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**ALEUTIAN/AMCHITKA
SEISMIC PROGRAM**

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**U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY**

March 12, 1971

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Kenneth W. King, Chief
Special Projects Party
Las Vegas, Nevada

March 12, 1971

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ALEUTIAN/AMCHITKA SEISMIC PROGRAM

INTRODUCTION

The National Ocean Survey (NOS), Las Vegas Special Projects Party, under contract with the Atomic Energy Commission's Nevada Operations Office, has installed a seismic network in the Aleutian Islands for the purpose of investigating the seismicity of the area on and near Amchitka Island. The primary objective is to determine and define the seismicity of the Rat Island Group and to monitor the possible changes to the seismic normalcy, during or after nuclear detonations on Amchitka. The network consists of a five station seismic array on Amchitka, a near-island array consisting of Rat, Semisopchnoi, and Amatignak Islands and a regional network which includes Adak, Shemya, Granite Mountain, and Cape Sarichef, Figures 1, 2, and 3.

The seismic systems use a combination of telephone telemetry, radio telemetry, and hard wire to transmit data to centralized recording locations, Figures 4 and 5. The Amchitka and near-island group data are recorded on Amchitka. The three regional stations are recorded at the Palmer Observatory near Anchorage, Alaska, where the data are integrated with an existing NOS Alaskan seismic network.

The seismic data from the Amchitka recording site are mailed routinely to the Las Vegas office, where the basic analysis is performed. The correlative computer output, issued as a monthly bulletin, plus special associated seismic reports are published by the National Oceanic and Atmospheric Administration/ National Ocean Survey (NOAA/NOS), Rockville, Maryland office.

ON-ISLAND SEISMOMETER NETWORK

The on-island seismic instrumentation consists of five seismic stations; one station on the north end of the island, one station on the center portion of the island, and one seismic tripartite array on the south end of the island, Figure 2.

North and Central Locations

The north and central island seismometer positions are in semi-remote areas and use instrumentation capable of long durations of unattended operations. The central location radio telemeters two levels of vertical seismic information to the central recording site on the south end of the island, while the north location transmits one level.

The seismometer used on these locations as well as on the near-island network is a moving coil, velocity-sensitive transducer with a single wound coil that has approximately a 630 volt-second per meter generator constant.

The five kilogram moving mass has a 6.3 millimeter maximum travel from stop to stop at 1.0 second with a damping of 0.63 critical.

The analog signal from the transducer is transferred by a short cable into a signal conditioning stage. The stage consists of a modular solid-state, low-noise, high-gain amplifier which consists of a 70 db preamplifier, a 6 db step attenuator on the preamplifier, a 0.75 to 24 Hz band-pass filter

network and a high and low gain output dual channel. The filter characteristics are maximally flat (Butterworth) with an attenuation rate beyond the cutoff frequencies of 12 db per octave. The high-gain channel has a second stage amplifier which adds 18 db amplification, and is set to operate at a 76 db amplification which is roughly equivalent to 100,000 gain for displacement at 5 Hz. The recording dynamic range is approximately 36 db whereas the system dynamic range is approximately 100 db when measuring the rms signal to noise ratio.

The amplified data signals are then modulated on a center frequency which is proportional band-width, frequency modulated with a 7.5% deviation. The FM signal is transmitted by a two-watt transmitter through a 12 db yagi antenna to the receiver site on the south end of Amchitka.

The FM signals are received by a 12 db yagi antenna and transmitted by cable to a band-pass filter, a demodulator and a discriminator system which are designed for high stability (0.05% long term) and low noise. The demodulated analog signals are transmitted by cable to the recorder network.

Tripartite Seismometer Array

The south tripartite array is located in a general right triangle configuration with the legs being approximately 8, 13, and 15 kilometers long. Due to the close proximity to the planned nuclear event, the seismometers and amplifiers used on the south tripartite are not of the same type as the central, north

island and the near-island sites.

A moving coil, velocity sensitive, vertical transducer is used on the northernmost position of the tripartite array. The seismometer has a 1.0 kilogram mass, a transduction constant of 270 volts second/meter, a 1.0 second period and a damping of 0.65 critical. The seismometer hinges have a high tolerance to shock and the instrument is therefore adaptable to major event motion survival with adequate transduction to give a low signal to noise ratio necessary for natural phenomena studies. The tolerance is necessary as this position is relatively near surface zero of the proposed Cannikin event, Figure 3.

The southernmost position on the tripartite array is instrumented by orthogonal, moving magnet, velocity sensitive, one second period seismometers. The transduction of the seismometers is approximately 290 volts second/meter with a mass weight of 12 kilograms. The period is set at 1.0 second and the damping is 0.65 of critical.

The amplifier matched to this seismometer is designed with attenuation and split level data outputs in front of the amplifying stage to prevent saturation of the amplifier from overloading input signals. The multi-stage signal amplifier gives the needed dynamic range necessary for event/natural phenomena recording. Two levels of data separated by 18 db are recorded from each of the seismometers. A third level at -36 is recorded from the vertical seismometer.

The easternmost position on the tripartite array is instrumented by the same type of vertical seismometer as is used on the southern position. Two levels of data separated by 18 db are recorded from this position. The data from the southern and eastern positions are transmitted by cable to the central recording site. The northernmost station radio transmits the data to the recording site.

Amchitka Recording Site

The NOS Amchitka Recording Site is located in housing near the airstrip on the southern part of Amchitka. The site contains selected filters, recording networks, and recorders for the Amchitka and near-island seismic sites.

Filtering

A 2 Hz high-pass filter is in line with the vertical high-gain channels, Figure 6. Filtering of the low frequencies allows higher gains of the observed frequencies of local seismic phenomena, thus increasing the detection range. The 2 Hz high-pass filter is down 3 db at 2 Hz and 48 db one octave lower. The high-pass response is flat with 0 db attenuation or gain. The regenerated analog seismic signals are attenuated and impedance matched to the recording system.

Recording

The data are recorded by four systems: A primary continuous system, a backup continuous system, a monitor system, and an emergency system.

The primary recording system consists of two 20-channel Develocorders which record the analog seismic signal on 16 mm photographic film. After exposure, the film is automatically developed, fixed, washed, dried, and moves through a monitor viewer and on to a storage reel. The recording speed is 30 mm/min. on 142 feet of film/day. The natural frequency of the galvanometer is $16 \text{ Hz} \pm 5\%$ with a 50 mm focal length. The record resolution is 1 Hz sine wave on each trace at an amplitude 75% of film width.

The back-up system consists of a 14 track, frequency-modulated, magnetic tape recorder. The tape transport operates at 3/16 inches per second with an IRIG standard format on one-inch magnetic tape. The data are recorded on 7200 foot reels of 1.0 mil thick tape which will provide approximately 5-1/2 days recording time. The data are modulated on a 168.8 Hz carrier with 40% deviation. The signal to noise rms is 40 db. The nominal level input is 1/4 volt peak to peak.

The monitoring system consists of two direct-writing recorders. Each recorder consists of a heated stylus driven by a galvanometer which slowly translates along the axis of a revolving drum, recording the data on heat-sensitive paper in compact helical form. The recording sensitivity is 2 mv per mm with a flat response from dc to 35 Hz down 3 db at 45 Hz. The recorder is coupled with an amplifier that allows impedance matching and 60 db variable attenuation settings.

The emergency back-up system is a 6-channel, strip chart Brush recorder. The input signals are impedance matched and conditioned through an internal network. The frequency response is flat to 40 cps with a variance of $\pm 2\%$. The chart transport speed is variable but is set at one millimeter per second.

Timing

The timing system consists of a primary, a back-up, an emergency, and a time calibration/set system. The timing systems and their calibrations are recorded simultaneously on all records. In addition the Develocorders have an internal day and year coding system which is impressed on the record.

The primary timing system is a crystal-controlled programmer which can be synchronized with a standard time station. The system stability is one part in 10^8 per day. The recorded program is 10 second, minute and hour coding.

The back-up system is a crystal-controlled programmer with a coding similar to the primary system and a drift rate of approximately one part in 10^7 per day.

The emergency system is a crystal-controlled chronometer which has 2×10^6 drift rate per day and will give programmed minute marks.

The timing systems are daily checked against a radio time standard transmitted by the National Bureau of Standards (WWV) from Boulder, Colorado. The time is synchronized by a strobe/scope to within 0.01 second. The WWV signal is received by a 6-channel, 1 microvolt sensitive receiver and is recorded daily on each data

record for time corrections. The program time crystal drift is documented and graphed each day and corrected periodically when necessary.

NEAR-ISLAND INSTRUMENTATION

The Amatignak, Semisopochnoi, and Rat Island array of the Aleutian Seismic Project utilizes velocity sensitive seismometers to detect orthogonal components of ground motion on each of the islands, Figure 2. The data is continuously radio telemetered to a central recording site on Amchitka. The seismometers and amplifiers are identical to the central and north Amchitka seismometer stations.

The amplified analog data signals are modulated on a center frequency which is a proportional band-width frequency modulated with 7.5% deviation. The FM seismic signals are combined into one composite signal with each channel having a separate band-width. The composite is then remodulated on a transmitter carrier frequency that has a 50 KC band-width. The summed signal is transmitted by a two-watt transmitter through a 12 db directional yagi antenna.

The seismic systems, as well as other environmental monitoring systems and the transmitter systems on Rat, Semisopochnoi and Amatignak Islands are powered by 33 watt radioisotope thermal-nuclear generators that will provide a constant power source for five years. The seismic field system draws less than 8 watts power from the generator. The seismic, power and

transmission systems are designed for air or surface transportation, marginal environmental operating conditions and unattended operation of 2.5 years or more duration.

Near-Island Frequency Modulation System

<u>Seismometer</u>		<u>Carrier Freq.</u>	<u>Transmitting Carrier Frequency</u>
Vertical	High Gain	2300 Hz	
	Low Gain	3000	SSI 170.575 MHZ
Horizontal (1)	High Gain	3900	AMA 164.275 MHZ
	Low Gain	5400	RAT 172.050 MHZ
Horizontal (2)	High Gain	7350	
	Low Gain	10500	

The summed signal is received by a 12 db yagi antenna on Amchitka and is separated by a band-pass filter. The separated composite seismic signal is transmitted by a cable through an isolation transformer, a line balance amplifier and a second isolation transformer. The line network insures the integrity of the seismic signal, by reducing cable loss and filters out spurious noise that may be picked up by the cable. The composite seismic FM signal is then separated into individual channels by a set of narrow band-pass filters. (Butterworth designed 12 db cutoff). The individual FM channels are demodulated by discriminators which are designed for high stability (0.05% long term) and low noise (rms 0.01% of full scale).

REGIONAL SYSTEM

The regional seismic system consists of three program installed seismic stations and the existing National Ocean Survey seismic network, Figures 1 and 7. The NOS data used in the Aleutian study are from:

NOS Palmer Network

PMR	Palmer, Alaska
PWA	Palmer West
PMS	Palmer North
GIL	Gilmore
KDC	Kodiak
SIT	Sitka
ADK	Adak

Cooperative/Univ. of Alaska Network

BIG	Big Mountain
PJD	Pedro Dome
SCM	Sheep Creek Mountain
TNN	Tanna

Other Cooperative Alaska Stations

AMU	Anchorage
BRW	Barrow
CMO	Fairbanks
COL	College (2)
MID	Middleton Island

Other Cooperative World Stations That Record the Area Well

BMO	Blue Mountain, Oregon
MAT	Matsushiro, Japan
SHF	Shillong, India
TFO	Tonto Forest, Arizona
UPP	Upsala, Sweden

The distant station data are included for their unique degree distance from Amchitka.

Program Stations

The program installed seismic stations are located at Shemya Island, Unimak Island, and Granite Mountain, Alaska. The instrumentation is similar to the near island system except for the amplifier band-pass. The band-pass used for these stations is 0.01 to 5.0 Hz. The stations data are frequency modulated and transmitted on a radio voice channel to the Palmer Observatory. The data are demodulated, conditioned and recorded on a Develocorder at the Palmer Observatory.

ADDITIONAL NOS AMCHITKA EQUIPMENT

Accelerograph

A back-up strong motion seismograph system is located on the south end of

Amchitka to record major motions that would overload the velocity system. The NOS accelerograph is the basic instrument used for strong-motion earthquake investigation.

The instrument contains orthogonal, optical-mechanical accelerometers and two horizontal optical-mechanical displacement meters. The instrument records by a reflected collimated light beam from the detectors onto a 12" wide photo-sensitive strip chart. The source light and camera drive are activated by a pendulum starter. The starter is set to respond to motions as low as 0.5 mm.

The pendulum starter also activates an alarm system which is cabled to a warning light in the central recording site and to a buzzer and warning light in the on-site operator's living quarters.

The accelerometers are a simple unifilar suspension type with a small mirror attached to a loop-vane mass which allows direct recording by optical methods on the 12" strip photographic paper. The accelerometers have a pendulum period of 0.056 second, a static magnification of about 120, and sensitivity of 9.5 centimeters per gravity unit.

The displacement meters are inverted pendulums suspended by cross hinges and stabilized by a torsion wire located in line with the axis of rotation. A mirror is located on the axis of rotation to permit recording of the pendulum motion. The meter is set to have a 3.5 second period and a 5.0 static magnification.

Wood-Anderson

To help support the study to refine magnitudes of local earthquakes a Wood-Anderson seismograph is located on the south end of Amchitka. The Wood-Anderson is a torsion type seismometer consisting of a small mass suspended on a fine vertical fiber so that it acts as a horizontal pendulum. The natural period of the instrument is 0.8 second. The Wood-Anderson seismograph records on 35 mm film by direct optical-mechanical means with a one-half meter optical lever. The approximate magnification of the instrument is 1400 times the ground displacement.

Portable Microtremor Systems

Several sites on Amchitka and one site on Adak were instrumented temporarily for a seismic network refinement and a microtremor study. The sites were chosen according to their location within the existing seismic network and proximity to known geologic features. However, due to the high micro seismic background, which prevails during the winter months, the project can operate effectively only during the summer months.

The three to five portable seismic systems used for the microtremor program consist of 2 Hz vertical seismometers recording on smoked paper. The sensitivity of each system is 1.7 cm/cm/sec minimum to 2.7×10^4 cm/cm/sec maximum. The seismic signals are recorded on smoked paper by a galvanometer driven stylus which translates along the axis of a revolving drum.

The drum is covered with a smoked paper and the data are recorded as a continuous trace in helical form. Seismograms are preserved by dipping them into a clear shellac solution.

Tide Gauge

A Bristol type tide gauge is located on a pier in Constantine Harbor. The water levels are telemetered by an impulse duration method through a cable to the central recording site where it is recorded on a strip chart.

NOS AMCHITKA CANNIKIN CLOSE-IN PROGRAM

Six additional sites are to be instrumented 2 to 3 months before event Cannikin. The locations were selected for their proximity to significant geological features, and for their range and azimuth from Cannikin surface zero. The data will help establish the ambient local seismicity and will accurately relate local seismicity to significant geologic structures in the area of the Cannikin site.

The seismometers and amplifiers used for this array are the same type as used for the northern position of the tripartite array. The analog data are to be transmitted to the NOS Amchitka recording site by cable. The seismic systems will overload on the nuclear event but will maintain their integrity through the shock and will record all aftershocks. The systems will record approximately three months after the detonation of the Cannikin event.

OPERATION SCHEDULE

The general operations will follow the schedule below:

- Annual: Inspection/calibration of regional and near island.
- Monthly: Inspection/calibration of on-island seismometer with P.M. tape recorder and helicorders.
- Weekly: Change record on seismic magnetic tape back-up system, change record on oceanographic magnetic tape back-up system, change tide gauge record test power system and P.M. Develocorders.
- Daily: Change 16 mm film on Develocorders, check all recording systems, calibrate timing systems.

The data recorded per film or gram are as follows:

Develocorder #1 (16 mm film)

<u>Priority</u>	<u>Station</u>	<u>State</u>
4	ASD (Z)	Unfilt. low gain
7	ASB (V)	Unfilt. low gain
8	ASC (V)	Unfilt. low gain
6	AND (V)	Unfilt. low gain
5	ANA (V)	Unfilt. low gain
12	ASD (V)	Filtered
15	ASB (V)	Filtered
16	ASC (V)	Filtered
14	ANB (V)	Filtered
13	ANA (V)	Filtered
17	ASB (V)	Unfilt. low gain
18	ASB (N)	Unfiltered
19	ASB (E)	Unfiltered

Develocorder #2

<u>Priority</u>	<u>Station</u>	<u>State</u>
1	AMA (V)	Unfilt. low gain
2	SSI (V)	Unfilt. low gain
3	RAT (V)	Unfilt. low gain
9	AMA (V)	Filtered
10	SSI (V)	Filtered
11	RAT (V)	Filtered
20	AMA (N)	Unfiltered
21	AMA (E)	Unfiltered
22	SSI (N)	Unfiltered
23	SSI (E)	Unfiltered
24	RAT (N)	Unfiltered
25	RAT (E)	Unfiltered

Configuration #1 (Standard Operating Procedure)

Develocorder A	14-channel	Data total
Develocorder B	13-channel	25 channels
Helicorder A	1-channel (duplicates ASD)	
Magnetic tape	12-channel (duplicates top 12 priority)	

In case of loss of one or two recorders the given configurations are as follows:

Configuration #2 (loss of one Develocorder)

Develocorder	20-channel	Data total
Helicorder	1-channel	25 channels
Helicorder	2-channel	
Helicorder	2-channel	
Magnetic tape	12-channel (duplicates top 12 priority)	

Configuration #3 (loss of two Develocorders)

Helicorder	1-channel	Data total
Helicorder	2-channel	17 channels
Helicorder	2-channel	
Brush recorder	6-channel	
Brush recorder	6-channel	
Magnetic tape	12-channel (duplicates top 12 priority)	

Program integrity minimum is 8 channels in the priority line. The present date priorities were established from the in-progress analytical programs and are subject to adjustment with future developments in the analysis.

DATA ANALYSIS

The data recorded at Amchitka are mailed twice a week to the NOS Las Vegas field laboratory where preliminary record analysis is performed, Figures 8 thru 11. The records are inspected to assure quality continuity in the operations.

The pertinent seismic phases are scaled from significant events and put into a digital format as designed by NOS Analytical Department at Rockville. The data may be further analyzed, for parallel but subordinate programs, depending on data and time available. The completed data format and records are forwarded to the analytical center in Rockville, Maryland, where it is integrated with data from the Palmer Observatory and the world wide network.

The various analysis and reports as defined by the NOS Rockville Analytical Branch are prepared and published by the NOS Rockville office. The data are published in routine PDE cards and the yearly seismicity publication.

A monthly progress report is given to AEC and the analysis is published on a progress basis in scientific periodicals.

Principal participants in the program are:

Seismology Division, Chief	L. Murphy
Principal Scientist	E. Engdahl
Assistant Scientist	A. Tarr
Senior Analyst	S. Brockman
Geophysicist	W. Spence
Geophysicist	K. Bayer
Geophysicist	R. Mallis
Operations Manager	K. King
Operations Coordinator	D. Overturf
On-Site Operators	Alternate from Las Vegas Lab.
Palmer Observatory, Chief	H. Butler

Figure 1

Figure 2

AMCHITKA SEISMIC PROGRAM
NATIONAL OCEAN SURVEY
PROPOSED CANNIKIN PLAN

- Existing Permanent Stations
- ▲ Proposed Temporary Stations

Figure 3
20

NOS AMCHITKA SEISMIC SYSTEM

Figure 4

NATIONAL OCEAN SURVEY

SPECIAL PROJECTS PARTY

AMCHITKA SEISMIC SYSTEM ARRAY

AMCHITKA, ALASKA

Figure 5

Figure 6

Figure 7 - Station ASD NGC-
21 System
24

1. SHEMA, GRANITE MT., & CAPE SARICHEF (RELATIVE)

2. AMCHITKA NETWORKS (DOES NOT INCLUDE DEVELOCORDER RESPONSE)

Figure 8

AMCHITKA $\Delta = 160$ Km

← 1 MIN →

EUREKA, NEVADA $\Delta = 45.2^\circ$

← 1 MIN →

Figure 9 - Comparative Amchitka -
Eureka, Nevada
Seismogram

18 OCT 1970
H=21-48-25.7
51.49 N 178.96 E
DEPTH=21 KM MAG=0.4

Figure 10 Amchitka Develocorder
Seismogram

20 OCT 1970
H=19-05-28.6
52.02 N 179.36 E
DEPTH=182 KM

Figure 11 Amchitka Develocorder
Seismogram

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