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REPORT ON THE SECOND PHASE OF THE SEISMIC PROGRAM ACROSS THE SUPERIOR-CHURCHILL BOUNDARY ZONE IN SOUTHERN CANADA

Z. Hajnal,
58 pp. including 20 illustrations

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Cooperative Near Vertical Incident Reflection and Refraction Seismic Surveys Across the Superior-Churchill Boundary Zone in Southern Canada

Location, Outline of Objectives, Field Procedures,
Field Parameters
Tape Formats and Preliminary Computer Results

DSS Contract No: OSU79-00033

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S7N OWO

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INTRODUCTION

En août 1979, le groupe CO-CRUST* a poursuivi l'exécution de son programme coopératif de sondages sismiques dans le sud du Manitoba et de la Saskatchewan. La première étape des travaux a commencé en juillet 1977, et ses résultats ont été divulgués par Green et Stephenson (1978) et par Green et ass. (1980). Cette étude avait pour objectif de découvrir la nature de la zone limitrophe située entre les provinces tectoniques Churchill et Supérieur du Bouclier canadien. Green et Stephenson (1978) ont décrit les caractéristiques géologiques de surface de la zone de transition, ainsi que les anomalies géophysiques connexes.

Le présent rapport contient une brève description des objectifs, l'emplacement géographique de la partie visée par l'étude en 1979, les méthodes de travail utilisées sur le terrain, les paramètres du terrain, le format des rubans porteurs des données numériques, et un court résumé de l'interprétation préliminaire.

* Consortium for Crustal Reconnaissance Using Seismic Techniques (Groupe de sondage sismique de la croûte terrestre)

INTRODUCTION

In August 1979 the CO-CRUST* group continued its cooperative seismic survey program in the southern part of Manitoba and Saskatchewan. The first phase of the project was undertaken in July 1977 and its findings were reported by Green and Stephenson (1978) and Green et al. (1980). The rationale of the study was to obtain information about the nature of the boundary zone between the Churchill and Superior Tectonic Provinces of the Canadian Shield. The surface geological characteristics of the transition zone and the associated geophysical anomalies were described by Green and Stephenson (1978).

This report includes a brief outline of the objectives, the geographic setting of the 1979 portion of the survey, field procedures, field parameters, digital data tape formats, and a short summary of the preliminary interpretation.

* Consortium for Crustal Reconnaissance Using Seismic Techniques.

OUTLINE OF OBJECTIVES

The Nelson Front or Churchill Superior Boundary zone is located in the Canadian Shield, extending south southwest for about 1600 km from the west coast of Hudson Bay. Green and Stephenson (1978) prepared a detailed description of the associated geologic features as well as the magnetic and gravity anomalies. A systematic presentation was provided of the economic and scientific significance of the boundary zone and the subsequent parts of the Churchill and Superior provinces. Green _et al_. (1979), compiling recent magnetic and gravity information, extended the boundary zone southwards to the Canada-U.S.A. border.

The continental dimensions of the Nelson Front, its association with significant mineral deposits and its location between two major tectonic regions of the Canadian Shield make it an excellent target area for a comprehensive crustal seismic investigation. The decision to locate the survey in the southern segment of the boundary zone was based on several factors. All of these were described by Green and Stephenson (1978).

1979 REFRACTION SURVEY

a) Survey Lines

Three refraction lines A, B, and C (Figure 1) were completed in this phase of the program. Line A (Figure 2) was located in a north-south direction in the vicinity of Manitoba Highway 83 along approximate longitude of 101° 02'W. Its position between stations 19 to 34 is along the projected Superior Boundary (Green et al. 1979). From site 18 to 1 the line segment is in the boundary zone (Figure 1).

Line B (Figure 1 and 3) was also in a north-south direction but located along Highway 35 in Saskatchewan. Its longitudinal position is approximately 103°45'W. According to the present understanding of the regional geology it was positioned well within the eastern portion of the Churchill Province.

Both lines A and B were reversed. Line C (Figure 1 and 4) which starts near Carlyle, Saskatchewan, extends east-west along Highway 13 as far as Assiniboia at its western end. This line was not reversed. It was shot only from its western end. This profile is an extension of the 1977 east-west line into the Churchill Province. The line is along latitude 49°40', and between longitudes 102° and 106°W. All recording sites were selected along roads such that any lines do not deviate from straight lines more than ±2 km (Figures 2, 3, and 4). The average separation between recording stations is 8 km.

b) Shot and Receiver Locations

The latitude, longitude, and elevation of all recording sites and shot locations were taken from 1:50,000 topographic maps. The accuracy of the provided coordinates is in the range of $\pm 0.0005^{o}$. The elevations have an estimated error of ± 4.00 m.

All the necessary information is tabulated in the following tables:

Table-1

Line-A, latitude, longitude, and elevation of shot and receiver locations.

Table-2

Line-A, distances between shot and receiver sites.

Table-3

Line-B, latitude, longitude, and elevation of shot and receiver locations.

Table-4

Line-B, distances between shot and receiver sites.

Table-5

Line-C, latitude, longitude, and elevation of shot and receiver locations.

Table-6

Line-C, distances between shot and receiver sites.

TABLE 1

REFRACTION RECEIVER LOCATIONS - LINE A

GAINSBOROUGH-ROBLIN

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
1	49.0289°	101.1031°	1480	451
2	49.0869	101.1041	1495	456
3	49.1557	101.0885	1487	453
4	49.2254	101.0923	1487	453
5	49.2908	101.1035	1500	457
6	49.3530	101.1020	1500	463
7	49.4289	101.1184	1520	463
8	49.5027	101.1097	1535	468
8A	49.5263	101.1040	1537	468
9	49.5751	101.1048	1520	463
10	49.6475	101.1097	1515	462
11	49.7394	101.1097	1550	473
12	49.8128	101.1099	1580	482
13	49.8716	101.0987	1605	489
14	49.9460	101.1031	1600	488
15	50.0193	101.1030	1570	479
16	50.0932	101.1143	1540	469
17	50.1643	101.1254	1525	465
18	50.2408	101.1000	1525	465

...2/

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
19	50.3143°	101.1060°	1570	479
20	50.3580	101.1070	1650	503
21	50.4470	101.1202	1715	523
22	50.5059	101.1070	1760	536
23	50.5500	101.1540	1780	542
23A	50.5888	101.0903	1810	551
24	50.6365	101.1822	1825	556
24A	50.6833	101.1557	1825	556
25	50.7383	101.1535	1862	567
26	50.8009	101.1830	1880	573
27	50.8860	101.1830	1980	604
28	50.9629	101.1712	2005	611
29	51.0369	101.1849	1900	579
30	51.1134	101.1756	1975	602
31	51.1695	101.1805	1915	584
32	51.2280	101.1761	1850	564
33	51.2546	101.1719	1800	548
33A	51.2843	101.1858	1950	594
34	51.3398	101.1761	2000	609

...3/

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
NORTH END SHOT HOLE ARRAY				
S4	51.3579°	101.1691°	2025	617
SOUTH END SHOT HOLE ARRAY				
S4	49.0077°	101.1088°	1500	457

TABLE 2

LINE A - SHOT HOLE ARRAY AT NORTH END

RECEIVER NUMBER	DISTANCE (KM.)	RECEIVER NUMBER	DISTANCE (KM.)
1.0	259.110	19.0	116.183
2.0	252.659	20.0	111.323
3.0	245.033	21.0	101.395
4.0	237.277	22.0	94.885
5.0	229.987	23.0	89.885
6.0	223.073	23.5	85.742
7.0	214.611	24.0	80.262
8.0	206.415	24.5	75.056
8.5	203.800	25.0	68.940
9.0	198.372	26.0	61.975
10.0	190.314	27.0	52.509
11.0	180.095	28.0	43.946
12.0	171.933	29.0	35.730
13.0	165.416	30.0	27.206
14.0	157.135	31.0	20.976
15.0	148.986	32.0	14.460
16.0	140.746	33.0	11.494
17.0	132.819	33.5	8.271
18.0	124.370	34.0	2.072

ALL DISTANCES CALCULATED WITH RESPECT TO SHOT HOLE AT 51.3579° ± .0005° LATITUDE, 101.1691° ± .0005° LONGITUDE, AT THE NORTH END OF THE LINE.

LINE A - SHOT HOLE ARRAY AT SOUTH END

RECEIVER NUMBER	DISTANCE (KM.)	RECEIVER NUMBER	DISTANCE (KM.)
1.0	2.394	19.0	145.327
2.0	8.815	20.0	150.188
3.0	16.526	21.0	160.090
4.0	24.241	22.0	166.640
5.0	31.487	23.0	171.577
6.0	38.406	23.5	175.867
7.0	46.850	24.0	181.245
8.0	55.053	24.5	186.405
8.5	57.678	25.0	192.520
9.0	63.106	26.0	199.528
10.0	71.158	27.0	208.992
11.0	81.379	28.0	217.526
12.0	89.543	29.0	225.778
13.0	96.086	30.0	234.272
14.0	104.360	31.0	240.519
15.0	112.513	32.0	247.019
16.0	120.733	33.0	249.973
17.0	128.647	33.5	253.296
18.0	137.152	34.0	259.456

ALL DISTANCES CALCULATED WITH RESPECT TO SHOT HOLE AT 49.0077° ± .0005° LATITUDE, 101.1088° ± .0005° LONGITUDE, AT THE SOUTH END OF THE LINE

TABLE 3

REFRACTION RECEIVER LOCATIONS - LINE B

N-S BROMHEAD-KELLIHER REFRACTION LINE

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
1	49.0361°	103.8524°	2275	693
2	49.0861	103.8512	2250	686
2A	49.1256	103.8525	2100	640
3	49.1714	103.8512	2025	617
4	49.2562	103.8500	2000	610
5	49.3182	103.8405	1975	602
6	49.3729	103.8520	1975	602
7	49.4586	103.8500	1925	587
8	49.5204	103.8349	1900	579
9	49.5753	103.8353	1875	571
10	49.6368	103.8397	1875	571
11	49.6918	103.8540	1887	575
12	49.7534	103.8500	1925	587
13	49.8083	103.8413	1950	594
14	49.8724	103.8500	1950	594
15	49.9206	103.8505	1950	594
16	50.0179	103.8421	1975	602
17	50.0727	103.8513	1975	602
18	50.1580	103.8423	2020	616
19	50.1891	103.8524	2075	632

...2/

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
20	50.2833°	103.8368°	2175	663
21	50.3672	103.8368	2175	663
22	50.4540	103.8504	2200	670
23	50.5393	103.8368	2125	648
24	50.6251	103.8425	1975	602
24A	50.6712	103.8530	1900	579
25	50.7171	103.8558	1875	571
26	50.7696	103.8409	1875	571
27	50.8338	103.8385	1925	587
28	50.9193	103.8500	2000	610
29	51.0052	103.8427	2075	632
30	51.0908	103.8427	2150	655
31	51.1833	103.8389	2150	655
32	51.2688	103.8429	2212	674
32A	51.3080	103.8567	2225	678
33	51.3390	103.8528	2225	678
34	51.4010	103.8532	2250	686

...3/

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
NORTH END SHOT HOLE ARRAY				
S4	51.4475°	103.8542°	2206	672.4
SOUTH END SHOT HOLE ARRAY				
S1	49.0232°	103.8512°	2300	701

TABLE 4

LINE B - SHOT HOLE ARRAY AT NORTH END

RECEIVER NUMBER	DISTANCE (KM.)	RECEIVER NUMBER	DISTANCE (KM.)
1.0	268.235	19.0	139.994
2.0	262.675	20.0	129.521
2.5	258.282	21.0	120.189
3.0	253.188	22.0	110.527
4.0	243.757	23.0	101.045
5.0	236.863	24.0	91.497
6.0	230.778	24.5	86.365
7.0	221.246	25.0	81.259
8.0	214.377	26.0	75.424
9.0	208.271	27.0	68.285
10.0	201.429	28.0	58.765
11.0	195.309	29.0	49.215
12.0	188.457	30.0	39.693
13.0	182.353	31.0	29.413
14.0	175.221	32.0	19.897
15.0	169.860	32.5	15.521
16.0	159.039	33.0	12.072
17.0	152.942	34.0	5.174
18.0	143.456		

ALL DISTANCES CALCULATED WITH RESPECT TO SHOT HOLE AT 51.4475° ± .0005° LATITUDE, 103.8542° ± .0005° LONGITUDE, AT THE NORTH END OF THE LINE.

LINE B - SHOT HOLE ARRAY AT SOUTH END

RECEIVER NUMBER	DISTANCE (KM.)	RECEIVER NUMBER	DISTANCE (KM.)
1.0	1.437	19.0	129.676
2.0	6.995	20.0	140.158
2.5	11.389	21.0	149.491
3.0	16.482	22.0	159.143
4.0	25.913	23.0	168.635
		23.5	173.813
5.0	32.818	24.0	178.178
6.0	38.892	24.5	183.305
7.0	48.424	25.0	188.411
8.0	55.310	26.0	194.253
9.0	61.414	27.0	201.396
10.0	68.249	28.0	210.905
11.0	74.361	29.0	220.462
12.0	81.213	30.0	229.986
13.0	87.322	31.0	240.277
14.0	94.449	32.0	249.789
15.0	99.810	32.5	254.150
16.0	110.635	33.0	257.598
17.0	116.728	34.0	264.496
18.0	126.218		

ALL DISTANCES WITH RESPECT TO SHOT HOLE AT 49.0232° ± .0005° LATITUDE, 103.8512° ± .0005° LONGITUDE, AT THE SOUTH END OF THE LINE.

TABLE 5

REFRACTION RECEIVER LOCATIONS - LINE C

CARLYLE-LIMERICK

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
0	49.6216°	102.0913°	2087	636
1	49.6375	102.1858	2050	625
2	49.6363	102.3204	2050	625
3	49.6351	102.4333	2050	625
4	49.6370	102.5418	2025	617
5	49.6191	102.6567	1975	602
6	49.6368	102.7921	2012	613
7	49.6370	102.8851	2012	613
8	49.6368	102.9256	2025	617
9	49.6365	103.0883	2000	610
10	49.6368	103.2020	2025	617
11	49.6363	103.3098	2000	610
12	49.6368	103.4241	2000	610
13	49.6368	103.5383	2000	610
14	49.6368	103.6530	1975	602
15	49.6368	103.7676	1900	579
16	49.6368	103.8383	1875	571
17	49.6368	103.9691	1900	579
18	49.6365	104.1045	1912	583
18A	49.6261	104.1706	1962	598

.. .2/

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	meters
19	49.6246°	104.2383°	2012	613
20	49.6397	104.3333	2100	640
21	49.6248	104.4206	2137	651
22	49.6413	104.5340	2125	648
23	49.6415	104.6242	2200	670
24	49.6368	104.7570	2387	727
24A	49.6371	104.805	2400	731
25	49.6369	104.8717	2387	727
26	49.6368	104.9858	2325	709
27	49.6368	105.1216	2375	724
28	49.6368	105.2550	2350	716
29	49.6368	105.3863	2525	770
30	49.6370	105.6358	2312	705
31	49.6383	105.7535	2300	701
32	49.6383	105.8677	2325	708
33	49.6393	105.9080	2350	716
34	49.6358	106.0231	2475	754

...3/

STATION	LATITUDE (decimal of degrees)	LONGITUDE (decimal of degrees)	ELEVATION feet	ELEVATION meters
WEST END SHOT HOLE ARRAY				
S4	49.6373°	106.0707°	2450	746.7

TABLE 6

LINE C - SHOT HOLE ARRAY AT WEST END

RECEIVER NUMBER	DISTANCE (KM.)	RECEIVER NUMBER	DISTANCE (KM.)
0.0	287.477	18.5	137.275
1.0	280.600	19.0	132.388
2.0	270.884	20.0	125.498
3.0	262.734	21.0	119.219
4.0	254.893	22.0	111.000
5.0	246.649	23.0	104.485
6.0	236.818	24.0	94.897
7.0	230.101	24.5	91.429
8.0	227.176	25.0	86.611
9.0	215.426	26.0	78.369
10.0	207.214	27.0	68.560
11.0	199.429	28.0	58.923
12.0	191.173	29.0	49.439
13.0	182.924	30.0	31.416
14.0	174.640	31.0	22.913
15.0	166.363	32.0	14.664
16.0	161.256	33.0	11.755
17.0	151.808	34.0	3.443
18.0	142.029		

ALL DISTANCES CALCULATED WITH RESPECT TO SHOT HOLE AT 49.6373° ± .0005° LATITUDE, 106.0707° ± .0005° LONGITUDE, AT THE WEST END OF THE LINE.

c) Shot Point Information

All shot holes were drilled to a depth of 30.48 m. The average load per hole was 200 kg of 60% Geogel (46 cm x 13 cm sticks).

A minimum of two shots was fired at every shot point. The smaller shot was 400 kg in two holes, the larger shot was 1200 kg in six.

Table 7 provides the shot numbers, as they were referred to on the data tapes, the exact timing of the shots, and the charge sizes. Shots 10 and 15 are mis-fires, therefore, this information is not part of the regular data set. The locations of the shot point with respect to their relevant refraction line are shown in Figures 1, 2, 3, and 4.

The shot hole configurations are illustrated on Figures 5, 6, 7, 8, and 9. These diagrams also reveal the point of reference for the individual shot points.

All shots were timed to a recording of the standard WWV time code signal.

d) Field Procedures; Instrumentation

The instrumentation for the refraction survey was provided by the Earth Physics Branch of the Canada Department of Energy, Mines and Resources (EMR) and by the Department of Geophysics, University of Western Ontario (UWO). EMR fielded twelve recording systems. UWO provided seven field units plus a spare back-up unit that was also deployed for three shots.

All recording systems were pre-programmed to a set of specific recording times. The EMR stations recorded one vertical and one horizontal component. The horizontal components in most cases were

TABLE 7

Shot Times
Refraction Survey 1979
CO-CRUST

Location	Shot No.	Date	Time Hr.	M.	Sec.	±	Charge size kg.
Line #A							
Hwy #83 Manitoba Roblin North End	9	Aug. 15	05:	59.97	.01		400
Hwy #83 South end Melita	10	Aug. 15	06:	31:	06.183	0.003	200
"	11	Aug. 15	07:	31:	04.488	0.003	1000
"	12	Aug. 16	06:	31:	02.925 +	0.003	425
Hwy #83 North End Roblin	13	Aug. 17	06:	00.97	0.1		1200
Line #B							
Hwy #35 Saskatchewan Leross North End	14	Aug. 18	06:	01.97	0.1		350
Hwy #35 South End Oungre	15	Aug. 18	06:	31:	03.145	0.003	400
"	16	Aug. 19	07:	31:	02.819	0.003	983
Hwy #35 North End Leross	17	Aug. 20	06:	00.97	0.01		1249
Hwy #35 South End Oungre	18	Aug. 20	06:	31:	02.582	0.003	250
Line #C							
Hwy #13 West End Assiniboia Sask.	19	Aug. 21	06:	01:	03.458	0.03	250
"	20	Aug. 21	21:	01:	02.749	0.003	1375

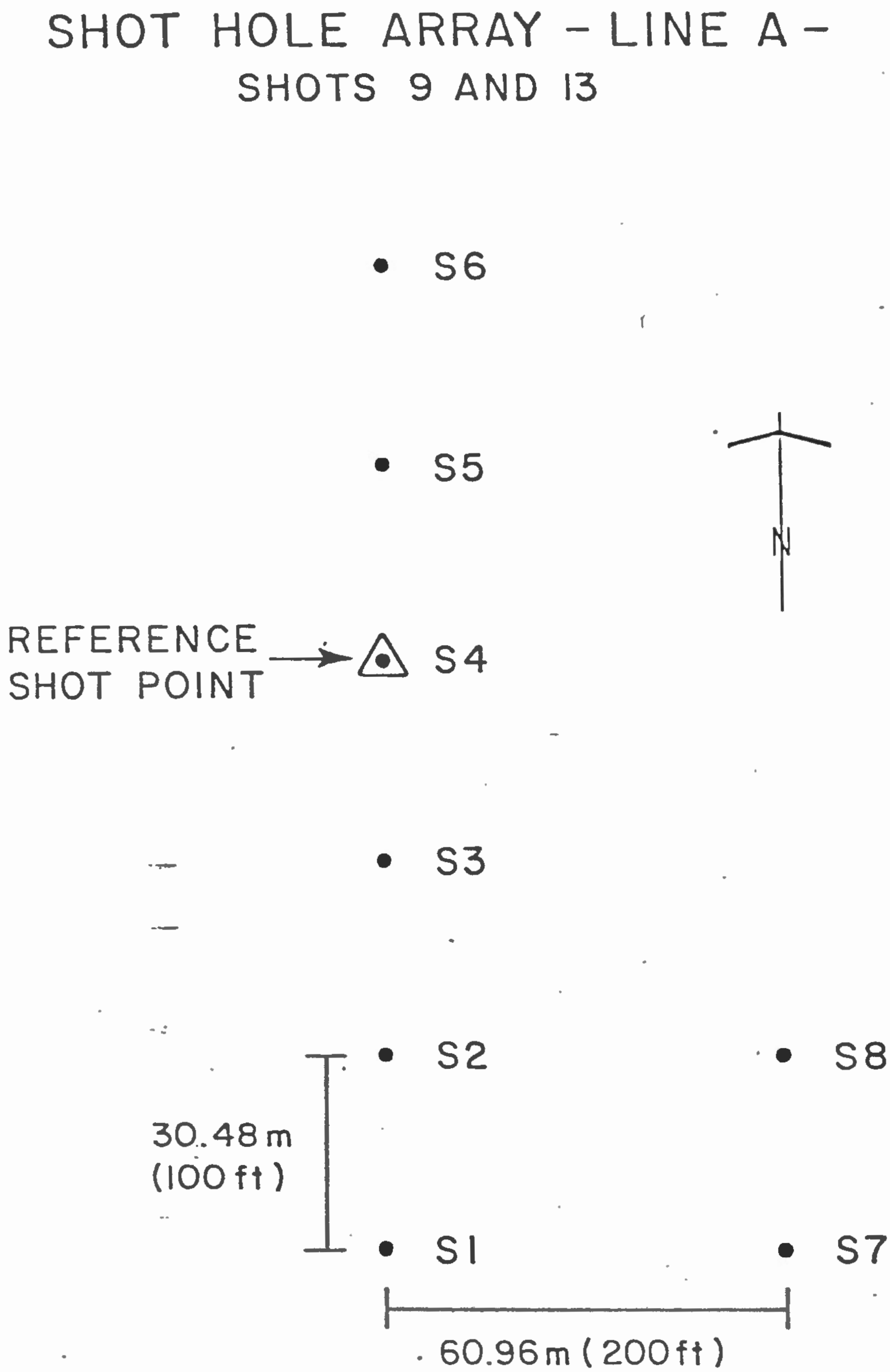

SHOT HOLE ARRAY - LINE A -
SHOTS 9 AND 13
S6
S5
N
REFERENCE SHOT POINT
S4
S3
S2
S8
30.48 m (100 ft)
S1
S7
60.96 m (200 ft)

FIGURE 5

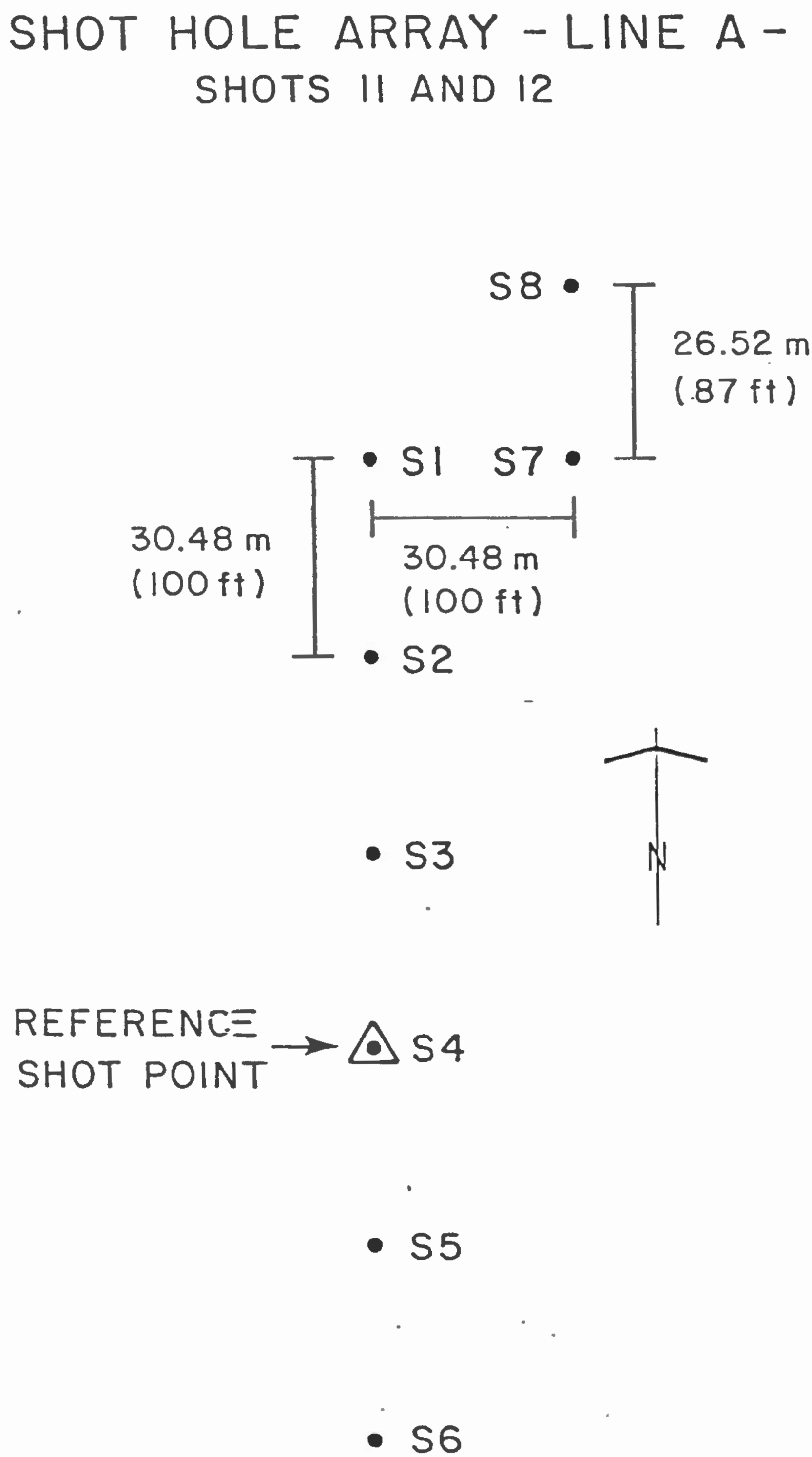

SHOT HOLE ARRAY - LINE A -
SHOTS 11 AND 12
S8
26.52 m
(87 ft)
S1
S7
30.48 m
(100 ft)
30.48 m
(100 ft)
S2
S3
N
REFERENCE
SHOT POINT
S4
S5
S6

FIGURE 6

SHOT HOLE ARRAY - LINE B -
SHOTS 14 AND 17

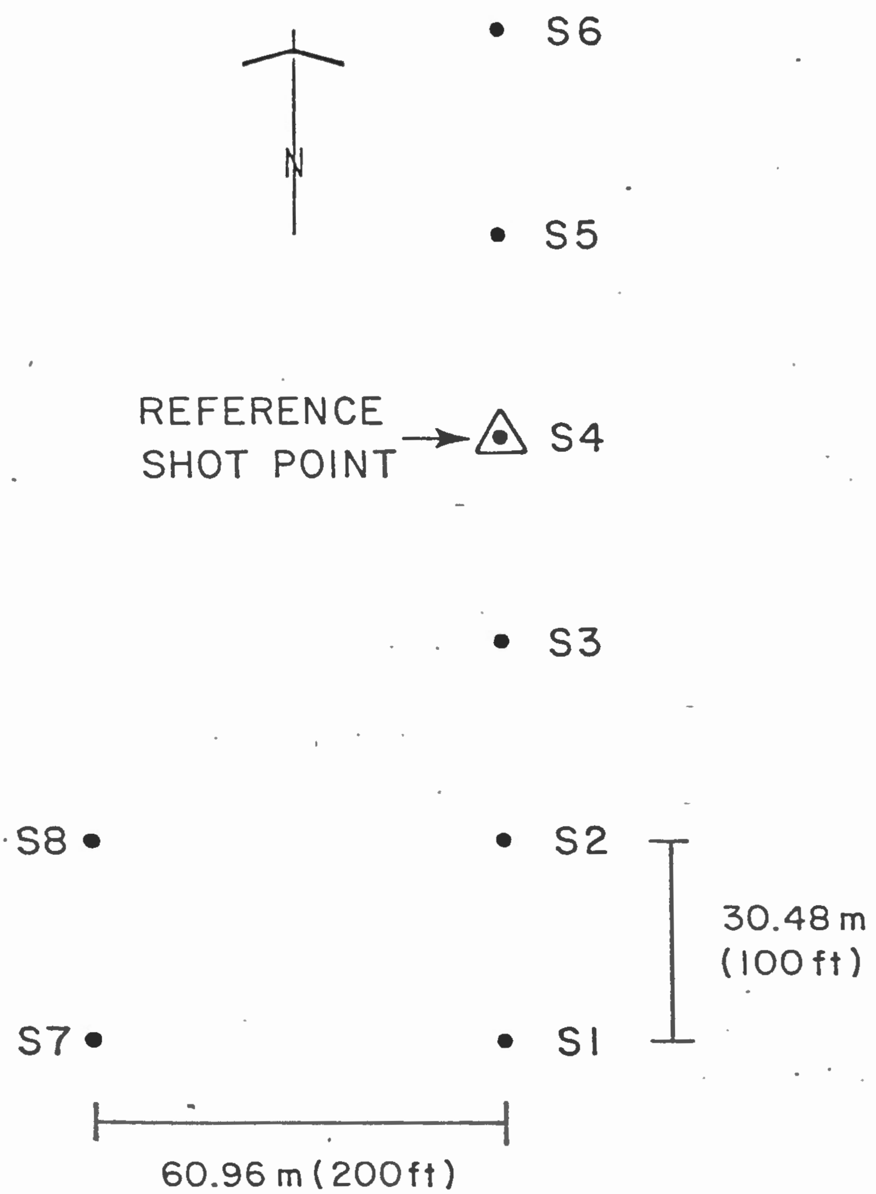


FIGURE 7

SHOT HOLE ARRAY - LINE B -
SHOTS 16 AND 18

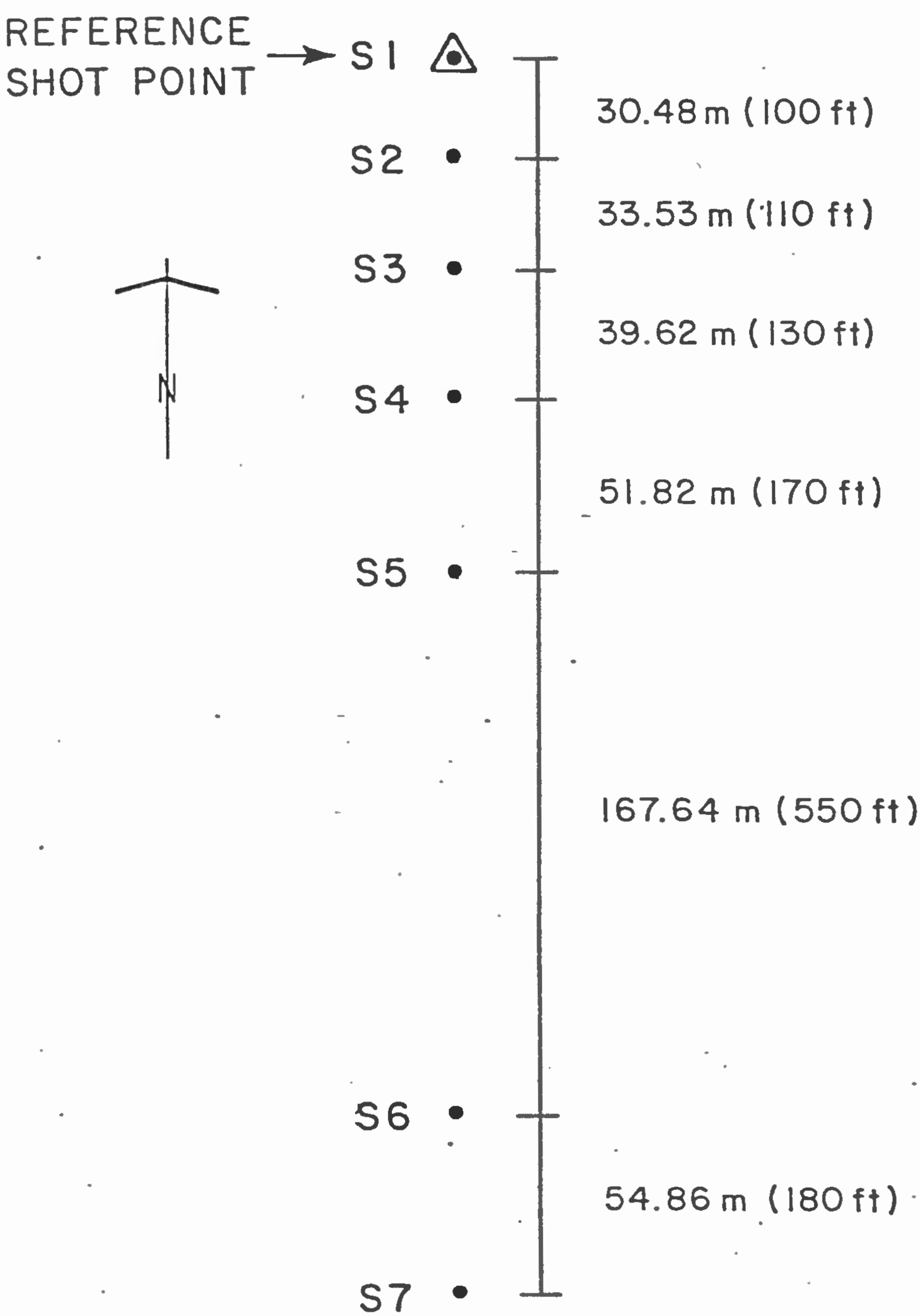


FIGURE 8

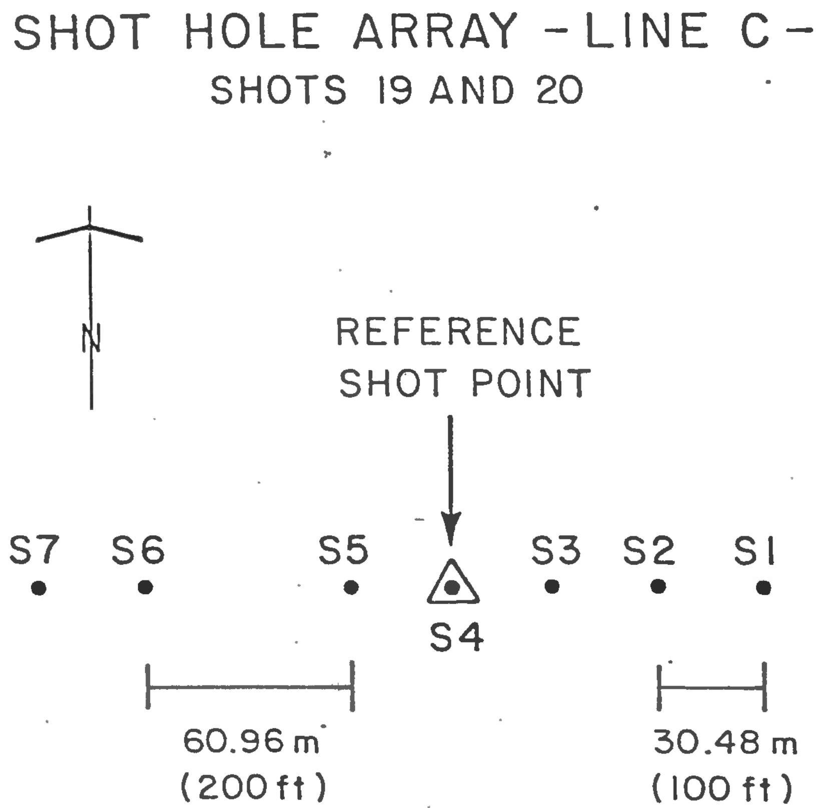

SHOT HOLE ARRAY - LINE C -
SHOTS 19 AND 20
N
REFERENCE
SHOT POINT
S7
S6
S5
S4
S3
S2
S1
60.96 m
(200 ft)
30.48 m
(100 ft)

FIGURE 9

set in the shot direction. UWO sites observed one vertical and two horizontal seismometers. These horizontal components were set N/S and E/W.

Nineteen stations were occupied within one set-up and one shot was fired into this array from each end of the line. Thus every set-up recorded one small and one large charge.

Table 8 indicates the instrumentation of the individual recording sites for all three lines.

All EMR stations recorded digitally. The UWO stations recorded FM analog signals. The EMR data digital interval was 0.01667 sec. The UWO data was digitized in the laboratory. The digital interval on this set of data was not constant, it varied between 0.0172 to 0.0163 sec. The sampling interval of each individual trace was indicated on the trace header of the digital data. For accurate timing and plotting of these data this additional variable must be recognized.

e) Refraction Data, Tape Format

All 1979 refraction data were compiled on a single digital tape. The total set of information is condensed in 10 digital files. Specific details of the format are described in Table 9. One file contains all the headers for each individual trace for a single line. This is followed by the file that contains all the data traces for that specific line. The first three data samples contain the following information: receiver number, shot number, component number.

Component numbers are:
- 1 vertical
- 3 N/S
- 4 E/W.

TABLE 8

INSTRUMENTATION SETUP

LINE A

ST	CREW
1.0	UWO
2.0	UWO
3.0	UWO
4.0	UWO
5.0	UWO
6.0	UWO
7.0	UWO
8.0	EMR
8.5	EMR
9.0	EMR
10.0	EMR
11.0	EMR
12.0	EMR
13.0	EMR
14.0	EMR
15.0	EMR
16.0	EMR
17.0	EMR
18.0	EMR
19.0	UWO
20.0	UWO
21.0	UWO
22.0	UWO
23.0	UWO
23.5	UWO
24.0	EMR
24.5	EMR
25.0	EMR
26.0	EMR
27.0	EMR
28.0	EMR
29.0	EMR
30.0	EMR
31.0	EMR
32.0	EMR
33.0	EMR
33.5	EMR
34.0	EMR

LINE B

ST	CREW
1.0	EMR
2.0	EMR
2.5	EMR
3.0	EMR
4.0	EMR
5.0	EMR
6.0	EMR
7.0	EMR
8.0	EMR
9.0	EMR
10.0	EMR
11.0	EMR
12.0	UWO
13.0	UWO
14.0	UWO
15.0	UWO
16.0	UWO
17.0	UWO
18.0	UWO
19.0	UWO
20.0	UWO
21.0	UWO
22.0	UWO
23.0	UWO
24.0	EMR
24.5	EMR
25.0	EMR
26.0	EMR
27.0	EMR
28.0	EMR
29.0	EMR
30.0	EMR
31.0	EMR
32.0	EMR
32.5	EMR
33.0	EMR
34.0	EMR

TABLE 8

INSTRUMENTATION SETUP

LINE C

ST	CREW
0.0	UWO
1.0	UWO
2.0	UWO
3.0	UWO
4.0	UWO
5.0	UWO
6.0	UWO
7.0	UWO
8.0	EMR
9.0	EMR
10.0	EMR
11.0	EMR
12.0	EMR
13.0	EMR
14.0	EMR
15.0	EMR
16.0	EMR
17.0	EMR
18.0	EMR
18.5	UWO
19.0	UWO
20.0	UWO
21.0	UWO
22.0	UWO
23.0	UWO
24.0	UWO
24.5	EMR
25.0	EMR
26.0	EMR
27.0	EMR
28.0	EMR
29.0	EMR
30.0	EMR
31.0	EMR
32.0	EMR
33.0	EMR
34.0	EMR

TABLE 9

TAPE CHARACTERISTICS - COCRUST '79 REFRACTION DATA

1. Tape holds 10 files:

File #	Contents
1	Alpha numeric record headers for Line A - N.S. (S.P. at N. end)
2	Data - Line A - N.S.
3	Headers - Line A - S.N.
4	Data - Line A - S.N.
5	Headers - Line B - N.S.
6	Data - Line B - N.S.
7	Headers - Line B - S.N.
8	Data - Line B - S.N.
9	Headers - Line C
10	Data - Line C

2. Each trace is made up of 7200 digital samples

3. 1600 BPI

4. Record Length - 80 Bytes

5. Block Size - 4800 Bytes

6. Headers written as follows:

```
   INTEGER IHDR (200)
   WRITE (10,40) (IHDR(I), I = 1,200)
40 FORMAT (20A4)
```

7. Data written as follows:

```
   REAL TRACE (7200)
   WRITE (10,50) (TRACE(I), I = 1,7200)
50 FORMAT (5E16.6)
```

8. IBM floating point format

9. Tape contains <u>No</u> <u>Labels</u>

Brian Reilkoff
June 12, 1980

1979 REFLECTION SURVEY

a) Survey Line

The reflection survey was conducted along Manitoba Provincial Highway 255 in an east-west direction. This line represents the direct continuation of the 1977 survey (Figure 1 and 10). The rationale for the location and the direction was well documented by Green and Stephenson (1978).

The 1979 survey was relocated 1.609 km south of line 3 of the 1977 program. This move made it possible to conduct the entire survey as a continuous profile. The first shot point was located at the NE corner of Section 2, Township 9, Range 25 W1. The final recording site was at the NW corner of section 5, Township 9, Range 28 W1. The first shot point is 1.609 km south of station 210 of the 1977 survey. This provides a 10 km overlap of the two surveys. The total length of the seismic profile is 37.01 km. Details of the position of the line are illustrated in Figure 5.

b). Field Parameters

Table 10 consists of the observers' notes which provide most of the pertinent information. Some of the main values are:

1) Seismic line

Seismometer group spacing	200 m
Number of geophone groups/shot	48
Geophones interval	7.62 m
Number of geophones/station	18

Group length	129.54 m
Geophone type	Mark Products L-15
Standard frequency	8 Hz
Total number of receiver locations	190
Group layout	linear

2). Shot Point

Shot point spacing	400 m
Number of shot/spread	24
Total number of shots	82
Explosives (60% Geogel, 46cm. x 13cm.)	33 kg
Shot hole depth	15.24 m

The survey geometry followed the following pattern: minimum offset was 400 m, maximum 9300 m. Shots were fired from the east end of the line. Shooting at every second receiver location and following the above pattern provided a 12-fold common depth point (CDP) survey for the line. Figure 11 reveals the exact CDP coverage at the individual sites. Every shot point and receiver site was established by a local survey. The elevation of each location above sea level was determined by high quality leveling. Table 11 contains the individual station elevation values.

c) Drilling

Drilling was contracted to Graham Drilling Ltd. from Bredenbury, Saskatchewan. Shot hole drilling was done in the road allowance alongside the road.

TABLE 11

REFLECTION PROFILE - STATION ELEVATIONS

STATION	ELEVATION	STATION	ELEVATION (meters)
1	433.523	26	431.134
2	433.968	27	431.396
3	433.874	28	431.097
4	437.982	29	431.225
5	438.254	30	431.365
6	436.099	31	431.228
7	437.025	32	430.963
8	437.242	33	430.567
9	435.983	34	430.612
10	434.890	35	430.981
11	433.435	36	430.902
12	433.005	37	431.085
13	432.831	38	431.210
14	433.000	39	431.262
15	431.390	40	431.615
16	431.100	41	432.188
17	430.999	42	433.045
18	430.999	43	432.883
19	431.173	44	431.902
20	431.222	45	431.487
21	431.344	46	431.487
22	431.240	47	431.853
23	431.213	48	431.978
24	431.073	49	432.209
25	431.100	50	433.624

STATION	ELEVATION	STATION	ELEVATION (meters)
51	432.462	81	435.958
52	432.456	82	436.720
53	432.398	83	438.107
54	432.420	84	440.406
55	432.493	85	444.292
56	432.880	86	448.833
57	433.365	87	449.202
58	433.383	88	449.153
59	433.600	89	449.495
60	433.224	90	450.476
61	433.167	91	450.089
62	433.374	92	448.394
63	433.740	93	447.913
64	433.910	94	447.870
65	433.554	95	449.156
66	433.291	96	449.473
67	433.578	97	450.287
68	433.709	98	451.589
69	433.612	99	452.783
70	433.352	100	453.658
71	433.654	101	454.396
72	433.895	102	455.655
73	433.883	103	456.322
74	434.066	104	456.270
75	434.160	105	457.081
76	434.529	106	457.547
77	434.169	107	457.365
78	434.057	108	458.608
79	434.517	109	459.702
80	435.041	110	458.224

STATION	ELEVATION	STATION	ELEVATION (meters)
111	457.282	141	477.591
112	457.648	142	477.871
113	458.596	143	478.740
114	460.495	144	479.713
115	461.772	145	480.255
116	461.370	146	480.913
117	463.305	147	481.493
118	463.912	148	482.239
119	464.015	149	484.443
120	464.000	150	484.217
121	465.061	151	484.845
122	465.865	152	484.644
123	465.792	153	485.232
124	465.795	154	484.522
125	466.283	155	483.215
126	466.692	156	484.035
127	467.018	157	482.081
128	467.350	158	479.280
129	468.624	159	478.426
130	469.846	160	477.021
131	471.151	161	475.762
132	471.879	162	474.400
133	472.690	163	470.636
134	473.498	164	469.029
135	474.647	165	467.158
136	475.253	166	465.070
137	476.040	167	464.131
138	476.640	168	463.823
139	477.055	169	463.503
140	477.189	170	463.787

STATION	ELEVATION	STATION	ELEVATION (meters)
171	464.195		
172	465.302		
173	467.268		
174	467.258		
175	467.420		
176	468.490		
177	468.136		
178	466.627		
179	468.170		
180	469.584		
181	472.727		
182	474.628		
183	479.460		
184	485.178		
185	487.760		
186	492.273		
187	496.458		
188	499.884		
189	503.389		
190	505.432		

d) Instrumentation; Shooting Procedures

The data were recorded with a Texas Instruments model DFS III 48 trace seismic system. Record length was 20 seconds; sampling rate was 2 msec. This recording system is equipped with binary gain ranging amplifiers with fifteen 2 to 1 gain steps, providing a 90 db dynamic range and giving a total range of 32,768:1.

The shooting procedure was conducted with an Input/Output Incorporated Model DEC 200 FM decoding system. The FM pulse, generated remotely by the shooter, triggered the entire recording system thus providing an accurate zero time as well as transmitting the uphole time to the recording truck.

e) Corrections

Attached to this report are two seismic sections which represent a preliminary interpretation of the reflection data (Figures 19 and 20). Two sets of corrections were applied to the data. These are static corrections that include elevation and weathering corrections and normal moveout corrections.

1) Static corrections

The static corrections were computed to effectively place all the shots and receivers to a common datum of 380 m above the sea level. This is the same elevation used as datum for the 1977 program.

The actual corrections are listed in Table 12. The large receiver spacing and long spread length made the first break information ineffective for weathering corrections. Chevron Standard Ltd. of Calgary recorded an exploration seismic line over the same

TABLE 12

1979 Reflection Data, Elevation and Weathering Corrections
(Datum = 380.09 m A.S.L.)

STA.	RCR STAT. SEC.	SHOT STAT. SEC.	STA.	RCR STAT. SEC.	SHOT STAT. SEC.
1	.034	.019	31	.034	.019
2	.034		32	.034	
3	.034	.019	33	.034	.019
4	.034		34	.034	
5	.034	.019	35	.034	.019
6	.034		36	.034	
7	.034	.019	37	.034	.019
8	.034		38	.034	
9	.034	.019	39	.034	.019
10	.034		40	.034	
11	.034	.019	41	.034	.019
12	.034		42	.034	
13	.034	.019	43	.034	.019
14	.034		44	.034	
15	.034	.019	45	.034	.019
16	.034		46	.034	
17	.034	.019	47	.034	.019
18	.034		48	.034	
19	.034	.019	49	.034	.019
20	.034		50	.034	
21	.034	.019	51	.034	.019
22	.034		52	.034	
23	.034	.019	53	.034	.019
24	.034		54	.034	
25	.034	.019	55	.034	.019
26	.034		56	.034	
27	.034	.019	57	.034	.019
28	.034		58	.034	
29	.034	.019	59	.034	.019
30	.034		60	.034	

STA.	RCR STAT. SEC.	SHOT STAT. SEC.	STA.	RCR STAT. SEC.	SHOT STAT. SEC.
61	.034	.019	95	.037	.023
62	.034		96	.040	
63	.034	.019	97	.039	.026
64	.034		98	.042	
65	.034	.019	99	.042	.030
66	.034		100	.041	
67	.034	.019	101	.036	.024
68	.031		102	.039	
69	.031	.017	103	.040	.028
70	.034		104	.046	
71	.031	.019	105	.042	.030
72	.032		106	.039	
73	.033	.021	107	.044	.032
74	.034		108	.046	
75	.034	.020	109	.046	.033
76	.033		110	.045	
77	.034	.019	111	.045	.033
78	.034		112	.045	
79	.032	.020	113	.044	.032
80	.034		114	.044	
81	.032	.018	115	.051	.035
82	.033		116	.049	
83	.036	.024	117	.049	.037
84	.040		118	.047	
85	.045	.026	119	.047	.034
86	.045		120	.049	
87	.046	.027	121	.048	.035
88	.043		122	.049	
89	.040	.027	123	.055	.036
90	.048		124	.049	
91	.044	.028	125	.051	.037
92	.038		126	.050	
93	.042	.028	127	.049	.036
94	.038		128	.052	

STA.	RCR STAT. SEC.	SHOT STAT. SEC.
129	.052	.039
130	.051	
131	.050	.037
132	.052	
133	.049	.037
134	.054	
135	.053	.041
136	.053	
137	.055	.043
138	.056	
139	.056	.043
140	.057	
141	.058	.044
142	.057	
143	.058	.045
144	.059	
145	.058	.045
146	.060	
147	.061	.046
148	.062	
149	.062	.048
150	.060	
151	.063	.048
152	.065	
153	.062	.048
154	.063	
155	.061	.047
156	.060	
157	.061	.046
158	.060	
159	.060	.045
160	.059	
161	.058	.043
162	.057	

STA.	RCR STAT. SEC.	SHOT STAT. SEC.
163	.054	.039
164	.054	
165	.053	.038
166	.052	
167	.051	.036
168	.051	
169	.051	
170	.051	
171	.051	
172	.052	
173	.053	
174	.053	
175	.053	
176	.053	
177	.053	
178	.052	
179	.053	
180	.054	
181	.057	
182	.058	
183	.060	
184	.063	
185	.064	
186	.066	
187	.068	
188	.070	
189	.071	
190	.072	

locality. The corrections computed from these data were adapted for the present program. The data provide excellent quality information and at most receiver locations direct correlation could be made between the two survey sites. The replacement velocity for the upper till section was 1.859 km/sec and for the underlying Cretaceous beds 2.133 km/sec.

2) Normal moveout corrections

The velocity function used for NMO correction was taken from two sources. For the sedimentary section Chevron Standard Ltd. released the values which they adopted to process the exploration data. Beyond the Phanerozoic-Precambrian contact the function used by Sereda (1978) for the Sifton site (Figure 1) in Manitoba was adapted. This information was reproduced on Figure 21; where curve 'c' represents the pertinent velocity function.

f) Data Tape Format

The raw reflection data are provided in shot sort form. The sampling rate of the data on the tape is 4 msec. The format of the information, as transcribed on the submitted tape, is illustrated in detail in Table 13.

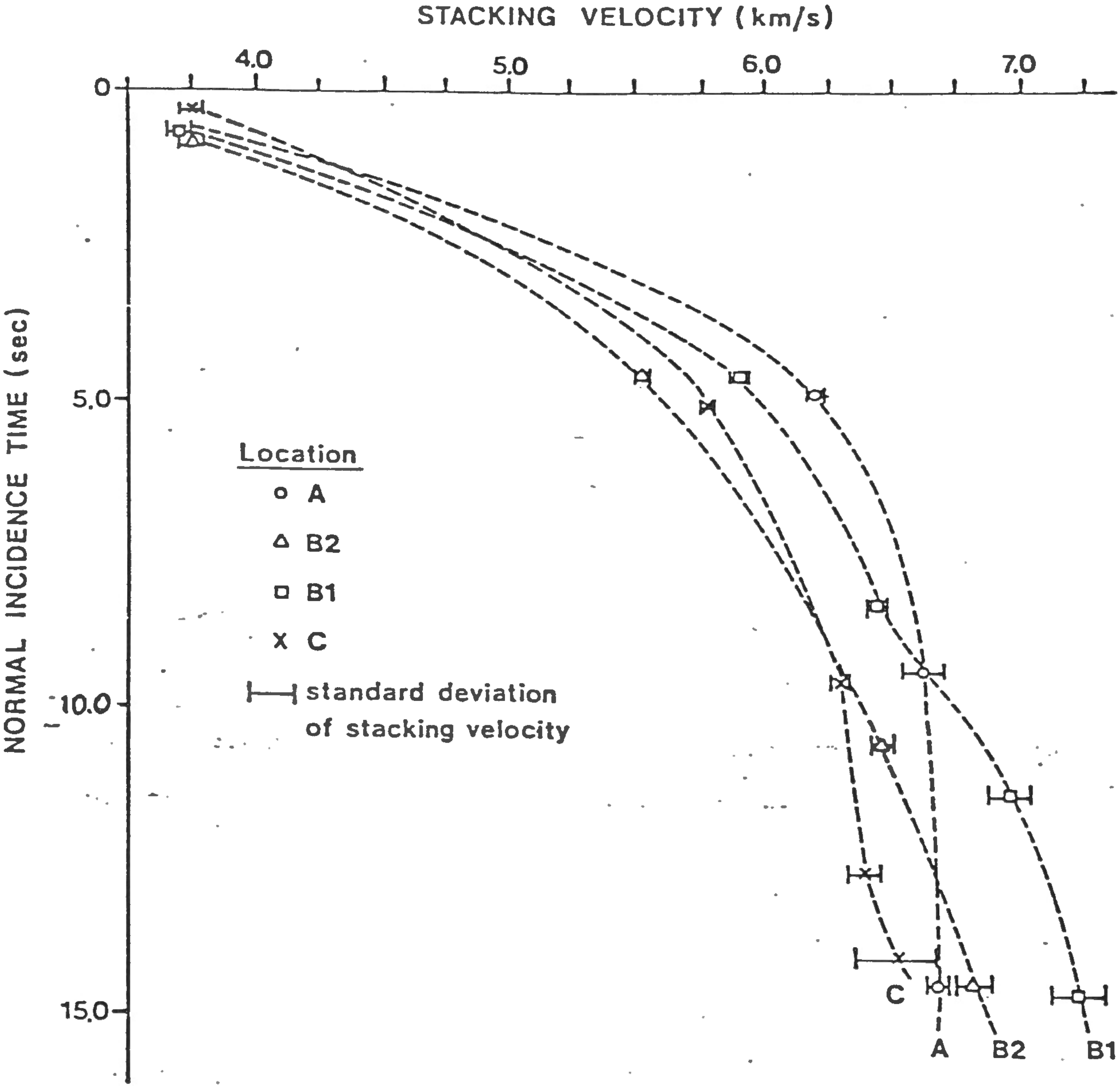


Figure 21 - Crustal stacking velocity functions.

TABLE 13

TAPE CHARACTERISTICS: EMR1 & EMR2

1. Tapes hold the "shot sorts"

2. Both tapes are 1600 BPI

3. EMR1 contains 2 files:
   - first file holds a tape header
   - second file contains data

4. EMR2 contains 1 file of data

5. Tape header:

Byte #	Contents	Description
0-3	'CC79'	Project
4-7	'UofS'	Crew
8-11	1.0	Line #
12-15	82.0	# of shots
16-19	48.0	# traces/shot
20-23	4.0	Sampe rate (msec.)
24-27	5000.0	# Samples/trace
28-31	3936.0	Total # traces in line
32-35	0.0	
36-39	0.0	

6. Each trace has a header written onto it:

Byte #	Description	
0-3	Shot #	(1-82)
4-7	Trace #	(1-48)
8-11	Shot position	(1-167)
12-15	Receiver #	(1-190)
16-19	Offset in meters	(400-9800)
20-23	Shot depth (meters)	
24-27	Charge size (kilograms)	
28-31	Digital filter passband	
32-35	0.0	
36-39	0.0	

7. Record Length = Blocksize = 20000 Bytes

8. Tapeheader & data are in binary IBM floating point format:

```
      REAL TRACE (5000)
      WRITE (10,20) (TRACE(I), I=1,5000)
   20 FORMAT (5000 A4)
```

9. Tape contains <u>NO LABELS</u>

B. Reilkoff (June 16, 1980)

MISCELLANEOUS

a) Personnel

1) Refraction Survey

Supervisor	Organization	Number of crew
Dr. A. Mair	Earth Physics Branch	4
Dr. R.F. Mereu	University of Western Ontario	2

2) Reflection Survey

Supervisor	Organization	Number of crew
Dr. Z. Hajnal	University of Saskatchewan	6
	University of Manitoba	3
	University of Alberta	2

b) Permits

Manitoba

Geophysical License No. 155

Road Allowance Permit No. 151

Saskatchewan

License to Conduct Geophysical Exploration No. 1089

Geophysical Crew Certificate No. 41

c) Clean Up

Along the reflection line several holes were cratered on account of loose unconsolidated, fine-grained sand near the surface. B. Williamson Construction Company of Pierson, Manitoba, was contracted to fill the holes and repair all effects of the shot hole drilling.

d) Timing

The reflection survey was conducted in the time period of August 1 to August 10, 1979. Approximately 2.5 days were lost due to poor weather and waiting for the driller.

The refraction program was undertaken between August 14 and 21, 1979. One day was lost due to blaster box malfunction and lack of finished holes.

e) Weather

During the reflection survey period there was one rainy stormy day and the heavy lightning the following day prevented field operations. The weather at the time of the refraction program was ideal. With the exception of the last shot all explosions were fired in the early morning hours, in an almost completely windless environment.

PRELIMINARY RESULTS

I. Refraction lines

Computer plots of the vertical component refraction records are shown in Figures 12 to 16. All records were plotted with a reduced time scale. The time reduction was trace offset divided by a velocity of 6.8 km/sec. The data quality is very high. Excellent signal to noise ratio is indicated on every line. The maximum amplitude on all plotted traces was set to 2.54 cm, therefore the sections indicate only relative amplitude variation. The first break information is very well recognizable and arrival times were determined on the majority of the records with an accuracy of 0.01 sec. or better. All sections reveal some uneven gaps in between traces. This occurrence is a result of technical problems encountered when reading several EMR digital magnetic cassette tapes. The data presented on the above sections represent the unfiltered raw information as recovered from field records.

a) Travel Time Interpretation

Figures 12-16 indicate the initial attempt to interpret the first arrival information. Apparent velocities and intercept times were computed from linear least-square fits of the data. The linearity of the data is illustrated by the rather high correlation coefficient obtained in all cases. The lowest correlation coefficient was 0.9913 on the last segment of line C. Although the correlation appears to be good, the variation of velocities within reversed profiles and from line to line, as well as the appearance of a complex set of large amplitude secondary arrivals on all the sections, illustrate that the crustal picture in the area is much more complex than the first arrivals indicate. The present results are very preliminary and will require significant modifications after an analysis of later events and some experimentation with modelling.

Velocities and intercept times are shown in Table 14.

b) North-South Models

Although the velocity information of the different line segments shows considerable lateral heterogeneity there is enough similarity in character between them that as a first approximation the crust is assumed to be formed by a set of layers separated by dipping interfaces. For this type of analysis of the data equations derived by Masuda (1975) were adopted. Figure 17 presents a rudimentary interpretation of all north south lines. On the premises of Green *et al.* (1979, 1980) respecting the interpretation of magnetic gravity and seismic data, the 1977 profile was located in the Superior Province -- line A mainly in the eastern margin of the boundary zone and line B in the Churchill Province. In spite of the apparent different geological regions, with the exception of the sedimentary layers, all sections show a south to north dip within the crust. A near 6.0 km/sec uppermost crustal layer exists in all the regions. It is thinnest in

TABLE 14

Line A

LAYER NUMBER	RECORDS USED IN LEAST SQUARES	NUMBER OF RECORDS	LEAST SQUARE APPARENT VELOCITIES (KM/S)	LEAST SQUARE INTERCEPT (SEC.)	CORRELATION COEFFICIENT	COMMENTS
1		V LOG	3.62			
2	245, 260, 290	3	6.09 ± 0.001	0.55 ± 0.01	0.9999	RELIABLE
3	180 to 230 235, 240	8	6.25 ± 0.002	0.76 ± 0.05	0.9998	RELIABLE
4	90, 110 to 130 160, 170	6	6.32 ± 0.001	1.20 ± 0.45	0.9994	RELIABLE
5	20 to 60	5	8.05 ± 0.006	8.61 ± 0.61	0.9998	RELIABLE
1		V LOG	3.62			
2	20, 30	2	5.75 ± 0.020	0.81 ± 0.12	1.0000	UNRELIABLE
3	40 to 120	9	6.30 ± 0.002	0.85 ± 0.11	0.9996	RELIABLE
4	160 to 230 235, 240, 245 250, 260	13	6.34 ± 0.002	1.09 ± 0.20	0.9997	RELIABLE
5	280 to 310, 335	5	8.06 ± 0.010	8.52 ± 0.75	0.9991	RELIABLE

Line B

LAYER NUMBER	RECORDS USED IN LEAST SQUARES	NUMBER OF RECORDS	LEAST SQUARE APPARENT VELOCITIES (KM/S)	LEAST SQUARE INTERCEPT (SEC.)	CORRELATION COEFFICIENT	COMMENTS
1		V LOG	4.0	0		
2	260, 280 300, 330	4	6.05 ± 0.001	0.29 ± 0.26	0.9996	RELIABLE
3	170 to 240	9	6.37 ± 0.004	1.14 ± 0.14	0.9998	RELIABLE
4	100, 110, 130 to 160	6	6.49 ± 0.004	1.69 ± 0.06	1.0000	RELIABLE
5	10 to 70	8	8.26 ± 0.001	8.22 ± 0.41	0.9993	RELIABLE
1		V LOG	3.20	0		
2	20, 25, 30 to 70	7	6.05 ± 0.001	1.57 ± 0.05	0.9997	RELIABLE
3	100, 110, 130 to 200	10	6.38 ± 0.003	2.09 ± 0.33	0.9984	RELIABLE
4	220, 230, 235 240, 245, 260 270	7	6.49 ± 0.005	2.36 ± 0.26	0.9998	RELIABLE
5	280, 290, 310 330, 340	5	8.26 ± 0.011	9.05 ± 1.67	0.9951	RELIABLE

Line C

LAYER NUMBER	RECORDS USED IN LEAST SQUARES	NUMBER OF RECORDS	LEAST SQUARE APPARENT VELOCITIES (KM/S)	LEAST SQUARE INTERCEPT (SEC.)	CORRELATION COEFFICIENT	COMMENTS
1		V LOG	3.2	0		
2	240, 245, 250 to 270	10	6.07 ± 0.001	1.40 ± 0.11	0.9995	RELIABLE
3	170, 180, 185, 190 to 230	8	6.56 ± 0.001	2.82 ± 0.17	0.9998	RELIABLE
4	90, 110, 130, 150	4	6.65 ± 0.001	3.21 ± 0.29	0.9999	UNRELIABLE
5	0 to 70	8	7.99 ± 0.005	8.97 ± 1.76	0.9913	RELIABLE

the boundary zone. The underlying intermediate layer reveals significant velocity heterogeneity or anisotropy from east to west, starting with 6.21 km/sec in the east and reaching 6.38 km/sec in the Churchill Province. The lowest crustal layer appears also heterogeneous as it has the highest velocity in the Superior Province and the lowest in the boundary zone, where it reaches over 29 km in thickness.

The Moho is apparently dipping to the south in the Superior Province; to the north in the boundary zone; and is relatively flat in the Churchill Province. The upper mantle velocity in the Churchill Province appears anomalously high. The first break information does not reveal, on any of the 1979 profiles, a 7 km/sec type of lower crustal layer. This zone, however, was recognized in many parts of the Superior Province (Hall and Hajnal, 1973) and also in the Churchill Province (Chandra and Cumming, 1972). Preliminary modelling by Green et al. (1980) seems to indicate that this lower crustal zone may appear as a hidden layer in the boundary zone region.

c) East-west models

Except for the upper most crust the subsurface sampled by the east-west line lies within the boundary zone, mainly in the Churchill Province (Figure 18). The complications of the reversed segment of the 1977 line were described by Green et al. (1980). The complexity of the travel time branches near the source on the east end of the line was interpreted as an indication of the start of the boundary zone. The near 6.04 km/sec uppermost layer was not observed on the west side of the 1977 profile. It was observed, however, on line B and also on line C. It appears that this layer is rather thin, or perhaps does not exist in most parts of the transition zone. One interpretation of the related figures on line B and C is that this layer is relatively thin in the most easterly part of the Churchill Province and reaches a thickness of 13.7 km at the west end of line C. The second layers of line B and C with velocities of 6.38 km/sec and 6.56 km/sec are very likely inter-related but the different dip variations along the respective lines must be established first in order that the true velocity of this zone be determined. The lower crustal layer reaches a depth of 44 km at its most westerly point of study. If the observed velocities are true velocities, this layer is heterogeneous or anisotropic with an increasing value from east to west. The crust thickness is increasing to the west. It is 44 km just east of Assiniboia and 45 km near Swift Current, according to Chandra and Cumming (1972). They, however, reveal a 7.17 km/sec layer above the Moho that is not recognized on either line C or the 1977 part of the cross section. A more thorough analysis of the entire data set is necessary before correlation between the different layers of the different profiles is established with considerable confidence.

II Reflection Profile

A standard, commercially processed form of the reflection data is presented in Figures 19 and 20.

Judging from the near-surface section of the profile the reflection data quality are rather good. The patterned nature of the reflections from the top of the Paleozoic around 0.7 sec two way time is due to the influence of the long spread length. It was impossible to eliminate the effect of the first break wave components on these shallow events. The smooth correlation of the basement reflections around 1.0-1.1 sec illustrates that the static and dynamic corrections adopted from Chevron's exploration data are quite suitable to this crustal information.

The major processing sequences on the data are:

1) Time variant bandpass filter

   8-50 Hz   0-4.00 sec.

   8-25 Hz   4.00-20 sec.

2) Static corrections

3) NMO corrections

4) Predictive deconvolution

   50 ms. prediction distance

   200 ms. operator length

5) Automatic residual static correction

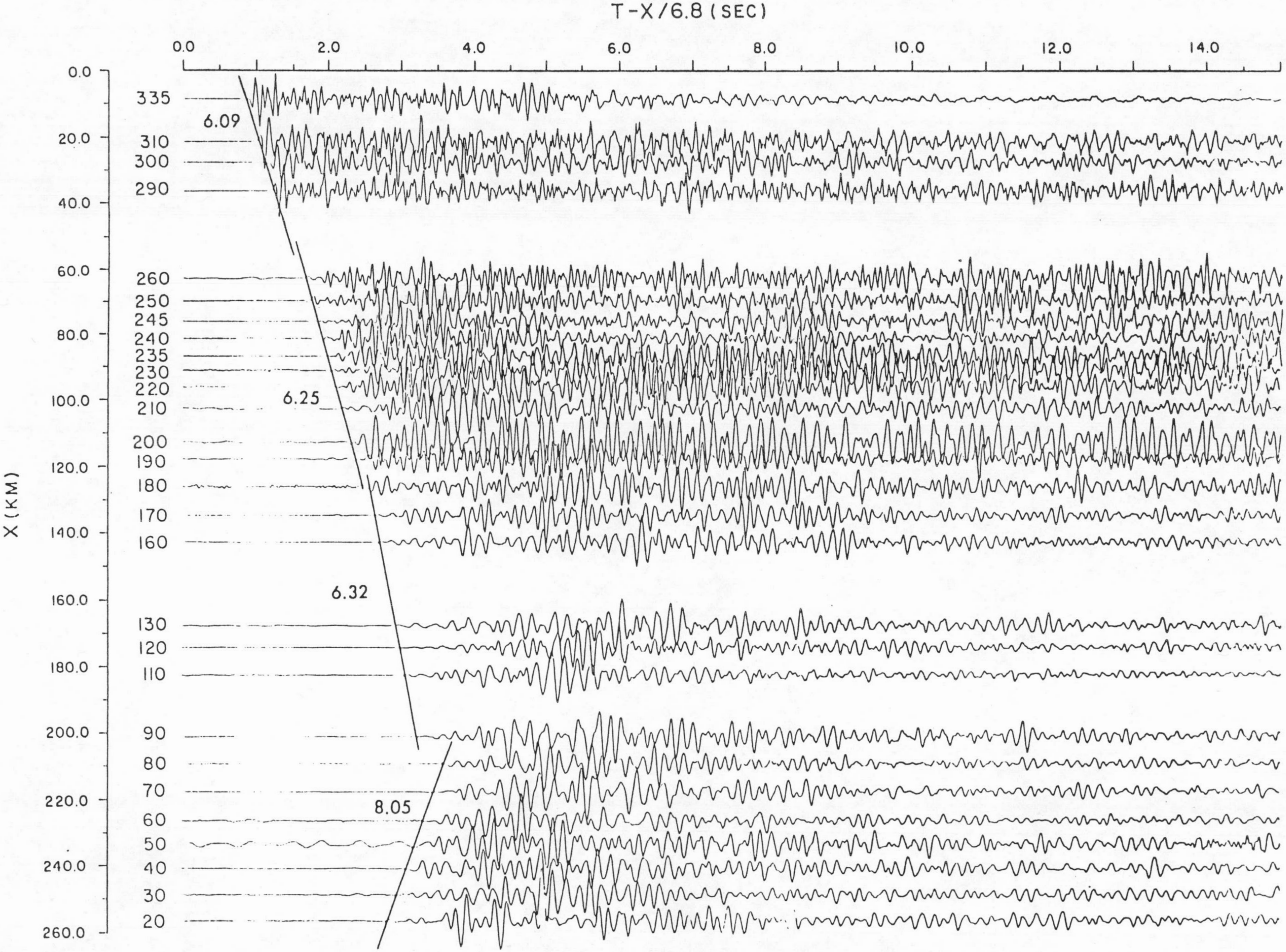
6) Stack

7) Time variant bandpass filter, same as before.

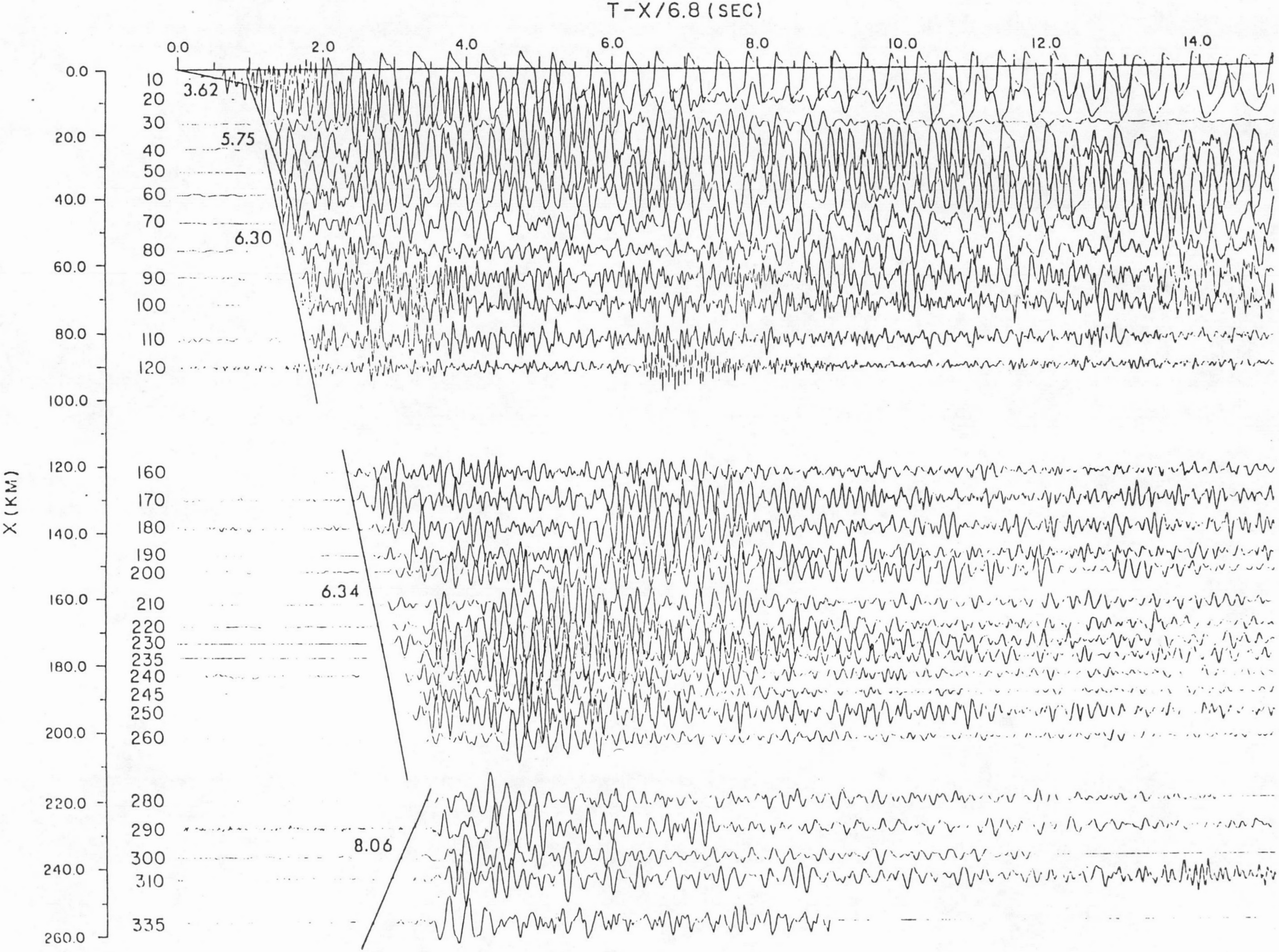
The deeper segment of the section reveals several sets of relatively continuous events. Large numbers of westerly dipping events were recognized between 4.0-10.8 sec. The origin of these arrivals requires further investigation. Some of them can be easily correlated over 10 km. Assuming normal crustal velocities in this area, they could originate from a depth of at least 12 km. They could also be diffraction patterns or side sweeps from nearby, shallower sources. However, their visual characteristics appear to eliminate this possibility. The majority of these events appear to terminate abruptly between CDP points 91 and 117. East of this line the character of the section changes considerably. The general nature of it is not as coherent as the events to the west. On the west side of the profile again, but in deeper segments, several easterly dipping reflections are shown at 12.8 seconds to 20 seconds; some of these can also be easily correlated at a significant distance.

In general the section reveals an enormous amount of detail about the crust in this area. It shows that the crust is significantly disturbed. East of CDP point 91 the section is relatively transparent to acoustic waves. Green et al. (1979) described local magnetic and gravity anomalies in this region. It is possible that the seismic section is delineating this magnetically anomalous body. One can also postulate that the easterly termination of the dipping reflecting interfaces is the most westerly limit of the Superior Province in that area.

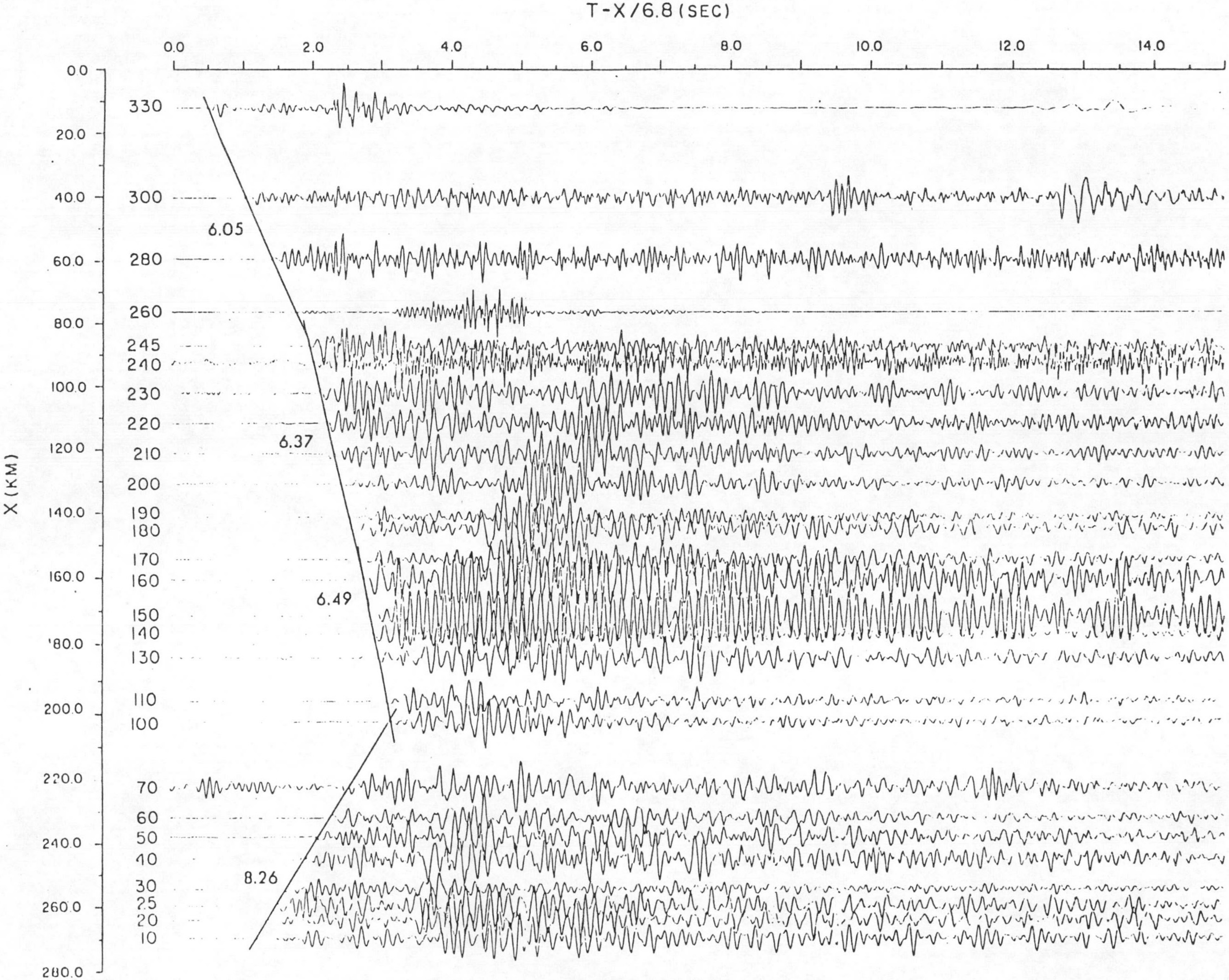
Attempts are being made for further analysis of this information. One of the first steps in this program will be migration of the data with several forms of migration algorithms. This test will very likely provide additional, perhaps convincing, evidence about the sources of these deep crustal reflection events.



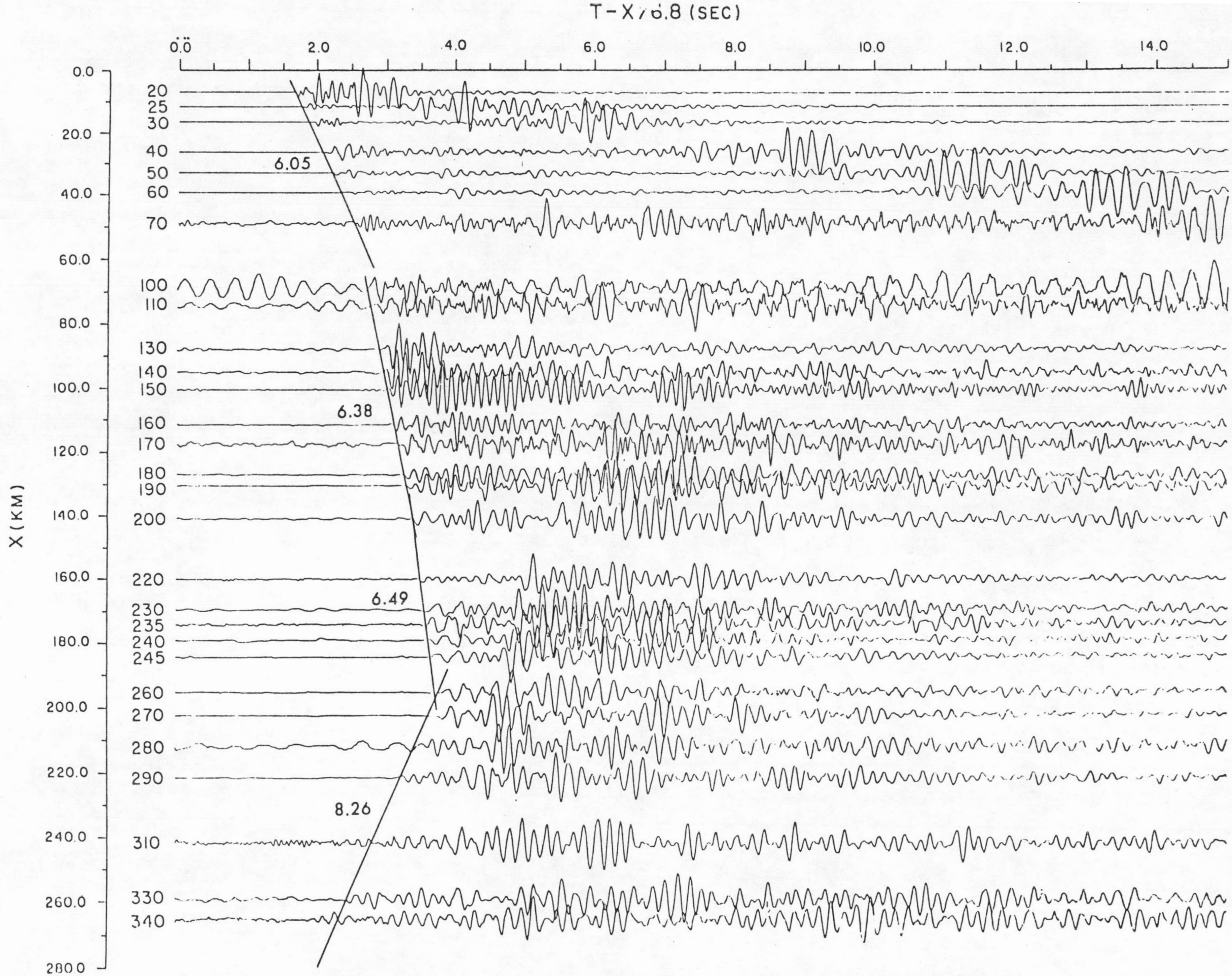
COCRUST '79 REFRACTION LINE A-NS-VERTICAL COMPONENT



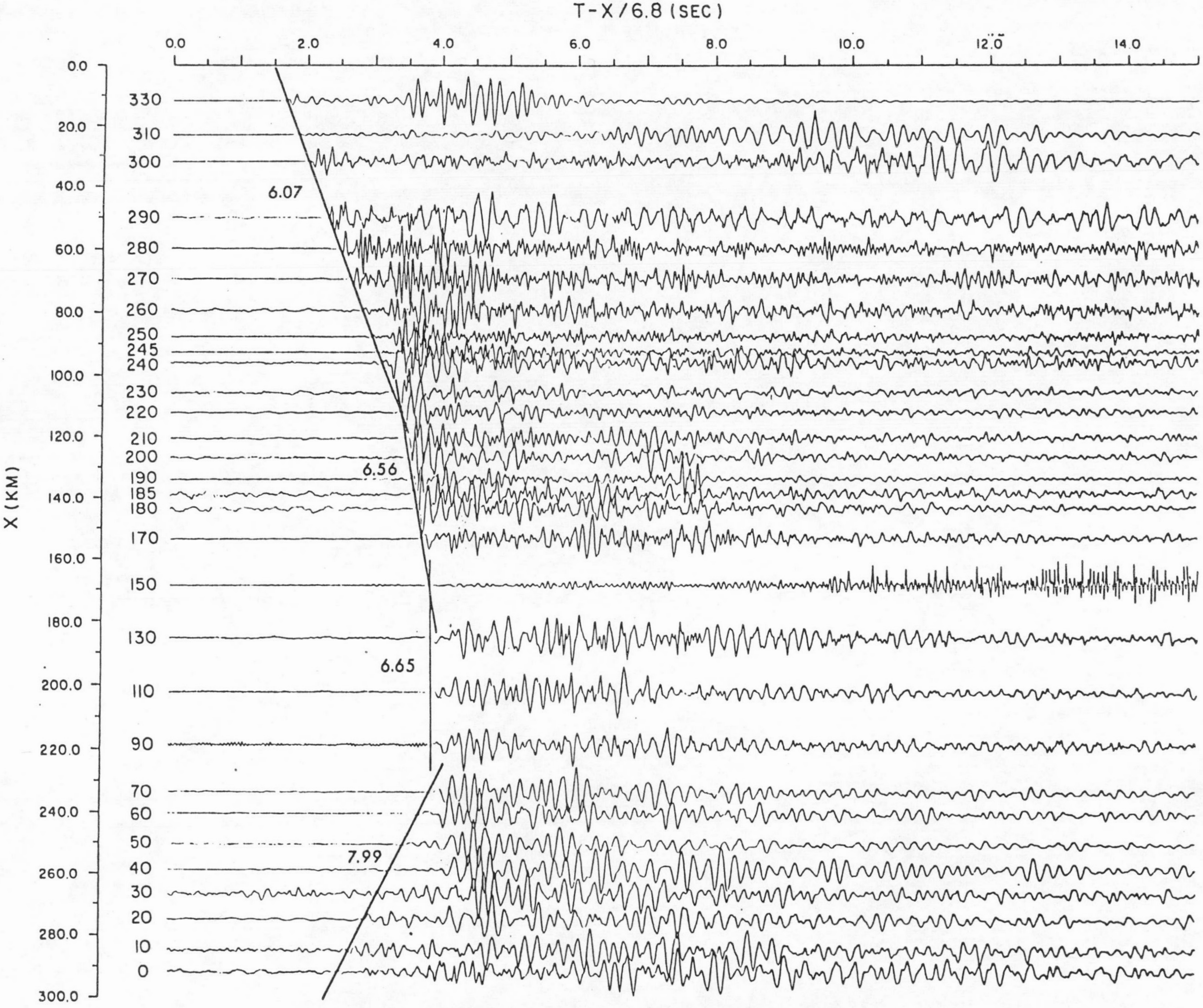
COCRUST '79 REFRACTION LINE A-SN-VERTICAL COMPONENT



COCRUST '79 REFRACTION LINE B - NS - VERTICAL COMPONENT



COCRUST REFRACTION LINE B - SN - VERTICAL COMPONENT



COCRUST '79 REFRACTION LINE C - VERTICAL COMPONENT

FIGURE 11

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