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A BRIEF OUTLINE OF THE SEISMIC HAZARD IN THE FAIRBANKS/NORTH POLE AREA

By

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Alaska Division of
Geological and Geophysical Surveys

March 1983

THIS REPORT HAS NOT BEEN REVIEWED FOR TECHNICAL CONTENT (EXCEPT AS NOTED IN TEXT) OR FOR CONFORMITY TO THE EDITORIAL STANDARDS OF DGGS.

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A Brief Outline of the Seismic Hazard in the Fairbanks/North Pole area

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Introduction

The following report has been hastily prepared at the request of Susan Regen, Land Development Planer, Land Management Department, Fairbanks North Star Borough. Specifically requested was an evaluation of the seismic hazard in the Peede Road area in connection with a proposed land disposal involving Sections 16, 21, and 28, T1S and R2E. A complete seismic hazard evaluation cannot be made on such short notice because some essential data have not been collected, and the time is too short to give adequate consideration to the problem.

In this report I will summarize, in almost outline form, what is known, point out important gaps in our knowledge, offer my professional opinion as to the level of hazard, and make some recommendations for future study. Since the collision of the Pacific plate with Alaska provides most of the energy for earthquakes in the Fairbanks-North Pole area, I will begin with a brief description of the proximity of Fairbanks to this collision zone. Next I'll describe the seismicity of the interior of Alaska with emphasis on the Fairbanks area. Following these seismicity descriptions, I will discuss the level of hazard implied by the Uniform Building Code and several other sources. Lastly I'll give my evaluation of all of this and some recommendations.

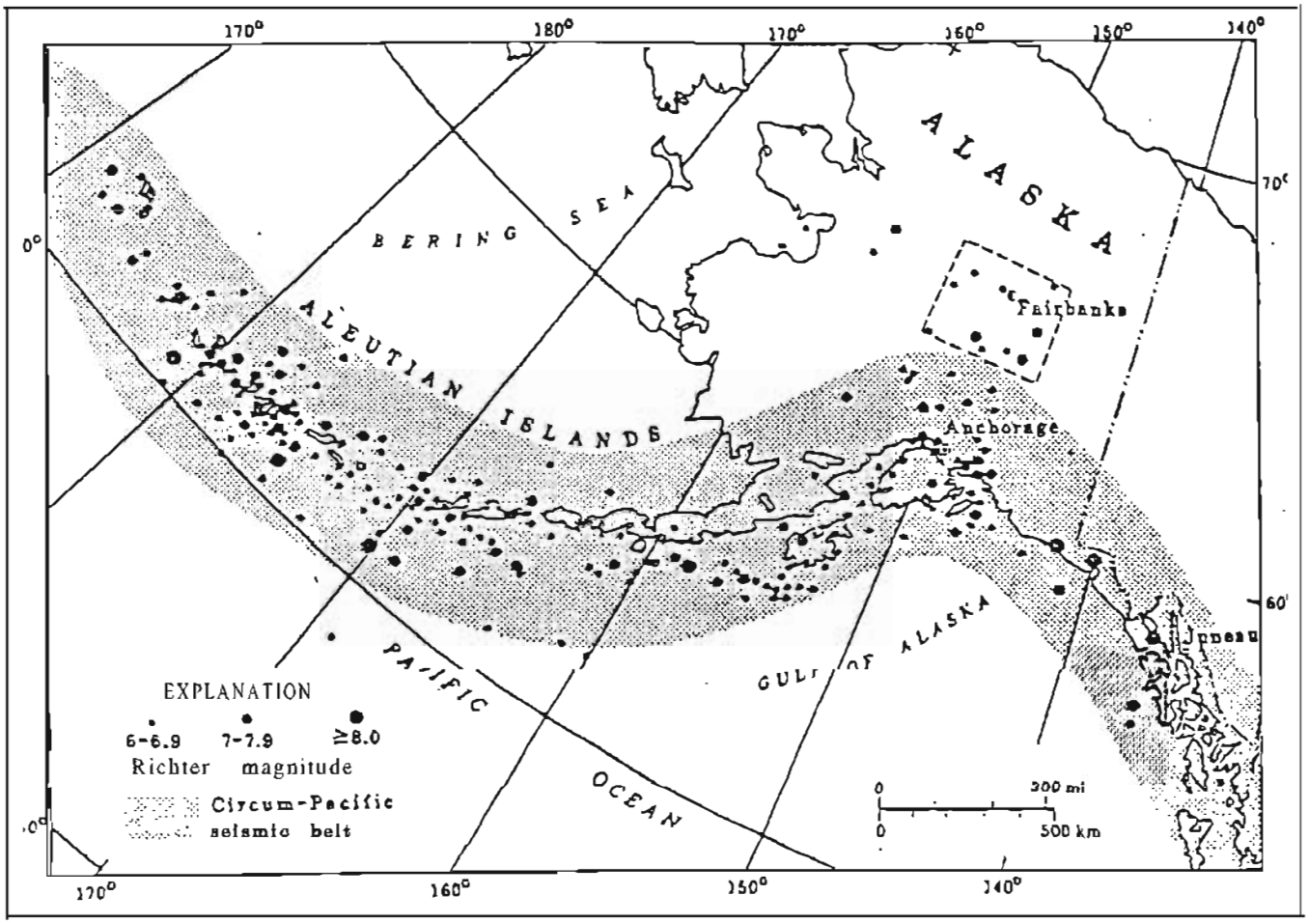
Note that I've begun to write Fairbanks instead of "Badger Road" or "Fairbanks-North Pole area". I will continue this shorthand throughout the remainder of the report.

Plate Tectonic Setting of Fairbanks

The proximity of Fairbanks to the Circum-Pacific seismic belt is shown in figure 1. The high level of seismic activity along the Aleutian Islands and the south coast of Alaska results from the collision of the Pacific Plate with Alaska. The floor of the Pacific Ocean is moving northwestward with respect to Alaska at about 6 cm/yr. This motion is taken up by the Pacific Plate being thrust under Alaska at an angle of about 45". This underthrusting is illustrated in figure 2. The northernmost edge of the Pacific Plate, beneath central Alaska, is below the northern frontrange of the Alaska Range; under Healy, Gold King and perhaps Delta Junction for example. This means that at its closest point of approach the Pacific Plate is about 50 to 75 mi south of Fairbanks and some 100 mi below groundlevel. On the scale of the Pacific-Plate this is a very small distance, which means that we should expect the effect of the collision of the Pacific Plate with Alaska to be felt strongly in Fairbanks, and this is indeed the case.

Seismicity of the Interior of Alaska

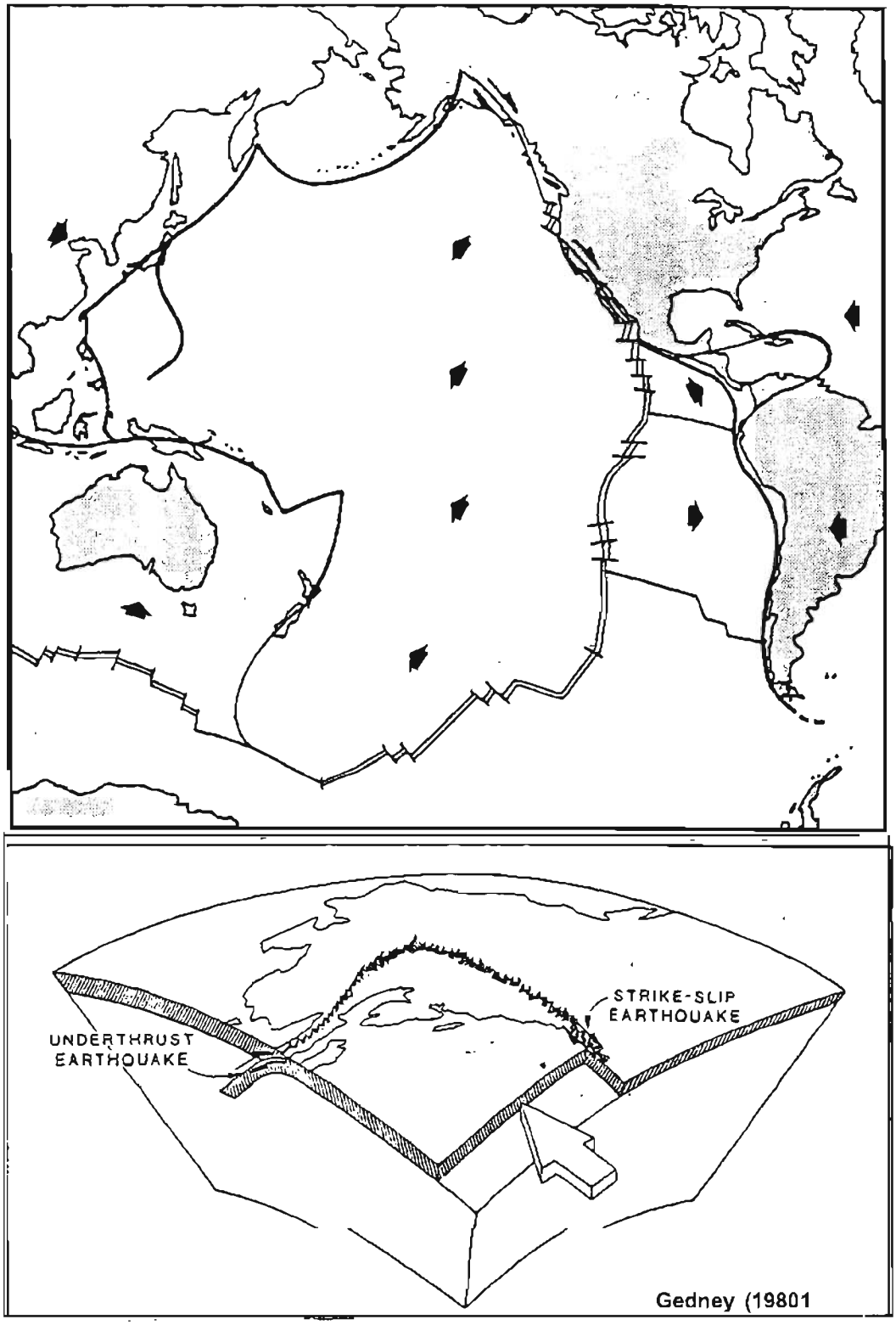
The effect of this collision is illustrated in figure 3, which shows the locations of all shallow (less than 30 mi deep) earthquakes of magnitude greater than 6.0 that have occurred in Alaska north of 63.5°N latitude. The epicenters of these earthquakes all lie in a band extending from Delta Junction through Kotzebue. Not shown in this figure is the fact that the larger events tend to occur closer to the east end of this band. The largest event was a magnitude 8 earthquake that occurred in 1904 (see appendix). Several other shocks in the greater Fairbanks area have had magnitudes of approximately 7½.



Epicenters of earthquakes with Richter magnitudes 6.0 and larger in Alaska from 1699 to 1967. Shaded area represents the Circum-Pacific seismic belt in Alaska. The dashed rectangle encloses area shown in figure 81 (modified from Jordan and others, 1966).

Figure 1: Map showing the relationship of the Fairbanks area to the Circum-Pacific seismic belt. From Pewé (1982).

PACIFIC "RING OF FIRE"
Schematic



Geophysical Institute, UAF Natural Hazards Br., DGGS

Figure 2: Schematic diagram of the boundary between the pacific Plate and Alaska (top) and of the geometry of the underthrusting of the Pacific Plate beneath Alaska (bottom) From Gedney (1980).

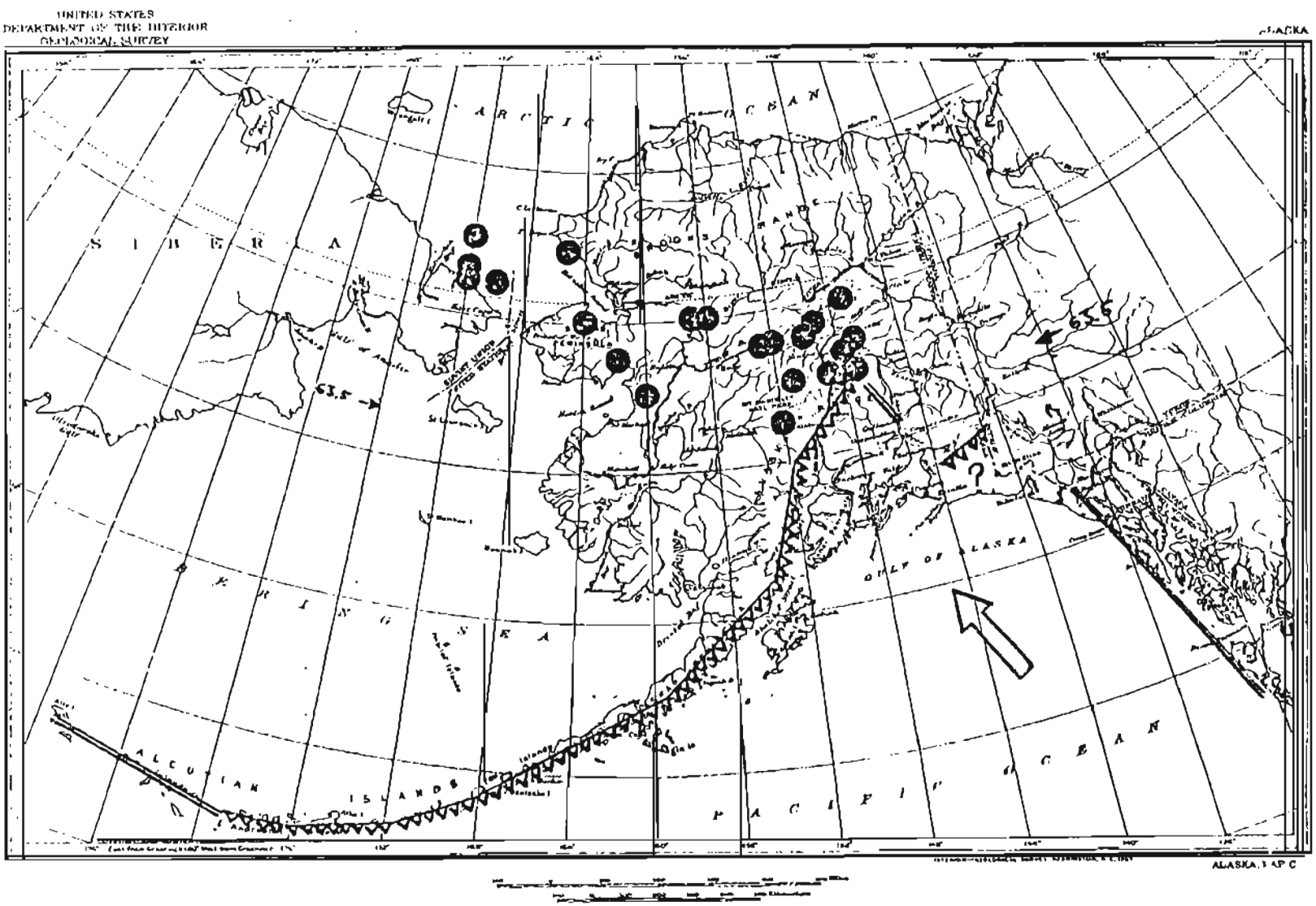


Figure 3: Map showing the locus of all shallow earthquakes of magnitude greater than 6.0 in Alaska north of 63.5°N in relation to the Pacific plate-Alaska boundary. The arrow indicates the direction of motion of the Pacific plate with respect to Alaska. From Davies (1983).

This distribution of earthquakes is just what you would expect if you modeled the Pacific Plate as a rigid indenter pushing into a plastic-elastic material (Alaska), All of these earthquakes occur along one of the principal slip lines predicted by the above model. This slip line should not be thought of as a large fault or shear zone extending across Alaska, rather it is a zone of relatively high stress within which favorably oriented and (probably) preexisting faults are reactivated from time to time.

The Fairbanks area lies in the eastern end of this zone, near the actual Pacific-Alaska collision zone and therefore is in a position where we would expect the highest stress levels and hence the largest earthquakes. As long as the Pacific plate continues to be thrust under Alaska, we can expect these large, shallow earthquakes in the Fairbanks area. This is likely to be the case for at least thousands of years.

The distribution of earthquakes within this zone of high stress is probably not random. The locations of events will be controlled by faults that already exist in the area. A major difficulty is that many of the faults in interior Alaska are buried many miles underneath recent sediments. This is the case for the Badger Road earthquakes. To date, no one has mapped the structure on which these events occur.

The Badger Road area has been the source area for many small earthquakes ever since the 1967 Fairbanks earthquakes. By contrast, other areas are relatively quiet except for an occasional burst of activity. An example of this is the Yukon Flats area as shown in figures 4a, 4b and 4c. In each of these figures, which show central Alaskan earthquakes for the months of February, April and September, 1972 respectively, the Fairbanks area is seen to be quite active whereas the Yukon Flats area is quiet in February and September, only showing a brief burst of activity in April.

This sporatic activity which may occur on buried faults indicates the need for long-term, continuous seismic recording. In some cases, the seismic record may be the only way to know that an active fault exists in a given area. Before the 1967 earthquakes, for example, the Badger Road area was not particularly active; but a long enough seismic record would likely have shown it as an area in which to expect larger earthquakes.

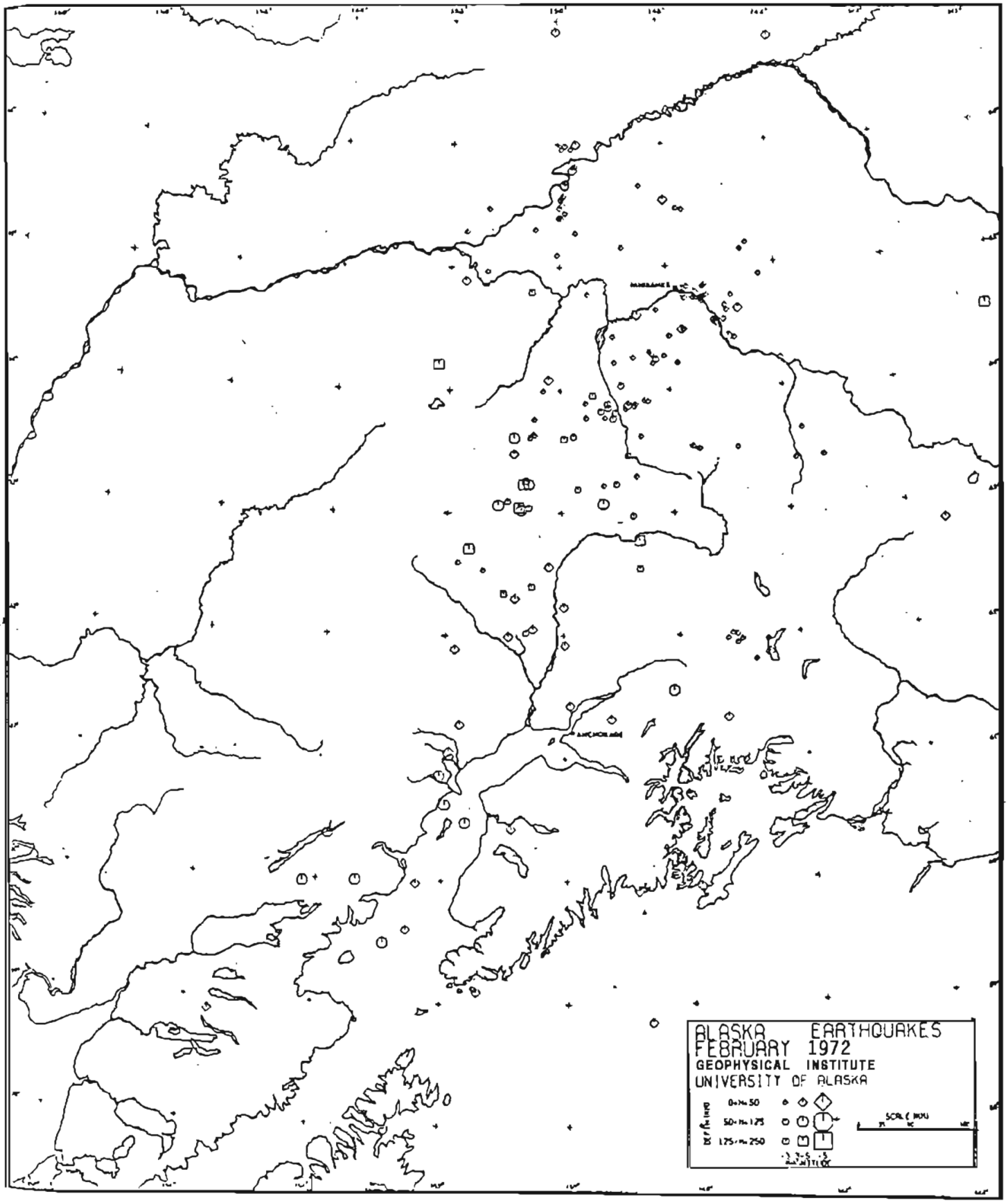
Seismicity of the Fairbanks Area

At least since the 1967 earthquakes in the Badger Road area, Fairbanks has been one of the most active seismic zones in the Interior of Alaska. Figure 5 shows that Fairbanks is located at the intersection of two trends of seismic activity, one extending about east-west and subparallel to the Chena River Valley, and the second, a somewhat more diffuse northwest-southeast trend following the Tanana River Valley between Fairbanks and Salcha.

While it is likely that these two river valleys are structurally controlled, no faults have been mapped along their trends and the nature of the structural contacts or faults along which the earthquakes are occurring remains unknown (see figure 7).

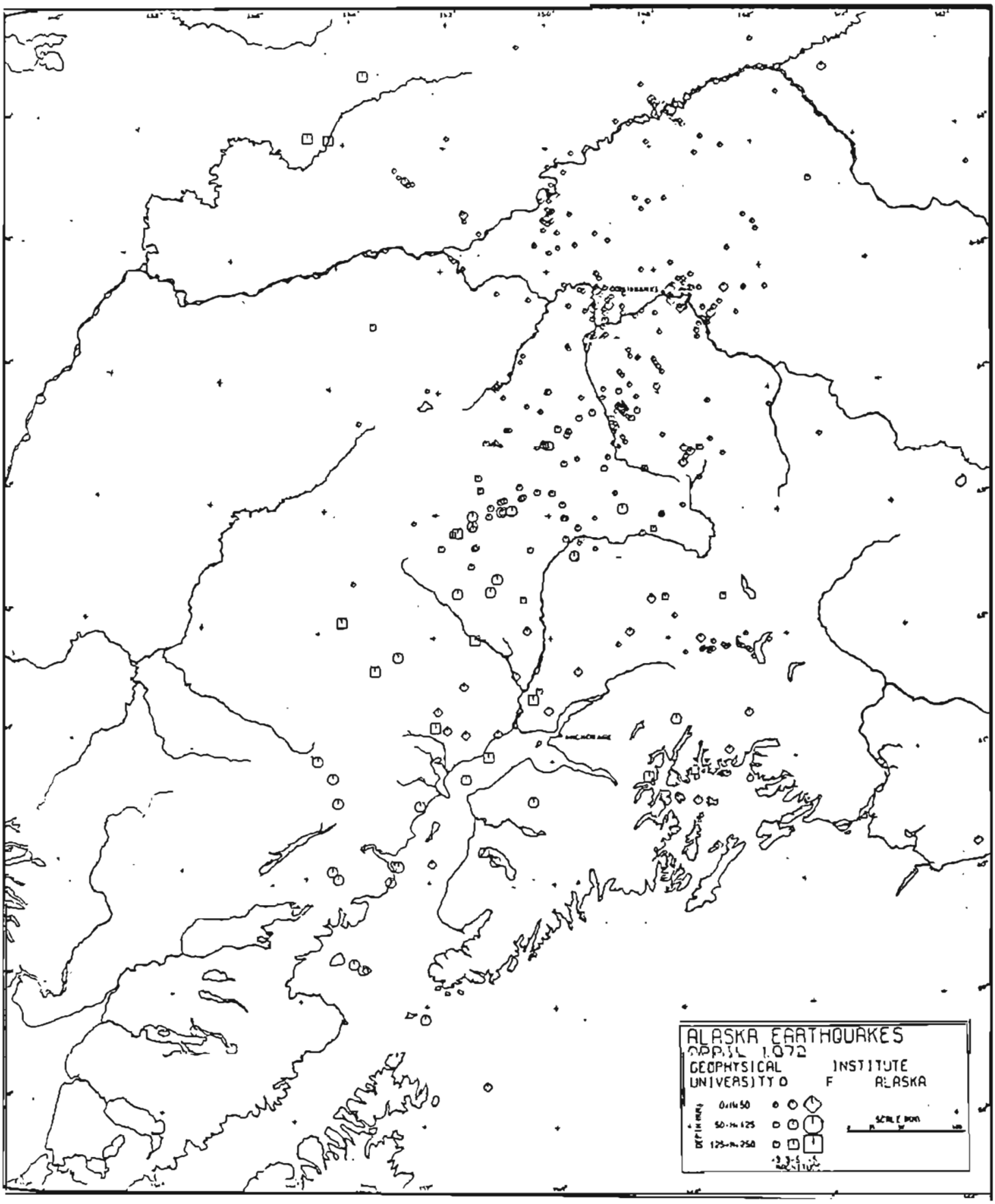
Since 1967 there have been four notable sequences of earthquakes in the Fairbanks area. These are shown in figure 6. The shaded area marked (1) corresponds to the aftershock zone of the 1967 earthquakes. Areas (2), (3), (4), and (5) mark the locations of earthquake sequences that occurred in 1970-71, 1977, 1979, and 1951, respectively. Typical depths for earthquakes in these zones range from 10 to 20 km. Areas (3), (4), and (5)

Figure 4a: Central Alaska earthquakes located by the University of Alaska Geophysical Institute for the month of February 1972. Note activity in Fairbanks area and absence of activity in the Yukon Flats north of Fairbanks. From VanWormer, Davies, and Gedney (1973).



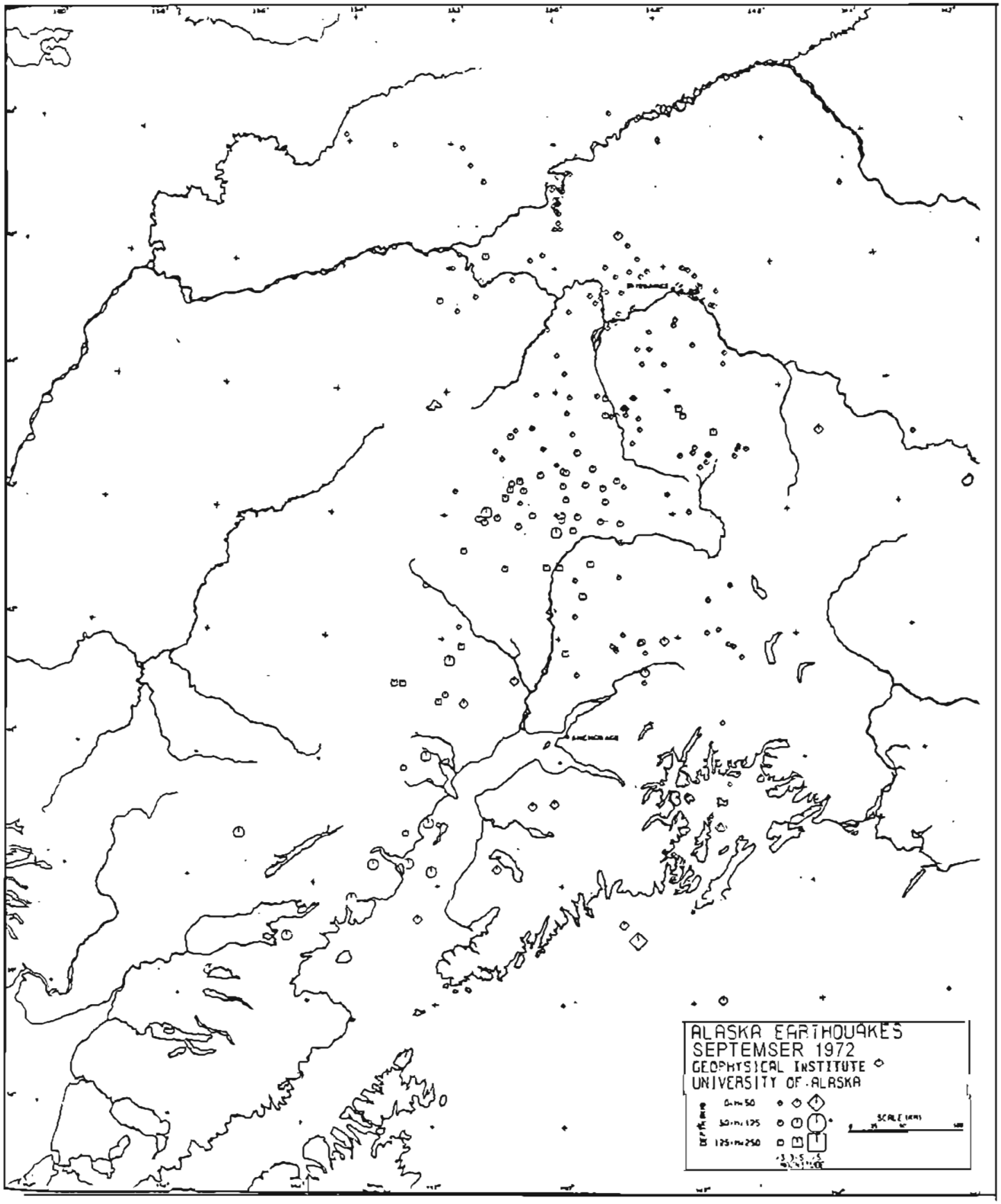
February 1972 epicenter map.

Figure 4b: Same as 4a, for the month of April, 1972. Note continuing activity in Fairbanks area and new activity in Yukon Flats. From VanWormer, Davies, and Gedney (1973).



April 1972 epicenter map. Note activity in Yukon Flats.

Figure 4c: Same as 4a, for the month of September, 1972. Note continuing activity in the Fairbanks area and cessation of activity in the Yukon Flats. From VanWormer, Davies, and Gedney (1973).



September 1972 epicenter map.

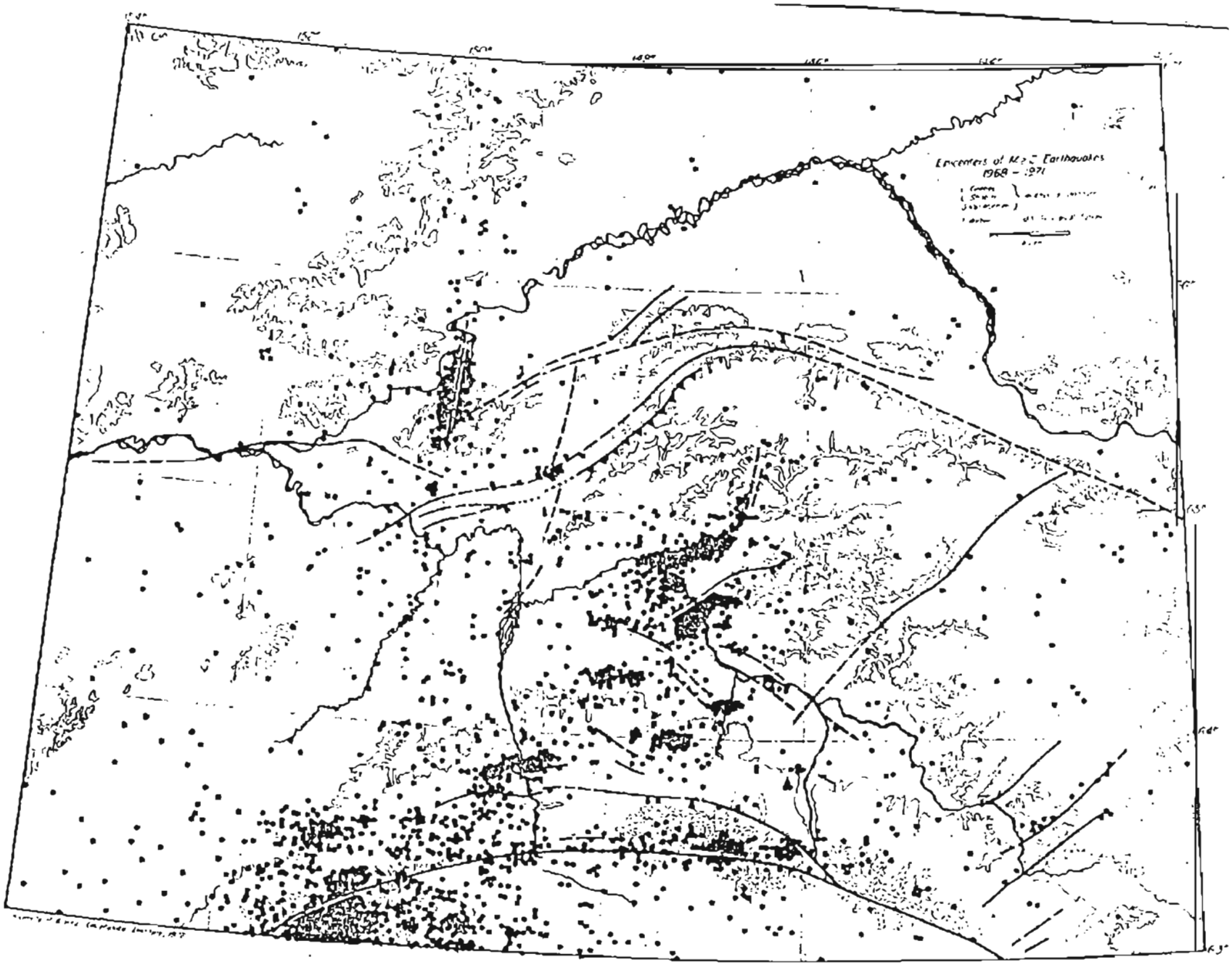
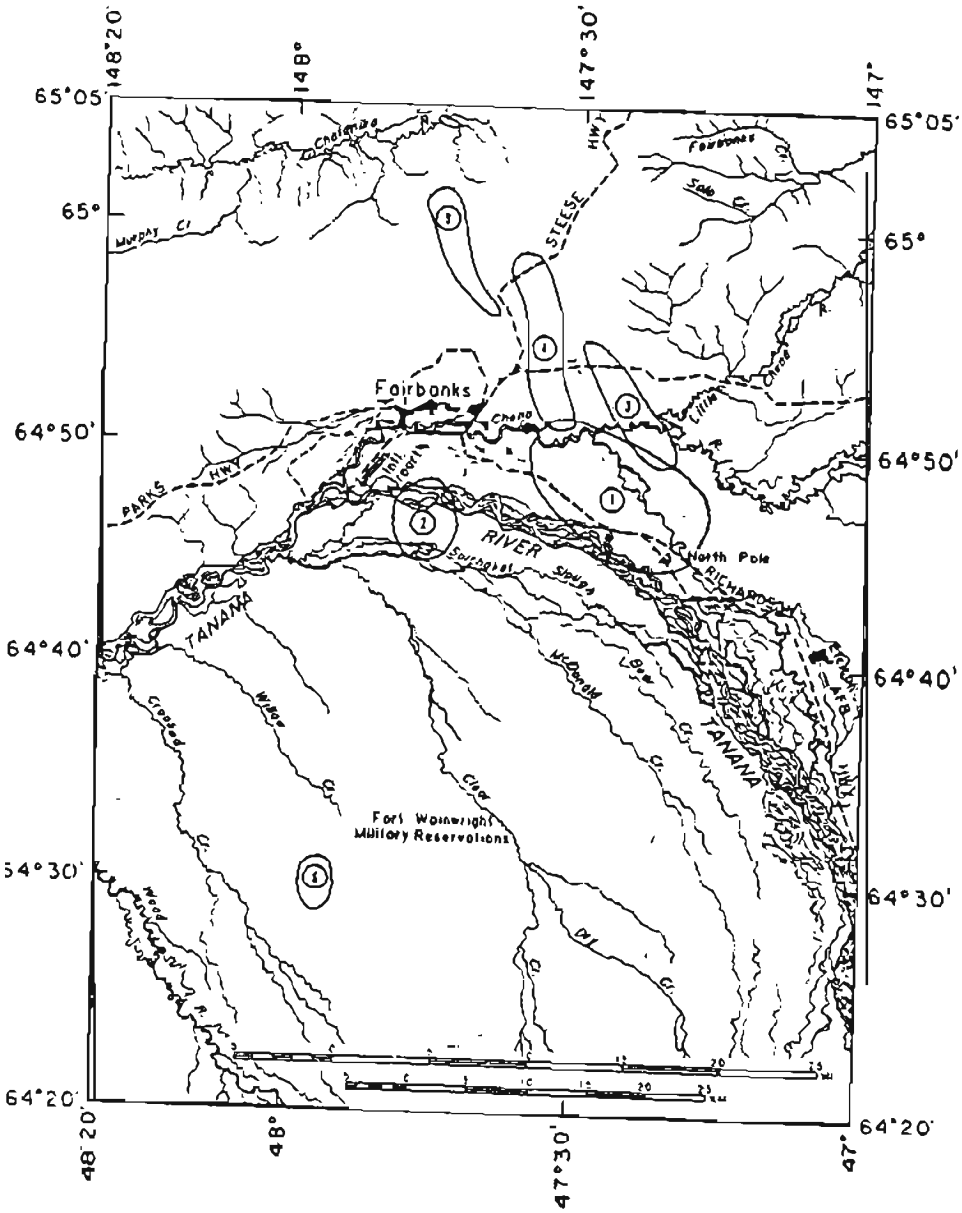


Figure 5: Correlation of epicenters with mapped faults. Note both ENE-WSW and NNW-SSE alignments of epicenterstrendirig-through.- Fairbanks area. From Gedney and others (1972).



Shaded areas indicate locations of earthquake swarms referenced in text. Area labeled 1 is aftershock zone of June 1967 earthquakes. Area 2 is epicentral area of swarm which developed in late 1970, early 1971. Swarms in areas 3 and 4 developed in February 1977 and February 1979, respectively. Swarm in area 5 occurred in October 1981, and earthquakes in area 6, some of which are unexplained in Table 1, began on 30 December 1981.

Figure 6: Recent aftershock zones and areas of swarming in Fairbanks area, Note en echelon arrangement of zones 3, 4, and 5 and general NNW-SSE alignment of the group comprising zones 1, 3, 4, and 5. From Gedney and others (1982).

delimit an interesting, en echelon pattern that appears to extend the Badger Road zone along a northwesterly extention of the above mentioned Tanana River trend. Area (2) might represent a westerly extention of the Chena River trend. Again, note that no faults have been mapped in these areas (figure 7). The depths of these events are consistent with their occurrences on some sort of buried structure or fault. Critical questions in this regard are "How long are these buried structures.", "Is there one long fault, all of which could break in a single, large earthquake?" or "Are there several smaller structures each of which might generate a maximum earthquake of only magnitude six?"

Hazard Estimates for Fairbanks

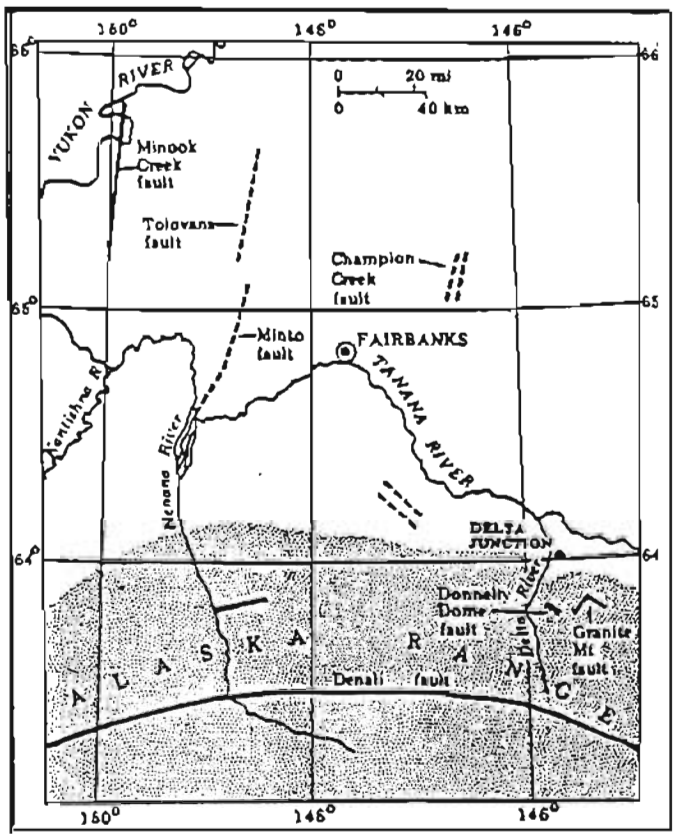
That the general earthquake hazard in the Fairbanks area is relatively high can be deduced from the foregoing descriptions of previous seismic activity. The level of the hazard has been assessed in a general way by the seismic zonation map for Alaska adopted by the Uniform Building Code (see figure 8, top). On this map Fairbanks is shown to be in zone 3, the penultimate ranking on a scale which ranges from 0 (negligible hazard) to 4 (highest level of hazard). A similar general picture of the hazard is given by the map shown in the bottom of figure 8. This map, published by the Applied Technology Council (ATC 3-06, 1978), depicts contours of the maximum level of peak accelerations expected across Alaska. Again, it can be seen that Fairbanks is in a zone where the expected level of strong ground motion during earthquakes is among the highest in the state (indeed, in the world).

How large an earthquake can we expect in the Fairbanks area? One answer to this question was given by seismologists of the U.S. Geological Survey (USGS) in connection with specifying the "design earthquakes" for various segments of the Trans Alaska Pipeline System (see figure 9). For the Fairbanks area, the USGS stipulated a design earthquake of magnitude 7.5.

A similar answer was given by seismologists at the University of Alaska, Fairbanks in assessing the probability of earthquake occurrences in the vicinity of the Chena flood control dam (see figure 10). The UAF seismologists were comfortable with specifying an average recurrence interval of 59 years for an earthquake of magnitude 7.5, but were uncertain that one could expect events of magnitude 8.0 or larger (hence the appearance of question marks in their table reproduced in figure 10).

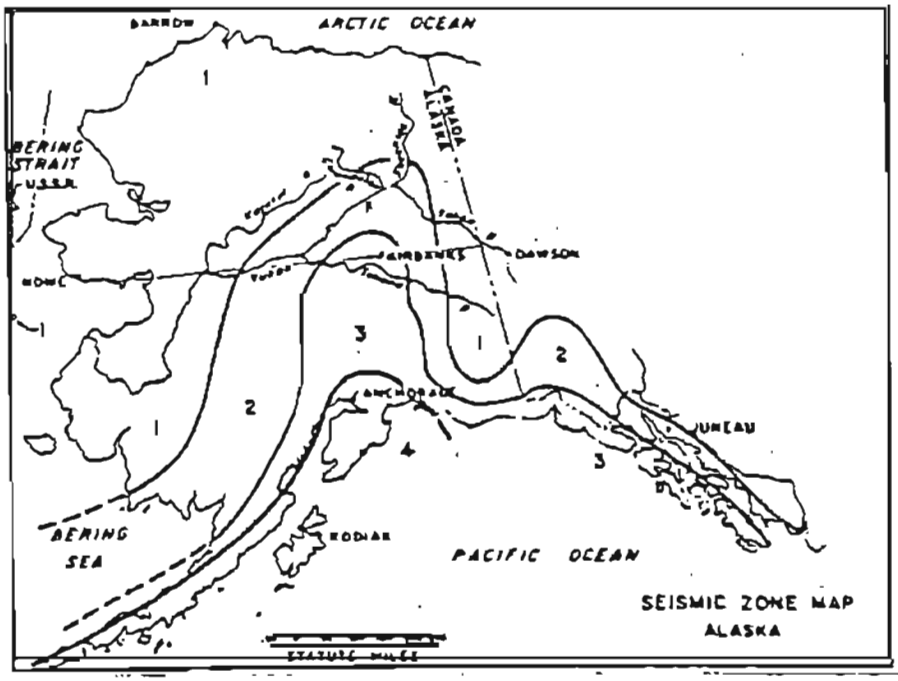
Discussion

What does all of this mean for the Badger Road area? There are two major unknowns which make it difficult to be more specific in the assessment of the hazard for a particular site near the Badger Road aftershock area, zone (1) in figure 6. The first is that we do not know the nature of the structure(s) on which the Fairbanks earthquakes are occurring. The second is that even if we could specify with certainty the level of acceleration to be expected for bedrock sites in this area, we would also need to know some details of the soil types and thicknesses at the site in question. For simple residential structures these questions need not be addressed exhaustively, but for more important structures, as fire stations, hospitals, large buildings, power plants, etc., these questions are critically important.



Active faults in central Alaska (Brogan and others, 1975; Gedney and others, 1972; Holmes and Péwé, 1965; Hudson and others., 1977; and Péwé and Holmes, 1964).

Figure 7: Napped faults in the Fairbanks area. Note that even though there are many earthquakes near Fairbanks, there are no mapped faults. From Pewé (1982).



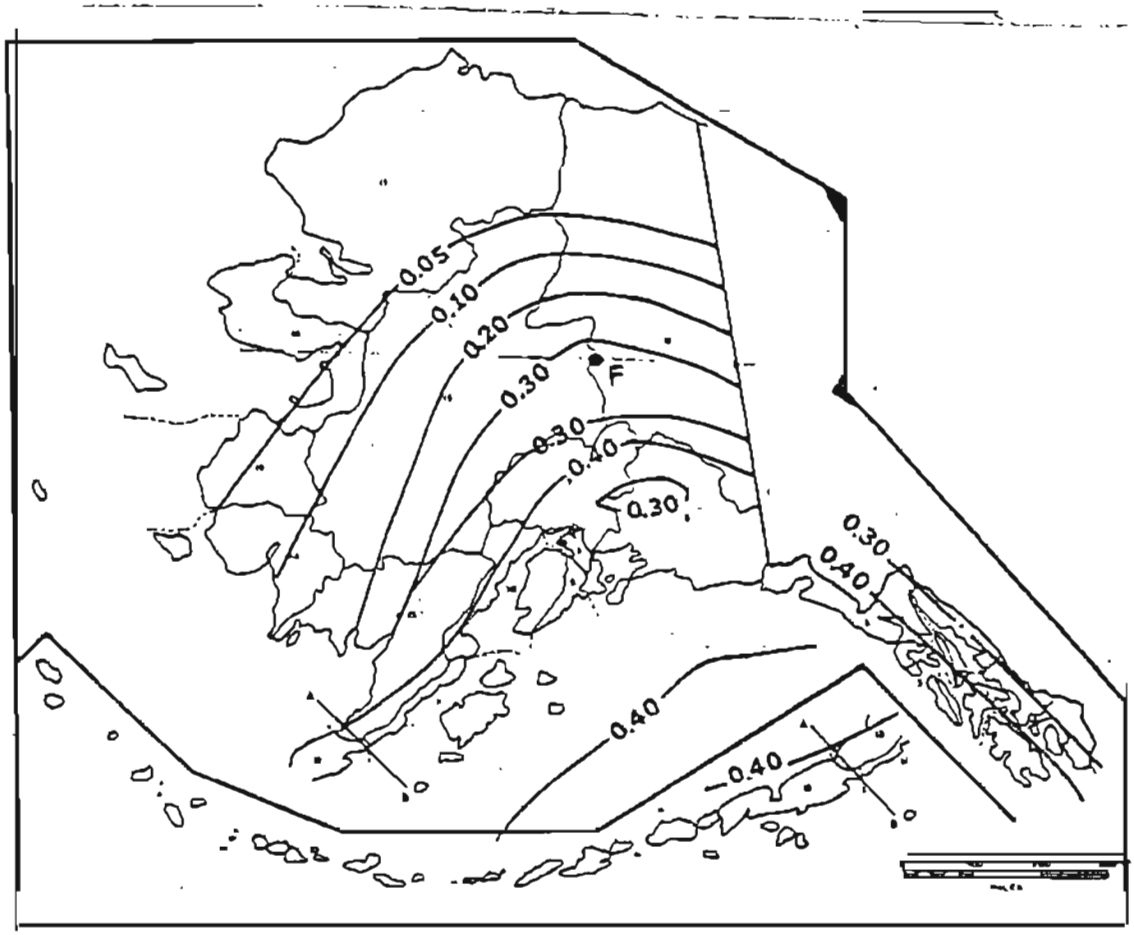
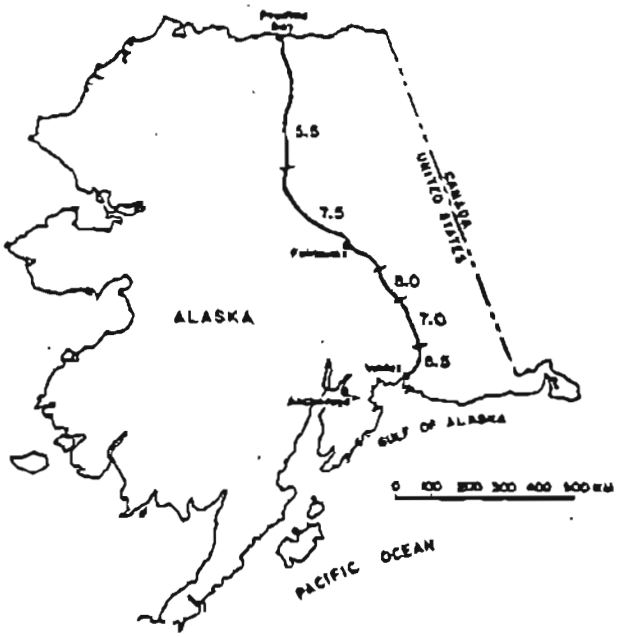


Figure 8: Uniform Building Code Seismic Zonation map for Alaska (top). Note that Fairbanks lies in zone 3. Applied Technology Council contour map of effective peak acceleration to be used for design purposes (bottom). For Fairbanks a value of slightly more than 0.3 g would be appropriate.



Map of proposed route of trans-Alaska oil pipeline showing seismic zonation and magnitude of design earthquakes.

Design earthquakes along the pipeline route

Seismic zone	Magnitude
Valdez to Willow Lake	8.5
Willow Lake to Paxson	7.0
Paxson to Donnelly Dome	8.0
Donnelly Dome to 67°N	7.5
67°N to Prudhoe Bay	5.5

Figure 9: Design earthquakes specified for the Trans Alaska Pipeline System. Note that in the Fairbanks area a maximum magnitude of 7.5 was specified. From Page and others (1972).

Predicted Recurrence Intervals for Earthquakes Greater than Specified Magnitude Occurring within 50 Miles of the Chena Flood Control Dam

Magnitude	Average Number Expected in 50 Years	Average Recurrence Interval
3.0	906	20 days
4.0	110	170 days
5.0	14	3.6 years
6.0	2.67	19 years
6.5	1.85	27 years
7.0	1.25	40 years
7.5	0.85	59 years
8.0	0.58(?)	86(?) years
8.5	?	no prediction

Figure 10: Table showing expected frequency of occurrence for earthquakes of various magnitudes. Note that an event of M = 7.5 is expected to occur 0.85 times in 50 years or, alternately, the recurrence interval for this event is 59 years. From Davis, Estes, and Gedney (1978).

If we assume that the Badger Road earthquakes are occurring on a buried fault that is long enough to sustain a magnitude 7.5 earthquake, 30 to 60 km (Slemmons, 1977, p. 36), and further that the shortest distance from any point on the fault to the site in question is about 10 km, then the expected level of peak acceleration on bedrock would be in the range 0.4 to 0.5g (Seed and Idriss, 1982, p. 38). Note that this is somewhat higher than the value of 0.3g given by the ATC map in the bottom of figure 8. There are two reasons for this. First, the ATC map incorporates a probability of about 10-20% for the exceedence of these values and second, the map presents smooth contours, averaged over large areas of the state, and is therefore not very sensitive to a single fault on the order of 50 km in length.

This probability level corresponds to a recurrence interval of about 475 yr. One cannot compare this directly to the average recurrence interval for an event of magnitude 7.5 given in the table in figure 10, but in my opinion the two values are roughly consistent. The important point is that these mean values are specified over some area, and that the probabilities for exceeding a certain value of peak acceleration in a given time interval will be larger than these means if the site in question is close to a particular fault.

A resonably conservative assumption, in light of the seismic activity of the Badger Road seismic zone, is that it does represent a buried fault capable of generating a magnitude 7.5 earthquake every 400 or 500 yr.; this would translate into design peak accelerations a little higher than those given by the map in the bottom of figure 8 and the assignment of the immediate Badger Road area to seismic zone 4 instead of zone 3 as specified by the UBC map shown in the top of figure 8.

The second major concern is the general absence of subsurface information about soil types and thicknesses. This concern has to be addressed on an almost site specific basis. Depending on the soil type and thickness, the bedrock peak acceleration values can be modified substantially, by factors of 2 or 3 in either direction, (depending also upon the frequencey of shaking).

Another possibility which depends on soil type is liquefaction during strong ground motion. In areas underlain by thick sandy layers (20-30 ft) and with a high water table this is a serious concern. The area-wide potential for liquefaction where the water table is close to the surface is moderate (unpublished map, Rod Combellick, 1982).

Conclusions

While much work remains to be done to adequately assess the seismic hazard in the vicinity of the Badger Road seismic zone, for the present, reasonable caution dictates serious attention to the following three problems:

(1) The Badger Road seismic zone is probably capable of generating a magnitude 7.5 earthquake often enough that sites within 10 km of the zone will experience strong shaking in excess of that implied by the UBC seismic zonation map for Alaska and the ATC 3-06 contour map of peak accelerations for Alaska.

(2) Sites located close to the Badger Road seismic zone, and on several hundred feet of sediments are likely to experience shaking several times stronger than comparable sites on bedrock.

(3) Sites located close to the Badger Road seismic zone and on several tens of feet of sandy soil and with a near-surface water table are likely to suffer from liquefaction of the sandy layer during strong ground motion.

Recommendations

(1) Sites within 10 km of the Badger Road seismic zone, area (1) on figure 6, should be considered to be in UBC seismic zone 4 for purposes of private dwellings and other non-engineered structures.

(2) For sites as in (1) above and on bedrock or stiff soils, peak accelerations of 0.45g should be assumed in the design of non-critical structures.

(3) For sites as in (1) above and not on bedrock or stiff soils, and where critical structures are proposed, a site specific study should be made of the expected response of the foundation soils to strong ground motion.

(4) For sites as in (1) above and not on bedrock and with a near surface water table, prospective occupants should be notified of the possibility that the foundation soils might liquify during strong ground motion.

(5) Research should be supported to establish the nature of the structures on which the Fairbanks area earthquakes are occurring.

(6) Area-wide mapping of soil types and thicknesses (clear to bedrock) should be initiated.

(7) Area-wide maps showing depth to the water table should be published.

(8) Maps combining information from (6) and (7) above to show liquefaction potential should be published.

(9) Maps should be published, combining information from (5) and (6) above, showing peak accelerations expected-to be exceeded at the 10% probability level for a 50 yr period.

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APPENDIX

Significant historical earthquakes in the Fairbanks area. This section is copied directly from Davis, Estes and Gedney (1978), p. 2-4.

Significant Historical Earthquakes

In interior Alaska, during the 20th Century, several large earthquakes have occurred; several of the epicenters were within 50 mi (80 km) of the Chena project (Moose Creek Flood Control Dam).

August 27, 1904: With magnitude 7-3/4, the 1904 earthquake is the largest ever reported in interior Alaska. Its listed location, 64°N, 151°W, is 80 km north of the Denali fault where it passes beside Mt. McKinley and directly on line with a topographic lineament along the course of the East Fork of the Kuskokwim River and extending northeast along the upper Kantishna River toward Nenana and Fairbanks. However, the location of the 1904 earthquake is very uncertain; location errors of order 100 km are possible. At Rampart, 180 km to the north of the stated location of the 1904 earthquake, "buildings cracked" (Davis and Echols, 1962).

July 7, 1912: This magnitude 7.4 earthquake is listed as occurring at 64°N, 147°W, a location 50 km north of the Denali fault and approximately 120 km southeast of Fairbanks. The event was reported as felt at Kennicott and violent at Fairbanks (Davis and Echols, 1962). As with the 1904 earthquake, the location of the 1912 earthquake should be considered uncertain. It could have been on the Denali fault or on one of the faults of the apparent conjugate fault sytem of the Yukon-Tanana region north of the Denali.

July 22, 1937: With a field epicenter at 64-3/4°N, 146-3/4°W (instrumental epicenter 64-1/2°N, 146-3/4°W) (Bramhall, 1938), this magnitude 7.3 earthquake caused slides which blocked the Richardson Highway at Mile 33 and it caused minor damage at Fairbanks. A published fault plane solution is compatible with left-lateral motion on a northeast trending fault, or its equivalent, right-lateral motion on a northwest trending fault. Field investigations did not reveal a fault trace.

October 16, 1947: This magnitude 7.D -earthquake was at 64.5°N, 148.6°W, southwest of Fairbanks. It caused minor damage in Fairbanks and Clear, and slumping of the bed of the Alaska Railroad at Mile 351. A series of seven major foreshocks eleven days earlier caused some cracking of plaster in Fairbanks. This earthquake may have occurred on a left-lateral fault striking northeasterly from Clear to Fairbanks. St. Amand (1948) assigned Mercalli intensities of VIII+ at Clear, near the epicenter, and VII at Fairbanks.

June 21, 1967: The 1967 Fairbanks area earthquake swarm was centered approximately 10 km southeast of the city, caused minor damage, and exhibited a NW-SE striking focal zone. Magnitudes of the larger shocks were 5.6, 4.3, 6.0 and 5.3, in temporal order (Berg et al., 1967). This earthquake zone underlies the area of the Chena Flood Control Dam.

October 29, 1968: The magnitude 6.5 earthquake of October 29, 1968, is thought to have occurred on the Minook Creek fault (Gedney et al., 1969) which undergoes left-lateral motion and strikes northerly where it may pass beneath the Yukon River bridge.

February and March 1977: During February and March of 1977, there was anomalous resurgence of activity on the Badger Road fault in the North Pole area. Several thousand earthquakes with maximum magnitude 4.1 occurred during the swarm that began in February, peaked in late February, and subsided by late March. No significant damage was caused (Estes et al., 1977).