Virginia Regional Seismic Network

Final Report (1986-1992)

Prepared by
G. A. Bollinger, M. S. Sibol, M. C. Chapman, J. A. Snoke

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Virginia Polytechnic Institute and State University

Prepared for
U.S. Nuclear Regulatory Commission

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ABSTRACT

In 1986, the Virginia Regional Seismic Network was one of the few fully calibrated digital seismic networks in the United States. Continued operation has resulted in the archival of signals from 2000+ local, regional and teleseismic sources.

Seismotectonic studies of the central Virginia seismic zone showed the activity in the western part to be related to a large antiformal structure while seismicity in the eastern portion is associated spatially with dike swarms. The eastern Tennessee seismic zone extends over a 300x50 km area and is the result of a compressive stress field acting at the intersection between two large crustal blocks. Hydroseismicity, which proposes a significant role for meteoric water in intraplate seismogenesis, found support in the observation of common cyclicities between streamflow and earthquake strain data.

Seismic hazard studies have provided the following results.

- Damage areas in the eastern United States are three to five times larger than those observed in the west.
- Judged solely on the basis of cataloged earthquake recurrence rates, the next major shock in the southeast region will probably occur outside the Charleston, South Carolina, area.
- Investigations yielded necessary hazard parameters (for example, maximum magnitudes) for several sites in the southeast.

Basic to these investigations was the development and maintenance of several seismological data bases.

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EXECUTIVE SUMMARY

Project efforts have been directed toward network operations, seismotectonic studies, seismic hazard assessment and the continuing effort to collect and document seismological data (e.g., earthquake catalogs) for Virginia and the southeastern United States.

Network Operations:

In 1985, an upgrade to the digital recording of the incoming analog signals, and development of a system calibration method, produced one of the few calibrated seismic networks in the United States. The resulting waveform data base consists of over 2000 signals from local, regional and teleseismic sources (earthquakes and blasts) for which true ground motion can be determined for several (12+) sites throughout Virginia and West Virginia.

Seismotectonic Studies:

- In the central Virginia seismic zone, the combination of seismic reflection studies and well located hypocenters indicates that earthquakes in the western portion of the zone may be related to reactivation of faults above and along the roof of a large antiformal structure in the upper crust. Activity in the eastern portion of the zone correlates spatially with a near vertical diabase dike swarm.
- The eastern Tennessee seismic zone extends over an area of 300 x 50 km. Our studies suggest that this activity results from a regional compressive stress field acting on an extended segment between a relatively weak seismogenic crustal block on the southeast and a relatively strong crust to the northwest.
- Hydroseismicity postulates that some intraplate earthquakes in rifted, fractured crust are triggered by repetitive transient increases in fluid pressure transmitted along preexisting fractures. Common cyclicities between streamflow and earthquake strain in several areas where large river basins and earthquake activity coexist lend support to the role of meteoric water in intraplate seismic activity.

Seismic Hazard Studies:

- An investigation of damage areas demonstrated that for a given earthquake ($5.5 \leq M \leq 7.5$), the damage area (MMI: VI-VII) in eastern North America would be three to five times larger than the damage area observed for the same size earthquake in the western United States.
- A study employing instrumental magnitudes for nearly 500 earthquakes, exploratory data analysis and robust estimation techniques, developed methods for converting maximum intensity (MM) and/or felt area to magnitude.
- Recurrence relations for the southeastern United States and several of its subdivisions were determined. A principal result of that study was that the recurrence interval for a 'Charleston earthquake' ($m_b(L_g) \sim 6.75$) in the Charleston area was 940-14,000 years (consistent with some paleoseismic studies), while the same interval for the remainder of the southeastern United States was a much shorter 250-560 years.
- Another study used coda waves from local and regional signals to develop a frequency dependent coda Q estimate ($Q = 811 f^{0.42}$, $1.5 \leq f \leq 12$ Hz) for the southern Appalachian region.

These last three studies provided a basis for the following site specific seismic hazard investigations.

- A study of the Savannah River Site in South Carolina described methods for determining various seismic parameters (e.g., seismic zonation, recurrence relations, etc.) for input to a probabilistic seismic hazard assessment (which was carried out by Lawrence Livermore National Laboratory).
- A study of the northwest elongation of the intensity pattern for the 1886 Charleston, South Carolina, earthquake employed synthetic ground acceleration time series for different thicknesses of unconsolidated surficial layers (meant to approximate Coastal Plain sediments). That study demonstrated that the apparent high intensity reports near the South Carolina Fall Line were probably due to thin surficial layer amplification there, while the relative high attenuation of vibrations through the thicker sediments reduced effects along the coast.
- Application of three different methods of maximum magnitude estimation in the Giles County, Virginia, seismic zone yielded a maximum magnitude estimate of $M_s = 6.8$ ($m_b = 6.3$) for the zone.
- A detailed search of historical archives in several communities in central Virginia provided a refined epicentral location of the 1875 central Virginia earthquake (the largest known to have occurred within the zone).

Seismological Data Collection and Documentation:

Since network operations began in 1977, this project has published the Southeastern United States Seismic Network Bulletin in a consistent and timely fashion. The bulletin provides hypocentral locations, magnitudes, felt/damage reports and arrival times for southeastern United States earthquakes. Over the last 14.5 years, on average, 80 earthquakes were reported each year of which nine were felt by residents. In 1991, the bulletin was distributed to over 230 institutions and individuals, including 40 foreign destinations.

INTRODUCTION

The Virginia Regional Seismic Network began operations in 1977. The Final Report for the work done through 1985 under Contract No. NRC-04-77-134 was presented in Bollinger and others (1986, 1987).

Since 1985, seismotectonic studies have been conducted in the central Virginia and the eastern Tennessee seismic zones. An hypothesis dealing with the role of meteoric water in intraplate seismogenesis, termed Hydroseismicity, has been developed. Seismic hazard studies have been developed at state, regional and national level scales. Data bases have been collected and maintained for local and regional earthquake catalogs, focal mechanisms and for digital waveforms of local, regional and teleseismic earthquakes as well as for mining and nuclear explosions. Results from the associated scientific studies were routinely published in refereed journals. The Southeastern United States Seismicity Network Bulletin, also published by this program, has provided locations, magnitudes and arrival times for southeastern United States earthquakes, as well as cumulative catalog statistics in a consistent and timely fashion.

The following sections will describe, in order: Previous Work, Network Operations, Seismotectonic Studies, Seismic Hazard Assessments, Data Bases, and Publications.

PREVIOUS WORK

This report chronicles the seismic research results and hazard assessments derived from the data acquired from the Virginia Regional Seismic Network during the seven year report period from 1986 through 1992. Network operations began in 1977 and the Final Report for the work done through 1985 under Contract No. NRC-04-77-134 was presented in Bollinger and others (1986, NUREG/CR-4502) and Bollinger and others (1987, NUREG/CR-4974).

Significant advances in the understanding of seismotectonics in Virginia and its host region, the southeastern United States, were made during that initial monitoring period from 1977 through 1985. In particular, the eight years of monitoring with a 20-station regional network developed epicenters, focal depths and focal mechanisms of adequate number and quality from earthquakes with $M \leq 4$ to reveal considerable differences between the two seismically active portions of Virginia. Those two areas are in the southwestern (Giles County) and central parts of the state and are separated by only 200 km. Despite their spatial proximity, the two zones exhibit remarkable differences in geological and mechanical characteristics. In Giles County, seismic energy is released by predominately strike-slip faulting in a near vertical, northeasterly-trending tabular zone (~40 km long) that is below the Appalachian décollement. In central Virginia, the seismicity is derived from mixed dip-slip and strike-slip faulting within a large, coin-shaped volume (~100 km diameter; ~10 km vertical thickness), above the major detachment faulting. Stress estimates, as derived from single- and composite-focal mechanism solutions P-axes, are NE to ENE in Giles County while they vary from NE at the shallower depths (< 8 km) to NW for the deeper earthquakes in central Virginia.

The causes for the observed variability are unknown. The two zones are in different geologic/topographic provinces (Giles County within the Valley & Ridge and central Virginia is within the Piedmont) but, because Giles County activity is sub-detachment, that aspect did not appear to be a controlling difference. They may also be in different tectonostratigraphic (suspect) terranes, and that difference could be relevant. The Hydroseismicity model proposed by Costain and Bollinger and their co-workers in 1985 ascribes the observed secular seismicity variations in Virginia and throughout the Southeast to different drainage basin hydrologic characteristics (Giles County and the New River; central Virginia and the James River) plus differences in upper crustal fracturing due to ancestral periods of extensional tectonics.

As noted above, the vertical disparity between the seismic energy release in the zones is pronounced: It is sub-décollement (5-25 km) in Giles County and supra-décollement (< 13 km) in central Virginia. The mean and 90% depths (depths for which 90% of the earthquake foci lie above) are 12 and 18 km, respectively, in Giles County and 8 and 14 km, respectively, in central Virginia. The mean depths are statistically different (p -value = 0.01).

The focal mechanism solutions also exhibit the pervasive differences that exist between the two Virginia seismic zones. In Giles County, there is a predominately strike-slip faulting response to a northeasterly, sub-horizontal maximum compressive stress (P-axes). A very similar stress-faulting combination was found some 400 km to the southwest along strike in southeastern Tennessee. Central Virginia focal mechanisms, on the other hand, display both dip-slip and strike-slip modes of faulting and both northeasterly and northwesterly oriented P-axes. Thus, while there is relative uniformity in the stress and faulting estimates for Giles

County (and eastern Tennessee) seismicity, there is considerable variability in those same estimates for central Virginia.

Reflection seismology studies were conducted for the Giles County seismic zone. Gresko and others (1985) interpreted a series of down-to-the-east normal faults that appear to offset basement reflectors (Precambrian) at depths of 5-10 km while the overlying Upper Cambrian and Ordovician sequences appear to be undisturbed. This lack of faulting in the younger strata is taken as evidence that the fault growth ended during the Cambrian. These faults could be the Iapetan features as postulated by Bollinger and Wheeler (1982, 1983). The northeasterly-striking nodal planes of the Giles County focal mechanism solutions dip steeply to the east and to the west. Of primary importance here is the fact that both focal mechanism and reflection seismology data sets indicate steeply dipping fault planes and are thereby in general agreement for the Giles County zone.

At the end of the initial period of study, a seismotectonic model for the Giles County seismic zone had been developed as a northeasterly trending 40 km long fault system in autochthonous Grenville basement rocks that dips steeply and exhibits predominately strike-slip movements. The present-day seismicity is interpreted to be due to reactivation of ancestral Eocambrian extensional faults in a modern compressive stress field. The geometry and architecture of the central Virginia seismic zone had been defined by accurately located foci and focal mechanism solutions, but a seismotectonic model had not yet been developed. Additionally, focal mechanism studies had been conducted for the important eastern Tennessee seismic zone.

NETWORK OPERATIONS

Overview

Since its installation in 1977, the Virginia Regional Seismic Network has consisted of from 14 to 20 seismic stations. Figure 1 shows the current configuration of the network. All sites have single (vertical) or three-component 1 Hz sensors and analog telemetry. The entire recording system has a dynamic range of approximately 40 dB. Operational statistics were reported routinely in the Quarterly Reports #85-121-1 through #85-121-28 and will not be repeated here. In general, the average downtime for the various subnetworks ranged from a minimum of 2% (Giles County subnetwork) to a maximum of 7.5% (North Anna subnetwork). A Virginia seismicity map for the period 1978-1992 is shown in Figure 2.

Data Acquisition

Beginning in 1985, digital data acquisition was initiated at the central recording site, but data telemetry remained analog, primarily by leased telephone lines. For 1985-1989, digitization was performed by a Digital Equipment PDP 11/34 with a LPA 11-K digitizer. Analysis was performed on a second PDP 11/34. Later, the

Figure 1. Current configuration of the Virginia Regional Seismic Network. Station locations are indicated by the triangles. Three-component stations are indicated by filled triangles while all others are short-period vertical component only.

Figure 2. Earthquakes ($0 \leq M \leq 4.1$) detected and located since the installation of the Virginia Regional Seismic Network in 1978. Epicenters are shown by filled circles and N indicates number of events plotted.

principal analysis system became a VAXStation II. In 1989, the data acquisition PDP 11/34 was replaced by a Sun 3/50 computer collecting data from a Cutler Data Sampler digitizer and running acquisition software provided by Peter Ward of the U.S. Geological Survey. Both the PDP 11/34 and the current Sun 3/50 digitizing systems recorded 32 channels of network data with 12 bit resolution at a rate of 100 samples per second. Currently, two Sun Sparcstations are also used as analysis systems. All of the computers used for data acquisition and analysis are nodes on the Internet communication network.

Network Calibration

Principal Reference:

Chapman, M. C., J. A. Snoke and G. A. Bollinger, (1988), A procedure for calibrating short-period telemetered seismograph systems, Bull. Seism. Soc. Am., 78, p. 2077-2088.

Chapman and others (1988) developed and applied a network calibration method that began with a traditional Fourier analysis of system response to transient test functions applied to the seismometer calibration coils for each channel. However, such a technique can be applied over only a limited bandpass (typically 0.2-10 Hz) because of system noise, ambient ground noise and the limited dynamic range of the short-period sensors. By treating the seismometer separately from the rest of the system, the frequency range can be broadened considerably. With the seismometer replaced by a signal generator, the amplitude response for the remainder of the system over the range 0.02-50 Hz can be obtained. From the total

response over the limited 0.2-10 Hz range, one can then solve for the sensor amplitude response. Assuming the sensor to be an ideal, damped harmonic oscillator, least-squares iteration is used to solve for the natural frequency and damping coefficient for each sensor. The theoretical seismometer equation with these parameters fixed can then be used to extrapolate the seismometer response to the full desired frequency range thereby allowing a reliable estimate of the total system amplitude response over that range. The phase response was determined by assuming the system to be minimum phase, and using a very stable method to calculate Hilbert transforms.

For the Giles County subnetwork, instrument calibrations were initiated in late 1985. Calibrations of the central Virginia and North Anna subnetworks were performed during the first half of 1986. Periodic checking and recalibrations have been performed since that time. Figure 3 shows the Virginia Tech standard instrument response to which all channels are routinely corrected. Table 1 provides the pole-zero and the frequency-amplitude-phase representation of that response.

Figure 3. Standard displacement amplitude response of the Virginia Regional Seismic Network stations.

TABLE 1

Virginia Tech Seismological Observatory Standard Instrument Response
in Both Pole-Zero and Frequency-Amplitude-Phase Formats

Pole-Zero Format:

A0 = 7.0585E+11

9 RESPONSE POLES:

```
( -1.31947, 0.0 ) ( -0.879646, 0.0 ) ( -50.2655, 0.0 )
( -56.5487, 0.0 ) ( -125.664, 0.0 ) ( -4.39823, -4.48709 )
( -4.39823, 4.48709 ) ( -62.8319, -108.828 ) ( -62.8319, 108.828 )
```

5 RESPONSE ZEROES 5 ZERO VALUES:

Frequency-Amplitude-Phase Format:

<u>Frequency</u>	<u>Displ. Amp.</u>	<u>Phase</u>	
0.0100	2.6646E-06	-1.4345	-82.1933
0.0500	7.6566E-03	-0.9072	-51.9766
0.1000	0.1965	-0.3320	-19.0242
0.1500	1.127	0.1314	7.5258
0.2000	3.552	0.5013	28.7220
0.3000	15.70	1.0567	60.5419
0.4000	41.56	1.4731	84.3997
0.5000	84.76	1.8190	104.2216
0.6000	147.1	2.1260	121.8135
0.7000	227.7	2.4078	137.9575
0.8000	323.1	2.6690	152.9216
0.9000	428.0	2.9101	166.7367
1.0000	536.8	3.1306	179.3678
1.5000	1038.	3.9470	226.1454
2.0000	1440.	4.4509	255.0202
3.0000	2080.	5.0941	291.8704
4.0000	2564.	5.5523	318.1237
5.0000	2910.	5.9299	339.7585
6.0000	3137.	6.2599	358.6681
7.0000	3265.	6.5571	375.6926
8.0000	3317.	6.8297	391.3114
9.0000	3310.	7.0834	405.8502
10.0000	3260.	7.3226	419.5538
15.0000	2631.	8.3930	480.8845
20.0000	1695.	9.3193	533.9539
30.0000	496.1	10.4919	601.1415
40.0000	167.9	11.0523	633.2474
50.0000	70.28	11.3697	651.4354
100.0000	4.496	11.9765	686.2023

Note that the Virginia Regional Seismic Network is one of the few fully calibrated seismic networks in the United States.

The advantages of determining and maintaining a calibrated network are obvious. Figure 4 shows four different traces for the same earthquake recorded at network station BLA in Blacksburg, Virginia. The top trace shows the uncorrected data in digitizer counts. The next three traces show the same waveform corrected to the Virginia Tech standard, to a Worldwide Standard Seismic Network (WWSSN) type of instrument and to a Wood-Anderson instrument. A principal use for such traces is the determination of magnitude estimates consistent with their original definition. For example, correcting all of the network short period vertical recordings to WWSSN traces allows the calculation of several estimates of $m_b(L_g)$ for an earthquake in a manner consistent with Nuttli's (1973) definition of the $m_b(L_g)$ magnitude scale. For

Figure 4. Seismograms from the 15 March 1991 central Virginia earthquake as recorded at BLA. Top trace is in uncorrected digitizer counts. The three lower traces are corrected (from top to bottom) to the Virginia Tech standard instrument, the WWSSN SPZ standard instrument and a Wood-Anderson instrument, respectively.

example, an $m_b(L_g)$ estimate for the 15 March 1991, central Virginia earthquake can be made by measuring the amplitude and period of the L_g wave in the third trace shown in Figure 4, knowing the epicentral distance is 240 km, and using the appropriate equation for $m_b(L_g)$ and calibration curve for the WWSSN short period instruments (Note: the numbers 38.2 and -45.9 shown to the right of the third trace represent millimeters of trace amplitude on a WWSSN record).

Data Archiving and Sharing

Since 1985, 140 local/regional earthquakes, 600 teleseisms and 1600 mining blasts have been recorded and archived. Listings of these events are provided in Appendix A. Waveform data are archived in the original data format (i.e., in digitizer counts) on 9-track magnetic tape.

Recordings of the seismic events have been made available to the general seismological community and other interested persons. Most requests have been for hardcopy playouts of particular events; for example large scale playouts (e.g., two seconds per inch) of P waves recorded across the network. Requests for the digital data have been filled by providing waveform time series, corrected to the Virginia Tech standard instrument, on either floppies or magnetic tape, or accessible on our anonymous ftp account.

SEISMOTECTONIC STUDIES

Overview

Monitoring of both Virginia zones continued during the report period of 1986-1992, but principal research emphasis was placed on the development of seismotectonic models for the central Virginia and eastern Tennessee seismic zones. In the process, a general model for intraplate seismicity termed "Hydroseismicity" was also developed. That model incorporated the subsurface effects of meteoric waters as a principal component. Each of these three models will be described in the following sections.

Central Virginia Seismic Zone

Principal References:

- Coruh, C., G. A. Bollinger and J. K. Costain, (1988), Seismogenic structures in the central Virginia seismic zone, Geology, 6, p. 748-751.
- Bollinger, G. A. and M. S. Sibol, (1985), Seismicity, seismic reflection studies, gravity and geology of the central Virginia seismic zone: Part I. Seismicity, Geol. Soc. Am. Bull., 96, p. 49-57.

A correlation between earthquake hypocenters and seismic reflection data in central Virginia was revealed by special studies of seismic reflection data. With the reprocessed Virginia I-64 reflection Vibroseis data extended to 14 seconds, reflectors were imaged from both the lower and upper portions of the crust. Specifically, the improved resolution and data quality produced an image of an antiformal structure bounded by mid-crustal reflections on the bottom and by major thrust faults at the top. The reflections that define the roof of the antiform are most prominent from about 6 seconds (18 km depth) near Richmond under the Coastal Plain sediments, to 1-1.3 seconds (3-4 km) between Richmond and Charlottesville and to 3.5 seconds (10.5 km) on the west. Seismic signatures that can be followed downward from the ground surface between Charlottesville and Richmond appear to be truncated at the roof of this antiform.

The distribution of hypocenters in the area shows an excellent spatial correlation with the westward-dipping reflectors that form the roof of the antiform on its western flank and with the structures above the roof (Figure 5). Thus, the earthquake activity in that locale may be related to reactivation of the thrusts defining the roof and/or faults above the antiformal structure. The distribution of the easternmost and deepest set of hypocenters, however, is spatially related to a completely separate, poor-reflection zone that is interpreted to be a near-vertical diabase dike swarm of Mesozoic age.

To examine the spatial correlation between reflectors and hypocenters, only the 26 hypocenters with a ± 5 km or less vertical error were considered. A velocity of 6 km/sec was used for the conversion of vertical reflection traveltime to depth. Focal mechanisms from 11 of these earthquakes exhibit northeast-trending P (maximum compressive stress) axes for shallow sources (< 8 km) and northwest-trending axes for deeper foci (> 8 km; Figure 5). A mixture of reverse and strike-slip faulting is observed on planes that exhibit an average dip of $62^\circ \pm 16^\circ$. There are, however, two deeper foci with northeast-trending P axes that are apparent exceptions to the above

1 ○ No focal mechanism solution 2 ⊙ Northeast-trending P axes 3 ⊙ Northwest-trending P axes

Shallow (3-7 km)

Deeper (8-13 km)

Figure 5. Upper: Cross section of I-64 seismic reflection line. A: Parautochthonous lower Paleozoic shelf strata. Below shelf strata is poorly reflective Grenville basement. Distinctive difference in reflectivity of crust is apparent with respect to western and eastern parts of profile. Large antiform is defined by reflections B, F, and E at roof and C at floor. Ramp R is interpreted to east. D is believed to be Mesozoic dike swarm; mafic material is interpreted below station 2800. Note that slope of Moho (M) reflectors at east and west of dike swarm D is different. BRT is Blue Ridge master décollement; DT is deeper detachment; TS is transported Taconic suture; BDT is brittle-ductile transition zone; and east-dipping reflectors E are Alleghanian and earlier shear zones and thrusts. Circles and diagonal bars indicate projected hypocenters and orientation of P-axes, respectively. Lower: Orientation of all of the P-axes that fit the polarity and amplitude data from focal mechanism solutions for 11 events.

grouping, but not necessarily given the ± 5 km focal depth error range. A current listing and plots of focal mechanism solutions for Virginia earthquakes can be found in the DATA BASES section of this report.

The correlation between the hypocenters, the reflectors and a poorly reflective zone at the southeastern end of the profile may indicate that different seismogenic structures is associated with two different groups of hypocenters. One group of hypocenters are related to the structures at and above the roof of the antiform. They have shallower depths (3-7 km) and northeast-trending P axes that coincide with the general tectonic strike in the area. A second group of hypocenters is related to the dike swarm (poorly reflective zone) within the antiform. They are deeper (8-13 km) and have northwest-trending P axes. Our seismotectonic model suggests that the earthquake activity in the central Virginia seismic zone may be detachment-related only on the west flank of the roof of the antiform and to a vertical dike swarm on the east flank. The hypocenters do not occur below the mid-crustal level, and there is no earthquake activity east of the Fall Line, although the imaged crustal reflectors continue eastward. Our correlations between the reflectivity and the distribution of the hypocenters suggest, therefore, that the earthquake activity is limited to those parts of the Virginia crust that are intensely sheared and stretched.

Eastern Tennessee Seismic Zone

Principal References:

- Teague, A. G., G. A. Bollinger and A. C. Johnston, (1986), Focal mechanism analyses for eastern Tennessee earthquakes, Bull. Seism. Soc. Am., 76, p. 95-109.
- Powell, C. A., G. A. Bollinger, M. C. Chapman, A. C. Johnston and R. L. Wheeler, (1993), A seismotectonic model for eastern Tennessee, Geology, in press.

A well-documented zone of concentrated, northeasterly-trending seismic activity in eastern Tennessee extends for some 300 km in length and 50 km in width (Figure 6). When normalized by crustal area, this large zone has produced the second highest release of seismic strain energy in the United States east of the Rocky Mountains during the last decade. Only the New Madrid region in the central Mississippi River valley is more seismogenic. Unlike the New Madrid region, however, eastern Tennessee has not had a large, damaging earthquake in historical time, and its potential for producing such a destructive earthquake is poorly understood.

The seismic activity in eastern Tennessee includes a portion of eastern Tennessee and parts of North Carolina and Georgia, and it is contained almost exclusively within the Valley & Ridge province. This spatial association has led us to name the zone the Valley & Ridge Seismic Zone (VRSZ), as first suggested by Bollinger (1973). Seismicity in the VRSZ has been monitored by the Memphis State University Southern Appalachian Regional Seismic Network since 1981, with stations spaced roughly 45 to 80 km apart throughout eastern Tennessee and western North Carolina (Johnston and others, 1985). Seismic events are routinely located using a laterally-homogeneous, three-layer velocity model. The ability of this model to provide accurate, relatively unbiased hypocentral parameters was demonstrated by Johnston and others (1985). Except for the southernmost portion that extends into Georgia, the VRSZ lies within the seismic network. Studies indicate that the

Figure 6. Epicenter map showing 926 earthquakes reported in the Southeastern United States Seismic Network Bulletin for 1977.5-1991. The area of highest activity in eastern Tennessee is indicated by the dashed box which encloses 628 events ($0 \leq M \leq 4.2$).

concentrated nature of seismicity within the VRSZ for the time period illustrated cannot be attributed to nonuniform station distribution, an inadequate crustal velocity model or to variable detection capabilities.

The VRSZ trends NE-SW aligned with the trend of the southern Appalachians. Both of the host provinces, the Valley & Ridge and the Blue Ridge, are thrust and fold complexes underlain by a master décollement (e.g., Cook and others, 1983). Maximum depth to the décollement beneath the VRSZ is approximately 5 km. Mean focal depth for earthquakes within the VRSZ is 15 km (Johnston and others, 1985; Teague and others, 1986; Bollinger and others, 1991). Thus, the vast majority of earthquakes occur in inferred Grenville-age, crystalline basement rocks and are not directly associated with the décollement or the overlying, detached rocks.

Instrumentally located epicenters in the VRSZ coincide spatially with, and trend with, the New York-Alabama (NY-AL) lineament (King and Zietz, 1978). Johnston and others (1985) have proposed that the NY-AL lineament marks the northwestern boundary of the seismogenic basement crustal block they termed the Ocoee block. The proposed southeastern boundary of their Ocoee block was termed the Clingman magnetic lineament (Nelson and Zietz, 1983).

As is generally the case with eastern North American earthquakes, earthquakes within the VRSZ cannot be attributed to known faults. Focal mechanism solutions indicate primarily sub-vertical, strike-slip faulting with either right-lateral motion along NS-striking planes or left-lateral motion along EW-striking planes (Figure 7 herein; Johnston and others, 1985; Teague and others, 1986; Bollinger and others, 1991). Note that neither set of nodal planes strikes parallel to the trend of the VRSZ, but rather both are oriented roughly 45° to the northeasterly trend of the seismic zone. A listing of focal mechanism solutions for Eastern Tennessee earthquakes can be found in the DATA BASE section of this report.

Figure 7. Single event focal mechanisms for eastern Tennessee study region (inset map). Each solution is labeled with an event number. All solutions are equal-area, lower hemisphere projections with the compressional quadrant shaded.

Linear seismic zones are known to often trend at large angles to the orientation of maximum in-situ compressive stress field (σ_1). For example, the San Andreas fault system trends almost 90° to σ_1 (Mount and Suppe, 1987) while the

southwest trending branch of the New Madrid seismic zone trends roughly 45° to σ_1 (Mitchell and others, 1991). In contrast, the VRSZ trends roughly parallel to the maximum compressive stress axis in the southeastern United States. This axis is approximately horizontal and is oriented NE-SW in eastern Tennessee (Zoback and Zoback, 1989; Zoback, 1992a, 1992b). A similar orientation ($N50^\circ E$) for σ_1 in the area was determined by an inversion of the full set of focal mechanism solutions for the zone (Davison, 1988).

Four unusual features can be defined for the VRSZ that require explanation. These features are: 1) Apparent recent narrowing in the horizontal width of the zone by westward migration of seismicity from North Carolina into eastern Tennessee; 2) Alignment of the zone roughly parallel to σ_1 ; 3) Orientation of focal mechanism nodal planes at roughly 45° to the trend of the zone; 4) Strong spatial association with a magnetic lineament that may reflect a major basement crustal boundary.

The seismotectonic model that we propose is that the VRSZ is an evolving seismic zone in which slip on scattered, widely distributed north and/or east-striking fractures is in the process of coalescing into an elongated NE-trending zone. We cannot at this stage speculate as to whether the associated faults are new or represent a reactivation of ancient faults that were partially healed or simply quiet during a prolonged period of past inactivity. Another important characteristic is that the seismicity occurs preferentially in the southeastern basement block. Orientations of focal planes within the block are north-south and are appropriate for failure in the NE-SW oriented, maximum compressive stress field. These N-S orientations differ from the NE-SW trend of the zone because this trend, and abrupt termination of seismicity along the NY-AL magnetic lineament, appear to be controlled by the subsurface geometry of the southeastern block. Thus, we suggest that the VRSZ represents seismic activity that results from the regional compressive stress field and is coalescing near an extended segment of the juncture between a relatively weak, seismogenic block on the southeast and a relatively strong crust to the northwest.

Hydroseismicity Hypothesis

Principal References:

- Costain, J. K., G. A. Bollinger and J. A. Speer, (1987), Hydroseismicity: A hypothesis for the role of water in the generation of intraplate seismicity, Seism. Res. Letters, **58**, p. 41-64.
- Bollinger, G. A. and J. K. Costain, (1988), Long-term cyclicities in earthquake energy release and major river flow volumes in Virginia and Missouri seismic zones, Seism. Res. Letters, **59**, p. 279-283.
- Costain, J. K. and G. A. Bollinger, (1991), Correlations between streamflow and intraplate seismicity in the central Virginia, U.S.A., seismic zone: Evidence for possible climatic controls, Tectonophysics, **186**, p. 193-214.

This hypothesis deals with the role of meteoric water in intraplate seismogenesis. It was introduced by J. K. Costain and G. A. Bollinger, their colleagues C. Çoruh, A. Speer and M. S. Sibol, and their students, S. Setterquist, G. Tsoflias and D. Hopkins, in a series of three papers, two M. S. theses and ten abstracts in the time interval from 1985 through 1991.

An hypothesis termed Hydroseismicity was proposed that is composed of hydrologic (diffusion of pore pressure transients from recharge areas of groundwater basins), geologic (rifted, fractured crust) and chemical (solubility of minerals) elements that seeks to ascribe a role for meteoric water in the generation of intraplate seismicity. Its basis is a spatial correlation in the southeastern United States between (1) Seismogenic crustal volumes of relatively high seismicity, (2) Large gravity-driven river basins that can provide an adequate supply of water to the upper- and mid-crust, and (3) A permeable crust that is tectonically stressed close to failure (Figure 8). It is suggested that in such crustal volumes with a combination of connected fractures and adequate groundwater, natural transient increases in hydraulic head in recharge areas of groundwater basins can be transmitted to depths of 10-20 km, and thereby trigger earthquakes. The flow-path geometry resembles a model familiar to groundwater hydrologists for near-surface flow except for scale.

Figure 8. Major rivers, historical seismicity and instrumentally located epicenters. Hachuring shows distribution of Hadley and Devine (1974) of > 16 historical earthquakes per 10^4 km^2 with intensity $> \text{MM III}$ during period 1800-1972. Buried Mesozoic basin is clearly imaged on Vibroseis line VT-5 in area of the Charleston, South Carolina, earthquake of 1886. Epicenters labeled a, b and c in North Carolina parallel exposed early Mesozoic basins (EMB) and lie on extension of trend of EMB in central Virginia.

Possible trigger mechanisms for Hydroseismicity include small increases in fluid pressure at hypocentral depths caused by repetitive transient surface increases, and hydrolytic weakening of minerals leading to structural weakening. Implicit in the model is a diffuse distribution of epicenters (as is observed in the region) rather than concentrations along discrete geologic (faults) or geomorphic (rivers) elements. Open fractures can exhibit roughness, that is, asperities which, even under a high stress field, can keep the fractures open. Abundant petrologic evidence is available to justify an assumption of such fracture permeability to depths of 20 km near passive rifted margins. Some of the intraplate earthquakes in such a fractured crust are thus postulated to be triggered by repetitive transient increases in fluid pressure transmitted along preexisting fractures.

The four principal seismogenic volumes in the southeastern United States (Giles County, VA; central Virginia; eastern TN; Charleston, SC) are within large, gravity-driven groundwater basins that provide an abundant supply of water to the upper crust, and that also intersect known or suspected Eocambrian or Mesozoic rifted crustal volumes. These host basins have, for the region, the largest surface recharge areas and contain rivers with the highest average stream gradients (as measured from their headwaters to the Fall Line in the region).

Seismicity in the Southeast is characterized by steeply dipping focal mechanism nodal planes and diffuse alignments and/or clusters of epicenters. These geometric characteristics are compatible with a steep to vertical fracture fabric currently being reactivated by pore pressure diffusion from surface recharge of groundwater basins.

Time series for earthquake strain factors and for flow volumes from the major rivers that bisect the regions of seismicity in Virginia (Giles County; central Virginia) and Missouri (New Madrid) seismic zones were investigated. The procedure was to integrate the time series with respect to time, over data lengths up to 70 years duration, and then to subtract a least squares straight-line fit. The resulting residual earthquake strain factor and flow volume time series and their spectral densities were found to exhibit dominant periods in the 20-30 year range (Figure 9). These common cyclicities lend support for an important role of water in intraplate seismogenesis.

The fracture permeability of crystalline rocks, caused by a long history of compressional and extensional tectonic episodes, together with the driving potential supplied by long-term cyclical variations in streamflow, can result in the diffusion of fluid pressure transients to focal depths as deep as 20 km. At those depths, there can also be a quasi-static, hydrolytic weakening effect of water on asperities present in the fault zones. This combination of mechanical and chemical effects is postulated to cause some intraplate earthquakes.

From the one-dimensional diffusion equation, the time response of fluid pressure at depths, ψ , in a hydraulically diffusive crust to an impulsive change in fluid pressure at the surface of a groundwater basin was calculated. These responses were then convolved with the surface streamflow residuals. Root-mean-square values (rms) of the convolutions were computed for $\psi = 5, 10, 15$ and 20 km and various values of the hydraulic diffusivity. For central Virginia, the number of earthquakes, N , within a crustal slice centered on a depth, ψ , was found to be proportional to the rms value of the convolution, suggesting that the number of intraplate earthquakes generated is directly proportional to the magnitude of the rms changes in fluid pore pressure within each crustal slice.

Figure 9. Comparison of the James River streamflow data and strain factor for the central Virginia seismic zone (upper set of plots) and the New River streamflow data and the Giles County, Virginia, seismic zone (lower set of plots). Each set of plots shows cumulative streamflow (upper left) and strain energy (upper right) with residual streamflow (lower left) and residual strain energy (lower right). Dashed lines in upper pair of plots for each show the linear least-squares fits to the cumulative time series.

The Hydroseismicity hypothesis has not yet been generally accepted by the seismological community, and it remains controversial. For this reason, it is difficult to get papers published in some of the better journals and nearly impossible to secure funding to continue investigation of the hypothesis.

We remain convinced, however, that it is a physically viable hypothesis and worthy of continued study. It may be that eventually the hypothesis will be disproven. What may be more likely, however, is that it will persist in some modified form to describe the role of meteoric water, perhaps in conjunction with connate and juvenile waters, and perhaps at pressures elevated above hydrostatic, in the generation of intraplate seismicity.

Review of Southeastern United States Seismicity

Principal Reference:

Bollinger, G. A., A. C. Johnston, P. Talwani, L. T. Long, K. M. Shedlock, M. S. Sibol and M. C. Chapman, (1991), Seismicity of the southeastern United States; 1698-1986, in Slemmons, D. B., E. R. Engdahl, M. D. Zoback and D. D. Blackwell (eds.), Neotectonics of North America: Boulder, CO, Geol. Soc. Am. Decade Map Volume 1, p. 291-308.

Even though this paper carries a 1991 date, there was actually considerable delay in its being printed. It covers only the period up to 1986 and does not, therefore, contain virtually all of the material being covered in this report. It is, however, a thorough review of the pre-1987 seismicity of the region with contributions from all of the principal network operators in the area as co-authors.

SEISMIC HAZARD STUDIES

Overview

The applied nature of this research program requires the application of the seismic network data to the general task of seismic hazard assessment in the study area. This has been done on three different scales: National, Regional (southeastern United States) and State (Virginia and South Carolina). The individual contributions at each scale level have been in the form of studies related to the specification of the input parameters required by formal hazard calculations: seismic zonation, maximum magnitude estimation and earthquake recurrence rates, rather than in the direct estimation of hazard. There have also been studies of the factors associated with emergency preparedness/mitigation/response to strong seismic shaking (e.g., size of earthquake damage areas in the United States), with the stochastic estimation of strong ground motions (e.g., Q factors; response spectral levels) and with the influence of the Coastal Plain sedimentary wedge on the strong ground motions from the 1886 Charleston, South Carolina, earthquake. The principal results from these investigations are presented in the following sections.

National Seismic Hazard Study

Damage Areas Study

Principal Reference:

Bollinger, G. A., M. C. Chapman and M. S. Sibol, (1993), A comparison of earthquake damage areas as a function of magnitude across the United States, Bull. Seism. Soc. Am., 83, in press.

The felt areas mapped for earthquakes east of the Rocky Mountains are observed to be consistently larger than those associated with comparably-sized shocks centered in the western United States. This difference is due to the low eastern attenuation rates (higher Q values) that have been documented instrumentally. However, damage areas extend for only relatively short epicentral distances (generally < 100 km) and, thus, the associated anelastic attenuation effects, while contributory, are not dominant.

The purpose of this study is to examine the size of earthquake damage areas, as measured by Modified Mercalli Intensity (MMI) levels VI and VII, in the United States. Specifically, an East versus West comparison is sought to test for possible differences in the effects of strong seismic ground motions between those two regions.

Isoseismal area estimates from 109 earthquakes at the MMI VI and VII levels were collected to form the basic data set available for analysis (Figure 10). Of those, 21 are in eastern North America ($4.4 \leq M \leq 7.4$) and 88 are in the western United States (California, Nevada, Idaho and Texas; $3.9 \leq M \leq 7.9$).

The earthquake size estimate used for analysis is moment magnitude (M). The moment magnitude estimates available in the literature have not been determined in a uniform manner. Often various conversions, other than direct instrumental measurement, have been employed to arrive at the estimates of moment or moment

Figure 10. Map showing the number of earthquakes, by state, for which moment magnitude and MMI damage area data were used in this study. WUS = western United States; ENA = eastern North America.

magnitude. Several such conversion schemes have been published, and rather than choosing between them, a direct comparison is made below between M_0 , M_L and $m_b(L_g)$. This allows an East versus West calibration of the two regional short period magnitude scales, using M_0 as a standard.

The M_0 - M_L data sets as published by Bakun and Joyner (1984) and by Stover and Coffman (1993) were fit with a quadratic curve to obtain:

$$\text{Log } M_0 = 17.8 + 0.654 M_L + 0.0887 M_L^2 \quad (1)$$

Figure 11 shows that fit and also shows the same M_0 - M_L curve superimposed on the M_0 - $m_b(L_g)$ data set from Stover and Coffman (1993). We judge the M_0 versus $m_b(L_g)$ data to be sufficiently well represented by equation (1), given the scatter in both data sets, to say that,

$$M_L = m_b(L_g) \quad 4 \leq M \leq 6 \quad (2)$$

The conversion scheme utilized herein to obtain M_0 is to use equations (1) and (2). This scheme is employed only when direct instrumental determinations of M_0 or M_S are not available.

Figure 11. Plots of $\text{Log } M_0$ versus M_L for the western United States (Bakun and Joyner, 1984; Stover and Coffman, 1993) and $\text{Log } M_0$ versus $m_b(L_g)$ for eastern North America (Stover and Coffman, 1993). The quadratic curve shown is a fit to the $\text{Log } M_0$ versus M_L data set, and that same curve is shown superimposed on the $\text{Log } M_0$ versus $m_b(L_g)$ data set. The $m_b(L_g)$ data are slightly below ($\leq 0.2 \text{ Log } M_0$ units) the M_L based curve. This is judged to be within the scatter, so that $M_L = m_b(L_g)$. Assuming the solid curve represents a $\text{Log } M_0$ versus $m_b(L_g)$ relationship that incorporates a stress factor of 100 bars, then the dashed curves are for stress factors of 50 bars (above the solid curve) and for 200 and 500 bars (below the solid curve).

Also shown in Figure 11 are $\text{Log } M_0$ versus $m_b(L_g)$ curves for several different stress-factor levels. Hanks and Boore (1984) concluded that a stress-drop of 100 bars is appropriate for most California earthquakes. Our data fit and their model for a stress-drop of 100 bars and $f_{\max}$ of 15 Hz are very close together (Hanks, written comm., 1992). Assuming a stress-drop of 100 bars is valid for equation (1) and that $m_b(L_g)$ is proportional to the logarithm of the spectral amplitude at 1 Hz, we have calculated how that curve would change for stress-drops of 50, 200 and 500 bars. The difference in the $\text{Log } M_0$ versus $m_b(L_g)$ curves between 50 bars and 200 bars stress-drops is seen to be very small over the limited range of the data set. Thus, we cannot constrain the stress-drop level to better than a factor of at least 4 with the available M_0 - $m_b(L_g)$ data set.

The M versus A_{VI} (area inside MMI VI contour in km^2) and A_{VII} data sets and their respective least-squares straight-line fits are shown in Figure 12. The equations for those line fits are:

MMI VI:	$\text{Log } A = 0.57 + 0.66 M$	$R^2 = 69\%$	ENA (3)
	$\text{Log } A = -0.63 + 0.76 M$	$R^2 = 77\%$	WUS
MMI VII:	$\text{Log } A = -1.64 + 0.90 M$	$R^2 = 49\%$	ENA (4)
	$\text{Log } A = -2.51 + 0.91 M$	$R^2 = 78\%$	WUS

where, ENA = Eastern North America and WUS = Western United States. The results from Figure 12 indicate that A_{VI} and A_{VII} for shocks in the M 4.5 to 7.5 range are an average of some five times larger in eastern North America than in the western United States.

Figure 12. Isoseismal areas, at the MMI = VI and VII levels, versus moment magnitude for 21 ENA earthquakes and 88 WUS earthquakes with 95 VI areas and 54 VII areas. The straight-line fits to each data set indicate that eastern North American damage areas are about five times greater than those for the western United States.

Hanks and Johnston (1992) studied the relationships between M and A_{felt} , A_{IV} , A_V , A_{VI} and A_{VII} for ENA and WUS earthquakes. They found that the separation between the ENA and WUS regression lines was the greatest at the lowest intensity level (A_{felt}) and that separation decreased continuously to virtual coincidence between the ENA-SCR (stable continental regions) curve and the WUS curve at an MMI of VII. They noted, however, that the MMI VII results were not definitive due to the sparse amount of data for ENA-SCR and its scatter (four ENA and five SCR earthquakes). Primarily on the basis of this decreasing difference between eastern and western felt areas with increasing MMI level and the relatively short distance extent of damaging strong ground motions (short attenuation paths), Hanks and Johnston (1992) concluded that damage areas between ENA and WUS are not

appreciably different for earthquakes with $M < 7 \frac{1}{2}$. However, they did present evidence for systematic differences of 3.6X at $M = 5.5$ to 1.2X at $M = 7.5$ in the isoseismal areas at the MMI VI level (their Table 4). This compares to our damage area differences of 4.5X at $M = 5.5$ to 2.8X at $M = 7.5$ for the MMI VI level in this study (equation 3). Hanks and Johnston (1992) presented arguments that the MMI VI areal differences may be attributable to stress drops in the East being approximately a factor of 2 higher than in the West.

Three points must be taken into consideration when comparing the Hanks and Johnston (1992) results with the present study. First, Hanks and Johnston (1992) used only events for which direct instrumental or geological determinations of seismic moment were available, whereas we have relaxed this criterion and included additional eastern North American earthquakes for which the moments have been estimated indirectly from instrumentally determined short-period magnitudes. The second consideration also involves the results of employing the stringent moment criteria used by Hanks and Johnston (1992), which results in a small, non-definitive data set for eastern North America at the MMI VII level. Finally, Hanks and Johnston (1992) supplemented the eastern North American data at VII MM with earthquakes drawn from the global SCR data set compiled by Johnston (1993), whereas we have included only eastern North American earthquakes in this study. Where there are common earthquakes, the data from the two studies agree fairly well. The different results appear to be related to those events in the SCR data set that are not from the study area (i.e., not eastern North American earthquakes).

Admittedly, the critical data set for intensity VII MM in eastern North America is too sparse for firm conclusions to be drawn. However, we favor an alternative interpretation to that offered by Hanks and Johnston (1992). We interpret the data at intensity MMI VII to show essentially the same trend as that exhibited at MMI VI. That is, the area ratios (East/West) are significantly greater than unity and point to important differences in the generation and/or propagation of strong ground motions in the two regions.

In terms of possible explanations for the greater horizontal extent of strong ground motions in eastern North America, differences in the stress-drop, as suggested by Hanks and Johnston (1992) and/or differences in average surface conditions between the East and the West are obvious candidates. However, the eastern strong ground motion data base is inadequate to define such differences, much less provide explanations - if there were enough strong ground motion data, there would be no need to analyze the intensity data base.

Stochastic source models have been used for theoretical prediction of ground motion in eastern North America (see, e.g., Hanks and McGuire, 1981; Boore, 1983; Boore and Atkinson, 1987; Atkinson and Boore, 1990). Those models can be applied here to address the question, "What stress factor differences and/or what type of crustal models will result in the same level of ground motions as has been observed in the western United States, but at roughly twice the epicentral distances?" The strong ground motion data base available for the western United States in the form of the regression analyses of Joyner and Boore (1988) will serve as reference. It is understood that the results from this type of modeling approach are not unique. Rather, it is for possible insight into basic source and path characteristics that the modeling is being done.

To determine source and site parameters consistent with the above results, Response Spectral levels for eastern North America were stochastically simulated and

compared to Response Spectral ordinates derived from recorded strong ground motion data in the western United States. Stress-drop values of 200 bars, combined with a surficial 2 km thick low velocity "sedimentary" layer over rock basement, produced results that are compatible with the intensity observations, that is, similar Response Spectral levels in the East at approximately twice their epicentral distance in the western United States distance (Figure 13).

Figure 13. Response spectra (PSV; 1 Hz; 5% damping; dashed curves) versus distance for the eastern North America model and for stress factors of 200 bars (upper left) and 100 bars (lower left). Western United States response spectra (solid curves) are from Joyner and Boore (1988). Horizontal bars denote the distance ranges where ENA and WUS curves at the same PSV level are separated by a factor of two. Note that the 200 bar model provides the two times distance factor somewhat better (at the required nearer distances) than does the 100 bar model while the average residual is somewhat high. Also shown (right side plots) are the residuals of the eastern North American strong ground motion observational data (Atkinson, 1990) with respect to the PSV models depicted on the left side of

the figure. The hachured portion of the residual plots are for distances not considered in the modeling procedures.

This type of result suggests that ground motion modeling in eastern North America may need to incorporate source and site parameters different from those presently in general use. The results are also of importance to eastern United States hazard assessments as they require allowance for the larger damage areas in preparedness and mitigation programs.

In summary, for earthquakes in the M 4.5 to 7.5 range, Modified Mercalli intensity VI and VII levels of shaking extend to approximately two times the distances in eastern North America as they do in the western United States. These observations are possible evidence for regional differences in either the high frequency source spectral levels for earthquakes of a given seismic moment and/or as evidence for regional differences in average site conditions. In particular, larger near-surface impedance contrasts at "rock" sites in the East may be present.

Stochastic models of eastern United States ground motion incorporating a stress parameter of approximately 200 bars and a shallow crustal velocity gradient of lower shear velocity, derived from the observed propagation of the R_g phase, provide results that are consistent with both the available observed strong ground motion data bases and the observed regional differences in Modified Mercalli isoseismal equivalent circular radii in the two regions. We recommend that these results be incorporated into ground motion modeling and seismic hazard studies for the region.

Regional Seismic Hazard Studies

Principal References:

- Bollinger, G. A., F. C. Davison, Jr., M. S. Sibol and J. B. Birch, (1989), Magnitude recurrence relations for the southeastern United States and its subdivisions, J. Geophys. Res., **94**, p. 2857-2873.
- Chapman, M. C. and M. J. Rogers, (1989), Coda Q in the southern Appalachians, Geophys. Res. Letters, **16**, p. 531-534.
- Sibol, M. S., G. A. Bollinger and J. B. Birch, (1987), Estimation of magnitudes in central and eastern North America using intensity and felt area, Bull. Seism. Soc. Am., **77**, p. 1635-1654.

Earthquake Recurrence Rates: Southeastern United States

Southeastern United States recurrence relations were developed for the region and for various subregions (three geologic provinces and four seismic zones) from a combination of historical (1698-1977) and network (1978-1986) earthquake catalogs. The synthesis of these two data sets was accomplished by the application of MM intensity-to- $m_b(L_g)$ conversions in the form of discrete distributions to the historical catalog using the technique of Sibol and others (1987). Aftershocks were removed from the resulting catalog, it was tested for completeness and then a maximum likelihood curve fitting technique for unequal periods of observation was employed. Tests were also made for different size magnitude intervals and for different maximum and minimum magnitudes to assess the stability of the various data sets. The recurrence equations developed are as follows:

Southeastern U.S.	$\text{Log } N_c = (3.12 \pm 0.08) - (0.84 \pm 0.02)$	$m_b(L_g)$	$N = 861$
VR&BR	$\text{Log } N_c = (2.67 \pm 0.08) - (0.82 \pm 0.03)$	$m_b(L_g)$	$N = 395$
Piedmont	$\text{Log } N_c = (2.18 \pm 0.18) - (0.81 \pm 0.05)$	$m_b(L_g)$	$N = 191$
Coastal Plain	$\text{Log } N_c = (2.22 \pm 0.16) - (0.78 \pm 0.05)$	$m_b(L_g)$	$N = 188$
Giles County, VA	$\text{Log } N_c = (1.07 \pm 0.25) - (0.64 \pm 0.08)$	$m_b(L_g)$	$N = 28$
Central Virginia	$\text{Log } N_c = (1.18 \pm 0.19) - (0.64 \pm 0.06)$	$m_b(L_g)$	$N = 94$
Eastern Tennessee	$\text{Log } N_c = (2.72 \pm 0.10) - (0.90 \pm 0.04)$	$m_b(L_g)$	$N = 239$
Charleston, SC	$\text{Log } N_c = (1.69 \pm 0.25) - (0.77 \pm 0.08)$	$m_b(L_g)$	$N = 84$

where VR&BR is the Valley & Ridge and Blue Ridge physiographic province, and N is the number of earthquakes input to the completeness testing and after deletion of aftershocks (Figures 14-16). The regional recurrence relation is similar to those for the New Madrid area ($\text{Log } N_c = 3.43 - 0.88 m_b$) and the New England area ($\text{Log } N_c = 2.87 - 0.84 M_c$).

The primary purpose for the determination of recurrence relations for the various subregions is to gain understanding of their relative contributions to the earthquake frequencies for the region as a whole. A problem with this approach is that as smaller subsets of the catalog are considered, the precision of the $\text{Log } N$ versus m model results decreases. We see such an expected decrease, but invoke recurrence interval estimates from confidence interval (CI) bands, rather than simply point estimates, to assess the variability associated with our calculations. It is in the context of those interval estimates that we derive some insights into the relative contributions to the regional $\text{Log } N$ versus m . A principal result is that the region as a whole (excluding the Charleston zone) has a much shorter recurrence interval (250-560) for a "Charleston earthquake" ($m_b(L_g) = 6.75$) than does the host Charleston zone (940-14,000). The centuries long recurrence estimates are in general accord with paleoseismic estimates for the Charleston area. Table 2 provides recurrence interval estimates, for various confidence intervals, by magnitude, for each of the study areas.

Attenuation of Seismic Coda Waves: Southern Appalachian Region

A separate study involved investigation of the attenuation of seismic coda waves in the southern Appalachian region. Signal sources were five local and regional earthquakes and one explosion located in Ohio, Virginia and South Carolina. The data were recorded digitally by the Giles County subnetwork of seven stations in western Virginia. Joint least squares estimates of the quality factor Q , relative recording site responses and coda source amplitudes were obtained in five frequency bands using the single scattering model, and assuming body wave geometrical spreading. The results indicate a frequency dependent coda Q , represented by $Q = 811 f^{0.42}$, $1.5 \leq f \leq 12$ Hz, for lapse times in the range 15 to 250 seconds (Figure 17). Site responses determined relative to the average network response differ by less than a factor of two in the range 3 to 12 Hz at five of the seven stations. However, the differences in the response of the other two sites increase with frequency, amounting to a factor of five at 12 Hz. Estimated relative coda source amplitude spectra exhibit similar shapes, consistent with the assumption that the scattering process is independent of path in the study region.

Figure 14. Top: Seismicity map of the southeastern United States with historical (small solid circles) and network (x's) epicenters for the time period 1772-1986. Large, heavy circles enclose seismic zones, counterclockwise from upper right: Central Virginia; Giles County, Virginia; eastern Tennessee; and Charleston, South Carolina. Bottom: Plot of $\text{Log } N_I$ (interval number of earthquakes per year, $m \pm 0.25 \Delta m$) versus $m_b(L_g)$ for the southeastern United States. 95% confidence intervals (dashed lines) shown about the maximum likelihood (heavy line).

Figure 15. Seismicity maps (top) and recurrence relations (bottom) for the eastern Tennessee seismic zone (left) and the Giles County, Virginia, seismic zone (right). Symbols are the same as in Figure 14.

Figure 16. Seismicity maps (top) and recurrence relations (bottom) for the central Virginia seismic zone (left) and the Charleston, South Carolina, seismic zone. Symbols are the same as in Figure 14.

TABLE 2

Recurrence Interval Estimates (Years) by Magnitude With $\Delta m = \pm 0.25$ For
The Southeastern United States and Several of Its Subdivisions

Confidence Interval, %	Magnitude						
	4.25	4.75	5.25	5.75	6.25	6.75	7.25
<u>Southeastern United States</u>							
68	2-3	7-8	18-23	46-62	120-170	310-450	790-1,200
84	2-3	7-9	17-24	43-65	110-180	280-490	710-1,400
95	2-3	6-9	16-26	40-71	100-200	250-550	630-1,500
<u>Valley and Ridge and Blue Ridge</u>							
68	6-8	15-20	39-54	97-140	240-380	610-1,000	1,500-2,700
84	6-8	15-21	36-58	90-160	220-420	550-1,100	1,400-3,000
95	6-9	14-23	33-63	81-170	200-470	480-1,300	1,200-3,600
<u>Piedmont</u>							
68	17-22	40-60	97-160	230-430	560-1,200	1,400-3,100	3,200- 8,300
84	16-24	37-65	88-180	210-490	480-1,400	1,100-3,700	2,600-10,000
95	15-26	34-72	76-200	170-580	390-1,700	890-4,800	2,000- 1,400
<u>Coastal Plain</u>							
68	12-16	28-41	67-110	160-270	370-710	850-1,900	2,000-4,800
84	11-17	26-44	61-120	140-310	320-810	730-2,200	1,700-5,900
95	11-18	24-48	53-130	120-360	270-970	590-2,600	1,300-7,100
<u>Giles County, Virginia</u>							
68	42- 85	82-190	160-430	310- 970	590-2,200	1,100- 5,000	2,200-11,100
84	37- 97	69-220	130-530	240-1,200	450-2,900	830- 6,700	1,500-16,700
95	30-120	55-280	99-690	180-1,700	310-4,200	550-10,000	960-25,000
<u>Central Virginia</u>							
68	36-53	71-120	140-260	270-560	520-1,200	1,000-2,800	2,000- 6,200
84	33-57	64-130	120-290	230-660	440-1,500	830-3,400	1,600- 7,700
95	30-64	56-150	100-340	190-810	340-1,900	630-4,500	1,200-11,100
<u>Eastern Tennessee</u>							
68	10-14	27-40	75-120	200-340	550-1,000	1,500-2,900	4,000- 8,300
84	9-15	25-43	68-130	180-380	480-1,100	1,300-3,400	3,400-10,000
95	9-16	23-48	60-150	160-450	410-1,400	1,100-4,200	2,800-13,000
<u>Charleston, South Carolina</u>							
68	33-55	74-140	170-380	370-1,000	830-2,700	1,800- 7,100	4,000-20,000
84	30-61	65-170	140-460	300-1,300	650-3,400	1,400-10,000	2,900-25,000
95	26-70	54-200	110-580	230-1,700	460-4,800	940-14,000	1,900-50,000

Estimates are in years rounded to reflect accuracy levels better.

This Q estimate is particularly useful in that it allows a network-specific attenuation estimate to be incorporated into any stochastic strong ground motion modeling for the state or region.

Figure 17. Solid dots show estimates of Q . The bold line indicates the least squares fit to those data. Also shown are results from some previous studies in eastern North America.

Magnitude from Intensity and Felt Area: Central and Eastern North America

Another study dealt with the estimation of earthquake magnitudes in central and eastern North America using intensity and felt area. Over 480 earthquakes having instrumental m_b magnitudes and maximum Modified Mercalli intensities (I_0), were examined using exploratory data analysis techniques and robust estimation modeling methods.

Linear regression models using I_0 and/or felt area (and several transformations) were tested. The robust linear regression models

$$m_b = 2.48 + 0.0769 \text{ Log}^2 (\text{FA})$$

and

$$m_b = 2.16 + 0.0219 I_0^2 + 0.0596 \text{ Log}^2(\text{FA})$$

(where FA is felt area in square kilometers) proved to be the most accurate magnitude estimation models for central and eastern North American earthquakes (Figure 18). In studies where conversion of intensity to magnitude for groups of earthquakes is required (e.g., studies involving the Gutenberg-Richter recurrence relation), the underlying distribution of magnitudes (or its approximation), as given in the paper, for each intensity should be used rather than the above-listed formulas.

Figure 18. Results from Sibol and others (1987) for the central and eastern North America (CENA) and western North America (WNA), and several previous studies, for the conversion of MM intensity to magnitude (left), and for the conversion of felt area to magnitude (right).

A comparison of regional felt area models also indicated that regional differences in attenuation of seismic waves may exist between central and eastern North America that becomes apparent only for events of sufficient magnitude. Those differences appear as somewhat larger felt areas for earthquakes of central North America as compared to earthquakes of eastern North America.

Finally, a previously undocumented but distinct offset of magnitudes was observed between Modified Mercalli intensities VI and VII in both the central and eastern North America data set and a separate western North American catalog of earthquakes. The offset is most probably a characteristic of the Modified Mercalli scale and brings into question the often assumed linear relationship between magnitude and intensity. In particular, the linear regression models should not be used to estimate magnitudes for larger, $I_0 = VII$ or $VIII$, events. Instead, robust estimates of center and spread for individual intensity interval distributions are recommended.

State Seismic Hazard Studies for South Carolina and Virginia

Principal References:

- Bollinger, G. A., (1992), Specification of the source zones, recurrence rates, focal depths and maximum magnitudes for earthquakes affecting the Savannah River Site in South Carolina, U.S. Geol. Survey Bull. 2017, 57 p.
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- Bollinger, G. A., M. S. Sibol and M. C. Chapman, (1992), Maximum magnitude estimation for an intraplate setting - Example: The Giles County, Virginia, seismic zone, Seism. Res. Letters, 63, p. 139-152.
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- Oaks, S. D. and G. A. Bollinger, (1986), The epicenter of the m_b 5.0, December 22, 1875, Virginia, earthquake: New findings from documentary sources, Eqke. Notes, 57, p. 65-75.

Savannah River Site Study: South Carolina

This report presents documentation for the development of seismicity parameters to be used as input for probabilistic seismic hazard analyses at the Savannah River Site in South Carolina (Figure 19). The formal hazard analysis is by personnel at the Lawrence Livermore National Laboratory, and the author was one of several seismicity experts providing the requisite seismicity parameters of seismic zonation, magnitude recurrence relations, focal depth distributions and maximum magnitude estimates.

Discussion is presented on the selection of seismic zones that might affect the site as well as for the determination of the three required input parameters for each of those zones. The spatial distribution of historical seismicity is given primary emphasis in the definition of zonal boundaries (Figure 20). Specific procedures for the estimation of maximum magnitudes, magnitude recurrence relations and focal depth distributions for seismic zones with sparse earthquake catalogs are presented and are then applied in this study.

Figure 19. Seismicity map for central and eastern North America, 1568-1987. The six circles, centered on the Savannah River Site (star symbol), have radii of 100, 200, 350, 400, 600 and 800 km, respectively, outward from the site. The area within the 350 km radius is designated as "local"; greater distances are "regional" for purposes of this study. Number of earthquakes is 819.

Maximum magnitude estimates are derived from a combination of the magnitude of the 1000-year earthquake, the historical maximum earthquake plus one magnitude unit and the values calculated using various published relationships between magnitude and fault plane area. These maximum value estimates range from $5.75 \leq m_b(L_g) \leq 7.35$ ($5.8 \leq M_s \leq 8.75$) and are judged to be conservative, but not too conservative, given the many deficiencies in our knowledge and the fact that strong earthquakes have occurred where they were not expected them to occur.

EXPLANATION

CZ	Complementary Zone	Background
LZ1	Local Zone 1	Charleston, South Carolina, seismic zone
LZ2	Local Zone 2	Bowman, South Carolina, seismic zone
LZ3	Local Zone 3	South Carolina Piedmont and Coastal Plain seismic zone
LZ4	Local Zone 4	South Carolina Fall Line seismic zone
LZ5	Local Zone 5	Area of Local Zone 3 minus area of Local Zone 4
LZ6	Local Zone 6	Savannah River Site
RZ1	Regional Zone 1	New Madrid, Missouri, seismic zone (small)
RZ2	Regional Zone 2	New Madrid, Missouri, seismic zone (large)
RZ3	Regional Zone 3	Giles County, Virginia, seismic zone
RZ4	Regional Zone 4	Eastern Tennessee seismic zone (RZ4A the same area as RZ4)
RZ5	Regional Zone 5	Northwestern South Carolina and southwestern North Carolina seismic zone
RZ6	Regional Zone 6	Central Virginia seismic zone

MAGNITUDE

⊙	5
⊖	4
⊙	3
⊙	2
⊙	1
•	0

Figure 20. Seismic zone map showing regional zones (RZ1-RZ6), Complementary (background) Zone (CZ1) and local zones (LZ6; the Savannah River Site). LZ3 has an alternate configuration as LZ4 (central portion) and LZ5 (northwestern and southeastern portions: thus, LZ5 = LZ3 excluding LZ4).

For zones with adequate seismicity data, recurrence relations are determined using conventional maximum likelihood techniques. Recurrence relations for sparse catalog areas, however, involve (1) Assuming the regional b-value (slope) applies to the subject area, and then (2) Calculating the frequencies of $M \geq 3$ and $M \geq 4$ earthquakes for their periods of completeness. This procedure yields two N_c (cumulative number of earthquakes per year) values for substitution into the Gutenberg-Richter relation (solved for the intercept a-value): $a = \log N_c + bM$. Comparison of the two a-values obtained in this manner provides a qualitative measure of the stability of the estimate. $M \geq 3$ and $M \geq 4$ values of N_c are used because these lower energy level shocks are the more numerous in occurrence and thus are apt to be well reported during the modern instrumental network period. Given the availability of instrumental data, this procedure yields a reproducible, semiquantitative procedure for recurrence estimates. Interestingly, for the seven estimates, the a-values determined from $M \geq 3$ are all slightly larger than those determined from $M \geq 4$. The reason for this type of uniformity in this small sample is not known. See Table 3 for specific maximum magnitude estimates and recurrence parameters.

TABLE 3

Listing of Maximum Magnitude Estimates and Recurrence Equation Parameters for the Savannah River Site Source Zones (refer to Figure 20)

Source ID	Seismic Zone	Maximum Magnitude		Recurrence Parameters	
		$m_b(L_g)$	M_s	a	b
CZ1	Complementary (Background)	5.75	5.8	2.70	0.84
RZ1	New Madrid, MO (small)	7.35	8.75	3.32	0.91
RZ2	New Madrid, MO (large)	6.70	7.65	3.43	0.88
RZ3	Giles County, Virginia	6.30	6.8	1.065	0.64
RZ4	Eastern Tennessee	6.45	7.15	2.72	0.90
RZ4A	Eastern Tennessee	7.35	8.75	2.72	0.90
RZ5	NW. SC and SW. NC	6.0	6.2	2.14	0.82
RZ6	Central Virginia	6.4	7.1	1.18	0.635
LZ1	Charleston, South Carolina	6.9	8.1	1.69	0.77
LZ2	Bowman, South Carolina	6.0	6.2	1.34	0.78
LZ3	SC Piedmont and Coastal Plain	6.0	6.2	1.86	0.80
LZ4	South Carolina Fall Line	6.25	6.5	1.58	0.81
LZ5	Area of LZ3 minus Area of LZ4	6.0	6.2	1.695	0.80
LZ6	Savannah River Site	6.5	7.2	1.34	0.80

For focal depth distributions, the 10% and 90% quantiles of the reasonably well-constrained foci (vertical error estimates of 5 km or less) in each zone are used to define a linear distribution wherein the larger magnitudes occur at the greater depths. Two decades ago, prior to the installation and operation of seismic networks in the region and their attendant accurate focal depth estimates, such a procedure would have been impossible. See Table 4 for focal depth distribution parameters.

TABLE 4
Focal Depth Distributions

Source Zone	D _U = 10% Quantile (km)	D _L = 90% Quantile (km)
CZ1	3.3	18.5
LZ1	5.0	10.2
LZ2	2.4	5.8
LZ3	0.8	7.4
LZ4	0.9	6.1
LZ5	0.9	6.5
LZ6	0.8	7.4
RZ1	3.0	11.6
RZ2	2.8	12.4
RZ3	4.4	15.1
RZ4, 4A	7.6	20.8
RZ5	2.3	11.2
RZ6	4.5	13.4

In the process of the development of the required seismicity parameters, this study necessarily provided comprehensive analyses of the existing historical and instrumental earthquake catalogs available for the study area. Specifically, multiple epicentral plots, magnitude recurrence equations and vertical focal depth distribution plots were presented for all major and minor seismic zones. These results are expected to be useful to a wide range of geological, geophysical and engineering studies of the southeastern United States.

Seismic Response of the Coastal Plain Sedimentary Wedge: South Carolina

The portion of the Atlantic Coastal Plain province in South Carolina formed a unique meizoseismal host area for the M = 7.5, 1886 Charleston, South Carolina, earthquake. It was a unique host in that it consists of a landward thinning wedge of very soft, low velocity, low Q (50-200) sediments. Its thickness varies from more than a kilometer at the coastal Charleston location to a feather-edge near the capital at Columbia in the central part of the state some 200 km northwest of the coast.

The propagation of the seismic energy away from the 1886 focus resulted in strong ground motions that expressed the interaction between anelastic absorption and layer-thickness dependent resonances. To study these effects, linear regression analysis and ground motion modeling were employed. Statistical tests applied to 264 MM intensity reports, at epicentral distances less than 400 km, showed that the intensities in the Coastal Plain near the coast averaged from 0.5 to 1.0 units less than intensities within other areas over comparable distances. Also, simulated ground acceleration time histories were generated along two profiles: one trending northwest from the epicenter toward the Fall Line and another trending northeast from the epicenter parallel to the coastline.

The principal conclusions from these regression and ground motion modeling studies of the 1886 Charleston, South Carolina, earthquake intensity data are as follows:

- The variation in spatial distribution of intensity effects in South Carolina can be attributed in large part to the variation in thickness of the Coastal Plain sedimentary section.
- There is a rapid decay of intensity with distance in thick Coastal Plain sediments to the northeast and southwest from Charleston along the coast, in contrast to lower attenuation to the northwest (toward the Piedmont) in the direction of Coastal Plain sediment thinning.
- The apparent high intensity at or near the Fall Line in South Carolina, documented by Dutton (1889), is probably a relative effect due to stronger anelastic absorption of high frequency vibrations in the thicker Coastal Plain sediments to the southeast of the Fall Line.
- The data suggest that earthquakes occurring in the lower Coastal Plain (near the coastline) produce an asymmetrical intensity pattern, in which isoseismals are often extended significantly to the northwest in the direction of sediment thinning.
- This effect is apparent in the intensity pattern of the 1886 shock where the area of intensity VIII includes a large portion of the Coastal Plain and southeastern Piedmont, extending in an arc from Augusta, Georgia, northeast along the Fall Line to approximately the South Carolina-North Carolina border.
- It was this feature of the 1886 Charleston earthquake intensity pattern that Seeber and Armbruster (1981) cited as primary evidence for a postulated large sub-horizontal detachment focal mechanism for the 1886 earthquake. Clearly, such an unusual focal mechanism for an intraplate earthquake is unsubstantiated if the Coastal Plain sediments influence the intensity pattern as suggested by our modeling.
- The intensity patterns associated with the $m_b = 4.5$, February 3, 1972, and $m_b = 4.3$, November 22, 1974, South Carolina earthquakes were also examined. Those isoseismal maps also exhibited felt areas extending to the northwest.
- Important parameters for which we have no data are the focal mechanism, focal depth and source spectrum of the 1886 earthquake. Thus, the extent to which these and other parameters influenced the intensity pattern and character of ground motion at different locations in the study area is unknown.

We found no evidence for a systematic increase of intensity along the Fall Line which cannot be attributed to decreasing attenuation of high-frequency motions caused by the pinch-out of unconsolidated Coastal Plain sediments. However, because of the strong, near-surface velocity and density contrasts, frequency dependent local site effects can play a dominant part in determining the response at some sites near the Piedmont-Coastal Plain contact. An example of such sites may be those referred to by Dutton (1889) near Langley and Florence, South Carolina. Accordingly, site response should be considered carefully for critical structures in this area.

Maximum Magnitude Estimate for the Giles County, Virginia, Seismic Zone

The process of maximum magnitude estimation is intrinsically subjective and depends directly on the experience and judgment of the analyst. Coppersmith et al. (1987) have discussed six methods for determining the maximum magnitude earthquake for a seismogenic zone. Those include: (1) Addition of an increment to the largest historical earthquake, (2) Extrapolation of magnitude recurrence relations, (3) Use of source dimensions to estimate magnitude, (4) Statistical approaches (application of extreme value theory and maximum likelihood

techniques), (5) Strain rate or moment release rate methods, and (6) Reference to a global data base. Each technique has associated uncertainties in its applicability to the zone under consideration as well as in the specification of the key parameters involved.

For the six techniques listed above, only the first three are applicable to the data bases presently available for intraplate areas. Application of methods 1, 2 and 3 to the Giles County, Virginia, seismic zone (Figure 21) leads to the following results: $M_{S,I} = 6.9$ (second subscript indicating which of the six methods was used) from adding a 1.0 increment to the maximum historical earthquake known to have occurred in the zone (May 31, 1897; MMI = VIII; $m_b = 5.8$, $M_S = 5.9$), $M_{S,II} = 7.0$ from extension of the magnitude recurrence curve for the zone to a recurrence interval of 1000 years, and $M_{S,III} = 6.5$ from the average of six estimates for the fault zone area. For a single estimate of maximum magnitude, the average of the above three values $M_S = 6.8$ or equivalently, $m_b = 6.3$ can be used.

Figure 21. Seismicity map for the Giles County, Virginia, seismic zone showing only those earthquakes for which the epicenters and focal depths are known within ± 10 km.

Epicenter for the 1875 Central Virginia Earthquake

This study reexamined the effects of the important December 22, 1875, $I_0 = VII$ MM, $m_b = 5.0$, central Virginia earthquake. The previously identified higher intensity area ($\geq V$ MM), which included the central Virginia counties that lie between Richmond and Charlottesville, was the focus of this investigation. Primary documentary sources were used exclusively, and those sources included previously unused historical documents such as weather observers' reports, military records and plantation records. The new documentary evidence assembled also included data from sites other than the 1875 population centers.

The new felt reports helped to determine more about the earthquake effects in different parts of the city of Richmond. For example, it was found that residents of the James River waterfront experienced moderately severe shaking (VII MM) while those in upland sections of the city took far less notice of the event (IV MM).

Based on the damage reports and the number and severity of aftershocks, a new meizoseismal area is defined as one centering around Louisa, Goochland and Powhatan Counties. An epicentral location ($37.8^\circ N - 78.0^\circ W$) was assigned within that area. The inferred epicenter is located near the small communities of Othma, Sandy Hook and Gum Spring. The epicentral interpretation (which is rounded to the nearest tenth of a degree) is made to place the epicenter near the center of the meizoseismal contour identified by the new documentary evidence. The new epicenter might be at least 20 km in error because of James River alluvial deposits which may have amplified the shock. Another factor contributing to the possibility of a 20 km error is the scarcity of documentary information from this agrarian region of post-Civil War Virginia.

DATA BASES

Overview

Since 1985, digital waveforms recorded by the Virginia Regional Seismic Network are routinely analyzed and archived on magnetic tape. Since 1977, the Virginia Tech Seismological Observatory has maintained local and regional earthquake catalogs, as well as a catalog of combined historical and instrumental earthquakes of the southeastern United States. Focal mechanism solutions for local earthquakes have been determined and reported routinely in the NRC quarterly reports. Mechanisms contributed by network members are reported on an annual basis in the Southeastern United States Seismic Network Bulletin.

Digital Waveforms Recorded and Archived Since 1985

Since 1985, 140 local/regional earthquakes, 600 teleseisms and 1600 mining blasts have been recorded and archived (see Appendix A). These data consist of 32 channels of waveform data from all Virginia Regional Seismic Network stations, sampled at 100 sps on a 12 bit digitizer. The recording system has a dynamic range of less than 40 dB. As discussed earlier in the NETWORK OPERATIONS section of this report, network calibrations allow for the correction of recorded waveform data to true ground motion.

Earthquake Catalogs for Virginia and the Southeastern United States

The local earthquake catalog consists of events recorded and located by Virginia Tech in Virginia and surrounding border areas (Figure 22). Selected earthquakes since 1974, but prior to the installation of the network, have been included. Earthquakes in central Virginia recorded by the full North Anna network and reported by Dames & Moore (1977) were relocated by Virginia Tech. Regionally recorded earthquakes from 1974 through 1977, located by Dewey and Gordon (1984), were also incorporated. A listing of the earthquake catalog appears in Appendix B.

The Virginia Tech Seismological Observatory routinely publishes the Southeastern United States Seismic Network Bulletin. The SEUSSN currently consists of over 100 stations located throughout the southeastern United States (Figure 23). Since 1978, the SEUSSN Bulletin has provided hypocentral locations, magnitudes, felt/damage reports and arrival times for southeastern United States earthquakes in a consistent and timely fashion (e.g., typically a Bulletin covering a particular year reaches users in June or July of the following year). Figure 24 is an epicenter map of the 1162 tectonic earthquakes reported since 1977.5 through 1991. Appendix C lists the locational parameters and magnitudes for those earthquakes. There have also been 681 reservoir-related earthquakes and 182 explosion events reported. Table 5 is a brief tabulation of statistics for the tectonic earthquake catalog for the period from July 1977 through 1991 (14.5 years)

Figure 22. Seismicity map for Virginia and surrounding areas of events since 1974. Epicenters include earthquakes located by Virginia Tech during this project period, pre-network earthquakes located by Dewey and Gordon (1984) and events in central Virginia originally reported by Dames and Moore (1977) and relocated by Virginia Tech. N indicates number of earthquakes plotted.

Recent SEUSSN Bulletins contain both rep. + period and cumulative listings of earthquake statistics (more extensive than shown above), depth and magnitude distributions, catalog completeness estimates, recurrence rates, strain histories and an epicentral density contour map showing number of events ($M \geq 2.0$) per 10,000 km^2 . In 1991, the Bulletin was distributed to over 230 institutions and individuals, including 40 foreign destinations.

Figure 23. Seismic stations (triangles) operating in the Southeastern United States Seismic Network during 1991. The SEUSSN monitoring area is outlined. N indicates number of stations.

Figure 24. Epicenter map showing tectonic earthquakes reported in the SEUSSN Bulletins for the period July 1977 through December 1991.

TABLE 5

Earthquake Statistics For The SEUSSN Tectonic Earthquake Catalog:
(July 1977 through December 1991)

	<u>Number</u>	<u>Rate</u> (No/year)
Number of earthquakes ($M \geq 0.0$).....	1162	80
Number of earthquakes ($M \geq 2.5$).....	201	14
Number of earthquakes ($M \geq 3.5$).....	24	1.7
Number of felt earthquakes	136	9.4
Number of earthquakes with $D_{min} \leq 5.0$ km	85	
Number of earthquakes with $D_{min} \leq 10.0$ km	202	
Number of earthquakes with $ERH \leq 5.0$ km	1030	
Number of earthquakes with $ERZ \leq 5.0$ km	861	
Largest earthquake.....: 27 July 1980 18:52 - Sharpsburg, KY, $m_b = 5.2$, $MMI = VII$		

Virginia Tech also developed and maintains a catalog of historic and instrumentally recorded earthquakes for the southeastern United States (Figure 25). That catalog is a combination of the United States Geological Survey State Seismicity Map listings (Stover and others, 1984), the Canadian Earthquake Epicentre File and the SEUSSN Bulletins mentioned above. Additional data (for example, magnitudes from Sibol and others (1987), new SEUSSN data, etc.) and various upgrades and corrections have been incorporated as they became available. Organizations that have requested the catalog include the Branch of Geologic Risk Assessment of the U.S. Geological Survey, Lawrence Livermore National Labs, Argonne National Laboratory in Illinois and the Electric Power Research Institute. The catalog has also been provided to several other research organizations, universities and consulting firms.

Figure 25. Epicenter map showing historic and instrumentally located earthquakes with either $M \geq 4$ or I_0 (MM) $\geq V$.

Focal Mechanism Solutions for Virginia and Tennessee Earthquakes

Table 6 lists current focal mechanism solutions for earthquakes in Virginia and eastern Tennessee. Consistent with what has been reported earlier for the Giles County, Virginia, seismic zone, the in-situ stress field inferred from the focal mechanism solutions, is a northeasterly trending subhorizontal maximum compressive stress (Figure 26). As was discussed earlier (see the previous section entitled SEISMOTECTONIC STUDIES, Central Virginia Seismic Zone), the shallow sources (depth < 8 km) within the central Virginia seismic zone exhibit northeast trending maximum compressive stress while the deeper events (depth > 8 km) indicate mostly northwest trending maximum compressive stress (Figure 27).

TABLE 6

Parameters for Focal Mechanism Solutions in Virginia and Eastern Tennessee

Giles County, Virginia, Seismic Zone:

Event Date	Fault Planes		F Axis		T Axis		B Axis	
	(Dip, Strike, Rake)	(Dip, Strike, Rake)	(TR, PL)	(TR, PL)	(TR, PL)	(TR, PL)	(TR, PL)	(TR, PL)
12/02/80	(85, 340, -178;	88, 250, -5)	205, 5	295, 2	45, 85			
1/25/83	(90, 340, 145;	55, 70, 0)	31, 24	289, 24	160, 55			
5/26/83	(30, 180, -171;	86, 82, -60)	21, 42	147, 34	260, 30			
7/10/83	(82, 20, -174;	84, 290, -8)	245, 10	335, 1	70, 80			
12/09/83	(64, 206, 164;	76, 303, 27)	73, 7	167, 29	330, 60			
7/02/84	(66, 207, -147;	60, 102, -28)	67, 40	334, 3	240, 50			
6/10/85	(35, 45, 0;	90, 315, 125)	15, 35	255, 35	135, 35			
3/26/86	(18, 49, 33;	80, 288, 105)	5, 34	215, 52	105, 15			
8/30/90	(71, 93, 30;	62, 352, 158)	221, 6	315, 34	123, 55			

Central Virginia Seismic Zone:

Event Date	Fault Planes		P Axis		T Axis		B Axis	
	(Dip, Strike, Rake)	(Dip, Strike, Rake)	(TR, PL)	(TR, PL)	(TR, PL)	(TR, PL)	(TR, PL)	(TR, PL)
8/04/80	(41, 341, 139;	64, 104, 57)	218, 13	329, 57	120, 30			
9/26/80	(82, 220, 174;	84, 310, 8)	85, 1	175, 10	350, 80			
2/11/81	(67, 346, 117;	35, 113, 42)	56, 18	294, 58	155, 25			
2/11/81	(35, 278, 81;	55, 108, 96)	194, 10	41, 79	285, 5			
1/18/82	(79, 346, 136;	47, 86, 15)	43, 21	296, 38	155, 45			
5/06/82	(61, 158, -8;	83, 252, -151)	119, 26	22, 14	265, 60			
6/25/82	(42, 316, 129;	59, 89, 60)	199, 9	308, 63	105, 25			
9/20/82	(79, 327, 17;	74, 233, 168)	99, 3	191, 20	0, 70			
8/10/83	(45, 333, -5;	86, 66, -135)	300, 33	191, 27	70, 45			
8/17/84	(59, 335, 16;	76, 236, 148)	288, 11	191, 33	35, 55			
10/17/84	(63, 3, 14;	78, 267, 152)	318, 10	222, 28	65, 60			
12/10/86	(45, 326, 74;	47, 168, 105)	247, 1	152, 79	337, 11			
4/11/87	(25, 340, 35;	76, 217, 111)	291, 28	152, 54	32, 20			
3/15/91	(35, 273, -173;	86, 177, -55)	119, 39	239, 32	354, 35			

TABLE 6
(continued)

Eastern Tennessee Seismic Zone:

Event Date	Fault Planes						P Axis	T Axis	B Axis
	(Dip, Strike, Rake;	Dip, Strike, Rake)					(TR, PL)	(TR, PL)	(TR, PL)
11/25/81	(78, 76, 9;	81, 344, 168)					30, 3	300, 15	130, 75
9/24/82	(64, 284, 16;	76, 187, 153)					237, 7	143, 29	340, 60
9/24/82	(86, 280, 9;	81, 190, 176)					55, 3	145, 9	305, 80
1/18/83	(74, 78, -12;	79, 172, -163)					36, 20	304, 3	205, 70
1/27/83	(84, 63, -35;	56, 157, -173)					14, 28	115, 19	235, 55
4/05/83	(78, 318, 28;	63, 222, 166)					88, 10	183, 28	340, 60
5/16/83	(87, 69, -20;	70, 161, -176)					23, 16	117, 11	240, 70
5/25/83	(85, 287, -70;	21, 29, -167)					217, 46	359, 37	105, 20
5/26/83	(74, 277, -53;	40, 27, -154)					226, 48	340, 20	85, 35
7/08/83	(63, 293, 31;	63, 187, 149)					60, 0	150, 40	330, 50
7/15/83	(71, 304, -7;	83, 36, -161)					261, 18	169, 8	55, 70

Table 6 Description: All entries (except date) in degrees. TR and PL are the trend and plunge of the P, T, or B axes. Sign conventions for angles, according to Aki and Richards (1980, Section 4.5). The strike is the azimuth of the fault with the convention that if one faces down dip, the strike direction is to the left. The dip is measured down from the horizontal and is bounded by 0° and 90° . The rake angle (Θ) is measured within the fault plane and is bounded by -180° and $+180^\circ$ measured from the strike direction. If $0^\circ < \Theta < +180^\circ$, the fault is a reverse fault or thrust fault, and if $-180^\circ < \Theta < 0^\circ$, the fault is a normal fault. If $\Theta = +90^\circ$ or $\Theta = -90^\circ$, the fault is dip-slip. A right-lateral fault is one for which an observer standing on one side of the fault sees the block on the other side move to the right. If $\Theta = 0^\circ$, the fault is left-lateral strike-slip, and if $\Theta = +180^\circ$, the fault is right-lateral strike-slip. Herrmann (1975) includes a complete discussion about relationships among these different parameters.

Figure 26. Epicenter map showing earthquakes in the Giles County, Virginia, seismic zone. Solid symbols indicate earthquakes with focal mechanisms. Mechanisms are lower hemisphere, equal area projections, with compressional quadrants shown in black. P axes for each earthquake are shown in a composite plot with heavy arrows indicating the average azimuth.

Figure 27. Epicenter map showing earthquakes in the central Virginia seismic zone. Solid symbols indicate earthquakes with focal mechanisms. Mechanisms are lower hemisphere, equal area projections, with compressional quadrants shown in black. P axes for earthquakes with depths of less than 8 km and greater than 8 km, are shown in composite plots with heavy arrows indicating the average azimuth. Index map shows the central Virginia area on a outline map of Virginia.

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APPENDICES

APPENDIX A

Digital Waveforms Recorded And Archived Since 1985 By The Virginia Tech Seismological Observatory

(Listed as local/regional earthquakes, teleseismic earthquakes, and blasts, respectively)

25-MAR-93 14:02:47 for the program SIGSORT
Master File Sorted According to the Following Criteria:

- 1) Earliest date: 850911511 Latest date: 990000000
- 2) Local and regional quakes only.

	file	net	remarks
APR 14 1985	851041142	R	REGIONAL EARTHQUAKE, OHIO-PENNSYLVANIA BORDER
APR 22 1985	851121821	J	CV EQKE, NEAR MT. VERNON, MAG=2.0
JUN 10 1985	851611223	J	GC LOCAL EQ -- BLACKSBURG, MD=2.8
SEP 19 1985	852450458	J	EARTHQUAKE NEAR GHV
OCT 19 1985	852921008	J	EARTHQUAKE AT ARDSLEY, NY
DEC 21 1985	853551011	J	RICHMOND VA QUAKE 21 DEC 1985
DEC 22 1985	853560056	J	EAST TENN QUAKE 22 DEC 1985
JAN 7 1986	8600070128	J	EAST TENN EARTHQUAKE, NEAR DECATUR, TN, M=3.1
JAN 31 1986	8600311647	J	EARTHQUAKE NEAR PERRY, OHIO
MAR 13 1986	8600332151	J	EARTHQUAKE NEAR RICHMOND, VA, MD=1.3
FEB 13 1986	8600441137	J	EARTHQUAKE NEAR LAKE KEOWEE, SC, M=3.5
MAR 26 1986	8600611507	J	PROB EAST TENN EQKE
MAR 26 1986	8600851635	J	BLACKSBURG EARTHQUAKE II, MD=2.9
MAY 23 1986	8601221354	J	REGIONAL EARTHQUAKE - LANCASTER PA, M=2.5
MAY 23 1986	8601431749	J	POSSIBLE EQ NEAR WASHINGTON DC (ACCOKEE, MD), MD=2.5
JUL 12 1986	8601921427	J	REGIONAL EQ IN NW GEORGIA, MBLG=3.8
AUG 30 1986	8601930820	J	EARTHQUAKE IN LIMA, OHIO
SEP 30 1986	8602210758	J	LOCAL QUAKE NEAR HILLSVILLE, VA (MD=2.2)
OCT 18 1986	86022761022	J	EARTHQUAKE NEAR GHV, MD=1.6
OCT 18 1986	8602910832	J	CENTRAL NORTH CAROLINA EARTHQUAKE, M=2.5
OCT 25 1986	8602981718	J	REGIONAL EARTHQUAKE, ROCK HILL SC, M=2.9
NOV 7 1986	860333111555	J	NEW HAMPSHIRE EQ
DEC 3 1986	860333709444	J	EARTHQUAKE OFF CAPE HATTERAS
DEC 14 1986	8603581759	J	RICHMOND EARTHQUAKE
JAN 13 1987	86070131451	J	RICHMOND EARTHQUAKE
MAR 27 1987	8607051310	J	RICHMOND EARTHQUAKE
MAR 27 1987	8607051310	J	REGIONAL EQ - GREAT FALLS, SC M=3.2
MAR 27 1987	8607051310	J	EASTERN T MESSIE EARTHQUAKE, VONORE TN, M=4.2
APR 11 1987	8607051310	J	EARTHQUAKE NEAR FARMVILLE, VA, MD=2.0
APR 11 1987	8607051310	J	EARTHQUAKE NEAR MICHAUX VA, MD=1.7
APR 11 1987	8607051310	J	EARTHQUAKE NEAR COOL WATER VA, MD=0.6
MAY 10 1987	86071301948	J	EARTHQUAKE IN KENTUCKY, M=3.0
JUN 10 1987	860716123550	J	ILLINOIS EARTHQUAKE
JUL 11 1987	860716421220	J	AFTERSHOCK FROM ILLINOIS
JUL 11 1987	860719200005	J	JEFFERSON CITY, TN EARTHQUAKE, M=3.7
JUL 11 1987	86071920049	J	JEFFERSON CITY, TN EARTHQUAKE, M=3.3
SEP 26 1987	86072651724	J	EARTHQUAKE LOUDON, TN, M=3.3
OCT 4 1987	86072720006	J	MBLG 4.5 NEW MADRID
NOV 4 1987	860728715526	J	REGIONAL EQ IN KY OR MO
NOV 4 1987	860728715526	J	LOCAL QUAKE IN KY OR MD
NOV 4 1987	860728715526	J	POSSIBLE EVENT FROM NORTHEAST
NOV 4 1987	860728715526	J	EARTHQUAKE PENNINGTON GAP, VA M=3.5
DEC 1 1987	860734300734	J	REGIONAL EQ (OKLAHOMA)
DEC 1 1987	860734300734	J	REGIONAL EQ (GA-SC BORDER?, NEAR CLARK HILL RES.?)
JAN 1 1988	860734300734	J	EARTHQUAKE (TELLICO PLAINS, TN) M=3.4
JAN 1 1988	860734300734	J	EARTHQUAKE SUMMERVILLE SC, M=3.5
JAN 1 1988	860734300734	J </tr	

APR	29	1991	911191512	E	1	GILES CO. EARTHQUAKE
MAY	14	1991	911240119	E	1	NEW MADRID, M = 4.6/SE MISSOURI/36.5N-89.7W
JUN	17	1991	911680853	N	1	NY EQKE, M = 4.1
JUN	28	1991	911791834	N	1	POSSIBLE EQ IN WVA
JUL	7	1991	911882125	N	1	Oregon, MO eqk. M=4.0, 36.7N 91.6W, shallow.
JUL	22	1991	911882127	N	1	Oregon, MO eqk.
AUG	15	1991	912041351	N	1	Microearthquake ?
SEP	14	1991	912270716	N	1	Regional Earthquake from the Northeast
SEP	24	1991	912570735	N	1	CVA EARTHQUAKE - Maq. ??
NOV	11	1991	912670721	N	1	REGIONAL EARTHQUAKE TENNESSEE?
JAN	1	1992	913150922	N	1	COMPLEX REGIONAL SIGNAL - POSSIBLE EQ'S
JAN	1	1992	920021154	N	1	Lg PHASE - ODESSA - TEXAS mb 4.7
JAN	1	1992	920030421	N	1	REGIONAL EVENT - NEAR CLARK HILL RESERVOIR SC-GA
JAN	1	1992	920090851	N	1	NEW JERSEY EARTHQUAKE 40.3N 74.3W m=3.0
JAN	1	1992	920180101	N	1	PLUVAL REGIONAL EARTHQ.
FEB	1	1992	920411829	N	1	LOCAL QUAKE NEAR NAV (MD=1.2) #176
FEB	3	1992	920501409	N	1	EQ (M=1.8) NEAR GHV AND NA12
MAR	1	1992	920560452	N	1	POSSIBLE EARTHQUAKE ??
MAR	1	1992	920750614	N	1	REGIONAL EQ, OHIO?
MAR	1	1992	920820428	N	1	SMALL QUAKE UNDER GHV -
MAY	1	1992	920892011	N	1	EARTHQ ?? NEAR PKV
MAY	1	1992	921272119	N	1	EQ OR MINE BUMP NEAR FAYETTEVILLE, WVA
MAY	1	1992	921400844	N	1	CARROLL COUNTY QUAKE
JUL	1	1992	922000311	N	1	LOCAL QUAKE
AUG	1	1992	922390511	N	1	CVA LOCAL QUAKE
SEP	1	1992	922732322	N	1	PROB. REG. QUAKE? OR BIG BLAST IN KENTUCKY
NOV	1	1992	922790511	N	1	SMALL GILES CO. EQ. #183
DEC	1	1992	923601183	N	1	HILLSVILLE EQ
DEC	26	1992	923611191	N	1	EQ ?
JAN	1	1993	930010507	N	1	North Carolina Eq
JAN	1	1993	930150204	N	1	CHATTANOOGA-ETOWA TENNESSEE QUAKE 3.1 MBLG
JAN	1	1993	930180418	N	1	PROB. REGIONAL QUAKE?
MAR	10	1993	930691431	N	1	Columbia, MD (14:32:22,39.204N,76.881W,2.5Md)

There are 141 events in this list.

25-MAR-93 14:08:17 for the program SIGSORT
Master File Sorted According to the Following Criteria:

- ```

1) Earliest date: 850911511 Latest date: 990000000
2) Teleseisms only.

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|     |    |      | file       | net | remarks                                              |
|-----|----|------|------------|-----|------------------------------------------------------|
| APR | 9  | 1986 | 8509371317 | T   | IMPULSIVE TELESEISM.                                 |
| APR | 9  | 1986 | 8509371317 | T   | MONSTER TELESEISM CENT. CHILE                        |
| APR | 10 | 1986 | 8509371317 | T   | TELESEISM                                            |
| APR | 10 | 1986 | 8509371317 | T   | PROBABLY CP OF TELESEISM                             |
| APR | 10 | 1986 | 8509371317 | T   | TELESEISM                                            |
| APR | 10 | 1986 | 8509371317 | T   | TELESEISM                                            |
| APR | 10 | 1986 | 8509371317 | T   | IM-PULSIVE TELESEISM                                 |
| APR | 10 | 1986 | 8509371317 | T   | EXC LINT                                             |
| MAY | 1  | 1986 | 8509371317 | T   | DEEP FOCUS TELESEISM P WAVE                          |
| MAY | 1  | 1986 | 8509371317 | T   | SAME TELESEISM; SCS                                  |
| MAY | 1  | 1986 | 8509371317 | T   | SAME TELESEISM; S                                    |
| MAY | 1  | 1986 | 8509371317 | T   | TELESEISM                                            |
| MAY | 1  | 1986 | 8509371317 | T   | GCC TELFRASEISM                                      |
| MAY | 1  | 1986 | 8509371317 | T   | GCC TELFRASEISM                                      |
| MAY | 1  | 1986 | 8509371317 | T   | GCC TELFRASEISM                                      |
| MAY | 1  | 1986 | 8509371317 | T   | GCC TELFRASEISM                                      |
| JUN | 10 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUN | 12 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUN | 13 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUN | 14 | 1986 | 8509371317 | T   | P WAVE FROM VIRGIN ISLANDS                           |
| JUN | 26 | 1986 | 8509371317 | T   | S WAVE FROM VIRGIN ISLANDS                           |
| JUN | 30 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 6  | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 9  | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 20 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 21 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 21 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 22 | 1986 | 8509371317 | T   | P ARRIVAL                                            |
| JUL | 22 | 1986 | 8509371317 | T   | S ARRIVAL                                            |
| JUL | 23 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 25 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 26 | 1986 | 8509371317 | T   | SMALL TELESEISM                                      |
| JUL | 26 | 1986 | 8509371317 | T   | TELESEISM 2ND PHASE                                  |
| JUL | 29 | 1986 | 8509371317 | T   | TELESEISM                                            |
| JUL | 29 | 1986 | 8509371317 | T   | TELESEISM 2ND PHASE                                  |
| JUL | 29 | 1986 | 8509371317 | T   | TELESEISM                                            |
| AUG | 8  | 1986 | 8509371317 | T   | TELESEISM 2ND PHASE                                  |
| AUG | 8  | 1986 | 8509371317 | T   | 2ND PHASE OF ABOVE TELE.                             |
| AUG | 8  | 1986 | 8509371317 | T   | ANOTHER TELE. PROBABLY FROM SAME AREA                |
| AUG | 15 | 1986 | 8509371317 | T   | YET ANOTHER TELESEISM (SEISMIC CRISIS IN THE MAKING) |
| AUG | 15 | 1986 | 8509371317 | T   | BEST TELESEISM I'VE EVER SEEN (SHARPEST PHASE) MCC   |
| AUG | 21 | 1986 | 8509371317 | T   | TELESEISM (MID-ATLANTIC RIDGE?)                      |
| AUG | 21 | 1986 | 8509371317 | T   | SECOND PHASE OF ABOVE                                |
| AUG | 26 | 1986 | 8509371317 | T   | TELESEISM                                            |
| AUG | 26 | 1986 | 8509371317 | T   | POSSIBLE TS 1ST PHASE                                |
| AUG | 27 | 1986 | 8509371317 | T   | POSSIBLE TS 2ND PHASE                                |
| SEP | 1  | 1986 | 8509371317 | T   | IMPULSIVE TELESEISM                                  |
| SEP | 1  | 1986 | 8509371317 | T   | TELESEISM                                            |
| SEP | 12 | 1986 | 8509371317 | T   | 2ND PHASE OF TS OR SECOND TELESEISM                  |
| SEP | 15 | 1986 | 8509371317 | T   | TELESEISM                                            |
| SEP | 19 | 1986 | 8509371317 | T   | TELESEISM                                            |
| SEP | 21 | 1986 | 8509371317 | T   | M=7.8 OFF WESTERN COAST OF MEXICO                    |
| SEP | 22 | 1986 | 8509371317 | T   | M=7.3 AFTER SHOCK OF MEXICAN MEGA-QUAKE              |
| OCT | 8  | 1986 | 8509371317 | T   | IMPULSIVE TELESEISM                                  |
| OCT | 8  | 1986 | 8509371317 | T   | IMPULSIVE TELESEISM                                  |
| OCT | 9  | 1986 | 8509371317 | T   | TELESEISM (ALASKA?)                                  |
| OCT | 9  | 1986 | 8509371317 | T   | TELESEISM - ANOTHER PHASE                            |
| OCT | 23 | 1986 | 8509371317 | T   | ANOTHER TELESEISM                                    |
| OCT | 24 | 1986 | 8509371317 | T   | FROM ECUADOR - GOOD DEPTH PHASE                      |
| OCT | 25 | 1986 | 8509371317 | T   | TELESEISM                                            |
| OCT | 25 | 1986 | 8509371317 | T   | TELESEISM                                            |
| NOV | 9  | 1986 | 8509371317 | T   | TELESEISM                                            |
| NOV | 9  | 1986 | 8509371317 | T   | TELESEISM                                            |
| NOV | 9  | 1986 | 8509371317 | T   | TELESEISM                                            |
| NOV | 9  | 1986 | 8509371317 | T   | TELESEISM                                            |
| NOV | 9  | 1986 | 8509371317 | T   | TELESEISM                                            |
| NOV | 9  | 1986 | 8509371317 | T   | NEW HEBRIDES                                         |
| NOV | 9  | 1986 | 8509371317 | T   | NEW HEBRIDES                                         |
| DEC | 1  | 1986 | 8509371317 | T   | TELESEISM                                            |
| DEC | 1  | 1986 | 85         |     |                                                      |





- CHILE  
 - CHILE  
 TELESEISM  
 - 2ND PHASE  
 - 2ND PHASE  
 (SOUTH AMERICA)  
 2ND PHASE  
 2ND PHASE  
 - ANOTHER PHASE  
 - 2ND PHASE  
 - CALIFORNIA  
 - SOUTH AMERICA  
 (?)  
 - 2ND PHASE  
 NM AZIMUTH  
 NM AZIMUTH  
 PASADENA CALIF.  
 FOCUS  
 P WAVE FROM S. AMERICA  
 ARRIVAL (S) FROM S. AMERICA  
 CAL-ARIZONA BORDER EQ  
 CANADIAN ARCTIC (UNIQUE EVENT)  
 (REAL TIME 880220054)  
 (REAL TIME 880220416)  
 (REAL TIME 880221223)  
 S-WAVE  
 TELESEISM  
 FROM WESTERN NORTH AMERICA  
 - SECOND PHASE  
 - GULF OF ALASKA - MAG = 7.2  
 TELESEISM  
 TELESEISM WITH AFTERSHOCK  
 - TRINIDAD  
 TELESEISM - POLARITY CHECK  
 WITH SEVERAL PHASES  
 - NM TERRITORY - M = 6  
 - 2ND PHASE  
 - Lq  
 EARTHQUAKE - 1ST PHASE  
 EARTHQUAKE - 2ND PHASE  
 TELESEISM  
 EARTHQUAKE IN NORTH ATLANTIC  
 TELESEISM  
 SMALL TELESEISM  
 SMALL TELESEISM  
 SMALL TELESEISM IMPULSIVE P-WAVE  
 SMALL TELESEISM P-WAVE  
 FROM INDIA  
 - ANOTHER PHASE OR SECOND SHOCK  
 - WESTERN PACIFIC

TELESEISM - SOUTH AMERICA  
EARTHQUAKE - UTAH  
LG ARRIVAL FROM 882272008  
TELESEISM  
NEVADA TEST SITE - MONITORED NUCLEAR BLAST  
NTS BLAST; SECONDARY TRIGGER  
NTS BLAST; SECONDARY TRIGGER  
NTS BLAST; SECONDARY TRIGGER  
NTS BLAST; SECONDARY TRIGGER  
NTS BLAST; SECONDARY TRIGGER  
NTS BLAST; SECONDARY TRIGGER  
M=6.4 IN INDIA  
M=5.4 BERMUDA  
TELESEISM  
TELESEISM - 2ND PHASE  
TELESEISM  
TELESEISM  
TELESEISM P-WAVE  
TELESEISM P-WAVE  
GUATAMALA TS P-WAVE; M = 6.0  
GUATAMALA TS; LATER PHASES  
PUERTO RICO TS P & S WAVES; M = 5.5  
PUERTO RICO TS; LATER ARRIVALS  
PUERTO RICO AFTERSHOCKS (?)  
PUERTO RICO AFTERSHOCKS (?)  
TELESEISM  
TELESEISM  
MB=4.2 QUEBEC P WAVE  
QUEBEC S WAVE  
QUEBEC P & S WAVES; M = 6.0  
QUEBEC CODA WAVES; M = 6.0  
QUEBEC CODA WAVES; M = 6.0  
TELESEISM  
TELESEISM  
TELESEISM (BAD GLITCH IN P WAVE)  
LARGE TELESEISM (ARMENIA MS 6.9, 50 K DEAD)  
DEEP FOCUS TELESEISM  
TELESEISM  
M=5.4 UTAH (P)  
UTAH (S-LG)  
INTERMEDIATE DEPTH EQ; TALOUD ISLANDS (132 DEG)  
P WAVE (3 MIN S-P)  
ALASKA  
DEEP FOCUS  
DOMINICAN REPUBLIC  
TELESEISM; UNUSUAL AZIMUTH  
SO. AMER.; LARGE AND DEEP; MANY DEPTH PHASES; SEE BLAB  
SMALL TELESEISM P-WAVE  
SMALL TELESEISM P-WAVE; DEEP?  
TELESEISM P-WAVE; M= 8.2; MCQUARRIE ISL. (SO. OF NEW ZEL.)  
TELESEISM SECOND PHASES; M= 8.2; MCQUARRIE ISL.  
TELESEISM P-WAVE; 3.5 MIN. S-P  
TELESEISM S AND CODA; 3.5 MIN. S-P  
LARGE TELESEISM P-WAVE  
TELESEISM COMPLEX P-WAVE (4 MIN. S-P); CARIBBEAN?  
TELESEISM S WAVE & CODA (4 MIN. S-P); CARIBBEAN?  
SMALL TELESEISM P-WAVE; DEEP?  
TS P-WAVE  
ECUDOR; P-WAVE; M = 5.9  
HAWAII; P-WAVE; M = 7.1  
TELESEISM  
TELESEISM; REPLACEMENT DIGITIZER  
INDONESIA P WAVE; MAG=6, 100 KM DEEP  
P WAVE FROM CARIBBEAN?  
S WAVE FOR CARIBBEAN  
FINE TELESEISMIC P WAVE  
TELESEISM  
TELESEISM  
TELESEISM ( OK ON SC STATIONS)  
TELESEISM  
OFF COAST OF MEXICO; M = 6.5  
DEEP FOCUS, PROBABLY  
TELESEISM?  
SOUTH OF PANAMA; M = 6.0  
TELESEISMIC P (GOOD AT SC STATIONS TOO)  
TELESEISMIC S (GOOD AT SC STATIONS TOO)  
TELESEISM  
ADAK, ALASKA; M = 6.6  
SAN FRANCISCO; M = 6.9  
SAN FRANCISCO, LATER ARRIVALS  
TELESEISM FROM SOUTH  
BOLIVIA P-WAVE; M = 5.6, D = 140 KM  
PUERTO RICO P-WAVE; M = 4.8  
PUERTO RICO S ETC.; M = 4.8  
HONSHU JAPAN; M = 7.3; BLAST IN FRONT OF TS  
TS WITH DEPTH PHASES  
TELESEISM  
TELESEISM  
SOUTHERN PERU; M = 6.1; D = 120 KM  
RIO GRAND VALLEY, MEXICO; P-WAVE; M = 4.5; FELT IN TEXAS  
RIO GRAND VALLEY, MEXICO; S-WAVE & ETC.  
ADAK ALASKA; M = 5.8; D = 50 KM  
SMALL TELESEISM WITH DEPTH PHASES  
PERU/BRAZIL BORDER; M = 6.0; D = 157 KM  
TELESEISM  
TELESEISM  
PHILLIPINES REGION: MS=7.3  
S. AMERICA DEEP IE  
S. AMERICA DEEP ONE  
TELESEISM  
TELESEISM  
TELESEISM FROM EAST; P-WAVE; BERMUDA OR CARIBBEAN  
TELESEISM FROM EAST; S ETC.; BERMUDA OR CARIBBEAN  
TELESEISM  
TELESEISM  
TELESEISM P  
TELESEISM S  
TELESEISM  
TELESEISM P - SOUTH AMER :  
TELESEISM S - SOUTH AMER :  
LA. TELESEISM P  
LA. TELESEISM S  
TELESEISM P  
IMPULSIVE TELESEISM  
TELESEISM P  
TELESEISM P-WAVE

[illegible]

There are 628 events in this list.

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25-MAR-93 14:03:55 for the program SIGSORT  
Master File Sorted According to the Following Criteria:

- 1) Earliest date: 850911511 Latest date: 990000000
- 2) Blasts only.

|       | file      | net | remarks                                               |
|-------|-----------|-----|-------------------------------------------------------|
| APR 1 | 850911511 | B   | REGIONAL BLAST GILES CO. NET: S-P ABOUT 20 SEC.       |
| APR 1 | 850911511 | B   | REGIONAL BLAST CV NET: S-P ABOUT 15 SEC.              |
| APR 1 | 850911511 | B   | LOCAL BLAST (VERDON?) CV NET:                         |
| APR 1 | 850911511 | B   | REGIONAL BLAST GILES CO. NET: S-P ABOUT 25 SEC.       |
| APR 1 | 850911511 | B   | LOCAL BLAST (HI TEST?)                                |
| APR 1 | 850911511 | B   | LOCAL BLAST (CHARLOTTEVILLE QUARRY).                  |
| APR 1 | 850911511 | B   | REGIONAL BLAST GILES CO. NET: S-P ABOUT 20 SEC.       |
| APR 1 | 850911511 | B   | LOCAL BLAST IN CV NET.                                |
| APR 1 | 850911511 | B   | LOCAL BLAST IN GC NET.                                |
| APR 1 | 850911511 | B   | REG. BLAST GC NET                                     |
| APR 1 | 850911511 | B   | LOCAL BLAST CV NET                                    |
| APR 1 | 850911511 | B   | LOCAL BLAST NEAR PETERSBURG                           |
| APR 1 | 850911511 | B   | REGIONAL BLAST IN GC NET                              |
| APR 1 | 850911511 | B   | REGIONAL BLAST GC NET: S-P ABOUT 20 SEC               |
| APR 1 | 850911511 | B   | LOCAL BLAST (HI TEST?)                                |
| APR 1 | 850911511 | B   | LOCAL BLAST IN CV NET                                 |
| APR 1 | 850911511 | B   | REGIONAL BLAST GC NET: S-P ABOUT 20 SEC               |
| APR 1 | 850911511 | B   | LOCAL BLAST IN CV NET                                 |
| APR 1 | 850911511 | B   | LOCAL BLAST NEAR GHV                                  |
| APR 1 | 850911511 | B   | LOCAL BLAST GC NET                                    |
| APR 1 | 850911511 | B   | REGIONAL BLAST GC NET                                 |
| APR 1 | 850911511 | B   | LOCAL BLAST IN CV NET                                 |
| APR 1 | 850911511 | B   | REGIONAL BLAST GC NET                                 |
| APR 1 | 850911511 | B   | REGIONAL BLAST GC NET                                 |
| APR 1 | 850911511 | B   | LOCAL BLAST CV NET                                    |
| APR 1 | 850911511 | B   | REG. BLAST GC NET                                     |
| APR 1 | 850911511 | B   | REG. BLAST CV NET                                     |
| APR 1 | 850911511 | B   | LOCAL BLAST CV NET                                    |
| APR 1 | 850911511 | B   | LOCAL BLAST IN CV NET                                 |
| APR 1 | 850911511 | B   | LOCAL BLAST IN CV NET                                 |
| APR 1 | 850911511 | B   | LOCAL BLAST IN CV NET: CVILLE QUARRY                  |
| APR 1 | 850911511 | B   | LOCAL BLAST CV NET                                    |
| APR 1 | 850911511 | B   | REGIONAL BLAST CV NET                                 |
| APR 1 | 850911511 | B   | LOCAL BLAST CV NET                                    |
| APR 1 | 850911511 | B   | CV BLAST WITH DISPERSION                              |
| APR 1 | 850911511 | B   | GC BLAST REGIONAL                                     |
| APR 1 | 850911511 | B   | CV NOISE(?) FORTUITOUS TRIGGER                        |
| APR 1 | 850911511 | B   | REG. BLAST W/ DISPERSION                              |
| APR 1 | 850911511 | B   | GC REG. BLAST W/ DISPERSION                           |
| APR 1 | 850911511 | B   | REG. BLAST                                            |
| APR 1 | 850911511 | B   | GC REG. BLAST                                         |
| APR 1 | 850911511 | B   | REG. BLAST W/ DISPERSION                              |
| APR 1 | 850911511 | B   | CV NET, LOCAL BLAST (HI TEST?)                        |
| APR 1 | 850911511 | B   | GC REGIONAL BLAST                                     |
| APR 1 | 850911511 | B   | GC REGIONAL BLAST W/DISPERSION                        |
| APR 1 | 850911511 | B   | CV LOCAL BLAST                                        |
| APR 1 | 850911511 | B   | GC REGIONAL EVENT-LATE FOR BLAST                      |
| APR 1 | 850911511 | B   | CV LOCAL BLAST                                        |
| APR 1 | 850911511 | B   | CV REGIONAL BLAST BERKLEY SPRINGS                     |
| APR 1 | 850911511 | B   | CV LOCAL BLAST                                        |
| APR 1 | 850911511 | B   | CV LOCAL BLAST (HI-TEST?)                             |
| APR 1 | 850911511 | B   | CV LOCAL BLAST (HI TEST?)                             |
| APR 1 | 850911511 | B   | CV PROBABLE LOCAL BLAST                               |
| APR 1 | 850911511 | B   | CV LOCAL BLAST (K) SHOWING AIR WAVE AT NA             |
| APR 1 | 850911511 | B   | GC REG. BLAST SHOWING WEAK PN                         |
| APR 1 | 850911511 | B   | GC REG. BLAST WITH GOOD SURFACE WAVES                 |
| APR 1 | 850911511 | B   | GC REG. BLAST WITH GOOD SURFACE WAVES (SAME AS ABOVE) |
| APR 1 | 850911511 | B   | GC REG. BLAST WITH GOOD SURFACE WAVES (SAME AS ABOVE) |
| APR 1 | 850911511 | B   | GC REG. BLAST WITH GOOD SURFACE WAVES (SAME AS ABOVE) |
| APR 1 | 850911511 | B   | GC LOCAL SHOT NEAR PMV: GOOD ARRIVALS AT ALL STATIONS |
| APR 1 | 850911511 | B   | GC LOCAL BLAST                                        |
| APR 1 | 850911511 | B   | CV LOCAL BLAST                                        |
| APR 1 | 850911511 | B   | GC REGIONAL BLAST WITH LP S WAVE AND SOME DISPERSION  |
| APR 1 | 850911511 | B   | CV LOCAL BLAST-HITEST LABS                            |
| APR 1 | 850911511 | B   | CV LOCAL BLAST                                        |
| APR 1 | 850911511 | B   | HI TEST LOCAL SHOT                                    |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGION BLAST (S-P) APPROX. 40 SEC                     |
| APR 1 | 850911511 | B   | MINE INDUCED EVENT, NEAR GRUNDY, VA                   |
| APR 1 | 850911511 | B   | LOCAL BLAST? GC NET                                   |
| APR 1 | 850911511 | B   | REGIONAL BLAST? (MAYBE A REGIONAL EQKE)               |
| APR 1 | 850911511 | B   | LATE MYSTERIOUS REGIONAL BLAST                        |
| APR 1 | 850911511 | B   | LOCAL SHOT IN CV                                      |
| APR 1 | 850911511 | B   | REGIONAL BLAST WITH CLEAN SURFACE WAVES               |
| APR 1 | 850911511 | B   | BLAST NEAR PUV                                        |
| APR 1 | 850911511 | B   | BLAST NEAR CVL                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | LOCAL BLAST (?)                                       |
| APR 1 | 850911511 | B   | LOCAL BLAST (?)                                       |
| APR 1 | 850911511 | B   | LOCAL BLAST                                           |
| APR 1 | 850911511 | B   | LOCAL BLAST                                           |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | BLAST IN GC CAUGHT SOMETHING ELSE IN CV               |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | LOCAL BLAST                                           |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | LOCAL BLAST                                           |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | SMALL LOCAL BLAST                                     |
| APR 1 | 850911511 | B   | REGIONAL BLAST (?)                                    |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | REGIONAL BLAST ON BOTH SUBNETS                        |
| APR 1 | 850911511 | B   | LOCAL BLAST                                           |
| APR 1 | 850911511 | B   | VERDON BLAST                                          |
| APR 1 | 850911511 | B   | VERDON BLAST                                          |
| APR 1 | 850911511 | B   | REGIONAL BLAST                                        |
| APR 1 | 850911511 | B   | HI-TEST BLAST                                         |
| APR 1 | 850911511 | B   | REGIONAL BLAST OF LONG DURATION                       |
| APR 1 | 850911511 | B   | SMALL LOCAL BLAST NEAR NORTH ANNA                     |
| APR 1 | 850911511 | B   | SMALL GILES CO BLAST                                  |
| APR 1 | 850911511 | B   | BIG BLAST NEAR GILES CO NET                           |



|     |    |      |        |        |   |
|-----|----|------|--------|--------|---|
| FEB | 25 | 1986 | 860556 | 1816   | B |
 
| MAR | 1  | 1986 | 860606 | 1588   | B |
| MAR | 1  | 1986 | 860606 | 1589   | B |
| MAR | 1  | 1986 | 860606 | 1590   | B |
| MAR | 1  | 1986 | 860606 | 1591   | B |
| MAR | 1  | 1986 | 860606 | 1592   | B |
| MAR | 1  | 1986 | 860606 | 1593   | B |
| MAR | 1  | 1986 | 860606 | 1594   | B |
| MAR | 1  | 1986 | 860606 | 1595   | B |
| MAR | 1  | 1986 | 860606 | 1596   | B |
| MAR | 1  | 1986 | 860606 | 1597   | B |
| MAR | 1  | 1986 | 860606 | 1598   | B |
| MAR | 1  | 1986 | 860606 | 1599   | B |
| MAR | 1  | 1986 | 860606 | 1600   | B |
| MAR | 1  | 1986 | 860606 | 1601   | B |
| MAR | 1  | 1986 | 860606 | 1602   | B |
| MAR | 1  | 1986 | 860606 | 1603   | B |
| MAR | 1  | 1986 | 860606 | 1604   | B |
| MAR | 1  | 1986 | 860606 | 1605   | B |
| MAR | 1  | 1986 | 860606 | 1606   | B |
| MAR | 1  | 1986 | 860606 | 1607   | B |
| MAR | 1  | 1986 | 860606 | 1608   | B |
| MAR | 1  | 1986 | 860606 | 1609   | B |
| MAR | 1  | 1986 | 860606 | 1610   | B |
| MAR | 1  | 1986 | 860606 | 1611   | B |
| MAR | 1  | 1986 | 860606 | 1612   | B |
| MAR | 1  | 1986 | 860606 | 1613   | B |
| MAR | 1  | 1986 | 860606 | 1614   | B |
| MAR | 1  | 1986 | 860606 | 1615   | B |
| MAR | 1  | 1986 | 860606 | 1616   | B |
| MAR | 1  | 1986 | 860606 | 1617   | B |
| MAR | 1  | 1986 | 860606 | 1618   | B |
| MAR | 1  | 1986 | 860606 | 1619</ |   |

LOCAL BLAST  
 LOCAL BLAST  
 LARGE REGIONAL BLAST  
 BLAST NEAR CVL  
 REGIONAL BLAST - W. KENTUCKY 37.2N 83.3W  
 REGIONAL BLAST SAME AS 860661548  
 SMALL PROBABLE BLAST  
 BLAST NEAR CVL  
 PROBABLE REGIONAL BLAST  
 LOCAL BLAST  
 HI-TEST LABS  
 HI-TEST BLAST  
 HI-TEST BLAST  
 LOCAL BLAST  
 HI-TEST BLAST  
 LOCAL BLAST  
 HI-TEST BLAST  
 CENT VA LOCAL BLAST  
 CENT VA LOCAL BLAST  
 HI-TEST BLAST  
 LOCAL BLAST  
 HI-TEST BLAST  
 LOCAL BLAST  
 LOCAL BLAST  
 LOCAL BLAST  
 HI-TEST BLAST  
 LOCAL BLAST  
 LOCAL BLAST  
 LOCAL BLAST  
 REGIONAL BLAST WITH LOW FREQUENCY  
 LOCAL BLAST  
 LOCAL BLAST  
 HI-TEST BLAST  
 REGIONAL BLAST  
 HI-TEST BLAST  
 NUCLEAR TEST- NEVADA  
 HI-TEST BLAST  
 LOCAL BLAST  
 HI-TEST BLAST  
 LOCAL BLAST  
 REGIONAL BLAST ??  
 LOCAL BLAST  
 HI-TEST BLAST  
 WEIRD BLAST PHASE  
 WEIRD BLAST PHASE  
 REGIONAL BLAST  
 LOCAL BLAST NEAR NET 2  
 HI-TEST BLAST  
 HI-TEST BLAST  
 HI-TEST BLAST  
 HI-TEST BLAST  
 MANAKIN BLAST - BOSCOBEL  
 HI-TEST BLAST  
 REG BLST - CAUGHT SMALL BLAST NEAR BAY  
 LOCAL BLAST  
 LOCAL BLAST  
 LOCAL BLAST  
 LOCAL BLAST  
 HI-TEST BLAST  
 HI-TEST BLAST  
 REGIONAL BLAST  
 HI-TEST BLAST  
 HI-TEST BLAST (PLUS NOISE ON NET 1)  
 HI-TEST BLAST  
 REGIONAL BLAST  
 LOCAL BLAST  
 REGIONAL(?) BLAST  
 REGIONAL BLAST  
 LOCAL BLAST  
 SMALL LOCAL BLAST(?) NEAR GHV  
 LOCAL BLAST (2A)  
 LOCAL BLAST (HI-TEST LABS)  
 LOCAL BLAST (HI-TEST LABS)  
 LOCAL BLAST (2B)  
 LOCAL BLAST  
 LOCAL BLAST AT CVL (SHADWELL)  
 LOCAL BLAST  
 LARGE REGIONAL BLAST  
 LARGE REGIONAL BLAST  
 LARGE REGIONAL BLAST  
 LOCAL BLAST AT CVL (SHADWELL)  
 LARGE REGIONAL BLAST  
 BLAST NEAR NAS (2B)  
 REGIONAL BLAST(?)  
 REGIONAL BLAST  
 REGIONAL BLAST  
 HI-TEST BLAST  
 LOCAL BLAST NEAR NA5 (2E)  
 LOCAL BLAST NEAR CVL (2D)  
 LOCAL BLAST NEAR NA12 (2F)  
 LOCAL BLAST NEAR NA5 (2E)  
 LOCAL BLAST NEAR NA5 (2B)  
 LOCAL BLAST NEAR DUBLIN (1A)  
 LOCAL BLAST NEAR NA5 (2G)  
 LOCAL BLAST NEAREST FRV (2H)  
 LOCAL BLAST NEAR GHV (2I)  
 LOCAL BLAST NEAR NA5 (2E)  
 LOCAL BLAST NEAR CVL (SHADWELL)  
 LARGE REGIONAL BLAST  
 LOCAL BLAST NEAR NA5 (2E)  
 LOCAL BLAST NEAR NA5 (2B)  
 REGIONAL BLAST(?) - POOR RECORDING  
 BLAST NEAR PMV (1B)  
 LOCAL BLAST (HI-TEST LABS)  
 LOCAL BLAST NEAR GHV (2A)  
 LOCAL BLAST (HI-TEST LABS)  
 LOCAL BLAST (HI-TEST LABS)  
 LOCAL BLAST NEAR PUV (1C)  
 LOCAL BLAST (HI-TEST LABS)  
 LOCAL BLAST NEAR NA5 (2E)  
 REGIONAL BLAST  
 LOCAL BLAST NEAREST GHV (2A)  
 LOCAL BLAST NEAREST CVL (SHADWELL)  
 BLAST NEAREST GHV (HI-TEST LABS)  
 BLAST NEAREST CVL (SHADWELL)  
 BLAST NEAREST GHV (HI-TEST LABS)  
 REGIONAL BLAST NEAREST BATH COUNTY  
 LOCAL BLAST NEAREST FRV OR PBV (2J)  
 LOCAL BLAST NEAREST NA5 (2E)





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REGIONAL BLAST
REGIONAL BLAST
LOCAL BLAST NEAR NA5 (2B)
LOCAL BLAST NEAR NA12 (2F)
LOCAL BLAST NEAR NA5 (VERDON?)
LOCAL BLAST NEAR CVL
LOCAL BLAST NEAR PBV
LOCAL BLAST NEAR CVL (SHADWELL)
LOCAL BLAST NEAR PHV (1B)
LOCAL BLAST NEAR PHV (1B)
LOCAL BLAST NEAR PHV
REGIONAL BLAST
LOCAL BLAST NEAR GHV (BIG HI-TEST)
LOCAL BLAST NEAR NA5 (2E)
REGIONAL BLAST
LOCAL BLAST NEAR NA5 (2E)
LOCAL BLAST NEAR NA5 (2E)
PROBABLE BLAST
REGIONAL BLAST
REGIONAL BLAST - SHOWS WELL ON BV'S
REGIONAL BLAST
LOCAL BLAST NEAR NA5 (2E)(TIME = 2118)
LOCAL BLAST NEAR NA12 (2F)(TIME = 2153)
LOCAL BLAST NEAR NA5 (2E)(TIME = 2205)
LOCAL BLAST NEAR NA5 (2E)
REGIONAL BLAST
LOCAL BLAST
LOCAL BLAST
POSSIBLE LOCAL BLAST
LOCAL BLAST NEAR NA5 (2E)
LOCAL BLAST NEAR NA12 (2F)
LOCAL BLAST NEAR CVL
LOCAL BLAST
MINE BUMP, EXTREME SW VIRGINIA OR SO. WVA
LOCAL BLAST NEAR NA5 (2E)
LOCAL BLAST NEAR GHV (HI-TEST LABS)BIG!
REGIONAL BLAST
LOCAL BLAST NEAR PBV (20)
LOCAL BLAST NEAR PBV (20)
LOCAL BLAST
LOCAL BLAST
POSSIBLE BLAST - BUCHANAN
REGIONAL BLAST
SAME SIGNAL AS 870410538
LOCAL BLAST NEAR GHV (HI-TEST LABS)
REGIONAL BLAST
REGIONAL BLAST
REGIONAL BLAST
SAME SIGNAL AS 870410538
SAME SIGNAL AS 870410538
REGIONAL BLAST
REGIONAL BLAST
LOCAL BLAST NEAR NA5 (2E)
REGIONAL BLAST
REGIONAL BLAST LIKE 870410538
REGIONAL BLAST
LOCAL BLAST NEAR NA5 (2E)
REGIONAL BLAST
LOCAL BLAST NEAR FRV (2H)
REGIONAL BLAST S OR SE OF CV STATIONS
REGIONAL BLAST
LOCAL BLAST NEAR HWV (1D)
REGIONAL BLAST
LOCAL BLAST - MANAKIN(?)
LOCAL BLAST NEAR FRV (2J?)
LOCAL BLAST NEAR NA5 (2E)
REGIONAL BLAST (?)
LOCAL BLAST NEAR GHV (2A)
LOCAL BLAST NEAR CVL (2D)
LOCAL BLAST (?)
LOCAL BLAST NEAR GHV (HI-TEST)
PROBABLE NOISE
LOCAL BLAST NEAR NA5 (2E)
LOCAL BLAST NEAR NA5 (2E)
REGIONAL BLAST
LOCAL BLAST
NOISE NEAR GHV - LOOKS LIKE BLAST
LOCAL BLAST NEAR PBV (20)
LOCAL BLAST NEAR PHV (1E)
REGIONAL BLAST
LOCAL BLAST NEAR GHV (HI-TEST LABS)
LOCAL BLAST NEAR CVL (SHADWELL)
LOCAL BLAST NEAR CVL (SHADWELL)
LOCAL BLAST NEAR PBV (20)
LOCAL BLAST NEAR NA5 (2E)
LOCAL BLAST NEAR NA5 (2E)
LOCAL BLAST NEAR GHV (HI-TEST LABS)
REGIONAL BLAST
LOCAL BLAST NEAR NA5 (2G)
LOCAL BLAST NEAR NA2 (2L)
REGIONAL BLAST
REGIONAL BLAST
REGIONAL BLAST
LOCAL BLAST NEAR NA5 (2E)
REGIONAL EVENT
LOCAL BLAST NEAR FRV (2H)
LOCAL BLAST NEAR GHV (2A)
LOCAL BLAST NEAR GHV (HI-TEST LABS)
LOCAL BLAST NEAR NA5 (2E)
LOCAL BLAST
REGIONAL BLAST
REGIONAL BLAST
LOCAL BLAST
LOCAL BLAST
REGIONAL BLAST
LOCAL BLAST
LOCAL BLAST NEAR GHV (HI-TEST LABS)
LOCAL BLAST NEAR GHV (HI-TEST LABS)
LOCAL BLAST NEAR GHV (HI-TEST LABS)
LOCAL BLAST NEAR GHV (HI-TEST LABS)
LOCAL BLAST NEAR CVL
LOCAL BLAST
LOCAL BLAST NEAR GHV (HI-TEST LABS)
LOCAL BLAST
LOCAL BLAST NEAR GHV (HI-TEST LABS)
REGIONAL BLAST

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LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST NEAR PHV  
REGIONAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
REGIONAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LARGE LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
LOCAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
REGIONAL BLAST ON NET 1; LOCAL BLAST ON NET 2  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
REGIONAL BLAST(?)  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST OR POSSIBLE EQ  
REGIONAL BLAST OR POSSIBLE EQ S PHASE  
ANOTHER HI TEST  
GOOD SHOT NEAR PBV  
GOOD 20 SEC S-P EVENT IN CVA  
ANOTHER GOOD 20 SEC S-P SHOT IN CVA  
BIG SHOT NEAR PBV  
LOCAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
REGIONAL BLAST ON NET 1; HI-TEST LABS ON NET 2  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST  
LOCAL BLAST NEAR CVL  
LOCAL BLAST  
REGIONAL BLAST  
LOCAL BLAST NEAR CVL  
LOCAL SIGNAL  
QUARRY SHOT AT NEWBORN NEAR CLAYTOR LAKE  
LIKELY SHOT AT FLINT HILL QUARRY (PRETTY GOOD SIGNAL)  
SHOT AT CHARLOTTESVILLE STONE CO. QUARRY (GOOD SIGNAL)  
SHOT FROM RADFORD STONE CORP #2 QUARRY  
SHOT AT LESEAU OR SOLITE OR ARVONIA-BUCKINGHAM  
REGIONAL BLAST FROM THE WEST  
ACTUALLY RECORDED A ROCKVILLE,VULCAN OR TIDEWATER SHOT  
REGIONAL BLAST  
LOCAL BLAST  
ALABAMA (ETC SAYS BLAST, MC THINKS EQ)  
PROBABLE BLAST IN HARLAN CO. KY: BUT CLOSE TO LEE CO., VA.  
BLAST NEAR PHV  
REGIONAL BLAST IN NET 2  
LARGE REGIONAL BLAST  
POSSIBLE EQ, PROBABLE LONGHALL COLLAPSE IN BUCH. CO.  
PROB. ROOF COLLAPSE WEST OF GILES CO.  
LOCAL BLAST NEAR NA5  
LOCAL BLAST NEAR CVL  
REGIONAL BLAST  
PROB. ROOF COLLAPSE WEST OF GILES CO. (IDENTICAL TO 87359)  
PROBABLE BLAST  
ANOTHER ROOF FALL WEST OF GC (IDENTICAL TO 87359)  
REGIONAL BLAST  
LOCAL BLAST NEAR CVL  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST (REAL TIME 880212109)  
REGIONAL BLAST  
REGIONAL BLAST  
NOISE ON NET 2; BLAST NEAR BLA IN NET 1  
BLAST NEAR GHV (HI-TEST LABS)  
BLAST NEAR GHV (HI-TEST LABS)  
BLAST NEAR GHV (HI-TEST LABS)  
REGIONAL BLAST  
LOCAL BLAST  
LOCAL BLAST NEAR GHV (HI-TEST LABS)  
BLAST AT A.H. SMITH STONE CO. (NEAR NA12)

| DATE        | TIME      | LOCATION                                                  | DESCRIPTION |
|-------------|-----------|-----------------------------------------------------------|-------------|
| FEB 8 1988  | 080391526 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 8 1988  | 080391703 | REGIONAL BLAST ON NET 2, LOCAL BLAST NEAR BLA ON NET 1    |             |
| FEB 8 1988  | 080391809 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 10 1988 | 080411608 | REGIONAL BLAST                                            |             |
| FEB 16 1988 | 080472035 | LOCAL BLAST                                               |             |
| FEB 17 1988 | 080481617 | REGIONAL BLST ON NET 1, LOCAL BLST ON NET 2               |             |
| FEB 17 1988 | 080482039 | REGIONAL BLAST                                            |             |
| FEB 18 1988 | 080492158 | LOCAL BLAST                                               |             |
| FEB 19 1988 | 080501632 | LOCAL BLAST                                               |             |
| FEB 19 1988 | 080501947 | REGIONAL BLAST                                            |             |
| FEB 19 1988 | 080502038 | REGIONAL BLAST                                            |             |
| FEB 22 1988 | 080531650 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 22 1988 | 080531837 | LOCAL BLAST NEAR CVL                                      |             |
| FEB 22 1988 | 080531859 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 22 1988 | 080532104 | REGIONAL BLAST                                            |             |
| FEB 24 1988 | 080552027 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 24 1988 | 080601548 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 24 1988 | 080601641 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 24 1988 | 080601817 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| FEB 24 1988 | 080601911 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAR 1 1988  | 080612033 | REGIONAL BLAST                                            |             |
| MAR 1 1988  | 080621615 | LOCAL BLAST NEAR CVL                                      |             |
| MAR 1 1988  | 080621658 | REGIONAL BLAST                                            |             |
| MAR 1 1988  | 080621924 | REGIONAL BLAST                                            |             |
| MAR 1 1988  | 080622007 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAR 1 1988  | 080622044 | REGIONAL BLAST                                            |             |
| MAR 1 1988  | 080641422 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAR 1 1988  | 080641505 | VERDON BLAST                                              |             |
| MAR 1 1988  | 080642018 | LOCAL BLAST                                               |             |
| MAR 1 1988  | 080651955 | REGIONAL BLAST                                            |             |
| MAR 1 1988  | 080691838 | LOCAL BLAST NEAREST GHV                                   |             |
| MAR 1 1988  | 080741830 | MANAKIN BLAST                                             |             |
| MAR 1 1988  | 080751354 | PROBABLE BLAST IN WEST VIRGINIA                           |             |
| MAR 1 1988  | 080751546 | NOTHING ON NET 2, BUT CAUGHT BLAST NEAR BLA               |             |
| MAR 1 1988  | 080751912 | LOCAL BLAST                                               |             |
| MAR 1 1988  | 080761428 | LOCAL BLAST                                               |             |
| MAR 1 1988  | 080771829 | LOCAL BLAST NEAR CVL                                      |             |
| MAR 1 1988  | 080791630 | REGIONAL BLAST - BUT IN DIRECTION OF OHIO                 |             |
| MAR 1 1988  | 080821821 | LOCAL BLAST                                               |             |
| MAR 1 1988  | 080822115 | LOCAL BLAST                                               |             |
| MAR 1 1988  | 080831834 | REGIONAL BLAST                                            |             |
| MAR 1 1988  | 080841601 | LOCAL BLAST                                               |             |
| MAR 1 1988  | 080842116 | LOCAL BLAST                                               |             |
| MAR 1 1988  | 080881725 | LOCAL BLAST NEAR CVL                                      |             |
| MAR 1 1988  | 080912047 | REGIONAL BLAST ON NET 1 - CAUGHT A BLAST NEAR CVL         |             |
| APR 1 1988  | 080971720 | LOCAL BLAST                                               |             |
| APR 1 1988  | 080982200 | LOCAL BLAST: A.H. SMITH STONE CO. NEAR NORTH ANNA (K)     |             |
| APR 1 1988  | 080991616 | LOCAL BLAST                                               |             |
| APR 1 1988  | 081031500 | NOTHING ON NET 2 - CAUGHT A BLAST NEAR BLA                |             |
| APR 1 1988  | 081112109 | CLEAR SIGNAL FROM WEST: POSSIBLY FROM BUCHANAN CO.        |             |
| APR 1 1988  | 081131911 | GOOD REGIONAL BLAST RECORDED BY GC NET                    |             |
| APR 1 1988  | 081170157 | ANOTHER LIKELY EVENT FROM BUCHANAN CO.                    |             |
| APR 1 1988  | 081191532 | BLAST ON NET 1 - TRIGGERED ON NET 2                       |             |
| APR 1 1988  | 081202332 | REGIONAL SIGNAL, TRIGGERED NET 2                          |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST - PLUS LOCAL BLAST NEAR PWV                |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR BLA                                      |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST - BOTH NETS                                   |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | POSSIBLE MISS SHOT                                        |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST NEAR GHV                                   |             |
| MAY 1 1988  | 081261947 | PROBABLE ROOF FALL NEAR GRUNDY, BUCHANAN CO, VA           |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR PBV                                      |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | BLAST NEAR PETERSBURG                                     |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR PUV                                      |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR GHV                                      |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR PETERSBURG                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST (MANAKIN?)                                    |             |
| MAY 1 1988  | 081261947 | BLAST NEAREST BLA                                         |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR GHV (HI-TEST LABS?)                      |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST NEAR GHV (HI-TEST LABS)                       |             |
| MAY 1 1988  | 081261947 | PROBABLE BLAST; PBV CLOSEST STATION                       |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST                                            |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | POSSIBLE EARTHQUAKE                                       |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST                                               |             |
| MAY 1 1988  | 081261947 | SHOT AT SOLITE CORP                                       |             |
| MAY 1 1988  | 081261947 | SHOT AT SMITH STONE CO. (NEAR NA NETWORK)                 |             |
| MAY 1 1988  | 081261947 | BLAST NEAR BLA                                            |             |
| MAY 1 1988  | 081261947 | USSR NUCLEAR TEST                                         |             |
| MAY 1 1988  | 081261947 | REGIONAL BLAST S - P = 16 SEC AT GHV                      |             |
| MAY 1 1988  | 081261947 | BLAST AT LONE STAR, JACK QUARRY NEAR PBV                  |             |
| MAY 1 1988  | 081261947 | BLAST NEAR PWV (PROBABLY PENDELTON CONST. CO, WOLF CREEK) |             |
| MAY 1 1988  | 081261947 | NEAR CVL (MARTIN, MARIETTA CO RED HILL QUARRY)            |             |
| MAY 1 1988  | 081261947 | HI-TEST LABS BLAST                                        |             |
| MAY 1 1988  | 081261947 | CV SMALL BLAST                                            |             |
| MAY 1 1988  | 081261947 | CV SMALL BLAST                                            |             |
| MAY 1 1988  | 081261947 | HI TEST                                                   |             |
| MAY 1 1988  | 081261947 | CENT VA BLAST                                             |             |
| MAY 1 1988  | 081261947 | GCO PROBABLE PWV BLAST (LARGE)                            |             |
| MAY 1 1988  | 081261947 | SMALL REGIONAL BLAST ?                                    |             |
| MAY 1 1988  | 081261947 | LOCAL BLAST, MANAKIN ?                                    |             |
| MAY 1 1988  | 081261947 | LATE NIGHT REGIONAL EVENT                                 |             |

|     |    |      |        |      |   |
|-----|----|------|--------|------|---|
| OCT | 17 | 1988 | 882911 | 904  | B |
| OCT | 21 | 1988 | 882911 | 721  | B |
| OCT | 22 | 1988 | 882960 | 531  | B |
| OCT | 30 | 1988 | 883004 | 181  | B |
| NOV | 10 | 1988 | 883004 | 1254 | B |
| NOV | 10 | 1988 | 883015 | 2101 | B |
| NOV | 11 | 1988 | 883017 | 1904 | B |
| NOV | 15 | 1988 | 883020 | 712  | B |
| NOV | 15 | 1988 | 883020 | 724  | B |
| NOV | 15 | 1988 | 883020 | 2206 | B |
| DEC | 28 | 1988 | 883036 | 1726 | B |
| DEC | 31 | 1988 | 883066 | 2113 | B |
| JAN | 1  | 1989 | 900517 | 1733 | B |
| JAN | 1  | 1989 | 901609 | 939  | B |
| JAN | 16 | 1989 | 901722 | 221  | B |
| FEB | 24 | 1989 | 902421 | 135  | B |
| FEB | 25 | 1989 | 904614 | 17   | B |
| FEB | 25 | 1989 | 905231 | 1753 | B |
| MAR | 1  | 1989 | 905619 | 11   | B |
| MAR | 1  | 1989 | 906641 | 1216 | B |
| MAY | 31 | 1989 | 906919 | 940  | B |
| JUN | 7  | 1989 | 915115 | 1803 | B |
| JUN | 7  | 1989 | 915819 | 907  | B |
| JUN | 7  | 1989 | 915821 | 243  | B |
| JUN | 13 | 1989 | 915923 | 303  | B |
| JUN | 14 | 1989 | 916415 | 1500 | B |
| JUN | 19 | 1989 | 916518 | 20   | B |
| JUN | 20 | 1989 | 917015 | 1536 | B |
| JUN | 20 | 1989 | 917115 | 11   | B |
| JUN | 22 | 1989 | 917117 | 1715 | B |
| JUN | 22 | 1989 | 917119 | 14   | B |
| JUN | 23 | 1989 | 917318 | 59   | B |
| JUN | 24 | 1989 | 917415 | 1545 | B |
| JUN | 29 | 1989 | 917516 | 262  | B |
| JUL | 4  | 1989 | 918016 | 1606 | B |
| JUL | 4  | 1989 | 918502 | 252  | B |
| JUL | 10 | 1989 | 918914 | 133  | B |
| JUL | 12 | 1989 | 919115 | 1517 | B |
| JUL | 12 | 1989 | 919319 | 303  | B |
| JUL | 19 | 1989 | 920017 | 749  | B |
| JUL | 22 | 1989 | 920318 | 1853 | B |
| JUL | 25 | 1989 | 920607 | 172  | B |
| AUG | 5  | 1989 | 921717 | 753  | B |
| AUG | 8  | 1989 | 922022 | 19   | B |
| AUG | 8  | 1989 | 922123 | 41   | B |
| AUG | 20 | 1989 | 923204 | 23   | B |
| SEP | 28 | 1989 | 924012 | 1207 | B |
| SEP | 1  | 1989 | 924618 | 1812 | B |
| SEP | 1  | 1989 | 925522 | 224  | B |
| SEP | 2  | 1989 | 926119 | 1928 | B |
| SEP | 2  | 1989 | 926313 | 339  | B |
| SEP | 2  | 1989 | 926314 | 409  | B |
| SEP | 26 | 1989 | 926920 | 2024 | B |
| SEP | 30 | 1989 | 927300 | 335  | B |
| SEP | 10 | 1989 | 927308 | 01   | B |
| OCT | 10 | 1989 | 927319 | 101  | B |
| OCT | 13 | 1989 | 927831 | 1941 | B |
| OCT | 14 | 1989 | 928266 | 2040 | B |
| OCT | 16 | 1989 | 928714 | 1423 | B |
| OCT | 16 | 1989 | 928913 | 323  | B |
| OCT | 17 | 1989 | 928917 | 1725 | B |
| OCT | 17 | 1989 | 929017 | 1723 | B |
| OCT | 20 | 1989 | 929220 | 2005 | B |
| OCT | 20 | 1989 | 929314 | 151  | B |
| OCT | 20 | 1989 | 929318 | 19   | B |
| OCT | 20 | 1989 | 929605 | 03   | B |
| OCT | 20 | 1989 | 929619 | 1955 | B |
| OCT | 20 | 1989 | 929812 | 105  | B |
| OCT | 20 | 1989 | 929819 | 1949 | B |
| OCT | 20 | 1989 | 929912 | 1204 | B |
| OCT | 20 | 1989 | 930016 | 1659 | B |
| NOV | 2  | 1989 | 930515 | 1506 | B |
| NOV | 2  | 1989 | 930629 | 1958 | B |
| NOV | 2  | 1989 | 930629 | 958  | B |
| NOV | 2  | 1989 | 930720 | 107  | B |
| NOV | 9  | 1989 | 931217 | 1725 | B |
| NOV | 11 | 1989 | 931219 | 1901 | B |
| NOV | 11 | 1989 | 932201 | 149  | B |
| NOV | 13 | 1989 | 932617 | 1717 | B |
| NOV | 22 | 1989 | 932627 | 1448 | B |
| NOV | 24 | 1989 | 932829 | 2042 | B |
| NOV | 26 | 1989 |        |      |   |

REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL SIGNAL (BLAST OR EQ)  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST (BERKELY SPRINGS?)  
LOCAL BLAST  
LOCAL BLAST  
SHOT AT HI TEST, SOLITE OR LASAUER  
REGIONAL SIGNAL (LARGE BLAST?)  
LITTLE SHOT AT GENERAL CRUSHED STONE (NEAR NA2)  
SIGNAL IN SWVA: UNLOCATABLE  
SIGNAL IN NICHOLS COUNTY, MVA: LIKELY BLAST  
REGIONAL BLAST  
LIKELY BLAST SE OF NA NET  
BIG SHOT NEAR CVL  
CLEAN REGIONAL BLAST  
SOMETHING IN BUCHANAN CO  
TRIGGER DURING TIME OF MONITORING AT CRAIG CREEK  
SMALL PROB. BLAST NEAR CVL; NOTE: GCO TRIGGERED  
REGIONAL SHOT, GC NET  
REGIONAL SHOT, GC NET  
REGIONAL SHOT, GC NET  
SMALL SHOT NEAR NA (QUARRY TO NW OF NETWORK)  
HI TEST LABS; UNUSUAL BIG AND DEEP SHOT  
HI-TEST SPECIAL SHOT; GHV DOWN; PBV P\*?  
SMALL BLAST NEAR CVL; RED HILL?  
HI-TEST; REGULAR SHOT?; CVL, GHV, NA12 WORKED ON THIS WEEK  
LARGE REGIONAL BLAST  
LOCAL BLAST NEAR HWV AND VMV  
CV, SMALL PROB BLAST  
PHV; PROB. BLAST  
BLA BLAST  
MINE RELATED, PROBABLY  
REGIONAL BLAST, GOOD RG  
CV BLAST; MANAKIN?; SC STATIONS RUNNING  
NEAR CVL  
REGIONAL BLAST  
GILES CO REGIONAL BLAST  
PROBABLE MINE BUMP  
FINE BLAST OR MINE INDUCED SIGNAL: NEAREST HWV  
REGIONAL BLAST (GOOD RG)  
REGIONAL BLAST (GOOD RG)  
MINE BUMP OR BLAST  
SMALL SIGNAL MARTIN WANTS SAVED  
REGIONAL BLAST  
REGIONAL BLAST  
MONO-FREQUENCY BLAST, CENT.VA  
REGIONAL BLAST  
CVL BLAST  
HI-TEST LABS BLAST  
REGIONAL EQ. OR BLAST  
REGIONAL EQ. OR BLAST  
MINE BUMP ?  
REGIONAL BLAST SAVED FOR GAB  
LARGE BLAST NEAR PBV; TRIG. NET GCO ???  
MINE RELATED?; RECORDED WELL OUT TO CVA  
HI-TEST LABS; GHV P LOOKS DIFFERENT; NO ACOUSTIC; DRY  
HI-TEST LABS; FOR COMPARISON; NO ACOUSTIC; DRY  
HI-TEST LABS; WITH ACOUSTIC; WET  
LARGE REGIONAL BLAST; REC. IN CVA  
PROB. BLAST NEAR GHV  
PROB. BLAST NEAR HI-TEST LABS  
LATE NIGHT BLAST? FROM WEST  
REGIONAL BLAST  
REGIONAL BLAST  
CVA BLAST  
REGIONAL BLAST: 2 GURALPS  
REGIONAL BLAST FROM WEST; WELL RECORDED IN CVA  
LARGE BLAST WEST OF GCO  
CVA MANAKIN BLAST?  
REG. E KY TYPE BLAST.  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST OR BUMP AT ARCH 37 MINE  
CVA BLAST  
REGIONAL BLAST  
REGIONAL BLAST (OHIO OR MVA)  
TWO LARGE REGIONAL BLASTS  
GCO REGIONAL BLAST  
HI TEST WITH AIR WAVE  
HI TEST WITH AIR WAVE  
HI TEST WITH AIR WAVE  
REGIONAL BLAST  
REGIONAL BLAST  
LOCAL BLAST, CENT. VA  
REGIONAL BLAST  
BLAST AT GENERAL CRUSHED STONE: AIR WAVE AT CNV (CORBIN)!  
LOCAL BLAST NE OF CVL  
REGIONAL BLAST WITHOUT CLEAR RG  
SIMILAR REG. BLAST TO ABOVE, BUT TREMENDOUS RG  
REGIONAL BLAST  
CV LOCAL BLAST  
REGIONAL BLAST (BIG RG)  
REGIONAL BLAST  
REGIONAL BLAST WITH RG  
ULTRA SMALL EVENT NEAR FRV (PROB. BLAST)  
GCO REG. BLAST WITH RG  
CVL LOCAL BLAST  
HWV BLAST (6 SEC) BIG RG  
REGIONAL BLAST  
REGIONAL BLAST OR BUMP TO WEST OF GC NET  
GCO LOCAL (?) BLAST, SAVED ON CLYDE  
GCO LARGE REGIONAL BLAST (SAVED ON CLYDE)  
REGIONAL BLAST  
REGIONAL BLAST  
GILES CO REGIONAL BLAST  
BLAST NEAR PBV  
GC REGIONAL BLAST  
GC REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST  
REGIONAL BLAST





|     |    |      |           |   |   |                                                        |
|-----|----|------|-----------|---|---|--------------------------------------------------------|
| JUN | 22 | 1990 | 901731956 | B | 1 | REGIONAL BLAST                                         |
| JUN | 22 | 1990 | 901761907 | B | 1 | REGIONAL BLAST                                         |
| JUN | 27 | 1990 | 901781336 | B | 1 | REGIONAL BLAST                                         |
| JUN | 28 | 1990 | 901791610 | B | 1 | REGIONAL BLAST                                         |
| JUN | 30 | 1990 | 901810243 | B | 1 | REGIONAL BLAST                                         |
| JUL | 4  | 1990 | 901851913 | B | 1 | REGIONAL BLAST                                         |
| JUL | 5  | 1990 | 901861903 | B | 1 | REGIONAL BLAST                                         |
| JUL | 9  | 1990 | 901901907 | B | 1 | REGIONAL BLAST                                         |
| JUL | 9  | 1990 | 901902000 | B | 1 | REGIONAL BLAST                                         |
| JUL | 9  | 1990 | 901902037 | B | 1 | REGIONAL BLAST                                         |
| JUL | 10 | 1990 | 901911717 | B | 0 | BLAST                                                  |
| JUL | 11 | 1990 | 901921917 | B | 1 | REGIONAL BLAST WITH LG.                                |
| JUL | 21 | 1990 | 902021253 | B | 1 | REGIONAL BLAST                                         |
| JUL | 26 | 1990 | 902071436 | B | 1 | BLAST WITH LARGE S                                     |
| JUL | 26 | 1990 | 902072136 | B | 1 | REGIONAL BLAST                                         |
| JUL | 27 | 1990 | 902081645 | B | 1 | REGIONAL BLAST                                         |
| JUL | 27 | 1990 | 902081932 | B | 1 | REGIONAL BLAST                                         |
| JUL | 28 | 1990 | 902091806 | B | 1 | REGIONAL BLAST                                         |
| JUL | 31 | 1990 | 902121440 | B | 1 | REGIONAL BLAST                                         |
| AUG | 1  | 1990 | 902132101 | B | 1 | REGIONAL BLAST                                         |
| AUG | 1  | 1990 | 902132106 | B | 1 | LOCAL BLAST                                            |
| AUG | 8  | 1990 | 902201937 | B | 1 | BLAST TO COMPARE WITH CLYDE                            |
| AUG | 10 | 1990 | 902221813 | B | 1 | REGIONAL BLAST                                         |
| AUG | 12 | 1990 | 902242156 | B | 1 | BLAST                                                  |
| AUG | 14 | 1990 | 902262225 | B | 1 | LARGE REGIONAL BLAST                                   |
| AUG | 16 | 1990 | 902281817 | B | 1 | REGIONAL BLAST                                         |
| AUG | 16 | 1990 | 902281957 | B | 1 | REGIONAL BLAST                                         |
| AUG | 17 | 1990 | 902290002 | B | 1 | BLAST                                                  |
| AUG | 20 | 1990 | 902321938 | B | 1 | BLAST?                                                 |
| AUG | 24 | 1990 | 902361959 | B | 1 | BLAST GCN                                              |
| AUG | 25 | 1990 | 902370105 | B | 1 | BLAST GCN                                              |
| AUG | 25 | 1990 | 902371943 | B | 1 | BLAST GCN                                              |
| AUG | 26 | 1990 | 902381745 | B | 1 | BLAST GCN                                              |
| AUG | 27 | 1990 | 902392054 | B | 1 | BIG BLAST NEAR PWV                                     |
| AUG | 27 | 1990 | 902392347 | B | 1 | BLAST GCN                                              |
| AUG | 28 | 1990 | 902401847 | B | 1 | BLAST GCN                                              |
| AUG | 28 | 1990 | 902401927 | B | 1 | BLAST GCN                                              |
| AUG | 28 | 1990 | 902402148 | B | 1 | BLAST GCN                                              |
| SEP | 1  | 1990 | 902441527 | B | 1 | LOCAL BLAST GCN                                        |
| SEP | 2  | 1990 | 902451827 | B | 1 | BLAST GCN                                              |
| SEP | 4  | 1990 | 902472031 | B | 1 | SMALL BLAST                                            |
| SEP | 6  | 1990 | 902491539 | B | 1 | LOCAL BLAST                                            |
| SEP | 6  | 1990 | 902491832 | B | 1 | LOCAL BLAST                                            |
| SEP | 8  | 1990 | 902501808 | B | 1 | BIG BLAST - MOLUCCA SEA/5.5 MB ??                      |
| SEP | 9  | 1990 | 902511700 | B | 1 | BIG BLAST                                              |
| SEP | 10 | 1990 | 902521914 | B | 1 | BIG SHOT IN SOUTHEAST OHIO (E.G., PERRY CO)            |
| SEP | 10 | 1990 | 902531939 | B | 1 | BLAST GCN                                              |
| SEP | 12 | 1990 | 902532002 | B | 1 | BLAST GCN                                              |
| SEP | 12 | 1990 | 902551927 | B | 1 | BLAST GCN                                              |
| SEP | 16 | 1990 | 902552036 | B | 1 | BLAST GCN                                              |
| SEP | 18 | 1990 | 902591721 | B | 1 | SMALL BLAST                                            |
| SEP | 19 | 1990 | 902612029 | B | 1 | BLAST NEAR HWV VMV                                     |
| SEP | 19 | 1990 | 902621809 | B | 1 | BLAST NEAR HWV VMV                                     |
| SEP | 21 | 1990 | 902622150 | B | 1 | BLAST                                                  |
| SEP | 22 | 1990 | 902642152 | B | 1 | LOCAL BLAST GCN                                        |
| SEP | 22 | 1990 | 902651559 | B | 1 | BLAST GCN                                              |
| SEP | 22 | 1990 | 902651759 | B | 1 | BLAST GCN                                              |
| SEP | 22 | 1990 | 902651957 | B | 1 | BLAST W/ATRY PHASES                                    |
| SEP | 24 | 1990 | 902671213 | B | 1 | SMALL BLAST GCN                                        |
| SEP | 24 | 1990 | 902671846 | B | 1 | SMALL BLAST NEAR PBV                                   |
| SEP | 26 | 1990 | 902672119 | B | 1 | BIG BLAST NEAR VMV                                     |
| SEP | 26 | 1990 | 902691524 | B | 1 | PROBABLE MINE ASSOCIATED EVENT: NEAR CHARLESTON, WVA   |
| SEP | 29 | 1990 | 902721543 | B | 1 | BLAST GCN                                              |
| OCT | 1  | 1990 | 902722239 | B | 1 | BLAST GCN                                              |
| OCT | 1  | 1990 | 902741611 | B | 1 | BLAST GCN                                              |
| OCT | 1  | 1990 | 902751935 | B | 1 | BLAST GCN                                              |
| OCT | 1  | 1990 | 902761613 | B | 1 | SMALL BLAST GCN                                        |
| OCT | 1  | 1990 | 902762231 | B | 1 | LARGE BLAST NEAR HWV-VMV                               |
| OCT | 1  | 1990 | 902812111 | B | 1 | SMALL BLAST GCN                                        |
| OCT | 1  | 1990 | 902831654 | B | 1 | BLAST NEAR PWV                                         |
| OCT | 1  | 1990 | 902852242 | B | 1 | BLAST GCN.                                             |
| OCT | 1  | 1990 | 902871830 | B | 1 | BLAST GCN.                                             |
| OCT | 1  | 1990 | 902932224 | B | 1 | MINE COLLAPSE NEAR PWV                                 |
| OCT | 1  | 1990 | 902951516 | B | 1 | BIG BLAST NEAR CVL                                     |
| OCT | 1  | 1990 | 902962108 | B | 1 | BLAST                                                  |
| NOV | 3  | 1990 | 903041644 | B | 1 | LOCAL BLAST AT CVL - CLEAR WAVELET                     |
| NOV | 7  | 1990 | 903070904 | B | 1 | BLAST                                                  |
| NOV | 9  | 1990 | 903091720 | B | 1 | BLAST                                                  |
| NOV | 9  | 1990 | 903092027 | B | 1 | BLAST                                                  |
| NOV | 10 | 1990 | 903101749 | B | 1 | BLAST                                                  |
| NOV | 12 | 1990 | 903121001 | B | 1 | REGIONAL QUAKE?                                        |
| NOV | 12 | 1990 | 903121008 | B | 1 | TWO CONSECUTIVE REGIONAL QUAKE FOLLOWING THE PREVIOUS? |
| NOV | 16 | 1990 | 903202002 | B | 1 | REGIONAL BLAST                                         |
| NOV | 17 | 1990 | 903212106 | B | 1 | REGIONAL BLAST                                         |
| NOV | 20 | 1990 | 903242002 | B | 1 | SMALL BLAST                                            |
| NOV | 27 | 1990 | 903312022 | B | 1 | REGIONAL BLAST                                         |
| DEC | 3  | 1990 | 903337214 | B | 1 | BLAST                                                  |
| DEC | 3  | 1990 | 903382046 | B | 1 | small blast                                            |
| DEC | 3  | 1990 | 903392211 | B | 1 | two consecutive blasts.                                |
| DEC | 7  | 1990 | 903411014 | B | 1 | blast                                                  |
| DEC | 7  | 1990 | 903411617 | B | 1 | blast hwv                                              |
| DEC | 10 | 1990 | 903441357 | B | 1 | REGIONAL BLAST                                         |
| DEC | 11 | 1990 | 903451925 | B | 1 | BLAST                                                  |
| DEC | 11 | 1990 | 903462009 | B | 1 | REGIONAL BLAST                                         |
| DEC | 15 | 1990 | 903491456 | B | 1 | BLAST                                                  |
| DEC | 26 | 1990 | 903602108 | B | 1 | REGIONAL BLAST                                         |
| JAN | 1  | 1991 | 910042018 | B | 1 | LARGE REGIONAL BLAST                                   |
| JAN | 1  | 1991 | 910051420 | B | 1 | 9:20AM SAT MORNING; REG BLAST/ROOF FALL?               |
| JAN | 1  | 1991 | 910092017 | B | 1 | BLAST GCN                                              |
| JAN | 1  | 1991 | 910141818 | B | 1 | SMALL BLAST CVL                                        |
| JAN | 1  | 1991 | 910150849 | B | 1 | DREGS. OF POSSIBLE REG. EQ.                            |
| JAN | 1  | 1991 | 910171917 | B | 1 | BLAST NEAR NA12                                        |
| JAN | 1  | 1991 | 910171919 | B | 1 | BLAST GCN                                              |
| JAN | 1  | 1991 | 910172245 | B | 1 | SMALL BLAST GCN                                        |
| JAN | 1  | 1991 | 910181710 | B | 1 | BLAST                                                  |
| JAN | 1  | 1991 | 910181807 | B | 1 | BLAST NEAR NA12                                        |
| JAN | 1  | 1991 | 910361856 | B | 1 | BLAST NEAR CVL                                         |
| JAN | 1  | 1991 | 910362033 | B | 1 | SMALL BLAST                                            |
| JAN | 1  | 1991 | 910362175 | B | 1 | MINE BUMP?                                             |
| JAN | 1  | 1991 | 910362184 | B | 1 | LOCAL BLAST-CVL                                        |
| JAN | 1  | 1991 | 910362182 | B | 1 | LOCAL BLAST NA12                                       |
| JAN | 1  | 1991 | 910362182 | B | 1 | MINE BLAST                                             |
| JAN | 1  | 1991 | 910362182 | B | 1 | REGIONAL BLAST                                         |
| JAN | 1  | 1991 | 910362182 | B | 1 | BLAST                                                  |
| JAN | 1  | 1991 | 910362182 | B | 1 | REGIONAL BLAST                                         |
| JAN | 1  | 1991 | 910362182 | B | 1 | BLAST NEAR BLACKSBURG                                  |
| JAN | 1  | 1991 | 910362182 | B | 1 | GOOD REGIONAL BLAST, WEST OF HAZARD GROUP              |
| JAN | 1  | 1991 | 910362182 | B | 1 | LOCAL BLAST                                            |
| JAN | 1  | 1991 | 910362182 | B | 1 | BLAST GCO                                              |



MAR 13 1991 910721511 B 1  
MAR 13 1991 910772037  
MAR 13 1991 910791619  
MAR 13 1991 910802018  
MAR 13 1991 910821849  
MAR 13 1991 910841424  
MAR 13 1991 910841720  
MAR 13 1991 910842054  
MAR 13 1991 910892035  
MAR 13 1991 910942229  
MAR 13 1991 910962101  
MAR 13 1991 910980344  
MAR 13 1991 910992027  
MAR 13 1991 911012006  
MAR 13 1991 911021420  
MAR 13 1991 911031910  
MAR 13 1991 911051900  
MAR 13 1991 911061842  
MAR 13 1991 911061944  
MAR 13 1991 911072204  
MAR 13 1991 911081902  
MAR 13 1991 911082002  
MAR 13 1991 911082259  
MAR 13 1991 911102001  
MAR 13 1991 911115125  
MAR 13 1991 911115201  
MAR 13 1991 911115200  
MAR 13 1991 911115231  
MAR 13 1991 911116188  
MAR 13 1991 911116224  
MAR 13 1991 911119213  
MAR 13 1991 911119213  
MAR 13 1991 911120063  
MAR 13 1991 911120235  
MAR 13 1991 911121002  
MAR 13 1991 911121195  
MAR 13 1991 911123120  
MAR 13 1991 911123184  
MAR 13 1991 911126073  
MAR 13 1991 911126204  
MAR 13 1991 911127160  
MAR 13 1991 911129193  
MAR 13 1991 911129231  
MAR 13 1991 911131192  
MAR 13 1991 911131195  
MAR 13 1991 911136185  
MAR 13 1991 911136193  
MAR 13 1991 911136200  
MAR 13 1991 911140200  
MAR 13 1991 911148172  
MAR 13 1991 911151160  
MAR 13 1991 911157200  
MAR 13 1991 911165164  
MAR 13 1991 911169190  
MAR 13 1991 911173155  
MAR 13 1991 911187181  
MAR 13 1991 911193115  
MAR 13 1991 911193180  
MAR 13 1991 911200210  
MAR 13 1991 911201103  
MAR 13 1991 911201220  
MAR 13 1991 911205120  
MAR 13 1991 911205175  
MAR 13 1991 911206145  
MAR 13 1991 911227212  
MAR 13 1991 911236203  
MAR 13 1991 911239145  
MAR 13 1991 911239195  
MAR 13 1991 911240185  
MAR 13 1991 911240200  
MAR 13 1991 911242211  
MAR 13 1991 911246201  
MAR 13 1991 911250180  
MAR 13 1991 911252144  
MAR 13 1991 911253161  
MAR 13 1991 911253200  
MAR 13 1991 911254163  
MAR 13 1991 911255214  
MAR 13 1991 911257195  
MAR 13 1991 911259143  
MAR 13 1991 911260224  
MAR 13 1991 911267200  
MAR 13 1991 911274225  
MAR 13 1991 911276142  
MAR 13 1991 911276160  
MAR 13 1991 911278204  
MAR 13 1991 911284141  
MAR 13 1991 911285150  
MAR 13 1991 911287142  
MAR 13 1991 911291195  
MAR 13 1991 911294162  
MAR 13 1991 911296153  
MAR 13 1991 911297215  
MAR 13 1991 911298163  
MAR 13 1991 911299200  
MAR 13 1991 911304203  
MAR 13 1991 911306205  
MAR 13 1991 911306210  
MAR 13 1991 911310173  
MAR 13 1991 911311201  
MAR 13 1991 911315213  
MAR 13 1991 911316174  
MAR 13 1991 911316194  
MAR 13 1991 911318170  
MAR 13 1991 911318213  
MAR 13 1991 911319164  
MAR 13 1991 911319191  
MAR 13 1991 911319211  
MAR 13 1991 911338214  
MAR 13 1991 911345204  
MAR 13 1991 911348160  
MAR 13 1991 911349190  
MAR 13 1991 911350203  
MAR 13 1991 911355214  
MAR 13 1991 911355214  
MAR 13 1991 911362214  
MAR 13 1991 920072040  
MAR 13 1991 920072052

PROBABLE LOCAL BLAST IN W VA  
BLAST  
BLAST OR EQ. GHV-NA12  
HIGH TEST LAB - 2 SHOT  
BLAST  
BLAST  
BLAST BLA  
BLAST GHV  
BLAST  
BLAST GHV  
BLAST REGULAR SIGNAL VWV  
BIG BLAST/ROOF-FALL NEAR HAZARD  
BLAST WEST VA  
BLAST GCO  
BLAST GHV-CVL HIGH TEST LAB.  
BLAST WEST VA. - HMV  
BLAST WEST VA  
LOCAL EVENT NA12.  
LARGE BLAST HMV.  
BLAST  
BLAST KENTUCKY??  
LOCAL BLAST HMV  
BLAST WITH LONG S-CODA  
BLAST  
BLAST  
Req. Blast; Clyde Experiment; BacAzm= 287, Rec= 0.76  
Req. Blast; Clyde Experiment; BacAzm= 298, Rec= 0.69  
Req. Blast; Clyde Experiment; BacAzm= 303, Rec= 0.63  
Req. Blast; Clyde Experiment; BacAzm= , Rec=  
Req. Blast; Clyde Experiment; BacAzm= , Rec=  
BLAST GCO - EXPER?  
BLAST GCO - EXPER?  
POSSIBLE QUAKE CVA (MS)  
BLAST  
BLAST NEAR PMV  
BLAST  
BLAST GCO  
GCO BLAST  
BLAST-ROOF COLLAPSE  
BLAST GCO  
LARGE BLAST GCO; CLYDE EXPERIMENT  
LARGE BLAST GCO  
BLAST  
POOR BLAST  
BLAST GCO  
Two GCO Req. Blasts; Clyde experiment  
GCO Req. Blast; Clyde experiment  
GCO Req. Blast; Clyde experiment  
GCO REG. BLAST; CLYDE EXPERIMENT  
GCO/WV Blast; 5 sec s-p at HMV and VWV  
HUGE WEST VA SHOT  
REGIONAL BLAST  
BIG WV BLAST  
Req. Blast (KY Shooter)  
Large Req. Blast  
LARGE MVA BLAST  
Regional Blast  
KY Shooter  
Blast; 7 sec s-p @ PMV  
Regional Signal-Probable Blast  
Probable Blast; Strange Signal  
Good Hi-test Labs Blast  
GCO Blast; 5 sec S-P at HMV  
GCO Blast; 5 Sec S-P at VWV  
KY Blast(s)  
GCO Reg. Blast  
Micro-Signal in CVA (probable blast)  
GCO Reg. Blast  
GCO Reg. Blast (first arriv. PMV )  
Small blast GCO  
Blast near VWV (GCO)  
Blast near (VWV)  
Blast covered by GCO and CVA stations.  
Blast local to CVL  
Blast near HMV  
BLAST GCO  
BLAST near HMV  
BLAST near VWV  
BLAST ALL GCO  
BLAST NORTH ANNA STATIONS  
BLAST ALL GCO  
BIG BLAST VWV  
REGULAR BLAST-(HMV - VWV )  
BLAST near HMV  
Regional Blast  
BIG BLAST VWV - HF. on P arrival  
Regional Blast  
Weird signal(M.S)  
Blast HMV - VWV  
Either Regional Signal or Two Blasts  
Peculiar Blast WVM  
Blast  
Blast (peculiar) for later relocation  
BLAST HMV NAV  
Small Blast near BLA  
Blast near VWV signal recorded as far as CVL  
BLAST NEAR BLA  
BLAST GCO  
BLAST HMV  
EVENT NEAR HMV -(EASTERN KENTUCKY) S-P = 25.25 secs.  
LOCAL BLAST GCO  
BLAST HMV  
BLAST HMV  
BLAST HMV HMV  
BLAST HMV HMV  
BLAST SOUTHERN WEST VA  
BLAST HMV  
BLAST SOUTHERN WEST VA  
Little event within GCO (M.Sibol)  
BLAST WEST VA  
BLAST KENTUCKY ??  
P-TELE SEISM PERU  
A.H. STONE CO. (NEAR NA12)  
BLAST  
BLAST  
BLAST VWV  
BLAST GCO ( SMALL EVENT )  
BLAST NEAR PMV  
CVA BLAST NEAR HITEST,SOLITE,ARVONIA-BUCKINGHAM ETC  
BLAST GCO

[illegible]

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CVA BLAST NEAR HITEST,SOLITE,ETC (SAME AS 1/7/92)
BLAST GCO
BLAST GCO
BLAST GCO
DIDACTIC WAVEFORM FOR P-S- SURFW (small blast)
BLAST GCO
BLAST GCO
BLAST at NVA? - no NVA IS OUT - this record is noise
BLAST HWV
REGIONAL BLAST
REGIONAL BLAST
BLAST GCO
BLAST GCO
REGIONAL BLAST
REGIONAL BLAST
REGIONAL BLAST
REGIONAL BLAST ?
REGIONAL BLAST
LARGE BLAST NEAR LOGAN, WVA
BLAST IN KENTUCKY
BLAST IN KVA
BLAST IN WVA
BLAST KENTUCKY
BLAST IN WVA
BLAST WVA
BLAST EASTERN KENTUCKY.
BLAST
BLAST WVA
BLAST GCO - PWV - HWV
BLAST WVA
BLAST WVA
BLAST KENTUCKY(s-p=31) (good P)
BLAST KENTUCKY(s-p=31) same source as before (good P)
BLAST s=18 secs (GCO)
BLAST WEST VA vet **
*ANOTHER LARGE BLAST NEAR LOGAN,WVA (SAME SOURCE AS 0812109)
BLAST WVA
BLAST KENTUCKY??
BLAST WVA
BLAST HWV PWV
BLAST HWV PWV
BLAST KENTUCKY ?
BLAST KENTUCKY ?
BLAST WVA
BLAST GCO
REGIONAL BLAST
REGIONAL BLAST - KTY MAYBE
BLAST WEST VA
BLAST Eastern Kentucky.
BLAST
BLAST
REGIONAL Blast
REGIONAL Blast (Kentucky)
REG. Blast (WV)
REGIONAL BLAST
REGIONAL BLAST
WVA BLAST
KENTUCKY BLAST
WVA BLAST
WVA BLAST
BLAST IN KENTUCKY(?)
BLAST IN WEST VIRGINIA
PWV CAL PULSE
blast(biq)
blast
BLA CAL PULSE
blast
blast
blast
BLAST IN WEST VA
BLAST IN KENTUCKY
BLAST IN WEST VA
BLAST IN WEST VIRGINIA
BLAST I WEST VIRGINIA
MV? Blast
MV? Blast
WVA BLAST
KY? BLAST
WVA BLAST
WVA BLAST
WEST VA BLAST
WEST VA BLAST
WEST VA BLAST
WEST VA BLAST
BLAST IN KY(?)
BLAST IN KY
BIG BLAST IN KENTUCKY
BLAST IN KENTUCKY
BLAST IN WEST VA
BLAST IN WEST VA
BIG BLAST IN WEST VA
BIG BLAST IN WEST VA
BIG BLAST IN WEST VA
BIG BLAST IN WEST VA
BLAST IN WEST VA
BLAST IN WEST VA
BLAST IN WEST VA
BLAST IN WVA(?)
BLAST IN KY(?)
BLAST IN WEST VA
BLAST IN KENTUCKY
BLAST IN KENTUCKY
BLAST IN W. VA
GCO LOCAL BLAST
GCO REG. BLAST(WV?)
GCO REG. BLAST
GCO REG. BLAST(KY?)
REG. BLAST
REG. BLAST
CVA PROB. BLAST
CVA PROB. BLAST
REG. BLAST (WVA?)(TIME IS DEFF. TO CLYDE)
GCO BLAST
KENTUCKY BLAST
WEST VA BLAST
WVA PROB. NOT RUFFNER
WVA PROB. NOT RUFFNER
WVA RUFFNER (JULY 18 7:01 PM CONFIRMED)
BIG BLAST IN WEST VIRGINIA
BLAST IN WVA

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|    |      |           |   |   |                                                             |
|----|------|-----------|---|---|-------------------------------------------------------------|
| 10 | 1993 | 930412100 | B | 1 | REG. BLAST (KY/WVA BORDER?)                                 |
| 11 | 1993 | 930441220 | B | 1 | GOOD BLAST IN WVA                                           |
| 12 | 1993 | 930446230 | B | 1 | SHALL KY blast, about time of major WV shaking, no relation |
| 13 | 1993 | 930472100 | B | 1 | REG. BLAST IN WVA                                           |
| 14 | 1993 | 930492100 | B | 1 | REG. BLAST IN WVA                                           |
| 15 | 1993 | 930502100 | B | 1 | REG. BLAST IN WVA                                           |
| 16 | 1993 | 930532100 | B | 1 | BIG. REG BLAST (IN KY OR OHIO?)                             |
| 17 | 1993 | 930620045 | B | 1 | LATE NIGHT BLAST OR LOCAL QUAKE IN WVA                      |
| 18 | 1993 | 930622100 | B | 1 | LOCAL BLAST IN CENTRAL VIRGINIA                             |
| 19 | 1993 | 930622119 | B | 1 | REG. BLAST IN KY?                                           |
| 20 | 1993 | 930762106 | B | 1 | GOOD REG BLAST IN WVA (NEAR RUFFNER)                        |
| 21 | 1993 | 930812106 | B | 1 | BLAST IN WVA                                                |
| 22 | 1993 | 930822009 | B | 1 | BIG BLAST NEAR HWV, WVA                                     |
| 23 | 1993 | 930832143 | B | 1 | BLAST IN KY OR OHIO?                                        |

There are 1682 events in this list.

## INSTRUMENTALLY LOCATED REGIONAL AND LOCAL EARTHQUAKES FOR VIRGINIA

| Lab-Req | Origin<br>YrModv | Time UT<br>HrMnSec | Hypocenter Location<br>Lat-N Long-W Depth | Location<br>Sta P/S | Parameters<br>GAP Umin RMS | SQD | Error<br>ERH10AZ | Ellipsoids<br>ERH2 | ERZ | Q | Magn<br>mb | Md | MM<br>I | Src |
|---------|------------------|--------------------|-------------------------------------------|---------------------|----------------------------|-----|------------------|--------------------|-----|---|------------|----|---------|-----|
| 91      |                  | 06                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 92      |                  | 18                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 93      |                  | 23                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 94      |                  | 02                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 95      |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 96      |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 97      |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 98      |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 99      |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 100     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 101     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 102     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 103     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 104     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 105     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 106     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 107     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 108     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 109     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 110     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 111     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 112     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 113     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 114     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 115     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 116     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 117     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 118     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 119     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 120     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 121     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 122     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 123     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 124     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 125     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 126     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 127     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 128     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 129     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 130     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 131     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 132     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 133     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 134     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 135     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 136     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 137     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 138     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 139     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 140     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 141     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 142     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 143     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 144     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 145     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 146     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 147     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 148     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 149     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 150     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 151     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 152     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 153     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 154     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 155     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 156     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 157     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 158     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 159     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 160     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 161     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 162     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 163     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 164     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 165     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 166     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 167     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 168     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 169     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 170     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 171     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 172     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 173     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 174     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 175     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 176     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 177     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 178     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 179     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 180     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 181     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 182     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 183     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 184     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 185     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 186     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 187     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 188     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 189     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 190     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 191     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 192     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 193     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 194     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 195     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 196     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 197     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 198     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 199     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |
| 200     |                  | 00                 |                                           |                     |                            |     |                  |                    |     |   |            |    |         |     |

There have been 200 earthquakes listed so far.

## INSTRUMENTALLY LOCATED REGIONAL AND LOCAL EARTHQUAKES FOR VIRGINIA

| Lab-Reg | Origin YrMoDv | Time UT HrMnSec | Hypocenter Lat-N | Location Long-W | Depth    | Location Sta | Parameters P/S | GAP | Dmin | RMS | SQD | Error ERH1 | Ellipse ERH2 | Q   | Mag. mb | MM Md | I   | Src |
|---------|---------------|-----------------|------------------|-----------------|----------|--------------|----------------|-----|------|-----|-----|------------|--------------|-----|---------|-------|-----|-----|
| 180     | WV            | 920506          | 212023.9         | 38-7.06         | 81-4.15  | 10.3         | 7              | 7/7 | 273  | 62  | 0.2 | 1.59       | -76          | 1.0 | 1.2     | B     | 2.3 | 1   |
| 180     | VA            | 920519          | 084206.3         | 38-45.99        | 80-42.63 | 2.3          | 7              | 4/5 | 201  | 45  | 0.2 | 1.49       | -05          | 0.6 | 2.1     | B     | 2.0 | 3   |
| 180     | CV            | 920627          | 185516.7         | 37-45.70        | 78-5.97  | 7.0          | 7              | 2/2 | 254  | 49  | 0.4 | 99.09      | -84          | 1.0 | 99.0    | D     | 1.8 | 1   |
| 180     | GC            | 921124          | 022650.7         | 37-47.41        | 80-5.05  | 12.3         | 7              | 4/4 | 147  | 15  | 0.4 | 0.59       | -77          | 0.9 | 1.1     | A     | 1.3 | 1   |
| 184     | VA            | 921225          | 183313.6         | 36-45.68        | 80-42.45 | 1.7          | 7              | 7/7 | 254  | 44  | 0.4 | 2.29       | -05          | 0.9 | 2.7     | C     | 2.2 | 2   |

There are 205 earthquakes in this list.

## Abbreviations For Regions:

BC: Bath County, Virginia, area,  
 CV: Central Virginia Seismic Zone,  
 GC: Giles County, Virginia, Seismic Zone,  
 NA: North Anna, Virginia, area,  
 KY: Kentucky area,  
 NV: Northern Virginia area,  
 VN: Virginia / North Carolina area,  
 VW: Virginia / West Virginia area,  
 WV: West Virginia,

R : Events that have been relocated for special studies. Calculated using either, a new technique (JHD, JED, HYPOELLIPSE, etc.) or a different velocity model.

## Sources and/or References

- 1: VTSD records, NRC reports, SEUSSN Bulletins, or G. A. Bollinger personal files.
- 2: Dames and Moore, 1977. A Seismic Monitoring Program At The North Anna Site In Central, Virginia - January 24, 1974 Through August 1, 1977. Submitted to VEPCO, 1977.
- 5: Coffman, Jerry L., and C. W. Stover, 19XX. U. S. Earthquakes, 19XX; annual publication by NOAA and the USGS.
- 7: USGS Preliminary determination of epicenters, 19XX, monthly listings.
- 11: Dewey and Gordon, 198?. Relocation of major eastern North American earthquakes using JED/JHD.

## APPENDIX C

Tectonic Earthquake Catalog Reported In  
The Southeastern United States Seismic Network Bulletins:  
July 1977 Through December 1991

18-MAR-93 11:03:12 for the program RWSEUSSN-IBM

Input data from file.....: (SIBOL.SEUSSN)TECTONIC.DAT

| Code | Date   | HrMnSec  | Lat-N | Lon-W  | Depth | mb(Lq) | MLD  | In | Ph | Dmin | Gap | RMS | ERH1d   | AZ   | ERH2 | ERZ | QE | QL  | S/D | Source |
|------|--------|----------|-------|--------|-------|--------|------|----|----|------|-----|-----|---------|------|------|-----|----|-----|-----|--------|
| TN   | 770727 | 220321.2 | 38.9  | 84.356 | 12.6  | 3.5N   | 3.2N | 5  | 22 | 58   | 67  | 0.3 | 1.83+37 | 1.1  | 3.0  | B   | C  | B/D | V   | 10 01  |
| SC   | 770823 | 134455.9 | 38.9  | 80.161 | 6.9   | 3.5N   | 3.3S | 4  | 13 |      |     | 0.1 | 0.78+00 | 0.6  | 1.1  |     |    |     |     | 22 01  |
| SC   | 770825 | 042000.7 | 38.3  | 80.693 | 7.0   | 3.5N   | 3.3S | 4  | 18 |      |     | 0.1 | 0.78+00 | 0.6  | 1.1  |     |    |     |     | 22 01  |
| SC   | 770901 | 210533.2 | 40.0  | 80.661 | 6.3   | 1.8S   | 1.8S |    |    |      |     | 0.1 | 0.78+00 | 0.6  | 1.1  |     |    |     |     | 22 01  |
| NC   | 770925 | 062233.7 | 0.0   | 82.678 | 5.0   | 2.5N   | 2.8N |    | 7  | 215  | 143 | 0.2 | 5.00+52 | 2.2  | 24.6 | C   | D  | C/D | V   | 10 01  |
| VA   | 771023 | 075141.1 | 38.5  | 82.134 | 10.0  | 2.8N   | 2.8N |    | 8  | 127  | 191 | 0.1 | 5.50+00 | 0.9  | 0.9  |     |    |     |     | 10 01  |
| SC   | 771110 | 112455.9 | 38.5  | 80.689 | 2.2   | 0.0S   | 0.0S |    | 11 |      |     | 0.1 | 0.50+00 | 0.4  | 1.9  |     |    |     |     | 22 01  |
| SC   | 771215 | 071555.5 | 38.5  | 80.263 | 11.2  | 1.1S   | 1.1S |    | 17 |      |     | 0.1 | 0.50+00 | 0.4  | 0.9  |     |    |     |     | 22 01  |
| SC   | 771215 | 191643.3 | 38.5  | 80.170 | 8.8   | 1.6S   | 1.6S | 5  | 17 |      |     | 0.1 | 0.50+00 | 0.4  | 0.6  |     |    |     |     | 22 01  |
| SC   | 771216 | 111434.4 | 38.5  | 80.310 | 7.7   | 1.3S   | 1.3S |    | 25 |      |     | 0.1 | 0.70+00 | 0.4  | 0.6  |     |    |     |     | 22 01  |
| SC   | 771216 | 112553.7 | 38.5  | 80.309 | 7.5   | 1.8S   | 1.8S |    | 27 |      |     | 0.1 | 0.70+00 | 0.4  | 0.6  |     |    |     |     | 22 01  |
| SC   | 771218 | 015833.7 | 38.5  | 80.287 | 15.9  | 1.8S   | 1.8S |    | 15 |      |     | 0.1 | 0.90+00 | 0.4  | 1.0  |     |    |     |     | 22 01  |
| SC   | 771220 | 234122.2 | 38.5  | 80.239 | 11.6  | 1.8S   | 1.8S |    | 11 |      |     | 0.2 | 1.50+90 | 1.5  | 4.0  |     |    |     |     | 22 01  |
| AL   | 780108 | 113422.2 | 38.5  | 88.25  | 5.0   | 3.0N   |      |    | 9  | 233  |     | 0.1 | 5.90+34 | 1.3  | 3.0  | C   | D  | D/D | N   | 10 02  |
| VA   | 780128 | 231322.3 | 38.5  | 80.747 | 4.5   | 1.6V   |      |    | 6  | 11   |     | 0.1 | 5.90+34 | 1.3  | 3.0  | C   | D  | C/C | V   | 10 02  |
| NC   | 780225 | 035332.7 | 38.5  | 80.318 | 21.1  | 2.2V   |      |    | 9  | 35   | 162 | 0.3 | 9.90+44 | 1.4  | 3.8  | C   | D  | C/C | V   | 10 02  |
| AL   | 780301 | 140825.5 | 38.5  | 86.71  | 15.9  | 2.5N   |      |    | 5  | 133  |     | 0.4 | 3.70-22 | 2.8  | 5.8  | C   | C  | C/C | N   | 10 02  |
| VA   | 780317 | 182634.4 | 38.3  | 80.737 | 15.9  | 2.8V   |      |    | 4  | 28   | 154 | 0.4 | 3.70-22 | 2.8  | 5.8  | C   | C  | C/C | V   | 10 02  |
| NC   | 780402 | 02220    | 38.5  | 81.19  | 10.0  | 2.8V   |      |    | 3  |      |     | 0.0 |         |      |      |     |    |     |     | 02 02  |
| GA   | 780502 | 014611.1 | 38.5  | 82.738 | 10.0  | 2.8V   |      |    | 3  |      |     | 0.0 |         |      |      |     |    |     |     | 02 02  |
| VA   | 780510 | 041909.6 | 38.5  | 80.830 | 26.2  | 0.0S   |      |    | 6  | 12   | 268 | 0.1 | 4.40+44 | 1.5  | 3.0  | B   | D  | C/D | V   | 10 02  |
| GA   | 780520 | 2203     | 38.5  | 84.32  |       | 1.5G   |      |    |    |      |     | 0.1 |         |      |      |     |    |     |     | 02 02  |
| GA   | 780521 | 2300     | 38.5  | 84.54  |       | 1.6G   |      |    |    |      |     | 0.1 |         |      |      |     |    |     |     | 02 02  |
| VA   | 780525 | 083025.1 | 38.5  | 80.794 | 12.1  | 1.5G   |      |    | 8  | 3    | 269 | 0.2 | 4.30+04 | 2.7  | 3.8  | B   | D  | C/D | V   | 10 02  |
| GA   | 780616 | 204016.6 | 38.5  | 85.04  | 9.0   | 2.3G   |      |    |    |      |     | 0.0 |         |      |      |     |    |     |     | 02 02  |
| NC   | 780709 | 070335.5 | 38.5  | 82.798 | 9.0   | 2.3G   |      |    | 3  |      |     | 0.0 |         |      |      |     |    |     |     | 02 02  |
| NC   | 780728 | 083940.0 | 38.5  | 80.690 | 11.8  | 0.6V   |      |    | 7  | 10   | 146 | 0.3 | 4.90+39 | 2.2  | 8.1  | C   | D  | C/C | V   | 10 03  |
| VA   | 780804 | 084844.1 | 38.5  | 82.441 | 17.6  | 2.3V   |      |    | 18 | 126  | 100 | 0.3 | 4.90+39 | 2.2  | 8.1  | C   | D  | C/C | V   | 10 03  |
| NC   | 780814 | 045000.8 | 38.5  | 80.874 | 23.0  | 1.6V   |      |    | 13 | 39   | 243 | 0.3 | 3.70-50 | 1.2  | 3.3  | C   | D  | C/C | V   | 10 03  |
| VA   | 780830 | 021933.5 | 38.5  | 80.668 | 8.4   | 0.5V   |      |    | 12 | 12   | 158 | 0.1 | 3.10+28 | 1.0  | 6.4  | C   | C  | C/C | V   | 10 03  |
| SC   | 780907 | 225322.2 | 38.5  | 80.209 | 10.1  | 2.6S   |      |    | 4  | 28   |     | 0.1 | 0.30+00 | 0.3  | 0.5  |     |    |     |     | 22 04  |
| AL   | 781027 | 135355.5 | 38.5  | 87.43  | 10.1  | 2.9N   |      |    | 10 | 294  |     | 0.1 |         |      |      |     |    |     |     | 03 03  |
| VA   | 781029 | 122242.2 | 38.5  | 78.083 | 10.4  | 0.6V   |      |    | 6  | 24   | 242 | 0.0 | 0.70-45 | 0.1  | 1.4  | B   | C  | B/D | V   | 18 04  |
| SC   | 781030 | 091512.1 | 38.5  | 80.159 | 6.7   | 1.0S   |      |    | 12 |      |     | 0.1 | 0.40+90 | 0.3  | 1.2  |     |    |     |     | 22 04  |
| SC   | 781030 | 091614.1 | 38.5  | 80.162 | 2.2   | 1.5S   |      |    | 14 |      |     | 0.1 | 0.40+90 | 0.4  | 0.8  |     |    |     |     | 22 04  |
| SC   | 781030 | 100442.1 | 38.5  | 80.216 | 19.9  | 1.1S   |      |    | 5  |      |     | 0.1 | 0.40+90 | 1.1  | 0.8  |     |    |     |     | 22 04  |
| SC   | 781102 | 111212.1 | 38.5  | 82.244 | 5.0   | 1.0S   |      |    |    |      |     | 0.4 |         |      |      |     |    |     |     | 03 03  |
| GA   | 781114 | 200255.0 | 38.5  | 82.385 | 5.0   | 1.6S   |      |    | 6  |      |     | 0.6 |         |      |      |     |    |     |     | 03 03  |
| VA   | 781115 | 040909.9 | 38.5  | 82.115 | 11.9  | 1.1S   |      |    | 8  |      |     | 0.1 |         |      |      |     |    |     |     | 03 03  |
| GA   | 781115 | 083334.7 | 38.5  | 77.561 | 13.4  | 1.6V   |      |    | 5  | 50   | 196 | 0.2 | 0.90-45 | 0.8  | 1.8  | B   | D  | B/D | V   | 18 03  |
| AL   | 781211 | 020656.1 | 38.5  | 88.47  | 3.3   | 3.5S   |      |    |    |      |     | 0.1 |         |      |      |     |    |     |     | 03 03  |
| GA   | 790116 | 182833.1 | 38.5  | 82.090 | 3.7   | 2.1S   |      |    | 9  | 251  |     | 0.4 | 0.80+90 | 0.7  | 7.8  | D   |    |     |     | 04 04  |
| SC   | 790127 | 135555.1 | 38.5  | 80.173 | 9.0   | 2.1S   |      |    | 17 |      |     | 0.2 | 9.90+09 | 2.5  | 9.0  | D   |    |     |     | 22 04  |
| SC   | 790704 | 115322.2 | 38.5  | 80.155 | 1.0   | 3.5S   |      |    | 3  | 165  |     | 0.0 | 4.10-73 | 1.4  | 1.0  | D   |    |     |     | 05 05  |
| TN   | 790719 | 102770.3 | 38.5  | 84.822 | 10.1  | 2.9T   |      |    | 15 | 70   | 255 | 0.3 | 4.10-73 | 1.4  | 1.0  | B   | D  | C/D | V   | 12A 05 |
| NC   | 790811 | 021115.6 | 38.5  | 80.234 | 10.0  | 1.5S   |      |    | 18 |      |     | 0.1 | 0.60+00 | 0.6  | 1.8  |     |    |     |     | 22 05  |
| GA   | 790813 | 051855.6 | 38.5  | 84.335 | 22.2  | 3.7S   |      |    | 39 | 72   | 76  | 0.3 | 1.00-58 | 0.9  | 1.8  | A   | C  | B/D | V   | 10 05  |
| NC   | 790906 | 023810.4 | 38.5  | 83.241 | 10.0  | 1.1T   |      |    | 4  | 315  |     | 0.8 | 9.90-39 | 28.0 | 99.0 | D   | B  | B/B | V   | 10 05  |
| TN   | 790912 | 062240.6 | 38.5  | 83.941 | 17.1  | 3.2S   |      |    | 5  | 18   |     | 0.1 | 0.80-45 | 1.1  | 1.4  | A   | B  | B/B | V   | 10 05  |
| VA   | 790916 | 093922.2 | 38.5  | 80.240 | 14.4  | 1.6V   |      |    | 13 | 28   | 202 | 0.2 | 0.80-45 | 0.5  | 1.2  | C   | D  | C/D | V   | 18 05  |
| VA   | 790919 | 004455.4 | 38.5  | 80.244 | 17.2  | 2.0V   |      |    | 20 | 29   | 190 | 0.2 | 0.80-45 | 0.4  | 2.9  | C   | D  | C/D | V   | 18 05  |
| SC   | 791005 | 230555.4 | 38.5  | 80.287 | 9.9   | 1.1S   |      |    | 14 |      |     | 0.1 | 0.60+00 | 1.2  | 1.0  |     |    |     |     | 22 05  |
| SC   | 791021 | 071022.1 | 38.5  | 80.206 | 6.6   | 1.6S   |      |    | 10 |      |     | 0.1 | 0.60+00 | 0.8  | 1.6  |     |    |     |     | 22 05  |
| TN   | 791029 | 202247.7 | 38.5  | 84.778 | 3.6   | 1.6S   |      |    | 5  | 83   | 226 | 0.2 | 4.70-50 | 1.3  | 2.8  | B   | D  | C/D | V   | 12A 05 |
| VA   | 791031 | 083247.7 | 38.5  | 81.207 | 6.8   | 1.3V   |      |    | 16 | 28   | 269 | 0.1 | 0.60-81 | 1.3  | 2.8  | C   | D  | C/D | V   | 18 05  |
| VA   | 791106 | 030445.5 | 38.5  | 78.220 | 6.0   | 1.3V   |      |    | 24 | 28   | 103 | 0.1 | 0.60-81 | 0.3  | 1.2  | A   | D  | B/C | V   | 18 05  |
| VA   | 791107 | 222212.2 | 38.5  | 82.886 | 6.4   | 1.3V   |      |    | 24 |      |     | 0.1 | 9.90+05 | 17.8 | 99.0 | C   | D  | B/C | V   | 18 05  |
| KY   | 791109 | 072215.3 | 38.5  | 82.869 | 4.4   | 1.6S   |      |    | 5  | 200  |     | 0.2 | 0.50-70 | 0.4  | 13.2 | D   | D  | C/D | V   | 18 05  |
| VA   | 791112 | 072215.3 | 38.5  | 82.869 | 4.4   | 1.6S   |      |    | 5  | 200  |     | 0.2 | 0.50-70 | 0.4  | 13.2 | D   | D  | C/D | V   | 18 05  |
| SC   | 791207 | 054455.7 | 38.5  | 80.169 | 0.0   | 1.2V   |      |    | 4  | 54   | 173 | 0.1 | 0.00+00 | 0.6  | 1.0  |     |    |     |     | 22 05  |
| VA   | 791217 | 134455.7 | 38.5  | 80.667 | 0.0   | 1.2V   |      |    | 6  |      |     | 0.1 | 0.00+00 | 0.6  | 1.0  |     |    |     |     | 22 05  |
| VA   | 800106 | 135500.6 | 38.5  | 81.478 | 0.0   | 1.1V   |      |    | 23 | 69   | 147 | 0.4 | 0.00+00 | 1.2  | 3.4  | C   | D  | C/D | V   | 18 06  |
| TN   | 800124 | 041555.8 | 38.5  | 81.271 | 2.0   | 0.6V   |      |    | 7  | 37   | 157 | 0.2 | 0.00+00 | 1.7  | 14.8 | C   | C  | C/C | V   | 10 06  |
| VA   | 800218 | 031358.5 | 38.5  | 80.593 | 14.6  | 0.6V   |      |    | 14 | 322  | 198 | 0.2 | 0.60+19 | 0.5  | 0.7  | A   | C  | B/D | V   | 18 06  |
| KY   | 800323 | 213338.1 | 38.5  | 86.690 | 6.0   | 3.3S   |      |    | 4  | 126  |     | 0.2 | 0.60+19 | 0.5  | 0.7  |     |    |     |     | 06 06  |
| NC   | 800410 | 220447.7 | 38.5  | 84.848 | 79.9  | 2.8S   |      |    | 5  | 353  |     | 0.3 | 9.90-45 | 92.6 | 37.4 | D   | D  | D/D | V   | 18 06  |
| VA   | 800419 | 223333.1 | 38.5  | 81.111 | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| TN   | 800421 | 223333.1 | 38.5  | 84.13  | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| TN   | 800422 | 031333.1 | 38.5  | 84.13  | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| NC   | 800422 | 031333.1 | 38.5  | 84.13  | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| VA   | 800426 | 031333.1 | 38.5  | 84.13  | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| VA   | 800518 | 031333.1 | 38.5  | 84.13  | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| NC   | 800610 | 031333.1 | 38.5  | 84.13  | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| VA   | 800618 | 031333.1 | 38.5  | 84.13  | 5.0   | 2.8S   |      |    | 3  | 19   | 263 | 0.3 | 2.60-60 | 1.2  | 99.0 | D   | D  | D/D | V   | 12A 06 |
| SC   | 800622 | 223333.1 | 38.5  | 80.155 | 1.0   | 1.6S   |      |    | 22 | 115  |     | 0.1 | 0.60+00 | 0.8  |      |     |    |     |     |        |



There have been 200 events listed so far.



[illegible]

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There have been 400 events listed so far.

There have been 500 events listed so far.





There have been 700 events listed so far.



| Code | Date   | HrMnSec | Lat-N  | Lon-W  | Depth | mb(Lq) | MLD | In   | Ph | Dmin | Gap  | RMS  | ERH10 | AZ   | ERH2 | ERZ  | QE   | QL   | S/D  | Source |
|------|--------|---------|--------|--------|-------|--------|-----|------|----|------|------|------|-------|------|------|------|------|------|------|--------|
| TN   | 880622 | 075010  | 164580 | 120503 | 13    | 1.6A   | 32  | 13   | 64 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| SC   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| TN   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| TN   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13   | 68 | 0.00 | 0.00 | 0.00 | 0.00  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00   |
| VA   | 880622 | 080622  | 125731 | 105058 | 13    | 1.3T   | 25  | 13</ |    |      |      |      |       |      |      |      |      |      |      |        |



[illegible]

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There have been 1000 events listed so far.

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There have been 1100 events listed so far.



**END**

**DATE  
FILMED**

**9 / 30 / 93**