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Geophysical Investigations of the Western Ohio-Indiana Region

Annual Report
October 1986 - September 1987

Prepared by S. Y. Schwartz, D. H. Christensen, T. Lay, B. P. Cohee

Department of Geological Sciences
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Previous Reports

Four major reports concerning this investigation were published under previous contract NRC 04-76-192:

Mauk, F.J., D. Coupland, D. Christensen, J. Kimball, P. Ford, 1979, Geophysical Investigations of the Anna, Ohio, Earthquake Zone: Annual Progress Report for the U. S. Nuclear Regulatory Commission, July 1978-July 1979, NUREG/CR-1065.

Mauk, F.J., S.G. Henry, D.H. Christensen, J. Sauber, C. Lanford, W. Meerschaert, J.K. Kimball, 1980, Geophysical Investigations of the Anna, Ohio, Earthquake Zone: Annual Progress Report for the U. S. Nuclear Regulatory Commission, July 1979-1980, NUREG/CR-1649.

Mauk, F.J., D.H. Christensen, 1980, A Probabilistic Evaluation of Earthquake Detection and Location Capability for Illinois, Indiana, Kentucky, Ohio and West Virginia: Report for the U. S. Nuclear Regulatory Commission, September 1980, NUREG/CR-1648.

Jackson, P.L., D.H. Christensen, F.J. Mauk, 1982, Geophysical Investigations of the Western Ohio - Indiana Region: Final Report for the U. S. Nuclear Regulatory Commission, November 1975-September 1981, NUREG/CR-2484.

Five reports were published under contract NRC-04-81-195-04:

Christensen, D.H., M.G. Wiedenbeck, P.L. Jackson, 1983, Geophysical Investigations of the Western Ohio - Indiana Region: Annual Report for the U. S. Nuclear Regulatory Commission, October 1981-September 1982, NUREG/CR-3145, Vol.1.

Pollack, H.N., D.H. Christensen, 1984, Geophysical Investigations of the Western Ohio - Indiana Region: Annual Report for the U. S. Nuclear Regulatory Commission, October 1982-September 1983, NUREG/CR-3145, Vol. 2.

Pollack, H.N., D.H. Christensen, 1985, Geophysical Investigations of the Western Ohio - Indiana Region: Annual Report for the U. S. Nuclear Regulatory Commission, October 1983-September 1984, NUREG/CR-3145, Vol. 3.

Pollack, H.N., D.H. Christensen, J. Welc, 1986, Geophysical Investigations of the Western Ohio - Indiana Region: Annual Report for the U. S. Nuclear Regulatory Commission, October 1984-September 1985, NUREG/CR-3145, Vol. 4.

Christensen, D.H., H.N. Pollack, T. Lay, S.Y. Schwartz, 1987, Geophysical Investigations of the Western Ohio - Indiana Region: Final Report for the U. S. Nuclear Regulatory Commission, October 1981-September 1986, NUREG/CR-3145, Vol. 5..

Abstract

Earthquake activity in the Western Ohio - Indiana region has been monitored with a precision seismograph network consisting of nine stations located in west-central Ohio and four stations located in Indiana. One local and eleven near-regional earthquakes have been recorded during this report period. The local event had a duration magnitude of 0.7 and was not large enough to be felt. Its location is very close to the larger (m_b= 4.5) 12 July 1986 St. Marys, Ohio earthquake. Many of the regional events were felt with magnitudes ranging from m_bLg = 2.7-4.9. The two largest of these events (27 March 1987 in northeastern Tennessee, m_bLg = 4.2, and 10 June 1987 in southeastern Illinois, m_bLg = 4.9) had minor damage reported in each case. P_n travel time residuals, computed for all well-recorded regional events since deployment of the Anna Seismic Network, display a strong azimuthal dependence with positive residuals (slow observed arrival times) obtained from events with northeasterly through southerly back azimuths and negative residuals (fast observed arrival times) from events with westerly back azimuths. This pattern has larger residuals, but is similar to the azimuthal dependence displayed in the teleseismic P-wave residuals, supporting an interpretation that shallow structural heterogeneity is responsible for the P_n residual pattern.

Summary

During the period from October, 1986 through September, 1987 the Western Ohio - Indiana network has been operational an average of 89% of the time. Changes in the array include the replacement of the Teledyne Geotech S-500 geophones with the original Mark Products L-4C geophones at six of the nine Ohio stations. The return to the L-4C geophones was necessitated by continual water leakage into the S-500 geophone connectors which rendered them inoperable.

One local and eleven near-regional earthquakes have been recorded during this year. These events range in magnitude from 0.7 to 4.9 m_bLg. The two largest of these events (27 March 1987 in northeastern Tennessee, $m_bLg = 4.2$, and 10 June 1987 in southeastern Illinois, $m_bLg = 4.9$) were felt with minor damage reported in each case. The focal mechanism for the southern Illinois event represents strike-slip motion on a NW-SE or SW-NE nodal plane with the horizontal compressional stress axis oriented E-W. This mechanism is very similar to other solutions obtained for earthquakes occurring in the Anna Seismic Zone.

A total of 54 local and near-regional events have been recorded by the Ohio-Indiana array since its deployment in 1976. The only local event recorded this year was located very close to the St. Marys, Ohio event of 12 July, 1986 ($m_b = 4.5$). The occurrence of the 1986 St. Marys event suggests that the proposed Anna-Champaign fault is the source of the larger events in the Anna area (see discussion in Appendix A).

Travel time data from regional earthquakes have been analyzed to gain insight into the local velocity structure. P_n travel time residuals computed for the largest of the 54 regional earthquakes recorded by the Anna array, show a strong azimuthal dependence. Events located to the northeast through south of the Anna Network stations have late P_n arrivals, while events to the west have early arrivals compared with theoretical times calculated for a two crustal layer model. The data are consistent with teleseismic P-wave residuals which have been extensively discussed in previous reports.

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PREFACE

This is the first annual report under the two year contract NRC-04-86-122, a continuation of the effort funded under contracts NRC-04-76-192 and NRC-04-81-195-04. The contract includes maintenance and systematic processing of a nine-station seismic array in western Ohio initiated in 1976, and the subsequent expansion in 1981 to include a four-station array in Indiana. Portions of this report have been taken directly from earlier reports for completeness. We wish to express our appreciation to Scott Baird for keeping a wide range of instruments and computer peripherals in constant working condition, and to Judi Sheridan, and Aden Medal for their help in successfully operating the seismic network.

I
THE WESTERN OHIO - INDIANA SEISMIC ARRAY

The Western Ohio - Indiana seismic network currently consists of thirteen local and one regional (ACM) short period vertical stations. The thirteen local stations are formed by the original nine stations of the Anna, Ohio network, fully operational since June 1978, and a sub-network of four stations located in Indiana which were installed in February 1981. Locations, elevations, magnifications and other station information are listed in Table 1 and the station locations are shown in Figure 1.

Some field equipment deployed in the array was replaced in 1984 in an attempt to improve data quality. The original Mark Products L-4C, 1 hz geophones and Interproducts Amplifier/VCO (Voltage Controlled Oscillators) were replaced by Teledyne Geotech S-500 geophones and Teledyne Geotech 42.50-1 and 46.22 VCO/amplifier systems. However, this new configuration proved to be unsatisfactory due to difficulties encountered in preventing water leakage into the new geophones. In order to alleviate the water leakage problems, we replaced the Teledyne Geotech S-500 geophones with the original Mark Products L-4C geophones at six of the nine Ohio stations. The instrument design for the nine west-central Ohio stations are schematically illustrated in Figure 2a. The data from these stations are transmitted by radio to a central tower at Wapakoneta, Ohio. The four Indiana stations are designed as shown schematically in Figure 2b and the data transmitted by telephone link to the receiving facility at Wapakoneta, Ohio. The receiving facility at Wapakoneta, Ohio is shown schematically in Figure 2c. At this facility, signals from the thirteen Ohio and Indiana stations are multiplexed onto three trunk lines and transmitted to the recording facility at the University of Michigan in Ann Arbor, Michigan. The recording facility is shown schematically in Figure 2d. Individual station data are discriminated from the multiplexed signal and recorded at the University of Michigan.

The full system response curve for the three Ohio stations (AN7, AN8, and AN9) for which the Teledyne Geotech S-500 geophones are still operational is shown in the unity gain curve in Figure 3a. The response curve for the Indiana stations, and the regional station, ACM is shown in Figure 3b. The response of the six remaining Ohio stations (AN1, AN3, AN4, AN10, AN11, and AN12), for which the Mark Products L-4C geophones are used, is identical to the Indiana stations response in the frequency band between 0.4 - 50 Hz. Outside of this band the response falls off slightly faster than indicated in Figure 3b. The curves in Figure 3 represent the response of the system using a 12.5 hz low

TABLE 1

STATION CHARACTERISTICS OF THE OHIO-INDIANA SEISMIC ARRAY

Station Code	Lat.°N	Long.°W	Elevation (Feet)	Displacement Gain (Peak)	Carrier (MHz) (x1000)	Subcarrier (Hz)
AN1	40.4792	84.1309	1003.	246.7	164.0093	1700
AN3	40.5489	83.8121	1070.	246.7	165.8093	1400
AN4	40.2222	83.8978	1134.	493.5	173.1940	1400
AN7	40.8235	83.8602	922.	493.5	171.4060	1700
AN8	40.2441	84.2860	992.	246.7	166.4218	680
AN9	40.7118	84.4967	835.	246.7	167.8090	2040
AN10	40.4729	84.4700	901.	246.7	167.1937	1020
AN11	40.5638	84.6804	895.	246.7	166.6565	1020
AN12	40.9217	84.1823	741.	493.5	163.7937	2040
IN1	40.542	85.894	837.	342.6	phone line	680
IN2	39.939	86.783	872.	342.6	phone line	1020
IN3	39.265	85.785	722.	342.6	phone line	1400
IN4	39.570	84.903	1025.	342.6	phone line	1700
ACM	42.6475	85.8517	880.	342.6	phone line	1700

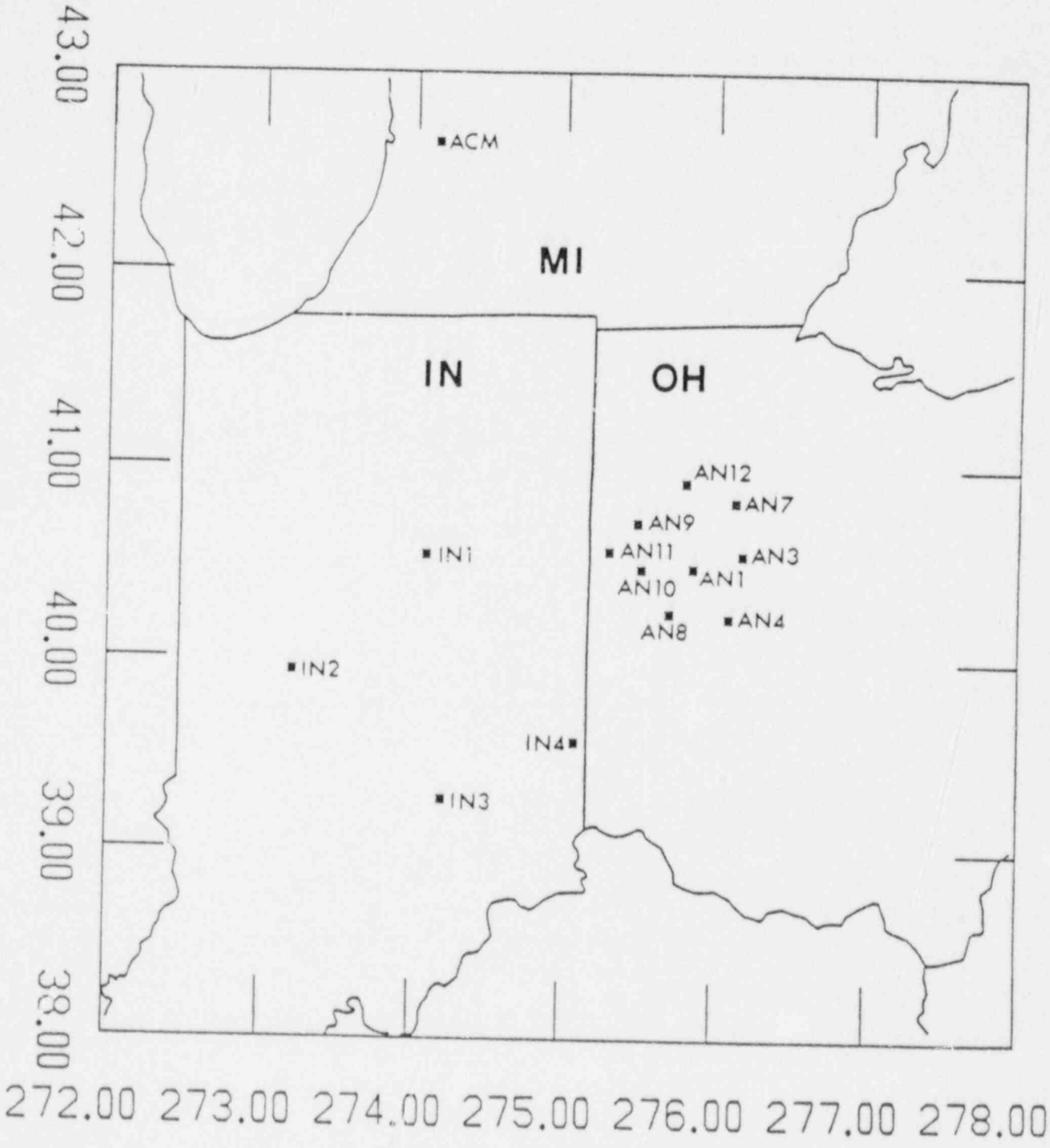

Figure 1. Station Locations for the Ohio-Indiana Seismic Array.

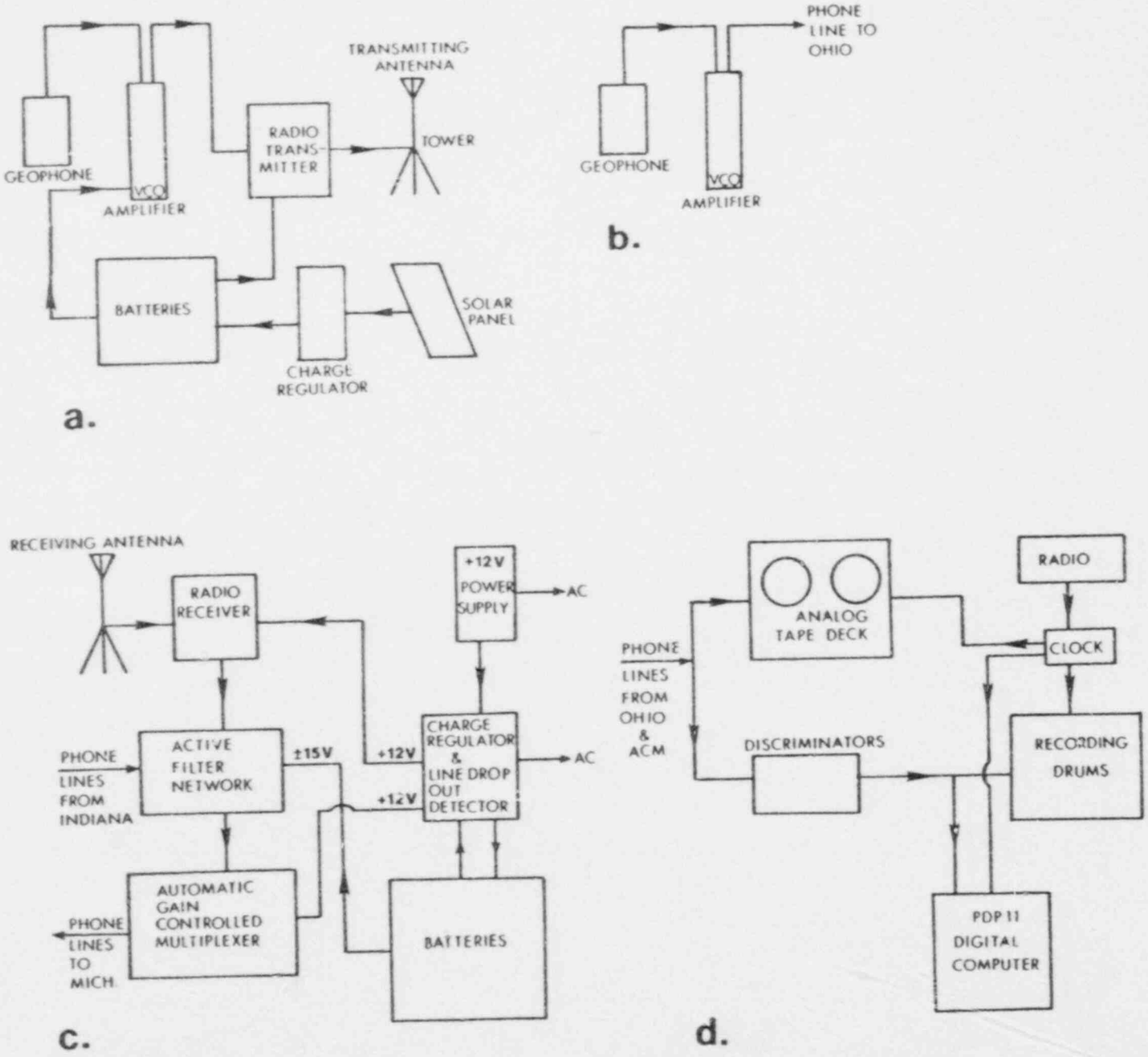

Figure 2. Schematics of Field Installations, Multiplexing and Recording Facilities (see legend, following page).

a. GEOPHONE - Teledyne S-500, 1 Hz, or Mark Products L-4C, 1 Hz
AMPLIFIER VCO - Teledyne 42.50-1 and 46.22
RADIO TRANSMITTER - Delco Radio Transmitter
TRANSMITTING ANTENNA - Db Products, 7db gain antenna
TOWER - TRI-X radio tower
Batteries - GNB-Absolite, 12 volt, 100 AH
CHARGE REGULATOR - Solarex SR012075AF, 75 watts
SOLAR PANEL - Solarex 6600/12 Solar cell system
with 66 watts DC peak power output

b. GEOPHONE - Mark Products L-4C, 1 Hz, 0.7 critical
damping
AMPLIFIER VCO - Interproducts

c. RECEIVING ANTENNAS - Db Products, 7 db gain antennas,
mounted on a 300 foot tower
RADIO RECEIVERS - Repco Radio Receiver
ACTIVE FILTER NETWORK
AUTOMATIC GAIN CONTROLLED (AGC) MULTIPLEXER
POWER SUPPLY - Power Mate PT 15 C.
CHARGE REGULATOR
BATTERIES - MDP5 NICAD

d. ANALOG TAPE DECK - Hewlett-Packard 3964A
DISCRIMINATORS - Teledyne Geotech 46.12
RADIO - Kinemetrics Model WVTR Mark IV
CLOCK - Teledyne Geotech TG-120
RECORDING DRUMS - Sprengnether, VR-65-3 (3) and
VR-55-3 (2)
PDP 11 DIGITAL COMPUTER - DEC PDP-11 Model 23 Minclab
digital computer

Figure 2 (Legend)

Response Curve	Pen Amplifier Setting	Peak Magnification
(a)	100 mv/mm	493.5k
(b)	100 mv/mm	342.6k
(c)	100 mv/mm	85.7k

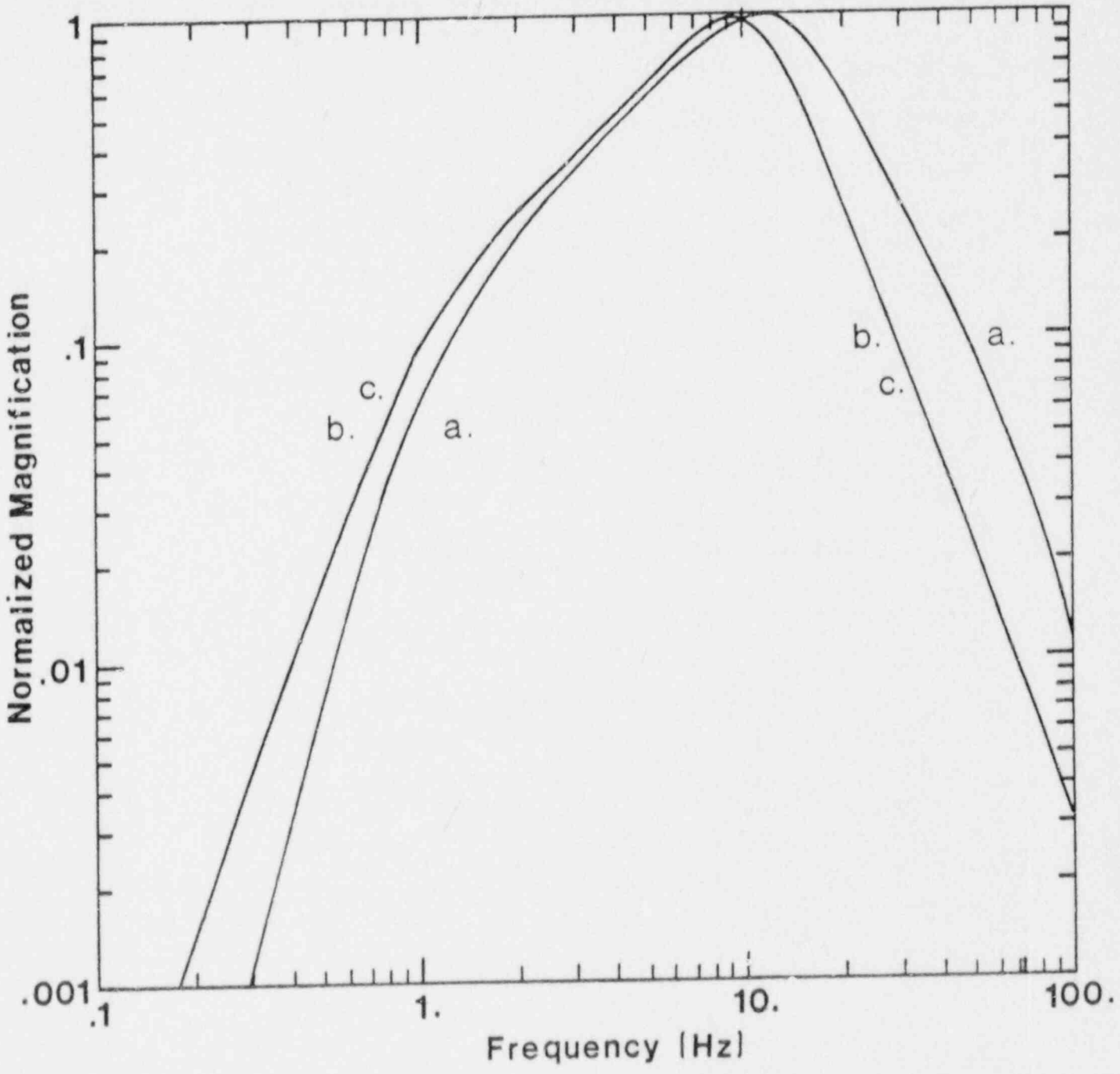

Figure 3. Normalized System Frequency Responses for
(a) Ohio stations - S-500 seismometer,
(b) Indiana stations and ACM- L-4C seismometer,
(c) Ohio stations -L-4C seismometer.

pass filter, which is used for the visual pen-and-ink recordings.

During the last fiscal year (October 1986 - September 1987) the stations have been operational approximately 89% of the time. Individual station reliability data averaged for each month of the fiscal year are given in Table 2. Detailed daily station up-times for the fiscal year (October 1986 - September 1987) are listed in Appendix B. The downtime reflected in the aforementioned reliability data includes both periods of instrumental failures (e.g. mechanical breakdown) and periods in which the records were not interpretable due to other factors (e.g. weather, cultural noise, etc.).

Further descriptions of the Anna array instrumentation can be found in previous annual progress reports by Mauk et al. (1979, 1980), Jackson et al. (1981), and Christensen et al. (1983).

II
LOCAL AND NEAR-REGIONAL EVENTS

During the report period (October 1986 - September 1987) one local and eleven regional earthquakes were recorded by the Anna Seismic Network. The location of these events are shown in Figure 4, and their origin times, epicenters, and estimated magnitudes listed in Table 3. The one local earthquake recorded by the array, occurred on 17 November 1986 and was located near the town of St. Marys, Ohio. This same region experienced a larger earthquake on 12 July 1986 (m_b= 4.5) and two small earthquakes on 10 March 1985. This cluster of activity falls on the proposed Anna-Champaign Fault and together with the 17 June 1977 event and the historical events of 1931 and 1937, form a NW-SE linear trend of seismicity (Figure 5). This emerging linear pattern of seismicity and the occurrence of the larger St. Marys event with a possible nodal plane paralleling the Anna-Champaign Fault, suggests that this structure may be a dominant control on earthquake occurrence in the Anna region (see Appendix A).

The regional events recorded by the Anna Array include four events in northeastern Ohio (hypocentral parameters obtained from John Carroll University), three events in southeastern Illinois (St. Louis University), two events in northeastern Tennessee (Center for Earthquake Research and Information), one event in southeastern Ohio (University of Kentucky), and one event in northeastern Missouri (St. Louis University). The two largest events (27 March 1987 in northeastern Tennessee, m_bLg =4.2, and 10 June 1987 in southeastern Illinois, m_bLg =4.9) were widely felt with minor damage reported in each case. The focal mechanism of

TABLE 2

STATION RELIABILITY DATA (%)

Monthly Summary	Stations AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM	Monthly Total
OCT 1986	98	100	98	96	100	16	100	100	99	99	96	100	96	95	92
NOV 1986	98	100	100	100	100	100	99	100	99	95	1	100	96	93	92
DEC 1986	70	99	100	100	99	72	100	99	99	100	0	95	99	100	88
JAN 1987	41	57	60	93	99	99	99	99	99	99	0	99	99	99	82
FEB 1987	48	89	99	99	96	98	100	61	97	95	0	95	97	98	84
MAR 1987	89	94	94	91	95	100	99	44	98	99	67	98	98	100	90
APR 1987	96	95	98	99	99	92	100	96	99	98	86	65	96	98	94
MAY 1987	96	96	96	99	100	96	99	94	100	100	100	0	100	54	88
JUN 1987	100	100	99	99	100	97	99	99	99	100	62	27	99	90	91
JUL 1987	100	100	100	100	100	92	100	99	100	100	100	95	99	89	98
AUG 1987	90	98	73	39	100	94	99	97	99	74	99	58	99	99	87
SEP 1986	86	100	100	97	100	78	100	100	100	100	97	72	58	99	92
Station Total	85	94	91	90	99	87	94	90	99	93	58	76	97	93	Total 89

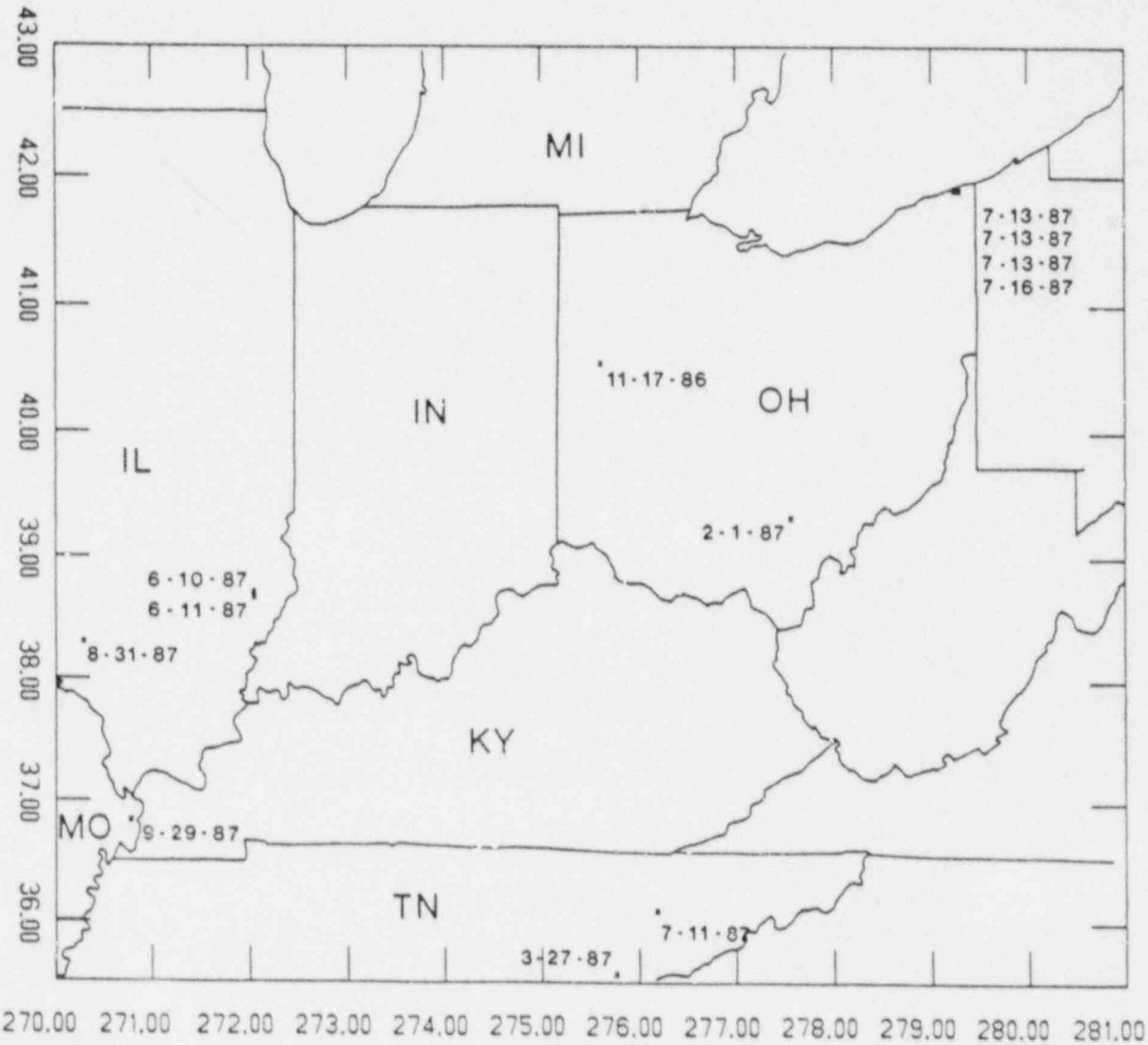

Figure 4. Local and Near-Regional Earthquake Locations from October, 1986 Through September, 1987.

TABLE 3
LOCAL AND REGIONAL EVENTS FROM
JUNE 1977 THROUGH SEPTEMBER 1987

No	Date Year	Mo	Da	Origin Time Hr Mi Sec (GMT)	Location Lat. °N	Long. °W	Magnitude (duration)	Depth (km)
1	1977	06	17	15:39:47.3	40.57	84.67	3.3 m_b	--
				15:39:46.9	40.705	84.707	(Dewey and Gordon, 1984)	
2	1979	11	09	21:29:58.7	38.417	82.869 (NEIS)	3.6 m_{bLg}	--
3	1980	07	10	11:40:53.3	40.415	84.111	0.9	--
4	1980	07	27	18:52:21.7	38.18	83.94	5.1 m_b	15
5	1980	08	20	09:34:54.0	41.97	82.99 (Revised)	3.2 m_{bLg}	--
6	1980	09	26	12:27:25.6	40.430	84.085	0.5	--
7	1980	10	04	11:46:58.0	39.80	83.75	2.0	--
8	1980	12	10	02:30:54.3	40.43	84.11	1.2	--
9	1981	01	04	07:17:37.1	40.418	84.087	1.8	5-7
10	1981	02	07	05:45:43.0	40.417	84.087	1.8	5-7
11	1981	03	15	03:46:30.3	41.10	84.35	1.2	--
12	1981	05	15	23:15:14.0	40.88	84.34	0.8	--
13	1981	05	19	05:56:11.7	40.407	84.085	1.2	2-8
14	1982	11	26	08:25:04.9	42.17	85.48	2.0-2.5	--
15	1983	01	12	02:49:41.1	39.28	84.60	1.9	--
16	1983	01	22	07:46:59.3	41.86	81.16	2.7 m_{bLg}	--
17	1983	07	05	02:58:52.9	40.43	84.10	2.1	5-7
18	1983	07	13	01:17:34.8	40.43	84.10	1.4	--
19	1983	09	30	02:33:44.8	41.59	84.33	1.3	--
20	1983	11	04	21:00:59.8	40.43	84.10	0.4	--
21	1983	11	04	22:50:00.5	40.43	84.10	0.9	--
22	1983	11	05	02:36:35.8	39.68	85.73	1.1	--
23	1983	12	03	21:29:41.0	42.70	88.30	1.4	--
24	1983	12	07	22:57:01.6	41.70	83.50	1.1	--
25	1983	12	10	19:01:55.2	40.43	84.11	0.7	--
26	1984	01	03	07:57:58.6	40.42	84.11	0.4	--
27	1984	01	14	20:14:32.5	41.67	83.45 (Revised)	2.6 m_b	--
28	1984	07	28	23:39:27.3	39.27	87.09	4.0 m_{bLg}	--
29	1984	08	29	06:50:59.0	39.25	87.50	3.2 m_{bLg}	--
30	1984	08	29	18:56:27.2	39.09	87.69	2.7 m_{bLg}	--
31	1985	03	10	20:46:01.1	40.52	84.39	1.4	--
32	1985	03	10	20:49:14.1	40.52	84.40	1.7	--
33	1985	03	17	11:57:06.7	39.65	83.46	1.9	--
34	1985	04	14	11:39:51.3	41.40	80.37	2.0	--
35	1985	08	25	14:30:01.6	38.54	84.98	1.6	--
36	1985	08	25	16:27:11.9	40.97	84.22	1.5	--
37	1985	09	09	22:06:31.0	41.850	88.006 (NEIS)	3.0 m_{bLg}	--
38	1986	01	12	11:38:50.2	40.77	83.27	0.8	--
39	1986	01	13	11:39:20.4	40.80	84.13	0.5	--

No	Date Year	Mo	Da	Origin Time Hr	Mi	Sec (GMT)	Location Lat. °N	Long. °W		Magnitude (duration)	Depth (km)
40	1986	01	31	16:46:41.4			41.59	81.21	(NEIS)	5.0 m_b	--
41	1986	03	30	07:42:42.1			41.37	83.67		1.4	--
42	1986	07	12	08:19:39.5			40.55	84.39	(Revised)	4.5 m_b	5
43	1986	11	17	07:03:04.6			40.55	84.37		0.7	--
44	1987	02	01	12:01:55.7			39.23	82.43	(UK)		
45	1987	03	27	07:29:30.5			35.57	84.23	(CERI)	4.2 m_{bLg}	19
46	1987	06	10	23:48:54.0			38.80	87.90	(NEIS)	4.9 m_b	5
47	1987	06	11	00:15:50.0			38.87	87.95	(SLU)		
48	1987	07	11	00:04:29.5			36.10	83.82	(CERI)	3.6	
49	1987	07	13	05:49:18.9			41.90	80.73	(JCU)	3.8 m_{bLg}	2
50	1987	07	13	07:52:12.2			41.90	80.70	(JCU)	3.0 m_{bLg}	2
51	1987	07	13	13:05:23.1			41.91	80.75	(JCU)	2.9 m_{bLg}	2
52	1987	07	16	04:49:40.3			41.91	80.75	(JCU)	2.7 m_{bLg}	2
53	1987	08	31	17:12:35.2			38.30	89.71	(SLU)	3.1 m_{bLg}	9
54	1987	09	29	00:04:57.5			36.84	89.21	(SLU)		

NEIS: National Earthquake Information Service
CERI: Center for Earthquake Research and Information
UK : University of Kentucky
SLU : St. Louis University
JCU : John Carroll University

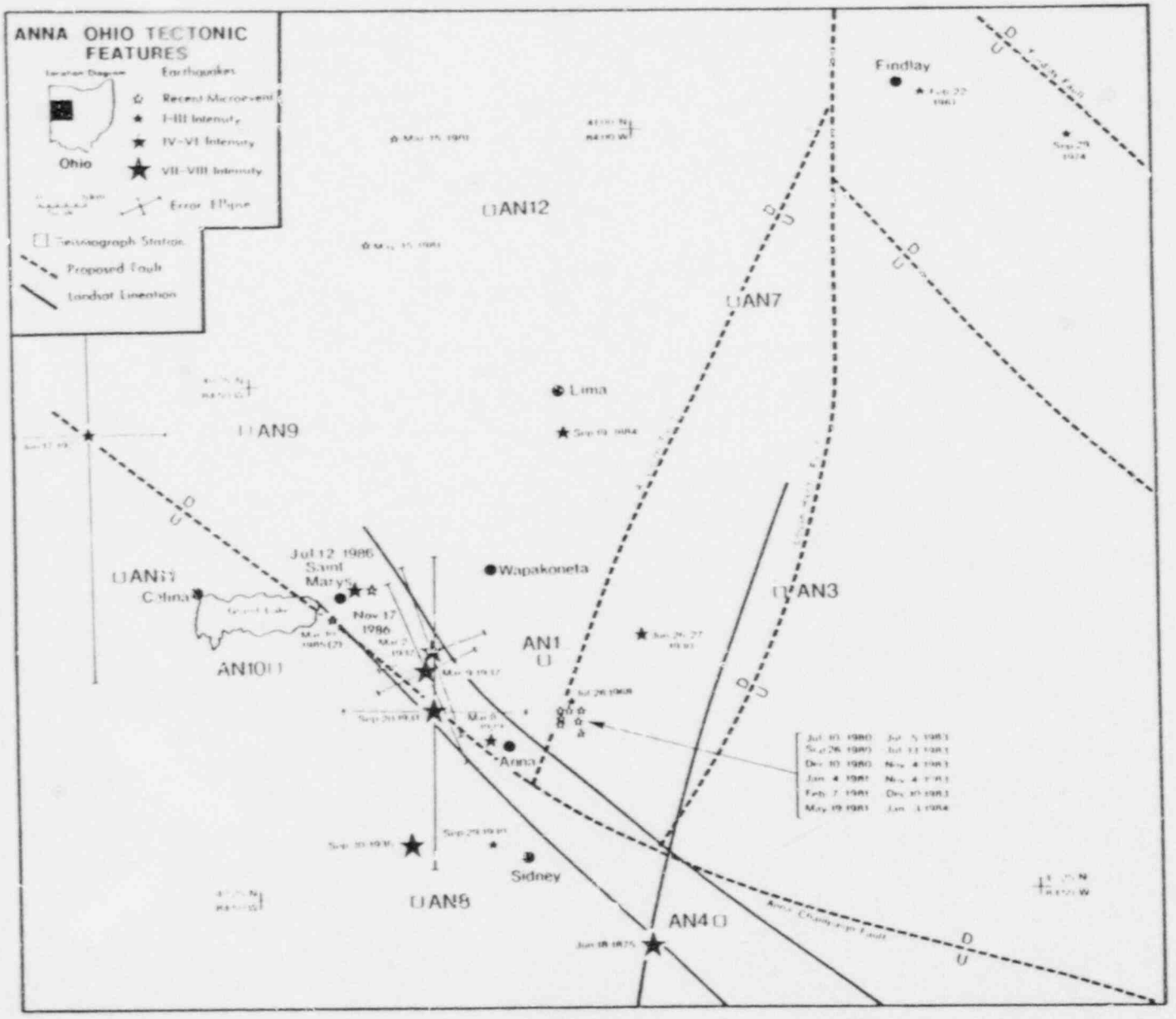

Figure 5. The Anna, Ohio Seismic Zone, Historical Seismicity, Proposed Faults, and Observed LANDSAT Lineaments.

the 10 June 1987 event was determined by St. Louis University and represents strike-slip motion on a NW-SE or SW-NE nodal plane with a nearly horizontal p-axis oriented east-west. This solution is similar to many of the larger events in this region (e.g., 12 July 1986 St. Marys, Ohio event, 31 January 1986 Perry, Ohio event, and the 27 July 1980 Sharpsburg, Kentucky earthquake).

There have been a total of 54 local and near-regional events that have been well-recorded by the Ohio - Indiana array since its initiation in 1976. A complete listing of their dates, origin times, locations and magnitudes can be found in Table 3; the events are displayed in Figure 6. The arrival times recorded by the Anna stations for the events in Table 3 are listed in Appendix C of this report.

III
P_n AND TELESEISMIC P-WAVE RESIDUALS

P_n arrival times have been tabulated for six regional events recorded this past year and for four of the larger regional events recorded since 1979. The arrival times for each of these events can be found in Appendix C. The geographic distribution of these ten events produces arrivals with differing azimuths and epicentral distances with respect to the array, allowing for an investigation of the variations in shallow regional velocity structure. Figure 7 shows the epicentral locations of the ten events used in the P_n analysis. These locations were determined by other workers (see Appendix C) and are not dependent on arrival times recorded by our array stations. P_n residuals (observed time minus predicted) have been determined for all arrivals using the velocity model of Nuttli et al.(1969) appropriate for the central United States. This velocity model consists of two 20 km thick crustal layers with P-wave velocities of 6.15 and 6.70 km/s, overlying the mantle. The mantle is modeled with a P-wave discontinuity at 57 km with a velocity change from 8.18 to 8.37 km/s.

The P_n residuals are tabulated in Table 4, and show a range of values between +3.0 and -1.9 s. Averaged arrivals from individual stations show no distinct pattern, however a strong azimuthal dependence is apparent. Earthquakes with northeasterly through southerly back azimuths have positive residuals (slow arrival times) which decrease in amplitude in a clockwise direction, while events with westerly back azimuths have negative residuals (fast arrival times). P_n residuals for all the events have been azimuthally averaged in 30° bins and plotted on a polar plot in Figure 8. Although there is sparse azimuthal coverage, with no data in the northwest quadrant, there is a clear azimuthal pattern of large positive residuals to the northeast, smaller

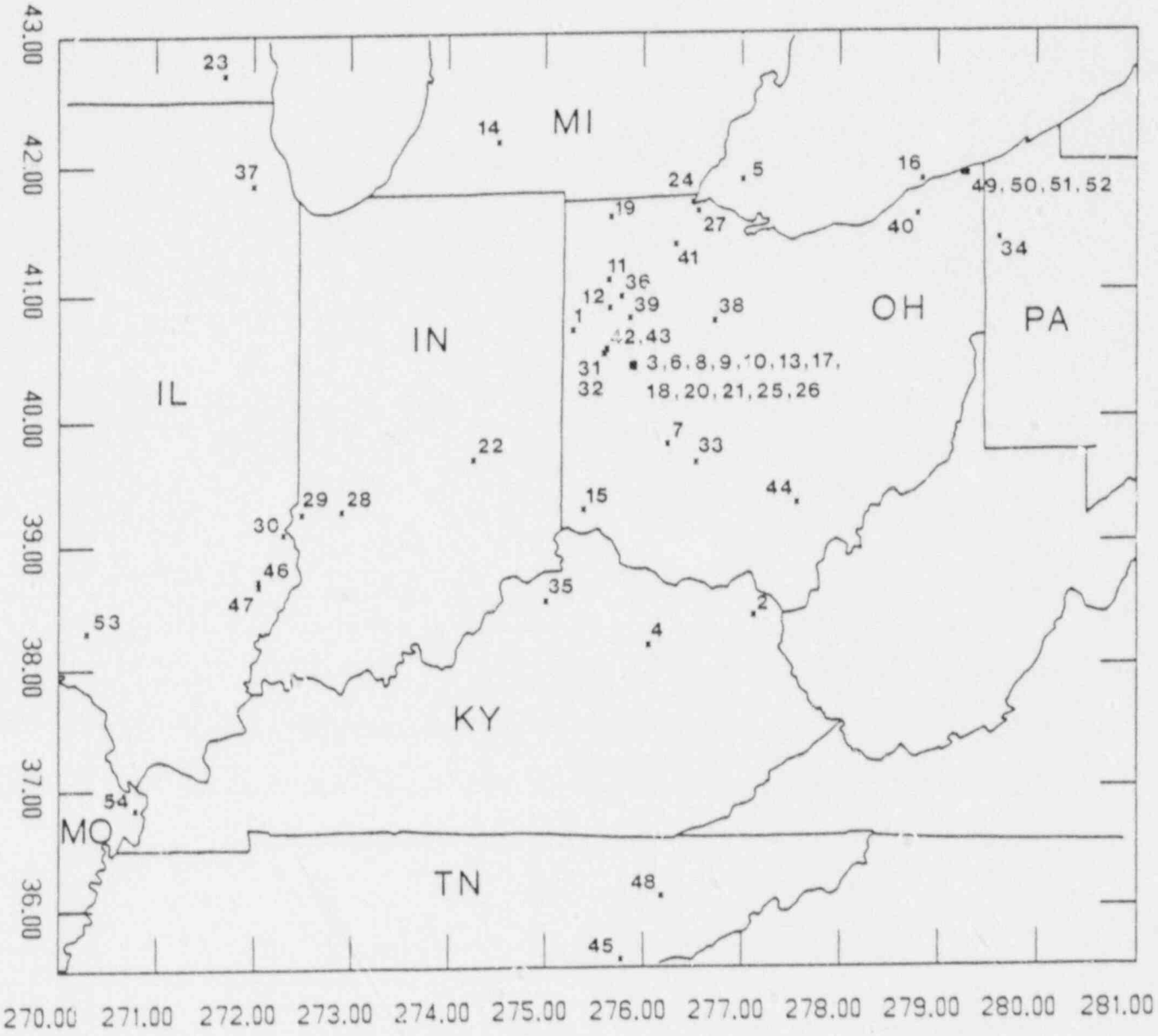

Figure 6. Local and Near-Regional Earthquake Locations from July, 1977 Through September, 1987. Numbers Correspond to Events Listed in Table 3.

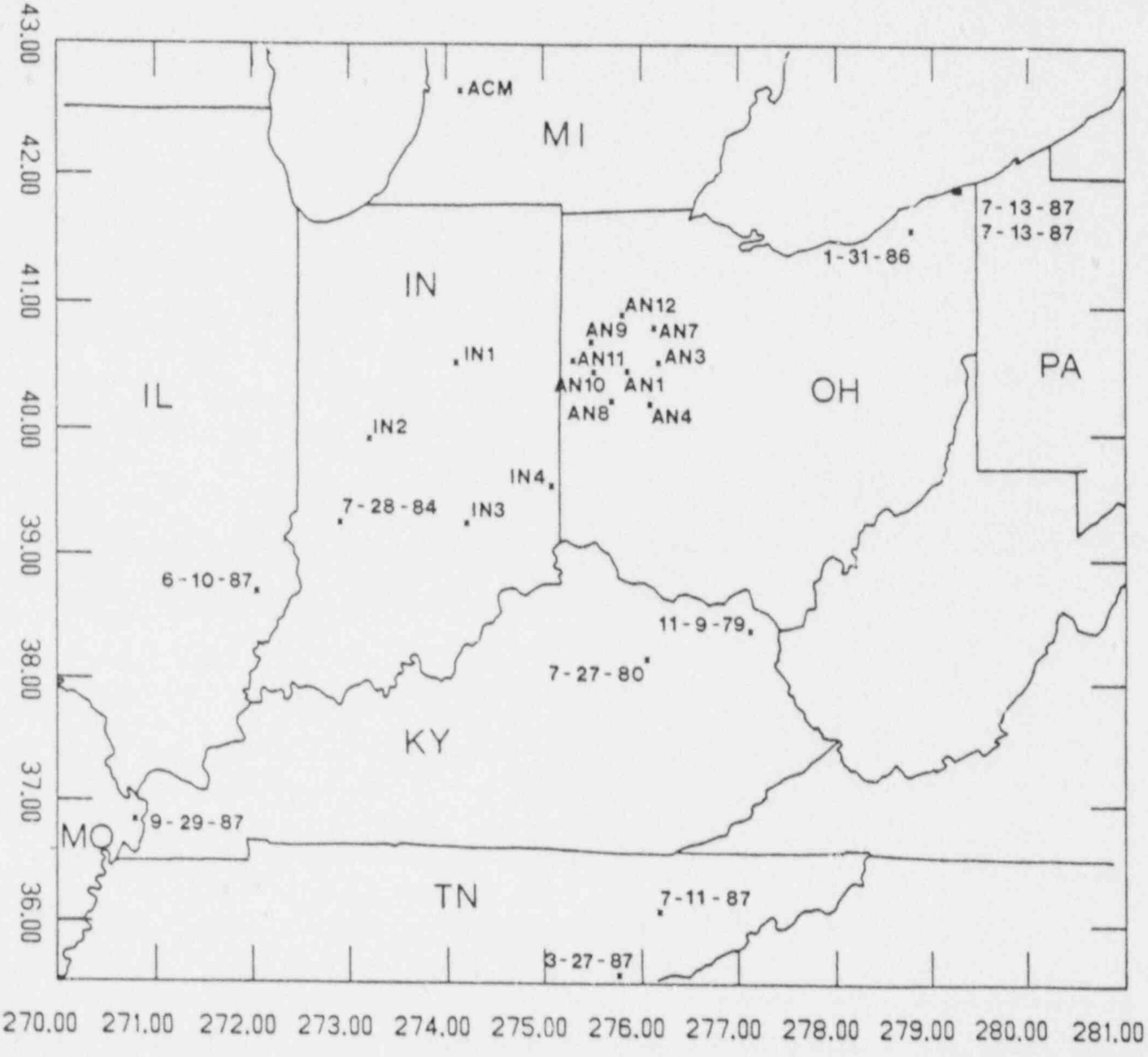

Figure 7. Location of Regional Earthquakes Used in P_n Residual Analysis Relative to Array Stations.

TABLE 4

F_n RESIDUALS FROM REGIONAL EARTHQUAKES

9 November 1979

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	0.67	0.36	0.06	****	0.71	1.40	0.99	0.99	1.48	****	****	****	***	0.33
BAZ	154	161	156	****	149	151	148	146	158	****	****	****	***	151
DIS	254	250	219	****	237	291	267	285	300	****	****	****	***	534

27 JULY 1980

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	0.22	0.30	****	****	0.35	0.03	0.07	-0.10	****	****	****	****	***	***
BAZ	176	182	****	****	173	170	170	166	****	****	****	****	***	****
DIS	256	264	****	****	231	285	259	272	****	****	****	****	***	****

28 JULY 1984

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	0.07	0.00	-0.09	-0.20	0.10	-0.41	-0.03	-0.19	****	-0.51	****	****	0.04	***
BAZ	242	243	249	238	245	234	239	235	****	215	****	****	259	***
DIS	288	315	294	327	265	275	263	253	****	178	****	****	191	***

31 JANUARY 1986

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	1.75	1.70	1.45	1.51	****	1.75	1.79	1.53	1.78	0.58	0.72	***	0.65	***
BAZ	62	60	55	67	****	69	64	68	71	71	66	****	259	***
DIS	282	254	280	244	306	299	307	319	266	416	511	****	392	***

27 MARCH 1987

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	1.98	2.23	1.78	****	****	3.18	2.45	2.64	****	0.71	2.48	1.45	****	***
BAZ	181	184	183	****	****	178	178	176	****	165	154	161	****	***
DIS	545	554	518	****	****	572	545	556	****	571	535	433	***	***

10 JUNE 1987

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	****	****	-1.66	****	-1.72	-1.85	-1.59	-1.78	****	-1.49	****	****	-1.15	-1.30
BAZ	****	****	246	****	243	234	238	235	****	222	****	****	251	203
DIS	****	****	387	****	359	370	357	348	****	269	****	****	280	472

11 JULY 1987

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	****	1.32	1.54	****	1.23	****	****	****	1.29	****	****	****	1.68	***
BAZ	****	180	179	****	175	****	****	****	177	****	****	****	166	****
DIS	****	494	457	****	462	****	****	****	536	****	****	****	396	***

13 JULY 1987

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	1.89	1.46	0.82	1.46	1.50	1.58	****	1.66	****	1.49	****	0.02	****	***
BAZ	60	59	54	65	57	66	****	65	****	69	****	54	****	***
DIS	326	299	325	288	351	342	****	363	****	459	***	519	***	***

13 JULY 1987

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	1.71	1.37	****	2.18	1.43	1.49	****	****	****	2.10	****	****	****	***
BAZ	60	59	****	65	57	66	****	****	****	69	****	****	****	***
DIS	328	301	****	290	353	344	****	****	****	461	****	****	****	***

29 SEPTEMBER 1987

STA	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
RES	0.34	1.07	****	****	-0.32	0.47	****	0.97	****	-0.25	0.91	****	****	***
BAZ	229	231	****	****	230	225	****	225	****	216	212	****	****	***
DIS	599	624	****	****	572	594	****	571	****	502	404	****	396	***

RES: P_n residual (observed time - predicted) in seconds
BAZ: Azimuth of wavefront approach to the station in degrees
DIS: Epicentral distance in degrees

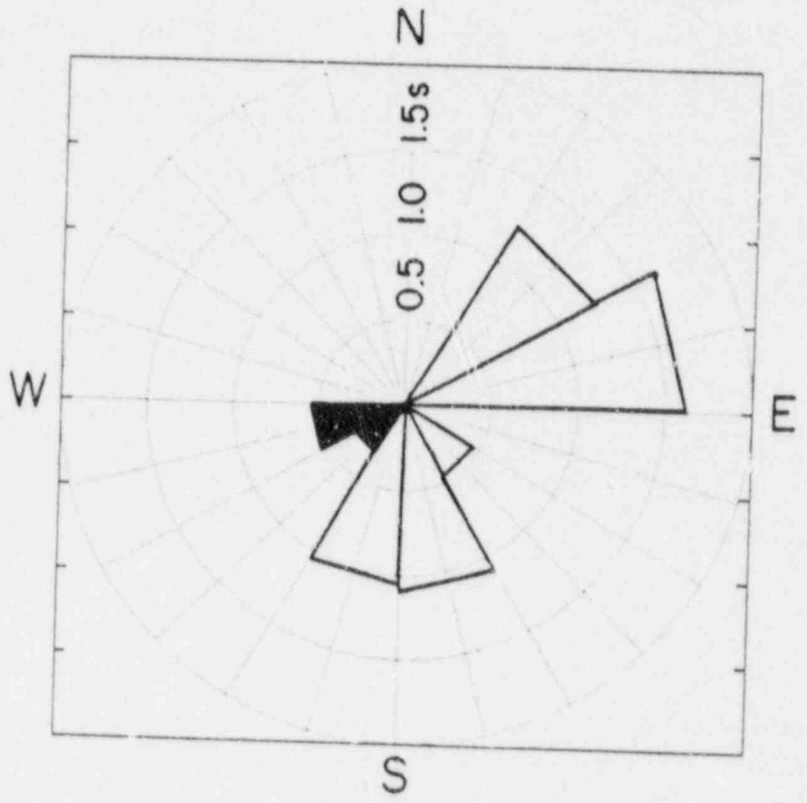

Figure 8 Polar Plot of P_n Residuals From Regional Earthquakes Averaged Over 30 Degree Azimuthal Increments. Shaded Region Indicates Negative Residuals.

positive residuals to the south, and negative residuals to the southwest.

Before an interpretation of the P_n residuals can be made, it is important to identify how much of this pattern may be due to near receiver structure. Evaluation of teleseismic P-wave residuals for the stations of the Anna Array has been ongoing since 1978. The results of that study which have been extensively discussed in previous reports, are summarized in Figure 9. This figure shows the azimuthally averaged teleseismic P-wave travel time residuals at each of the fourteen array stations. At most stations, over 250 observations have been included in the averages. The azimuthal averaging should tend to remove source and path effects, leaving only local effects directly beneath the receivers. The range in observed teleseismic residuals between eastern and western stations is about .3 s. Refracted phases arrive at the receiver with shallower angles than teleseismic phases and therefore travel longer paths in the near receiver crustal structure. The longer legs of the P_n phase in the crust should produce a corresponding .5 s variation in P_n arrival times over distance ranges of our concern. If comparable crustal heterogeneity is assumed to exist at the source, this would contribute an additional .5 s to the range in P_n residuals. The observed range in averaged P_n residuals is about 2 s, leaving about 1 s unexplained. The remaining residual pattern could result from either differences in crustal thickness or differences in mantle velocity between regions to the east and west of the array. Differences in crustal thickness could result from an abrupt transition in crustal properties, or occur more gradually with a gently dipping Moho and crustal thickening to the east. It has been suggested that the Grenville front which is the N-S trending Precambrian lithologic/structure contact between the older Superior province to the west and Grenville province to the east, lies approximately 20-30 km east of the Anna area (see Bass, 1961; Owens, 1967). This structural boundary may separate crust of different thickness and be partially responsible for the observed residual pattern.

The azimuthal pattern displayed in the P_n travel time residuals is similar to the azimuthal pattern observed in station differenced teleseismic P-wave residuals (Christensen et al., 1987). Differencing P-wave residuals between stations eliminates travel time anomalies resulting from hypocentral mislocation, structure at the source and mantle path structure since all of the rays travel essentially the same path to the stations. This leaves only the shallow heterogeneous structure beneath the stations to account for the differences. The similarity between P_n and teleseismic P-wave travel time residuals lends support to interpretations made in previous reports that a change in

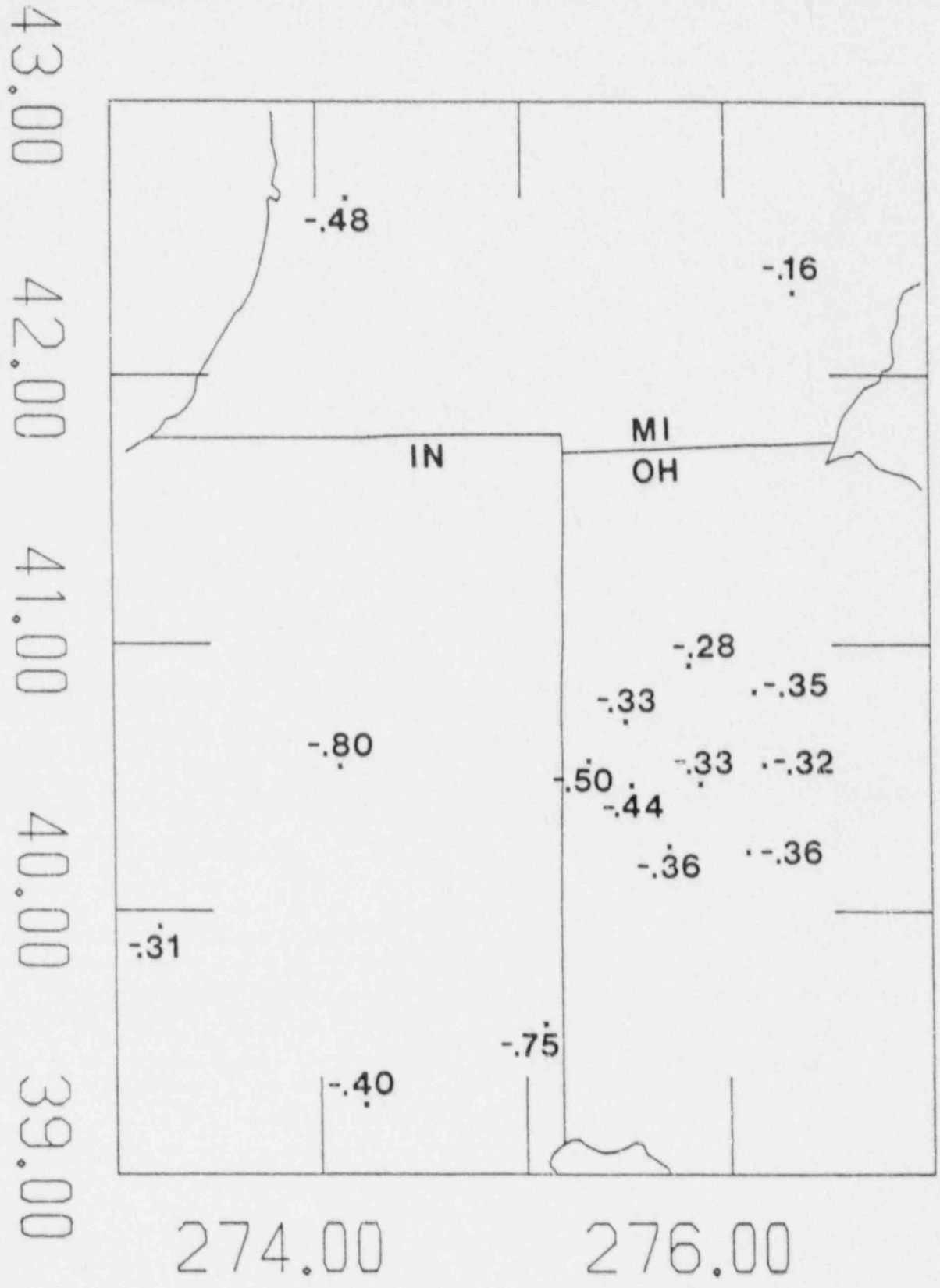

Figure 9 . Map of P-Wave Residuals for the Ohio-Indiana Network (with respect to the J-B Tables). The Residuals are Azimuthally Averaged Over 10 Degree Increments at Each Station.

the shallow velocity structure occurs beneath the Anna Array. This transition yields relatively fast velocities in the western portion of the array and slower velocities in the eastern section.

We have constructed a P_n travel time curve for all arrivals from the ten regional earthquakes. Figure 10 shows the arrivals from each earthquake plotted with a different symbol. Variation in the apparent P_n velocities (slope of the travel time curve) for the different earthquakes is obvious. We grouped earthquakes occurring in the same geographic region together and calculated apparent P_n velocities for six regions. Earthquakes in northeastern Ohio yield the highest apparent velocity of 8.5 km/s. The next fastest velocity (8.4 km/s) was obtained from the 10 June 1987 earthquake in southeastern Illinois. Earthquakes in southwestern Indiana, northeastern Kentucky, and northeastern Missouri all yield apparent P_n velocities of 8.2 km/s, a value that agrees very well with the P_n velocity obtained from a refraction study that we conducted in western Ohio (Pollack et al., 1986, Christensen et al., 1987). The slowest apparent P_n velocity was obtained from earthquakes in northeastern Tennessee (8.1 km/s). This range in apparent P_n velocity is consistent with values reported by Herrin and Taggart (1962) for the central United States; however, since we have not determined velocities for reversed profiles, we can not assume that our apparent velocities represent true mantle values. A dipping Moho will produce erroneous apparent P_n velocities if not accounted for correctly. Fast apparent P_n velocities are obtained from earthquakes located both to the east and to the west of the array. This pattern is inconsistent with the P_n residual pattern.

In conclusion, about one-half of the observed range in the P_n travel time residuals may be attributed to very near source and receiver structure. The remaining portion of the travel time residual is most likely due to differences in crustal thickness or mantle velocities between regions to the east and west of the array. No simple relationship between apparent P_n velocities and P_n residuals exists. Reversed path P_n velocity values are necessary to understand the mantle contribution to the observed P_n residual pattern.

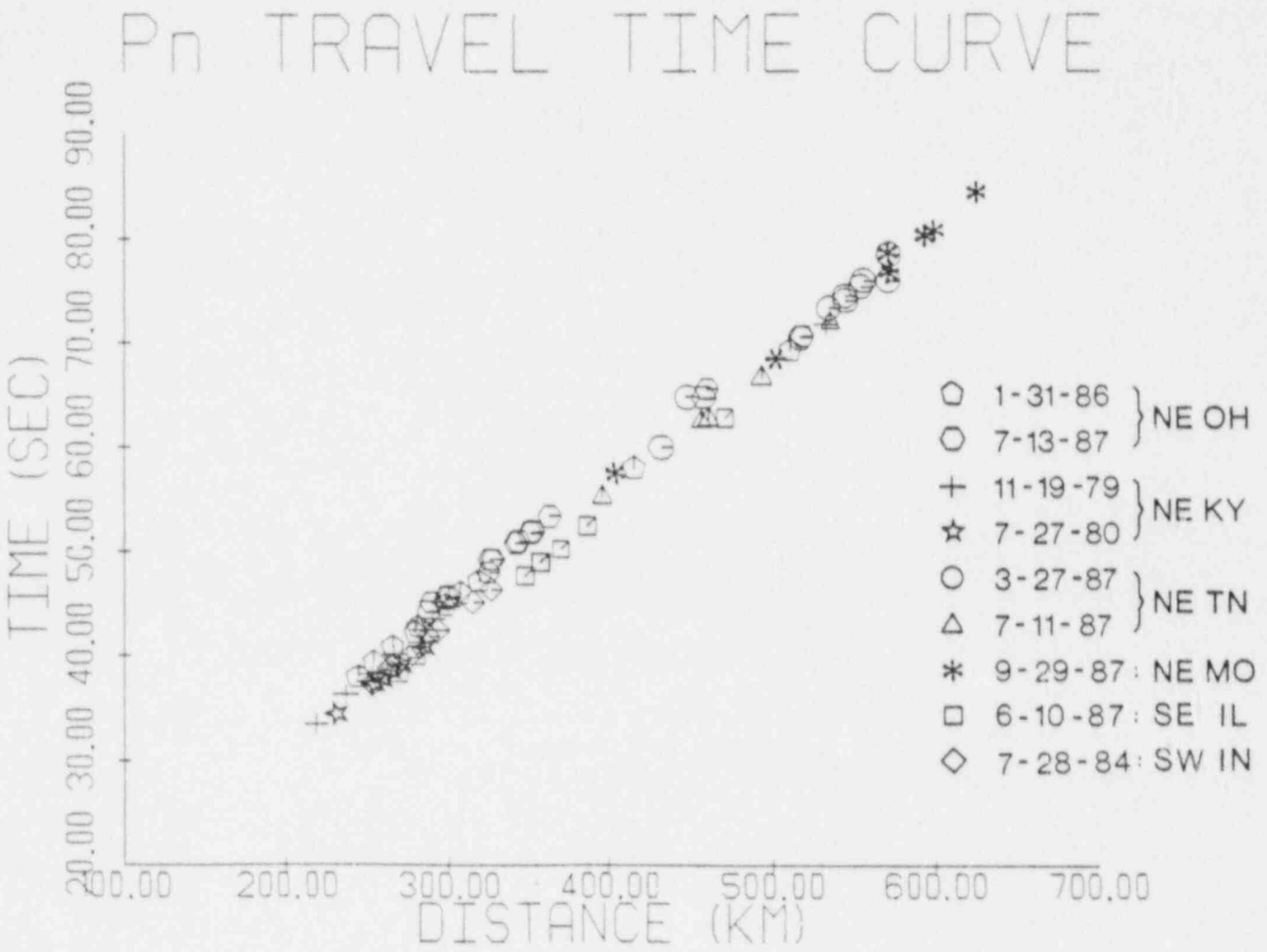

Figure 10. P_n Travel Time Curve for Ten Regional Earthquakes. Arrivals From Different Earthquakes are Indicated With Different Symbols

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Appendix A

The 12 July 1986 St. Marys, Ohio Earthquake and Recent Seismicity in the Anna, Ohio Seismogenic Zone

A manuscript concerning seismological aspects of the 12 July 1986 St. Marys, Ohio earthquake and its relationship to the seismicity in the Anna Seismogenic Zone will be published in Seismological Research Letters, a publication of the eastern section of the Seismological Society of America, in early 1988.

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13. ABSTRACT (200 words or less)

Earthquake activity in the Western Ohio - Indiana region has been monitored with a precision seismograph network consisting of nine stations located in west-central Ohio and four stations located in Indiana. One local and eleven near-regional earthquakes have been recorded during this report period. The local event had a duration magnitude of 0.7 and was not felt. Its location is close to the larger (m_b = 4.5) July 12, 1986 St. Marys, Ohio earthquake. Many of the regional events were felt with magnitudes ranging from m_bLg = 2.7-4.9. The two largest of these events (March 27, 1987 in northeastern Tennessee, m_bLg = 4.2, and June 10, 1987 in southeastern Illinois, m_bLg = 4.9) produced minor damage.

P_n travel time residuals, computed for all well-recorded regional events since deployment of the Anna Seismic Network, display a strong azimuthal dependence with positive residuals (slow arrival times) obtained from events with northeasterly through southerly back azimuths and negative residuals (fast arrival times) from events with westerly back azimuths. This pattern has larger residuals, but is similar to that displayed in the teleseismic P-wave residuals, supporting an interpretation that shallow structural heterogeneity is responsible for the P_n residual pattern.

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FINAL REPORT, OCTOBER 1986 - SEPTEMBER 198?

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Appendix B

Station Reliability Tables (Up-Times)
(October 1986 - September 1987)

This appendix contains daily and monthly tabulations of running time for each station. The numbers reported represent percentage of time that each station was recorded. The down-times reflected in the reliability data includes not only periods of instrumental failures due to mechanical or electrical problems, but also times in which the records were not interpretable due to other factors (e.g. weather, cultural noise, etc.).

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
86/10/ 1	100%	100%	100%	20%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/ 2	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/ 3	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/ 4	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/ 5	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	1%
86/10/ 6	80%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	80%
86/10/ 7	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/ 8	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/ 9	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/10	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/11	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/12	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/13	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/14	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/15	80%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/16	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	95%	100%	100%	100%
86/10/17	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	95%	100%	100%	100%
86/10/18	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	85%	100%	100%	80%
86/10/19	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/20	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	85%	100%	100%	100%
86/10/21	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	95%	100%	100%	85%
86/10/22	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	97%	100%	100%	100%
86/10/23	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	99%	100%	100%	100%
86/10/24	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/25	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/26	100%	100%	40%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/27	100%	100%	100%	70%	100%	100%	100%	100%	99%	100%	100%	100%	100%	100%
86/10/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	95%	100%	0%	100%
86/10/29	100%	100%	100%	100%	100%	100%	100%	100%	100%	90%	90%	100%	100%	100%
86/10/30	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
86/10/31	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	40%	100%	100%	1[illegible]%
MONTHLY SUMMARY FOR OCT	98%	100%	98%	96%	100%	16%	100%	100%	99%	99%	96%	100%	96%	95%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
86/11/ 1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	25%	100%	100%	100%
86/11/ 2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/ 3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	80%
86/11/ 4	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/ 5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	99%
86/11/ 6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	15%	100%	100%	100%
86/11/ 7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
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86/11/15	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	0%	100%	99%	100%
86/11/16	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/17	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%	100%
86/11/18	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/19	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/20	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/21	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/22	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/23	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/24	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/25	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/26	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/27	85%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/29	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/11/30	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
MONTHLY SUMMARY FOR NOV	98%	100%	100%	100%	100%	100%	99%	100%	99%	95%	1%	100%	96%	99%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
86/12/ 1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/ 2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/ 3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/ 4	99%	99%	100%	100%	99%	100%	100%	99%	99%	100%	0%	100%	100%	100%
86/12/ 5	99%	99%	100%	100%	99%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/ 6	100%	100%	100%	100%	100%	37%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/ 7	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/ 8	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/ 9	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/10	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/11	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	0%	100%	100%
86/12/12	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/13	100%	100%	100%	100%	100%	15%	100%	100%	100%	100%	0%	95%	100%	100%
86/12/14	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/15	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/16	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/17	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/18	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/19	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/20	25%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/21	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/22	60%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	80%	100%	100%
86/12/23	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	80%	100%
86/12/24	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/25	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/26	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/27	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/28	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/29	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/30	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/12/31	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
MONTHLY SUMMARY FOR DEC	70%	99%	100%	100%	99%	72%	100%	99%	99%	100%	0%	95%	99%	100%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 1/ 1	0%	100%	75%	75%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/ 1/ 2	0%	100%	100%	75%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/ 3	0%	100%	95%	60%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/ 4	0%	100%	90%	90%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/ 5	0%	95%	50%	50%	100%	100%	100%	100%	100%	98%	0%	100%	100%	100%
87/ 1/ 6	0%	0%	97%	100%	85%	100%	100%	85%	98%	100%	0%	100%	100%	100%
87/ 1/ 7	0%	0%	75%	80%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
86/ 1/ 8	0%	0%	0%	80%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/ 9	0%	0%	0%	100%	100%	90%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/10	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/11	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/12	0%	0%	0%	100%	100%	100%	100%	100%	100%	90%	0%	100%	100%	100%
87/ 1/13	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 1/14	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	99%	100%	100%
87/ 1/15	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/16	0%	0%	0%	100%	100%	100%	99%	100%	100%	100%	0%	100%	100%	100%
87/ 1/17	0%	0%	0%	100%	100%	100%	100%	98%	100%	100%	0%	100%	100%	100%
87/ 1/18	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/19	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/20	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/21	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 1/22	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/23	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	90%
87/ 1/24	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/25	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/26	100%	95%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/27	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/29	100%	95%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/30	100%	90%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 1/31	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
MONTHLY SUMMARY FOR JAN	41%	57%	60%	93%	99%	99%	99%	99%	99%	99%	0%	99%	99%	99%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 2/ 1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 2/ 2	100%	100%	100%	100%	100%	100%	100%	95%	100%	100%	0%	100%	100%	100%
87/ 2/ 3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 2/ 4	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 2/ 5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 2/ 6	100%	100%	98%	98%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 2/ 7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 2/ 8	60%	75%	80%	95%	60%	70%	100%	60%	90%	60%	0%	60%	98%	55%
87/ 2/ 9	60%	80%	95%	100%	75%	100%	100%	90%	100%	85%	0%	85%	98%	95%
87/ 2/10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 2/11	80%	80%	100%	100%	80%	100%	100%	80%	80%	100%	0%	100%	98%	100%
87/ 2/12	80%	80%	100%	100%	80%	100%	100%	80%	80%	100%	0%	100%	98%	100%
87/ 2/13	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 2/14	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	98%	100%
87/ 2/15	75%	80%	100%	100%	100%	100%	100%	100%	100%	100%	0%	90%	90%	100%
87/ 2/16	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 2/17	0%	0%	100%	100%	100%	100%	100%	75%	100%	100%	0%	100%	100%	100%
87/ 2/18	0%	100%	100%	100%	100%	100%	100%	40%	100%	100%	0%	100%	95%	100%
87/ 2/19	0%	100%	100%	100%	100%	100%	100%	100%	95%	100%	0%	100%	95%	100%
87/ 2/20	0%	100%	100%	100%	100%	100%	100%	0%	100%	40%	0%	40%	100%	100%
87/ 2/21	0%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	100%
87/ 2/22	0%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	100%
87/ 2/23	0%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	80%	100%
87/ 2/24	0%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	98%	100%
87/ 2/25	0%	100%	100%	100%	100%	100%	100%	0%	90%	100%	0%	100%	100%	100%
87/ 2/26	0%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	98%	100%
87/ 2/27	0%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	100%
87/ 2/28	0%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	100%
MONTHLY SUMMARY FOR FEB	48%	89%	99%	99%	96%	98%	100%	61%	97%	95%	0%	95%	97%	98%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 3/ 1	0%	100%	95%	100%	90%	100%	100%	0%	100%	95%	0%	100%	100%	100%
87/ 3/ 2	10%	100%	65%	100%	65%	100%	100%	0%	100%	90%	0%	100%	100%	100%
87/ 3/ 3	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	100%
87/ 3/ 4	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	100%
87/ 3/ 5	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	98%	100%
87/ 3/ 6	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	95%	100%
87/ 3/ 7	95%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	85%	100%
87/ 3/ 8	98%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	100%
87/ 3/ 9	60%	45%	70%	75%	75%	100%	100%	0%	100%	100%	0%	80%	100%	100%
87/ 3/10	50%	10%	10%	50%	40%	100%	100%	0%	100%	100%	0%	90%	100%	100%
87/ 3/11	100%	95%	100%	100%	100%	100%	100%	0%	75%	100%	90%	90%	100%	100%
87/ 3/12	100%	100%	100%	100%	100%	100%	100%	0%	95%	100%	100%	100%	100%	100%
87/ 3/13	100%	100%	100%	100%	100%	100%	100%	0%	95%	100%	100%	90%	100%	100%
87/ 3/14	100%	100%	100%	100%	100%	100%	100%	0%	95%	100%	95%	100%	100%	100%
87/ 3/15	100%	100%	100%	95%	100%	100%	100%	0%	90%	100%	95%	100%	100%	100%
87/ 3/16	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	98%	100%
87/ 3/17	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	98%	100%
87/ 3/18	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 3/19	100%	98%	100%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 3/20	75%	100%	100%	90%	100%	100%	100%	100%	100%	100%	100%	100%	90%	100%
87/ 3/21	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/30/22	100%	100%	100%	60%	100%	100%	100%	100%	100%	100%	100%	100%	98%	100%
87/ 3/23	100%	100%	100%	80%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/30/24	100%	100%	100%	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 3/25	100%	100%	100%	90%	90%	100%	90%	100%	100%	100%	100%	100%	100%	100%
87/ 3/26	100%	100%	100%	80%	100%	100%	100%	90%	100%	100%	100%	100%	100%	100%
87/ 3/27	100%	100%	100%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 3/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 3/29	100%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 3/30	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 3/31	100%	100%	100%	80%	100%	100%	100%	90%	100%	100%	100%	100%	100%	100%
MONTHLY SUMMARY FOR MAR	89%	94%	94%	91%	95%	100%	99%	44%	98%	99%	67%	98%	98%	100%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 4/ 1	90%	70%	100%	100%	100%	100%	100%	100%	100%	90%	80%	100%	100%	100%
87/ 4/ 2	100%	80%	70%	100%	100%	100%	100%	90%	100%	100%	100%	100%	100%	100%
87/ 4/ 3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/ 4	70%	60%	100%	100%	100%	100%	100%	90%	100%	100%	90%	100%	100%	100%
87/ 4/ 5	40%	50%	90%	90%	80%	100%	100%	50%	98%	100%	75%	100%	100%	100%
87/ 4/ 6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/ 7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/ 8	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	95%	100%
87/ 4/ 9	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/11	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/12	100%	100%	90%	98%	100%	100%	100%	100%	100%	100%	100%	100%	90%	100%
87/ 4/13	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/14	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	25%	100%
87/ 4/15	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/16	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/17	100%	100%	100%	100%	100%	10%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 4/18	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 4/19	100%	100%	100%	100%	100%	75%	100%	100%	100%	100%	0%	100%	100%	100%
87/ /20	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	25%	55%	90%	100%
87/ 4/21	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	0%	100%	100%
87/ 4/22	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	90%	100%
87/ 4/23	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 4/24	100%	100%	100%	100%	100%	100%	100%	95%	100%	100%	100%	0%	100%	100%
87/ 4/25	100%	100%	100%	100%	100%	100%	100%	95%	100%	75%	75%	0%	100%	100%
87/ 4/26	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	95%
87/ 4/27	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 4/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 4/29	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 4/30	100%	100%	100%	100%	100%	100%	100%	80%	100%	100%	100%	0%	100%	70%
MONTHLY SUMMARY FOR APR	96%	95%	98%	99%	99%	92%	100%	96%	99%	98%	86%	65%	96%	98%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 5/ 1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/ 2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	25%
87/ 5/ 3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	5%
87/ 5/ 4	100%	100%	100%	8	100%	85%	85%	50%	100%	100%	100%	0%	100%	0%
87/ 5/ 5	100%	100%	100%	100%	100%	100%	100%	60%	100%	100%	100%	0%	100%	0%
87/ 5/ 6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/ 7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/ 8	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/ 9	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/11	100%	100%	100%	100%	100%	100%	99%	100%	100%	100%	100%	0%	100%	0%
87/ 5/12	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/13	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/14	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/15	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/16	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/17	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/18	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	80%
87/ 5/19	100%	100%	100%	100%	100%	20%	100%	100%	100%	100%	100%	0%	100%	0%
87/ 5/20	100%	100%	100%	100%	100%	80%	100%	100%	100%	100%	100%	0%	100%	90%
87/ 5/21	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/22	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/23	100%	100%	100%	100%	100%	100%	100%	80%	100%	100%	100%	0%	100%	100%
87/ 5/24	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/25	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/26	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/27	100%	100%	100%	100%	100%	100%	100%	50%	100%	100%	100%	0%	100%	100%
87/ 5/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/29	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/30	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 5/31	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
MONTHLY SUMMARY FOR MAY	96%	96%	96%	99%	100%	96%	99%	94%	100%	100%	100%	0%	100%	54%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 6/ 1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 6/ 2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 6/ 3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 6/ 4	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	85%	0%	100%	95%
87/ 6/ 5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%	0%	100%	100%
87/ 6/ 6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%	0%	100%	100%
87/ 6/ 7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	70%	0%	100%	100%
87/ 6/ 8	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	70%	0%	100%	100%
87/ 6/ 9	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	0%	100%	100%
87/ 6/10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	0%	100%	100%
87/ 6/11	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%	0%	100%	100%
87/ 6/12	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
87/ 6/13	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	30%	0%	100%	100%
87/ 6/14	100%	100%	100%	100%	100%	100%	100%	99%	99%	100%	50%	0%	95%	95%
87/ 6/15	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	20%	0%	100%	0%
87/ 6/17	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	30%	0%	100%	5%
87/ 6/18	100%	100%	100%	100%	100%	100%	99%	100%	100%	100%	30%	0%	100%	100%
87/ 6/19	100%	100%	100%	100%	100%	99%	99%	100%	100%	100%	20%	0%	100%	100%
87/ 6/19	100%	100%	90%	90%	100%	90%	90%	100%	100%	100%	20%	0%	100%	100%
87/ 6/20	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	100%	100%
87/ 6/21	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	100%	100%
87/ 6/22	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	25%	100%	100%
87/ 6/23	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
87/ 6/24	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 6/25	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 6/26	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 6/27	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 6/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 6/29	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 6/30	100%	100%	100%	100%	100%	40%	100%	100%	100%	100%	100%	100%	100%	10%
MONTHLY SUMMARY FOR JUN	100%	100%	99%	99%	100%	97%	99%	99%	99%	100%	62%	27%	99%	90%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 7/ 1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/ 2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/ 3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/ 4	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/ 5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/ 6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	20%
87/ 7/ 7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%
87/ 7/ 8	100%	100%	100%	100%	100%	20%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/ 9	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/11	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/12	100%	100%	100%	100%	100%	30%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/13	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/14	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/15	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/16	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
87/ 7/17	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%	100%
87/ 7/18	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%	99%
87/ 7/19	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%	99%
87/ 7/20	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%
87/ 7/21	100%	100%	100%	100%	100%	100%	100%	99%	100%	100%	100%	100%	100%	95%
87/ 7/22	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	90%
87/ 7/23	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	97%	99%
87/ 7/24	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	90%
87/ 7/25	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	85%
87/ 7/26	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
87/ 7/27	100%	100%	100%	100%	100%	15%	100%	100%	100%	100%	100%	100%	100%	88%
87/ 7/28	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	60%
87/ 7/29	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	60%	100%	100%
87/ 7/30	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	100%	100%
87/ 7/31	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	60%	100%	100%
MONTHLY SUMMARY FOR JUL	100%	100%	100%	100%	100%	92%	100%	99%	100%	100%	100%	95%	99%	89%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 8/ 1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	60%	100%	100%
87/ 8/ 2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	100%	100%
87/ 8/ 3	100%	90%	95%	95%	100%	90%	95%	85%	100%	100%	100%	75%	100%	100%
87/ 8/ 4	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	60%	100%	100%
87/ 8/ 5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	25%	100%	100%
87/ 8/ 6	100%	100%	85%	15%	100%	85%	75%	95%	100%	100%	100%	35%	100%	90%
87/ 8/ 7	100%	100%	100%	0%	100%	15%	100%	100%	100%	100%	100%	60%	100%	100%
87/ 8/ 8	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	60%	100%	100%
87/ 8/ 9	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	60%	100%	100%
87/ 8/10	100%	100%	100%	0%	100%	100%	100%	65%	100%	100%	100%	60%	100%	100%
87/ 8/11	100%	100%	100%	0%	100%	100%	100%	80%	100%	100%	100%	55%	100%	100%
87/ 8/12	100%	100%	100%	0%	100%	100%	100%	100%	95%	100%	100%	50%	100%	100%
87/ 8/13	100%	100%	100%	0%	100%	100%	100%	100%	90%	100%	100%	55%	100%	100%
87/ 8/14	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	65%	100%	100%
87/ 8/15	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	65%	100%	100%
87/ 8/16	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	65%	100%	100%
87/ 8/17	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	65%	100%	100%
87/ 8/18	100%	100%	100%	0%	100%	95%	100%	100%	100%	100%	100%	65%	100%	100%
87/ 8/19	100%	95%	100%	0%	100%	95%	100%	100%	100%	90%	95%	50%	95%	100%
87/ 8/20	100%	95%	100%	0%	100%	95%	100%	100%	100%	100%	100%	65%	100%	100%
87/ 8/21	85%	95%	100%	0%	100%	95%	100%	100%	100%	100%	100%	50%	100%	95%
87/ 8/22	45%	100%	100%	0%	100%	95%	100%	100%	100%	100%	100%	65%	100%	100%
87/ 8/23	50%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	40%	100%	100%
87/ 8/24	10%	80%	0%	100%	100%	95%	100%	100%	100%	30%	100%	10%	100%	100%
87/ 8/25	1%	100%	0%	100%	100%	100%	100%	100%	100%	0%	100%	15%	100%	100%
87/ 8/26	100%	100%	0%	100%	100%	95%	100%	100%	100%	0%	100%	75%	100%	100%
87/ 8/27	100%	100%	0%	100%	100%	95%	100%	100%	100%	0%	100%	100%	95%	100%
87/ 8/28	100%	100%	0%	10%	100%	95%	100%	100%	100%	0%	100%	90%	100%	100%
87/ 8/29	100%	100%	0%	100%	100%	100%	100%	100%	100%	0%	100%	65%	100%	100%
87/ 8/30	100%	100%	0%	100%	100%	100%	100%	100%	100%	0%	100%	70%	100%	100%
87/ 8/31	100%	100%	0%	100%	100%	95%	100%	100%	100%	0%	100%	100%	100%	100%
MONTHLY SUMMARY FOR AUG	90%	98%	73%	39%	100%	94%	99%	97%	99%	74%	99%	58%	99%	99%

DATE	AN1	AN3	AN4	AN7	AN8	AN9	AN10	AN11	AN12	IN1	IN2	IN3	IN4	ACM
87/ 9/ 1	100%	100%	0%	100%	100%	95%	100%	100%	100%	0%	100%	70%	100%	100%
87/ 9/ 2	100%	100%	0%	100%	100%	95%	95%	100%	100%	0%	100%	95%	100%	100%
87/ 9/ 3	100%	100%	0%	100%	100%	90%	100%	100%	100%	0%	100%	65%	95%	100%
87/ 9/ 4	100%	100%	0%	95%	100%	95%	100%	90%	85%	0%	100%	90%	100%	100%
87/ 9/ 5	100%	100%	0%	100%	100%	95%	100%	100%	98%	0%	100%	75%	98%	100%
87/ 9/ 6	100%	100%	0%	100%	100%	100%	98%	100%	100%	0%	100%	80%	100%	100%
87/ 9/ 7	100%	100%	0%	100%	100%	100%	100%	95%	100%	0%	100%	70%	40%	100%
87/ 9/ 8	100%	100%	0%	100%	100%	95%	0%	90%	95%	0%	100%	95%	50%	100%
87/ 9/ 9	100%	95%	100%	100%	100%	90%	0%	100%	100%	0%	100%	40%	0%	100%
87/ 9/10	98%	95%	100%	100%	100%	90%	0%	85%	100%	0%	100%	70%	100%	98%
87/ 9/11	100%	100%	100%	100%	95%	80%	0%	10%	100%	0%	100%	80%	95%	98%
87/ 9/12	100%	100%	100%	100%	100%	95%	0%	95%	100%	0%	95%	25%	100%	100%
87/ 9/13	100%	100%	100%	100%	100%	100%	10%	95%	98%	0%	100%	25%	95%	100%
87/ 9/14	100%	100%	100%	100%	95%	95%	20%	100%	100%	85%	95%	25%	90%	100%
87/ 9/15	95%	100%	100%	100%	100%	90%	40%	90%	100%	100%	90%	100%	100%	100%
87/ 9/16	100%	100%	100%	100%	100%	90%	20%	98%	100%	100%	95%	100%	100%	100%
87/ 9/17	100%	98%	100%	100%	100%	90%	10%	98%	100%	100%	95%	95%	100%	100%
87/ 9/18	100%	100%	98%	98%	100%	80%	20%	100%	100%	100%	95%	100%	100%	100%
87/ 9/19	100%	100%	100%	80%	95%	95%	5%	100%	100%	100%	98%	100%	100%	100%
87/ 9/20	100%	100%	100%	60%	98%	98%	1%	100%	100%	100%	98%	100%	95%	100%
87/ 9/21	100%	100%	100%	0%	100%	85%	2%	100%	100%	100%	90%	100%	100%	100%
87/ 9/22	100%	100%	100%	0%	100%	70%	5%	100%	100%	100%	95%	95%	100%	100%
87/ 9/23	100%	100%	100%	0%	100%	95%	2%	80%	95%	100%	80%	100%	100%	100%
87/ 9/24	85%	100%	98%	0%	100%	90%	2%	100%	100%	100%	80%	100%	95%	100%
87/ 9/25	90%	100%	100%	0%	100%	90%	2%	95%	100%	100%	80%	95%	50%	100%
87/ 9/26	100%	100%	90%	0%	100%	90%	10%	100%	100%	100%	70%	80%	100%	100%
87/ 9/27	100%	95%	95%	0%	100%	98%	10%	100%	100%	100%	80%	80%	95%	100%
87/ 9/28	95%	98%	98%	0%	95%	95%	5%	100%	100%	100%	85%	90%	95%	100%
87/ 9/29	98%	100%	100%	0%	100%	90%	5%	100%	100%	100%	70%	70%	90%	70%
87/ 9/30	100%	100%	90%	0%	100%	80%	100%	100%	100%	100%	100%	85%	95%	0%
MONTHLY SUMMARY FOR SEP	98%	99%	72%	64%	99%	91%	32%	94%	99%	56%	89%	80%	89%	95%

Appendix C

Arrival Time Data
Local and Near Regional Events
(June 1977 - September 1987)

This appendix contains phase arrival information for local and near regional events which have been well recorded by the Anna Seismic Network. All events have been located by The University of Michigan unless specified otherwise. S-wave arrival times were used in the location inversions only if the onset of the S wave was very impulsive, or in cases where the P-wave data alone was not sufficient to locate the earthquake adequately. The magnitudes were calculated from the duration formula md = 1.8*(duration)-2.2 (Bollinger et al., 1976) unless otherwise specified.

***** 17 JUNE 1977 - OHIO *****

O.T.=15:39:47.3 LAT=40.57°N LONG=84.67°W MAG=3.3m_b
O.T.=15:39:46.9 LAT=40.705°N LONG=84.707°W (Dewey and Gordon, 1984)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1a	iP	15:39:55.80	eS	15:40:01.70
AN3	iP	15:40:00.00	eS	15:40:08.60
AAM	eP	15:40:19.20	eS	15:40:46.00
BGO	eP	15:40:08.70	eS	15:40:23.50

(The coordinates for station AN1a are 40.4310°N, 84.1240°W)

***** 9 NOVEMBER 1979 - KENTUCKY *****

O.T.=21:29:58.7 LAT=38.417°N LONG=82.869°W MAG=3.6m_{bLg}
(Location and magnitude from NEIS)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	21:30:37.00	eS	21:31:04.20
AN3	eP	21:30:36.30	eS	21:31:03.80
AN4	iP	21:30:32.20	eS	21:30:57.00
AN8	iP	21:30:35.00	eS	21:31:01.00
AN9	eP	21:30:42.28	eS	21:31:15.50
AN10	iP	21:30:38.93	eS	21:31:10.00
AN11	iP	21:30:41.15	eS	21:31:14.10
AN12	iP	21:30:43.50	eS	21:31:17.90
ACM	eP	21:31:10.50	eS	21:31:05.40
AAM	eP	21:31:02.40		

(Additional arrival times can be found in Mauk et al., 1980)

***** 10 JULY 1980 - OHIO *****

O.T.=11:40:53.3 LAT=40.415°N LONG=84.111°W MAG=0.9

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	11:40:55.40	eS	11:40:57.70
AN4	iP	11:40:59.10	eS	11:41:03.55
AN9	iP	11:41:02.25	eS	11:41:07.35
AN10	iP	11:40:59.65	eS	11:41:03.95
AN11	iP	11:41:03.05	eS	11:41:09.50
AN12	eP	11:41:04.20	eS	11:41:10.20

***** 27 JULY 1980 - KENTUCKY *****

O.T.=18:52:21.7 LAT=38.18°N LONG=83.94°W MAG=5.1m_b
DEP=15km

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	18:52:59.30		
AN3	iP	18:53:00.30		
AN8	iP	18:52:56.40		
AN9	iP	18:53:02.70		
AN10	iP	18:52:59.50		
AN11	iP	18:53:01.00		
AAM	iP	18:53:24.30		

(Additional arrival times can be found in Mauk et al., 1982)

***** 20 AUGUST 1980 - CANADA *****

O.T.=09:34:54.0 LAT=41.97°N LONG=82.99°W MAG=3.2m_{bLg}

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
UTO	iP	09:35:03.30	eS	09:35:10.90
AAM	iP	09:35:03.50	iS	09:35:09.70
ACM	iP	09:35:32.60	eS	09:36:02.00
CLE	iP	09:35:15.00	eS	09:35:31.20
BLA	eP	09:36:10.5		

***** 26 SEPTEMBER 1980 - OHIO *****

O.T.=12:27:25.6 LAT=40.430°N LONG=84.085°W MAG=0.5

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	12:27:28.10		
AN3	iP	12:27:31.20	iS	12:27:35.10
AN4	iP	12:27:31.60	iS	12:27:35.30
AN8	iP	12:27:31.20	eS	12:27:34.00
AN9	iP	12:27:34.40	iS	12:27:40.10
AN10	iP	12:27:31.50	eS	12:27:37.20

***** 4 OCTOBER 1980 - OHIO *****

O.T.=11:46:58.0 LAT=39.80°N LONG=83.75°W MAG=2.0

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	11:47:12.70		
AN3	iP	11:47:13.05	eS	11:47:24.00
AN4	iP	11:47:07.30	eS	11:47:14.00
AN8	iP	11:47:10.05		
AN9	iP	11:47:18.65	eS	11:47:33.70
AN10	iP	11:47:14.85		
AN11	iP	11:47:18.00	eS	11:47:33.50

***** 10 DECEMBER 1980 - OHIO *****

O.T.=02:30:54.3 LAT=40.43°N LONG=84.11°W MAG=1.2

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	02:30:56.10		
AN3	iP	02:30:59.70	eS	02:31:03.20
AN4	iP	02:30:59.90	eS	02:31:03.60
AN8			eS	02:31:02.30
AN9	iP	02:31:02.30	eS	02:31:07.80
AN10	iP	02:31:00.10	eS	02:31:04.00
AN11	iP	02:31:03.70		

***** 4 JANUARY 1981 - OHIO *****

O.T.=07:17:37.1 LAT=40.418°N LONG=84.087°W MAG=1.8

DEP=5-7km

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	07:17:38.61		
AN3	iP	07:17:41.95		
AN4	iP	07:17:42.15		
AN7	iP	07:17:45.18		
AN8	iP	07:17:41.67	eS	07:17:44.93
AN9	iP	07:17:44.81	eS	07:17:50.34
AN10	iP	07:17:42.45		
AN11	iP	07:17:45.84	eS	07:17:52.14

***** 7 FEBRUARY 1981 - OHIO *****

O.T.=05:45:43.0 LAT=40.417°N LONG=84.087°W MAG=1.8

DEP=5-7km

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	05:45:45.02		
AN3	iP	05:45:48.33		
AN4	iP	05:45:48.57	eS	05:45:53.00
AN7	iP	05:45:51.62		
AN8	iP	05:45:48.00		
AN9	iP	05:45:51.22	eS	05:45:56.73
AN10	iP	05:45:48.87		
AN11	iP	05:45:52.28	eS	05:45:58.63
IN1	eP	05:46:08.40		
IN2	eP	05:46:19.70		
IN3	eP	05:46:14.32		
IN4	eP	05:46:02.70	eS	05:46:17.65

***** 15 MARCH 1981 - OHIO *****

O.T.=03:46:30.3 LAT=41.10°N LONG=84.35°W MAG=1.2

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN3	iP	03:46:43.20		
AN4	iP	03:46:47.97		
AN7	iP	03:46:39.23	eS	03:46:45.10
AN8	iP	03:46:46.47		
AN9	iP	03:46:38.49	eS	03:46:43.80
AN10	iP	03:46:42.45	eS	03:46:50.85
AN11	iP	03:46:41.53	eS	03:46:49.59
AN12	iP	03:46:34.64		
IN1	iP	03:46:53.97		

***** 15 MAY 1981 - OHIO *****

O.T.=23:15:14.0 LAT=40.88°N LONG=84.34°W MAG=0.8

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	23:15:22.90		
AN3	iP	23:15:24.30	eS	23:15:31.30
AN4	eP	23:15:29.00		
AN7	iP	23:15:21.60		
AN8	iP	23:15:26.60		
AN9	iP	23:15:18.60	eS	23:15:20.80
AN10	iP	23:15:22.40	eS	23:15:28.60
AN11	iP	23:15:22.10		
AN12	iP	23:15:16.90		
IN4	iP	23:15:39.00		

***** 19 MAY 1981 - OHIO *****

O.T.=05:56:11.7 LAT=40.407°N LONG=84.085°W MAG=1.2

DEP=2-8km

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	05:56:13.32	eS	05:56:14.22
AN3	iP	05:56:16.62		
AN4	iP	05:56:16.80		
AN8	iP	05:56:16.32		
AN9	iP	05:56:19.46	eS	05:56:25.35
AN10	iP	05:56:17.26	eS	05:56:21.22
AN11	iP	05:56:20.77	eS	05:56:27.10
AN12	eP	05:56:21.46		
IN4	eP	05:56:30.40		

***** 26 NOVEMBER 1982 - MICHIGAN *****

O.T.=08:25:04.9 LAT=42.17°N LONG=85.48°W MAG=2.0-2.5

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN3	iP	08:25:40.70		
AN4	eP	08:25:45.40		
AN7	iP	08:25:37.60	eS	08:26:01.00
AN9	iP	08:25:34.20	eS	08:25:56.70
AN11	iP	08:25:35.60	eS	08:25:59.20
AN12	eP	08:25:34.00	eS	08:25:54.20
IN1	iP	08:25:34.90	eS	08:25:58.20
IN2	iP	08:25:45.90		
ACM	iP	08:25:14.70	eS	08:25:22.00

***** 12 JANUARY 1983 - OHIO *****

O.T.=02:49:41.1 LAT=39.28°N LONG=84.60°W MAG=1.9

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	02:50:01.20		
AN4	iP	02:50:00.90		
AN7	iP	02:50:10.00	eS	02:50:31.70
AN8	iP	02:49:59.10		
AN11	iP	02:50:03.70	eS	02:50:21.50
AN12	iP	02:50:10.80		
IN2	iP	02:50:12.40		
IN3	iP	02:49:57.90		
IN4	iP	02:49:48.20	eS	02:49:53.00
L6KY	iP	02:50:07.05	eS	02:50:26.80
SBKY	iP	02:50:02.20	eS	02:50:18.30

***** 22 JANUARY 1983 - OHIO *****

O.T.=07:46:59.3 LAT=41.86°N LONG=81.16°W MAG=2.7m_{bLg}

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	07:47:41.30		
AN3	iP	07:47:38.70	eS	07:48:09.50
AN7	iP	07:47:36.30		
AN9	iP	07:47:43.90		
AN12	iP	07:47:39.40		
ELF	iP	07:47:23.04		
LDN	iP	07:47:20.75		
DLA	iP	07:47:17.67		
DHN	iP	07:47:38.79		
WVLY	iP	07:47:33.08		

***** 5 JULY 1983 - OHIO *****

O.T.=02:58:52.9 LAT=40.43°N LONG=84.10°W MAG=2.1

DEP=5-7km

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	02:58:54.35		
AN3	iP	02:58:57.62		
AN4	iP	02:58:57.90		
AN7	iP	02:59:00.90		
AN8	iP	02:58:57.37		
AN9	iP	02:59:00.55		
AN10	iP	02:58:58.30		
AN11	iP	02:59:01.35		
AN12	iP	02:59:01.97		
IN2	eP	02:59:27.80		
IN3	eP	02:59:22.75		
ACM	eP	02:59:34.40		

***** 13 JULY 1983 - OHIO *****

O.T.=01:17:34.8 LAT=40.43°N LONG=84.10°W MAG=1.4

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	01:17:36.10		
AN3	iP	01:17:39.40		
AN4	iP	01:17:39.60		
AN8	iP	01:17:39.10		
AN9	iP	01:17:42.30		
AN10	iP	01:17:40.00		
AN11	iP	01:17:43.40		
AN12	iP	01:17:43.60		

***** 30 SEPTEMBER 1983 - OHIO *****

O.T.=02:33:44.8 LAT=41.59°N LONG=84.33°W MAG=1.3

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	02:34:05.20	eS	02:34:19.60
AN4	iP	02:34:10.40	eS	02:34:28.00
AN7	iP	02:33:59.60		
AN12	eP	02:33:57.00	eS	02:34:05.50
IN1	iP	02:34:13.20		
ACM	iP	02:34:12.90		

***** 4 NOVEMBER 1983 - OHIO *****

O.T.=21:00:59.8 LAT=40.43°N LONG=84.10°W MAG=0.4

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	21:01:01.00		
AN3	iP	21:01:04.40		
AN4	iP	21:01:04.70	eS	21:01:08.30
AN8	iP	21:01:04.00		
AN9	iP	21:01:07.10		
AN11	iP	21:01:08.30		

***** 4 NOVEMBER 1983 - OHIO *****

O.T.=22:50:00.50 LAT=40.43°N LONG=84.10°W MAG=0.9

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	22:50:01.70		
AN3	iP	22:50:05.10		
AN4	iP	22:50:05.30		
AN8	iP	22:50:04.70		
AN9	iP	22:50:07.90		
AN11	iP	22:50:08.90		
AN12	iP	22:50:09.40		

***** 5 NOVEMBER 1983 - INDIANA *****

O.T.=02:36:35.8 LAT=39.68°N LONG=85.73°W MAG=1.1

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	02:37:02.20		
AN3	iP	02:37:06.20		
AN4	iP	02:37:02.50		
AN8	iP	02:36:58.00		
AN11	iP	02:36:57.40		
AN12	iP	02:37:06.70		
IN1	iP	02:36:51.50		
IN2	iP	02:36:51.00		
IN3	iP	02:36:43.30	eS	02:36:49.00
IN4	iP	02:36:48.10		

***** 3 DECEMBER 1983 - WISCONSIN *****

O.T.=21:29:41.0 LAT=42.70°N LONG=88.30°W MAG=1.4

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
IN1	iP	21:30:29.50		
IN2	iP	21:30:28.10		
ACM	iP	21:30:13.30	iS	21:30:36.50

***** 7 DECEMBER 1983 - OHIO *****

O.T.=22:57:01.6 LAT=41.70°N LONG=83.50°W MAG=1.1

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN7	iP	22:57:18.20	iS	22:57:30.00
AN8	iP	22:57:29.40	eS	22:57:51.30
AN12	iP	22:57:18.60	iS	22:57:30.60

***** 10 DECEMBER 1983 - OHIO *****

O.T.=19:01:55.2 LAT=40.43°N LONG=84.11°W MAG=0.7

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	19:01:56.50		
AN3	iP	19:02:00.00		
AN4	iP	19:02:00.10	eS	19:02:03.80
AN7	iP	19:02:03.00	eS	19:02:08.80
AN8	iP	19:01:59.50	eS	19:02:02.70
AN9	iP	19:02:02.80		
AN11	iP	19:02:03.60		
AN12	iP	19:02:04.00	eS	19:02:10.80

***** 3 JANUARY 1984 - OHIO *****

O.T.=07:57:58.60 LAT=40.42°N LONG=84.11°W MAG=0.4

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	07:57:59.70		
AN4	iP	07:58:03.20	eS	07:58:07.00
AN7	eP	07:58:06.40		
AN8	iP	07:58:02.70		
AN9	eP	07:58:06.00	eS	07:58:11.40
AN11	iP	07:58:07.10		
AN12	iP	07:58:08.20		

***** 14 JANUARY 1984 - OHIO *****

O.T.=20:14:32.5 LAT=41.67°N LONG=83.45°W MAG=2.6m_b

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN3	iP	20:14:52.70		
AN4	iP	20:14:58.70	eS	20:15:18.00
AN7	iP	20:14:48.00	eS	20:14:59.50
AN8	iP	20:14:59.60		
AN9	iP	20:14:54.20		
AN11	iP	20:14:57.70		
AN12	iP	20:14:48.80	eS	20:15:00.50
ACM	eP	20:15:07.60	eS	20:15:35.10
AAM	eP	20:14:43.20		
DLA	iP	20:15:04.80	eS	20:15:30.00
LDN	iP	20:15:08.45	eS	20:15:37.75
ELF	iP	20:15:09.00	eS	20:15:38.25

***** 28 JULY 1984 - INDIANA *****

O.T.=23:39:27.3 LAT=39.27°N LONG=87.09°W MAG=4.0m_{bLg}

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	23:40:09.20		
AN3	iP	23:40:12.50		
AN4	iP	23:40:09.80		
AN7	iP	23:40:13.70		
AN8	eP	23:40:06.40		
AN9	eP	23:40:07.20		
AN10	iP	23:40:06.00		
AN11	iP	23:40:04.70		
IN1	iP	23:39:55.20		
IN2	iP	23:39:41.10		
IN3	iP	23:39:46.00		
IN4	iP	23:39:57.30		
BBG	iP	23:40:43.90		
ETT	iP	23:40:35.20		
BHT	eP	23:40:25.80		
GBTN	eP	23:40:32.50		
TKL	eP	23:40:35.62		
ELC	eP	23:40:09.15		
WCK	eP	23:40:10.85		
TYS	eP	23:40:12.30		
FVM	eP	23:40:14.00		
WSIL	iP	23:39:46.40		

***** 29 AUGUST 1984 - INDIANA *****

O.T.=06:50:59.0 LAT=39.25°N LONG=87.50°W MAG=3.2m_{bLg}

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN4	eP	06:51:45.20		
AN8	eP	06:51:42.10		
AN9	eP	06:51:43.00		
AN10	iP	06:51:41.50		
AN11	iP	06:51:39.70		
IN1	iP	06:51:29.80	eS	06:51:54.20
IN2	iP	06:51:15.00		
IN3	iP	06:51:23.10	eS	06:51:40.90
IN4	iP	06:51:33.60	eS	06:52:01.10
BLO	iP	06:51:13.60	eS	06:51:22.60
WSIL	iP	06:51:13.80	eS	06:51:24.10
GOIL	iP	06:51:34.88	eS	06:52:03.04
FVM	iP	06:51:42.13	eS	06:52:15.60

***** 29 AUGUST 1984 - ILLINOIS *****

O.T.=18:56:27.2 LAT=39.09°N LONG=87.69°W MAG=2.7m_{bLg}

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
IN1	iP	18:57:01.10		
IN3	iP	18:56:54.10		
IN4	iP	18:57:04.00		
FVM			eS	18:57:35.82
WCK			eS	18:57:34.89
TYS			eS	18:57:33.42
ELC			eS	18:57:29.84
GOIL			eS	18:57:23.22

***** 10 MARCH 1985 - OHIO *****

O.T.=20:46:01.10 LAT=40.52°N LONG=84.39°W MAG=1.4

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	20:46:04.97		
AN3	iP	20:46:09.20		
AN4	iP	20:46:10.25		
AN7	iP	20:46:10.30		
AN8	iP	20:46:06.40		
AN9	iP	20:46:05.00		
AN10	iP	20:46:02.75		
IN1	eP	20:46:21.20	eS	02:46:37.00
IN4	eP	20:46:19.30	eS	02:46:33.50

***** 10 MARCH 1985 - OHIO *****

O.T.=20:49:14.1 LAT=40.52°N LONG=84.40°W MAG=1.7

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	20:49:18.07		
AN3	iP	20:49:22.30		
AN4	iP	20:49:23.15		
AN7	iP	20:49:23.40		
AN8	iP	20:49:19.50		
AN9	iP	20:49:18.05		
AN10	iP	20:49:15.90		
AN12	eP	20:49:22.85		
IN1	ip	20:49:34.25		
IN2	eP	20:49:46.65		
IN3	eP	20:49:42.35		
IN4	eP	20:49:32.15		

***** 17 MARCH 1985 - OHIO *****

O.T.=11:57:06.7 LAT=39.65°N LONG=83.46°W MAG=1.9

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	11:57:24.5		
AN3	iP	11:57:23.9		
AN4	iP	11:57:18.8	eS	11:57:27.6
AN7	iP	11:57:28.6	eS	11:57:44.1
AN8	iP	11:57:22.6		
AN9	iP	11:57:30.4	eS	11:57:47.6
AN12	iP	11:57:31.6	eS	11:57:49.5
IN1	eP	11:57:41.3		
IN2	eP	11:57:49.4		
IN3	iP	11:57:38.4	eS	11:58:03.5
IN4	iP	11:57:27.0		

***** 14 APRIL 1985 - PENNSYLVANIA *****

O.T.=11:39:51.3 LAT=41.40°N LONG=80.37°W MAG=2.0

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN3	iP	11:40:35.30	eS	11:41:08.70
AN7	iP	11:40:35.00		
AN10	eP	11:40:42.80		
AN12	iP	11:40:37.80	eS	11:41:12.50
IN1	iP	11:40:56.20		
SCP	iP	11:40:26.50	eS	11:40:52.10
BV1	eP	11:40:42.50		
WVLY	iP	11:40:21.59	eS	11:40:44.18
PTN	eP	11:41:10.67	eS	11:42:04.64
WNY	iP	11:41:15.52	eS	11:42:18.36
PRIN	eP	11:40:57.18	eS	11:41:49.03
GPD	eP	11:40:59.83	eS	11:41:49.54
WEO	iP	11:40:38.30		
CKO	iP	11:41:05.80		
WBO	iP	11:41:08.10		
EEO	iP	11:41:09.85		
GAC	iP	11:41:14.70		
VDQ	iP	11:41:32.10		

***** 25 AUGUST 1985 - KENTUCKY *****

O.T.=14:30:01.6 LAT=38.54°N LONG=84.98°W MAG=1.6

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	14:30:37.1		
AN3	eP	14:30:38.4		
AN4	eP	14:30:35.0		
AN10	iP	14:30:35.8		
AN11	iP	14:30:36.7		
AN12	eP	14:30:41.4		
IN2	eP	14:30:35.2		
IN3	iP	14:30:19.1	eS	14:30:31.8
IN4	iP	14:30:20.0	eS	14:30:34.7

***** 25 AUGUST 1985 - OHIO *****

O.T.=16:27:11.9 LAT=40.97°N LONG=84.22°W MAG=1.5

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	16:27:21.0	eS	16:27:28.1
AN3	iP	16:27:21.1	eS	16:27:28.3
AN7	iP	16:27:17.4	eS	16:27:21.0
AN10	iP	16:27:21.9	eS	16:27:29.2
AN11	iP	16:27:22.0	eS	16:27:29.7
AN12	iP	16:27:14.3		
IN4	iP	16:27:37.6		

***** 9 SEPTEMBER 1985 - ILLINOIS *****

O.T.=22:06:31.0 LAT=41.85°N LONG=88.01°W MAG=3.0m_{bLg} (NEIS)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
ACM	iP	22:07:02.2		
IN1	iP	22:07:06.4	eS	22:07:32.5
IN2	iP	22:07:08.1	eS	22:07:34.9

***** 12 JANUARY 1986 - OHIO *****

O.T.=11:38:50.2 LAT=40.77°N LONG=83.27°W MAG=0.8

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	11:39:03.6	eS	11:39:13.4
AN3	iP	11:38:58.6	eS	11:39:05.4
AN4	eP	11:39:03.7	eS	11:39:13.8
AN7	eP	11:38:58.4		
AN9			eS	11:39:19.7
AN10	iP	11:39:07.8	eS	11:39:21.3
AN11	eP	11:39:10.2	eS	11:39:24.9
AN12	eP	11:39:03.2	eS	11:39:12.5

***** 13 JANUARY 1986 - OHIO *****

O.T.=11:39:20.4 LAT=40.80°N LONG=84.13°W MAG=0.5

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	11:39:26.5	eS	11:39:31.6
AN3	iP	11:39:26.8	eS	11:39:31.9
AN7	eP	11:39:24.3		
AN9	iP	11:39:25.9	eS	11:39:30.0
AN10	eP	11:39:28.6	eS	11:39:33.4
AN11	iP	11:39:29.2	eS	11:39:35.8
AN12	iP	11:39:22.8	eS	11:39:24.3
IN1			eS	11:40:02.1
IN4			eS	11:40:03.4

***** 31 JANUARY 1986 - OHIO *****

O.T.=16:46:43.3 LAT=41.65°N LONG=81.16°W MAG=5.0m_b (NEIS)

DEP=10km (Location from NEIS)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	ePd	16:47:26.1		
AN3	iPd	16:47:22.7		
AN4	iPd	16:47:25.6		
AN7	iPd	16:47:21.3		
AN9	ePd	16:47:28.2		
AN10	iPd	16:47:29.3		
AN11	ePd	16:47:30.5		
AN12	iPd	16:47:24.2		
IN1	iPd	16:47:41.4		
IN2	ePd	16:47:52.7		
IN4	iPd	16:47:38.5		

***** 30 MARCH 1986 - OHIO *****

O.T.=07:42:42.1 LAT=41.37°N LONG=83.67°W MAG=1.4

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iP	07:42:59.4	eS	07:43:12.2
AN4	iP	07:43:03.2	eS	07:43:18.9
AN7	iP	07:42:52.4	eS	07:42:59.7
AN9	iP	07:42:58.6		
AN10	iP	07:43:01.9	eS	07:43:15.9
AN11	iP	07:43:02.2		
AN12	eP	07:42:52.8	eS	07:43:00.0
IN4	iP	07:43:16.8	eS	07:43:45.1
UTO	iP	07:42:47.5	eS	07:42:50.8

***** 12 JULY 1986 - OHIO *****

O.T.=08:19:39.5 LAT=40.55°N LONG=84.39°W MAG=4.5m_b (NEIS)
DEP=5-10km

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN4	iPc	08:19:48.3		
AN7	iPd	08:19:47.9		
AN8	iPc	08:19:45.2		
AN9	iP	08:19:42.7		
AN10	iPc	08:19:41.5		
AN11	iPd	08:19:43.6		
AN12	iPc	08:19:46.4		
IN1	iPd	08:19:59.8		
IN2	eP	08:20:12.0		
IN3	iPd	08:20:08.5		
IN4	iPc	08:19:58.4		
AAM	iPc	08:20:11.7		
UTO	ePd	08:20:01.6		

***** 17 October 1986 - OHIO *****

O.T.=07:03:4.6 LAT=40.55°N LONG=84.37°W MAG=0.7

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	iPc	07:03:08.2	eS	07:03:11.0
AN3	iPc	07:03:12.3	eS	07:03:17.8
AN7	iPc	07:03:13.3	eS	07:03:20.0
AN8	iPc	07:03:10.4	eS	07:03:14.9
AN9	eP	07:03:07.9		
AN10	eP	07:03:06.6		
AN11	eP	07:03:09.0	eS	07:03:12.0
AN12			eS	07:03:16.9
IN1	eP	07:03:25.2	eS	07:03:41.2
IN3	eP	07:03:33.9		

***** 1 FEBRUARY 1987 - OHIO *****

O.T. =12:01:55.7 LAT=39.323°N LONG=82.428°W
DEP=4km (Location from Univ. of Kentucky)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN3	eP	12:02:24.8		
AN7	iP	12:02:28.7		
AN8	eP	12:02:25.9		

***** 27 March 1987 - TENNESSEE*****

O.T. =07:29:30.45 LAT=35.568°N LONG=84.230°W MAG=4.2m_{bLg}
DEP=19km (Location from CERI)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	07:30:44.6		
AN3	eP	07:30:45.9		
AN4	eP	07:30:41.0		
AN9	eP	07:30:49.0		
AN10	eP	07:30:45.0		
AN11	eP	07:30:46.5		
IN1	eP	07:30:46.5		
IN2	eP	07:30:43.8		
IN3	ePc	07:30:30.5		
IN4	eP	07:30:35.3		

***** 10 JUNE 1987 - ILLINOIS*****

O.T. =23:48:54.8 LAT=38.713°N LONG=87.954°W MAG=4.9m_{bLg}
DEP=5km (Location from SLM)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN3	iPd	23:49:44.1		
AN4	iPd	23:49:47.3		
AN7	iPd	23:49:47.9		
AN8	iPd	23:49:43.8		
AN9	iPd	23:49:45.1		
AN10	iPd	23:49:43.8		
AN11	iPd	23:49:42.5		
AN12	iPd	23:49:44.0		
IN1	iPd	23:49:33.2		
IN4	iPd	23:49:34.9		
ACM	iPc	23:49:57.7		

***** 11 JUNE 1987 - ILLINOIS*****

O.T. =00:15:50.0 LAT=38.67°N LONG=87.95°W MAG=2.6
(Location from SLM)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
IN1	eP	00:16:29.5		

***** 11 JULY 1987 - TENNESSEE*****

O.T. =00:04:29.46 LAT=36.102°N LONG=83.817°W MAG=3.6m_{bLg}
DEP=25km (Location from CERI)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN3	eP	00:05:36.2		
AN4	eP	00:05:32.0		
AN8	eP	00:05:32.2		
AN12	eP	00:05:41.4		
IN1	eP	00:05:39.6		
IN4	eP	00:05:24.7		

***** 13 JULY 1987 - OHIO*****

O.T. =05:49:18.94 LAT=41.90°N LONG=80.726°W MAG=3.8m_{bLg}
DEP=2km (Location from John Carrol Univ.)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	05:50:08.2		
AN3	eP	05:50:04.5		
AN4	eP	05:50:07.0		
AN7	eP	05:50:03.2		
AN8	eP	05:50:10.8		
AN9	eP	05:50:09.8		
AN11	eP	05:50:12.4		
IN1	eP	05:50:23.8		
IN3	eP	05:50:29.7		

***** 13 JULY 1987 - OHIO*****

O.T. =07:52:12.22 LAT=41.90°N LONG=80.703°W MAG=3.0m_{bLg}
DEP=2km (Location from John Carrol Univ.)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	07:53:01.5		
AN3	eP	07:52:57.9		
AN7	eP	07:52:57.4		
AN8	eP	07:53:04.2		
AN9	eP	07:53:03.2		
IN1	eP	07:53:17.9		

***** 13 JULY 1987 - OHIO*****

O.T. =13:05:23.1 LAT=41.908°N LONG=80.75°W MAG=2.9m_{bLg}
DEP=2km (Location from John Carrol Univ.)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN7	eP	13:06:07.9		
AN8	eP	13:06:14.6		

***** 16 JULY 1987 - OHIO*****

O.T. =04:49:40.27 LAT=41.905°N LONG=80.75°W MAG=2.7m_{bLg}
DEP=2km (Location from John Carrol Univ.)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN7	eP	04:50:25.3		
AN8	eP	04:50:32.0		
AN11	eP	04:50:32.1		

***** 31 AUGUST 1987 - ILLINOIS*****

O.T. =17:12:35.2 LAT=38.30°N LONG=89.71°W MAG=3.1m_{bLg}
DEP=9km (Location from SLM)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
IN 3	eP	17:13:24.8		

***** 29 SEPTEMBER 1987 - MISSOURI*****

O.T. =00:04:57.5 LAT=36.84°N LONG=89.21°W MAG=3.6m_{bLg}
DEP=1km (Location from SLM)

STA	PHASE	ARRIVAL TIME	PHASE	ARRIVAL TIME
AN1	eP	00:06:18.3		
AN3	eP	00:06:22.0		
AN8	eP	00:06:14.4		
AN9	eP	00:06:17.8		
AN10	eP	00:06:16.1		
AN11	eP	00:06:16.3		
IN1	iPc	00:05:55.2		
IN2	iPc	00:05:55.4		