South Carolina Seismic Network Bulletin

Volume XI
2001

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SPONSORS:

Department of Energy/Westinghouse Savannah River Company
United States Geological Survey

AUGUST 2002

PREFACE

Volume XI of the South Carolina Seismic Network (SCSN) Bulletin describes the seismicity in the state in 2001. The largest event with a magnitude M_L 2.8 occurred on December 23, 2001 near Charleston. Seismicity continued near Monticello Reservoir where 18 events were located. Increased seismicity was recorded in the Middleton Place Summerville Seismic Zone (MPSSZ). A total of 30 events (Table 2) were located indicating a significant increase in the annual seismicity over the previous years. Three events were located near Lakes Jocassee and Keowee, and six events were located in other parts of the state.

The South Carolina Seismic Network web site was established in 1998. It lists historical and instrumental seismicity in South Carolina and location of the current seismicity on a website which is located at http://scsn.seis.sc.edu.

In 2001 the SCSN continued routine digital recording of seismicity in the state. The data from Coastal Plain stations surrounding MPSSZ are recorded in an event triggered format at Charleston Southern University (CSU) near Summerville, accessed via the Internet from the University of South Carolina (USC), where other digital data are recorded continuously. Earthworm systems were installed in 1998 at CSU and USC that record both continuous and triggered events.

Successful operation of the SCSN is due in part to the support from various agencies. In particular we thank the U.S. Geological Survey and Westinghouse Savannah River Company. This bulletin is the result of the efforts of the staff and students at USC.

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I. INTRODUCTION

Volume XI of the South Carolina Seismic Network (SCSN) Bulletin covers the period from January to December, 2001. This issue presents the details concerning the observed seismicity and network operation in the state during 2001.

We observed increased seismicity in the Middleton Place Summerville Seismic Zone (MPSSZ) over previous years, the largest event a M_L 2.8 occurred on December 23, 2001.

Monticello Reservoir continued to be active in 2001, 18 events were located near the reservoir area, with the largest magnitude a M_L 1.8. Low level seismicity continued to be observed near Lakes Jocassee and Keowee with the largest magnitude a M_L 2.2. During 2001, eight events with magnitudes from M_L 1.0 to 2.5 were located in areas outside the MPSSZ, Monticello Reservoir, and Lakes Jocassee and Keowee.

In 1995 the SCSN began routine digital recording of seismicity in the state. The data from Coastal Plain stations surrounding MPSSZ are recorded in an event triggered format at Charleston Southern University (CSU) near Summerville, accessed via the Internet from the University of South Carolina (USC), where other digital data are recorded continuously. In 1998, an Earthworm system was installed, by the U.S. Geological Survey, and now all SCSN data can be retrieved via this new system.

Details of investigations of seismicity at each of these locations are presented in three parts. They are:

a). Earthquakes originating in the Coastal Plain, particularly in the MPSSZ.

b). Induced earthquakes originating in the vicinity of the three reservoirs mentioned above.

c). Tectonic earthquakes in the other regions in South Carolina.

The bulletin is arranged in four sections. The next section deals with the network operations, current methods of data acquisition, retrieval and processing. An analysis of the seismicity of the state in 2001 is presented in the third section. Future plans of the SCSN, (http://scsn.seis.sc.edu), are presented in the last section.

II. SOUTH CAROLINA SEISMIC NETWORK OPERATION - 2001

II.1. Station Locations

In 2001, the SCSN consisted of twenty-three stations. These included six stations in the Lake Jocassee, four stations in the "main net", eight stations in the Coastal Plain network and five stations in the Monticello Reservoir sub-network. The present configuration of the seismic network is shown in Figure 1. The stations of the "main" SCSN (JSC, LHS and SFQ) cover the area in the lower Piedmont and (COW) covers the upper Coastal Plain. Data from these stations are telemetered and recorded at the USC. The Coastal Plain Seismic Network consists of CSU, RGR (bore hole stations), and HBF (a new bore hole station), was brought on-line on August 22, 2000. Surface stations, DRC, MGS, SVS, TWB and WAS which cover the MPSSZ are concentrated primarily around the Charleston meizoseismal area in the Coastal Plain (Figure 2) are telemetered and recorded at Charleston Southern University.

The configuration of stations in the vicinity of Monticello Reservoir area is shown in Figure 3. The stations of the Lake Jocassee network are located so as to monitor seismicity around Lakes Jocassee, Keowee and Bad Creek Reservoir (Figure 4). Duke Engineering and Services, Inc., maintained a separate recording facility at the Jocassee Hydroelectric Station near Jocassee Dam until June 2001. Data from the five station Monticello Reservoir sub-network (Figure 3) are telemetered and recorded at the USC Seismic Laboratory in Columbia. Data from BG3, MMC, SMM and SMT (Figure 4) are recorded digitally at the Jocassee Dam. These data, together with data from CCK and JVW are telemetered and recorded at the USC.

II.2. Recording Facilities

Digital data are recorded continuously at USC on **TAL2** at 50 samples/second. To facilitate easier storage of the continuous data being recorded by **TAL2** at USC, a DAT tape drive was installed on our analysis workstation, **SCSN2**. This tape drive can store approximately 2 gigabytes of data on a single tape. Accumulating data at the rate of 288 Mb per day, the new tape drive has given us the ability to mass dump data each morning from hard disk to tape. A backlog of 30 days data is maintained at the present time.

At USC data are also recorded on five Helicorders, of these one is used to record data from stations in the Coastal Plain, one is devoted to a Piedmont station, JSC and three stations are dedicated to data from the induced seismicity sub-networks. Data from the Coastal Plain stations are recorded on the three Helicorders at CSU.

In October of 1998, the USGS initiated a new phase of cooperative seismic monitoring. The recording operations of both the Charleston Southern University and USC facilities were augmented with the installation of "Earthworm". Earthworm is a PC-based, event triggered and short term continuous data recording system that utilized the Internet for data transfer and sharing. This allows data from the SCSN to be shared with networks at CERI (Memphis) and the USGS in Golden, Colorado as part of the Advanced National Seismic System (ANSS) for the Central and Southeast US region. It also gives the main data analysis group at USC the ability to import data from stations throughout the southeast, thereby enhancing our event detection and location capabilities.

II.3. Operational Status

Yearly operational status of the stations of the main SCSN in 2001 is shown in Figure 5. Most of the stations were completely operational throughout the year. The downtime ranges from 1.5% to 7%.

The yearly operational status of the sub-nets at Lakes Jocassee and Monticello Reservoirs are shown in Figure 6. The station BG3 was operational throughout the year. The

Jocassee sub-nets experienced downtimes ranging from 1% to 70%, the Monticello sub-nets from 1% to 7%.

II.4. Data Analyses

Data are analyzed at the USC's seismological laboratory. Identification of blasting activity, documentation of regional and teleseismic events, location and analyses of local earthquakes form a part of the routine analyses. The increased hard disk storage capacity of the new digital recording system allows for more flexibility in the event triggering formula for the total network. The present configuration of triggering operators consists of six separate triggering parameters encompassing the several sub-networks and the main network and some combinations. This increased triggering has allowed for the recording and locating of events of $M_L < 1.0$. Examples of the system digital playbacks are shown in Figures 7a to 7d. These include M_L 2.8 event in MPSSZ on December 23, 2001 (Figure 7a), the M_L 2.2 Lake Jocassee event on June 28, 2001 (Figure 7b), the M_L 1.8 Monticello event on April 29, 2001 (Figure 7c) and a teleseism M_w 5.7 Caribbean event on October 16, 2001 (Figure 7d).

The ability to store data on 8 mm digital tapes is an added advantage of using a digital recording system. The data are processed using the Seismic Analyses Code (SAC) and Pascal Quicklook programs on the Sun workstations. Hypocentral locations are obtained using HYPO71 and HYPOELLIPSE programs with an appropriate velocity model for each region. Format of the HYPO71 output is given in Table 1. Event magnitudes are determined using the following relation:

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

where D is the signal duration in seconds.

Detailed analyses of recorded seismic activity include spatial correlations with seismogenic structures, mapped or inferred from subsurface data. The results of seismic monitoring in the state during 2001 is presented in the next section.

III. SOUTH CAROLINA SEISMICITY: 2001

Nine felt earthquakes occurred in South Carolina during 2001. The largest, M_L 2.8 event occurred in MPSSZ on December 23, 2001.

Aside from these, low level activity continued in the MPSSZ (30 located events) and near Lakes Keowee and Jocassee (3 located events). 18 events with magnitudes less than 2.5 occurred near the Monticello Reservoir (Figures 3 and 8). Seismicity in the different regions is discussed below, first tectonic seismicity is presented (Sections III.1 and III.2) and then the induced seismicity (Section III.3).

III.1. Middleton Place Summerville Seismic Zone

The MPSSZ continued to be the most active (non RIS) seismic source zone in the Coastal Plain in 2001 (Figures 2 and 9). There was a marked increase in the seismicity at MPSSZ in the year 2001 compared to previous years. Thirty events were located with magnitudes ranging between M_L = 0.9 and M_L = 2.8 at depths shallower than 12 km (Tables 2, Figure 2). The seismicity in 2001 was moderate. Temporally, the seismicity was distributed throughout the year (Figure 10).

III.2. Other Tectonic Activity

Although most of the events recorded by the Monticello Reservoir Network were associated with the reservoir, one earthquake was located about 10 km southeast of the reservoir (Figure 3). This earthquake occurred at 3.26 km, and the maximum magnitude was M_L 1.0. Earthquakes at this location had been observed in 1995, 1996, 1998, 1999 and 2000 appear to be associated with the Rion Pluton.

Eight felt events were located outside the MPSSZ, Monticello Reservoir and Lakes Jocassee and Keowee in 2001 (Table 4, Figure 8). Four of them were located near Savannah River Site on November 8, 2001, with magnitudes in the range of M_L 1.0 and 2.5. One M_L 2.1

event was located in Union County on March 18, 2001, one M_L 1.8 in Chester County on June 11, 2001, one M_L 1.9 in Anderson County on August 17, 2001.

III.3. Reservoir Induced Seismicity

III.3.1. Monticello Reservoir

Eighteen earthquakes were located near Monticello Reservoir area during 2001 (Table 5). They all had a $M_L < 2.0$. One of these events was related to the Rion Pluton. Seventeen events were located within the reservoir, between stations MR10 and MR01 (Figure 3). Except for one event, all depths were shallower than 3 km.

The monthly distribution of the earthquakes around Monticello Reservoir is given in Figure 11. There was a marked increase in the number of earthquakes in the month of April.

III.3.2. Lake Jocassee

Seismicity at lake Jocassee continued at a low level during 2001 (Table 6). All three located events recorded by the Jocassee sub-network were in the vicinity of Lake Jocassee (Figure 4) and located at depths generally less than 3.5 km (Table 6). A M_L 2.2 event was located on June 28, 2001. The monthly distribution of earthquakes recorded and located using the Lake Jocassee sub-network is given in Figure 12. The earthquakes occurred in the first half of the year.

III.3.3. Lake Keowee

In 2001 no earthquakes were recorded around Lake Keowee (Figure 4).

III.3.4. Bad Creek

No events were located near Bad Creek Reservoir in 2001 (Figure 4).

IV. RECORDING FACILITIES AND DIGITAL UPGRADE AT THE SCSN

In 1994 we implemented several changes in the recording facilities at both the USC and CSU. The location of stations of the SCSN are shown in Figure 1. Data from stations of the Monticello Reservoir network are telemetered to the USC as are data from stations JSC, LHS, and COW (Figure 13). Data from the Lake Jocassee network are sent by a dedicated telephone line to the USC. Data from other stations in the MPSSZ; BCS, (CSU bore hole site), TWB, DRC, RGR (borehole site), WAS, HBF (borehole site), SVS and MGS are telemetered and recorded at CSU (Figure 14). A station SFQ was installed to monitor the blasting activities at Sandy Flats quarry and it was operational from July 28, 2001. We continue to record analog data on Helicorders. The instrument acquisition and deployment history is given in earlier bulletins of the SCSN. Analog data are recorded on three Helicorders at CSU. Data from the Helicorders are analyzed at the USC.

IV.1. Future Plans

We hope to bring the bore hole stations at TWB on-line in 2002.

V. SCSN Web Page

We have established a SCSN Web Page. It can be accessed at http://scsn.seis.sc.edu. The historical and instrumental data are displayed on the web site. We also maintain an updated list, and locations of current seismicity.

TABLE 1

HYPO71/HYPOELLIPSE FORMAT

Column	1	Date
Column	2	Origin time (UTC) 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 = Ri2/No, where Ri 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*
Column	13	Quality of the epicentral location.

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

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

Table 2

List of Earthquakes Located in the MPSSZ During 2001

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
20010204	03 34 12.04	32-56.82	80-10.14	6.41	1.60	12	137	5	0.054	0.3	0.6	A
20010211	10 31 34.82	32-58.52	80-10.77	7.56	1.27	12	180	6	0.085	0.5	0.7	A
20010223	14 24 30.37	33-03.14	80-10.03	2.80	1.79	14	114	9	0.097	0.3	0.8	A
20010308	07 34 26.25	32-55.49	80-09.61	11.43	1.74	12	98	3	0.126	0.5	0.5	A
20010310	03 46 48.61	33-00.81	80-11.89	3.32	1.46	6	315	7	0.014	0.8	2.4	B
20010311	11 32 06.68	33-02.37	80-09.26	6.15	2.41	12	101	10	0.098	0.3	1.3	A
20010313	18 46 56.49	32-54.05	80-07.54	8.23	0.86	10	218	1	0.196	0.5	0.7	A
20010324	06 02 39.59	32-54.30	80-10.33	9.39	1.44	14	130	2	0.131	0.3	0.4	A
20010330	23 26 19.00	33-00.81	80-15.36	1.73	1.47	8	150	13	0.146	0.4	27.3	D
20010415	19 43 38.22	32-59.26	80-10.42	7.69	1.34	12	132	7	0.045	0.4	0.8	A
20010428	07 27 03.31	32-55.88	80-09.83	10.82	2.14	12	108	6	0.085	0.3	0.5	A
20010612	10 49 16.31	32-55.10	80-09.57	8.13	2.10	14	095	3	0.074	0.3	0.4	A
20010612	21 29 19.57	32-55.29	80-09.42	7.37	1.62	9	107	3	0.086	0.5	0.6	A
20010614	03 32 30.99	32-54.89	80-09.77	7.55	1.55	10	101	3	0.080	0.4	0.5	A
20010617	17 57 30.76	32-56.63	80-09.22	2.97	1.33	10	132	5	0.138	0.2	0.6	A
20010627	04 36 52.41	32-57.48	80-10.43	7.89	2.18	14	102	6	0.069	0.3	0.6	A
20010722	19 05 06.96	32-57.48	80-10.73	8.19	2.34	14	102	6	0.048	0.3	0.6	A
20010723	02 56 29.42	32-58.93	80-10.18	8.52	1.90	14	125	7	0.070	0.4	0.7	A
20010801	21 53 55.36	32-56.61	80-10.68	7.03	1.50	10	132	4	0.056	0.3	0.6	A
20010829	08 23 48.64	32-55.77	80-09.17	6.04	.824	8	180	5	0.065	0.4	0.7	A
20010929	07 33 42.80	32-57.25	80-08.50	5.89	1.42	6	260	6	0.026	1.4	2.1	B
20010930	03 59 35.05	32-56.88	80-09.82	7.88	1.88	10	138	5	0.075	0.3	0.6	A
20011001	12 00 35.39	32-58.86	80-06.88	7.86	2.47	12	179	4	0.045	0.6	0.7	A
20011019	22 45 59.66	32-54.02	80-11.38	8.75	1.92	14	139	1	0.121	0.3	0.4	A
20011201	15 17 05.74	32-57.19	80-10.27	6.80	1.84	12	146	5	0.057	0.3	0.6	A
20011208	04 49 34.55	33-02.48	80-09.87	5.65	1.93	12	196	11	0.073	0.3	1.1	B
20011209	10 11 39.68	32-55.84	80-08.52	5.57	.994	10	131	4	0.076	0.3	0.6	A
20011216	08 04 40.96	32-59.46	80-12.99	5.22	2.17	12	143	4	0.038	0.3	0.6	A
20011219	06 52 02.62	32-56.64	80-09.45	6.75	1.88	8	195	5	0.015	0.8	0.8	A
20011223	05 57 41.72	32-56.04	80-08.92	6.29	2.75	18	118	4	0.078	0.3	0.5	A

Table 3

List of Earthquakes Located Outside of MPSSZ, Monticello Reservoir and Lakes Jocassee/Keowee During 2001

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	SEH	SEZ	Q
20010318	16 22 32.46	34-42.56	81-32.45	5.42	2.12	14	187	42.0	0.09	0.7	2.1	C
20010611	15 29 49.94	34-43.27	81-16.82	8.72	1.84	14	295	39.1	0.06	0.6	2.8	C
20010817	05 59 46.06	34-23.13	82-31.64	4.57	1.93	14	229	71.0	0.11	0.5	0.5	A
20010902	13 56 09.80	33-52.13	82-22.23	5.00	2.40	20	109	82.0	0.35	0.2	0.4	A
20010919	23 25 42.04	33-15.51	81-15.52	5.69	1.49	8	139	13.0	0.06	3.0	6.5	D
20011008	00 23 01.22	33-19.20	81-39.51	3.90	2.50	(SRS located)						
20011008	02 56 07.00	33-19.06	81-40.29	4.14	1.00	(SRS located						
20011008	08 53 50.00	33-20.24	81-40.88	4.22	1.40	(SRS located)						
20011014	06 05 08.54	33-20.86	81-39.75	2.97	0.73	6	220	10.0	0.02	1.0	1.9	C

Table 4

List of Earthquakes Located Near Monticello Reservoir During 2001

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
20010210	06 36 28.48	34-19.80	81-19.20	0.30	0.01	12	103	1.8	0.04	0.1	0.4	A
20010310	02 58 05.13	34-20.17	81-18.34	0.52	0.82	13	96	1.0	0.04	0.2	0.5	A
20010310	03 59 41.99	34-20.23	81-18.24	0.97	0.37	12	155	1.0	0.05	0.2	0.3	A
20010310	04 01 09.54	34-20.49	81-18.55	0.13	0.01	10	155	1.6	0.13	0.5	1.4	B
20010411	02 39 09.38	34-20.01	81-18.26	0.70	0.11	10	128	0.8	0.04	0.2	0.3	A
20010411	02 39 13.84	34-20.01	81-18.13	1.26	0.12	10	134	0.6	0.05	0.3	0.3	A
20010411	02 45 59.71	34-19.93	81-18.34	1.07	0.24	10	123	0.9	0.06	0.3	0.4	A
20010412	02 55 02.72	34-20.01	81-18.26	0.72	0.95	14	95	0.8	0.06	0.2	0.3	A
20010415	22 57 59.54	34-21.07	81-18.25	0.94	0.44	12	195	2.3	0.05	0.2	0.9	B
20010417	19 39 29.79	34-20.94	81-18.43	1.32	0.12	10	185	2.2	0.01	0.1	0.2	A
20010421	04 38 08.61	34-20.01	81-18.16	0.83	0.29	10	132	0.7	0.03	0.2	0.3	A
20010421	04 45 10.40	34-20.01	81-18.09	1.18	0.21	10	137	0.6	0.04	0.2	0.2	A
20010421	19 59 43.85	34-20.12	81-18.06	0.88	0.21	12	158	0.6	0.05	0.2	0.3	A
20010427	01 15 44.78	34-19.68	81-19.46	1.07	0.12	12	120	1.5	0.04	0.2	0.4	A
20010427	08 25 57.43	34-19.59	81-19.47	0.60	0.01	8	181	1.6	0.02	0.2	0.4	A
20010429	15 05 56.50	34-19.99	81-19.58	0.80	1.75	14	103	1.1	0.08	0.3	0.4	B
20010508	05 08 28.61	34-17.33	81-11.09	3.26	0.95	14	143	7.0	0.04	0.2	1.0	B
20010707	08 37 55.44	34-20.40	81-19.29	1.70	0.82	12	117	1.5	0.07	0.3	0.5	A

Table 5

List of Earthquakes Located Near Lakes Jocassee and Keowee During 2001

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
20010131	22 02 12.98	34-57.59	82-57.84	1.95	. 450	8	153	3	0.025	0.3	1.6	B
20010416	02 58 53.84	34-57.74	82-57.70	3.06	.146	8	155	4	0.024	0.4	0.9	A
20010628	22 04 25.52	34-57.28	82-55.75	6.05	2.18	8	162	4	0.081	1.3	1.3	B

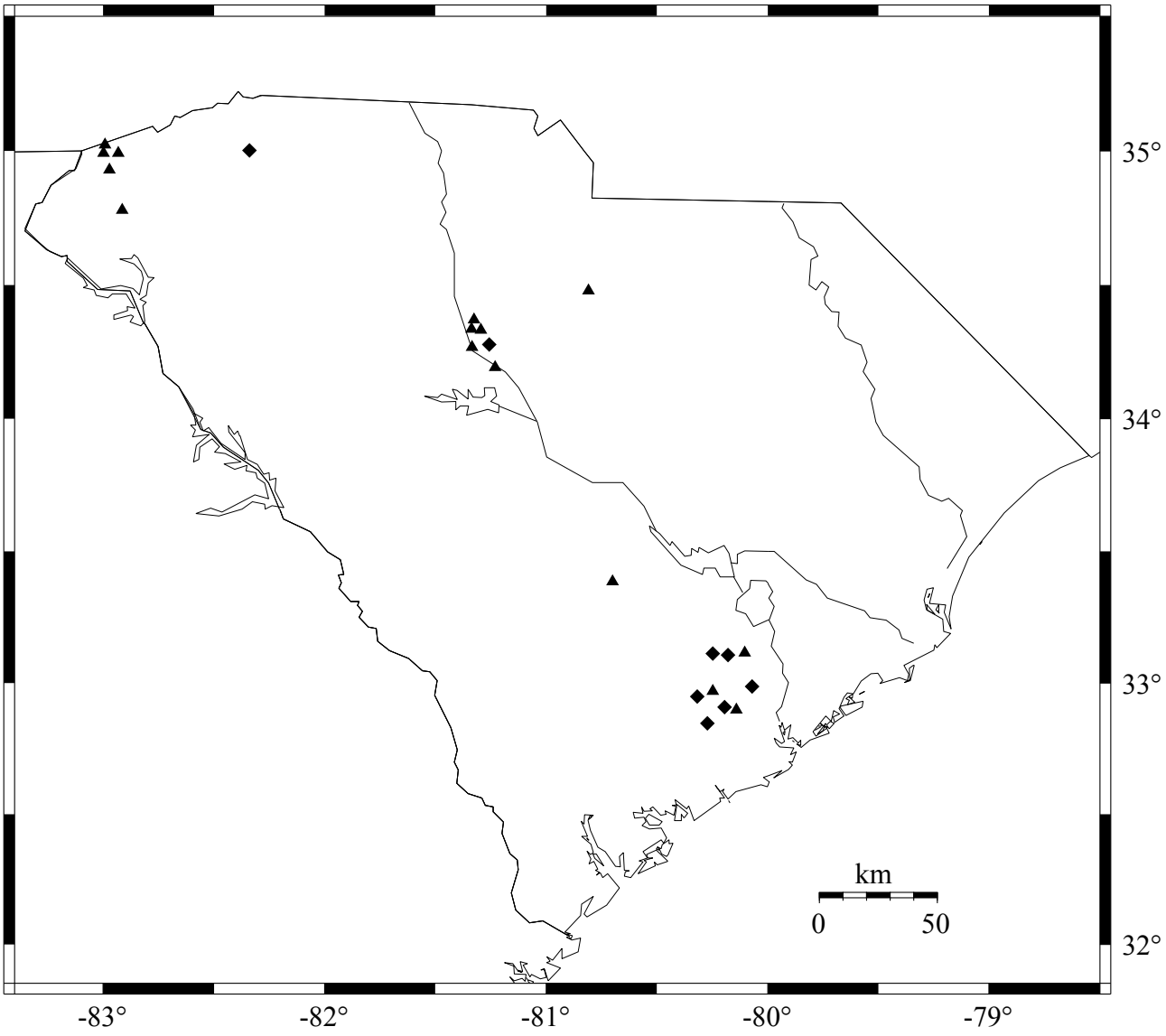

Figure 1. Distribution of stations/subnets of the South Carolina Seismic Network during 2001. Triangles represent single component stations while diamonds siginfy three component stations.

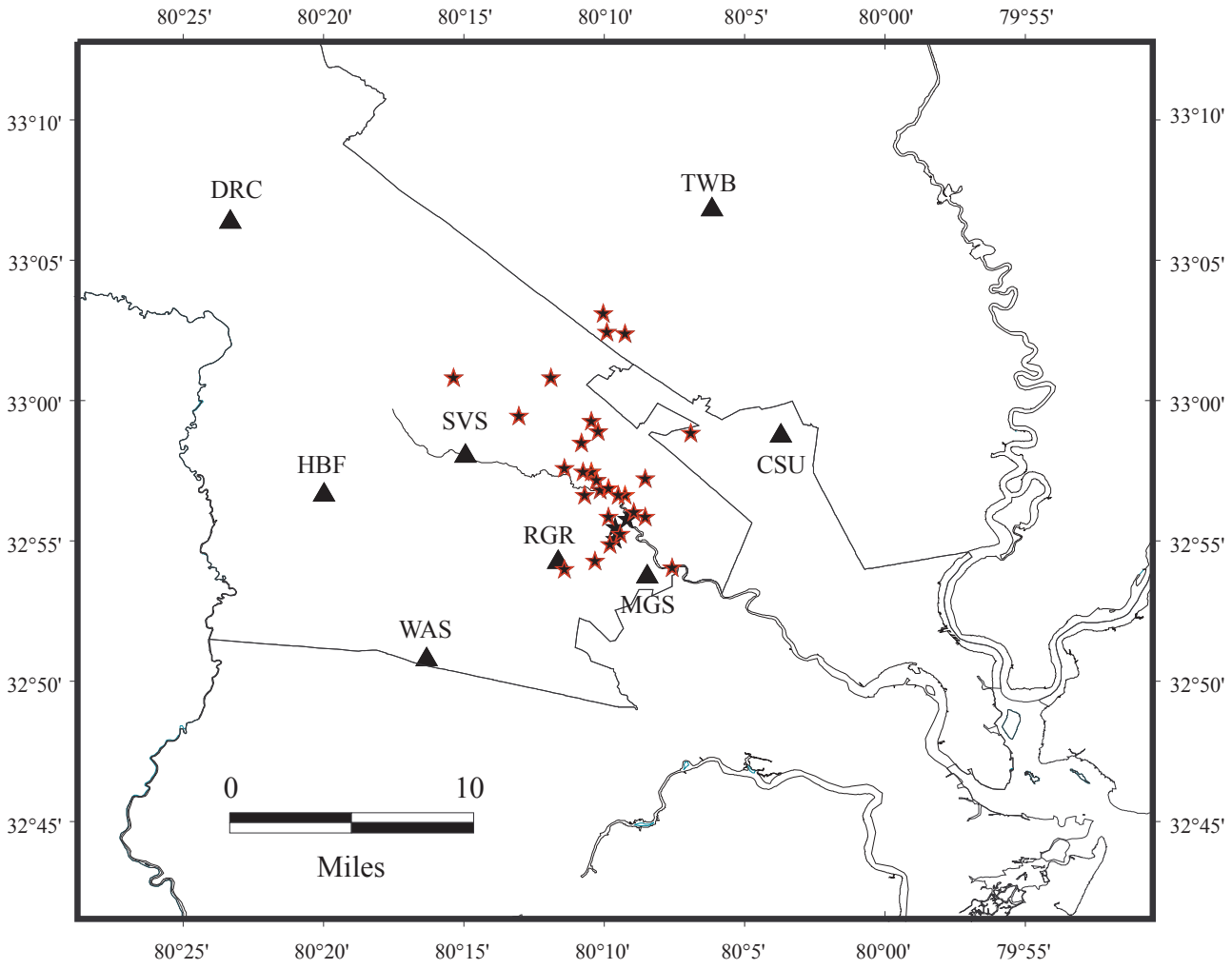

Figure2□ All earthquakes located in the MPSSZ during 2001. Station locations of the □ □ SCSN in the Coastal Plain.

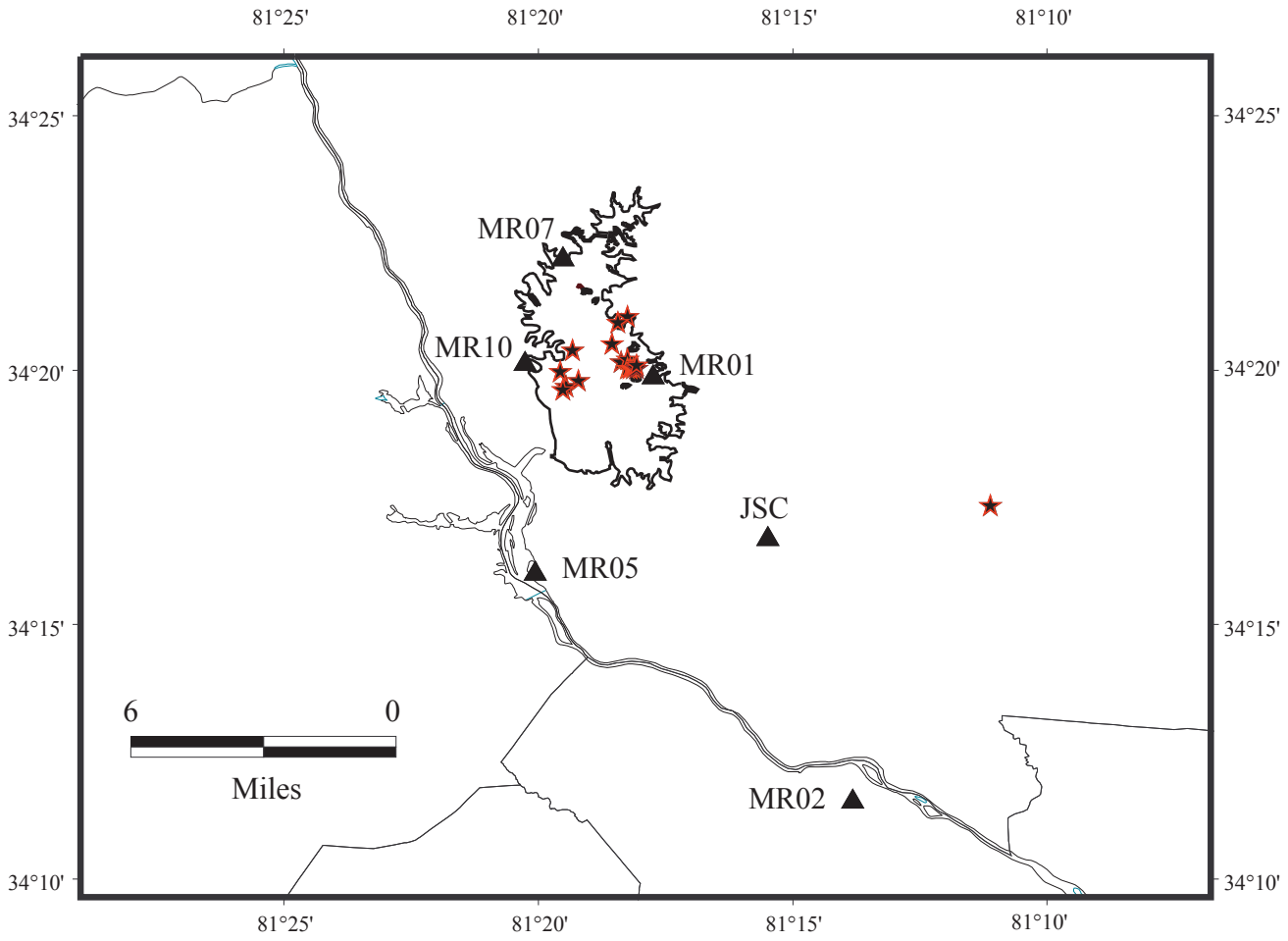

Figure 3. All events located near the Monticello reservoir during 2001(H). Station locations of the Monticello Reservoir subnetwork (s).

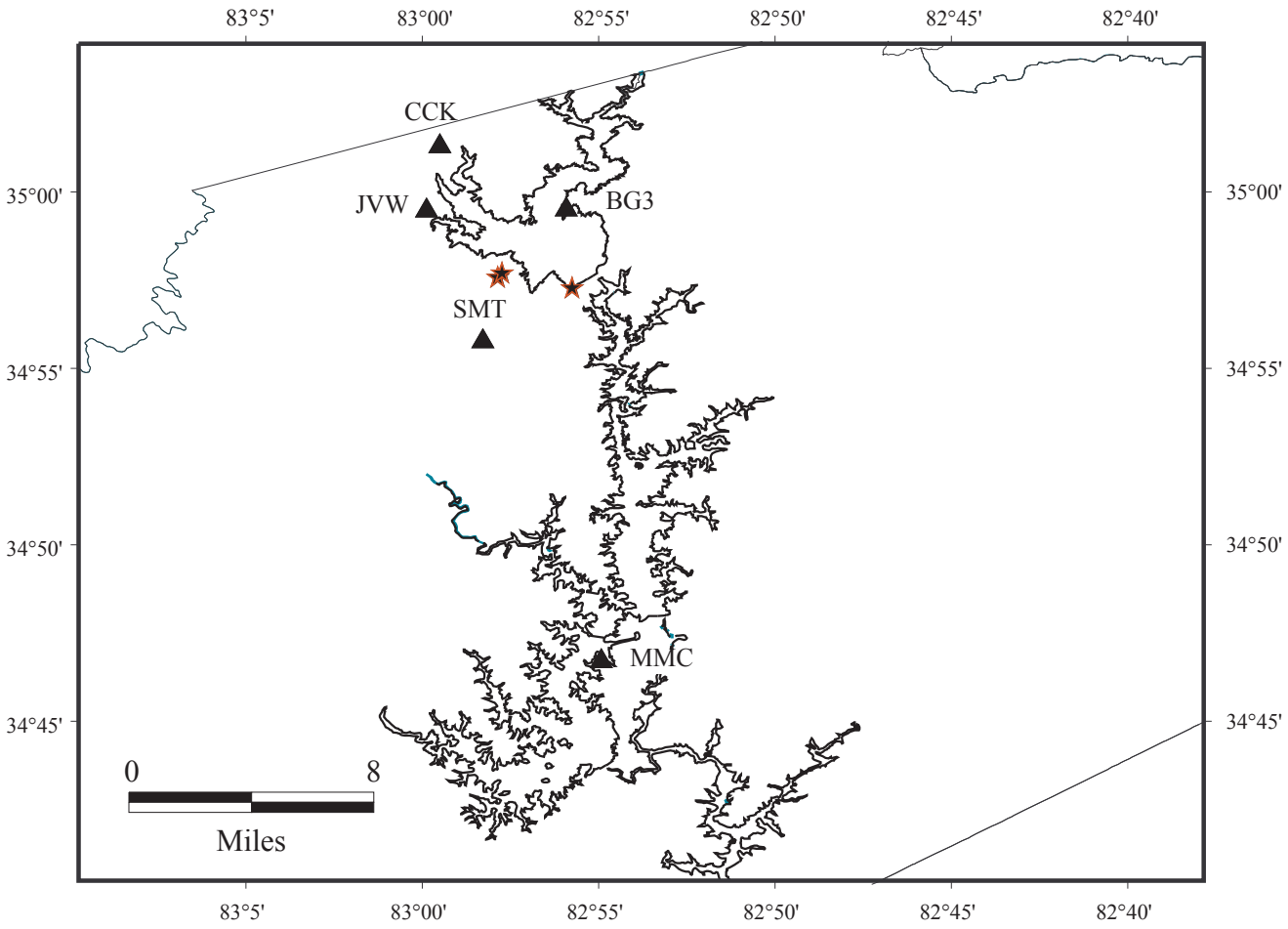

Figure 4. All earthquakes located near lakes Jocassee and Keowee during 2001(H). Station locations of the Lake Jocassee subnetwork(s).

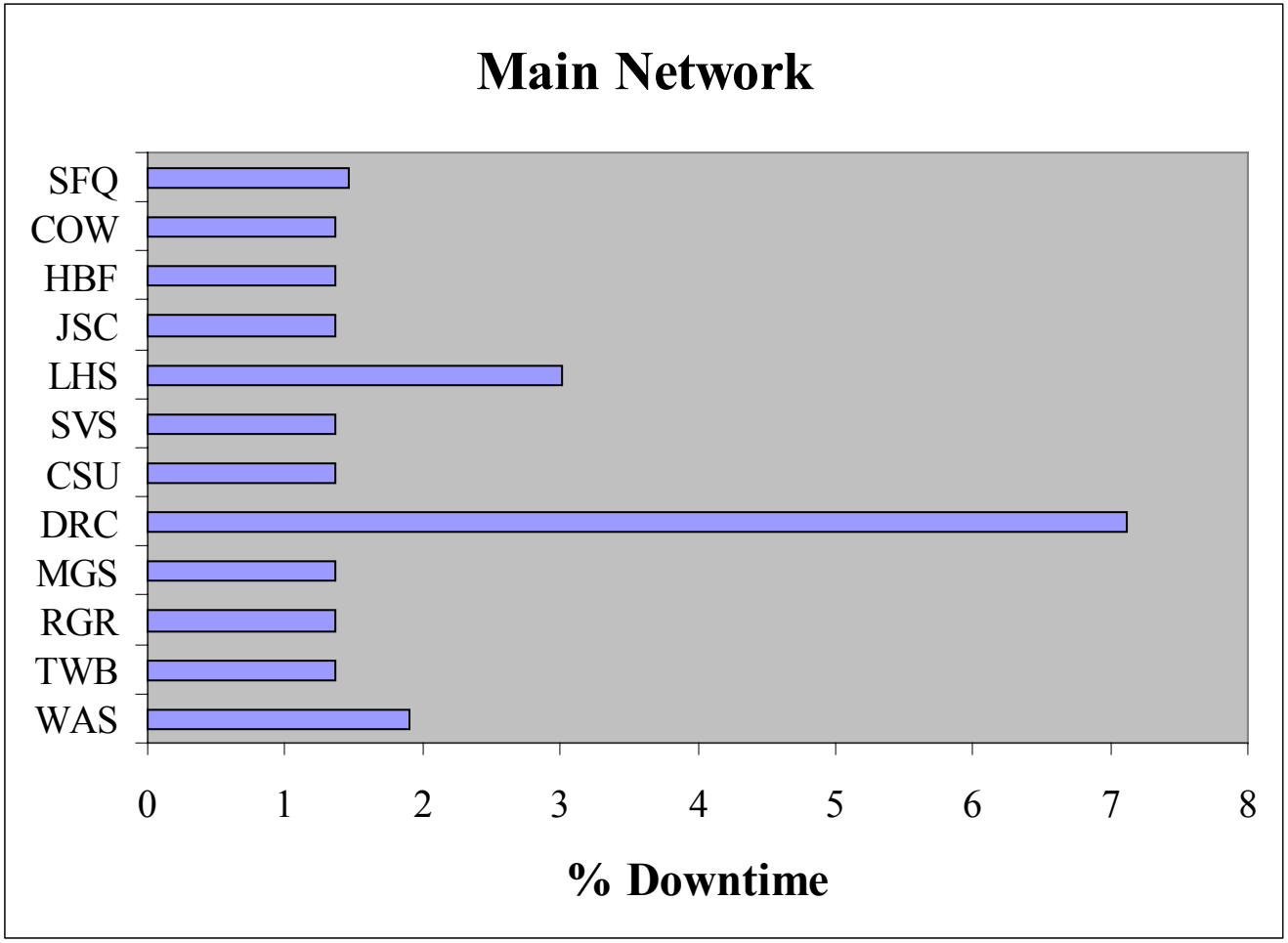

Figure 5. Operational status of the main network of the SCSN during 2001

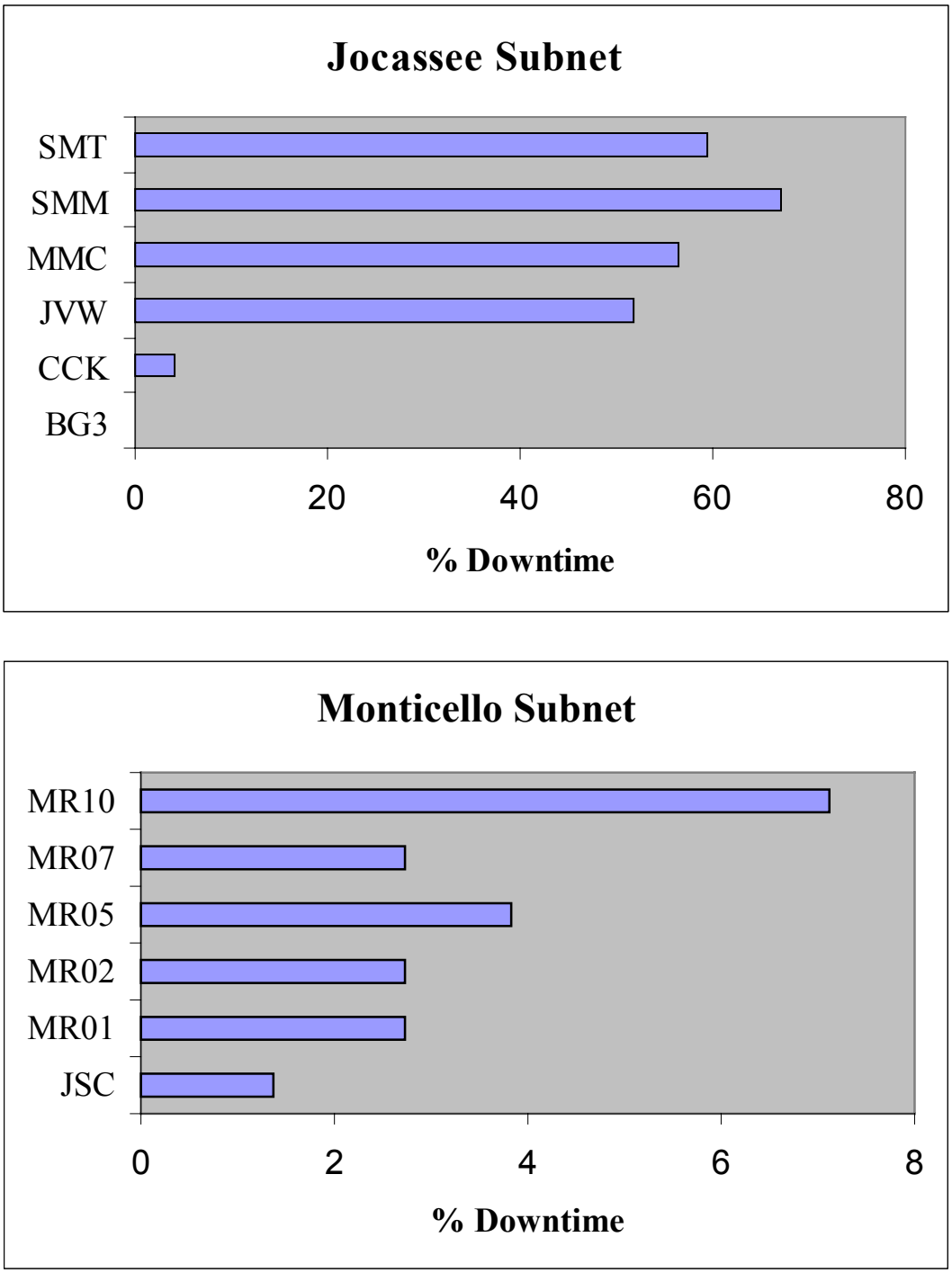

Figure 6. Yearly operational status of the Lake Jocassee and Monticello Reservoir subnetworks

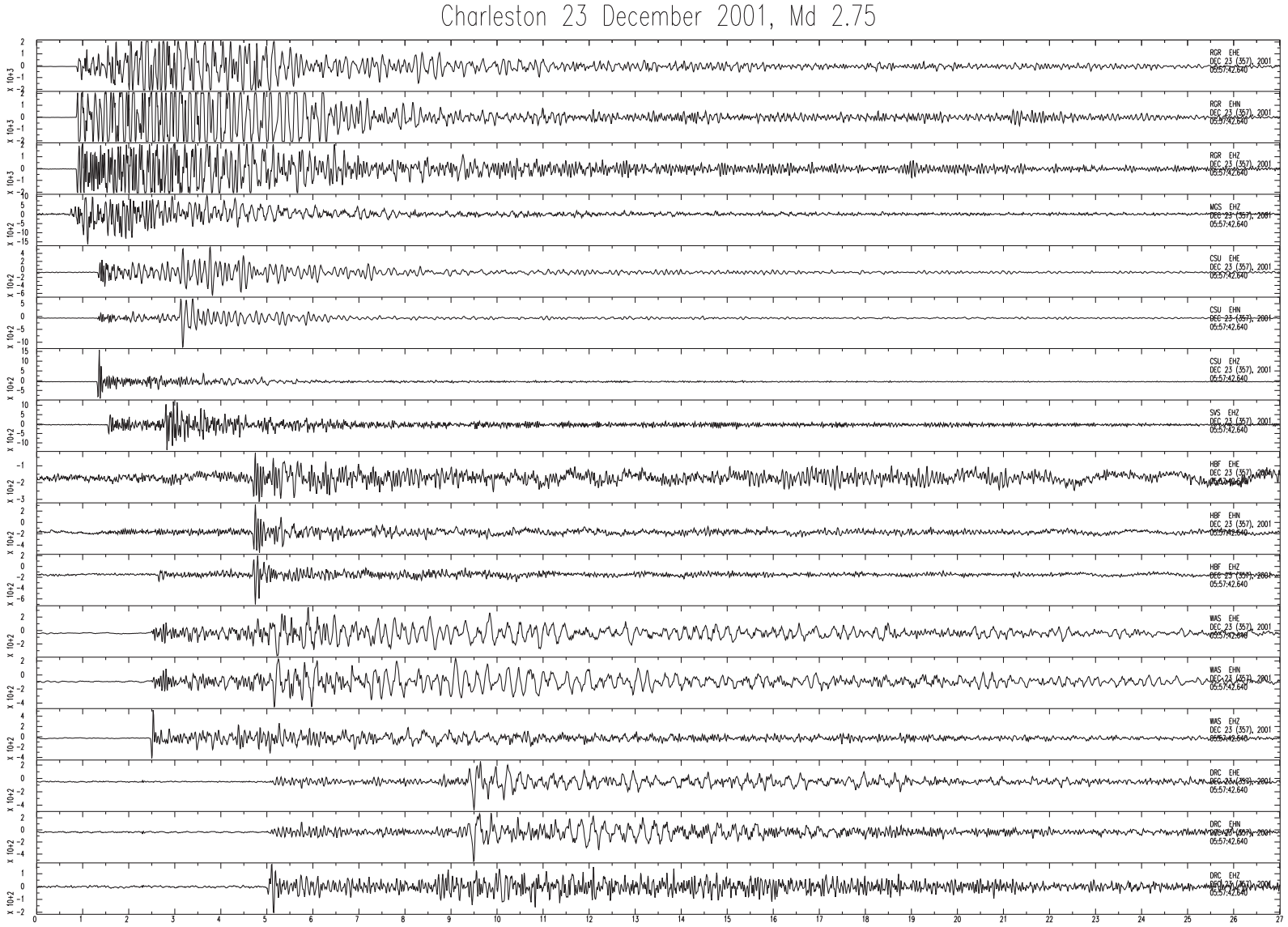

Figure 7a. Digital playback of a ML2.8 earthquake in the MPSSZ during 2001.

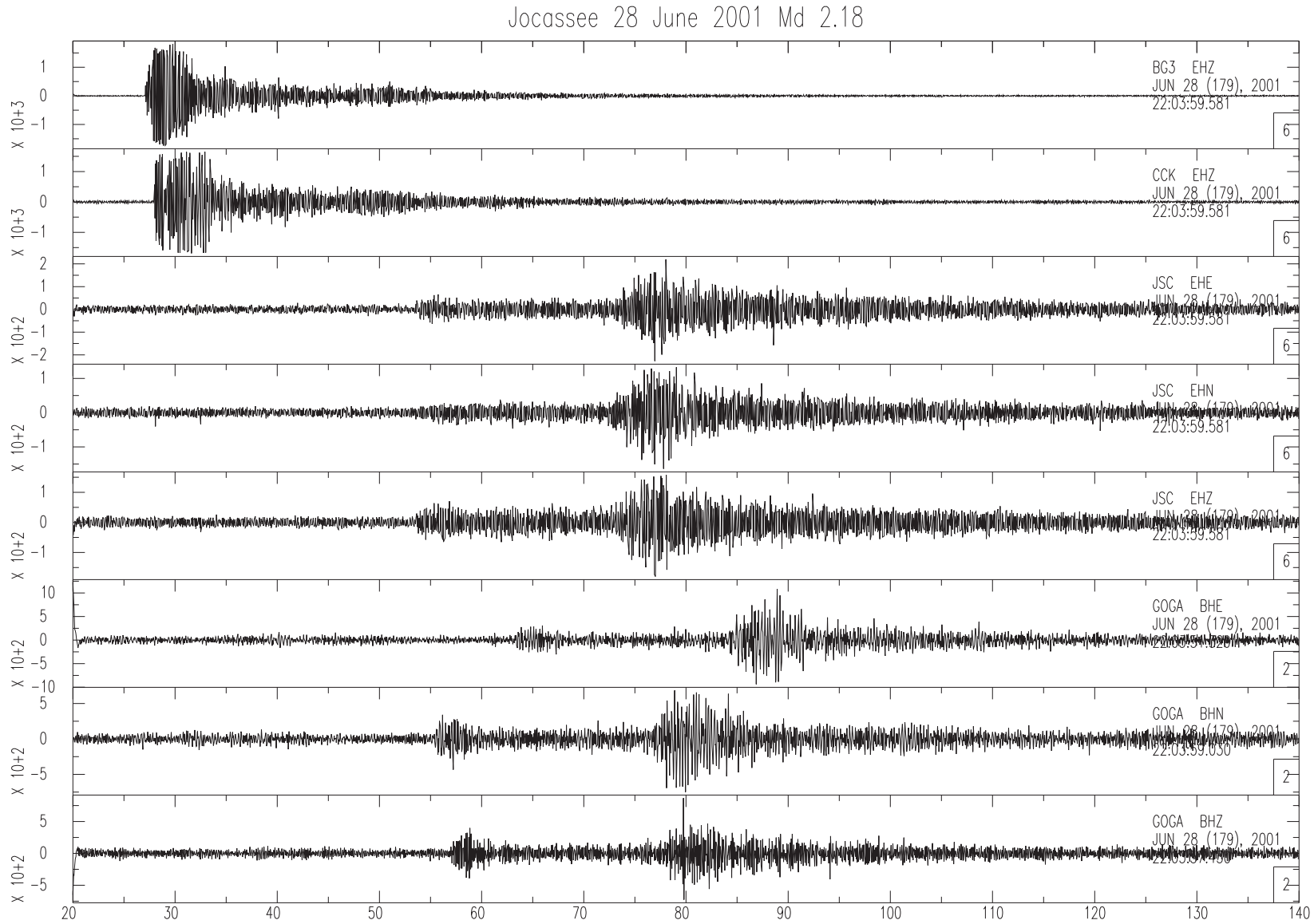

Figure 7b. Digital playback of a ML 2.2 Lake Jocassee earthquake on June 28, 2001.

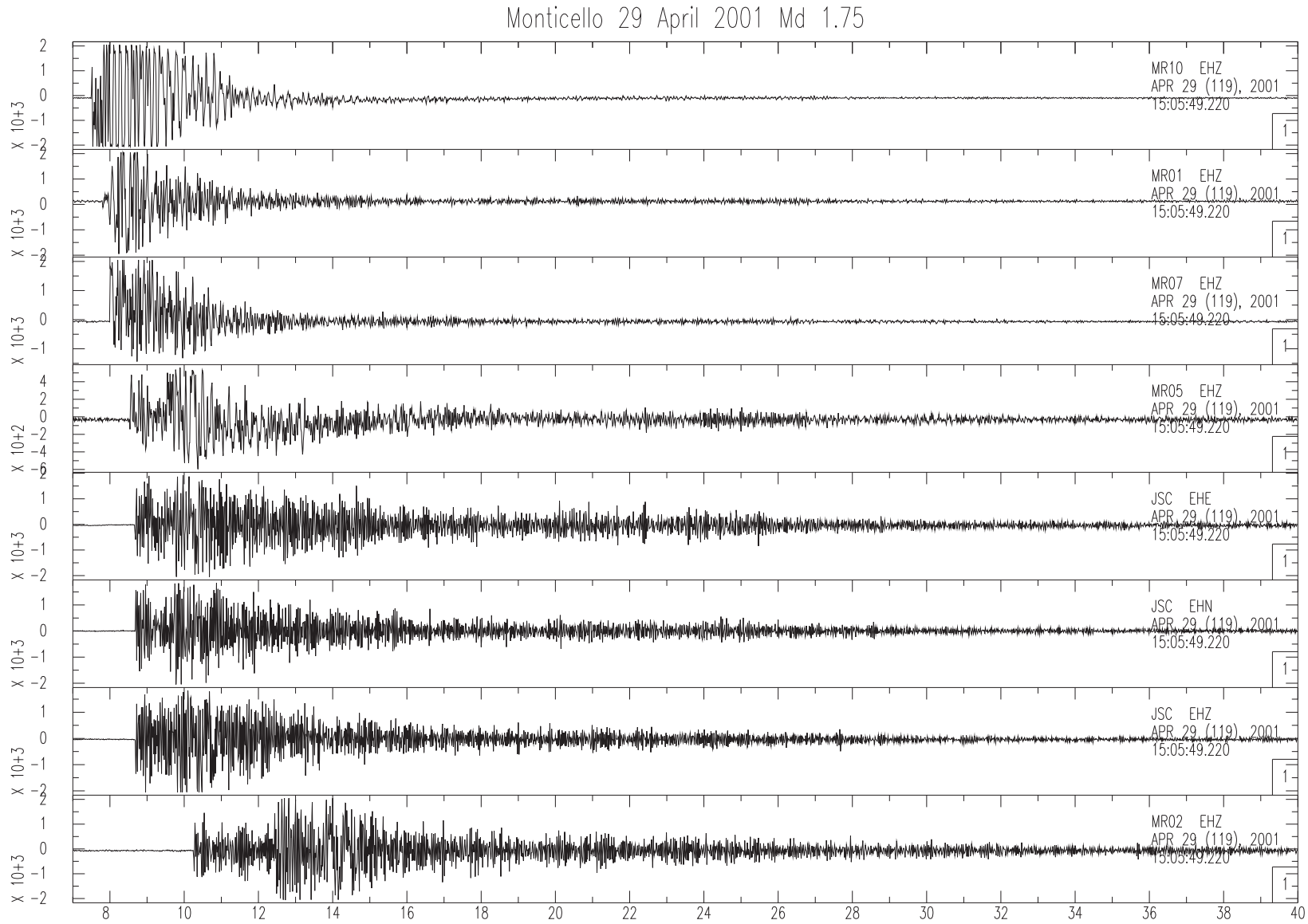

Figure 7c. Digital playback of a ML 1.8 Monticello Reservoir earthquake on April 29, 2001.

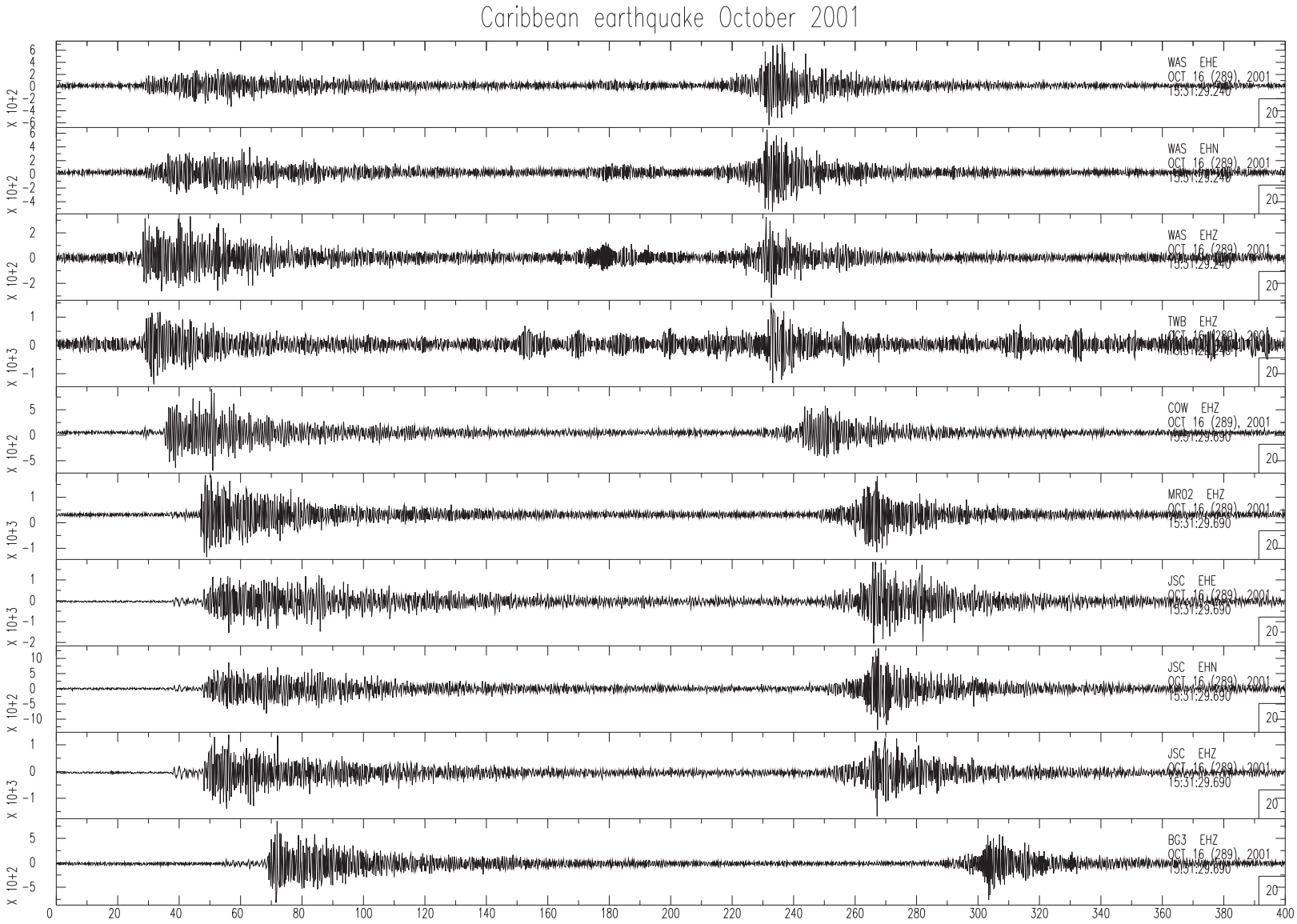

Figure 7d. Digital playback of a Mw 5.7 earthquake near Puerto Rico on October 16, 2001.

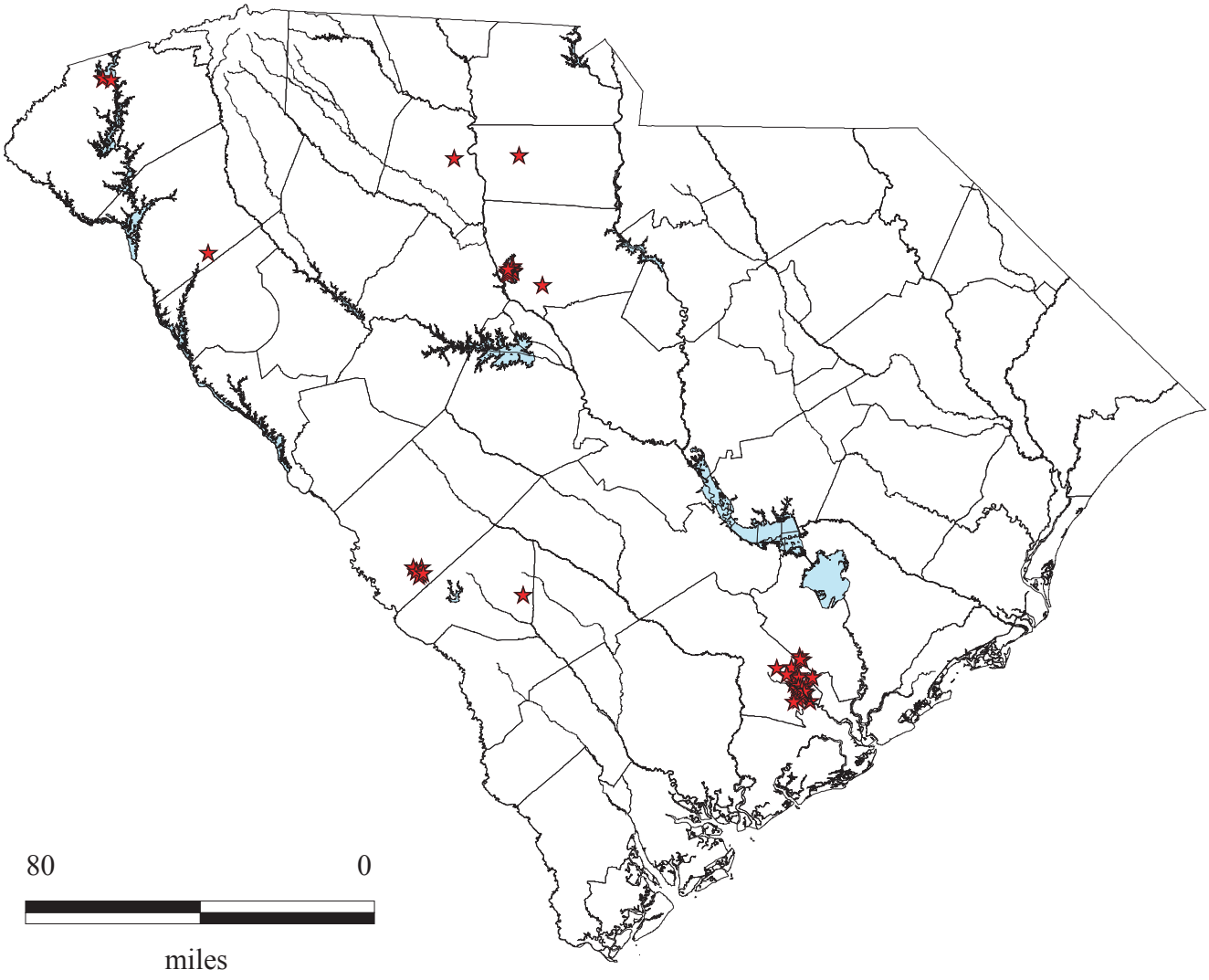

Figure 8. Cumulative seismicity throughtout South Carolina during 2001.

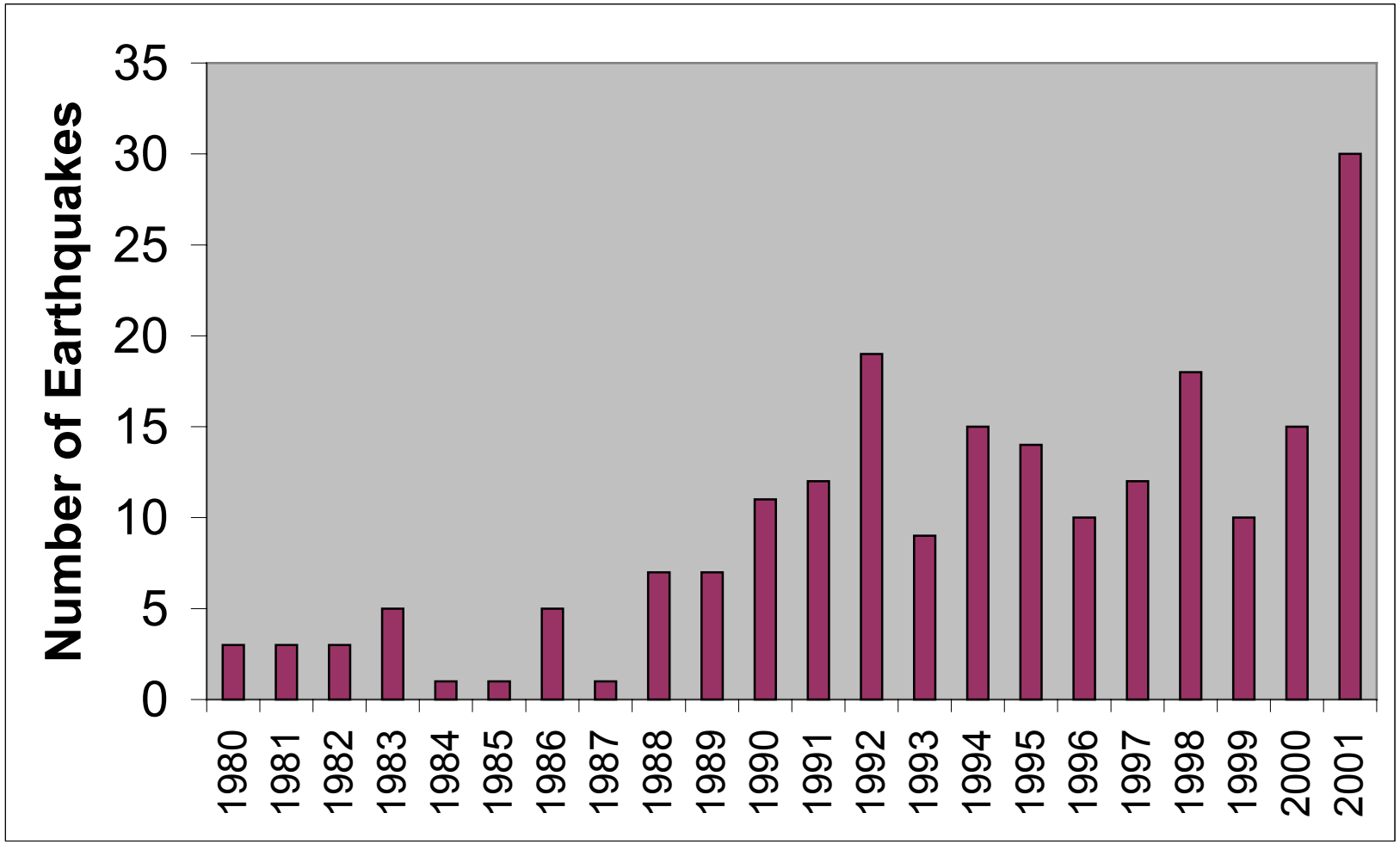

Figure 9. Number of located earthquakes in MPSSZ with magnitudes > 0.6 for the period 1980 – 2001

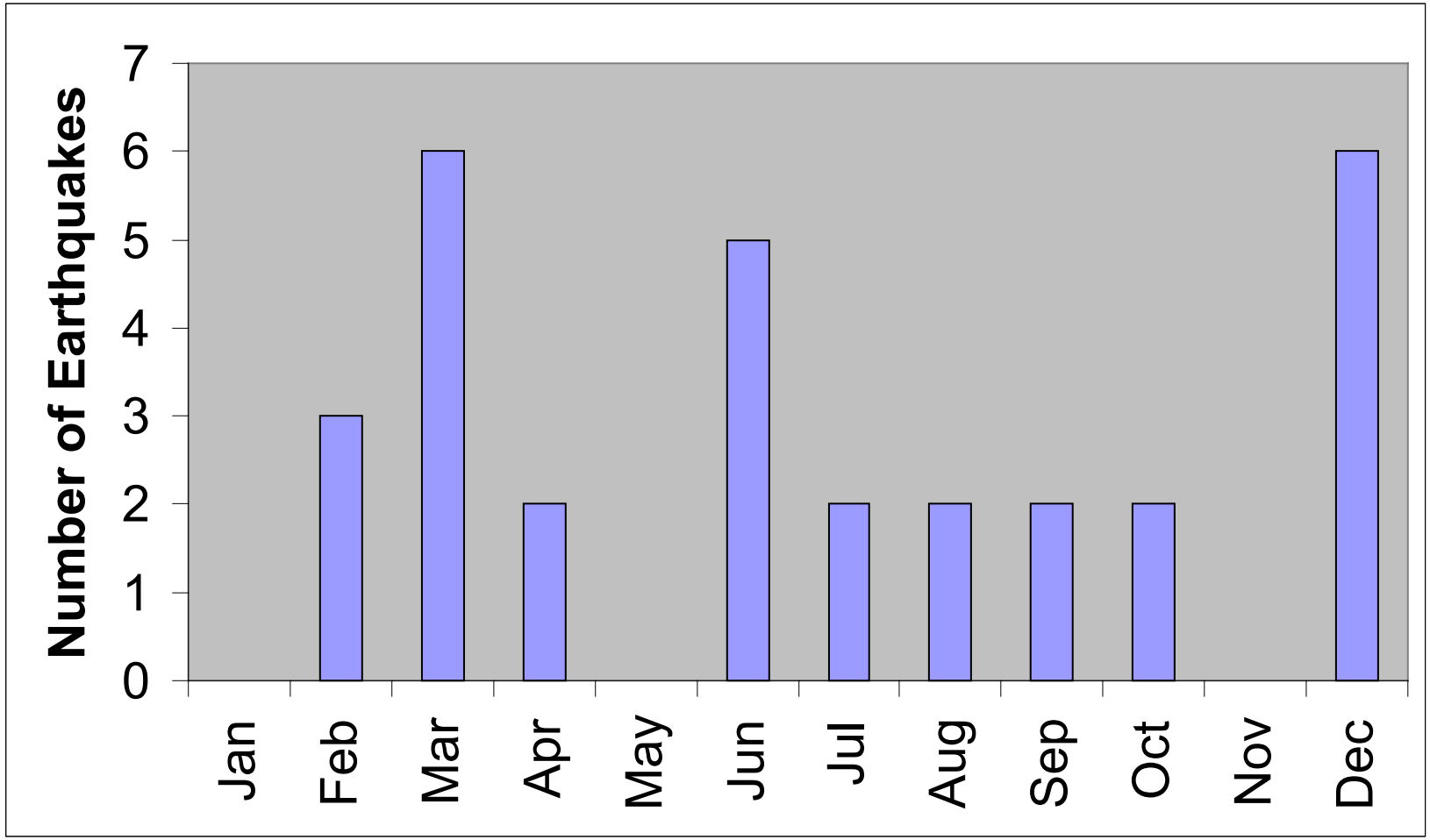

Figure 10. Monthly Distribution of earthquakes located in MPSSZ during 2001

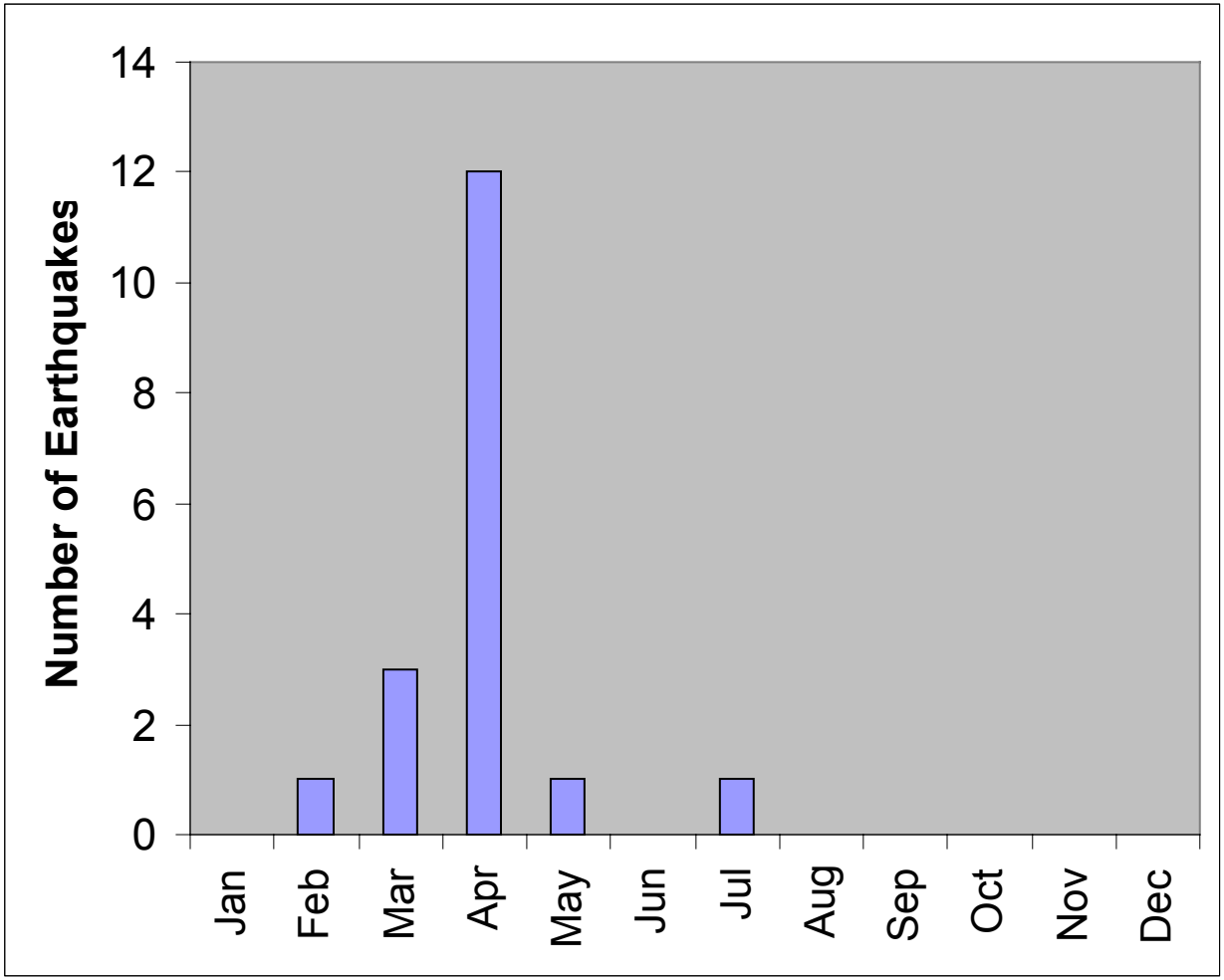

Figure 11. Monthly Distribution of located earthquakes at Monticello Reservoir during 2001

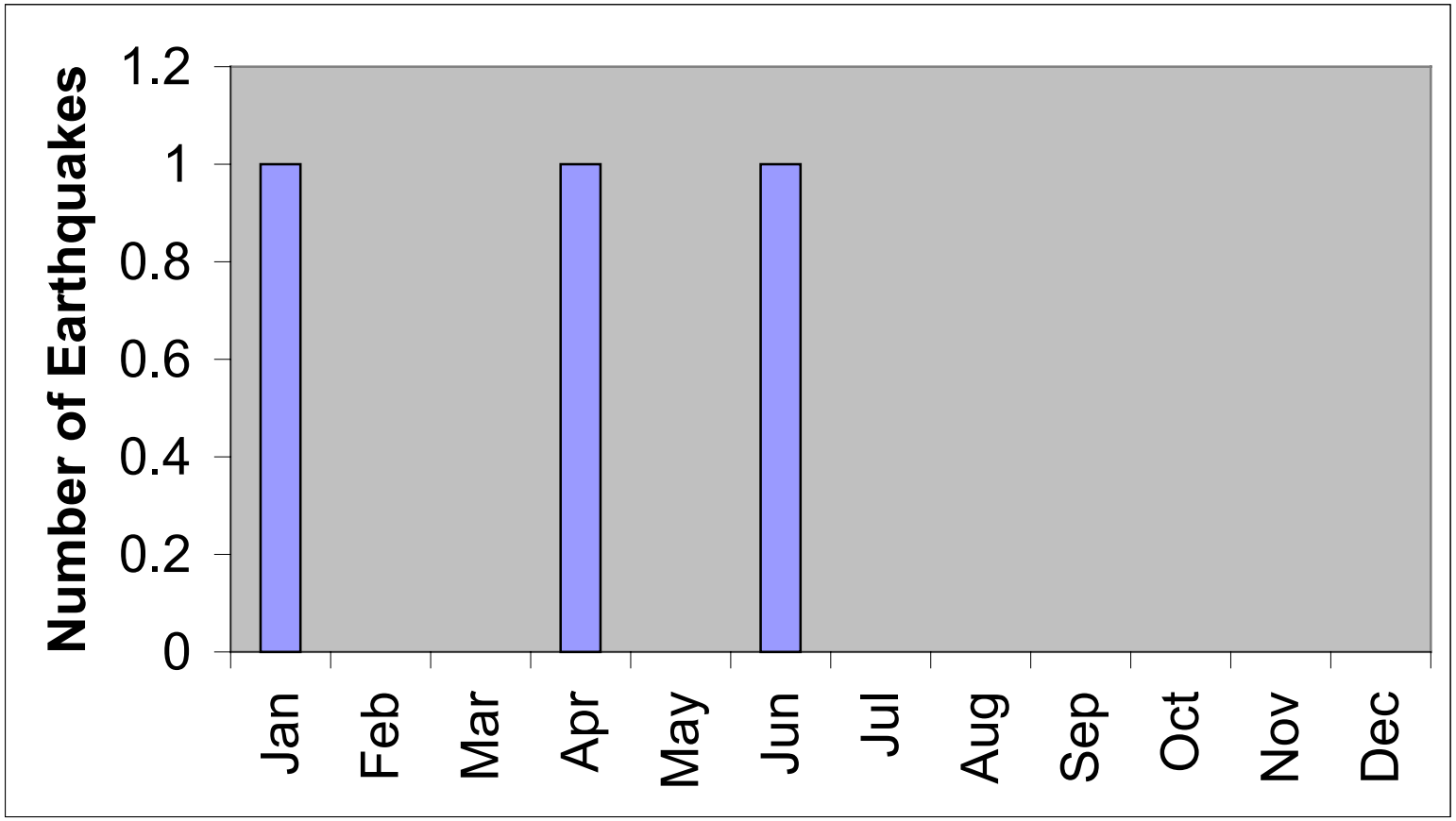

Figure 12. Monthly Distribution of located earthquakes at Lakes Jocassee and Keowee and Bad Creek Reservoir during 2001

South Carolina Seismic Network

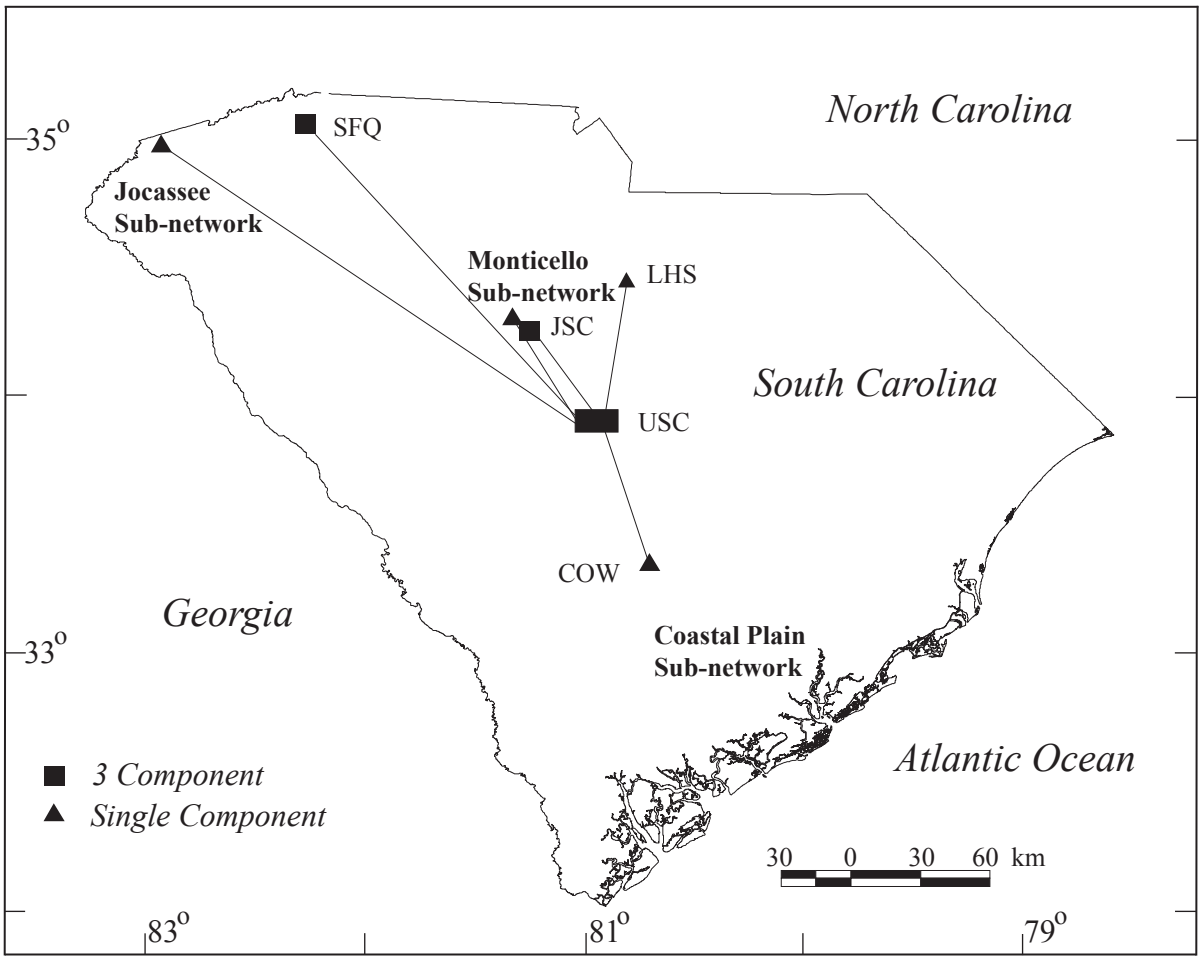

Figure 13. Telemetry routes for seismic data transmitted to USC.

Coastal Plain Sub-Network

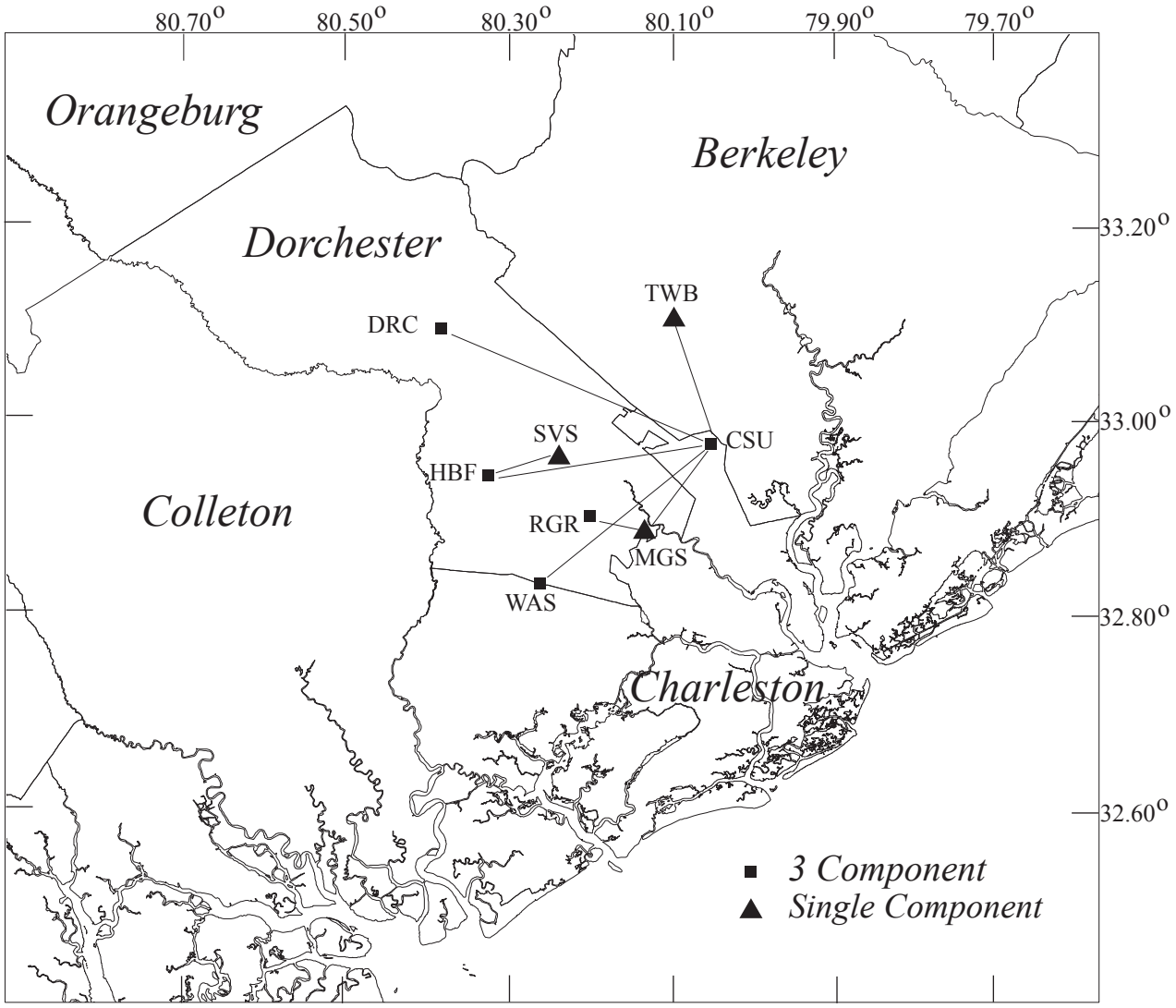

Figure 14. Telemetry routes for seismic data to Charleston Southern University.