Seismicity Report

GL07184

Induced Seismicity Studies at Roosevelt Hot Springs Thermal Area, Utah and Raft River Geothermal Project, Idaho, September 30, 1980

INTRODUCTION

Part of the plan for exploitation of geothermal resources involves reinjection of the fluid produced; it has been shown that such downhole fluid injection can trigger earthquakes; production of fluid may also induce seismicity. Induced seismicity is thus a possible by-product of geothermal power generation.

The contracts to which this report is addressed for study of possible induced seismicity at Raft River Geothermal Project, Idaho and Roosevelt Hot Springs thermal area, Utah, were placed with ESLD/UURI in September 1979, and April 1980, respectively. Seismic networks have been established in both areas and are currently monitoring seismicity unperturbed by production. The objective is to collect baseline seismicity data against which post-production seismicity will be compared. Roosevelt Hot Springs is planned to begin production in 1983; the schedule for bringing the demonstration plant at Raft River on line currently forcasts full-scale plant operation in February 1981.

IMPLEMENTATION

Raft River work before September 1979 consisted of a few planning sessions and trips to the Raft River site to evaluate equipment and sites, and to make plans to re-establish a seismograph array there. EG&G operated a three station array at Raft River for about two years ending in January 1978.

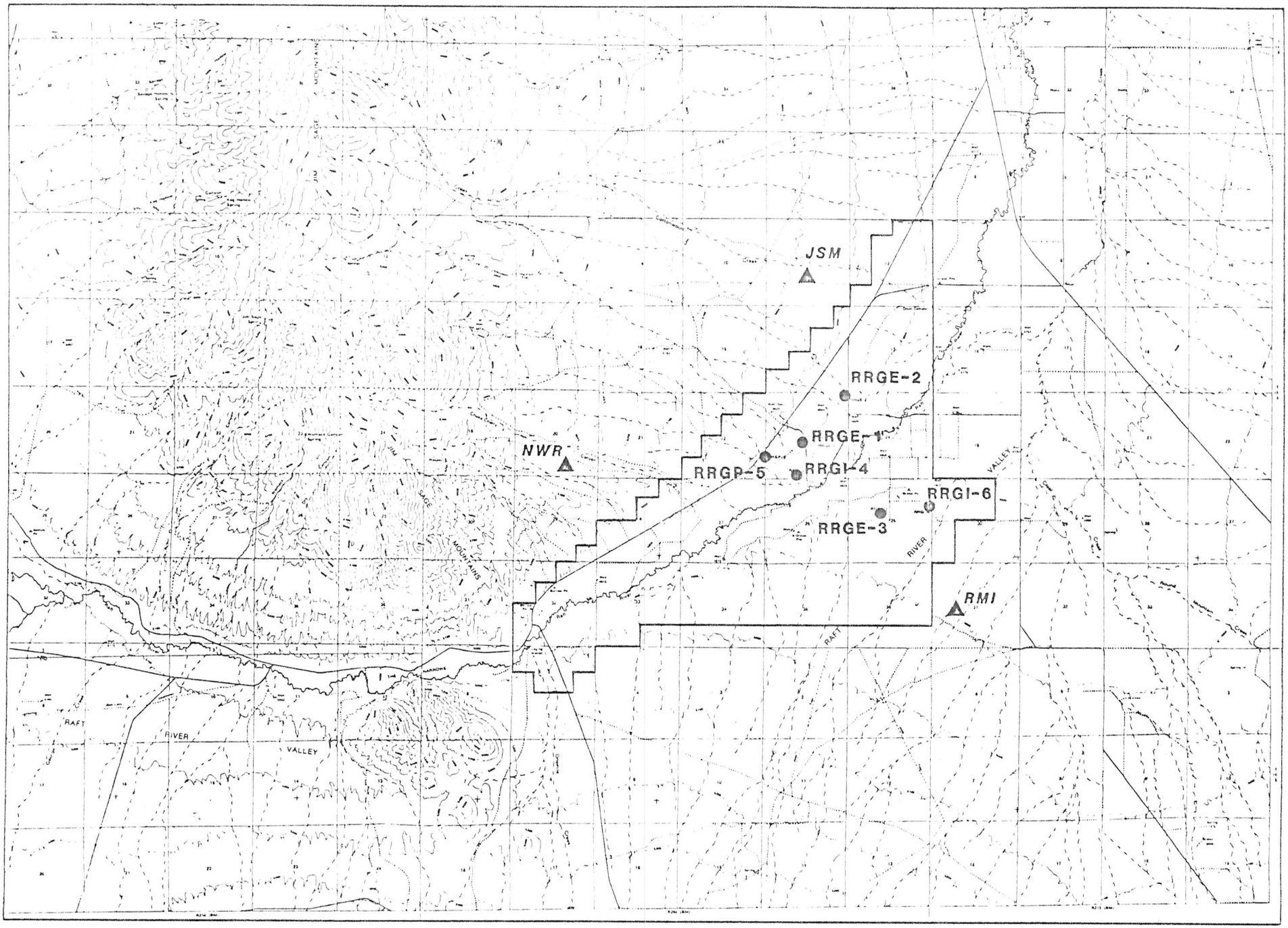


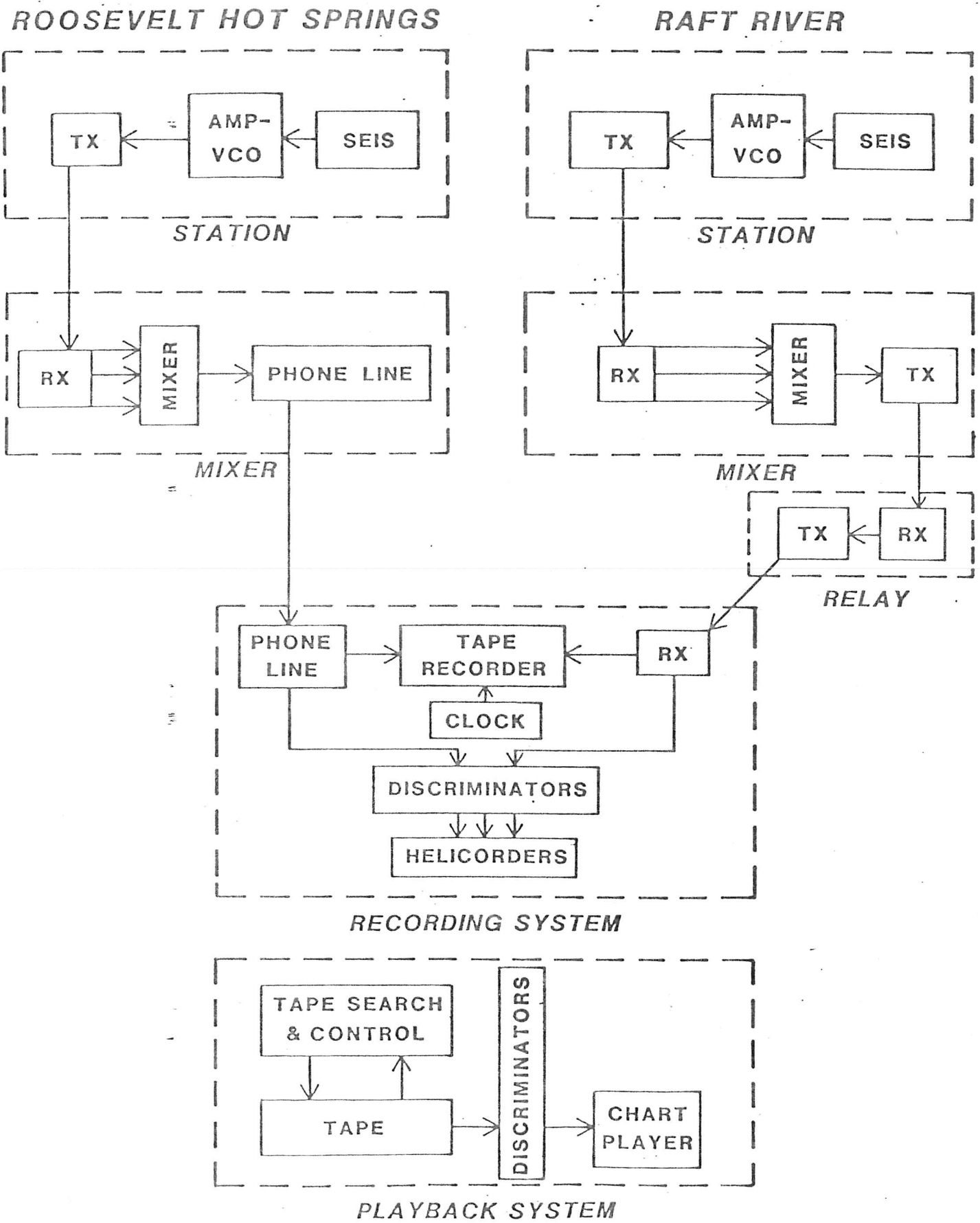
Fig.1 SEISMOGRAPH ARRAY AT RAFT RIVER

The records are sufficient only to support a qualitative estimate of activity; no earthquakes were recorded within the array during its operation. Due to the low gain, only the larger regionals and teleseisms were recorded.

Ordering of equipment and frequency permitting for Raft River began in September 1979. Site studies with portable seismographs were conducted in October and November, and the site-permitting process was started. Construction and instrumentation of the field sites began in March 1980, following receipt of site permits from BLM. Frequency permits were received in mid-April, which allowed frequency-crystals for the radios to be ordered. At the request of DOE/ID, portable seismographs were installed on 1 April 1980 at the permanent sites to monitor a planned injection test in mid-April. These portables were removed on 2 May 1980, at the request of their owner due to a prior commitment. Unfortunately, the planned injection test was postponed, and occurred during the gap in instrumental coverage. The radios were received on 9 May 1980. The radios were installed and recording of the telemetered data began on 12 May 1980. There were some initial problems with some of the older equipment, but since June 1980 data quality from the Raft River array has been good to excellent. Figure 1 shows Raft River geothermal wells and the seismograph array.

Seismic data are transmitted and recorded by standard telemetry techniques; Figure 2 shows a schematic diagram of the system. Field equipment at Roosevelt Hot Springs consists mainly of Geotech S-13 seismometers, Develco VCO-amplifiers and Monitron radios; a few Emheiser-Rand VCO's and radios are also in use as well as three L-4 seismometers. Field equipment at Raft River

FIG. 2 DATA ACQUISITION SYSTEM



consists of Geotech S-500 seismometers, Sprengnether VCO-amplifiers, and Monitron radios. Mixed seismic signals and time are recorded on a Bell and Howell VR-3700 B tape recorder. An identical tape recorder plays back through Develco discriminators onto an 8-channel Gould Brush chart recorder.

The Three stations in the Raft River Valley transmit their FM-encoded signals to a relay in the Black Pine mountains south of the valley. There the signals are mixed and transmitted to another relay, near the south end of the Great Salt Lake. This relays the signals across the Salt Lake Valley to the ESLD recording facility, where the signal is recorded onto magnetic tape.

Figure 3a shows the Roosevelt array's telemetry configuration in April 1980. The received signals at Delta, Utah, were placed on telephone lines for transmission to Salt Lake City. Transmission noise was entering the system in the BAP-Delta radio link. To eliminate this noise, the telemetry configuration was changed to that shown in Fig. 3b. This resulted in an immediate improvement in data quality, as shown in Figures 4a and b. Data quality from the Roosevelt array has been good to excellent since the change in telemetry.

The plans for production at Roosevelt Hot Springs have recently been submitted by Phillips Petroleum Co., the unit operator, to the USGS for approval; in light of these plans another site survey was conducted and the following changes in the Roosevelt Hot Springs array are planned (see Figure 3): 1) to move station LWA approximately 2 km NNW, 2) to move station MWA approximately 1 1/2 km E, and 3) to establish a three-component station in an abandoned mine approximately 1 km North of well #82-33. LWA currently

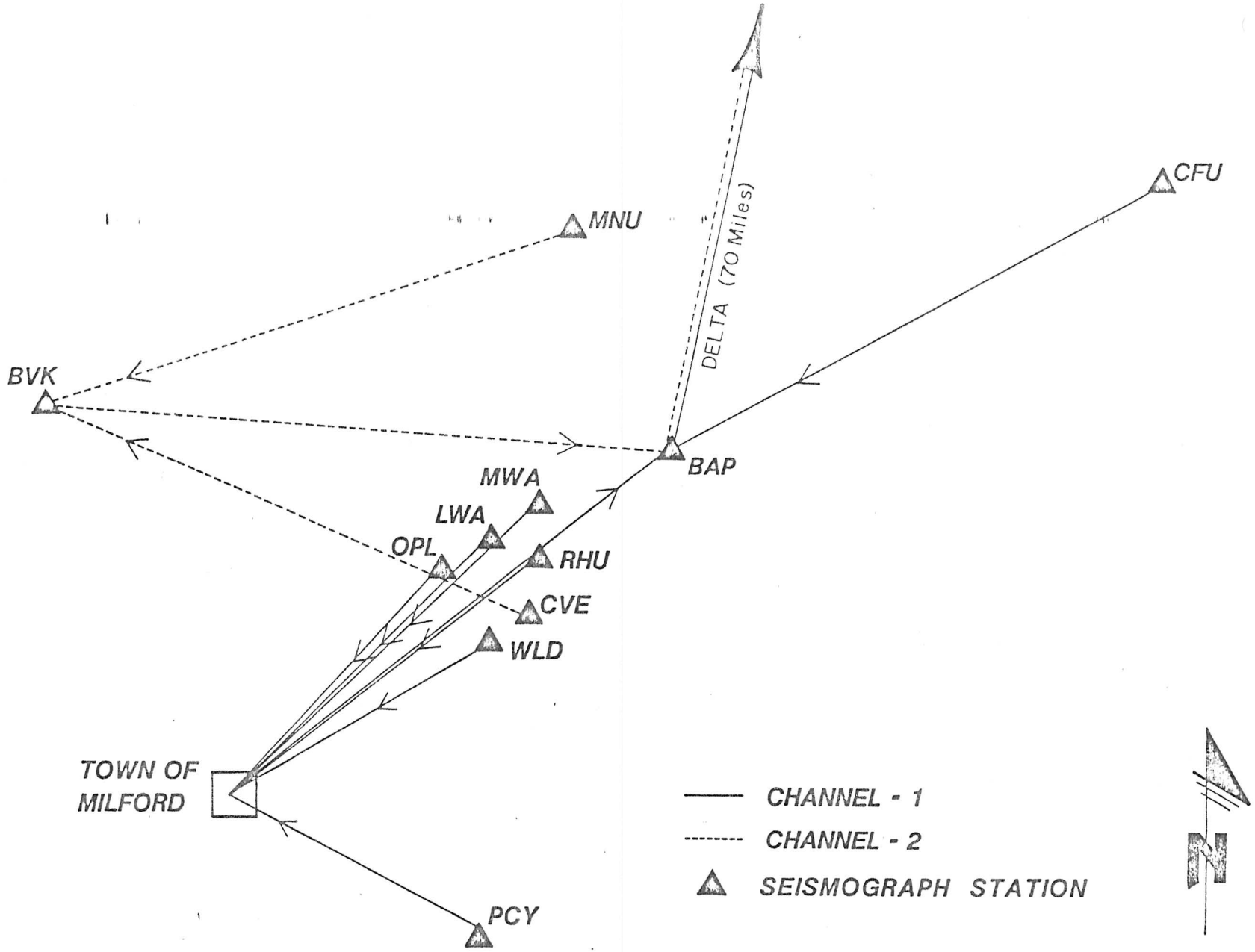


FIG. 3a PRIOR TELEMETRY CONFIGURATION

Ut/RHS/S-002

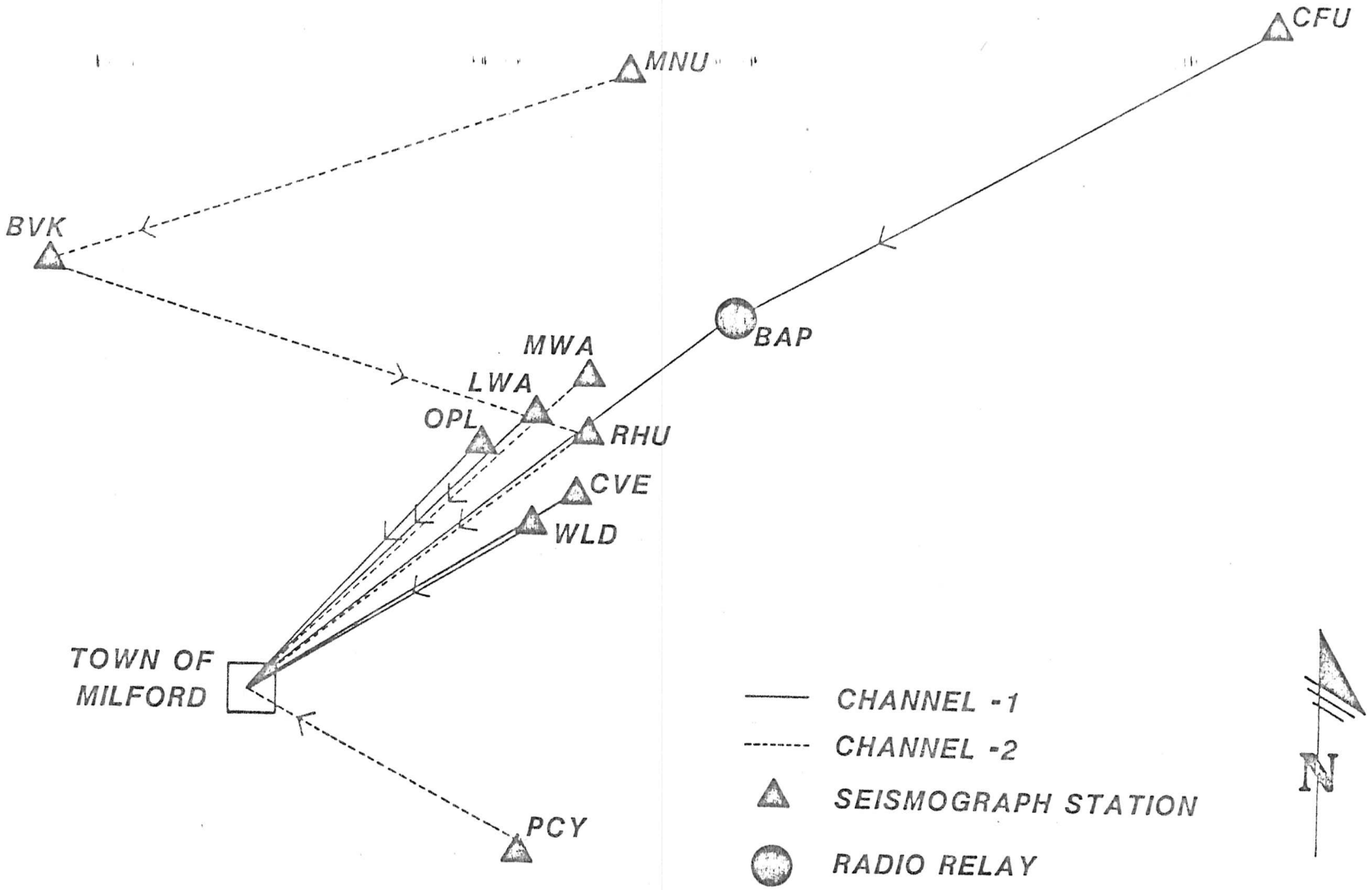


FIG.3b CURRENT TELEMETRY CONFIGURATION

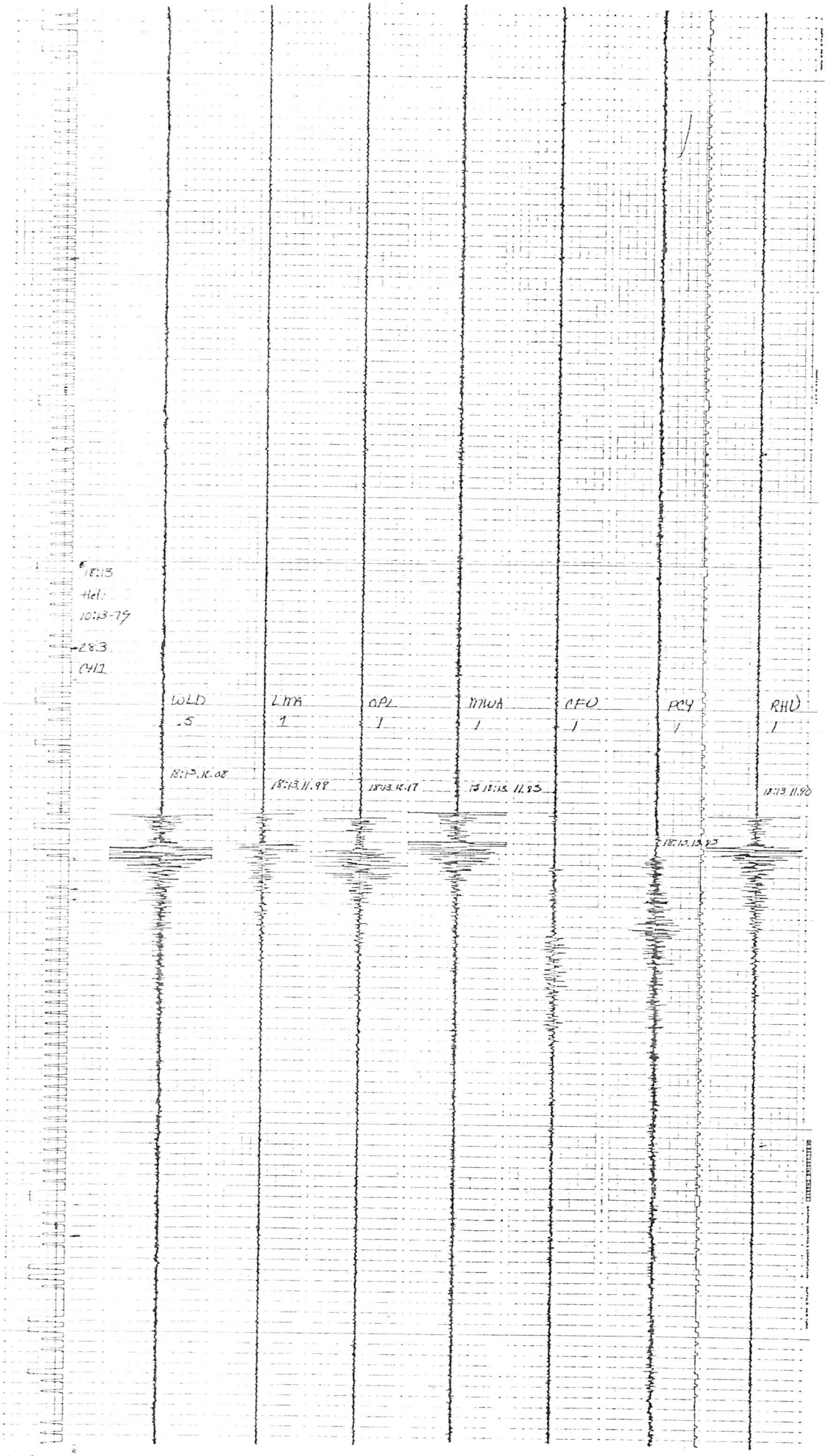


Fig. 2a TYPICAL SEISMOGRAM, OLD TELEMETRY

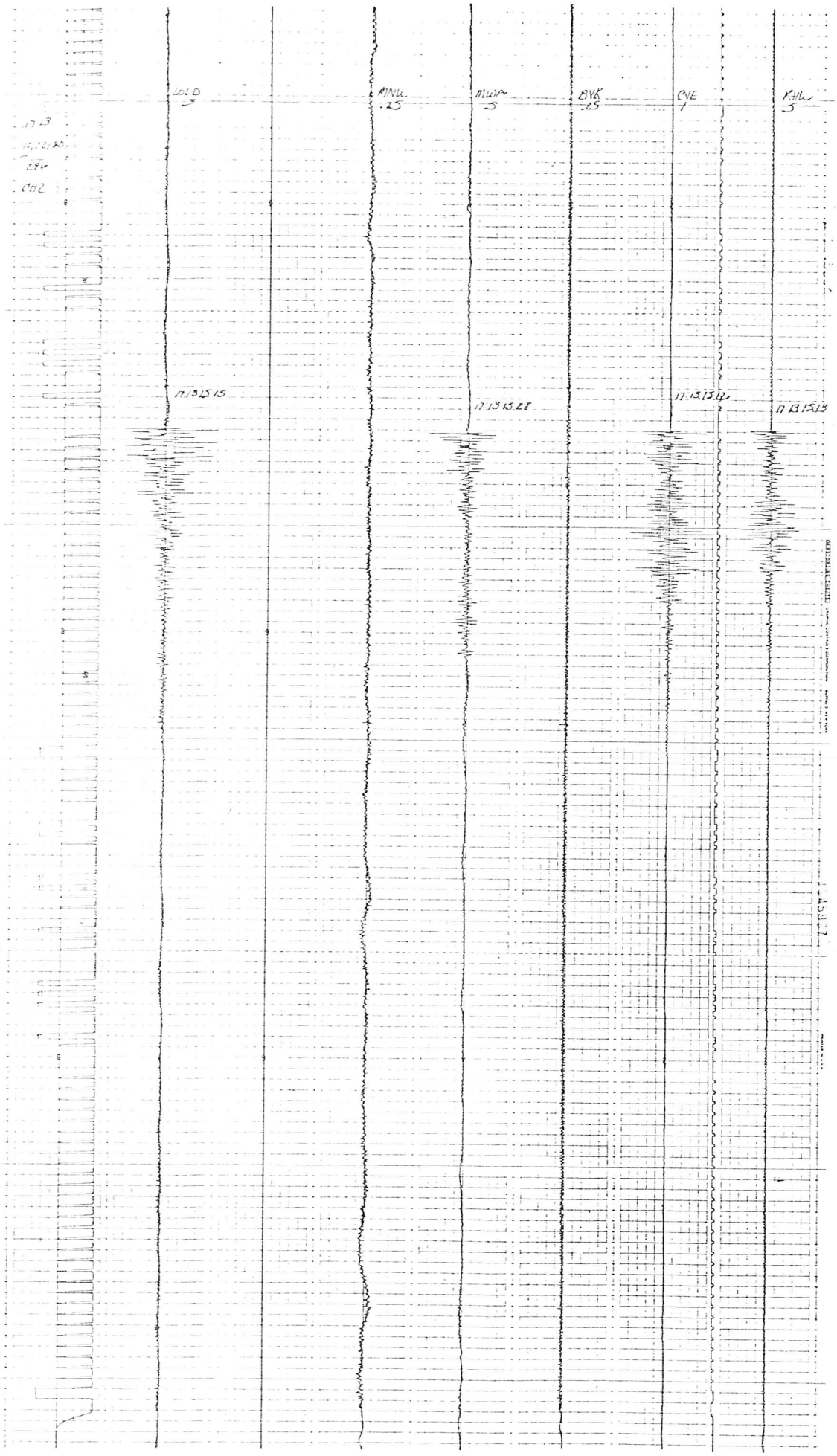
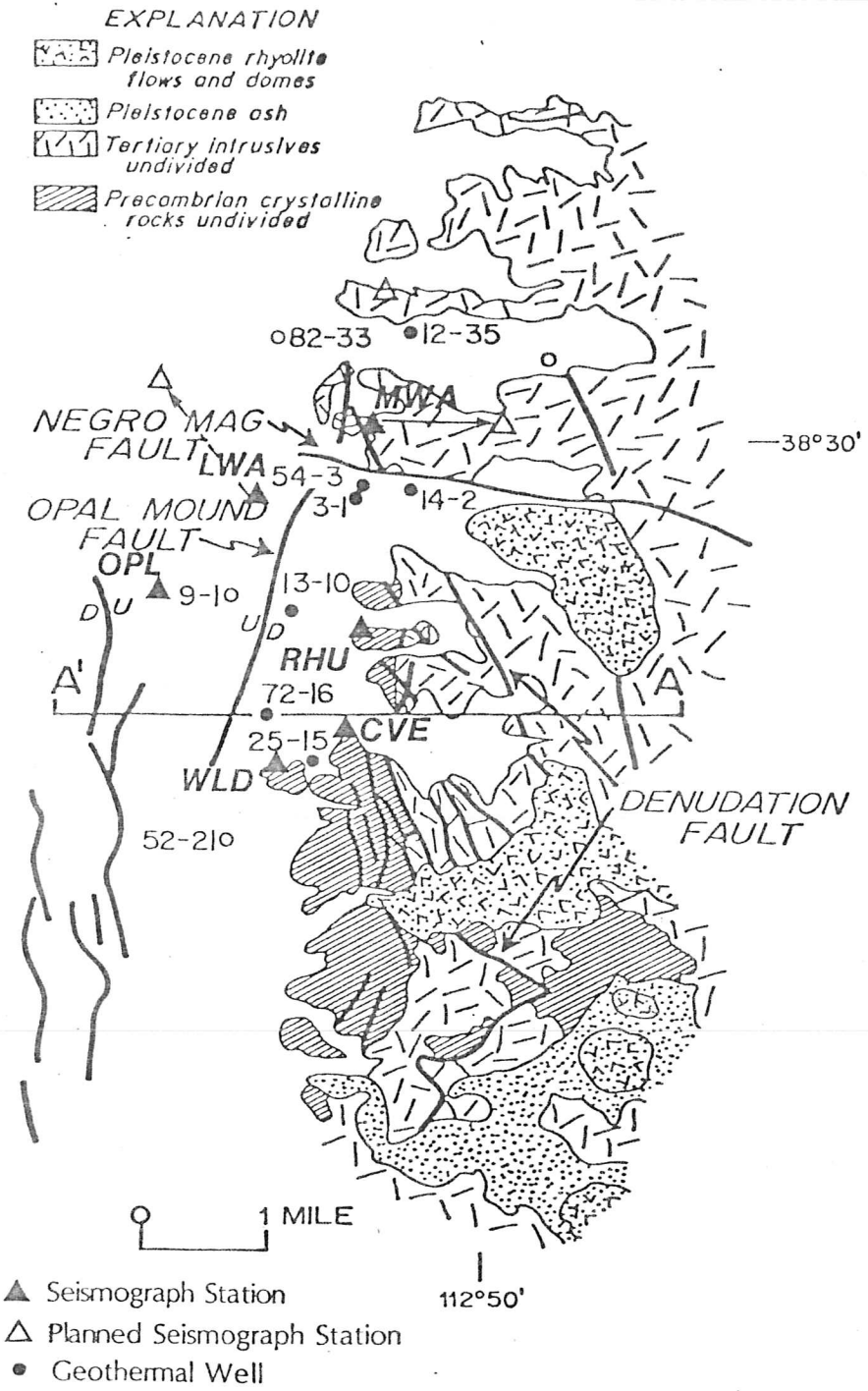


Fig. 4b TYPICAL SEISMOGRAM, NEW TELEMETRY



GEOLOGIC STRUCTURE AND SEISMOGRAPH STATIONS

Roosevelt Hot Springs Production Zone

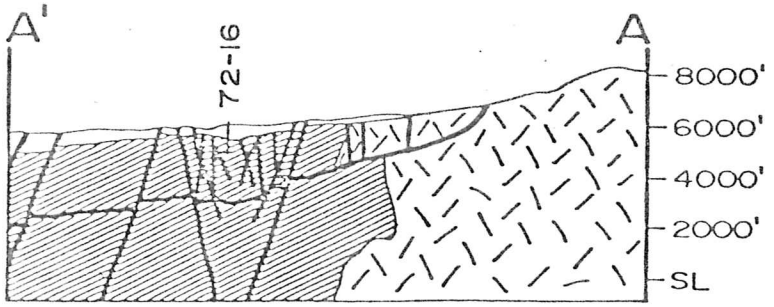


Fig. 5

occupies the planned plant site; the move of LWA and MWA and the installation of the three-component station will place the entire production/reinjection area within the array. See Figure 5 for current and proposed stations.

ANALYSIS

Earthquakes have been located on a production basis at Roosevelt Hot Springs since September 1979. Velocity models in the Roosevelt Hot Springs are zone well-constrained; reflection and refraction surveys have been run across the area, and velocity data are available from some of the geothermal wells. Regional and teleseismic events at Raft River record well and one local event (S-P time approx. 8 sec) has been recorded; no earthquakes have been recorded within the Raft River array.

As Figures 6a through n show, seismicity in the immediate vicinity of Roosevelt Hot Springs is of a low level and somewhat episodic in nature. To date, no earthquakes have been located within the production zone or on the Opal Mound fault, which is thought to be the system's main hot water conduit. The linear trend of earthquakes across the Mineral Mountains may lie on an eastern extension of the Negro Mag Fault; a few earthquakes may be associated with range front faults on the east side of the Mineral Mountains. Unfortunately, due to the station distribution, these locations are not well

constrained in the east-west direction. Therefore, the linearity of the epicenters along extension of the Negro Mag Fault may be a manifestation of this lack of control. We plan to improve these locations by use of a joint-hypocenters-location program which has recently been implemented on the UURI PRIME computer. The reality of the occurrence of these earthquakes on the Negro Mag Fault is important to establish. The fault has been postulated to be a possible recharge conduit for the Roosevelt geothermal field. If it is connected to the geothemal field, production may affect seismicity on the fault. For this reason, we plan to improve locations of earthquakes in this region and establish a baseline for the seismicity prior to production.

The activity in the NE corner of the map is associated with the Cove Fort geothemal system. The activity between the Mineral Mountain and Cove Fort is of uncertain origin; however these earthquakes are definitely located beneath the alluvium-filled valley between Cove Fort and the Mineral Mountains.

Field calibrations have been performed on both the Raft River and Roosevelt arrays; these are currently being reduced to yield amplitude of grand motion and system frequency response. After calibration is complete, our first motion and amplitude data will be studied in an attempt to determine earthquake focal mechanisms, magnitudes, and recurrence statistics.

Synthesis of existing velocity surveys at Roosevelt Hot Springs is underway; this will yield a more accurate model of cyustal velocities, for more accurate location of earthquake hypocenters.

Computer program JHD 77 has recently been implemented on the UURI PRIME

400 computer; it will be used for joint determination of hypocenters and station corrections. These will produce more accurate hypocenter locations. An FFT program is also operational; this is being used for calibrations and will later be used for calculation of the spectra of earthquakes.

Measurement of the seismic source parameters of dislocation, rupture area, stress drop, and seismic moment will be attempted. This work will be done in co-operation with Dr. George Zandt of University of Utah Seismograph Stations. These parameters are of interest for both naturally-occurring and induced earthquakes, and as a possible discriminant between them. Spectra of recorded earthquakes will be computed; it is possible that the source parameters will be determinable from those spectra. A more likely technique is to attempt to infer these parameters for a group of events by using the coda method.

Other work will be done hopefully in the future includes comparison of Roosevelt Hot Springs and Raft River with other case histories of production/injection related seismicity and subsidence, and mathematical modeling of the pore-pressure distribution within the reservoir due to production and injection.

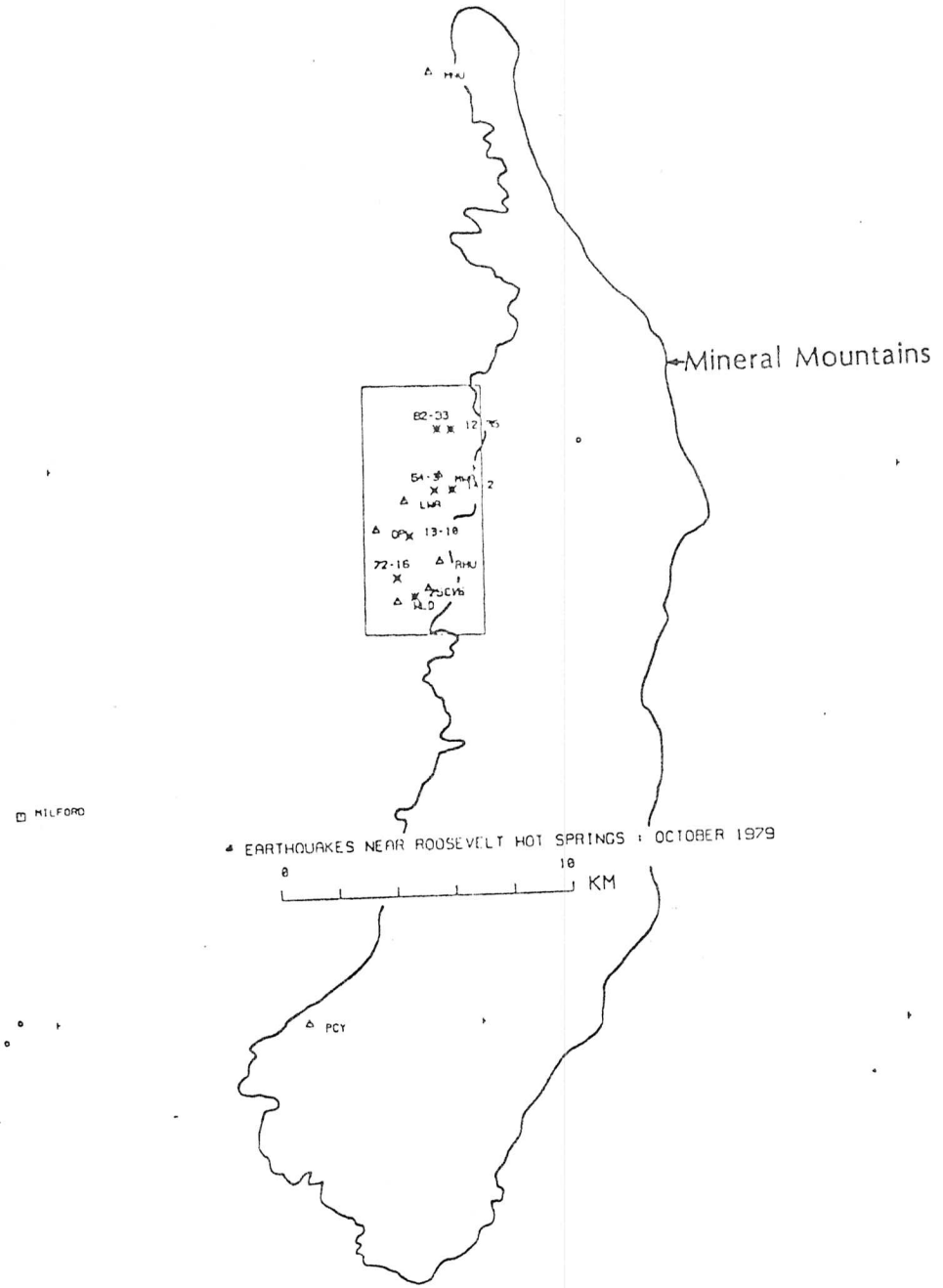

Mineral Mountains
MILFORD
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : OCTOBER 1979
0
10
KM

Fig 3a

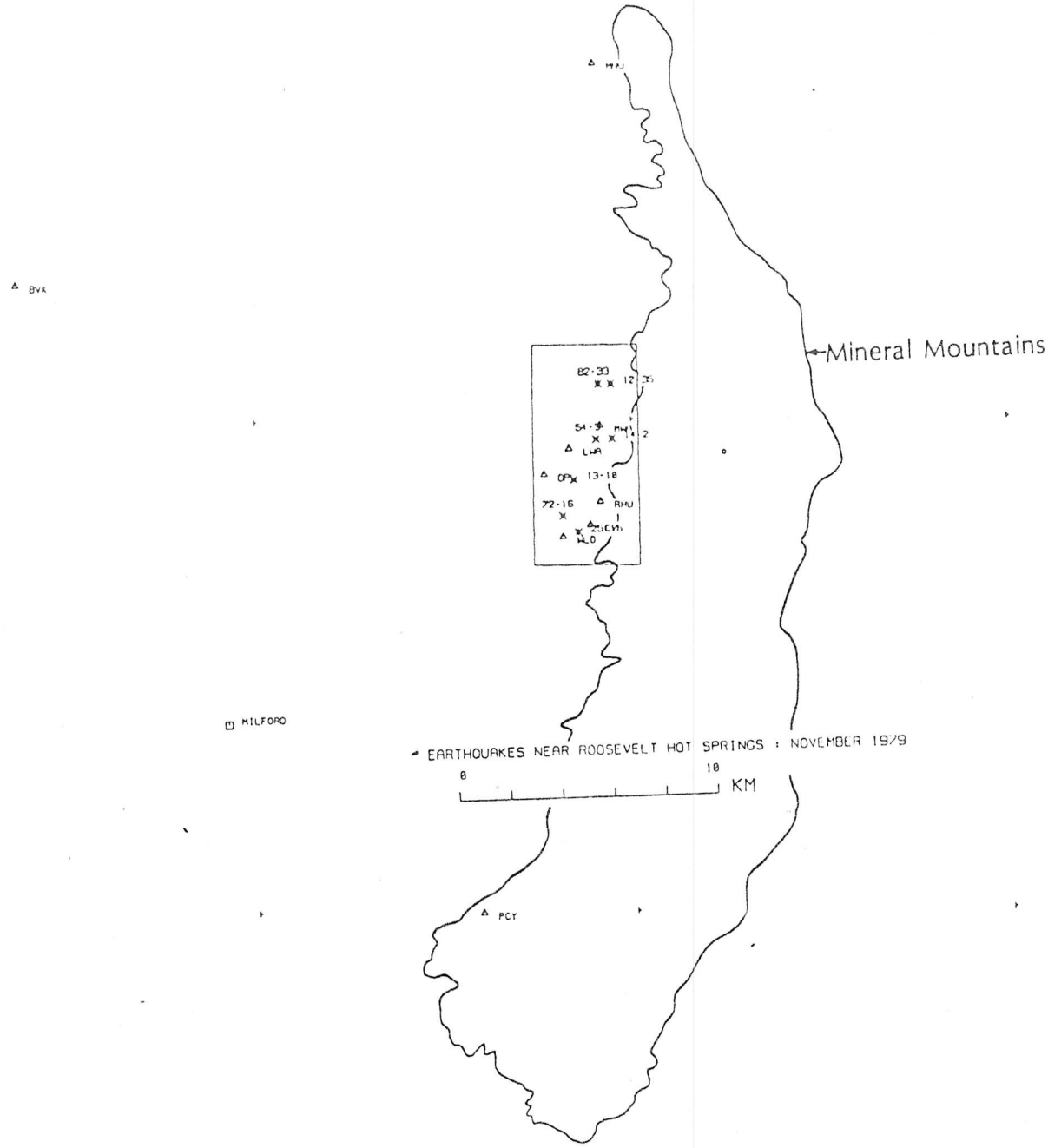

Mineral Mountains
MILFORD
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : NOVEMBER 1979
0
10
KM

Fig 6b

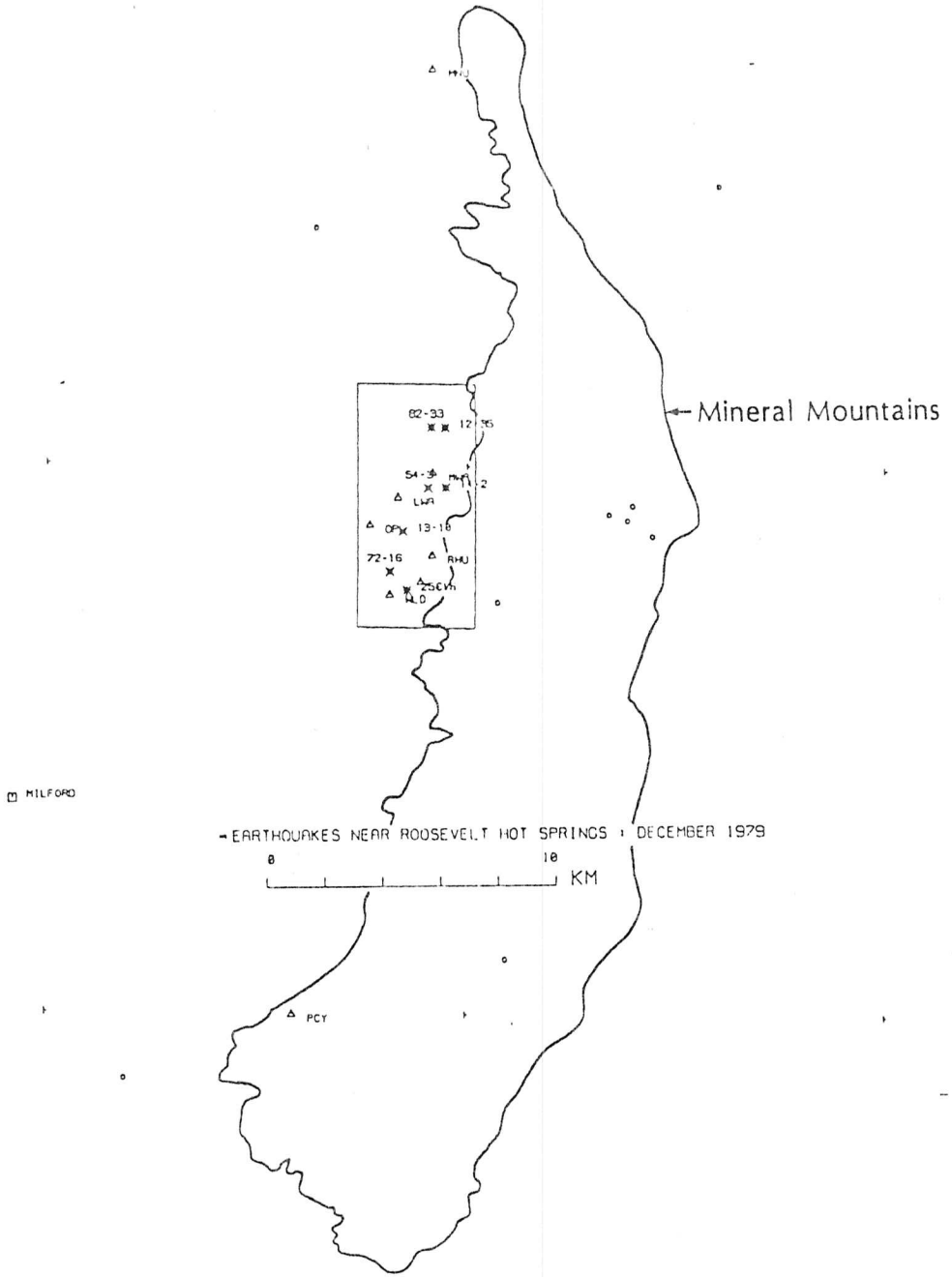

Mineral Mountains
BVK
MILFORD
PCY
CFU
LWR
RHU
82-33
72-16
13-18
25 KM
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : DECEMBER 1979
0
10
KM

Fig. 6c

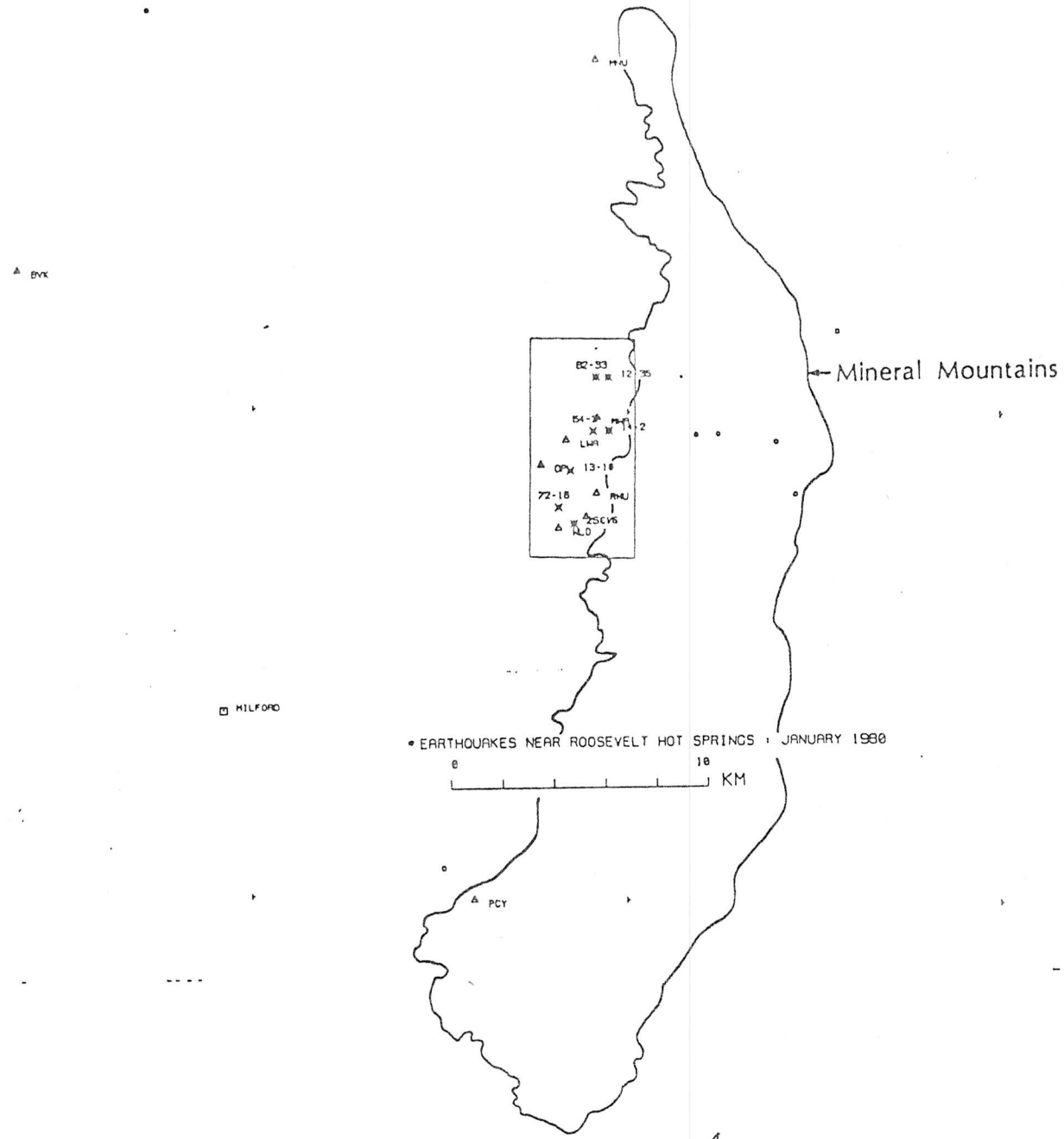

Mineral Mountains
MILFORD
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : JANUARY 1980
0
10
KM

Fig. 6d

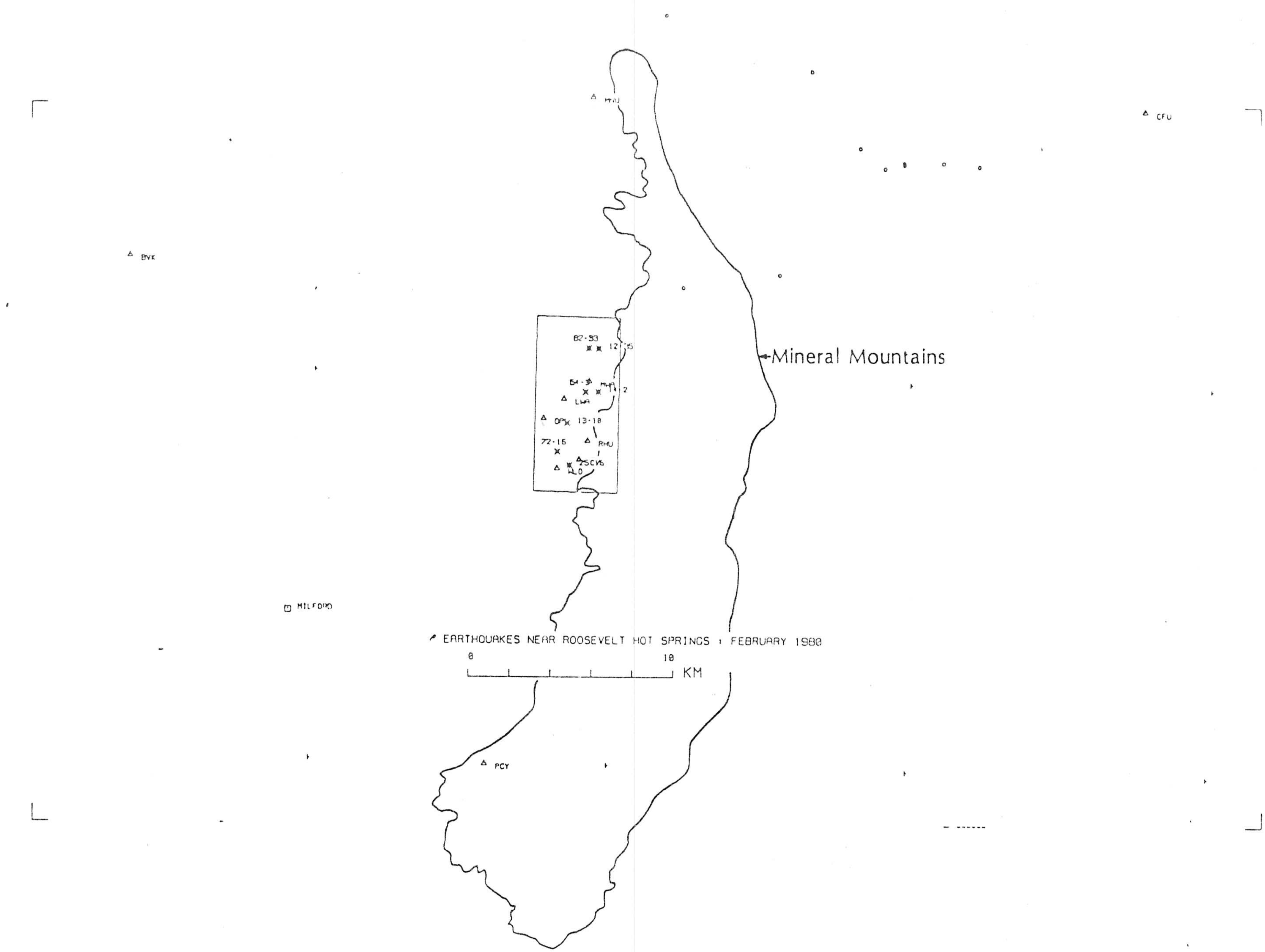

BVK
CFU
Mineral Mountains
MILFORD
PCY
RHU
LMA
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : FEBRUARY 1980
0
10
KM

Fig. 6e

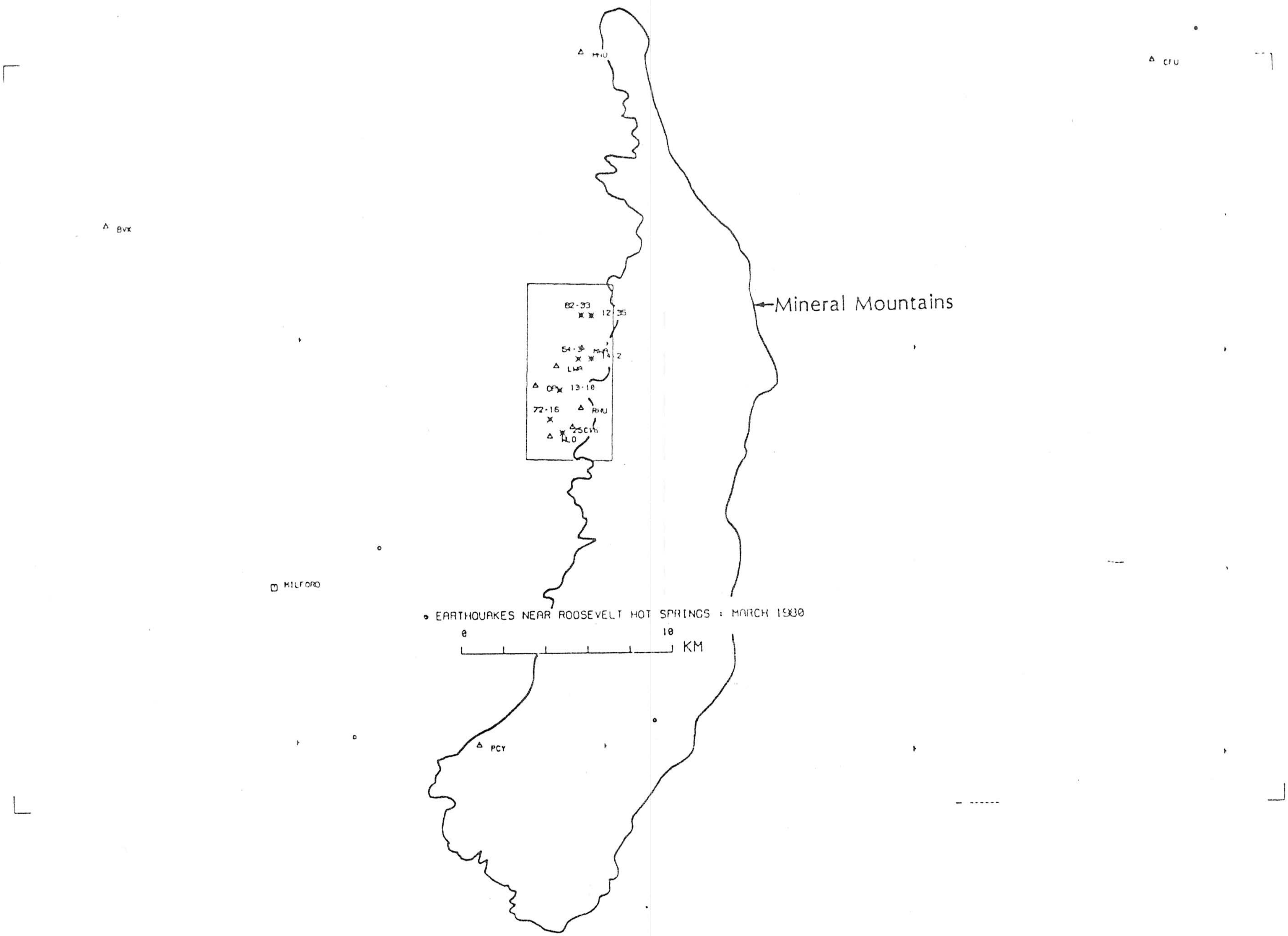

EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : MARCH 1980
0
10
KM
Mineral Mountains
MILFORD
BVX
CFU
PCY
LWA
RHU
82-33
12 35
54-3
13-10
72-16
25 ch

Fig. 6f

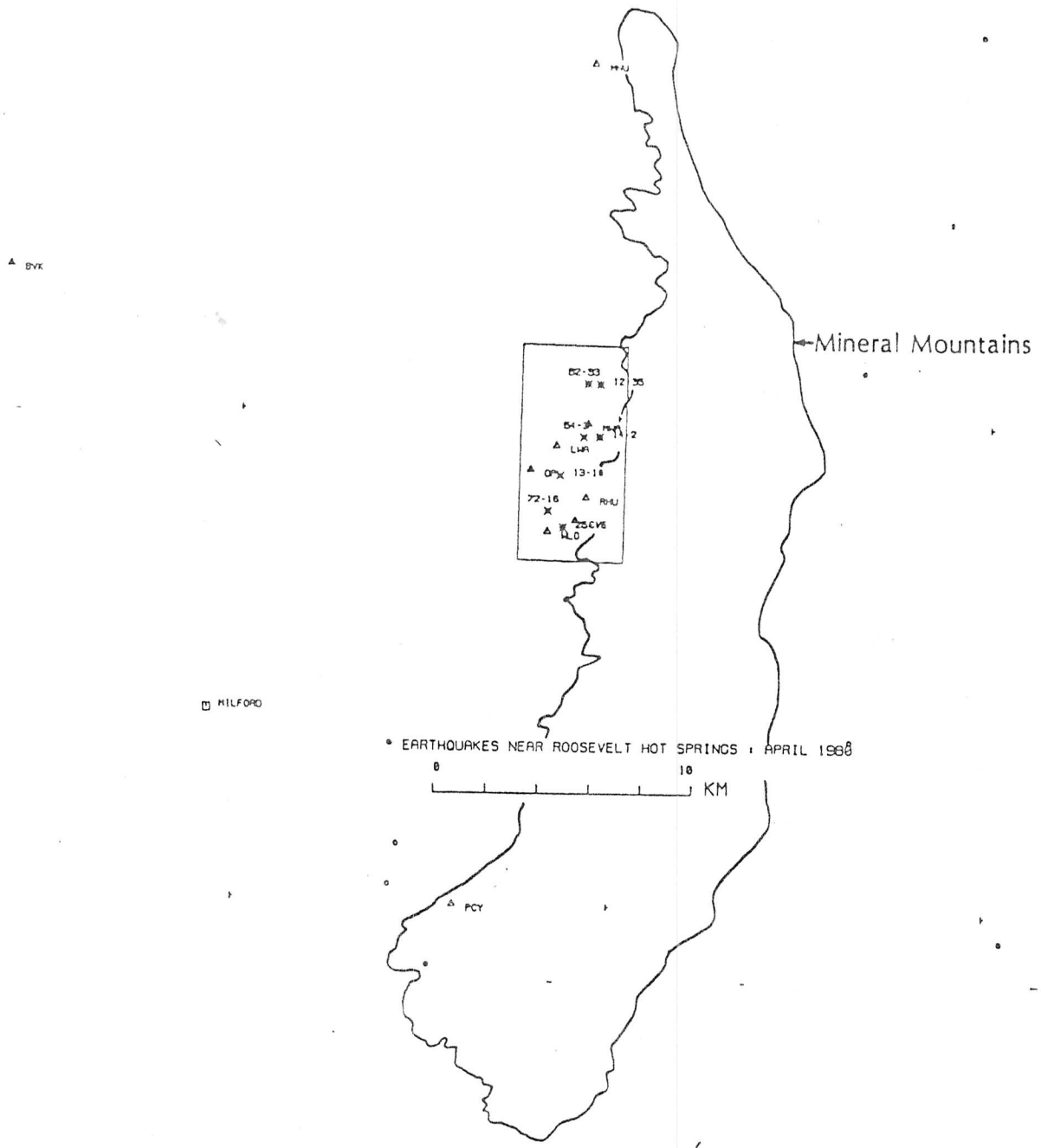

Mineral Mountains
MILFORD
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : APRIL 1968
0
10
KM

Fig. 6g

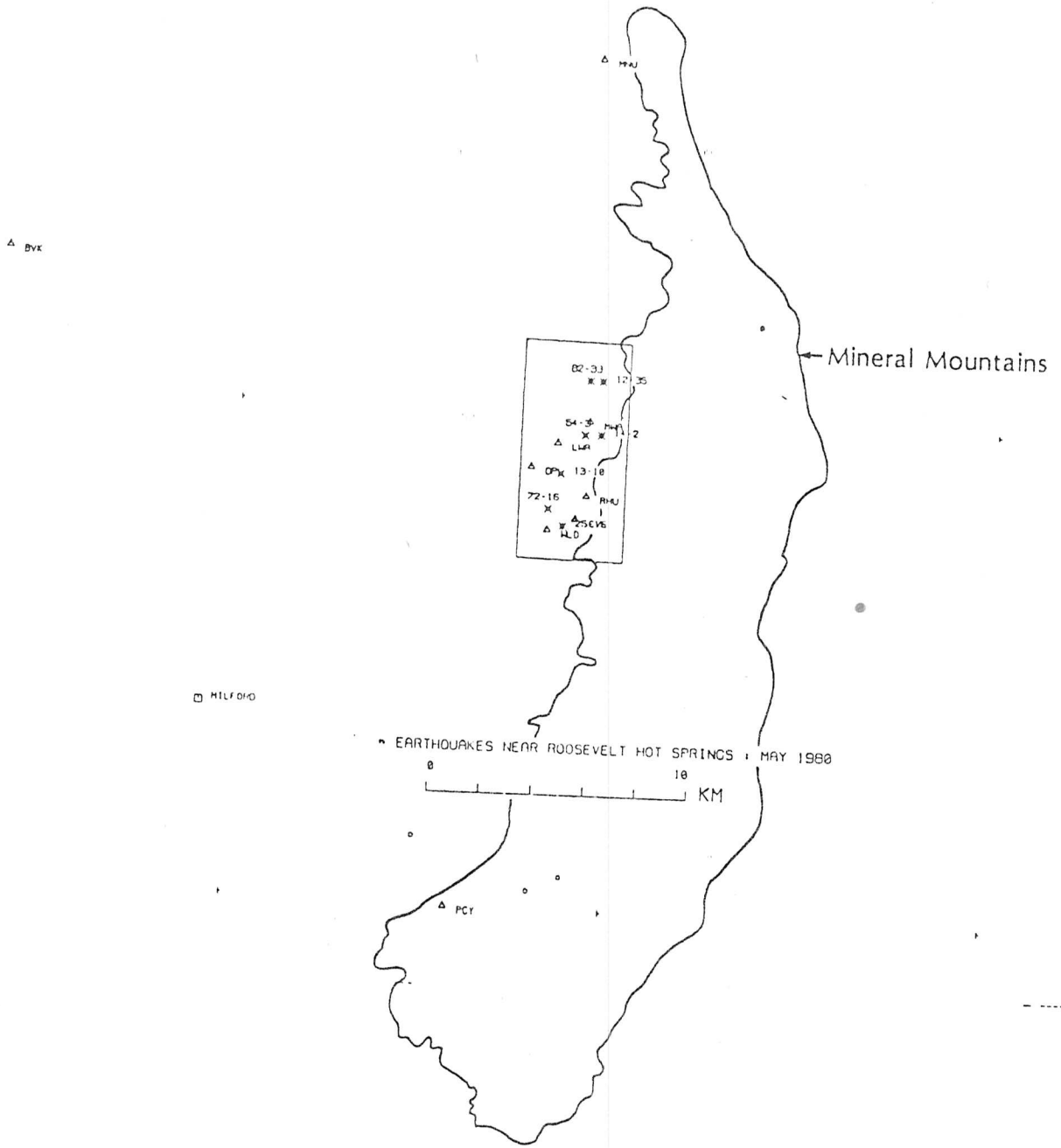

Mineral Mountains
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : MAY 1980
0
10
KM
MHU
CFU
BVK
MILFORD
PCY
82-33
12-35
54-35
14-2
LHR
OPK
13-18
72-16
RHU
25CM6
NLO

Fig. 6h

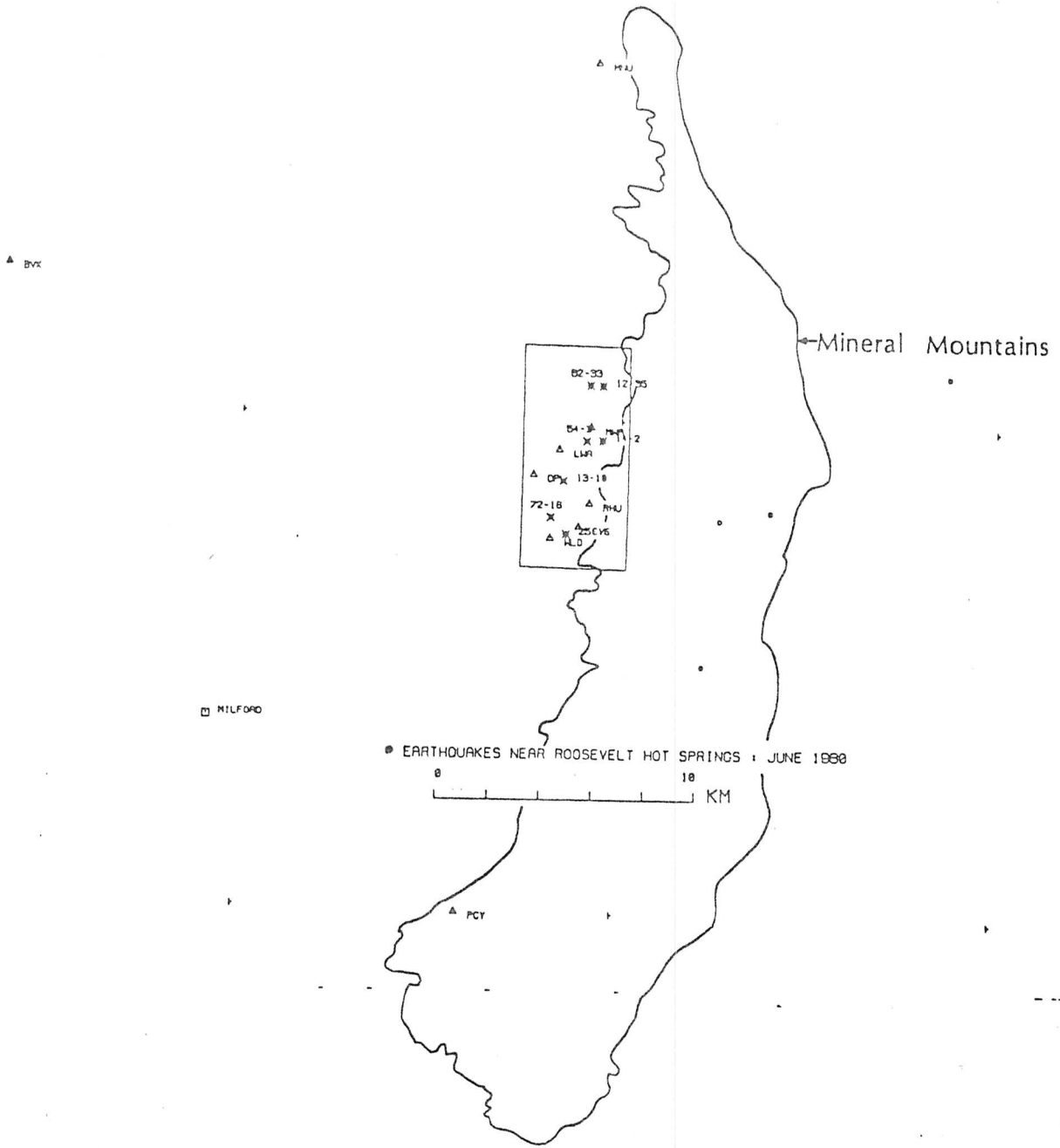
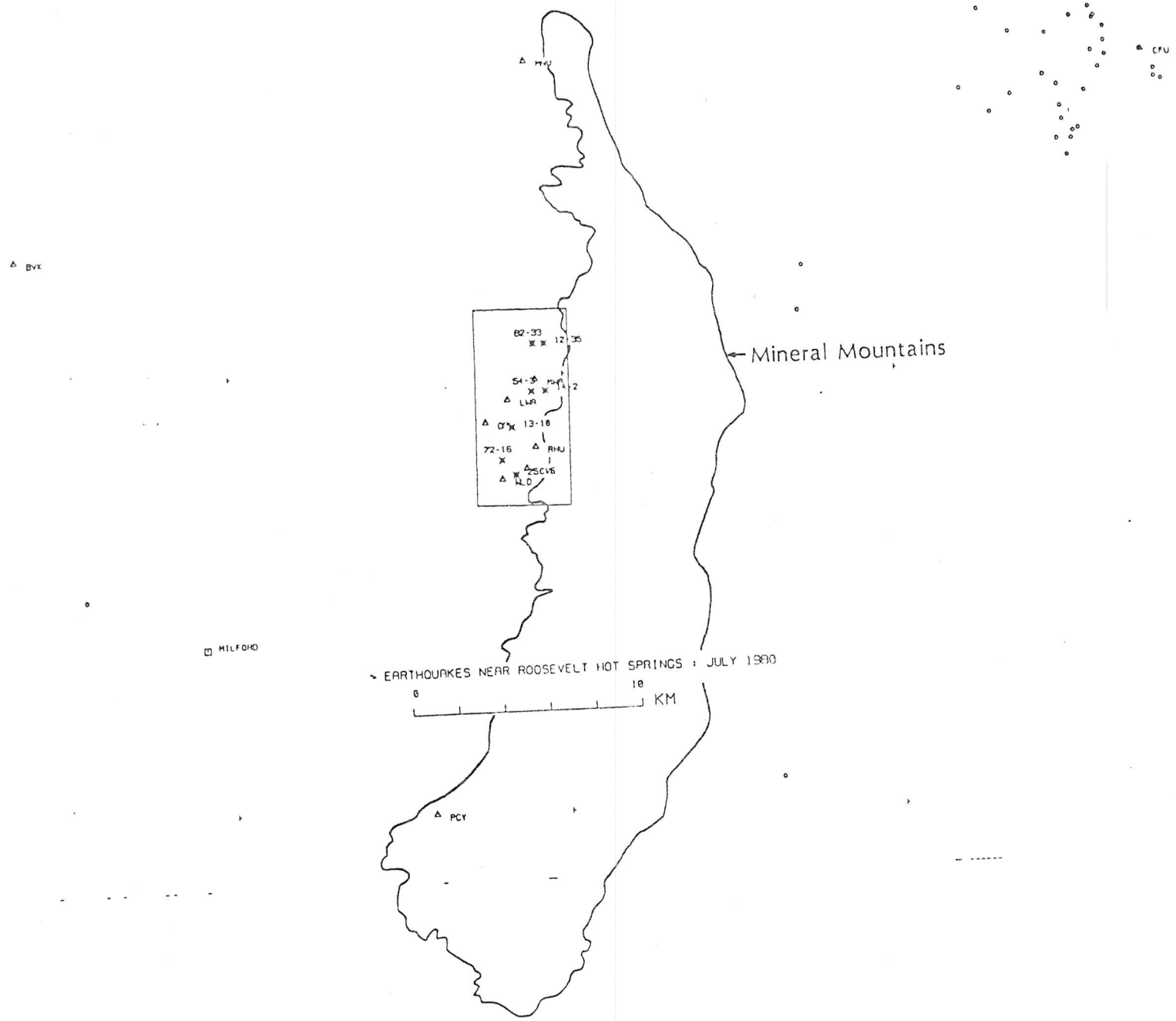

Mineral Mountains
MILFORD
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : JUNE 1980
0
10
KM

Fig. 6


MHU
CFU
BVX
82-33
12-35
54-35
MHP
12-2
LHR
07
13-18
72-16
RHU
25CV6
RLO
Mineral Mountains
MILFORD
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : JULY 1980
0
10
KM
PCY

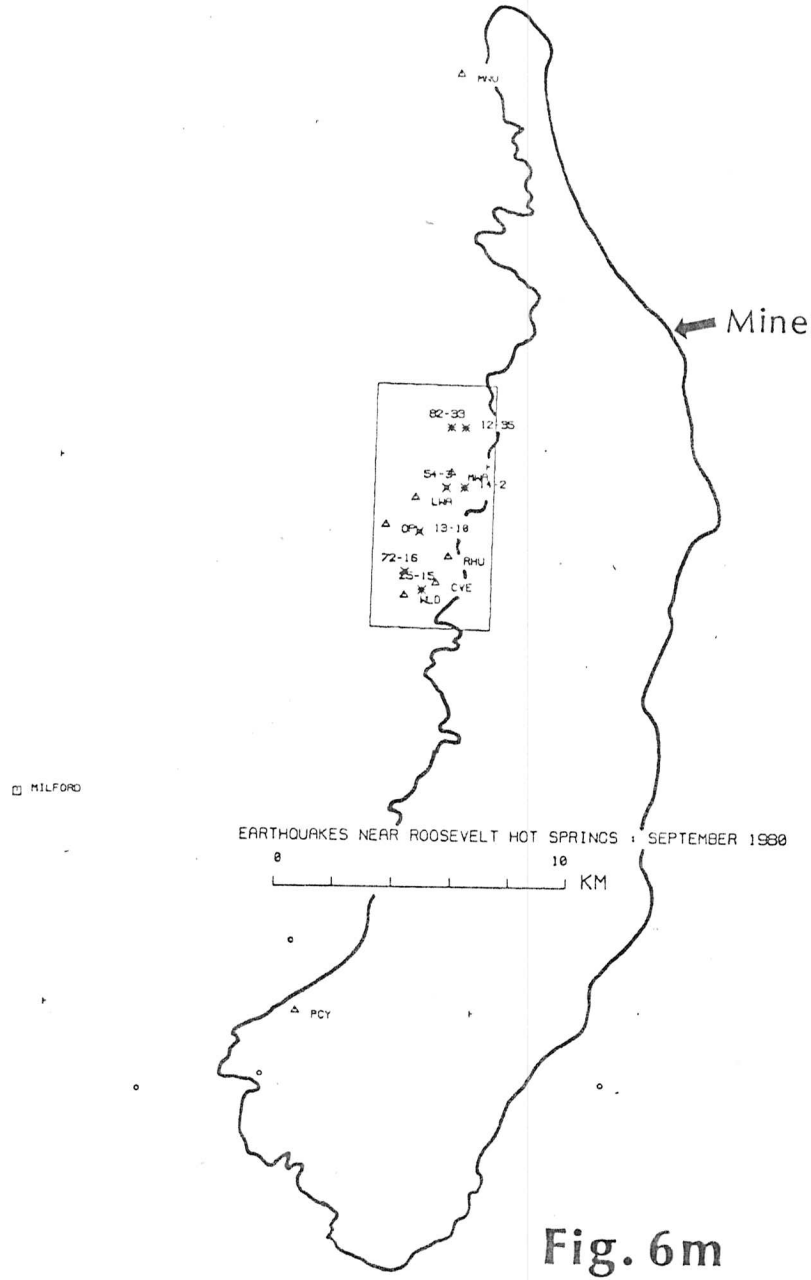

MVU
CFU
BVK
Mineral Mountains
82-33
12-35
54-3
14-2
LHH
OPX
13-18
72-16
RHU
25-15
CVE
HLO
MILFORD
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : SEPTEMBER 1980
0
10
KM
PCY

Fig. 6m

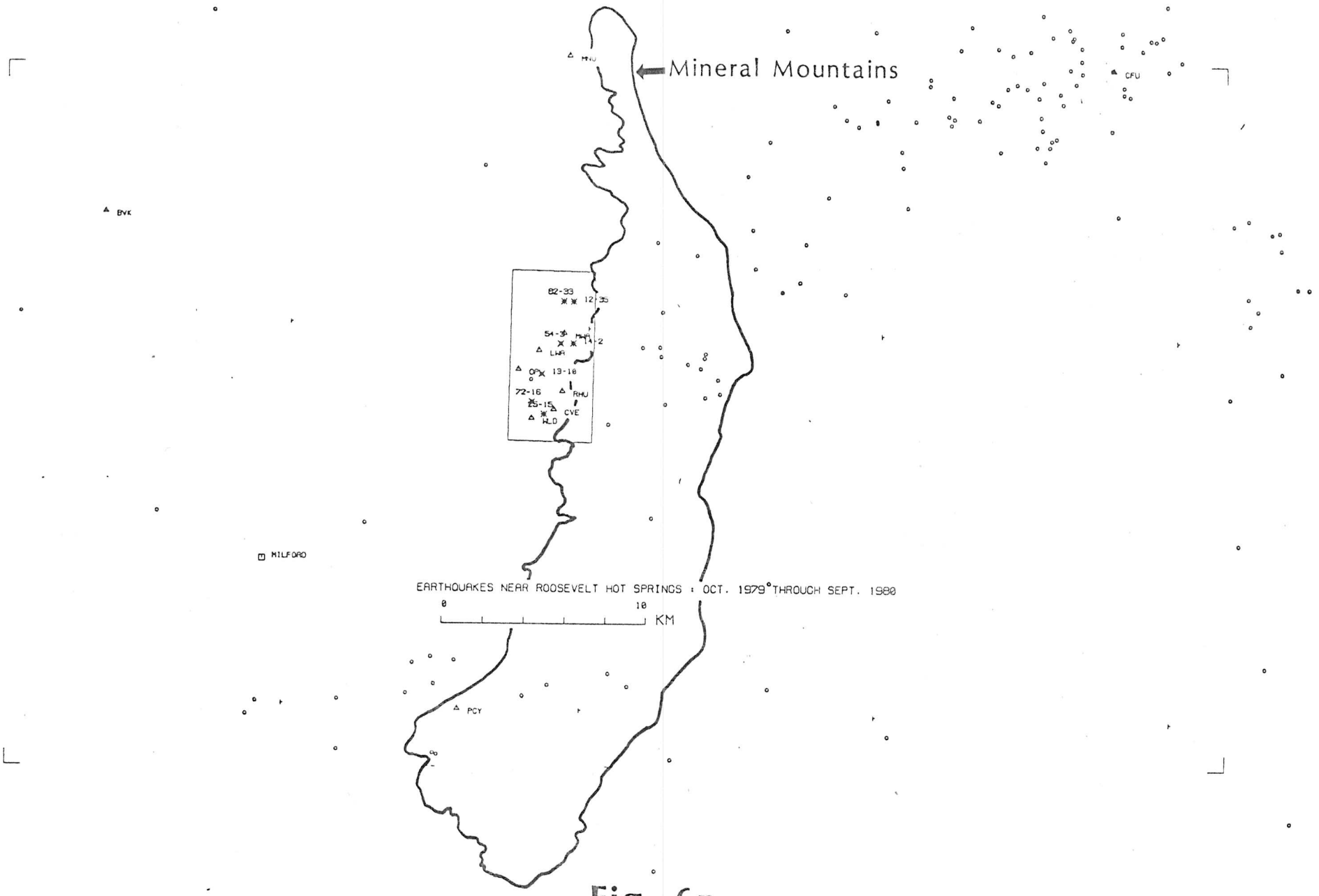

Mineral Mountains
MHU
CFU
BVK
MILFORD
82-33
12-35
54-34
MHR
14-2
LHR
OPX
13-16
72-16
RHU
25-15
CVE
WLO
PCY
EARTHQUAKES NEAR ROOSEVELT HOT SPRINGS : OCT. 1979 THROUGH SEPT. 1980
0
10
KM

Fig. 6n