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Geophysics and Atmospheric Sciences

Summary Report:

Permafrost Active Layer Seismic Interferometry Experiment (PALSIE) Refraction Microtremor (ReMi) Active Source Survey

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Project Description

The Permafrost Active Layer Seismic Interferometry Experiment (PALSIE) is an ongoing research endeavor focused on advancing our knowledge of the effects of climate change on the seasonal variability of permafrost layers in the Artic. In July 2014, an active source seismic experiment, along with direct measurement techniques, were undertaken at the Poker Flat Research Range, near Fairbanks, Alaska. The aim was to provide ground truth for the active layer thickness with two techniques. The direct measurement relied on using a large sharp aluminum rod driven into the ground to measure the depth to the permafrost. Once the frozen layer was encountered, the depth, defined as the top of the moss to the frozen ground, was recorded. The depth to the permafrost was measured along six transects (Figure 1 and Appendix 1). The second technique utilized active-source Refraction-Microtremor (ReMi) surveys for shear-wave velocity profile determination. Three separate ReMi surveys, using GS-11D geophones and two hammers (8.0 lbs. and 2.5 lbs.), were conducted (see Figure 2). All geophone latitudes and longitudes are available in Appendix 2.

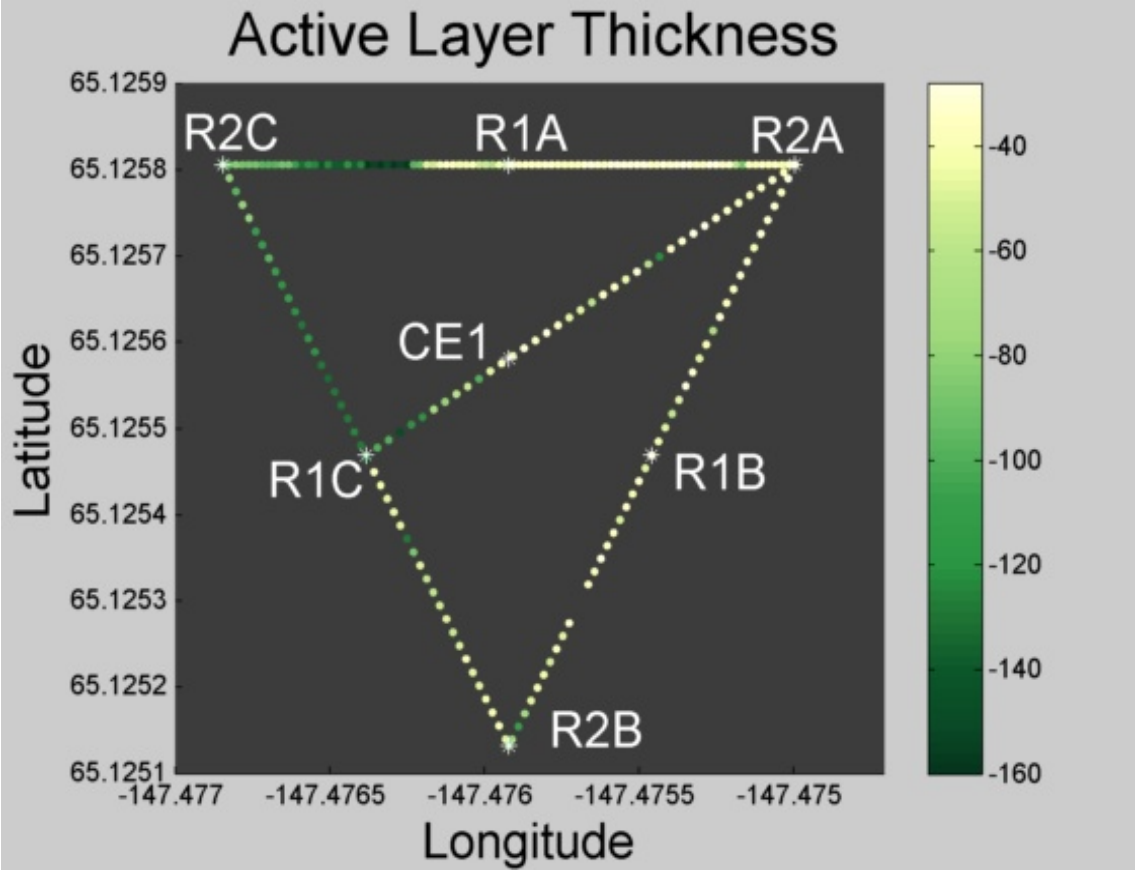

Figure 1: Active layer thickness. Only five of the six transects are shown. The sixth transect was east of this location near the PIC-2 station. All data, including the results from the sixth transect, are tabulated in Appendix 1.

Figure 2: Hammer strikes in the marshy summer conditions.

Survey I:

The first survey was completed on July 9, 2014. The weather was reasonably warm and calm. Using 48 GS-11D geophones, the survey line was laid out with 1.5 meters spacing beginning at station R2A and terminating 4.5 meters from station R1C (Figure 3). For this survey, the geophones were placed in the ground by lightly hammering them in with a PVC pipe. The calibration tests showed that all geophones were operational, but observations of variable coupling with the ground were noted. It should also be noted that channel 33 consistently displayed low frequency noisy oscillations. Observations suggest that some of the geophones may have been deployed in a tilted fashion.

Table 1: Survey I Geometrics Parameters

Survey Mode	Refraction
Geophone Interval	1.5 m
Gain	All low gain
Roll	Disable
Sample Interval	1 ms
Record Length	1 s
Delay	0
Acquisition Filters	None
Correlation	Off
Stack	16 shots

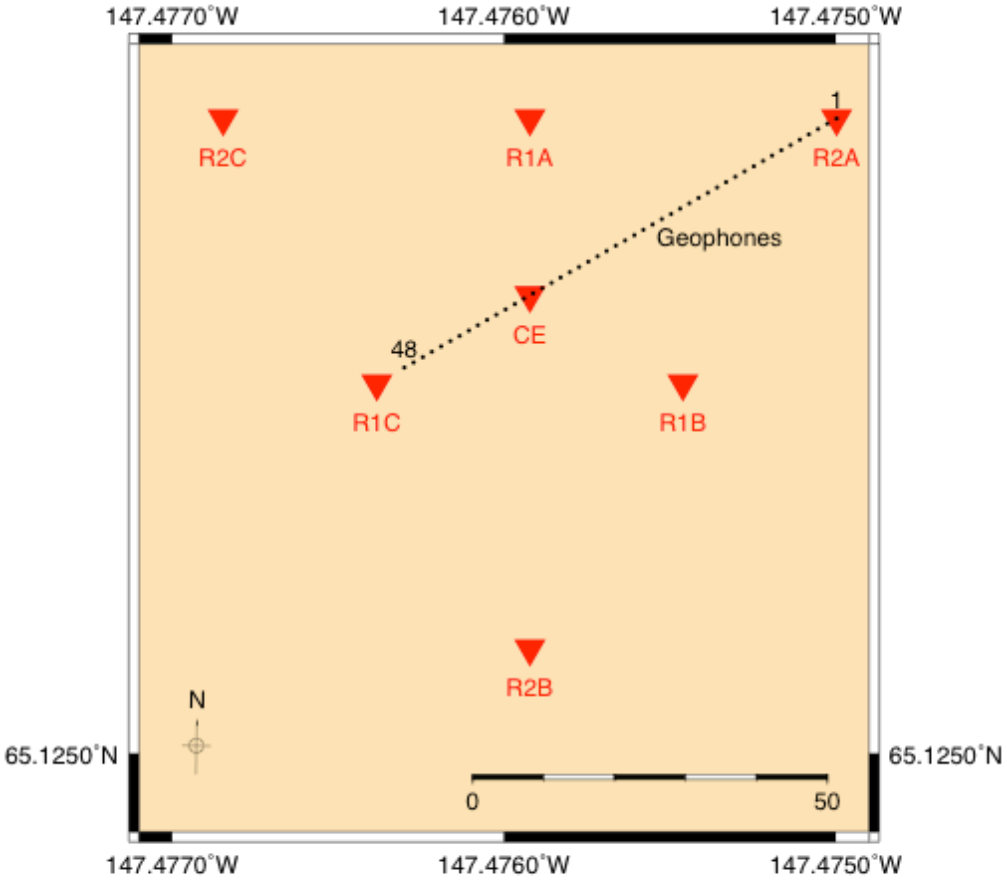

Figure 3: Map of survey I. Upside-down red triangles indicate locations of permanent seismic stations while black dots represent the locations of the 48 geophones. Data from the permanent stations is not submitted here.

For this survey, three files were collected each consisting of a stack of 16 shots from various source locations: 4.5 meters northeast of R2A and channel 1, 7.5 meters southwest of station R1C (12 m southwest of channel 48), and halfway between channels 24 and 25 (Table 2). The source for all 48 shots in this survey was the 8.0 lbs. hammer. Note that the GroupX coordinates in the SEGY headers are describing relative offset from the source in the direction of the receiver line, not a location relative to a N-S/E-W grid. See Appendix II for latitude and longitude of receiver locations.

Table 2: Description of Data Acquisition for Survey 1

File Name	Source Type	Latitude	Longitude	Source Location Description
110.segy	8.0 lbs. hammer	65.12582542	-147.4749148	4.5 meters off channel 1, towards the east-northeast, as an extension of the receiver line
111.segy	8.0 lbs. hammer	65.12543523	-147.4765216	12 meters off channel 48, towards the west-southwest, as an extension of the receiver line
112.segy	8.0 lbs. hammer	65.12564715	-147.475649	Half way between channels 24 and 25

Survey II:

The second survey was also conducted on July 9th, 2014 with the weather turning more towards a mix of rain and sun. The survey was along the same azimuth as survey I but much shorter, with only 33 cm spacing between geophones (Figure 4). To overcome the issue of weak ground coupling and tilted orientation, geophones were emplaced in 10 cm holes that were then back-filled with sand. The calibration tests for this survey showed a better signal-to-noise ratio then survey I. Most of the geometrics parameters remained constant except for the sampling rate and recording duration, which changed to 4,000 Hz and 0.5 s, respectively.

For this survey, both the 8.0 lbs. and 2.5 lbs. hammers were used for sources in three separate locations. The first four groups of shots originated 2.4 meters to the northeast of station R2A. Following this, the next four groups were shot from 2.3 meters southwest of geophone 48 and the final group had a source location 5.1 meters southwest of geophone 48. See Table 3 for source locations and Appendix II for receiver locations. Note that the GroupX coordinates in the SEGY headers are describing relative offset from the source in the direction of the receiver line, not a location relative to a N-S/E-W grid.

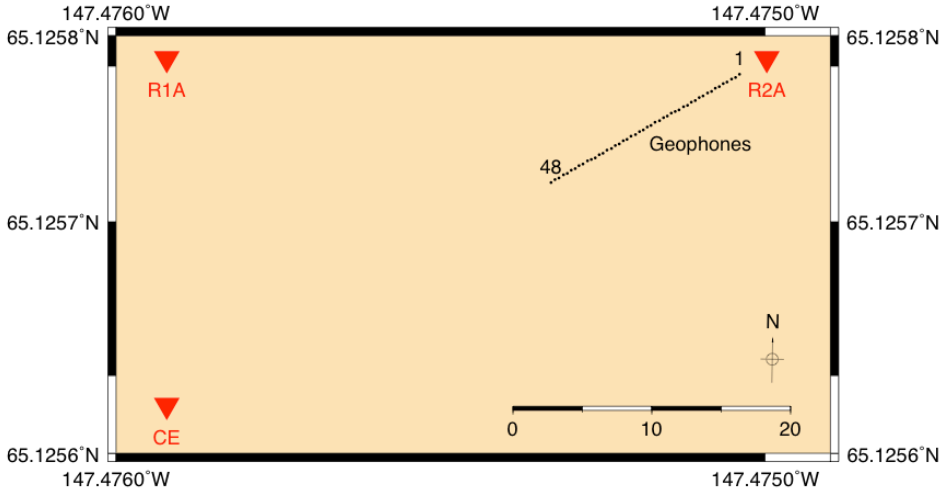

Figure 4: Map of the second survey. Symbols are the same as in figure 2.

Table 3: Description of Data Acquisition for Survey 2

File Name	Source Type	Latitude	Longitude	Source Location Description
201.segy	8.0 lbs. hammer	65.12581978	-147.4749543	8.7 meters off channel 1, towards the east-northeast, as an extension of the receiver line
202.segy	2.5 lbs. hammer	65.12581978	-147.4749543	
203.segy	2.5 lbs. hammer	65.12581978	-147.4749543	
204.segy	2.5 lbs. hammer	65.12581978	-147.4749543	
205.segy	8.0 lbs. hammer	65.12571106	-147.4753718	2.3 meters off channel 48, towards the west-southwest, as an extension of the receiver line
206.segy	2.5 lbs. hammer	65.12571106	-147.4753718	
207.segy	2.5 lbs. hammer	65.12571106	-147.4753718	
208.segy	2.5 lbs. hammer	65.12571106	-147.4753718	
209.segy	2.5 lbs. hammer	65.12571106	-147.4753718	
210.segy	8.0 lbs. hammer	65.12569409	-147.4754227	5.1 meters off channel 48, towards the west-southwest, as an extension of the receiver line

Survey III:

The final survey was performed on July 10th, 2014 with identical geometrics parameters to survey II including the 33 cm spacing. The weather this day was breezy with overcast skies. Just north of PIC-2, there is well-consolidated soil, which made the installation of the east to west line of geophones relatively easy. No pre-drilled holes were required and only a slight push with a hand or foot was needed to plant the geophones. Calibration tests showed the best signal-to-noise ratio of any of the surveys.

Both the 8.0 lbs. and 2.5 lbs. hammers were used in four separate locations (See Table 4). The first shot location was 2.33 meters west of channel 48. The second was 8.0 meters west of channel 1, near the middle of the line. The third and fourth were 0.85 m and 4.5 m east of channel 1 respectively. See Table 4 for source locations and Appendix II for receiver locations. Note that the GroupX coordinates in the SEGY headers are describing relative offset from the source in the direction of the receiver line, not a location relative to a N-S/E-W grid.

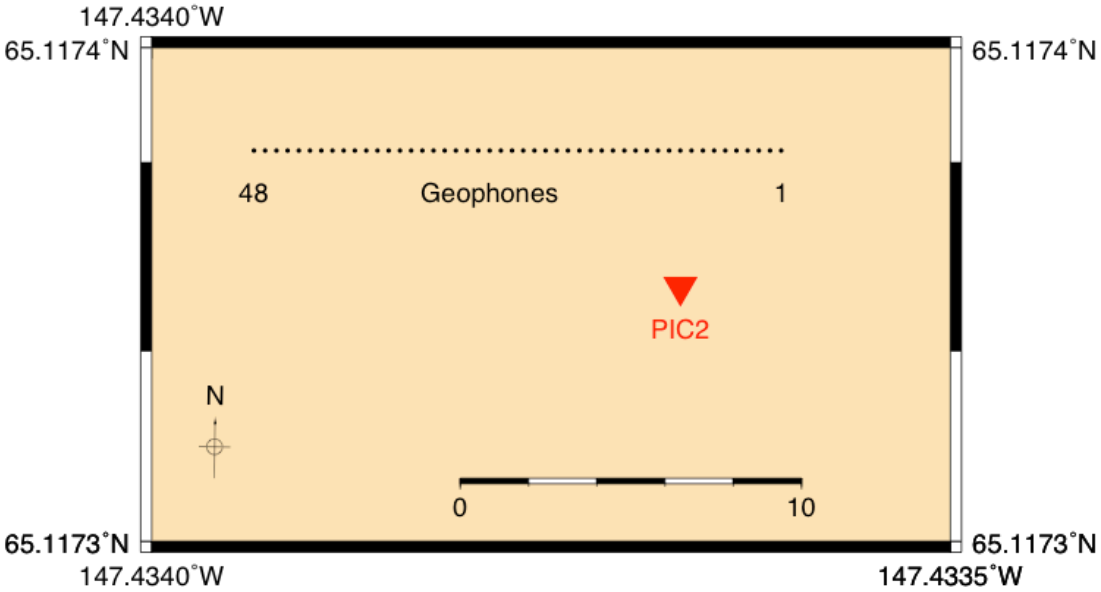

Figure 4: Map of the third survey. Symbols are the same as in Figure 2.

Table 4: Description of Data Acquisition for Survey 3

File Name	Source Type	Latitude	Longitude	Source Location Description
301.segy	8.0 lbs. hammer	65.11735288	-147.4339854	2.3 meters off channel 48, towards the west, as an extension of the receiver line
302.segy	2.5 lbs. hammer	65.11735288	-147.4339854	
303.segy	8.0 lbs. hammer	65.11735288	-147.4341057	8.0 meters off channel 48, towards the west, as an extension of the receiver line
304.segy	2.5 lbs. hammer	65.11735288	-147.4341057	
305.segy	2.5 lbs. hammer	65.11735288	-147.4335878	0.85 meters off channel 1, towards the east, as an extension of the receiver line
306.segy	2.5 lbs. hammer	65.11735288	-147.4335878	
307.segy	8.0 lbs. hammer	65.11735288	-147.4335103	4.5 meters off channel 1, towards the east, as an extension of the receiver line

References

Abbott, R.E. (2013), Seismic Spatial Autocorrelation as a Technique to Track Changes in the Permafrost Active Layer, Abstract C43A-0661 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 10-14 Dec.

Lee, R.F., R. E. Abbott, H. A. Knox, and A. Pancha (2014), Seasonal Changes in H/V Spectral Ratio at High Latitude Seismic Stations, Abstract S41A-4438 presented at 2014 Fall Meeting, AGU, San Francisco, Calif., 15-19 Dec.

Appendix 1: Active Layer Thickness

Table 5: Active Layer Thickness for R2A-R2C Transect

Transect: R2A-R2C		Date: 7/7/14
Meter Mark	**Thickness (cm)**	**Comments**
87	40	At R2A
86	42	
85	45	
84	38	
83	41	
82	38	
81	43	
80	40	
79	90	Lake
78	63	
77	36	
76	40	
75	31	
74	31	
73	39	
72	38	
71	31	
70	32	
69	34	
68	38	
67	32	
66	39	
65	38	
64	31	
63	34	
62	35	
61	32	
60	33	
59	32	
58	41	
57	36	
56	32	
55	36	
54	41	

53	40	
52	41	
51	40	
50	36	
49	35	
48	38	
47	38	
46	38	
45	39	
44	40	
43	61	
42	45	At R1A
41	66	
40	55	
39	55	
38	40	
37	45	
36	45	
35	40	
34	35	
33	42	
32	55	
31	50	
30	92	Lake
29	100	Lake
28	160	Lake
27	155	Lake
26	160	Lake
25	149	Lake
24	162	Lake
23	155	Lake
22	160	Lake
21	125	Lake
20	140	Lake
19	121	Lake
18	140	Lake
17	140	Lake
16	125	Lake
15	145	Lake
14	125	Lake
13	120	Lake

12	135	Lake
11	110	Lake
10	90	Trees
9	90	Trees
8	100	Trees
7	100	Trees
6	100	Trees
5	90	Trees
4	90	Trees
3	90	Trees
2	85	Trees
1	100	Trees
0	100	At R2C

Table 6: Active Layer Thickness for Transect R2A-R1B

Transect R2A-R1B		Date: 7/7/14
Meter Mark	**Thickness (cm)**	**Comments**
0	40	At R2A
2	30	
4	42	
6	36	
8	35	
10	34	
12	43	
14	35	
16	35	
18	40	
20	41	
22	35	
24	70	
26	43	
28	49	
30	36	
32	32	
34	50	
36	60	
38	50	
40	45	
42	40	

Table 7: Active Layer Thickness for Transect R1B-R2B

Transect R1B-R2B		Date: 7/7/14
Meter Mark	**Thickness (cm)**	**Comments**
0	45	At R1B
2	50	
4	38	
6	46	
8	38	
10	52	
12	40	
14	40	Lake
16	32	Lake
18	40	Lake
20	40	Lake
22	--------	Lake
24	--------	Lake
26	35	Lake
28	50	
30	40	
32	54	
34	45	
36	44	
38	50	
40	75	
42	110	
44	80	
45	88	At R2B

Table 8: Active Layer Thickness for Transect R2B-R2C

Transect R2B-R2C		Date: 7/7/14
Meter Mark	**Thickness (cm)**	**Comments**
86	50	
84	42	
82	44	
80	45	
78	50	
76	50	Tall Shrub
74	42	

72	52	
70	58	
68	50	
66	55	
64	60	
62	60	
60	50	
58	88	
56	130	
54	50	
52	48	
50	50	
48	45	
46	40	
44	140	At R1C
42	130	Wet
40	125	Wet
38	130	Wet
36	130	Wet
34	130	Wet
32	135	Wet
30	130	Wet
28	120	Wet
26	118	Wet
24	130	Dry
22	122	
20	110	
18	120	
16	110	
14	100	
12	110	
10	110	
8	80	
6	81	
4	100	
2	80	
0	92	At R2C

Table 9: Active Layer Thickness for Transect R2A-R1C

Transect R2A-R1C		Date: 7/8/14
Meter Mark	**Thickness (cm)**	**Comments**
76	42	
74	40	
72	36	
70	38	
68	40	
66	38	
64	36	
62	34	
60	28	
58	30	
56	33	
54	36	
52	122	
50	65	
48	32	
46	45	
44	35	
42	38	
40	61	
38	48	
36	48	
34	35	
32	31	
30	36	
28	32	At CE
26	45	At CE
24	40	
22	48	
20	100	
18	56	
16	60	
14	78	
12	70	Deep in H2O
10	120	Deep in H2O

8	120	Deep in H2O
6	14	Deep in H2O
4	100	Deep in H2O
2	100	Deep in H2O
0	120	At RIC

Table 10: Active Layer Thickness for Transect PIC-2

Transect PIC-2		7/8/14
Meter Mark	**Thickness (cm)**	**Comments**
0	39	
2	32	
4	43	
6	44	
8	40	
10	48	
12	47	
13	38	
15	48	
16	47	

Appendix 2: Geophone Locations

Table 11: Geophone Locations for Survey I

Station ID	Manufacturer	Model	Type of Sensor	Latitude	Longitude
1	Geospace	GS-11D	Geophone	65.12580523	-147.4749979
2	Geospace	GS-11D	Geophone	65.1257985	-147.4750256
3	Geospace	GS-11D	Geophone	65.12579178	-147.4750533
4	Geospace	GS-11D	Geophone	65.12578505	-147.475081
5	Geospace	GS-11D	Geophone	65.12577832	-147.4751087
6	Geospace	GS-11D	Geophone	65.1257716	-147.4751364
7	Geospace	GS-11D	Geophone	65.12576487	-147.4751641
8	Geospace	GS-11D	Geophone	65.12575814	-147.4751918
9	Geospace	GS-11D	Geophone	65.12575142	-147.4752195
10	Geospace	GS-11D	Geophone	65.12574469	-147.4752472
11	Geospace	GS-11D	Geophone	65.12573796	-147.4752749
12	Geospace	GS-11D	Geophone	65.12573124	-147.4753026
13	Geospace	GS-11D	Geophone	65.12572451	-147.4753304
14	Geospace	GS-11D	Geophone	65.12571778	-147.4753581
15	Geospace	GS-11D	Geophone	65.12571105	-147.4753858
16	Geospace	GS-11D	Geophone	65.12570433	-147.4754135
17	Geospace	GS-11D	Geophone	65.1256976	-147.4754412
18	Geospace	GS-11D	Geophone	65.12569087	-147.4754689
19	Geospace	GS-11D	Geophone	65.12568415	-147.4754966
20	Geospace	GS-11D	Geophone	65.12567742	-147.4755243
21	Geospace	GS-11D	Geophone	65.12567069	-147.475552
22	Geospace	GS-11D	Geophone	65.12566397	-147.4755797
23	Geospace	GS-11D	Geophone	65.12565724	-147.4756074
24	Geospace	GS-11D	Geophone	65.12565051	-147.4756351
25	Geospace	GS-11D	Geophone	65.12564379	-147.4756628
26	Geospace	GS-11D	Geophone	65.12563706	-147.4756905
27	Geospace	GS-11D	Geophone	65.12563033	-147.4757182
28	Geospace	GS-11D	Geophone	65.12562361	-147.4757459
29	Geospace	GS-11D	Geophone	65.12561688	-147.4757736
30	Geospace	GS-11D	Geophone	65.12561015	-147.4758013
31	Geospace	GS-11D	Geophone	65.12560343	-147.475829
32	Geospace	GS-11D	Geophone	65.1255967	-147.4758567
33	Geospace	GS-11D	Geophone	65.12558997	-147.4758844
34	Geospace	GS-11D	Geophone	65.12558325	-147.4759121
35	Geospace	GS-11D	Geophone	65.12557652	-147.4759398
36	Geospace	GS-11D	Geophone	65.12556979	-147.4759675

37	Geospace	GS-11D	Geophone	65.12556307	-147.4759952
38	Geospace	GS-11D	Geophone	65.12555634	-147.476023
39	Geospace	GS-11D	Geophone	65.12554961	-147.4760507
40	Geospace	GS-11D	Geophone	65.12554288	-147.4760784
41	Geospace	GS-11D	Geophone	65.12553616	-147.4761061
42	Geospace	GS-11D	Geophone	65.12552943	-147.4761338
43	Geospace	GS-11D	Geophone	65.1255227	-147.4761615
44	Geospace	GS-11D	Geophone	65.12551598	-147.4761892
45	Geospace	GS-11D	Geophone	65.12550925	-147.4762169
46	Geospace	GS-11D	Geophone	65.12550252	-147.4762446
47	Geospace	GS-11D	Geophone	65.1254958	-147.4762723
48	Geospace	GS-11D	Geophone	65.12548907	-147.4763

Table 12: Geophone Locations for Survey II

Station ID	Manufacturer	Model	Type of Sensor	Latitude	Longitude
1	Geospace	GS-11D	Geophone	65.125795	-147.47504
2	Geospace	GS-11D	Geophone	65.125793	-147.475046
3	Geospace	GS-11D	Geophone	65.125792	-147.475052
4	Geospace	GS-11D	Geophone	65.12579	-147.475059
5	Geospace	GS-11D	Geophone	65.125789	-147.475065
6	Geospace	GS-11D	Geophone	65.125787	-147.475071
7	Geospace	GS-11D	Geophone	65.125786	-147.475077
8	Geospace	GS-11D	Geophone	65.125784	-147.475083
9	Geospace	GS-11D	Geophone	65.125783	-147.475089
10	Geospace	GS-11D	Geophone	65.125781	-147.475096
11	Geospace	GS-11D	Geophone	65.12578	-147.475102
12	Geospace	GS-11D	Geophone	65.125778	-147.475108
13	Geospace	GS-11D	Geophone	65.125777	-147.475114
14	Geospace	GS-11D	Geophone	65.125775	-147.47512
15	Geospace	GS-11D	Geophone	65.125774	-147.475126
16	Geospace	GS-11D	Geophone	65.125772	-147.475133
17	Geospace	GS-11D	Geophone	65.125771	-147.475139
18	Geospace	GS-11D	Geophone	65.12577	-147.475145
19	Geospace	GS-11D	Geophone	65.125768	-147.475151
20	Geospace	GS-11D	Geophone	65.125767	-147.475157
21	Geospace	GS-11D	Geophone	65.125765	-147.475163
22	Geospace	GS-11D	Geophone	65.125764	-147.47517
23	Geospace	GS-11D	Geophone	65.125762	-147.475176
24	Geospace	GS-11D	Geophone	65.125761	-147.475182
25	Geospace	GS-11D	Geophone	65.125759	-147.475188
26	Geospace	GS-11D	Geophone	65.125758	-147.475194

27	Geospace	GS-11D	Geophone	65.125756	-147.4752
28	Geospace	GS-11D	Geophone	65.125755	-147.475207
29	Geospace	GS-11D	Geophone	65.125753	-147.475213
30	Geospace	GS-11D	Geophone	65.125752	-147.475219
31	Geospace	GS-11D	Geophone	65.12575	-147.475225
32	Geospace	GS-11D	Geophone	65.125749	-147.475231
33	Geospace	GS-11D	Geophone	65.125747	-147.475237
34	Geospace	GS-11D	Geophone	65.125746	-147.475244
35	Geospace	GS-11D	Geophone	65.125744	-147.47525
36	Geospace	GS-11D	Geophone	65.125743	-147.475256
37	Geospace	GS-11D	Geophone	65.125741	-147.475262
38	Geospace	GS-11D	Geophone	65.12574	-147.475268
39	Geospace	GS-11D	Geophone	65.125739	-147.475274
40	Geospace	GS-11D	Geophone	65.125737	-147.475281
41	Geospace	GS-11D	Geophone	65.125736	-147.475287
42	Geospace	GS-11D	Geophone	65.125734	-147.475293
43	Geospace	GS-11D	Geophone	65.125733	-147.475299
44	Geospace	GS-11D	Geophone	65.125731	-147.475305
45	Geospace	GS-11D	Geophone	65.12573	-147.475311
46	Geospace	GS-11D	Geophone	65.125728	-147.475318
47	Geospace	GS-11D	Geophone	65.125727	-147.475324
48	Geospace	GS-11D	Geophone	65.125725	-147.47533

Table 13: Geophone Locations for PIC-2 Survey

Station ID	Manufacturer	Model	Type of Sensor	Latitude	Longitude
1	Geospace	GS-11D	Geophone	65.11735288	-147.4336058
2	Geospace	GS-11D	Geophone	65.11735288	-147.4336128
3	Geospace	GS-11D	Geophone	65.11735288	-147.4336198
4	Geospace	GS-11D	Geophone	65.11735288	-147.4336268
5	Geospace	GS-11D	Geophone	65.11735288	-147.4336339
6	Geospace	GS-11D	Geophone	65.11735288	-147.4336409
7	Geospace	GS-11D	Geophone	65.11735288	-147.4336479
8	Geospace	GS-11D	Geophone	65.11735288	-147.4336549
9	Geospace	GS-11D	Geophone	65.11735288	-147.433662
10	Geospace	GS-11D	Geophone	65.11735288	-147.433669
11	Geospace	GS-11D	Geophone	65.11735288	-147.433676
12	Geospace	GS-11D	Geophone	65.11735288	-147.4336831
13	Geospace	GS-11D	Geophone	65.11735288	-147.4336901
14	Geospace	GS-11D	Geophone	65.11735288	-147.4336971
15	Geospace	GS-11D	Geophone	65.11735288	-147.4337041
16	Geospace	GS-11D	Geophone	65.11735288	-147.4337112

17	Geospace	GS-11D	Geophone	65.11735288	-147.4337182
18	Geospace	GS-11D	Geophone	65.11735288	-147.4337252
19	Geospace	GS-11D	Geophone	65.11735288	-147.4337322
20	Geospace	GS-11D	Geophone	65.11735288	-147.4337393
21	Geospace	GS-11D	Geophone	65.11735288	-147.4337463
22	Geospace	GS-11D	Geophone	65.11735288	-147.4337533
23	Geospace	GS-11D	Geophone	65.11735288	-147.4337603
24	Geospace	GS-11D	Geophone	65.11735288	-147.4337674
25	Geospace	GS-11D	Geophone	65.11735288	-147.4337744
26	Geospace	GS-11D	Geophone	65.11735288	-147.4337814
27	Geospace	GS-11D	Geophone	65.11735288	-147.4337884
28	Geospace	GS-11D	Geophone	65.11735288	-147.4337955
29	Geospace	GS-11D	Geophone	65.11735288	-147.4338025
30	Geospace	GS-11D	Geophone	65.11735288	-147.4338095
31	Geospace	GS-11D	Geophone	65.11735288	-147.4338165
32	Geospace	GS-11D	Geophone	65.11735288	-147.4338236
33	Geospace	GS-11D	Geophone	65.11735288	-147.4338306
34	Geospace	GS-11D	Geophone	65.11735288	-147.4338376
35	Geospace	GS-11D	Geophone	65.11735288	-147.4338446
36	Geospace	GS-11D	Geophone	65.11735288	-147.4338517
37	Geospace	GS-11D	Geophone	65.11735288	-147.4338587
38	Geospace	GS-11D	Geophone	65.11735288	-147.4338657
39	Geospace	GS-11D	Geophone	65.11735288	-147.4338728
40	Geospace	GS-11D	Geophone	65.11735288	-147.4338798
41	Geospace	GS-11D	Geophone	65.11735288	-147.4338868
42	Geospace	GS-11D	Geophone	65.11735288	-147.4338938
43	Geospace	GS-11D	Geophone	65.11735288	-147.4339009
44	Geospace	GS-11D	Geophone	65.11735288	-147.4339079
45	Geospace	GS-11D	Geophone	65.11735288	-147.4339149
46	Geospace	GS-11D	Geophone	65.11735288	-147.4339219
47	Geospace	GS-11D	Geophone	65.11735288	-147.433929
48	Geospace	GS-11D	Geophone	65.11735288	-147.433936