

La Malbaie
Experiments to October 1984
by
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Seismological Service of Canada

Internal Report #85-1 (S)

Division of Seismology and Geomagnetism

Earth Physics Branch

Energy, Mines and Resources Canada

Ottawa, Canada

December 1984

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SUMMARY

The La Malbaie P-wave velocity monitoring experiments commenced in 1974. A description of the experiments from then on can be found in the following Internal Reports of the Division.

Period	Report No.
1974 - 1976	77 - 7
1977	78-4
June 1978	78-7
Aug. 1978 - June 1979	79-13
Oct. 1979 - June 1982	82-3
Oct. 1982 - Oct. 1983	83-3

In order to have a complete record of the experiments the period from June to October 1984 will be described in the present report.

In addition two refereed papers have been published, Buchbinder and Keith (1979) and Buchbinder (1981), and a third paper has been accepted for publication, Buchbinder, Kurtz and Lambert (1983).

The present report will describe shots 23 and 24 set off on the north shore and shots 117 and 118 set off on the south shore.

There have been no noteworthy changes in the experiment: no changes in instrumentation nor stations.

Absolute travel times have been determined for most stations, high background noise does not permit this at some stations. Changes in travel time for all shots and stations were obtained by cross-correlating the wave forms.

Experiments

A complete list of the explosions on the north shore is given in Table 1, and those for the south shore are given in Table 2. The station

coordinates and their distances from the shot points are given in Table 3. (Figure 1.)

The shot point on the north shore is a water-filled open air mine and the precise location of the shot point does not change to within a few meters. On the south shore holes are drilled for each shot and corrections are determined for shot point migration. The locations of the recently used holes are sketched in Fig. 2. Shots 117, and 118 were set off in holes 17, and 19 respectively, for the location of hole 17 see Internal report 83-3.

Stations

The station locations and the shot points are shown in Fig. 1. There has been no changes in the layout of the experiments. However at most stations the cement base pads for the seismometers had deteriorated and were replaced, mostly in 1982. Also since more horizontal seismometers have been purchased the number of stations with pads for horizontals was also increased at that time.

Shot Point Timing

For all the shots described for this report the delayless shooter box was used. This box has delays of the order of 0.2 ms and thus has no effect on the timing precision as already mentioned in the last report (82-3).

After shot 114 the correction for shot 112 was made absolute since the near in station 40 had already been used for shot 112. Unfortunately shots 17, 18 and 111 remain floating. The necessary corrections are given in Table 4 for these four shots. A portion of the correction is on the data cards used in the cross-correlation program and another portion is applied in the program that plots the residuals from the cross-correlation process. These corrections are headed CARDS and PROG in Table 4.

Placing a seismograph near to each shot was continued during these last experiments. However, no attempt should be made to remove the residual determined at station 40 (near the southern shot point) for a particular shot from all the stations observing that shot. The reason is that for all the stations the shot point migration correction is determined using, very reasonably, a phase velocity of 6 km/s. However at station 40 the velocity is about 4 km/s, therefore its correction needs to be increased by about 1/3.

The very short distance of 1.03 km of station 40 from the shot point makes the wave form observed at 40 a very sensitive function of the shot point migration. Therefore instead of using 100 data points in the cross-correlation only the first 1/2 cycle is used, consisting of a few data points. Both station 40 and 83 are useful as monitors of the shot point timing.

Array Timing

The array timing has been described in previous reports. It can only be repeated that it was not designed with millisecond accuracy in mind.

Significant Changes

A number of significant changes were undertaken during the course of the experiment, although none during this reporting period. All these changes are listed for convenience in Table 5.

Cross Correlations

For each station changes in travel time have been obtained for all the shots on the north shore and separately for all shots on the south shore. This represents a total of 458 data points. The data are shown in Tables 6 and 7 respectively. The combined data are also plotted in Figure 3.

In Figure 3 the horizontal scale is time in years and cumulative days. At the top are the shot numbers. The vertical scale is in milliseconds, and represents changes in travel time, those above the horizontal line are delays and those below the line are advances with respect to some reference shot. For all stations for this report the reference shot is 23 for the north shore shots and 117 for the south shore shots. The reference shot is arbitrary and was chosen to show changes from June to October 1984.

In addition to the clock corrections the corrections in Table 4 have been applied where necessary. All shot residuals are absolute with respect to the reference shots except for three shots in 1982 i.e. 17, 18, and 111. These are floating to the extent that their averages were adjusted to be zero with the averages of shots 16 and 110. As mentioned earlier the reason for this is that these shots were delayed by unknown amounts due to instrumental problems.

The lengths of the wave form used for cross-correlating is 100 samples at 120 samples/second. Generally the results are acceptable as evidenced by the high value of the cross-correlation function cc. For station 40 only the first 1/2 cycle consisting of a few data points is used.

Travel Times

Arrival times and corrected travel times for the new shots are given in Table 8, together with estimates of their accuracy. This accuracy applies to the digitized sample that was estimated to be the first arrival and hence the estimate may be poor if the waveform is emergent. For sharp arrivals the estimate is good to within \pm one half sample or + 4 ms. Stations where the background noise is large have not been included in Table 8.

Errors

A summary of errors for shots up to 14 and 108 in 1979 is given in Table 9. The errors for the remaining shots are given in Table 10. Errors in 1984 are equal to those in 1982 and are not shown in the Table. The upper 4 lines give the instrumental and clock errors. The lower 4 lines give the R.M.S. errors for the various combinations of recording instruments. The last line gives the R.M.S. error when a BP and an array site record the same shot. The errors for the shots in 1981 do not include uncertainties for d-c offset, nor do any shots include errors due to tilt of the array heads.

Results

Whilst the changes of residuals shown in Fig. 3 vary in detail from station to station a number of points should be noted. From 1974 to 1977 the residual increased, as exemplified by station 60, followed by a decrease in early 1978. Other stations, as 54, dropped at the start of 1980. This was followed by a sinusoidal variation between 1980 and 1984.

Recommendations

Significant changes continue to occur during the six months intervals between the shots. In order to keep track of these changes it is necessary to shoot at the twice a year rate as in the past years. Further, in order to have detailed knowledge of possible changes in velocity before a large earthquake it is necessary to continue shooting until the next large earthquake occurs.

Whilst changes in S wave velocity can be monitored by the present recording of explosions an understanding of the type of cracking involved in the rock mass, S waves from earthquakes with steeply incident ray paths are needed. Therefore a number of microearthquakes have been recorded with the backpacks operated in trigger mode, this will be analyzed in the near future.

References

Buchbinder, G.G.R. Velocity changes in the Charlevoix Region, Quebec, Earthquake Prediction - An International Review. Maurice Ewing Series 4, A.G.U. 367-376, 1981.

Buchbinder, G.G.R. and C.M. Keith. Stability of travel times in the region of La Malbaie, Quebec, Bull. Seism. Soc. Am., 69, 463-481, 1979.

Buchbinder, G.G.R., R.D. Kurtz and A. Lambert. A review of time-dependent geophysical parameters in the Charlevoix Region, Quebec, accepted for publication Earthquake Prediction Research 1983.

Scholz, C.H., L.R. Sykes and Y.P. Aggarwal. Earthquake prediction: a physical basis. Science, 181, 803-810, 1973.

Figure Captions

- Fig. 1. Triangles represent seismometer stations, stars are shots points.
- Fig. 2. Sketch of shot holes for shots including 117 to 118.
- Fig. 3. a, b, c, d. Travel time delays for all stations. Solid bars are for shots on the north shore. Open bars are for shots on the south shore. Horizontal scale is time in years and days. Vertical scale is in milli seconds.
- Fig. 4. Relative average shot residuals for the two shot points.

TABLE 1

St. Jerome Mine
List of Explosions

No.	47.534°N	70.556°W	Charge Size	
	Date	Hour	Lb.	Kg.
1	19 June 74 (170)	17:08:09.305 UT	1000	450
2	13 July 74 (194)	17:11:06.752 UT	1000	450
3	23 July 74 (204)	17:26:08.925 UT	5000	2300
4	24 Sept 75 (267)	17:53:00.036 UT	5000	2300
5	15 Dec. 76 (350)	20:25:59.989 UT	500	230
6	31 Aug. 77 (243)	22:30:00.000 UT	2000	900
7	31 May 78 (151)	21:30:00.000 UT	1500	680
8	01 June 78 (152)	21:30:00.000 UT	500	230
9	24 Aug. 78 (236)	21:30:00.000 UT	2000	900
10	02 Nov. 78 (306)	05:00:00.000 UT	1500	680
11	02 Nov. 78 (306)	22:00:00.000 UT	1500	680
12	27 June 79 (178)	22:00:00.000 UT	1500	680
13	28 June 79 (179)	22:00:00.000 UT	500	230
14	06 Sept 79 (249)	22:00:00.000 UT	1500	680
15	04 June 80 (156)	21:50:00.000 UT	1500	680
16	16 Oct. 80 (290)	21:00:00.000 UT	1500	680
17	11 June 81 (162)	21:30:00.000 UT	1500	680
18	05 Nov. 81 (309)	21:30:00.000 UT	1500	680
19	10 June 82 (161)	21:30:00.000 UT	1500	680
20	21 Oct. 82 (294)	21:00:00.000 UT	1500	680
21	09 June 83 (160)	22:00:00.000 UT	1500	680
22	20 Oct. 83 (293)	21:00:00.000 UT	1500	680
23	07 June 84 (159)	22:00:00.000 UT	1500	680
24	01 Nov. 84 (306)	21:00:00.000 UT	1500	680

TABLE 2

List of Explosions
La Pocatière Shot Hole

No.	47.3500°N	70.0112°W	Charge Size	
	Date	Hour	Lb.	Kg.
101	06 Oct. 75 (280)	15:16:00.000 UT	1000	450
102	28 Oct. 76 (302)	16:26:00.000 UT	1000	450
103	16 Dec. 76 (351)	17:26:00.000 UT	2000	900
104	30 Aug. 77 (242)	23:30:00.000 UT	1500	680
105	30 May 78 (150)	21:30:00.000 UT	1000	450
106	23 Aug. 78 (235)	21:30:00.000 UT	1000	450
107	26 June 79 (177)	23:00:00.000 UT	700	320
108	05 Sept 79 (248)	22:00:00.000 UT	1000	450
109	05 June 80 (157)	22:00:00.000 UT	1000	450
110	15 Oct. 80 (289)	21:00:00.000 UT	1000	450
111	10 June 81 (161)	22:00:00.000 UT	1000	450
112	04 Nov. 81 (308)	22:00:00.000 UT	1000	450
114	20 Oct. 82 (293)	21:00:00.000 UT	1000	450
115	08 June 83 (159)	22:00:00.000 UT	1000	450
116	19 Oct. 83 (292)	21:00:00.000 UT	1000	450
117	06 June 84 (158)	22:00:00.000 UT	1000	450
118	31 Oct. 84 (305)	21:30:00.000 UT	1000	450

TABLE 3

Station Coordinates

Station	Latitude N	Longitude W	Distances	
			N-Shore Km	S-Shore Km
10	47.2460	-70.1930	42.18	17.98
11	47.2430	-70.1970	42.24	18.42
16	47.4680	-70.0100	41.82	13.13
18	47.5190	-69.8640	52.18	21.84
20	47.7060	-69.6900	67.90	46.42
21	47.7040	-69.6900	67.84	46.23
30	47.3360	-69.9410	51.39	5.53
40	47.3408	-70.0094	46.52	1.03
50	47.7860	-70.7410	31.30	73.30
52	47.4270	-70.5200	12.21	39.39
54	47.4570	-70.4130	13.77	32.60
56	47.5500	-70.3270	17.34	32.61
58	47.5250	-70.2130	25.87	24.72
60	47.6920	-70.0930	39.02	38.55
61	47.6937	-70.0912	39.22	38.71
62	47.7520	-70.0090	47.75	44.73
64	47.8270	-69.8910	59.66	53.84
74	47.6330	-70.4610	13.11	46.28
76	47.6430	-70.2410	26.63	36.92
83	47.5217	-70.5540	1.38	45.21

TABLE 4

CORRECTIONS IN MS
(other than clock corrections)

Shot Nos.	BP	Array	Shot Point	
14	-	-	-	
108	-	-	-	
15	+18	-	-	
109	+18	-	-	
16	+18	-27 except stn 60	-	
110	+18	-27 except stn 60	-	
17	+18	-	Cards	Prog
111	+18	-	-81	-8*
18	+18	-	-81	-7*
112	+18	-		-48*
19	+18	-		-50
20	+18	-		
114	+18	-		
21	+18	-		
115	+18	-		
22	+18	-		
116	+18	-		
23	+18	-		
117	+18	-		
24	+18	-		
118	+18	-		

*Corrections are floating

TABLE 5

Significant Changes

Type of change	Date	Starting with Shot No.
Delay-less blaster box	June 1979	12, 107
New BP	June 1980	15, 109
Station 60 becomes 61	05 June 1981	17, 111
Array high gain channels on one head	June 1981	17, 111
Station 40	Nov. 1981	112
Station 83	June 1982	19

Table 6

VALUES FROM CROSS-CORRELATION
IN MILLISECONDS

SHOT JUL. D CUM. D DATE	3 204	4 267 429	5 350 877	6 243 1136	7 151 1409	8 152 1410	9 236 1494	10 306 1564	11 306 1564	12 178 1801	13 179 1802	14 249 1872	15 156 2143	16 290 2278	17 162 2516	18 309 2663	19 161 2880	20 294 3013	21 160 3244	22 293 3377	23 159 3608	24 306 3755
23	24	15	31	31	1	24	2	2	27	28	6	4	16	11	5	10	21	9	20	7	1	
74	75	76	77	78	78	78	78	78	78	79	79	79	80	80	81	81	82	82	83	83	84	84
60	A	BP	A	A	A	A	A	A	A	A	A	BP	A BP	BP	BP	A	A	A BP	ABP	ABP	BP	
-6	16	21	40	5	3	5	6	5	5	20	7	4	7	4	-1	-5	1	17	10	-3	0	
54	A	BP	A	A	A	A	A	A	A	A	A	A	BPA	A	A		A BP	A BP	BP	BP	A	BP
2	16	25	33	19	30	25	36	33	33	44	31	8	1	1	8	10	11	2	-4	-3	-3	0
04			A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
11			30	18	26	24	32	32	30	40	27	8	-2	7	8	-9	10	0	-4	0	13	
16			A	A	A	A	A	A	A	A	A											
11			27	20	27	16	28	26	25	36	19											
16			A	A	A	A	A	A	A	A	A	A	A BP	A	A	A BP	A BP	A	A	A	A	A
11			12	24	21	29	27	27	38	23	9	-8	-11	-1	2	-15	-8	-3	-4	-3	0	15
16			A	A		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
11			31	14		22	34	30	30	38	28	12	-2	3	8	-10	8	-3	0	0	17	
50		BP	BP	BP		A	A	A	A	A	A	BP	BP	BP	BP		BP	BP	BP	BP	BP	
15		15	26	11		9	8	7	10	27	9	5	3	0	-8		-4	-4	-5	0	-1	
50				BP		BP	BP	BP	BP	BP	BP	BP	BP	BP	BP		BP	BP	BP	BP	BP	
13						11	13	14	9	21	11	2	2	-1	-3		-4	2	-2	0	1	
58	A	A	BP				BP		BP	BP	BP	BP	BP		BP	BP	BP	BP	BP	BP	BP	
-1	21		33				15		10	21	14	3	-1		-5	3	-2	-1	0	0	-4	
74		BP	BP	BP		BP	BP				BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	
18		18	29	8		8	8				10	2	-2	0	-1	-4			0	0	-8	
76			BP			BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP		BP	BP	BP	BP	
36			36			15	14	15	11	21	16	8	7	-3	-4		5	0	-2	0	-5	
02				BP		BP	BP	BP	BP		BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	
16						16	16	17	13		15	9	6	2	4		4	5	7	0	1	
30	A	A	BP	BP		BP			BP			BP		BP	BP	BP		BP	BP	BP	BP	
11	26		38	17		17			15			18		9	11	14		3	0	0	-2	
18	A	A	BP									BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	
-25	-10		1									1	0	-1	-7	0	-6	-4	-5	0	-9	
70																						
83																	BP	BP	BP	BP	BP	
0								BP	BP								0	1	-4	0	0	

Corrections

Shot No.	ms
17	-89
18	-48

Table 7

VALUES FROM CROSS-CORRELATION
IN MILLISECONDS

SHOT JUL. D CUM. D DATE	101 280 442	102 302 829	103 351 878	104 242 1135	105 150 1408	106 235 1493	107 177 1800	108 248 1871	109 157 2145	110 289 2277	111 161 2515	112 308 2662	114 293 3012	115 159 3243	116 292 3376	117 158 3607	118 305 3754
SIN	7 10 75	28 10 76	16 12 76	30 8 77	30 5 78	23 8 78	26 6 79	5 9 79	5 6 80	15 10 80	10 6 81	4 11 81	20 10 82	8 6 83	19 10 83	6 6 84	31 10 84
60	A 19	BP 40	BP 35	A 49	A 14	A 21	A 13	A 15	BP 12	A BP 13 9	BP 11	BP 10	A 27	A BP 24 5	BP 5 9	A 0	BP 3
54	A 11		BP 28	A 32	A 24		A 41		A BP 5 4	BP 4 7	A 9	A 16	A BP 15 5	A BP 11 10	BP 0	ABP 0	BP 1
64				A 34	A 20	A 36	A 34	A 29	A 5	A 1	A 5	A 15	A 13	A 13	A 0	A 0	A 5
11				A 24	A 14	A 24	A 19	A 19	A 3	A -10	BPA -14 -9	A BP -1 -6	A -3	A -5	A -3	A 0	A -2
16			BP 10		A 12	A 30	A 22	A 24	A 2	A BP -9 -10	A -3	A 2	A BP 2 -11	A 2	A 0	A 0	A 3
21				A 30	A 14	A 30	A 26	A 25	A 2	A -5	A -4	A 5	A 5	A 4	A -2	A 0	A 1
56		BP 53	BP 50	BP 24	BP 14	A 16	A 7	BP 13	BP 1	BP -2	BP -1	BP 4	BP 2	BP 4	BP -3	BP 0	BP -5
52					BP 16	BP 23		BP 17	BP 11	BP 2		BP 10	BP 10	BP 4	BP 0	BP 0	BP 6
58	A 11	BP 34	BP 22	BP 25			BP 11	BP 14	BP 0	BP 0	BP 4	BP 5	BP 4	BP 5	BP -3	BP 0	BP 4
71		BP 29		BP 36		BP 20		BP 17	BP 10	BP 4	BP 0	BP 9		BP 4	BP 2	BP 0	BP 8
76				BP 26	BP 17	BP 26	BP 16	BP 19	BP 8	BP 1	BP -1	BP 5	BP 7	BP 9	BP -2	BP 0	BP 8
62				BP 25		BP 25	BP 12	BP 16	BP 10	BP 5	BP 2	BP 6	BP 5	BP 7	BP 3	BP 0	BP 4
30	A 17				BP 18	BP 24	BP 11			BP 0	BP -2	BP 9	BP 0	BP -3	BP -2	BP 0	BP -1
18	A 14			BP 19				BP -2	BP 2	BP 4	BP -4	BP 7	BP 0	BP 9	BP -1	BP 0	BP 2
40												BP -2	BP -1	BP -8	BP -1	BP 0	BP -1
83																	
50																	

Corrections

Shot No.	ms
111	-88
112	-50

TRAVEL TIMES FOR LA MALBAIE AREA SHOTS

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS			
17	152 11. 0. 1981	21 30 0.000	2 U	0	14	-91	0
ST INST	ARR. TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS			
54	A 2.435	4 S	2 22 0 U	2.378 .007			
61	A 6.567	4 S	2 22 0 U	6.512 .007			
64	A 7.699	4 S	2 22 0 U	9.644 .007			
52	BP 2.225	4 S	2 -24 3 U	2.125 .007			
56	BP 3.644	4 S	2 -18 3 U	2.952 .007			
58	BP 4.549	4 S	2 -22 3 U	4.453 .007			
60	BP 6.573	4 S	2 -21 3 U	6.478 .007			
61	BP 6.599	4 S	2 -17 3 U	6.508 .007			
74	BP 2.225	4 S	2 -21 3 U	2.137 .007			
76	BP 4.553	4 S	2 -19 3 U	4.460 .007			

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS			
18	309 5. 12. 1981	21 30 0.000	2 U	0	0	-50	0
ST INST	ARR. TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS			
52	BP 2.175	4 S	2 -14 3 U	2.120 .007			
56	BP 2.999	4 S	2 -5 3 U	2.955 .007			
58	BP 4.415	4 S	2 -17 3 U	4.359 .007			
61	BP 6.565	4 S	2 -17 3 U	6.512 .007			
62	BP 7.620	4 S	2 -6 3 U	7.763 .007			
74	BP 2.172	4 S	2 0 3 U	2.133 .007			
76	BP 4.504	4 S	2 -26 3 U	4.439 .007			

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS			
19	161 10. 6. 1982	21 30 0.000	2 U	0	21	0	0
ST INST	ARR. TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS			
74	BP 2.132	4 S	2 0 3 -14	2.142 .007			
58	BP 4.336	4 S	2 0 3 7	4.367 .007			
63	BP 2.270	4 S	2 -29 3 U	.271 .007			
15	A 7.165	4 S	2 0 0 1	7.167 .007			
61	A 6.497	4 S	2 0 0 1	6.519 .007			
64	A 7.621	4 S	2 0 0 1	9.643 .007			
21	A 7.215	4 S	2 0 0 1	7.237 .007			

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS			
20	294 21. 10. 1982	21 0 0.000	2 U	0	15	0	0
ST INST	ARR. TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS			
61	A 6.514	4 S	2 11 0 U	6.540 .007			
64	A 7.651	4 S	2 11 0 U	9.677 .007			
54	A 2.375	4 S	2 11 0 U	2.349 .007			
21	A 11.315	4 S	2 11 0 U	11.341 .007			
16	A 7.175	4 S	2 11 0 U	7.199 .007			
17	A 7.242	4 S	2 11 0 U	7.268 .007			
52	BP 2.120	4 S	2 -20 3 U	2.126 .007			
54	BP 2.401	4 S	2 -37 3 U	2.362 .007			
63	BP 2.279	4 S	2 -25 3 U	.272 .007			
56	BP 2.974	4 S	2 -35 3 U	2.957 .007			
58	BP 4.380	4 S	2 -31 3 U	4.375 .007			
76	BP 4.465	4 S	2 -22 3 U	4.461 .007			

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS			
21	160 7. 0. 1983	22 0 0.000	2 U	0	11	0	0
ST INST	ARR. TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS			
54	A 2.357	4 S	2 -5 0 U	2.343 .007			
61	A 6.517	4 S	2 -5 0 U	6.523 .007			
64	A 7.650	4 S	2 -5 0 U	9.662 .007			
11	A 7.245	4 S	2 -5 0 U	7.251 .007			
16	A 7.169	4 S	2 -5 0 U	7.175 .007			
21	A 12.277	4 S	2 -5 0 U	11.133 .007			
52	BP 2.315	4 S	2 -199 3 U	2.128 .007			
54	BP 2.545	4 S	2 -180 3 U	2.379 .007			
56	BP 3.139	4 S	2 -196 3 U	2.957 .007			
58	BP 4.550	4 S	2 -188 3 U	4.376 .007			

61 BP	6.690	4	5	2	-192	3	0	6.512	.007
62 BP	7.936	4	5	2	-167	3	0	7.785	.007
74 BP	2.228	4	5	2	-107	3	0	2.135	.007
76 BP	4.647	4	5	2	-198	3	0	4.463	.007
83 BP	.265	4	5	2	-3	3	0	.274	.007

SHUT DAY DATE ORIGIN TIME ERRORS CORRECTIONS ALL IN MS

22 293 20.10.1963 21 0 0.000 2 0 0 7 0 0

ST INST ARR. TIME ERRORS CORRECTIONS TRAVEL TIME +/- ERRORS

52 BP	2.136	4	5	2	-21	3	0	2.125	.007
54 BP	2.357	4	5	2	5	3	0	2.382	.007
55 BP	2.955	4	5	2	-11	3	0	2.954	.007
55 BP	4.374	4	5	2	-10	3	0	4.388	.007
61 BP	6.521	4	5	2	-19	3	0	6.512	.007
62 BP	7.800	4	5	2	-20	3	0	7.790	.007
74 BP	2.109	4	5	2	15	3	0	2.134	.007
76 BP	4.468	4	5	2	-11	3	0	4.459	.007
83 BP	.262	4	5	2	2	3	0	.274	.007
01 A	6.445	4	5	2	72	0	0	6.524	.007
16 A	7.127	4	5	2	72	0	0	7.206	.007
74 A	7.536	4	5	2	72	0	0	9.615	.007
21 A	11.265	4	5	2	72	0	0	11.339	.007

SHUT DAY DATE ORIGIN TIME ERRORS CORRECTIONS ALL IN MS

23 157 7. 6.1984 22 0 0.000 2 0 0 16 0 0

ST INST ARR. TIME ERRORS CORRECTIONS TRAVEL TIME +/- ERRORS

52 BP	2.107	4	5	2	-8	3	0	2.120	.007
54 BP	2.376	4	5	2	-11	3	0	2.378	.007
56 BP	2.945	4	5	2	-12	3	0	2.950	.007
51 BP	6.503	4	5	2	-19	3	0	6.503	.007
74 BP	2.125	4	5	2	-8	3	0	2.134	.007
76 BP	4.444	4	5	2	-4	3	0	4.459	.007
83 BP	.254	4	5	2	-2	3	0	.271	.007
16 BP	6.857	4	5	2	-5	3	0	8.871	.007
54 A	2.387	4	5	2	-11	0	0	2.392	.007
61 A	6.517	4	5	2	-11	0	0	6.522	.007
16 A	7.196	4	5	2	-11	0	0	7.203	.007

SHUT DAY DATE ORIGIN TIME ERRORS CORRECTIONS ALL IN MS

24 306 1.11.1964 21 30 0.000 2 0 0 16 0 0

ST INST ARR. TIME ERRORS CORRECTIONS TRAVEL TIME +/- ERRORS

52 BP	2.141	4	5	2	-25	3	0	2.135	.007
54 BP	2.395	4	5	2	-17	3	0	2.395	.007
56 BP	2.955	4	5	2	-10	3	0	2.966	.007
55 BP	4.357	4	5	2	-8	3	0	4.360	.007
61 BP	6.545	4	5	2	-41	3	0	6.526	.007
74 BP	2.137	4	5	2	-9	3	0	2.147	.007
76 BP	4.471	4	5	2	-14	3	0	4.476	.007
83 BP	.255	4	5	2	-19	3	0	.263	.007
16 BP	6.864	4	5	2	-8	3	0	8.875	.007
61 A	6.544	4	5	2	-12	0	0	6.548	.007
54 A	7.851	4	5	2	-12	0	0	9.655	.007

SHUT DAY DATE ORIGIN TIME ERRORS CORRECTIONS ALL IN MS

111 161 10. 6.1961 22 0 0.000 2 0 0 20 -91 0

ST INST ARR. TIME ERRORS CORRECTIONS TRAVEL TIME +/- ERRORS

61 A	6.905	4	5	2	11	-2	0	6.843	.007
54 A	7.279	4	5	2	-11	-2	0	9.167	.007
11 A	3.590	4	5	2	11	1	0	3.531	.007
16 A	2.721	4	5	2	11	-2	0	2.659	.007
21 A	3.431	4	5	2	11	-2	0	8.369	.007
52 BP	6.906	4	5	2	-13	3	0	6.819	.007
55 BP	2.504	4	5	2	-11	3	-1	5.824	.007
58 BP	4.658	4	5	2	-12	3	-1	4.587	.007
60 BP	6.896	4	5	2	-13	3	-2	6.813	.007
61 BP	6.904	4	5	2	-12	3	-2	6.827	.007
62 BP	7.791	4	5	2	-9	3	-2	7.712	.007

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS		
11 BP	3.590	4 5 2 -5	3 1	3.518	.007	
18 BP	4.070	4 5 2 -9	3 -2	3.991	.007	
30 BP	1.273	4 5 2 -12	3 1	1.194	.007	
112 300	4.11.1961	22 0 0.000	2 0	0 12 -50	0	
ST INST	ARK.TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS		
40 BP	.309	4 5 2 -15	3 1	.260	.007	
52 BP	0.971	4 5 2 -8	3 2	6.930	.007	
56 BP	5.007	4 5 2 0	3 1	5.833	.007	
58 BP	4.030	4 5 2 -7	3 0	4.594	.007	
01 BP	0.075	4 5 2 -8	3 -1	6.831	.007	
02 BP	7.781	4 5 2 -9	3 -2	7.735	.007	
74 BP	3.002	4 5 2 -3	3 1	7.965	.007	
76 BP	0.584	4 5 2 -4	3 0	6.545	.007	
11 BP	3.002	4 5 2 -35	3 3	3.535	.007	
18 BP	4.067	4 5 2 -34	3 -3	3.995	.007	
30 BP	1.270	4 5 2 -26	3 -2	1.215	.007	
40 BP	.300	4 5 2 -15	3 1	.259	.007	

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS		
114 293	21.10.1962	21 0 0.000	2 0	0 14 0	0	
ST INST	ARK.TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS		
16 A	2.293	4 5 2 -26	0 -2	2.679	.007	
01 A	0.071	4 5 2 -26	0 -2	6.857	.007	
11 A	3.549	4 5 2 -26	0 2	3.539	.007	
21 A	0.593	4 5 2 -26	0 -2	8.384	.007	
54 A	5.071	4 5 2 -26	0 0	5.859	.007	
52 BP	0.433	4 5 2 -25	3 1	6.926	.007	
56 BP	0.232	4 5 2 -28	3 0	5.821	.007	
58 BP	4.002	4 5 2 -27	3 -1	4.591	.007	
76 BP	0.550	4 5 2 -26	3 -1	6.540	.007	
16 BP	2.078	4 5 2 -31	3 -2	2.662	.007	
18 BP	4.000	4 5 2 -28	3 -2	3.907	.007	
30 BP	1.270	4 5 2 -24	3 -1	1.207	.007	
40 BP	.258	4 5 2 -26	3 2	.251	.007	

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS		
115 159	8. 0. 1963	22 0 0.000	2 0	0 13 0	0	
ST INST	ARK.TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS		
01 A	0.761	4 5 2 69	0 -3	6.840	.007	
04 A	7.109	4 5 2 69	0 -4	9.167	.007	
11 A	3.441	4 5 2 69	0 4	3.527	.007	
16 A	2.004	4 5 2 69	0 -4	2.682	.007	
21 A	0.529	4 5 2 69	0 -4	8.407	.007	
52 BP	7.104	4 5 2 -198	3 2	6.924	.007	
56 BP	5.997	4 5 2 -197	3 -1	5.815	.007	
58 BP	4.764	4 5 2 -197	3 -1	4.502	.007	
01 BP	7.010	4 5 2 -197	3 -3	6.832	.007	
02 BP	7.097	4 5 2 -191	3 -4	7.720	.007	
74 BP	0.123	4 5 2 -178	3 -1	7.960	.007	
76 BP	0.777	4 5 2 -198	3 -2	6.543	.007	
18 BP	3.998	4 5 2 -13	3 -4	3.997	.007	
30 BP	1.270	4 5 2 9	3 -1	1.222	.007	
40 BP	.230	4 5 2 -8	3 3	.249	.007	

SHOT DAY	DATE	ORIGIN TIME	ERRORS	CORRECTIONS ALL IN MS		
116 242	17.10.1963	21 0 0.000	2 0	0 10 0	0	
ST INST	ARK.TIME	ERRORS	CORRECTIONS	TRAVEL TIME +/- ERRORS		
02 BP	0.914	4 5 2 -13	3 -3	6.911	.007	
06 BP	0.017	4 5 2 -11	3 0	5.819	.007	
03 BP	4.573	4 5 2 -7	3 1	4.500	.007	
01 BP	0.010	4 5 2 -13	3 3	6.821	.007	
52 BP	7.724	4 5 2 -13	3 4	7.728	.007	
74 BP	7.549	4 5 2 -4	3 0	7.958	.007	
76 BP	0.500	4 5 2 -10	3 2	6.505	.007	
30 BP	1.193	4 5 2 -3	3 3	1.206	.007	

40 BP	.249	4	5	2	-3	3	-3	.256	.007
16 A	2.620	4	5	2	42	0	4	2.682	.007
61 A	6.781	4	5	2	42	0	0	6.833	.007
11 A	3.444	4	5	2	42	0	-5	3.491	.007
64 A	9.070	4	5	2	42	0	4	9.132	.007
21 A	6.530	4	5	2	42	0	5	8.395	.007

SHOT DAY DATE ORIGIN TIME ERRORS CORRECTIONS ALL IN MS
 117 150 6. 6. 1964 22 0 0.000 2 0 0 15 0 0

ST INST ARR. TIME ERRORS CORRECTIONS TRAVEL TIME +/- ERRORS

22 BP	6.922	4	5	2	-11	3	-5	6.924	.007
26 BP	5.619	4	5	2	-12	3	-4	5.821	.007
28 BP	4.585	4	5	2	-12	3	-3	4.586	.007
61 BP	6.623	4	5	2	-12	3	-1	6.828	.007
62 BP	7.714	4	5	2	-16	3	0	7.716	.007
74 BP	7.950	4	5	2	-11	3	-4	7.959	.007
18 BP	3.485	4	5	2	-7	3	5	3.999	.007
30 BP	1.185	4	5	2	-5	3	5	1.203	.007
61 A	6.670	4	5	2	-40	0	-1	6.844	.007
16 A	2.693	4	5	2	-40	0	0	2.673	.007
40 BP	.243	4	5	2	-6	3	1	.256	.007

SHOT DAY DATE ORIGIN TIME ERRORS CORRECTIONS ALL IN MS
 118 305 31.10.1964 21 30 0.000 2 0 0 4 0 0

ST INST ARR. TIME ERRORS CORRECTIONS TRAVEL TIME +/- ERRORS

22 BP	6.932	4	5	2	-16	3	-5	6.921	.007
26 BP	5.622	4	5	2	-16	3	-4	5.814	.007
28 BP	4.597	4	5	2	-14	3	-3	4.592	.007
61 BP	6.641	4	5	2	-22	3	-1	6.830	.007
62 BP	7.731	4	5	2	-15	3	0	7.728	.007
64 BP	9.131	4	5	2	-17	3	1	9.127	.007
74 BP	7.967	4	5	2	-13	3	-4	7.962	.007
76 BP	6.535	4	5	2	-12	3	-2	6.537	.007
18 BP	3.493	4	5	2	-14	3	3	3.994	.007
30 BP	1.194	4	5	2	-15	3	5	1.196	.007
40 BP	.250	4	5	2	-14	3	1	.249	.007
61 A	6.677	4	5	2	-39	0	-1	6.846	.007

TABLE 9

SUMMARY OF ERRORS

3	4	5	6	7	8	9	10	11	12	13	14	SHOT NUMBERS
	101	102 103	104		105	106			107		108	
1974	1975	1976	1977	1978				1979				YEAR
4	4	4	4	4	4	4	4	4	4	4	4	Array digit.
	2	2	2	2	2	2	2	2				Blaster box
	2	2	2	2	2	2	2	2	2	2	2	Shooter clock
2	2	2	2	2	2	2	2	2	2	2	2	Recorder clock
7												Commerc. blaster
		8	8									BP Micropr.
5	5	5	5	5	5	5	5	5	5	5	5	BP-A
		9	9	5	5	5	5	5	4	4		BPxBP
10	7	7	7	7	7	7	7	7	7	7		A x A
		11	11	8	8	8	8	8	8	8		BPXA



TABLE 10
SUMMARY OF ERRORS

CHOT		14	15	16	17	18	19
NUMBERS		108	109	110	111	112	
YEAR		1979	1980		1981		1982
ARRAY	BP	4	4	4	4	4	4
	Array Digit	4	4	4	4	4	4
	Shooter Clock	2	2	2	2	2	2
	Recorder Clock	2	2	2	2	2	2
	BP - A	5	5	5	5	5	5
RMS	BP x BP	4	4	4	4	4	4
	A x A	7	7	7	7	7	7
	BP x A	8	8	8	8	8	8
	BP x A	7	7	7	7	7	7
	Same Shot						

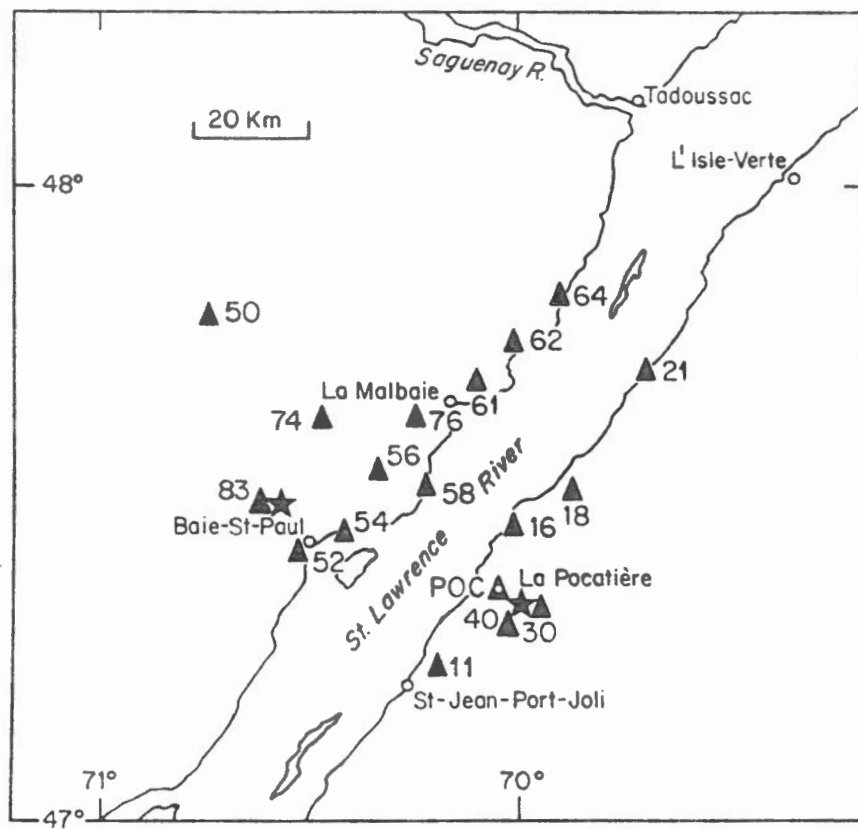


Fig. 1

LA POCAIÈRE SHOT POINT

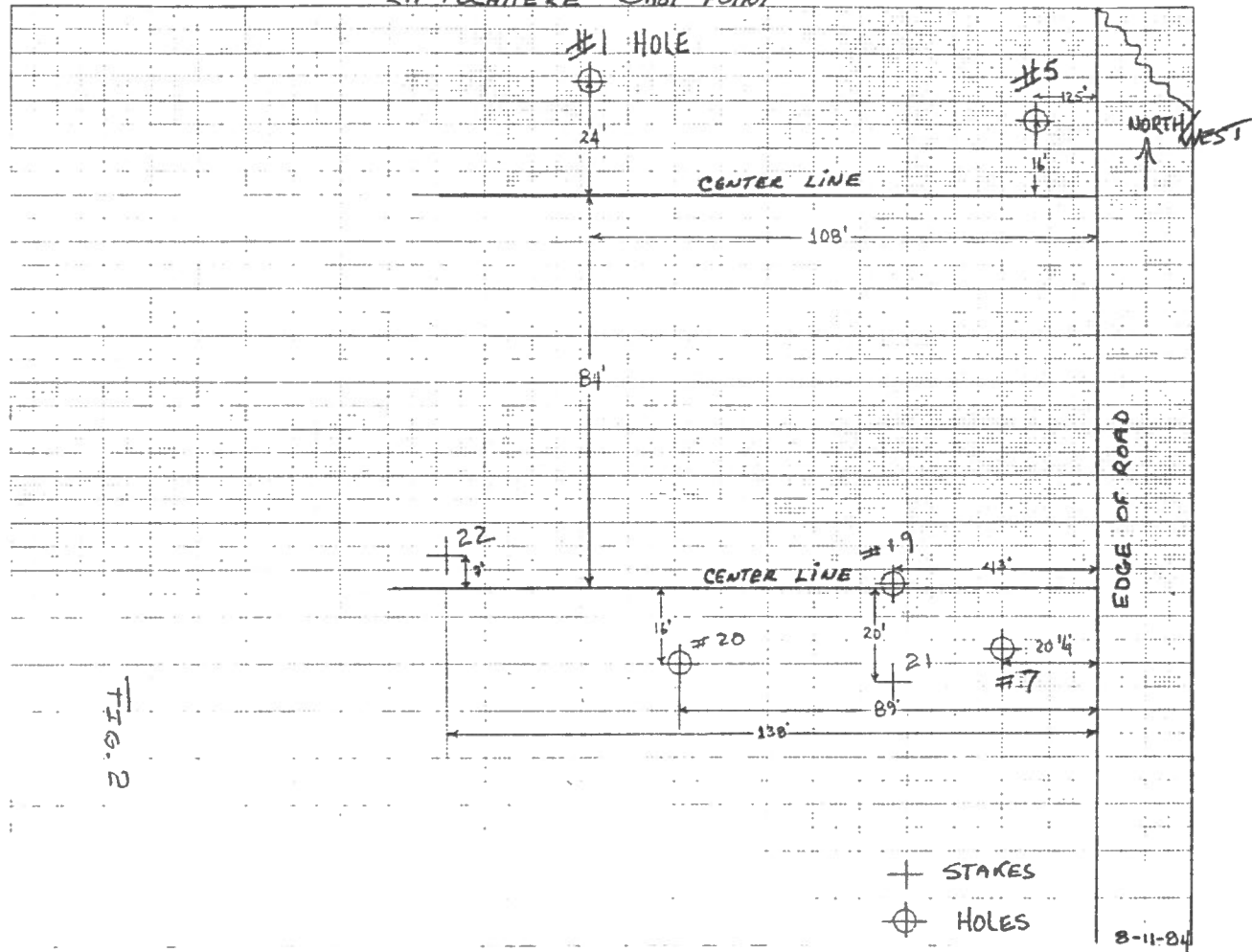


FIG. 2

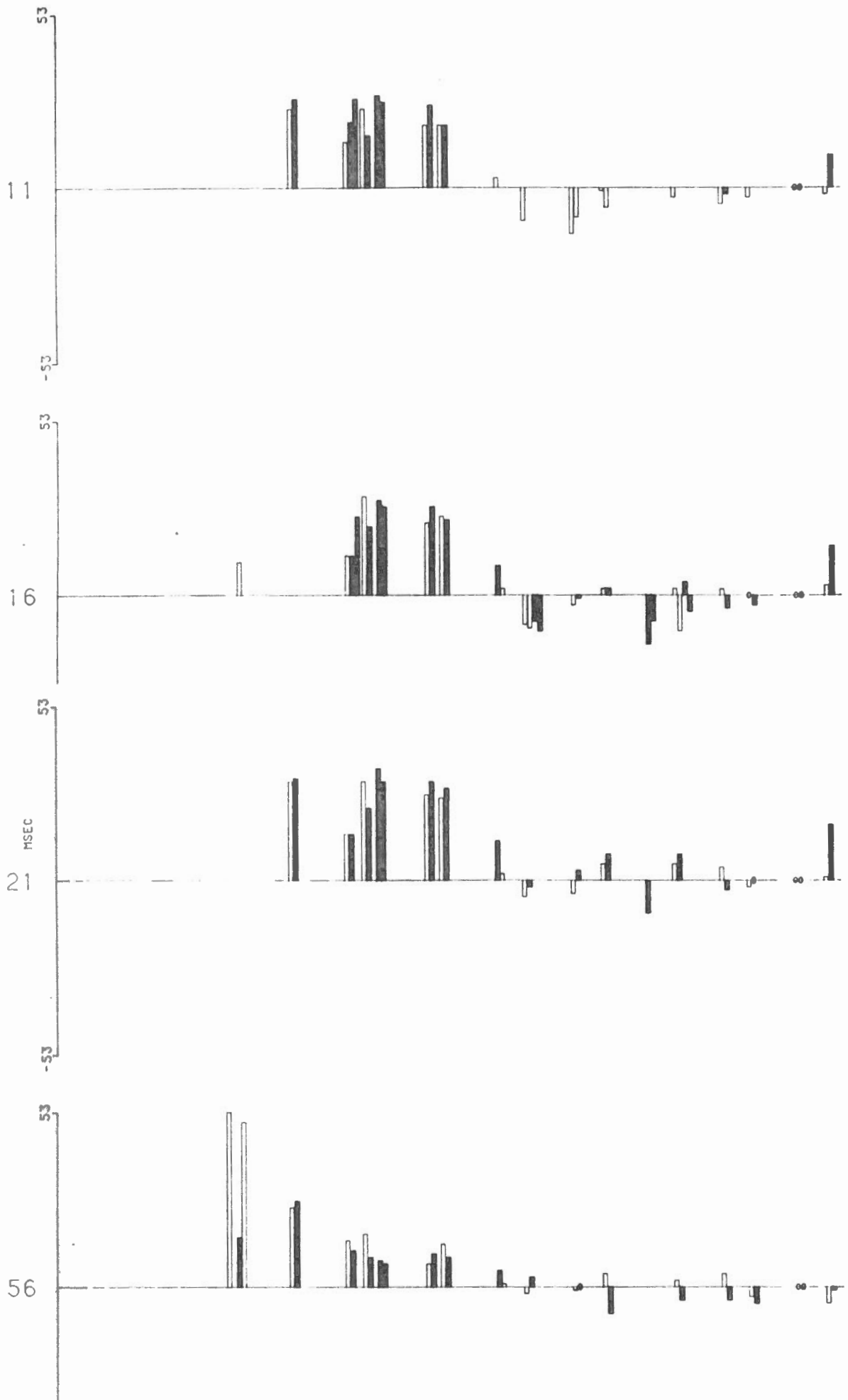
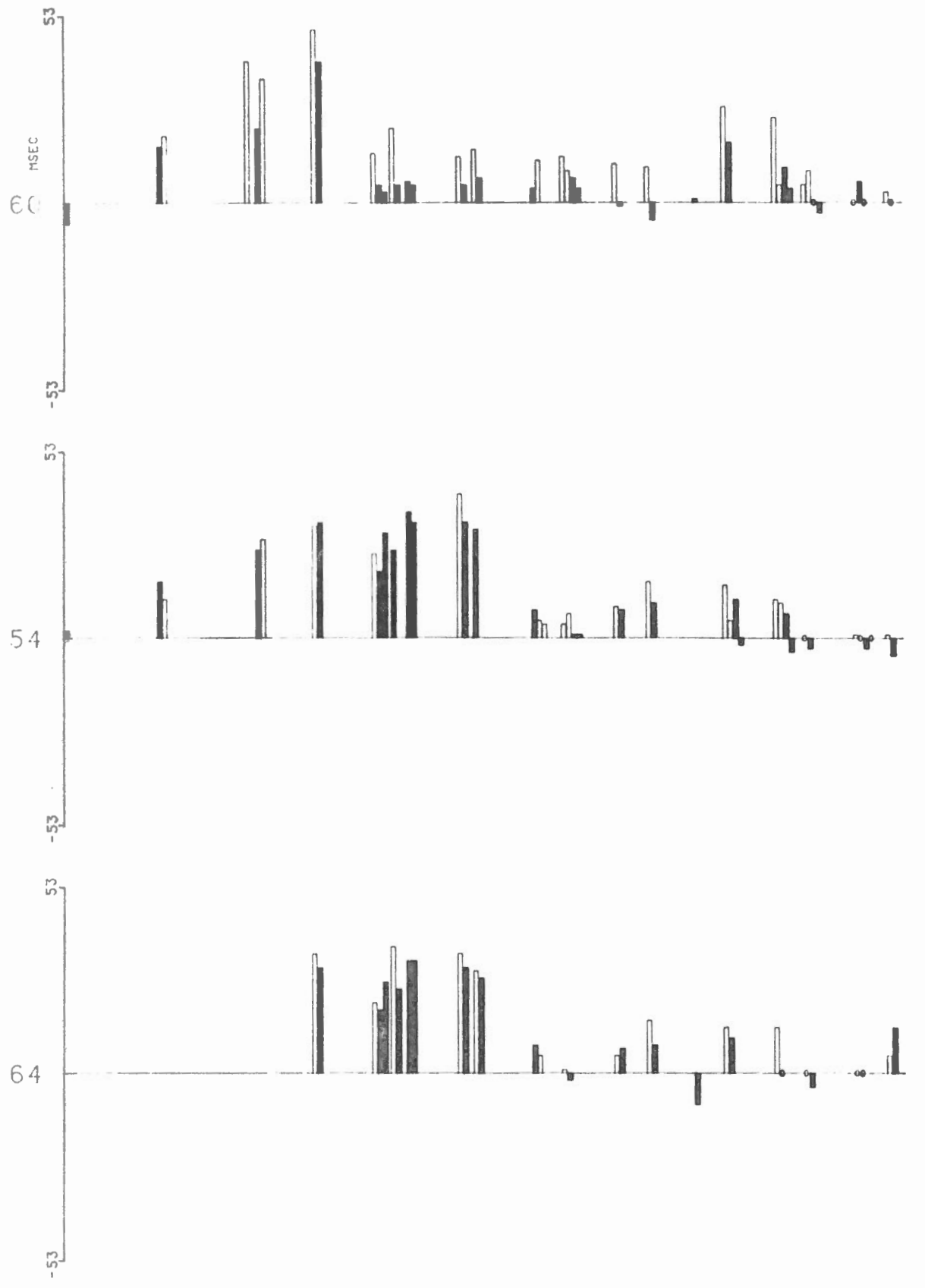
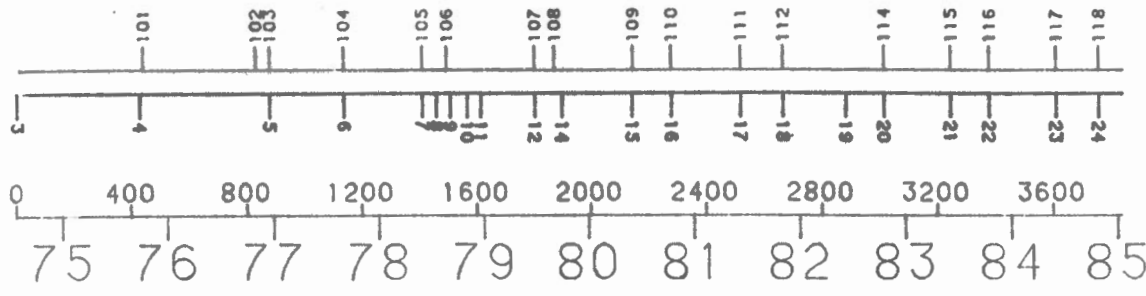
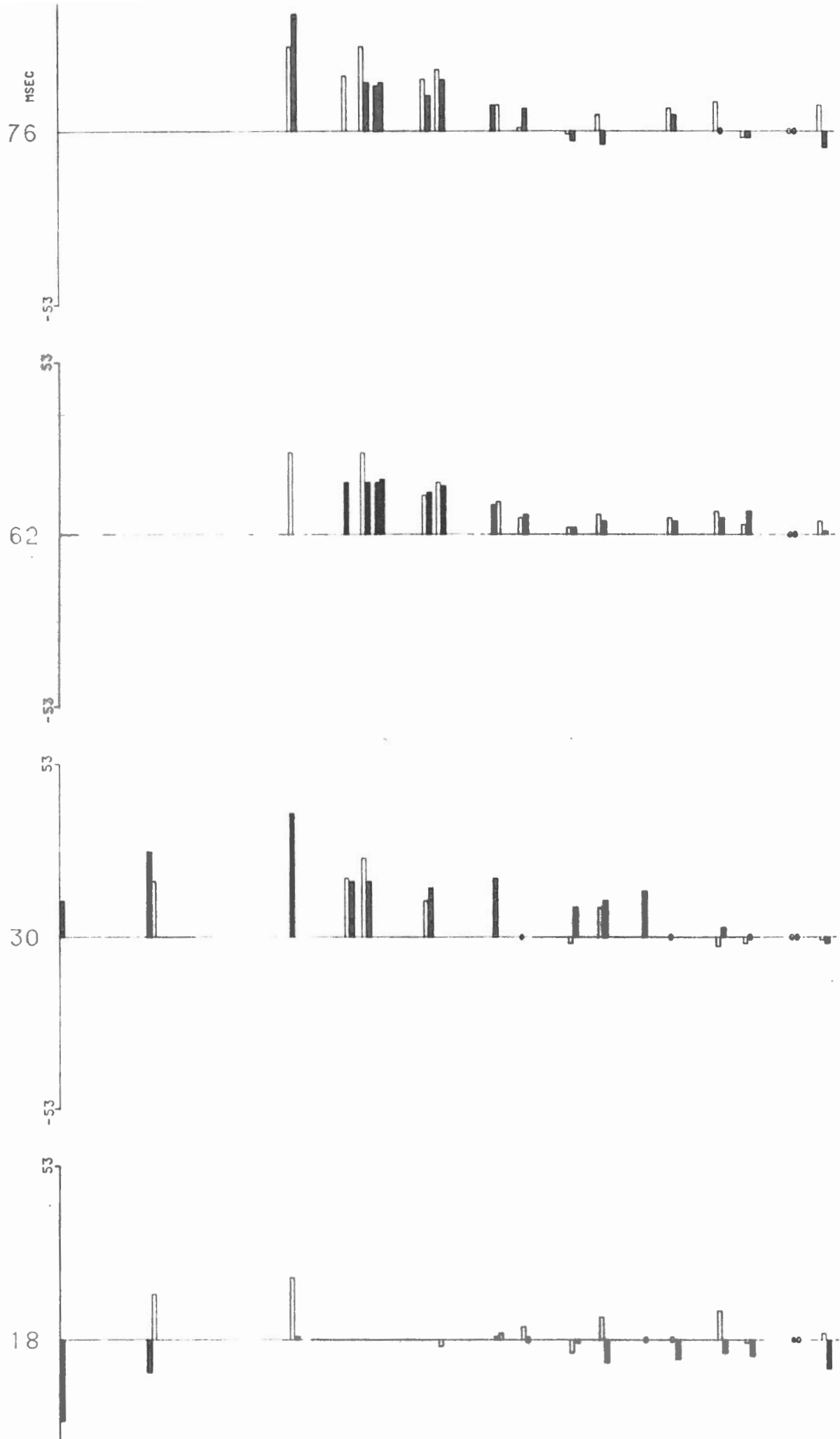


Figure 3





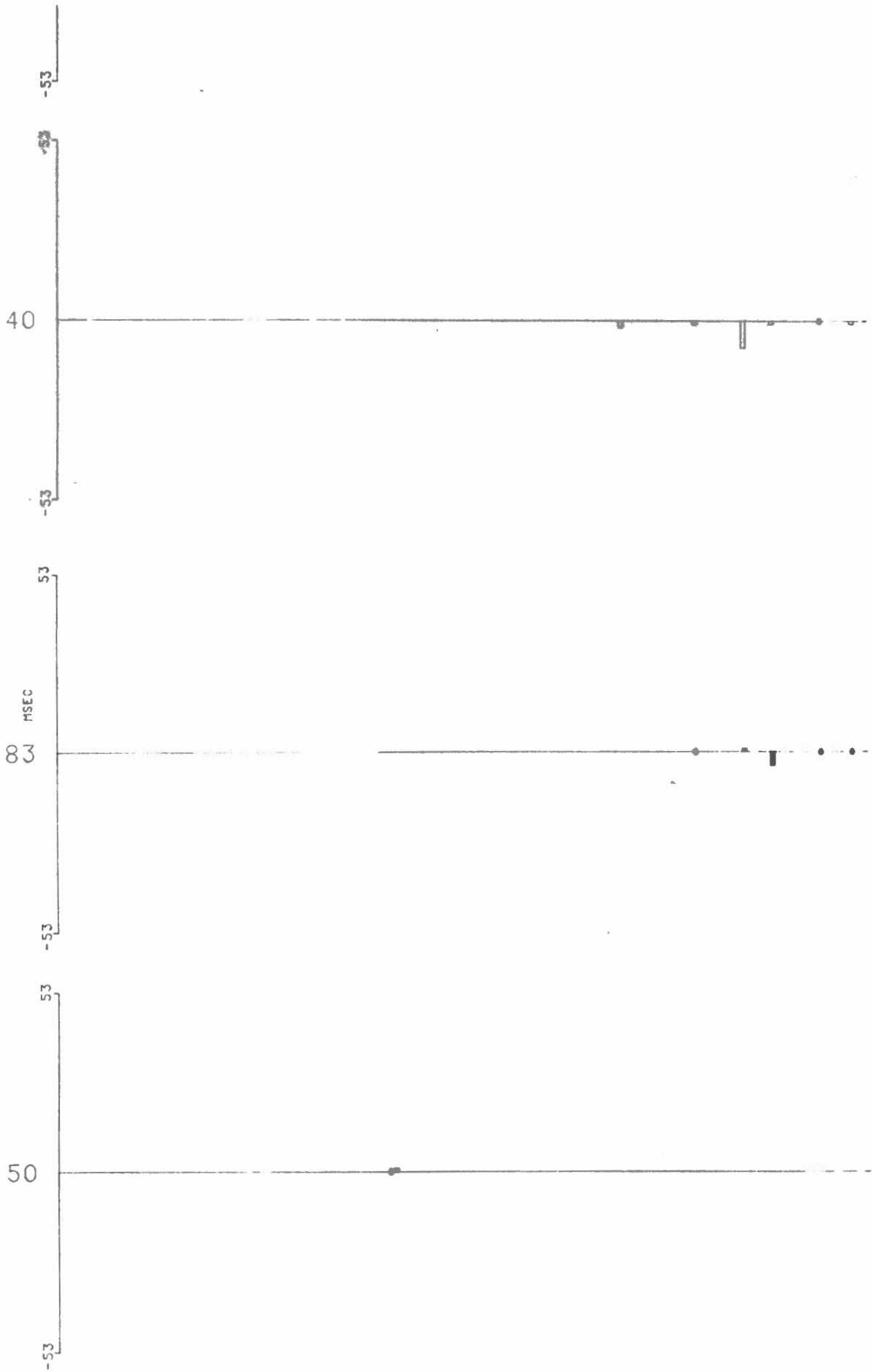
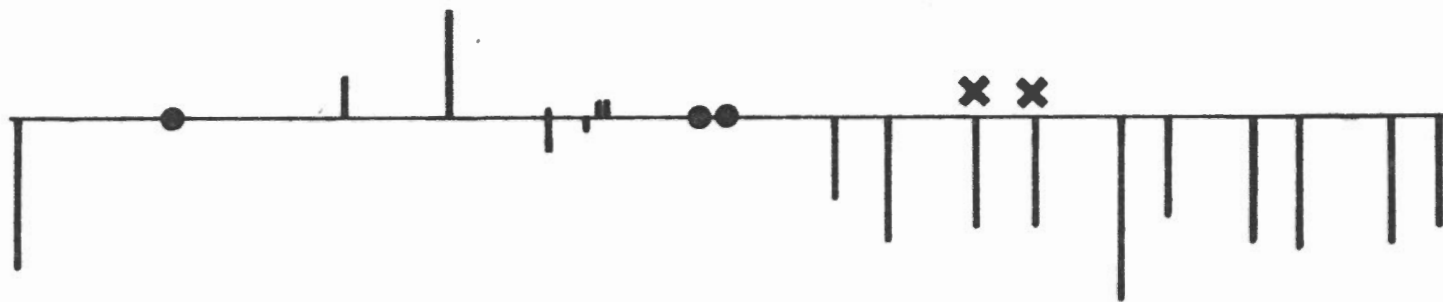


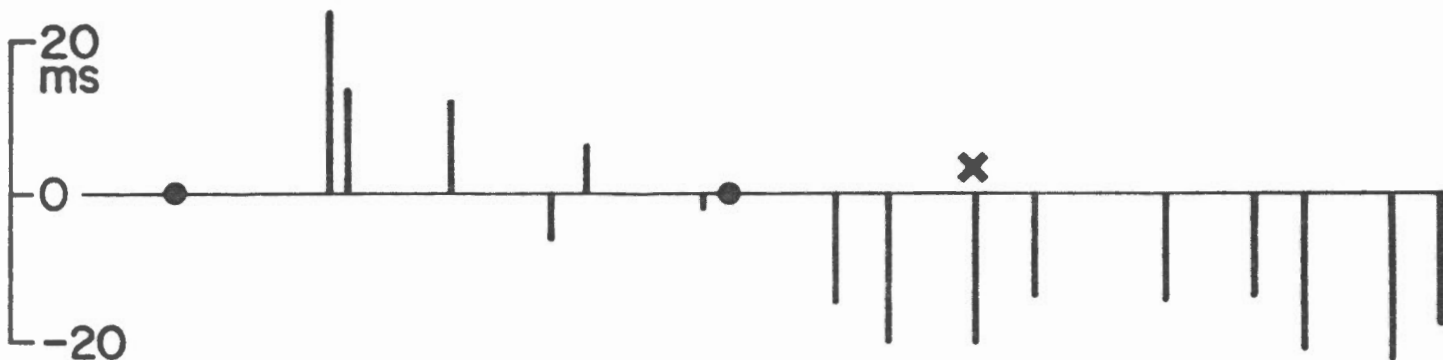
FIG 4

RELATIVE AVERAGE SHOT RESIDUALS

NORTH SHORE



SOUTH SHORE



× floating

YEARS

74 75 76 77 78 79 80 81 82 83 84