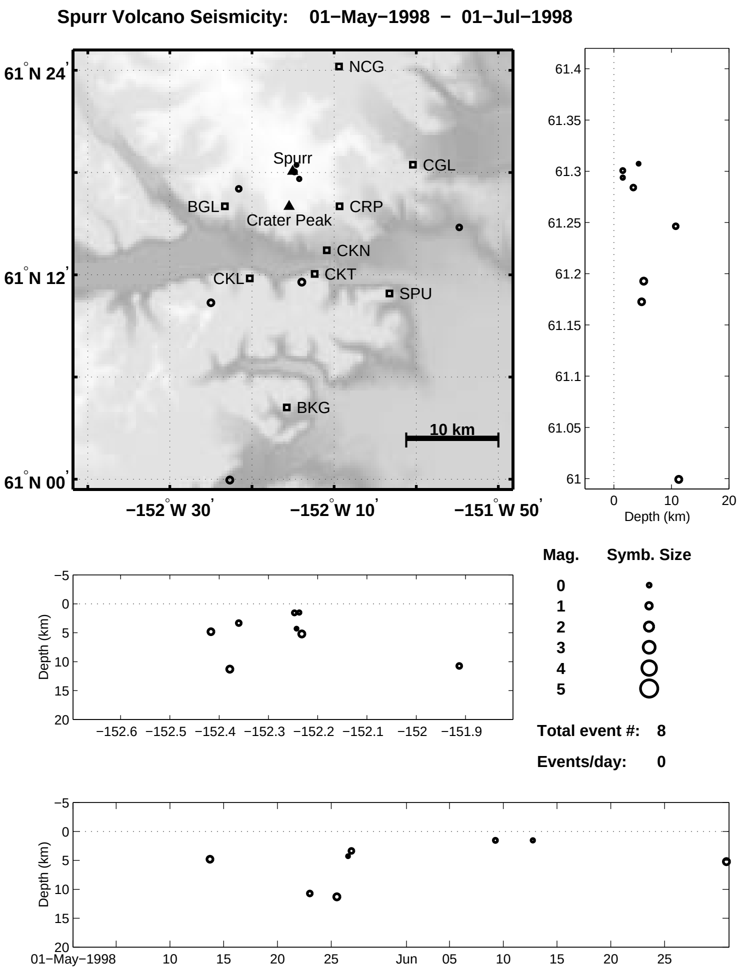

Figure 4a: Locatable Spurr seismic events in space and time for May through June.

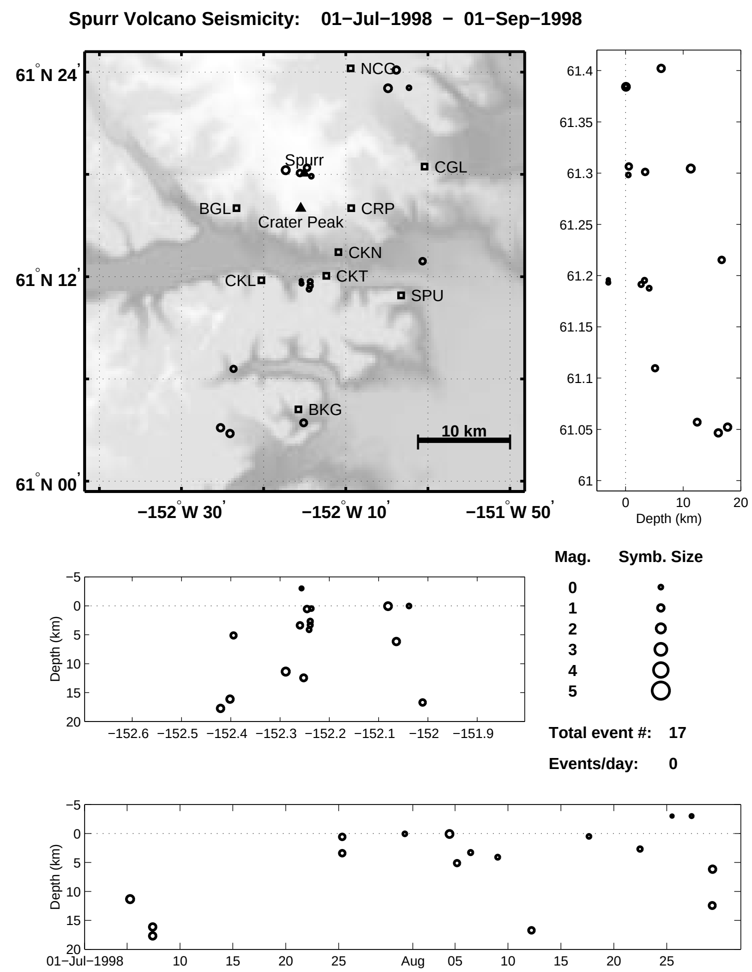

Figure 4b: Locatable Spurr seismic events in space and time for July through August.

Seismicity

Discussion of activity as well as the various plots showing activity are subdivided into May-June and July-August time periods. Guy Tytgat made a few changes to VolPlot, which is the program used to produce the seismicity maps, cross-sections and time-depth plots. The boundaries for the Spurr seismicity map have been resized such that the vast majority of the Strandline Lake events will not appear on the Spurr map; the Strandline Lake events will appear on a separate map. Another, change was made to incorporate a useful feature that was present in the previous program (i.e. VP) used to generate used maps and time-depth plots (see Bimonthly Reports prior to the July-August 1997 issue for examples of VP plots). Earthquakes having hypocentral depths in excess of 20 km will now be represented by inverted triangles; this symbol will be plotted on the seismicity map and will straddle the 20 km depth (the maximum plotted depth) of the cross-sections and the time-depth plots. Prior to this change to VolPlot, such earthquakes were simply not plotted on the cross-sections and time-depth plots.

Spurr/Strandline Lake Region:

During May and June 1998, there were a total of eight earthquakes located in the general vicinity of Spurr (figs. 4a, 15a and 16a). The largest earthquake had a magnitude of M_L=0.8. This event was located about 17 km south-southwest of the summit of Spurr (~14 km southwest of Crater Peak). Of the eight located events, half had epicentral distances of over 10 km from the summit. These earthquakes are probably regional tectonic events unrelated to volcanic activity in the Spurr area. The remaining four events were located in close proximity (<10 km) to the summit. The largest such event had a magnitude of M_L=0.4 and was located about 6 km west-southwest of the summit. The other three “proximal” events were located within 1 km of the summit. The four proximal events all had hypocentral depths of less than 5 km.

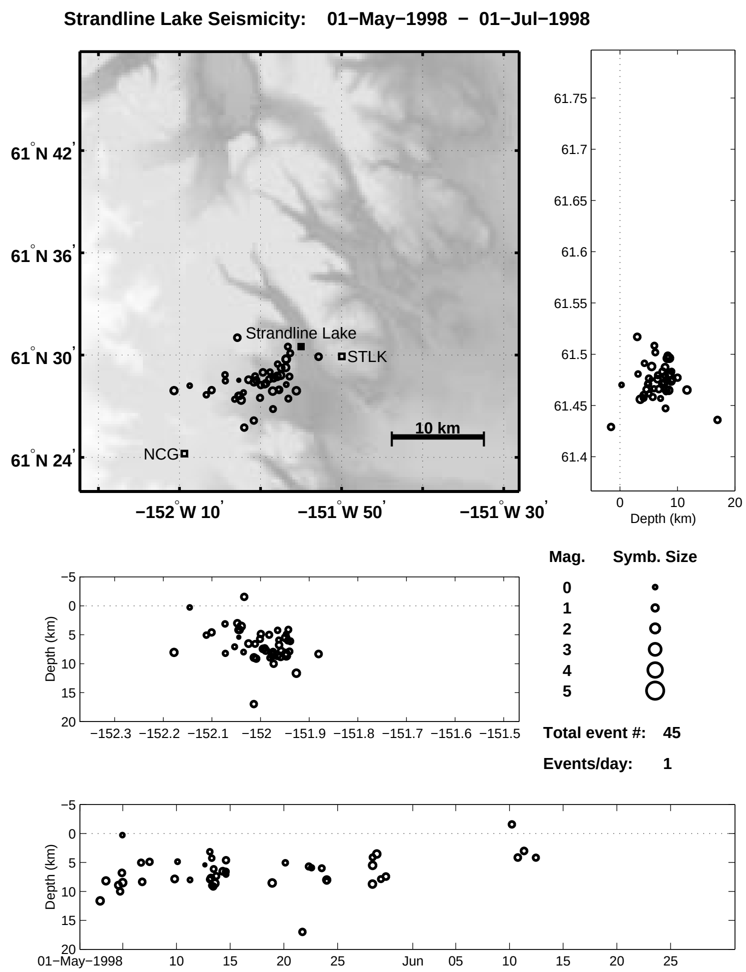

Figure 5a: Locatable Strandline Lake seismic events in space and time for May through June.

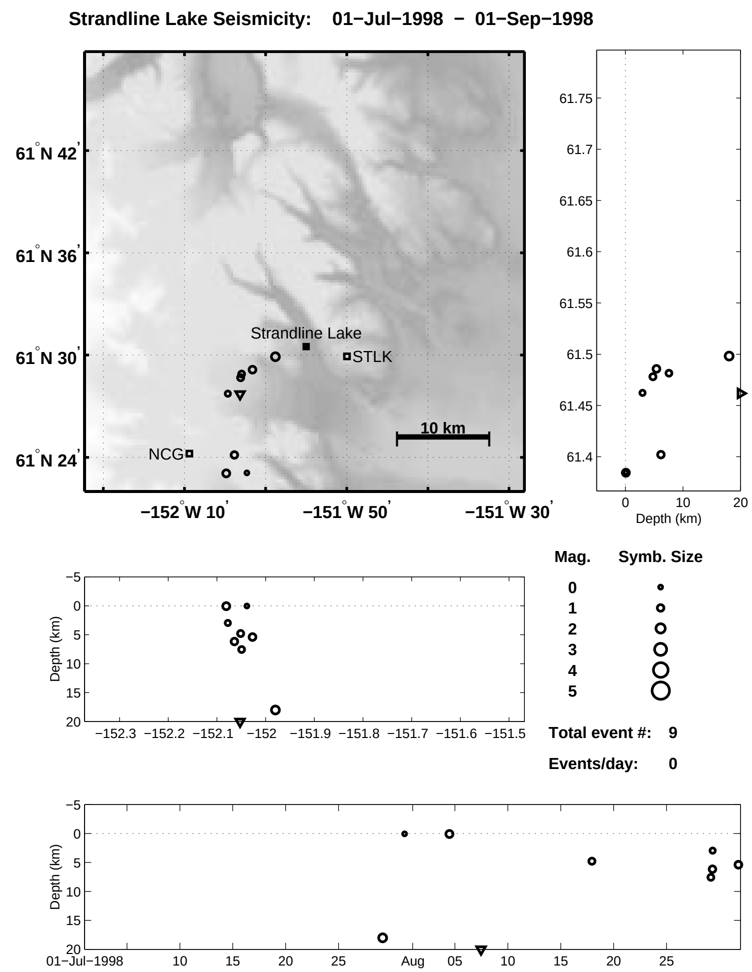

Figure 5b: Locatable Strandline Lake seismic events in space and time for July through August.

The observed rate of seismicity within 10 km of the summit is lower than the 4-year mean rate of 8 events per month. The main reason for this is problems with telemetry, rather than a real change at the volcano. One of the data phone lines, a 56 KB line, was noisy during June and was terminated on June 22. After that date, 5 stations were temporarily not recorded on the standard AVO system (stations CKT, CP2, CRPN, NCG, and RDT). These stations were telemetered and recorded on a digital system instead, and were not used for routine analyses. New software and hardware are needed to convert the digital data to AVO's analog format. Acquisition and implementation of such equipment and software is in progress. Although the stations appeared to be operational during May, only two events were located within 10 km of the summit. This value is much lower than the eight located earthquakes per month expected from the 4-year mean seismicity rate.

A total of 45 earthquakes, the largest of which had a magnitude of M_L=1.1, were located in the Strandline Lake region during May and June 1998 (fig. 4a). These events are believed to be part of a persistent swarm of regional tectonic earthquakes. However, it is also possible that they may be driven by volcanic processes. With continued monitoring of such seismicity, this issue may eventually be resolved. Location of the Strandline Lake events was particularly affected by station outages, problems with the 56 kilobaud telephone line and it's subsequent termination. This is because station STKL has not been in operation since shortly after its installation in the summer of 1997 and the noise associated with the 56 kilobaud telephone line rendered station NCG nearly useless. NCG was also one of the stations no longer recorded by AVO when this telephone line was finally terminated.

The station outages that plagued the Spurr network during June continued to do so during July and, to a lesser extent, August. Also, those stations lost during the termination of the 56 kilobaud line were still not being recorded by AVO, while we awaited delivery and testing of the hardware and software

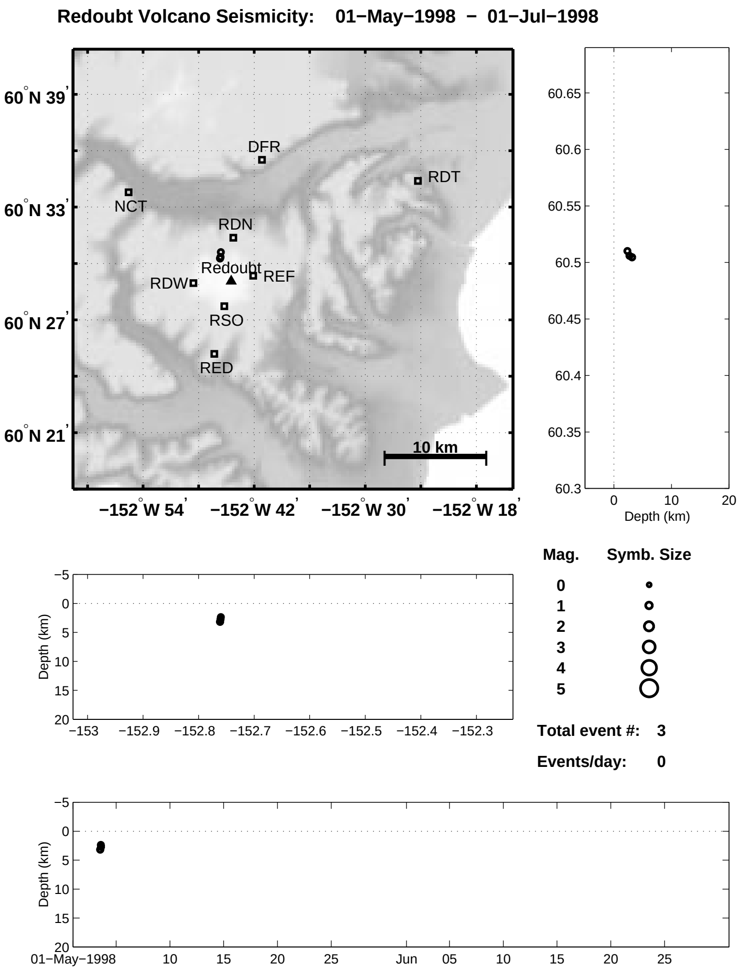

Figure 6a: Locatable Redoubt eismic events in space and time for May through June.

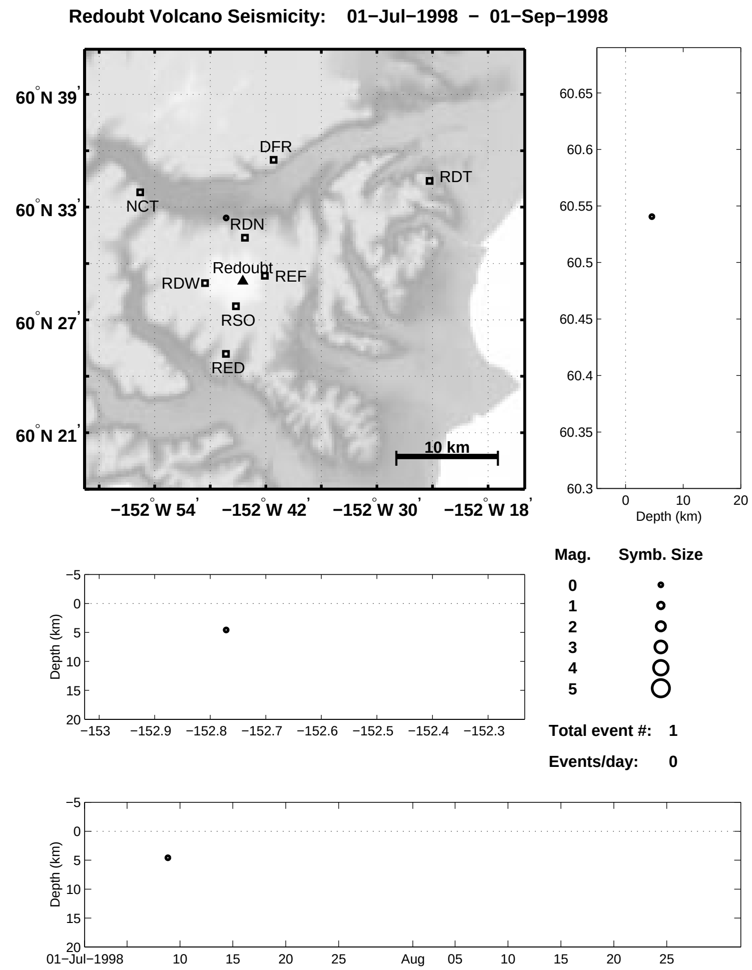

Figure 6b: Locatable Redoubt seismic events in space and time for July through August.

needed to carry out the digital to analog data conversion. A total of 17 earthquakes were located in the Spurr region during July and August 1998 (figs. 5b, 15b and 16b). The largest of these events had a magnitude of M_L=1.3 and was located about 2 km west-northwest of the summit at a depth of about 11 km. There were a total of four events within 10 km of the summit. The additional three such events were all located within 1 km of the summit. Two of these events had hypocentral depths of less than 1 km while the third event had a depth of 3 km. Since the remaining 13 earthquakes were all located some distance from both Spurr and Crater Peak they are probably regional events unrelated to volcanic activity in this area.

A total of only nine earthquakes were located in the Strandline Lake region during July and August 1998 (fig. 5b). The largest of these events had a magnitude of M_L=1.4. Since this event has a hypocentral depth of slightly over 20 km it is represented by an inverted triangle, thus illustrating the modification made to VolPlot (fig. 5b). The three events near station NCG in the Spurr seismicity map (fig. 4b) also appear to be Strandline Lake events. The reason so few of these earthquakes were located in this region during this two-month period is that not only were the two nearest stations, NCG and STLK, unavailable for routine processing, but the next closest station, CGL, was also not functioning during July and about half of August.

Redoubt:

During May and June the data from the Redoubt network suffered from station outages as well as the problems associated with the telephone line used to relay the seismic data to Fairbanks. During May and June 1998 only three earthquakes, the largest of which had a magnitude of M_L=0.6, were located in the Redoubt region (figs. 6a, 15a and 16a). These three events were located about 2-3 km north-northwest of the summit of Redoubt and had hypocentral depths of 2-3 km.

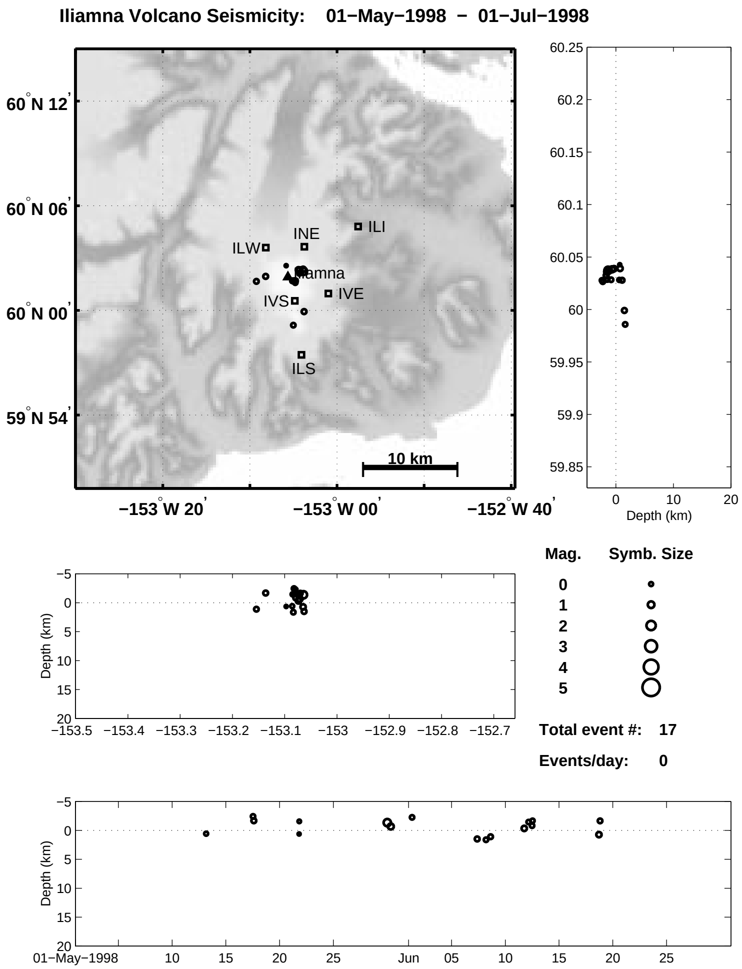

Figure 7a: Locatable Iliamna seismic events in space and time for May through June.

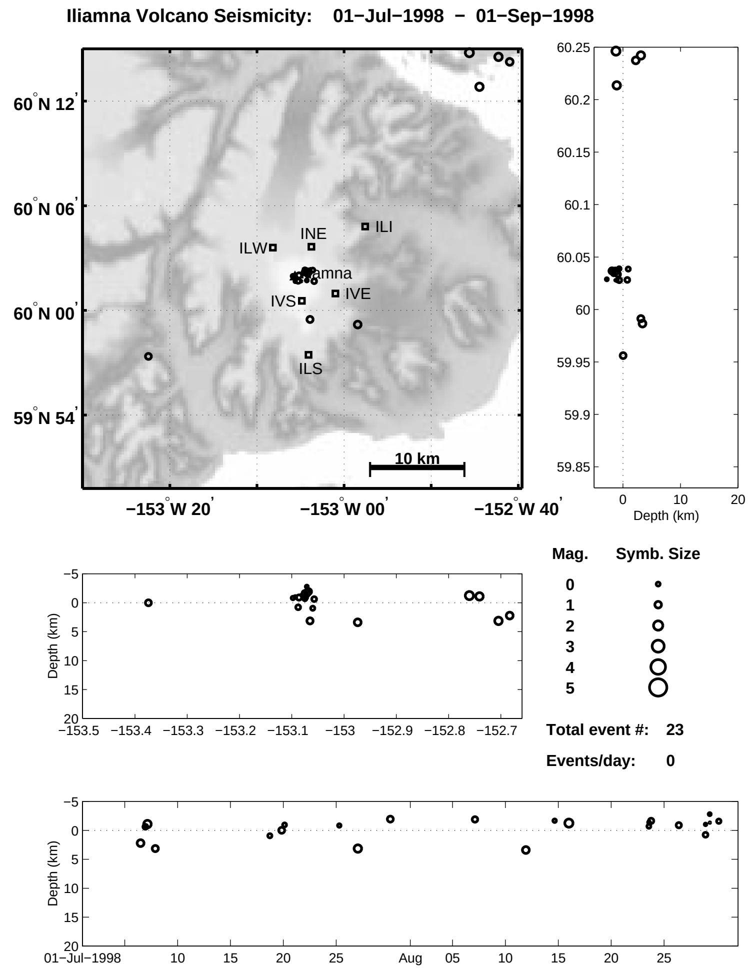

Figure 7b: Locatable Iliamna seismic events in space and time for July through August.

Only one of the Redoubt stations recorded by AVO, RDT, was adversely affected by the termination of the 56 kilobaud line. The loss of this single station probably had less effect on the detection and location of Redoubt earthquakes than the station outages and problems with the telephone line. Based upon the 4-year mean seismicity rate for Redoubt, one would expect there to be about 15 earthquakes located within 10 km of the summit during a two-month interval. The discrepancy between the observed number of events and this estimate probably results from the fact that the detection threshold at Redoubt was severely compromised during this time period.

Problems with respect to station failures at Redoubt continued throughout July and August 1998. During this two-month period, only one earthquake was located in the vicinity of Redoubt (figs. 6b, 15b and 16b). This earthquake had a magnitude of M_L=0.0 and was located about 6 km north-northwest of the summit at a depth of about 5 km.

Iliamna:

A total of 17 earthquakes were located in the vicinity of Iliamna during May and June 1998 (figs. 7a, 15a and 16a). The largest had a magnitude of M_L=1.3 and was located 2 km east-northeast of the summit at a depth of -1 km (i.e. 1 km above sea-level). This event was part of a cluster of seven earthquakes located 2-3 km east-northeast of the summit. There is also a second cluster of six events, 0.5-1 km southeast of the summit. Two events were located 3 km southwest of the summit. The remaining two earthquakes were located 3-4 km west of the summit. The number of events located in the vicinity of Iliamna during May and June is fairly low compared to the 28 such events predicted from the 10-month mean seismicity rate for Iliamna.

During July and August 1998, a total of 23 earthquakes were located at Iliamna and the surrounding region (figs. 7b, 15b and 16b). The largest such event had a magnitude of M_L=1.6. This event and three others were located 30 km northeast of

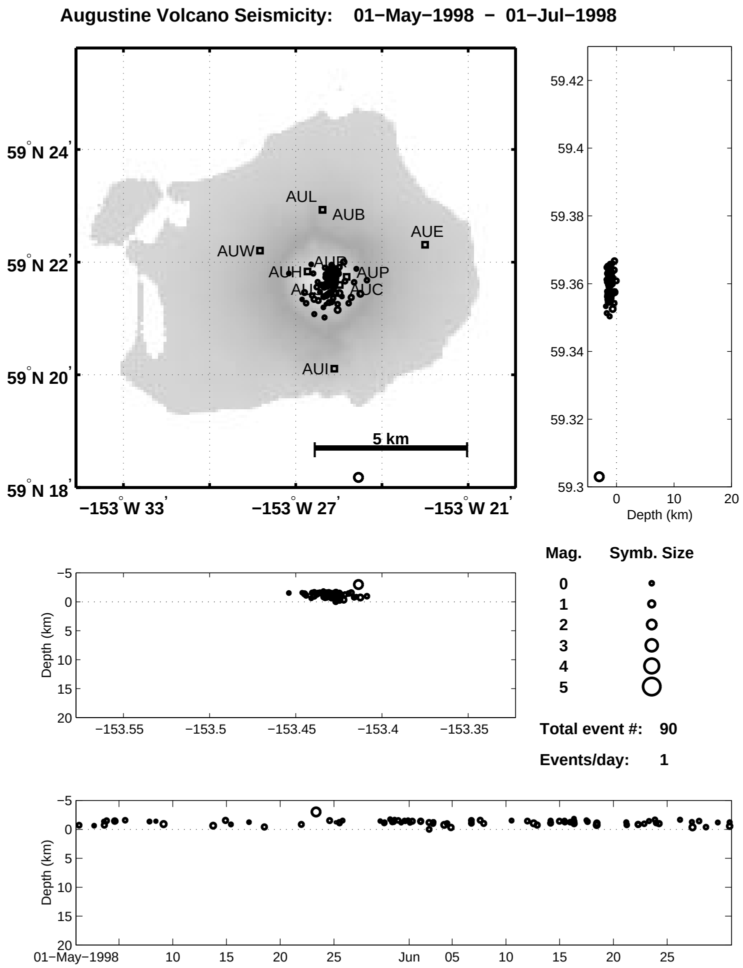

Figure 8a: Locatable Augustine seismic events in space and time for May through June.

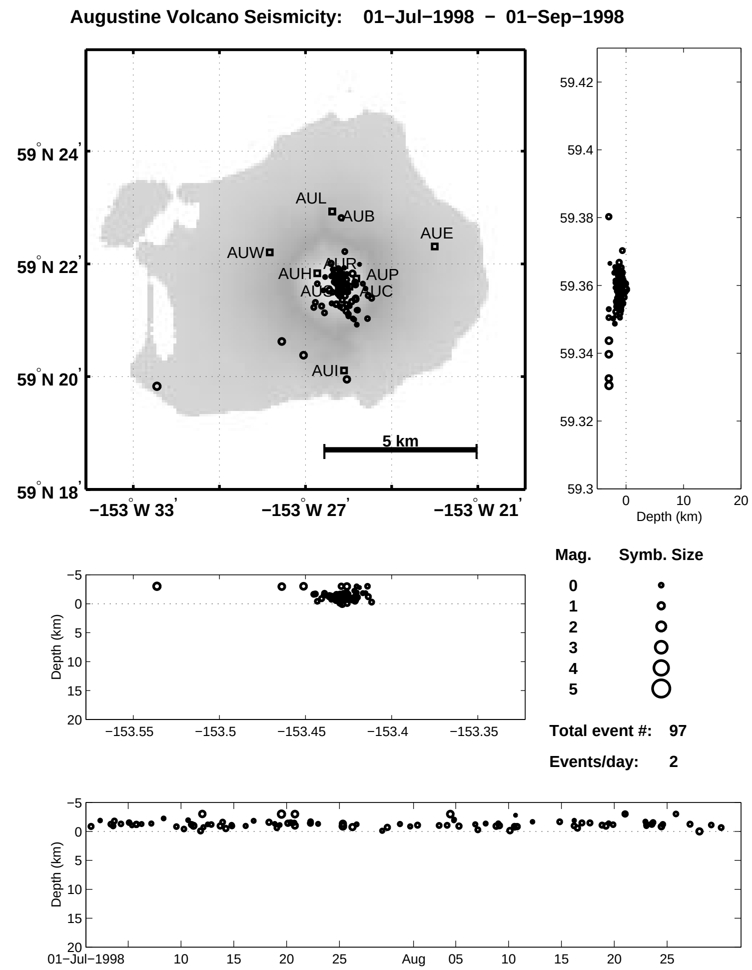

Figure 8b: Locatable Augustine seismic events in space and time for July through August.

Iliamna. Because of their distance from Iliamna, we conclude that these events are tectonic events unrelated to volcanic activity at Iliamna. Another likely regional tectonic event is the earthquake located 20 km west-southwest of Iliamna. Therefore, there appear to have been only 18 earthquakes that actually were associated with Iliamna. All but two of these events were located in a zone that included the summit and extended 2 km to the east. One of the remaining two earthquakes was located 5 km south-southeast of the summit. This event had a magnitude of M_L=0.9 and was thus the largest earthquake located close to Iliamna during this two-month period. The final event was located 8 km southeast of the summit. As was the case with the previous two-month period, the number of located events at Iliamna is lower than the estimated number of events predicted from the 10-month mean seismicity rate.

Augustine:

A total of 90 earthquakes were located in the vicinity of Augustine during May and June 1998 (figs. 8a, 15a and 16a). The largest event located in the region during this two-month period had a magnitude of M_L=1.7 and was located offshore 7 km south of the summit. The waveform of this event was similar to typical Augustine events, but the S-waves were quite different. Unlike usual Augustine events, this event has what appears to be clear S-arrivals with S-P times of about 2-3 seconds, as opposed to the subtle S-waves and S-P times of less than a second, which is generally the case. This event may simply be a regional tectonic earthquake that happens to be located near Augustine Island. If so, the similarity of its waveform to that of typical Augustine events is somewhat puzzling. This similarity may be due to the fact that much of this event's ray path was spent within the rocks comprising Augustine Island, and thus was subjected to the same natural filtering normally experienced by Augustine events.

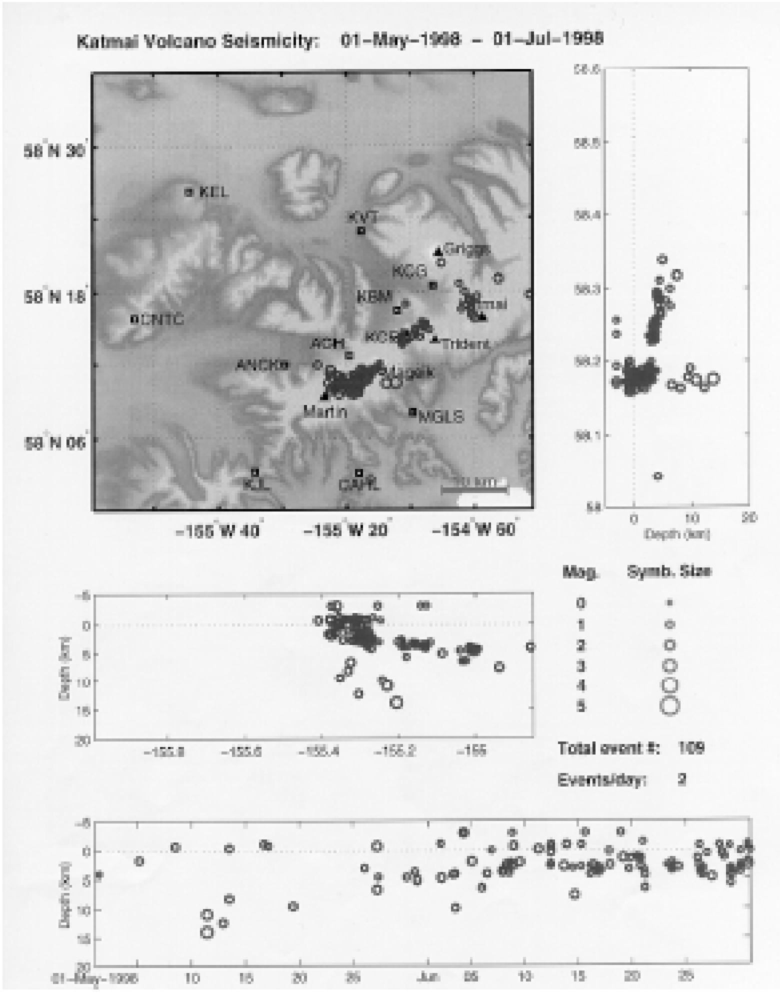

Figure 9a: Locatable Katmai seismic events in space and time for May through June.

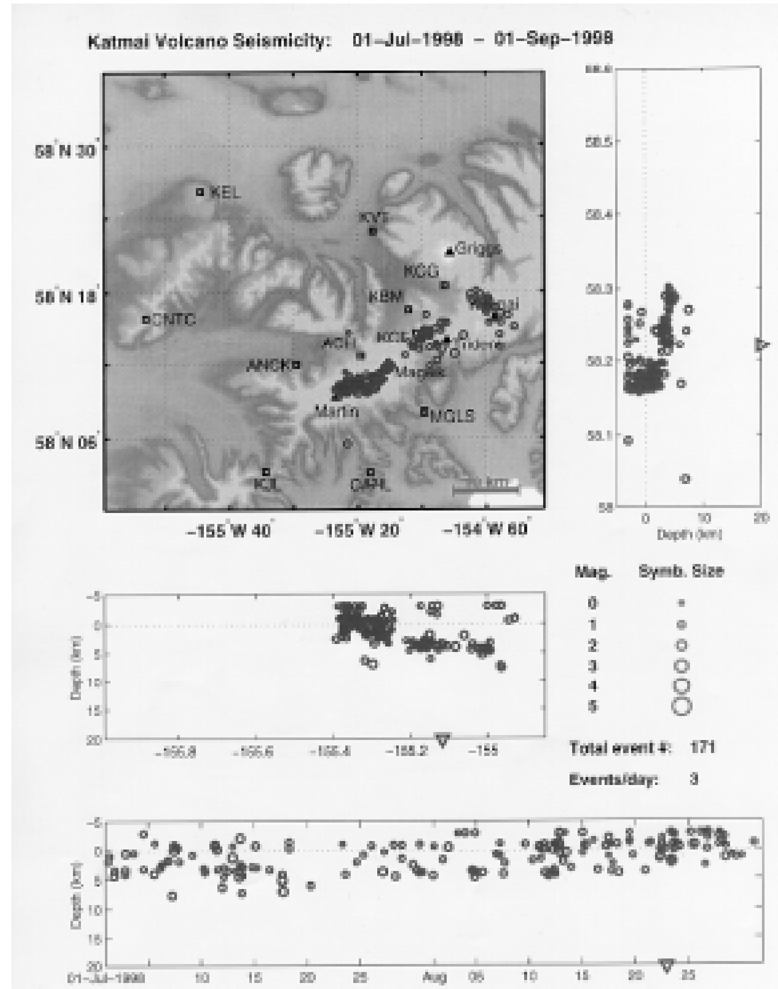

Figure 9b: Locatable Katmai seismic events in space and time for July through August.

The remaining 89 located earthquakes were all located within about 1.5 km of the summit. These events had shallow hypocentral depths which placed them within the volcanic pile. The number of events located at Augustine during this two-month period exceeds that of the previous two-month period and far exceeds the 17 located events predicted from the 4-year mean seismicity rate.

There were a total of 97 earthquakes located in the Augustine region during July and August 1998 (figs. 8b, 15b and 16b). The largest Augustine event located during this period had a magnitude of M_L=1.0 and was located about 7 km west of the summit. This event, as well as the other four outlying events (i.e. events not part of the main summit cluster), are similar with respect to waveforms to the outlying event located during May. These events appear to have clear S-arrivals and S-P times that are significantly greater than that of typical Augustine earthquakes. Since these events were actually located beneath Augustine Island, it is much more difficult to dismiss these as being regional tectonic events. All five of these outlying events seem to be real; they do not appear to be comprised of multiple overlapping events which could give the impression of there being single events with clear S-arrivals. At present, it is unclear what significance should be placed on them. They may be of importance in that they may be the result of a change in the local stressfield. Doug Lalla (personal comm.), noted that several non-summit events were located at Augustine prior to the 1976 eruption.

The remaining 92 earthquakes were all located in the summit region (i.e. within 2 km of the summit). The largest of these events had a magnitude of M_L=0.8. The total number of Augustine events located during July and August was slightly greater than that of the previous two-month period. The level of activity observed at Augustine during July and August is greater than what has been observed since the 44 earthquakes located there during April 1998. Although this is significant, one must keep this in perspective by realizing that the detection threshold and location

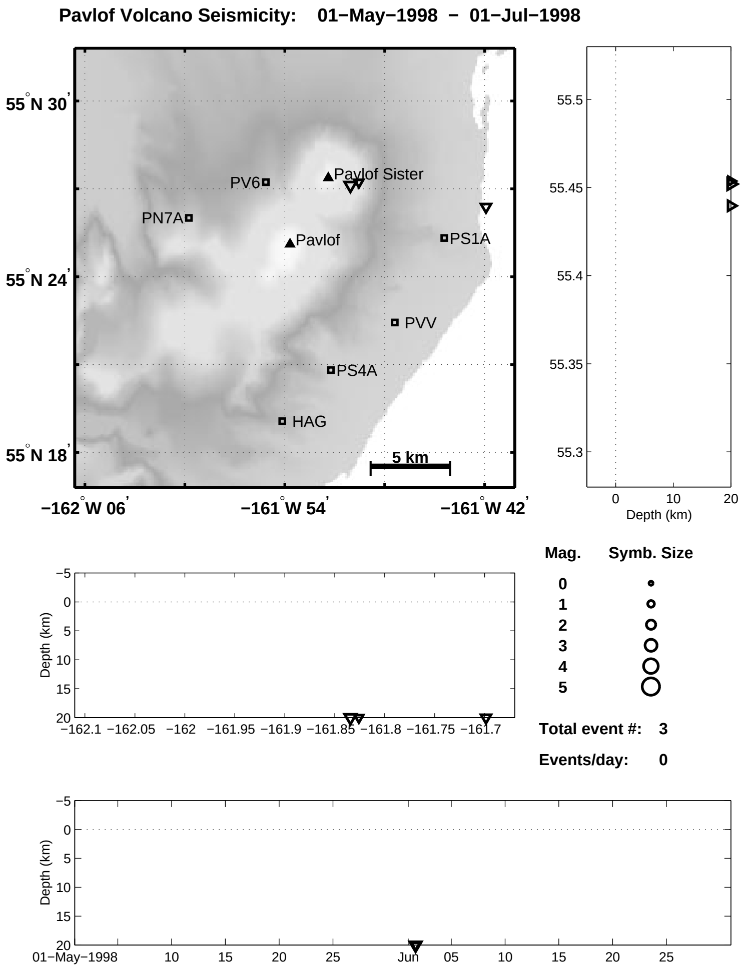

Figure 10a: Locatable Pavlof seismic events in space and time for May through June.

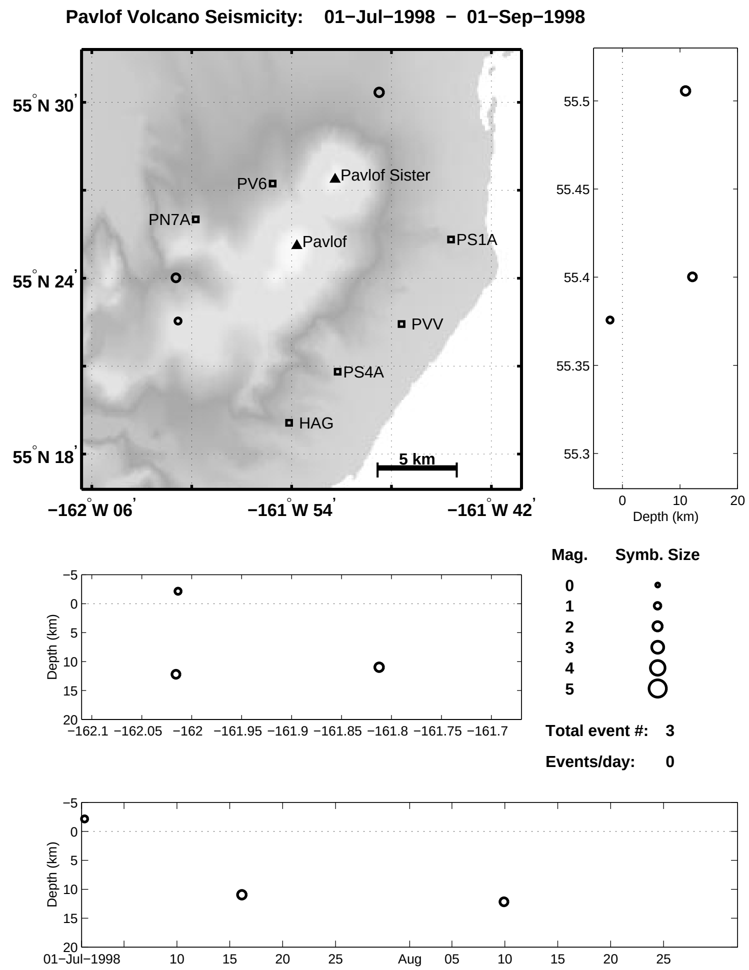

Figure 10b: Locatable Pavlof seismic events in space and time for July through August.

capability underwent a significant improvement in September 1997 when station AUC was added to the acquisition system. Therefore, care must be taken when making comparisons of the present level of seismicity to periods prior to September 25, 1997. Also, the Augustine stations have had an unprecedented "survival" rate this past year, which may also account for the detection and location of more earthquakes than were previously observed.

Katmai:

During May and June, a total of 109 earthquakes were located in the Katmai/ Valley of Ten Thousand Smokes region (figs. 9a, 15a and 16a). The largest such event had a magnitude of M_L=2.6, which was located about 4 km southeast of Mageik. As usual, the Martin/Mageik area was the most active area. Also as usual, there was spatial clustering of events in the Martin/Mageik, Novarupta/ Trident and Mount Katmai areas. The number of events associated with each of the Katmai region volcanoes for May and June is shown in Table 1. Also given are the corresponding values for the previous two-month interval, those for July and August, as well as the predicted number of events based upon 8-month mean seismicity rates. Earthquakes were designated as being associated with a particular volcano if the distance between the epicenter and the volcano was $\leq$ 5.0 km. If an earthquake happened to be within 5.0 km of more than one volcano the event would be assigned to the volcano closest to it. Epicentral distances were determined using the NEAREST program.

Application of the above criteria can result in some earthquakes not being assigned to any of the volcanoes in the Katmai/Valley of Ten Thousand Smokes region. In the case of the May and June data, only three events were not assigned to a volcano.The total number of events within the map area and those associated with each of the volcanoes for May and June are greater than those for April and May. This is to be expected, because during April many of the Katmai stations were operating only intermittently. The values in Table 1

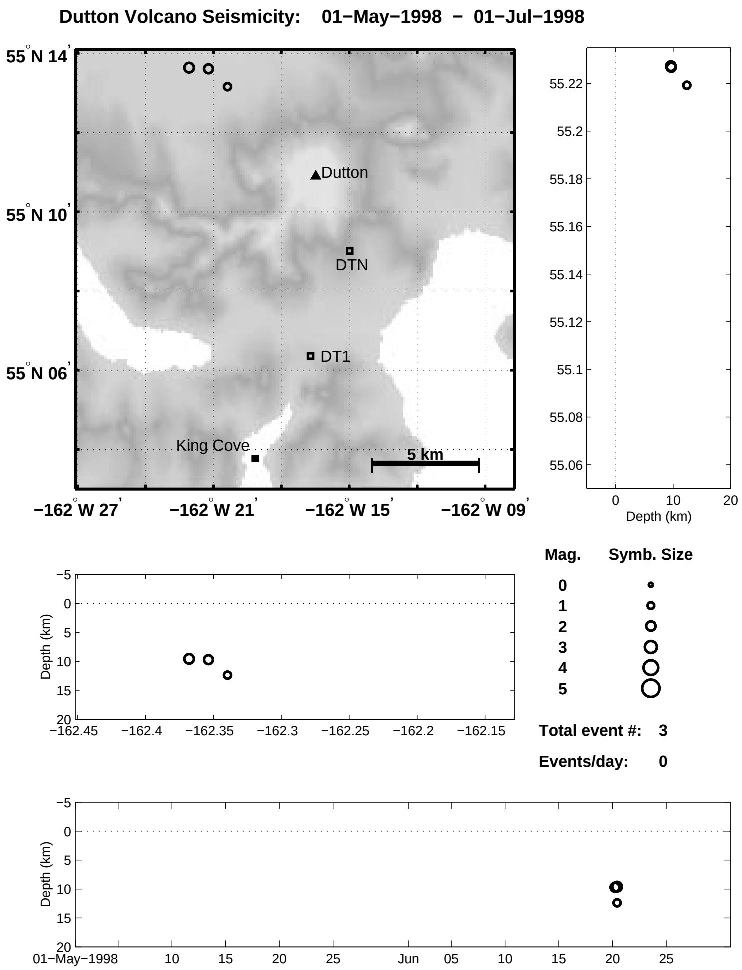

Figure 11a: Locatable Dutton seismic events in space and time for May through June.

Table 1

Volcano Region	March-April 1998	May-June 1998	July-August 1998	Predicted from the Mean Seismicity Rate
Entire Map Area	71	109	171	170
Griggs	0	1	0	1
Katmai	7	11	18	20
Mageik	15	33	37	36
Martin	27	40	72	66
Martin/Mageik	42	73	109	102
Novarupta	13	19	27	28
Trident	1	2	12	8

for May and June, however, are mostly quite a bit lower than the predicted values. The notable exceptions to this are Mageik and Griggs. The number of events located near Mageik is fairly close to the predicted value (33 vs. 36) and the single event associated with Griggs is in agreement with the mean seismicity rate value.

A total of 171 earthquakes were located in the Katmai/Valley of Ten Thousand Smokes region during July and August 1998 (figs, 9b, 15b and 16b). The largest Katmai event located during this two-month period had a magnitude of M_L=2.6 and was located 2 km south-southwest of Trident. This earthquake was a deep low frequency event with a hypocentral depth of 34 km. Based upon its stacked velocity spectrum this earthquake appears to be a deep LP event; the stacked velocity spectrum has the characteristic shape associated with that of other deep LP events (J. Power personal comm.).

The deep LP event seems to have been the only anomaly with respect to seismicity in the Katmai region during July and August. As usual the majority of the seismicity was associated with Martin and Mageik. The typical clusters of activity at Martin/Mageik,Novarupta/ Trident and Mt. Katmai are readily apparent on the seismicity map. Three events were located off the main volcanic axis. One event was located 8 km north of Martin, one was located 9 km south of Martin and the final event was located 15 km south-southeast of Martin. These events, particularly the former, may be regional tectonic earthquakes unrelated to volcanic activity.

As was the case with the May and June data, the Katmai earthquakes for July and August were also assigned to the various volcanoes in the manner described above. For July and August, a total of five earthquakes were not designated as being associated with any of the volcanoes. The number of events associated with each of the volcanoes are summarized in Table 1. With the exception of Griggs, all of the volcanoes had more events than was the case with the May and June data. The values for the July and August data were very similar to values predicted from the mean seismicity rates. The only exception to this was the number of events associated with Trident. In this case, the number of events was much greater (50%) than the corresponding predicted value.

Aniakchak:

No earthquakes were located in the Aniakchak region during May and June or for July and August 1998. Although the histogram of the detected events indicates there were no local Aniakchak triggers during this time, the plot of the Helicorder event counts shows there were at least some small local events (figs.15a and 15b,16a and 16b). There were also no locatable earthquakes at Aniakchak during the previous two-month period. In fact, there has not been a single earthquake located in this region since December 5, 1997.

Pavlof:

There were three deep low frequency events located in the Pavlof region during May and June 1998 (figs. 10a, 15a and 16a). The largest of these events had a magnitude of M_L=2.3 and a hypocentral depth of 34 km. This event was located about 0.5 km east of Pavlof Sister (~5 km northeast of Pavlof). A second event with a hypocentral depth of 31 km was located east of the M_L=2.3 event. The third earthquake was located 9 km east of Pavlof Sister (~12 km east-northeast of Pavlof) and had a hypocentral depth of 32 km. The number of located earthquakes in the Pavlof area during this two-month period was less than that of the previous two-month period (3 events vs. 5 events) but was greater than the two such events predicted from the 1-year mean seismicity rate.

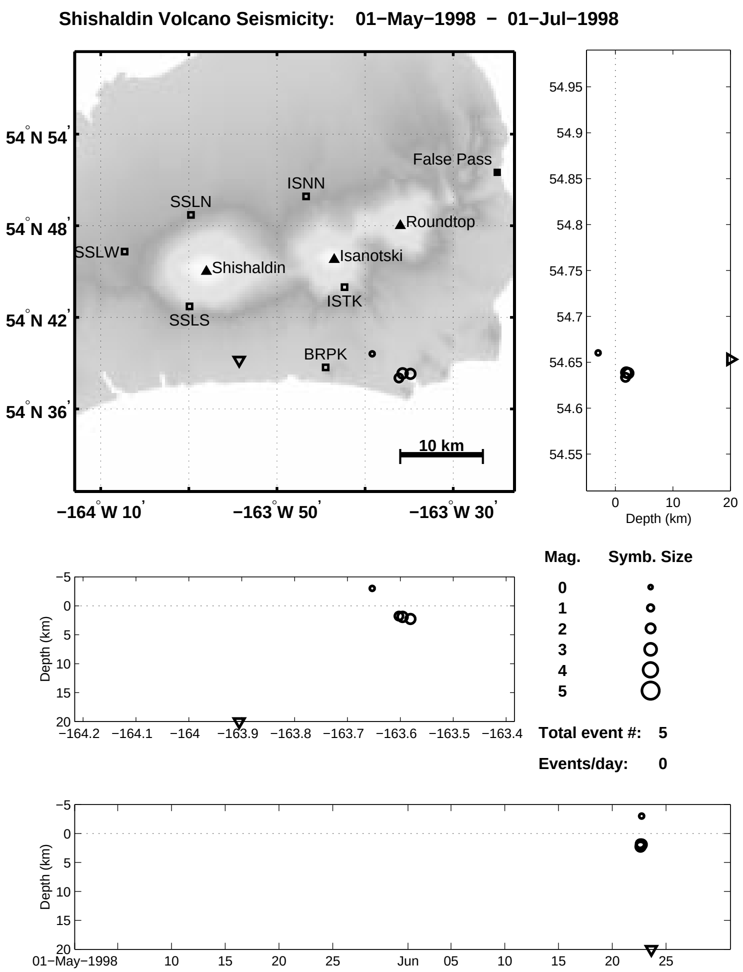

Figure 12a: Locatable Shishaldin seismic events in space and time for May through June.

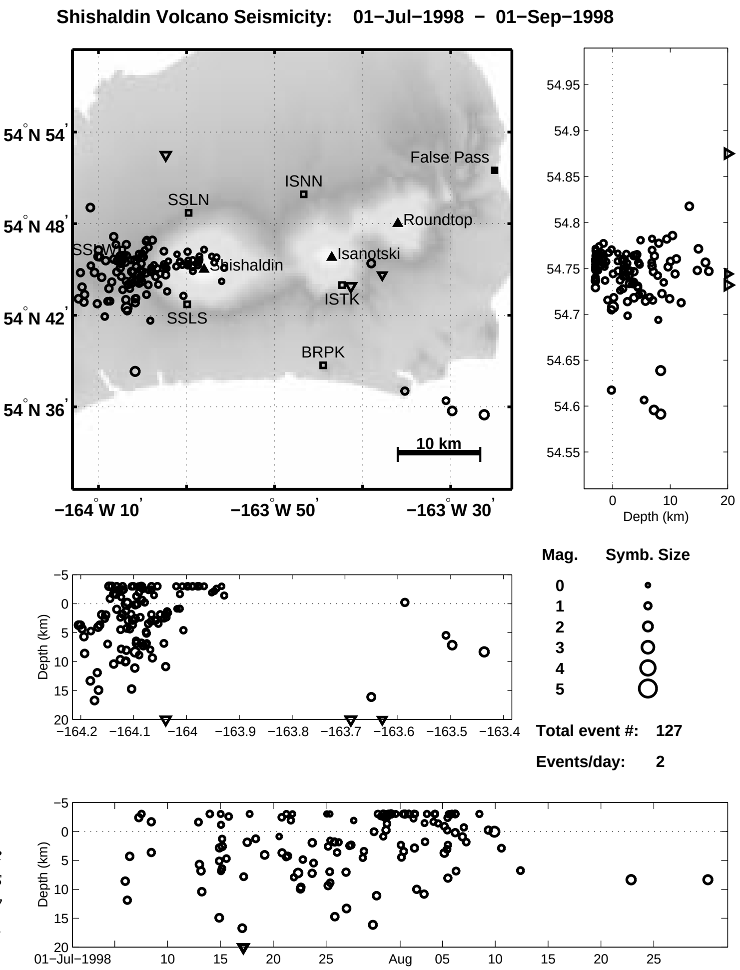

Figure 12b: Locatable Shishaldin seismic events in space and time for July through August.

A total of three earthquakes were located in the Pavlof region during July and August 1998 (figs. 10b, 15b and 16b). The largest event had a magnitude of M_L=1.8 and was located 6 km north-northeast of Pavlof Sister (~11 km north-northeast of Pavlof) with a hypocentral depth of 11 km. One of the remaining two events was located 2 km west-northwest of Hague (~9 km west-southwest of Pavlof). Based upon the relatively low frequencies dominating its waveforms, this event was designated as being a b-type event. This fact combined with an above sea-level hypocentral depth suggests that this earthquake may be an icequake or glacial event. The final earthquake in this region was located 4 km north-northwest of Hague (~8 km west-southwest of Pavlof) at a depth of 12 km. As noted above, three located events over a two-month period is greater than would be predicted using the mean seismicity rate.

Dutton:

Three earthquakes were located in the Dutton area during May and June 1998 (figs. 11a, 15a and 16a). These events were located 6-8 km northwest of Dutton with hypocentral depths of ~10-12 km. The largest of these earthquakes had a magnitude of M_L=2.1. All three of these events occurred during a single day (June 20, 1998). The number of events located in the Dutton region during May and June was greater than that of March and April (3 events vs. 1 event). This value was also much greater than the number of located events predicted from the 1-year mean seismicity rate (3 events vs. 0.6 events).

No earthquakes were located in the Dutton region during July and August 1998. There were also no local events large enough to trigger the event detection and acquisition system (fig.15b). There were, however, six events too small to trigger the acquisition system but sufficiently large to be counted and thus appear in the plot of the Helicorder event counts (fig.15b).

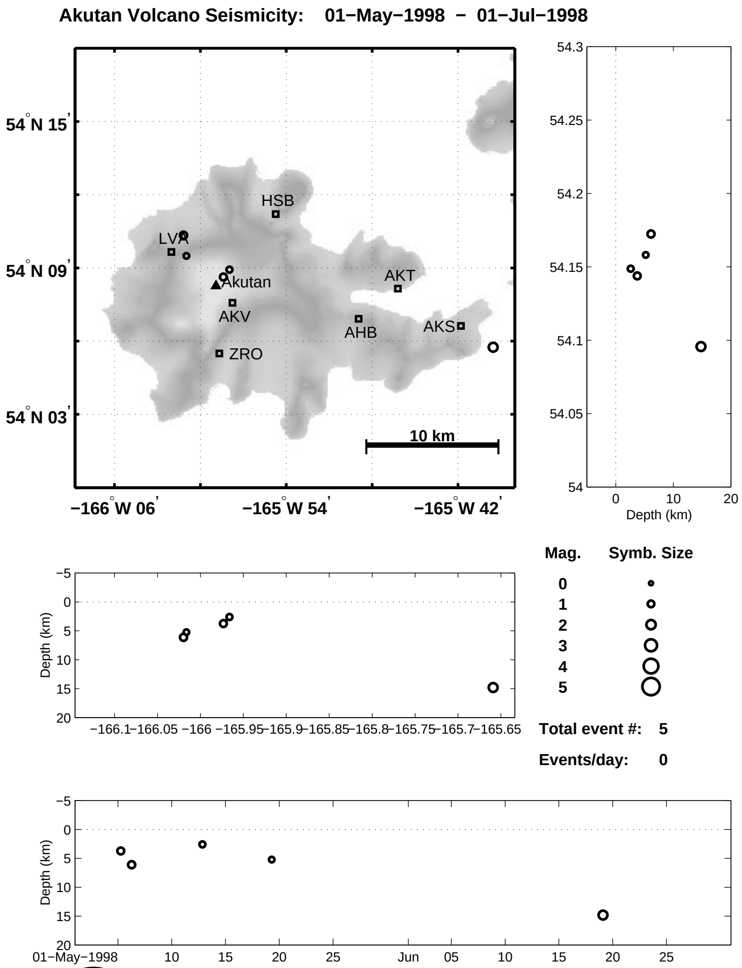

Figure 13a: Locatable Akutan seismic events in space and time for May through June.

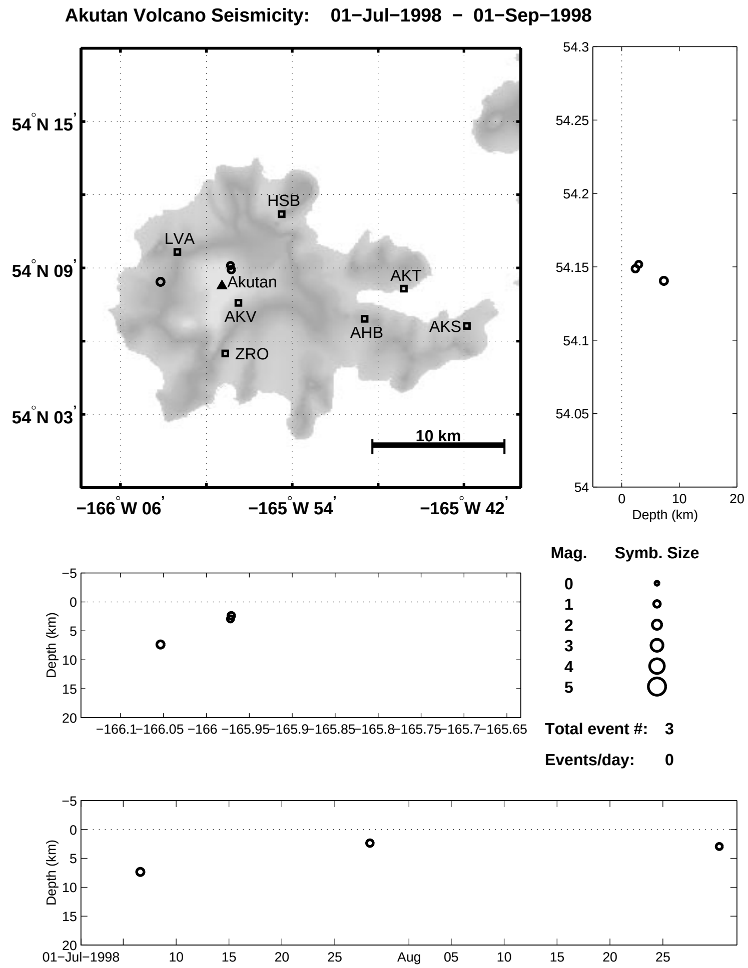

Figure 13b: Locatable Akutan seismic events in space and time for July through August.

Shishaldin:
A total of five earthquakes were located in the Shishaldin region during May and June 1998 (figs. 12a, 15a and 16a). The largest located event had a magnitude of M_L=2.2 and was located along the southeastern coast of Unimak Island 2 km north of Cape Lazaref at a depth of 4 km. Three of the four remaining events were also located in this area. One event was located 12 km south-southeast of Shishaldin. Due to the relatively low frequencies of its waveforms, this event was designated as being a b-type event. These low frequencies may be due to the natural filtering of the higher frequency components by the earth, which is particularly apparent in deep earthquakes. Since this event was located at a hypocentral depth of over 50 km it was certainly subjected to filtering. The number of events located in the Shishaldin area during May and June was the same as that of the previous two-month period. This value, however, was much lower than the 15 events predicted based upon the mean seismicity rate. This fairly large discrepancy between the observed and the predicted number of located events may indicate that the 4-months over which the mean seismicity rate was determined included a period of anomalous seismicity which has thus skewed the results of the rate calculation.

One such period of anomalous activity in the Shishaldin area appears to have taken place during July and August 1998 (figs. 12b, 15b and 16b). During this two-month period of time, a total of 127 earthquakes were located in the general vicinity of Shishaldin. The largest event located had a magnitude of M_L=1.8 and occurred about 4 km south-southeast of Isanotski (~18 km east of Shishaldin) with a hypocentral depth of 29 km. Two other relatively deep earthquakes (i.e. Z > 15 km) were located fairly close to the M_L=1.8 event. Based upon their relative arrival times, these three events do not appear to have been significantly mislocated but rather appear to have originated from a region distinct from that of the vast majority of the Shishaldin earthquakes (i.e. west of Shishaldin). The third deep event was located 14 km north-northwest of the

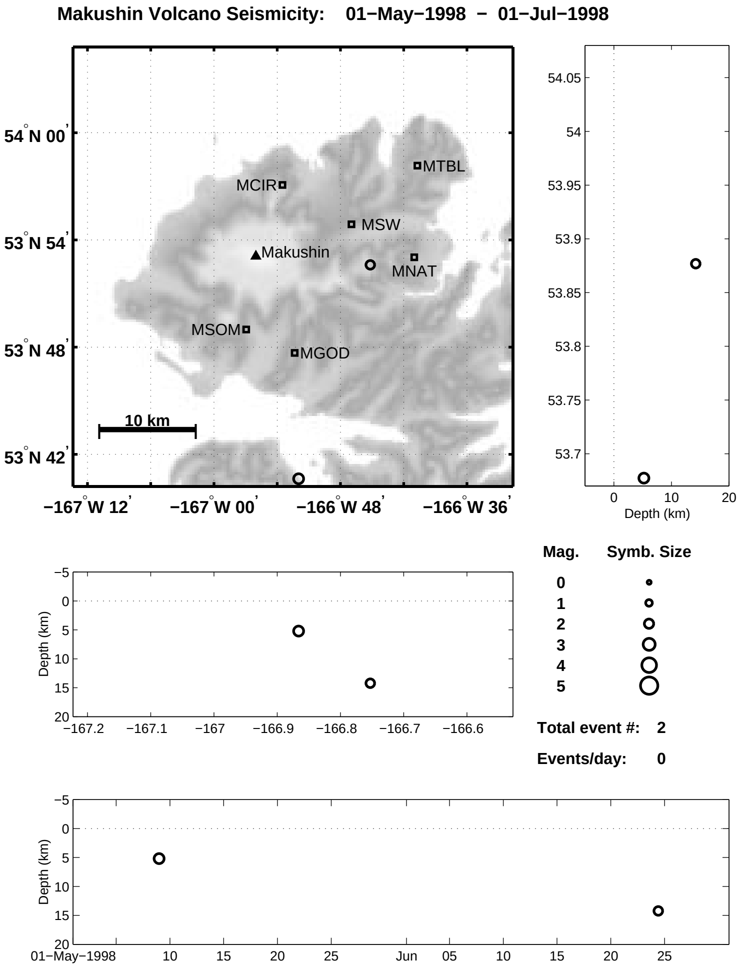

Figure 14a: Locatable Makukshin seismic events in space and time for May through June.

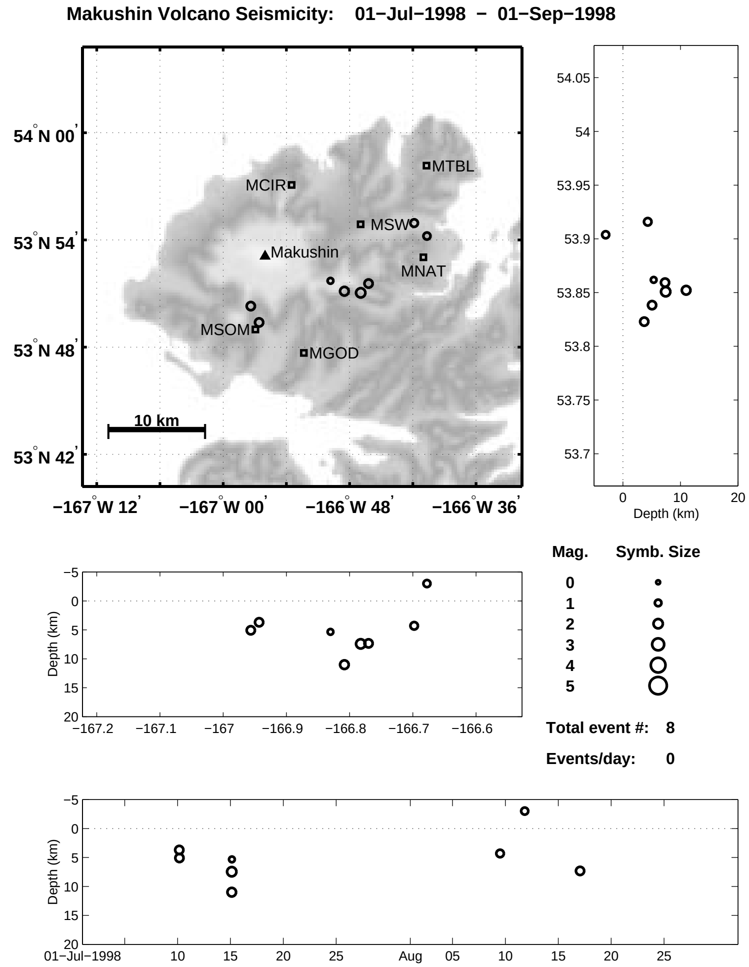

Figure 14b: Locatable Makushin seismic events in space and time for July through August.

summit of Shishaldin at a depth of 32 km. Although the three "deep" events, represented by inverted triangles, were plotted as three distinct symbols on the seismicity map and the two cross-sections, there was only a one such symbol on the time-depth plot. Because all three of these deep events occurred within an hour of each other on the same day (July 17, 1998) the corresponding symbols on the time-depth plot were all plotted in essentially the same place thus appearing to be a single symbol. Only the four events which were located in the region south-east of Cape Lazaref were the usual volcano-tectonic (VT) earthquakes; the remaining 123 located earth-quakes all had relatively low frequency waveforms and were, therefore, classified as being b-type events. Although in most cases station SSLW would have been the nearest station to the epicenters, it was not used in the location of any of these events. SSLW was functional and operating properly but it was not possible to record these data until the new circuit out of Cold Bay was hooked up. Without SSLW, the station distribution is very poor for locating events west of Shishaldin. The locations of these earthquakes are not very well constrained particularly with respect to hypocentral depth. The rather large spread of depths apparent in the cross-sections and the time-depth plot (see fig. 10b) is a reflection of this. Several of these events had quite shallow depths and considering the fairly large vertical error estimates of these locations there is a possibility that much of this seismicity is glacial in nature.

Some members of AVO have argued that the volumes and the aerial extents of the glaciers associated with Shishaldin were too small to account for the observed seismicity. Although there has been debate about the possible glacial origin of these events, at present this issue is still unresolved. Hopefully, similar events will occur in this area once SSLW is restored, which should result in better constrained locations and hypocentral depths. By analogy and similarity of waveforms, one may be able to shed light on the issue of a possible glacial origin or lack thereof for the present seismicity in the Shishaldin region.

Akutan:

A total of five earthquakes were located in the Akutan region during May and June 1998 (figs. 13a, 15a and 16a). The largest event had a magnitude of M_L=1.9 and was located off the eastern tip of Akutan Island near Green Bight at a depth of 15 km. Two events were located 1-2 km northeast of the summit of Akutan while the remaining two events were located 3-5 km northwest of the summit. The number of events located in the Akutan region during this two-month period was much lower than the 19 such events located there during March and April. This value is also lower than the seven such events predicted from the 1-year Akutan mean seismicity rate.

Three earthquakes were located in the vicinity of Akutan during July and August 1998 (figs. 13b, 15b and 16b). The largest of these events had a magnitude of M_L=1.3 and was located 4 km west of the summit of Akutan at a hypocentral depth of ~7 km. The remaining two events were located 2 km north-northeast of the summit and had hypocentral depths of 2-3 km. The number of events located at Akutan during July and August is lower than that for May and June as well as the predicted value for a two-month period.

Makushin:

Two earthquakes were located in the Makushin region during May and June 1998 (figs. 14a, 15a and 16a). The largest of these had a magnitude of M_L=2.3 and was located ~24 km south of Makushin. Because of its large distance from Makushin or the other volcanic centers on Unalaska Island, this event may be a regional tectonic event unrelated to the volcanic activity in Makushin. The final event had a magnitude of M_L=1.8 and was located 11 km east of Makushin and had a hypocentral depth of 14 km. The number of events located in the Makushin region during May and June is greater than that of March and April, but it is much smaller than the 15 located events predicted for this region based upon the 1-year mean seismicity rate.

A total of eight earthquakes were located in the Makushin region during July and August 1998 (figs. 14b, 15b and 16b). These events appear to be grouped into three spatial clusters. The largest event located had a magnitude of M_L=2.0 and was part of the central cluster. This cluster consisted of four events and was located 7-11 km east-southeast of Makushin. These four events had hypocentral depths of 5-11 km. The other two clusters of activity consisted of two events each. Two events were located 6-8 km south of Makushin and had hypocentral depths of ~4-5 km. The remaining two events were located 15-16 km east of Makushin. Of these two final events, one had a hypocentral depth of 4 km while the other was located 3 km above sea-level (i.e. -3.00 km). The number of events located during July and August was greater than that of the previous two-month period but it is only about one half the predicted value.

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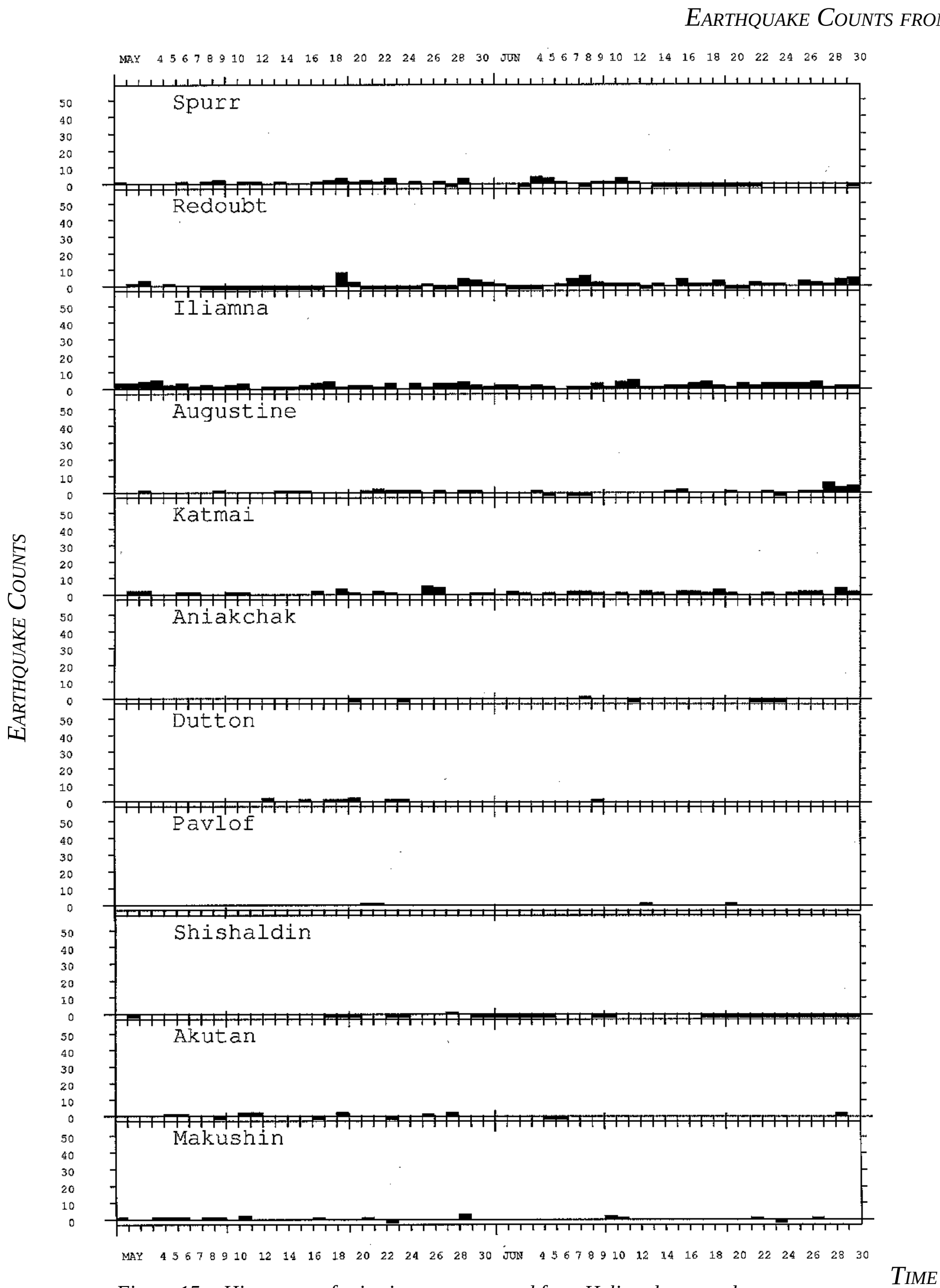

Figure 15a: Histogram of seismic events counted from Helicorder records during May through June.

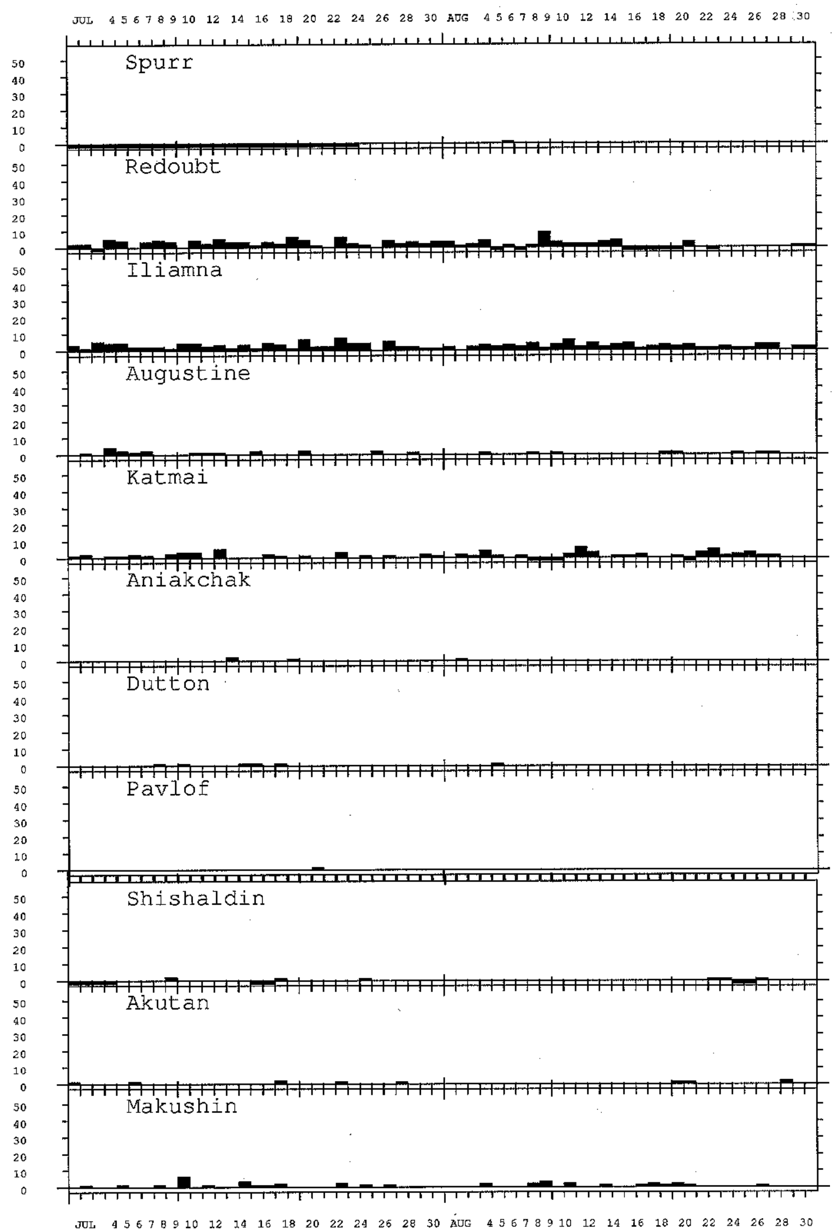

Figure 15b: Histogram of seismic events counted from Helicorder records during July throuogh August.