A Report on the Seismic Activity at Lake Jocassee Between June 1 and August 31, 1978

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INTRODUCTION

During the reporting period seismicity was monitored at Lake Jocassee. Low level (averaging about one event per day), low magnitude ($M_L \leq 2.3$), shallow ($Z \leq 4.5$) activity was recorded in the vicinity. A magnitude 2.3 event occurred on August 21, 1978.

SEISMIC STATION DEPLOYMENT

Up to four portable seismographs (Sprengnether MEQ 800 model) were used, together with Duke Power Company's permanent station at SMT. The location of sites occupied are listed in appendix I and are shown in Figure 1. In identifying the sites in later discussion and in tables, the location number (first column) is used. The deployment times at various sites are shown in Figure 1.

RESULTS

Events were located using a computer program HYPO-71 (Lee and Lahr, 1972) and a velocity model developed for the Clark Hill reservoir area (Appendix II). The relative location accuracy is about ±200 m while the depths are usually good to ±400 m.

In the reporting period (June 1 - August 31, 1978) 96 events were recorded. Of these, 42 events were located and are shown in Figure 2 and listed in Appendix IV. The activity was scattered throughout the Jocassee network. During the period (June 1 - August 31, 1978) 6 events with a magnitude greater than 1.0 were recorded, and are listed in Table 1. The largest was a magnitude 2.3 event on August 21, 1978. Figure 3 shows the location of all the events between November 8, 1975 and August 31, 1978.

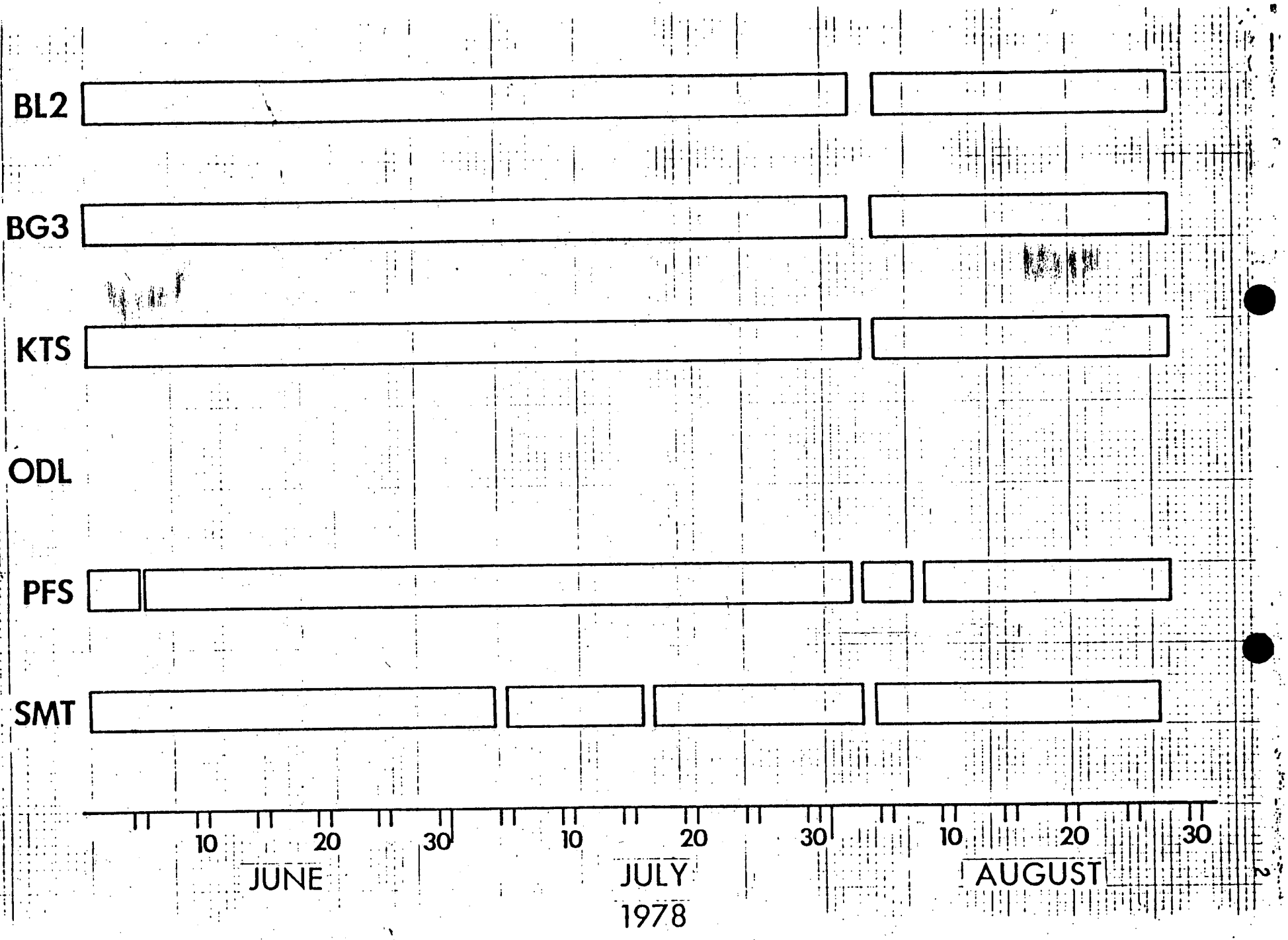
BL2
BG3
KTS
ODL
PFS
SMT
10
20
30
10
20
30
10
20
30
JUNE
JULY
AUGUST
1978

Figure 1

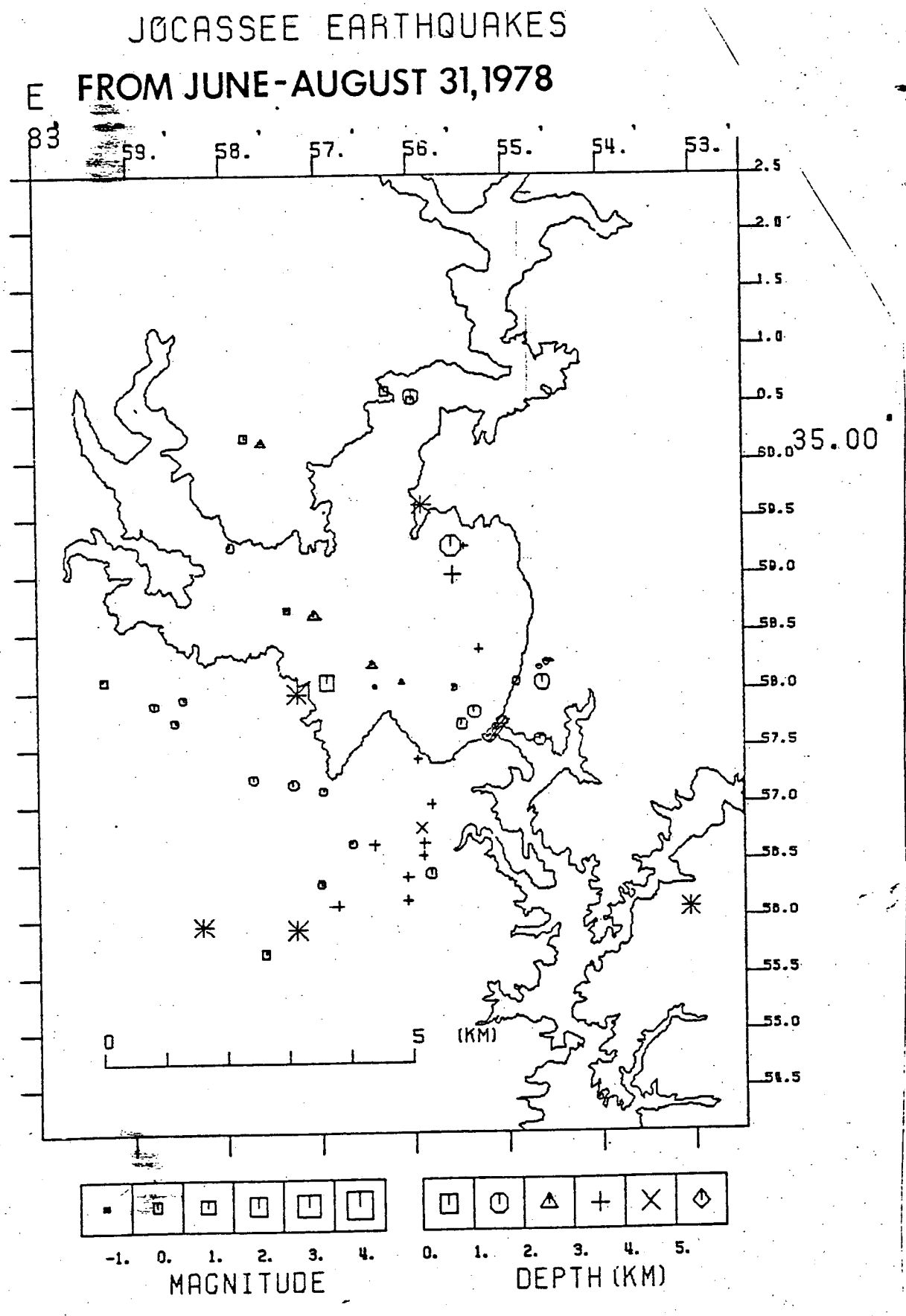
JOCASSEE EARTHQUAKES
FROM JUNE-AUGUST 31,1978
E
83
59.
58.
57.
56.
55.
54.
53.
2.5
2.0
1.5
1.0
0.5
0.0
35.00
59.5
59.0
58.5
58.0
57.5
57.0
56.5
56.0
55.5
55.0
54.5
0
5
(KM)
-1. 0. 1. 2. 3. 4.
MAGNITUDE
0. 1. 2. 3. 4. 5.
DEPTH (KM)

Figure 2

Table 1

LIST OF EVENTS $M_L > 1$

DATE (1978)	TIME (UCT) H:M	M_L
06:01	16:32	1.6
06:11	16:22	1.1
06:27	06:03	1.2
07:22	15:18	1.1
08:17	05:08	1.7
08:21	13:53	2.3

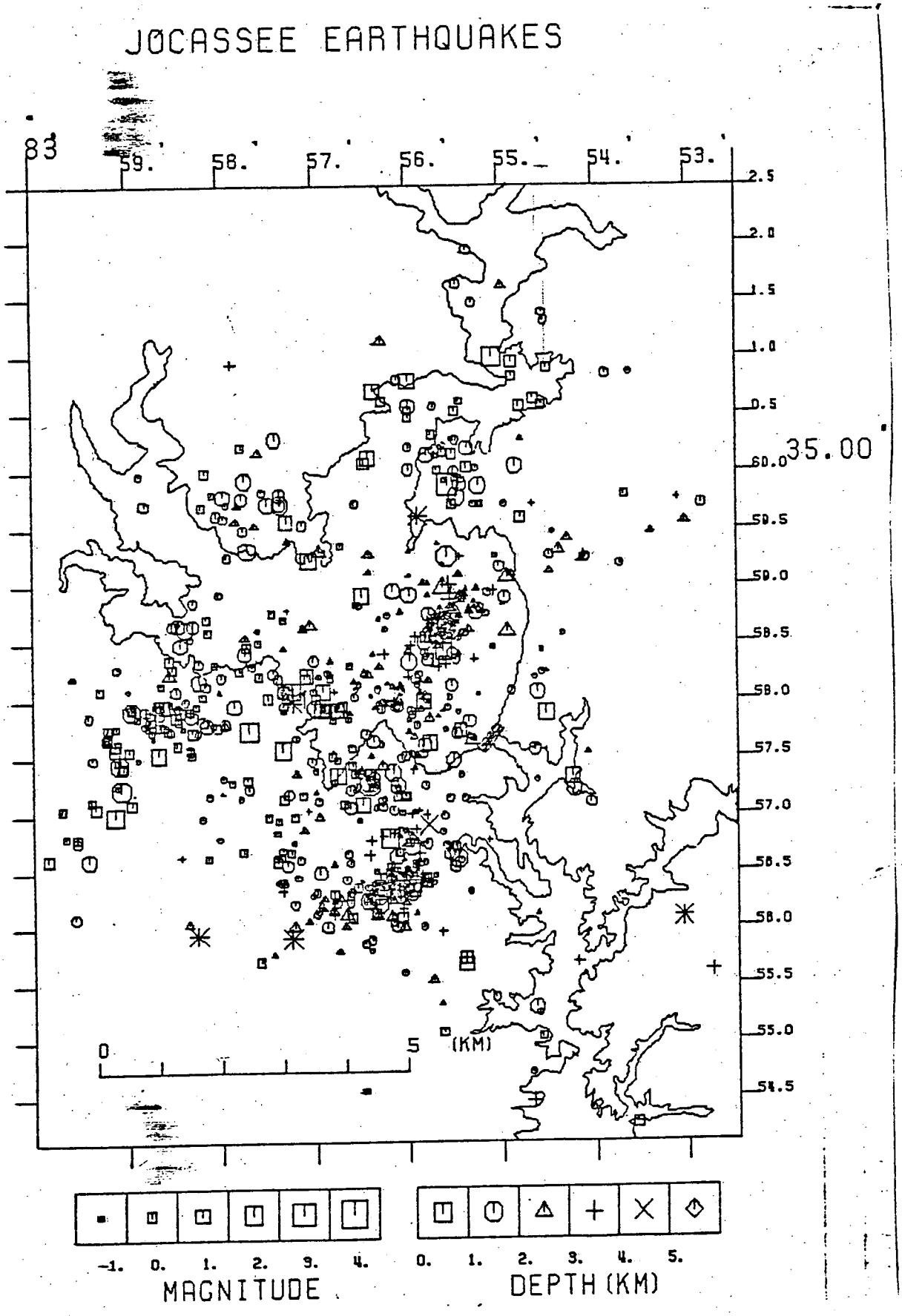
JOCASSEE EARTHQUAKES
83
59.
58.
57.
56.
55.
54.
53.
2.5
2.0
1.5
1.0
0.5
0.0
35.00
59.5
59.0
58.5
58.0
57.5
57.0
56.5
56.0
55.5
55.0
54.5
0
5
(KM)
-1. 0. 1. 2. 3. 4.
MAGNITUDE
0. 1. 2. 3. 4. 5.
DEPTH (KM)

Figure 3

In Figure 4, the seismicity is compared with water level fluctuations. These data are plotted on the same time axis for the period June 1 to August 31, 1978. Starting at the top are the daily water level readings at 8 A.M. (local time). The bars indicate the maximum and minimum water level for that day. In the ordinate, 100 feet corresponds to a full pond elevation of 1110 feet above sea level. The daily variation of water level (computed for readings at 8 A.M. and plotted midway between them) is shown in the next row. The daily energy release and the number of events are shown in the two bottom rows.

The seismic activity in June and August is possibly related to rapid lowering of the lake level in May 1978 and raising it in July 1978 respectively. Figure 5 shows data over a three and a half year period (January 1975 - August 1978). Each data point represents a 10-day period. From top to bottom: first row shows the average water level in Lake Jocassee over a 10-day period, with the bars indicating the maximum and minimum water level in that 10-day period. The change in water level between the 10-day mean water levels is shown in the next row. In order to quantify this change, the area in each segment, below and above the zero (or no change) line was calculated in arbitrary units. This 'change time', representing the duration and amount of change, is plotted in the next row. This was compared with the total number of events (in 10-day period) and the times of events with magnitude greater than 2 were noted.

The large change time in July - August appears to be associated with the occurrence of a magnitude 2.3 event on August 21, 1978, an observation consistent with our hypothesis on the cause of these earthquakes.

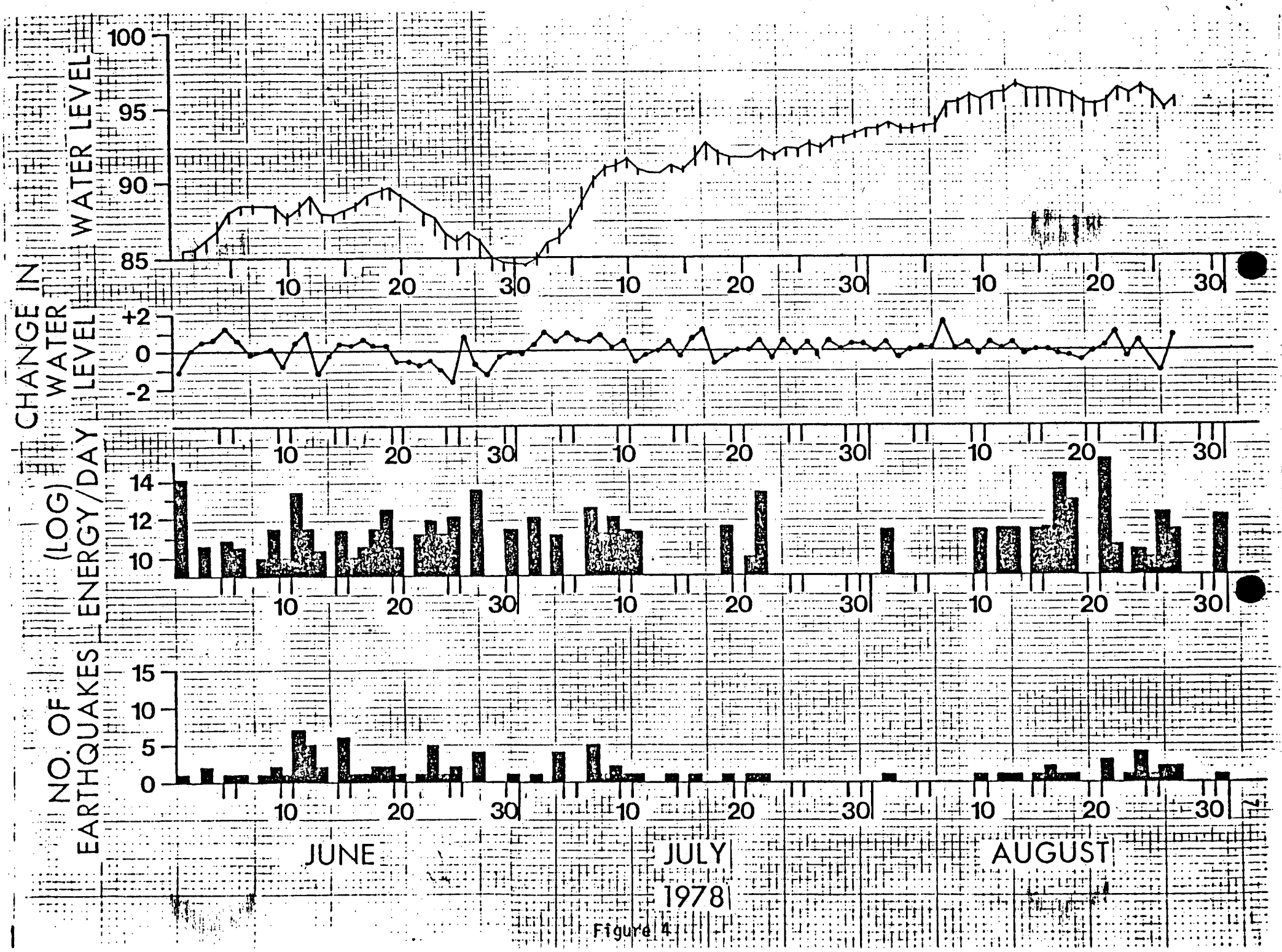
WATER LEVEL
100
95
90
85
CHANGE IN WATER LEVEL
+2
0
-2
(LOG) ENERGY/DAY
14
12
10
NO. OF EARTHQUAKES
15
10
5
0
10
20
30
JUNE
JULY
AUGUST
1978

Figure 4

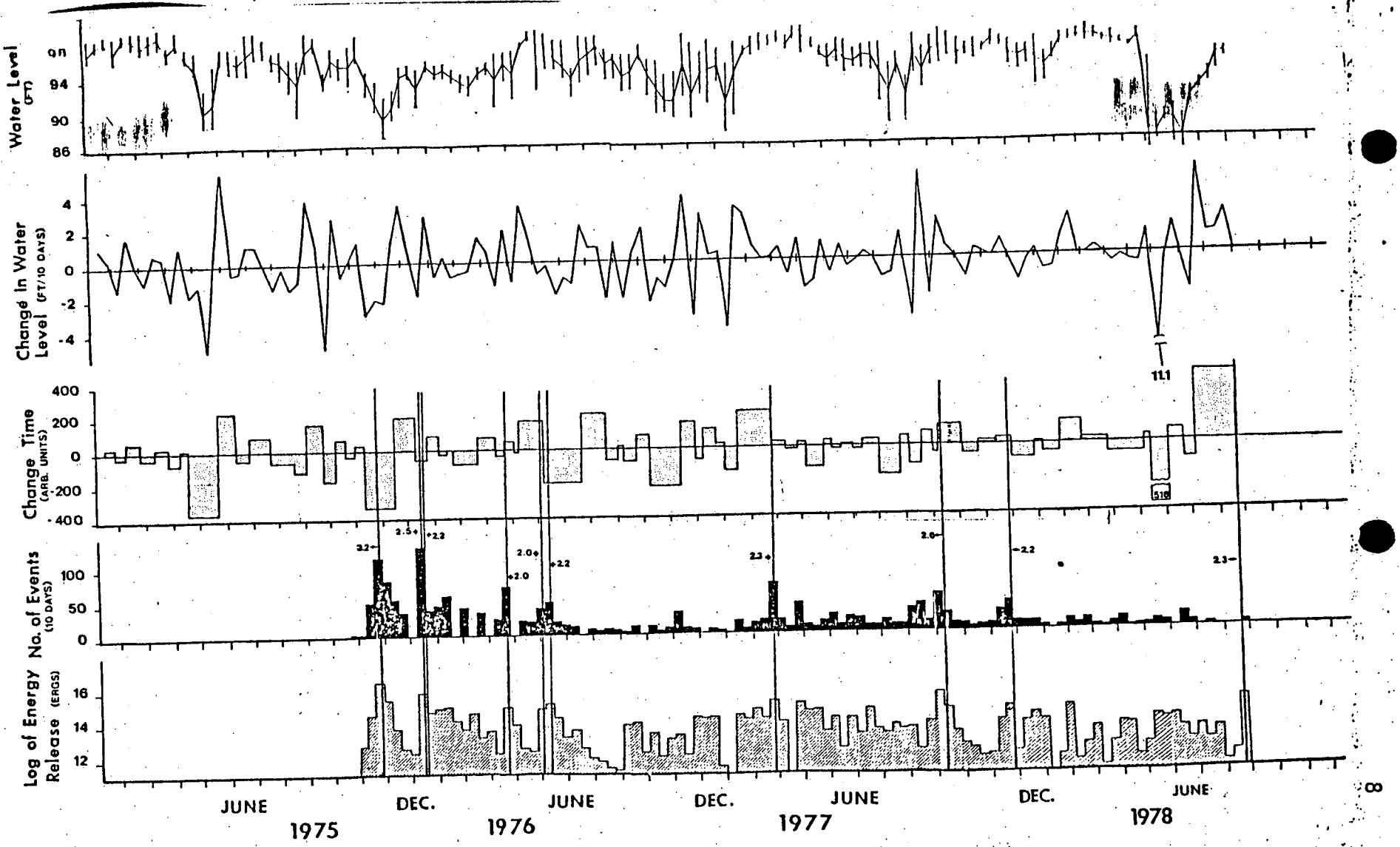
Water Level (FT)
98
94
90
86
Change In Water Level (FT/10 DAYS)
4
2
0
-2
-4
11.1
Change Time (ARB. UNITS)
400
200
0
-200
-400
519
No. of Events (10 DAYS)
100
50
0
3.2
2.5
2.2
2.0
2.0
2.2
2.3
2.0
2.2
2.3
Log of Energy Release (ERGS)
16
14
12
JUNE
1975
DEC.
1976
JUNE
DEC.
1977
JUNE
DEC.
1978
JUNE

Figure 5

CONCLUSIONS

Low level seismicity is still continuing in the vicinity of Lake Jocassee. A notable feature of the activity in this and the previous reporting periods is that compared to the first half of 1976, there is a marked decrease in activity-- from an average of about 5 events per day to about 1 event per day. We also observe a general increase in the depths of the hypocenters, and an occasional $M_L \geq 2.0$ event. These observations suggest that the process of induced seismicity is still continuing -- the decrease in activity representing a diminishing in the size and number of joints at greater depths.

APPENDICES

APPENDIX I

STATION LOCATIONS

No.	Stn.	Lat. N.	Long. W.
1	BL2	34°57.92	82°57.24
2	KTS	34°56.00	82°53.08
3	BG3	34°59.58	82°55.90
4	ODL	34°55.82	82°57.26
5	MCS	34°57.12	83°00.45
6	PFS	34°58.50	83°00.29
7	SMT	34°55.85	82°58.26
8	ELJ	34°59.05	82°54.57

APPENDIX II

VELOCITY MODEL

HYP071 was used to locate various events. The crustal model used is

Velocity km/sec	Depth km
5.75	0
6.2	0.5
8.1	30.0

This model was developed for the Clark Hill reservoir - also located on gneissic rocks in the South Carolina Piedmont (Talwani, 1975).

APPENDIX III

LIST OF EVENTS FROM JUNE 1 - AUGUST 31, 1978

In column 3 the "station of max. duration" refers to the location of a station where the recorded duration event was maximum. The station number corresponds to that listed in Appendix I. The maximum recorded duration for any event is given in column 4. In column 5 are listed the total number of stations recording the event. The daily energy release is listed in column 6. The daily energy is calculated using a simplified magnitude - energy relation (Gutenberg and Richter, 1956), i.e.,

$$\log_{10} E = 11.8 + 1.5 M_L$$

where M_L = calculated duration magnitude. For Jocassee (Talwani and others, 1976)

$$M_L = -1.83 + 2.04 \log D$$

where D = duration of event in seconds. Events with magnitude ≥ 1 are listed in column 7.

APPENDIX IV

LOCATION OF EVENTS FROM JUNE 1 - AUGUST 31, 1978

Computer printout of HYPO71 showing data for location of events.

Column 1	Date.
Column 2	Origin time (UCT) h.m.sec.
Column 3	Latitude (N) degrees, min.
Column 4	Longitude (W) degrees, min.
Column 5	Depth (km).
Column 6	Local duration magnitude.
Column 7	No. of station readings used to locate event. P and S arrivals from same stations are regarded as 2 readings.
Column 8	Largest azimuthal separation in degrees between stations.
Column 9	Epicentral distance in km to nearest station.
Column 10	Root mean square error of time residuals in sec. RMS $=\sqrt{R_i^2}/NO$, where R_i is the time residual for the ith station.
Column 11	Standard error of the epicenter in km*.
Column 12	Standard error of the focal depth in km*.

*Statistical interpretation of standard errors involves assumptions which may not be met in earthquake locations. Therefore standard errors may not represent actual error limits.

If ERH ~~or~~ ERZ is blank, this means that it cannot be computed, because of insufficient data.

DATE	TIME H:M:S	STN. OF MAX. DURATION	DURATION (SEC)	NO. OF STN REC. EVENT	ENERGY PER DAY (ERGS)	M_L>1
78:06:01	16:32:25	2	49	5	14.2	1.6
78:06:03	01:56:32	1	3	2	10.6	
	07:09:35	1	2	2		
78:06:05	13:19:15	1	4	3	10.89	
78:06:06	22:23:45	1	3	3	10.5	
78:06:08	01:55:09	1	2	2	9.9	
78:06:09	04:45:45	3	5	4	11.5	
	04:47:50	2	5	4		
78:06:10	13:02:30	3	2	1	9.9	
78:06:11	10:46:06	3	4	4	13.50	
	10:47:28	1	2	1		
	16:09:50	1	2	1		
	16:22:01	2	26	5		1.1
	18:30:41	3	2	1		
	19:28:48	2	17	5		
	19:29:19	3	1	1		
	20:24:11	3	3	1		
	20:40:02	3	1	1		
	21:25:32	3	1	1		
78:06:12	02:47:32	1	2	3	11.5	
	02:49:39	3	6	3		
	03:47:12	1	2	2		
	03:48:01	1	2	2		
	05:33:30	3	3	3		
78:06:13	20:50:21	3	4	2	10.27	
	22:43:02	1	2	2		
78:06:15	00:38:42	1	2	1	11.34	
	06:22:59	1	2	2		
	13:53:00	2	4	2		
	14:04:04	1	4	3		
	14:10:18	2	2	3		
	14:26:21	1	3	3		
78:06:16	23:10:09	1	2	3	9.9	
78:06:17	10:02:29	1	3	3	10.5	

DATE	TIME H:M:S	STN. OF MAX. DURATION	DURATION (SEC)	NO. OF STN. REC. EVENT	ENERGY PER DAY (ERGS)	M_L >1
78:06:18	12:04:52	6	6	4	11.5	
	21:14:47	3	3	2		
78:06:19	01:17:32	3	2	1	12.56	
	14:09:51	2	14	4		
78:06:20	07:33:13	6	3	4	10.5	
78:06:22	08:00:21	3	5	4	11.2	
78:06:23	00:47:16	1	3	4	11.9	
	00:50:32	1	3	3		
	02:12:31	6	7	5		
	02:49:45	3	3	2		
	07:41:17	3	6	5		
78:06:24	13:56:23	1	5	5	11.2	
78:06:25	08:06:21	1	2	1	12.1	
	12:23:34	2	10	5		
78:06:27	06:03:38	3	30	5	13.58	1.2
	06:28:48	3	6	3		
	06:21:57	3	7	1		
	07:17:43	3	6	1		
78:06:30	05:34:50	6	6	5	11.40	
78:07:02	14:26:02	1	10	5	12.11	
78:07:04	04:22:03	3	2	1		
	04:27:47	3	2	1	11.1	
	04:45:24	3	4	5		
	08:24:27	3	3	2		
78:07:07	01:30:20	3	12	4	12.59	
	09:08:12	3	5	2		
	10:36:02	2	10	4		
	10:44:34	3	2	1		
	20:06:	1	5	4		
78:07:08	00:42:	3	5	4	11.2	
78:07:09	13:11:35	3	7	5	12.14	
	15:57:52	2	9	4		
78:07:10	23:07:	3	6	4	11.43	

DATE	TIME H:M:S	STN. OF MAX. DURATION	DURATION (SEC)	NO. OF STN REC. EVENT	ENERGY PER DAY (ERGS)	M_L >1
78:07:11	06:45:	1	4	4	10.90	
78:07:12						
78:07:14	02:37:	1		5		
78:07:16	02:42:	1		5		
78:07:19	11:55:26	2	7	5	11.64	
78:07:21	01:05:16	1	1	2	9.05	
78:07:22	15:18:56	3	27	5	13.43	1.1
78:08:02	17:21:16	1	6	3	11.43	
78:08:10	07:49:39	1	6	5	11.43	
78:08:12	06:31:25	3	6	5	11.43	
78:08:13	08:16:02	2	6	3	11.43	
78:08:15	01:48:24	3	6	5	11.43	
78:08:16	21:59:17	3	6	5	11.45	
	22:38:48	3	2	3		
78:08:17	05:08:29	3	54	5	14.35	1.7
78:08:18	15:28:27	2	18	5	12.89	
78:08:21	11:37:37	1	2	1	15.21	
	12:53:13	3	5	3		
	13:53:01	7	103	5		2.3
78:08:22	04:28:23	2	3	4	10.5	
78:08:24	17:59:46	1	2	2	10.32	
	17:59:54	1	1	3		
	19:59:59	1	1	2		
	22:00:42	1	2	2		
78:08:25	00:44:49	1	2	1	9.9	
78:08:26	17:11:13	2	11	3	12.3	
	22:58:31	3	6	5		

DATE	TIME H:M:S	STN. OF MAX. DURATION	DURATION (SEC)	NO. OF STN REC. EVENT	ENERGY PER DAY (ERGS)	$M_L>1$
78:08:27	13:00:09	6	6	5	11.45	
	14:52:46	3	2	1		
78:08:31	06:05:51	2	10	5	12.11	

[redacted]

[redacted]

SOME IN TO AUGUST IN CUMULATIVE

	DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG NO	GAP	DMIN	RMS	ERH	ERZ	QM
1	780605	1315	13.27	35- 0.54	82-55.44	1.96	-0.60	6	302	7.5	0.21	5.5	17.1	D1
2	780606	2223	43.44	34-57.47	82-55.57	1.94	-0.00	6	254	2.5	0.04	1.3	1.1	C1
3	780609	445	45.03	34-56.42	82-57.00	1.54	-0.40	6	142	3.2	0.04	0.2	0.4	C1
4	780904	447	45.41	34-56.01	82-57.00	0.44	-0.40	6	283	4.3	0.07	1.2	2.0	C1
5	780911	1043	6.24	34-56.45	82-57.34	0.30	-0.00	6	234	1.4	0.00	1.1	1.0	C1
6	780911	1042	0.76	34-56.01	82-54.63	1.27	1.05	6	141	3.5	0.01	0.1	0.2	C1
7	780911	1942	47.45	34-56.60	82-57.03	2.33	0.06	6	172	2.5	0.01	0.1	0.3	B1
8	780915	14 8	3.44	34-56.15	82-54.54	1.70	-0.00	6	184	3.3	0.01	0.1	0.3	C1
9	780915	1460	20.15	34-56.15	82-54.50	1.96	-0.00	6	184	3.3	0.01	0.1	0.4	C1
10	780918	2311	7.44	34-57.45	82-56.41	0.32	-1.22	6	231	1.3	0.17	1.1	0.8	C1
11	780918	12 8	51.41	34-56.04	82-54.29	0.46	-0.24	4	245	3.1	0.02	0.0	0.0	C1
12	780919	14 8	51.00	34-57.70	82-54.70	1.43	0.51	6	135	3.7	0.02	0.1	0.5	B1
13	780920	733	11.41	34-56.02	82-56.13	2.04	-0.06	8	212	1.7	0.02	0.2	0.2	C1
14	780922	8 0	20.28	34-56.30	82-55.30	3.84	-0.40	6	163	2.5	0.02	0.2	0.3	B1
15	780923	047	17.14	34-55.14	82-54.54	2.01	-0.36	8	140	3.3	0.03	0.2	0.4	C1
16	780923	212	39.79	34-55.21	82-57.93	1.45	-0.11	10	262	2.6	0.05	0.4	0.6	C1
17	780923	741	15.05	34-57.10	82-57.71	1.97	-0.24	10	134	1.6	0.02	0.1	0.2	B1
18	780924	1336	23.22	34-57.05	82-56.51	1.50	-0.40	8	202	1.7	0.03	0.3	0.3	C1
19	780924	1423	34.33	34-57.11	82-57.29	1.76	0.21	10	107	1.5	0.03	0.1	0.2	B1
20	780927	6 3	36.57	35- 0.53	82-56.00	1.03	1.18	10	291	1.8	0.03	0.3	0.4	C1
21	780927	642	47.54	35- 0.55	82-56.29	0.68	-0.24	8	304	1.9	0.01	0.1	0.2	C1
22	780930	534	54.07	34-57.82	82-56.78	1.00	-0.24	10	190	2.3	0.03	0.2	0.6	C1
23	780702	1420	1.47	34-56.31	82-55.83	1.48	0.21	10	159	3.7	0.03	0.1	0.5	B1
24	780704	445	23.03	34-54.21	82-55.43	3.25	-0.50	10	194	1.0	0.04	0.3	0.3	C1
25	780707	130	20.05	35- 0.13	82-57.60	2.00	0.37	9	260	2.8	0.03	0.3	0.5	C1
26	780707	1036	0.59	34-56.03	82-56.46	3.43	0.21	10	171	2.2	0.03	0.2	0.3	B1
27	780707	20 5	55.44	34-57.67	82-55.54	1.82	-0.40	8	177	2.0	0.01	0.1	0.1	B1
28	780708	044	34.33	35- 0.30	82-56.00	0.82	-0.40	8	314	1.7	0.01	0.2	0.4	C1
29	780709	1257	40.78	34-56.25	82-56.08	3.48	0.12	10	180	3.4	0.04	0.2	0.4	B1
30	780710	23 7	24.49	34-56.02	82-54.91	1.40	-0.24	8	171	3.3	0.14	0.8	2.8	C1
31	780711	645	57.07	34-54.29	82-54.07	1.90	-0.60	8	208	3.5	0.05	0.8	1.6	C1
32	780714	237	24.54	34-56.57	82-56.43	3.59	0.12	10	143	2.8	0.04	0.2	0.4	B1
33	780716	242	43.75	34-57.04	82-55.50	1.89	0.21	10	139	2.7	0.04	0.2	0.5	B1
34	780719	1135	25.49	34-56.08	82-56.90	3.50	-0.11	10	171	3.3	0.06	0.3	0.6	B1
35	780722	1516	56.23	34-56.02	82-56.96	0.31	1.09	10	134	0.5	0.04	0.2	0.3	B1
36	780802	1721	15.44	34-57.07	82-56.43	1.35	-0.24	8	210	1.8	0.01	0.1	0.1	C1
37	780810	749	38.78	34-56.47	82-55.91	3.44	-0.24	8	151	3.8	0.03	0.2	0.4	B1
38	780815	146	23.04	34-56.55	82-56.00	1.51	-0.24	10	140	2.6	0.01	0.1	0.2	B1
39	780816	2159	16.43	35- 0.18	82-57.78	0.49	-0.24	10	262	3.1	0.07	0.8	1.8	C1
40	780817	5 8	23.44	34-56.59	82-55.57	3.25	1.70	10	154	1.2	0.06	0.4	0.5	B1
41	780818	1526	56.33	34-57.75	82-55.30	1.84	0.73	10	146	2.9	0.05	0.2	0.7	B1
42	780821	1253	12.61	34-56.17	82-56.44	2.21	0.21	8	195	1.3	0.02	0.3	0.2	C1
43	780821	1353	0.56	34-55.21	82-55.53	1.91	2.29	4	272	3.5	0.02	0.0	0.0	C1
44	780826	1711	11.74	34-56.72	82-55.93	4.09	0.29	10	138	3.0	0.07	-0.4	0.7	B1
45	780826	2256	30.03	34-56.93	82-55.86	3.52	-0.24	9	130	2.8	0.08	0.4	0.9	B1
46	780827	13 0	8.24	34-57.33	82-55.56	3.09	-0.40	9	114	2.2	0.05	0.3	0.7	B1
47	780831	8 5	46.72	34-56.53	82-55.49	3.03	0.21	10	145	3.2	0.03	0.1	0.3	B1