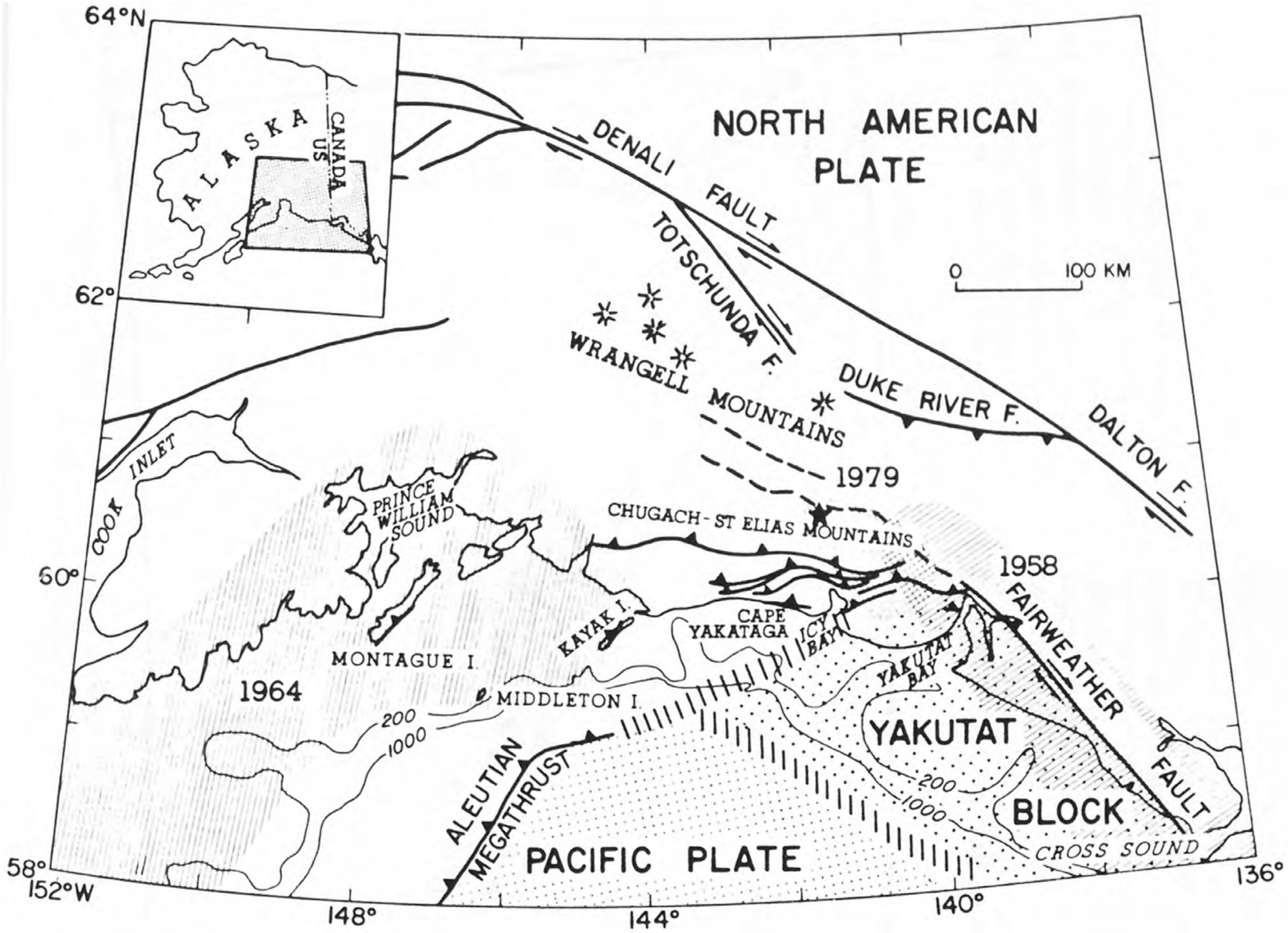


Figure 1. Regional tectonic setting of the NEGOA (after Stephens and others, 1980c). Major faults (heavy lines) and Quaternary volcanoes (light stars) after Plafker and others (1978) and Beikman (1980). Hatched lines represent inferred tectonic boundaries (Plafker and others, 1978). Slant-shaded areas indicate extent of aftershock zones from 1958 Fairweather fault, 1964 Prince William Sound earthquakes (Sykes, 1971) and 1979 St. Elias earthquake (Stephens and others, 1980c). Heavy star is located at the epicenter of the 1979 mainshock. The Pacific plate and overlying Yakutat block (stippled areas) move to the north-northwest with respect to the North American plate resulting in a complex zone of northward-directed convergence.

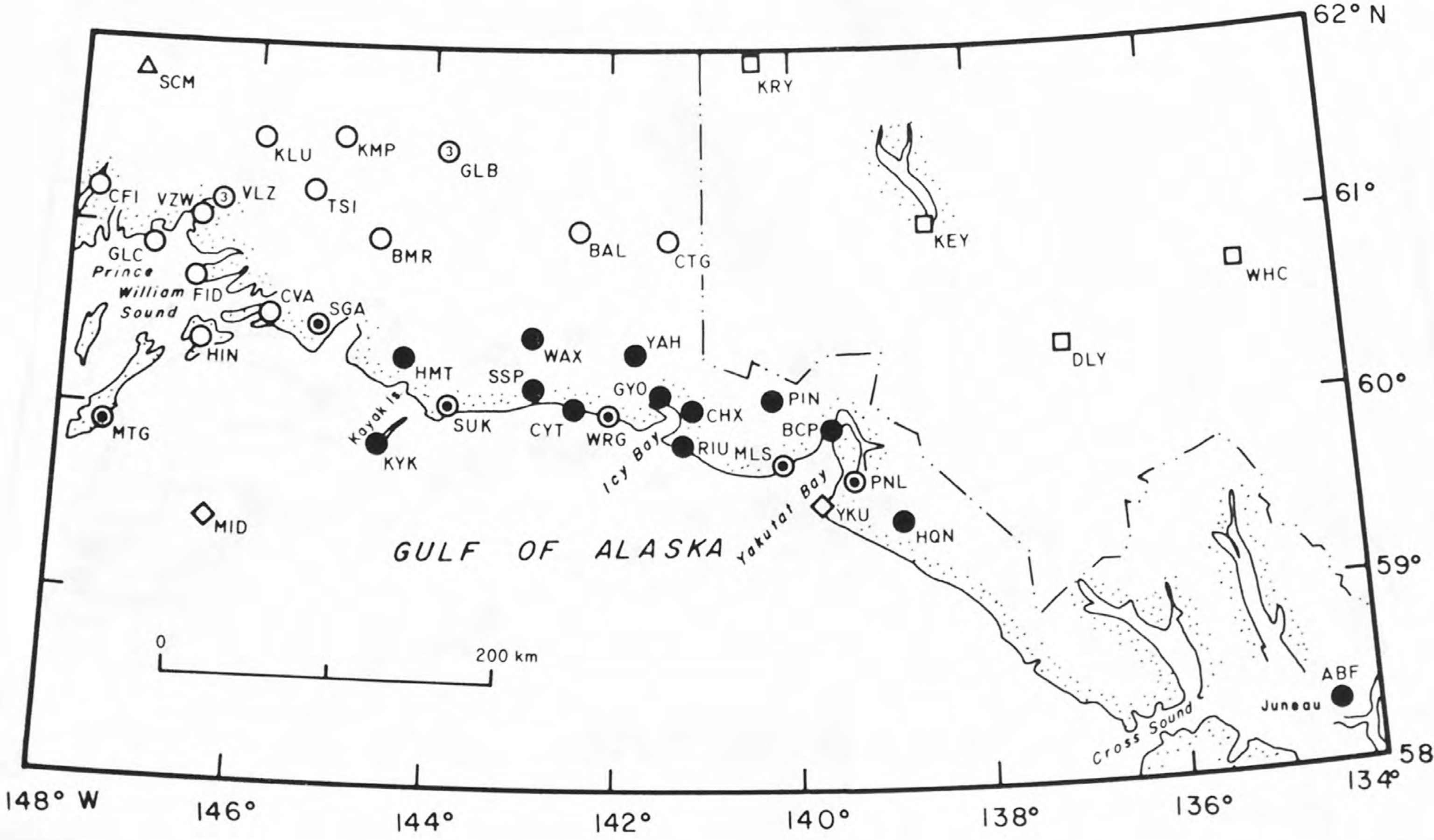


Figure 2. High-gain vertical-component seismic stations in the NEGOA and adjacent areas. The symbols are as follows: solid circles--primary USGS stations supported in part by OCSEAP; circles with center dot--backup USGS stations supported by OCSEAP; open circles--USGS stations not supported by OCSEAP, a "3" indicates north-south and east-west components in addition to the vertical component; diamonds--Alaska Tsunami Warning Center stations; triangles--University of Alaska stations; squares--Canadian stations operated by the Department of Energy Mines and Resources. The station at Middleton Island (MID) was not operational between March 1979 and February 1981.

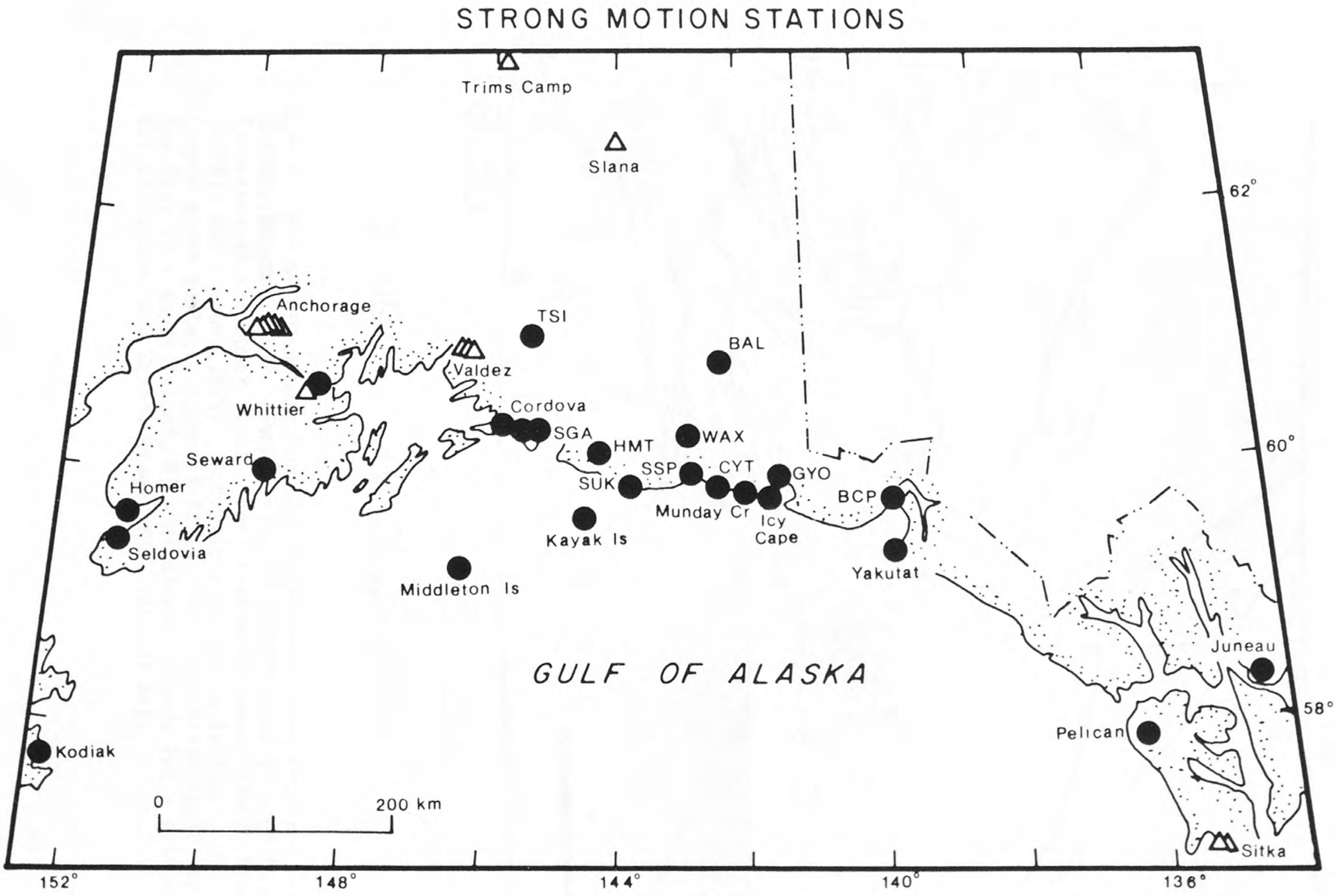


Figure 3. Location of USGS strong-motion instruments in southern Alaska. Stations supported by OCSEAP are indicated by solid circles.

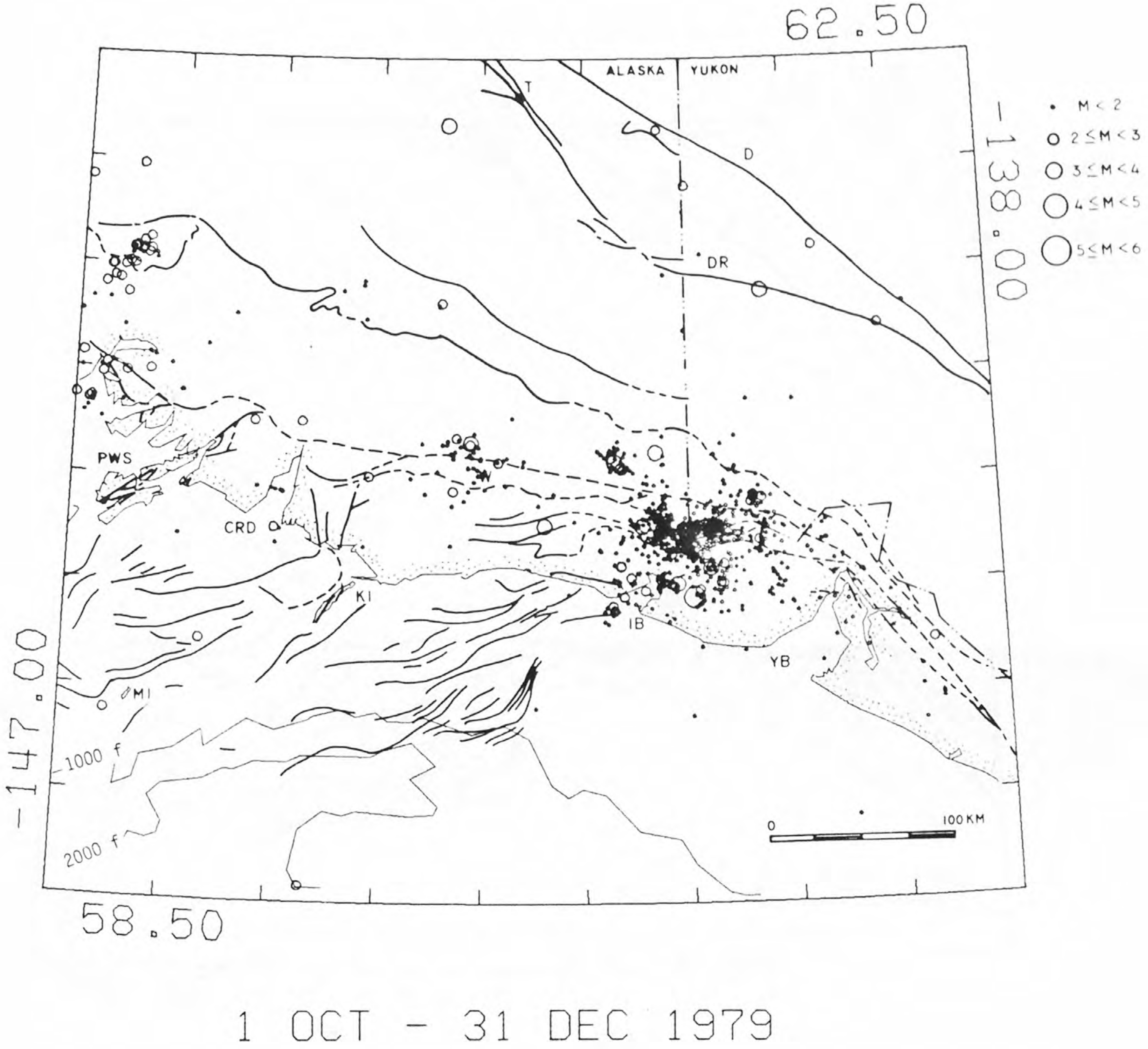


Figure 4. Map of epicenters for 1036 earthquakes that occurred during October-December 1979. Symbol size is proportional to magnitude as indicated at the upper right. Faults after Beikman (1980), Bruns (1979), and Clague (1979). Abbreviations are as follows: CRD - Copper River Delta; D - Denali fault; DR - Duke River fault; IB - Icy Bay; KI - Kayak Island; MI - Middleton Island; PWS - Prince Willaim Sound; W - Waxell Ridge; YB - Yakutat Bay.

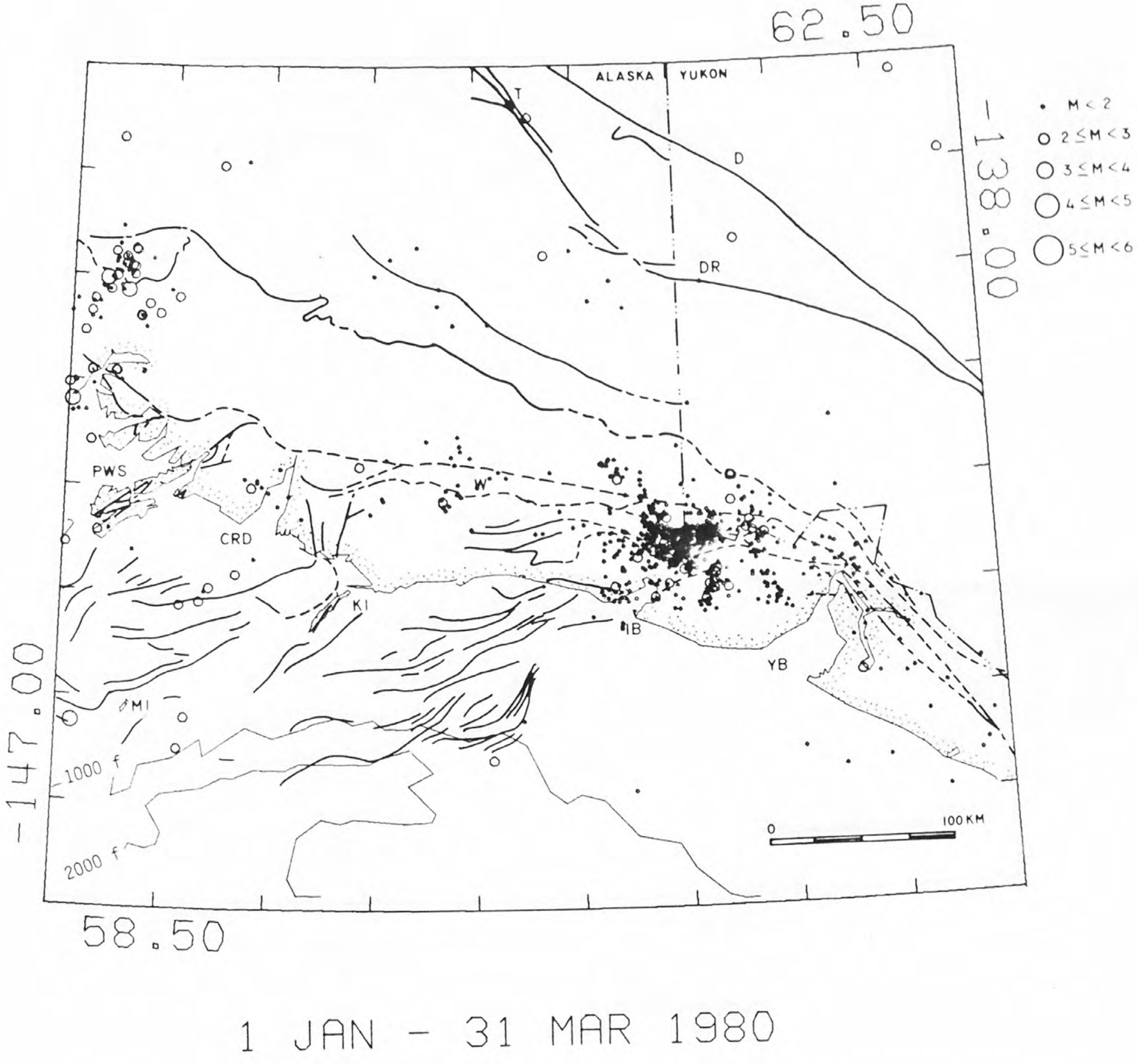


Figure 5. Map of earthquake epicenters for 914 earthquakes that occurred during January-March 1980. See Figure 4 for explanation of symbols.

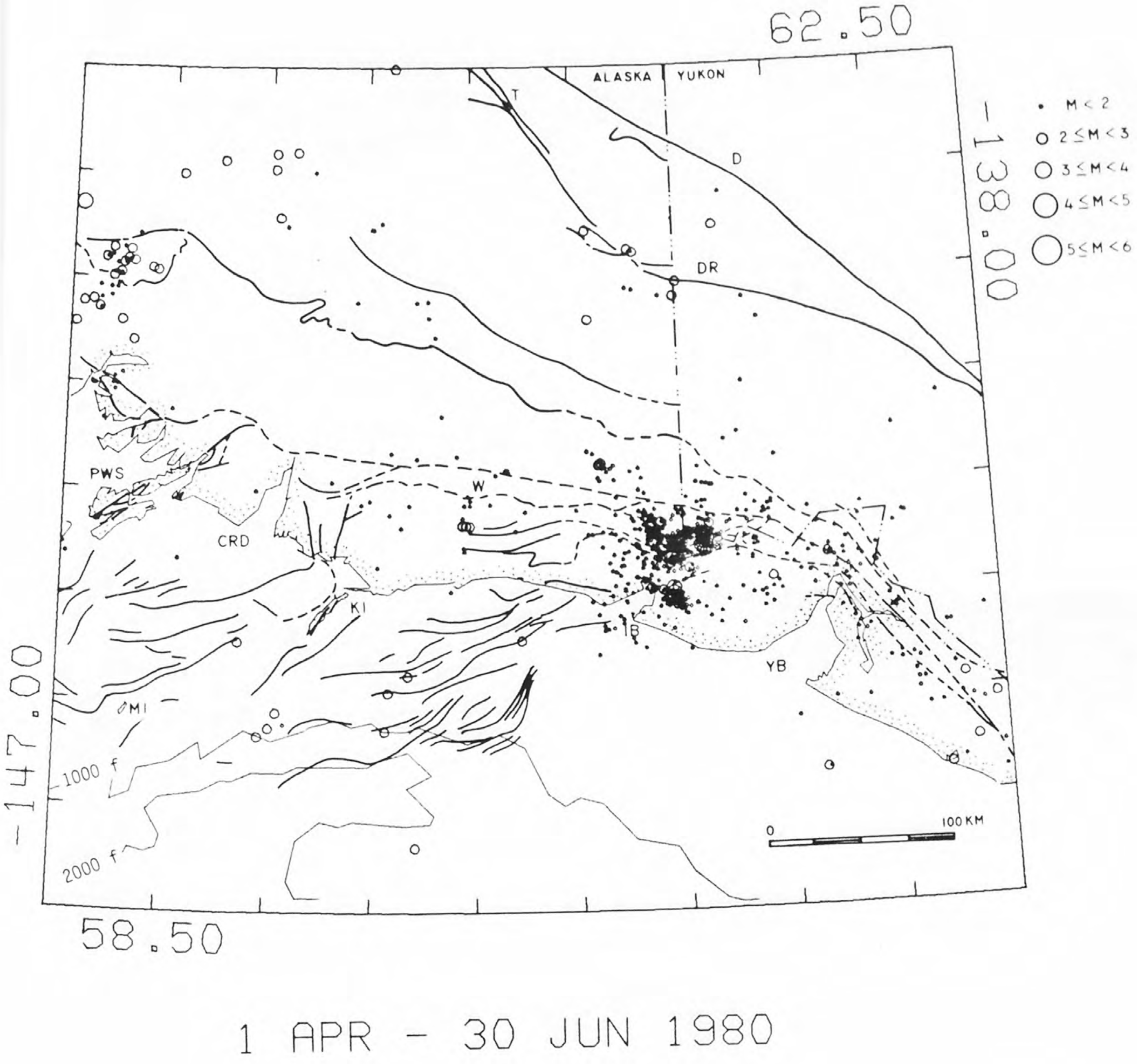


Figure 6. Map of earthquake epicenters for 819 earthquakes that occurred during April-June 1980. See Figure 4 for explanation of symbols.

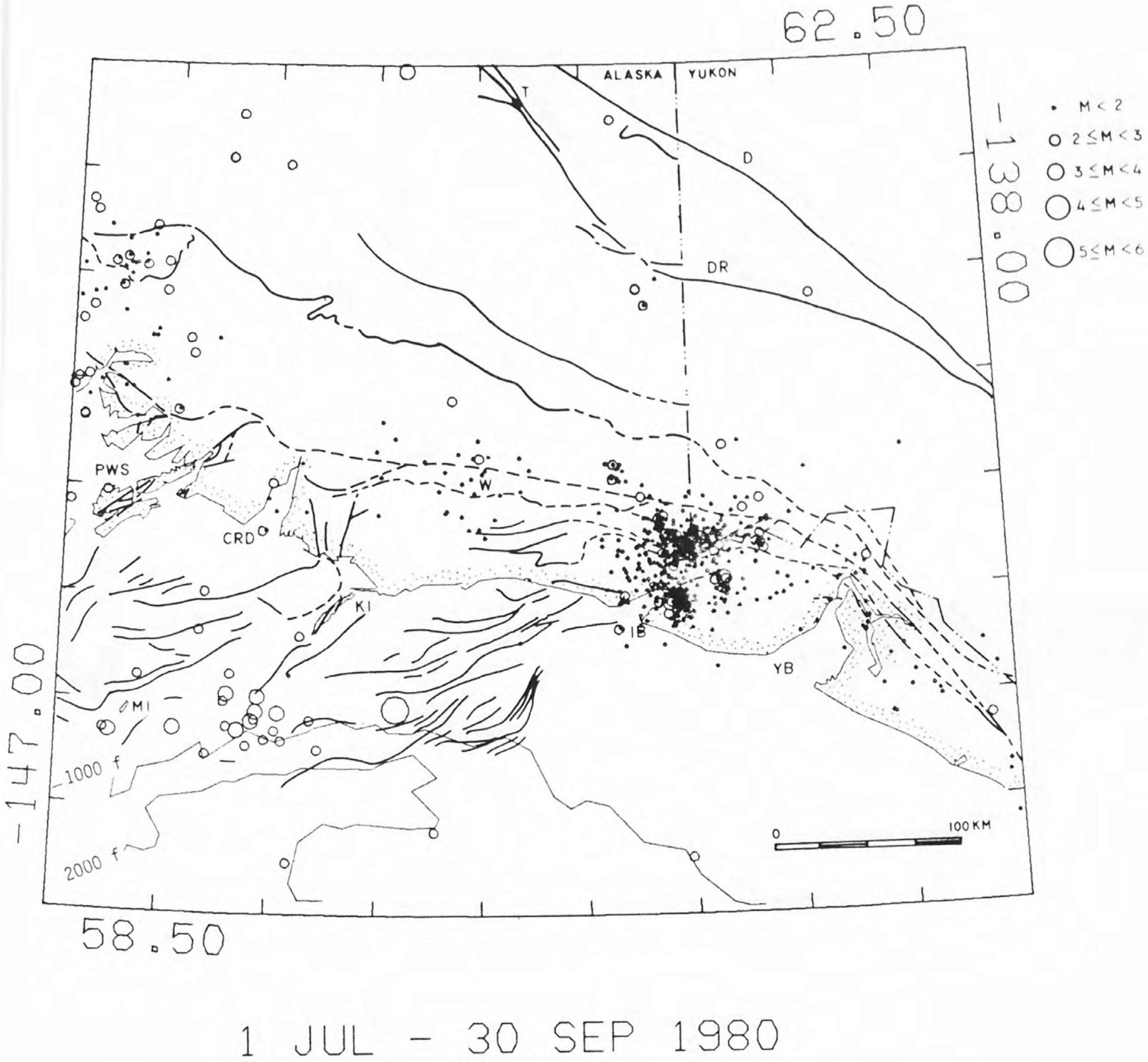
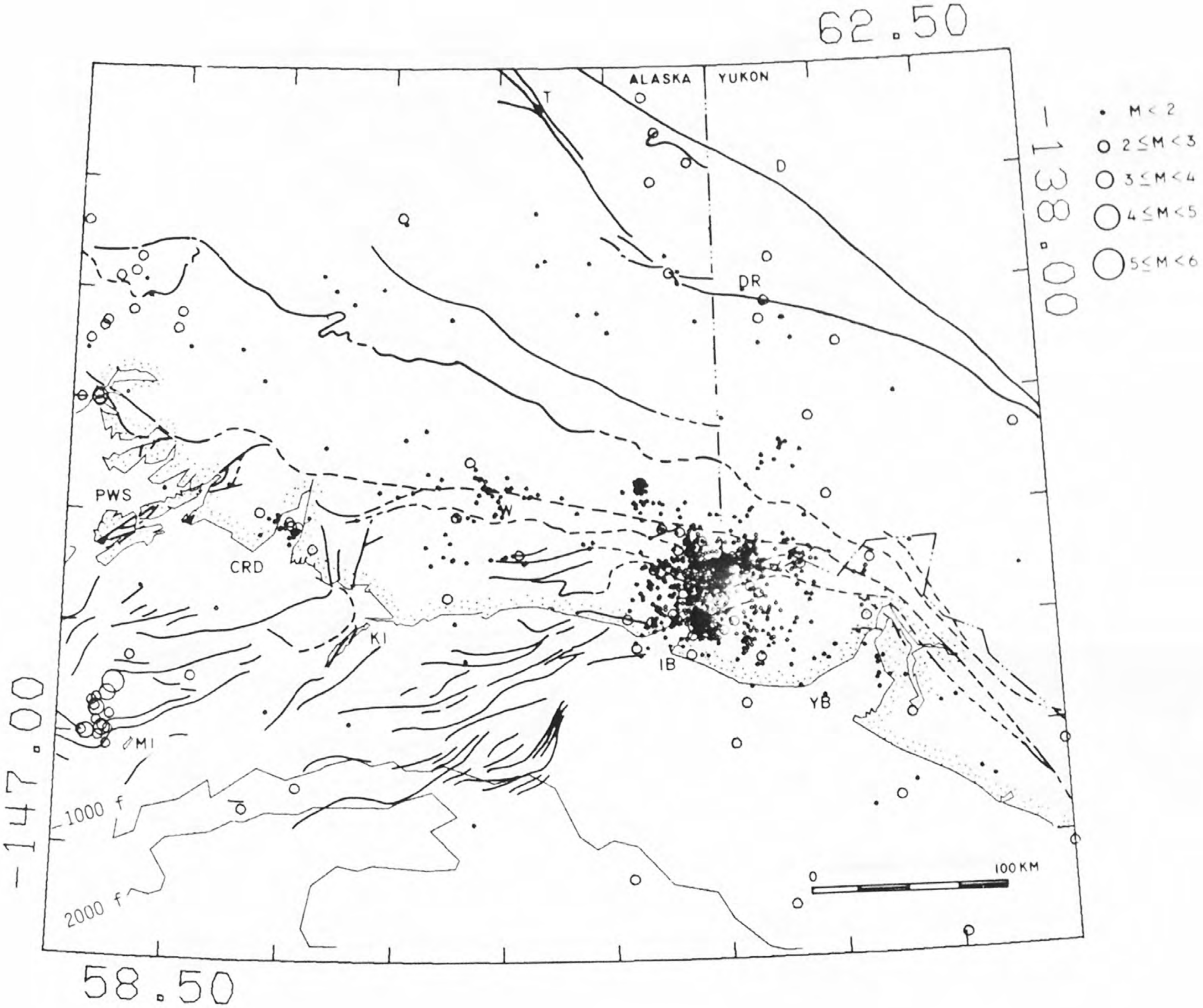


Figure 7. Map of earthquake epicenters for 775 earthquakes that occurred during July-September 1980. See Figure 4 for explanation of symbols.



1 OCT - 31 DEC 1980

Figure 8. Map of earthquake epicenters for 1192 earthquakes that occurred during October-December 1980. See Figure 4 for explanation of symbols.

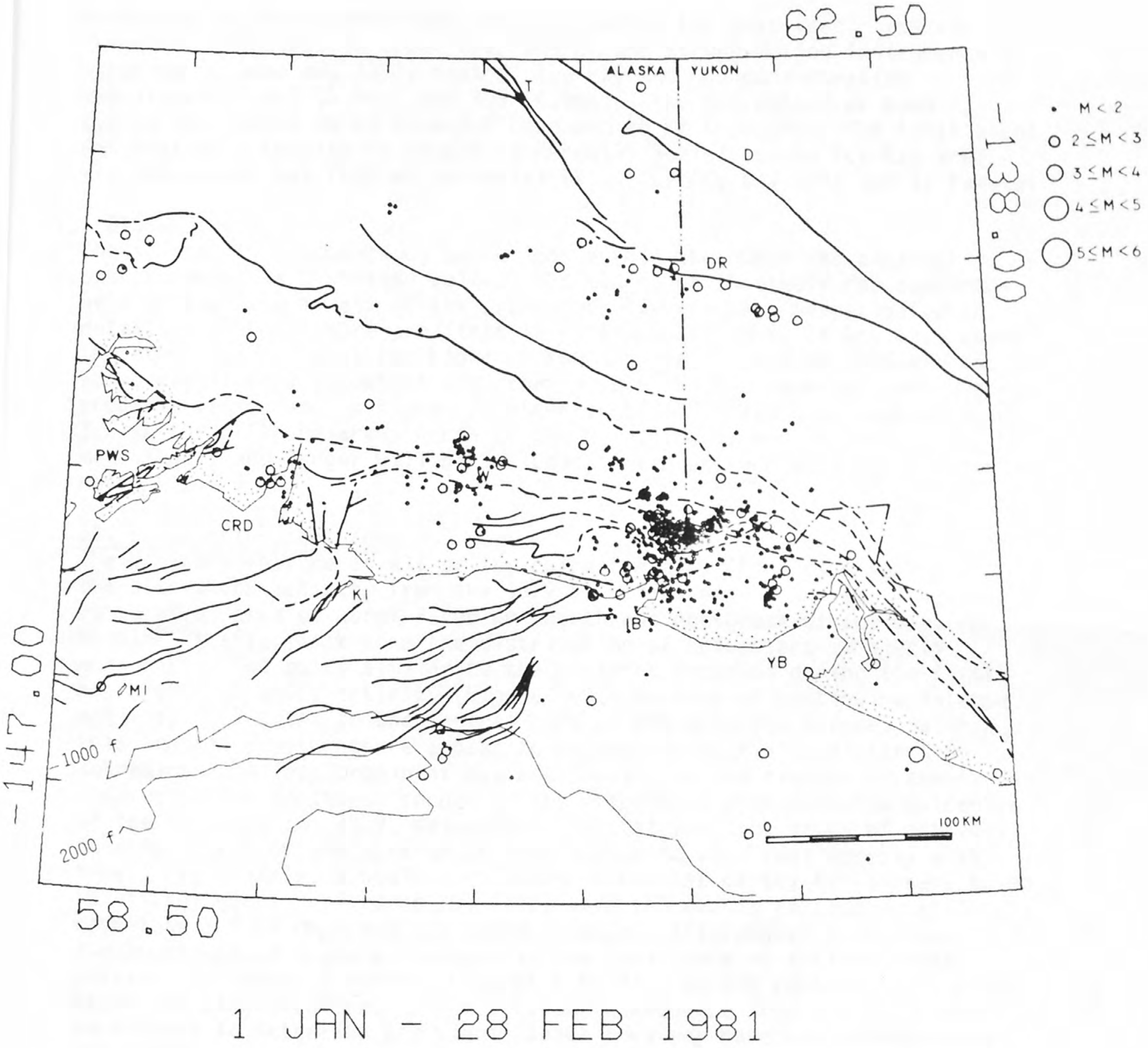


Figure 9. Map of earthquake epicenters for 691 earthquakes that occurred during January-February 1981. See Figure 4 for explanation of symbols.

No strong motion records were obtained during the past year. The two largest earthquakes to occur near any of the strong-motion instruments occurred on June 30, 1980, east of Icy Bay and had coda-duration magnitudes of 3.7 (5.0m_b) and 3.9 (4.9m_b). The epicenters of both events were about 30 km from Icy Cape and 25 km from GYO. The first event was felt at intensity IV (Modified Mercalli Scale) in the Icy Bay area, and the second was felt at intensity IV in the Icy Bay area and at Yakutat.

VII. DISCUSSION

The seismicity from various subregions within the NEGOA and adjacent onshore areas is discussed below. The magnitude threshold for completeness of the data in all of the subregions has not been investigated in detail. In the onshore area that is within about 75 km of Icy Bay, where the station density is the highest, the estimated level of completeness is about magnitude 2 (Stephens and others, 1980c). The level of completeness probably varies and is higher in other areas, and may be as high as 3 to 3.5 in the offshore areas north of 59° N latitude. Most events of magnitude 2 and larger will be included in the onshore areas within the network.

St. Elias Aftershock Zone

The dominant feature in all of the epicenter maps (Figures 4 to 9) is the aftershock activity from the 1979 St. Elias earthquake (M_S 7.1) that ruptured an area of about 3,200 km north and northeast of Icy Bay. Within the aftershock zone the distribution of epicenters is highly non-uniform but quite similar to the patterns observed during the first month of aftershock activity (Figure 10). An area of continuing intense activity is located in the central part of the aftershock zone. Within this central cluster there appear to be several spatially distinct subregions. A less prominent but continually active cluster of events is located at the northwest corner of the aftershock zone near the epicenter of the February 28, 1979, mainshock. In contrast, the rates of activity in other parts of the aftershock zone appear to vary considerably with time. For example, a small area about 15 km east of Icy Bay appears to be relatively quiet until June 30, 1980, when two events of coda-duration magnitude 3.7 (5.0m_b) and 3.9 (4.9m_b) occur. Aftershocks from these two events cause a sharp increase in the local rate of activity that persists for about 6 months (Figures 6 to 8). We are continuing to study these and other features in the aftershock sequence from the St. Elias earthquake to determine any significance they may have for interpreting the regional seismotectonic structure.

Waxell Ridge Area

Waxell Ridge is located in the Chugach Mountains about 75 km northeast of Kayak Island. A zone of diffuse, low-level shallow seismicity can be observed in the vicinity of this ridge throughout the time period since October 1979. A similar pattern of seismicity has been observed in this area since September 1974 when the seismic network east of Cordova was expanded to near its present configuration (e.g., Stephens and Lahr, 1979, 1981). Although the Waxell area has remained continually active, the rate of seismicity appears to fluctuate with time, as suggested by a space-time plot of the epicenters (Figure 11). The most striking feature of this plot is the relatively high rate of magnitude 2 and larger events during the 6-month period that preceded the February 1979 St. Elias earthquake as compared to the rate beginning in October 1979. Until the data set is

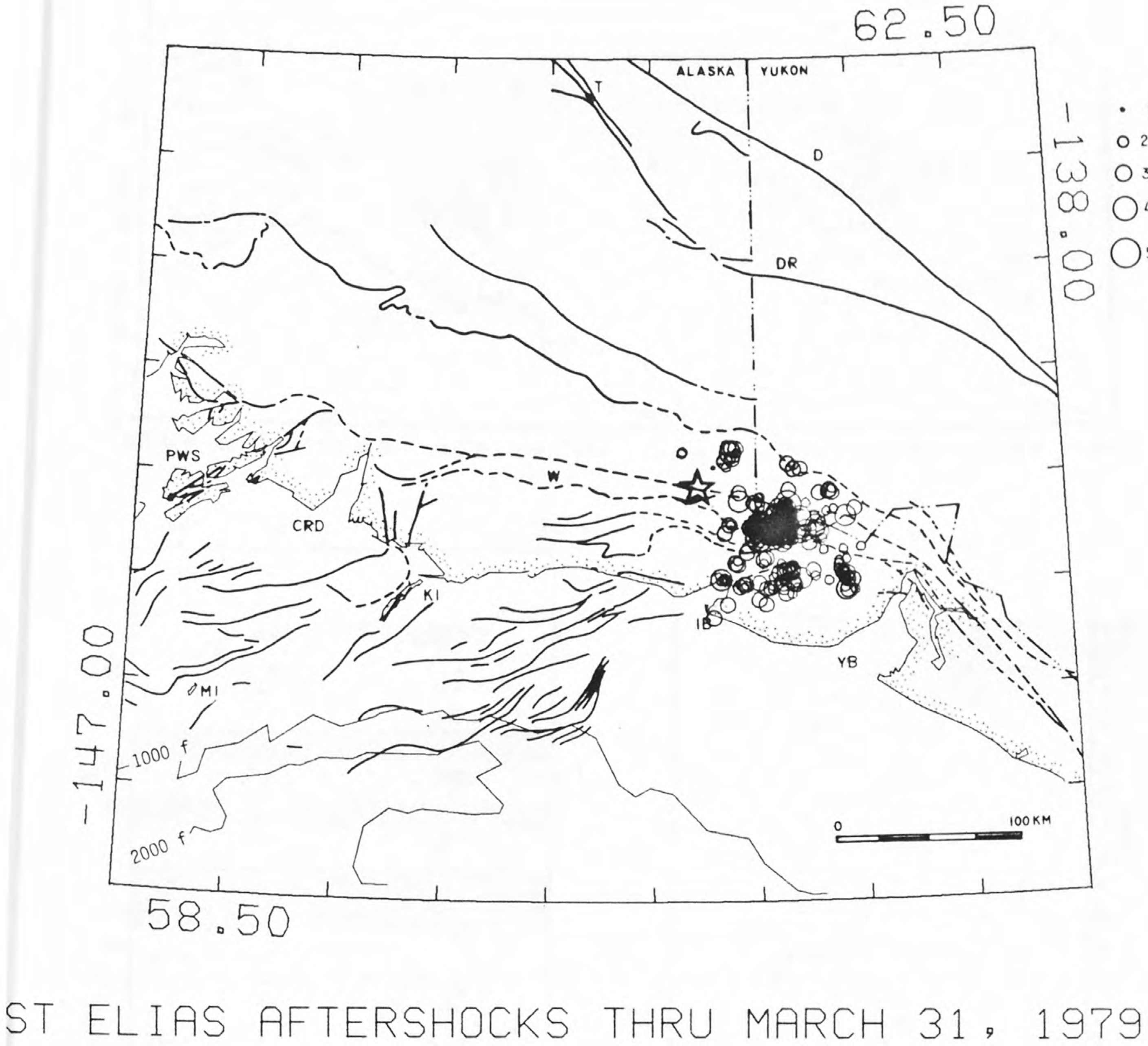


Figure 10. Aftershocks of the February 28, 1979, St. Elias earthquake that occurred through March 31, 1979 (Stephens and others, 1980). The epicenter of the mainshock is indicated by a star. The data set is probably only complete for earthquakes of magnitude 3.5 and larger. The two largest aftershocks that occurred during this time had coda-duration magnitudes of 4.9 (5.4 m_b) and 5.0 (5.4 m_b). One occurred about 25 km southeast of the epicenter of the main shock, and the other occurred within the central main cluster of aftershocks. See Figure 4 for explanation of symbols.

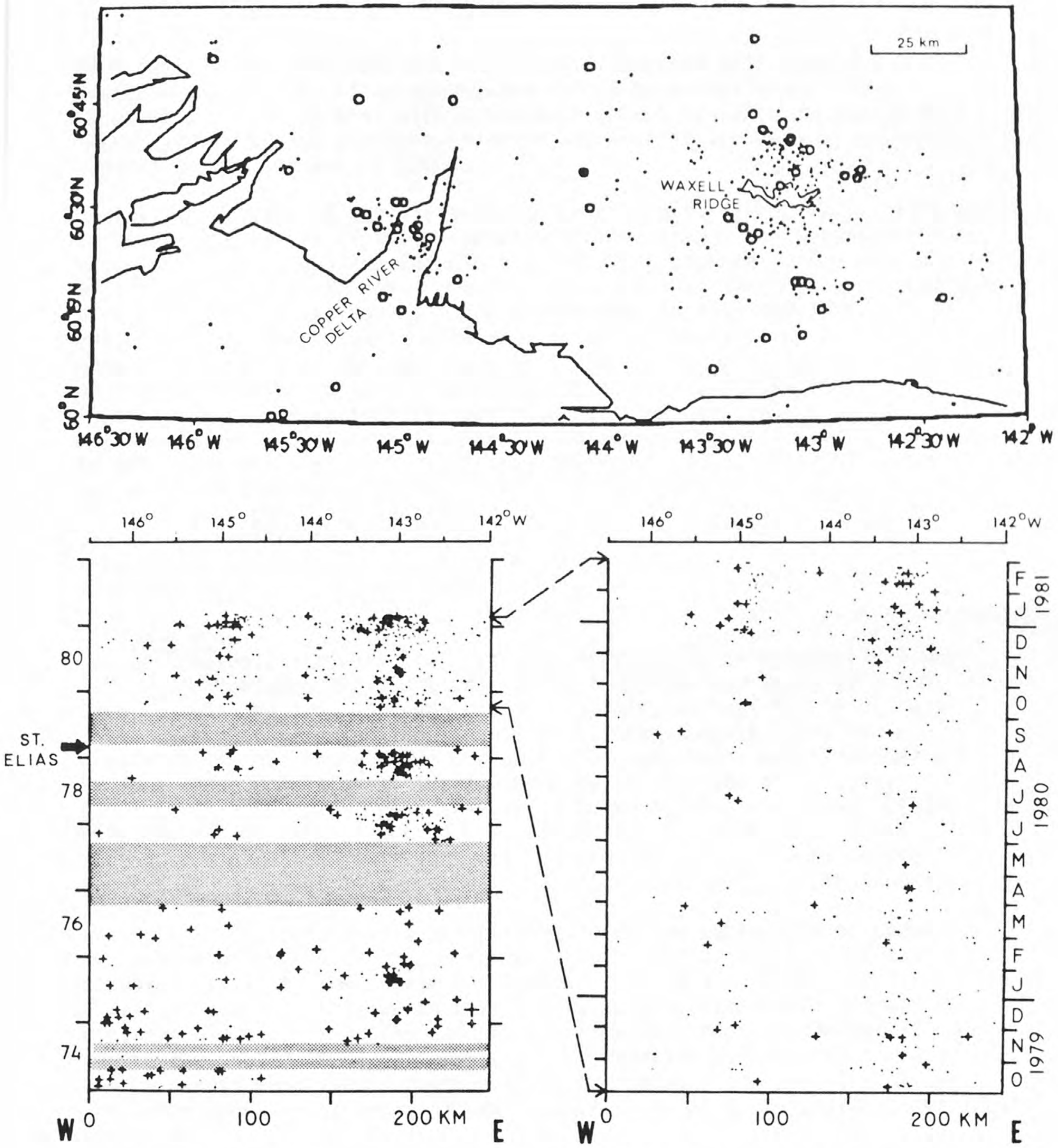


Figure 11. Space-time distribution of earthquake epicenters located near Waxell Ridge and Copper River Delta. Upper - Epicenters for the period October 1979 through February 1981. Larger plotting symbols correspond to earthquake magnitudes of 2 and larger. The 2000-m elevation contour around Waxell Ridge is shown for reference. Lower right - Space-time distribution of epicenters projected onto east-west line across center of map area above. Lower left - Space-time distribution of epicenters determined with USGS data for same map area since 1974. Shading indicates time periods for which available data has not yet been analyzed. The arrow indicates the time of the 1979 St. Elias earthquake.

more complete in time, the possible significance of this contrast as a precursor to the St. Elias earthquake cannot be established. It is interesting to note that within the most recent 17-month period of data there appears to be a slight relative increase in the rate of activity beginning near the end of 1980.

Because the depths of these events are poorly constrained, it is difficult to assess the nature of the seismicity in this area. The seismicity does occur within the Yakataga seismic gap, which is bounded to the west and east by areas known to have ruptured along shallow, low-angle, northward-dipping thrust faults during large earthquakes in 1964 and 1979. It is reasonable to assume that a similarly oriented thrust plane extends beneath the Yakataga gap and the Waxell Ridge area, and that at least some of the earthquakes in this area may occur on such a buried fault. Alternatively, the earthquakes may occur at shallower depths on the high-angle, east-west trending, northward-dipping reverse faults inferred to intersect the surface in this area (Beikman, 1980). Preliminary results from a detailed study of selected events from this area indicate that at least these few earthquakes occurred at depths between about 10 and 20 km, similar to the range of depths determined for most of the aftershocks from the St. Elias earthquake. This result and the diffuse distribution of hypocenters favor the low-angle faulting hypothesis.

Offshore area

The most notable activity that occurred offshore since October 1979 was in the area between 142° 30'W and 147° W longitude and south of 60° N latitude (Figure 12). Between October 1, 1979, and May 31, 1980, only about 15 events were located in this area. The largest event had a coda-duration magnitude of 3, and only one event had a magnitude below 2. In June 1980, a relatively sudden increase in the rate of activity occurred in a 50 km-diameter area about 50 km southwest of Kayak Island. This high local rate of activity continued for a period of almost 5 months, during which six events with coda-duration magnitudes between 3 and 3.5 and at least 14 events with magnitudes of 2 and larger occurred.

On September 4, before this sequence was over, an earthquake of coda-duration magnitude 5 ($5.2m_b$) occurred about 60 km to the east of the cluster. This is the largest earthquake to occur in the offshore area in almost 10 years. It is worth noting that while three events of magnitude 2 occurred about 3 1/2 months earlier near the epicenter of the magnitude 5 earthquake, no locatable aftershocks were detected for this earthquake, and no events were located within 40 km of the epicenter until February 1981 when four events of magnitude 2 occurred about 35 km southeast of the epicenter.

In October 1980, the activity southwest of Kayak Island subsided, but was followed shortly by a burst of activity located about 75 km farther west and about 20 km northwest of Middleton Island. The later activity was tightly clustered in both space and time. The two largest events had coda-duration magnitudes of 4.1 ($4.8m_b$) and 3.5 ($4.3m_b$). Following this activity, the seismicity rate in the offshore area decreased to a level similar to that observed during the 8-month period before June 1980. It is interesting to note that about one year earlier in September 1979 a similar pair of earthquakes with body-wave magnitudes of $4.7m_b$ and $4.2m_b$ occurred in the same area, but because the data

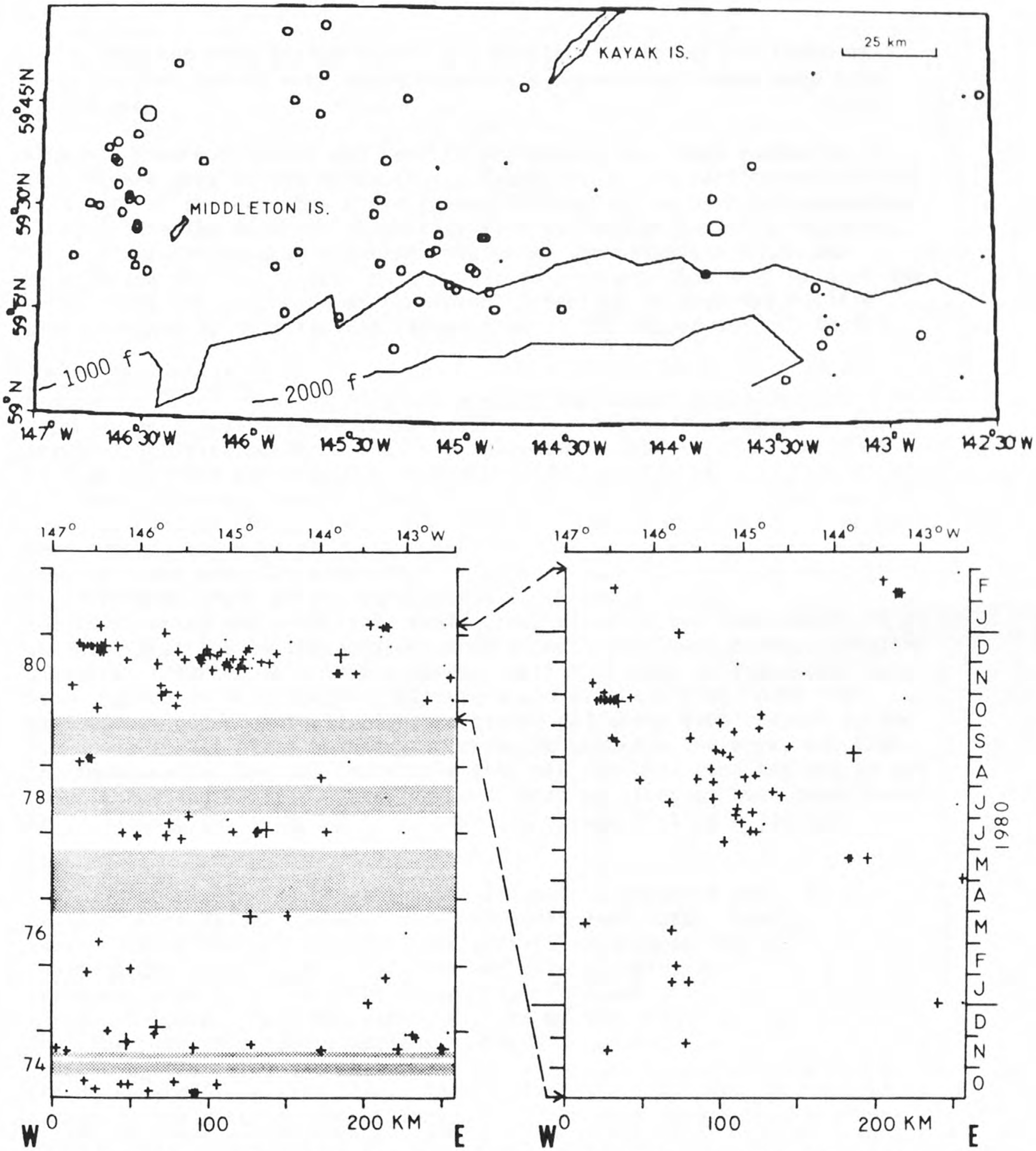


Figure 12. Spcae-time distribution of earthquake epicenters in the offshore area that was most seismically active between October 1979 and February 1981. Upper - Epicenters for the period October 1979 through February 1981. Symbol size is proportional to magnitude in three intervals: less than 2.0, 2.0 to 3.9, and 4.0 and larger. Lower right - space-time distribution of epicenters projected onto an east-west line across center of map area above. Lower left - Space-time distribution of epicenters determined by USGS for same map area since 1974. Shading indicates time periods for which available data has not yet been analyzed.

processing for this period is not yet complete it is not yet known if these earlier events were accompanied by a sequence of lower magnitude earthquakes.

Although numerous folded and faulted structures have been mapped in theoffshore area of the NEGOA (e.g., Bruns, 1979) and particularly in the area west of the Pamplona Ridge (about 142° 30'W), we have not attempted to correlate the offshore seismicity with particular mapped structures. Because the earthquakes occurred outside of the seismic network the hypocenters are poorly constrained. It is also possible that most of the earthquakes are occurring at the thrust interface between the Pacific plate and overlying structure rather than on the mapped surface faults.

Copper River Delta

A moderate level of seismicity centered at the Copper River Delta can be observed in the data since October 1979. A noticeable increase in the level of activity occurred starting in December 1980 at about the same time an increase was observed in the Waxell area (Figure 11). A distinct northwest-southeast trend is apparent in the epicenters for the Copper River Delta area (Figure 13). No faults that intersect this cluster have been mapped, but much of the surrounding area is covered by Quaternary deposits, and possible extensions of nearby mapped faults into this area is uncertain. Most of the earthquakes have depths between 10 and 30 km, and considering the relatively small uncertainty in the hypocenters it is unlikely that the earthquakes occurred at much shallower depths. Similar clusters of earthquakes that occurred north of Prince William Sound have been studied in more detail. Blackford and others (1976) found that earthquakes occur on fault planes oriented obliquely with respect to the low-angle thrust plate boundary inferred to underlie the area, but that the focal mechanisms are compatible with the regional stresses due to the understhrusting Pacific plate. A more detailed study of the Copper River Delta seismicity is needed to resolve the nature of this activity.

Other areas

A prominent clustering of earthquake epicenters occurred about 50 km north of Port Valdez centered near 61° 30'N, 146° 30'W. Similar clusters have been observed in this particular area in the past (e.g., Fogleman and others, 1978; Stephens and others, 1979) and in adjacent areas north of Prince William Sound (Blackford and others, 1976) as discussed above. Two interesting aspects of the recent seismicity are that the rate of activity appears to decrease with time during the period covered by the data, and that the distribution of epicenters appears to become more diffuse with time. This latter aspect is best illustrated by comparing the distribution of epicenters from this area during October-December 1979 (Figure 4) with that during July-September 1980 (Figure 7).

During the time interval from October 1979 to February 1981, 90 earthquakes were located north of about 61° N latitude and between 138° W and 142° W longitude. The seismicity is more pronounced in late 1980 and early 1981 than it was during the previous year beginning October 1979. It is not yet known whether this change represents an actual increase in the seismicity of this area or is due to an artifact of the data processing. All of the earthquakes were located at crustal depths less than 35 km. It is interesting that most of the epicenters define two separate trends that parallel two of the major faults mapped in the area,

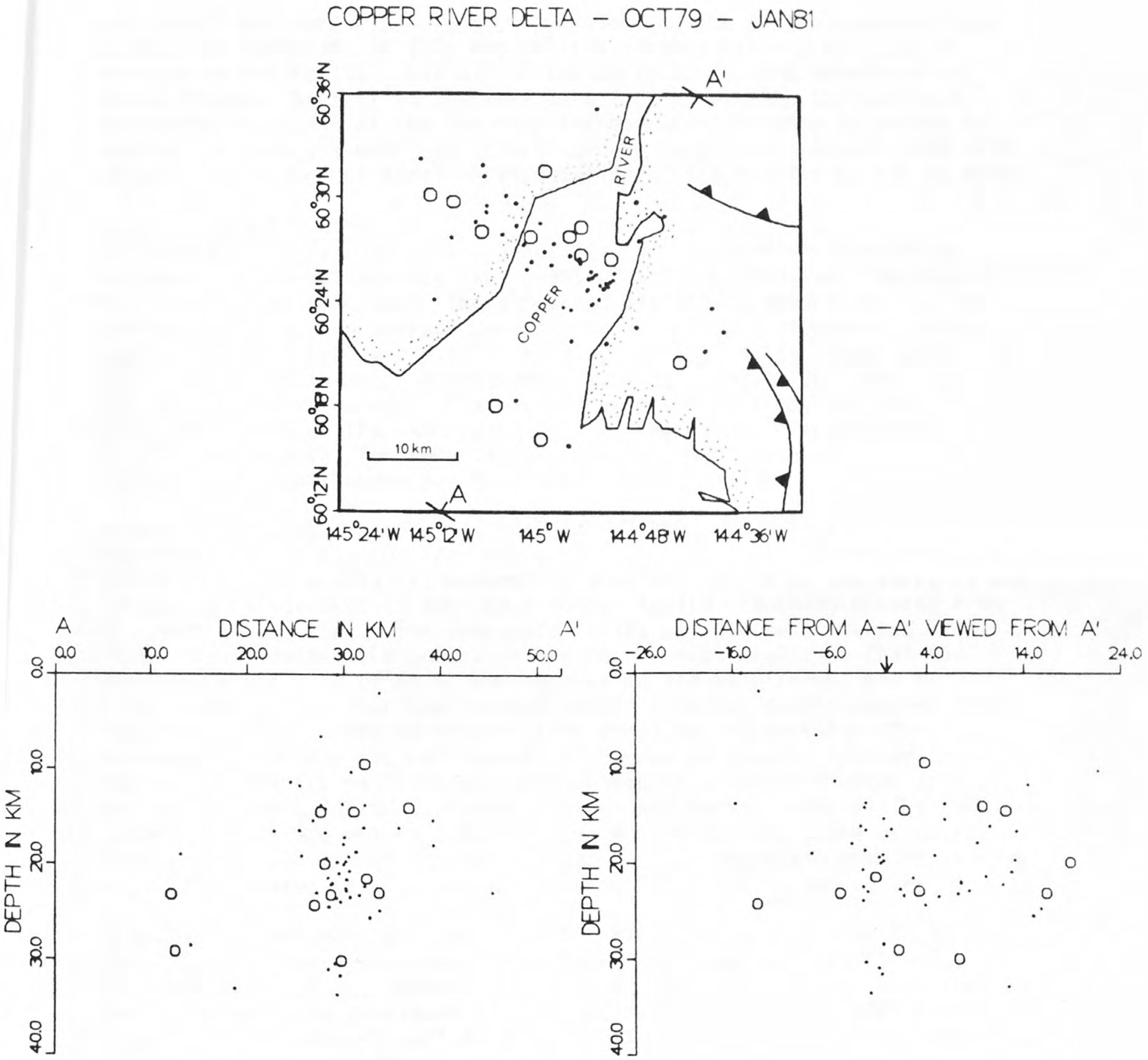


Figure 13. Hypocenters of earthquakes that occurred beneath the Copper River Delta between October 1979 and February 1981. Upper - Map view showing relation to nearby faults. Larger symbol size corresponds to events of magnitude 2 and larger. Lower - Hypocenters are projected onto vertical cross sections oriented along the line joining A-A' (lower left) and perpendicular to A-A' (lower right).

the Denali and Duke River faults. Considering the possible bias of the hypocenter locations in this region, the earthquakes may be closely related to the faults. Not all of the earthquakes were located along these trends. Several earthquakes were located beneath the Wrangell mountains southwest of the two main trends. Further work is needed to refine the velocity model structure used to locate earthquakes from this area before a more critical interpretation of the seismicity can be made.

Other relevant studies

Plafker and others (1981) have identified and studied three Holocene marine terraces between Icy Cape (west of Icy Bay) and Cape Yakataga in the Yakataga seismic gap. The dates and elevations determined for the terraces indicate an average uplift rate at Icy Cape of about 10 mm/yr during the past 5000 years. The two most recent uplift steps, which may be correlated with major earthquakes, were 16 m about 1300 years ago and 8 m about 2500 years ago. Plafker and others (1981) suggest that if the 1200 years between the two recent uplifts represent an approximate recurrence interval for tectonic earthquakes that cause the uplifts, then the next such earthquake may be overdue.

Recent studies by Yonekura and Shimazaki (1980) indicate that the episodic uplifts deduced from marine terraces near subduction zones are often localized spatially, suggesting that the uplift of the terraces may be caused by movement on imbricate thrust faults branching upwards from the main thrust zone. The imbricate faults may not be activated every time a major earthquake occurs on the main thrust fault, so that the average return time of major earthquakes on the main thrust may be significantly less than the average return time for events causing major tectonic uplift of the terraces. This model may account for the discrepancy between return times on the order of several hundred to a thousand years for major thrust earthquakes in southern Alaska, as estimated from uplifted terraces (Plafker and Rubin, 1978; Plafker and others, 1981), and return times of less than a hundred years estimated from relative plate motions and average slip at the plate boundary during major earthquakes (e.g., Lahr and others, 1980; McCann and others, 1980).

A comparison between 1959 and 1979/1980 geodetic surveys made on a 35-km aperture array centered about 25 km northwest of Cape Yakataga (Lisowski and Savage, 1980) indicates that the western portion of the survey network was displaced about 3 1/2 m in a direction S40°E with respect to the eastern part of the network. The relative displacement was attributed primarily to effects from the 1964 Prince William Sound earthquake. This conclusion is consistent with the pattern of tectonic uplift mapped by Plafker (1969) which indicates that co- or post-seismic displacements from the 1964 earthquake extended about 50 km farther east into what is now termed the Yakataga seismic gap than the eastern limit of the rupture based on the distribution of aftershocks (Sykes, 1971).

VIII. CONCLUSIONS

Many features in the spatial patterns of the recent seismicity are similar to those observed since 1974 in a comparable magnitude range (e.g., Stephens and Lahr, 1979). Similar distributions of seismicity have persisted over an even longer time period, based on data contained in the Preliminary Determination of Epicenters (PDE) file. This second point is illustrated in Figure 14 where the epicenters of earthquakes of coda-duration magnitude 2 and larger that occurred during the 17-month period between October 1979 and February 1981 are compared with data contained in the PDE file for a period of almost 11 years beginning in 1970. The PDE data is probably not complete below about magnitude 4 since at least 1970, and usually does not report earthquakes with magnitudes below 3.5. With the exception of the small cluster of activity at the Copper River Delta, all of the areas of relatively high seismicity discussed in the previous section can be identified in the PDE data. Conversely, the most prominent feature in the long-term seismicity that does not appear in the more recent data is the Pamplona Ridge sequence (near 59° 45'N, 142° 30'W) that occurred in 1970. This comparison emphasizes both the value and limitations of short-term monitoring for identifying seismically active areas. In particular, short-term fluctuations in seismicity rates can occur in areas that are continually active, while other areas may only be sporadically active over long periods of time.

The tendency for the low- to intermediate-level seismicity in the NEGOA and adjacent onshore areas west of Yakutat Bay to recur in localized areas over long periods of time suggests that the release of seismic energy is either structurally controlled, where the earthquakes occur on subsidiary faults within the plates, or is related to major asperites along the thrust interface between the Pacific plate and overlying continental structure. The accuracy of the hypocenter determinations for most areas are not sufficient to resolve between these two alternatives. However, mapping these centers of activity is important because they indicate possible areas where ruptures from future large earthquakes may initiate or terminate. For example, prior to the 1979 St. Elias earthquake the aftershock zone had been recognized as being one of the most seismically active areas between Kayak Island and Yakutat Bay (e.g., Stephens and Lahr, 1979). Most of the earlier seismicity was concentrated near the zone of intense aftershock activity at the center of the aftershock zone (Stephens and others, 1980c). The rupture of the mainshock initiated at the northwest corner of the aftershock zone and propagated to the southeast. On the basis of teleseismic evidence, Boatwright (1980) inferred the presence of a rupture propagation barrier that coincides with the main cluster of aftershocks. The nature of this proposed barrier is not known, but could be caused either by an asperity on a single thrust plane or by upward branching of the rupture onto a series of splay faults (Stephens and others, 1980c). Wyss and others (1981) report a particularly well-documented case for the 1975 Kalapana earthquake (M_S 7.2) in Hawaii in which at least two major asperities characterized by high seismicity rates and other anomalous features were identified within the eventual rupture zone of the earthquake. The epicenters of both the largest foreshock and the mainshock were located within one of the asperities. Although the Kalapana earthquake occurred on a low-angle normal fault, it is not unreasonable to expect similar asperities to occur

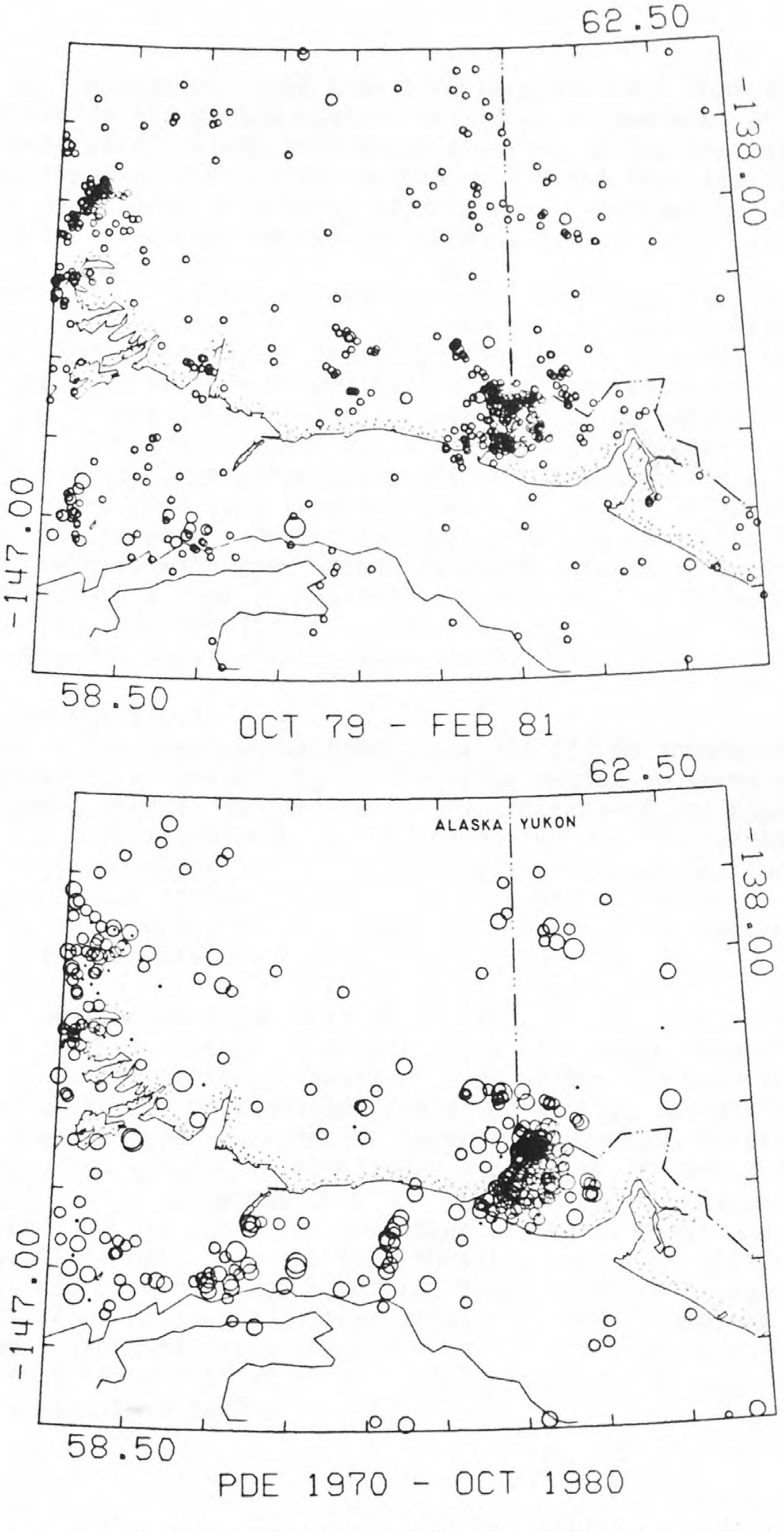


Figure 14. Upper - Epicenters determined by the USGS for earthquakes of magnitude 2 and larger that occurred between October 1979 and February 1980. Larger symbols correspond to magnitudes of 4 and larger. Lower - Epicenters of 430 earthquakes listed in the PDE for the period January 1970 through October 1980. Symbol size is proportional to magnitude (m_b or m_L) in intervals of 2 units, as in the upper map. Earthquakes for which no magnitude was reported are plotted as dots.

along the fault planes of large thrust earthquakes that rupture broad areas. The similarity of the spatial and temporal patterns of the seismicity near Waxell Ridge with those observed in the area of the 1979 St. Elias earthquake prior to the mainshock suggest that the Waxell area is likely to be an area of intense seismic energy release for a major earthquake that would rupture the surrounding area.

One important feature of the kinematic model for recent tectonic plate interaction in southeastern Alaska proposed by Lahr and Plafker (1980) is a postulated, but currently unidentified fault that directly connects the dextral strike-slip motions on the Fairweather and Totschunda faults. In their model, the Duke River fault is considered to accommodate only a small proportion of the relative plate motion. Since October 1979 the Duke River fault has been seismically active. However, there is no evidence in the seismic data from the same time period to support the existence of the proposed connecting fault. In contrast, the Denali fault east of its juncture with the Totschunda fault appears to be seismically active, contrary to a lack of geologic evidence for large Holocene displacements on this portion of the Denali fault (Richter and Matson, 1971; Plafker and others, 1977; Clague, 1979).

IX. NEEDS FOR FURTHER STUDY

As discussed in the previous sections, our ability to interpret the low-to-intermediate level seismicity in the NEGOA region in terms of tectonic structures and processes is limited by the accuracy of the hypocenter determinations. Improved relative locations for specific areas can be obtained by developing better velocity models and incorporating master event or homogeneous station location techniques. Studies of this nature are currently in progress for the Waxell Ridge area, the Copper River delta, and selected offshore sites.

Magnitude is an important parameter for characterizing the seismicity of a particular area. It is often difficult to compare observed characteristics from different areas or even within the same area through time because a variety of magnitude scales or methods for estimating magnitudes are employed. Currently, large discrepancies exist between the USGS-determined coda-duration magnitudes and body-wave magnitudes (m_b) reported in PDE. Local magnitudes (m_L) reported by the Alaska Tsunami Warning Center and the Canadian Department of Energy Mines and Resources are also usually larger than the coda-duration magnitude determined by the USGS. A revised coda-duration magnitude formulation is being developed for the USGS network using digitized seismic records. One method being investigated is that of Bakun and Lindh (1977) where seismic moments determined from the digitized records are used to relate coda durations to conventional magnitude scales.

X. SUMMARY OF OPERATIONS, JULY 1980 - MARCH 1981

A. Laboratory Activities

1. Scientific Party

a. Data Analysis

John Lahr, USGS, Project Chief
Chris Stephens, USGS, Geophysicist
Kent Fogleman, USGS, Geophysicist
Robert Cancilla, USGS, Data Analyst
Jane Freiberg, USGS, Data Analyst
Janet Melnick, USGS, Data Analyst
Roy Tam, USGS, Data Analyst
Brenda Romes, USGS, Physical Science Aid

b. Instrumentation

John Rogers, USGS, Electronics Engineer
Greg Condrotte, USGS, Technician
William Wong, USGS, Technician

2. Data Collected and Analyzed

A significant part of our efforts was devoted to the routine reduction and analysis of the seismic data collected since the beginning of FY 1980. The current status of the data for various time periods are summarized as follows:

TIME PERIOD	STATUS	CATALOG
October-December 1979	Final--Completed	Published (Stephens and others, 1980b)
January-March 1980	Final--Completed	Published (Stephens and others, 1980a)
April-June 1980	Final--In review	Submitted for Director's approval
July-September 1980	In final processing	In preparation
October-December 1980	Preliminary--complete	
January-February 1981	Preliminary--complete	
March 1981	Preliminary--not yet complete	

Lists of hypocenter parameters for October 1979-March 1980 have been submitted to OCSEAP. Later data will be submitted upon approval by the Director of the Geological Survey. Maps of the preliminary earthquake data for the period April 1980-February 1981 are shown in Figures 6 to 9.

The processing of seismic data from earlier time periods is being facilitated by the use of a newly developed scanning-digitizing machine. Development of this digiter was supported by the USGS. Two important features of this machine are that it allows all four

Develocorder films for each day to be viewed simultaneously, and that is has interactive digitizing and earthquake location capabilities. Currently a trained operator can process seismic data at about 1 1/3 times the rate using conventional equipment. It is anticipated that this improvement factor will increase to two.

B. Field Activities

1. Field trip schedule

The 1980 summer field season began in mid-June and lasted until the end of October. A second trip was made during February 1981.

2. Field party

John Rogers, USGS, Coordinator
John Lahr, USGS, Project Chief
Jack Pelton, USGS, Geophysicist
Mark Lipe, USGS, Field Assistant

3. Methods

The main objectives of these trips were:

- Installation of additional free-field strong-motion event recorders in the seismic gap area;
- Inclusion of the yearly maintenance of a portion of the USGS Seismic Engineering's strong-motion network into the Alaska Seismic Studies project;
- Continuation in upgrading both field stations and radio receiver sites;
- Installation of one station in southeastern Alaska near Juneau;
- Correction of certain electronic problems in the Palmer Tsunami Warning Center;
- Incorporation of newly acquired property into the project.

Because a significant reduction in funding was anticipated for FY 1981, one further objective was to reduce telemetry costs by decreasing the number of high-gain seismic stations being recorded and then reconfiguring the circuits for the remaining stations. Each of the main points mentioned above is discussed below in more detail.

Free-Field Strong Motion Event Recorders

A total of five new free-field SMA-1 event recorders were installed this past year. These instruments are located near the high-gain seismic stations at BCP, HMT, SGA, SUK, and WAX. An important feature of these instruments is that a special logic card located inside the neighboring seismic station is triggered each time the recorder turns on. This trigger generates a unique signal which is recorded in Palmer and can be used to provide accurate timing information.

The physical installations of all five sites are similar to those installed the previous year. A 36-inch diameter by 36-inch long culvert is partially buried in the ground and filled with rocks and about 800 pounds of concrete. The enclosure which houses the SMA-1 is anchored in the concrete, and the SMA-1 is connected via armored cable to the local voltage-controlled oscillator (VCO). The high-gain seismic installation at SUK had been dug out by animals (probably bears) for two successive years. To prevent disturbance at this installation, heavy-duty angle iron was driven into the ground.

At each site various tests are performed on the SMA-VCO combination to assure proper orientation. For example, battery voltage is measured, the clock set, the traces aligned, and the damping and natural frequency checked.

At TSI, GYO, and BAL, which were installed in 1979, the batteries were changed and the site calibrated and checked. All the instruments were operational and in good condition. No water or moisture damage was observed.

Other SMA-1 Installations

Alaska Seismic Studies took over operation of a portion of the strong motion network in Alaska previously managed by the USGS Seismic Engineering Branch. Generally, those stations which were transferred are within the Alaska Seismic Network and should save Seismic Engineering some special trips.

The stations visited were Pelican Cold Storage, Yakutat VORTAC, Trims Highway Camp, Auke Bay Fisheries Lab, Cordova FAA, Eccles School (Cordova), Cape Yakataga, and Icy Bay. In addition, the SMA located at Mentasta was moved to Slana Highway Maintenance Station.

At Whittier, Alaska, a SMA-1A was installed. The "A" designation indicates the availability of analog outputs from the accelerometers. Two of these outputs are connected to VCO's which treat the input signal as an auxiliary channel to achieve the correct amplification. These electronics were mounted in a rack along with the filter bridge (already in place). The two signals are then multiplexed with the other two radio signals and sent for recording to Palmer via a telephone line.

New Seismic Stations

In order to improve coverage in southeastern Alaska, a new station (ABF) was installed near Juneau at Auke Bay. This station was connected to the local SMA-1 (which had to be moved to allow for this connection) in a manner similar to that used at free-field sites. Thus, triggering information will also be sent along with the normal seismic data. A helicorder was installed in the State public library to provide a visual display of the seismic data.

At Cape Yakataga the local station was moved down from the hilltop above the White Alice site after a section of stairs collapsed. These stairs allowed access to the station and will not be repaired according to information we received from Alascom.

In Valdez the local three-component station was moved from the hill behind the earth station to an unused road also behind the earth station. This move was made necessary by growth of Alder making access and work at the station difficult.

Near Yakutat, the station electronics for PIN was moved to a flat area after severe damage to the antenna and mast again this year. The geophone was left in its original location.

Receive Site Electronics

New filter bridge units were installed at some sites in the network. The type being installed allows for monitoring of the output and input levels via light-emitting diodes (LED), a panel meter and speaker. This summer all of the remaining original version filter bridges were replaced with this newer model to allow for monitoring.

At Cape Yakataga two bridges were installed with one containing a special trigger feature for monitoring the local SMA-1. Each time the SMA triggers, an unmodulated signal is transmitted to Palmer. This signal gives timing information about the event and is easily distinguished from a normal seismic trace.

To improve radio reception, two GE receivers were installed for SUK and HMT-WAX. The higher sensitivity of these receivers should provide better data reliability as well as allowing for RF carrier monitoring via the carrier detecting LED.

In Valdez the receiver for VZW-GLC-FID was moved inside the earth station to a specially made bracket mounted on the filter bridge. The move became necessary due to servicing problems at the old site which was located on a nearby abandoned antenna tower. The antenna was also moved onto the earth station roof.

The old receive site for HIN-MTG in Cordova which was located behind the earth station on a small hill was moved to the U.S. Forest Service office downtown. The move is intended to ease servicing and increase reliability for the station. Also a GE radio receiver was employed to gain extra sensitivity.

In Yakutat the filter bridge which had been previously damaged by lightning was replaced. A spare audio signal generator was installed in the rack under the filter bridge to allow for quick telephone circuit tests.

To provide a degree of protection to the filter bridge electronics in Yakutat against future lightning strikes or power line noise, a rack-mounted isolation transformer and circuit breaker was installed.

The general idea behind the moves mentioned above was to place the receive electronics along with its associated monitoring features inside heated buildings. At each site individuals interested in our program have volunteered to do minor equipment troubleshooting and replacement, thus saving the expense of long trips to do these minor repairs. Additionally, the relocation of these electronics to a stable environment should help increase equipment reliability.

Field Station Work

Field work at the seismic stations consisted of continued improvements of the site installations, battery changes, and replacement of the older "202"-type VCO with the A1VCO.

This year batteries were changed at BAL, CFI, CHX, FID, GLB, GLC, GYO, HIN, HQN, KLU, KYK, MLS, PIN, PNL, SGA, SUK, VZW, WAX, and YAH.

New heavy duty antenna masts were installed at BAL, CFI, FID, GLB, GLC, HIN, HQN, KLU, KYK, PIN, and SGA.

At FID and SGA the old antennas were in trees with the RG-8 coaxial cable damaged by animals. The new mast installation has the cable running inside the mast, which makes animal damage less likely.

The VCO at CYT was replaced in February after it was damaged by an apparent static charge.

The station GLB was entirely rebuilt to accomodate new electronics. During this work two new masts were put up, one being for the receiver. The transmitter is now housed in a small (22-inch) culvert and should be more protected from water than previously. At GLC a similar culvert was installed to also provide a drier environment and ease routine maintenance.

Hinchinbrook Island (HIN) presents a severe weather problem due to antenna icing. It was therefore decided not to guy the mast, thus avoiding the extra ice load from the guys. Instead, 600 pounds of concrete was poured over rocks to give the masts a heavy base. SUK also has its mast anchored in concrete but is guyed using steel fence posts.

Fence posts driven into the ground with a sledge hammer seem to be good anchors for our antenna guys. They are made up in Anchorage at our shop with a thimble (wire guide) to speed field installation. They have been used for guying at many field sites and are faster to install than buried deadman.

The replacement of the older and trouble-prone "202" VCO with the A1VCO is almost complete in the NEGOA portion of the USGS seismic network. This year A1VCO's were installed at GLB east-west, GLB north-south, CYT, and ABF.

Other site work done of an unusual nature is as follows:

FID--Shortly after the year's visit, the geophone was dug out of the ground by an animal. To prevent a reoccurence, a section of fence post was driven into the ground and the geophone fastened to it by steel hose clamp.

HMT--An animal pulled the 12-inch receive culvert for WAX out of the ground after the SMA-1 was installed. It was then anchored by hose clamp and fence post.

SUK--To prevent the culvert from being dug out of the ground a third time, 400 pounds on concrete was poured around the culvert.

CTG--An animal attempted to dig out the entire site, including the antenna guy anchors. The geophone tube was bitten in half and the wire severed. The site was rebuilt and the geophone moved.

ALC--The recording rack was moved from the ALC-generator building to the Customs Building following GSA's approval of the new site. This new location provides a nice display for those entering the United States from the Yukon Territory. Additionally, access to the electronics is eased as the Customs Building is open 24 hours per day. A high school student interested in seismology is changing the records on the helicorder each day.
A True Time satellite time receiver has been installed in the station recording rack. The "slow code" output of this receiver is recorded and has an accuracy of a few tens of milliseconds. Visual monitoring of this code is provided for by a special Relay Driver Rack slow code LED. An isolation transformer was also mounted in the recording rack to prevent blowing fuses during generator switching.

Other Field Work

Shell Oil Stations--The USGS took over two Shell Oil strong motion stations located in the Yakataga seismic gap area. One station is on the east shore of Kayak Island and the other is near Munday Creek, about 25 miles east of Cape Yakataga. Both stations have two SMA-1 and one SMA-2 recorders. Power is supplied by solar panels backed up by 12-volt gel cell batteries. Both stations were visited with Earl Doyle from the Houston, Texas, office of Shell Oil. All six recorders appeared to be working. At the Kayak station an inch of water had entered the culvert and corroded the instrument cases and locks. At Munday Creek, several of the gel cell batteries were bad and were replaced.
The instruments were serviced in the normal manner, except for one (from Kayak) which had a badly corroded lock. This unit was taken back to Cordova, fixed, and returned to the site.

Digital Event Recorders--Two digital event recorders were deployed near Yakutat (Nunatak Fiord and Disenchantment Bay). The units were left at the sites for about one month and recovered. The data on the tapes is currently being analyzed, although problems may have reduced the usefulness of the data collected.

Ocean Bottom Seismic Recorders (OBS)--John Rogers and Jack Pelton helped Bruce Ambuter of the USGS, Woods Hole, in preparations for the deployment of five OBS systems.

Palmer Time Code Generator (TCG)--The IRIG-C time code problem was corrected during a visit to the Palmer Observatory. This problem had prevented use of IRIG-C by the Menlo Park playback center.

USGS Cape Yakataga Facility--A Butler-type building was acquired from the FAA on surplus earlier this year. The building is fairly large in size (1,300 square feet) and is in good condition. It was cleaned out in October and stocked with various field supplies, saving the cost of reshipment back to Anchorage. Leftover jet fuel (275 gallons) was also put inside the building to prevent theft during the winter.

Yakutat Pickup Truck--A surplus four-wheel-drive pickup truck was acquired at the beginning of this year from the Coast Guard. A USGS vehicle in Yakutat is desirable due to the lack of reliable rental vehicles. The truck was well utilized this first summer, resulting in significant savings to the various projects. It is being stored free of charge inside a heated hangar in Yakutat for the winter.

Reconfiguration of Network

Figure 2 shows the distribution of the 13 high-gain seismic stations in the NEGOA currently supported in part by OCSEAP (solid circles). Thirteen other stations (open circles) are no longer supported by OCSEAP. Six stations (open circles with dots) are operating but are not normally recorded. These latter stations will be recorded in the event that one of the primary stations fails.

XI. AUXILIARY MATERIALS

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