A PRECURSORY SUB-EVENT TO THE MONT-LAURIER EARTHQUAKE

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LEVEL OF REVIEW: This Internal Report contains two reports on the Mont-Laurier earthquake circulated in the month following the earthquake. Although the author's GSC colleagues have read and commented on the contents, the report has not undergone a formal review.

ABSTRACT

Two reports prepared in the month following the 1990 Mont-Laurier earthquake are included. Digitally-recorded waveforms for the m_N 5.0 Mont-Laurier mainshock on 19th November 1990 at 0701 UT (epicentre: 46.47N 75.59W; depth 11 km) show that the initiation of the mainshock rupture was preceded (by 0.15 s) by a precursory event (or foreshock) of about m_N 3.5 which may have initiated about 250 m northwest of the mainshock epicentre. Common first and second motion directions at most stations, but differences between the first and second motions at stations EEO and KGN, suggest a common NE-dipping plane for both the precursor and the mainshock but a larger strike-slip component for the mainshock.

PREFACE

(written August 1995)

This Internal Report contains two reports on the Mont-Laurier earthquake circulated to seismology staff on the 15th and 19th November 1990, about a month after the earthquake. Figure '0' shows the epicentre in relation to the recording stations of the GSC's Eastern Canada Telemetered Network, seismograms of which are figured in the reports.

For historical reasons, the exact texts and hand-annotated figures which were circulated have been retained. Thus there is not a single set of figures, and the "Part 2" partly updates the contents of the first report. The m_N for the main shock was subsequently revised to 5.0, so the precursor magnitude would now be about 3.5. Haddon and Adams (in prep.) now deduce a fault plane solution of str=305 dip=50 rake=95 for the mainshock; this has a similar strike and dip to the northeast-dipping plane derived for the precursor and mainshock in these early reports, but a much smaller strike-slip component than for the mainshock.

A better analysis of the relative locations of the precursor and mainshock may be warranted, although the confidence in the results is constrained by the 60 samples per second sampling rate of the ECTN. I currently interpret the delays on TRQ and MNT and on GRQ (Figure 3 of Part 1) as representing a timing delay of about 0.14 s between the precursor and mainshock initiation and a propagation delay of -0.04 s to GRQ and +0.04 s to both TRQ and MNT, hence the precursor would be about 250 m farther (using a P velocity of 6 km/s) from GRQ than the mainshock epicentre (In this respect the words on Fig. 3 of Part 1 are unfortunately wrong). It is intriguing that the radius associated with a simple M3.5 rupture is consistent with the mainshock initiating (after a delay of 0.14 s) on the perimeter of the precursor rupture and so re-rupturing the precursor rupture area. Haddon and Adams (in prep.) suggest that the energy released from the precursor rupture area during the mainshock episode was at least an order of magnitude larger than released during the precursor.

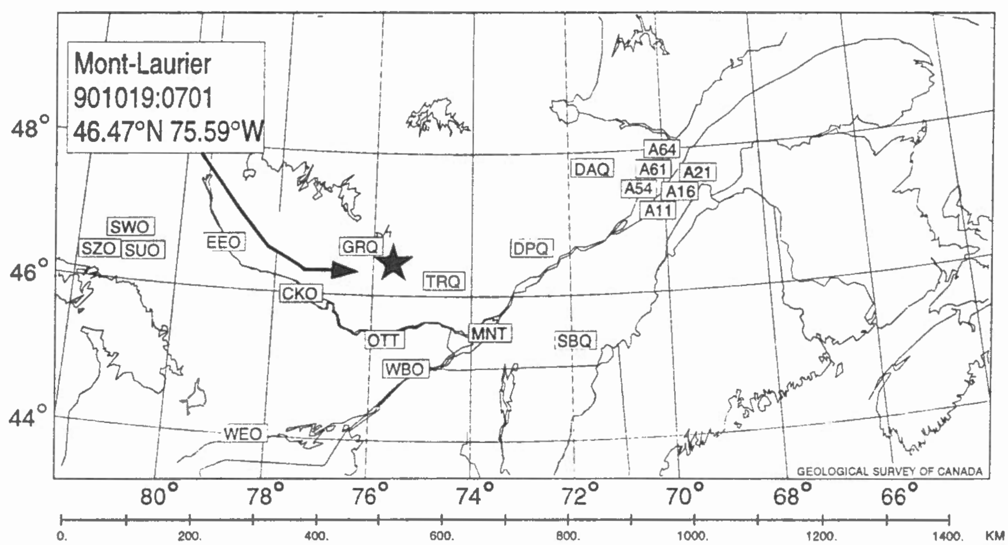
For further reading on this earthquake, see:

Atkinson, G.M., and P.G. Somerville (1994). Calibration of time history simulation methods, Bull. Seism. Soc. Am., 84, 400-414.

Haddon, R.A.W., and J. Adams (1995). The Mont-Laurier earthquake of October 1990: - definitely not a high stress drop event, American Geophysical Union, abstracts of 1995 Fall Meeting.

Haddon, R.A.W., and J. Adams (in prep). The Mont-Laurier earthquake of October 1990: - definitely not a high stress drop event (title subject to change), for submission to Geophysical Journal International.

Lamontagne, M., H.S. Hasegawa, D.A. Forsyth, G.G.R. Buchbinder and M. Cajka (1994). The Mont-Laurier, Quebec, earthquake of 19 October 1990 and its seismotectonic environment, Bull. Seism. Soc. Am., 84, 1506-22.



Mont-Laurier
901019:0701
46.47°N 75.59°W
48°
46°
44°
SWO
SZO
SUO
EEO
GRQ
TRQ
CKO
OTT
MNT
WBO
WEO
DPQ
DAQ
SBQ
A64
A61
A21
A54
A16
A11
GEOLOGICAL SURVEY OF CANADA
80°
78°
76°
74°
72°
70°
68°
66°
0.
200.
400.
600.
800.
1000.
1200.
1400.
KM

Figure 'O'

A PRECURSORY SUB-EVENT TO THE MONT-LAURIER EARTHQUAKE
(Originally circulated on 15th November 1990)

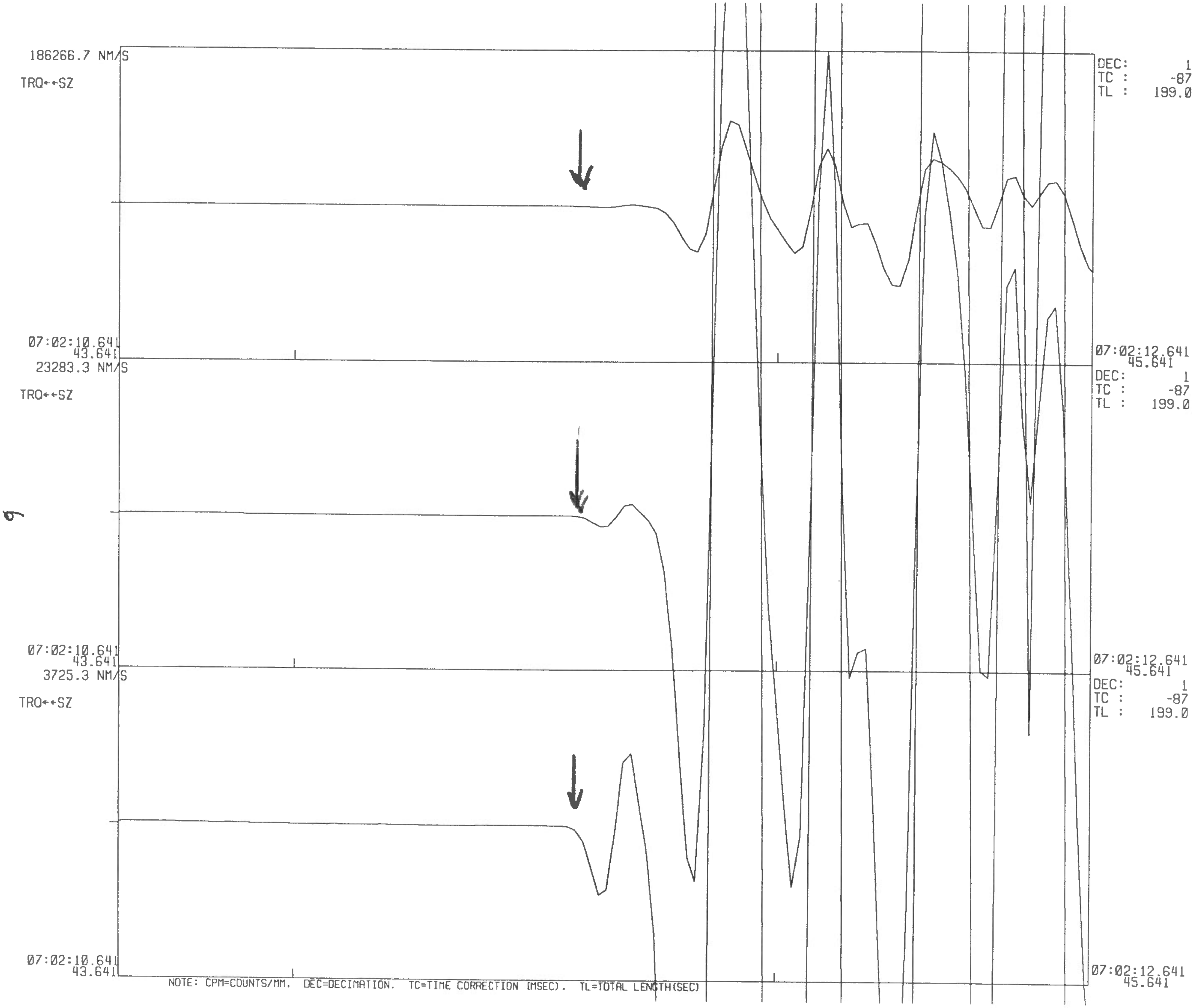
On many of the close-in stations the mainshock of the Mont-Laurier Earthquake of 19th October 1990 was preceded by one cycle of low amplitude waves seen only when the trace was magnified (Fig. 1).

This precursor is seen at most close-in stations, regardless of distance, and is seen at both Pg and Pn distances (Fig. 2a-g).

From the relative amplitudes of the first, positive half-cycle on GRQ (the precursor) and the second, positive half cycle (the mainshock), and presuming the P-wave radiation pattern for the two events was about the same, the precursor has 3% of the energy of the mainshock; if the mainshock is m_{bLg} 5.1, the precursor was m_{bLg} 3.6.

By measuring waveforms like Fig. 2a-g, I determined the delay between the beginning of the precursor and the onset of the large-amplitude event. The average delay was 0.15 s if the GRQ value of 0.10 s is included, and 0.16 s if not. As can be seen on Fig. 3, there is little azimuthal variation in the delay, and delays on the Pg and the Pn phases are similar. Hence the two events were in approximately the same place. For a delay of 0.15 s and a rupture velocity of 3 km/s, the initial rupture could have extended no more than 450 m in the time between the two events; indeed less than this if some lag is required between the precursor rupture intersecting the mainshock rupture and the initiation of the mainshock. From the difference between the GRQ delay and the average, the mainshock may have initiated a maximum of 350 m closer to GRQ than the precursor. A magnitude 3.5 earthquake would have a source radius of about 200 m (Hasegawa, 1983), so these observations are consistent with the conclusion that a M3.6 precursor acted as a trigger to the magnitude 5 mainshock. Possible geometric relationships are shown in Fig. 4.

Polarities for the precursor are similar to the mainshock for most stations (e.g. see waveforms Fig 2a-g and plots on Fig 5.). However EEO in particular gives a clear compression for the first arrival (precursor) that is inconsistent with dilatations recorded on the northern Ontario stations. EEO lacks a clear amplitude distinction between the precursor and the mainshock and has a lower frequency signal. A delay of 0.15 s places the mainshock arrival at the peak of the first arrival, in which case the mainshock polarity may be D; in any event the mainshock arrival is almost as weak as the precursor. This would likely fit the mainshock mechanism better.



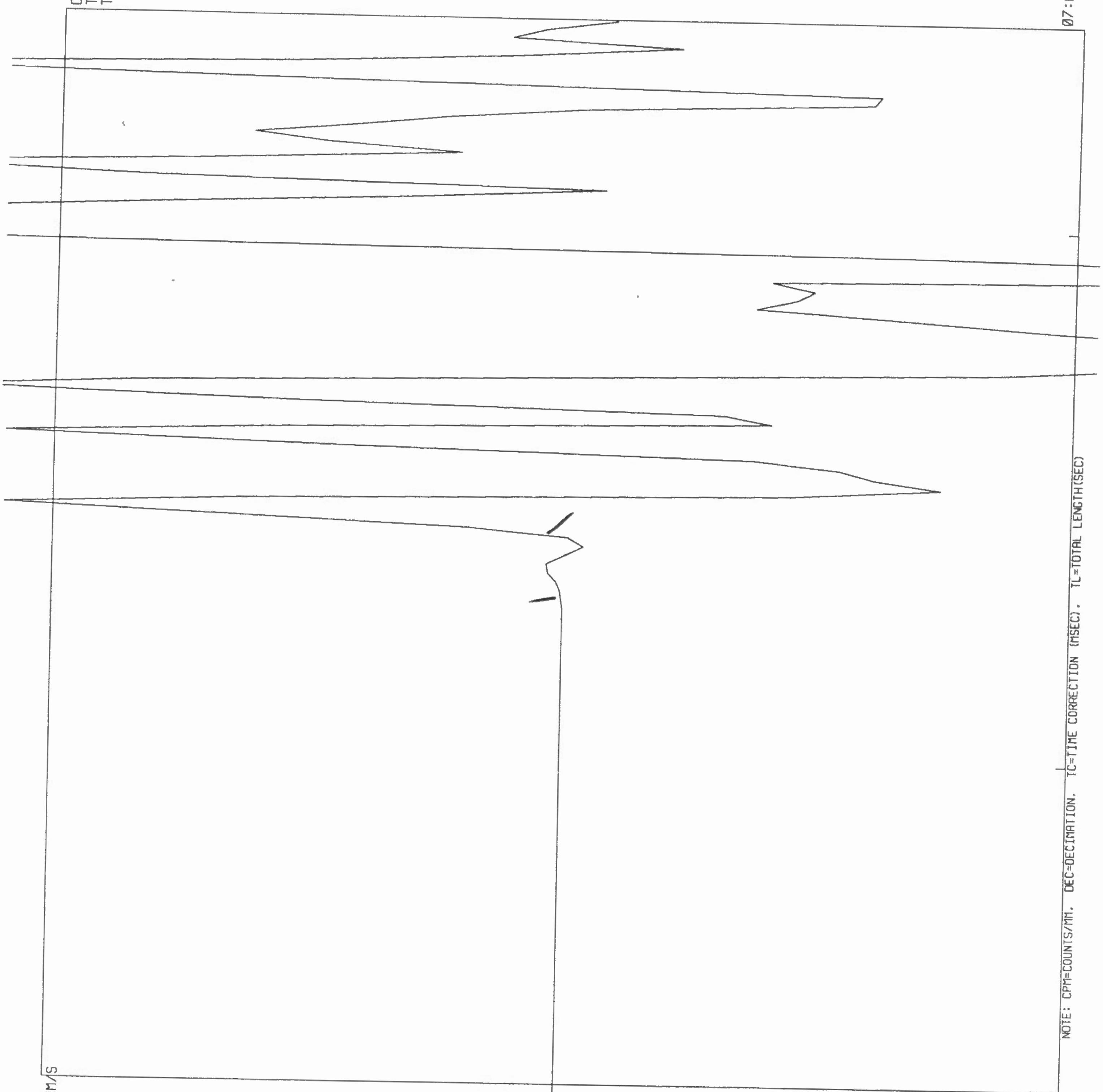
19/OCT/1990 07:01:27 EVENT FILE = 901019070.226L:1

Fig 1

2a

Fig 2a

19/OCT/1990 07:01:27 EVENT FILE = 901019070.226L:1



2b

Fig 2b

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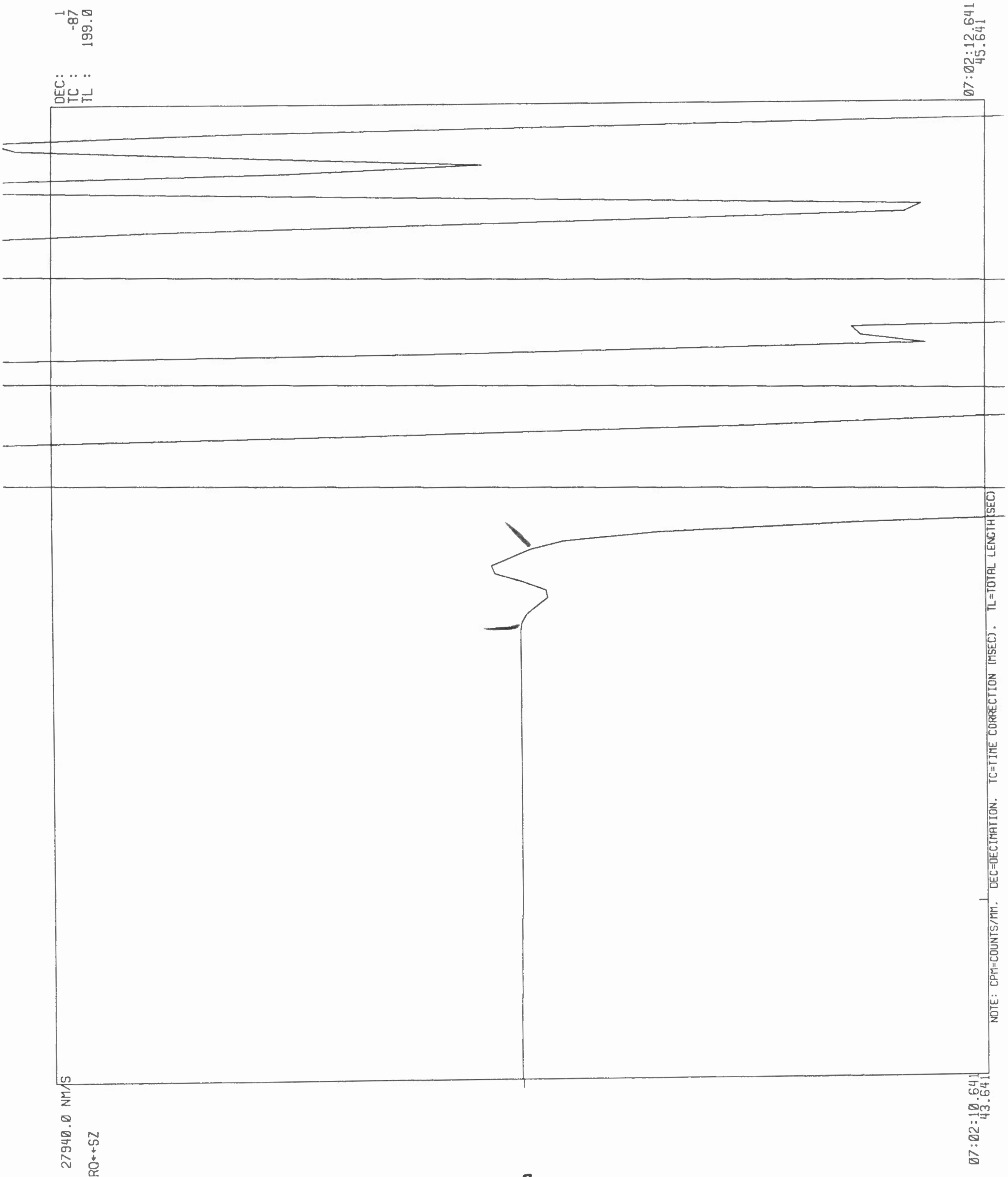

2c

Fig 2c

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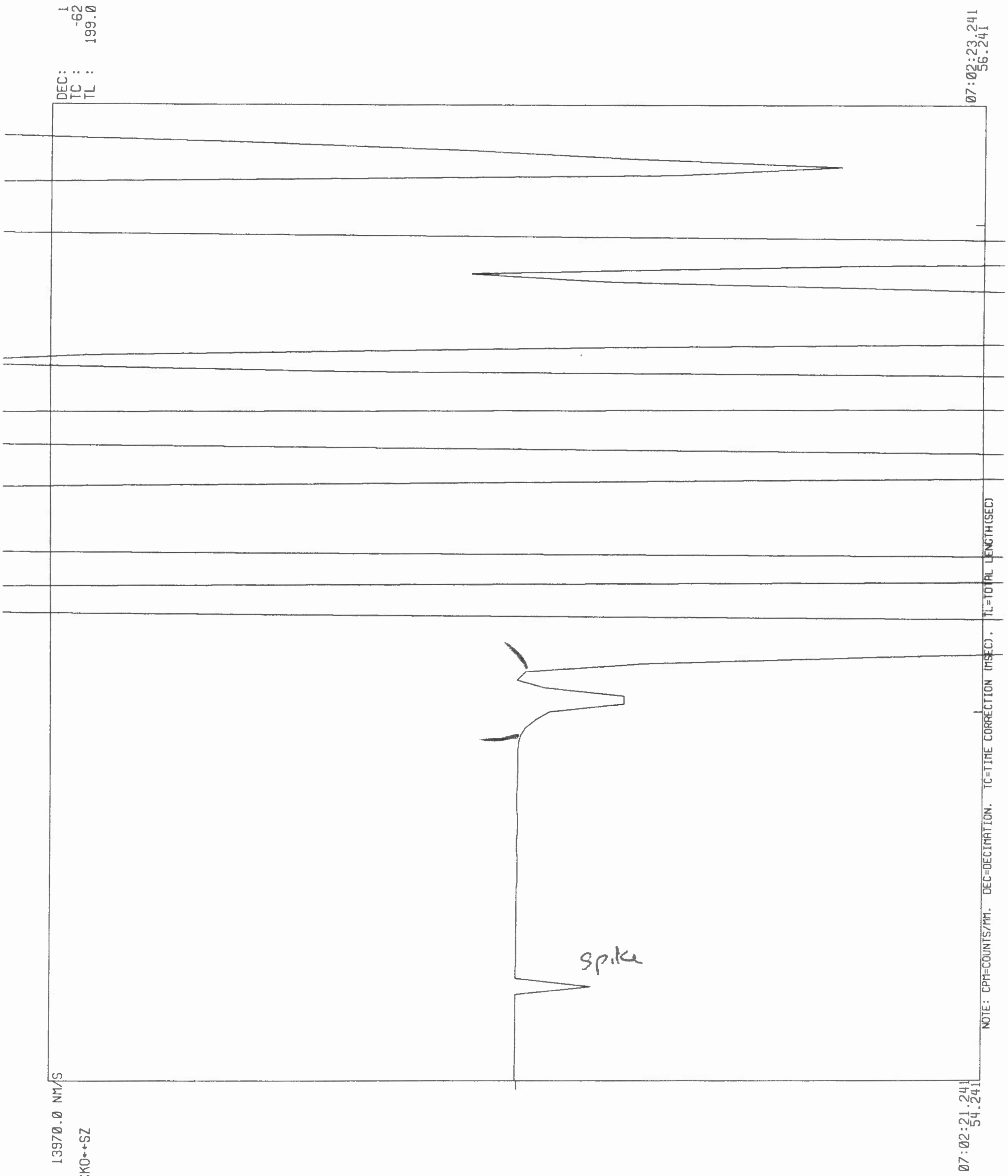

2d

Fig. 2d

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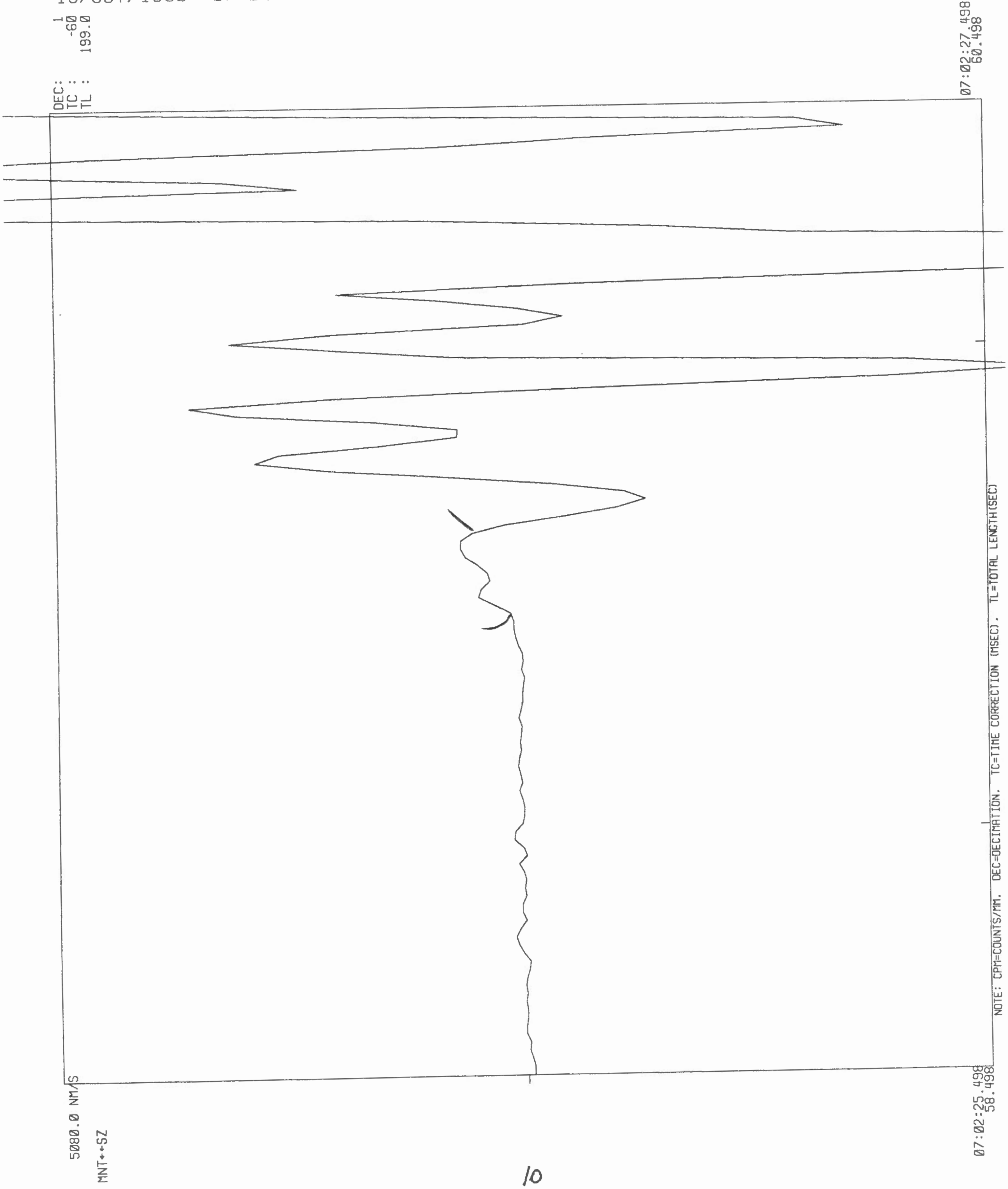

2e

Fig. 2e

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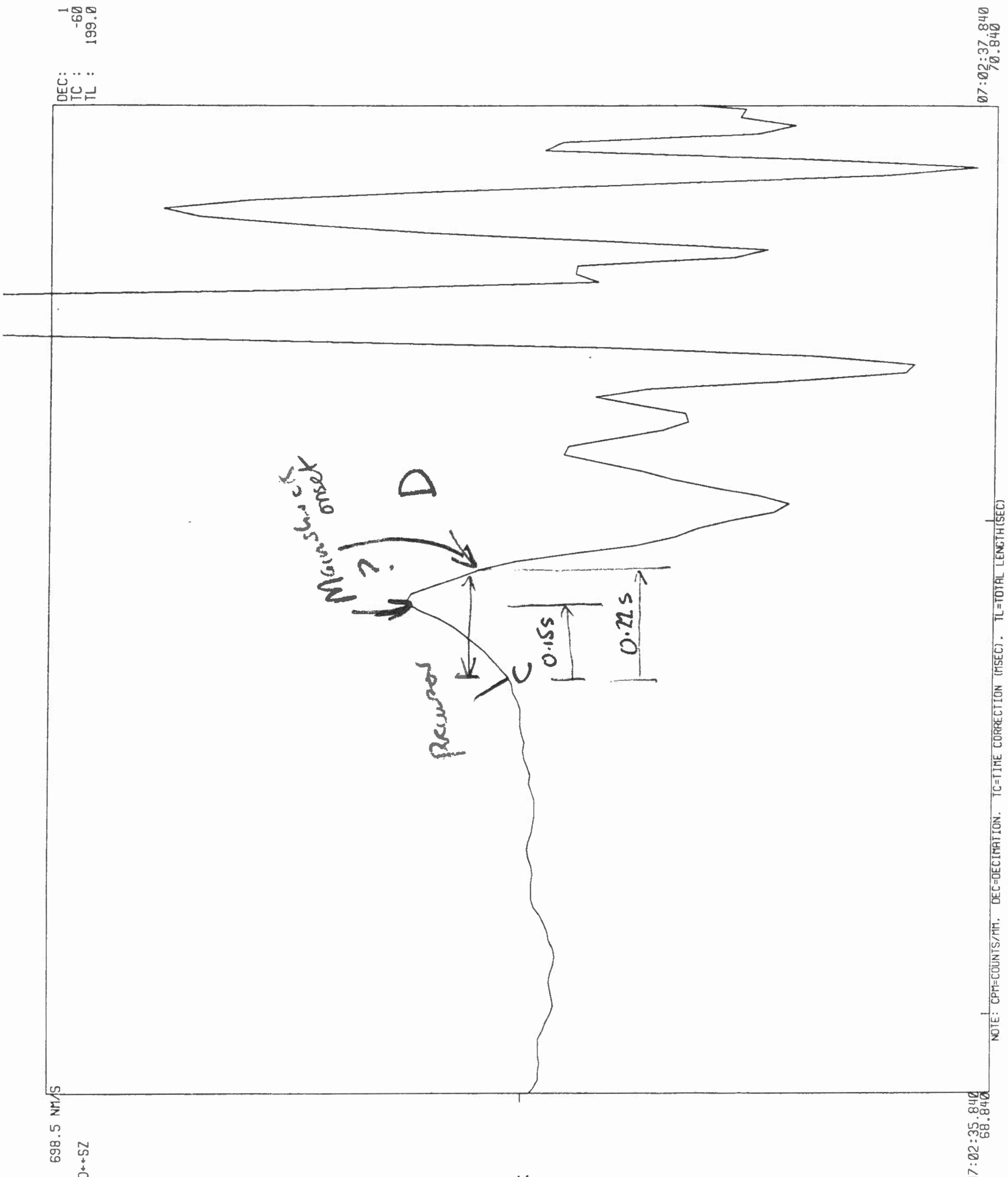

2f

Fig. 2f

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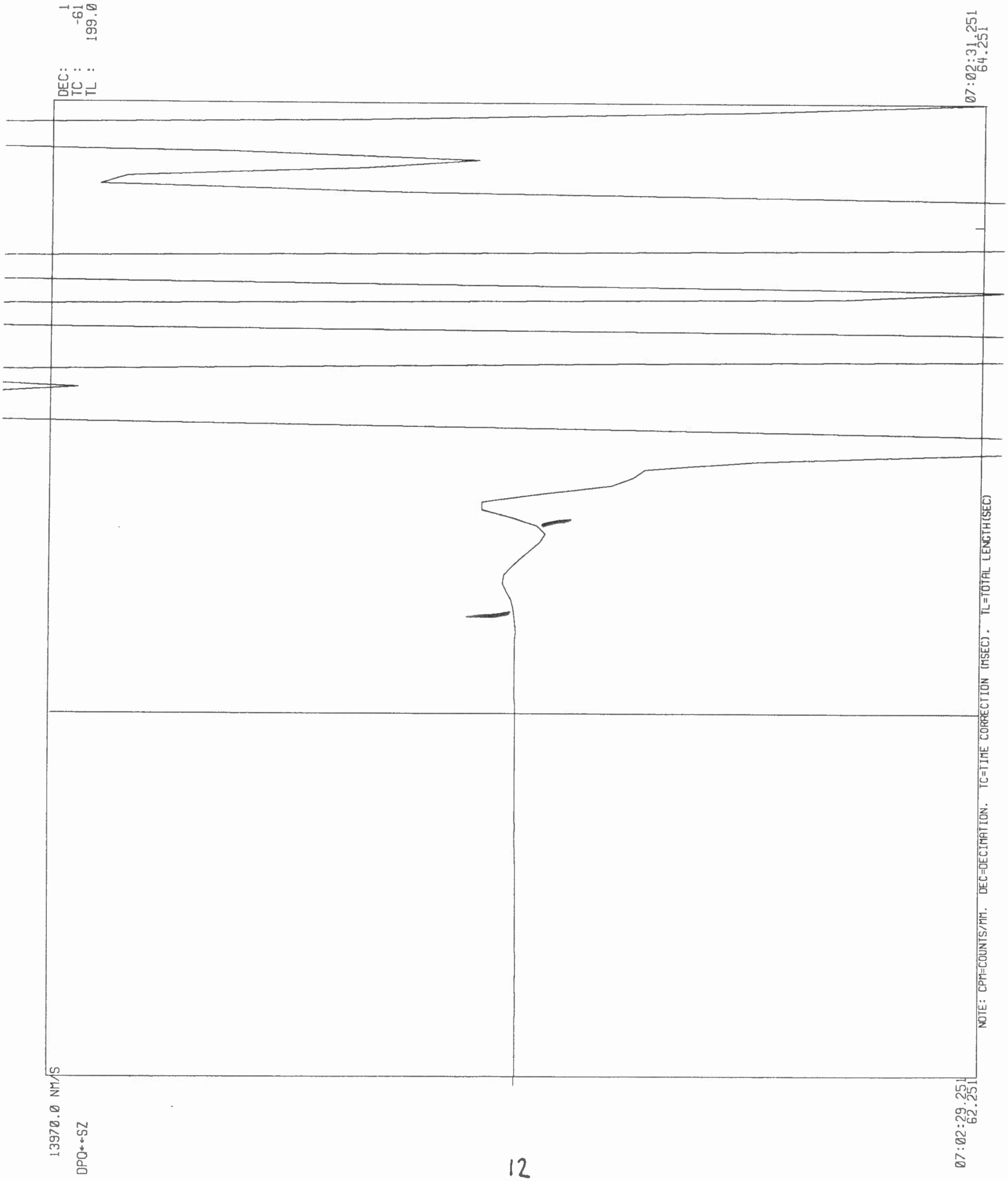
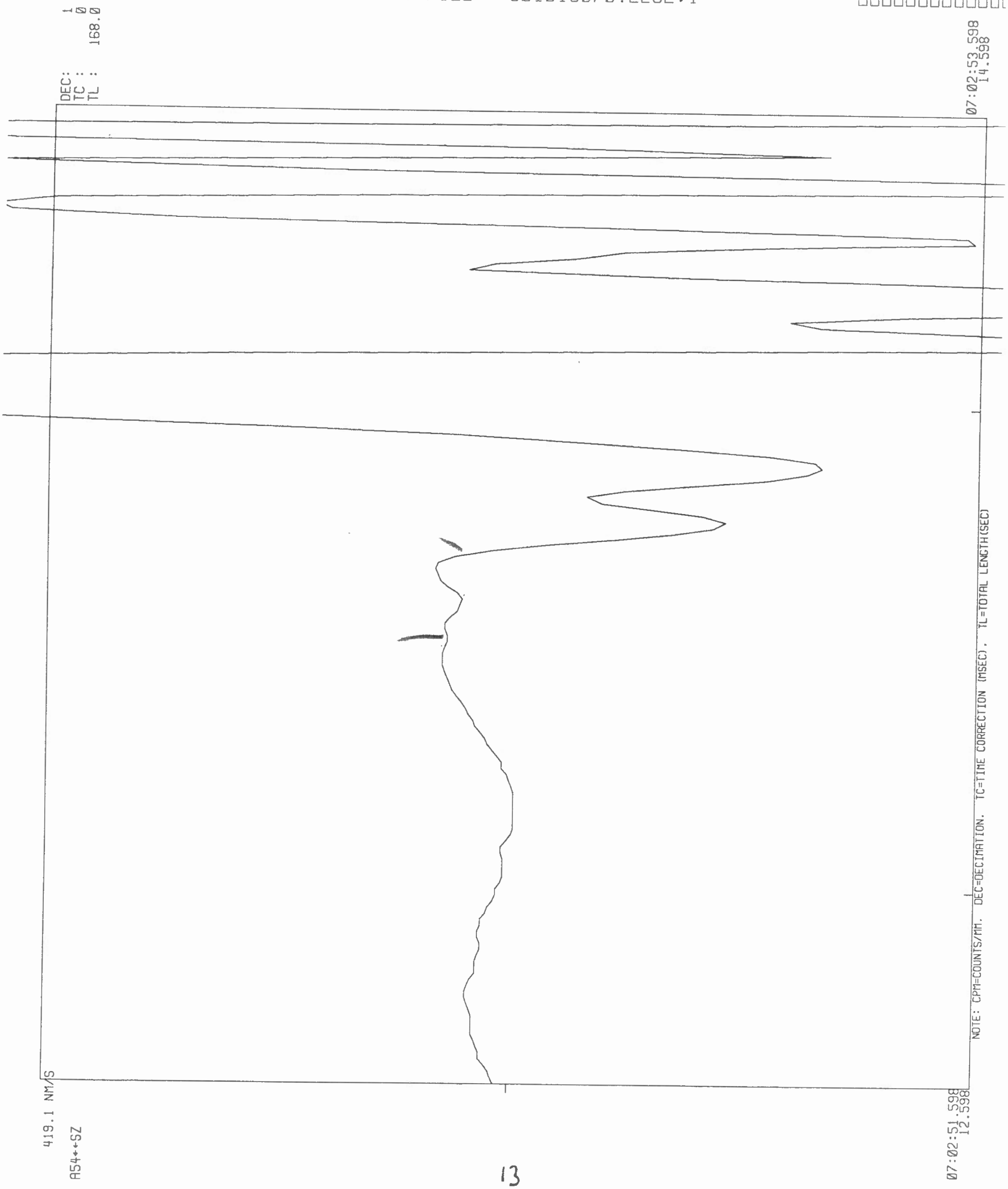
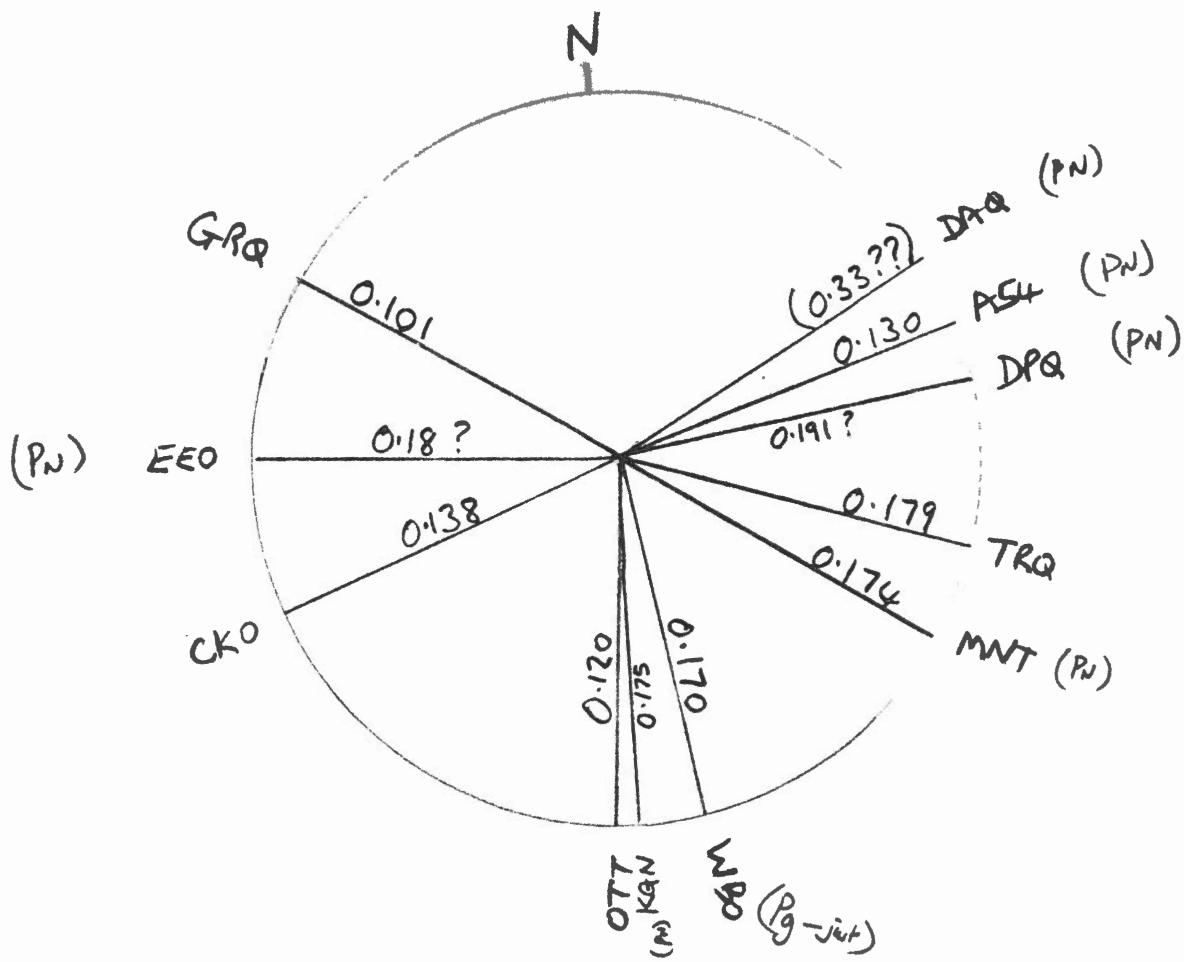


2g

Fig. 2g

19/OCT/1990 07:02:39 EVENT FILE = 901019070.226L:1





mean (9 values) 0.154 sec delay

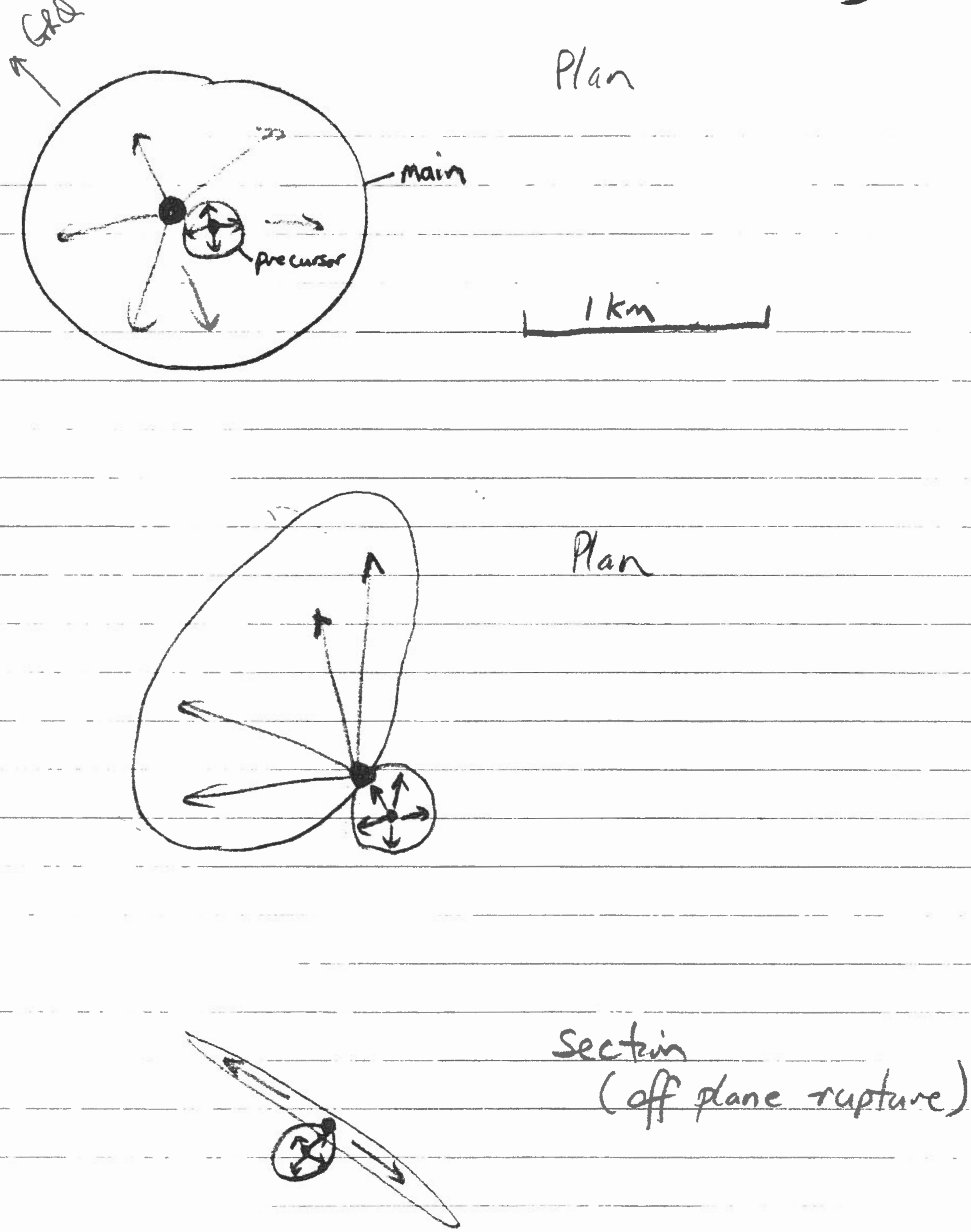
mean (8 values less GRQ) 0.160 sec delay

Δ (GRQ – Mean 8 values) = 0.06 sec

= 350 m @ 6 km/s

ie subevent may have been closer to GRQ by 350m

Fig 4



A PRECURSORY SUB-EVENT TO THE MONT-LAURIER EARTHQUAKE
PART 2 - the focal mechanism implications
(Originally circulated on 19th November 1990)

In Part 1, I noted that on many of the close-in stations, the mainshock of the Mont-Laurier Earthquake of 19th October 1990 was preceded by one cycle of low amplitude waves that I inferred represented a M3.6 precursor 0.15 s before the mainshock.

I have since looked at the polarity of the precursor and the mainshock and find that while polarities for the precursor are similar to the mainshock for most stations [Fig. A-C and figures in Part 1], on some stations — notably EEO and KGN (Kingston, Queens University) — the polarities are different [Figs D and E].

For KGN the precursor has a polarity DNe, while the mainshock 0.175 s later is CSW. For EEO the precursor has a C polarity, while 0.15 s after the onset the first half waveform has reached its peak and is thence a D. On EEO the frequency of the ground motion is such that the individual cycle of the precursor cannot be distinguished as it can on closer stations. Table 1 gives the polarity data for the precursor and Fig. 1 shows the data and the planes derived from FOCMEC. The mechanism is reasonably well constrained, although there is not a great deal of redundancy. The three fitting planes represent nearly pure reverse thrusting on moderately-dipping, northwest-striking planes.

If the first motions at KGN and EEO and other close ECTN stations belong to the precursor, then for consistency it is the polarity of the mainshock that should be used for combining with the CSN data to compute the mainshock mechanism (the precursor at M3.6 being invisible at greater distances). At most of the stations precursor and mainshock readings are the same, but for EEO and KGN D and C should be used respectively. This resolves one of the chief difficulties found when attempting to fit the mainshock mechanism — the EEO 'C' and the northern Ontario 'D's. With EEO as a D, the mechanism in Fig. 2 is found. It represents thrust/strike-slip faulting on N- NW-striking planes.

As can be seen by comparing Figs 1 and 2, the one of the three possible precursor mechanisms contains a NE-dipping plane almost identical to the NE-dipping plane of the mainshock (Fig. 3). This plane has the correct strike and dip to be the one I thought I found in the field aftershock hypocentres; it will be interesting to see if this pans out.

TABLE 1

19901019 07:01 MN=3.6 46.477N 75.590W 12.00 KM

			Precursor	Mainshock	
GRQ	305.000	-62.000	C	C	Good
TRQ	109.000	-81.000	D	D	Good
OTT	185.000	-84.000	D	D	Good
CKO	250.000	-85.000	D	D	Good
WBO	171.000	-85.000	-	D	Very weak
MNT	125.000	49.000	C	C	OK
DPQ	083.000	49.000	C	C	Good
KGN	196.000	49.000	D	C	OK
EEO	275.000	49.000	C	D?	Good
A54	073.000	49.000	+	+	OK
A64	069.000	49.000	+	-	OK
A61	071.000	49.000	C	D	OK
A21	071.000	49.000	+	+	Poor
A11	076.000	49.000	+	D	OK
DAQ	062.000	49.000	D	D	OK
WEO	220.000	49.000	-	+?	Poor

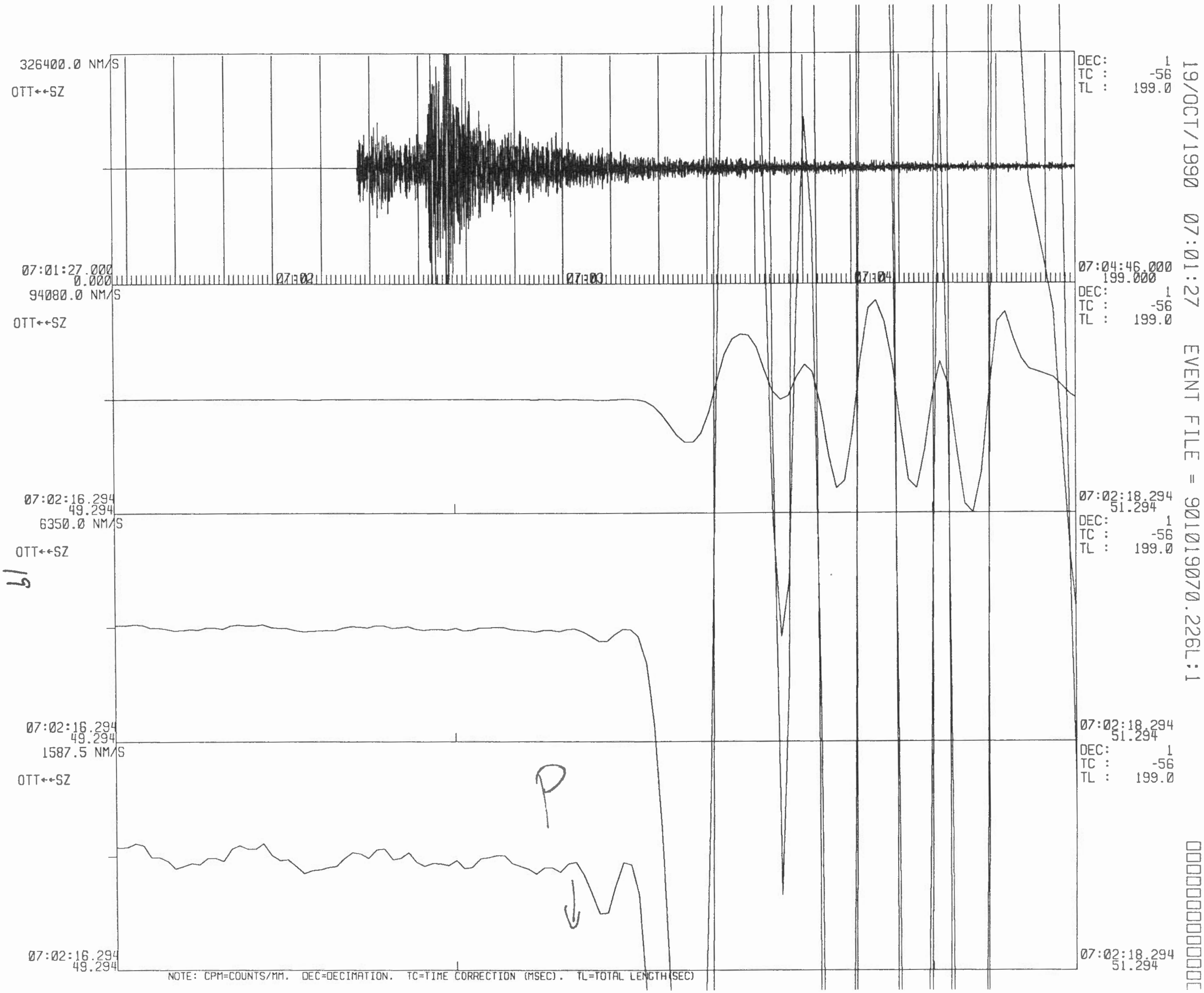
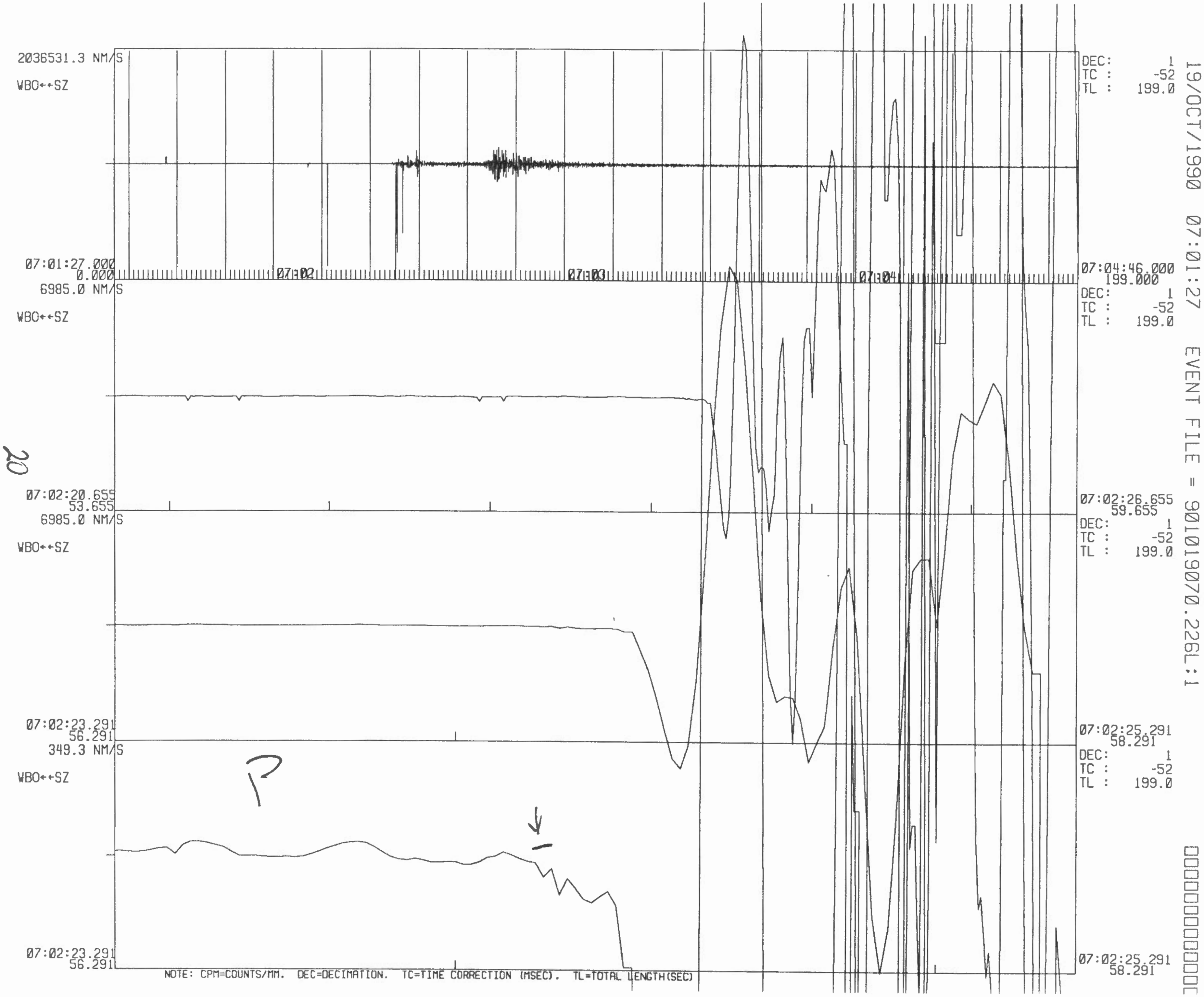

326400.0 NM/S
OTT←←SZ
07:01:27.000
0.000
07:02
07:03
07:04
07:04:46.000
199.000
DEC: 1
TC : -56
TL : 199.0
94080.0 NM/S
OTT←←SZ
07:02:16.294
49.294
07:02:18.294
51.294
DEC: 1
TC : -56
TL : 199.0
6350.0 NM/S
OTT←←SZ
07:02:16.294
49.294
07:02:18.294
51.294
DEC: 1
TC : -56
TL : 199.0
1587.5 NM/S
OTT←←SZ
P
07:02:16.294
49.294
07:02:18.294
51.294
DEC: 1
TC : -56
TL : 199.0
NOTE: CPM=COUNTS/MM. DEC=DECIMATION. TC=TIME CORRECTION (MSEC). TL=TOTAL LENGTH(SEC)
19/OCT/1990 07:01:27 EVENT FILE = 901019070.226L:1

Fig A



2036531.3 NM/S
WBO←+SZ
07:01:27.000
0.000
07:02
07:03
07:04
07:04:46.000
199.000
DEC: 1
TC : -52
TL : 199.0
6985.0 NM/S
WBO←+SZ
07:02:20.655
53.655
07:02:26.655
59.655
6985.0 NM/S
WBO←+SZ
07:02:23.291
56.291
07:02:25.291
58.291
349.3 NM/S
WBO←+SZ
P
07:02:23.291
56.291
07:02:25.291
58.291
NOTE: CPM=COUNTS/MM. DEC=DECIMATION. TC=TIME CORRECTION (MSEC). TL=TOTAL LENGTH(SEC)
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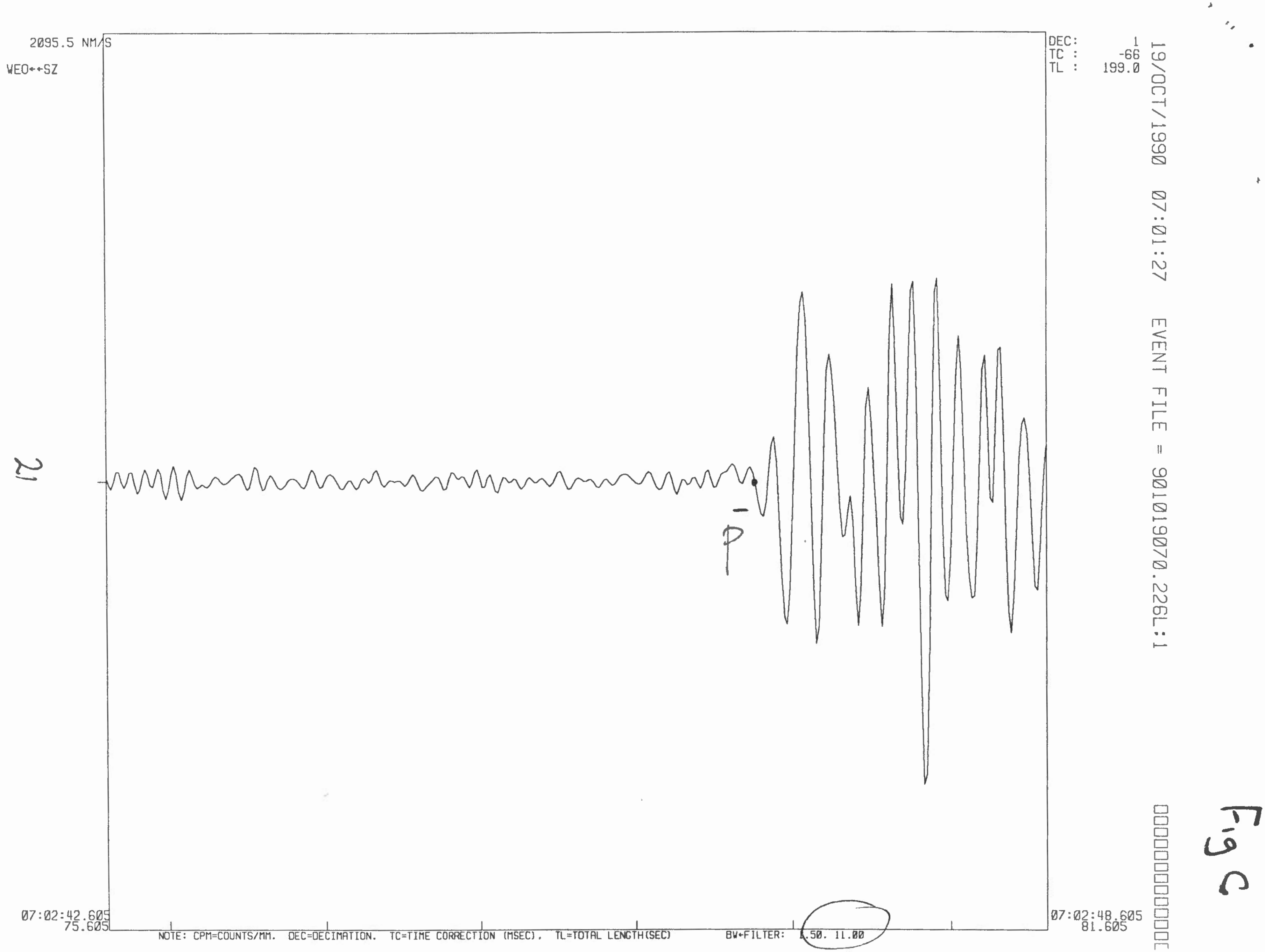
20

Fig 8


2095.5 NM/S
WEO←SZ
21
P
DEC: 1
TC : -66
TL : 199.0
19/OCT/1990 07:01:27 EVENT FILE = 901019070.226L:1
0000000000000
07:02:42.605
75.605
07:02:48.605
81.605
NOTE: CPM=COUNTS/MM. DEC=DECIMATION. TC=TIME CORRECTION (MSEC). TL=TOTAL LENGTH(SEC)
BW←FILTER: 1.50. 11.00
Fig C

2e.

Fig. 2e

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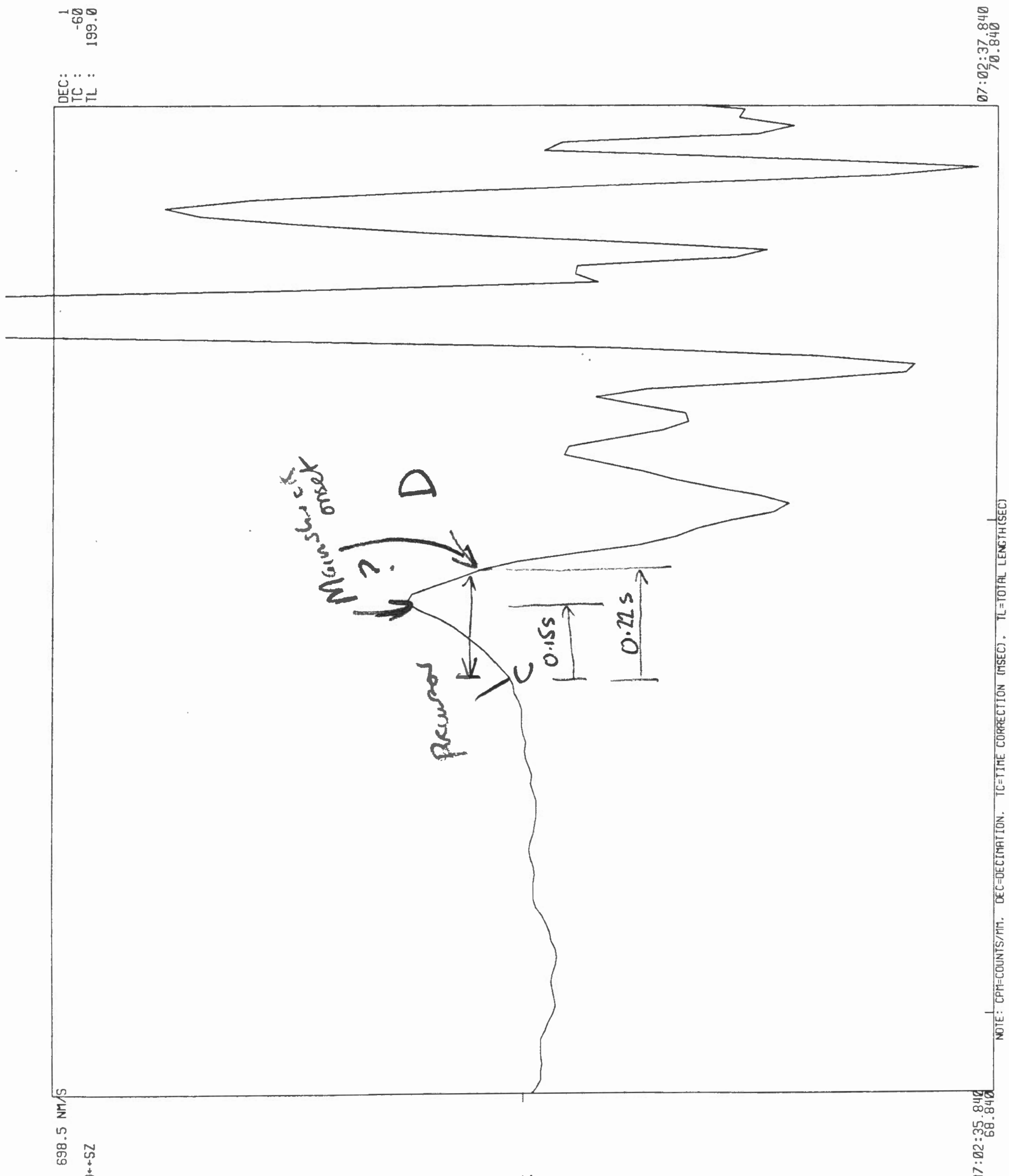
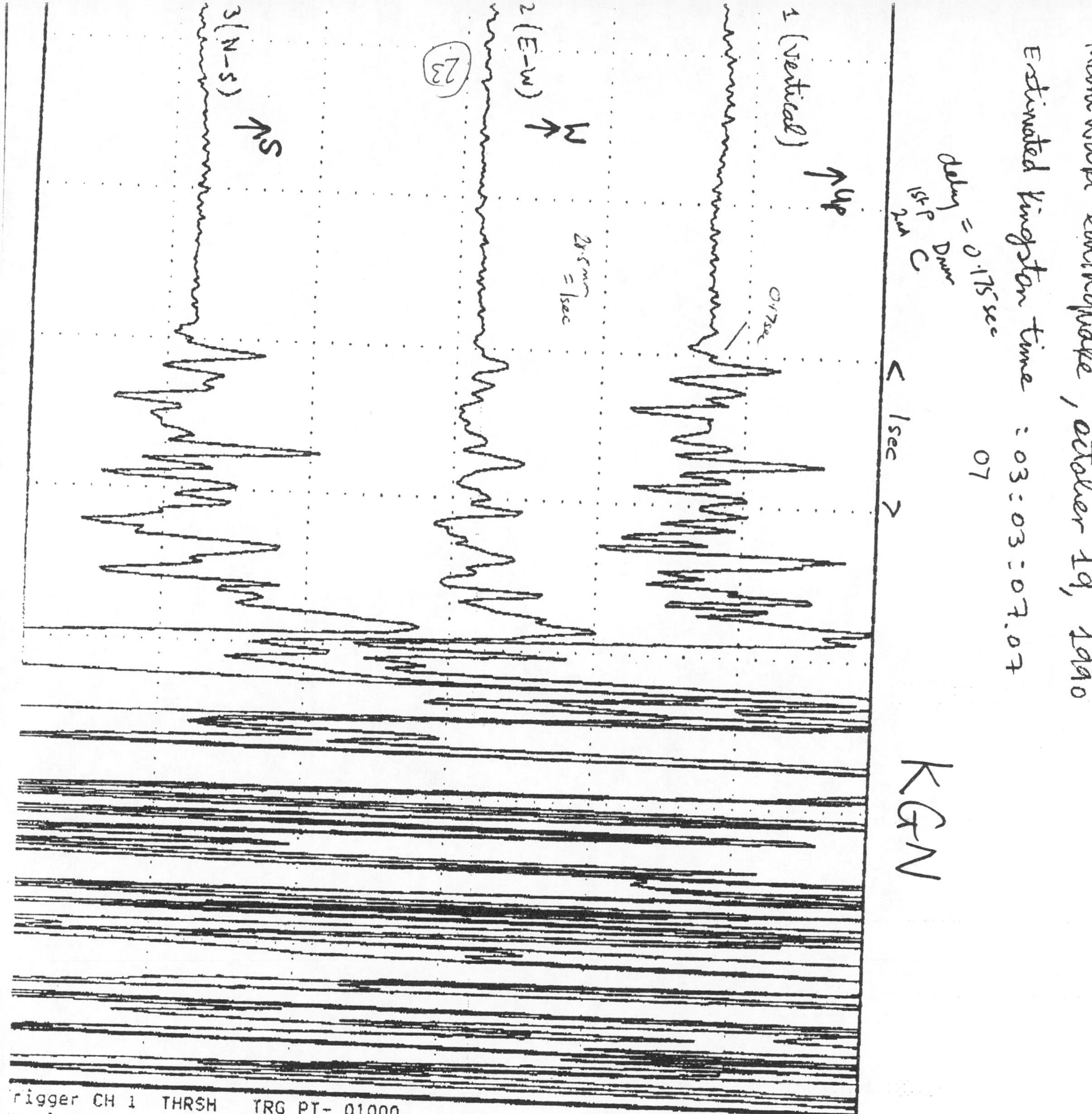


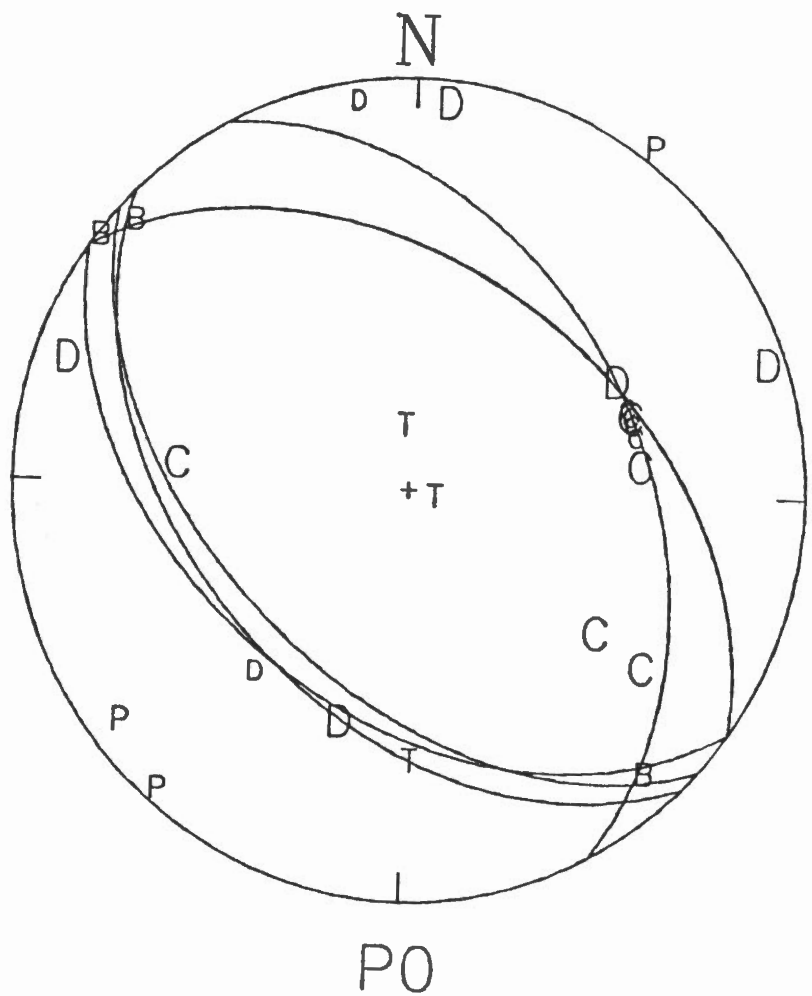


Trigger CH 1   THRSH   TRG PT- 01000
Sample 20 mS   Expand + 1 Display 596
Buffer 327 S   1.0 S/Div
CH1 - 1.00 V CH2 - 1.00 V CH3 - 1.00 V CH4 - off
CH5 - off   CH6 - off   CH7 - off   CH8 - off
CHA - off   CHB - off   CHC - off   CHD - off
CHE - off   CHF - off   CHG - off   CHH - off

Read as ~~DeN~~ DNe

Fig E

Fig 1



Precursor

Str	dip	rake
125	45	090
305	45	083
132	51	077

Fig 1

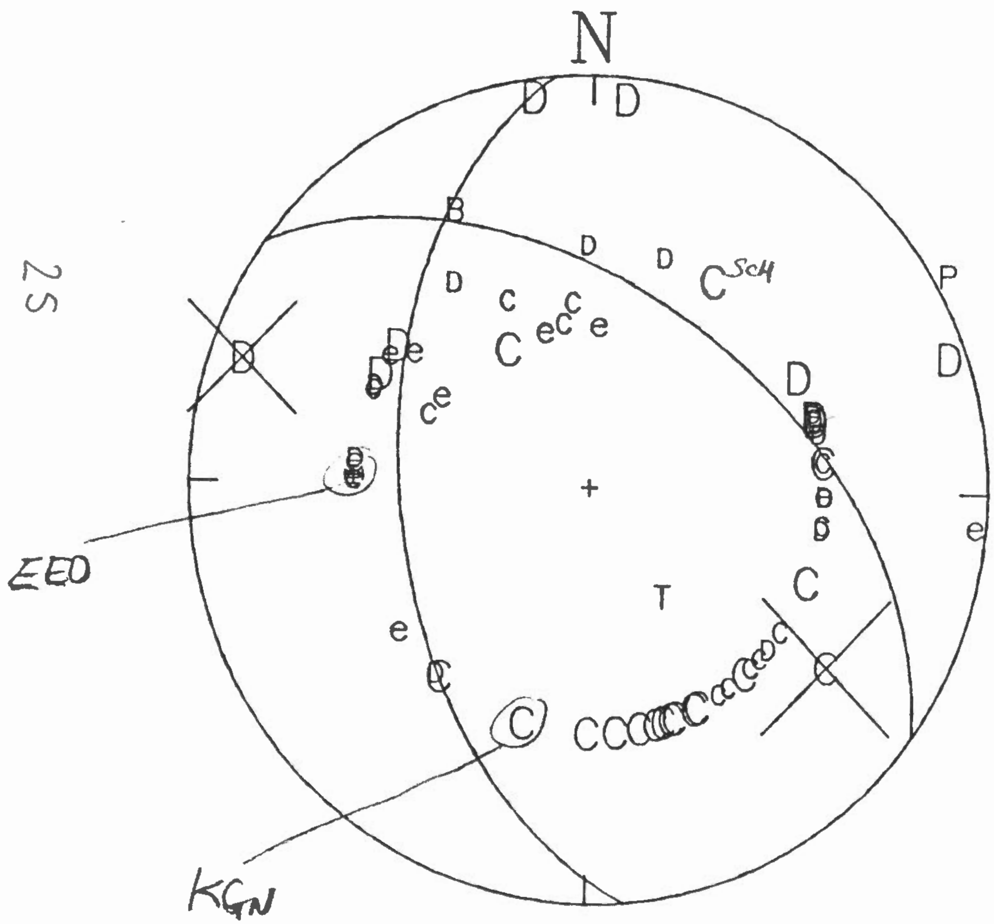
Fig 2

Mont – Laurier

Mainshock

Adams 901119

Str	Dip	Rak
305	51	54



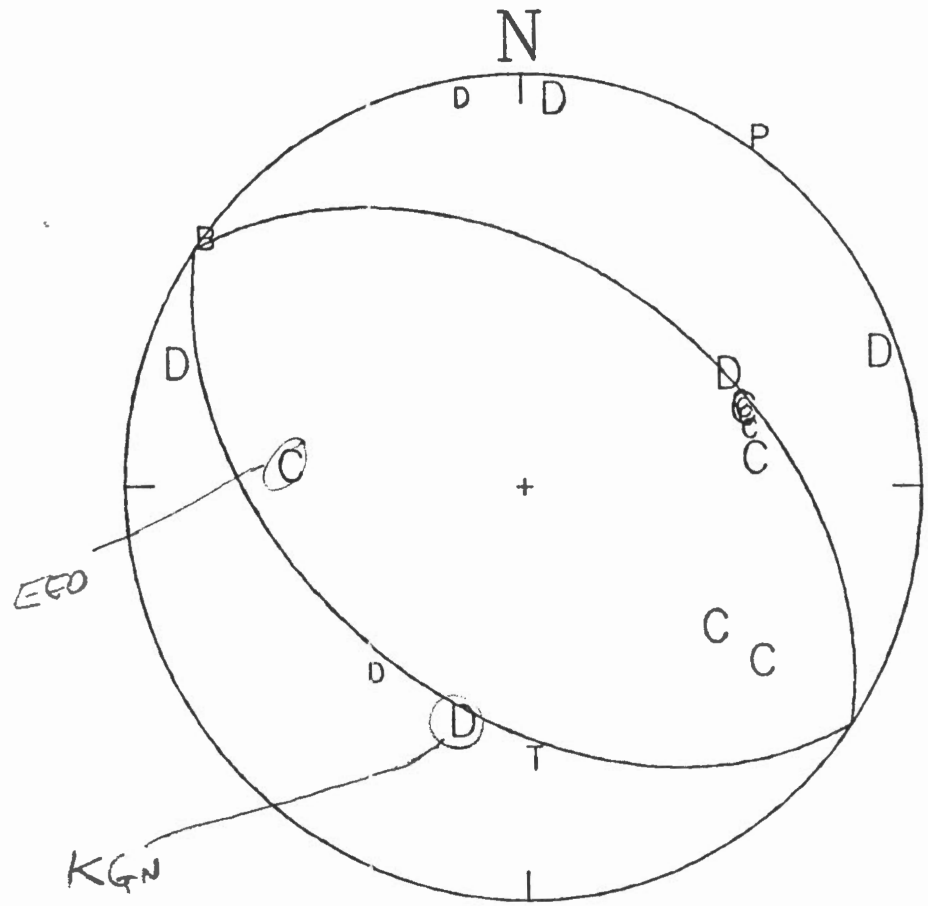
P3.5 R2

Fig 2

Fig 3

Precursor
(Plane most similar to mainshock)

Str	Dip	Rak	
~~125~~	~~45~~	~~090~~	~~Aux~~
305	45	090	

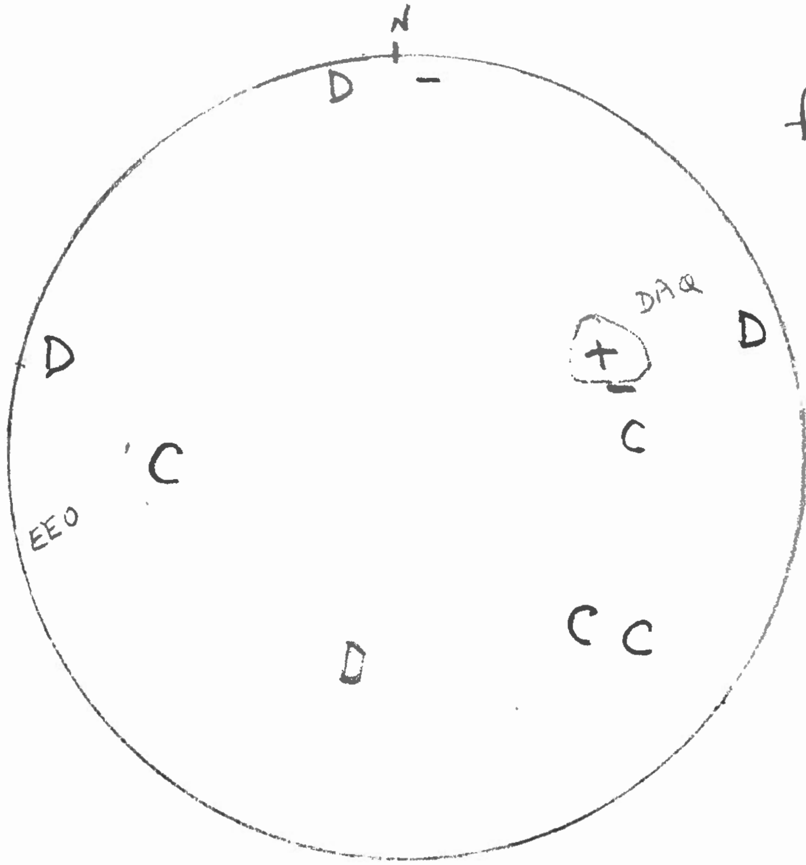


Precursor/mainshock plane

Fig. 3

Fig 5

foreshock
Lower Hem



Mainshock