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SEISMICITY REPORT ON BLACK ROCK DESERT PROJECT NORTHWEST NEVADA

AUGUST 25, 1974

MICRO GEOPHYSICS CORPORATION

1944 Goldenvue Drive Golden CO 80401 303/279-5412

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Gerlach, Nevada
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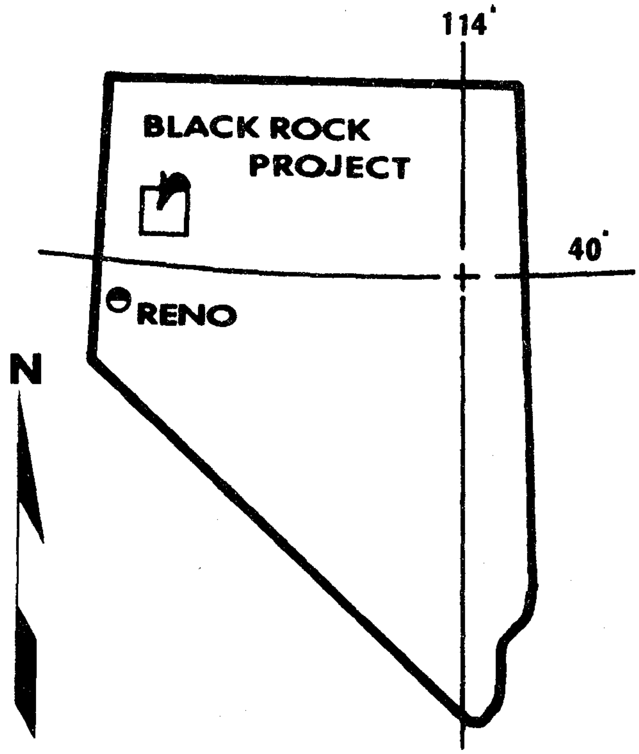
CAPITAL SYSTEMS GROUP, INC.
6110 EXECUTIVE BOULEVARD
SUITE 250
ROCKVILLE, MARYLAND 20852

SEISMICITY REPORT ON BLACK ROCK DESERT PROJECT-NORTHWEST NEVADA

Abstract

For the purpose of evaluating the geothermal potential of the area near Gerlach, Nevada, five high-gain (3-6M), high-frequency (1-30hz) seismic arrays with a detection threshold below magnitude -1.0 were operated for a total of 30 days in May and June of 1974. The area is seismically active. Over 400 local seismic events were detected, including an earthquake swarm of over 300 events. The swarm area, near Hualapai Flats, is interpreted as having the largest potential of the area surveyed for producing commercial earth steam.

LOCATION MAP



BLACK ROCK PROJECT
WASHOE, HUMBOLT,
PERSHING COUNTIES,
NEVADA

Figure 1

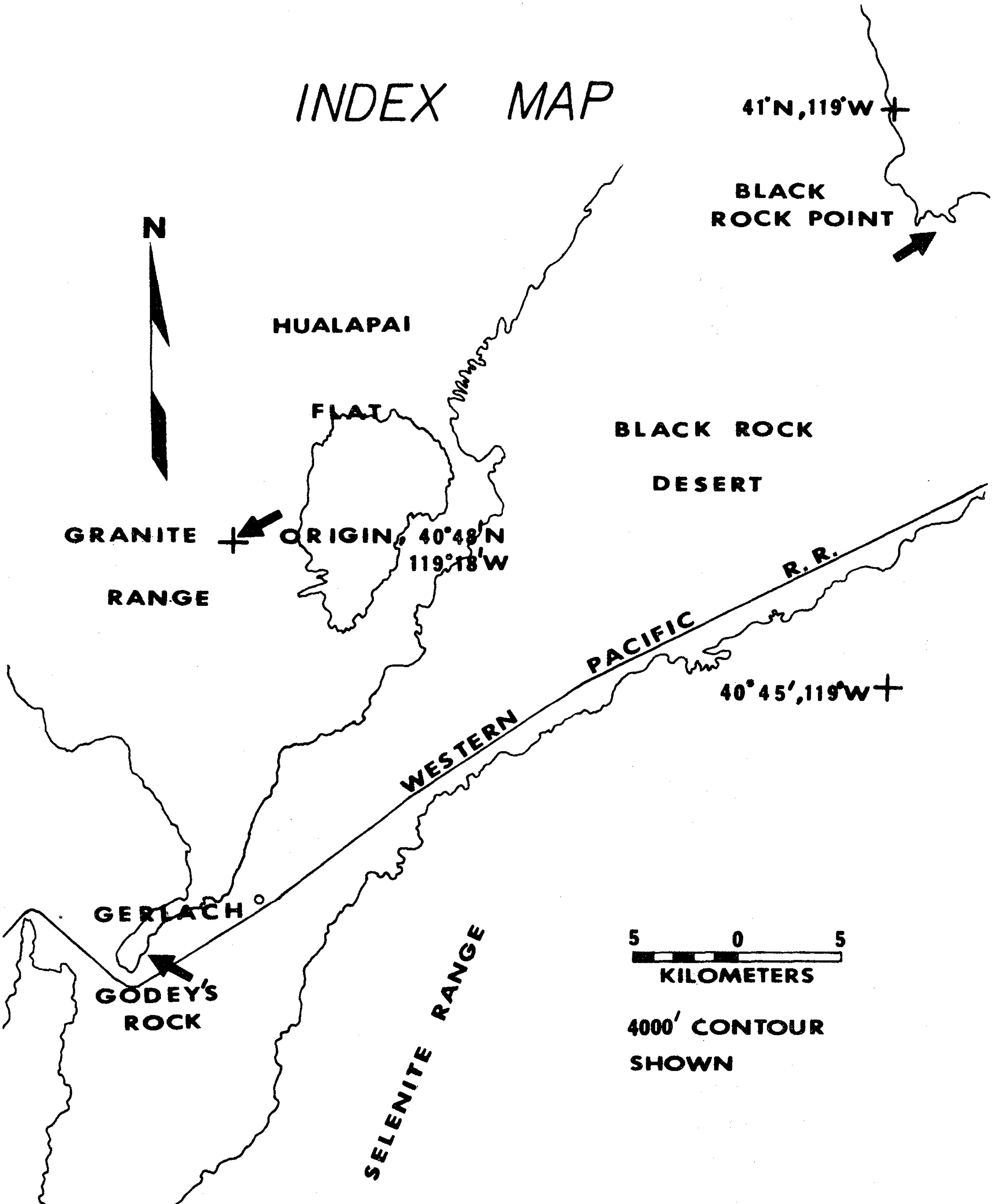

INDEX MAP
41°N, 119°W
BLACK ROCK POINT
N
HUALAPAI
FLAT
BLACK ROCK
DESERT
GRANITE
RANGE
ORIGIN, 40°48'N
119°18'W
WESTERN PACIFIC R.R.
40°45', 119°W
GERLACH
GODEY'S ROCK
SELENITE RANGE
5 0 5
KILOMETERS
4000' CONTOUR
SHOWN

Figure 2

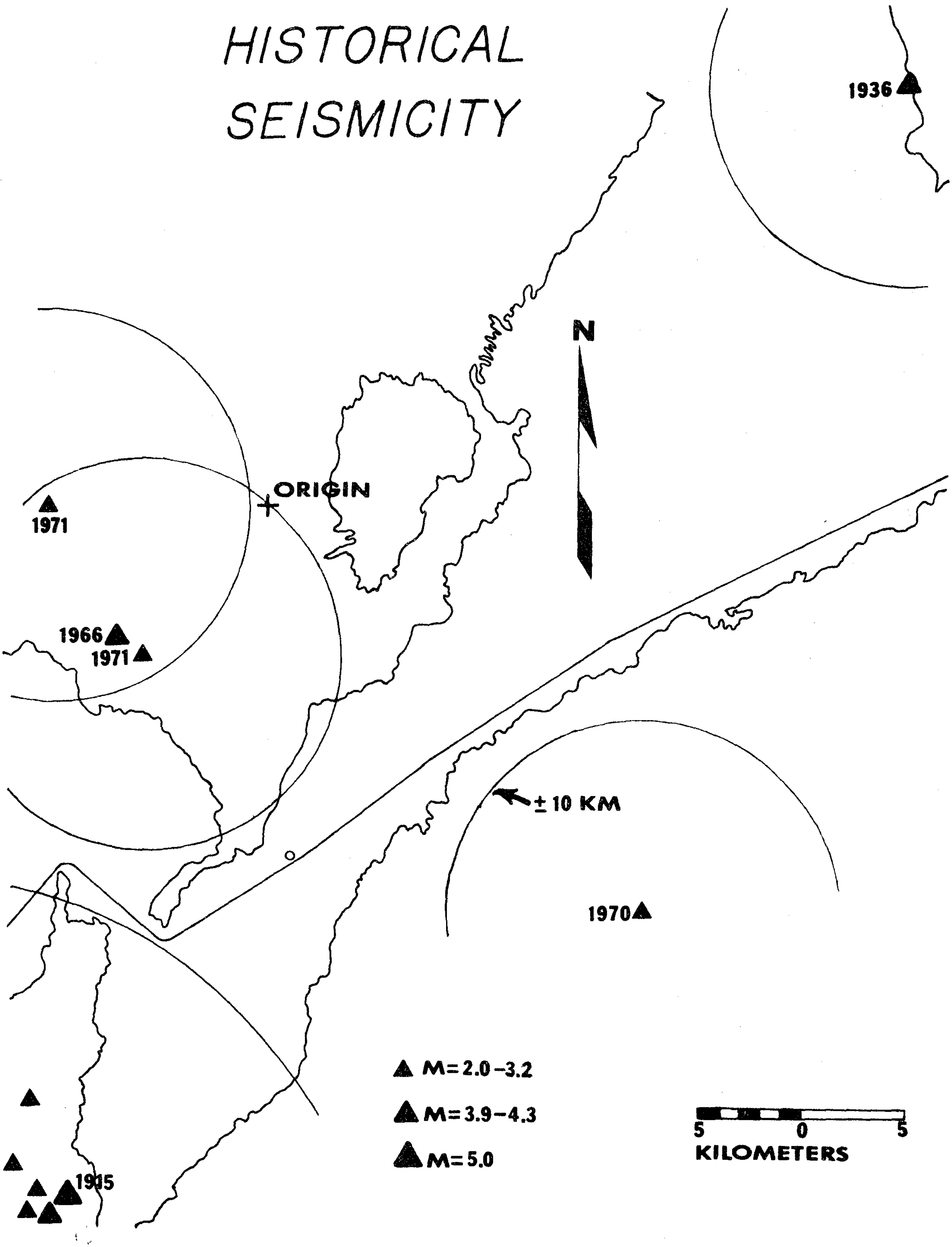

HISTORICAL
SEISMICITY
1936
N
ORIGIN
1971
1966
1971
± 10 KM
1970
1915
M=2.0-3.2
M=3.9-4.3
M=5.0
5
0
5
KILOMETERS

Figure 3

Introduction

More than 2800 km^2 (1100 sq mi) near Gerlach, Nevada (see location and index map, figs. 1 and 2) was surveyed for microearthquakes to aid in the evaluation of the geothermal potential of the area. The object of this survey was to detect and locate discrete seismic events (microearthquakes and ultra-microearthquakes). Recurrent, active, tectonic processes are felt by many (Westphal and Lange, 1962; Ward and Björnsson, 1971; Ward and Jacob, 1971; Hamilton and Muffler, 1972; Ward, 1972) to be a necessary, but not sufficient, ingredient of a practical geothermal occurrence.

The southern Black Rock Desert is in the Basin and Range Province and consists of a Quaternary sediment filled graben bounded on the west and southeast by Cretaceous igneous and metamorphic rocks. Historically earthquakes have been reported in this area (Slemmons, Jones, Gimlett, 1965). The historical epicenters and an estimate of the location accuracy are shown in figure 3. The 1915 group consists of an event of magnitude 5 and several of magnitude 2 located southwest of Gerlach. In 1966 and 1971, three events (one magnitude 4 event and two magnitude 2-1/2 events) were located west of the Granite Range about 15 km northwest of Gerlach. A magnitude 2 event in the Selenite Range 20 km east of Gerlach in 1970 completes the known historical seismicity of this area.

The next section of this paper outlines the instrumentation and operational methods employed in the field work. The observations and results are given in a section and are followed by an interpretation of the results. Conclusions and recommendations are listed in the last section of the body of the report.

Instrumentation and Operational Summary

Seven Sprengnether Instrument Co. MEQ-800-B portable seismic systems were used for this survey. Each system consists of a Mark Products model LC-4, 1-hz natural-frequency vertical seismometer, gain-stable amplifier, integral timing system, and smoked paper recording with 0.025mm stylus width and 120mm/min recording speed. The frequency characteristics of the instrument are summarized in figure 4. (Note that the velocity response is plotted; displacement response at a particular frequency f is obtained by multiplying the velocity response by $2\pi f$.) Gain changes are by 6 db steps down from the arbitrarily assigned level of 120 db plotted in the figure.

Clocks were synchronized daily with WWVB. Clock drifts for the first 15 days of the survey are shown in table No. 1. Clock drifts between synchronizations were below expected record reading errors, therefore no corrections were necessary.

Records were read to $\pm$0.1mm ($\pm$0.05 sec) for P arrivals and $\pm$0.1 sec for S-P times. Amplitudes, peak to peak, were read to nearest millimeter, and durations to nearest 0.5 sec.

During the course of the survey five distinct nets were operated. Stations were located on metamorphic or igneous outcrops if possible and the seismometers and cables buried to reduce background noise. All stations except #3 and #16 were located on crystalline rock outcrops.

Stations were operated at the gain limit allowed by ambient background noise. Those stations near the railroad (8, 10, 11, 12, 13 and 14) were operated with pen limiters at 5mm to allow them to be operated at gains comparable to the remainder of the net.

Velocity Response of System at Maximum Gain (120 db).

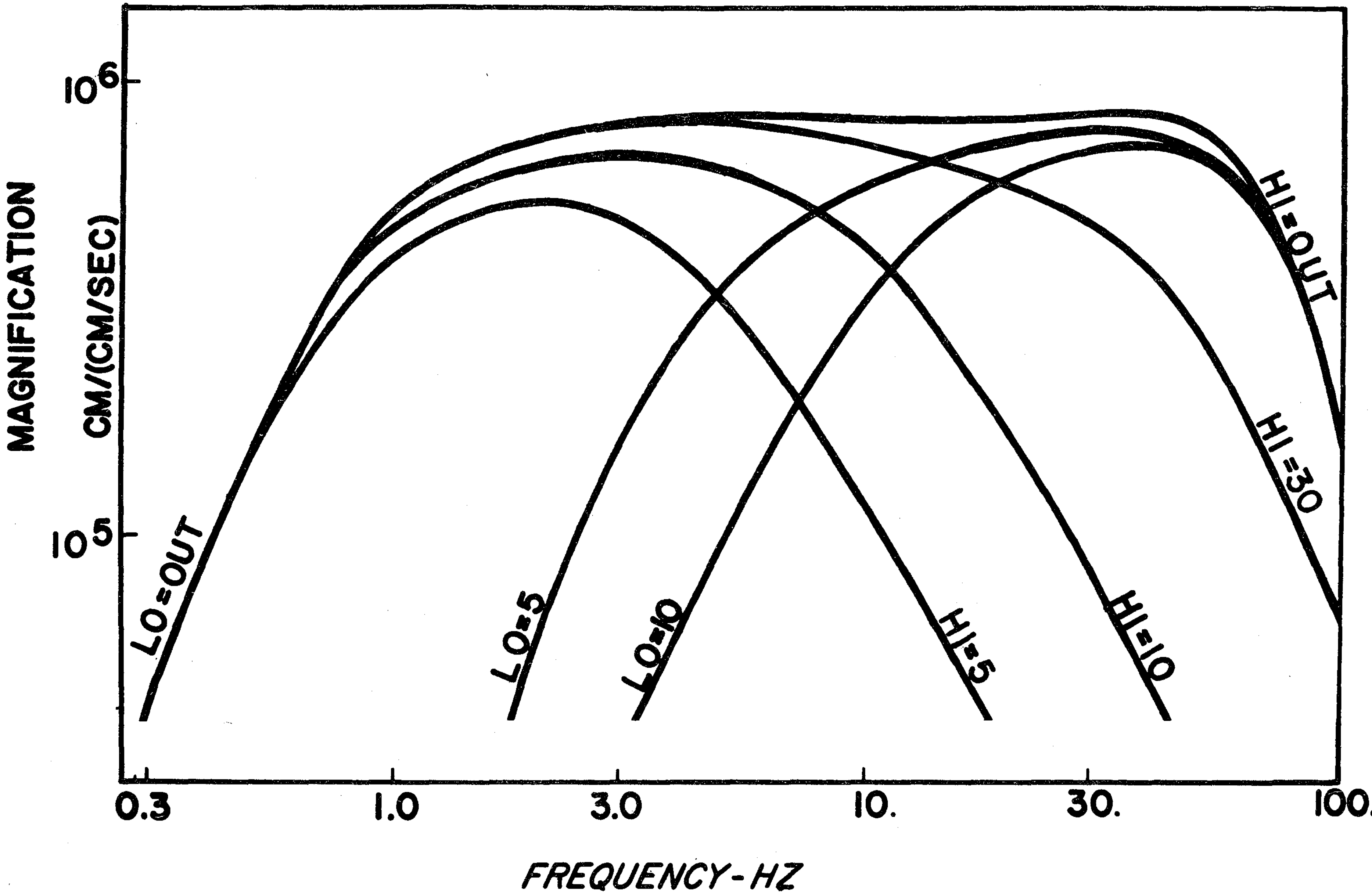


Table of Clock Drifts
(milliseconds/hour)

The first 15 days of 30 day Black Rock Survey

Julian Day 1974	Instrument Number						
	125	136	137	138	139	140	143
144	---	---	-0.71	-0.96	-1.38	0.04	0.17
145	---	-0.58	0.63	-2.16	-1.13	-0.08	0.00
146	---	0.08	0.08	-2.16	-0.88	0.00	1.13
147	---	0.00	1.38	-1.96	0.06	-0.13	0.75
148	---	0.50	0.75	-2.63	-1.08	-0.08	0.08
149	---	-0.92	0.08	-2.63	-1.08	0.04	0.46
150	---	-0.25	0.08	-2.70	-0.47	0.29	0.42
151	---	-0.66	1.08	-2.50	-0.50	0.00	0.75
152	0.08	0.08	0.25	-1.66	-0.42	----	0.75
153	0.17	-0.25	-0.08	-2.29	0.83	----	1.08
154	0.00	-0.38	0.17	-2.58	-0.67	----	0.25
155	0.17	0.08	-0.75	-3.20	0.08	----	-0.41
156	0.50	-0.08	1.29	-2.16	-0.63	----	-0.83
157	0.50	-0.20	0.29	-2.58	-0.20	----	0.16
158	0.17	-0.21	0.08	-2.54	-0.21	----	0.63

Note: 1) When drift is negative, clock is running fast, when drift is positive, clock is running slow.

2) WWVB used as time standard, received with ±2ms error.

Table 1

From 19 CUT (Coordinated Universal Time) hr on Julian Day 143 (Julian Day 143 = 23 May 1974) to 17 CUT hr on day 150 stations 1 through 7 were operated surrounding Hualapai Flats (fig. 5).

Stations 8 and 10 were then established to give better locations on events occurring to the east of Hualapai Flats (fig. 6). On day 159 the entire net was moved south to surround Gerlach (fig. 7). During the earthquake swarm on day 169 the southern stations of the Gerlach net were moved north to facilitate location of the swarm events (fig. 8). On the final two days of the survey (173-174) the net was moved to the area near Black Rock Point (fig. 9). A map and listing of all the station locations is shown in figure 10 and table 2. Table 3 illustrates detailed operating schedules.

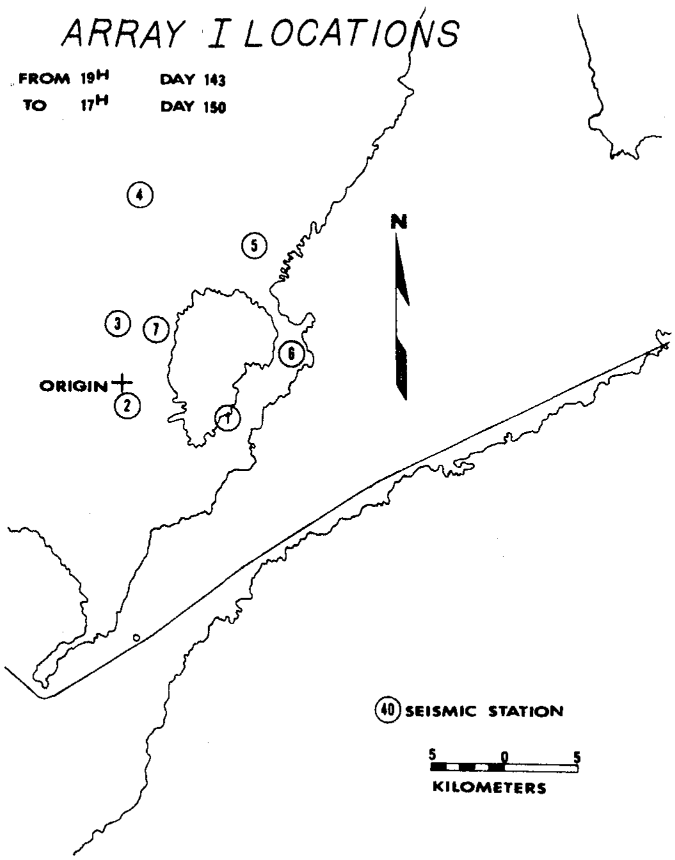


Figure 5

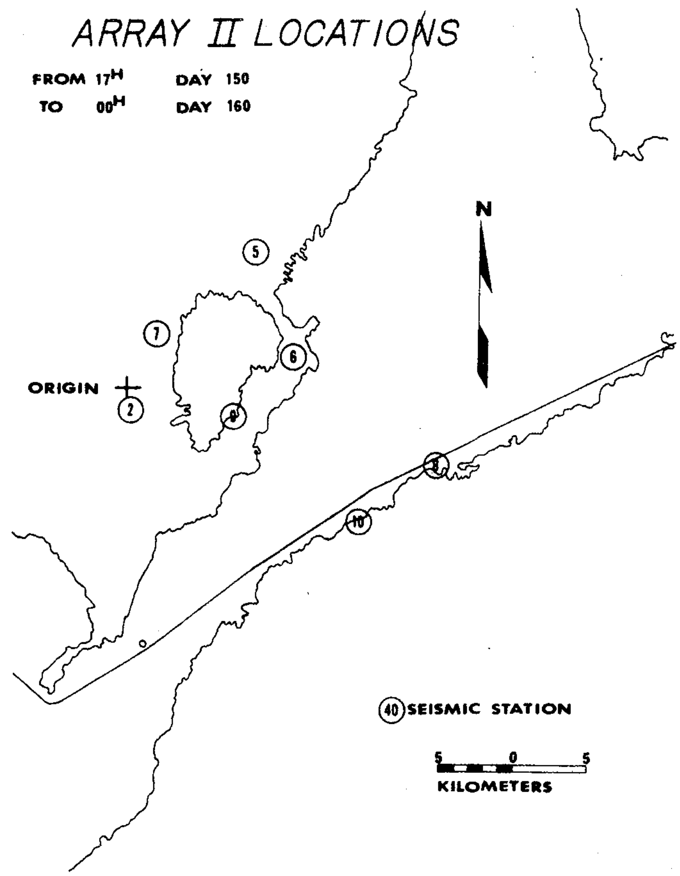


Figure 6

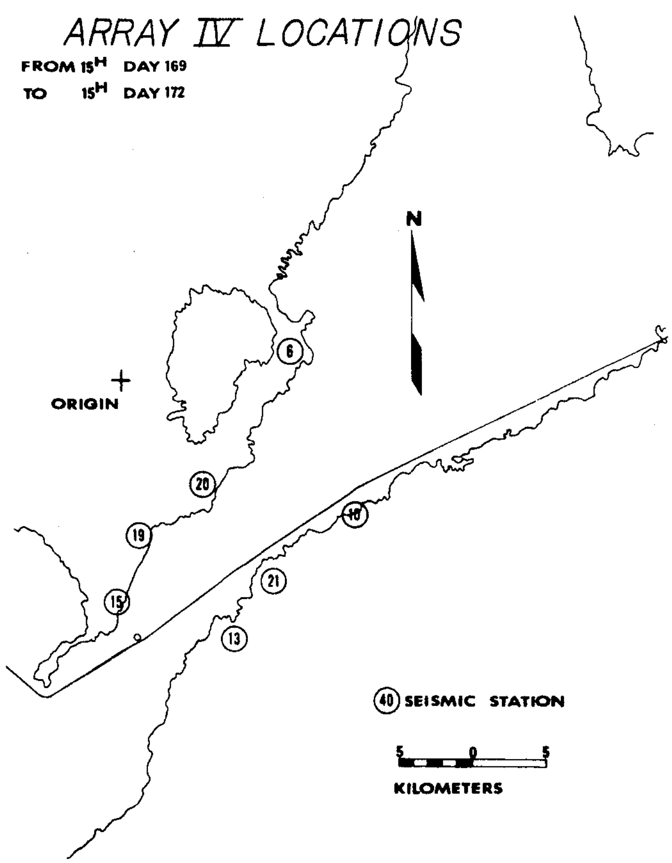


Figure 8

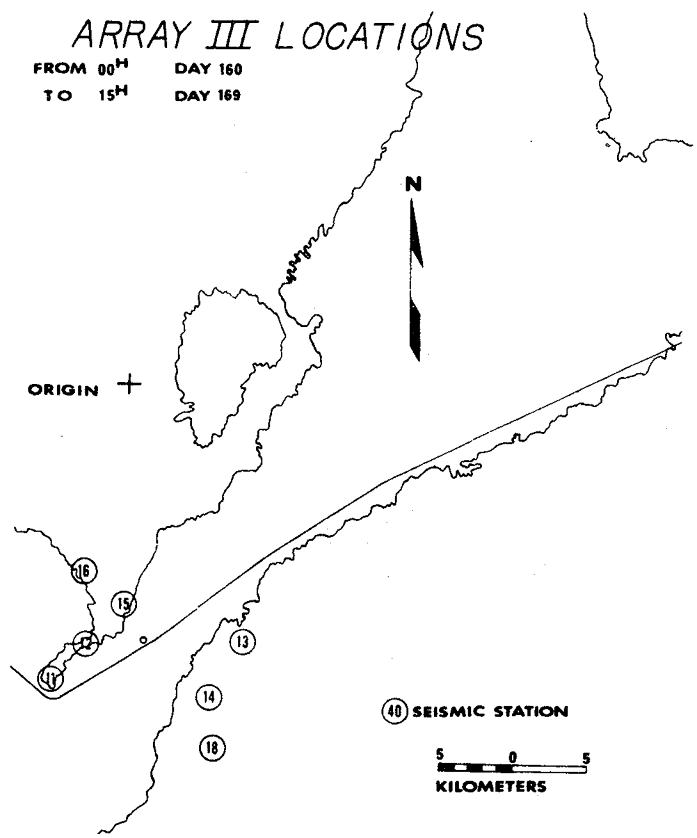


Figure 7

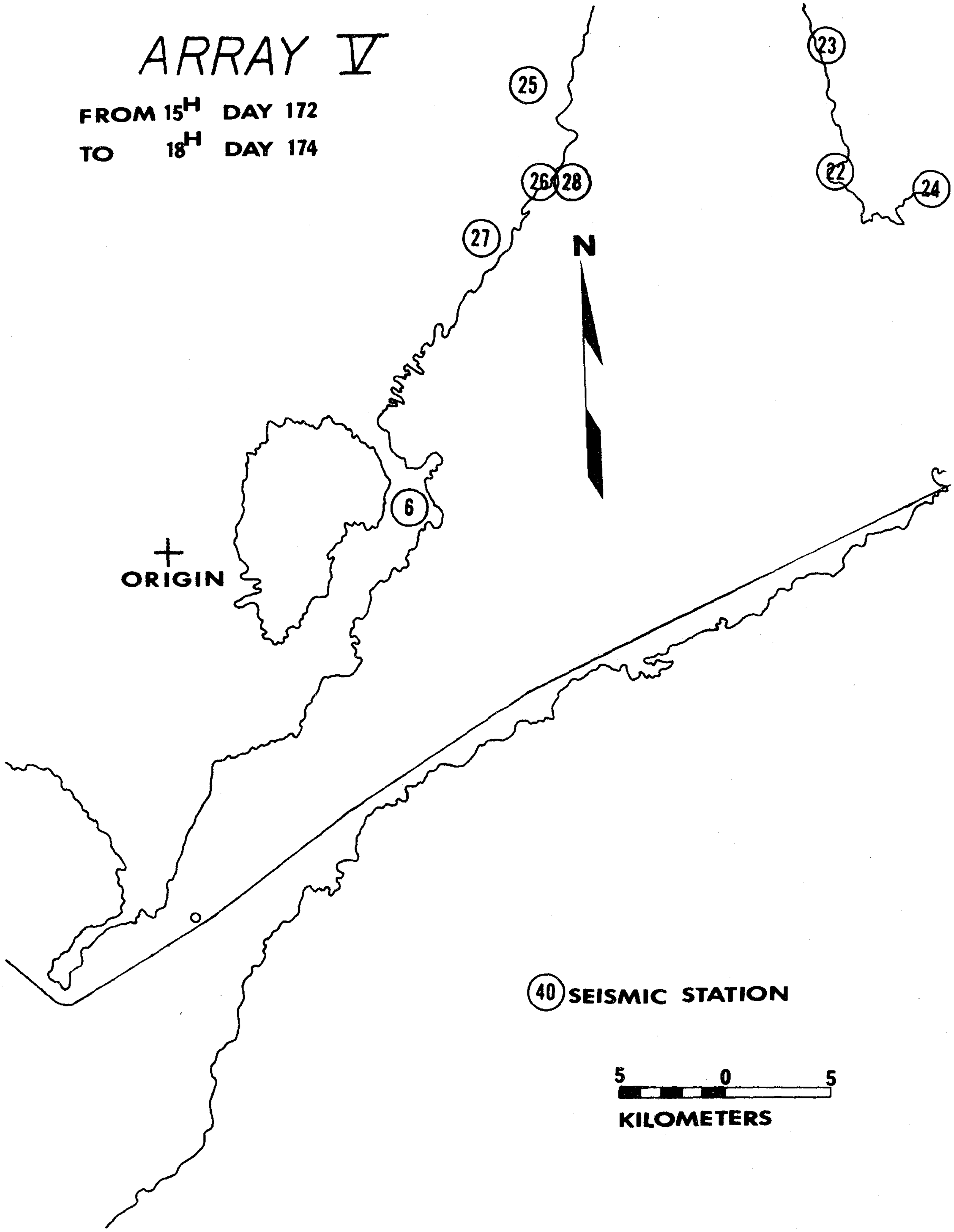

ARRAY V
FROM 15H DAY 172
TO 18H DAY 174
25
23
26
28
22
24
27
N
6
ORIGIN
40 SEISMIC STATION
5 0 5
KILOMETERS

Figure 9

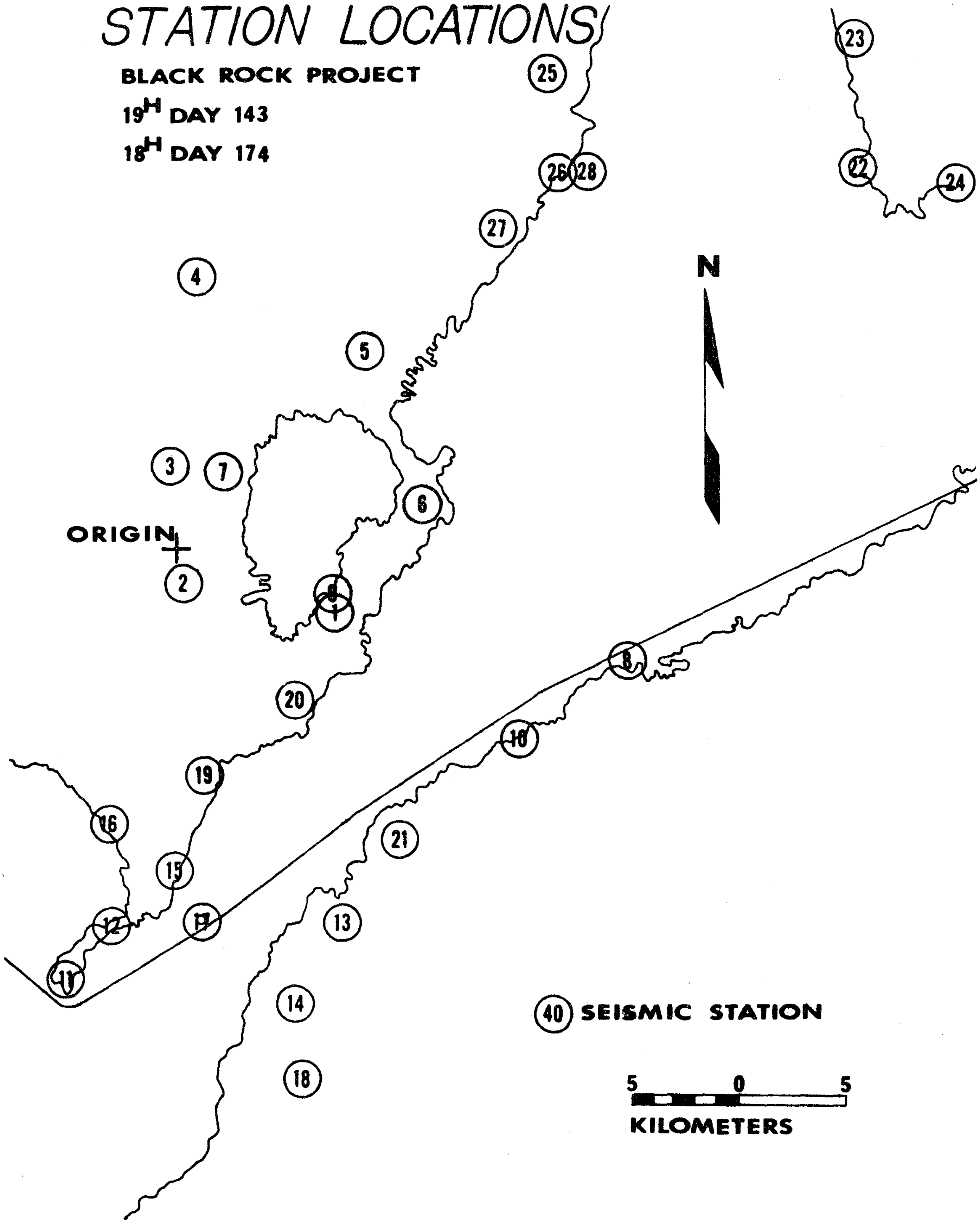

STATION LOCATIONS
BLACK ROCK PROJECT
19H DAY 143
18H DAY 174
ORIGIN
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
40 SEISMIC STATION
5 0 5
KILOMETERS

Figure 10

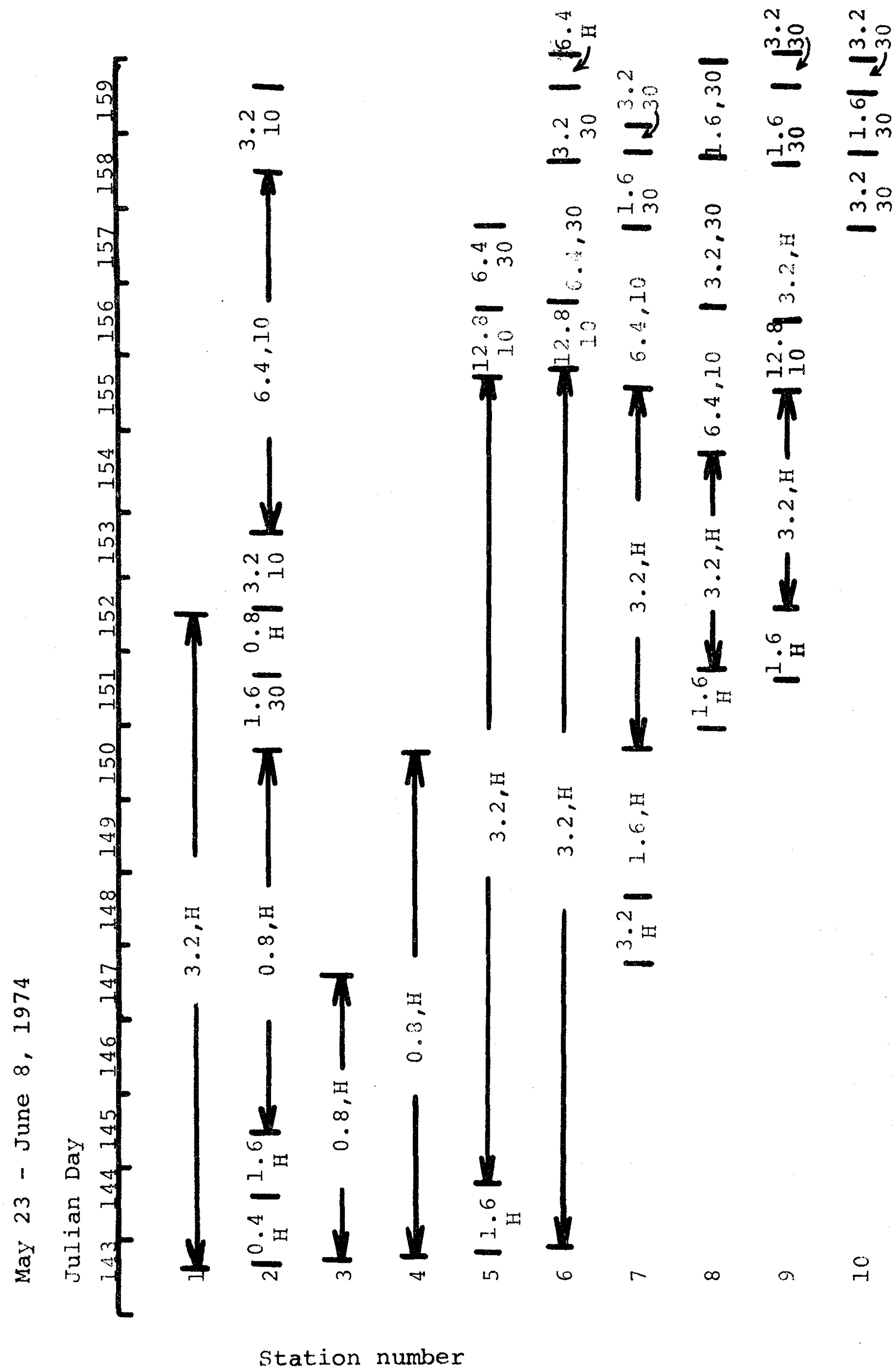
Black Rock Desert Station Locations

Station	x	y	Station	x	y
1	7.3	-2.3	15	0.5	-15.0
2	0.3	-1.5	16	-3.3	-12.9
3	-0.2	3.9	17	1.0	-17.2
4	1.1	12.8	18	5.7	-25.1
5	9.0	9.1	19	1.2	-10.6
6	11.5	1.8	20	5.5	-7.1
7	2.2	3.6	21	10.4	-13.9
8	20.7	-5.3	22	32.1	17.7
9	7.3	-1.9	23	32.1	23.6
10	15.8	-9.2	24	36.8	16.5
11	-5.3	-20.0	25	17.6	22.2
12	-3.3	-17.6	26	18.1	17.4
13	7.7	-17.6	27	15.3	15.0
14	5.5	-21.5	28	18.1	17.5

Note: Coordinates in kilometers from origin at N40°48.4', W119°22.7' or 100,000 m^2 identification 45.2, 3.0. Based on U.S. Army maps, 1/250,000, NK1110 Lovelock and NK11-7 Vya.

Table 2

Operating Schedule of Seismometer Stations



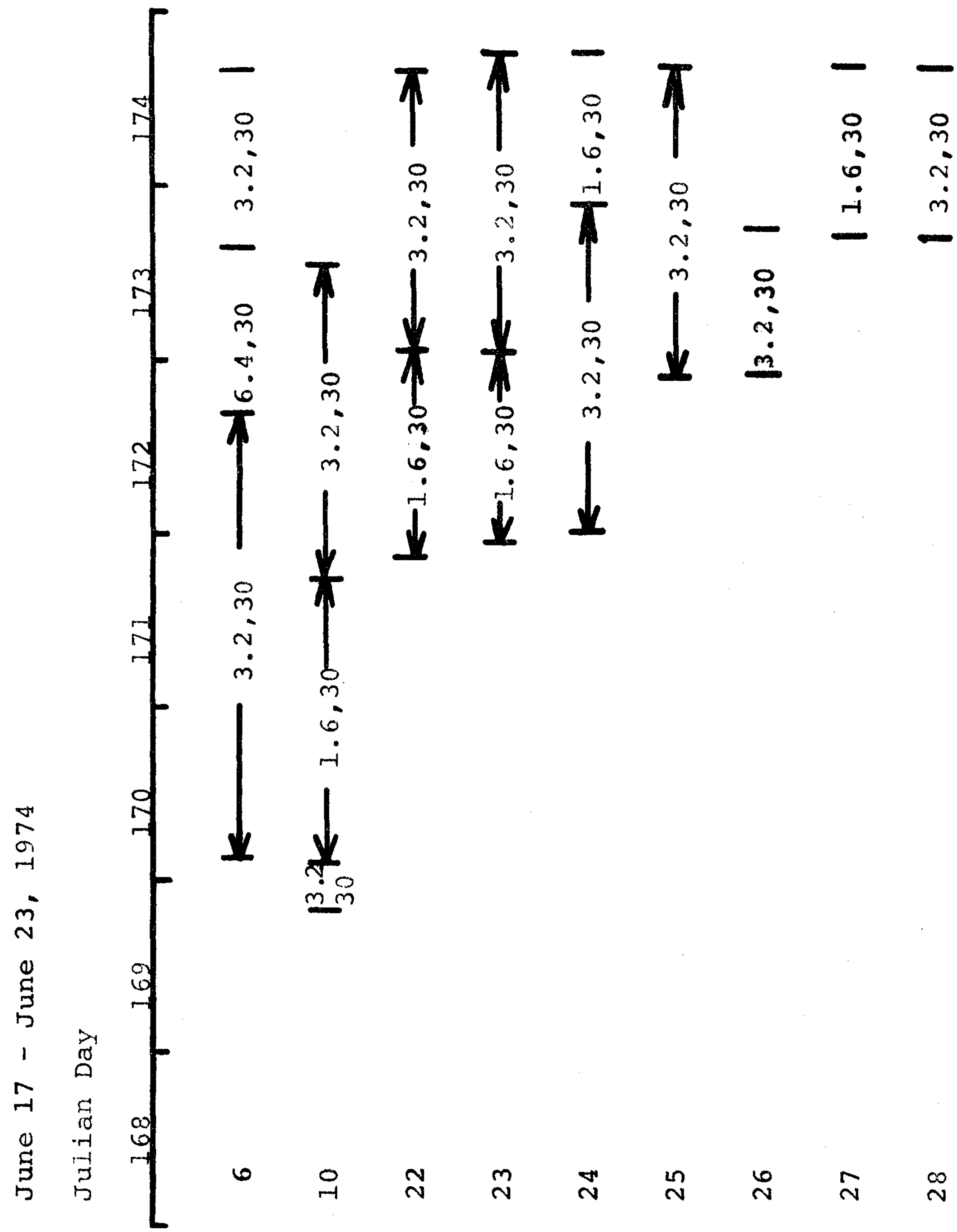
Key

Gain times 1 million (at 10 Hz), High-cut filter (in Hz)

H: High-cut filter out

Note: Low-cut filter is always out

Operating Schedule of Seismometer Stations



Station Number

Key

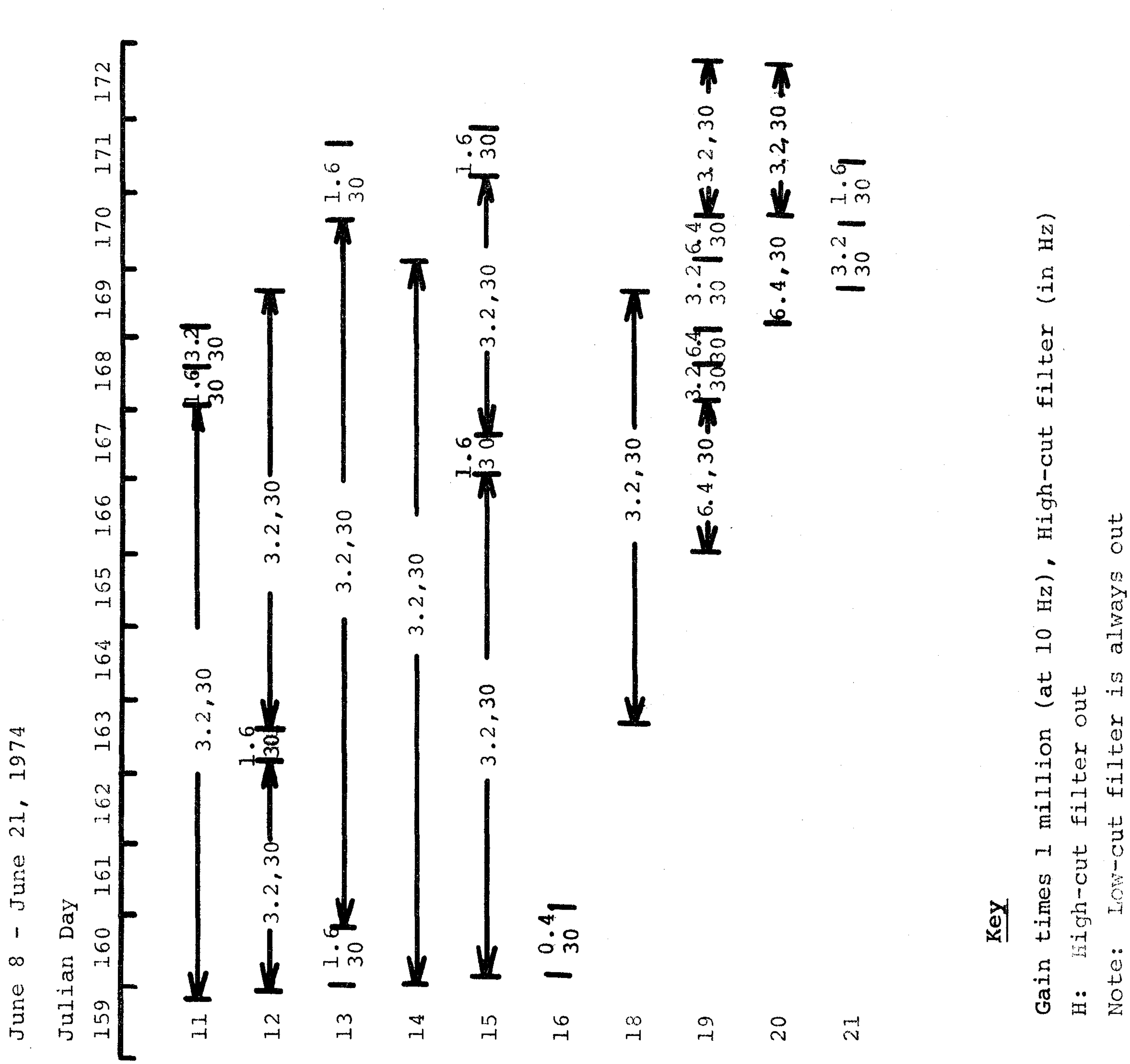
Gain times 1 million (at 10 Hz), High-cut filter (in Hz)

H: High-cut filter out

Note: Low-cut filter is always out

Table 3 (continued)

Operating Schedule of Seismometer Stations



Station Number

Table 3 (continued)

Observations

Events were regarded as seismic in origin if they appeared on two or more stations with moveouts corresponding to seismic velocities or if they had the characteristic signature and S-P time of less than 10 sec.

A plot of the number of local events vs the hour of the day shows no apparent correspondence to cultural activity (fig. 11). However the low number of events detected from 1400 to 2100 local time indicate that approximately 15 local events were not detected during the later afternoon due to high wind noise.

Another source of seismic noise was trains as recorded by arrays II, III, IV. This noise source had an adverse effect on the quality of the data for approximately 6 hours per day and data was obscured for about 1 hour per day. Train noise did not seem to affect the event count and therefore the resulting seismicity.

Figure 11 also shows that the occurrence of teleseisms (S-P times greater than 10 sec) is evenly distributed throughout the day. The high frequency wind noise had little effect on recognition of teleseisms because they are low frequency events and easily distinguished from the wind caused movements.

A cumulative plot of the number of events, local and teleseismic is shown in figure 12. Local events were recorded at a rate of two per day for the period day 144 through day 168. From 8 hr to 18 hr CUT on day 169 a swarm of over 300 local events were recorded and increased seismicity (9/day) continued until day 174, the end of the survey. Teleseisms were recorded at a rate of 4/day for the entire survey and demonstrate no rate change of the regional seismicity during the local swarm period. Due to the drastic change

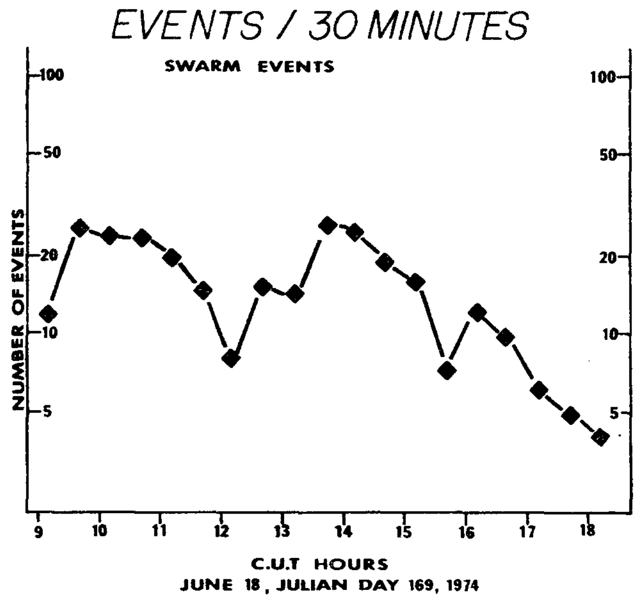


Figure 13

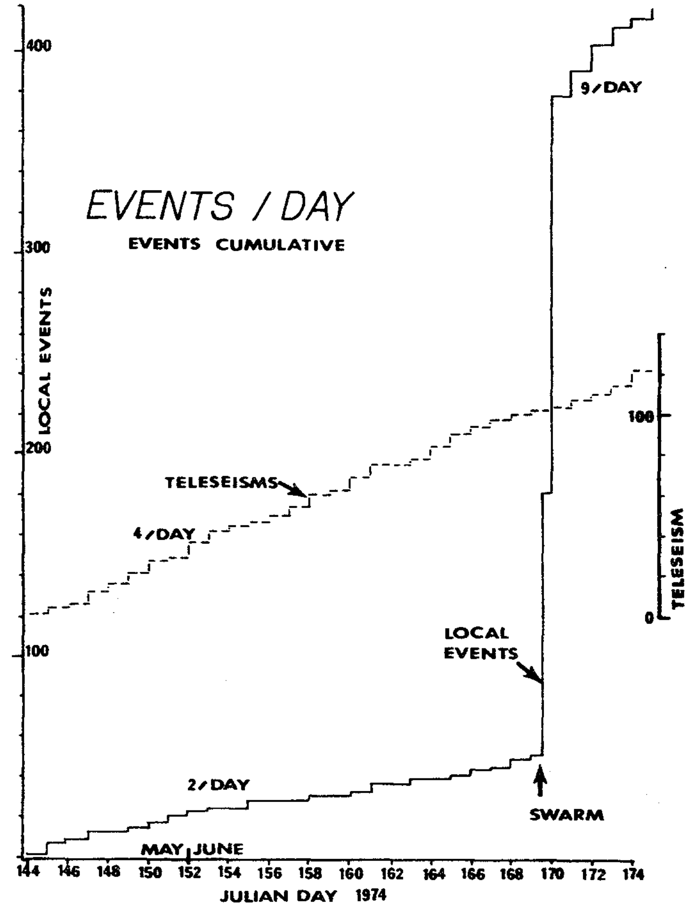


Figure 12

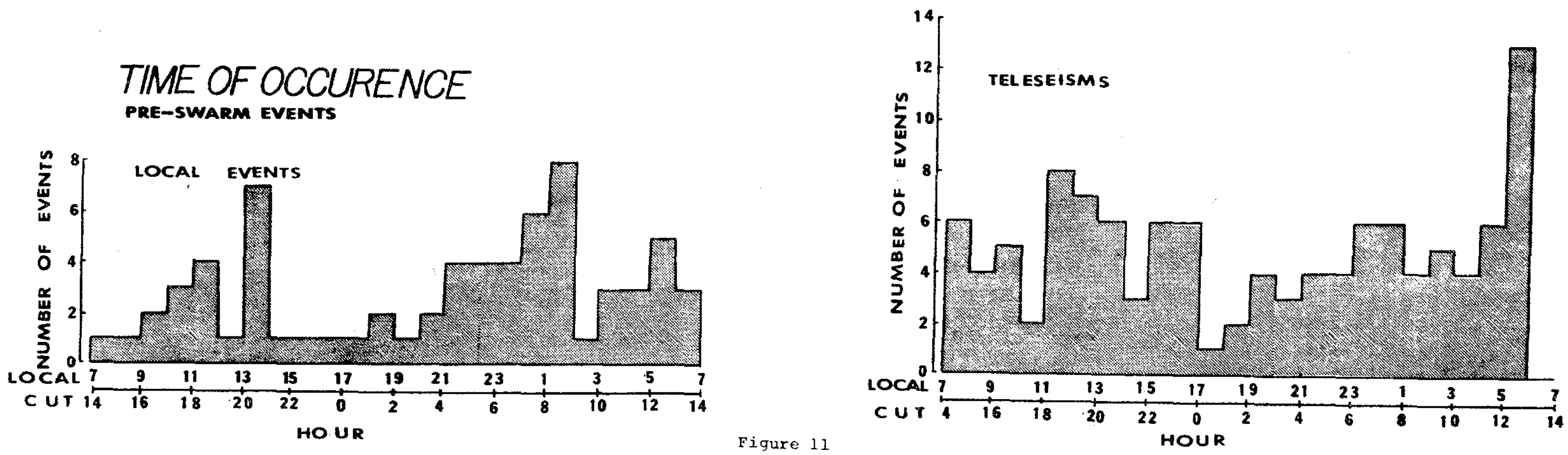


Figure 11

in local seismicity during day 169 the data was divided into two sets: events on days 144-168 are denoted as preswarm and events on days 169-174 as swarm.

A plot of number of local swarm events per 30 min vs time (fig. 13) shows 2 distinct peaks. The first of these is preceded by a large event (M=1.5) at 0849 CUT and the second by 3 events of approximately equal size (M=1.0) at 1241, 1244 and 1248 CUT.

Local events timed on 4 or more stations were located using a generalized inverse program. No attempt was made to locate teleseisms since they were beyond the area of immediate interest in this survey. Details of the velocity structure in this area are not known. The greatest source of error in locating the hypocenters to an accuracy of less than ±2km was the assumption of a constant velocity model. The location accuracy of this method falls off dramatically outside the array and is a function of the aperture of the array, in this case 10-20km for the different arrays used in this survey. Events more than 2 array apertures (20-40km) from the center of the array are probably located to within ±5km.

Using locations based on P arrivals a S-P travel time curve was constructed (fig. 14). From this a S-P velocity of 8.5km/sec was computed. The derived S-P velocity was used to locate events recorded on 2 or 3 stations with an accuracy of ±5km.

Figure 15 shows all located events. The epicenters fall in three major groups. The largest group of events is located east and southeast of Hualapai Flats (fig. 16). Most of these events occurred during the swarm. A second group of 11 events is located southwest of Gerlach in the vicinity of Godey's Rock. The third

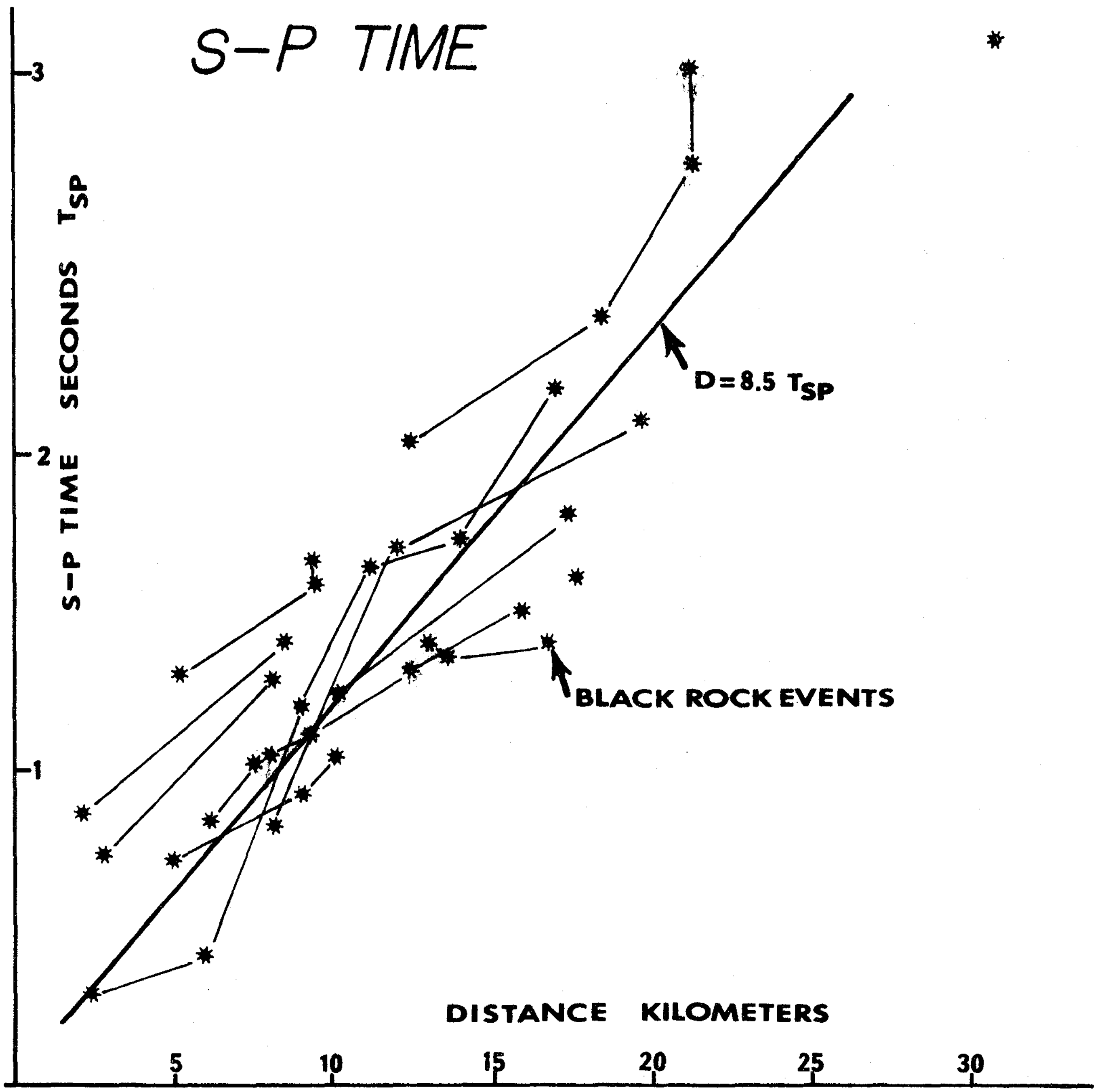

S-P TIME
3
2
1
S-P TIME SECONDS T_{SP}
D=8.5 T_{SP}
BLACK ROCK EVENTS
DISTANCE KILOMETERS
5
10
15
20
25
30

Figure 14

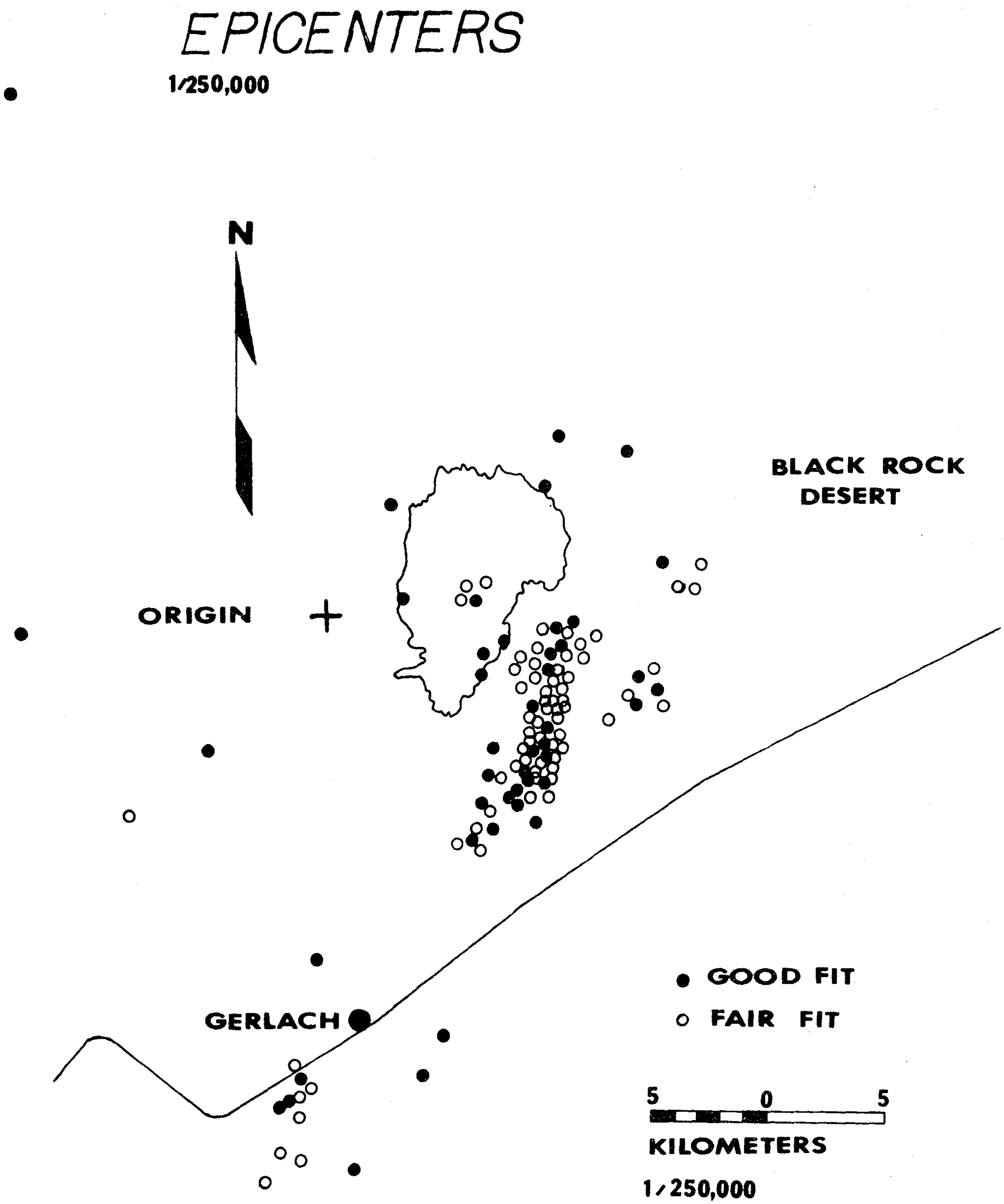

EPICENTERS
1/250,000
N
BLACK ROCK
DESERT
ORIGIN
GERLACH
GOOD FIT
FAIR FIT
5
0
5
KILOMETERS
1/250,000

Figure 15

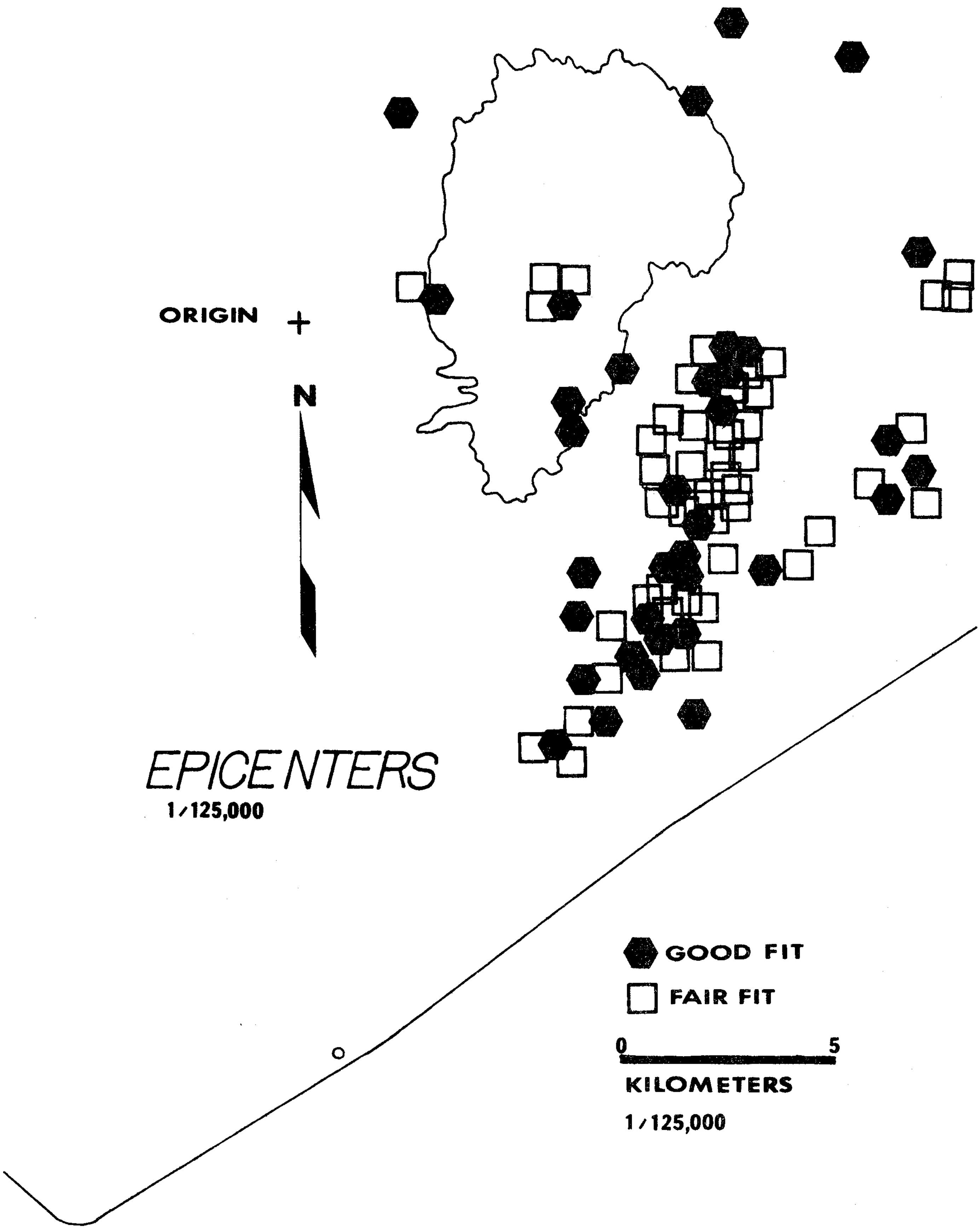

ORIGIN
N
EPICENTERS
1/125,000
GOOD FIT
FAIR FIT
0
5
KILOMETERS
1/125,000

Figure 16

group contain four events located to the west of the Granite Mountains in approximately the same area as the reported 1966 and 1971 shocks.

No events were detected near Black Rock Point. The network near Black Rock Point, Array V, was only operated for a short time (2 days) however several events of magnitude 0 from the swarm area were detected on the Black Rock net. Reciprocity indicates that events near Black Rock Point of magnitude 0.5 or greater would have been detected during the survey.

Another area of interest where no seismicity was recorded is the region between the swarm events and the events south of Gerlach. Various stations of the southern nets were operated for over fifteen days in close proximity to this area. No events of greater than magnitude -0.5 occurred in this area during these 15 days.

Wadati diagrams, S-P times plotted against the compressional arrival times (fig. 17) were drawn to find Poisson's ratio for the rocks under stress. The graph was then extrapolated to an S-P time of zero, yielding the earthquake origin time.

In equation form

$$S-P = (P-O)(K-1)$$

where S = S-wave arrival time

P = P-wave arrival time

O = Origin time

$K \simeq \alpha/\beta$ where

α = P-wave velocity

β = S-wave velocity

Note that S-P plotted vs P gives a straight line with a slope K-1. The equation connecting the ratio of α/β and Poisson's ratio is

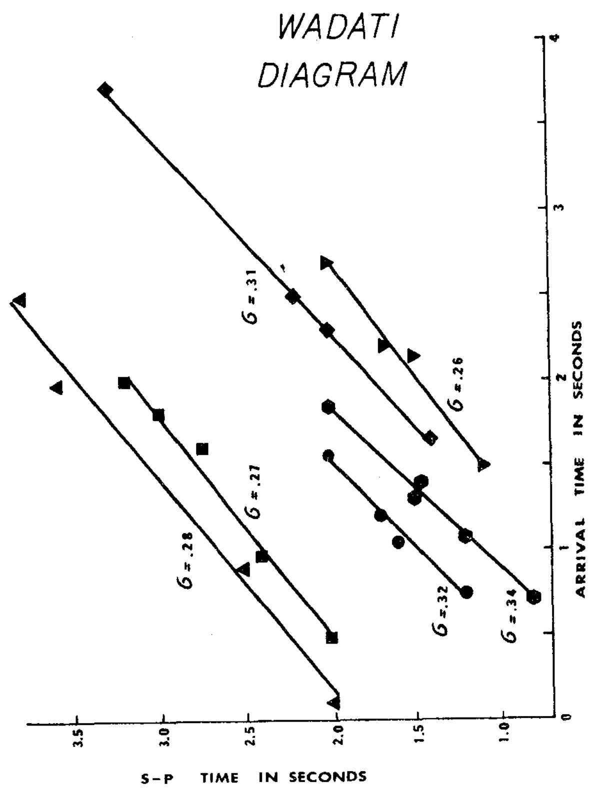


Figure 17

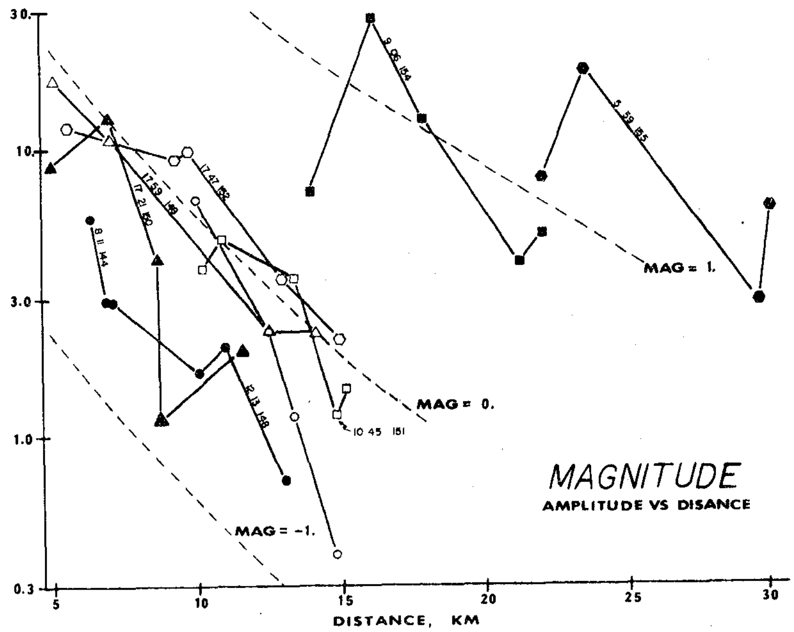


Figure 18

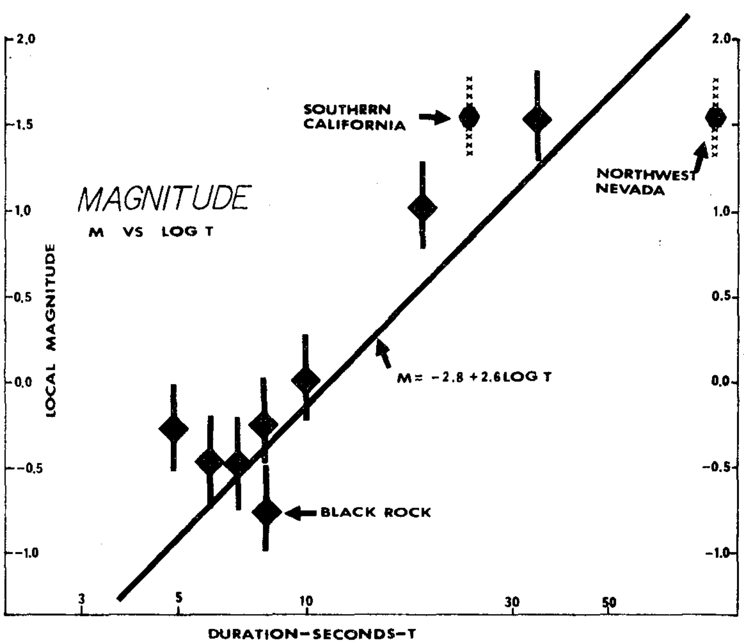


Figure 19

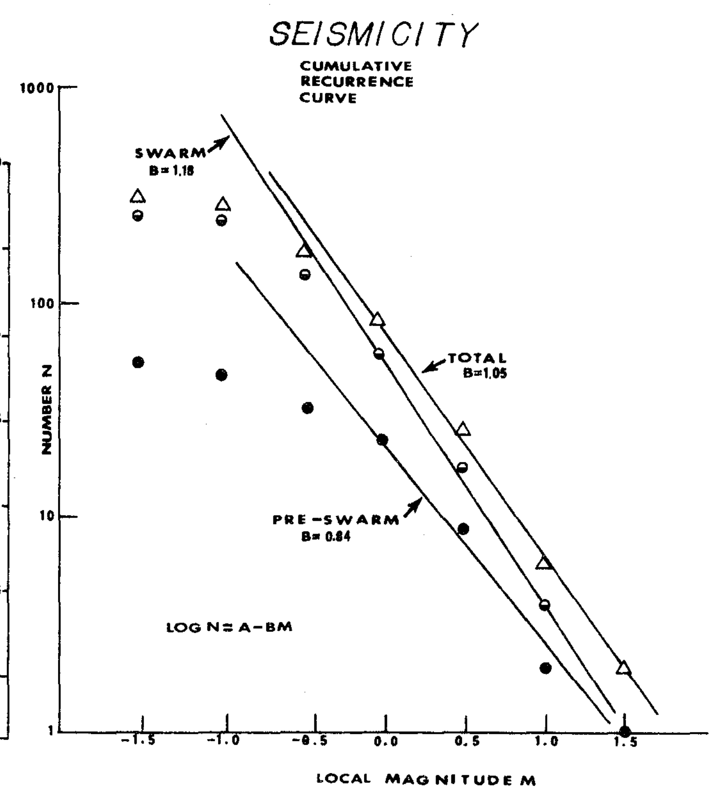


Figure 20

$$\sigma = \frac{K^2-1}{K^2-1/2}$$

The earthquakes, both swarm and preswarm, from different localities were used in the calculations of Poisson's ratio. The mean value of Poisson's ratio was .30 with a standard deviation of 0.02. The values were randomly distributed throughout the area of study, with no indications of local changes in Poisson's ratio. The Wadati diagram was also used as an independent confirmation of the computer fits by comparing origin times derived from both methods.

To determine magnitudes, a plot of the log of trace amplitude vs hypocentral distance (assuming 5km depth) for several representative earthquakes were plotted as is shown in figure 18. These curves were compared with curves developed for Southern California. On this basis magnitudes were assigned to the sample earthquakes and a duration vs magnitude curve was constructed (fig. 19). The remainder of the events were assigned magnitudes to the nearest 0.5 on the basis of this duration curve.

A plot of magnitude vs number of events was plotted in order to estimate a recurrence curve (fig. 20). Two slopes of .84 for the preswarm events and 1.18 for the swarm events were obtained.

The smallest events recorded in this survey had magnitudes of less than -1.5, however the recurrence curve indicates sampling was not complete for events of magnitude -0.5 and below.

The energy of each event was computed using the equation:

$$\text{Log } E = 11.4 + 1.5M \quad .$$

The total energy of the preswarm events was 6×10^{13} ergs (equivalent to a magnitude 1.6) and the energy of the swarm events totaled 1×10^{14} (magnitude 1.7).

Earthquake strain release distribution for located events was contoured using Benioff's method of adding the square roots of the earthquake energies. Figures 21 and 22 show the strain release distribution for the preswarm and total located events. The strain release distribution before and after the swarm, show the largest values in a zone southeast of Hualapai Flats.

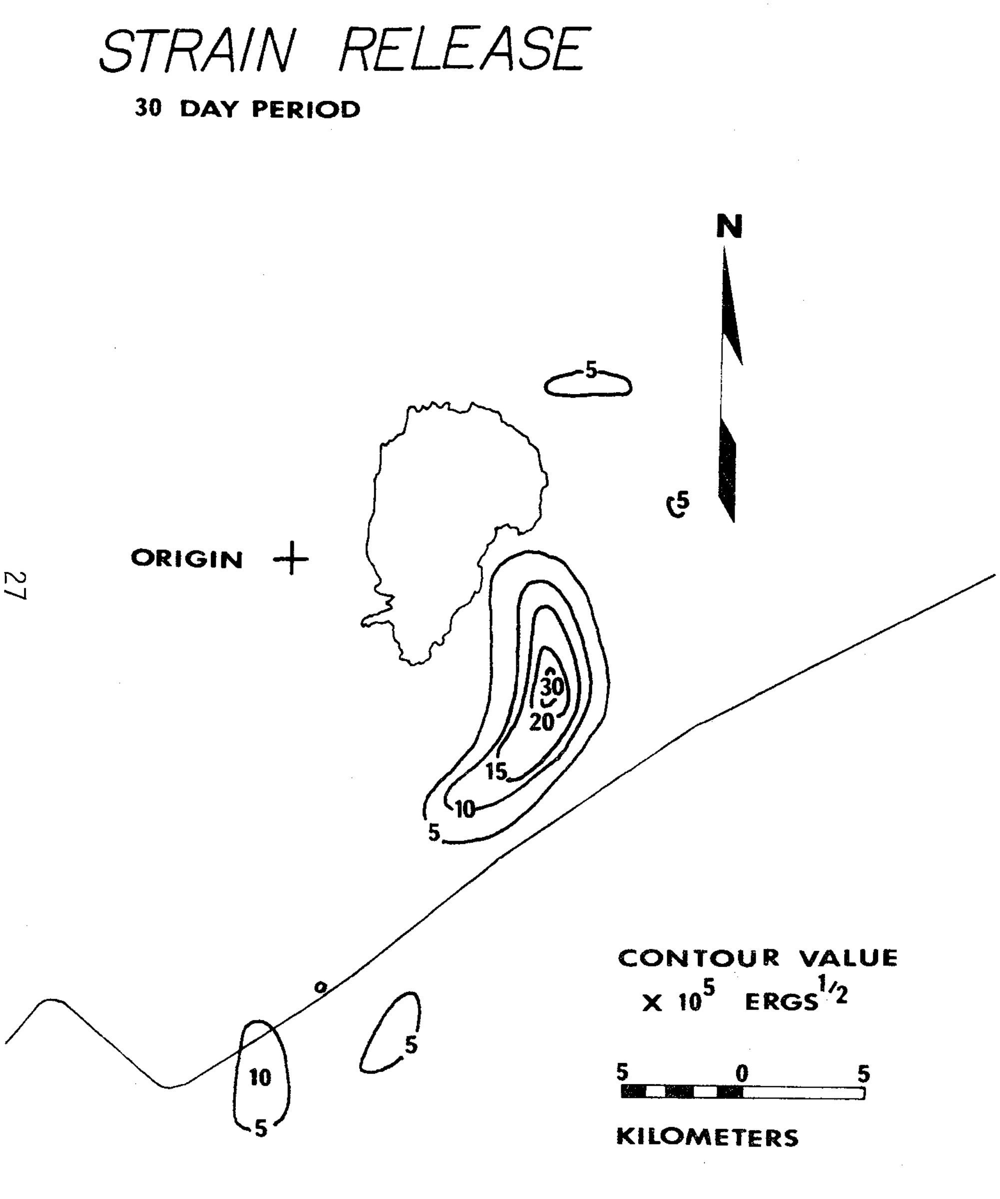


Figure 21

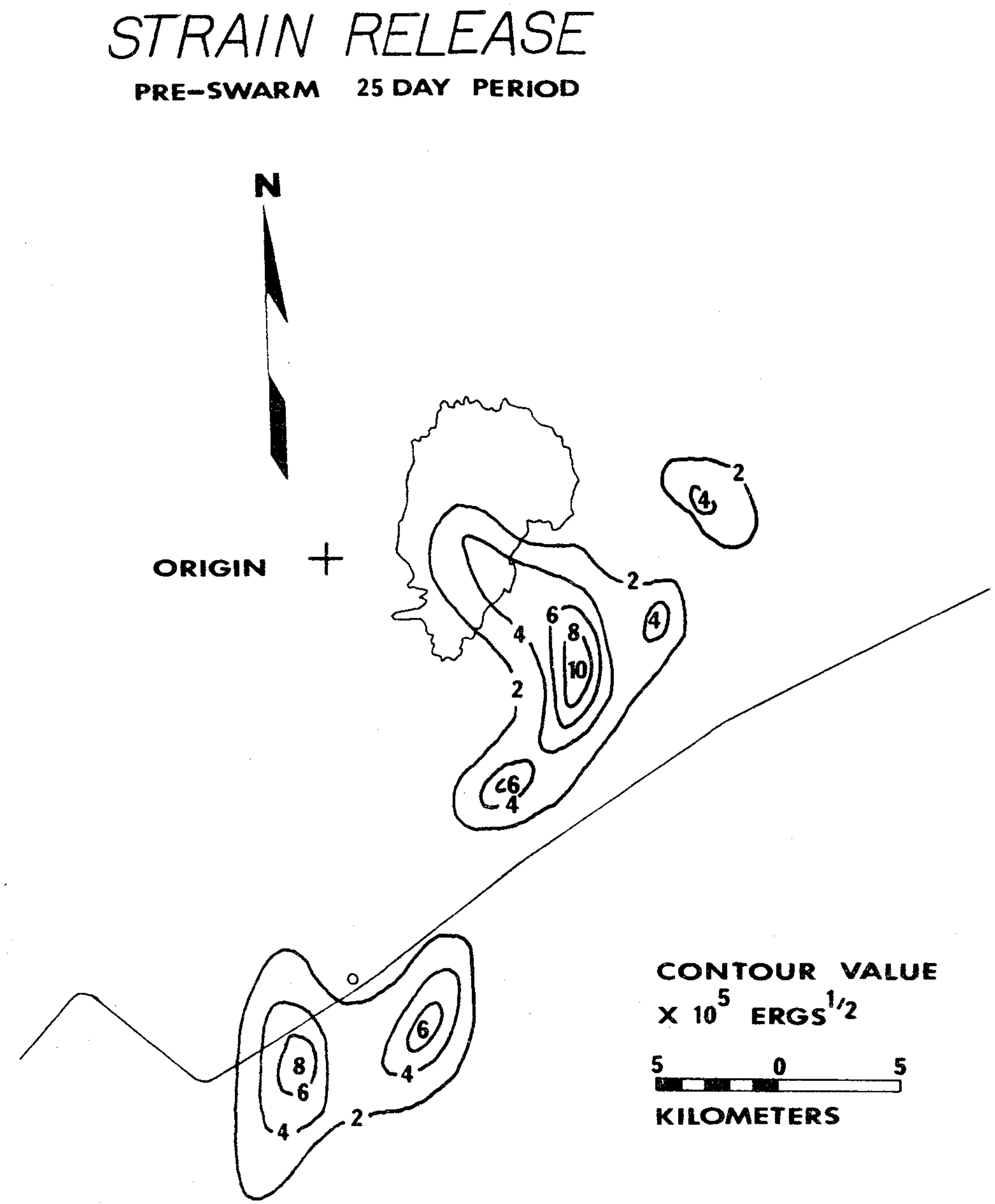


Figure 22

Interpretation

The above factual observations are interpreted below. Results include an interpretation of the velocity structure under the area, the delineation of geologic structures which are active at the present, an interpretation of the Poisson's ratio information, the significance of the strain release maps, and a discussion of the important aseismic areas. The interpretation is, of course, subject to clarification when reconciled with additional geological and geophysical data to be taken in the area.

For most of the survey area a half-space velocity of 5 to 5.5 km/sec produced the best epicenter locations. However, stations east of the Black Rock Desert on the Selenite Range exhibit early arrival times (up to a second for station 18), indicating a higher velocity of 6 to 6.5km/sec at depth along the Selenite Range. The existence of a major crustal boundary to the east of the area is consistent with the velocity information found. The three areas of immediate interest which exhibit a high rate of seismicity are west of the Granite Range, southwest of Gerlach and the area east and southeast of Hualapai Flats in the Black Rock Desert.

The activity west of the Granite Range indicates that a zone of active tectonism exists along the west side of the Granite Range, extending from Gerlach to the northwest. A detailed investigation of this area is beyond the scope of this report, but activity detected is consistent with the historical seismicity.

The second area, Godey's Rock, is southwest of Gerlach. This zone may be an extension of the Granite Range zone. Detected events in the Godey's Rock zone may also be associated with historical activity to the south-southwest.

These zones (Granite Range, Godey's Rock, and the historical seismic zone southwest of Gerlach), may be interpreted as one seismic zone that trends northwest/southeast along the west side of Granite Range, turns south near Gerlach and trends southwest in its southern extreme.

The third zone is east and southeast of Hualapai Flats. The southern part of this zone trends northeast/southwest along the western edge of the Black Rock Desert. The northern events of the swarm zone trend north to northwest through Hualapai Flats. The swarm zone may be a parallel seismic structure to the area south near Gerlach. There are also three small epicenter areas to the east and north of the swarm zone. These areas may be connected by a zone the same shape as the two seismic structures to the south. Figure 23 illustrates the above interpretation.

An alternative interpretation is that one major zone extends from southwest of Gerlach, trends northeast along the western edge of Black Rock Desert to the east of Hualapai Flats. This lineament, from the northeast which would link the active zones, established by this survey, intersects the Granite Range zone at Gerlach and continues southwest into the Fox Range. However, this feature must also extend through two aseismic areas established by the survey. One is just northeast of Gerlach on the western edge of the Black Rock Desert and the other aseismic area is northeast of Hualapai Flats also along the western edge of the Black Rock Desert.

The active areas exhibit a Poisson's ratio of approximately 0.30. This is a higher value than is normally attributed to crustal rock, and may indicate less than normal rock strength in the area of the survey. However, the Poisson's ratio was fairly constant over the area with no discernible local anomalies.

The area of greatest interest is the swarm area. The lack of large events in the seismic history (no events of magnitude 4 or greater have been recorded in the last 40 years) and the presence of the many small events detected by this survey indicate that the seismicity of this area is of the type found by others (Ward and Björnsson, 1971; Ward and Jacob, 1971) to be indicative of geothermal potential.

The strain release distribution maps show that the swarm area is the largest source of strain release during the thirty days. The peak contours of strain release may outline a region of weakness. This region is thought to exhibit the necessary character of a geothermal system. The area is undergoing current tectonism and the rock may be weak. Such an area is a potential reservoir site.

During the survey no seismic activity was detected near Black Rock Point. If we assume that a magnitude 4 earthquake occurs every 30 years at Black Rock Point (for the 1936 event M=4), and that b=0.81, as has been observed for northwest Nevada, then 5 magnitude 0 earthquakes would have been expected during this survey. However none were recorded, though reciprocity indicates that such events would have been detected. The area around Black Rock did not exhibit the normal background seismicity during the last few days of this survey when the detection threshold was well below 0. Therefore, the area around Black Rock Point is interpreted to be either aseismic or to exhibit an episodic type of tectonism not accompanied by the usual distribution of sizes of earthquakes.

Conclusions

1. Thirty days of seismic recording near Gerlach, Nevada with high-gain short-period seismic networks detected over 400 local seismic events, the largest of which is estimated to have a magnitude of 1.5.

2. An earthquake swarm in the area northeast of Gerlach near Hualapai Flats with over 300 events was recorded. This area is interpreted to have the highest geothermal potential of the area surveyed.

3. An interpretation of the seismicity has three subparallel active zones located near and to the northeast of Gerlach. Each of the seismic zones curve from a southwest trend to a northwest trend and are separated by aseismic areas. The apex of each zone is interpreted to be the most tectonically active part of each zone.

4. The area near Black Rock Point showed no seismicity during this survey.

5. The seismicity of this area, as based on this survey and the historical record, indicates that the earthquakes may pose a threat to the exploitation of a commercial geothermal field during the lifetime of the structures which accompany such development.