

## Seismicity

This seismicity report covers the four-month period of September-December 1998 time-period. The plots and corresponding discussion will focus on the standard two-month periods (i.e. September-October and November-December). Since the new Westdahl seismic network was added to the data acquisition system during this time-period, the Helicorder event count and detected event count histograms have been expanded to reflect this addition (figs. 19a and 20a). Guy Tytgat also added Westdahl to VolPlot, which is the program used to generate the standard seismicity maps, cross-sections and time-depth plots (fig. 17a). Also during this time the eastern Katmai seismic network came online and thus expanded our coverage in the Katmai/Valley of Ten Thousand Smokes region. Tytgat accordingly decreased the scale (increased areal coverage) of the corresponding seismicity map to allow the entire monitored area to be plotted (fig. 7a & b). To counter the resulting decrease in the resolution of the Katmai seismicity map, the monitored area was subdivided into five smaller, more detailed regions. These subregions correspond to the areas in which the seismicity has been observed to "cluster" within the Katmai/Valley of Ten Thousand Smokes region. Seismicity maps can thus be generated for the entire monitored region or for each of the five subregions. Care should be taken when looking at these more detailed maps, however, because some overlap between map areas was unavoidable.

### Spurr/Strandline Lake Region:

**S**eptember-October 1998: A total of 26 earthquakes were located in the vicinity of Spurr during September-October 1998 (figs. 2a, 20a and 21a). The largest event located during this period had a magnitude of  $M_L = 2.2$  and was located 17 km south of the summit of Spurr. A total of 12 events were located within 10 km of the summit of Spurr. The largest of these events had a magnitude of  $M_L = 0.7$  and was located 8 km north of the summit. One of the "proximal" events was located about 5 km east-northeast of the summit. Another such event was located 6 km west-northwest of the summit. The remaining nine proximal events were tightly clustered near the summit of Spurr and had hypocentral depths of less than 5 km. The 14 more distal earthquakes

were located relatively far away from both Spurr and Crater Peak and are, therefore, probably regional tectonic events unrelated to the volcanic activity in this region. The most northerly of the events plotted in figure 2A are also plotted on the Strandline Lake seismicity map (fig. 3a). The western most of these four events is the magnitude  $M_L = 0.7$  proximal event and thus was designated as being associated with Spurr. The other three overlapping events, on the other hand, are designated as being Strandline Lake events. Therefore, there is a total of 22 Spurr earthquakes for this two-month period. The number of events located in the total Spurr map area (fig. 2a) during September-October was greater (22 vs. 17 events) than that of the previous two-month period. The number of proximal Spurr events located during this time, however, was much greater than that of the July-August (12 vs. 4 events). The number of proximal events was, however, a bit lower than the 17 such events predicted from the 4-year mean seismicity rate for Spurr. Although the 56 kilobaud stations were still not being routinely recorded by AVO during September-October this probably has had less effect on the number of located events than the relative condition of the Spurr seismic network. The observed difference in numbers of located events is probably, to a large extent, due to an improvement in the overall "health" of the Spurr network following station repair and maintenance during the summer field-season.

A total of 35 earthquakes, the largest of which had a magnitude of  $M_L = 1.7$ , were plotted on the Strandline Lake seismicity map (figs. 3a, 20a and 21a). As indicated above, one of these events was actually a proximal Spurr event so the total number of Strandline Lake events is 34 rather than 35. The number of events located in this area during this two-month period was much greater than the nine such events that were located there during July-August. The observed increase in the number of located events in this region is also likely the result of improved station operation following repair and maintenance during the summer.

### November-December 1998:

During November-December 1998 a total of 30 earthquakes were located in the general vicinity of Spurr (figs. 32b, 20b and 21b). The largest such event had a magnitude of  $M_L = 1.6$  km at a hypocentral depth of about 1 km. This event and 12 others were located about 1-2 km ENE of the summit, forming a fairly linear zone of seismicity ~3-4 km in length and trending north-northwest to south-southeast. Nearly all events had hypocentral depths of less than 2 km (fig. 3a). In addition to the

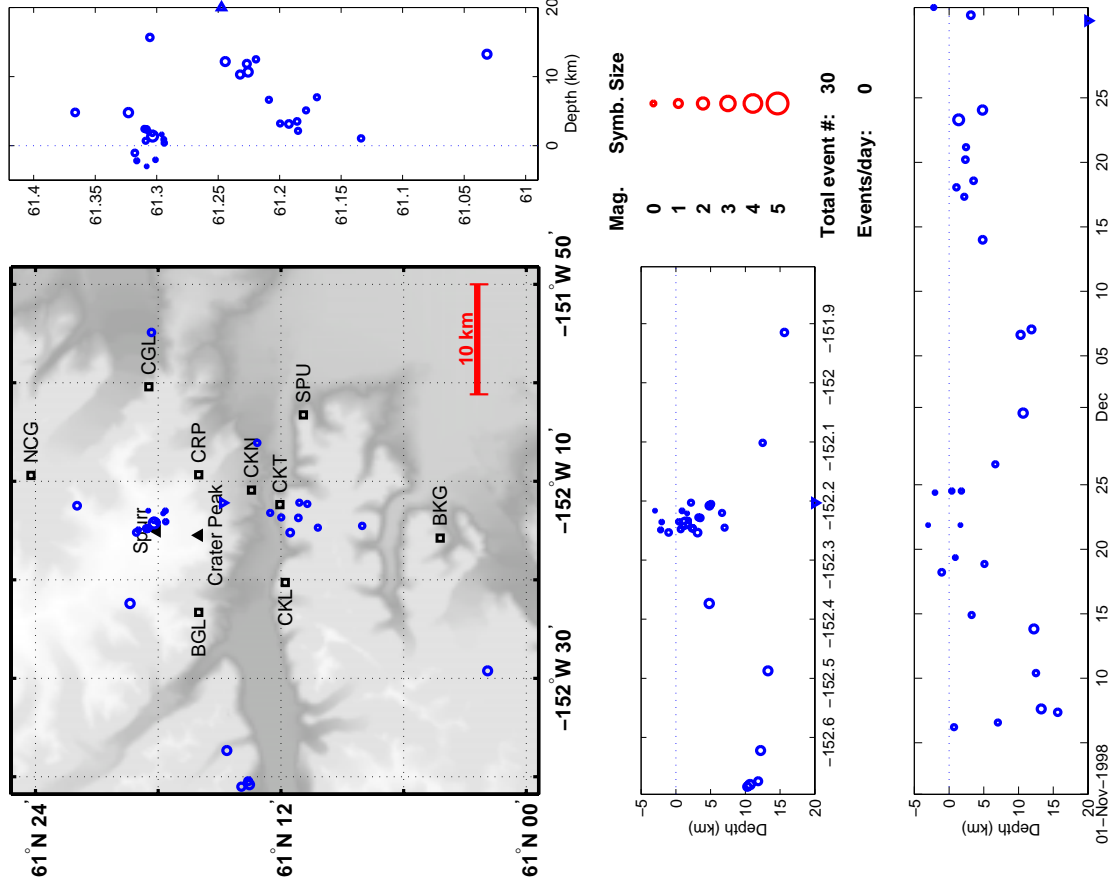
above 13 events, another three earthquakes were located within 10 km of the summit of Spurr. One of these events was located about 7 km west-northwest of the summit and had a hypocentral depth of 5 km. The waveform of this event had characteristics of both a- and b-type events and thus was designated as being a hybrid event (h-type). Another proximal event was located about 8 km north-northeast of the summit at a hypocentral depth of 5 km. The final proximal event was located 6 km south-southeast of the summit (~4 km southeast of Crater Peak) and had a hypocentral depth of ~24 km. "Deep" events are fairly common in this area. The latter two events were classified as being b-type events due to the low frequencies dominating their waveforms. The remaining fifteen events were located quite some distance from both Spurr and Crater Peak and are probably regional tectonic events unrelated to volcanic activity in this region. The number of proximal events located at Spurr during this two-month period is a bit larger than that of the September-October (15 vs. 12 events) but is lower than the 17 such events predicted from the 4-year mean seismicity rate.

A total of twenty-one earthquakes were located in the Strandline Lake region during November-December (fig. 3b). The largest of these events had a magnitude of  $M_L = 1.9$ . The number of Strandline Lake events located during November-December was lower than the 35 such events located during the previous two-month period.

### Redoubt:

**R**eptember-October 1998: A total of 10 earthquakes were located in the Redoubt region during September-October 1998 (figs. 4a, 20a and 21a). The largest had a magnitude of  $M_L = 2.4$  and was located 7 km north-northeast of the summit of Redoubt at a hypocentral depth of 6 km. Seven events were located within 10 km of the summit. One such earthquake was located 8 km northeast of the summit (~3 km east of the  $M_L = 2.4$  event). Two events were located 5 km and 10 km east of the summit. Another event was located 3 km north-northwest of the summit. The remaining two proximal events were located 7-8 km northwest of the summit of Redoubt. The final three earthquakes were located relatively far away from Redoubt and thus are probably regional tectonic events unrelated to volcanic activity in this area. The number of Redoubt

Spurr Volcano Seismicity: 01–Nov–1998 – 01–Jan–1999



Spurr Volcano Seismicity: 01–Sep–1998 – 01–Nov–1998

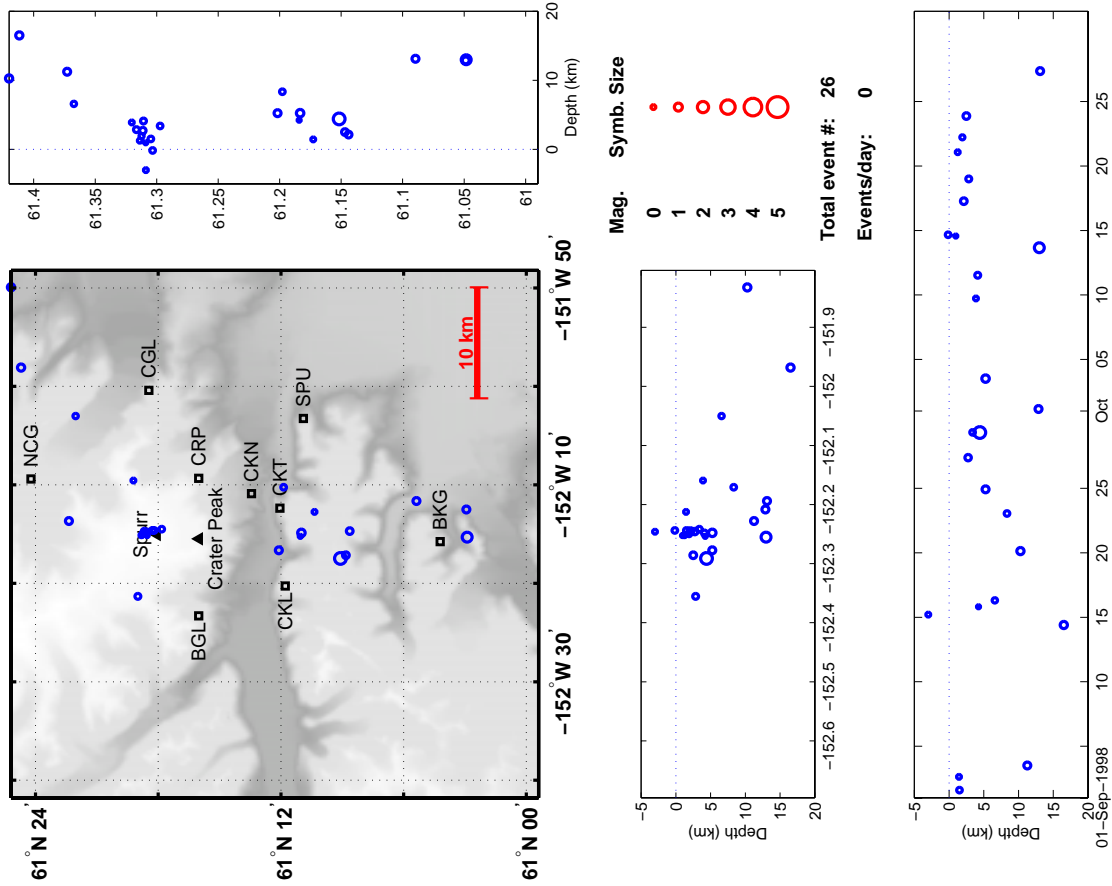
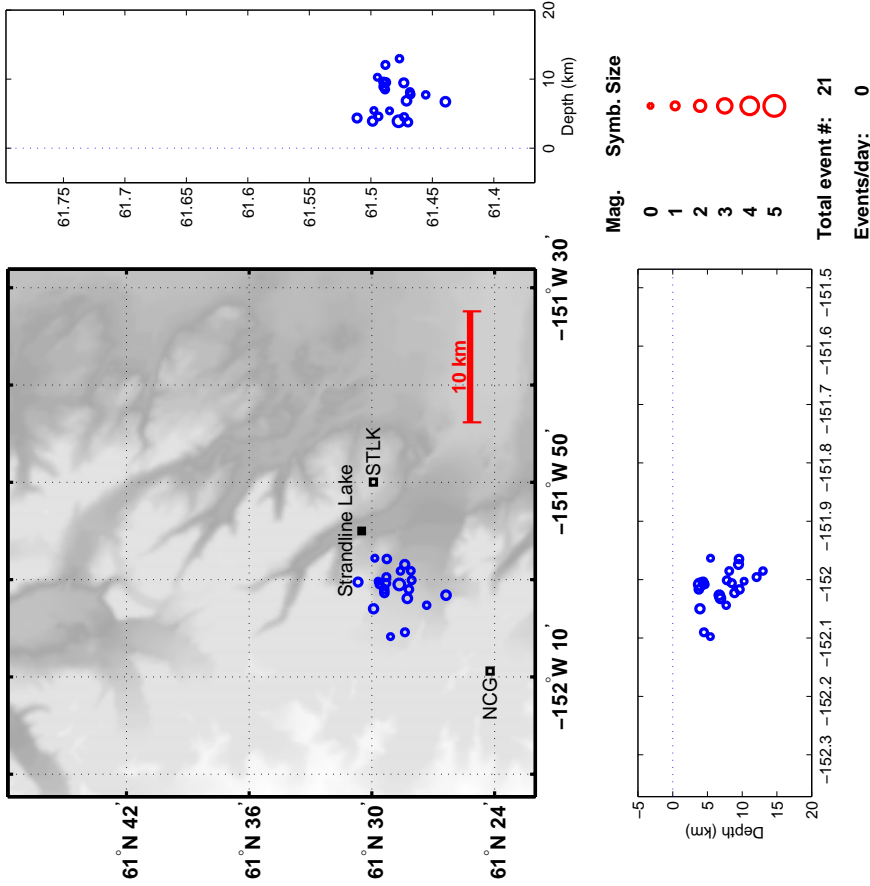


Figure 2a: Locatable Spurr seismic events in space and time for September through October.

Figure 2b: Locatable Spurr seismic events in space and time for November through December.

Strandline Lake Seismicity: 01–Nov–1998 – 01–Jan–1999



Strandline Lake Seismicity: 01–Sep–1998 – 01–Nov–1998

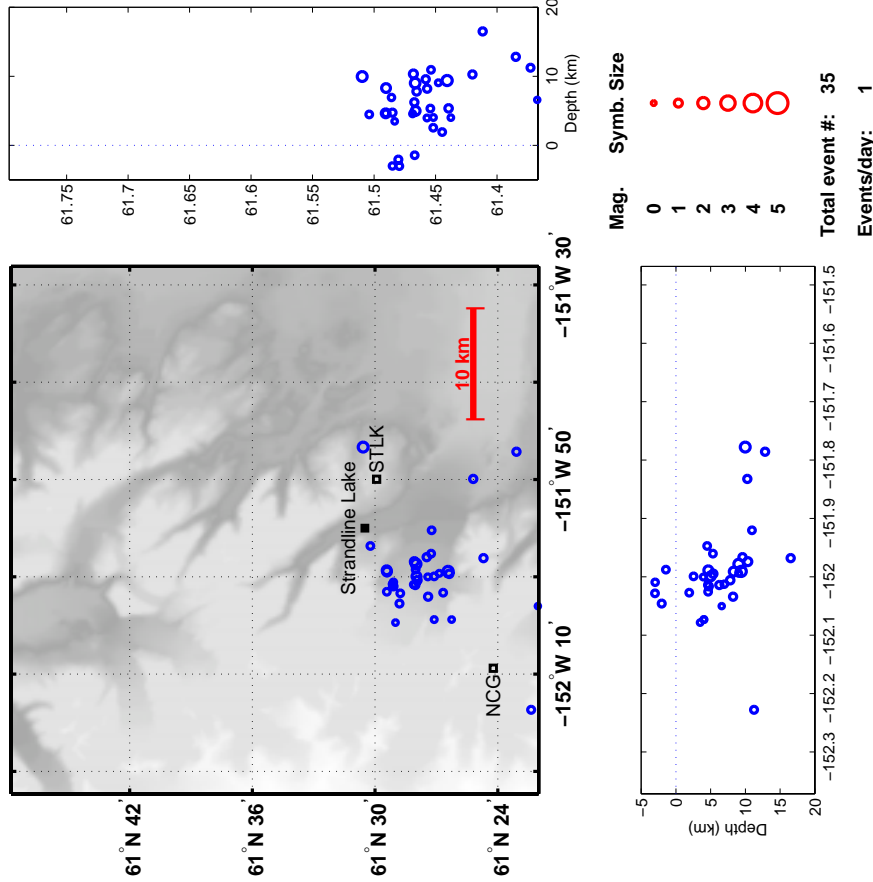


Figure 3b: Locatable Strandline Lake seismic events in space and time for November through December.

Figure 3a: Locatable Strandline Lake seismic events in space and time for September through October.

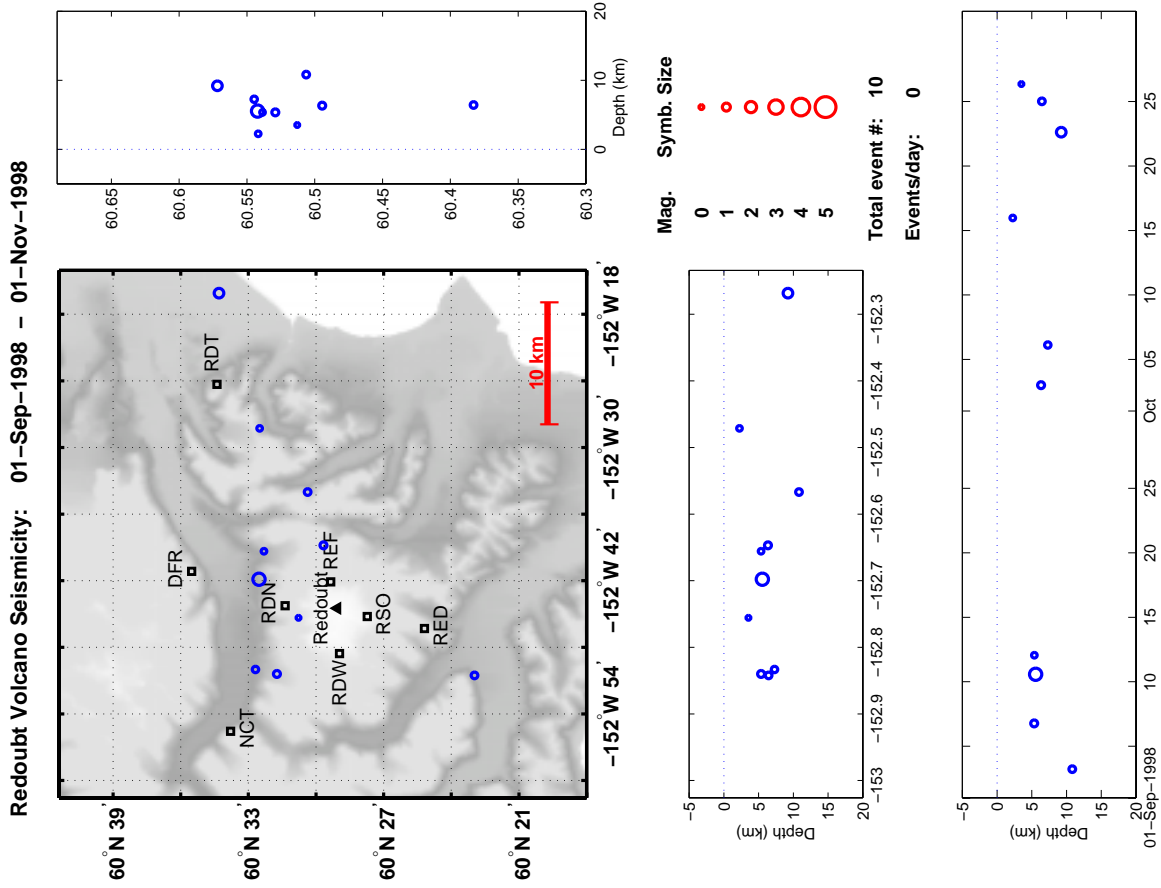


Figure 4a: Locatable Redoubt seismic events in space and time for September through October.

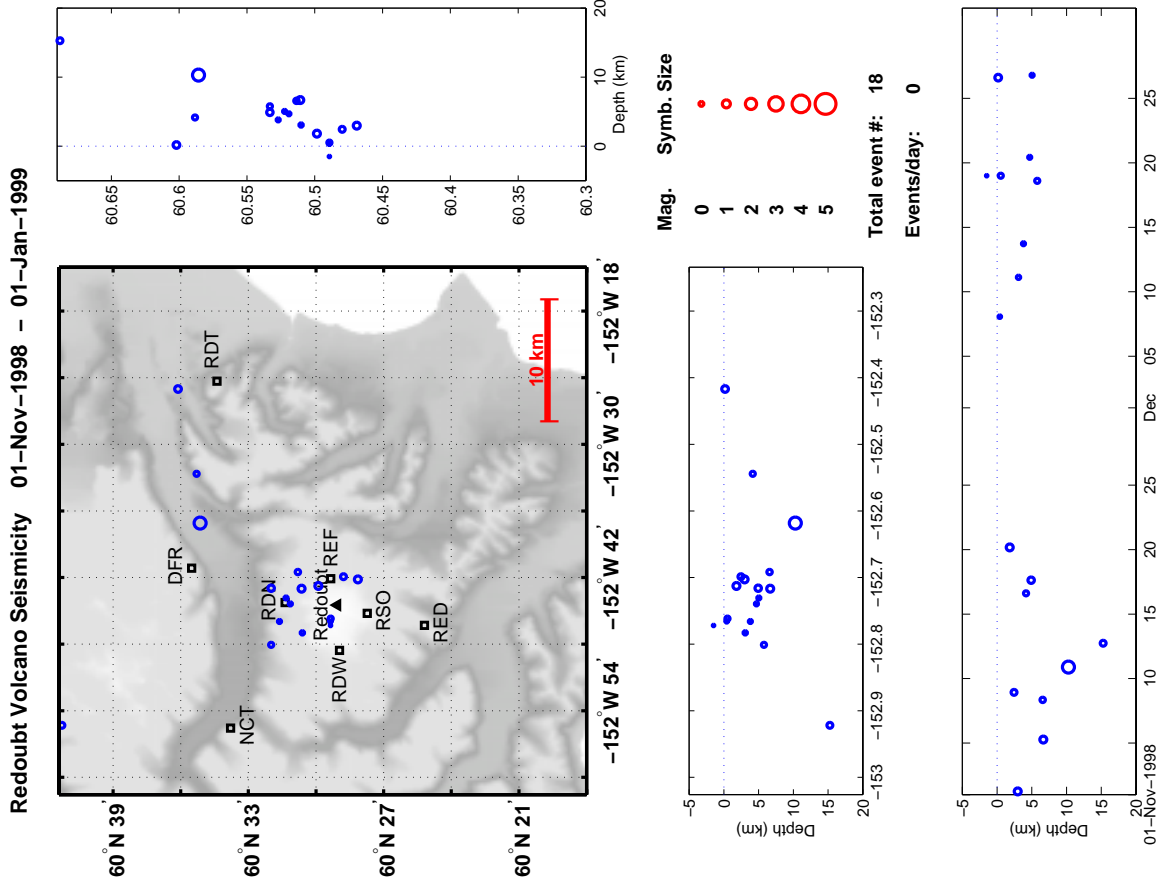


Figure 4b: Locatable Redoubt seismic events in space and time for November through December.



events located during this two-month period was much greater than the single such event located in this area during July-August. Once again the apparent increase in activity recorded is probably the result of station repair and maintenance during the summer rather than an actual increase in seismicity. The number of proximal events located during September-October was, however, about half the number predicted based upon the Redoubt 4-year mean seismicity rate.

#### November-December 1998:

Eighteen earthquakes, the largest of which had a magnitude of  $M_L=2.3$ , were located in the Redoubt area during November-December 1998 (figs. 4b, 20b and 21b). The largest event was located 13 km north-northeast of the summit of Redoubt. This earthquake is located quite some distance from the volcanic vent and is probably a tectonic earthquake not related to volcanic activity in this region. The same can also be said of the two events further to the east of the  $M_L=2.3$  event. A fourth event is 25 km north-northwest of Redoubt (nearly off the map) is also likely just a regional tectonic earthquake. The remaining 14 events were all located within 10 km of the summit of Redoubt and thus were close enough to Redoubt to be related to volcanic activity there. Two of these proximal events were located ~3 km southeast of the summit at hypocentral depths of 3 km. Another two were located about 1 km west-northwest of the summit at depths of 0.5 km. The remaining 10 proximal events were located 2-6 km from the summit. These events formed a diffuse zone of seismicity ~8 km in length and extending northeast to west-northwest of the summit. With the exception of one shallow event (i.e. above sea-level) these events had hypocentral depths of ~2-7 km. The number of events located during this two-month period was twice that of September-October. This value, however, was lower than the 15 such events predicted from the 4-year mean seismicity rate.

#### Iliamna:

##### September-October 1998:

During September-October 1998, a total of eight earthquakes were located in the Iliamna region (figs. 5a, 20a and 21a). The largest of these events had a magnitude of  $M_L=0.9$  and was located 6 km south-southeast of the summit and had a hypocentral depth of 3 km. The remaining seven earthquakes were clustered slightly east of the summit of Iliamna.

These events all had relatively shallow (i.e. above sea-level) hypocentral depths. The number of events located in the Iliamna area during September-October was much less than the 18 such events located there during July-August. This value is also considerably lower than the 28 located events predicted from the 10-month mean seismicity rate of Iliamna.

##### November-December 1998:

A total of 11 earthquakes were located in the Iliamna region during November-December 1998 (figs. 5b, 20b and 21b). The largest such event had a magnitude of  $M_L=0.7$  and was located 1 km north-northeast of the summit of Iliamna. A total of 10 events were located at shallow depth in the area between the summit and 2 km northeast of the summit. The one remaining event was located 8 km south of the summit at a hypocentral depth of nearly 3 km. The number of Iliamna events located during November-December was nearly half again as large as that of the previous two-month period (i.e. 11 vs. 8 events). This value, however, was less than half the number predicted (i.e. 28 events) from the mean seismicity rate. The network was stable, so the decreases in seismicity from September-December are real.

#### Augustine:

##### September-October 1998:

A total of 60 earthquakes, the largest of which had a magnitude of  $M_L=1.1$ , were located in the Augustine region during September-October 1998 (figs. 6A, 20a and 21a). One event was located off the eastern shore of Augustine Island about 5 km east-northeast of the summit. The locations of the remaining 59 earthquakes were all tightly clustered at shallow depth within the summit region (i.e. within the volcanic pile). The number of events located in the Augustine area during this two-month period was less than that of the July-August (60 vs. 97 events). However, this value is much greater than the 17 located events predicted from the Augustine 4-year mean seismicity rate.

##### November-December 1998:

During November-December 1998, a total of 19 earthquakes were located at Augustine (figs. 6B, 20b and 21b). These events, the largest of which had a magnitude of  $M_L=0.6$ , were all located in the summit region and had shallow (above sea-level) hypocentral depths. The number events located in the Augustine area during this two-month period was much lower than the 60 such events located during the previous two-

month period. This value was, however, close to the 17 events predicted on the basis of the Augustine 4-year mean seismicity rate. The Augustine seismic network was, for the most part, operating fairly well during November-December. During November station AUR was out for about 10 days. However, since there were another four summit stations that continued to be operational this outage should not have had much effect on the detection and location capabilities at Augustine. During December station AUC was out for the entire month. This outage normally would not have been a major problem. However, one of the remaining summit stations (i.e. AUP) was also out for about a week; this almost certainly affected our detection and location capabilities at Augustine during that time. Although the outages of AUP, AUC and to a lesser extent AUR may have somewhat reduced our capabilities at Augustine during November-December it is very unlikely that these outages could account for the large disparity in the number of located events between the November-December and the September-October periods. The apparent decrease in seismic activity at Augustine appears to be real. The Helicopter event counts (fig. 20b) which employed station AUS seem to support this interpretation. The event counts appear to have been lower during November-December than was the case during the previous two-month period (see fig. 21a for comparison).

#### Katmai:

Six of the seven new Katmai stations (i.e. KAHC, KAHG, KAIC, KAPH, KARR, and KAWH) were added to the data acquisition system on 10/19/98. The remaining new station, KABR, was added to the acquisition system at an earlier date (i.e. 08/12/98). Installation of these stations comprised a major eastward expansion of the Katmai seismic network. Because of this expansion the area covered by the seismicity basemap also needed to be increased. The new seismicity basemap is shown in figure 7A. Accompanying the increase in the area covered by the basemap was, of course, a corresponding decrease in the level of detail (i.e. decrease scale). To correct for this loss of detail five additional maps were generated. These maps cover those areas in which persistent seismic activity has been observed. The regions covered in detail are: Martin/

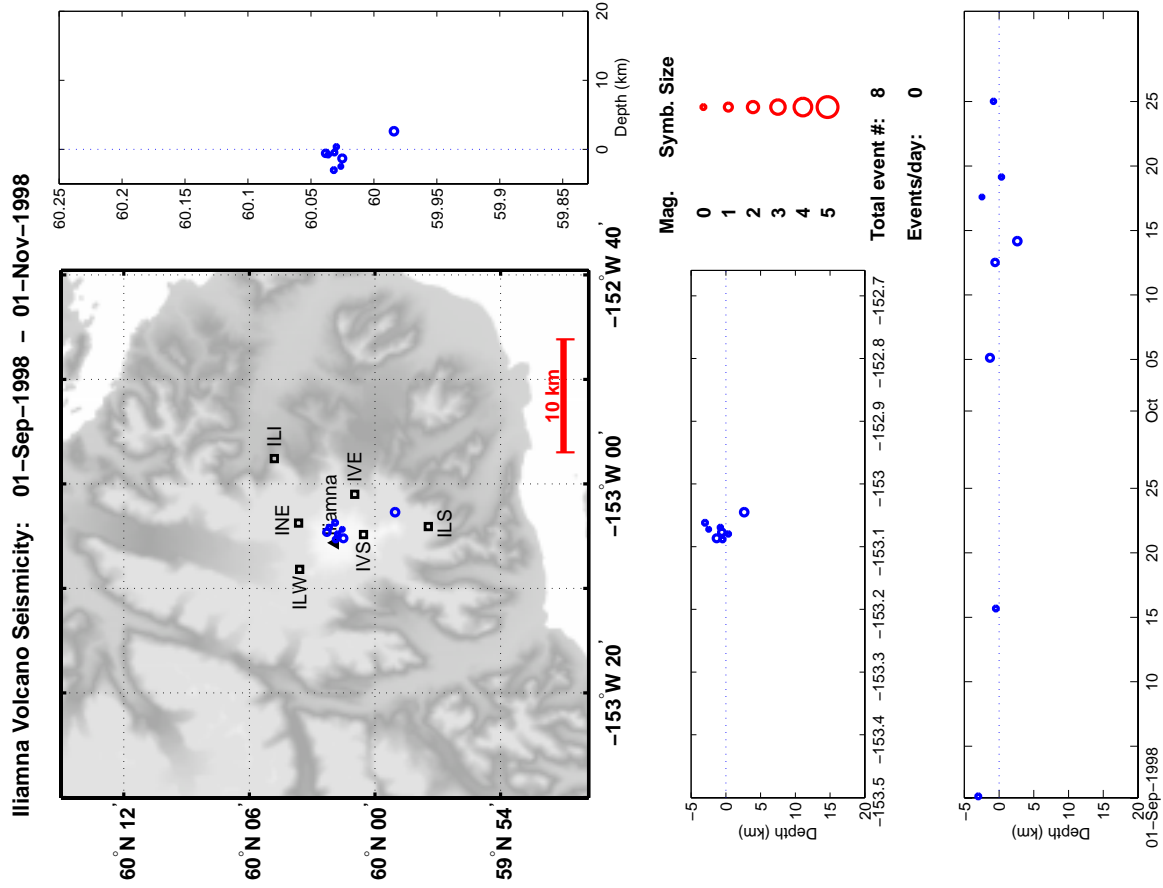


Figure 5a: Locatable Iliamna seismic events in space and time for September through October.

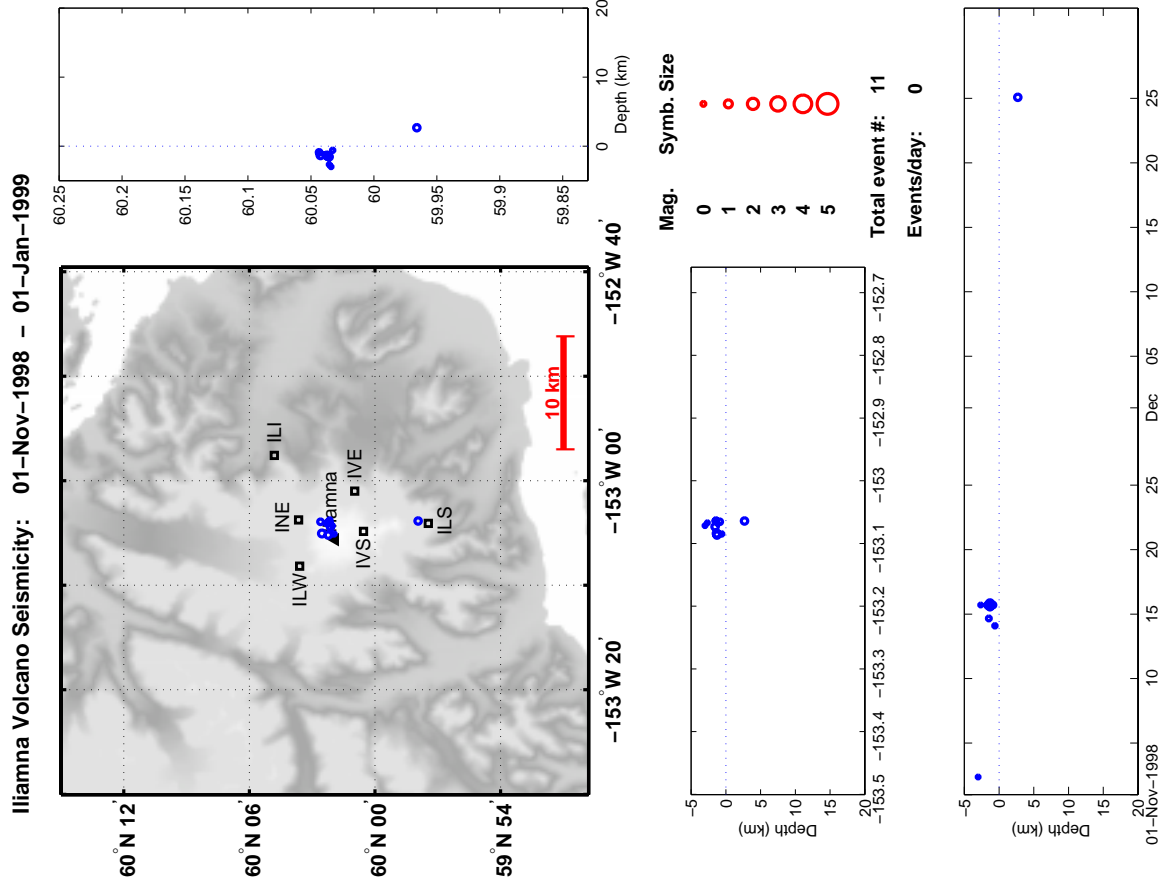
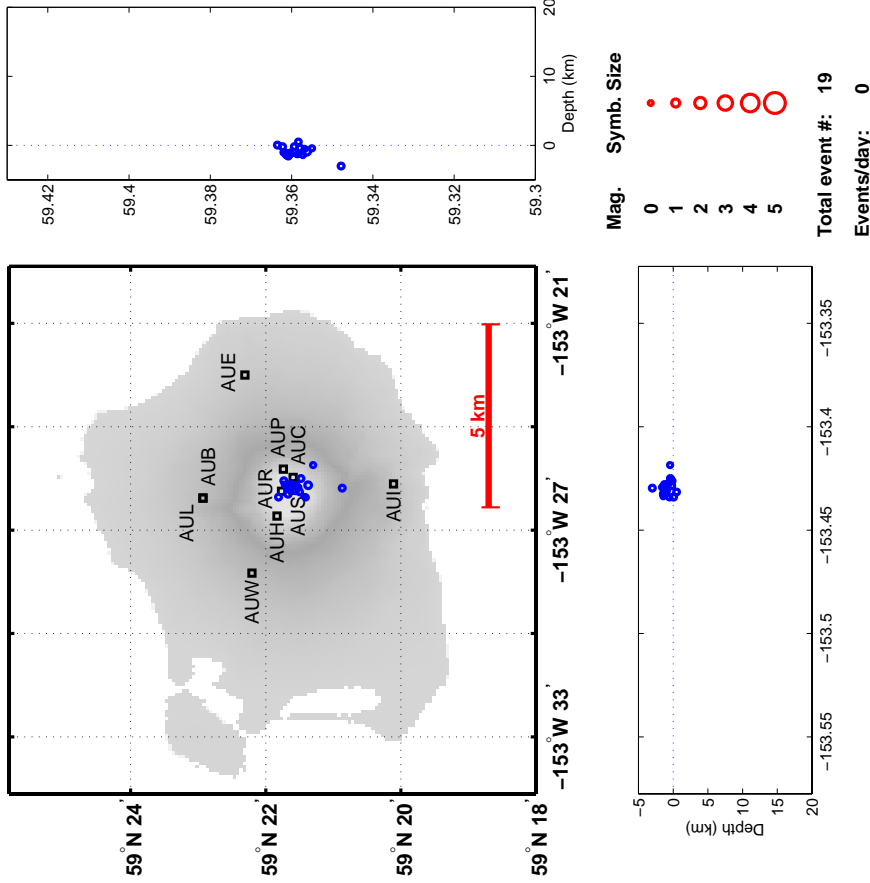


Figure 5b: Locatable Iliamna seismic events in space and time for November through December.

Augustine Volcano Seismicity: 01-Nov-1998 – 01-Jan-1999



Augustine Volcano Seismicity: 01-Sep-1998 – 01-Nov-1998

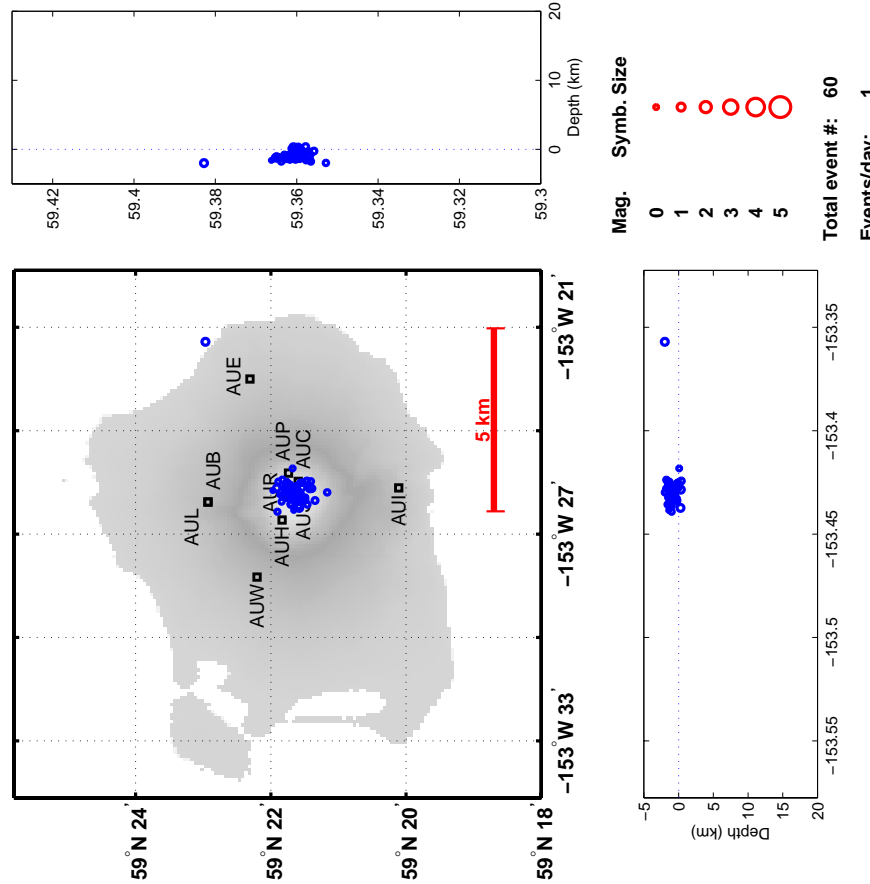


Figure 6b: Locatable Augustine seismic events in space and time for November through December.

Figure 6a: Locatable Augustine seismic events in space and time for September through October.

**Katmai Group 01-Sep-1998 – 01-Nov-1998**

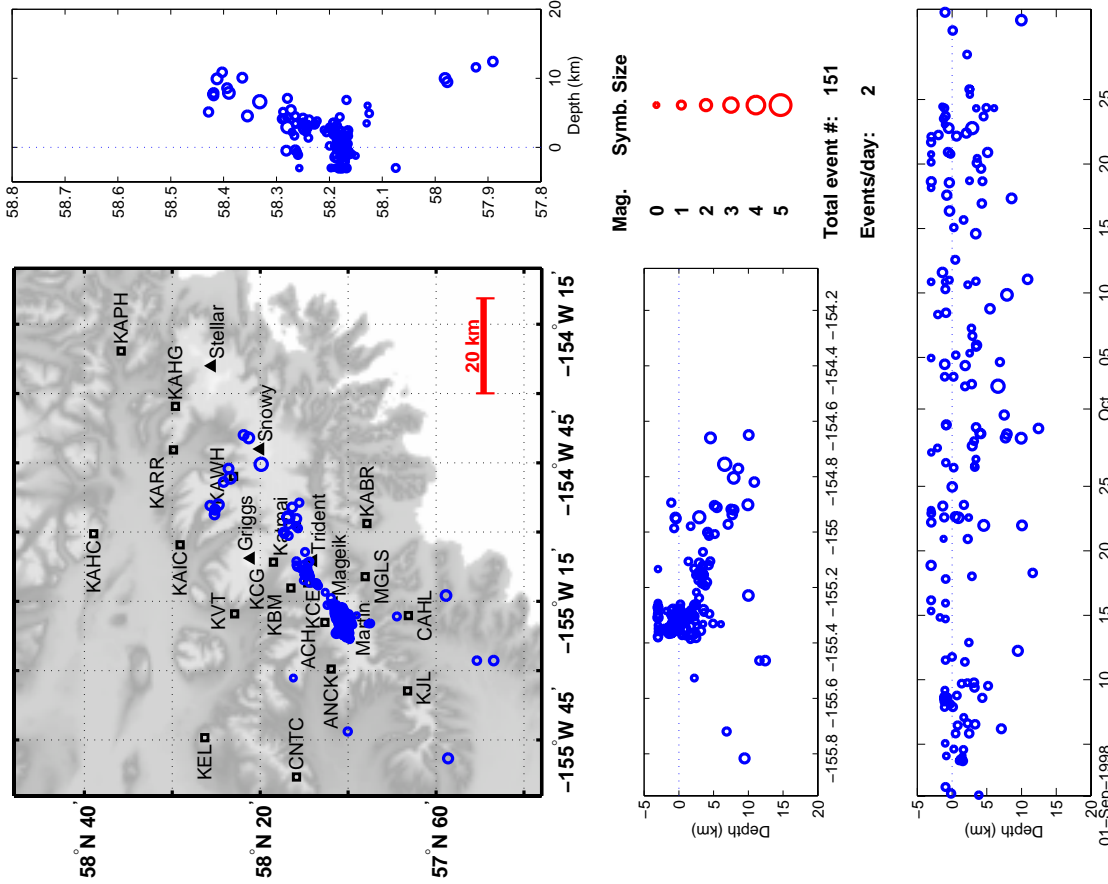


Figure 7a: Locatable Katmai seismic events in space and time for September through October.

**Katmai Group 01-Nov-1998 – 01-Jan-1999**

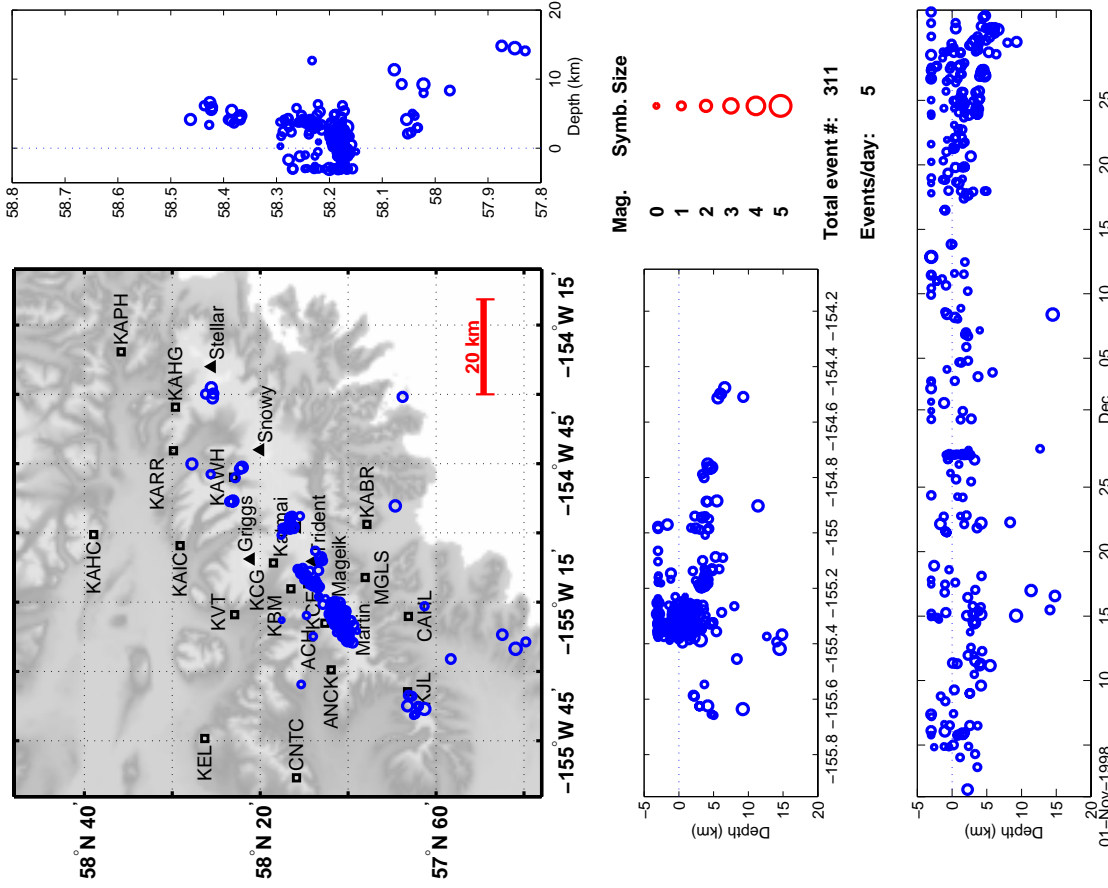
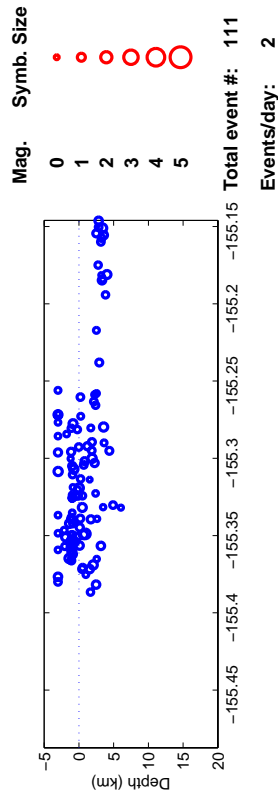
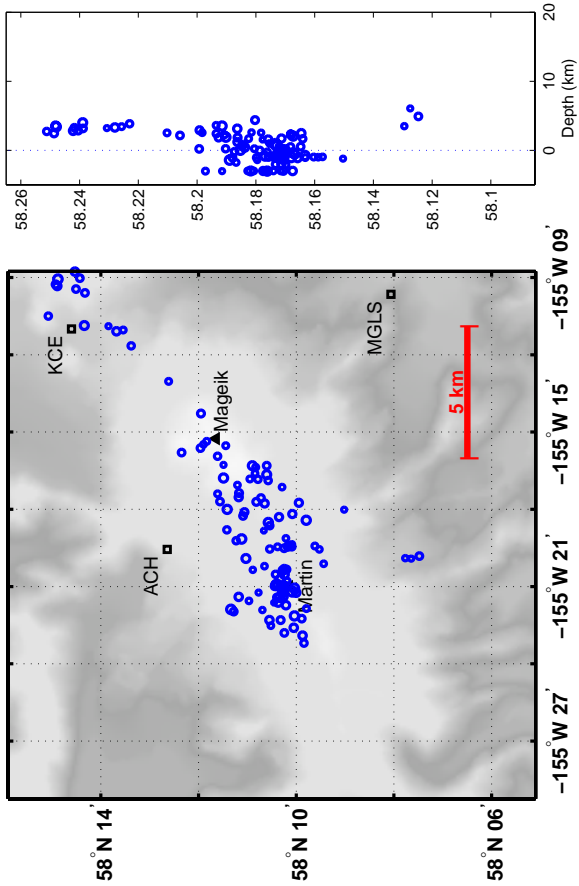


Figure 7b: Locatable Katmai seismic events in space and time for November through December.



Martin/Mageik Volcano Seismicity 01-Sep-1998 - 01-Nov-1998



Martin/Mageik Volcano Seismicity 01-Nov-1998 - 01-Jan-1999

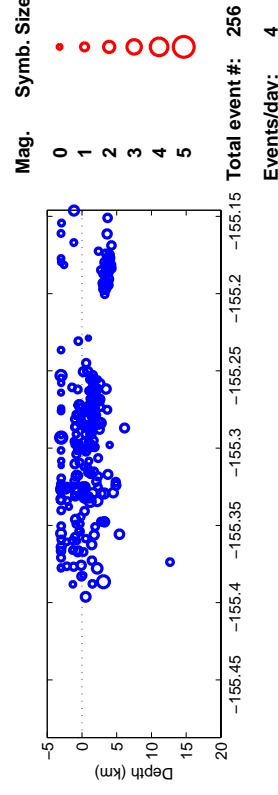
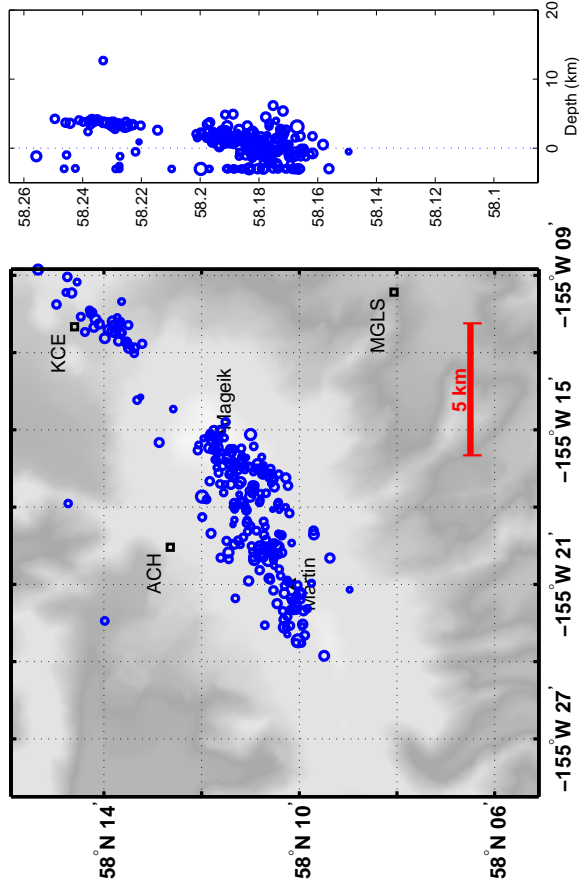
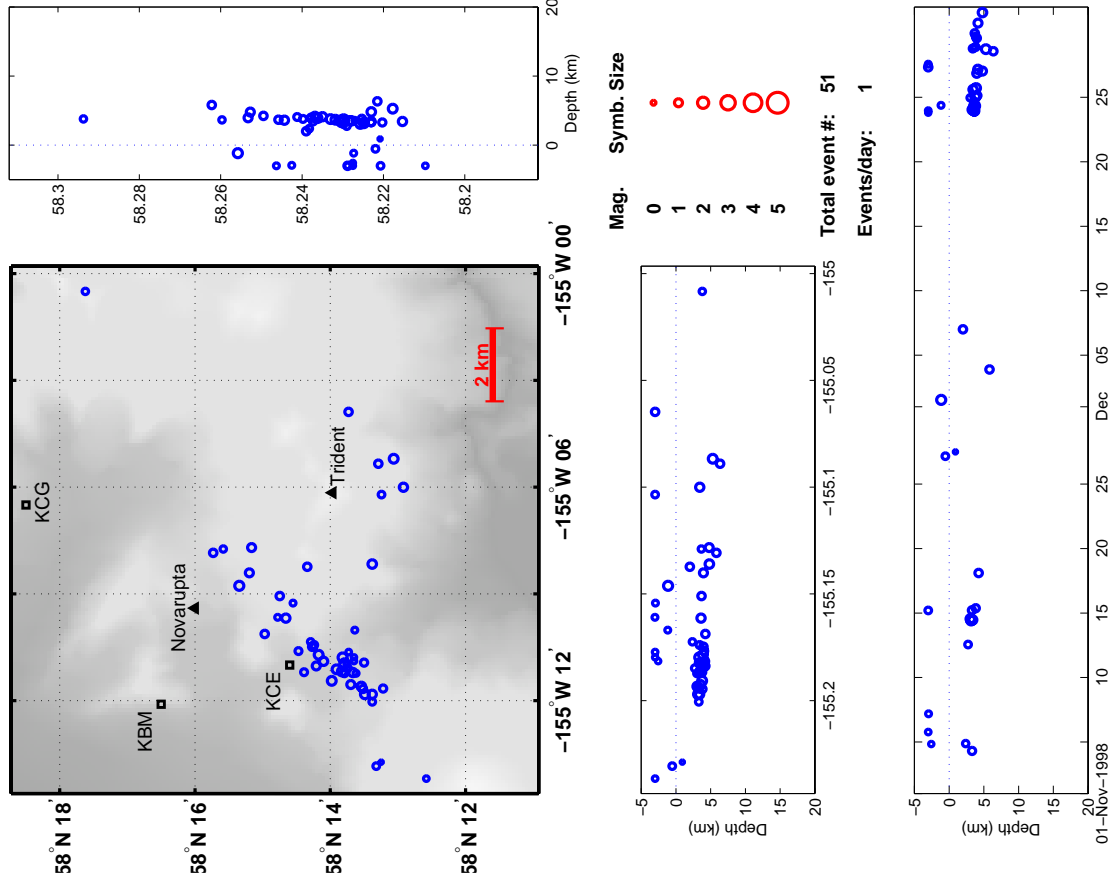


Figure 8a: Locatable Martin/Mageik seismic events in space and time for September through October.

Figure 8b: Locatable Martin/Mageik seismic events in space and time for November through December.

Novarupta/Trident Volcano Seismicity 01-Nov-1998 - 01-Jan-1999



Novarupta/Trident Volcano Seismicity 01-Sep-1998 - 01-Nov-1998

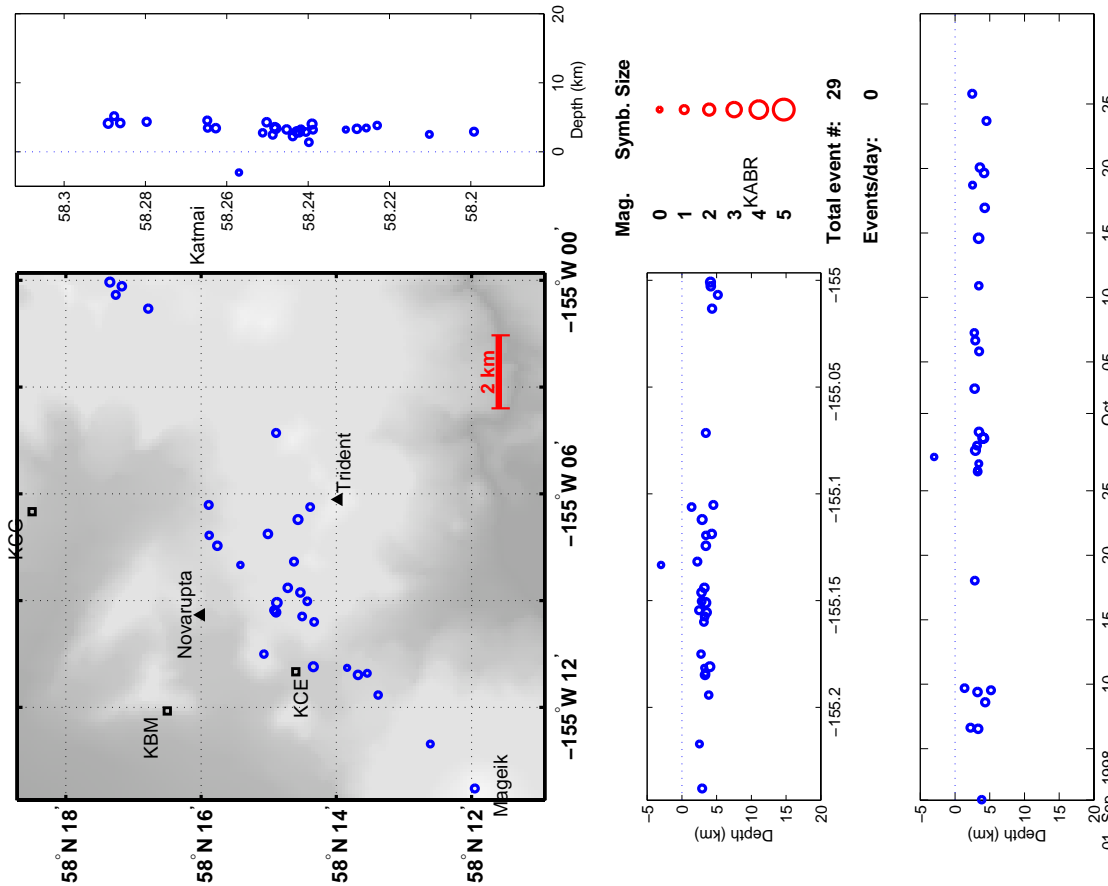


Figure 9a: Locatable Novarupta/Trident seismic events in space and time for September through October.

Figure 9b: Locatable Novarupta/Trident seismic events in space and time for November through December.