CONFIDENTIAL

MICROGEOPHYSICS CORPORATION

PASSIVE SEISMIC SURVEY NORTH COAST AREA HAWAII COUNTY on STATE LANDS

AREA II

10900 WEST 44TH AVENUE / WHEAT RIDGE, COLORADO 80033 / (303) 424-0499

CONTENTS

COMMENTARY

A roving, passive seismic survey was conducted in the area from east of Mauna Kea northwest through Kohala during the period of April 5 to May 22, 1978, by Microgeophysics Corporation for Atlantic Richfield Company. Six to ten microearthquake recording stations were operational on any one day. A nominal nine-station array was modified at a rate of two to three stations per day, until all stations in the survey had been occupied. Each station was therefore typically occupied for three to four days. Some stations were moved after only one recording day in order to increase the instrument gain and reduce the noise level. Station locations were determined by considerations of specific array geometry, access and coverage of the survey area.

Appendix I is a listing of the stations on state land, dates of their operation and the number of records obtained from each. A base map showing all locations on state land is in the pocket. Copies of the smoked-paper seismograms obtained at these stations, presented separately, are arranged in packets on a station-by-station basis. Each station packet consists of an identifying cover sheet and the seismogram copies arranged chronologically by Julian Day. No digital tape records were made.

Wind noise was a major problem in this area. Instrument gains were set low (typically 66-84 db), and low cut fulters were utilized in an attempt to reduce this noise to an acceptable level.

TABLE I

LOCATIONS ON STATE LAND - AREA II

Station	X(km)	Y(km)	Z(km)	No. of Records	Operating Dates
109	2.32	14.25	-2.73	5	May 31, June 01-04
115	1.46	25.38	-1.13	5	June 04-08
216	5.50	11.69	-2.36	3	June 18-20
217	1.10	7.85	-1.97	4	June 16-19
225	16.25	26.32	-1.16	1	June 23
231	-4.88	35.44	-1.19	3	June 25-27
234	-10.46	39.14	-1.32	2	June 28,29

Origin I (for Stations 109 & 115)
Station coordinates X, Y, Z are in kilometers.
+X East.
+Y North.
Altitude datum is sea level.
Origin is at longitude $155^{o}24.96'$ West, and
latitude $19^{o}45'$ North.

Origin II (for Stations 216-234)
Station coordinates X, Y, Z are in kilometers.
+X East.
+Y North.
Altitude datum is sea level.
Origin is at longitude $155^{o}37.50'$ West, and
latitude $19^{o}45'$ North.

INSTRUMENTATION

Introduction

The passive seismic system used for geothermal exploration and deployed by MicroGeophysics Corporation (MGC) is a hybrid system. The system consists of both independent seismographs and RF telemetered stations. The network station capability is from six to ten stations. A schematic of the system is shown in Figure 1. The independent stations are basically MEQ-800 visual drum recorders, with an integral timing system synchronized to universal coordinated time. As an option, the seismic signal can also be recorded by a continuous magnetic tape recorder. This independent station schematic is shown in Figure 1. The RF-telemetry system consists of from two to eight satellite stations with a central recording system. The satellite stations are comprised of a geophone, amplified voltage controlled oscillator with a RF transmitter.

The central system receives data from each of the satellite stations, discriminates them, and records them. The recording can be on smoked paper, and/or magnetic tape, and/or event recording on a high speed photographic recording. A schematic is shown in Figure 1. A detailed explanation of each of the component parts for each system is given in the following sections.

L4-C Seismometer

The L4-C is a one-Hertz-natural-frequency vertical seismometer (manufactured by Mark Products). The damping is 0.6 of critical damping. The L4-C has an output of 6.9 volts per inch/second. A typical specification sheet is shown in Figure 2.

As sensor options, other geophones can be utilized. A common option is the L-10 geophone (manufactured by Mark Products). A typical specification sheet is also shown in Figure 2.

MEQ-800-B

The MEQ-800-B is a visual microearthquake recorder. The smoked drum recording has a nominal 120 mm/min rotation speed with 1 mm spacing between succeeding traces. The stylus and trace width is 0.05 mm. The amplifier has a maximum of 120 db of gain and selectable corners at 1, 5, and 10 Hz. The high cut filter has selectable corners of 10, 20, and 75 Hz. The amplifier gains can be changed by precise 6 db steps down from 120 db. The maximum pen deflection is ±25 mm and can be limited under severe ground noise conditions to ±10 mm or ±5 mm.

The integral timing system consists of a clock, whose drift rate is less than ±1 part in 10^7 (approximately ±10 ms per day) and can be set to standard time and adjusted at 16 ms increments. Time is displayed on each trace by a slight deflection of the pen each second.

SYSTEM SCHEMATIC

INDEPENDENT STATIONS

4-5 Stations Available
Remote Station Location

Components:

Geophone
↓
Amplifier
↓
Filters
↓
*Recorder
Smoked Paper
Digital Tape (optional)

TELEMETRY STATIONS

4-5 Stations Available
Remote Station Location

Components:

Geophone
↓
Amplifier
↓
Filter
↓
Voltage Controlled
Oscillator (VCO)
↓
RF Transmitter

CENTRAL STATION

Components:
RF Receiver

Discriminator

*Recorder
Smoked Paper
Event Detection
Digital Tape

*Timing supplied by each station, synchronized daily.

FIGURE 1

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L4-C SPECIFICATIONS

Open Circuit Damping (b_o) = 0.28 Critical

Coil Current Damping (b_c) = $\frac{1.1\ R_c}{R_c + R_s}$

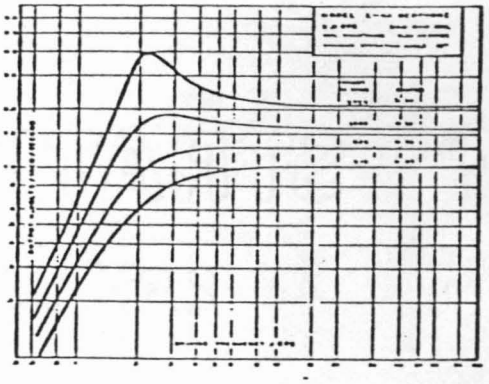
Total Damping (b_t) = $b_o + b_c$

L-4C 1.0 Hz GEOPHONE

Coil Resistance (ohms)	84	134	206	320	500	870	1280	2000	3500	5500
Transduction (volts/inch/sec.)	0.87	1.13	1.34	1.7	2.1	2.8	3.5	4.2	5.55	6.9
Transduction (volts/meter/sec.)	34.2	43.5	53	67	83	110	136	165	220	273
Coil Inductance (henries)	0.092	0.147	0.230	0.35	0.55	0.95	1.40	2.20	3.85	6.05
Analog Capacity (microfarads)	875	550	356	230	147	85	58	37	21	13.4
Analog Inductance (henries)	29	46.4	71	110	173	300	440	690	1200	1900
Shunt For 0.70 Critical Damping	133	215	333	520	810	1400	2070	3250	5650	8900
Shunt For 0.60 Critical Damping	205	325	500	780	1220	2120	3100	4900	8500	13400

L-4C 1.0 Hz GEOPHONE

TYPE	Moving dual coil, humbuck wound
FREQUENCY	1.0 → 0.05 Hz measured on 200 pound weight at 0.09 inches/second
FREQUENCY CHANGE WITH TILT	Less than 0.05 Hz at 5° from vertical
FREQUENCY CHANGE WITH EXCITATION	Less than 0.05 Hz from 0 to 0.09 inches/second
SUSPENDED MASS	1000 grams
STANDARD COIL RESISTANCES	See Table
LEAKAGE TO CASE	100 megohm minimum at 500 volts
TRANSDUCTION POWER	$8.8 \cdot 10^{-3}$ watts inch second or 13.6 watts meter second
OPEN CIRCUIT DAMPING	$(b_o) = 0.28$ critical
CURRENT DAMPING	$(b_c) = \frac{1.1\ R_c}{R_s - R_c}$ where: R_c = coil resistance - ohms, R_s = shunt resistance - ohms
COIL INDUCTANCE	$(L_c = 0.0011\ R_c$ L_c in m henries.
ELECTRIC ANALOG OF CAPACITY	$C_c = \frac{73,500}{R_c}$ (microfarads)
ELECTRIC ANALOG OF INDUCTANCE	$L_m = 0.345 R_c$ (henries)
CASE HEIGHT	5⅛ inches — 13 cm.
CASE DIAMETER	3 inches — 7.6 cm.
TOTAL DENSITY	3.7 grams cm³
TOTAL WEIGHT	4¾ pounds — 2.15 kilograms
OPERATING TEMPERATURE	Range: −20° to 140°F or −29° to 60° C.
OPERATING PRESSURE	500 PSI



L-10A SPECIFICATIONS

L-10A GEOPHONE

Suspended Mass (m) ..... 12.5 grams

Open Circuit Damping (b_o) ..... $b_o = \frac{4.2}{f} \pm 10\%$

Coil Circuit Damping (b_c) .... $b_c = \frac{15.7 \cdot R_c}{f(R_s + R_c)} \pm 10\%$

Analog Capacitance (C_c) ..... $C_c = \frac{5010}{R_c}$

R_c = Coil Resistance C_c = Microfarads

Analog Inductance (L_m) ..... $L_m = \frac{5.16 \cdot R_c}{f^2}$

f = geophone frequency L_m = henries

L-10B 4.5Hz

Coil Resistance (ohms)	21	34	54	90	138	215	374	590	940
Transduction (volts/inch/second)	0.193	0.245	0.30	0.387	0.49	0.60	0.80	0.98	1.25
Coil Inductance (henries)	0.004	0.006	0.010	0.016	0.024	0.038	0.067	0.105	0.167
Analog Capacitance (micro farads)	350	216	136	81.6	53.1	34.1	19.7	12.4	7.80
Analog Inductance (henries)	3.58	5.82	9.24	15.4	23.6	36.8	64.0	102	161
Shunt for 1.00 Critical Damping (ohms)	66.8	108.5	173	277	317	687	1200	1890	3000
Shunt for 0.70 Critical Damping (ohms)	191	311	494	824	1260	1750	3420	5410	8570
Shunt for 0.60 Critical Damping (ohms)	315	512	814	1355	2080	3240	5640	8910	10425

$b_o = .445$ $b_c = \frac{2.33\ R_c}{R_c + R_s}$

L-10B GEOPHONE

Suspended Mass (m) ..... m = 19 grams

Open Circuit Damping (b_o) ..... $b_o = \frac{2}{f} \pm 10\%$

Coil Circuit Damping (b_c) ..... $b_c = \frac{10.5 \cdot R_c}{f(R_s + R_c)} \pm 10\%$

Analog Capacitance (C_c) ..... $C_c = \frac{7330}{R_c}$

R_c = Coil Resistance C_c = Microfarads

Analog Inductance (L_m) ..... $L_m = \frac{3.41 \cdot R_c}{f^2}$

f = geophone frequency L_m = henries

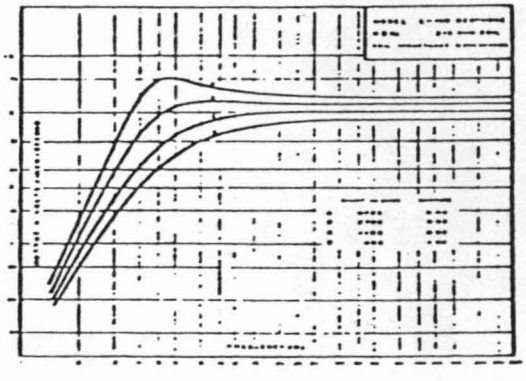
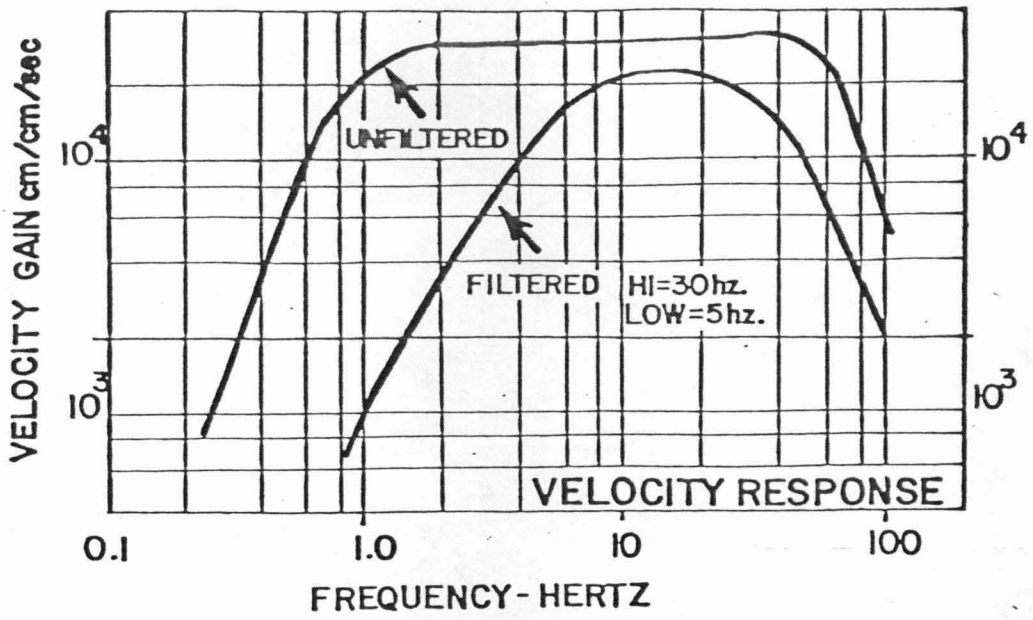


FIGURE 2

INSTRUMENT RESPONSE



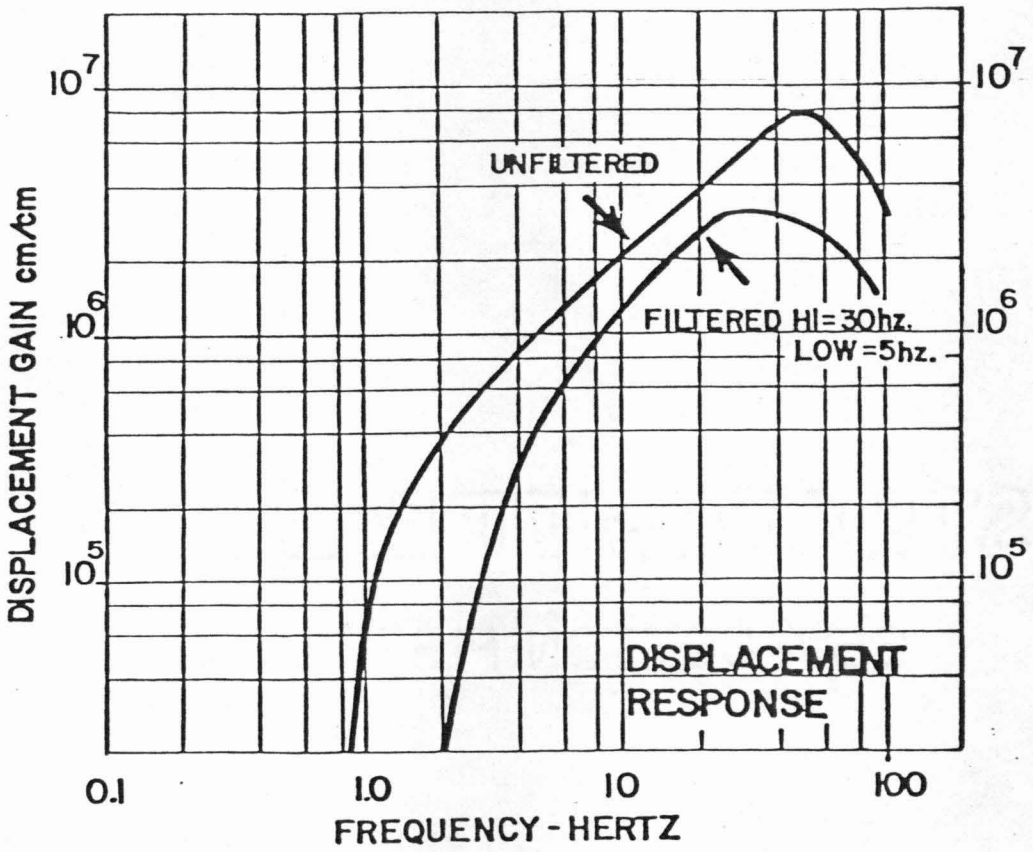


FIGURE 3

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The frequency characteristics of the instrument with an L4-C are summarized in Figure 3. Both the velocity and displacement response for the MEQ-800-B microearthquake system are shown. The displacement response at a particular frequency (f) can be calculated by multiplying the velocity gain at f times $2\pi f$. The filter response and gain level shown are typical settings for operations in the western continental United States.

DMTR

The digital magnetic tape recorder (DMTR) is a twelve-bit 100 sampler-per-second, reel-to-reel-tape recorder which records data continuously. Each data block begins on the minute at the command of the clock in the MEQ-800-B system. The hour and minute from the clock are written at the beginning of each block. WWVB is recorded continuously on one bit of the tape format. The dynamic range of 72 db on this tape recorder allows the recovery of data under exceptionally noisy conditions.

WWVB

WWVB is the radio call code for the National Bureau of Standards 60 kHz time-standard station in Fort Collins, Colorado. The WWVB time standard is used to set and synchronize the microearthquake system clocks. As shown in Figure 4 below, the signal consists of 60 markers each one minute, with one marker each second (time progresses from left to right). Each marker is generated by reducing the power of the carrier by 10 db at the beginning of the corresponding second and restoring it:

(1) 0.2 seconds later for a binary zero
(2) 0.5 seconds later for a binary one
(3) 0.8 seconds later for a 10 second position marker and for a minute reference marker.

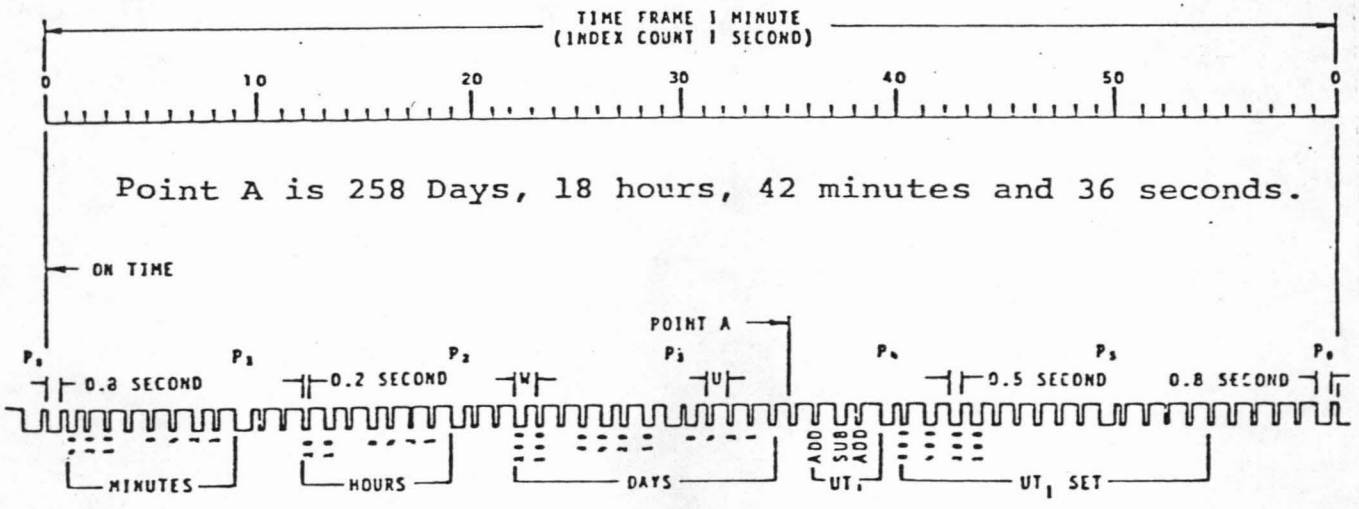


FIGURE 4

The WWVB code (as shown in Figure 3) is recorded daily on the visual drum as absolute time and date identification of the record, and is used to synchronize each MEQ system to standard time.

The MEQ systems' clocks are synchronized daily with WWVB by comparing (on an oscilloscope) the beginning of the WWVB second pulse with the MEQ-800-B internally generated one-second pulse. This comparison can be done to ±2 milliseconds. Daily records are kept on the amount of correction for each clock. These time corrections are then applied to the records. Common corrections are on the order of 15 ms per day or less than one millisecond per hour.

WWV

WWV is the radio call code for the National Bureau of Standards 5, 10, 15, 25 mHz time standard station in Fort Collins, Colorado, as used by MicroGeophysics Corporation. The voice channel is used to generally coordinate time, while the second signals are used to precisely coordinate time. The use is similar to that of the WWVB channel.

Amplifier

The amplifier used is the AS-110 (manufactured by Sprengnether Instrument Company). This amplifier has identical characteristics to the Sprengnether MEQ-800 amplifier.

Telemetry

The following are excerpts for the Sprengnether Manual for the VCO and Discriminator equipment:

Telemetry VCO TC-10

> The TC-10 Voltage Controlled Oscillator has been designed to fill a need for low cost, low power, high quality and versatile audio frequency telemetry components. Available in standard constant bandwidth channels from 340 to 3060 Hz with ±125 Hz deviation the TC-10 VCO satisfies requirements for FM geophysical data telemetry in the frequency range DC to 50 Hz by telephone, land line, or by radio link. When used with the companion TC-20 Discriminator, 60 dB dynamic range (peak measurement is achieved in the 0-10 Hz bandwidth).
>
> Versatility and simplicity of installation are assured by several special features incorporated into the VCO that are not normally available at such low cost. Eleven sensitivity ranges, from

50 mv to 100 v full scale deviation, are selectable on the front panel to facilitate system gain adjustments or multi-gain operations. Upper and lower band edge deviations can be effected from a front panel switch for ease in system setup and servicing. Center frequency, deviation, and output level can be monitored and adjusted from the front panel. Output is transformer coupled for flexible installation.

Power requirements are generous at ±10 to 15 VDC at 15 ma for low power remote field installations. Small physical size is ideal for compact field case installation (the TC-10 matches the AS-110 amplifier in size and connector configuration) or for high density packing in rack mount multi-channel operations.

The TC-110 VCO represents state-of-the-art in circuit design, user convenience, and low price, satisfying virtually all requirements for high quality audio frequency FM telemetry.

Discriminator TC-20

The TC-20 Discriminator has been designed to fill a need for low cost, low power, high quality and versatile audio frequency telemetry components. Available in standard constant bandwidth channels from 340 to 3060 Hz with ±125 Hz deviation the TC-20 satisfies requirements for FM telemetry of geophysical data in the frequency range DC to 50 Hz by telephone or land line or by radio link. When used with the companion TC-10 VCO, 60 dB dynamic range (peak measurement) is achieved in the 0-10 Hz bandwidth.

Several unique features are found on this low cost phase-locked loop discriminator that normally are incorporated only in more expensive units. A sense light on the front panel indicates low carrier level. Provision is made for a reference compensation tone and trim to effect compensation for frequency shifts in multiplexed tone bundles. The TC-20 also provides for an auxiliary-test input on the front panel to facilitate service checks and adjustments. The carrier after filtering can be monitored from the front panel and all major adjustments are made with front panel controls. The input is transformer coupled for flexibility in installation.

Power requirements are ±10 to 15 VDC at 18 ma. Output filters (3 pole Butterworth) at 1, 5, 10, 20, 50 Hz (3dB) are available, factory adjusted. The panel width of 1-1/2" allows dense packing in rack installations.

The TC-20 represents state-of-the-art in phase-locked loop discriminators, offering the maximum in flexibility and convenience features at the lowest possible cost.

RF Telemetry Link

These RF telemetry links are Monitron low-power FR transmitters and receivers (manufacturer Monitron Corporation). The output power is less than 100 mw. Specifications are shown below.

System Gains: The typical gains of each system with typical settings are shown below:

System: MEQ-800 (Smoked Paper)

Filter Settings:
Hi = 30 Hz
Lo = 5 Hz
Geophone L4-C

Gain Settings	Displacement Gain at 20 Hz
60	0.04×10^6
66	0.08×10^6
72	0.16×10^6
78	0.33×10^6
84	0.165×10^6
90	0.3×10^6
96	2.6×10^6
102	5.2×10^6

System: VCO-TELEMETRY-VR-60

Filter Settings
Hi = 30 Hz
Lo = 5 Hz
Geophone L4-C

VCO = 5 Volts/f.s.
VR-60 + 100 mu/mm

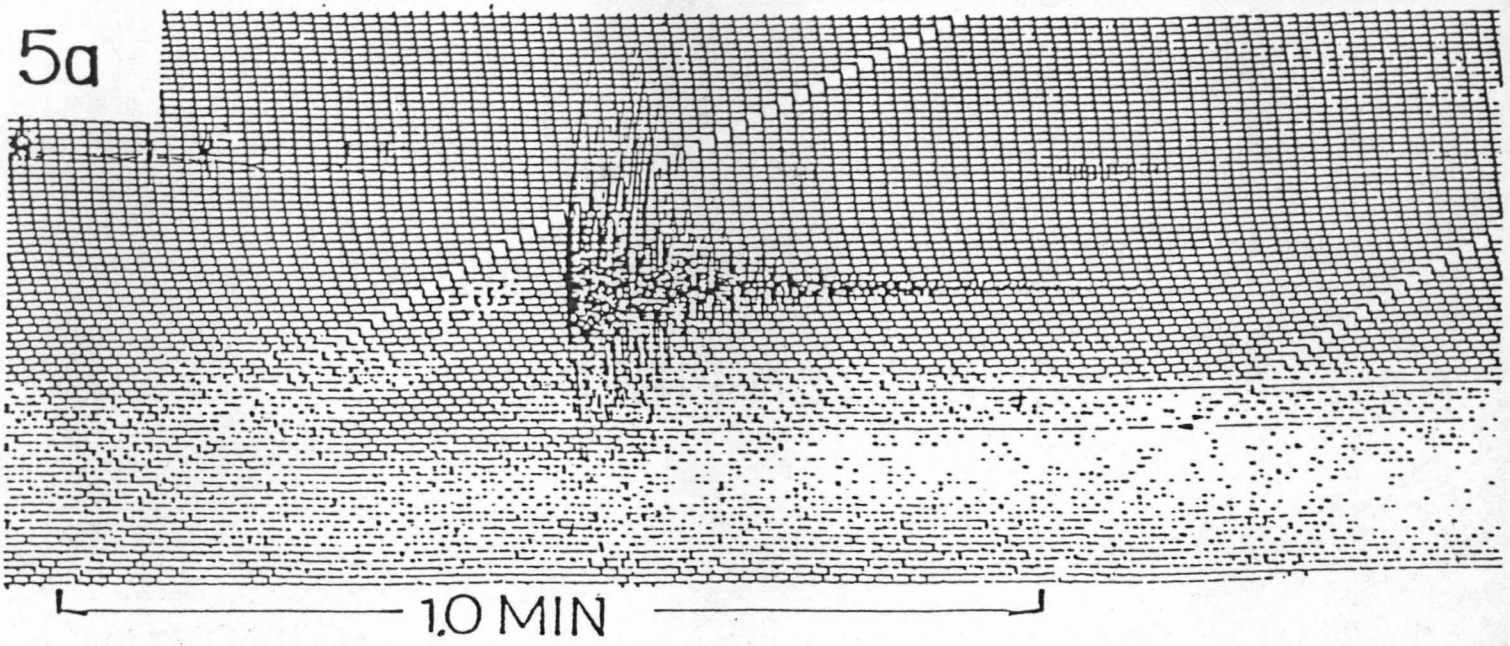
Gains Settings	Displacement Gain at 20 Hz
60	0.2×10^6
66	0.4×10^6
72	0.8×10^6
78	1.65×10^6
84	3.25×10^6
90	6.5×10^6
96	13.0×10^6
102	26.0×10^6

DATA

An example of the output of a microearthquake system is shown in Figure 6. The smoked-paper output is shown in Figure 6(a) while Figure 6(b) and Figure 6(c) are the same earthquake recorded on magnetic tape and played back at two different speeds. The playback format is illustrated in the figure.

The smoked-paper record is used at the time of the recording (in the field) to estimate the seismicity and to locate any recorded microearthquake approximately. The paper records can be picked under magnification to a precision of less than ±30 ms. The magnetic tape playbacks are then used to increase the timing precision of an event to ±10 ms, a precision close to the subjective level of interpretation by an experienced seismologist. The magnetic tape playbacks are also useful in increasing the effective gain of recording and thereby recording very small amplitude events. In noisy areas, the tape playbacks can be used to recover data obscured on the paper monitor records by cultural noise on adjacent traces.

5a



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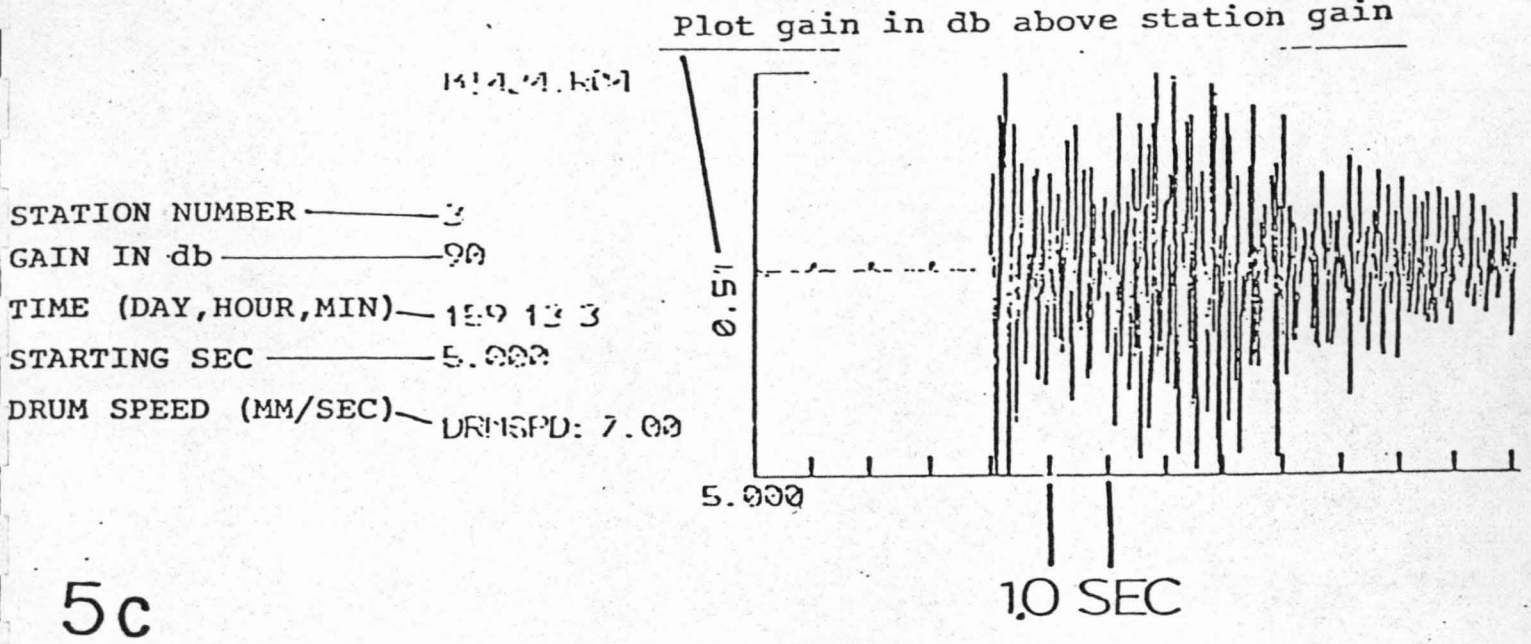

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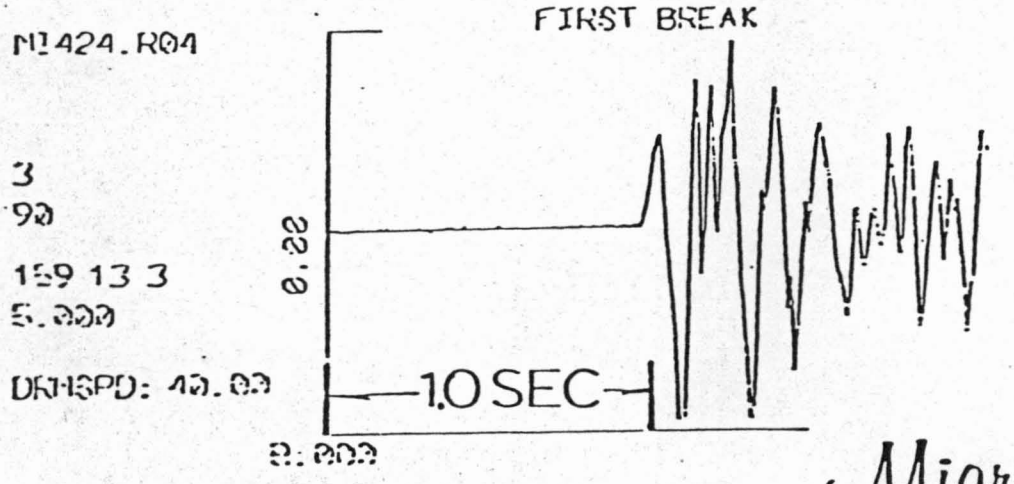

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