



SCEK 2014-2015 Final Report for Year 3 of the Induced Seismicity Monitoring Project (ISMP)

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March 26, 2015

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Background

A research consortium was created in 2012 between Geoscience BC, the Canadian Association of Petroleum Producers (CAPP), the BC Oil & Gas Commission (BCOGC) and Natural Resources Canada (NRCan) to help improve the accuracy of the Canadian National Seismograph Network (CNSN). The consortium's mandate is to collect, interpret and make public the data collected from the installation of six new seismograph stations and to complement the pre-existing CNSN network (Figure 1). The *Induced Seismicity Monitoring Project* (ISMP) has \$1 million in funding from 50/50 equity partners Geoscience BC and the SCEK Fund with in-kind support from CAPP, BCOGC and NRCan. The project has a mandate to monitor induced seismic activity for a total of five years (until June 2017) with an interim in June 2014 to assess the project's performance.

Summary of Activities

The enhanced network has been operational for over one and half years. The project's life can be subdivided into three stages, the initial stage (2012-2013) involving the procurement and installation of the enhanced monitoring network, the second stage began with the collection of data (2013-ongoing). We are now entering the last stage of the project which revolves around the interpretation of the data.

Operationally, there were two major events for the project this past year. First, two additional stations were brought into the CNSN network. One is located in Fort St. John (NBC7) and was funded by the BCOGC, the other at Buick Creek (NAB1), was funded by NRCan. The addition of these two new stations now brings a total of ten stations in NEBC (Figure 1) which can be used to monitor potential induced seismicity from shale gas operations.

The second event, was the hiring of a dedicated seismologist for the project. Dr. Alireza Mahani began working on the project in early February 2015 at NRCan's Pacific Geoscience Centre. He will be conducting his research, in consort, with other resident seismologists. Dr. Mahani holds a PhD from Western University and most recently finished his post-doctoral fellowship as part of Dr. Dave Eaton's Microseismic Industry Consortium at the University of Calgary. His main tasks will be to: 1) conduct real-time analysis of seismic events captured by the network; 2) evaluate the resolution of the network; 3) interpret the collected data; and 4) case studies of specific event clusters.

The collection of seismological data from the network is now providing various stakeholders with data on oil & gas-related induced seismicity which is being used to aid in decision making. For example, the BCOGC is using the data collected to help regulate oil & gas operations in NEBC and to ensure continued safe natural gas development. To date, in response to higher magnitude events (3-4 M_L) detected by the enhanced network within the Montney gas-trend fairway, the BCOGC has requested the placement of three dense seismograph arrays to monitor hydraulic fracturing operations. Data collected from dense seismograph arrays helps to pin-point location and depth of the induced seismic events. The BCOGC recently published findings on the seismological data collected over the Montney play (*Investigation of Observed Seismicity in the Montney Trend, 2014*).

Data collected by the network is also being used by NRCan to guide research within their Induced Seismicity Research Activity (part of the Shale Gas Research Project in the Environments Geoscience Program of NRCan). This year alone, the additional data being collected has spurred three articles based on induced seismicity in NEBC. Two of the articles focused on using innovative techniques to discern base level seismicity, while the third talked about the ongoing induced seismicity research in NEBC. The research currently being done has now become even more important given the recent (4.4 ML) hydraulic fracturing-induced events at Fox Creek AB and the public's need to understand the potential ramifications of additional natural gas development.

Data provided by the regional network has noted seven "hot spots" of induced seismic activity namely Caribou, Beg, Town, Graham Altares, Doe-Dawson and Septimus. Through the monitoring of seismicity operators have been working collaboratively with the BCOGC to design completion programs which will mitigate future seismic events.

Lastly, the dissemination of this data to the general public is providing the un-biased data needed for First Nations and communities in the region, to understand the risks due to induced seismicity from natural gas development.

Results and Discussion

The collection of data over the past year and a half will now allow a dedicated project seismologist to add further value to the project. The ability to conduct real-time analysis on all the incoming data will be beneficial, especially for the BCOGC who is dependent on this data to monitor anomalous seismicity. His first research task will be to assess the resolution of the network and make recommendations for improvements. It has been postulated (Dr. Honn Kao, pers. comm.) that the estimated current detection limits of the enhanced network could be as low as 1.5 M_L , but with the collection of almost two years' worth of data, it is becoming apparent that the data is likely artificially skewed towards the higher magnitudes. The improvement in the lower threshold detectability is possibly not reflected due to:

1. the initial CNSN detection is automatically generated and utilizes a conventional short-time-window vs. long-time-window amplitude ratios methodology. This methodology works well for relatively larger events that may have seismic hazard implications, which is the primary mandate of the CNSN. However, for smaller events whose amplitudes approach background noise level, its performance is much poorer – hence detection of smaller events is compromised; and/or,
2. all events listed in NRCan's earthquake catalog must be reviewed by a seismologist whose prime focus is the analysis of events which have seismic hazard implications; as such, verification of smaller events (especially those not picked up by the automatic detection system) is severely backlogged and ultimately may never get reviewed. The net result is that smaller events (those smaller than 2.5 M_L) are most likely under represented.

The addition of a dedicated seismologist to the project should allow the answering of the aforementioned questions and lead to recommendations which will optimize the network.

His other research focus will be to understand why some areas (e.g. Caribou, Beg-Town, Graham, Altares, Septimus and Doe-Dawson) have anomalously higher frequency of induced seismic events. Selective case studies from some of those areas might shed further light as to why they are more prone to creating induced seismicity. Recommendations from this research would be extremely beneficial to all companies conducting hydraulic fracturing, along with the regulator, First Nations and communities.

As the enhanced array approaches its third anniversary, maintenance will eventually become necessary. It is expected that the seismologist will be able to make recommendations on how optimally maintain the network.

Statistical analysis of the captured data shows the majority of the events are within 1.5-2.5 M_L range (Figure 2) with a mean of 2.08 M_L and a standard deviation of 0.53 M_L – meaning that 68.2% of the events lie between 2.61 M_L and 1.55 M_L magnitude (Figure 2). The mean magnitude detected from events this year (2.08 M_L) is slightly lower than last year (2.25 M_L), although there may be no causal reason for this decline it could be to:

1. improvements to the network allowing detection of lower magnitude events;
2. improved completion techniques that are mitigating induced seismic responses.

Seismic events within the range 1.55-2.61 M_L (one standard deviation from the mean) are generally not felt on surface where as those higher 3 M_L are more likely to be felt on surface. To date 13 events were felt on surface, all of which were well below the Mercalli damage threshold (BCOGC, 2014). The two largest events occurred in Fort St. John (13-05-27) – 4.2 M_L and south of Trutch - 4.4 M_L (15-08-04), both of which were felt on surface.

The BCOGC is currently using the network to aid them with regulatory decisions with respect to potential induced seismicity. Generally speaking, induced seismicity is usually characterized by clustered events of low magnitude, while naturally occurring events tend to be larger and not clustered (other than those aftershocks from a large event). At present, the BCOGC has noted seven areas with a high incidence of low-level seismicity (Caribou, Beg, Town, Graham Altares, Doe-Dawson and Septimus; Figure 3).

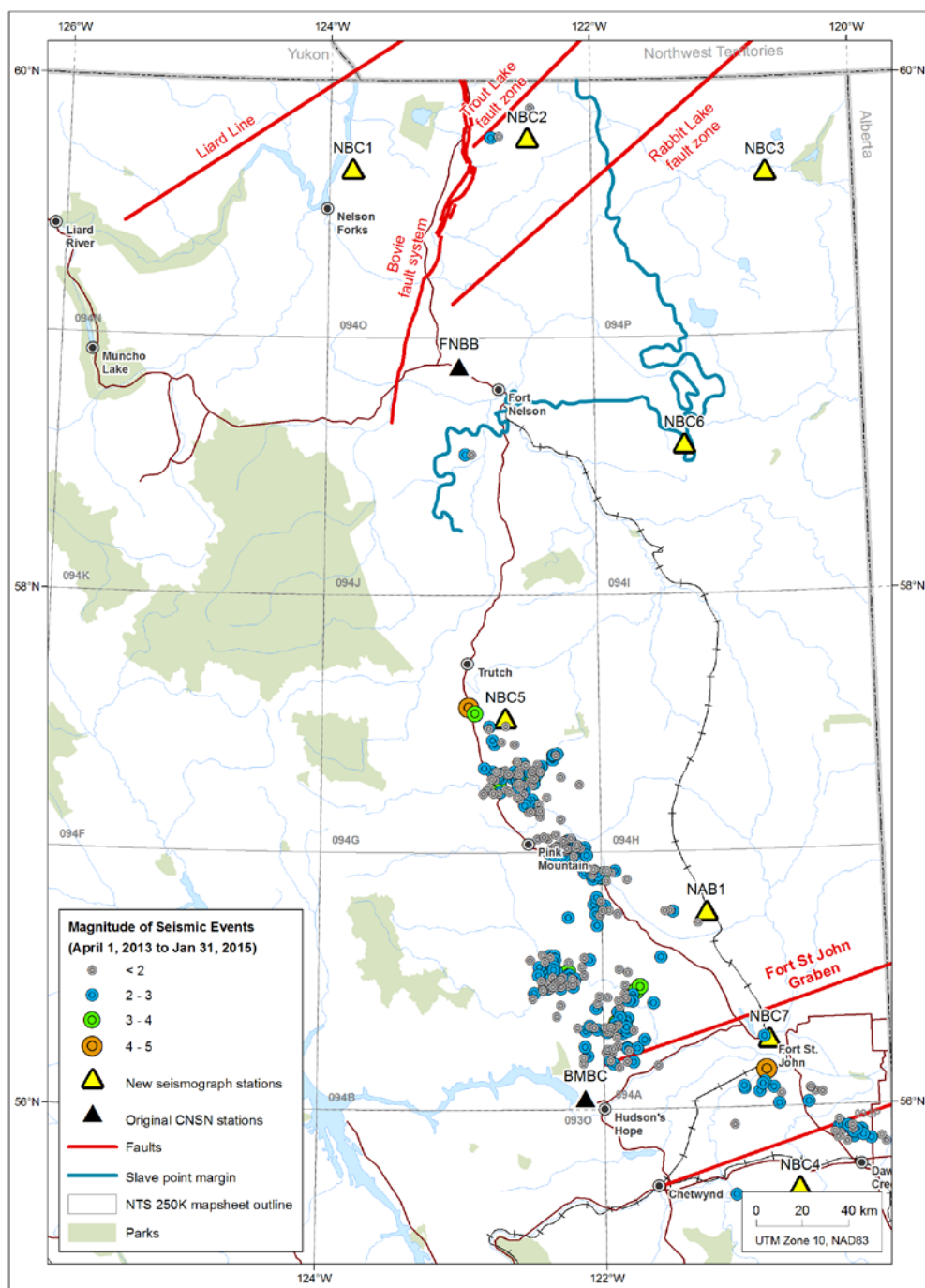


Figure 1. Seismic events captured by the seismic network from April 1, 2013 to January 31, 2015. A list of individual events is provided in Appendix A.

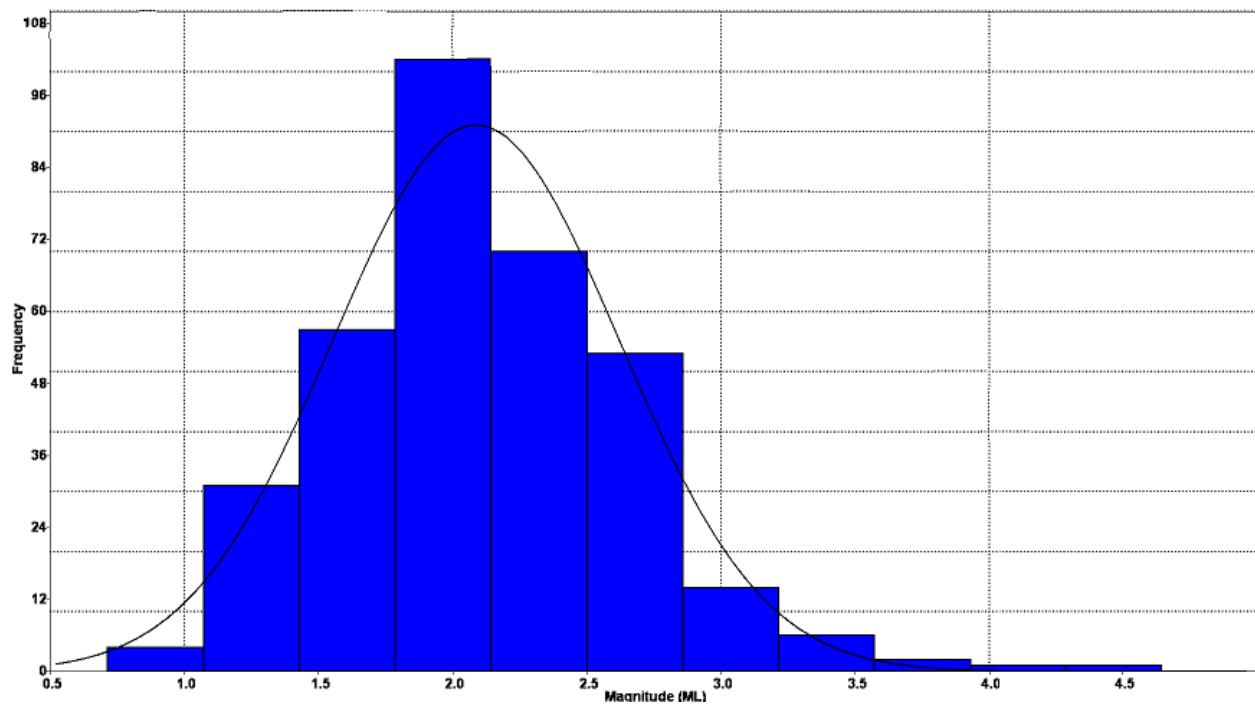


Figure 2. *Frequency vs. Magnitude histogram for all seismic events captured by the enhanced network from April 1, 2013 to January 31, 2015.*

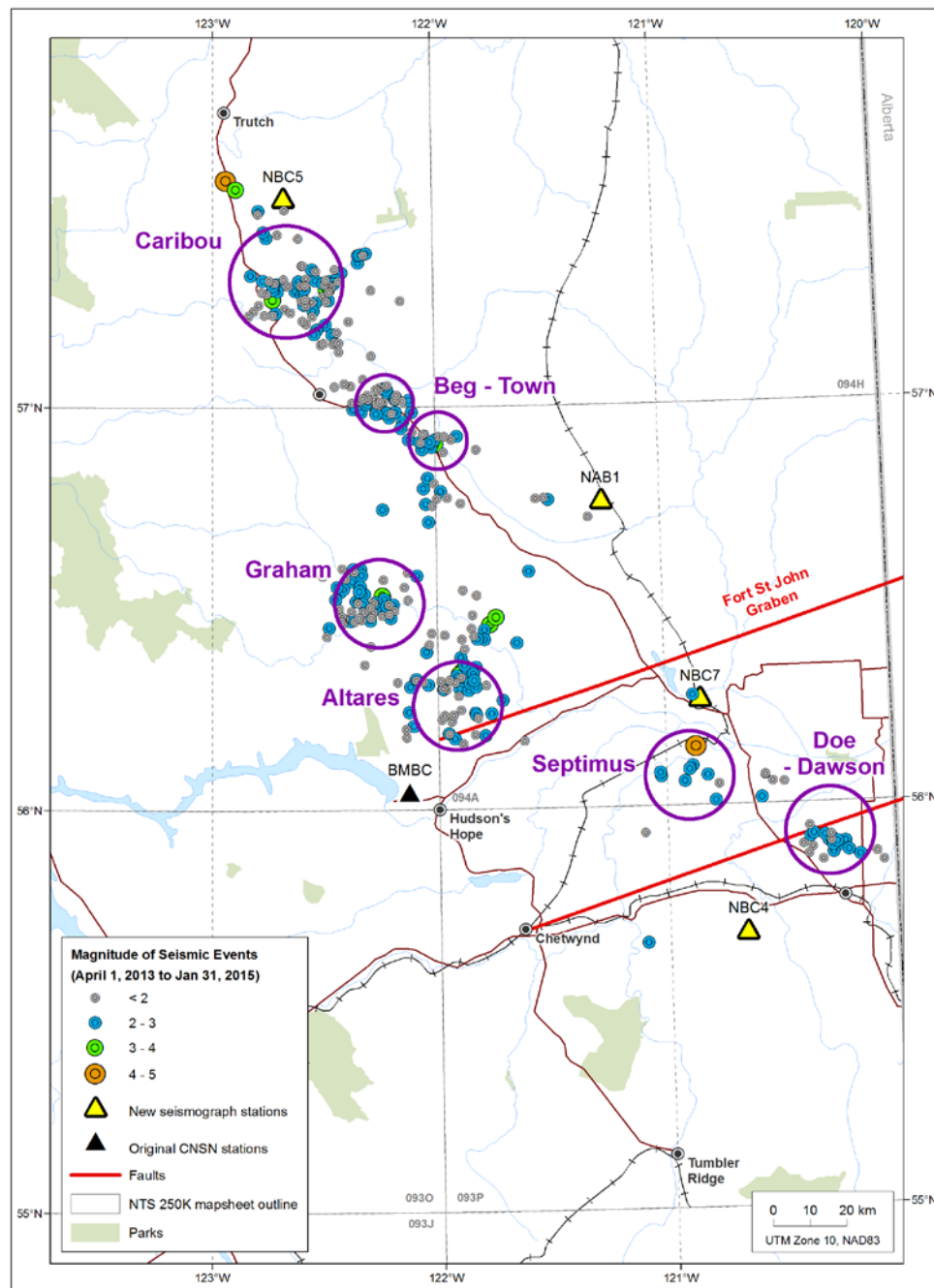


Figure 3. BCOGC-defined areas with a high incidence of low-level seismic activity.

Communication and Extension Plan

Throughout the past year, members of the consortium have presented the following papers or presentations:

- BC Oil & Gas Commission (2014): Investigation of Observed Seismicity in the Montney Trend; BC Oil & Gas Commission Technical Report, 32 p., URL <http://www.bcogc.ca/investigation-observed-seismicity-montney-trend> [March 2015].
- Farahbod, A.M., Kao, H., Walker, D.M., and Cassidy, J.F. (2015): Investigation of regional seismicity before and after hydraulic fracturing in the Horn River Basin, northeast British Columbia; Canadian Journal of Earth Sciences, v. 52(2), p. 112-112, URL www.nrcresearchpress.com/doi/abs/10.1139/cjes-2014-0162 [March 2015].

The following papers or presentations are planned for Year 4:

- “Speculation on the relationship between variation of regional seismicity and hydraulic fracturing operations in the Horn River Basin, Northeast BC, Canada”, a paper by A.M. Farahbod, H. Kao, J.F. Cassidy and D. Walker has been submitted for consideration to the Induced Seismicity Special Issue of The Leading Edge in February 2015.

The following news releases or promotional material was produced by Geoscience BC this past year:

- Half page non-technical article in Geoscience BC’s 2014 Annual Report (formerly called “Explorer Magazine”); URL http://www.geosciencebc.com/i/pdf/GeoscienceBCAnnualReport_14.pdf
- “Seismologist Hired to Study Induced Seismicity in Northeast B.C.”: Geoscience BC news release, January 21, 2015; URL <http://www.geosciencebc.com/s/NewsReleases.asp?ReportID=691014>
- Mention of ISMP in a one-page brochure: “Energy Projects”

The following articles or interviews covered the ISMP project this past year:

- Newspaper articles
 - Hoekstra, G. (2015): Seismologist to head up examination of link between earthquakes and fracking, Vancouver Sun, January 21, 2015, URL <http://www.vancouversun.com/technology/Seismologist+head+examination+link+between+earthquakes+fracking/10749360/story.html> [March 2015].
 - Pebbles, F. (2015): Seismologist investigating tremors, Prince George Citizen, January 21, 2015, URL <http://www.princegeorgecitizen.com/news/local-news/seismologist-investigating-tremors-1.1737870> [March 2015].
 - Scott, B. (2015): Seismologist hired to monitor how fracking affects the subterranean layers, Northeast News, January 31, 2015, URL <http://www.northeastnews.ca/seismologist-hired-to-monitor-how-fracking-affects-the-subterranean-layers/> [March 2015].
- Radio / TV
 - CKNW (radio) - Province chips in on study to determine if fracking causes quakes (by Sean Leslie; January 21, 2015)

- CKNW (radio) - More research underway to determine the impact of fracking (by Shelby Thom; Jan 21, 2015)
- CBC News Vancouver, Early Edition with Andrew Chang (TV) - In-studio Interview with Carlos Salas, January 23, 2015; URL <https://drive.google.com/a/cbc.ca/file/d/0B3839hIb7cRecDQ3WnE2NW5BSig/view?usp=sharing> [March 2015]
- CBC The National, Briar Stewart (TV) - Interview with Honn Kao (air date to be determined)

For Additional Information

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Appendix A: Earthquakes recorded between April 2013 and January 2015

Date	Time_UT	Lat	Long	Depth	Mag	Region_and		
29/01/2015	21:33:47	57.262	-122.549	4.6*	2	153	km	WNW of Fort St. John
21/01/2015	16:14:19	57.266	-122.597	7.0*	1.9	155	km	WNW of Fort St. John
21/01/2015	0:51:28	57.253	-122.577	10.5*	1.9	153	km	WNW of Fort St. John
20/01/2015	15:20:10	57.321	-122.575	7.5*	1.6	158	km	WNW of Fort St. John
18/01/2015	5:50:41	57.267	-122.474	5.0g	2.3	150	km	WNW of Fort St. John
18/01/2015	23:33:20	57.303	-122.656	5.0g	1.8	160	km	WNW of Fort St. John
16/01/2015	0:56:49	57.277	-122.5	5.0g	1.9	152	km	WNW of Fort St. John
15/01/2015	6:13:04	57.261	-122.533	5.0g	2.8	152	km	WNW of Fort St. John
15/01/2015	7:18:36	56.422	-121.822	10.0g	2.2	62	km	W of Fort St. John
15/01/2015	23:47:18	57.255	-122.586	5.0g	2.1	154	km	WNW of Fort St. John
15/01/2015	6:42:01	57.269	-122.58	10.0g	1.9	154	km	WNW of Fort St. John
15/01/2015	6:22:10	57.263	-122.484	5.0g	1.7	150	km	WNW of Fort St. John
14/01/2015	2:25:49	56.47	-122.297	5.0g	2.4	92	km	W of Fort St. John
11/01/2015	2:24:08	56.544	-121.885	10.0g	1.9	71	km	WNW of Fort St. John
08/01/2015	1:35:27	56.591	-122.368	5.0g	1.6	100	km	WNW of Fort St. John
05/01/2015	2:10:58	56.325	-121.918	10.0g	2.2	66	km	W of Fort St. John
02/01/2015	1:15:38	56.305	-122.122	20.0g	2.3	78	km	W of Fort St. John
29/12/2014	15:03:13	56.335	-121.905	5.0g	3.3	65	km	W of Fort St. John
27/12/2014	10:28:58	56.335	-121.843	5.9*	2.4	62	km	W of Fort St. John
26/12/2014	5:03:29	56.357	-121.882	0.0*	2.2	64	km	W of Fort St. John
23/12/2014	19:05:57	56.32	-121.949	5.0g	1.5	68	km	W of Fort St. John
21/12/2014	0:18:36	56.533	-122.242	5.0g	3.1	91	km	WNW of Fort St. John
20/12/2014	13:05:30	56.3	-121.905	20.0g	2.4	65	km	W of Fort St. John
18/12/2014	11:57:50	56.298	-121.962	15.0g	2	68	km	W of Fort St. John
18/12/2014	5:25:38	56.495	-122.19	10.0g	2	87	km	W of Fort St. John
17/12/2014	10:01:48	56.344	-121.89	7.9*	3.5	65	km	W of Fort St. John
17/12/2014	16:34:30	56.313	-121.858	5.0g	2.2	62	km	W of Fort St. John
16/12/2014	8:44:27	56.47	-122.384	11.8*	2.1	97	km	W of Fort St. John
16/12/2014	10:43:43	56.476	-122.412	13.9*	2	99	km	W of Fort St. John
16/12/2014	10:24:47	56.485	-122.289	0.0g	2	92	km	W of Fort St. John
13/12/2014	14:04:07	57.128	-122.282	1.0g	1.7	131	km	WNW of Fort St. John
13/12/2014	8:28:13	57.305	-122.493	5.0g	1.6	154	km	WNW of Fort St. John
13/12/2014	16:27:04	57.303	-122.579	1.0g	1.5	157	km	WNW of Fort St. John
11/12/2014	16:57:32	55.865	-120.161	10.0g	2.5	11	km	NE of Dawson Creek
11/12/2014	10:46:25	56.3	-121.979	15.0g	1.9	70	km	W of Fort St. John
08/12/2014	10:02:18	57.282	-122.597	5.0g	2.2	156	km	WNW of Fort St. John
07/12/2014	18:55:20	56.317	-121.903	5.0g	2.5	65	km	W of Fort St. John

Date	Time_UT	Lat	Long	Depth	Mag	Region_and		
06/12/2014	17:04:43	56.555	-122.341	10.0g	2.1	97	km	WNW of Fort St. John
06/12/2014	9:25:51	57.295	-122.584	5.0g	2.1	157	km	WNW of Fort St. John
05/12/2014	20:18:11	57.181	-122.458	5.0g	2.2	142	km	WNW of Fort St. John
02/12/2014	18:36:40	56.766	-121.498	10.0g	2.1	69	km	NW of Fort St. John
02/12/2014	18:59:29	56.77	-121.516	5.0g	2	70	km	NW of Fort St. John
02/12/2014	18:49:16	56.768	-121.554	10.0g	2	72	km	NW of Fort St. John
02/12/2014	11:17:21	56.492	-122.284	10.0g	2	92	km	W of Fort St. John
01/12/2014	19:55:34	57.245	-122.674	5.0g	2	157	km	WNW of Fort St. John
01/12/2014	8:22:37	56.721	-121.321	10.0g	1.8	59	km	NW of Fort St. John
26/11/2014	17:19:24	57.282	-122.753	5.0g	1.9	163	km	WNW of Fort St. John
25/11/2014	2:21:19	56.554	-122.444	10.0g	2.3	103	km	W of Fort St. John
24/11/2014	10:02:46	56.568	-122.376	10.0g	2.9	100	km	WNW of Fort St. John
24/11/2014	21:30:18	57.287	-122.778	5.0g	1.9	164	km	WNW of Fort St. John
23/11/2014	1:34:03	56.331	-121.873	10.0g	2.8	63	km	W of Fort St. John
22/11/2014	2:50:31	57.24	-122.544	6.0*	2.6	151	km	WNW of Fort St. John
22/11/2014	21:52:04	56.281	-121.909	5.0g	0	65	km	W of Fort St. John
01/11/2014	20:26:22	56.987	-122.104	12.9*	2.1	112	km	WNW of Fort St. John
01/11/2014	6:07:32	56.947	-122.152	11.8*	2.1	111	km	WNW of Fort St. John
31/10/2014	2:12:18	57.26	-122.583	11.5*	2.6	154	km	WNW of Fort St. John
31/10/2014	9:23:36	56.963	-122.143	11.4*	2.5	112	km	WNW of Fort St. John
31/10/2014	20:07:56	57.291	-122.281	5.6*	1.9	145	km	NW of Fort St. John
22/10/2014	2:35:20	56.583	-122.334	1.0g	2.4	98	km	WNW of Fort St. John
21/10/2014	5:57:59	56.598	-122.338	10.0g	2.7	99	km	WNW of Fort St. John
21/10/2014	5:06:42	56.477	-122.349	10.0g	1.1	95	km	W of Fort St. John
19/10/2014	9:42:49	56.303	-121.833	12.5*	2.2	61	km	W of Fort St. John
19/10/2014	11:05:54	57.139	-122.43	16.8*	1.7	138	km	WNW of Fort St. John
15/10/2014	15:30:17	56.314	-121.925	9.3*	1.6	66	km	W of Fort St. John
14/10/2014	0:22:54	56.482	-122.243	15.0*	1.9	89	km	W of Fort St. John
10/10/2014	16:54:08	56.051	-120.769	10.0g	1.8	22	km	SSE of Fort St. John
10/10/2014	1:56:25	56.433	-121.969	10.0g	1.8	71	km	W of Fort St. John
09/10/2014	10:59:55	56.464	-122.419	10.0g	1.7	99	km	W of Fort St. John
08/10/2014	6:32:37	56.473	-122.336	10.0g	1.8	94	km	W of Fort St. John
07/10/2014	10:25:58	57.03	-122.171	10.0g	1.6	118	km	WNW of Fort St. John
06/10/2014	2:01:32	57.02	-122.272	10.0g	1.7	122	km	WNW of Fort St. John
05/10/2014	23:53:00	56.398	-121.881	10.0g	1.7	65	km	W of Fort St. John
04/10/2014	16:59:57	56.985	-122.254	10.5*	2.6	118	km	WNW of Fort St. John
04/10/2014	6:52:44	57.236	-122.648	9.1*	2	155	km	WNW of Fort St. John
02/10/2014	1:34:06	55.895	-120.271	5.0g	2.7	14	km	NNW of Dawson Creek
01/10/2014	11:28:02	55.873	-120.277	10.0g	2.2	12	km	NNW of Dawson Creek
27/09/2014	23:30:10	56.519	-122.339	10.0g	2.3	96	km	W of Fort St. John
26/09/2014	16:42:24	56.514	-122.27	1.0g	2.9	92	km	W of Fort St. John

Date	Time_UT	Lat	Long	Depth	Mag	Region_and		
26/09/2014	20:10:51	56.48	-122.424	5.0g	2	100	km	W of Fort St. John
20/09/2014	17:35:34	56.053	-120.483	10.0g	1.8	31	km	ESE of Fort St. John
19/09/2014	23:09:04	57.343	-122.549	5.0g	2.1	159	km	WNW of Fort St. John
19/09/2014	13:06:33	57.339	-122.532	10.0g	1.5	158	km	WNW of Fort St. John
18/09/2014	12:49:40	56.317	-122.065	5.0g	1.5	75	km	W of Fort St. John
16/09/2014	10:20:52	56.015	-120.583	16.1*	2.3	30	km	SE of Fort St. John
11/09/2014	8:04:34	56.071	-120.566	5.0g	1.5	26	km	ESE of Fort St. John
10/09/2014	23:00:35	56.055	-120.534	10.0g	1.9	29	km	ESE of Fort St. John
10/09/2014	4:49:02	56.069	-120.566	5.0g	1.6	26	km	ESE of Fort St. John
07/09/2014	11:32:15	57.194	-122.527	10.0g	2.5	146	km	WNW of Fort St. John
03/09/2014	20:01:34	56.598	-122.371	5.0g	2.8	101	km	WNW of Fort St. John
27/08/2014	5:59:46	57.156	-122.512	10.0g	1.2	143	km	WNW of Fort St. John
27/08/2014	5:55:07	57.159	-122.499	10.0g	1.2	142	km	WNW of Fort St. John
26/08/2014	1:35:21	56.759	-121.888	5.0g	1.7	85	km	WNW of Fort St. John
26/08/2014	18:52:38	57.163	-122.445	10.0g	1.3	140	km	WNW of Fort St. John
25/08/2014	10:26:37	57.158	-122.454	5.0g	2	140	km	WNW of Fort St. John
24/08/2014	15:14:59	56.773	-121.949	5.0g	1.9	89	km	WNW of Fort St. John
24/08/2014	0:33:23	56.306	-121.788	5.0g	1.6	58	km	W of Fort St. John
24/08/2014	1:14:54	57.24	-122.814	5.0g	1.5	162	km	WNW of Fort St. John
24/08/2014	4:35:32	57.16	-122.43	5.0g	1.3	139	km	WNW of Fort St. John
24/08/2014	8:41:13	56.772	-121.994	5.0g	1.1	91	km	WNW of Fort St. John
23/08/2014	21:13:45	56.797	-122.055	5.0g	2.5	95	km	WNW of Fort St. John
23/08/2014	21:53:38	56.79	-121.977	6.5*	2.3	91	km	WNW of Fort St. John
23/08/2014	13:56:05	56.753	-122.015	12.2*	1.9	90	km	WNW of Fort St. John
22/08/2014	19:19:19	57.255	-122.79	5.0g	2	162	km	WNW of Fort St. John
21/08/2014	4:54:41	57.054	-122.213	5.0g	1.4	122	km	WNW of Fort St. John
19/08/2014	11:12:32	57.263	-122.15	13.8*	1.9	137	km	NW of Fort St. John
13/08/2014	11:59:20	56.327	-121.898	1.0g	1.7	65	km	W of Fort St. John
12/08/2014	20:11:02	56.542	-122.431	5.0g	2.5	102	km	W of Fort St. John
11/08/2014	3:25:19	57.053	-122.377	10.0g	1.8	129	km	WNW of Fort St. John
10/08/2014	6:21:32	56.361	-122.325	10.0g	1.5	91	km	W of Fort St. John
08/08/2014	21:54:55	57.489	-122.792	10.0g	2.7	147	km	S of Fort Nelson
05/08/2014	3:22:55	56.422	-121.892	10.0g	1.4	67	km	W of Fort St. John
04/08/2014	17:17:24	57.564	-122.942	5.0g	4.4	140	km	S of Fort Nelson
01/08/2014	23:44:53	56.553	-122.144	5.0g	1.5	86	km	WNW of Fort St. John
30/07/2014	21:23:56	57.542	-122.894	6.2*	3.8	142	km	S of Fort Nelson
30/07/2014	7:54:55	56.931	-122.049	5.0g	1.9	105	km	WNW of Fort St. John
29/07/2014	9:54:12	56.919	-122.118	12.6*	2.2	107	km	WNW of Fort St. John
29/07/2014	20:31:49	56.52	-122.13	5.0g	2	84	km	WNW of Fort St. John
29/07/2014	13:06:12	56.933	-122.047	5.0g	1.8	105	km	WNW of Fort St. John
29/07/2014	23:45:25	57.481	-122.794	1.8*	1.7	148	km	S of Fort Nelson

Date	Time_UT	Lat	Long	Depth	Mag	Region_and	
29/07/2014	10:27:53	56.938	-122.102	9.3*	1.7	108	km WNW of Fort St. John
29/07/2014	6:57:31	57.048	-122.246	10.9*	1.7	123	km WNW of Fort St. John
28/07/2014	17:42:10	56.918	-121.928	5.0g	1.8	99	km WNW of Fort St. John
26/07/2014	14:00:17	57.046	-122.232	5.0g	2.3	122	km WNW of Fort St. John
20/07/2014	4:52:52	57.044	-122.216	5.0g	2.2	121	km WNW of Fort St. John
19/07/2014	13:05:36	57.041	-122.254	5.0g	1.7	123	km WNW of Fort St. John
18/07/2014	19:30:38	57.044	-122.264	5.0g	1.7	123	km WNW of Fort St. John
17/07/2014	9:07:31	57.017	-122.116	10.0g	2.5	115	km WNW of Fort St. John
16/07/2014	17:44:06	57.268	-122.727	1.0g	3.7	161	km WNW of Fort St. John
15/07/2014	0:26:23	57.234	-122.714	5.0g	2.4	157	km WNW of Fort St. John
15/07/2014	0:12:35	57.228	-122.836	10.0g	1.5	162	km WNW of Fort St. John
15/07/2014	6:44:51	57.052	-122.45	5.0g	1.3	132	km WNW of Fort St. John
14/07/2014	6:37:20	57.23	-122.727	5.0g	1.6	158	km WNW of Fort St. John
14/07/2014	18:31:53	57.069	-122.321	10.0g	1.4	128	km WNW of Fort St. John
14/07/2014	17:34:57	57.059	-122.406	10.0g	1.3	131	km WNW of Fort St. John
14/07/2014	7:46:06	56.468	-122.425	5.0g	1.3	100	km W of Fort St. John
14/07/2014	7:12:37	57.23	-122.764	5.0g	0.9	159	km WNW of Fort St. John
11/07/2014	22:18:17	57.207	-122.576	5.0g	1.6	149	km WNW of Fort St. John
10/07/2014	8:22:26	56.589	-122.129	5.0g	1.3	87	km WNW of Fort St. John
08/07/2014	23:12:51	56.437	-122.026	10.0g	1.6	75	km W of Fort St. John
08/07/2014	13:19:23	57.42	-122.611	10.0g	1.4	155	km S of Fort Nelson
07/07/2014	22:33:10	56.431	-122.492	15.0g	1	103	km W of Fort St. John
03/07/2014	1:19:09	56.319	-121.84	5.0g	2.2	61	km W of Fort St. John
03/07/2014	6:10:22	56.233	-121.972	10.0g	1.5	69	km W of Fort St. John
02/07/2014	2:12:36	57.491	-122.674	1.0g	1.2	147	km S of Fort Nelson
01/07/2014	7:31:49	56.234	-121.832	5.0g	2.2	60	km W of Fort St. John
01/07/2014	18:45:46	56.429	-121.839	5.0g	1.7	64	km W of Fort St. John
30/06/2014	19:38:46	56.238	-121.837	1.0g	3	61	km W of Fort St. John
30/06/2014	20:25:59	56.226	-121.824	5.0g	1.6	60	km W of Fort St. John
30/06/2014	7:16:09	56.246	-121.899	5.0g	1	64	km W of Fort St. John
30/06/2014	10:59:23	56.233	-121.933	10.0g	0.9	66	km W of Fort St. John
26/06/2014	13:26:33	56.207	-122.11	5.0g	2.7	78	km W of Fort St. John
25/06/2014	7:48:22	56.6	-122.421	10.0g	2	104	km WNW of Fort St. John
25/06/2014	3:53:08	56.581	-122.509	10.0g	1.8	108	km WNW of Fort St. John
25/06/2014	3:45:50	56.574	-122.406	10.0g	1.6	102	km WNW of Fort St. John
19/06/2014	14:50:55	58.546	-122.92	20.0g	1.9	32	km SW of Fort Nelson
11/06/2014	8:27:11	56.514	-122.353	15.0g	1.9	97	km W of Fort St. John
03/06/2014	3:17:12	57.019	-122.3	5.0g	1.4	123	km WNW of Fort St. John
02/06/2014	9:40:39	56.996	-122.367	10.0g	2.9	124	km WNW of Fort St. John
26/05/2014	22:07:04	57.021	-122.322	5.0g	1.3	124	km WNW of Fort St. John
25/05/2014	18:09:23	55.933	-121.099	10.0g	1.6	38	km SW of Fort St. John

Date	Time_UT	Lat	Long	Depth	Mag	Region_and	
18/05/2014	23:13:36	56.273	-120.875	5.0g	2.2	3	km NW of Fort St. John
15/05/2014	7:37:56	57.014	-122.243	10.0g	1.5	120	km WNW of Fort St. John
14/05/2014	13:45:00	56.324	-122.096	5.0g	2.2	77	km W of Fort St. John
14/05/2014	13:49:04	56.316	-122.18	10.0g	1.9	82	km W of Fort St. John
12/05/2014	18:44:23	56.823	-122.034	10.0g	2.3	96	km WNW of Fort St. John
12/05/2014	0:47:29	56.511	-122.33	10.0g	2.2	95	km W of Fort St. John
28/04/2014	1:37:45	56.518	-122.361	10.0g	2.7	97	km W of Fort St. John
25/04/2014	20:05:51	56.988	-122.329	10.0g	2.7	122	km WNW of Fort St. John
25/04/2014	1:11:53	56.509	-122.214	10.0g	1.5	88	km W of Fort St. John
23/04/2014	12:56:45	56.409	-122.038	10.0g	1.8	75	km W of Fort St. John
21/04/2014	23:28:41	56.06	-120.919	10.0g	2.5	21	km SSW of Fort St. John
21/04/2014	23:58:54	56.523	-122.451	5.0g	2.3	103	km W of Fort St. John
16/04/2014	13:37:51	56.503	-122.297	10.0g	1.6	93	km W of Fort St. John
16/04/2014	12:13:19	57.017	-122.334	5.0g	1.5	124	km WNW of Fort St. John
15/04/2014	15:24:13	56.506	-122.224	10.0g	2.1	89	km W of Fort St. John
13/04/2014	13:12:17	56.993	-122.244	10.0g	2.8	118	km WNW of Fort St. John
13/04/2014	6:24:59	56.523	-122.234	10.0g	2.3	90	km W of Fort St. John
13/04/2014	3:37:32	56.501	-122.435	10.0g	1.2	101	km W of Fort St. John
10/04/2014	5:31:09	56.516	-122.272	15.0g	2.7	92	km W of Fort St. John
10/04/2014	19:28:44	57.011	-122.371	10.0g	1.8	125	km WNW of Fort St. John
10/04/2014	2:50:12	56.486	-122.212	10.0g	1.7	87	km W of Fort St. John
09/04/2014	22:29:47	56.377	-121.898	5.0g	2.4	66	km W of Fort St. John
09/04/2014	2:56:16	57.008	-122.307	10.0g	2.2	122	km WNW of Fort St. John
08/04/2014	7:02:40	56.179	-122.142	10.0g	1.9	80	km W of Fort St. John
08/04/2014	23:44:40	56.463	-122.421	10.0g	1.3	99	km W of Fort St. John
07/04/2014	7:28:22	57.287	-122.472	5.0g	1.5	152	km WNW of Fort St. John
07/04/2014	3:28:46	56.492	-122.329	10.0g	1.3	95	km W of Fort St. John
04/04/2014	11:04:36	59.893	-122.465	10.8*	1.5	120	km NNE of Fort Nelson
01/04/2014	2:19:08	56.322	-122.097	10.0g	1.7	77	km W of Fort St. John
31/03/2014	23:28:04	56.481	-121.843	5.0g	1.2	66	km WNW of Fort St. John
29/03/2014	7:00:34	57.024	-122.174	5.0g	2.6	118	km WNW of Fort St. John
29/03/2014	10:10:32	57.215	-122.593	10.0g	1.4	151	km WNW of Fort St. John
20/03/2014	21:21:48	56.588	-121.589	10.0g	2.3	59	km WNW of Fort St. John
16/03/2014	7:13:49	56.444	-121.791	5.0g	2.9	61	km WNW of Fort St. John
14/03/2014	2:32:38	56.537	-122.324	0.0g	2.3	96	km W of Fort St. John
13/03/2014	19:37:02	57.304	-122.474	5.0g	1.9	153	km WNW of Fort St. John
12/03/2014	7:38:17	57.316	-122.437	10.0g	2.4	153	km NW of Fort St. John
11/03/2014	15:15:27	57.314	-122.464	10.0g	2.9	153	km WNW of Fort St. John
11/03/2014	17:22:24	57.314	-122.443	10.0g	2.5	153	km NW of Fort St. John
11/03/2014	8:50:42	57.307	-122.451	10.0g	2.1	152	km WNW of Fort St. John
11/03/2014	8:49:08	57.309	-122.498	10.0g	2.1	154	km WNW of Fort St. John

Date	Time_UT	Lat	Long	Depth	Mag	Region_and		
11/03/2014	6:37:03	57.317	-122.485	10.0g	1.2	155	km	WNW of Fort St. John
10/03/2014	6:37:08	57.313	-122.428	5.0g	1.2	152	km	NW of Fort St. John
02/03/2014	22:24:23	57.295	-122.481	7.9*	3.2	153	km	WNW of Fort St. John
02/03/2014	10:39:44	57.335	-122.416	5.0*	2.6	153	km	NW of Fort St. John
02/03/2014	13:24:02	57.301	-122.461	9.2*	2	152	km	WNW of Fort St. John
01/03/2014	4:35:29	56.458	-121.766	5.0g	3.4	61	km	WNW of Fort St. John
01/03/2014	3:48:21	57.206	-122.489	5.0g	2.6	146	km	WNW of Fort St. John
01/03/2014	18:33:03	56.31	-122.043	14.7*	2.5	74	km	W of Fort St. John
01/03/2014	11:14:58	57.013	-122.299	12.4*	2.2	122	km	WNW of Fort St. John
27/02/2014	5:08:43	56.809	-122.007	10.0g	2	94	km	WNW of Fort St. John
25/02/2014	21:55:40	58.547	-122.967	5.0g	2.4	33	km	SW of Fort Nelson
19/02/2014	14:21:37	57.008	-122.263	10.0g	2	120	km	WNW of Fort St. John
19/02/2014	5:12:07	57.352	-122.592	5.0g	1.3	162	km	WNW of Fort St. John
18/02/2014	7:03:29	57.352	-122.595	5.0g	1.8	162	km	WNW of Fort St. John
11/02/2014	11:54:54	57.182	-122.541	5.0g	2.4	146	km	WNW of Fort St. John
09/02/2014	4:43:55	56.544	-122.346	10.0g	2.1	97	km	W of Fort St. John
07/02/2014	20:07:03	55.856	-120.324	5.0g	1.7	11	km	NW of Dawson Creek
07/02/2014	15:32:46	55.871	-120.386	5.0g	1.7	15	km	NW of Dawson Creek
28/01/2014	1:24:02	57.214	-122.384	5.0g	2	142	km	WNW of Fort St. John
27/01/2014	18:03:16	57.227	-122.548	5.0g	2	150	km	WNW of Fort St. John
23/01/2014	3:30:04	57.307	-122.705	10.0g	3	163	km	WNW of Fort St. John
23/01/2014	3:59:40	56.352	-121.83	10.0g	2.9	61	km	W of Fort St. John
23/01/2014	4:51:46	57.302	-122.666	10.0g	2	161	km	WNW of Fort St. John
23/01/2014	3:42:50	57.315	-122.744	10.0g	1.7	165	km	WNW of Fort St. John
22/01/2014	9:37:06	56.918	-122.001	10.0g	2.2	102	km	WNW of Fort St. John
22/01/2014	19:19:23	57.005	-122.25	10.0g	2	120	km	WNW of Fort St. John
21/01/2014	2:46:06	57.008	-122.272	10.0g	2.8	121	km	WNW of Fort St. John
21/01/2014	19:24:34	57.289	-122.705	5.0g	2.4	161	km	WNW of Fort St. John
21/01/2014	22:36:55	56.449	-121.849	5.0g	2	65	km	WNW of Fort St. John
19/01/2014	9:14:26	57.293	-122.727	5.0g	2.3	163	km	WNW of Fort St. John
17/01/2014	16:43:38	57.314	-122.611	12.2*	2.4	159	km	WNW of Fort St. John
16/01/2014	2:44:49	57.343	-122.446	5.0g	1.3	155	km	NW of Fort St. John
15/01/2014	0:04:43	57.29	-122.626	5.0g	2.7	158	km	WNW of Fort St. John
15/01/2014	4:22:34	57.303	-122.6	5.0g	1.9	158	km	WNW of Fort St. John
14/01/2014	16:10:52	57.315	-122.773	10.0g	2.8	166	km	WNW of Fort St. John
14/01/2014	12:40:22	57.328	-122.828	10.0g	2.6	165	km	S of Fort Nelson
14/01/2014	15:52:03	57.319	-122.678	10.0g	2	163	km	WNW of Fort St. John
13/01/2014	21:34:57	57.316	-122.532	0.0g	2.6	156	km	WNW of Fort St. John
13/01/2014	2:03:15	57.303	-122.726	10.0g	2.3	163	km	WNW of Fort St. John
13/01/2014	3:05:25	57.31	-122.717	5.0g	1.8	163	km	WNW of Fort St. John
12/01/2014	13:56:23	57.036	-122.211	10.0g	2.9	120	km	WNW of Fort St. John

Date	Time_UT	Lat	Long	Depth	Mag	Region_and		
11/01/2014	12:53:33	56.493	-122.242	5.0g	2.3	89	km	W of Fort St. John
06/01/2014	23:06:41	56.984	-122.263	1.0g	2.2	119	km	WNW of Fort St. John
29/12/2013	12:33:00	57.359	-122.339	12.7*	2.5	153	km	NW of Fort St. John
28/12/2013	11:40:02	57.378	-122.339	16.1*	2.5	154	km	NW of Fort St. John
28/12/2013	6:18:27	57.017	-122.178	5.0g	1.7	117	km	WNW of Fort St. John
28/12/2013	1:36:57	57.007	-122.261	7.6*	1.7	120	km	WNW of Fort St. John
25/12/2013	8:09:42	56.986	-122.217	5.0g	2.3	117	km	WNW of Fort St. John
24/12/2013	12:04:15	57.377	-122.315	10.0g	1.4	153	km	NW of Fort St. John
23/12/2013	12:26:05	57.379	-122.331	10.0g	2.4	154	km	NW of Fort St. John
23/12/2013	10:56:52	57.382	-122.303	10.0g	2.4	153	km	NW of Fort St. John
22/12/2013	9:46:23	56.468	-122.368	8.9*	1.9	96	km	W of Fort St. John
21/12/2013	0:53:58	56.294	-121.865	5.0g	2.4	62	km	W of Fort St. John
19/12/2013	6:06:20	56.477	-122.293	15.0g	1.7	92	km	W of Fort St. John
17/12/2013	2:34:05	56.542	-122.344	5.0g	2.5	97	km	W of Fort St. John
17/12/2013	14:01:32	56.406	-122.297	10.0g	2	90	km	W of Fort St. John
17/12/2013	11:59:18	57.187	-122.438	5.0g	1.9	142	km	WNW of Fort St. John
16/12/2013	3:52:41	56.493	-122.382	10.0g	2	98	km	W of Fort St. John
12/12/2013	7:59:33	56.089	-120.897	5.0g	2.1	18	km	SSW of Fort St. John
08/12/2013	16:48:09	56.318	-121.988	15.0g	1.8	70	km	W of Fort St. John
06/12/2013	15:43:43	56.974	-122.204	10.0g	2.6	115	km	WNW of Fort St. John
04/12/2013	12:06:37	56.453	-122.481	15.0g	2.2	103	km	W of Fort St. John
29/11/2013	16:29:00	56.746	-122.238	8.3*	2.8	101	km	WNW of Fort St. John
29/11/2013	7:38:32	56.55	-122.416	13.5*	2.5	102	km	W of Fort St. John
23/11/2013	13:14:56	56.894	-122.058	14.5*	2.3	103	km	WNW of Fort St. John
21/11/2013	7:36:28	56.758	-122.044	5.0g	2.1	92	km	WNW of Fort St. John
18/11/2013	8:33:05	56.411	-121.648	5.0g	2.7	52	km	WNW of Fort St. John
18/11/2013	20:00:32	56.714	-122.034	5.0g	2.3	89	km	WNW of Fort St. John
10/11/2013	2:34:07	56.988	-122.176	5.0g	2.4	115	km	WNW of Fort St. John
09/11/2013	13:14:26	56.984	-122.194	5.0g	2	115	km	WNW of Fort St. John
06/11/2013	12:13:55	56.42	-121.791	10.0g	2.7	61	km	W of Fort St. John
01/11/2013	22:10:39	56.892	-121.817	5.0g	1.9	92	km	WNW of Fort St. John
30/10/2013	2:43:37	56.509	-122.196	10.0g	2.3	87	km	W of Fort St. John
28/10/2013	12:01:03	55.906	-120.282	5.0g	2.7	15	km	NNW of Dawson Creek
26/10/2013	18:02:43	57.008	-122.283	5.0g	2.3	121	km	WNW of Fort St. John
26/10/2013	2:42:30	57.014	-122.23	6.9*	1.8	119	km	WNW of Fort St. John
25/10/2013	11:31:59	55.89	-120.24	5.0g	2.4	13	km	N of Dawson Creek
25/10/2013	19:06:36	55.9	-120.225	5.0g	2.3	14	km	N of Dawson Creek
25/10/2013	9:05:11	55.9	-120.26	5.0g	2.1	14	km	NNW of Dawson Creek
24/10/2013	5:10:45	55.901	-120.296	5.0g	2.8	15	km	NNW of Dawson Creek
24/10/2013	0:42:41	55.891	-120.279	5.0g	2.2	14	km	NNW of Dawson Creek
24/10/2013	12:40:48	57.03	-122.302	10.0g	1.8	124	km	WNW of Fort St. John

Date	Time_UT	Lat	Long	Depth	Mag	Region_and		
23/10/2013	7:55:37	55.921	-120.362	8.3*	2.2	18	km	NW of Dawson Creek
23/10/2013	9:33:56	55.888	-120.367	16.4*	2	15	km	NW of Dawson Creek
23/10/2013	15:02:47	55.902	-120.285	14.3*	1.9	15	km	NNW of Dawson Creek
23/10/2013	17:46:12	55.941	-120.378	5.0g	1.6	21	km	NW of Dawson Creek
23/10/2013	8:41:44	55.918	-120.287	5.0g	1.4	17	km	NNW of Dawson Creek
23/10/2013	9:05:39	55.872	-120.087	9.1*	1.2	14	km	NE of Dawson Creek
18/10/2013	10:37:33	55.914	-120.377	5.2*	2.4	18	km	NW of Dawson Creek
18/10/2013	9:49:08	55.878	-120.211	5.0g	2.2	12	km	NNE of Dawson Creek
18/10/2013	7:16:05	55.917	-120.314	5.0g	2.2	17	km	NNW of Dawson Creek
18/10/2013	9:05:15	55.661	-121.099	10.0g	2.1	55	km	W of Dawson Creek
18/10/2013	9:23:21	55.85	-120.057	5.0g	1.6	14	km	ENE of Dawson Creek
18/10/2013	8:39:14	55.896	-120.408	5.0g	1.4	18	km	NW of Dawson Creek
16/10/2013	17:46:10	56.993	-122.233	10.0g	3	118	km	WNW of Fort St. John
14/10/2013	2:33:12	57.019	-122.178	5.0g	2.7	118	km	WNW of Fort St. John
14/10/2013	9:34:11	59.783	-122.707	10.0g	2	107	km	N of Fort Nelson
07/10/2013	20:52:22	57.015	-122.144	1.0g	1.8	116	km	WNW of Fort St. John
02/10/2013	23:00:56	57.421	-122.757	5.0g	2.5	155	km	S of Fort Nelson
02/10/2013	22:54:47	57.436	-122.769	5.0g	2.5	153	km	S of Fort Nelson
02/10/2013	7:25:58	57.429	-122.706	1.0g	1.4	154	km	S of Fort Nelson
17/09/2013	7:19:26	59.777	-122.769	9.4*	2.6	106	km	N of Fort Nelson
04/09/2013	22:34:18	56.571	-122.238	5.0g	1.8	92	km	WNW of Fort St. John
03/09/2013	2:45:26	56.476	-121.738	5.0g	3.3	60	km	WNW of Fort St. John
01/09/2013	16:12:38	56.188	-121.954	11.8*	2.4	68	km	W of Fort St. John
01/09/2013	17:30:47	56.185	-121.838	11.2*	1.9	61	km	W of Fort St. John
01/09/2013	16:12:38	56.187	-121.953	11.7*	1.9	68	km	W of Fort St. John
31/08/2013	11:14:22	56.9	-122.016	6.7*	2.7	101	km	WNW of Fort St. John
26/08/2013	13:34:18	56.926	-121.902	1.0g	2.2	99	km	WNW of Fort St. John
26/08/2013	18:30:27	56.168	-121.621	5.0g	1.9	48	km	W of Fort St. John
23/08/2013	5:42:28	56.912	-122.024	6.6*	2.1	103	km	WNW of Fort St. John
22/08/2013	1:36:50	56.913	-122.067	5.0g	2.2	104	km	WNW of Fort St. John
21/08/2013	15:31:31	56.907	-122	10.0g	3.4	101	km	WNW of Fort St. John
21/08/2013	0:05:40	56.911	-122.063	5.0g	2	104	km	WNW of Fort St. John
21/08/2013	0:04:16	56.887	-121.965	1.0g	1.5	98	km	WNW of Fort St. John
20/08/2013	4:04:34	56.925	-121.959	1.0g	1.6	101	km	WNW of Fort St. John
20/08/2013	23:54:37	56.932	-122.055	5.0g	1.5	105	km	WNW of Fort St. John
19/08/2013	17:42:51	56.926	-121.984	5.0g	1.9	102	km	WNW of Fort St. John
16/08/2013	19:42:38	56.098	-120.882	1.4*	2.6	17	km	SSW of Fort St. John
14/08/2013	0:14:48	56.236	-121.764	0.0g	2.1	56	km	W of Fort St. John
10/08/2013	3:13:33	56.182	-121.794	1.7*	2.3	58	km	W of Fort St. John
09/08/2013	3:46:17	56.218	-121.942	10.4*	2	67	km	W of Fort St. John
07/08/2013	7:06:21	56.476	-122.207	10.0g	2.5	87	km	W of Fort St. John

Date	Time_UT	Lat	Long	Depth	Mag	Region_and	
30/07/2013	17:09:42	56.242	-122.13	0.1*	2.4	79 km	W of Fort St. John
27/07/2013	12:30:28	56.515	-122.282	10.0g	2	93 km	W of Fort St. John
25/07/2013	3:20:53	56.175	-121.929	10.0g	2.2	67 km	W of Fort St. John
25/07/2013	18:03:56	56.222	-121.984	5.0g	1.9	70 km	W of Fort St. John
25/07/2013	16:14:00	56.2	-122.142	5.0g	1.8	80 km	W of Fort St. John
25/07/2013	19:24:32	56.162	-121.892	10.0g	1.7	65 km	W of Fort St. John
16/07/2013	7:51:14	56.581	-122.089	5.0g	2.3	84 km	WNW of Fort St. John
13/07/2013	6:36:57	56.082	-121.026	1.0g	2.7	21 km	SW of Fort St. John
29/06/2013	6:57:17	56.074	-120.819	1.0g	2.9	19 km	S of Fort St. John
02/06/2013	0:56:05	56.011	-120.786	1.0g	2.5	26 km	SSE of Fort St. John
28/05/2013	4:36:08	56.145	-120.868	5.0g	4.2	11 km	S of Fort St. John
28/05/2013	4:48:25	56.073	-121.023	10.0g	2.8	22 km	SW of Fort St. John
27/04/2013	2:06:44	56.531	-121.823	0.0g	1.9	67 km	WNW of Fort St. John
24/04/2013	2:06:01	56.298	-121.976	15.0g	2.2	69 km	W of Fort St. John
16/04/2013	5:37:37	56.391	-122.049	1.0g	2.5	75 km	W of Fort St. John
10/04/2013	2:44:26	56.331	-121.916	10.0g	2.1	66 km	W of Fort St. John
07/04/2013	2:39:11	56.342	-121.852	10.6*	3.5	62 km	W of Fort St. John
07/04/2013	12:52:25	56.269	-121.714	20.0g	2.9	53 km	W of Fort St. John