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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

National Center for Earthquake Research
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CATALOG OF EARTHQUAKES IN SOUTH CENTRAL ALASKA
April - June 1972

by

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

INTRODUCTION

The National Center for Earthquake Research of the U.S. Geological Survey (USGS) installed a network of eleven seismograph stations in south-central Alaska in the summer of 1971 to collect seismological data for investigating seismic and tectonic processes in the Cook Inlet region, for evaluating the seismic hazard in the Cook Inlet region and in the Chugach Mountains along the southern end of the route of the proposed trans-Alaska oil pipeline, and for studying the structure of the crust and upper mantle in south-central Alaska. The first recordings from the network were obtained in late September 1971. The first earthquakes to be located with data from the network occurred in October 1971.

This earthquake catalog, which is the first to be compiled for the USGS Alaska network, presents origin times, focal coordinates and magnitudes for 210 shocks occurring in the second quarter of 1972 (except from June 15 to 23) in south-central Alaska, primarily in the Cook Inlet region. Readings from a total of 18 stations were used to locate the shocks. To supplement the readings from the 10 USGS stations that were operative during this quarter, arrival times were obtained from 6 stations operated by the Palmer Seismological Observatory of the National Oceanic and Atmospheric Administration (NOAA) and 2 stations operated by the Geophysical Institute of the University of Alaska (U of A).

The data in this catalog are the most detailed and precise earthquake data compiled to date for earthquakes within the Cook Inlet region. Earthquakes in south-central Alaska as small as magnitude 3.0 have been routinely located by the National Earthquake Information Center of NOAA (currently the National Earthquake Information Service of USGS) since the great Alaska earthquake of 1964 and published in the reports "Preliminary Determination of Epicenters" (PDE). In contrast the shocks included in this catalog are as small as magnitude 1.0 and most are smaller than magnitude 3.0. Data for the larger historic earthquakes in south-central Alaska have been tabulated by Davis and Echols (1962) and U.S. Coast and Geodetic Survey (1966).

The locations of the eleven stations of the NCER seismograph network are plotted in Figure 1 and listed in Table 1 along with the additional stations from which readings were obtained. The USGS stations have single, vertical-component seismometers except for NKA and SKL, which also have two horizontal seismometers. The station ERN was installed in the summer of 1971, however the telemetry circuit was not available until September 1972.

INSTRUMENTATION

The instrumentation in the USGS seismograph network as operated during the second quarter of 1972 is illustrated in the block diagram in Figure 2. Data from each seismometer are telemetered to a central recording point. The recording site was the USGS administrative office in Anchorage through June 14, 1972 and the NOAA Palmer Observatory starting June 24, 1972. The standard equipment at each field station includes a vertical seismometer with a natural frequency of 1.0 Hz (Mark Products, Model L-4C), a unit consisting of an amplifier and a

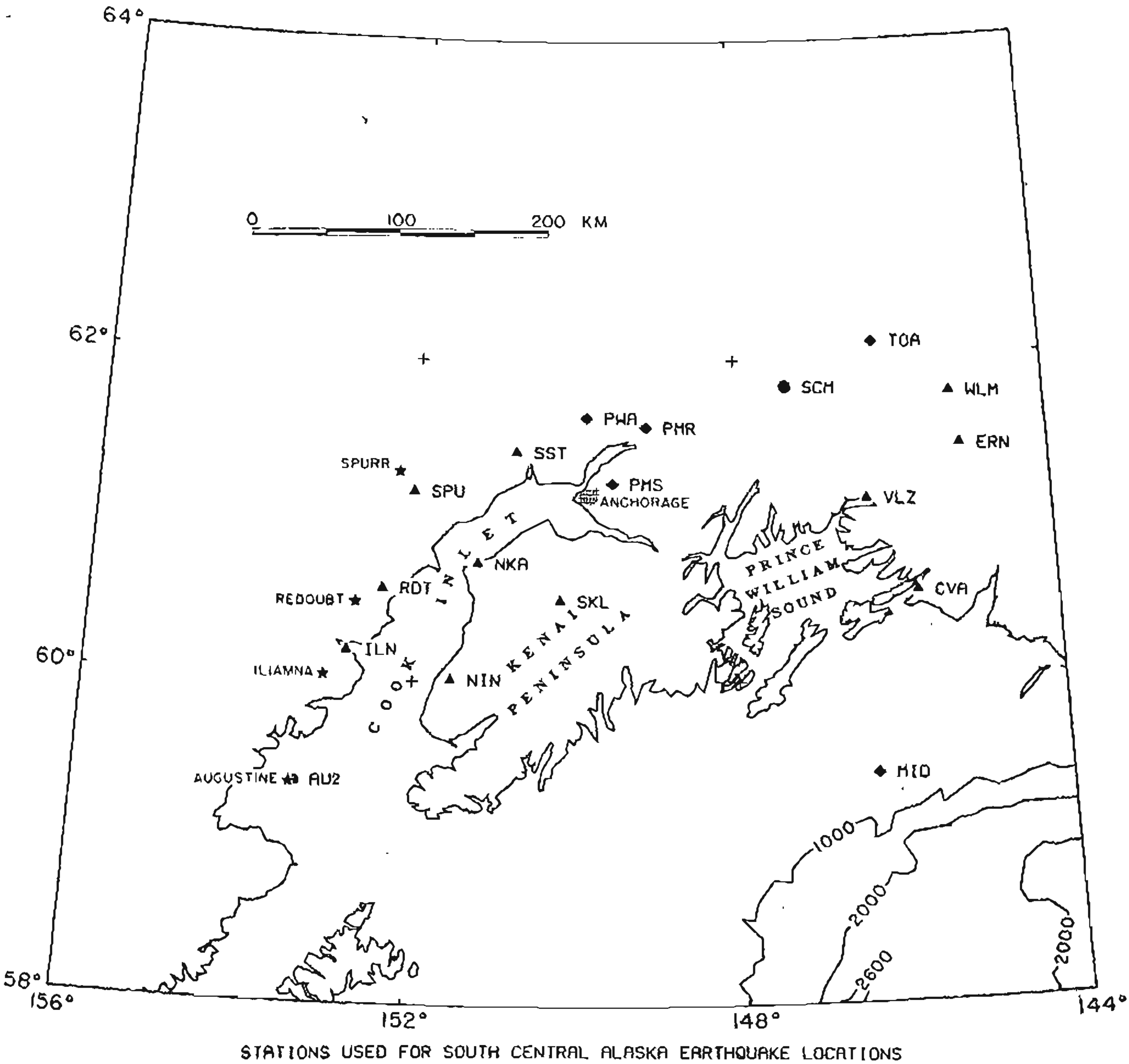


Figure 1. Map showing seismograph stations from which readings were obtained. Triangles, circles, and diamonds correspond to USGS, U of A, and NOAA stations respectively. Active volcanoes are indicated by stars. Depth contours in fathoms.

Table 1. Station Data

This table lists geographical coordinates and other pertinent information for stations used in the preparation of this catalog. Each station is designated by a three letter code (STA CODE). Latitude (LAT) and longitude (LON) are in degrees (DEG) and minutes (MIN): station eleveation (ELEV) is in meters (M). D is the thickness of the low-velocity surficial sedimentary layer in kilometers (KM) assigned in the calculation of traveltimes to a given station. DELAY is the station P-phase traveltime delay in seconds (SEC). The magnification (MAG) of the vertical seismograph component is given at 1 Hz. The institutions (INST) operating the stations are the National Center for Earthquake Research of USGS, the Palmer Seismological Observatory of NOAA, and the Geophysical Institute of the University of Alaska (UOFA). All of the USGS stations were inoperative from June 15 through June 23, 1972 when the recorder was moved from Anchorage to Palmer.

STA CODE	STATION NAME	LAT N DEG MIN	LONG W DEG MIN	ELEV M	D KM	DELAY SEC	MAG @ 1HZ	INST	NOTES
AUZ	AUGUSTINE IS.	59 22.22	153 22.69	195	.01	0.	0	UOFA	
CVA	CORDOVA	60 32.79	145 44.96	90	.01	0.	30000	USGS	
ERN	ERNESTINE	61 26.65	145 6.74	570	.01	0.	120000	USGS	INOPERATIVE
ILN	ILIAMNA	60 10.92	152 48.97	550	.01	.44	120000	USGS	
KDC	KODIAK	57 44.87	152 29.50	13	.01	0.	50000	NOAA	
MID	MIDDLETON IS.	59 25.67	146 20.34	37	.01	0.	6000	NOAA	
NIN	NINILCHIK	60 .67	151 32.13	110	4.00	.67	7500	USGS	
NKA	NIKISHKA	60 44.58	151 14.28	100	4.00	1.36	3750	USGS	
PMR	PALMER	61 35.53	149 7.85	100	.01	0.	100000	NOAA	
PMS	PALMER SOUTH	61 14.68	149 33.63	716	.01	0.	100000	NOAA	
PWA	PALMER WEST	61 39.05	149 52.72	137	.01	.70	100000	NOAA	
RDT	REDOUBT	60 34.43	152 24.37	930	.01	.36	60000	USGS	
SCM	SHEEP MTN.	61 50.00	147 19.66	1020	.01	0.	0	UOFA	
SKL	SKILAK	60 30.86	150 12.91	660	.01	.10	30000	USGS	
SPU	SPURR	61 10.90	152 3.26	800	.01	.39	60000	USGS	
SST	SUSITNA	61 26.05	150 46.82	780	.01	.67	60000	USGS	
TOA	TOLSONA	62 6.29	146 10.34	909	.01	0.	50000	NOAA	
VLZ	VALDEZ	61 7.89	146 19.92	10	.01	0.	120000	USGS	
WLM	WILLOW MTN.	61 46.42	145 11.88	985	.01	0.	60000	USGS	

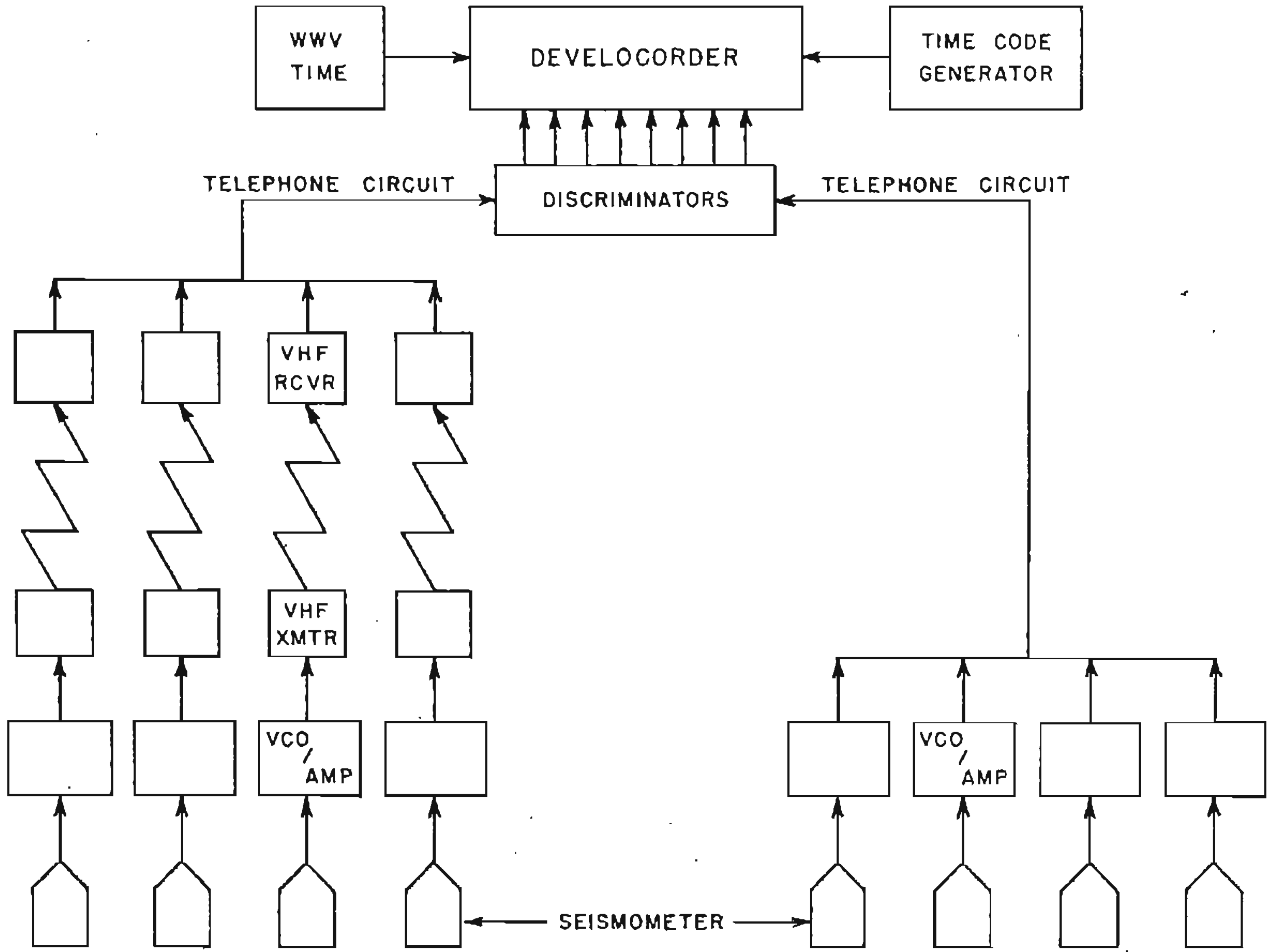


Figure 2. Block diagram of telemetered seismograph system in the USGS network.

voltage-controlled oscillator (VCO) (Develco, Model 6202), and air-cell storage batteries (Edison, Model US 102 or Eveready 2S10). Data are telemetered via a leased telephone circuit or a VHF (162-174 Mhz) radio link feeding a telephone circuit. The radio link is provided by a low-power transmitter (100 mw) and receiver adapted from a HT-200 Motorola handie-talkie transceiver and two Yagi antennae with 9 db directional gain (Scala, Model CAS-150). The central recording facility incorporates a bank of discriminators (Develco, Model 6203), a 16 mm-film multi-channel oscillograph (Geotech Develocorder, Model 4000D), a time-code generator (Datatron Model 3150-209-1) and a radio receiver for WWV time signals (Specific Products SR7R).

The principle of operation is as follows: The seismometer translates movement of the ground into an electrical voltage that is fed into the amplifier/VCO unit where the amplified voltage varies the frequency of an audio-band oscillator. The frequency-modulated (FM) tone from the amplifier/VCO unit is carried directly by voice-grade telephone circuit to the recording site or alternatively is fed through a VHF radio link onto a telephone circuit. At the recording site, the FM seismic signal is demodulated by a discriminator. The demodulated signal, which is simply an amplified form of the initial signal from the seismometer, is recorded photographically on a multichannel oscillograph together with time marks from a crystal-controlled chronometer. Two days of recording are recorded on a single 285-foot roll of film.

Signals from more than one seismograph can be transmitted on a single telephone circuit by employing VCO units with different center frequencies. In the standard configuration there is a 340-Hz separation between center frequencies and a fixed bandwidth of 250 Hz. Up to eight seismic channels with center frequencies ranging from 680 to 3060 Hz may be placed on a single voice-grade telephone circuit.

Figure 3 illustrates the response characteristics of the entire seismic system from seismometer to film viewer. The response level at each station is adjusted in steps of 6 decibels so that the ambient seismic noise produces a small deflection of the trace on the film. As a result, the actual response for an individual station may differ from that of the typical station by a factor of 2, 4, 8, etc. The magnification of the typical station is about 6×10^4 at 1 Hz and 10^6 at 10 Hz.

The installation of a typical radio-linked station is shown in Figure 4. During the first year of operation all the stations but one operated reliably through the winter from one summer field season to the next; occasional degradation or interruption of data transmission can be attributed in some instances to inclement weather conditions (Fig. 5).

DATA PROCESSING

The 16 mm films are mailed weekly to Menlo Park where the seismic data are processed by the following multistep routine:

1. Scanning. The films are scanned to identify and note times of all seismic events whether of local, regional, or teleseismic origin.

2. Timing. For the "well-recorded" local earthquakes identified in the scanning process, the following data are read from each station:

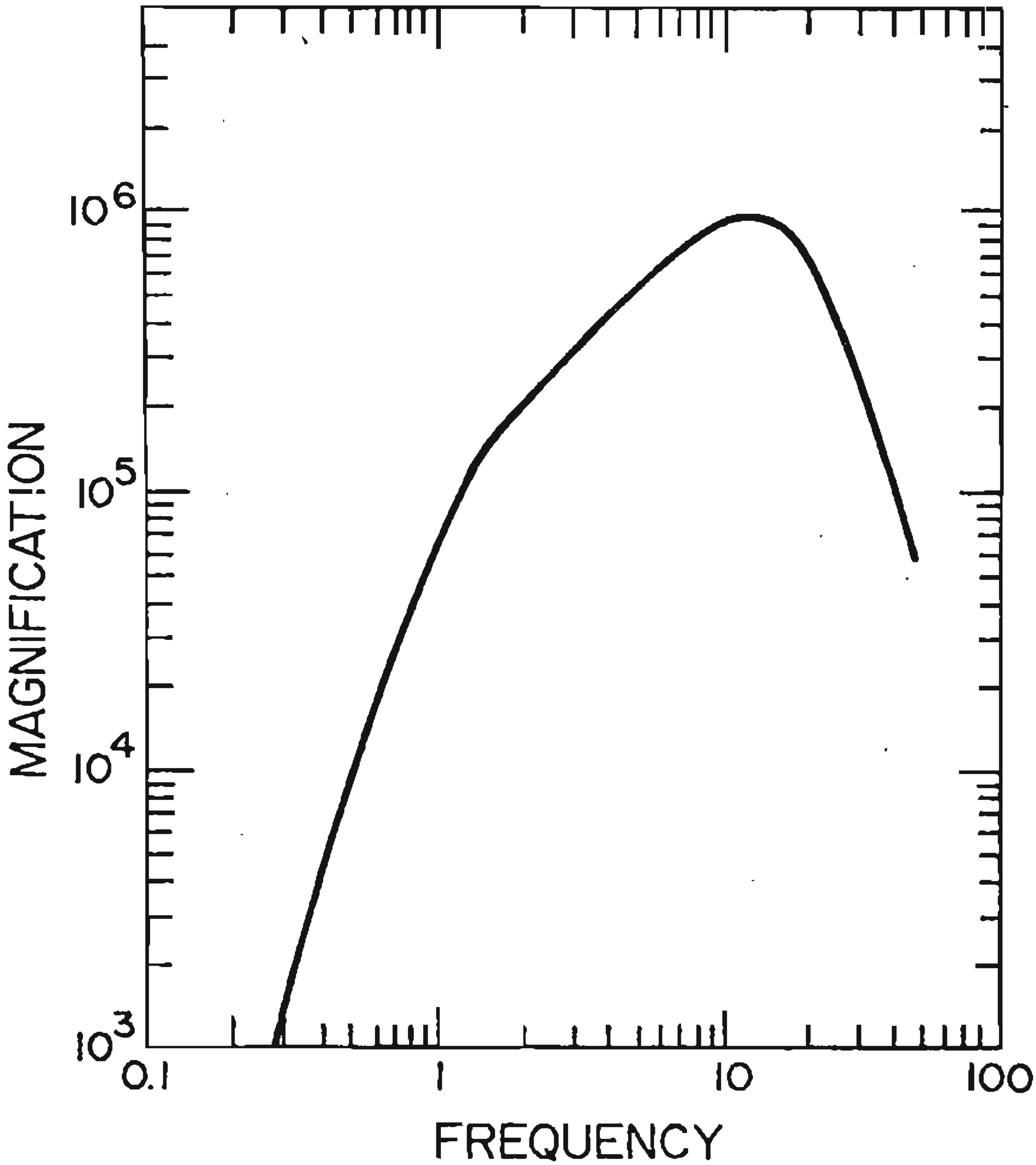


Figure 3. Response curve for a typical USGS seismograph station.

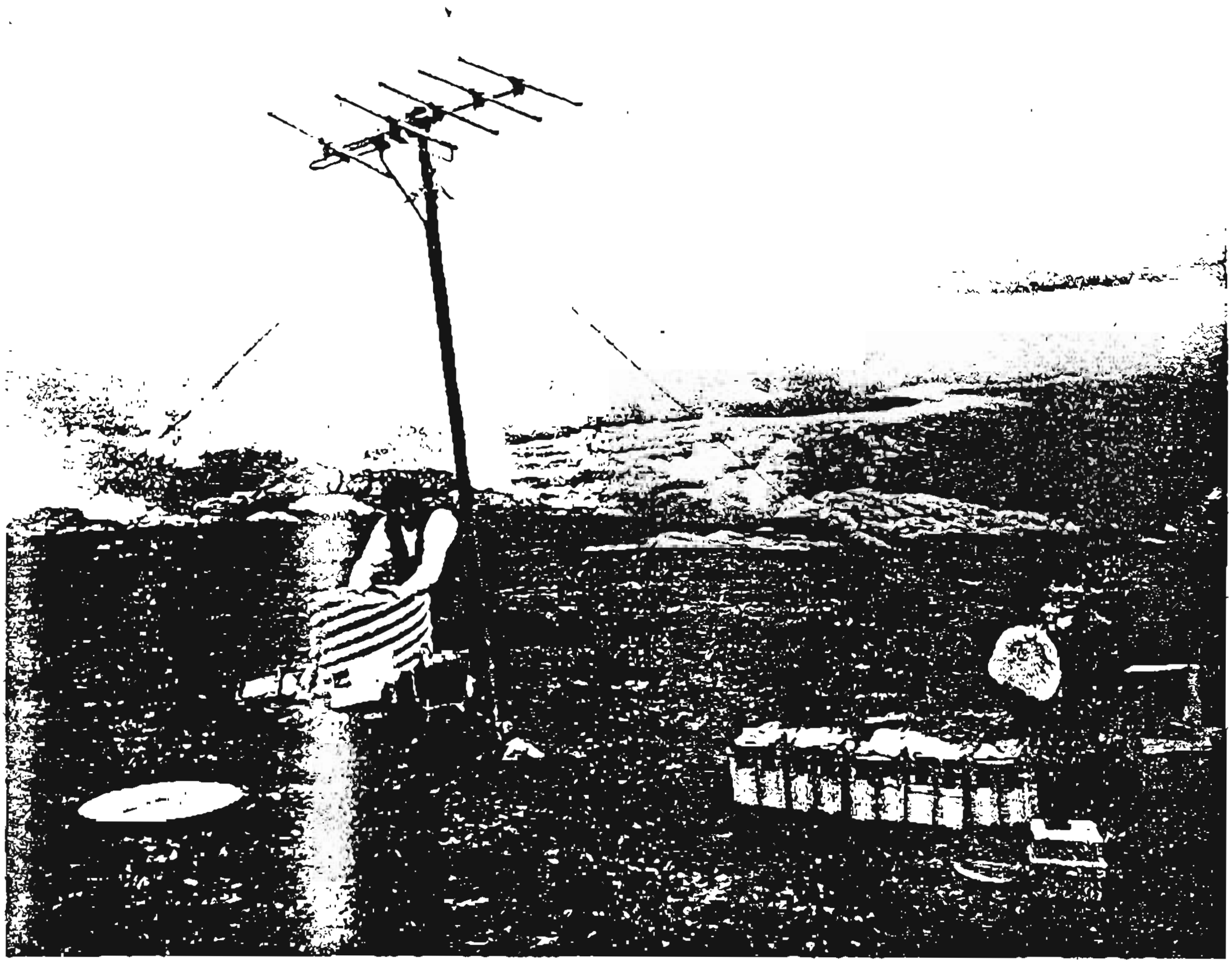


Figure 4. Installation of a typical seismograph station (RDT). VCO/amplifier unit, radio transmitter and batteries (being filled at right) are housed in 30-inch-diameter culvert partially set in ground at base of antenna. Seismometer is buried in ground about 30 m from culvert. Photograph by Elliot Endo.

Figure 5. Icing on antenna, such as that shown here for a receiving antenna on Big Mountain in October 1973, can degrade or interrupt transmission of data. Photograph by Ralph Cash.

P- and S-wave arrival times, direction of first motion, duration of signal in excess of a given threshold amplitude, and period and amplitude of maximum recorded signal. The criterion for a "well-recorded" event is different for events west of 150°W longitude than for events east of 150°W. West of 150°W the criterion is that the event must be clearly recorded on at least 6 stations with at least 3 impulsive P waves; east of 150°W the criterion is 4 stations with at least 2 impulsive P waves. This criterion has the tendency to eliminate all but a few events with S-P times greater than about 20 sec at the station closest to the source.

3. Initial computer processing. The data read from the films are punched on computer cards and batch processed by computer using the program HYPOELLIPSE (Lahr and Ward, in preparation) to obtain origin times, hypocenters, magnitudes and, if desired, first-motion plots for fault-plane solutions.

4. Analysis of initial computer results. Each hypocentral solution is checked for large traveltime residuals and for a poor spatial distribution of stations. Arrival times identified with large residuals are re-read. For shocks with a poor distribution of stations, readings from additional stations outside the USGS network are sought.

5. Final computer processing. The poor hypocentral solutions are re-run with corrections and the new solutions are checked for large residuals that might be due to remaining errors. Corrections are made as required before the final computer run is made.

The earthquake locations are based on P and S arrivals. S arrivals are important for determining depths of events in the Benioff zone beneath Cook Inlet. Unfortunately for some large events S cannot be read at any station because the traces on the film overlap each other or are too faint to follow.

The HYPOELLIPSE computer program determines hypocenters by minimizing differences between observed and computed traveltimes through an iterative least-squares scheme. In many respects the program is similar to HYPO71 (Lee and Lahr, 1972), which has been used in the preparation of catalogs of central California earthquake from January 1969 through September 1972. An important new feature available in HYPOELLIPSE is the calculation of confidence ellipsoids for each hypocenter. The ellipsoids provide valuable insight into the effect of station geometry on possible hypocentral errors.

All earthquakes are located using a horizontally layered velocity model. It is recognized that any model comprised of uniform horizontal layers is a poor representation of the actual velocity structure in the vicinity of a subduction zone (Mitronovas and Isacks, 1971; Jacob, 1972); however such a model does have the advantage of simplifying the computation of traveltimes. The P-wave velocity model used is based on Model A of Matumoto and Page (1969) derived for the eastern Kenai Peninsula-Prince William Sound region. A value of 1.78 for the velocity ratio between P and S is assumed for the entire model. The velocity model is specified as follows:

Layer	Depth (km)	P velocity (km/sec)
1	0 - D	2.75
2	D - 4	5.3
3	4 - 10	5.6
4	10 - 15	6.2
5	15 - 20	6.9
6	20 - 25	7.4
7	25 - 33	7.7
8	33 - 47	7.9
9	47 - 65	8.1
10	below 65	8.3

The thickness of the first layer is allowed to vary between stations to account for the presence of thick sections of low-velocity sediments beneath the stations NIN and NKA, which are located in the Cook Inlet basin. For these stations D is 4 km. For all other stations D is 0.01 km.

To reduce the residuals for earthquakes in the Benioff zone beneath Cook Inlet, a well-recorded Cook Inlet shock with a depth of 69 km was chosen as a master event, and station delays were assigned to SST, SPU, RDT, ILN, SKL, NIN and NKA so that this event would have zero residuals when located from the P-phases at these stations. As readings from additional stations were added to the USGS data, it became clear that a delay was also required at PWA. This delay was assigned to reduce the average residual at PWA for a large group of events. NIN, NKA and PWA are the only stations not located on rock. The P-phase delays are listed in Table 1 and are added to the calculated P-phase traveltimes at each station. For S-phases the delay is multiplied by 1.78, the P to S velocity ratio.

Magnitudes are determined from the signal duration or the maximum trace amplitude, or from both parameters. Eaton and others (1970) approximate the Richter local magnitude, whose definition is tied to maximum trace amplitudes recorded on standard horizontal Wood-Anderson torsion seismographs, by an amplitude magnitude based on maximum trace amplitudes recorded on high-gain, high-frequency vertical seismographs such as those operated in the Alaskan network. The amplitude magnitude XMAG used in this catalog is based on the work of Eaton and his co-workers and is given by the expression (Lee and Lahr, 1972)

$$XMAG = \log_{10} A - B_1 + B_2 \log_{10} D^2 \qquad (1)$$

where A is the equivalent maximum trace amplitude in millimeters on a standard Wood-Anderson seismograph, D is the hypocentral distance in kilometers, and B_1 and B_2 are constants. Differences in the frequency response of the two seismograph systems are accounted for in calculating A; however, it is assumed that there is no systematic difference between the maximum horizontal ground motion and the maximum vertical motion. The terms $-B_1 + B_2 \log_{10} D^2$ approximate Richter's $-\log_{10} A_0$ function (Richter, 1958, p. 342), which expresses the trace amplitude for a zero-magnitude as a function of epicentral distance. For small local earthquakes in central California, $B_1 = 0.15$ and $B_2 = 0.80$ for $\Delta = 1$ to 200 km and $B_1 = 3.38$ and $B_2 = 1.50$ for $\Delta = 200$ to 600 km.

For small, shallow earthquakes in central California, Lee and others (1972) express the duration magnitude FMAG at a given station by the relation

$$\mathrm{FMAG} = -0.87 + 2.00 \log_{10} \tau + 0.0035\, \Delta \tag{2}$$

where τ is the signal duration in seconds from the P-wave onset to the point where the peak-to-peak trace amplitude on the Geotech Model 6585 film viewer falls below 1 cm and Δ is the epicentral distance in kilometers.

Comparison of XMAG and FMAG estimates from equations (1) and (2) for 77 Alaskan shocks in the depth range 0 to 150 km and in the magnitude range 1.5 to 3.5 reveals a systematic linear decrease of FMAG relative to XMAG with increasing focal depth. To remove this discrepancy, a linear dependence on depth is added to the expression for FMAG as follows:

$$\mathrm{FMAG} = -1.15 + 2.00 \log_{10} \tau + 0.007z + 0.0035\Delta \tag{3}$$

where z is the focal depth in kilometers. Incorporating the depth term in the calculation of FMAG, the average and standard deviations between XMAG and FMAG for the 77 events are 0.02 and 0.29 respectively.

The magnitude assigned to each earthquake in this catalog is the mean of the average XMAG and FMAG (equation 3) estimates obtained for the USGS stations. For shocks larger than about magnitude 3.0, XMAG cannot be determined because the maximum trace amplitudes are off-scale or the traces are too faint to read. For many shocks smaller than about magnitude 2.0 the trace amplitude drops below 1 cm peak-to-peak between the P and S arrivals and FMAG is not determined.

For earthquakes larger than magnitude 3.0, FMAG values may be compared to m_b magnitudes listed in the PDE reports. The average and standard deviations for 47 events in the magnitude range 3.0 to 5.5 are 0.02 and 0.44 respectively; hence the two measures are compatible.

ANALYSIS OF QUALITY

Two types of errors enter into the determination of hypocenters: systematic errors limiting the accuracy of hypocenters and random errors limiting the precision. Systematic errors arise from an incorrect velocity model, misidentification of phases, or systematic timing errors and can be evaluated through controlled experiments such as locating the coordinates of a known explosion. Random errors result from random timing errors and are estimated for each earthquake through the use of standard statistical techniques.

For each earthquake, HYPOELLIPSE calculates the lengths and orientations of the principal axes of the joint confidence ellipsoid. The one-standard-deviation confidence ellipsoid describes the region of space within which one is 68 percent confident that the hypocenter lies assuming that the only source of error is random reading error. The ellipsoid is a function of the station geometry for each individual event, the velocity model assumed and the standard deviation of the random reading error. The standard deivation determined from repeated readings of the same phases by four seismologists is as small as 0.01 to 0.02 sec. for the most impulsive arrivals and as large as 0.10 to 0.20 for emergent arrivals. The confidence ellipsoids are computed for a standard deviation of 0.16 sec. and therefore likely overestimate the 68% confidence regions. The standard deviation of the residuals for an individual solution is not used to calculate the confidence ellipsoid because it contains information not only about random reading errors but also about the incompatibility of the velocity model to the data. Thus, the confidence ellipsoid is a measure of the precision of the hypocentral solution. In a few extreme cases the calculation of one of the ellipsoid axes blows up corresponding to a spatial direction with very great uncertainty. In these cases an upperbound length of 25 km was assumed.

To fully evaluate the quality of a hypocenter one must consider both the confidence ellipsoid and the root mean square (RMS) residual for the solution. The RMS residual reflects both systematic and random errors, but the random errors are typically much smaller. Hence the RMS residual is primarily a measure of the incompatibility of the velocity model, misinterpretation of phases and systematic timing errors. Interpretation of the RMS residual may depend upon the location of the earthquake. In areas where the velocity model is incompatible with the real earth RMS residuals could be large and betray the incompatibility; alternatively the RMS residuals could be small and not reflect the error in a bad hypocenter. Where the velocity model is compatible, however, a large RMS residual would indicate probable misreadings of phases.

Other parameters provided by HYPOELLIPSE that are useful in evaluating the quality of a hypocentral solution are: GAP, the largest azimuthal separation between stations measured from the epicenter; D3, the epicentral distance of the third closest station; NP, the number of P arrivals used in the solution; and NS, the number of S arrivals used in the solution. If GAP exceeds 180° the earthquake lies outside the network of available stations and the solution is generally less reliable than for events occurring inside the network.

DISCUSSION OF CATALOG

The Appendix lists origin times, focal coordinates, magnitudes and related parameters for 210 earthquakes from April, May and June 1972. Epicenters for these shocks are plotted in Figures 6 and 7. No earthquakes could be located for the interval June 15 through 23 during which the recorder was moved from Anchorage to Palmer. Vertical sections through the Benioff zone showing the depth distribution of the shocks are presented in Figures 8 and 9.

We estimate that this catalog is reasonably complete for shocks larger than magnitude 2.5 occurring beneath eastern Prince William Sound and in the Chugach Range to the north, and beneath the western Kenai Peninsula, Cook Inlet and the volcanic axis from Mt. Spurr to Mt. Iliamna. The minimum magnitude of the listed earthquakes ranges from about 1.0 for shallow shocks to about 2.0 for the deepest shocks.

The precision of the hypocenters or the relative accuracy of the locations of neighboring events is represented by the confidence ellipsoids. The precision of epicenters, expressed in terms of the maximum axes of the projected one-standard-deviation confidence ellipsoids (ERH), averages about 3 km. The precision of focal depth (ERZ) averages about 3.5 km for shocks in the Cook Inlet region and about 7 km for shocks in the Prince William Sound region where the station geometry is poorer.

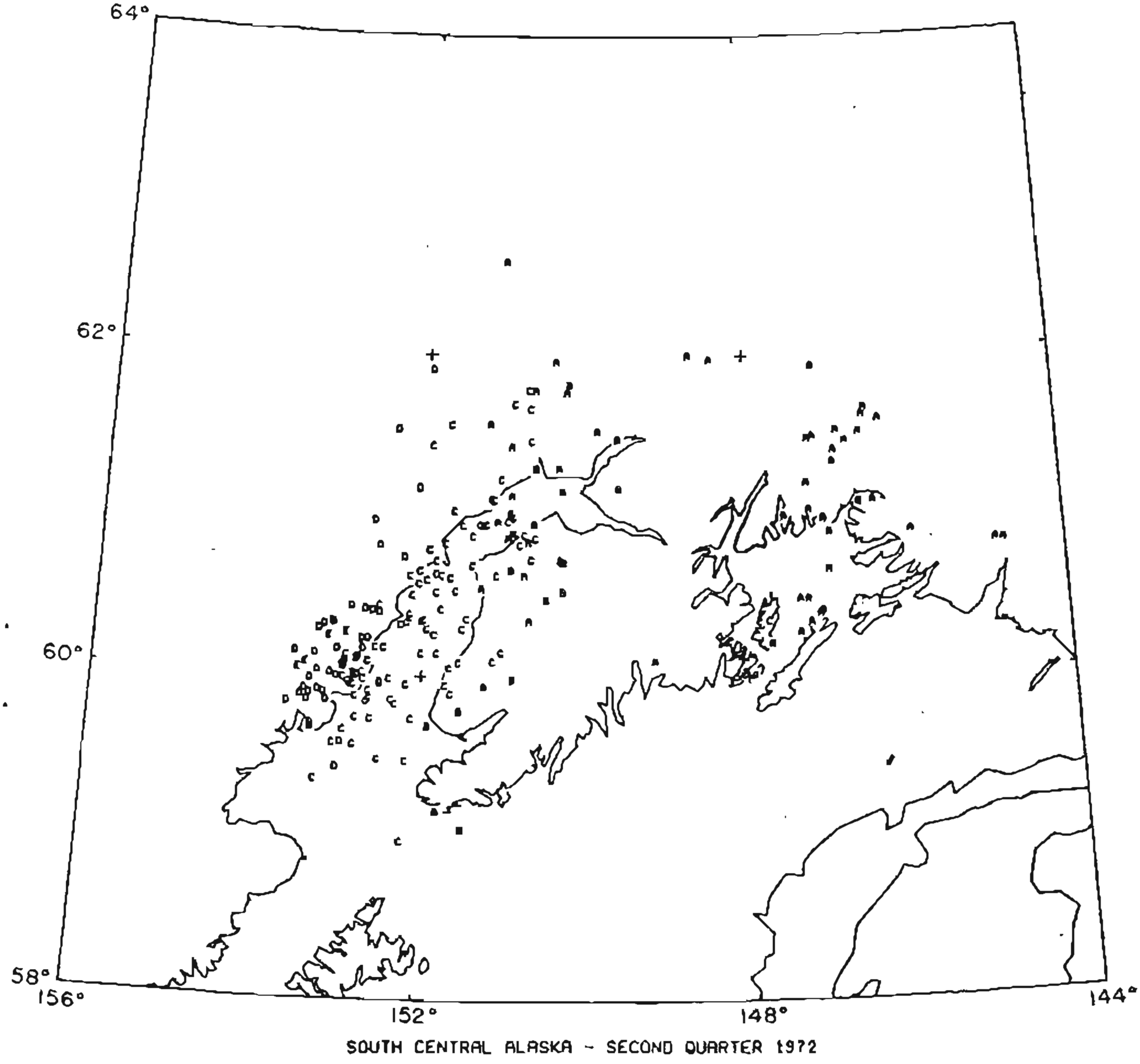


Figure 6. Map of earthquake epicenters plotted by depth range: A, 0-24 km; B, 25-49 km; C, 50-99 km; D, 100-149 km; and E, 150-200 km.

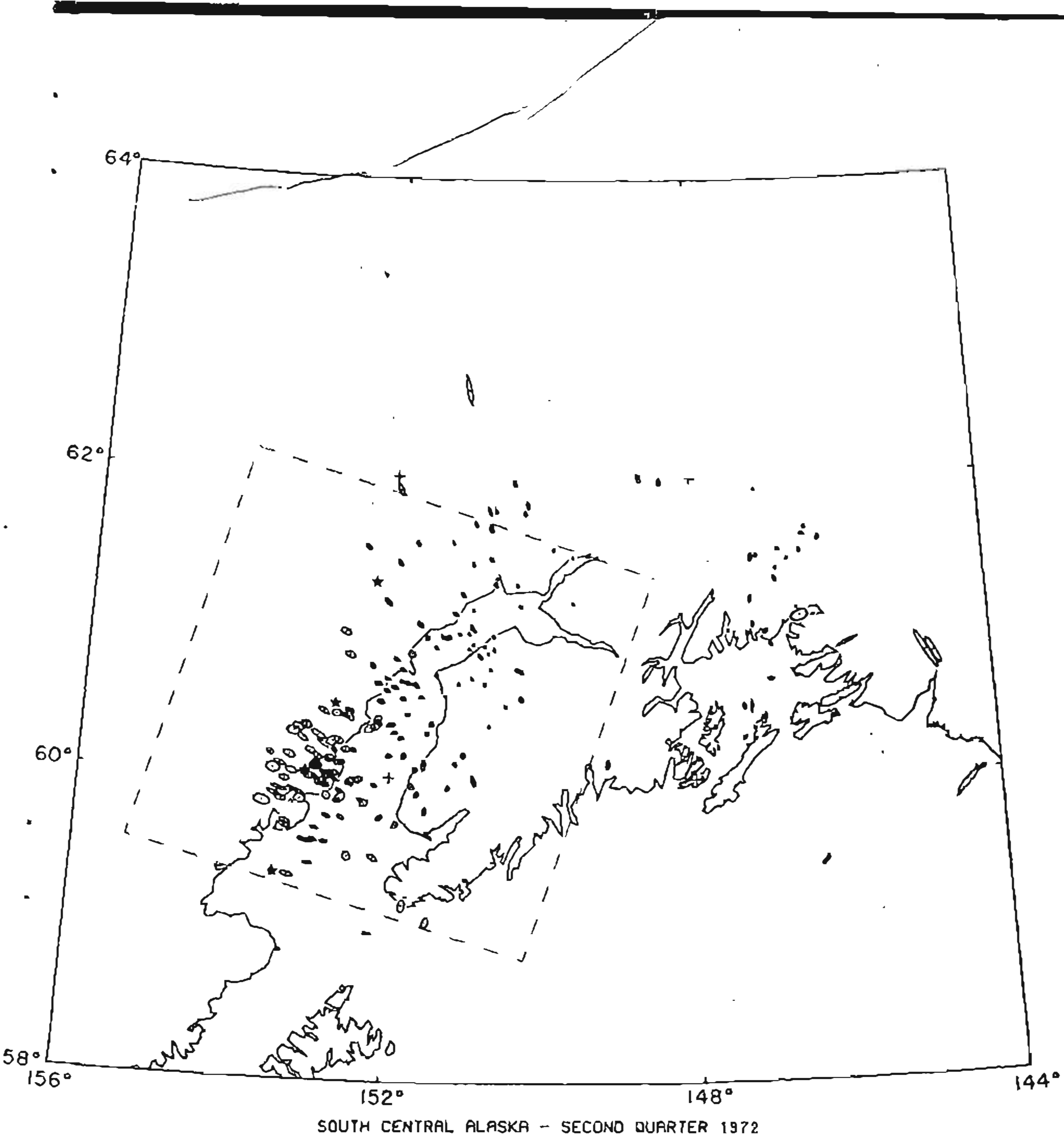
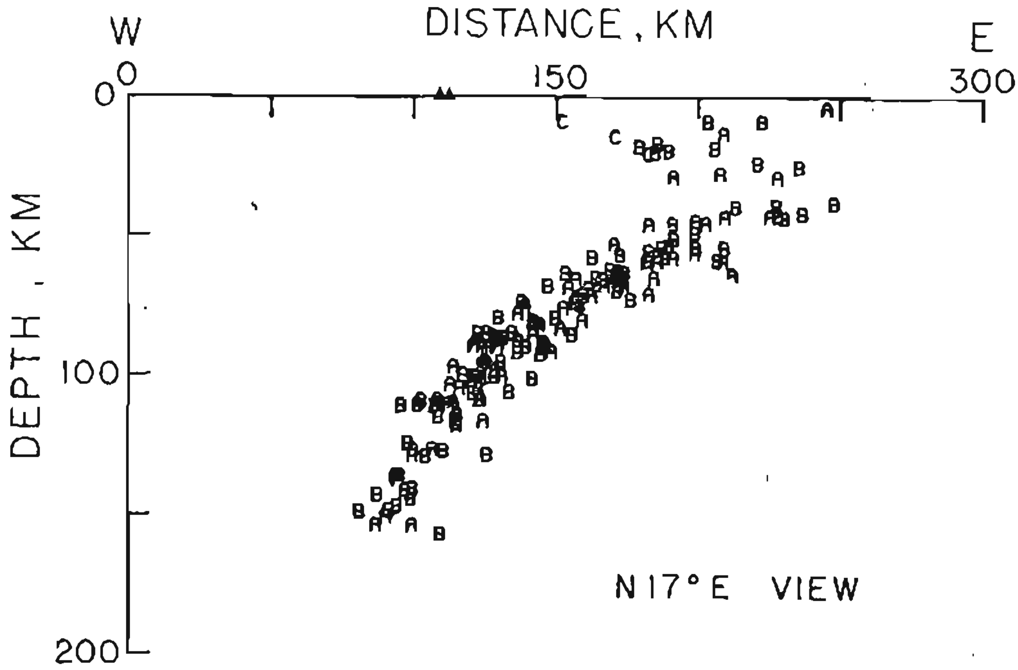


Figure 7. Map of earthquake epicenters showing the projection of the one-standard-deviation confidence ellipsoids onto horizontal plane. Active volcanoes are indicated by stars. Dashed rectangle encloses earthquakes shown in cross section in Figs. 8 and 9.



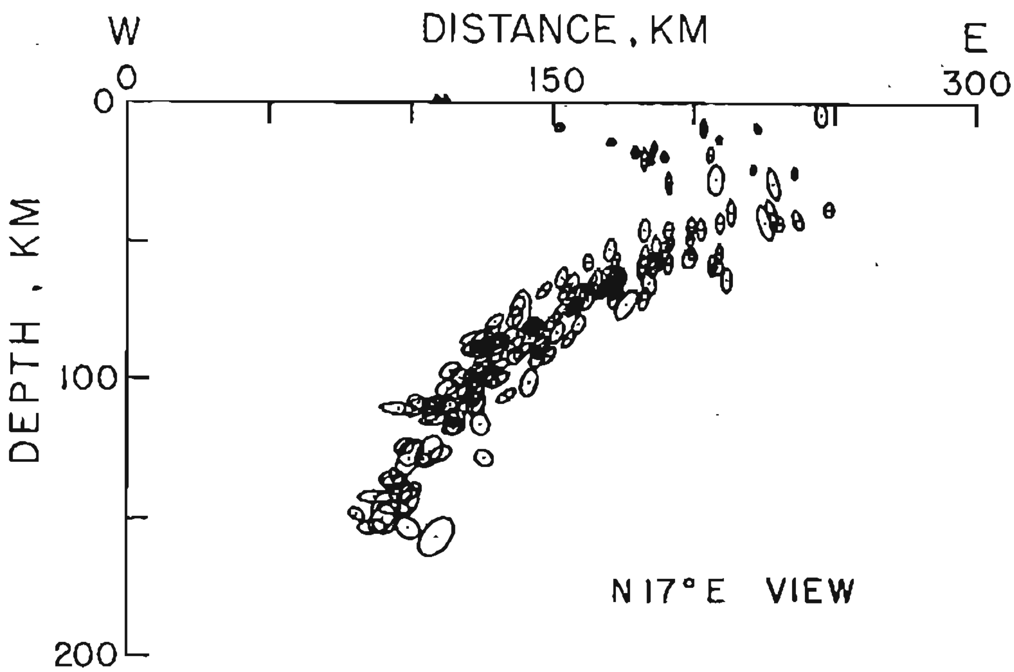
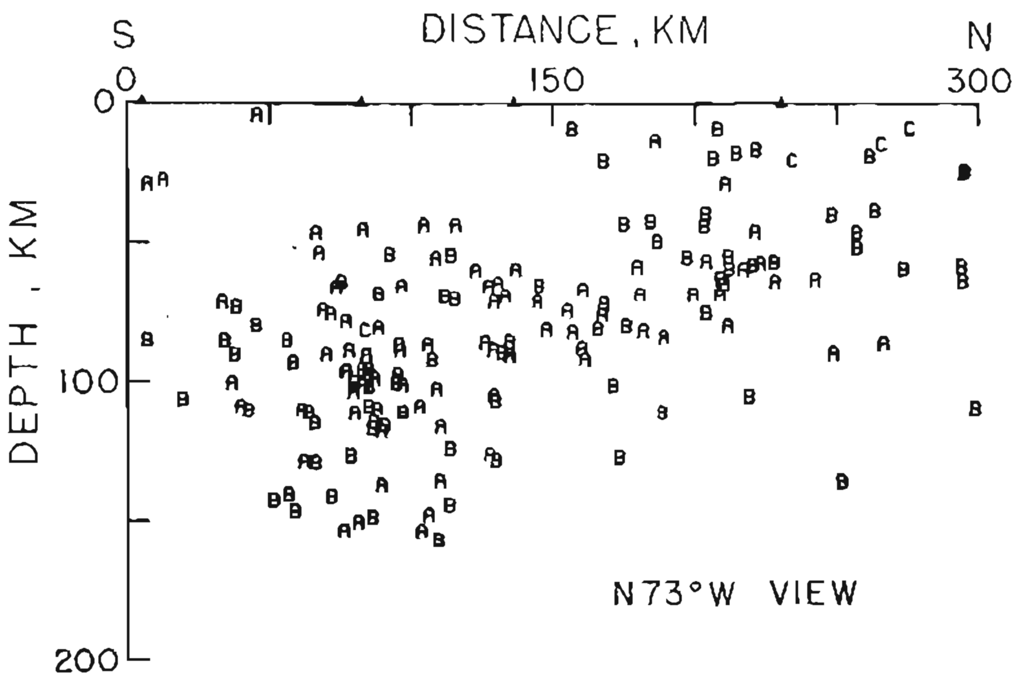


Figure 8. Vertical cross sections (looking N 17° E) of hypocenters from region outlined in Fig. 7. Section transverse to strike of Benioff zone. Active volcanoes are plotted as triangles at zero depth. (Upper) Hypocenters plotted by range of root-mean-square residual. A, B, C, and D respectively correspond to RMS of ranges of 0.0 to 0.19, 0.20 to 0.39, 0.40 to 0.59 and greater than 0.6 sec. (Lower) Projections of one-standard-deviation confidence ellipsoids for same events.



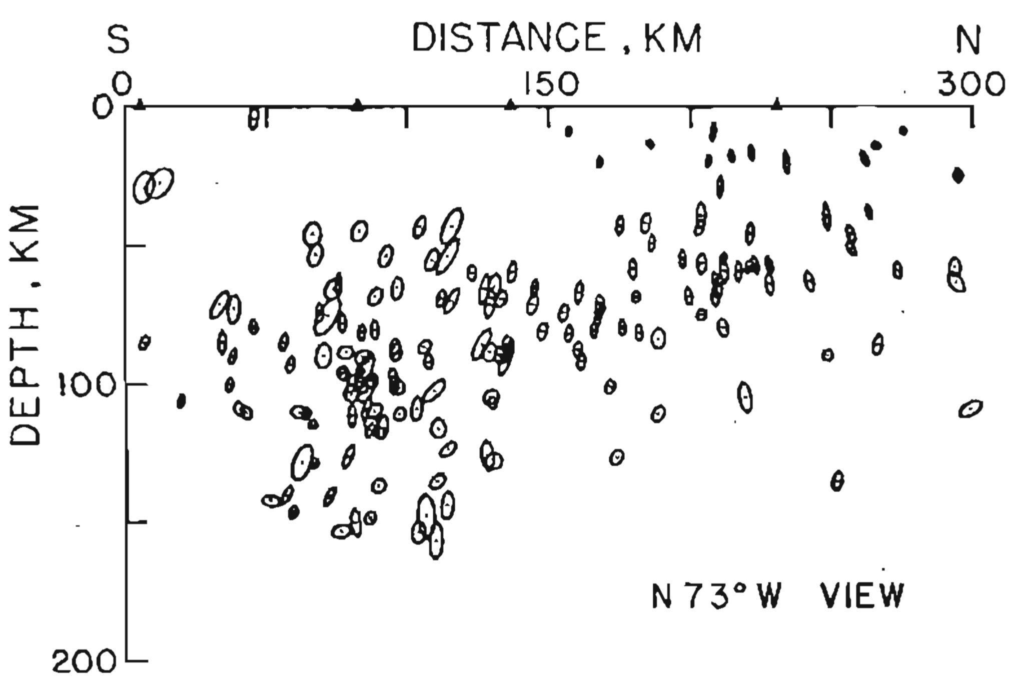


Figure 9. Vertical cross sections (looking N 73° W) of hypocenters from region outlined in Fig. 7. Longitudinal section parallel to strike of Benioff zone. Symbols and format same as those in Fig. 8. (Upper) Hypocenters plotted by range of root-mean-square residual. (Lower) Projections of one-standard-deviation confidence ellipsoids.

The absolute accuracy of the earthquake locations is difficult to evaluate in the absence of known explosions. Hypocenter biases equal to and larger than the dimensions of the confidence ellipsoids are likely to arise from the oversimplified velocity model assumed in the preparation of this catalog. To evaluate possible hypocenter biases for shocks in the Benioff zone beneath Cook Inlet, 37 events were relocated by J. C. Lahr and E. R. Engdahl using Engdahl's ray tracing location program that accommodates a laterally varying velocity model which is more representative of the actual velocity structure. Systematic hypocentral changes which increase gradually over the depth range 60 to 160 km were obtained, the epicentral shifts varying from zero to 25 km in a WNW direction and the depth changes varying from 3 km deeper to 10 km shallower. These results are tentative because the velocity model used is not well determined, but do give an indication of the type of bias to be expected.

In the Cook Inlet region there is a systematic increase of focal depths proceeding WNW from about 50 km beneath the western Kenai Peninsula, to about 70 km beneath Cook Inlet and to about 115 km beneath the active volcanoes west of Cook Inlet. In the northern Cook Inlet region and northward in the Susitna River lowlands numerous shocks occur above the principle dipping seismic zone at focal depths of less than 30 km. These features are most clearly presented in the transverse cross-section in Figure 8, which is a view in the direction N 16°E looking along the strike of the dipping seismic zone. The direction of this view minimizes the projected thickness of the seismic zone and also aligns the active volcanoes - Augustine, Iliamna, Redoubt and Spurr - thus indicating that earthquakes beneath the volcanoes occur at a common depth, nominally 115 km. As seen in the longitudinal cross-section in Figure 9, the maximum focal depth along the strike of the Benioff zone shoals from about 150 km on the southern edge of the network to about 100 km on the northern edge.

The contents of the Appendix may be obtained in forms amenable to computer input (punch cards or magnetic tape) by contacting the authors. Copies of Figures 6 and 7 at a scale of 1:1,000,000 are also available.

ACKNOWLEDGMENTS

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We are grateful to Drs. W. H. K. Lee and R. L. Wesson for the development of procedures and techniques for the preparation of earthquake catalogs and have patterned this catalog heavily upon their efforts for earthquakes in central California.

REFERENCES

Davis, T. N., and C. Echols (1962). A table of Alaskan earthquakes, 1788-1961, Geophys. Inst. Res. Rept. 8, 44 pp. University of Alaska, College, Alaska.

Eaton, J. P., M. E. O'Neill, and J. N. Murdock (1970). Aftershocks of the 1966 Parkfield-Cholame, California, earthquake: a detailed study, Bull. Seism. Soc. Am. 60, 1151-1197.

Lahr, J. C., and P. Ward (In preparation). HYPOELLIPSE: A computer program for determining local earthquake hypocentral parameters, magnitude, and first motion pattern.

Lee, W. H. K., and J. C. Lahr (1972). HYPO71: a computer program for determining hypocenter, magnitude, and first motion pattern of local earthquakes, U.S. Geological Survey, Open-file Report, 100 p.

Lee, W. H. K., R. E. Bennett, and K. L. Meagher (1972). A method of estimating magnitude of local earthquakes from signal duration, U.S. Geological Survey, Open-file Report, 28 p.

Matumoto, T., and R. A. Page (1969). Microaftershocks following the Alaska earthquake of 28 March 1964: "Determination of hypocenters and crustal velocities in the Kenai Peninsula-Prince William Sound area", The Prince William Sound, Alaska, Earthquake of 1964 and Aftershocks, vol. 2B & C, U.S. Coast and Geodetic Survey Publication 10-3, U.S. Govt. Printing Office, Washington, 157-173.

Mitronovas, W., and B. L. Isacks (1971). Seismic velocity anomalies in the upper mantle beneath the Tonga-Kermadec island arc, J. Geophys. Res. 76, 7154-7180.

Richter, C. F. (1958). Elementary Seismology, W. H. Freeman and Co., 768 pp.

U.S. Coast and Geodetic Survey (1966). "Seismicity of Alaska" in The Prince William Sound, Alaska, earthquake of 1964 and aftershocks, F. J. Wood, (editor), vol. 1, 11-73, Washington, 263 p.

APPENDIX

Catalog of Earthquakes (April-June, 1972)

Earthquakes from south central Alaska for April 1 through June 14 and for June 24 through 30, 1972 are listed in chronological order. The following data are given for each event:

(1) Origin time in Greenwich Civil Time (GCT): date, hour (HR), minute (MN), and second (SEC). To convert to Alaska Standard Time (AST) subtract ten hours.

(2) Epicenter in degrees and minutes of north latitude (LAT N) and west longitude (LONG W).

(3) DEPTH, depth of focus in kilometers.

(4) MAG, duration magnitude of the earthquake.

(5) NP, number of P arrivals used in locating earthquake.

(6) NS, number of S arrivals used in locating earthquake.

(7) GAP, largest azimuthal separation in degrees between stations.

(8) D3, epicentral distance in kilometers to the third closest station to the epicenter.

(9) RMS, root-mean-square error in seconds of the traveltime residuals:

$$RMS = \sqrt{\sum_i (R_{Pi}^2 + R_{Si}^2) / (NP + NS)}$$

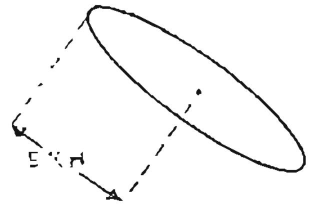
where R_{Pi} and R_{Si} are the observed minus the computed arrival times of P and S waves respectively at the i-th station.

(10) ERH, largest horizontal deviation in kilometers from the hypocenter within the one-standard-deviation confidence ellipsoid. This quantity is a measure of the epicentral

precision for an event.

Projection of ellipsoid

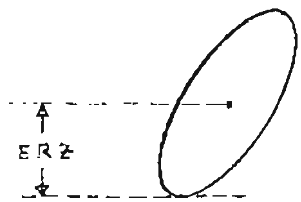
onto horizontal plane:



(11) ERZ, largest vertical deviation in kilometers from the hypocenter within the one-standard-deviation confidence ellipsoid. This quantity is a measure of the depth precision for an event.

Projection of ellipsoid

onto vertical plane:



(12) Q, quality of the hypocenter. This index is a measure of the precision of the hypocenter (see section Analysis of Quality, p.) and is calculated from ERH and ERZ as follows:

Q	ERH	ERZ
A	≤ 2.5	≤ 2.5
B	≤ 5.0	≤ 5.0
C	≤ 10.0	≤ 10.0
D	> 10.0	> 10.0

SOUTH CENTRAL ALASKA EARTHQUAKE CATALOG

* 1972	ORIGIN TIME HR	MN	SEC	LAT N DEG	MIN	LONG W DEG	MIN	DEPTH KM	MAG	NP	NS	GAP DEG	D3 KM	RMS SEC	ERH KM	ERZ KM	Q
APR 1	13	2	35.8	60	17.2	153	15.6	147.8	2.2	6	1	286	119	.08	4.9	7.9	C
2	0	41	29.5	61	4.7	146	22.5	14.4	2.0	8	3	129	115	.47	1.5	1.2	A
2	5	29	59.5	59	44.0	152	6.8	53.0	2.1	7	2	271	95	.16	2.7	4.2	B
2	13	8	19.6	59	53.1	153	20.9	128.5	5.1	10	0	218	102	.08	5.3	6.5	C
2	17	46	25.4	59	56.5	151	14.3	43.4	2.3	8	2	245	89	.12	2.1	3.9	B
2	21	1	10.8	60	.6	152	47.7	94.9	3.0	8	1	267	70	.15	4.0	6.5	C
2	22	9	37.5	61	6.3	151	11.0	63.7	2.2	8	3	110	48	.12	1.9	4.2	B
3	6	28	18.1	60	56.3	151	16.7	68.2	2.0	8	3	83	61	.19	1.7	3.4	B
3	6	31	44.3	60	56.7	151	15.0	64.3	2.5	9	1	84	60	.08	2.0	4.7	B
3	8	35	3.3	61	33.6	151	42.6	85.7	3.1	9	3	241	95	.18	2.3	3.7	B
3	9	24	51.0	60	51.9	150	58.6	19.3	1.8	8	3	72	64	.35	1.2	2.1	A
3	13	30	8.7	60	32.1	151	37.0	66.6	1.5	6	3	100	59	.16	2.0	4.3	B
3	13	44	59.0	58	58.3	152	12.2	55.8	2.7	8	2	159	139	.04	3.5	12.3	D
4	17	31	2.5	59	54.5	152	38.3	77.8	2.6	7	2	135	73	.15	2.7	3.5	B
4	20	29	53.8	60	19.1	152	16.5	85.6	2.7	6	1	113	53	.08	3.9	5.9	C
4	20	58	15.7	59	59.3	150	54.1	43.1	2.9	7	1	211	86	.08	4.7	6.6	C
5	12	37	59.1	61	34.1	151	13.1	8.8	3.0	10	2	217	72	.43	1.8	1.3	A
6	21	59	13.3	59	51.5	152	37.5	75.1	2.9	6	1	294	125	.11	5.0	7.3	C
7	3	16	24.5	59	58.0	152	30.3	101.3	4.9	10	1	185	111	.28	3.5	5.0	C
7	23	49	57.5	60	43.7	150	19.9	39.2	2.6	7	1	182	82	.22	2.1	4.8	B
8	1	23	10.1	59	28.7	152	30.3	71.2	3.0	8	1	208	81	.10	3.6	5.3	C
8	10	12	56.3	60	4.0	152	58.1	109.5	2.3	7	2	288	80	.12	3.9	2.6	B
8	11	17	18.1	60	36.0	151	57.8	91.6	2.0	7	3	93	65	.18	2.7	3.1	B
8	12	42	21.6	60	56.8	151	19.7	62.2	1.9	9	2	85	62	.28	1.9	3.2	B
8	19	11	15.1	59	43.9	152	36.1	92.7	3.0	11	2	119	67	.34	2.7	2.9	B
8	19	14	30.7	60	44.5	152	15.3	100.6	3.0	10	2	166	56	.25	2.4	2.5	B
9	9	7	32.9	59	57.6	152	53.3	88.3	2.3	7	2	283	76	.12	3.8	2.3	B
9	10	6	23.6	60	13.9	152	44.3	102.3	2.1	7	1	162	71	.05	4.9	4.2	B
9	10	12	42.5	60	7.9	153	17.8	137.0	2.6	8	1	207	85	.11	4.7	2.4	B
9	20	46	52.9	60	10.6	152	34.2	86.5	2.1	8	2	165	60	.16	3.1	2.5	B
9	21	7	20.7	59	20.0	150	58.7	4.1	2.6	10	1	185	140	.18	2.1	4.3	B
9	22	11	52.3	61	39.8	150	42.5	63.1	3.4	11	1	205	77	.25	3.3	3.6	B
10	2	45	32.4	59	41.6	153	18.7	110.0	2.9	9	1	197	106	.27	4.1	2.5	B
10	9	9	20.9	60	32.0	150	17.6	41.9	1.4	7	1	137	89	.24	2.1	3.7	B
10	10	37	48.0	60	37.0	151	40.8	71.4	2.1	6	2	125	68	.12	2.6	3.7	B
10	12	46	30.9	59	50.2	152	39.7	73.8	2.5	8	2	145	66	.11	2.6	3.6	B
11	8	49	51.1	61	1.5	151	38.9	79.5	2.1	6	2	97	65	.09	2.8	3.3	B
11	11	10	34.8	61	35.2	146	15.7	6.8	2.7	6	1	97	119	.38	2.0	5.7	C
11	15	56	32.3	61	25.7	151	56.4	89.4	2.6	10	3	238	85	.11	2.7	2.0	B
11	18	21	35.7	61	57.8	150	23.9	.1	3.8	13	0	221	79	.35	2.7	1.1	B
11	23	56	43.2	61	4.4	146	33.3	27.0	2.9	4	1	223	230	.11	6.3	24.4	D
13	5	54	13.6	60	24.9	152	42.3	104.5	2.6	7	1	189	79	.05	3.8	2.7	B
13	10	20	39.0	60	31.5	151	51.1	74.2	2.4	7	2	72	60	.08	2.2	3.4	B
13	13	10	11.2	60	50.2	150	43.7	9.0	2.1	10	2	88	67	.39	1.2	3.4	B
13	16	59	6.2	61	27.7	150	41.7	58.8	2.7	10	2	177	65	.21	2.0	3.1	B

SOUTH CENTRAL ALASKA EARTHQUAKE CATALOG (CONTINUED)

1972	ORIGIN HR	TIME MN	SEC	LAT N DEG	LAT N MIN	LONG W DEG	LONG W MIN	DEPTH KM	MAG	NP	NS	GAP DEG	D3 KM	RMS SEC	ERH KM	ERZ KM	Q
APR 14	5	53	56.3	60	15.6	151	51.9	65.4	2.4	7	1	114	53	.07	2.1	5.7	C
14	21	58	35.7	60	3.3	151	40.3	55.2	2.1	6	2	160	71	.06	2.3	4.1	B
15	6	34	43.0	60	20.8	147	44.3	76.5	3.2	7	3	188	141	.21	2.0	4.7	B
15	10	28	2.8	59	51.0	152	21.8	63.4	2.4	7	3	158	78	.29	2.1	3.9	B
15	12	14	45.1	60	5.3	151	33.8	54.0	2.2	6	1	112	71	.25	4.2	6.5	C
15	13	57	2.9	60	20.0	152	12.0	88.2	2.6	6	1	110	51	.08	2.9	3.4	B
16	23	51	22.4	60	28.9	147	14.4	8.1	2.5	5	2	186	164	.19	5.0	2.8	B
17	6	28	3.7	60	29.0	150	29.9	42.7	2.1	8	3	150	78	.27	1.5	3.7	B
17	8	25	54.6	60	21.1	151	59.4	85.4	2.3	7	3	101	50	.26	2.4	3.3	B
17	15	48	54.8	59	49.5	152	18.6	65.4	2.5	7	1	260	84	.10	3.1	3.7	B
17	23	54	35.0	60	49.6	151	44.9	83.3	2.0	6	1	131	46	.08	2.7	3.7	B
18	10	20	51.7	60	20.9	150	42.5	9.0	2.4	10	2	175	59	.23	1.1	1.8	A
18	16	1	19.2	60	25.1	151	47.2	65.0	2.3	9	3	82	47	.30	1.7	3.2	B
18	18	30	35.6	60	34.6	152	3.9	81.7	2.2	7	3	91	60	.13	2.6	3.0	B
19	1	57	57.9	59	52.3	152	47.8	89.6	3.3	7	1	281	72	.08	3.1	4.5	B
19	7	22	4.5	60	21.5	151	28.1	70.8	1.8	6	2	110	71	.07	1.9	4.2	B
19	8	48	32.7	60	37.8	151	47.2	73.4	2.3	7	2	87	63	.05	2.2	3.3	B
19	9	4	8.9	60	17.8	151	31.4	59.3	2.1	7	2	110	58	.08	1.7	4.0	B
19	12	46	42.2	60	16.5	147	20.6	11.5	3.2	9	1	114	162	.27	1.9	5.0	C
19	12	59	24.5	59	56.5	152	49.2	95.6	2.4	8	1	154	72	.18	3.4	2.5	B
19	16	46	33.1	60	37.5	152	10.5	87.5	2.0	7	2	120	61	.07	2.9	2.9	B
20	5	43	48.2	60	9.9	153	1.8	110.6	2.8	7	1	193	85	.20	4.0	2.3	B
20	13	31	13.2	60	51.7	150	38.6	58.9	1.9	7	3	95	64	.30	1.6	4.1	B
20	14	56	49.6	61	17.5	150	20.8	18.6	2.3	9	1	87	47	.22	1.6	2.8	B
20	15	14	51.9	60	8.7	151	49.6	69.8	4.0	11	1	86	57	.22	2.7	5.0	B
20	16	58	44.6	59	53.5	151	38.9	53.6	2.6	6	2	247	87	.21	2.4	3.9	B
20	17	27	16.5	59	50.3	153	22.7	140.3	4.6	11	2	206	98	.25	4.0	3.2	B
20	17	32	58.5	59	44.3	152	47.1	84.6	2.9	8	2	153	76	.23	3.3	3.4	B
21	21	45	24.0	61	5.8	151	9.0	56.8	2.1	9	4	107	50	.38	1.9	2.8	B
22	7	19	43.4	62	35.3	151	3.0	17.4	3.4	10	2	299	150	.25	12.7	20.2	D
22	11	37	16.2	60	3.2	152	57.0	114.1	2.0	7	2	288	79	.13	3.8	2.9	B
22	13	17	27.5	60	18.9	153	11.9	135.5	2.8	7	2	268	98	.15	4.4	2.7	B
23	4	30	36.5	60	47.3	151	56.7	81.2	2.2	7	3	126	44	.15	2.7	3.0	B
23	5	50	46.4	59	47.1	151	32.3	44.7	2.2	7	2	260	100	.14	2.8	3.6	B
24	1	1	10.7	60	1.2	152	43.2	98.4	2.5	7	3	253	66	.13	3.6	2.5	B
24	17	16	11.2	60	38.4	151	51.5	75.8	2.1	7	3	94	61	.11	2.2	3.2	B
24	17	22	44.7	59	56.7	152	11.4	80.3	2.4	8	2	148	71	.17	2.2	3.4	B
24	23	57	16.2	60	.1	152	47.2	90.0	2.5	7	2	266	70	.13	3.7	2.4	B
25	2	58	.1	60	57.8	151	6.5	17.7	1.9	9	2	83	57	.30	1.2	2.2	A
25	8	3	40.8	60	58.3	147	1.9	13.5	3.5	14	0	79	132	.26	1.1	11.5	D
25	13	35	55.7	62	.3	148	42.2	19.8	4.5	10	0	202	96	.20	3.6	17.8	D
25	14	45	7.8	59	59.2	152	57.1	99.7	3.3	8	2	180	73	.35	3.3	3.6	B
25	22	37	54.4	59	58.8	152	23.7	68.0	2.4	7	2	228	66	.22	2.9	3.0	B
26	2	4	44.3	60	30.2	152	8.6	80.9	2.1	7	2	78	56	.07	2.6	3.1	B
26	10	45	50.5	60	23.4	147	5.5	7.1	1.4	4	1	198	165	.04	3.2	6.2	C

SOUTH CENTRAL ALASKA EARTHQUAKE CATALOG (CONTINUED)

1972	ORIGIN TIME HR	MN	SEC	LAT N DEG	MIN	LONG W DEG	MIN	DEPTH KM	MAG	NP	NS	GAP DEG	D3 KM	RMS SEC	ERH KM	ERZ KM	Q
APR 26	17	51	30.3	60	4.7	152	56.3	117.5	2.7	7	2	184	79	.16	4.1	2.3	B
26	19	12	18.3	60	.6	147	55.8	3.4	2.0	8	2	158	138	.31	1.6	2.2	A
27	20	40	35.4	60	59.4	150	55.1	57.6	2.9	10	2	79	65	.30	1.7	2.3	A
27	22	4	45.1	61	31.7	152	22.7	135.3	2.9	10	5	255	106	.26	2.6	3.4	B
28	12	50	54.9	59	20.9	153	15.1	85.1	2.8	7	2	237	122	.24	5.0	2.5	C
28	15	31	19.2	60	24.7	147	3.7	5.2	1.7	5	2	196	165	.12	3.0	3.0	B
28	16	30	48.4	60	14.1	152	39.7	116.0	3.4	7	1	142	67	.04	3.3	3.9	B
28	17	13	15.9	61	23.8	146	51.3	11.6	3.3	11	1	104	97	.42	1.3	3.1	B
29	1	22	21.6	60	59.4	147	31.4	9.7	2.1	9	2	133	109	.15	1.6	2.9	B
30	2	21	29.0	61	25.8	150	56.7	14.1	2.2	10	2	181	66	.48	2.0	1.2	A
30	6	38	11.3	60	52.9	150	46.6	54.5	2.5	10	2	85	62	.26	1.3	2.1	A
30	9	21	55.4	60	12.4	147	42.5	13.3	2.2	10	3	199	142	.29	2.1	2.4	A
30	13	57	28.0	60	1.5	153	15.6	126.4	3.2	8	2	202	77	.28	4.2	4.4	B
30	21	47	54.4	60	17.6	151	57.3	70.8	2.7	7	1	112	49	.08	2.3	5.7	C
MAY 1	0	10	3.1	59	56.6	151	42.9	65.1	2.9	6	1	240	80	.12	2.6	4.2	B
1	4	45	11.4	60	48.6	144	51.9	4.9	1.2	3	1	248	109	.18	16.7	18.6	D
1	4	45	56.5	60	48.0	144	46.0	15.6	1.7	5	-0	254	111	.16	11.6	22.2	D
1	13	39	25.0	59	34.9	152	56.9	100.1	3.0	11	2	140	93	.16	3.4	2.6	B
1	18	26	42.9	60	58.9	147	1.0	18.0	.9	8	1	128	131	.11	1.9	4.0	B
3	5	2	10.6	59	3.2	151	29.0	29.0	2.7	8	2	305	177	.08	3.8	5.9	C
3	6	56	37.2	61	7.4	150	55.9	20.2	1.9	10	2	97	61	.47	1.1	4.3	B
3	9	50	27.8	60	26.2	152	32.4	89.6	2.2	7	3	170	73	.19	3.3	2.5	B
3	13	54	32.7	61	.2	150	57.3	16.6	1.7	9	2	87	63	.38	1.1	2.8	B
3	16	9	22.4	61	39.6	146	26.4	12.1	1.3	6	2	109	67	.38	1.3	5.4	C
4	5	37	27.0	60	9.3	151	2.5	64.3	2.0	7	1	191	66	.13	2.3	4.5	B
5	11	8	36.2	60	4.4	153	24.8	150.1	3.2	9	2	213	79	.16	4.8	4.9	B
6	12	32	1.3	59	56.6	152	51.3	95.9	2.4	9	2	160	74	.10	3.3	2.2	B
6	13	45	9.8	60	5.5	152	39.0	88.3	3.6	8	-0	219	63	.06	3.8	3.1	B
7	0	50	24.7	61	46.8	150	38.9	5.3	2.9	12	1	213	83	.56	2.7	1.4	B
7	9	15	13.7	61	10.1	152	5.0	104.8	4.3	10	1	205	68	.28	3.7	5.6	C
7	23	7	51.2	60	10.5	152	28.3	91.7	3.3	12	1	92	55	.35	2.3	2.8	B
8	4	32	13.0	60	48.7	152	33.2	126.7	3.0	10	1	202	72	.32	3.8	2.7	B
8	5	4	5.4	60	39.8	146	57.9	15.2	1.5	8	2	164	155	.22	2.3	7.3	C
9	22	9	53.6	61	17.6	150	37.7	51.1	1.9	9	3	95	70	.27	2.2	2.5	B
10	0	55	51.5	60	53.5	145	55.3	22.1	1.3	4	1	154	106	1.02	8.7	13.7	D
10	21	13	16.2	59	41.5	151	54.6	45.7	2.6	7	1	271	102	.19	3.0	4.2	B
11	17	39	46.1	60	49.1	150	50.0	56.3	3.7	10	-0	137	90	.09	2.8	3.7	B
12	6	24	42.0	60	8.5	152	1.0	68.7	2.3	8	3	157	53	.21	2.2	3.0	B
12	8	39	24.6	60	3.1	152	57.5	116.7	3.6	11	2	184	79	.28	3.1	2.9	B
12	9	36	53.5	60	39.5	152	3.4	80.6	2.0	7	4	116	58	.27	2.5	2.9	B
13	2	8	5.9	59	25.7	152	59.7	105.9	3.4	10	3	119	105	.23	3.4	2.6	B
13	11	2	40.8	60	20.6	152	1.3	68.8	2.8	9	1	104	47	.10	2.2	3.0	B
13	13	55	40.7	61	29.0	147	6.9	1.2	2.0	8	1	155	108	.34	1.7	3.4	B
13	15	34	53.9	61	19.6	146	52.3	28.3	2.0	8	2	137	124	.22	2.9	6.8	C
13	16	13	18.3	59	59.9	152	49.5	100.8	2.1	7	3	272	72	.17	2.7	2.1	B

1972	DAY	ORIGIN TIME HR	MN	SEC	LAT N DEG	MIN	LONG W DEG	MIN	DEPTH KM	MAG	NP	NS	GAP DEG	D3 KM	RMS SEC	ERH KM	ERZ KM	Q
MAY	13	17	13	23.0	61	30.5	146	31.4	19.4	2.0	8	2	100	76	.25	1.8	4.3	B
	13	19	16	56.0	59	50.7	153	8.3	109.9	2.8	8	2	303	91	.10	4.2	2.2	B
	13	19	23	58.6	61	28.2	147	11.4	15.3	1.6	5	1	155	111	.41	3.4	9.1	C
	14	1	52	2.5	59	54.5	153	14.9	128.8	2.9	10	4	198	88	.31	2.8	1.8	B
	14	9	39	57.4	61	49.1	150	13.1	35.9	4.0	13	1	207	63	.24	3.1	2.9	B
	14	18	36	44.6	59	39.5	152	55.6	79.2	2.6	11	2	148	87	.27	3.1	2.7	B
	14	20	15	24.7	61	11.7	147	12.8	1.0	1.8	5	1	147	125	.41	3.1	5.3	C
	15	0	15	33.8	60	2.3	153	30.1	153.2	2.6	6	2	300	110	.09	5.2	2.4	C
	15	1	47	21.4	60	37.9	151	6.9	58.1	1.9	6	3	137	71	.14	1.5	3.8	B
	15	2	36	34.8	59	58.4	153	20.7	140.8	3.5	12	2	206	85	.23	3.9	3.5	B
	15	8	1	4.2	60	41.5	151	24.7	68.0	2.6	9	2	78	65	.14	1.5	1.9	A
	15	9	15	8.0	60	5.4	152	39.6	86.3	2.3	8	2	222	63	.11	3.2	2.9	B
	15	14	41	50.6	60	56.2	151	32.5	74.7	2.5	8	2	85	62	.21	1.6	2.3	A
	15	18	6	39.4	60	20.2	147	12.6	13.8	2.4	8	2	121	163	.20	1.2	3.5	B
	16	2	23	3.5	60	24.4	152	37.1	106.4	2.6	10	2	176	75	.23	3.0	2.2	B
	16	3	58	35.5	60	7.7	152	55.7	96.9	2.3	8	1	185	79	.13	3.6	2.9	B
	16	18	45	12.1	61	55.7	147	6.2	41.5	3.5	8	2	170	102	.45	1.4	5.9	C
	17	23	9	12.0	60	57.8	152	37.7	110.4	2.7	9	-0	225	79	.35	4.1	2.9	B
	17	23	17	48.0	61	54.7	151	57.9	108.8	3.1	9	2	270	114	.32	5.2	3.0	C
	19	8	41	11.0	59	9.6	151	47.4	27.7	2.9	9	1	303	161	.07	4.8	5.6	C
	19	13	37	26.4	59	59.8	153	1.8	103.2	2.5	7	2	293	83	.08	3.9	2.9	B
	19	22	36	51.3	59	34.1	152	48.0	89.9	4.0	11	2	123	86	.24	2.9	3.0	B
	20	17	7	37.3	60	5.9	151	8.7	59.5	2.7	10	1	198	72	.15	2.0	2.8	B
	20	19	14	47.3	60	53.7	150	55.4	28.8	2.5	9	2	76	61	.19	1.0	4.3	B
	21	1	47	14.1	61	13.5	151	4.1	62.6	2.2	9	2	129	54	.12	2.4	3.9	B
	21	4	13	52.2	60	7.2	152	46.5	100.8	2.6	8	2	242	70	.19	3.6	2.8	B
	21	6	14	5.9	61	46.0	150	15.2	.2	2.9	13	1	204	63	.64	2.2	.8	A
	21	21	28	17.9	61	58.7	148	25.2	10.6	2.3	8	1	212	139	.49	3.1	5.4	C
	23	17	32	22.0	61	46.9	150	44.1	60.0	3.2	10	2	222	87	.26	3.9	3.2	B
	23	23	7	28.7	60	19.7	153	5.0	144.1	3.5	11	1	217	93	.25	3.8	5.2	C
	24	12	5	37.3	61	28.6	149	36.6	25.0	2.9	14	2	99	29	.38	1.2	2.2	A
	25	15	11	5.2	60	20.1	153	6.2	123.9	2.9	9	2	254	94	.21	3.5	2.8	B
	26	16	43	21.5	61	27.2	146	42.1	17.3	2.0	8	1	108	78	.15	1.2	2.8	B
	27	1	16	59.2	60	6.3	152	48.0	100.2	3.2	11	1	152	71	.25	2.9	3.4	B
	29	11	21	49.5	60	33.1	151	17.6	20.0	1.2	6	4	150	61	.25	1.2	2.0	A
	30	0	55	35.6	60	23.0	152	10.4	90.2	3.6	11	0	91	55	.18	3.1	6.9	C
	30	4	42	12.7	60	40.0	150	56.2	49.1	2.5	11	1	91	80	.34	1.5	3.1	B
	31	2	56	39.4	60	25.8	152	52.7	126.0	2.9	8	1	195	95	.12	4.8	5.7	C
	31	9	42	58.3	60	8.4	153	32.6	148.4	3.4	10	3	221	86	.30	2.8	2.2	B
	31	23	45	54.6	60	1.1	152	49.8	108.5	3.9	12	1	159	72	.24	3.1	4.1	B
JUN	3	11	47	2.5	61	31.6	149	51.9	23.9	2.5	15	2	99	40	.24	1.4	1.7	A
	3	14	21	8.8	59	40.2	153	19.0	108.6	2.4	9	1	196	107	.19	4.1	2.5	B
	3	16	30	21.9	60	.8	153	6.5	111.0	3.2	12	1	192	73	.17	3.5	4.4	B
	3	17	13	34.9	60	58.0	150	59.0	59.3	2.4	11	2	79	63	.19	1.7	3.8	B
	4	0	58	25.7	59	54.5	153	24.6	110.5	2.9	7	3	209	93	.25	6.5	2.0	C

1972		ORIGIN HR	TIME MN	SEC	LAT N DEG	MIN	LONG W DEG	MIN	DEPTH KM	MAG	NP	NS	GAP DEG	D3 KM	RMS SEC	ERH KM	ERZ KM	Q
JUN	6	6	24	39.2	61	1.1	150	57.0	57.0	2.0	7	4	105	62	.18	1.7	3.2	A
	6	11	49	45.9	59	34.5	153	2.8	84.9	3.4	10	1	151	117	.27	5.4	4.4	C
	6	15	25	32.5	60	57.0	150	39.4	45.8	2.6	10	1	93	54	.18	1.6	4.1	B
	6	17	23	41.5	60	10.3	152	43.1	108.7	3.1	9	1	103	97	.18	2.6	4.3	B
	7	5	1	29.8	59	58.7	152	42.5	95.2	2.6	8	4	142	78	.24	4.1	2.4	B
	7	16	45	38.8	60	42.9	150	17.1	43.5	3.2	11	1	92	71	.27	1.7	2.8	B
	8	4	45	25.5	61	9.1	150	18.1	39.6	2.3	10	2	101	60	.27	1.5	5.0	C
	8	10	32	51.8	60	43.2	151	51.3	79.4	2.0	6	4	117	53	.24	2.5	3.1	A
	9	10	57	17.5	61	36.8	146	28.5	17.1	1.9	5	1	107	70	.18	1.8	3.5	B
	9	16	34	23.0	60	21.5	152	10.0	89.3	2.7	7	3	160	66	.20	2.8	3.0	A
	9	18	58	33.2	60	43.8	150	41.4	54.5	2.0	8	4	110	79	.25	1.3	3.4	A
	9	19	58	29.5	60	14.6	153	8.1	153.6	4.1	9	1	202	98	.16	4.5	3.9	A
	9	21	38	53.3	61	31.2	146	48.8	18.0	2.9	8	0	112	90	.21	1.5	4.8	B
	10	0	56	11.7	59	52.3	153	27.6	146.4	3.6	8	3	213	98	.29	6.1	2.2	C
	10	21	14	1.5	60	52.4	151	25.0	67.9	1.9	7	3	79	64	.19	2.0	3.3	B
	10	22	50	40.0	59	57.1	152	30.2	81.2	4.1	11	2	116	81	.41	2.9	3.0	A
	11	8	13	49.2	61	1.8	147	11.5	9.7	1.3	5	1	156	121	.12	2.2	6.2	C
	12	23	12	9.6	61	41.6	150	55.0	57.7	2.3	9	3	228	83	.34	2.3	3.1	B
	12	23	56	13.9	60	53.7	146	57.2	15.5	1.7	5	2	136	136	.15	1.8	2.8	B
	13	1	17	10.9	59	49.4	153	37.0	142.3	3.5	9	1	225	107	.29	6.2	2.0	C
	13	5	13	47.4	59	53.6	153	10.4	114.5	2.7	8	3	192	87	.26	5.7	1.9	C
	13	14	12	56.3	59	28.3	152	10.5	72.8	3.6	8	2	217	124	.32	4.2	5.5	C
	14	0	52	36.7	60	16.1	152	55.8	156.7	5.2	10	1	191	103	.33	6.3	7.1	C
	14	8	21	14.1	60	28.9	147	20.4	13.2	1.5	6	2	186	147	.30	2.8	5.6	C
	14	11	37	9.9	60	5.3	152	56.4	115.6	3.0	9	1	185	84	.23	2.8	4.6	A
	14	19	7	8.6	60	23.8	152	31.8	128.1	4.1	8	2	163	81	.22	3.7	3.0	B
	26	3	21	50.7	60	6.2	149	9.6	2.8	3.3	8	1	197	173	.20	3.6	.7	B
	26	20	6	32.0	60	37.9	150	46.0	13.3	1.9	6	2	133	89	.18	1.4	1.5	A
	27	11	16	14.2	61	17.6	150	38.2	45.7	3.1	10	1	73	58	.23	1.9	3.0	B
	30	22	46	56.4	61	10.4	149	35.8	38.2	3.5	11	1	96	55	.28	1.6	2.7	B