FINAL TECHNICAL REPORT

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A STUDY OF HISTORICAL SEISMICITY OF THE FAIRBANKS, ALASKA REGION

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ABSTRACT

We have studied the historical seismicity of the Fairbanks region (1900-1973). This region of Alaska has been the site of most M>7 earthquakes occurring outside the North America-Pacific-Yakutat block plate boundary area or along the Denali fault. These earthquakes have produced intensities of up to VIII in the Fairbanks region, and the historic record suggests 2 to 3 similar events may occur each century. In this study we focused on: 1) relocations of sequences associated with magnitude > 5.5 events in the Salcha, Fairbanks, Minto Flats, Huslia and Rampart seismic zones occurring prior to 1974 to better define active structures associated with these sequences, 2) relocation of background seismicity occurring between 1922 and 1973 to obtain higher precision locations that can be compared with recent (post-1973) high quality relocations obtained by other researchers and 3) analysis of intensity information for larger events within the region to determine how strong ground motion in Interior Alaska may differ from that observed in other regions of Alaska. We have also collected a suite of seismograms for M>5.5 earthquakes within the study area that we will analyze at a later date.

These tasks provide us with high quality earthquake locations that can be used to better define the geometry of active faults within the Fairbanks region. Since none of the M>7 events within this region have been associated with observed surface rupture, we have compared our results with other geological and geophysical information to determine factors that may influence rupture during these sequences.

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Introduction:

In our original proposal we planned to focus on the region of interior Alaska extending from 64° to 65.5° N and 146° to 151° W located between the Denali and Kaltag/Tintina right-lateral strike-slip fault systems (Figure 1). However, after examination of earthquake sequences in central Alaska we felt in important to work within a larger study area (Figure 1) that included the1958 Huslia-Tanana earthquake sequence, the western Denali fault zone, and the eastern Tintina fault zone. We also examined the seismicity located between the Denali fault and the active structures of northern Cook Inlet (north of ~62.25°N) – a region that has not been examined in previous studies. Historic and recent seismicity of the Denali fault system has already been examined in a series of recent publications (e.g. Doser, 2004; Ratchkovski and Hansen, 2002).

We subdivided the study area into 8 smaller regions of interest indicated by the boxes in Figure 1. Most regions encompass earthquake sequences with M>6 events and were selected to highlight specific fault zones or seismic zones. For example, the Rampart study area includes the 1968 Rampart (M_S=6.5 mainshock) and 1985 Dall City (M_S=6.1 mainshock), earthquakes in a region that appears to transfer stress between the Kobuk and the Kaltag/Tintina fault systems.

Earthquake Relocations:

A major portion of the work we have completed involved relocating pre-1974 earthquakes within the study area. Phase data for earthquakes occurring between 1918 and 1962 were obtained from scanned copies of the International Seismological Summary (ISS). Phase data for earthquakes occurring between 1963 and 1973 were obtained directly from the International Seismological Centre's website. All earthquakes were relocated using the *jloc* software package (Lee and Dodge, 2006). This software has been specifically designed to locate poorly constrained earthquakes (e.g. non-uniform distribution of recording stations, highly variable quality of phase data) using a downhill simplex search algorithm. Relocated earthquakes are indicated by the red symbols in Figure 1. Figures 2 to 9 show relocations and recent seismicity from the Alaska Earthquake Information Center (AEIC) for each subregion of interest.

With the exception of the 2002 Denali fault earthquake, no earthquake occurring within the study area since 1922 has produced surface fault rupture. Thus we have compared seismicity to available gravity (Saltus et al., 2008), magnetic (Saltus et al. 1999), and geologic information (e.g. Wilson et al., 1998) in an attempt to understand the subsurface controls on earthquake occurrence. Figures 10 and 11 compare seismicity within the Minto Flats region to gravity and magnetics data. Figure 10 shows that the main band of seismicity within the Minto Flats Seismic Zone (MFSZ) is located within a gravity low that is bordered to the east by higher density rocks of the Livengood ultramafic and plutonic complex (Patton et al., 1994). This suggests that differences in rock properties across the region have led to the preferential concentration of stress (and earthquakes) near the western edge of the Livengood complex. Magnetic data (Figure 11) indicate the seismicity is concentrated in regions of relatively low magnetic intensity. Similar comparisons have been completed for the other 7 study areas shown in Figure 1, but space limitations preclude their inclusion in this report.

Analysis of Intensity Information:

We used intensity information for seven well recorded earthquakes in the interior Alaska region (62° to 66.5°N and 142° to 157° W) (Figure 12 and Table 1) to develop an intensity-magnitude attenuation relationship following the method of Bakun (2006). The relationship has the form of:

$$\mathrm{MMI}=C_0 + C_1\,\mathbf{M} + C_2\,\Delta_h + C3\log\Delta_h$$

where MMI is the observed intensity, **M** is the moment-magnitude, C_0 and C_1 are coefficients relating MMI and **M**, C_2 describes intrinsic attenuation and scattering and C_3 describes geometrical spreading. For interior Alaska our relationship is:

$$\mathrm{MMI}=2.08\pm4.64 + 1.19\pm0.90\,\mathbf{M} + 0.00846\pm0.00255\,\Delta_h + 1.56\pm0.72\log\Delta_h$$

This is similar to a relationship we obtained for south-central Alaska (Doser, 2008; 2009), suggesting that attenuation in the two regions is similar. We did, however, find a markedly different attenuation relationship for southeastern Alaska.

Table 1 – Source Parameter Information for Interior Alaska Calibration Events

Event	Date	Origin Time	Epicenter (°N, °W)	Magnitude* (**M**)	M_{MMI}	Depth (km)	Number MMI values	References+
I1	07/22/1937	1709	64.60 147.12	7.2w	7.0	8	17	FC,NE
I2	10/16/1947	0209	64.28 148.23	7.1w	6.7	6	25	FC,NE
I3	04/07/1958	1530	65.99 156.55	6.8w, 7.3S	7.6	8	46	FC,NE
I4	4/13/1958	0907	65.83 155.55	6.7U	6.2	10	11	NE
I5	06/21/1967	1813	64.80 147.40	6.1L	6.5	17	26	NE
I6	10/29/1968	2216	65.50 150.02	6.8L	6.8	7	22	HB
I7	10/23/2002	1127	63.54 148.00	6.7w	6.4	10	47	A,GM

* b=body wave magnitude, S=surface wave magnitude, L=local magnitude, w=moment-magnitude, U=unknown method

+ A=Alaska Earthquake Information Center, FC=Fletcher and Christensen (1996), GM=Global Centroid Moment Tensor Catalog, HB=Huang and Biswas (1983), NE=National Earthquake Information Center

We next compared how well this relationship could be used with intensity information to predict the observed locations and magnitudes of nine test events in the Interior Alaska region (see Figure 13). Table 2 indicates that the relationship should provide reasonable estimates of epicenters (± 50 km) and magnitudes (± 0.5 magnitude units) for more poorly recorded earthquakes, despite the sparse population density of this region.

Finally, we used the relationship to relocate several earthquakes that have insufficient phase data (but sufficient intensity data). These include the 1912 Delta River earthquake along the Denali fault (event IH1, Figure 13). The Delta River event's intensity center was located 150 km west of points where the 1912 rupture has been observed along the Denali fault (Carver et al., 2004) and its intensity magnitude (8.6) greatly overestimates its surface wave magnitude of 7.2 (Abe, 1981). This discrepancy is likely caused by an intensity of X observed at Cache Creek (at 63.27°N 150.75°W) that could be due to site amplification or directivity effects. Results of this study, along with analysis of intensity data for south-central and southeastern Alaska, was submitted to the Bulletin of the Seismological Society of America in February 2009 (Doser, 2009).

Table 2 - Source Parameter Information for Interior Alaska Test Events

Event number	Date	Origin Time	Epicenter (°N, °W)	**M**	Depth (km)	Intensity center (°N, °W)	M_I	Numb. MMI values	Refer-ences[+]
IT1	08/18/1962	1643	62.21 152.49	5.6w	24	61.81 151.69	5.8	9	D,NO
IT2	06/21/1967	1804	64.91 147.59	6.1L	15	64.27 147.28	5.6	9	A,NO
IT3	08/14/1970	0339	64.90 147.80	5.6L	19	65.09 149.00	5.1	9	A,NO
IT4	12/30/1981	1400	64.58 148.01	5.2L, 4.9b	14	64.68 148.41	4.2	8	A,NO
IT5	03/09/1985	1408	66.22 149.98	6.0S, 6.1L	12	66.18 151.64	6.1	16	NE,NO
IT6	11/29/2000	1035	63.89 150.35	5.8w	16	64.18 149.91	5.4	15	A,DY
IT7	11/03/2002	2212	63.51 147.46	7.9w	4	63.59 147.27	8.5	182	A,DY,G,C
IT8	11/03/2002	2232	63.30 145.67	5.8w	1	63.50 147.26	7.0	23	A,DY,G
IT9	11/08/2004	0621	63.05 151.43	4.9w	10	62.41 151.27	4.8	29	A,DY,G
IT10	12/04/2004	2104	63.48 149.01	4.8w	6	63.19 149.09	4.7	16	A,DY,G

[+]A=Alaska Earthquake Information Center, C=J. Cassidy (pers. comm.), D=Doser (2004), DY=U.S. Geological Survey "Did You Feel It?" website, G=Global Centroid Moment Tensor Catalog, NE=National Earthquake Information Center, NO=NOAA

Waveform Modeling

In our initial proposal we had planned to analyze seismograms of as many M>5.5 earthquakes within the study area as possible. We planned to first focus on a re-analysis of the two events studied by Fletcher and Christiansen (1996) (the 1937 Salcha and 1947 Fairbanks earthquakes). During a visit to the University of Alaska by Dr. Doser in May 2008 Dr. Christiansen was unable to locate the copies of the original seismograms used in their analysis, forcing us to re-request copies of these seismograms from individual seismograph stations. It took us nearly 6 months to receive all requested seismograms and we did not have time to analyze them prior to the end of the grant. The seismograms we have collected are given in Table 3. We plan to conduct waveform modeling and empirical Greens function analysis of these events over the next year.

Table 3 – Presently Available Historical Seismograms of Interior Alaska Events

Event Date	Time	Mag.	Location	Stations
January 21, 1929	1030	6.3	64.25 -148 Wood River	KEW , UCC
July 4, 1929	0428	6.5	64.25 -148 Wood River	KEW, UCC, DBN
March 25, 1932	2354 2358	6 6.9	62.5 -152.5 W. Denali	DUR, LPZ PAR, HEL, LPZ, DUR, EDI, KEW, UPP

July 22, 1937	1709	7.3	64.6 -147.1 Salcha/Fairbanks	UKI, HEL, CHI, ABU, DBN, TNT, OTT, TUC, SCO, PUL, VLA, TIF, MOS, PAS, DUR, PAR, UCC
October 7, 1947	0153	*	64.2 -148.3 Wood River	ABE, WES
October 15, 1947	1934	*	64.2 -148.3 Wood River	ABE, DUR, UCC, WES
October 16, 1947	0209	7.2	64.2 -148.3 Wood River	PAS, LPZ, SJG, TUC, DBN, PUL, ABU, TIF, DUR, ABE, UCC, WES
October 20, 1947	0143	6.8	64.2 -148.3 Wood River	ABE, DUR, KEW, DBN, UCC
April 7, 1958	1530	7.3	66 -155.6 Huslia	PUL, TRI, DBN, HKC, PAS, VLA, ABU, RVR, KIR, UPP, MAT, DUR, ABE, KEW, WES
April 8, 1958	0014	6.8	65.87 -155.95 Huslia	MAT, DBN, PUL, WES
April 13, 1958	1907	6.5	65.8 -155.6 Huslia	ABE, DBN, WES
May 10, 1958	2254	6.4	65.12 -152.1 Tanana	MAT, KEW, DBN, WES
May 11, 1958	0523	6.4	65 -152 Tanana	MAT, PUL, DBN
August 31, 1958	2300	6.2	63.2 -144.3 Central Denali	PAR, PUL
June 29, 1962	1628	6	62.4 -152.2 Pass Creek	PAS, WES
July 16, 1962	1254	6	62.3 -152.6 Pass Creek	MAT, PAR, WES
August 18, 1962	1643 1746	6.2 6.4	62.3 -152.5 62.2 -152.5 Pass Creek	DBN, NUR, WES, HKC, MAT, PAR
June 21, 1967	1804 1813 1824	6.1 6.1 5.9	64.9 -147.6 64.7 -147.7 64.8 -147.4 Fairbanks	MAT, DUR, ESK, HKC, DBN, WES
June 23, 1967	1154	5.6	64.8 -147.5 Fairbanks	DBN
October 29, 1968	2216	6.8	65.5 -150.1 Rampart	MAT, HKC, PUL, DBN
July 30, 1972	2145	7.6	56.8 -135.7 Sitka	KEV, MAT
March 9, 1985	1408	6.1	66.2 -149.98 Dall City	EPT
March 10, 1985	1330	5.6	66.1 -150.2 Dall City	EPT

Related Studies:

A paper that examines the seismicity of south-central Alaska (extending from eastern Prince William Sound to the Alaska Range volcanoes and from the Kennedy Entrance to 62.2°N) and its relationship to gravity, magnetic and tomographic studies of the region will be published in an upcoming volume of the Bulletin of the Seismological Society of America (Doser and Veilleux, 2009). A paper on the relation of seismicity to plate structure in the Prince William Sound region was published in 2008 (Doser et al., 2008). Work continues on relocation and source parameter studies of southeastern Alaska earthquakes with results presented at the fall 2008 meeting of the American Geophysical Union (Rodriguez and Doser, 2008; Escudero and Doser, 2008) as well as source parameter studies of south-central Alaska events (Romero and Doser, 2008). Dr. Doser will visit Alaska in May 2009 to discuss research results for Interior Alaska earthquakes with colleagues at the U.S. Geological Survey in Anchorage and the University of Alaska-Fairbanks. Dr. Doser also recently received a grant from the American Chemical Society's Petroleum Research Fund to test plausible models of the structure of the Border Ranges fault system using potential field data.

Reports Published:

Doser, D.I., Estimating magnitude and location from intensity for three regions of Alaska, Seismol. Res. Lett. 79, 322, 2008.

Doser, D.I., Estimating magnitude and location of Alaskan earthquakes using intensity data, submitted to Bull. Seismol. Soc Amer., February 2009.

Availability of Data Sets:

Copies of phase data for earthquakes occurring between 1922 and 1974 and scanned historic seismograms may be obtained from Dr. Diane Doser, (915)-747-5851 or doser@ utep.edu.

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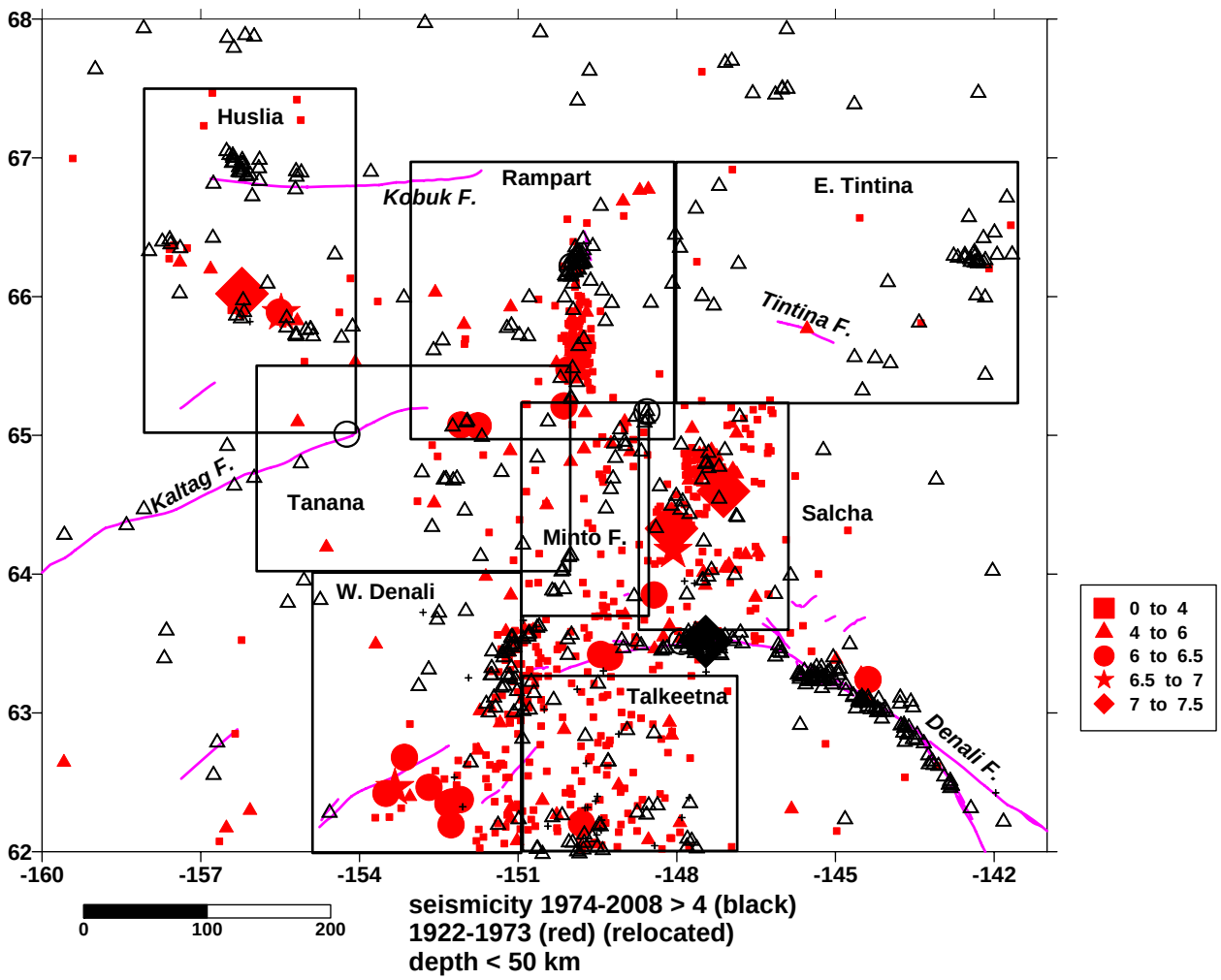

Figure 1 – Location of study areas (boxes) in interior Alaska. Red symbols are relocated earthquakes occurring between 1922 and 1973. Black symbols are M>4 earthquakes from the AEIC catalog. Symbol shape reflects magnitude as indicated. Magenta lines are faults showing evidence of Holocene movement from Plafker et al. (1994).

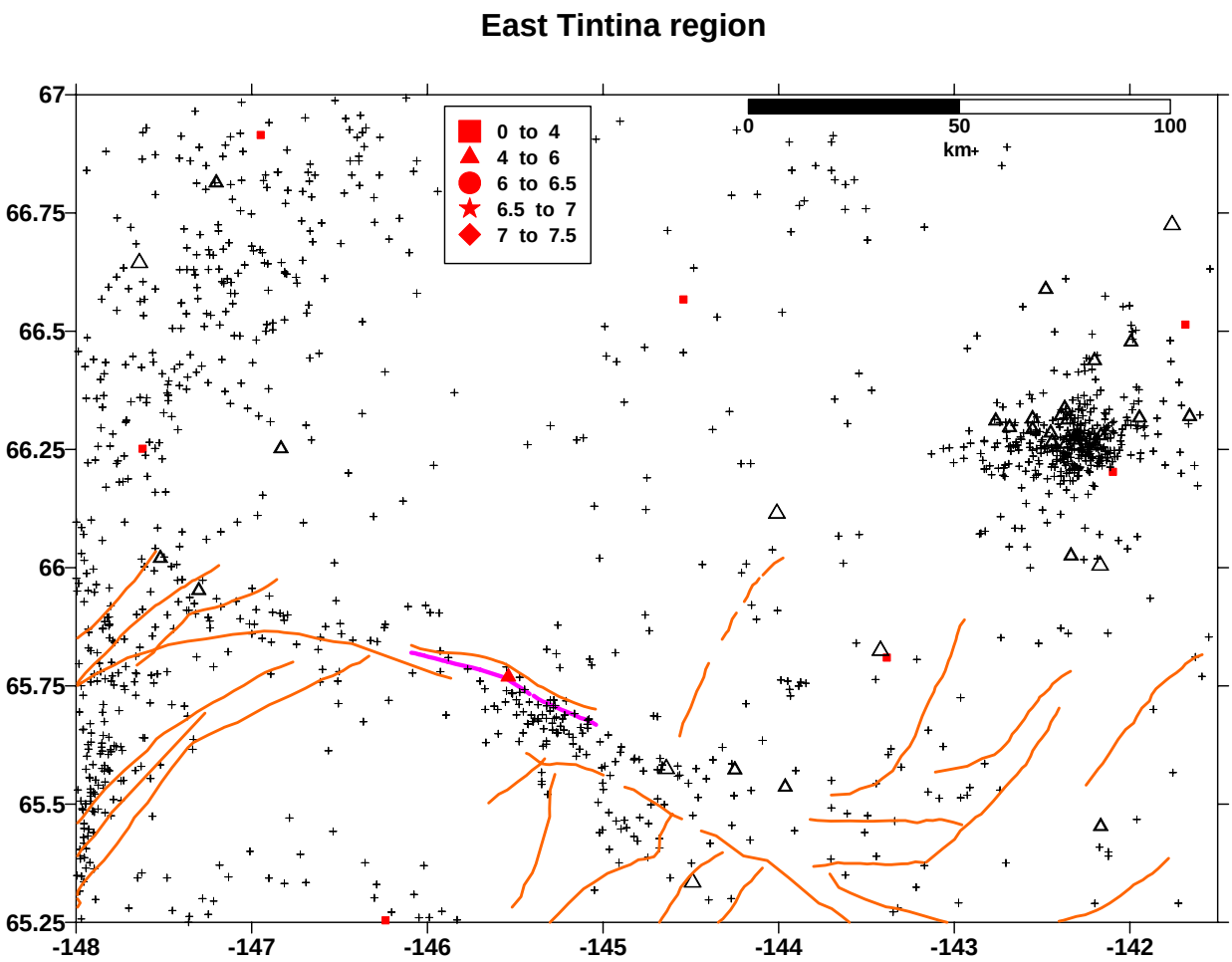

Figure 2- Seismicity of the East Tintina region (see Figure 1 for study area location). Magenta faults show Quaternary movement and orange faults show pre-Neogene movement (from Plafker et al., 1994). Red filled symbols are earthquakes occurring between 1922 and 1973. Black open symbols are earthquakes with M>0 occurring since 1973 from the AEIC catalog. Symbol shape reflects magnitude as indicated at top. Plusses are AEIC earthquakes with magnitudes of 0 to 4.

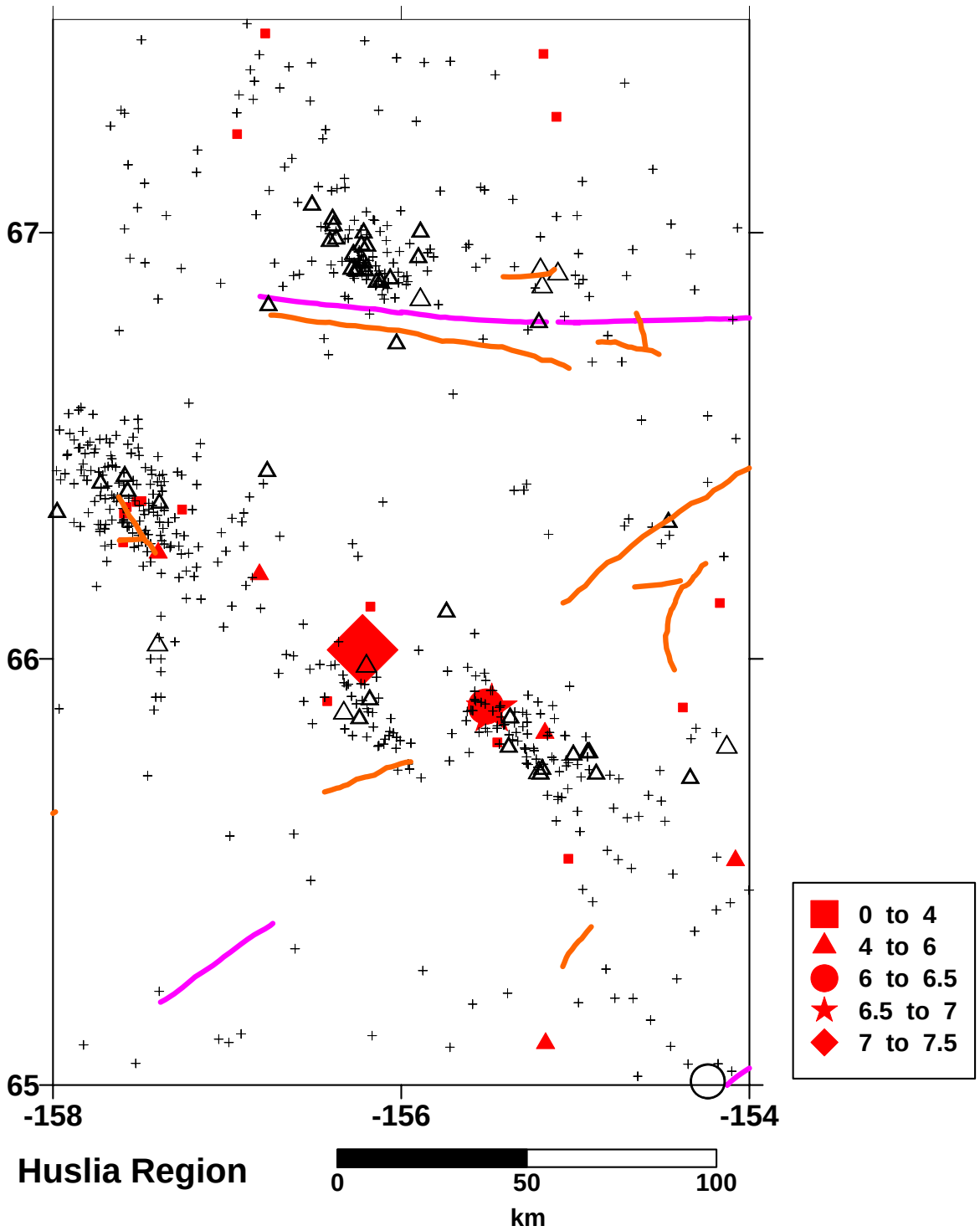

Figure 3-Seismicity of the Huslia region (see Figure 1 for location). Symbols and faults are the same as Figure 2.

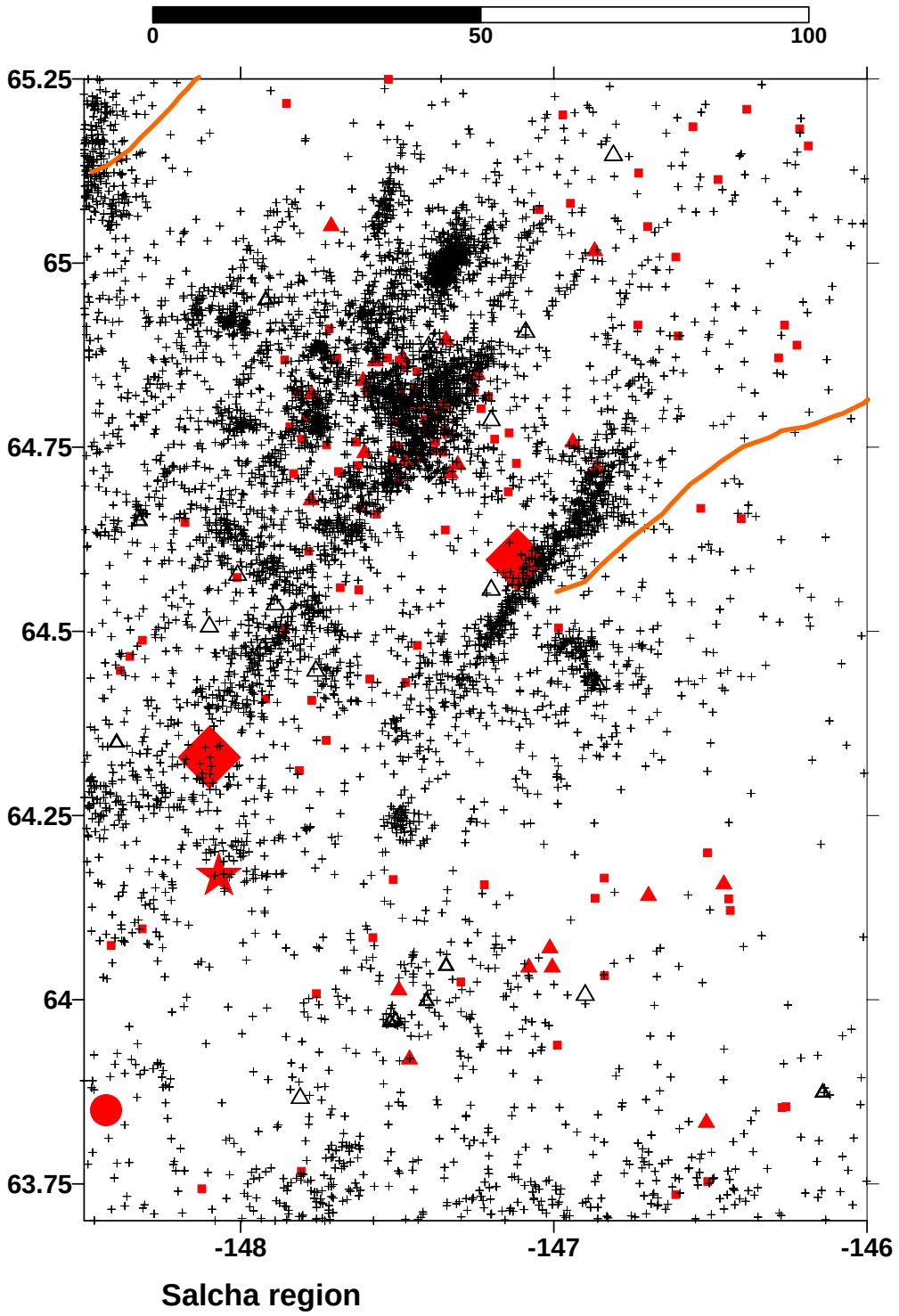

Figure 4-Seismicity of the Salcha region (see Figure 1 for location). Symbols and faults are the same as Figure 2.

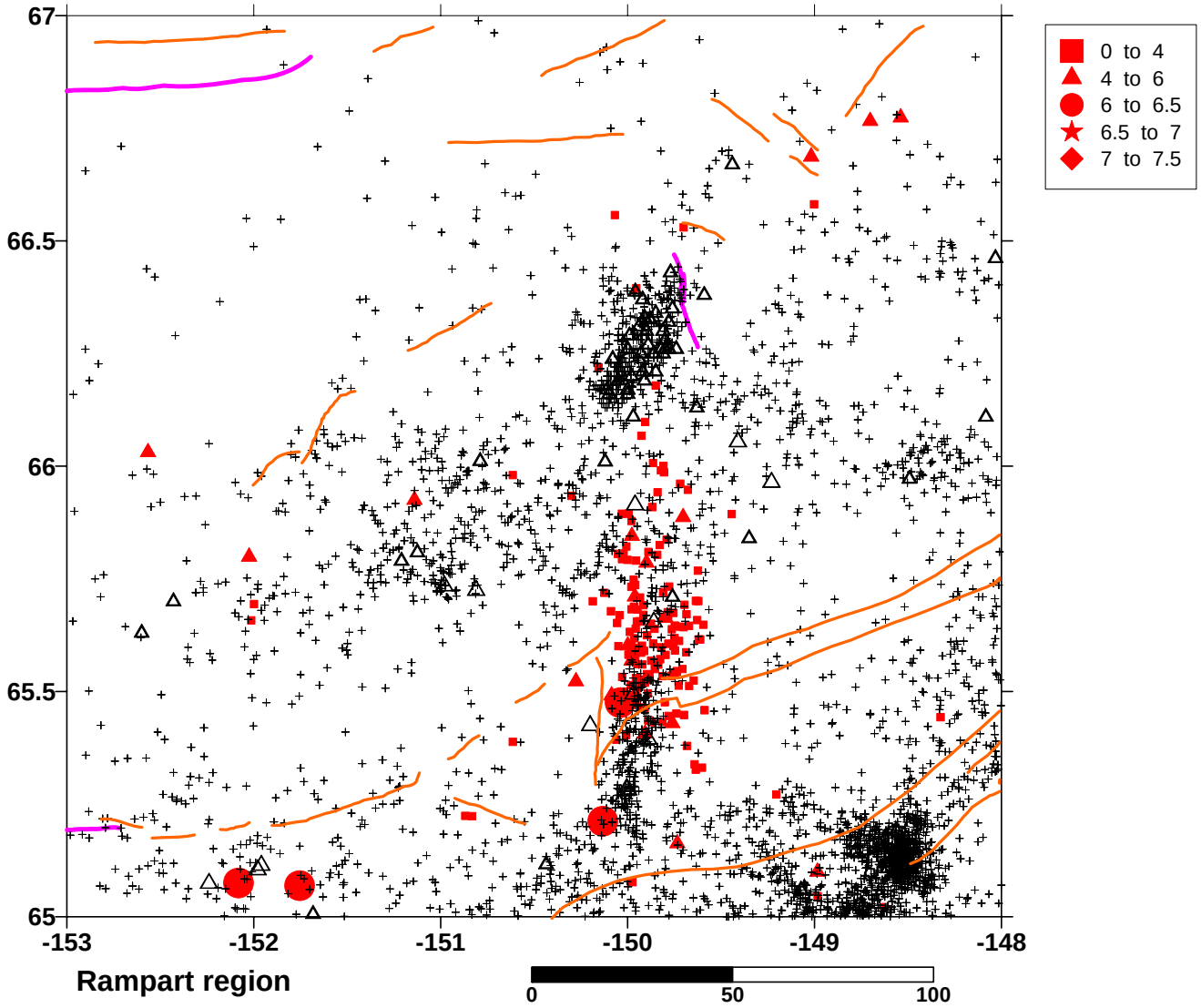

Figure 5-Seismicity of the Rampart region (see Figure 1 for location). Symbols and faults are the same as Figure 2.

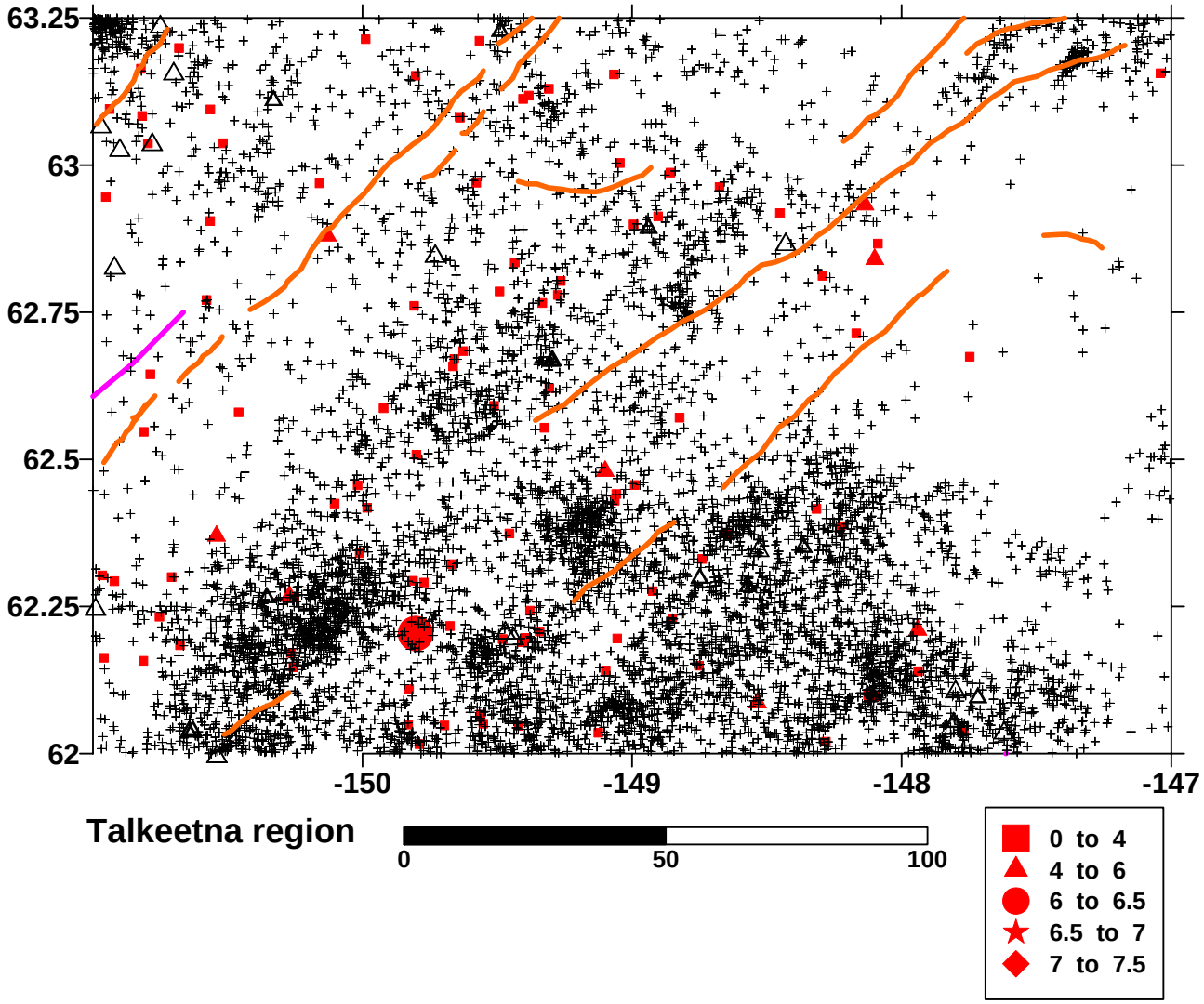

Figure 6-Seismicity of the Talkeetna region (see Figure 1 for location). Symbols and faults are the same as Figure 2.

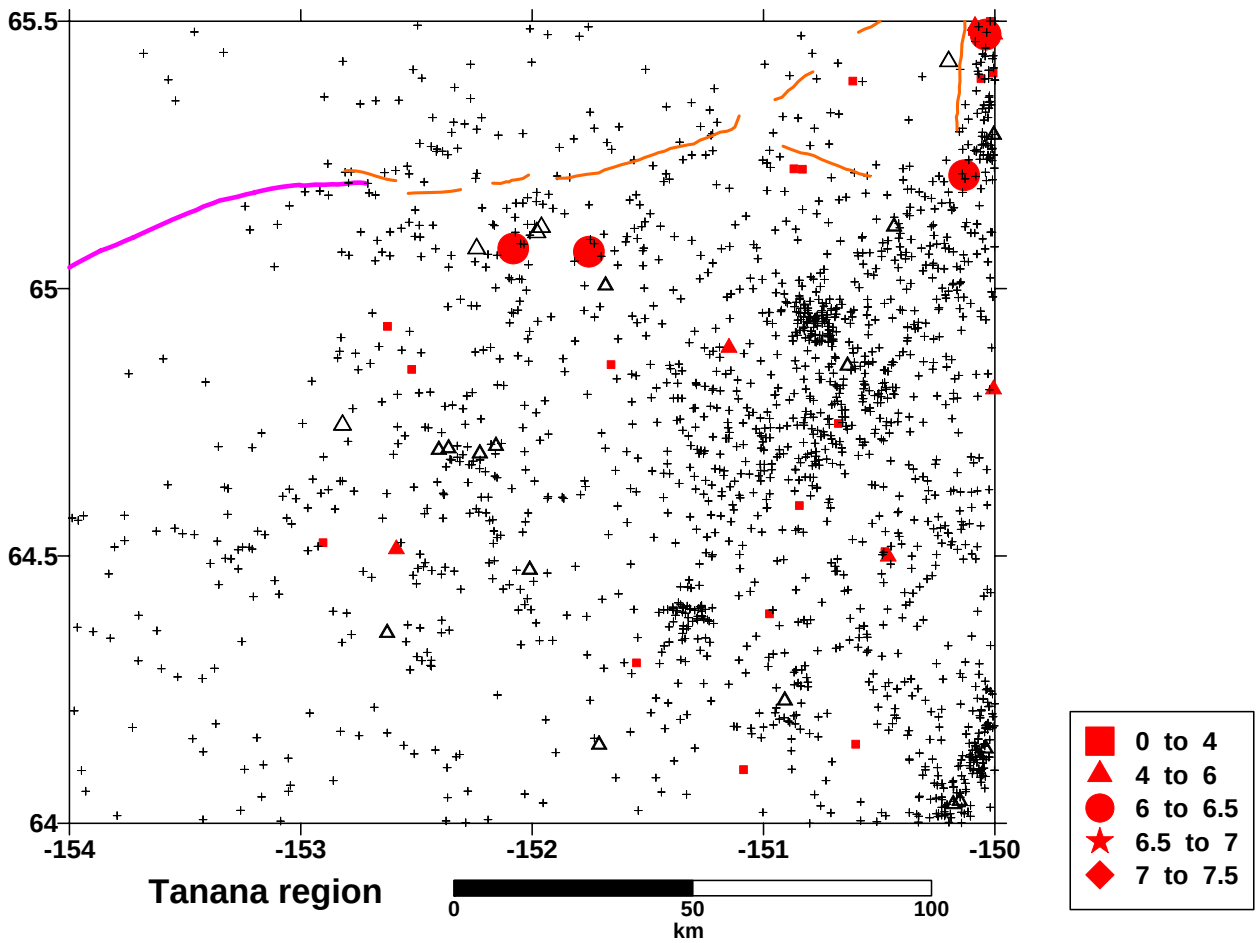

Figure 7-Seismicity of the Tanana region (see Figure 1 for location). Symbols and faults are the same as Figure 2.

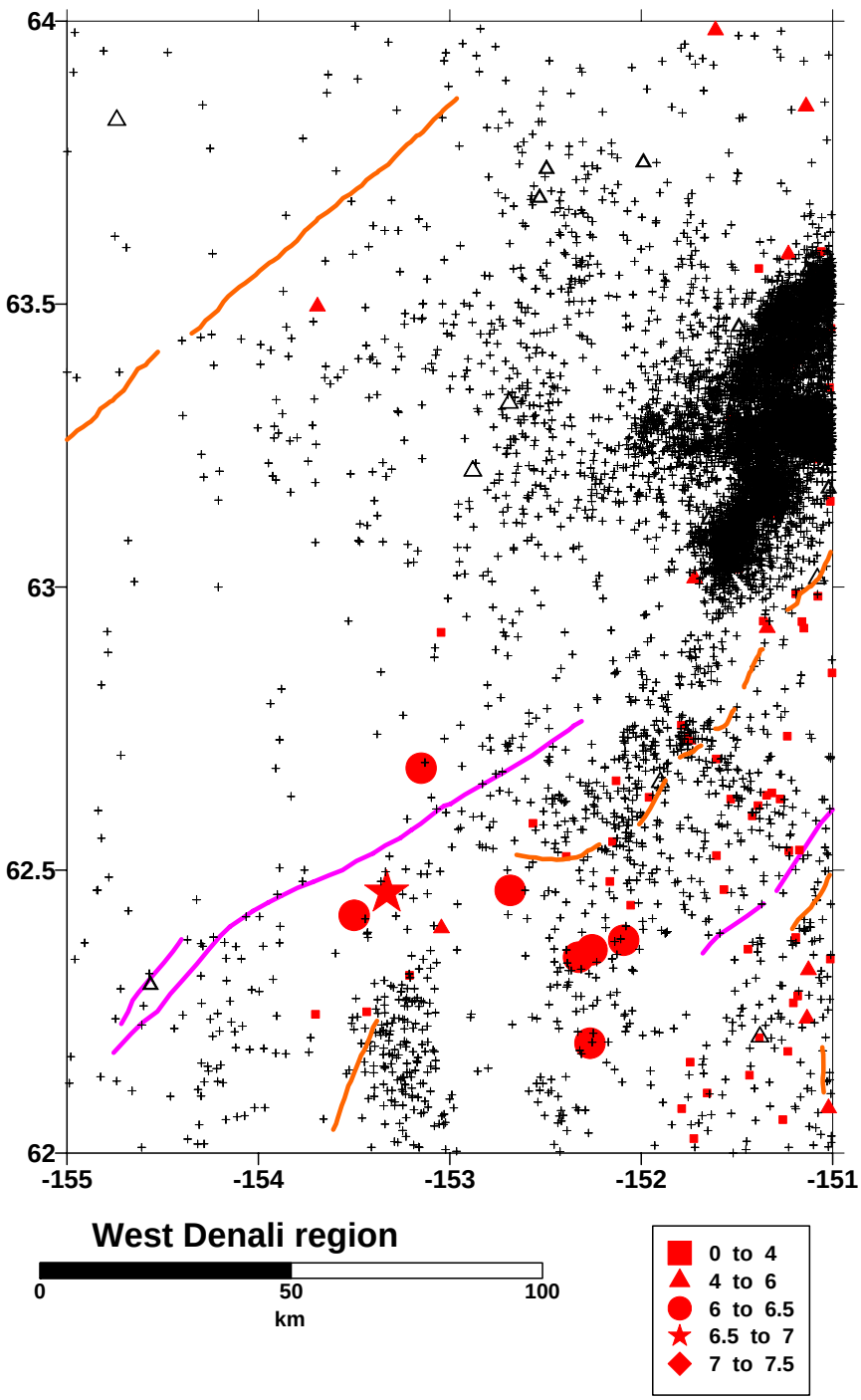

Figure 8 - Seismicity of the West Denali region (see Figure 1 for location). Symbols and faults are the same as Figure 2.

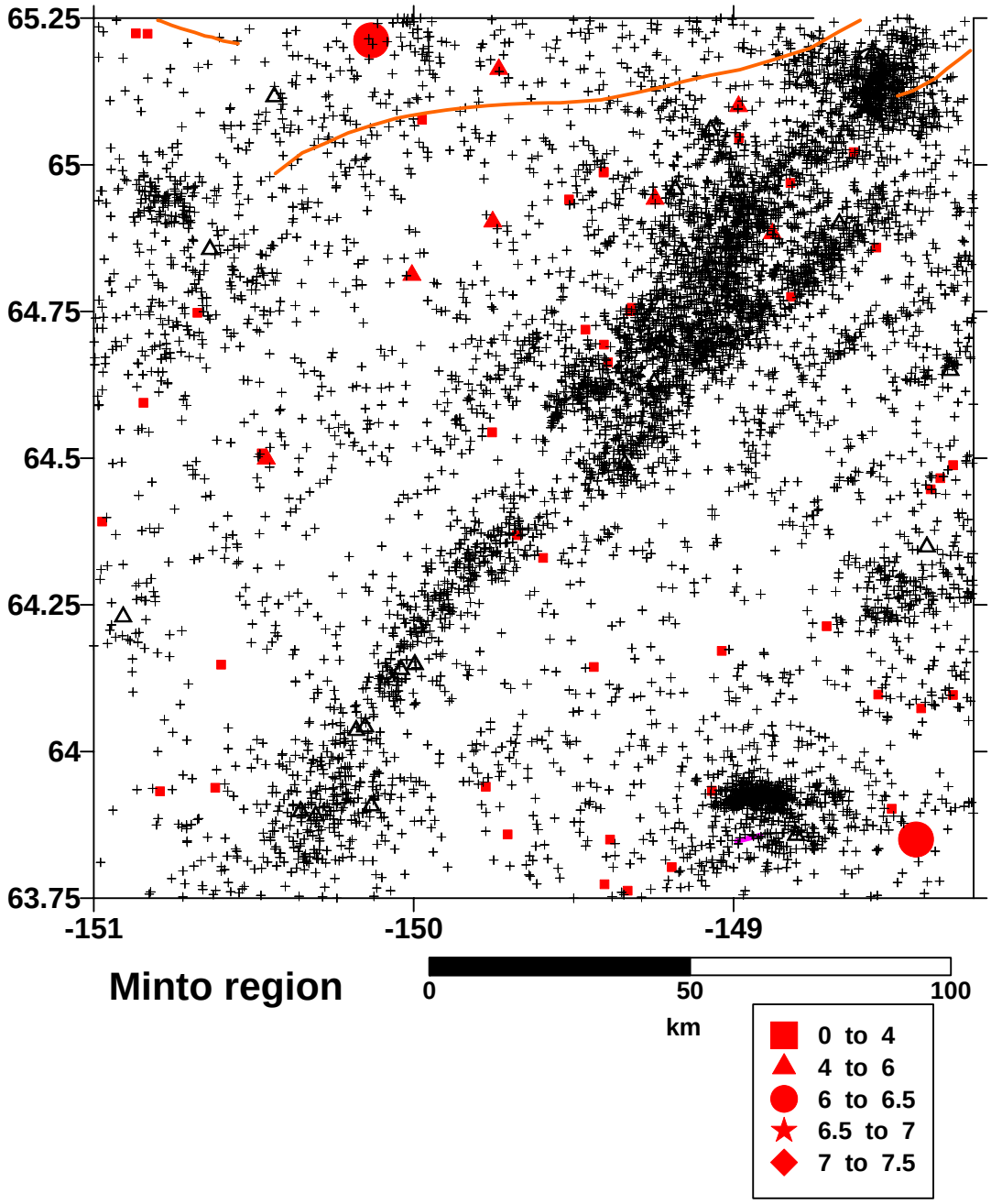

Figure 9 - Seismicity of the Minto region (see Figure 1 for location). Symbols and faults are the same as Figure 2.

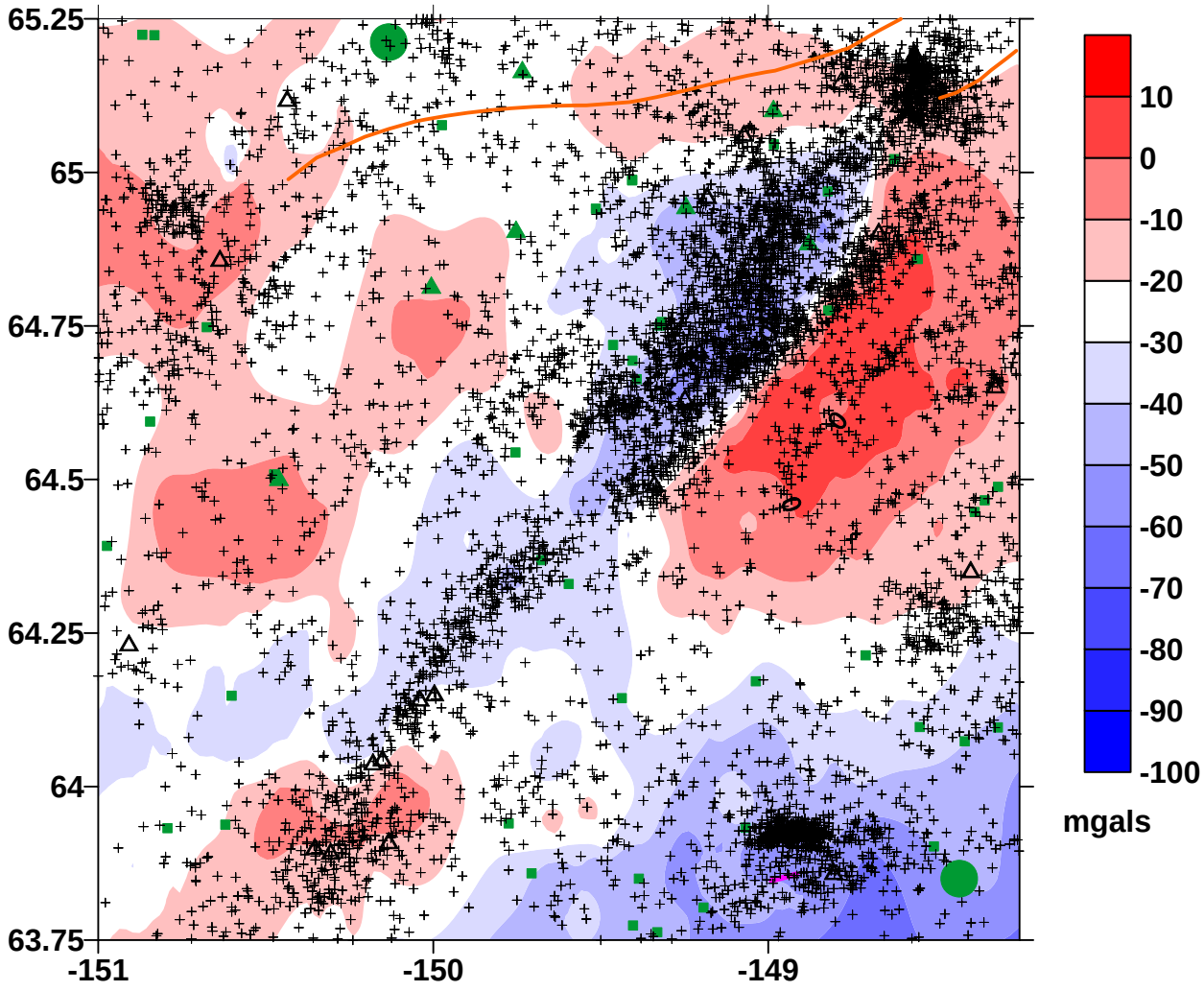

Figure 10 – Bouguer gravity (Saltus et al., 2009) for the Minto region (see Figure 1 for location). Green symbols are earthquakes occurring between 1922 and 1973. Note the correlation between the gravity low and the intense seismicity of the northern Minto Flats Seismic Zone (MFSZ). The gravity high to the east of the MFSZ is associated with denser rocks of the Livengood complex.

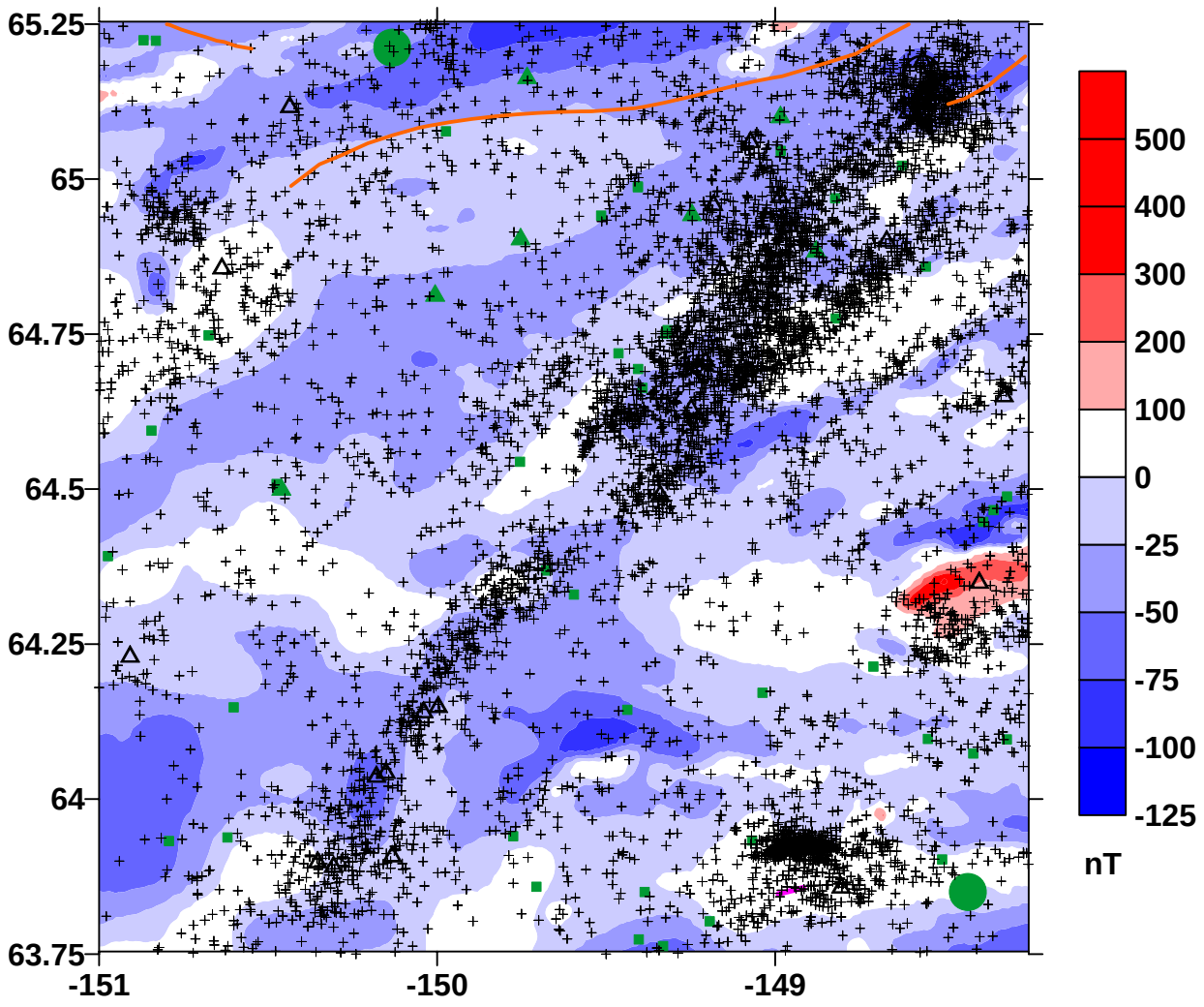

Figure 11 – Magnetic intensity map (data from Saltus et al., 1999) for the Minto region (see Figure 1 for location). Green symbols are earthquakes occurring between 1922 and 1973.

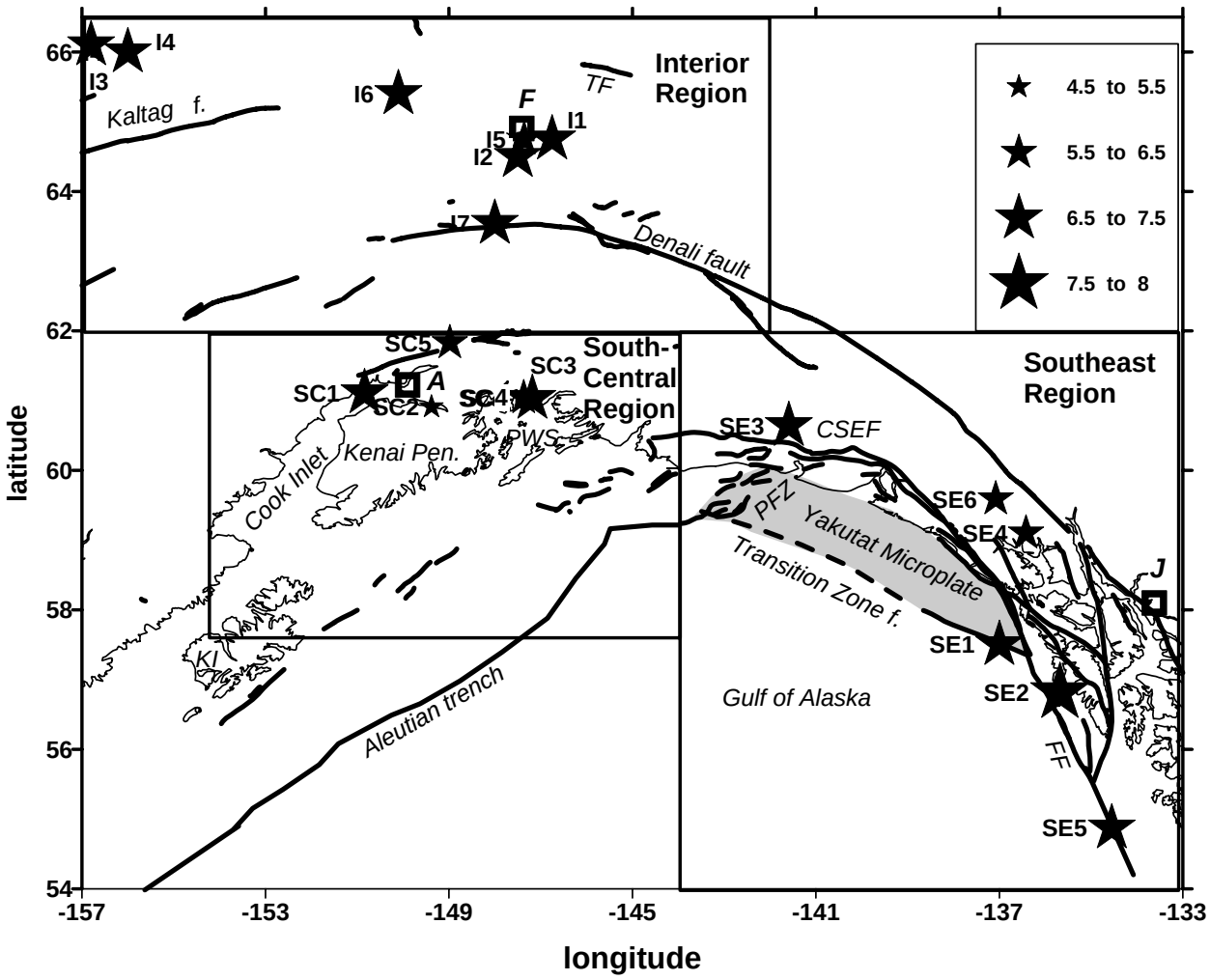

Figure 12 – Calibration events (stars) used to develop intensity-magnitude attenuation relationships. Events for Interior Alaska are labeled I1 to I7 (see Table 1). Square labeled F is Fairbanks. TF is Tintina fault.

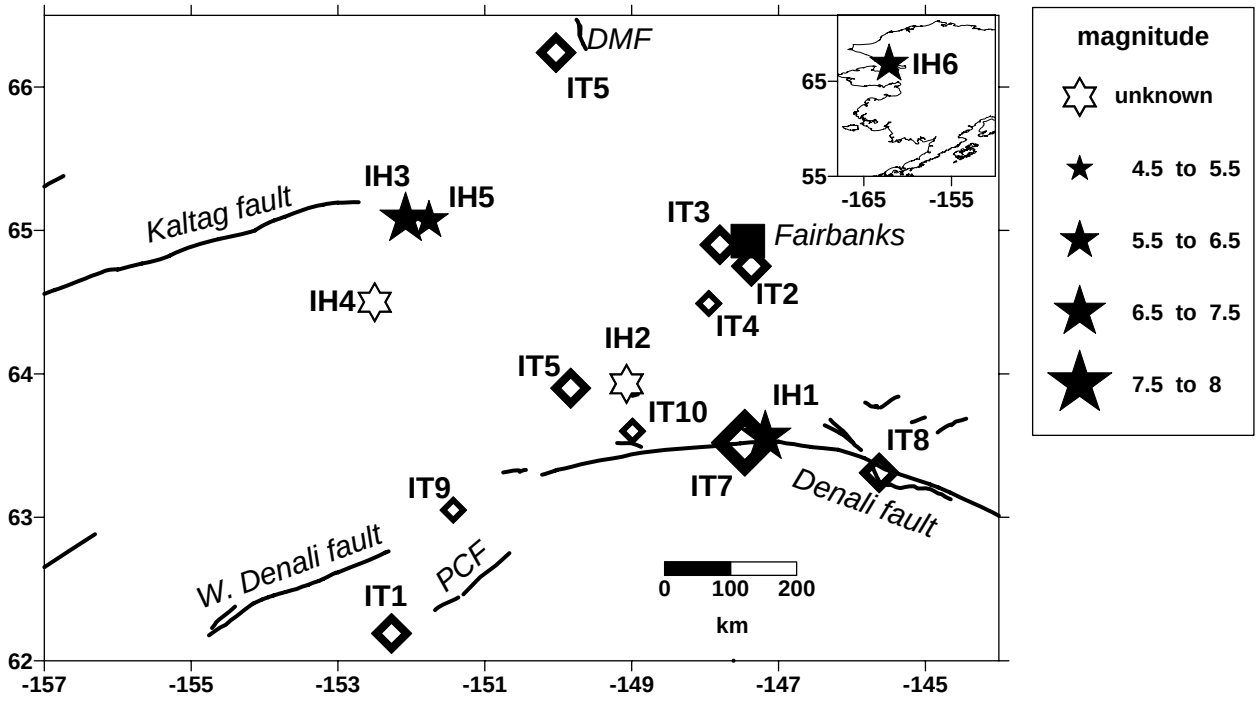

Figure 13 – Test events (diamonds denoted by "IT") and historic events (stars denoted by "IH") for the Interior Alaska region. Information on test events may be found in Table 2. Event IH1 is the Delta River earthquake. DMF is Dall Mountain fault, PCF is Pass Creek fault. Event IH6 is an event that lies outside the Interior Alaska study area; however its location and magnitude were well predicted using the Interior Alaska magnitude-intensity attenuation relationship.