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New York/New Jersey Regional Seismic Network

Annual Report for April 1990–March 1991

Prepared by
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Lamont-Doherty Geological Observatory
of Columbia University

Prepared for
U.S. Nuclear Regulatory Commission

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Washington, DC 20555
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Abstract

In the last 21 years the Lamont-Doherty Observatory has studied and monitored seismicity in the northeastern U.S. for the purpose of understanding tectonic processes responsible for seismogenesis in this intraplate area and for estimating earthquake hazard. Central to this effort has been a seismic network covering most of New York State, northern New Jersey, and northern and central Vermont (generally referred to as the New York State Seismic Network (NYSSN)). Temporary networks of portable stations have also been deployed in many instances to study aftershocks or other earthquake sequences of special significance. This multi-faceted program involving both an engineering and a scientific effort has been supported primarily by the Nuclear Regulatory Commission and by the US Geological Survey. Five digital strong ground motion accelerographs are also operated as part of a program sponsored by the National Center for Earthquake Engineering.

During the period covered by this report the NYSSN continued to undergo major changes. These changes reflect three factors:

a) changes in research directions and in data requirements,

b) improvements in the available technologies;

c) reductions of the budgets for earthquake monitoring by regional networks.

Basically, a centralized telemetered network, relying primarily on very expensive dedicated phone lines, has been transformed into four sub-networks with seismic field stations radio telemetered to "smart" recording stations. These recording stations are located at Palisades, NY (L-DGO); Newcomb, NY; Middlebury, Vt (Middlebury College); and Potsdam, NY (SUNY/Potsdam).

The major research effort during this year was related to a m2.8 earthquake which occurred on October 25, 1990, near Bridgeton, NJ. In addition to providing information leading to a more accurate velocity model for central New Jersey, it also provided additional information regarding the Newark Basin Seismic Zone.

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Introduction

This report describes activity during the period April 1, 1990 through March 31, 1991. The key personnel active in this program were N. Seeber, D. H. Johnson, and J. Armbruster. The activity during this period was reduced relative to earlier periods due to reduced funding, and the lack of significant aftershock field activity. Operation of the network was supported by both the NRC and the USGS: NRC support was used primarily for continued operation, with a substantially reduced research effort, and USGS support was used primarily for network improvements, with emphasis on reducing communication costs, and integration with the new US National Seismic Network (USNSN). A substantial amount of support was provided indirectly by the USGS by assuming the cost of leased telephone lines.

During this period we completed the transformation of the network from a centralized telemetered configuration, relying primarily on expensive dedicated phone lines, into four sub-networks with seismic field stations radio telemetered to "smart" recording stations. These recording stations are located at Palisades, NY (L-DGO); Newcomb, NY; Middlebury, Vt (Middlebury College); and Potsdam, NY (SUNY/Potsdam). The total number of active stations was reduced to 28, including four operated jointly with SUNY/Potsdam. Costs for leased telephone lines were reduced from $5,546/month to $2,583/month, during this period.

The principal scientific activity during this period stemmed from a m2.8 earthquake near Bridgeton, NJ on October 23, 1990. This event provided significant additional information regarding the Newark Basin Seismic Zone, and also resulted in a revised velocity model for central New Jersey.

Technical Activities

Seismicity Monitoring:

Events recorded and analyzed during this period were:
- Regional earthquakes: 29,
- Teleseismic earthquakes: 73,
- Blasts: 725.

The seismicity for the period 4/1/90-3/31/91 is shown in **Figure 1**, and the cumulative seismicity from 1970 to 3/31/91 is shown in **Figure 2.** A summary of the time distribution of the natural source activity (regional and teleseismic) for two one year periods starting 4/1/89 and 4/1/90 is shown in **Figure 3**.

The most significant regional earthquakes during this period both occurred outside the network in October, 1990:

a m4.0 at 07:01 north of Ottawa, Canada on the 19th,

a m2.8 at 01:34 in the Bridgeton area of New Jersey on the 23rd. It was felt in the surrounding area of Cumberland and Salem counties, and Kent county in Delaware. This event occurred in an area of little seismic activity. The relatively large signal allowed us to recalculate a more accurate velocity model for southern New Jersey.

Network Configuration:

Efforts continued on upgrading, cost reduction, and decentralization of recording of the network data. We have continued to implement the network changes outlined in A New Generation Seismic Network for New York State (D.W.Simpson and D.H. Johnson, 1989):

a) maintaining network operation;

b) reducing telephone costs to satisfy USGS budget requirements;

c) reconfiguring the network in accordance with the referenced plan, with particular emphasis on compatibility with the planned US National Network.

During this period we completed the transformation of the network (**Figure 4**) from a centralized telemetered configuration, relying primarily on expensive dedicated phone lines, into five sub-networks recorded at four nodes:

Palisades, NY (L-DGO),
Newcomb, NY,
Middlebury, Vt (Middlebury College),
Potsdam, NY (SUNY/Potsdam).

The network data communication system is shown in **Figure 5.**

The total number of active stations was reduced to 28, including four operated jointly with SUNY/Potsdam. Stations AMNH and WNY were discontinued. Station operational status during this period is summarized in **Figure 6**.

Costs for leased telephone lines were reduced from $5,546/month to $2,583/month during this period (**Figure 7**), in an effort to prepare for continued operation without NRC support. Our goal is to reduce telephone costs to less than $1,000/month and bring them into the USGS cooperative agreement as a direct cost (ie. not paid for directly by the USGS).

A set of Guralp CMG-4 seismometers was put into continuous operation at the PAL station at L-DGO. Performance to date is generally satisfactory, for good units. Unfortunately, there is still considerable variation in performance from unit to unit. Widespread use of this design cannot occur until these variations are eliminated, and all units provide a uniform satisfactory level of performance. The primary problems remaining are sporadic higher than specified noise levels in horizontals, and three verticals with very high noise levels. It is anticipated that these problems will be resolved by the manufacturer.

Network Review:

A Regional Network Review was held in Reston , Va. at the USGS on August 21, 1990. Most of the seismic networks in the United States presented brief descriptions of their networks, including both operational description, research, and future plans, to a review panel. The results of that review were published by the USGS in January, 1991 as "Report of the Review Panel on Regional Seismograph Networks in the United States".

Chronological List of Activities:

4/2: New technician hired
5/15: Repaired an intermittent connection at CRNY.
6/26: serviced ECO. Installed new VCO signal mixer.
6/26: serviced GNF.
6/27: repaired seismograph display at Adirondack Museum in Blue Mountain Lake.
6/27: serviced PGY.
7/18: serviced CRNY.
7/24,25: serviced DHN, confirmed that communication problem was due to telephone company equipment malfunction.
7/24: serviced MEDY. Station vandalized; removed all equipment for repair at LDGO.
7/25: serviced WVLY.
8/14: visited MDV; major construction adjacent to station which will probably continue for 6+mon.
8/14: investigated area between Middlebury and Burlington, Vt., for radio repeater site. Mt. Philo State Park is good potential site. Visited University of Vermont.Checked radio receivers for PNY, FLET, and HBVT. Determined site changes necessary to implement radio link south to Middlebury.
8/15: serviced MIV. Not working at arrival due to premature battery failure. Measured seismometer period.
8/21: USGS Regional Network Review
9/5: serviced TBR.
9/21: serviced HBVT.
9/21: serviced PNY.
9/22: Continued search for University of Vermont to Middlebury repeater site, since Mt. Philo Park site was not available.
Completed assembly of SUN/Cutler recording system for Adirondack Ecological Center in Newcomb, NY.
10/3: reinstalled MEDY electronics
10/4: replaced amp/vco at WVLY

10/15: Installed new SUN/Cutler recording system at Adirondack Ecological Center in Newcomb, NY

10/17-19: attend ESSA meeting in Va: paper re NYSSN

10/19: m4.0 at 07:01 north of Ottawa, Canada.

10/23: r 2.8 at 01:34 in the Bridgeton area of New Jersey. Felt in surrounding area of Cumberland and Salem counties, and Kent county in Delaware. This event occurred in an area of little seismic activity. The relatively large signal allowed us to recalculate a more accurate velocity model for southern New Jersey.

10/25: serviced HMC; premature battery failure.

10/31: measured seismometer period at HMC.

11/05: discontinued leased telephone line to Newcomb, NY.

11/13,14: installed new radio communication channel between the University of Vermont and Middlebury, Vt. Installed repeater in Charlotte, Vt., in addition to new equipment at U of Vt. and Middlebury College.

12/1: Started assembly of new Sun/Cutler recording system for Middlebury College.

12/20: Removed and reinstalled HMC after calibration at LDGO.

Completed construction of new SUN/Cutler system for Middlebury College.

Started continuous recording/evaluation of CMG-4 seismometers at LDGO (PAL station).

1/17: replaced rechargeable batteries at GPD with fully charged units: solar power system working normally: low voltage due to negative power budget (not enough sunshine!).

2/5: replaced suspect amp/vco at CRNY

2/7: Installed SUN/Cutler system at Middlebury College. Rerouted FLET and HBVT signals to Middlebury (in addition to PNY signal previously rerouted).

3/12:leased telephone line from Burlington and Middlebury discontinued.. This also eliminated stations WNY and AMNH. WNY will be replaced at some future date with a station which can be radio telemetered to Middlebury directly, if feasible. AMNH will be replaced by either a radio telemetered station (very difficult in the midst of NYC), or installation of an SSA-1 recorder (as currently used by NCEER for strong ground motion measurement), if funding is available.

3/27: serviced LVNJ. Replaced amp/vco

3/29: serviced CTR

3/29: repaired signal cable at ECO. Installed new GNF receiving antenna at Adirondack Ecological Center

Research Activities

Central New Jersey Velocity Model:

Analysis of the October 23, 1990 Bridgeton, NJ earthquake resulted in a modification of the velocity model for central New Jersey. The P wave velocity was changed as shown in **Table 1.**

The basis for the change is shown in **Figure 8**, with a similar seismic section across the entire network in **Figure 9**.

The solution for the event changed

from:

origin time: 90-10-23-01:34;50.67 @ 39°32.71', 75°26.15', h=18

to:

origin time: 90-10-23-01:34:49.08 @ 39°27.14', 75°17.73', h=5

Newark Basin Seismic Zone:

Analysis of the October 23,1990 Bridgeton, NJ earthquake has also increased our knowledge of the Newark Basin Seismic Zone (NBSZ).

The Newark Basin offers the clearest example of a basin spatially associated with a prominent cluster of epicenters; the NBSZ (**Figure 10**). Most of the well-located earthquake epicenters along the Atlantic Seaboard are situated near Mesozoic rift basins and related structures (e.g., Dewey and Gordon, 1984). Many basins, however, are not associated with known seismicity. This lack of a one-to-one correlation between seismicity and Mesozoic basins may reflect still unresolved differences in the neotectonic environment and be a permanent feature of the seismicity along the Atlantic Seaboard. Alternatively, the historic pattern of seismicity results from the short coverage which is unable to sample seismic zones that are temporarily quiescent. Seismicity is known to have been low in the Coastal Plain of South Carolina for at least 80 years before the 1886 Charleston earthquake and did not highlight the 1886 source zone in the background of the southeastern Seaboard (Seeber and Armbruster, 1987). In contrast, the 1886 event was followed by a burst of seismicity continuing to the present over an area at least as large as the NBSZ. Correlation between structure and seismicity in the NBSZ is detected over dimensions on the order of 100 km. The scale of this correlation is two orders of magnitude larger than the size of ruptures inferred for the largest known earthquakes in that area. Thus, the NBSZ cannot be a transient phenomenon associated with any one of these ruptures, but, in analogy with the post-1886 South Carolina seismic zone, might represent a long lived cluster of heightened activity following a still unidentified large prehistoric earthquake.

Seismicity is concentrated around the borders of the Newark Basin, particularly around the northern half of the basin, but very few epicenters occur within it (Aggarwal and Sykes, 1978; Yang and Aggarwal, 1981; Kafka et al., 1987). As might be expected from the general lack of seismicity in the sedimentary rock of the eastern North American platform, earthquakes do not seem to occur in the shallow layer of sedimentary rock within the basin. More surprisingly, the crystalline rock below the basin is also nearly devoid of seismicity. This spatial distribution of seismicity, which seems to characterize other rift basins along the Atlantic margin as well, has not yet been satisfactorily explained.

The Newark Basin is clearly asymmetric from the structural point of view, with a border fault on the northwest side and a feather edge unconformity on the southeast side. Similarly, the seismicity is also asymmetric about the basin; two distinct sub-zones of seismicity can be recognized, one along the Hudson Highlands and Reading Prong, on the northwest side of the basin, and the other along the Manhattan Prong and extending southwest into the Piedmont of eastern Pennsylvania, on the southeast side of the basin. These two zones of seismicity are similar in the number of earthquakes but distinct on the basis of their magnitude distribution: events larger than M=3 occur primarily on the southeast side of the basin.

Most of the M≥3 epicenters fall along a broad belt that follows Cameron's Line and the Martic Line, two segments of the early Paleozoic suture along the southeastern border of the basin (**Figure 11**). A comparison between seismicity and structure at low spatial resolution could suggest a neotectonic reactivation of this major suture. Both earthquake locations and rupture geometries, however, make a direct association of known seismicity with the Paleozoic suture unlikely. The seismicity southeast of the Newark Basin includes two recent M=4.0 events, one in 1984 near Lancaster, Pa. (Armbruster and Seeber, 1987b) and the other in 1985 near the town of Ardsley in Westchester Co., N.Y. (Seeber and Armbruster 1989). The ruptures of these events, as resolved from aftershocks and focal mechanisms, strike north and northwest, respectively, at large angles to the overall strike of the seismic zone and to the strike of the Paleozoic suture.

The 1990 Bridgeton Earthquake is an additional event on the southeast side of the NBSZ for which the fault plane solution has been determined (**Figure 12**). The surface expression of the Paleozoic suture southeast of the Newark Basin is a ductile structure with no evidence of reactivation during Mesozoic rifting (e.g., Merguerian, 1986); therefore, neotectonic reactivation of this structure would seem unlikely. In contrast, the Ramapo fault, the border fault on the northwest side of the basin, is a major brittle structure superimposed on earlier ductile structures. This

fault has apparently developed over several tectonic phases since at least the early Paleozoic (Ratcliffe et al., 1986) and the issue of its neotectonic reactivation remains controversial. Despite of the lack of any positive geologic evidence, we argue in the discussion below that neotectonic reactivation should not be ruled out for this fault.

So far, compelling correlations between structure and seismicity along the Atlantic Seaboard are rare (e.g., Ebel and K[illegible] 1987). Thus, the clear correlation between seismicity and pre-existing structures that characterize the NBSZ is exceptional. This correlation is probably in part the result of unusually high rate of seismicity combined with good documentation provided by one of the longest operating regional seismic networks in the eastern U.S.; therefore, it may not reflect an intrinsic property of the Newark Basin. At least two types of interaction between seismicity and structure can be considered: *reactivation*, i.e., movement on pre-existing faults that persist as zones of weakness in the current tectonic regime, and *stress concentration*, i.e., growth and reorientation of differential stress as a result of localized stress release and anisotropic resistance to failure controlled by rock fabric and lithology. As more and better data become available, systematics in the correlation between pre-existing structure and intraplate seismicity are expected to be more widely recognized. The nature of the interaction between seismicity and geologic structure is likely to become pivotal in tectonic models of intraplate seismogenesis.

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Table 1: Central NJ Velocity Model

	Depth(km)	Vp (km/sec)
Old Model:	0	5.98
	7	6.62
	35	8.1
New Model:	0	6.4
	18	6.8
	35	8.0

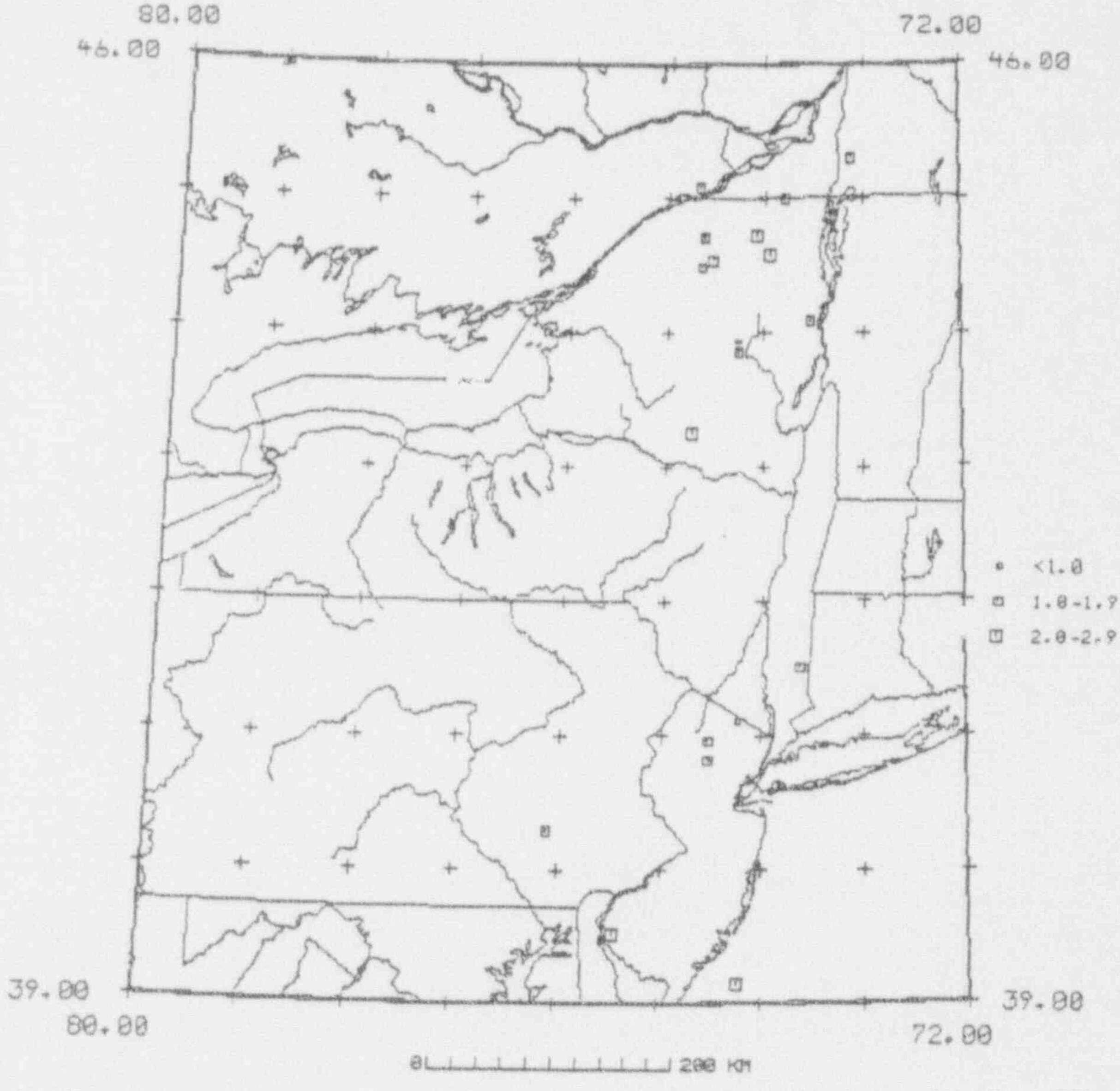


Figure 1. NYSSN Seismicity: April 1, 1990 - March 31, 1991

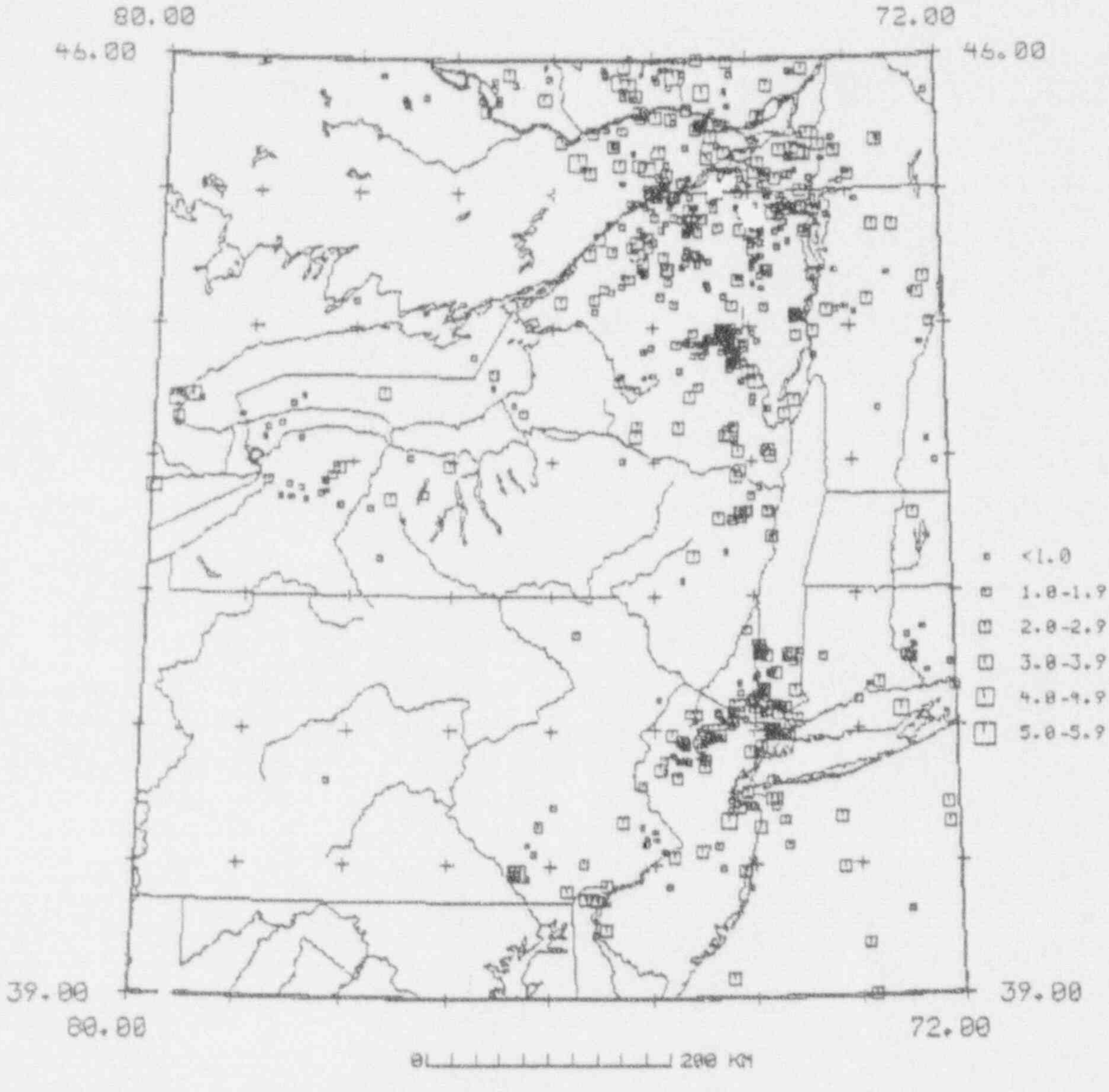
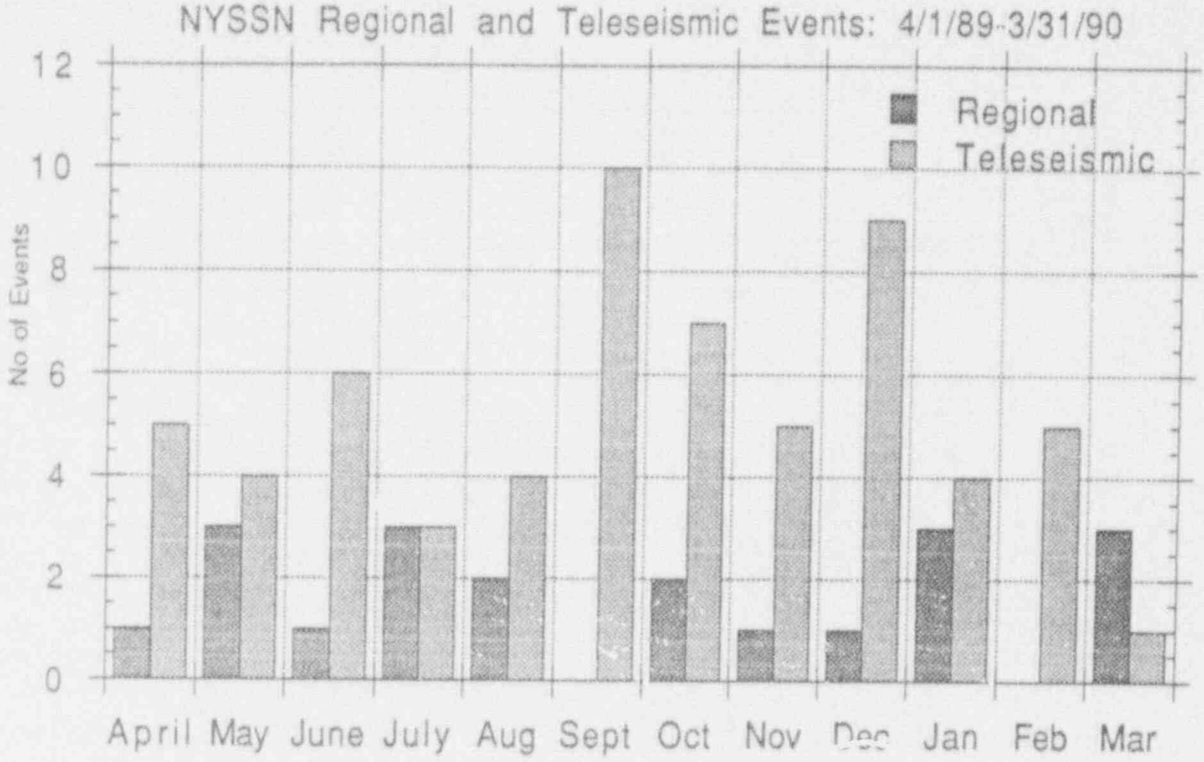


Figure 2. NYSSN Seismicity: 1970 - March 31, 1991



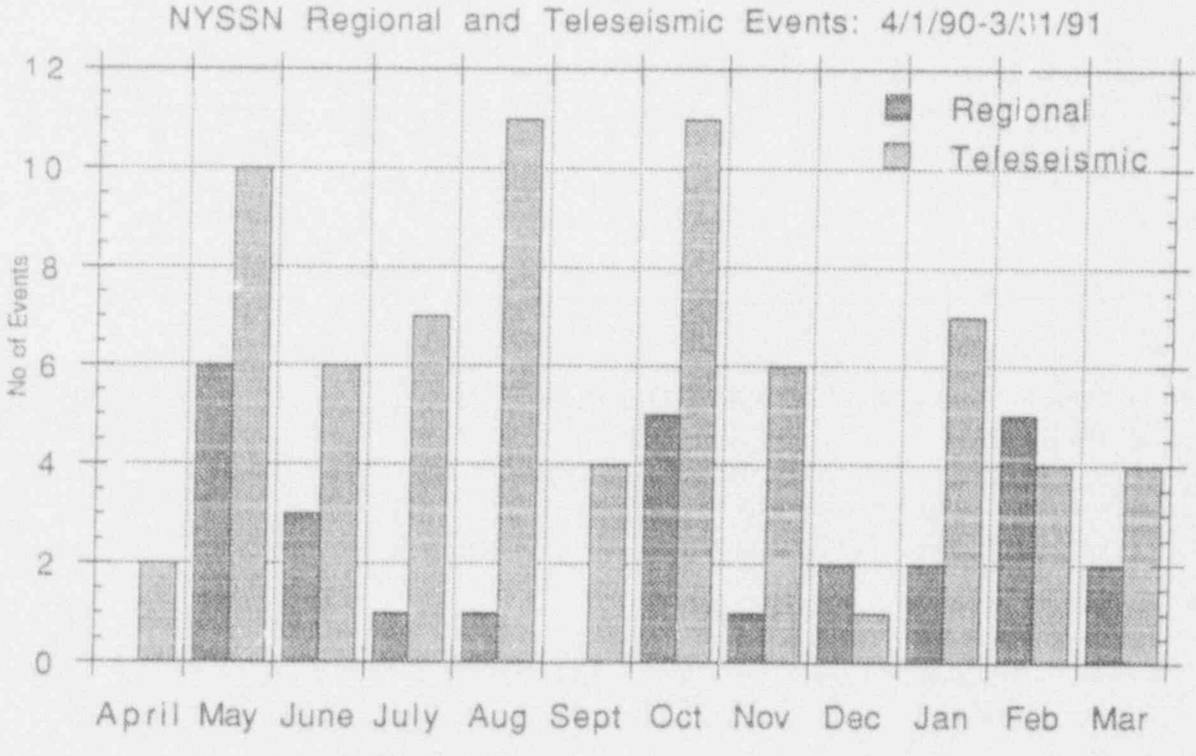


Figure 3. NYSSN Earthquake Rate from 4/1/89 to 3/31/91

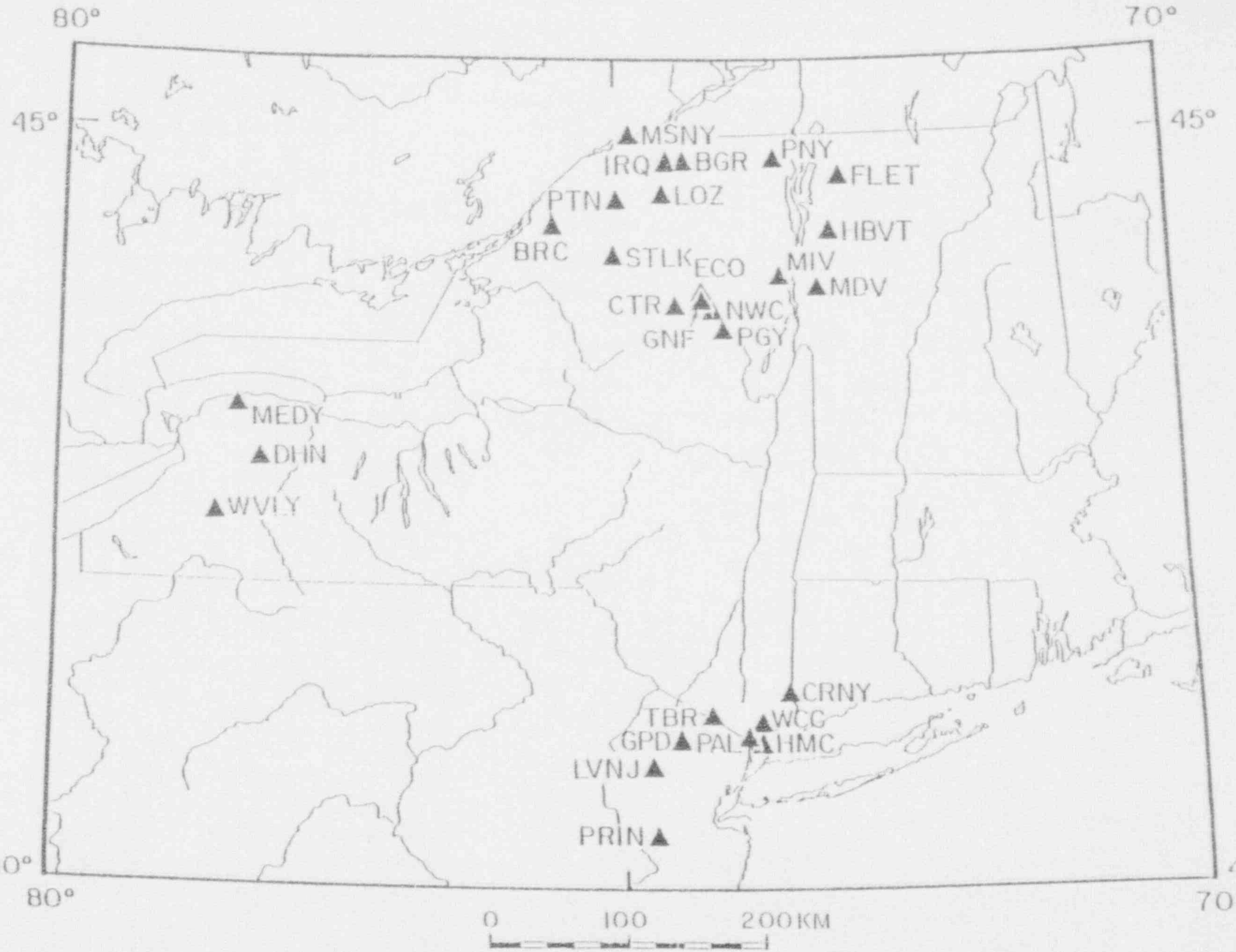


Figure 4. NYSSN Stations

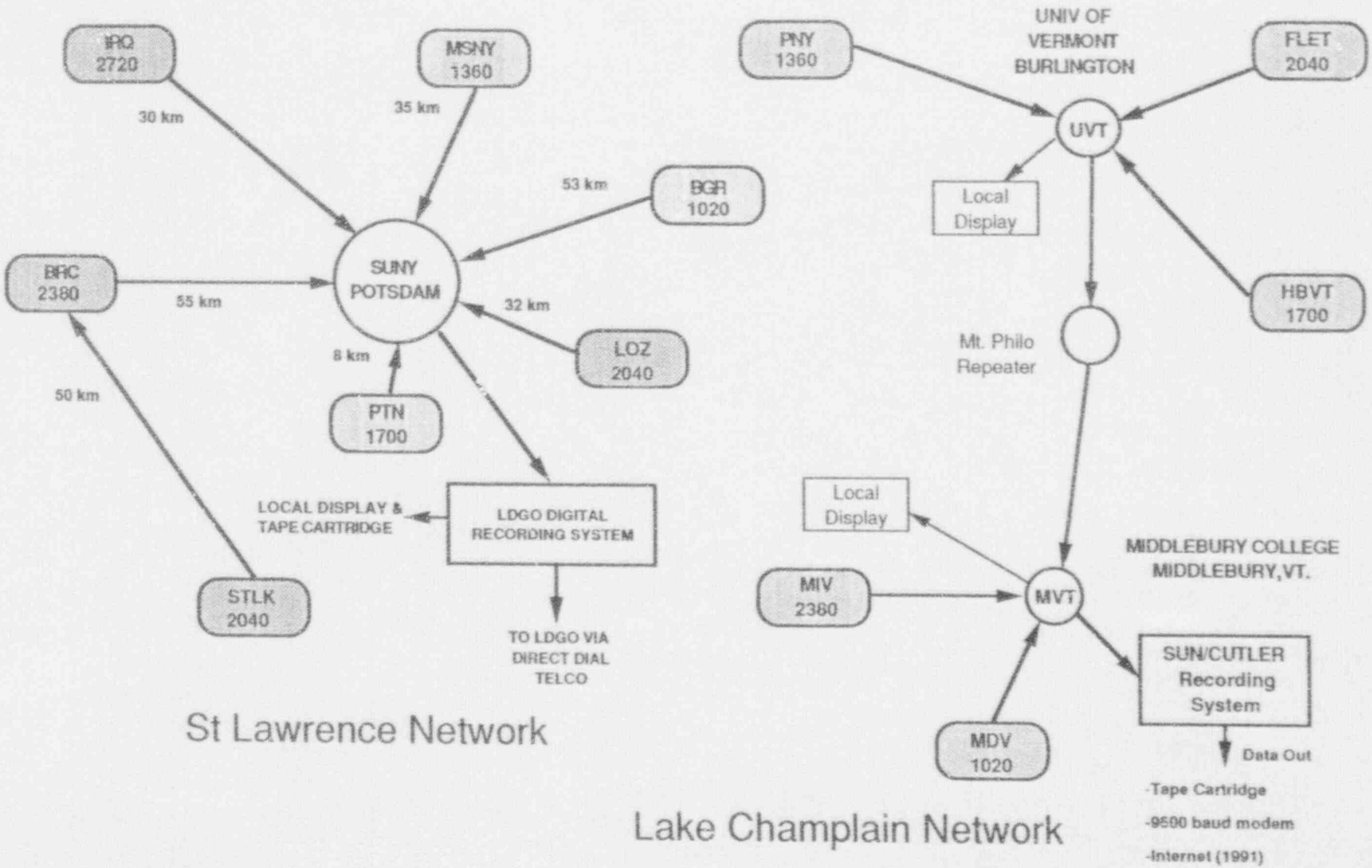


Figure 5a. NYSSN Data Communication Networks: St Lawrence & Lake Champlain

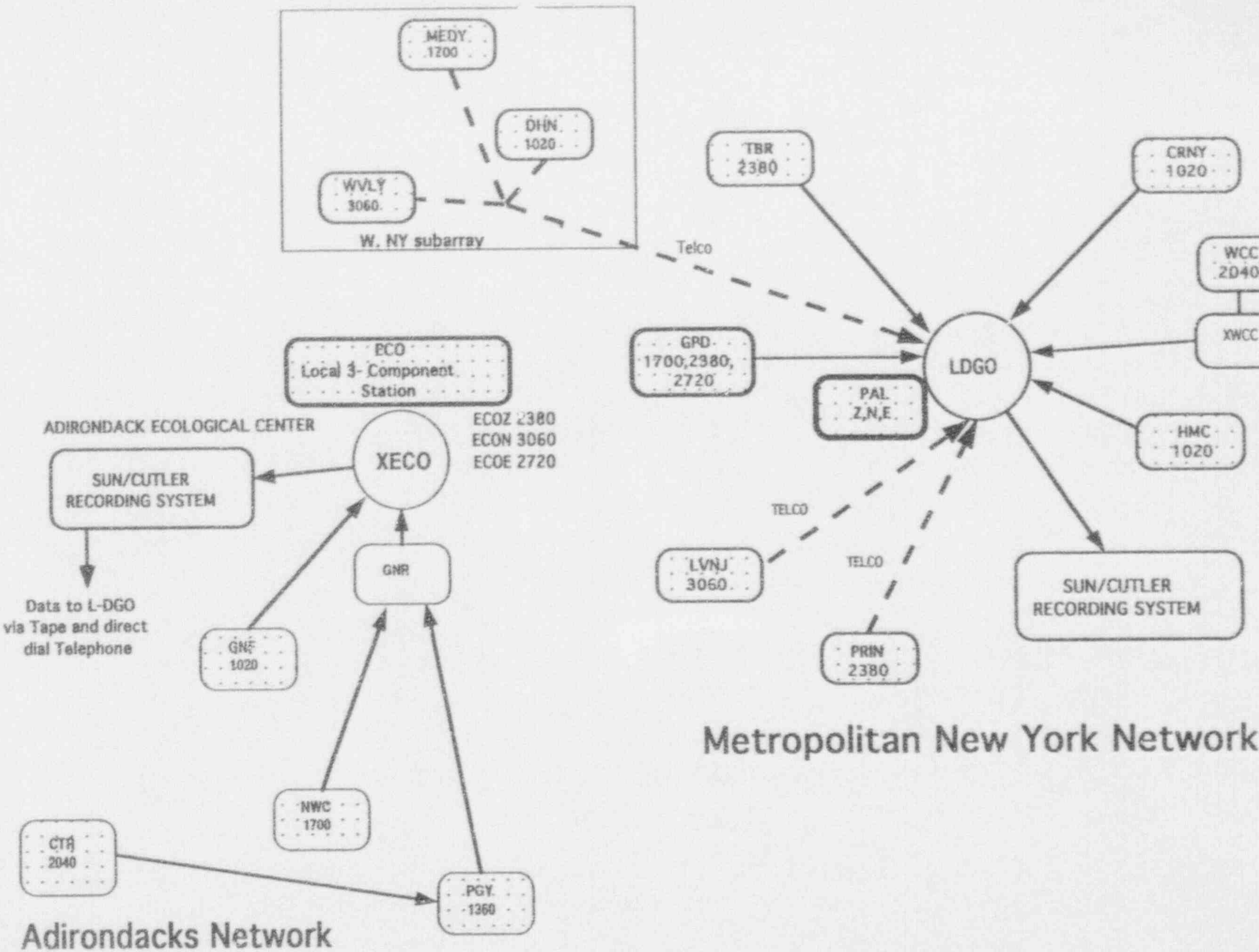


Figure 5b. NYSSN Data Communication Networks: Adirondacks and Metropolitan New York

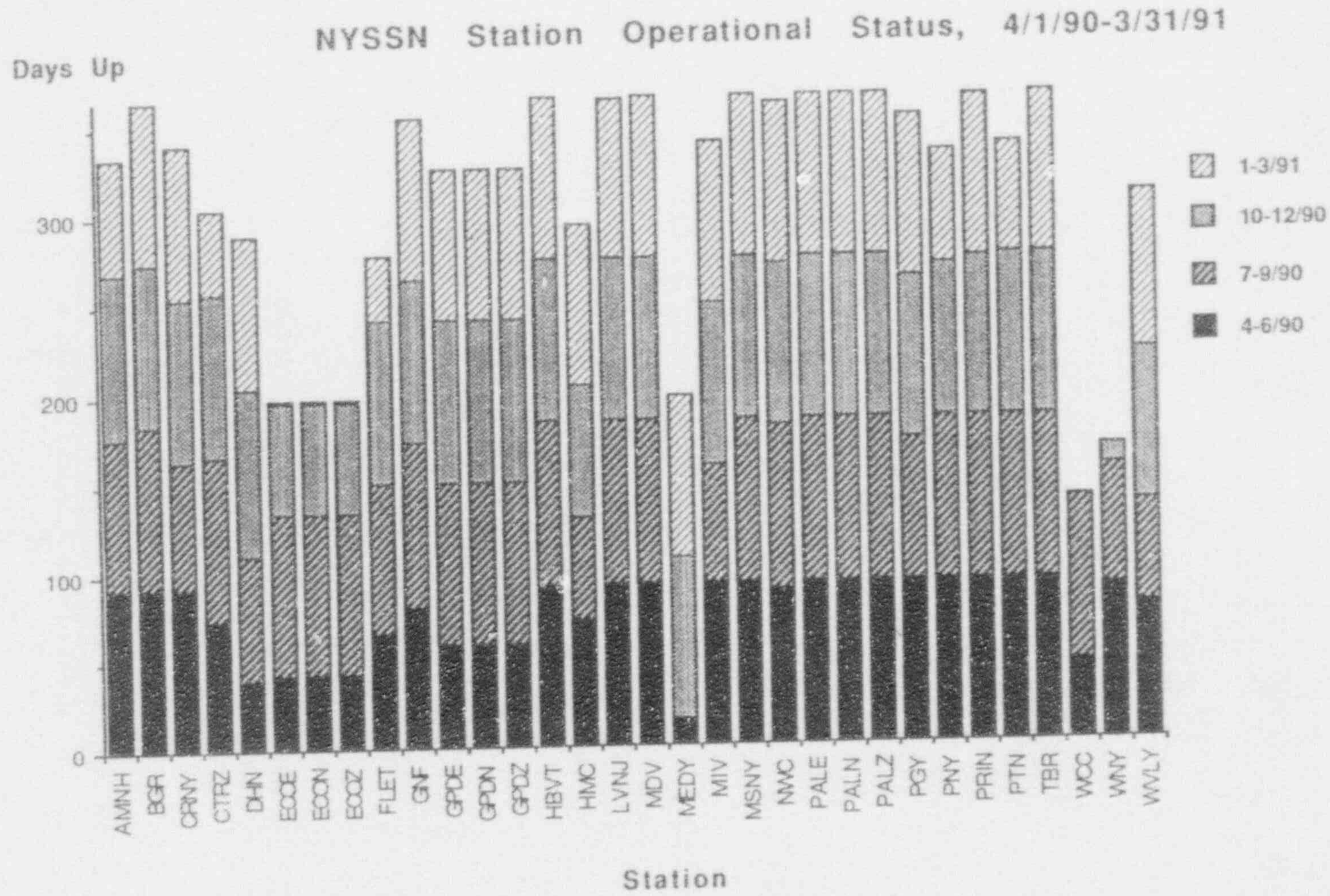


Figure 6. NYSSN Operational Status for Period 4/1/90 to 3/31/91.
WCC was deactivated on 5/14/90 as a result of nearby construction and vandalism. MEDY was vandalized, and the equipment was removed for repair 7/24/90 and reinstalled10/3/90. AMNH and WNY were discontinued in March 1991 in conjunction with elimination of leased telephone line service.

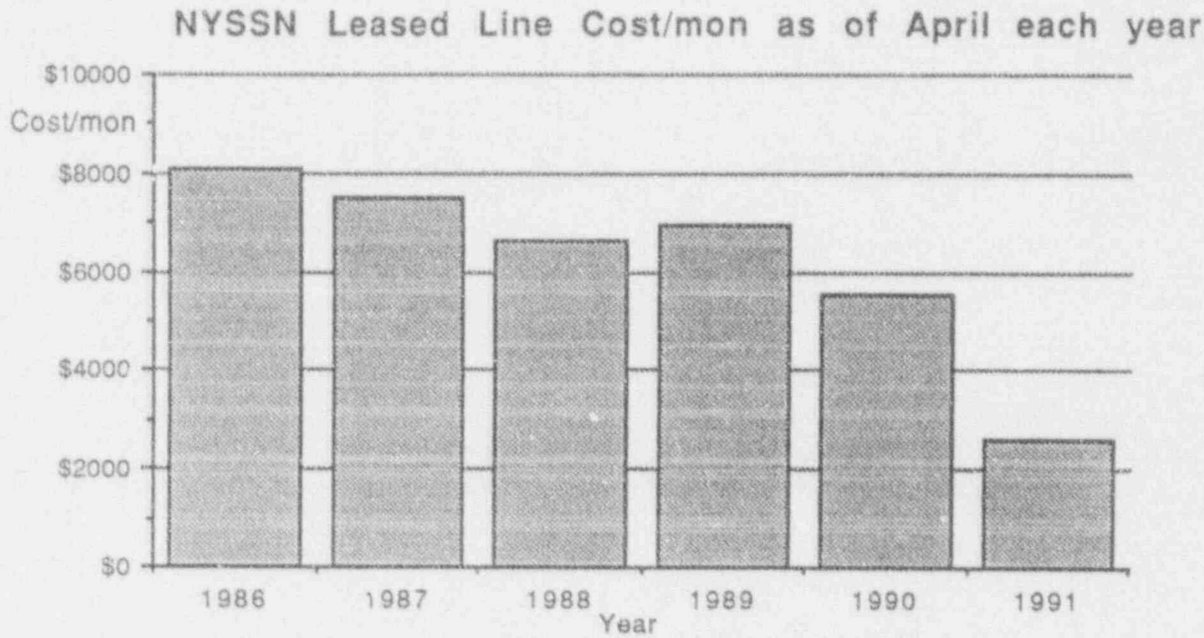


Figure 7. NYSSN Leased Telephone Line Cost History

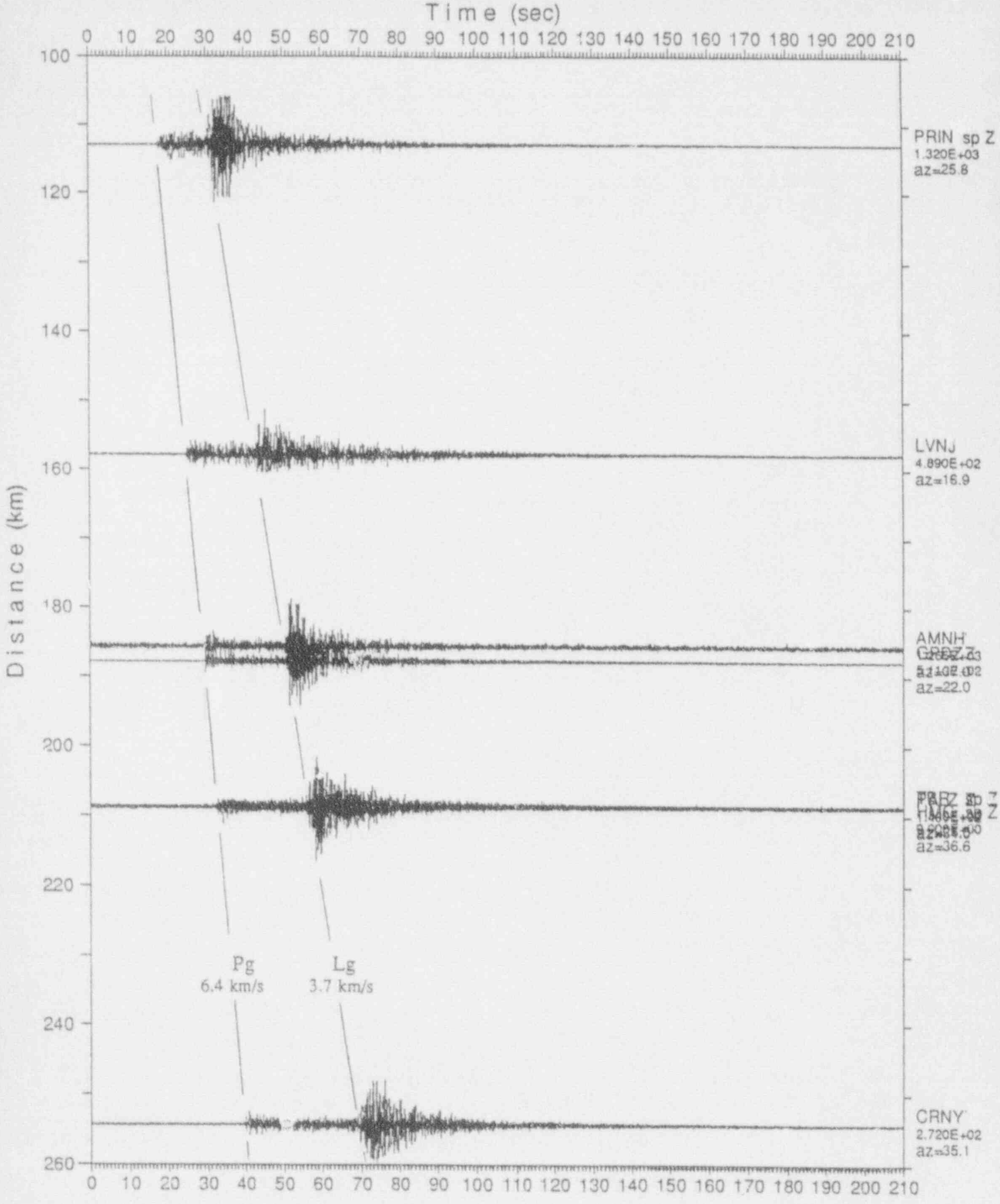


Figure 8. Seismic section of Bridgeton NJ event: metropolitan NY subnetwork

Southern New Jersey

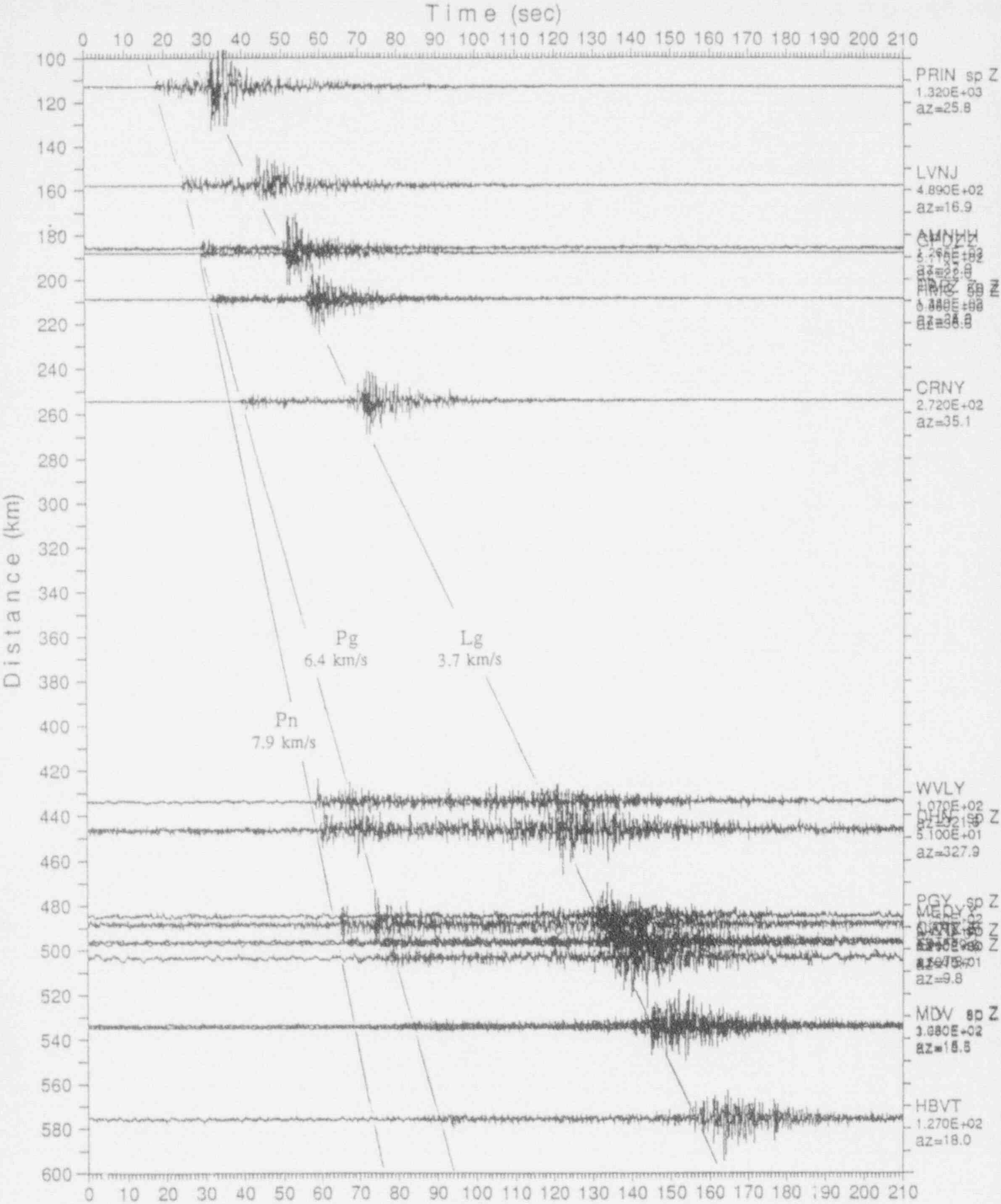


Figure 9. Seismic section of Bridgeton NJ event: entire NYSSN

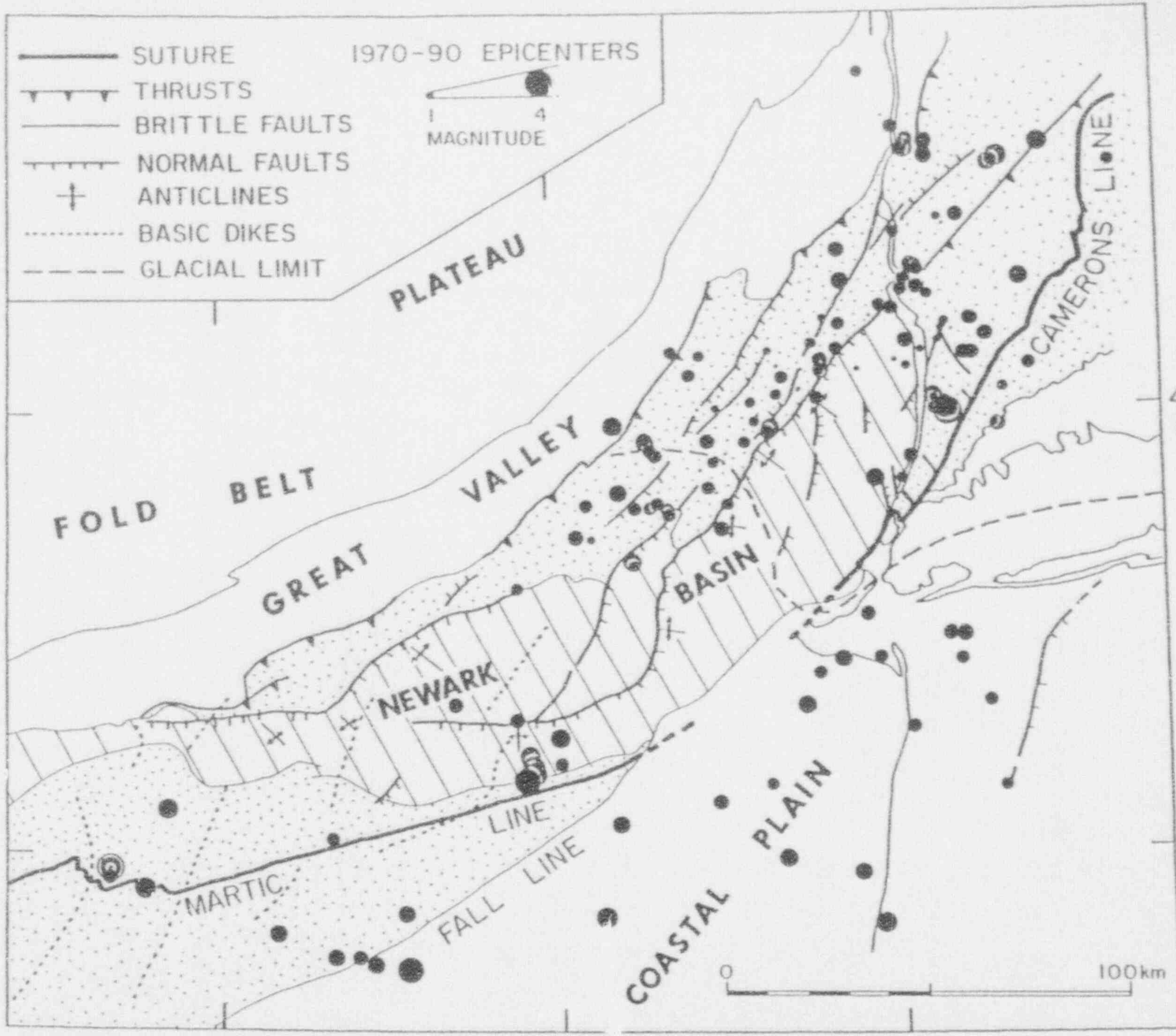


Figure 10. Newark Basin Seismic Zone: 1970-1990 Epicenters

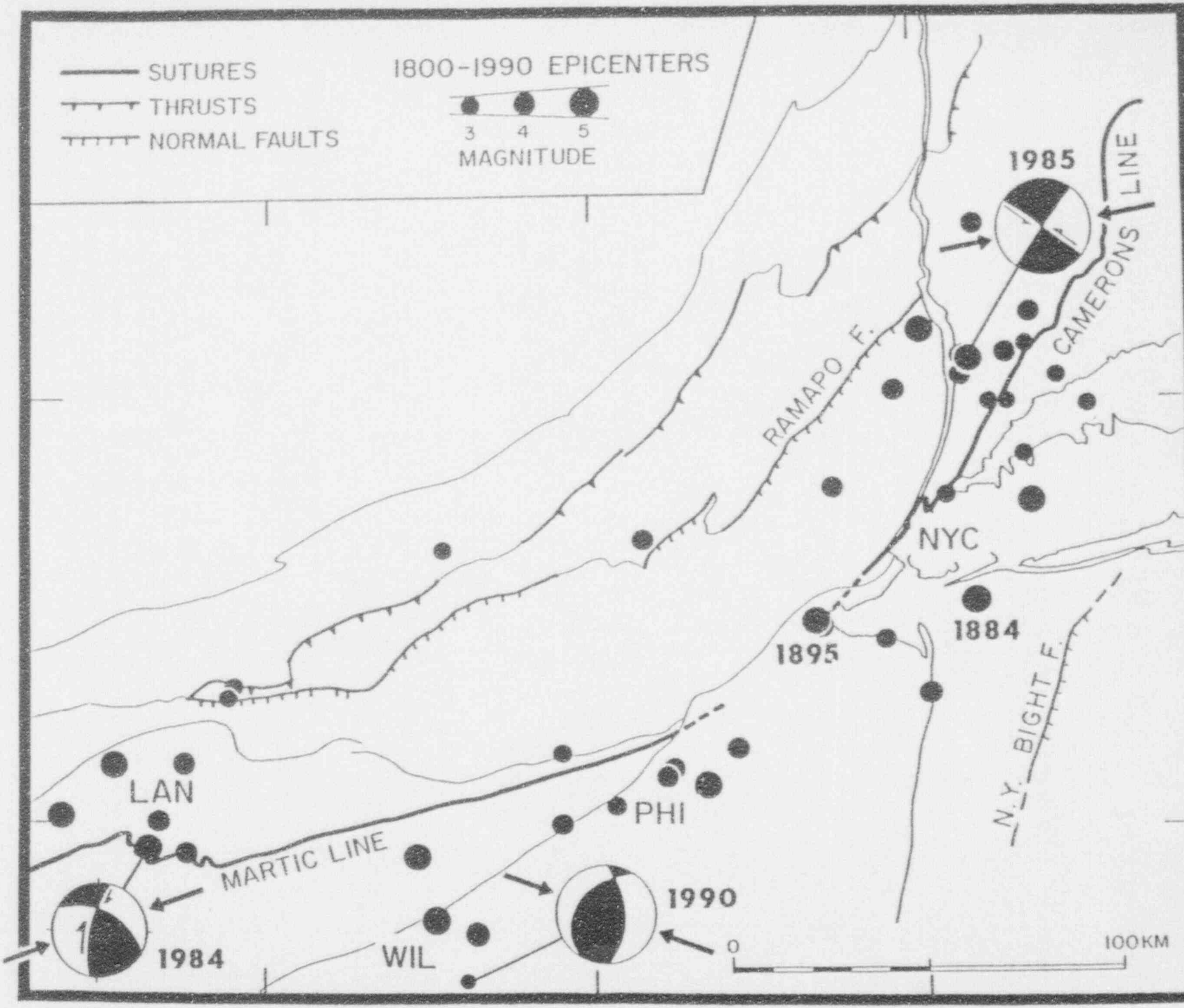


Figure 11. Newark Basin Seismic Zone: 1800-1990 Epicenters of M>3 Events

1990 10 23 1 34 49.20 sec 39.525 -75.454 5.00 km 0.0

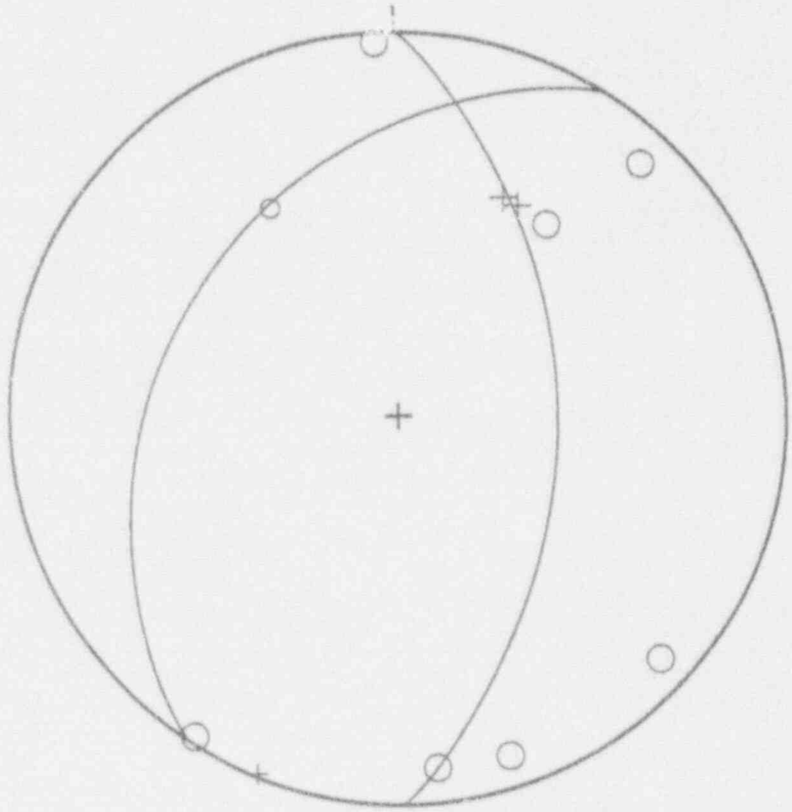


Figure 12. Bridgeton, NJ event Fault Plane Solution

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

In the last 21 years the Lamont-Doherty Observatory has studied and monitored seismicity in the northeastern U.S. for the purpose of understanding tectonic processes responsible for seismogenesis in this intraplate area. Central to this effort has been a seismic network covering most of New York State, northern New Jersey, and northern and central Vermont. Temporary networks of portable stations have also been deployed to study aftershocks or other earthquake sequences of special significance. This program has been supported primarily by the Nuclear Regulatory Commission and by the U.S. Geological Survey. Five digital strong ground motion accelerographs are also operated as part of a program sponsored by the National Center for Earthquake Engineering. The previously centralized network has been transformed into four cost effective sub-networks with seismic field stations radio telemetered to "smart" recording stations. The major research effort during this year was related to an m2.8 earthquake which occurred on October 25, 1990, near Bridgeton, N.J. The earthquake provided a more accurate velocity model for central New Jersey and additional information regarding the Newark Basin Seismic Zone.

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