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AUTHORITY

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LONG RANGE SEISMIC MEASUREMENTS

SCROLL

23 APRIL 1968

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER

Washington, D. C.

18 JULY 1968

By

TELEDYNE, INC.

Under

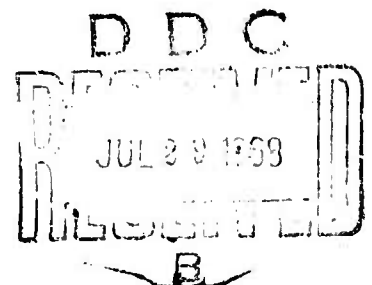
Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY

Nuclear Test Detection Office

ARPA Order No. 624



LONG RANGE SEISMIC MEASUREMENTS

SCROLL

23 April 1968

SEISMIC DATA LABORATORY REPORT NO. 220

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Went, D.C. 20383

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TABLE OF CONTENTS

	Page No.
EVENT DESCRIPTION	1
INTRODUCTION	2
INSTRUMENTATION AND PROCEDURE	2
DATA AND RESULTS	4

TABLES

- 1 Station Status Report - SCROLL
- 2 Principal Phases - SCROLL
- 3 Recording Site Information - SCROLL

FIGURES

- 1 Recording Stations and Signals Received
- 2 Unified Magnitudes
- 3 Adjusted Unified Magnitudes
- 4 Travel-Time Residuals, $T-\Delta/8.1$; T-JB
- 5 Maximum Amplitudes of Pn and P
- 6 Maximum Amplitudes of Pg
- 7 Maximum Amplitudes of Lg
- 8 Maximum Amplitudes of LR

SCROLL

EVENT DESCRIPTION

DATE: 23 April 1968

TIME OF ORIGIN: 17:01:30.0Z

YIELD:

MAGNITUDE: UNIFIED: 4.45 ± 0.44

ADJUSTED: 3.89 ± 0.46

LOCATION:

SITE: Nevada Test Site, Area U19n

GEOGRAPHIC COORDINATES:

Latitude: 37° 20' 16.0" N

Longitude: 116° 22' 32.0" W

ENVIRONMENT:

GEOLOGIC MEDIUM: Vitric Tuff

SURFACE ELEVATION: 6754 ft.

SHOT ELEVATION: 6004 ft.

SHOT DEPTH: 750 ft.

COMPUTED EPICENTER:

ALL STATIONS

LOCATE:

GEOGRAPHIC COORDINATES:

(Herrin 61 Surface)

Latitude: 37° 18' 21.6" N

Longitude: 116° 25' 01.2" W

TIME OF ORIGIN: 17:01:30.8Z

DEPTH CONSTRAINED TO: 0 km.

EPICENTER SHIFT: 4.2 km S 31° W

HYPO I

GEOGRAPHIC COORDINATES:

(Herrin 66 Surface)

Latitude: 37° 18' 36.0" N

Longitude: 116° 24' 25.2" W

TIME OF ORIGIN: 17:01:31.3Z

DEPTH CONSTRAINED TO: 0 km.

EPICENTER SHIFT: 4.6 km S 48° W

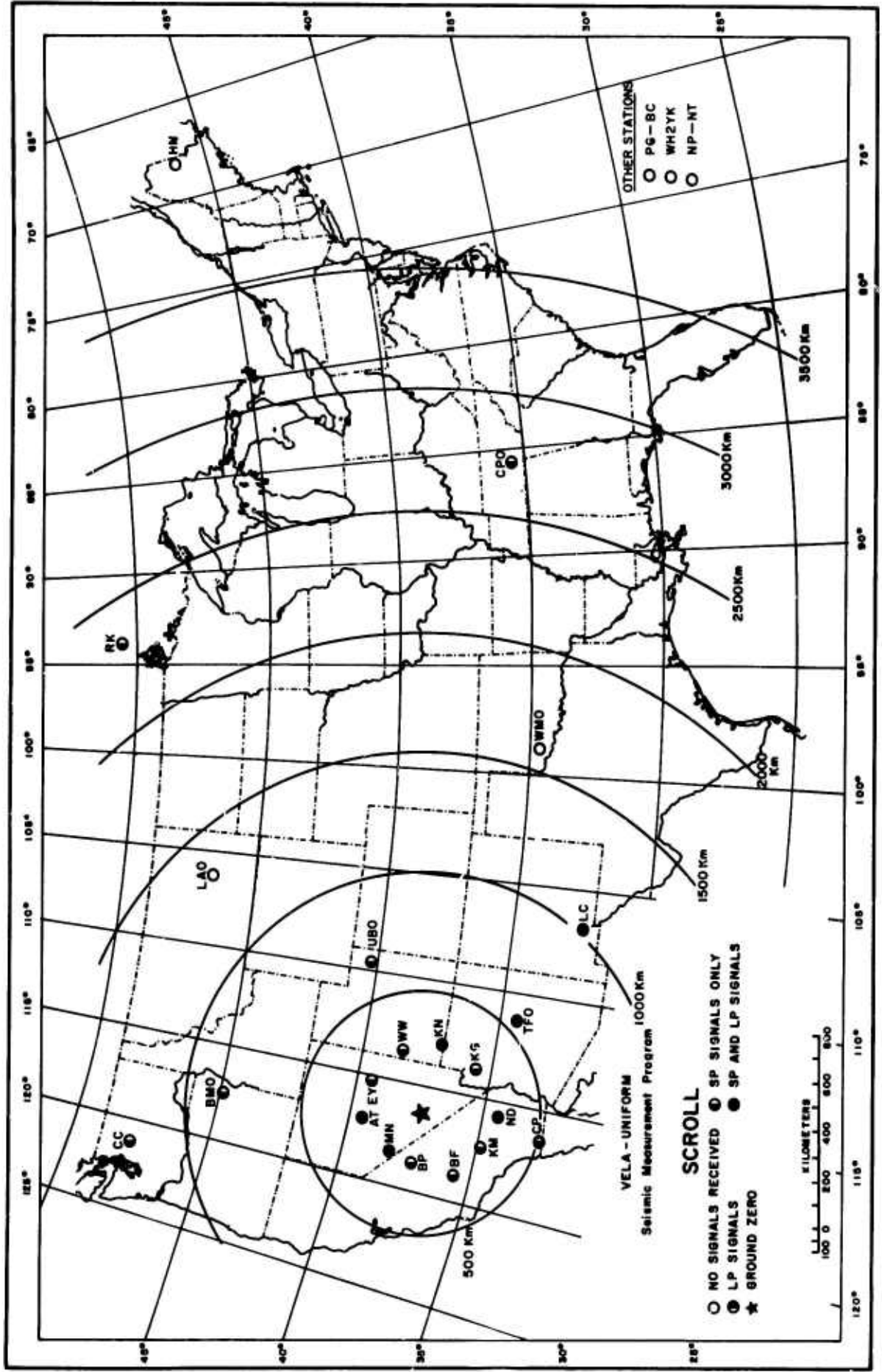
LRSM STATUS REPORT - SCROLL

Code	Station	Final							TIMING
		SPZ	SPR	SPT	LPZ	LPR	LPT	TAPE	
MN-NV	Mina, Nevada	+	+	+	+	+	+	*	P
BP-CI	Bishop California	+	+	+	-	-	-	*	P
AT-NV	Austin, Nevada	+	+	+	+	+	-	*	P
EY-NV	Ely, Nevada	+	+	+	-	-	-	*	P
WM-UT	Wah Wah Mountains, Utah	+	+	+	-	-]	*	P
KM-CL	Kramer, California]	+	+	-	-	-	*	P
KG-AZ	Kingman, Arizona	+	+	+	+	+	-	*	P
BF-CI	Bakersfield, California	+	+	+	-	-	-	*	P
ND-CI	Needles, California	+	+	+	+	+	-	*	P
KN-UT	Kanah, Utah	+	+	+	+	+	-	*	P
CP-LL	Campo, California	+	+	+	-	-	-	*	S
TF50	Tonto Forest Observatory, Arizona	+	+	+	+	+	-	*	P
UB50	Uinta Basin Observatory, Utah	+	+	+	-	-	-	*	P
BMSO	Blue Mountain Observatory, Oregon	+	+	+	-	-	-		P
LC-NM	Las Cruces, New Mexico	+	+	+	+	+	-	*	P
CC-WA	Cascade Tunnel, Washington	+	+	+	-	-	-	*	P
LAO	Subarray A0-10, Montana	-	N	N	-	-	-		P
WMSO	Wichita Mountain Observatory, Oklahoma	-	-	-	-	-	-	*	P
PG-BC	Prince George, British Columbia, Canada	-	-	-	-	-	-	*	P
RK-ON	Red Lake, Ontario, Canada	+	+	+	-	-	-	*	P
CPSO	Cumberland Plateau Observatory, Tennessee	+	-	-	-	-	-		P
WH2YK	Whitehorse, Yukon Territory, Canada	-	-	-	-	-	-	*	P
HN-ME	Houlton, Maine	-	-	-	-	-	-	*	P
SV3QB	Schefferville, Quebec, Canada	-	-	-	-	-	-	*	P
NP-NT	Mould Bay, Northwest Territories, Canada				OATA	NOT	RECEIVED		

+ Signal
 - No Signal
 * Magnetic Tape Available
 N No Instrument
 P Primary Timing
 S Secondary Timing
] Instrument Inoperative

STATION STATUS REPORT - SCROLL

Table 1



Recording Stations and Signals Received

Figure 1

INTRODUCTION

A long range seismic measurement (LRSM) program and several larger seismographic observatories were established under VELA-UNIFORM to record seismological data resulting from natural seismic activity and a planned series of U. S. underground nuclear tests. The LRSM teams are mobile and occupy locations selected to provide optimum data from events of special interest; the observatories are permanent installations as follows:

Wichita Mountains Seismological Observatory (WMSO)
Lawton, Oklahoma

Uinta Basin Seismological Observatory (UBSO)
Vernal, Utah

Tonto Forest Seismological Observatory (TFSO)
Payson, Arizona

Large Aperture Seismic Array (LASA)
Billings, Montana

The purpose of this report is to provide an analysis of data resulting from the SCROLL event recorded by the LRSM teams and the VELA observatories and a preliminary summary of data reported by other permanent and temporary seismographic stations.

INSTRUMENTATION AND PROCEDURE

The instrumentation at each of the LRSM locations consists of three-component short-period and three-component long-period seismographs. In general, data are recorded on 35 millimeter film and on one-inch 14-channel magnetic tape, although recently more portable instrumentation has been incorporated which records only on magnetic tape. The stations are all equipped to record

WWV continuously to provide accurate time control. Calibration is accomplished once each day and just prior to each shot at the operational settings. Pertinent information useful for analysis of LRSM data is available to qualified users of this data and is contained in Technical Report 65-43, "Interpretation and Usage of Seismic Data, LRSM Program." General information on LRSM van and portable system equipment and operation is given in Technical Report 66-27, "The LRSM Mobile Seismological Laboratory," and 65-74, "A Portable Seismograph." Copies of these reports may be obtained from DDC. The AD control number of Technical Report 66-27 is 480343. All the observatories have both long-period and short-period, three-component instrumentation, in addition to their other specialized facilities.

Station information is presented in Table 3. This includes the station name and code, the geographic coordinates, the distances and azimuths involved, the station elevations, and the type of instruments in use at each location. Representative instrumental response curves are shown in Appendix II(B), II(C), and II(D) of the BOURBON shot report, SDL Report No. 186, available from DDC as AD 816273.

The procedures used in measuring amplitudes and the unified magnitude are shown in Appendices II(A) and I(B), respectively, of the BOURBON shot report. The distance factors (B) beyond 16° are from Gutenberg and Richter*. For distance less than 16° values were read from a curve in the Gutenberg and Richter paper

*Gutenberg, B. and Richter, C.F., Magnitude and Energy of Earthquakes, Ann. Geofis., 9 (1956), pp. 1-15.

back to 10° and then extrapolated to 2° , using an inverse cube relationship. An additional magnitude for less than 16° was computed using a method described by Evernden*. (Figure 3)

A standard hypocenter location program for a digital computer was used to determine the location using data from all stations analyzed. Best-fit values of latitude, longitude, and time of origin are determined statistically by a least-squares technique. This utilizes a Jeffreys-Bullen travel-time curve as modified by Herrin in 1961 on the basis of Pacific surface-focus recordings. An additional location was made using a program called HYPO I. Precision of the computation is limited primarily by the accuracy of arrival times, the validity of the standard travel-time curve, and by local velocity deviations. These methods are based on P-wave arrivals with depth constrained to zero.

DATA AND RESULTS (LRSM AND VELA OBSERVATORIES)

The parameters of the SCROLL event and a summary of the seismic evaluation is shown on the Event Description page. The operational status of the 25 LRSM stations and observatories is given in Table 1, and illustrated in Figure 1.

Table 2 summarizes the measurements made of the principal phases from the SCROLL event at the LRSM and VELA stations. Included are the Pn and P arrival times, the maximum amplitudes (A/T) of the Pn and P motion, "b" amplitudes as defined in Appendix II(A) of the BOURBON shot report, and other phases as seen on the short-period instruments. Long-period Rayleigh wave motion is

*Evernden, J.F., Magnitude Determination at Regional and Near Regional Distances in the United States, AFTAC/VELA Seismological Center Technical Report VU-65-4A, (1965), pp.6,13.

also tabulated in (A/t) form. In addition, the individual station Rayleigh wave areas (mm^2) are indicated as measured on the LPZ only. Although reduced to 1K magnification, they have not been normalized to any magnitude. Eighteen stations recorded short-period signals and six recorded long-period signals.

The unified magnitudes determined from the LRSM and VELA observatories are shown in Figure 2. The average unified magnitude is 4.45 ± 0.44 . The average adjusted magnitude is 3.89 ± 0.46 .

The travel-time residuals from the Pn and P phases are shown in Figure 4. Figures 5 through 8 illustrate plots of the amplitudes of P, Pg, Lg, and LR.

Attached to the report are illustrative seismograms showing the signals recorded at five stations. The most distant station analyzed that recorded SCROLL was CPSO at a distance of 2756 kilometers.

Principal Phases
SCADLL
23 April 1988
17 01 30.02

CODE	STATION	DISTANCE (KM)	INST	MAGNIFICATION (X) FILM # 10	PHASE	TRAVEL TIME				PERIOD 1 (SEC)	MAXIMUM AMPLITUDE 4/T	MAGNITUDE (m)		AREA (mm ²) LPZ
						OBSERVED		COMPUTED (J-B)				M _b	M _s	
						(MIN)	(SEC)	(MIN)	(SEC)					
MN-NV	Mina, Nevada	198	SPZ	11.5*	Pn		32.2		32.42	0.5	346	4.58	3.98 ₇ g	5.96
			SPZ	11.5*	Pn _b						527			
			SPZ	11.5*	Pg	31.7			0.45	2196				
			SPT	11.0*	Lq				(0.6)	(760)				
			SPZ	29.2*	Lq				(7.5)	(163)				
			LPZ	19.7	LR				9.5	119				
BP-CL	Bishop, California	205	SPZ	24.25	Pn		33.4		33.44	0.55	207	4.42	3.85 ₇ g	
			SPZ	24.25	Pn _L					192				
			SPZ	5.83*	Pg	34.8			(0.6)	(1055)				
			SPT	5.7	Lq				0.8	(698)				
AT-NV	Austin, Nevada	246	SPZ	9.0*	Pn		38.9		38.65	0.5	473	4.97	4.40 ₇ g	
			SPZ	9.0*	Pn _b					556				
			SPZ	9.0*	Pg	(41.2)			0.5	652				
			SPT		Lq				---	---				
			LPZ	28.4	LR				(12.0)	(4.2)			4.62	
EY-NV	Ily, Nevada	248	SPZ	48.0	Pn		38.7		38.97	0.55	(56.8)	(4.07)	(3.36) ₇ g	
			SPZ	48.0	Pn _b					156				
			SPZ	48.0	Pg	(44.4)			---	---				
			SPT	5.94*	Lq				0.7	985				
MM-UT	Mah Mah Mountains, Utah	278	SPZ	10.8	Pn		(42.0)		42.72	0.4	84.2	4.76	3.62 ₇ g	
			SPZ	30.0*	Pn _b					(107)				
			SPZ	9.35*	Pg	(46.4)			0.45	1425				
			SPT	12.1*	Lq				(0.5)	(606)				
RM-CL	Kramer, California	284	SPZ	DATA QUESTIONABLE										
			SPT	41.6	Lq				(0.8)	(169)				
RG-AZ	Kingman, Arizona	290	SIZ	10.0	Pn		43.8		44.31	0.4	154	4.70	4.15 ₇ g	
			SPZ	10.0	Pn _b					265				
			SPZ	10.0	e	45.6			0.4	61.6				
			SPZ	10.0	e	46.6			0.4	77.0				
			SPT	10.0*	Pg	(48.6)			0.45	518				
			LPZ	10.0*	Lq				0.55	266				
BF-CL	Bakersfield, California	291	SPZ	28.75	Pn		44.5		44.32	0.5	107	4.52	3.93 ₇ g	
			SPZ	28.75	Pn _b					95.7				
			SPZ	28.75	Pg	49.5			0.6	294				
			SPT	58.25	Lq				0.8	(236)				
MO-CL	Needles, California	313	SPZ	88.3	Pn		46.7		47.10	0.6	12.4	3.70	2.96 ₇ g	
			SPZ	88.3	Pn _b					31.1				
			SPZ	16.7*	Pg	53.4			0.55	265				
			SPT	17.3*	Lq				0.6	427				
			LPZ	14.4*	LR				(11.0)	44.9				
BN-UT	Kanab, Utah	317	SPZ	15.8*	Pn		47.3		47.80	0.5	183	4.89	4.36 ₇ g	
			SPZ	15.8*	Pn _b					253				
			SPZ	15.8*	e	49.6			0.45	122				
			SPZ	15.8*	Pg	52.9			0.5	279				
			SPT	52.0*	Lq				0.6	479				
			LPZ	50.1	LR				(11.0)	(31.5)			2.05	
CP-CL	Campo, California	511	SPZ	45.0*	Pn	1	11.7		12.52	0.5	88.8	5.21	4.74 ₇ g	
			SPZ	45.0*	Pn _b					88.9				
			SPZ	45.0*	Pg	1	(27.4)	1	0.55	59.0				
			SPT	46.25*	Lq				(0.5)	(50.8)				
TISO	Tonto Forest Observatory, Arizona	572	SPZ-50	260	Pn	1	20.2	1	20.31	0.35	9.6	4.41	3.79 ₇ g	
			SPZ-60	260	Pn _b					11.5				
			SPZ-80	260	e	1	26.3		0.45	9.1				
			SPZ-60	260	Pg	1	15.8		0.7	44.3				
			SPN	30.0	Lq				0.8	32.0				
			SPT	30.0	Lq				0.8	28.0				
			LPZ	51	LR				14.5	8.9			3.74	
UBSO	Uinta Basin Observatory, Utah	677	SPZ-10	140	Pn	1	(15.1)	1	33.69	0.6	20.9	4.91	1.71 ₈ g	
			SPZ-10	140	Pn _b					19.6				
			SPZ-10	140	Pg	1	57.5		0.7	27.9				
			SPN	140	Lq				1.2	88.5				
			SPT	140	Lq				1.1	57.8				
BMSO	Blue Mountains Observatory, Oregon	838	SPZ-3	680	Pn	1	(55.1)	1	53.94	0.5	1.5	4.09	1.41 ₇ g	
			SPZ-3	680	Pn _b					(2.2)				
			SPZ-3	680	e	1	57.2		0.9	1.4				
			SPZ-3	680	e	2	07.0		0.6	3.6				
			SPT	680	Lq				---	---				
LC-NM	Las Cruces, New Mexico	1047	SPZ	392	Pg	2	(24.4)			0.7	6.1		5.13	
			SPT	388	Lq				(1.9)	17.41				
			LPZ	61.3	LR				10.0	41.0				
CC-WA	Cascade Junction, Washington	1221	SPZ	125.5	e	2	44.6			0.8	4.5			
AR-ON	Ard Lake, Ontario, Canada	2342	SPZ	287	e	4	45.9	4	47.89	0.55	5.4	1.84		
			SPZ	287	Pn _b					5.2				
			SPZ	287	e	4	47.6		0.7	7.2				
EPSD	Cumberland Plateau Observatory, Tennessee	2756	SPZ	400	e	5	(25.3)	5	24.75	0.6	(4.9)	(4.15)		

A/1 mu/sec (0-0)
() Doubtful Values or Phases
* Measurements Made from Ployouts
--- Maximum Amplitudes Clipped on Film & Tapp
... Unreadable on Film, Time Not Received
P- Second Half-Cycle of Signal, P-P in mu
(Assuming T=1.0 Seconds)

PRINCIPAL PHASES - SCROLL

Code	Station	Distance (km)	Geographic Latitude	Geographic Longitude	Elev. (km)	Computed Azimuth		Installed Azimuth		SP INST.	LP Inst.
						Epi. Sta.	Sta. Epi.	Radial	Tang.		
MN-NV	Mina, Nevada	198	38° 26' 10" N	118° 08' 53" W	1.52	309°	127°	308°	38°	L	**
BP-CL	Bishop, California	205	37° 21' 36" N	118° 41' 25" W	2.32	271°	90°	274°	4°	PS	**
AT-NV	Austin, Nevada	246	39° 28' 53" N	117° 04' 26" W	1.98	346°	165°	343°	73°	PS	**
EY-NV	Ely, Nevada	248	39° 24' 36" N	115° 18' 46" W	2.01	22°	202°	18°	108°	PS	**
WW-UT	Wah Wah Mountains Utah	278	38° 30' 50" N	113° 35' 20" W	1.83	61°	243°	58°	148°	PS	**
KM-CL	Kramer, California	284	34° 52' 52" N	117° 15' 24" W	0.85	196°	16°	200°	290°	PS	**
KG-AZ	Kingman, Arizona	290	35° 38' 30" N	113° 54' 28" W	1.07	130°	311°	130°	220°	PS	**
BF-CL	Rakersfield, Calif.	291	35° 38' 53" N	118° 51' 27" W	0.57	231°	49°	234°	324°	PS	**
NO-CL	Needles, California	313	34° 35' 57" N	115° 33' 05" W	0.37	166°	346°	169°	259°	PS	**
KN-UT	Kanab, Utah	317	37° 01' 22" N	112° 49' 39" W	1.74	95°	277°	95°	185°	L	**
CP-CA	Campo, California	511	32° 43' 44" N	116° 22' 16" W	1.19	180°	360°	162°	272°	PS	**
*TF50	Tonto Forest Observatory, Arizona	572	34° 17' 12" N	111° 16' 03" W	1.49	125°	308°	90°	0°	JM	**
*UB50	Uinta Basin Observatory, Utah	677	40° 19' 18" N	109° 34' 07" W	1.60	59°	243°	90°	0°	JM	**
*BM50	Blue Mountain Observatory, Oregon	838	44° 50' 56" N	117° 18' 20" W	1.19	355°	174°	0°	90°	JM	**
LC-NM	Las Cruces, New Mexico	1047	32° 24' 08" N	106° 35' 58" W	1.59	119°	304°	133°	223°	S	**
CC-WA	Cascade Tunnel, Wash.	1221	47° 46' 09" N	121° 05' 01" W	1.04	343°	160°	311°	41°	PS	**
*LA0	Subarray A0-10 Montana	1335	46° 41' 19" N	106° 13' 20" W	0.90	36°	223°	0°	90°	HS	**
*WM50	Wichita Mountain Observatory, Oklahoma	1627	34° 43' 05" N	98° 35' 21" W	0.51	95°	285°	90°	0°	JM	**
*PG-BC	Prince George, British Columbia, Canada	1912	53° 59' 50" N	122° 31' 23" W	0.91	348°	163°	110°	200°	L	**
NK-OA	Rad Lake, Ontario Canada	2342	50° 50' 20" N	93° 40' 20" W	0.37	43°	239°	58°	148°	S	**
*CP50	Cumberland Plateau Observatory, Tennessee	2756	35° 35' 41" N	75° 34' 14" W	0.57	85°	283°	90°	0°	JM	**
WH2YK	Whitehorse, Yukon Territory, Canada	2911	60° 41' 41" N	134° 58' 02" W	0.85	339°	145°	325°	55°	L	**
MN-ME	Moulton, Maine	4078	46° 09' 43" N	67° 59' 09" W	0.21	60°	274°	93°	183°	S	**
*SV3QB	Schafferville, Quebec Canada	4190	54° 48' 39" N	66° 45' 00" W	0.58	46°	263°	139°	229°	S	**
NP-NT	Mould Bay, Northwest Territories, Canada	4341	76° 15' 08" N	119° 22' 18" W	0.06	359°	176°	356°	86°	JM2 S	**

* Seismometers Not Orientated Toward N.T.S.

L Large Benloff

S Small Benloff

JM Johnson-Matheson

HS Mall Sears

PS Geotech Portable System

** Long Period Instruments At Site

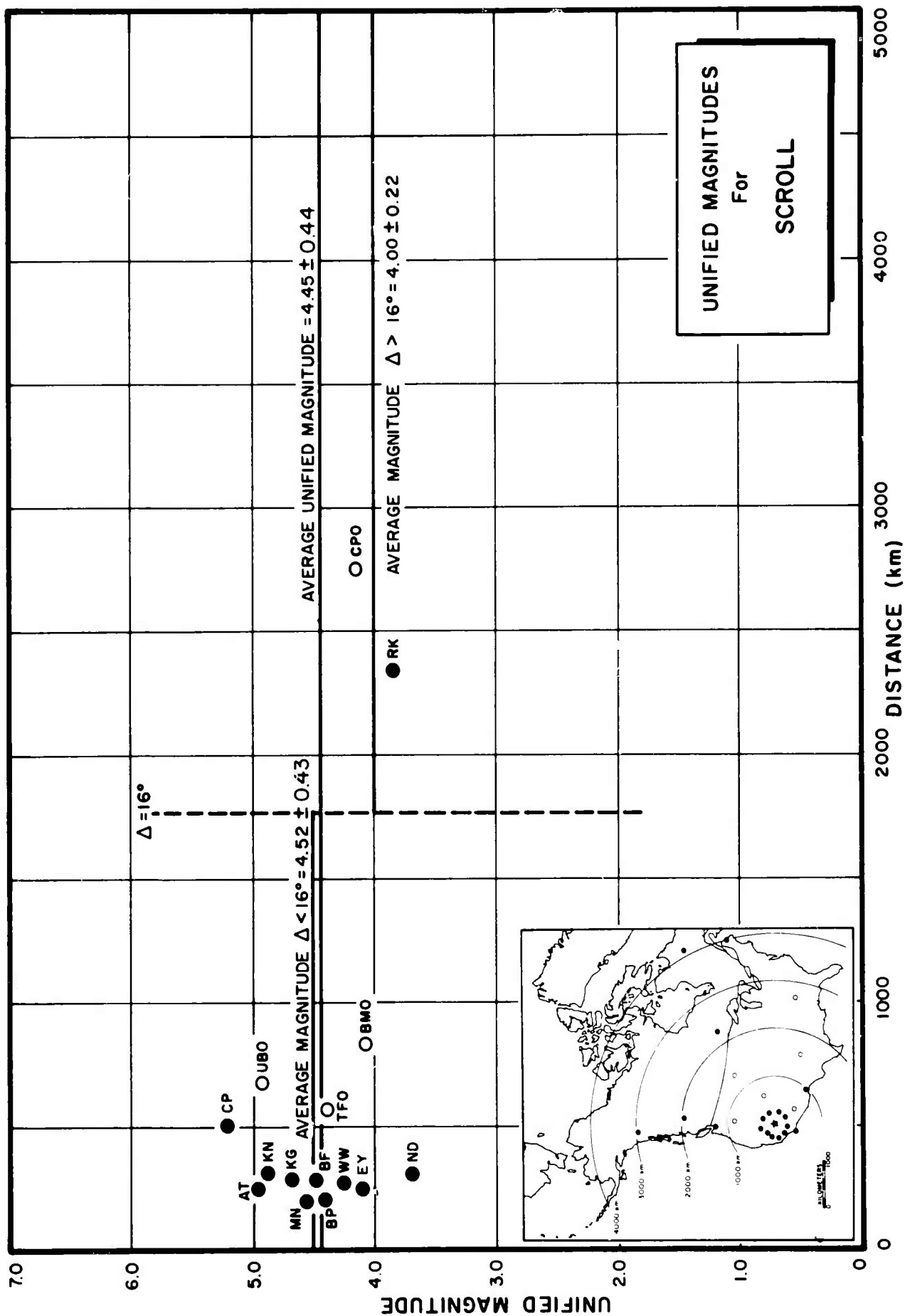


Figure 2

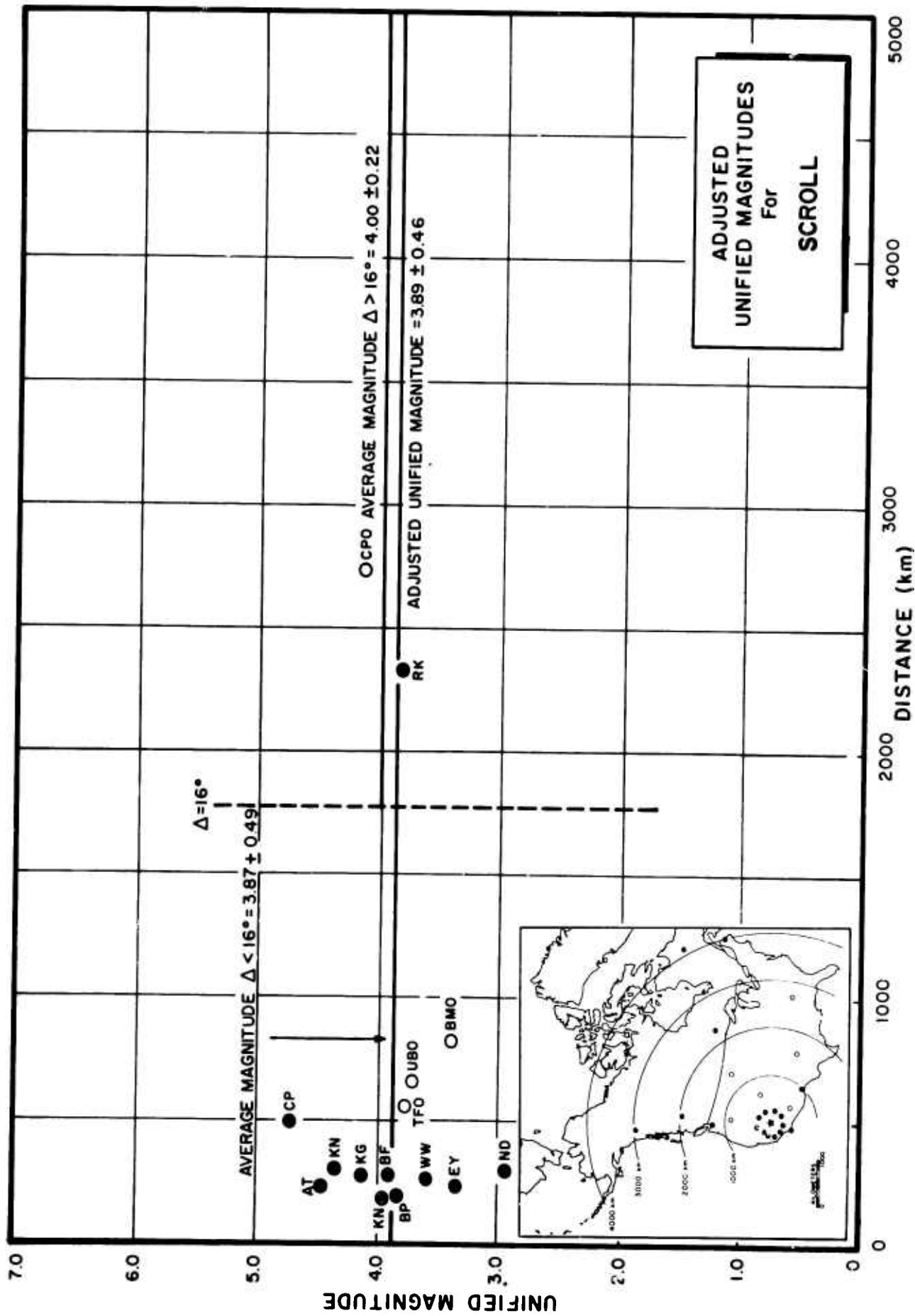


Figure 3

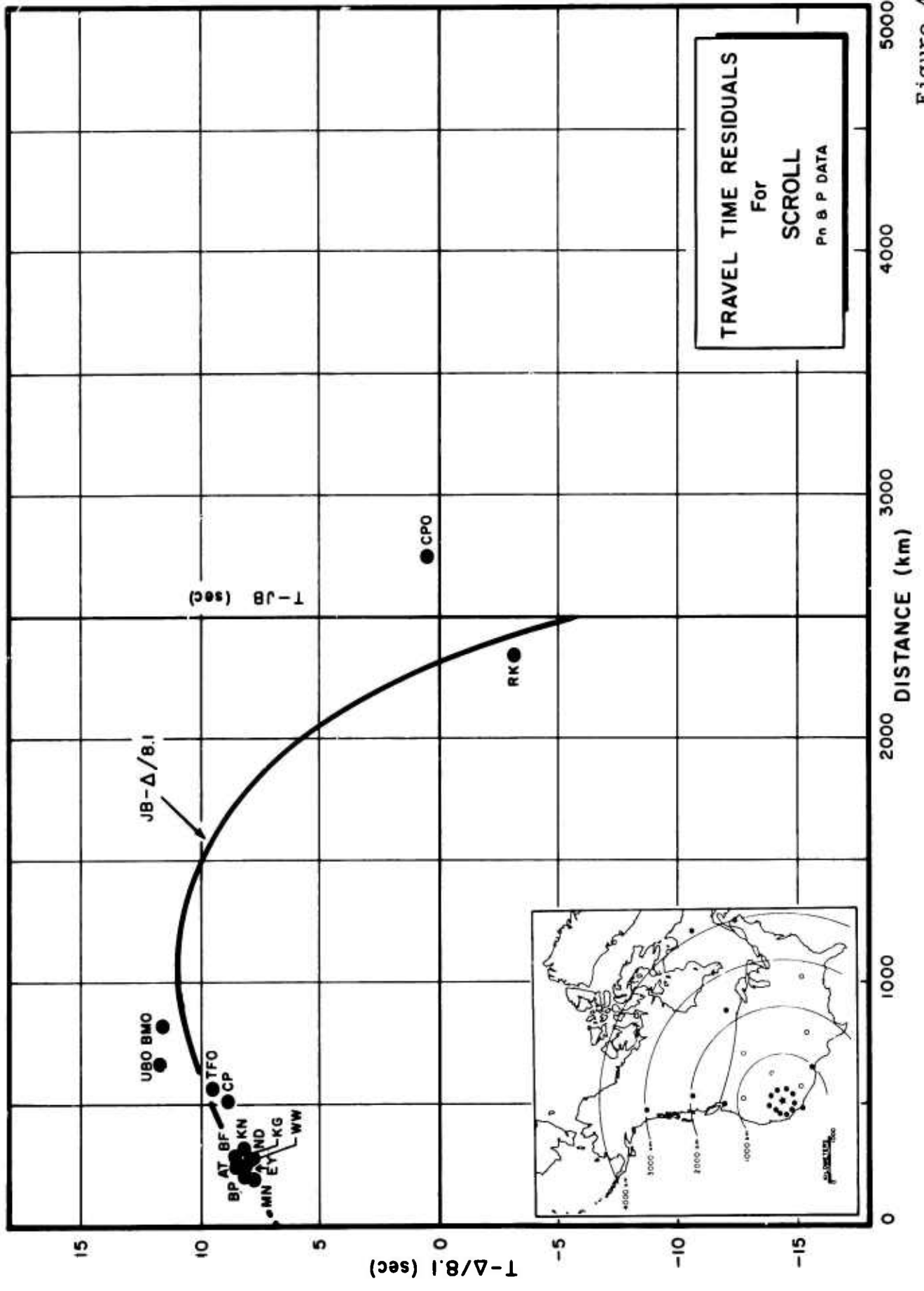


Figure 4

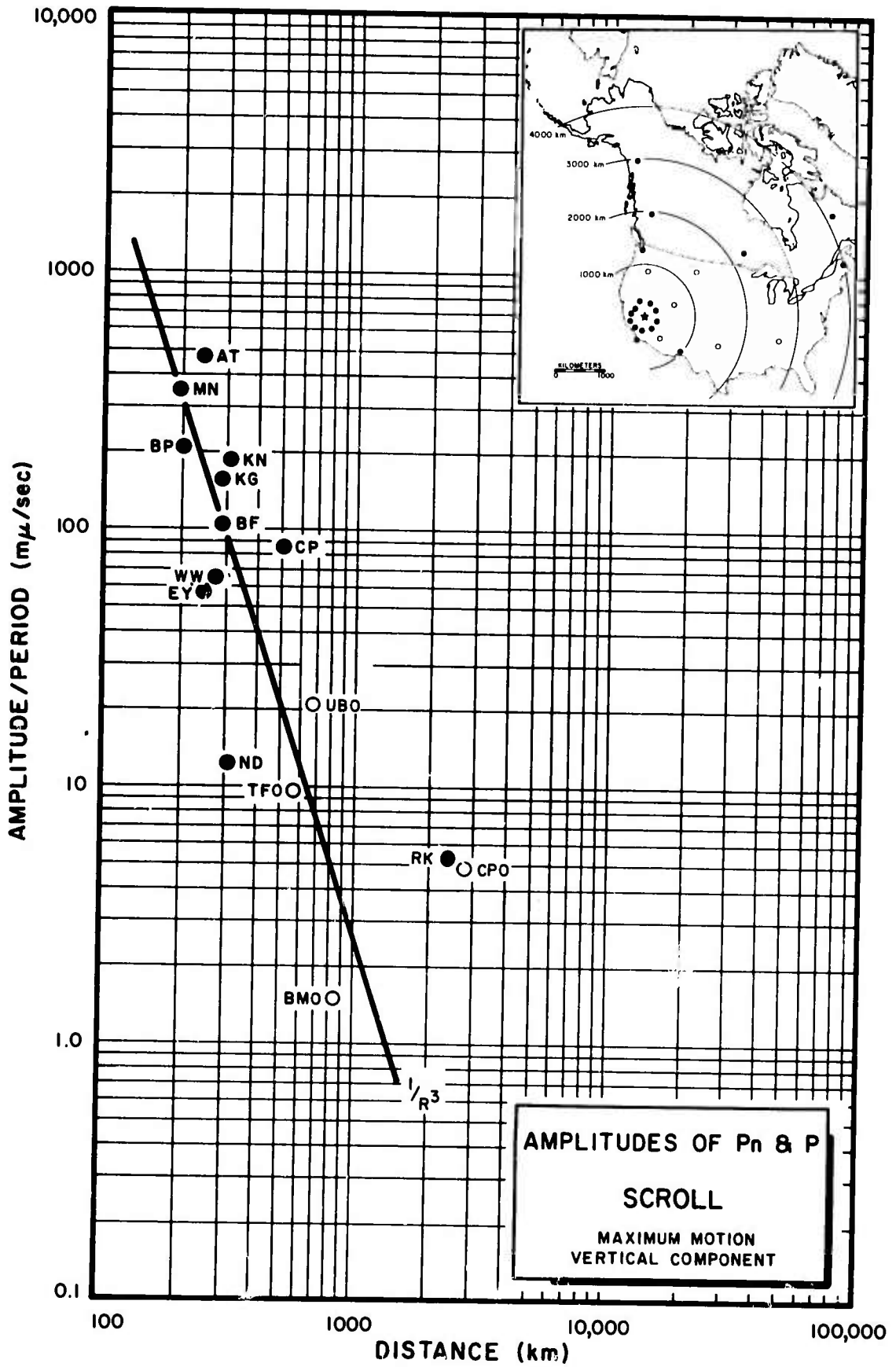


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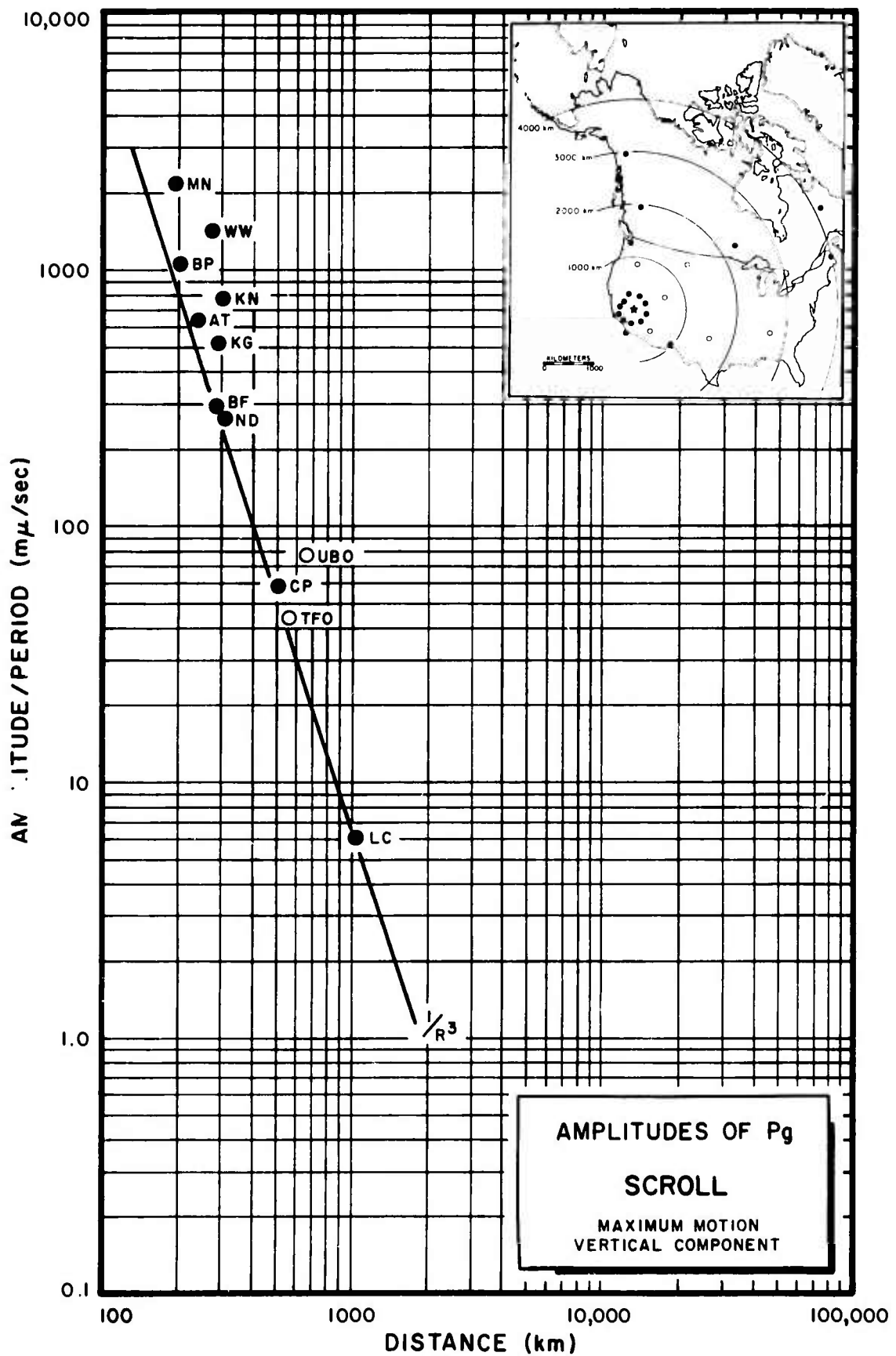


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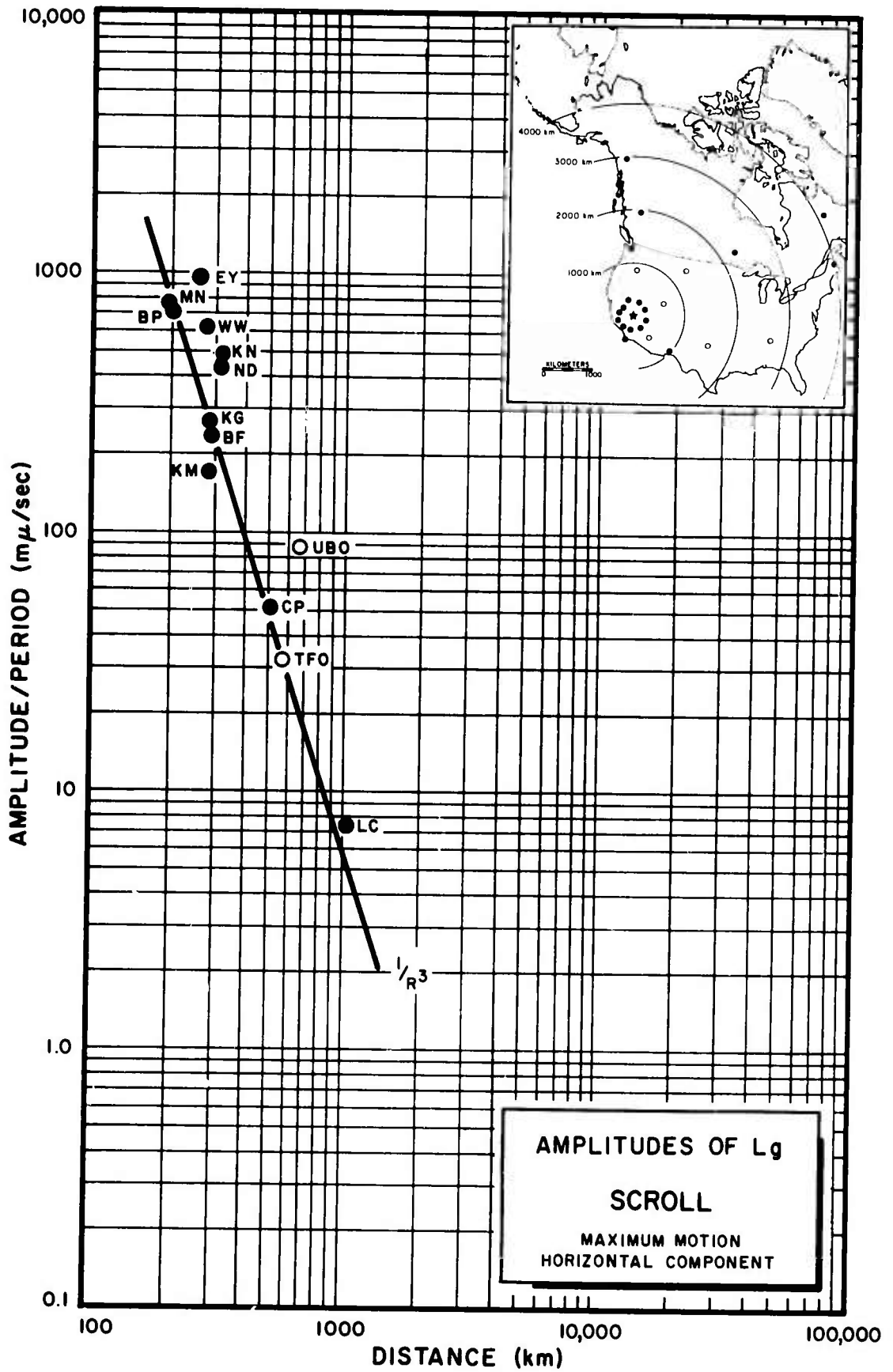


Figure 7

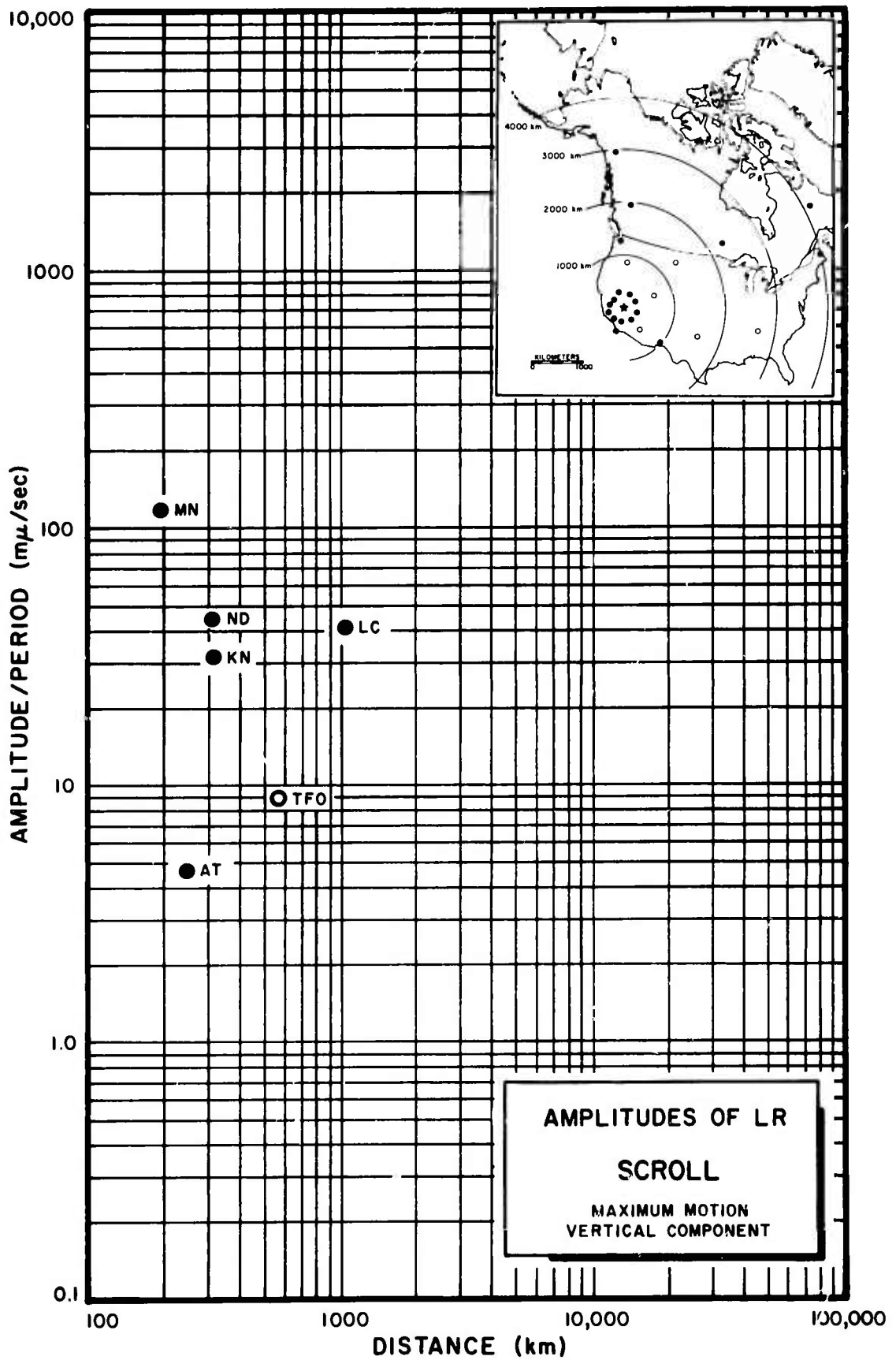


Figure 8

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) TELEDYNE INDUSTRIES, INC. ALEXANDRIA, VIRGINIA		2a REPORT SECURITY CLASSIFICATION Unclassified	
		2b GROUP	
3 REPORT TITLE Long Range Seismic Measurements - SCROLL			
4 DESCRIPTIVE NOTES (Type of report and Inclusive dates) Scientific			
5 AUTHOR(S) (Last name, first name, initial) Moore, E.W., Nelson, D.D.			
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11 SUPPLEMENTARY NOTES		12 SPONSORING MILITARY ACTIVITY ADVANCED RESEARCH PROJECTS AGENCY NUCLEAR TEST DETECTION OFFICE WASHINGTON, D. C.	
13 ABSTRACT An analysis of seismological data from an underground nuclear explosions as a continuing study to provide information to aid in distinguishing between earthquakes and explosions. A table of travel-times and amplitudes of P, Pg, Lg, and surface waves are included along with other unidentified phases.			
14 KEY WORDS Seismic Magnitude Seismic Travel-Time Seismic Amplitude Vela-Uniform Nuclear Tests			

SCROLL

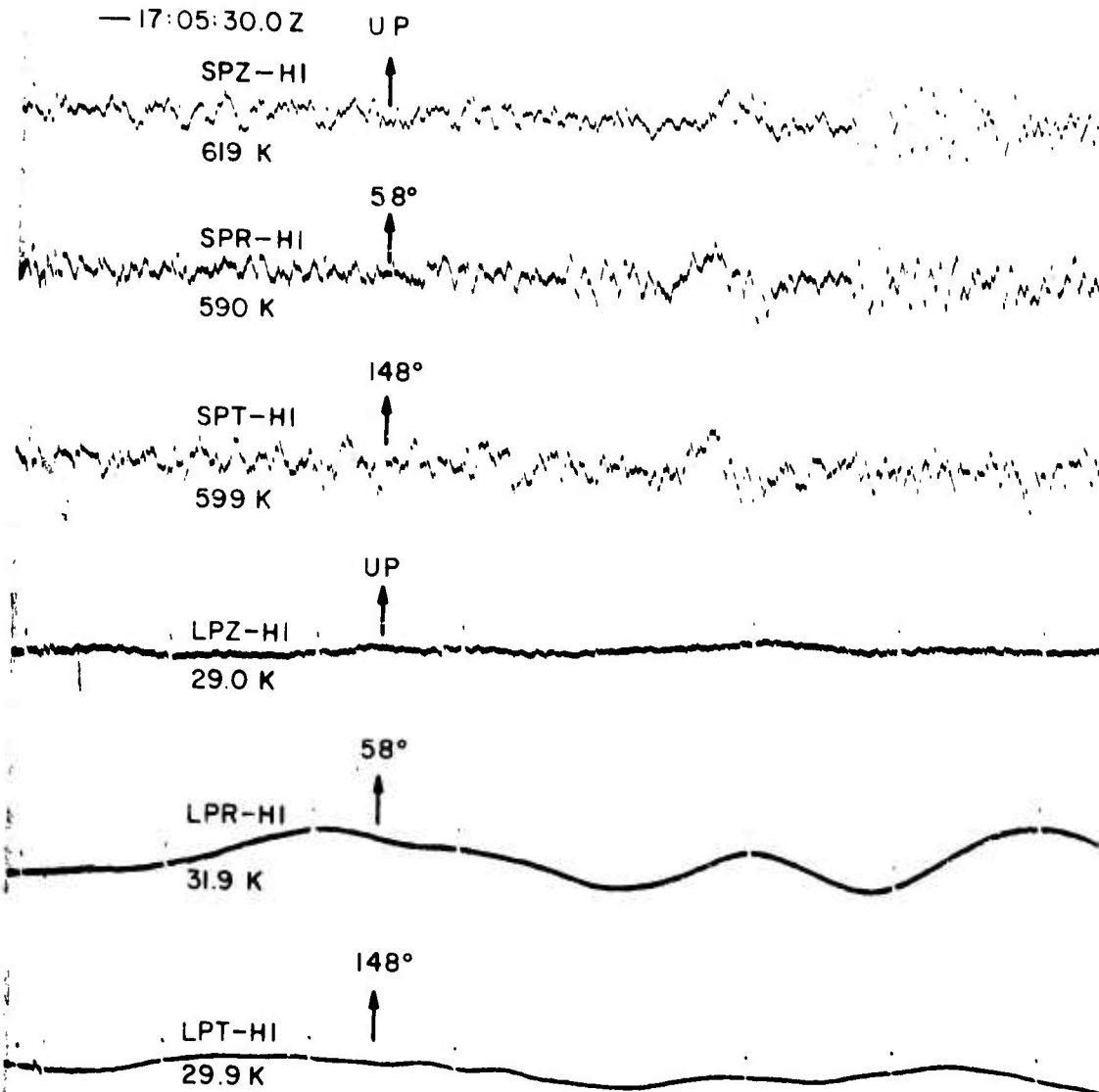
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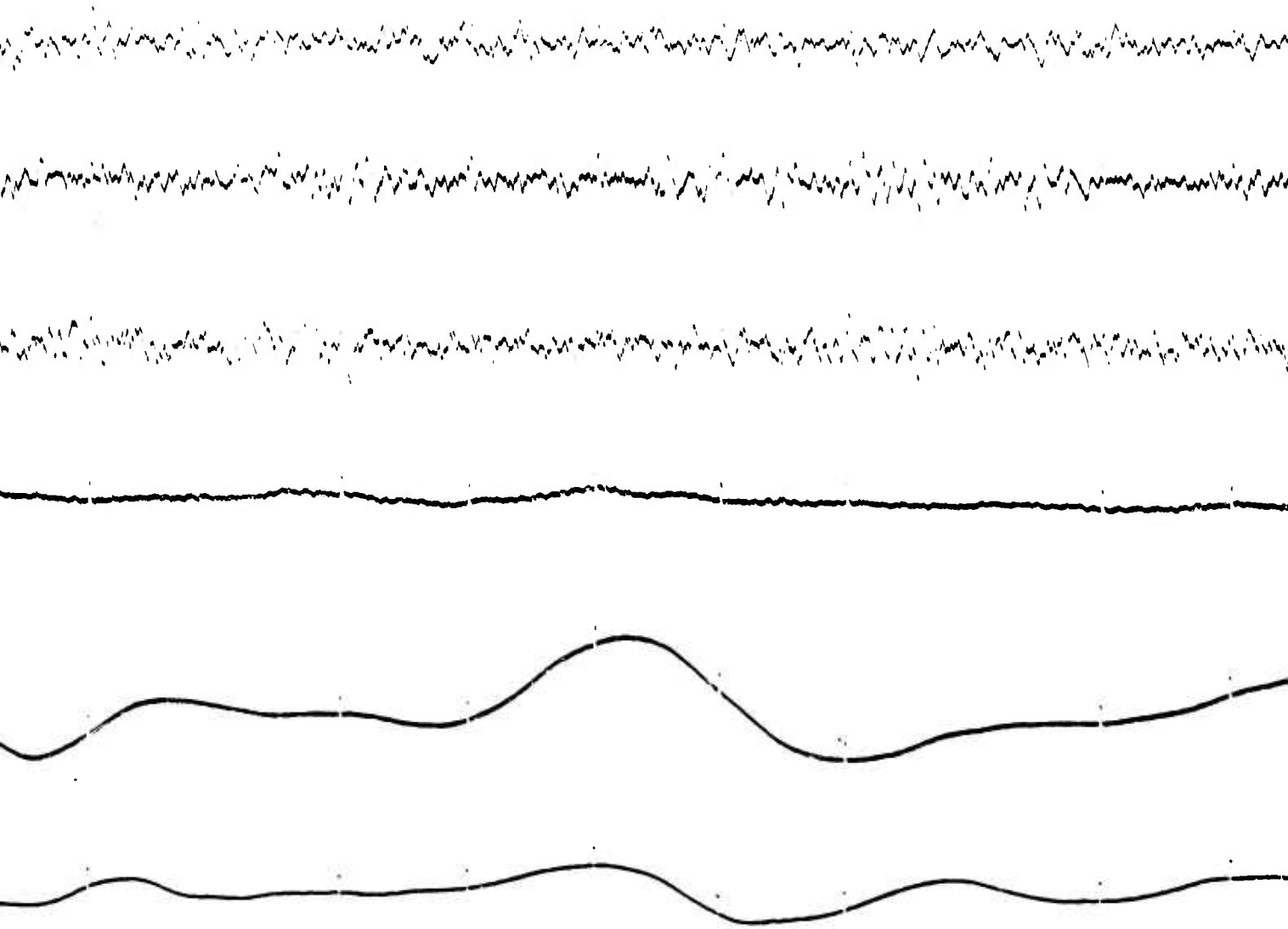
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23 APRIL 1968

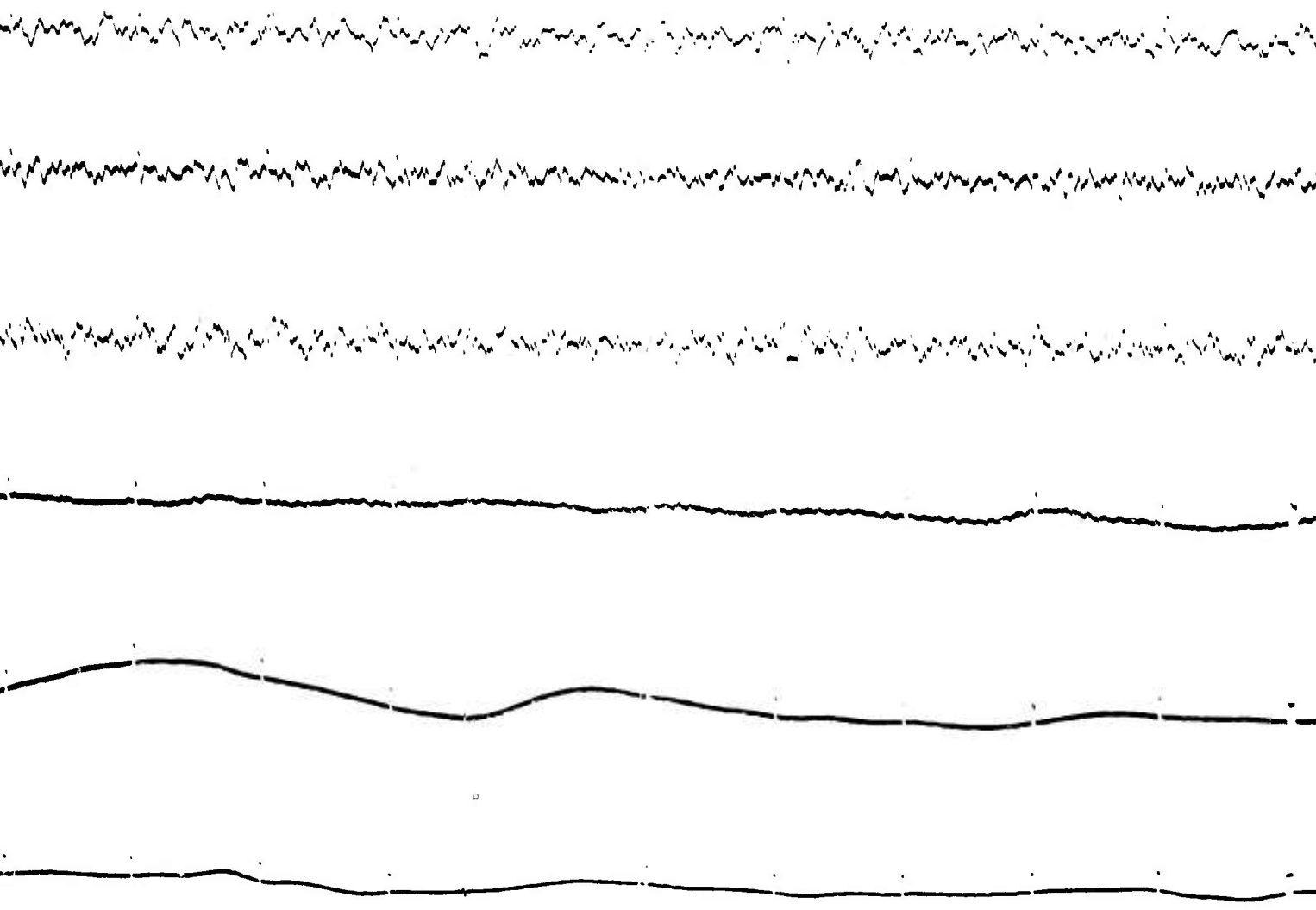
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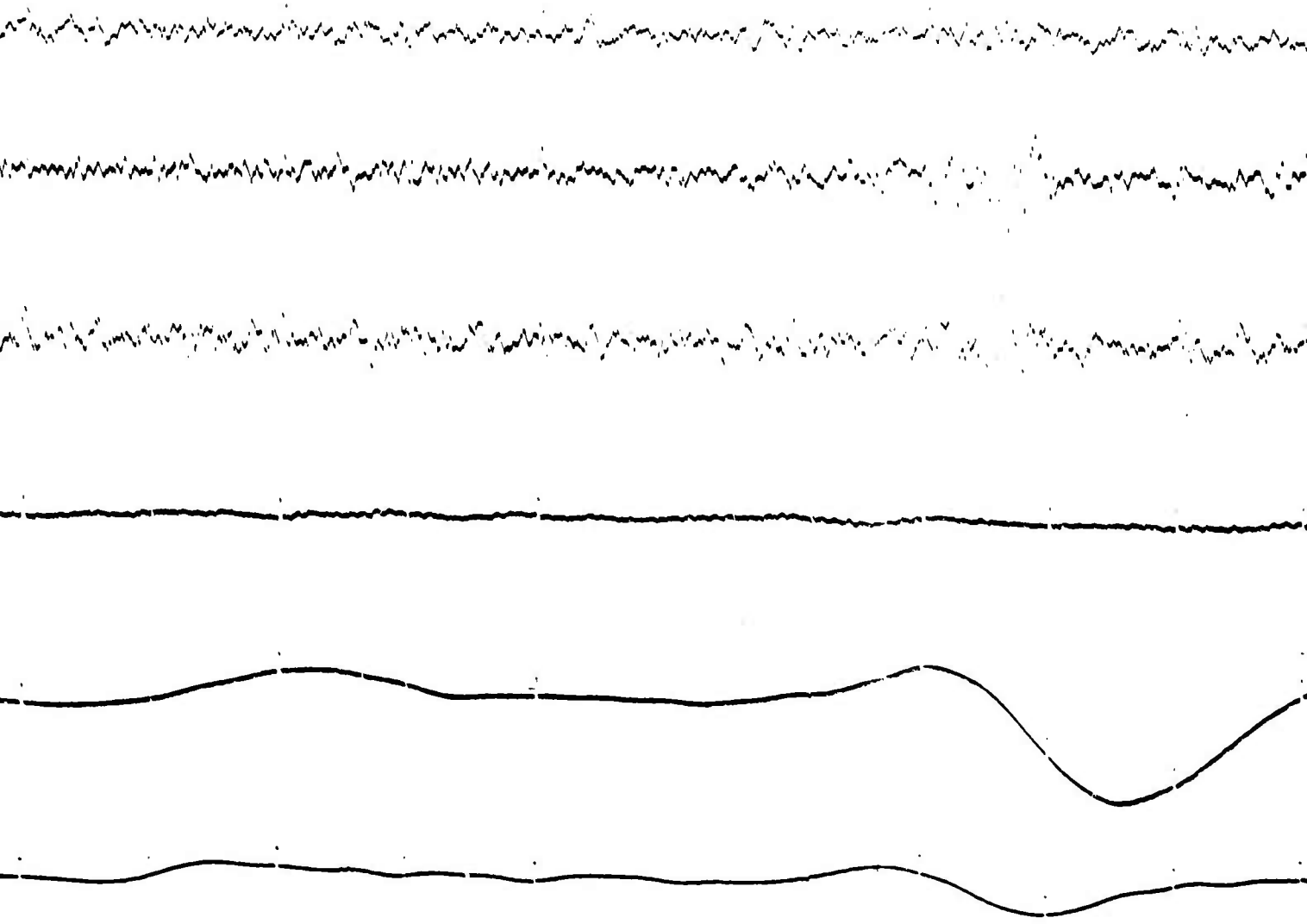
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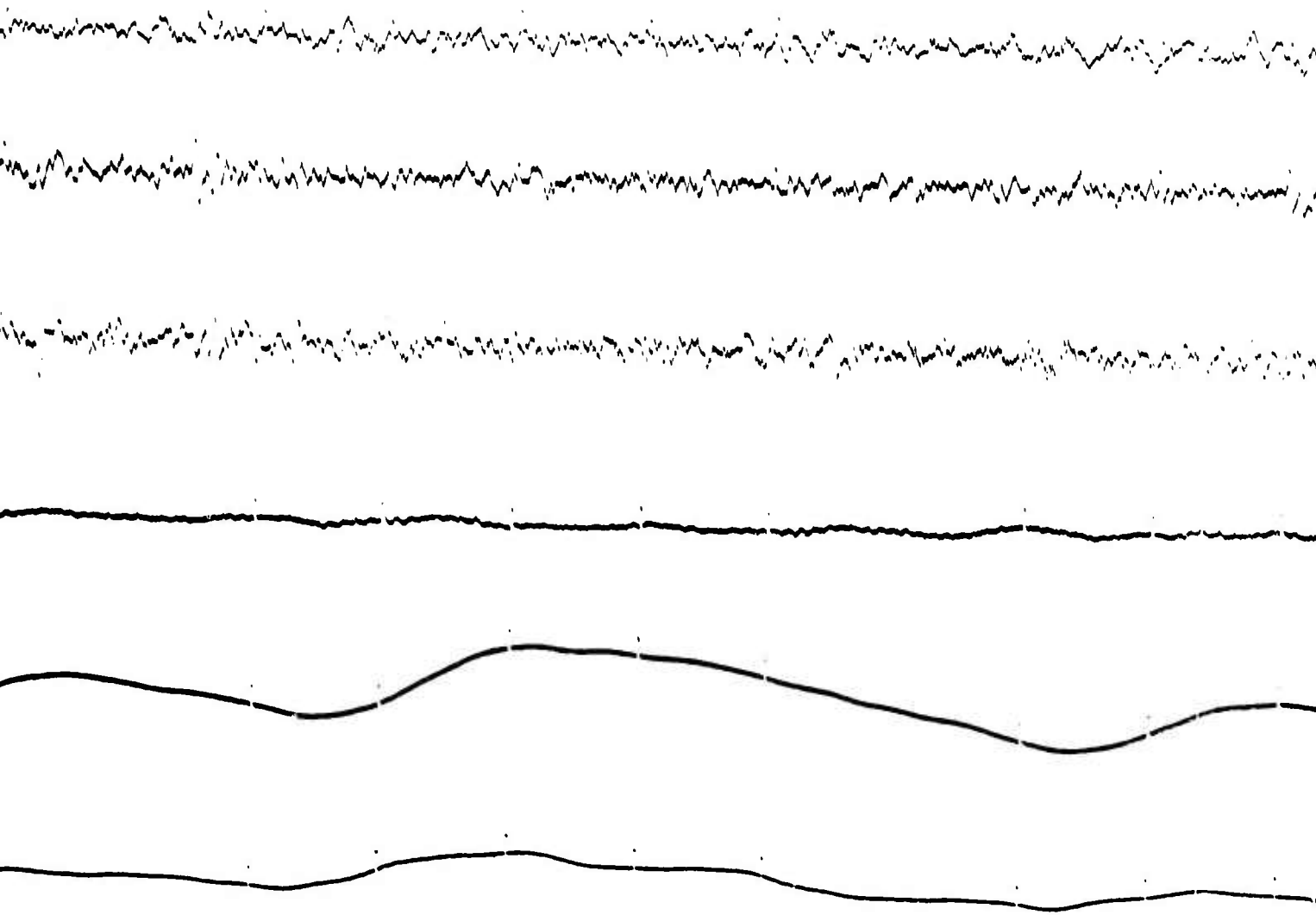
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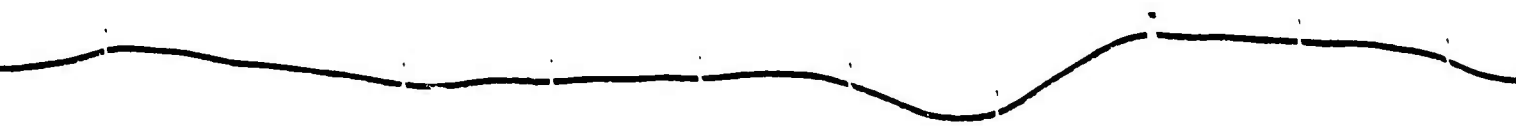
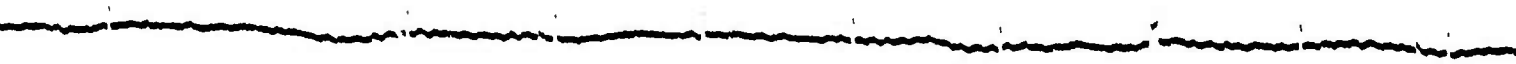
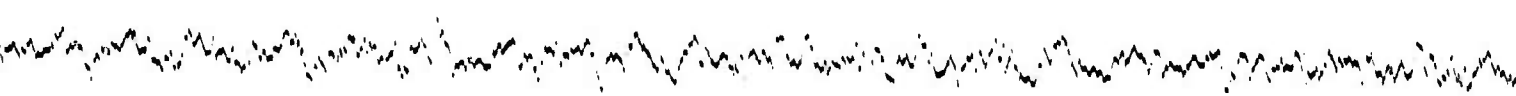
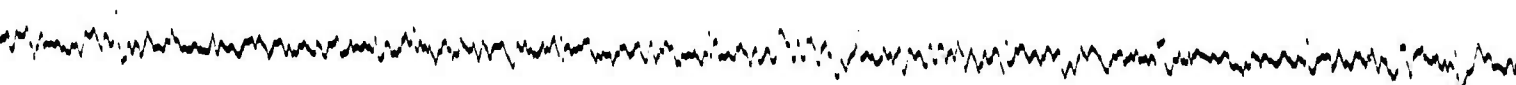
C.



D.



E.



F.

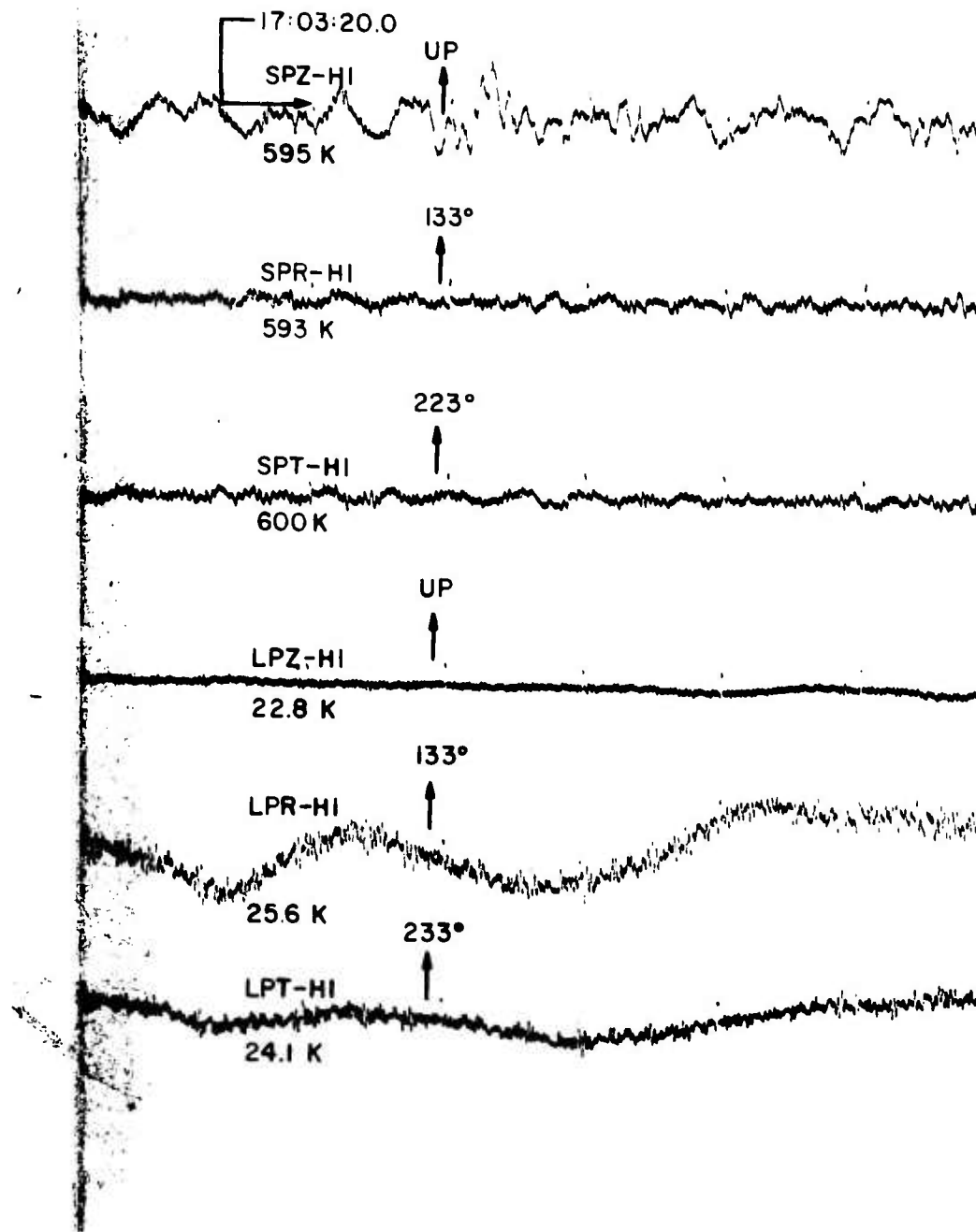
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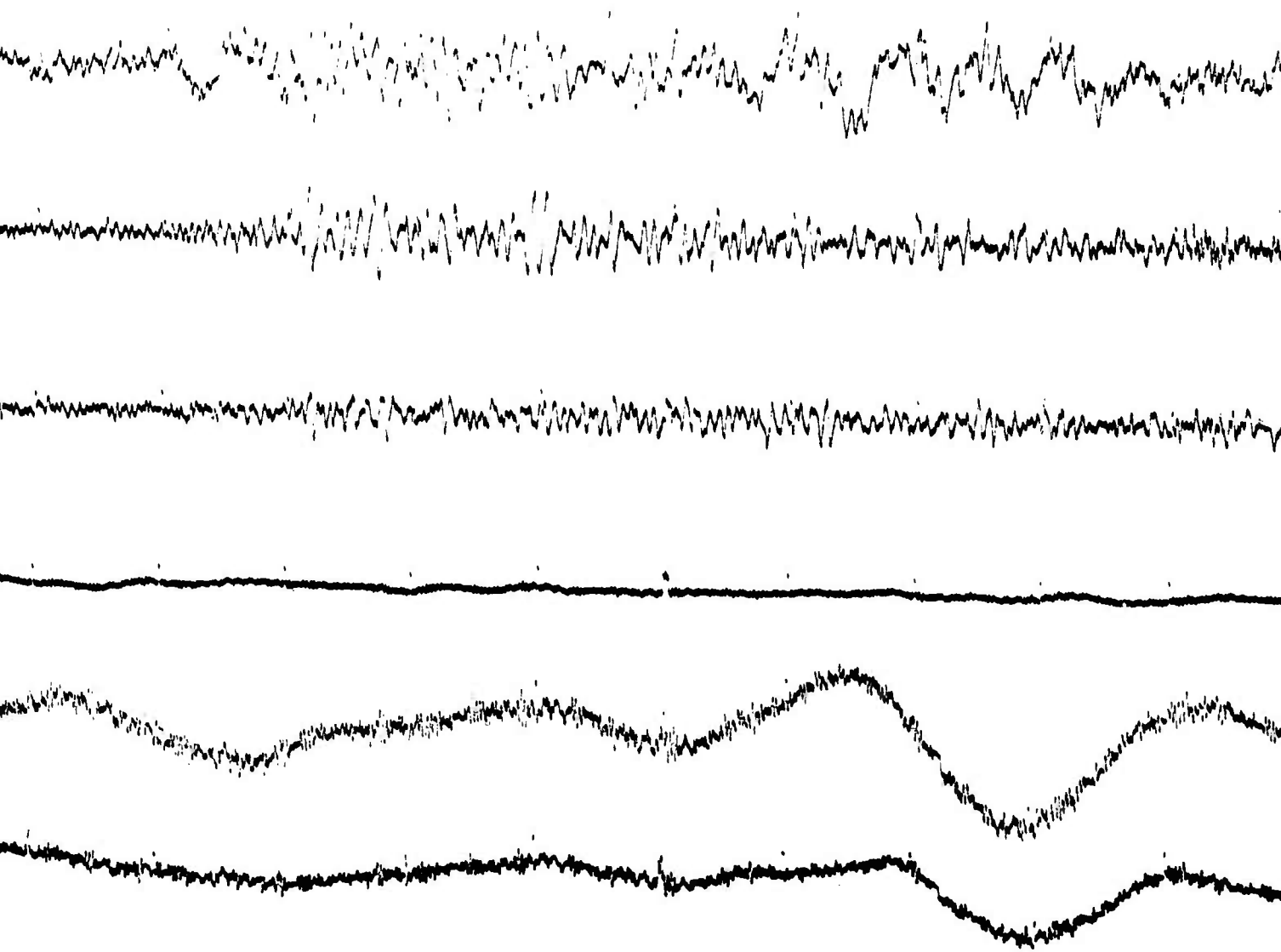
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LAS CRUSES,
NEW MEXICO

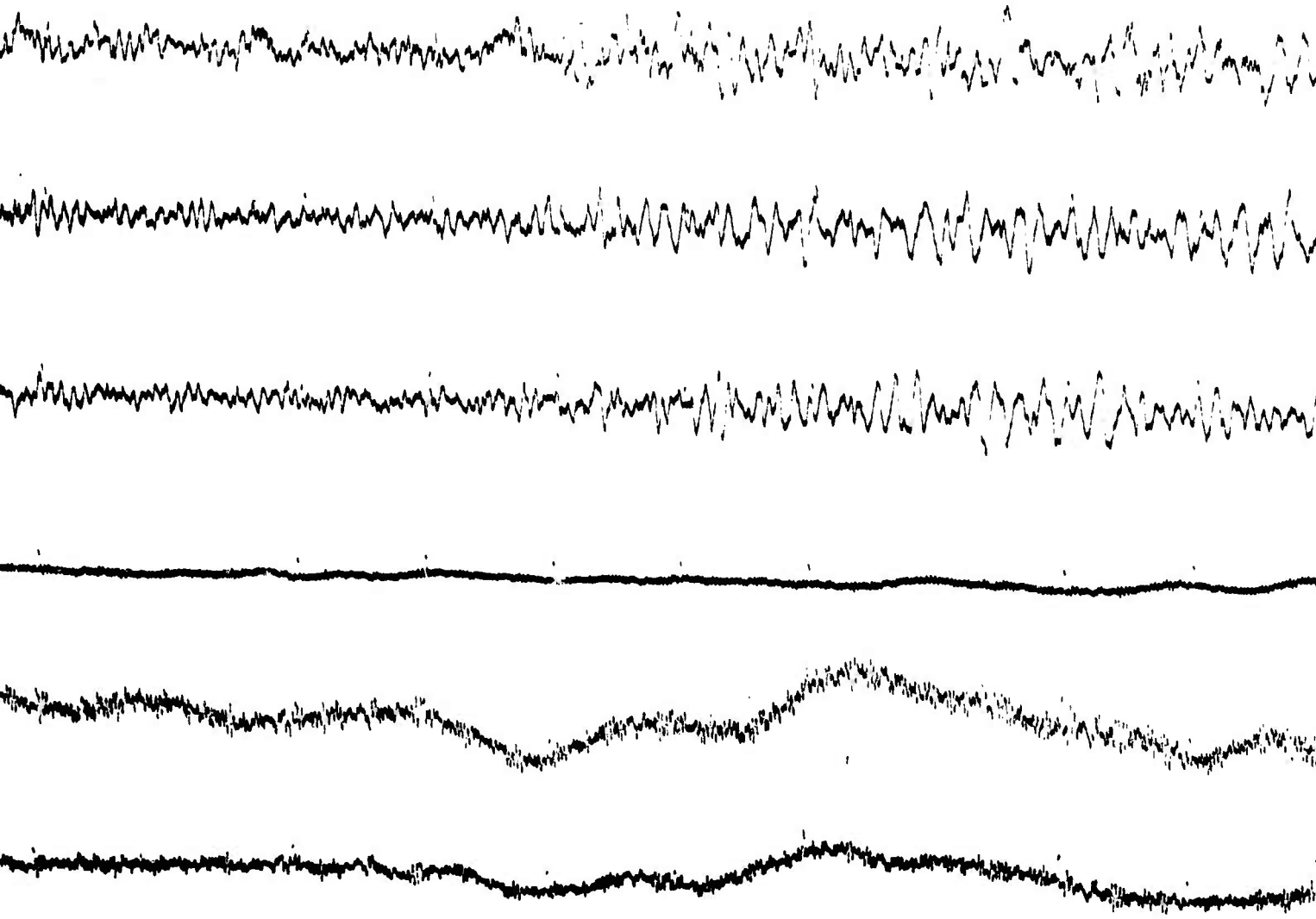
23 APRIL 1968

$\Delta = 1047$ Km

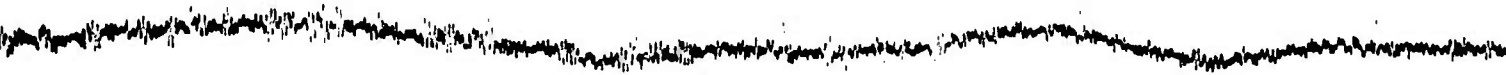
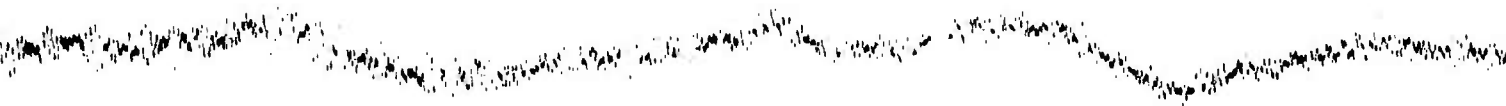
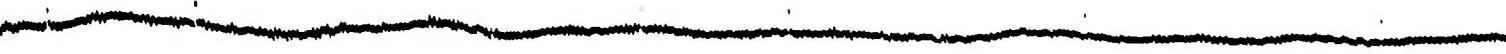
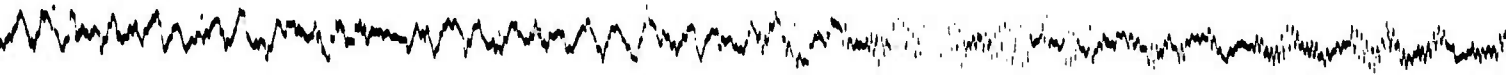




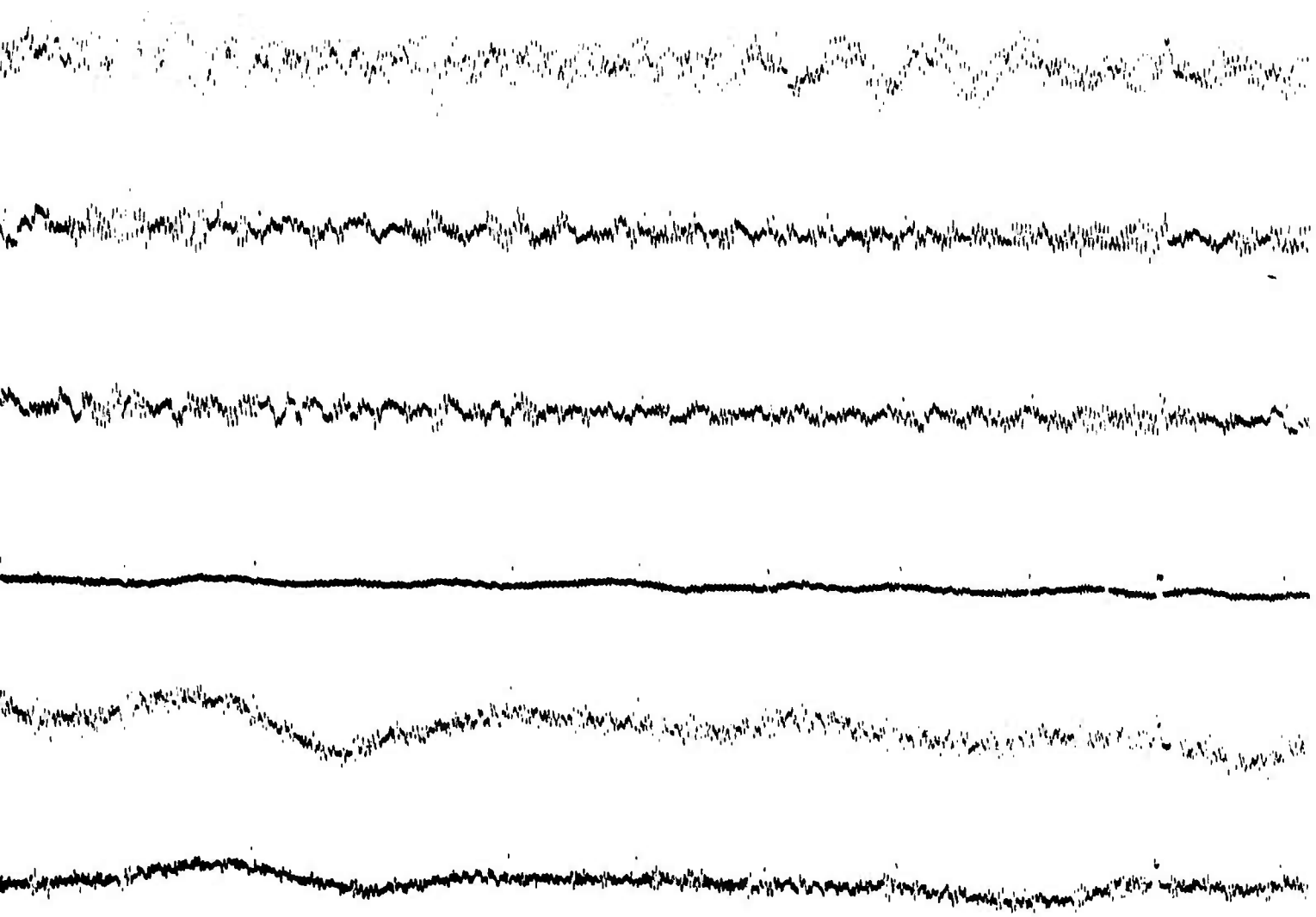
B



C.



D.



E.

SCROLL

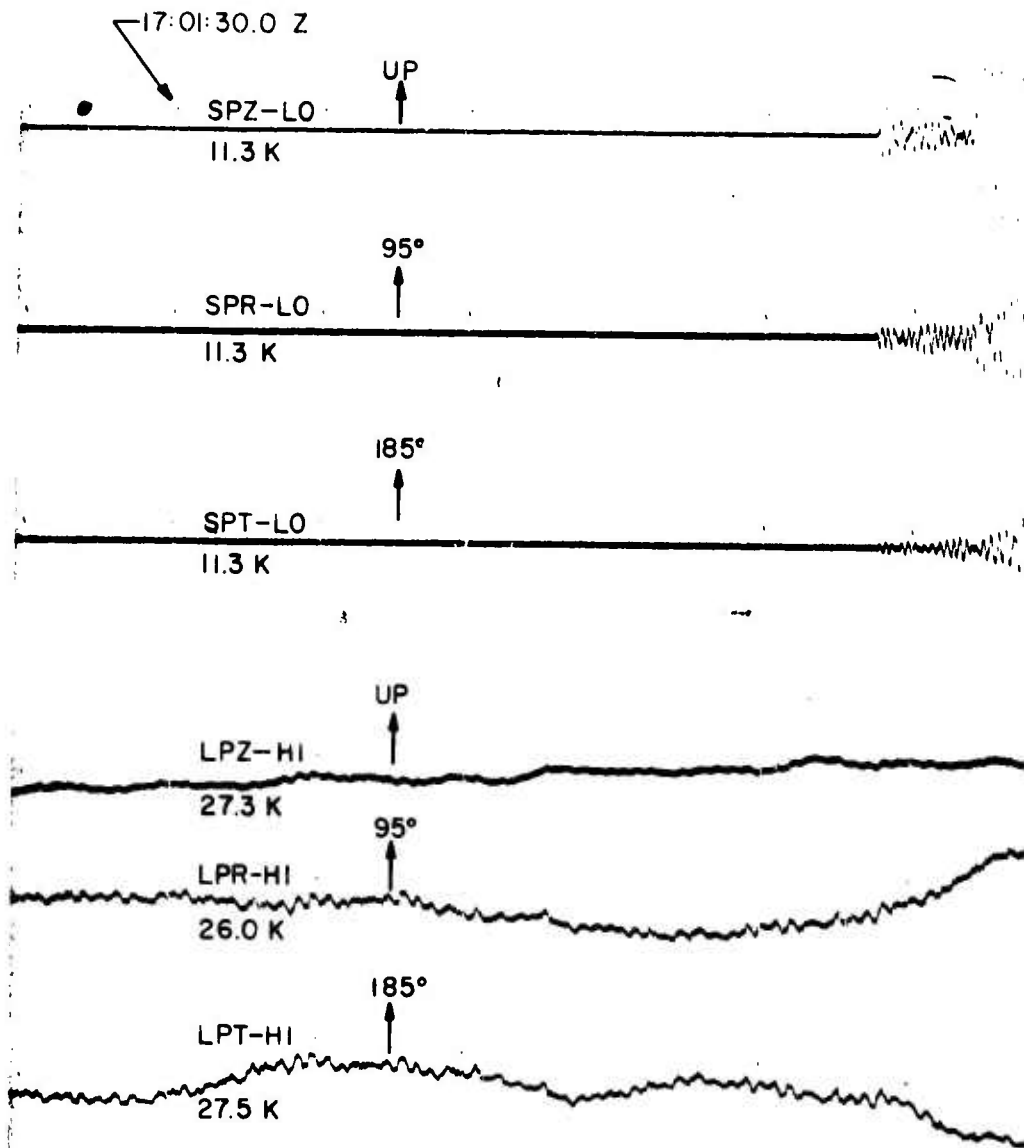
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KANAB,

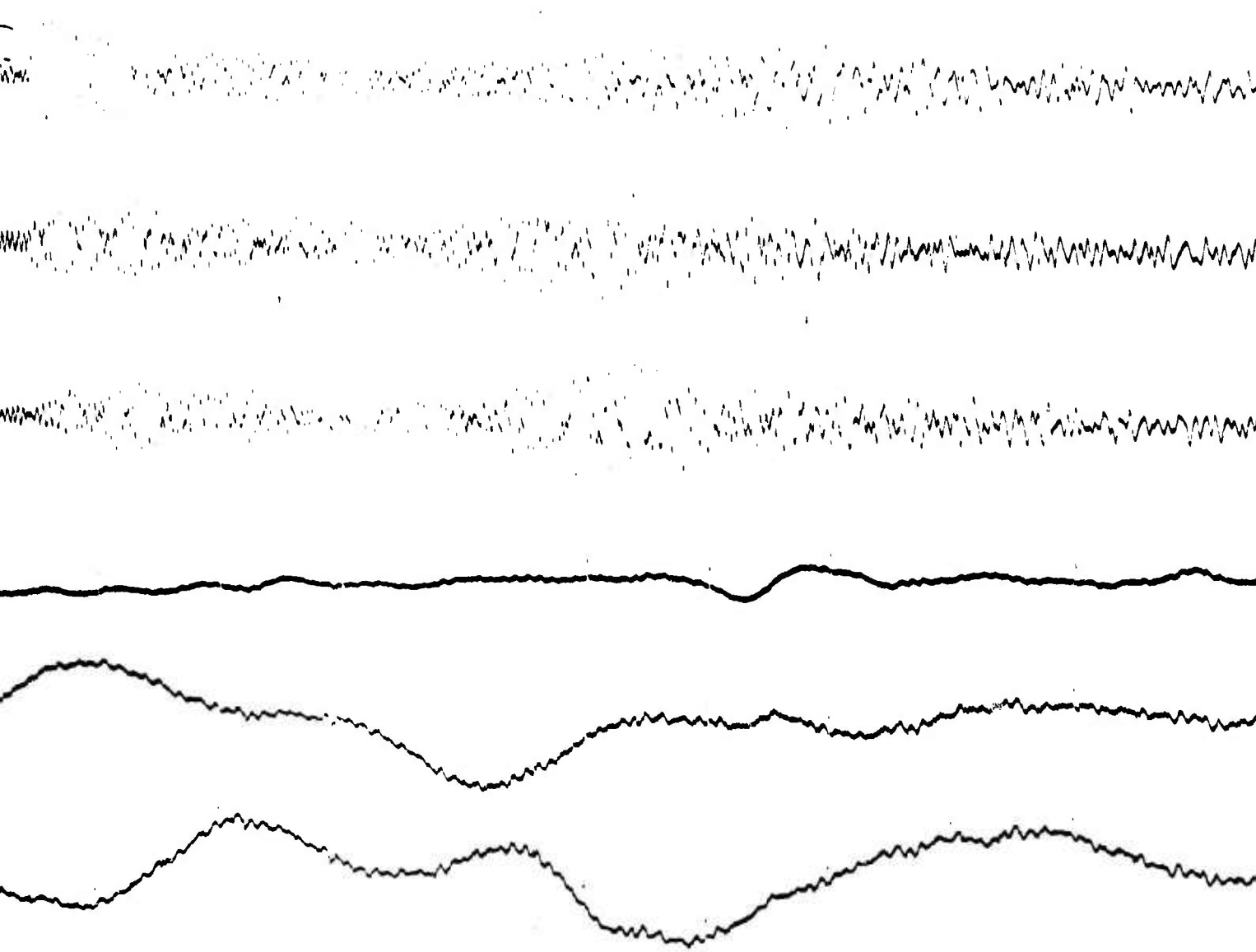
UTAH

23 APRIL 1968

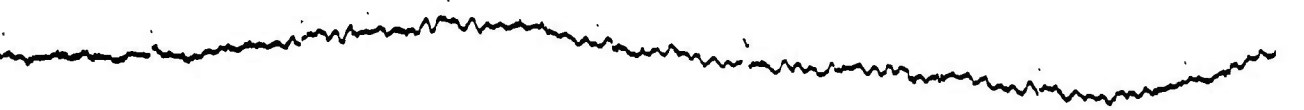
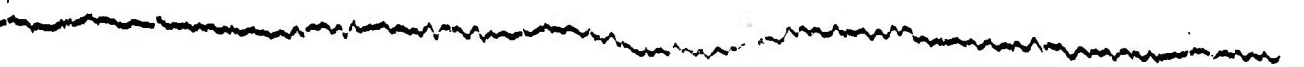
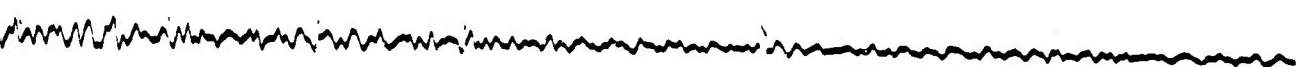
$\Delta = 317$ Km



A.



B.



c.

SCROLL

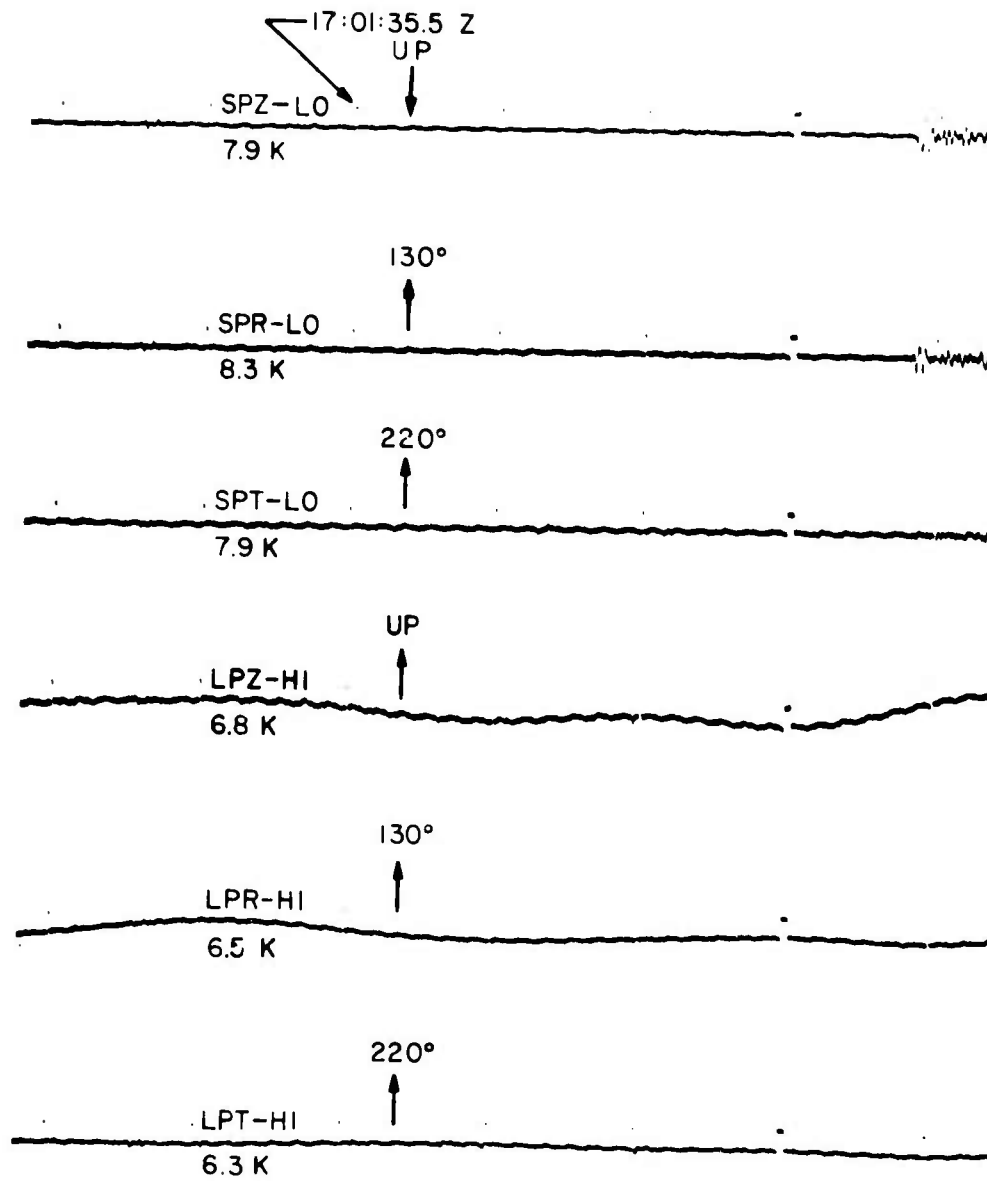
KG-AZ

KINGMAN,

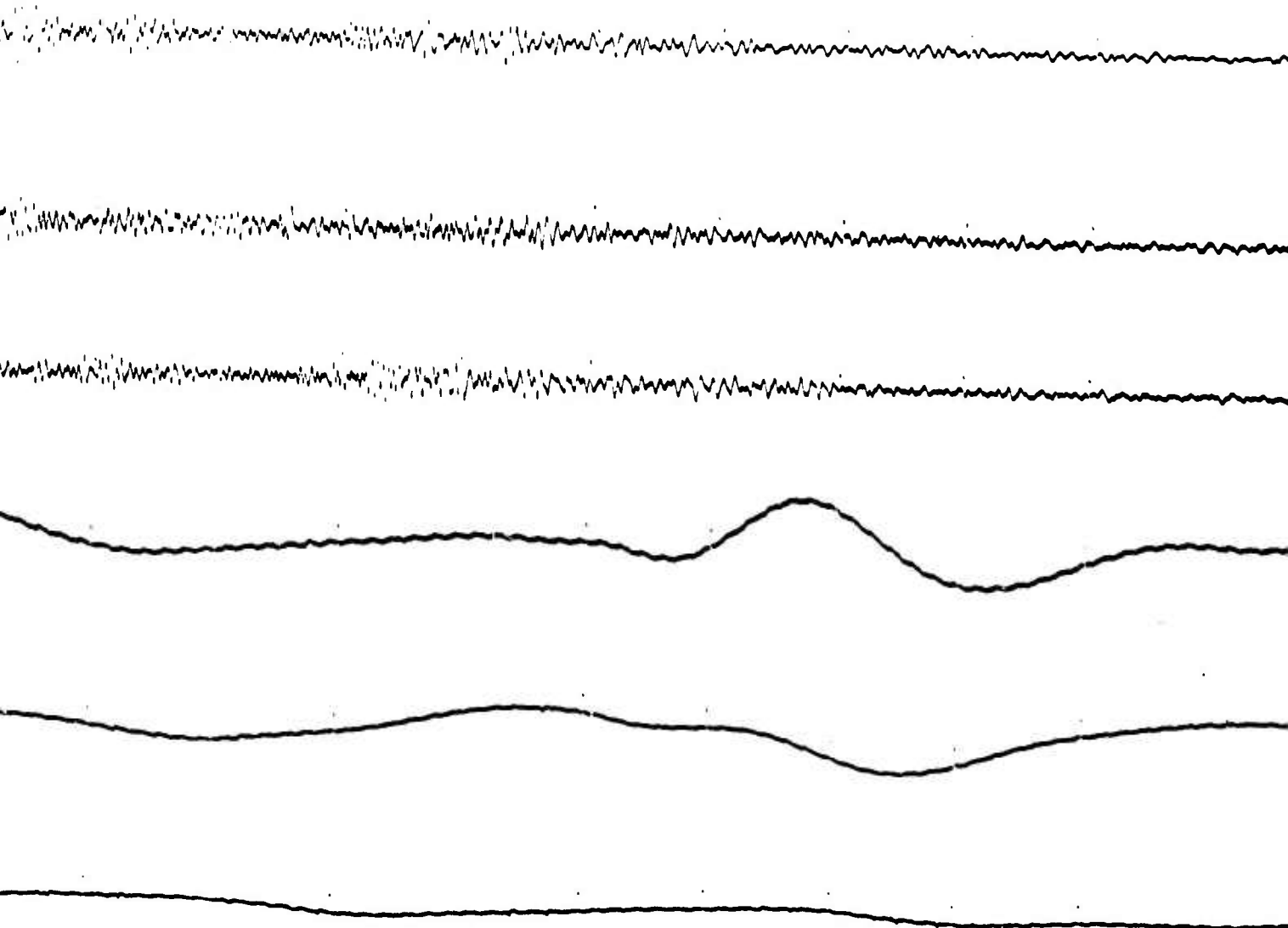
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23 APRIL 1968

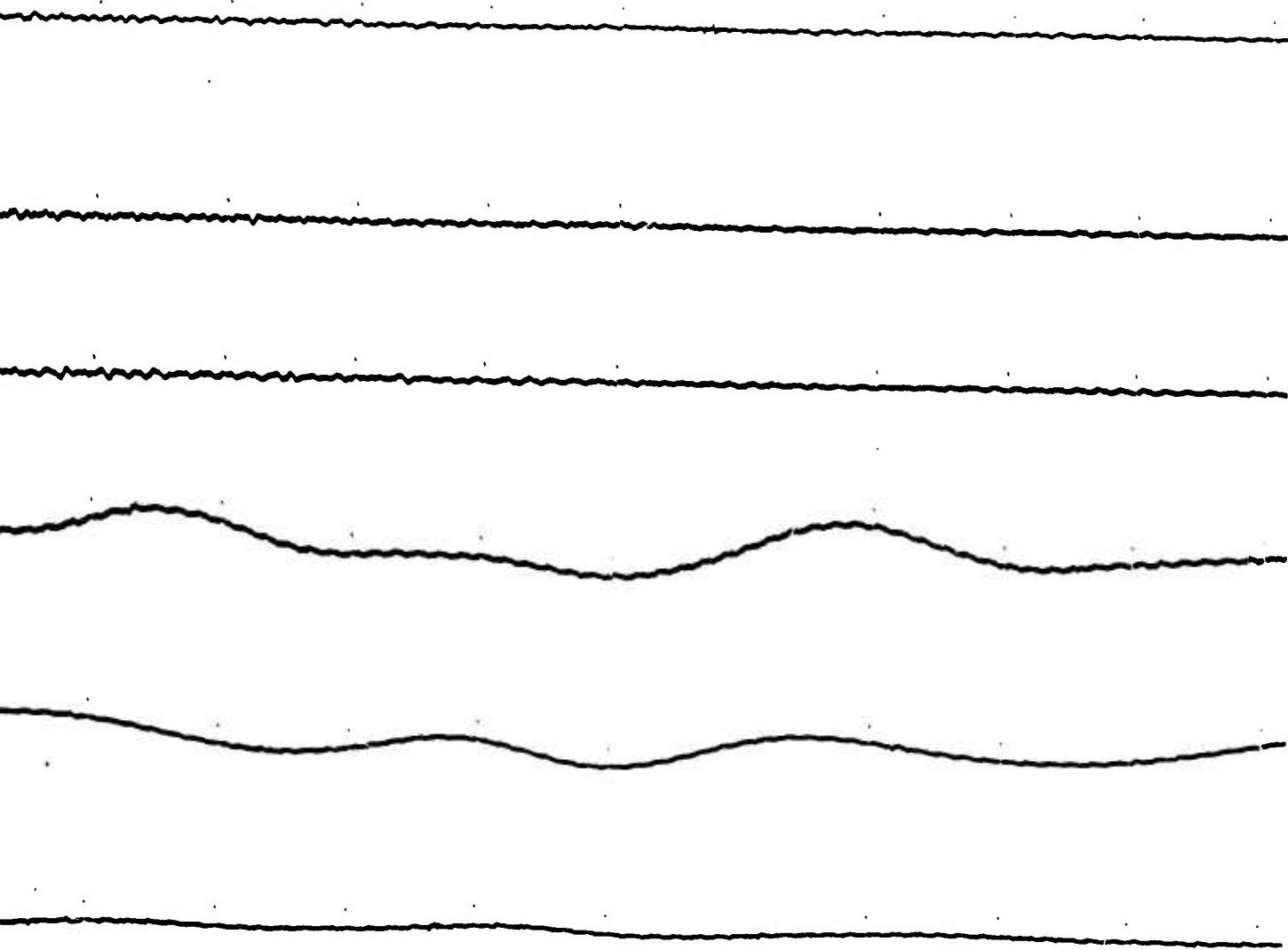
$\Delta = 290$ Km



A.



B.



c.

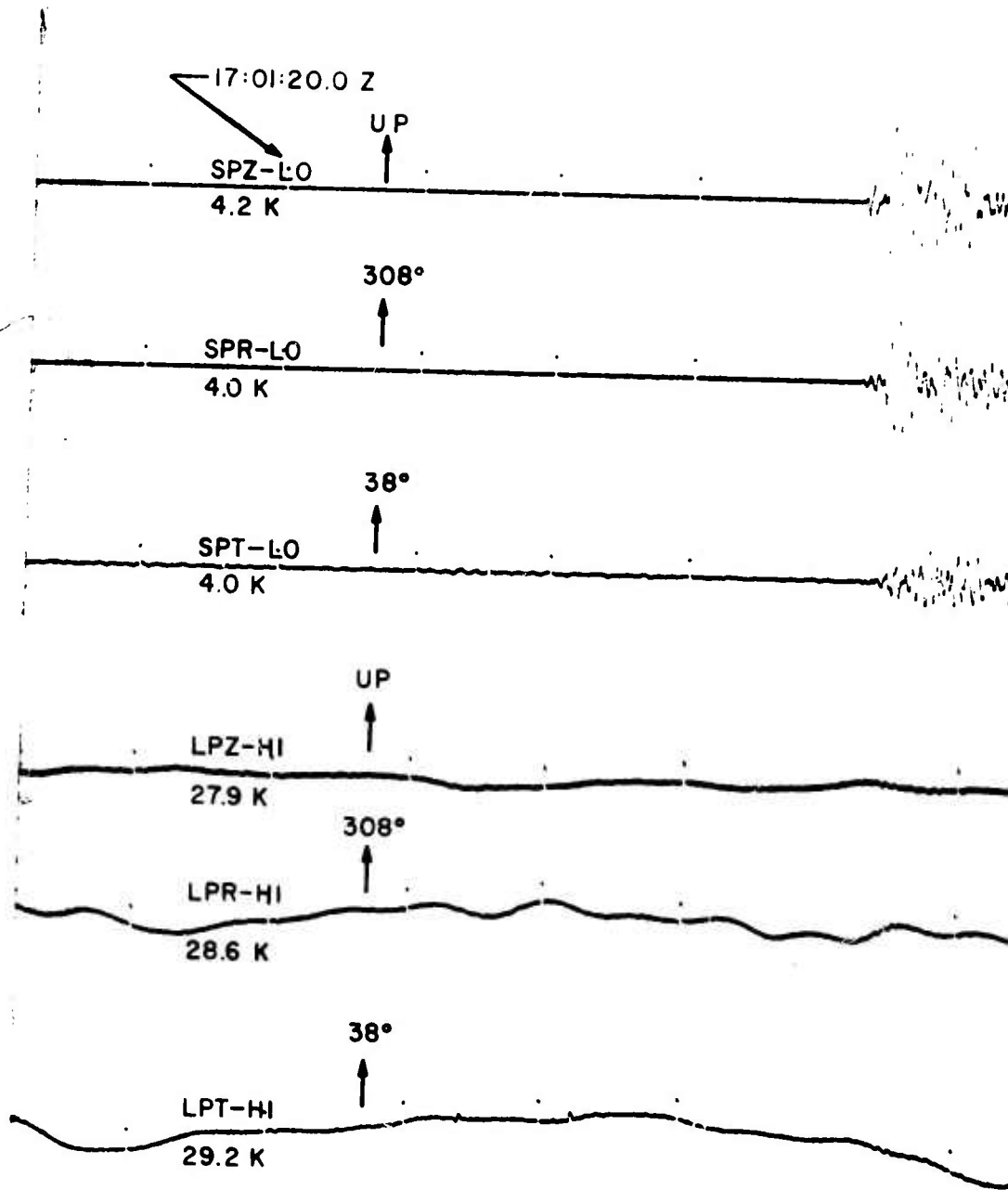
SCROLL

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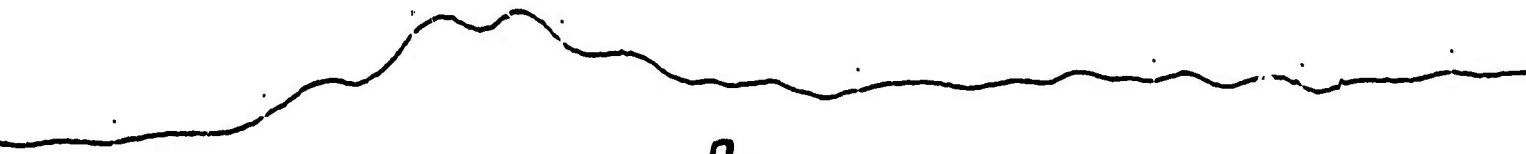
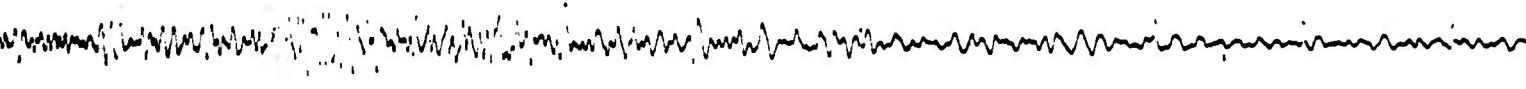
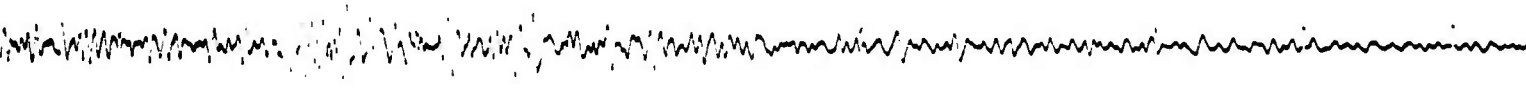
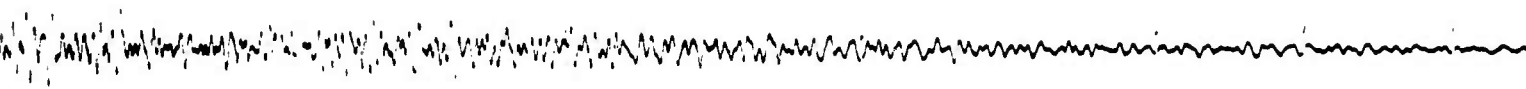
MINA,
NEVADA

23 APRIL 1968

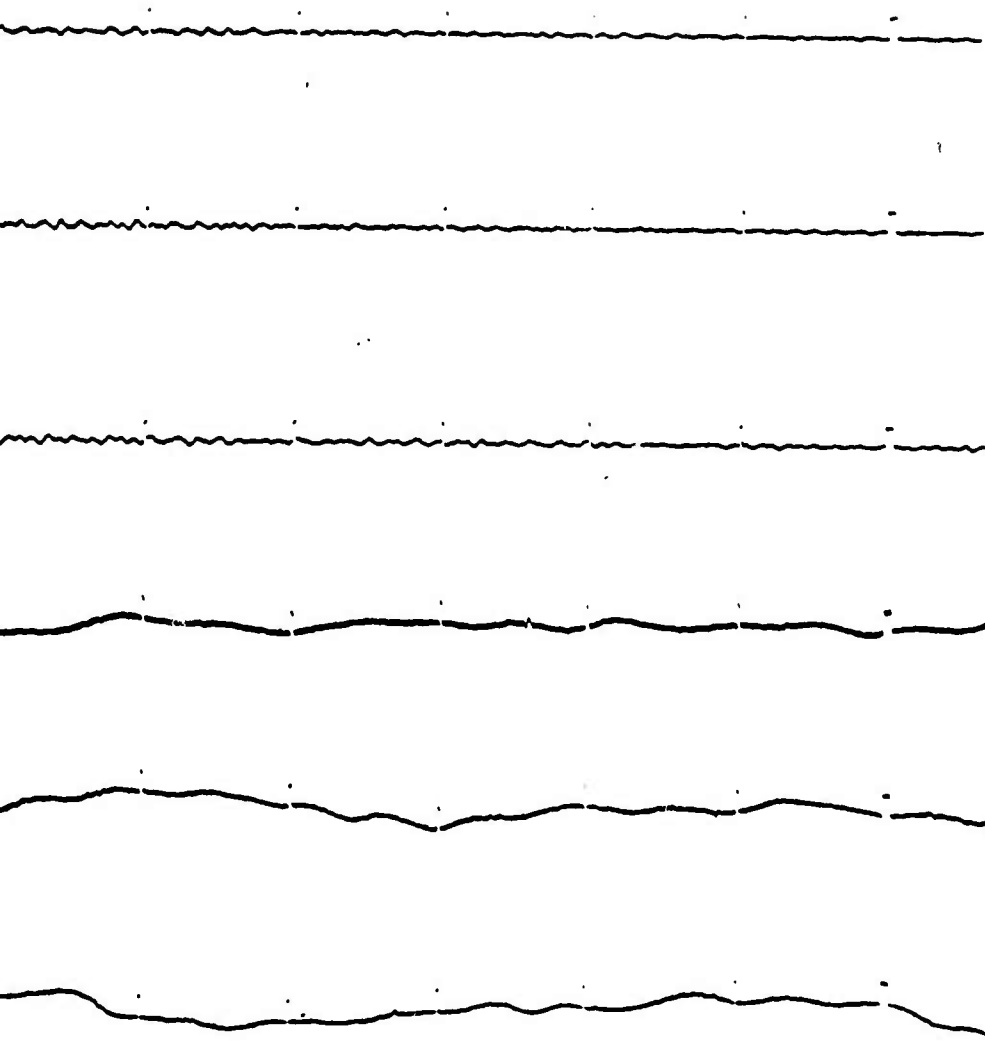
$\Delta = 198$ Km



A.



B.



d.