State of Delaware
DELAWARE GEOLOGICAL SURVEY
Robert R. Jordan, State Geologist

OPEN FILE REPORT NO. 42

CATALOG OF EARTHQUAKES IN DELAWARE

by

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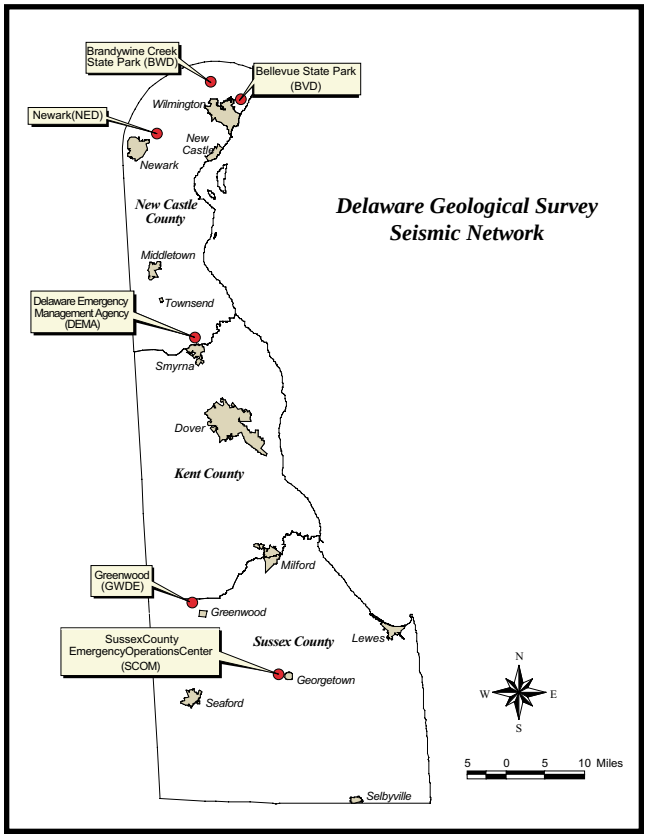

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Newark, Delaware
2000

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INTRODUCTION

The occurrences of earthquakes in northern Delaware and adjacent areas of Pennsylvania, Maryland, and New Jersey are well documented by both historical and instrumental records. Over 550 earthquakes have been documented within 150 miles of Delaware since 1677. One of the earliest known events occurred in 1737 and was felt in Philadelphia and surrounding areas. The largest known event in Delaware occurred in the Wilmington area in 1871 with an intensity of VII (Modified Mercalli Scale). The second largest event occurred in the Delaware area in 1973 (magnitude 3.8 and maximum Modified Mercalli Intensity of V-VI). The epicenter for this event was placed in or near the Delaware River. Sixty-nine earthquakes have been documented or suspected in Delaware since 1871.

The United States Geological Survey (USGS) and the Federal Emergency Management Agency (FEMA) in 1997 reclassified Delaware from a low seismic risk to a medium seismic risk (unpublished State Seismic Hazard Map, FEMA, ITS Mapping and Analysis Center, Washington, DC, 1997). Over the past several years, there has been an increase in public awareness of, and sensitivity to, earthquakes and the potential effects that earthquakes can have on public health, safety, and welfare.

This report revises and updates Delaware Geological Survey Report of Investigation No. 39. Refer to Delaware Geological Survey Special Publication 23 located at http://www.udel.edu/dgs/webpubl.html for an overview of what causes earthquakes, seismic waves, faults, magnitude and intensity, and how earthquakes are recorded.

DELAWARE GEOLOGICAL SURVEY SEISMIC NETWORK

Following an earthquake swarm in 1972 that lasted for several months, the Delaware Geological Survey (DGS) established its own seismic network of short-period vertical seismometers to detect local earthquake activity. The DGS currently operates a network of five seismic stations throughout the state which are strategically located between stations in northern New Jersey, New York, and southwestern Virginia, thereby providing a vital technological link between those two areas. Three stations are in the Newark-Wilmington area (NED, BVD, BWD), one station (DEMA) is at the Delaware Emergency Management Agency in southern New Castle County, and one station (SCOM) is located at the Sussex County Emergency Operations Center in Sussex County (Figure 1). Table 1 lists the latitude, longitude, elevation, date of establishment, and geographical location of each station.

The first seismic station to be established was NED in 1972 followed in 1977 by BBD near Blackbird and GTD near Georgetown (BBD and GTD were discontinued in 1991 due to lack of operational funds). Two new stations were established by the DGS in 1985 and have been in continuous operation. One is located in Bellevue State Park (BVD) and the other in Brandywine Creek State Park (BWD). Signals from the seismometers at NED, BVD, and BWD are transmitted to the DGS by telephone lines.

In 1998 the Delaware General Assembly provided funding to the DGS to establish two seismic stations located in central and southern Delaware (DEMA and SCOM) bringing the total number of stations in the network back to five. These two stations are linked to the DGS via microwave and radio signals.

An additional station, located near Greenwood, Delaware (GWDE), is part of the U. S. National Seismograph Network (USNSN) and is operated by the (USGS) and maintained by the DGS. This station is equipped with modern broadband seismometers that are designed to record the horizontal and vertical earth movements created by earthquakes of greater than 2.5 magnitude that occur within an approximate 200-mile radius. In addition, measurements of ground acceleration are recorded on three accelerometers at the site. Signals are transmitted via satellite to the National Earthquake Information Center in Golden, Colorado, for analysis and cataloging.

The DGS upgraded its seismic network to digital format in 1997 with the technical support and provision of hardware and software from Lamont-Doherty Earth Observatory (LDEO). The conversion to digital format from analog format enables the DGS to determine more rapidly and pre-

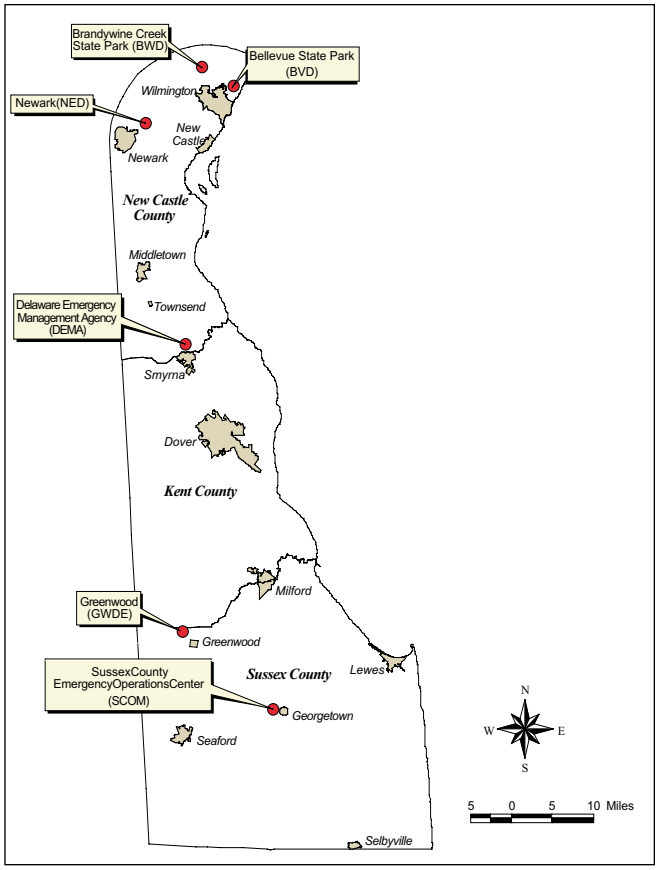

Figure 1. Locations of five Delaware Seismic Network stations and one U.S. National Seismograph Network Station (GWDE).

Table 1
Station information for Delaware Seismic Network stations and U.S. National Seismograph Network station.

Station	Lat/Long Deg/Min/Sec	Lat/Long Decimal Degrees	Elevation (meters)	Date Operational	Location
NED	394215.0 754217.4	39.70417 -75.70472	47	Nov. 72	Newark
BWD	394758.2 753436.0	39.79944 -75.57667	63	Feb. 85	Brandywine Creek State Park
BVD	394629.4 752957.6	39.77472 -75.49944	58	Feb. 85	Bellevue State Park
DEMA	391907.4 753635.3	39.31871 -75.60979	12.2	Oct. 99	Delaware Emergency Management Agency
SCOM	384428.8 752451.6	38.69567 -75.36271	12.2	Oct. 99	Sussex County Emergency Operations Ctr
***GWDE**	384932.2 753701.6	38.82560 -75.61710	19	Aug. 95	Greenwood

*This station is operated by the U.S. Geological Survey but is maintained by the DGS

cisely the times and locations of seismic events and to share such information with emergency managers, the public, and adjacent networks.

The DGS is a member of the Council of the National Seismic System (CNSS), the Northeast (NEUSSN) and Southeast (SEUSSN) U. S. Seismic Networks, and the Lamont-Doherty Cooperative Seismographic Network (LCSN). Through the provision and sharing of seismic data, we have been able to make progress in our understanding of seismicity in the Middle Atlantic area.

Acknowledgments

Julia Daly researched historical newspaper accounts. Scott A. Strohmeier researched DGS files and calculated felt area epicenters for many of the events that occurred in the 1970s following the installation of the seismic network. Over the years the paper on the seismographs (seismograms) has been changed on weekends and holidays by students from the University of Delaware and by all members of the DGS.

Earthquake Catalog

The earthquake map (Figure 2) and catalog (Appendix) show Delaware's earthquake history since 1871. Information was obtained primarily from Jordan et al. (1972), Woodruff et al. (1973), Pickett (1974), Woodruff (1984), and DGS unpublished records. For events that occurred from 1871 through 1937, information was obtained from newspaper reports. Additional sources include the NCEER-91 Earthquake Catalog for the Eastern United States (Armbruster and Seeber, 1992), United States Earthquake Data File (Stover et al., 1984), as well as computerized searches of the USGS Earthquake Database, New England Seismic Network Earthquake Catalog, Southeastern U. S. Earthquake Catalog, and events listed by the Lamont Cooperative Seismic Network.

REFERENCES CITED

Armbruster, J., and Seeber, L., 1992, NCEER-91 Earthquake Catalog for the Eastern United States: National Center for Earthquake Engineering Research, State University of New York at Buffalo.

Gordon, D. W., and Dewey, J. W., 1999, Earthquakes, *in* Shultz, C. H., editor, The Geology of Pennsylvania: Pennsylvania Geological Survey and Pittsburgh Geological Society, Pittsburgh, Pennsylvania, p. 763-769.

Jordan, R. R., Pickett, T. E., and Woodruff, K. D., 1972, Preliminary report on seismic events in northern Delaware: Delaware Geological Survey Open File Report No. 2, 15 p.

Pickett, T. E., compiler, 1974, Papers presented by staff members of the Delaware Geological Survey at the Baltimore meeting of the northeastern section of the Geological Society of America, March 1974: Delaware Geological Survey Open File Report No. 4, 21 p.

Sibol, M. S., Bollinger, G. A., and Birch, J. B., 1987, Estimation of magnitudes in central and eastern North America using intensity and felt area: Bulletin of the Seismological Society of America, v. 77, p. 1635-1654.

Stover, C. W., Reagor, B. G., and Algermissen, S. T., 1984, United States Earthquake Data File: U. S. Geological Survey Open File Report 84-225, 123 p.

Wood, H. O., and Neumann, Frank, 1931, Modified Mercalli scale of 1931: Seismological Society of America Bulletin, v. 21, p. 277-283.

Woodruff, K. D., 1984, Earthquakes in Delaware and nearby areas from June 1974 through June 1984: Delaware Geological Survey Report of Investigations No. 39, 35 p.

Woodruff, K. D., Jordan, R. R., and Pickett, T. E., 1973, Preliminary report on the earthquake of February 28, 1973: Delaware Geological Survey Open File Report No. 3, 16 p.

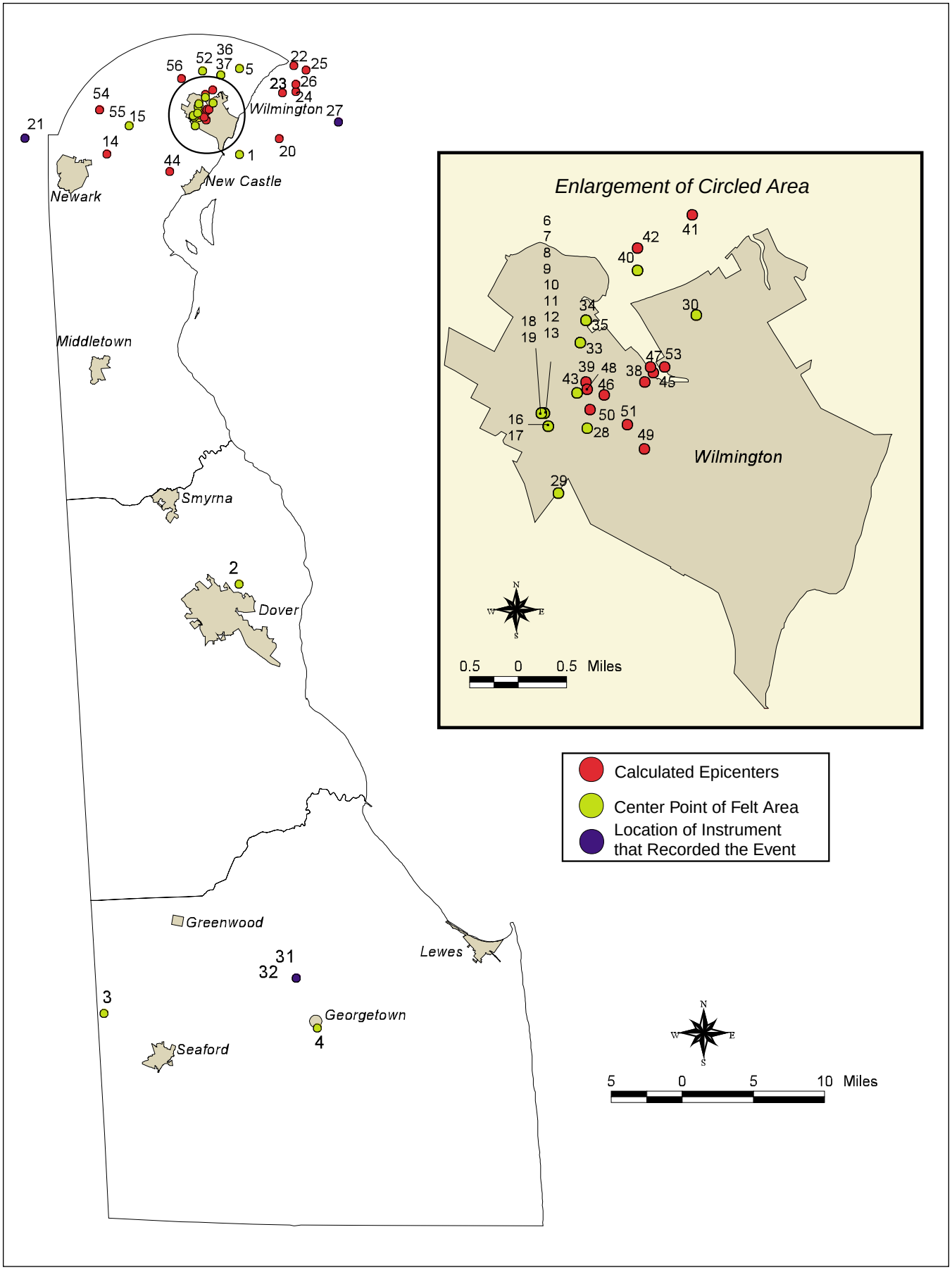

Figure 2. Locations of events listed in the Catalog of Delaware Earthquakes. Numbers refer to seismic events listed in the Appendix. For those events that do not have a calculated epicenter, either the center of the felt area or the location of the instrument that recorded the event is shown.

APPENDIX
Catalog of Earthquakes in Delaware
Explanation

Event Number is a number assigned to each event according to date and time of origin.

Date and Time (UTC) refers to Coordinated Universal Time. To convert to local time, subtract 5 hours if the event occurred during Eastern Standard Time; subtract 4 hours if the event occurred during Eastern Daylight Time. Hours are based on a 24-hour clock.

Date and Time (Local) are Eastern Standard or Eastern Daylight Time. Hours are based on a 24-hour clock.

Epicenter Latitude and Longitude are the geographic coordinates of the earthquake epicenter, if one has been calculated. Latitude is in degrees North and longitude is in degrees West. The first two digits refer to degrees, the next two refer to minutes, and the last two digits refer to seconds.

Felt Area Latitude and Longitude are the geographic coordinates of the area from which reports were received. Coordinates represent the center of the felt area.

Geographic Location is the town or area closest to where the event was felt or located.

Intensity used is the Modified Mercalli Scale as modified by Wood and Neumann (1931). By convention, Roman numerals are used to denote intensity.

Magnitude is calculated as stated in the Appendix. Several magnitude scales are represented in the list.

Data Source is the reference used for information about each event. (A) Gordon and Dewey, 1999; (B) Armbruster and Seeber, 1992; (C) DGS files; (D) Pickett, 1974; (E) Woodruff, 1984; (F) Newspaper accounts in DGS files

Event Number	Date (UTC)	Time (UTC)	Date (local)	Time (local)	Epicenter Latitude	Epicenter Longitude	Felt Area Latitude	Felt Area Longitude	Geographic Location	Intensity (Mercalli)	Magnitude	Data Source
1	10/9/1871	14:40	10/9/1871	09:40	-	-	394200	753000	Wilmington	VII	4.1	A,F
2	3/26/1879	00:30	3/25/1879	19:30	-	-	391200	753000	Dover	V	3.3	A,B,F
3	5/8/1906	17:41	5/8/1906	12:41	-	-	384200	754200	Seaford	IV	3.0	B,F
4	12/3/1937	17:15	12/3/1937	12:15	-	-	384100	752300	Georgetown	IV	2.8	D,F
5	-	unknown	1/8/1944	unknown	-	-	394800	753000	Wilmington	V	3.2	A,F
6	-	unknown	7/14/1971	unknown	-	-	394443	753410	Southwest Wilmington	III-IV	2.4	C
7	-	unknown	12/29/1971	unknown	-	-	394443	753410	Southwest Wilmington	IV-V	2.6	C
8	1/2/1972	07:08	1/2/1972	02:08	-	-	394443	753410	Southwest Wilmington	III-IV	2.4	C
9	1/2 - 1/3/1972	23:25-04:08	1/2/1972	18:25-23:08	-	-	394443	753410	Southwest Wilmington	III-IV	2.4	C
10	1/7/1972	03:45	1/6/1972	22:45	-	-	394443	753410	Southwest Wilmington	III-IV	2.4	C
11	1/22/1972	06:40	1/22/1972	01:40	-	-	394443	753410	Southwest Wilmington	III-IV	2.4	C
12	1/23/1972	01:35	1/22/1972	20:35	-	-	394443	753410	Southwest Wilmington	III-IV	2.4	C
13	1/23/1972	07:22	1/23/1972	02:22	-	-	394443	753410	Southwest Wilmington	III-IV	2.4	C
14	2/11/1972	00:16:30	2/10/1972	19:16:30	394200	754200	-	-	ENE Newark	V	3.2	A
15	2/11/1972	15:30	2/11/1972	10:30	-	-	394400	754000	Hockessin Area	III	2.9	C
16	8/14/1972	01:09	8/13/1972	21:09	-	-	394436	753407	Southwest Wilmington	III-IV	2.4	C
17	8/14/1972	01:55	8/13/1972	21:55	-	-	394436	753407	Southwest Wilmington	III-IV	2.4	C
18	11/26/1972	04:15	11/25/1972	23:15	-	-	394443	753412	Southwest Wilmington	III-IV	2.4	C
19	11/27/1972	13:46	11/27/1972	08:46	-	-	394443	753412	Southwest Wilmington	III-IV	2.4	C
20	2/28/1973	08:21:32	2/28/1973	03:21:32	394306	752624	-	-	Tri-State area, most intense Wilmington to Claymont	V-VI	3.8	A,B,D

Calculated using epicentral intensity and felt area (Sibol et al., 1987)

Calculated using wave amplitude

Calculated using signal duration (CODA) from station NED

Event Number	Date (UTC)	Time (UTC)	Date (local)	Time (local)	Epicenter Latitude	Epicenter Longitude	Felt Area Latitude	Felt Area Longitude	Geographic Location	Intensity (Mercalli)	Magnitude	Data Source
21	3/1/1973	20:57	3/1/1973	15:57	394305	754924	-	-	Aftershock - lat and long are for the instrument that recorded the event	I	-	C
22	3/2/1973	11:23:17	3/2/1973	06:23:17	394812	752506	-	-	Aftershock - Claymont Area	I	-	C
23	3/2/1973	18:57:22	3/2/1973	13:57:22	394618	752606	-	-	Aftershock - Claymont Area	I	-	C
24	3/3/1973	07:12:05	3/3/1973	02:12:05	394624	752454	-	-	Aftershock - Claymont Area	I	-	C
25	3/3/1973	16:20:28	3/3/1973	11:20:28	394754	752400	-	-	Aftershock - Claymont Area	I	-	C
26	3/3/1973	22:35:50	3/3/1973	17:35:50	394654	752454	-	-	Aftershock - Claymont Area	I	-	C
27	3/4/1973	02:56	3/3/1973	21:56	394417	752102	-	-	Aftershock - lat and long are for the instrument that recorded the event	I	-	C
28	7/10/1973	04:38:02	7/10/1973	00:38:02	-	-	394435	753340	Wilmington	IV	2.6	C
29	4/28/1974	14:19:20	4/28/1974	10:19:20	-	-	394400	753400	Wilmington	V	2.5	C
30	2/10/1977	19:14:26	2/10/1977	14:14:26	-	-	394536	753224	Wilmington	V	2.6	C
31	6/5/1977	09:47:23	6/5/1977	05:47:23	384429	752452	-	-	Near Georgetown - lat and long are for the instrument that recorded the event	-	<1.0	C
32	8/2/1977	17:29:41	8/2/1977	13:29:41	384429	752452	-	-	Near Georgetown - lat and long are for the instrument that recorded the event	-	~1.3	C
33	2/25/1980	05:44	2/25/1980	00:44	-	-	394521	753345	Wilmington	I	~1.0	C
34	11/17/1983	19:55:09	11/17/1983	14:55:09	394730	753600	394533	753341	Trolley Square area in Wilmington	V	2.9	C
35	11/17/1983	21:28:01	11/17/1983	16:28:01	394500	753400	394533	753341	Aftershock -Trolley Square area in Wilmington	-	~2.0	C
36	12/12/1983	05:15:12	12/12/1983	00:15:12	-	-	394734	753143	Northeast of Wilmington	IV	2.4	C
37	12/12/1983	16:42:52	12/12/1983	11:42:52	-	-	394734	753143	Possible aftershock	-	~1.7	C
38	1/19/1984	23:03:37	1/19/1984	18:03:37	394500	753300	-	-	Wilmington	IV	2.5	C
39	1/20/1984	00:46:13	1/19/1984	19:46:13	394500	753300	394500	753341	Wilmington	I-II	1.8	C
40	2/15/1984	12:17:54	2/15/1984	07:17:54	-	-	394600	753305	North of Wilmington	I-II	1.5	C
41	10/11/1985	01:47:51	10/10/1985	21:47:51	394605	753334	394630	753227	North of Wilmington	III-IV	1.9	C
42	10/20/1985	07:55:27	10/20/1985	03:55:27	394551	753304	394612	753305	North of Wilmington	III-IV	1.7	C
43	11/8/1993	18:47	11/8/1993	13:47	-	-	394454	753347	Wilmington	I-II	1.7	C
44	2/11/1994	15:46	2/11/1994	10:46	394048	753618	-	-	Wilmington Area	I	1.9	C
45	4/23/1994	09:09:43	4/23/1994	04:09:43	394505	753250	394505	753254	Wilmington	I-II	2.0	C
46	10/17/1995	02:12:29	10/16/1995	22:12:29	394518	753412	394453	753328	Wilmington	II	2.0	C
47	10/17/1995	08:51:43	10/17/1995	04:51:43	394522	753238	394508	753256	Wilmington	II-III	2.0	C
48	12/20/1995	16:32:03	12/20/1995	11:32:03	394511	753311	394456	753340	Wilmington	I-II	1.4	C
49	6/14/1996	03:52:11	6/13/1996	23:52:11	394428	753256	394424	753300	Wilmington	II-III	2.1	C
50	6/23/1996	19:53:11	6/23/1996	15:53:11	394442	753311	394445	753338	Wilmington	I-II	1.7	C
51	1/29/1997	03:12:29	1/28/1997	22:12:29	394438	753338	394437	753312	Wilmington	II	1.4	C
52	4/15/1997	13:29:44	4/15/1997	09:29:44	-	-	394751	753322	North of Wilmington	III-IV	1.6	C
53	3/15/1998	19:25:52	3/15/1998	14:25:52	394416	753223	394508	753246	Wilmington	III	1.8	C
54	3/19/1998	05:37:26	3/19/1998	00:37:26	394411	753214	394506	754240	Northwest of Wilmington	III	1.7	C
55	3/19/1998	06:27:55	3/19/1998	01:27:55	394404	753214	394506	754240	Northwest of Wilmington	I-II	<1.0	C
56	10/27/1998	06:41:17	10/27/1998	01:41:17	394718	753515	-	-	Near Montchanin	II	1.5	C

Calculated using epicentral intensity and felt area (Sibol et al., 1987)

Calculated using wave amplitude

Calculated using signal duration (CODA) from station NED