GROUNDNOISE SURVEY
of the MT PRINCETON AREA,
COLORADO, 1974

by

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9 July 1974

Introduction

A groundnoise survey was conducted for Amax by Senturion Sciences in the vicinity of Mt. Princeton, Chaffee County, Colorado, during the period 31 March through 6 April 1974. The survey was intended to reveal any anomalous noise levels in the valley and adjoining bedrock, that might be attributed to geothermal noise generators, as postulated by Douze & Sorrels (1972). A report containing data and interpretation has been submitted by Senturion. My report is the result of a scrutiny and reevaluation of Senturion's data.

Field Procedure

Six seismographs, utilizing 2 Hz HS-10, 2000-ohm seismometers as transducers, were deployed during the working day. Their outputs were transmitted by radio to a central receiver station containing a magnetic tape recorder and WWVB time code receiver. Data were collected throughout the ensuing night, and on the following day, six more stations were occupied. The tapes were played back in the laboratory. Three ten-minute segments during periods of low wind and cultural noise were selected for analysis from each station's record, from which power-spectral density (PSD) charts were automatically compiled for the frequency range 0.25 - 14Hz. The scales of the charts (Figure 1) compensate for the seismometer response characteristics; we have replotted the PSD's making this adjustment to a linear db scale (Figure 2).

In all, 32 stations were occupied specifically for groundnoise monitoring. Six additional PSD's were obtained from the stations of the preceding microearthquake survey. The records used were from the night of 30 March. The 32 groundnoise stations occupied are shown by circles in Figure 3; the microearthquake stations, by triangles. No reference station was maintained during the survey, so stationarity of data from one night to the next must be assumed. A day-by-day display of the PSD's can be found in the Mt. Princeton Folio in Amax' map files.

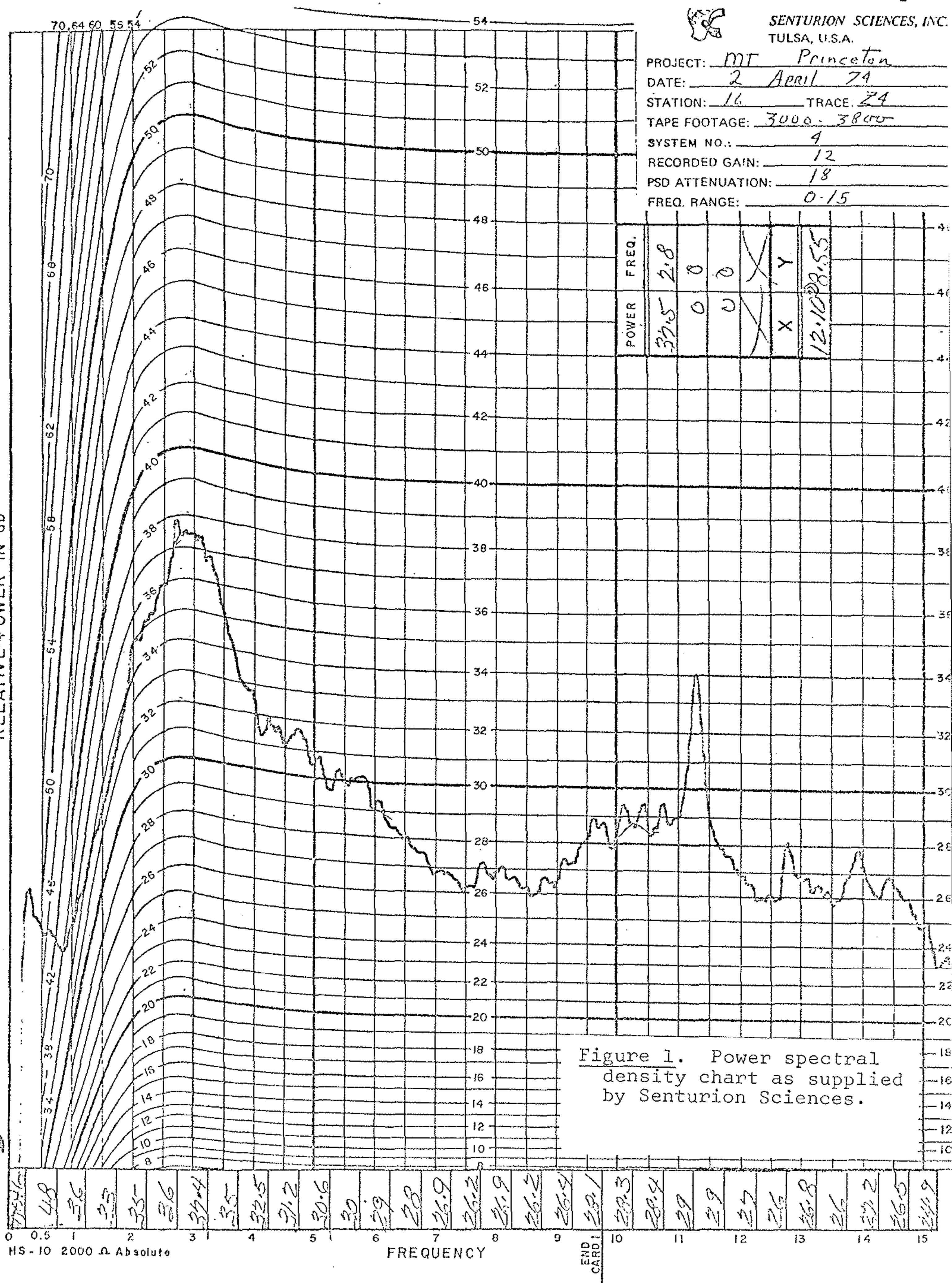


Figure 1. Power spectral density chart as supplied by Senturion Sciences.

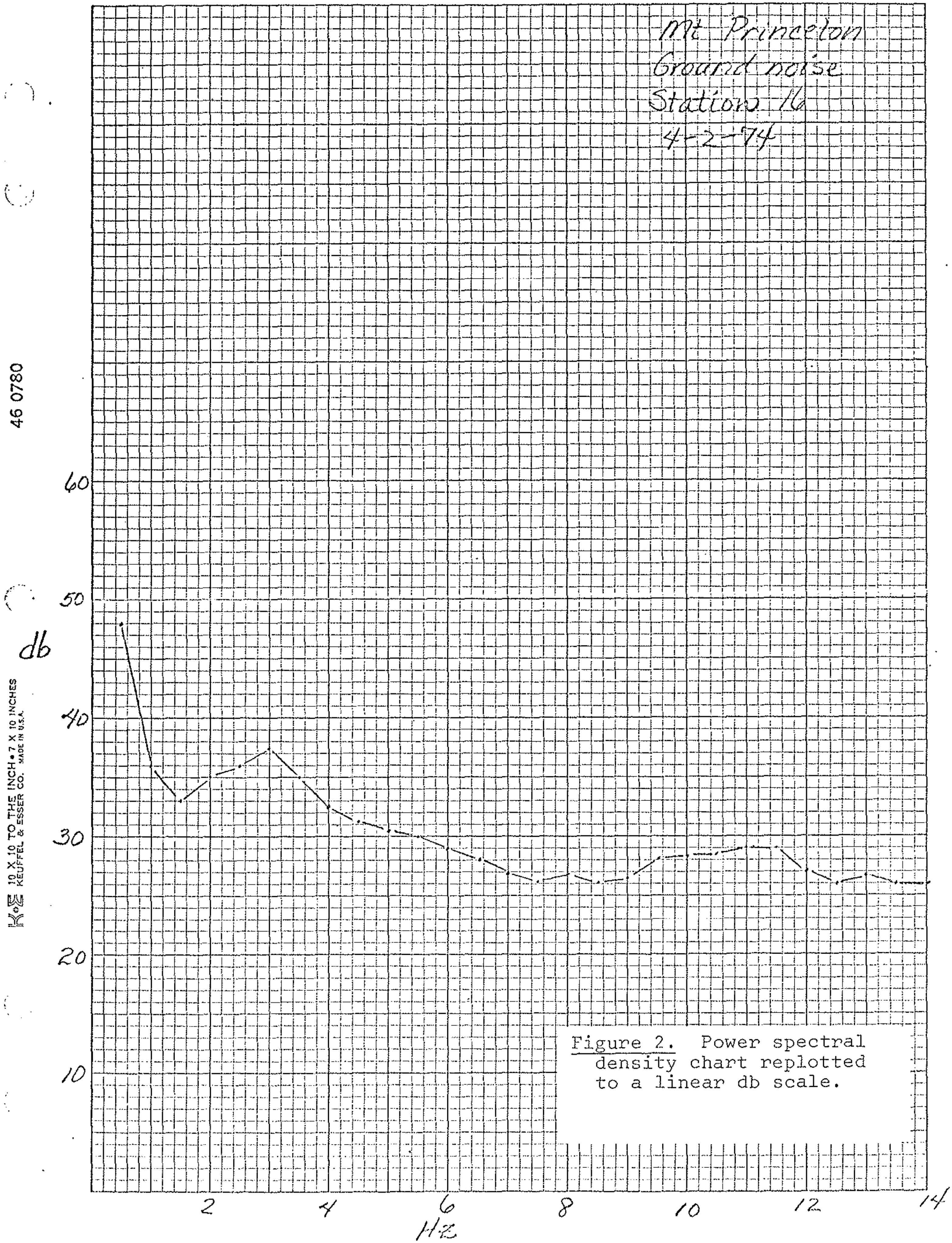


Figure 2. Power spectral density chart replotted to a linear db scale.

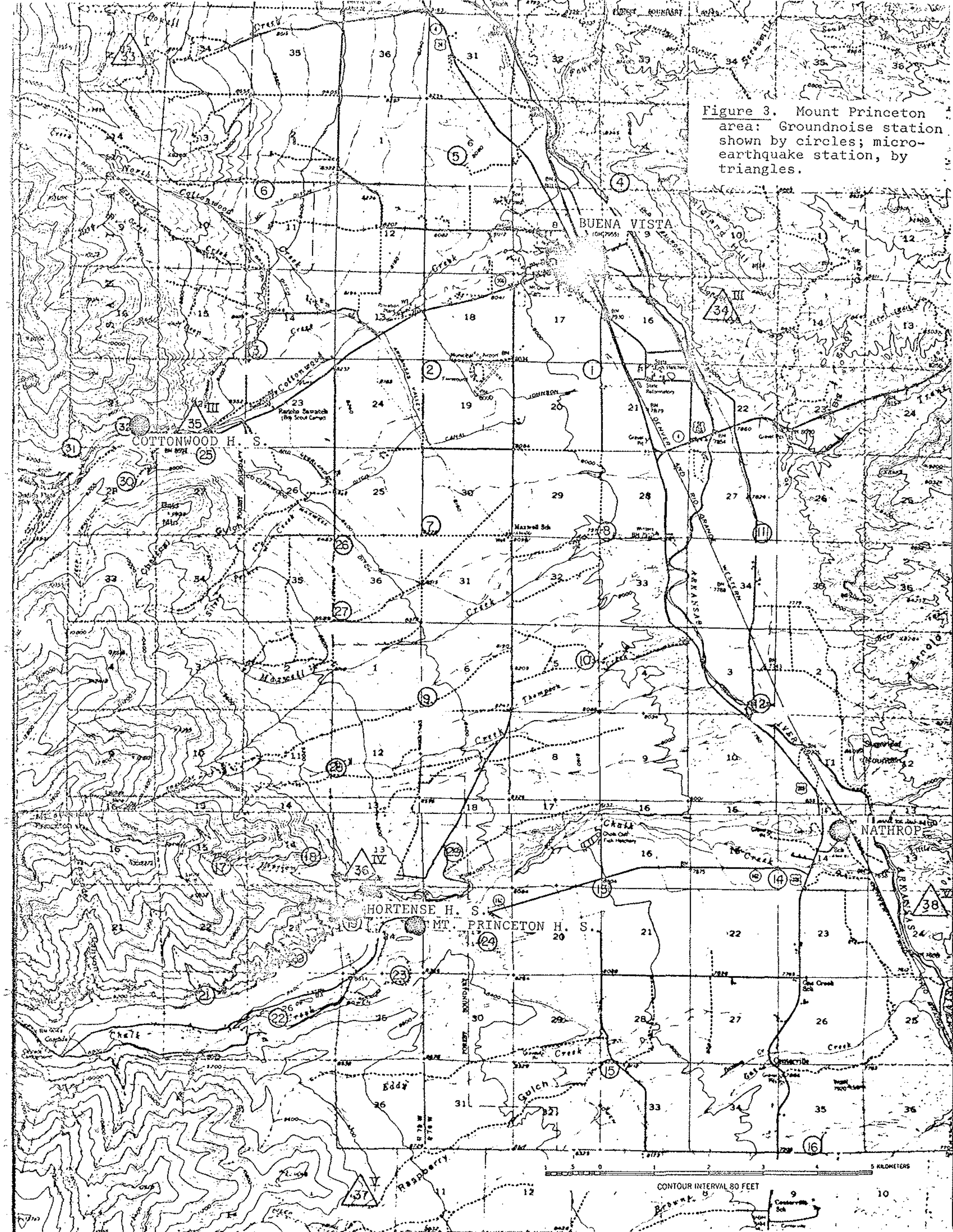


Figure 3. Mount Princeton area: Groundnoise station shown by circles; micro-earthquake station, by triangles.

Senturion Analysis

Senturion provided three maps representing their interpretations. Automated contouring was used in their preparation. The survey portions of these maps are reproduced herein, as follows:

1) Integrated Power (Figure 4): The area under the PSD curve at each station is computed between the limits of 0.5 and 14 Hz. From the map we see a conspicuous low along Chalk Creek and the Chalk Cliffs and a lesser low between Cottonwood Hot Spring and Buena Vista. Notable highs occurred at the south end of the survey, in the center, and at Station 36. The last (Microearthquake Station IV) was unusually noisy throughout the preceding survey. It was located on quartz monzonite bedrock, within one kilometer of Hortense Hot Springs. The integrated power map agrees generally with our own plot of the power within the frequency range 1-5 Hz (Figure 13).

2) Mean Frequency of the Integrated Power (Figure 5): This value at a station is obtained by multiplying each frequency by its corresponding power, summing the products and dividing by the sum of the individual powers. The mapped results suggest that the valley's edge yields generally higher frequencies than the center of the valley, while Chalk Creek yields low frequencies.

3) Anomalous zones (Figure 6): These are the shaded areas representing the overlap of high frequency and high power zones. In addition, faults are inferred from profile plots (Figure 6A) by the intersections of the frequency and power curves, according to Senturion's philosophy.

The portion of Senturion's report representing interpretation is reproduced below:

> Two groundnoise anomalies defined by high power and high frequency components are established in this survey. The northern anomaly occurs at the intersection of Sec. 7, 12, 13, 18, of T15S, R78W-79W and the southern anomaly is located near the intersection of Sec. 29, 30, 31, 32, of T15S, R78W.
>
> The northern anomaly may be generated by a thermal cell contiguous to a fault complex. The groundnoise defined-and topographically-inferred Merriam Creek fault (Y) could extend to this cell at depth and provide the conduits for Hortense and Mt. Princeton Hot Springs. Similarly, Fault G, cross section B-B', could supply this conduit.

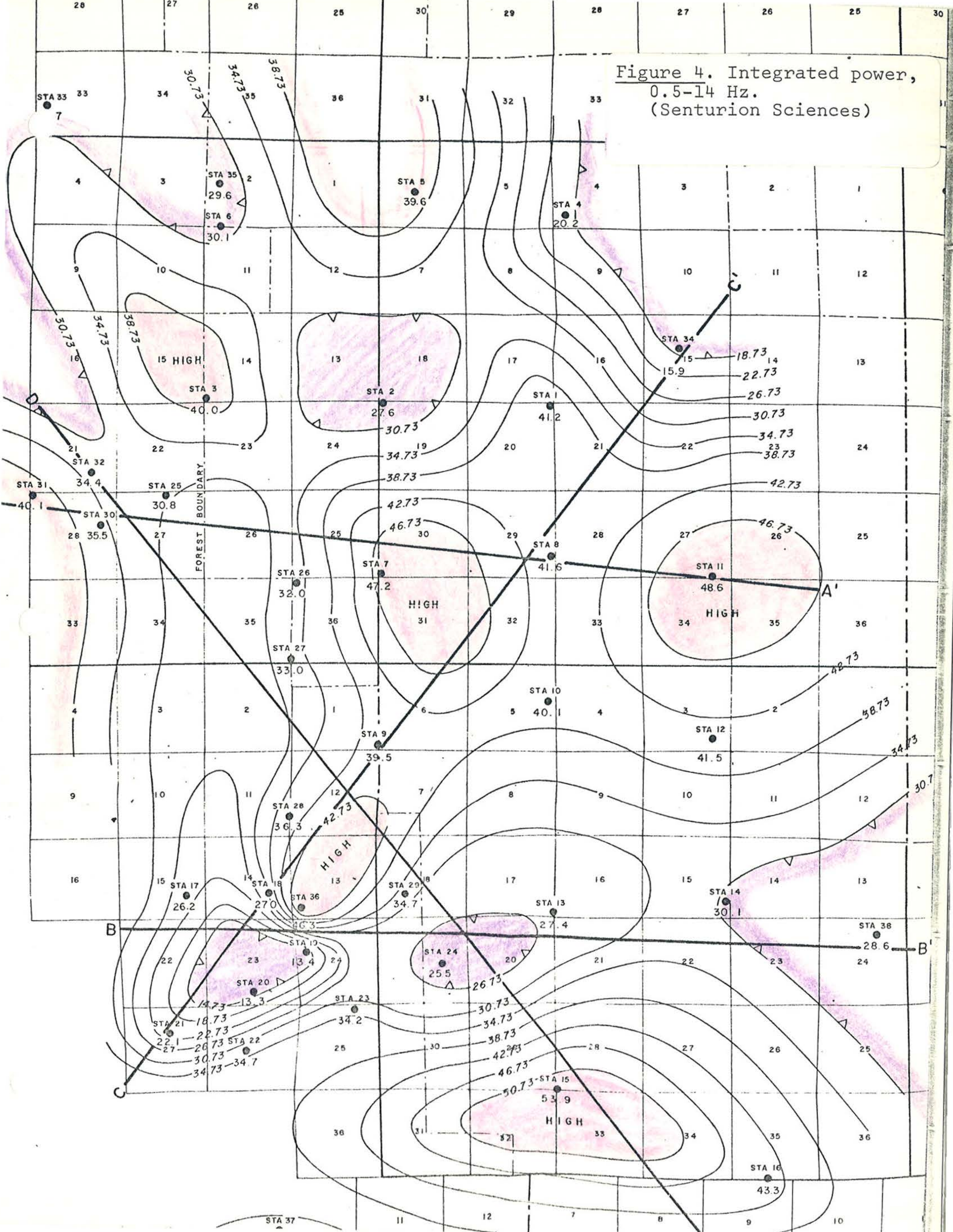
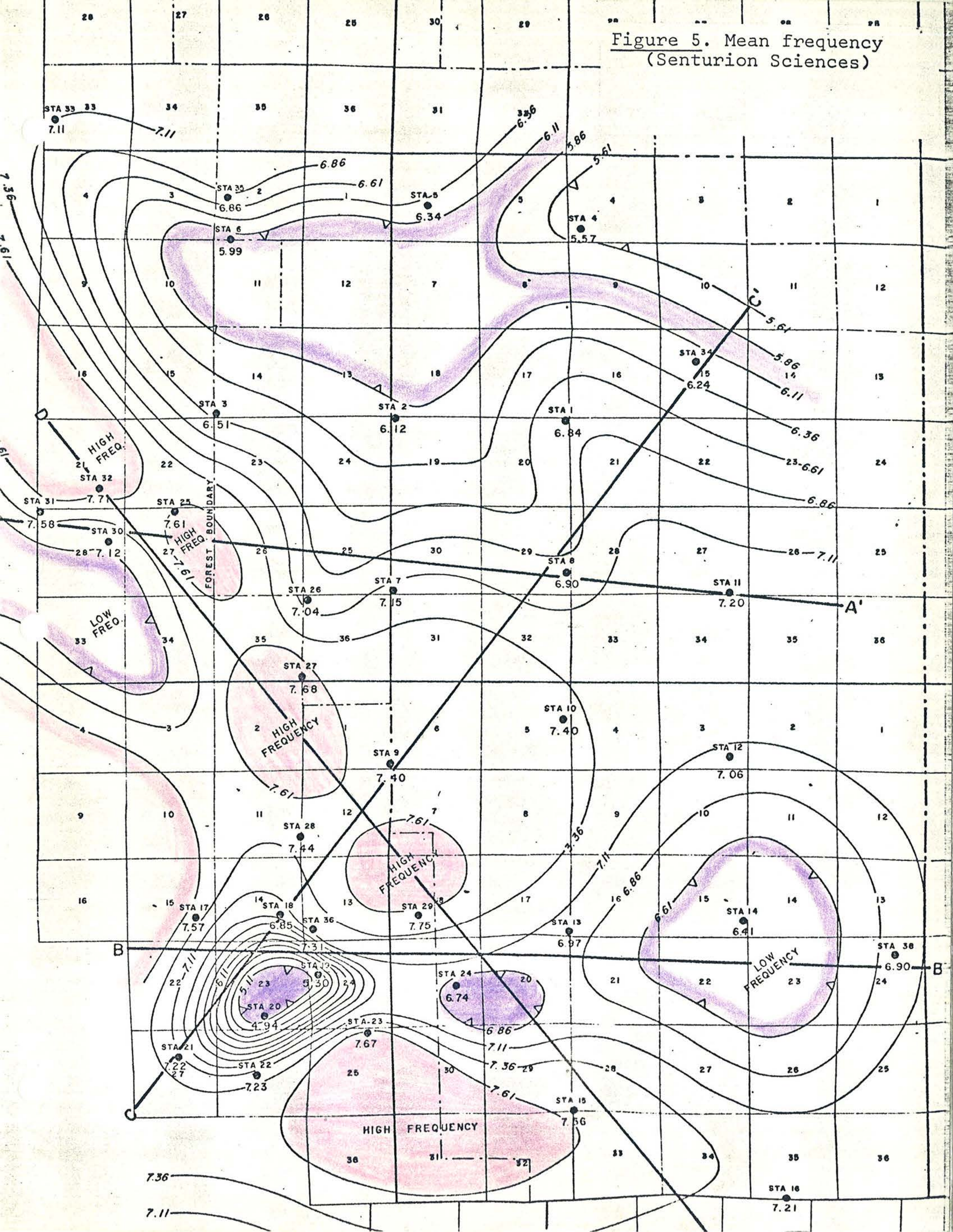


Figure 4. Integrated power, 0.5-14 Hz. (Senturion Sciences)

Figure 5. Mean frequency (Senturion Sciences)



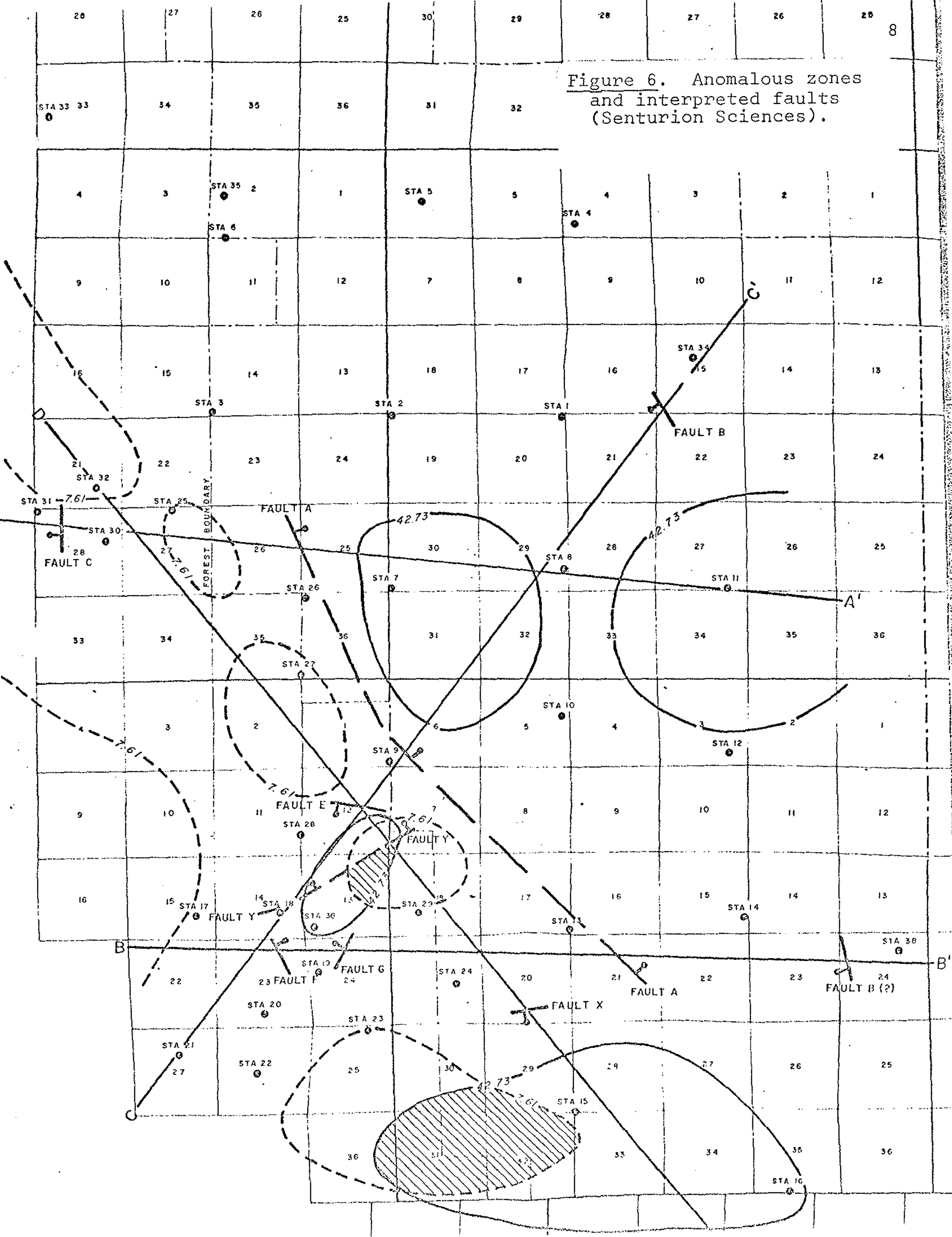


Figure 6. Anomalous zones and interpreted faults (Senturion Sciences).

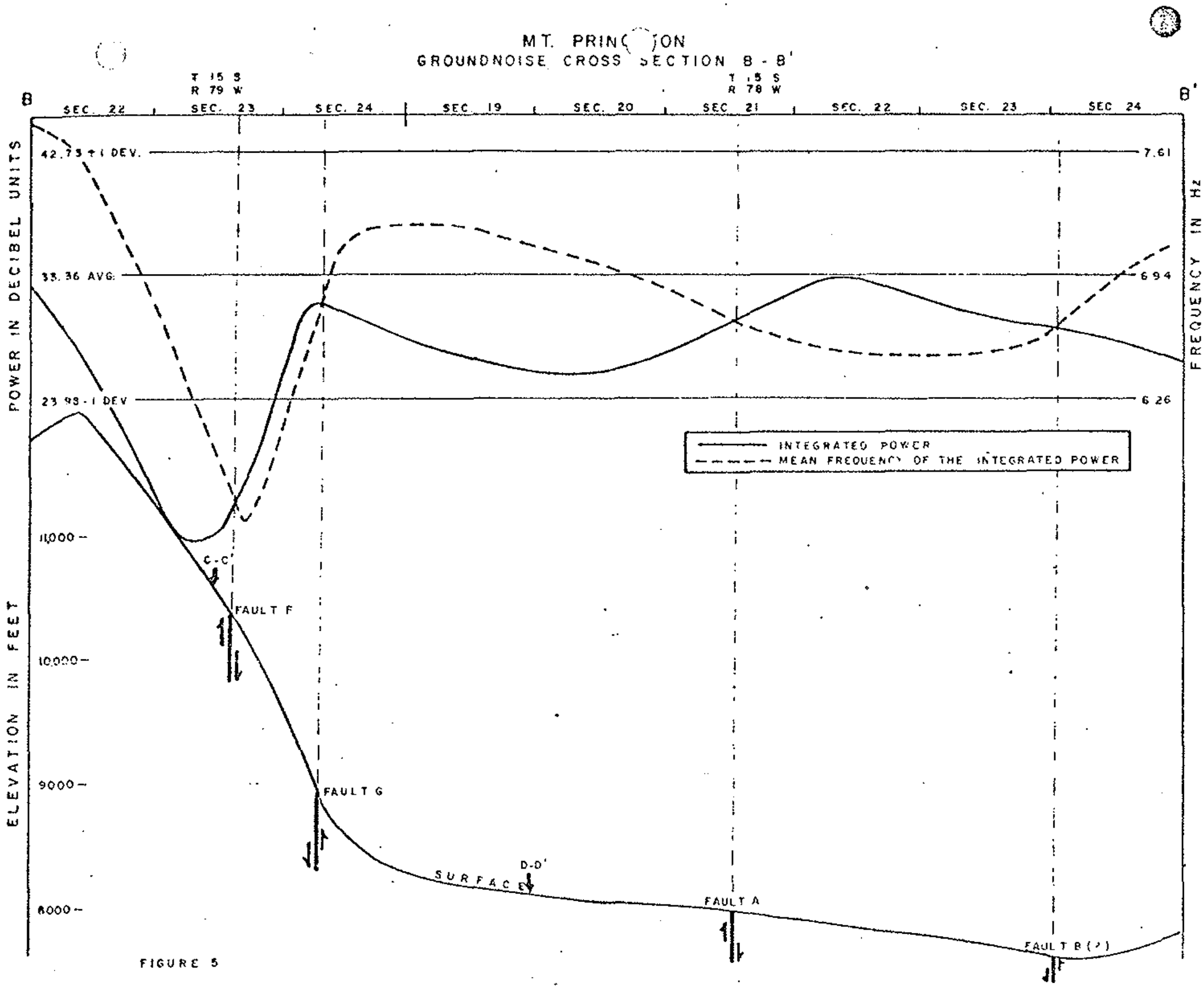


Figure 6A. Locating of faults by intersections of integrated power and mean frequency profiles, according to Senturion Sciences.

The southern anomaly exhibits a very high power component centered in Sec. 32. Fault X expressed by Chalk Creek and groundnoise defined on cross-sections B-B', Figure 5, could also supply the conduit for the Hot Springs Complex. Station density is lacking in this area for detailed resolution.

COMMENTS AND RECOMMENDATIONS

Two additional features of interest are noted. The NW-SE trend of Mean Frequency anomalies parallel to the Sawatch Range bear out the possibility of a major fault with this trend (Fault A). Higher frequencies are indicative of the dense Pre-Cambrian strata on the west side of the fault.

Sharp gradients in the anomalous areas could indicate separate cells or a deep central source. Statistical analysis and mapping of the lower frequencies would provide additional insight.

The southern anomaly lacks sufficient data-point density to presently be highly prospective. Heat flow test holes and/or additional survey stations could contribute pertinent data. Similarly, definition of the fault patterns would also be enhanced.

Amax Analysis

Because previous groundnoise surveys (Douze & Sorrells, 1972; Goforth, et al., 1972; Iyer, 1972; and discussion with GKI) reveal that most of the energy associated with geothermal sources occurs in the 1-5 Hz range, we separated out the responses for individual frequencies within that range and hand-countoured the results. These appear in Figures 7 through 13, of which the last two represent the power sum within the bands 1-3 and 1-5 Hz, respectively. The 1 and 2 Hz plots (these frequencies being regarded as the most important) are most similar. They emphasize the bulls-eye peak at Station 36, and the broader highs at the south end of the survey and diagonally across the middle. The lows seem to be associated with Chalk Creek and Cliffs, Cottonwood Hot Springs and Station 33 to the north. Similar, but not as well defined, patterns appear in the frequencies 3, 4 and 5 Hz. The composites bring out more clearly the E/W low extending from the Chalk Cliffs toward Nathrop. There is good agreement with Senturion's Integrated Power plot (Figure 4).

Station 36 is associated with a low-frequency disturbance of very local extent. The station is virtually on the frontal fault, as mapped by Fred Limbach for Amax. Station 35, on the other hand, between two faults is closer to being a noise low than a high.

A noise low extends from beneath the Chalk Cliffs (but not the valley bottom) eastward along the path of Chalk Creek towards Nathrop. This might be regarded as a noise sink. The anomaly seems to embrace Hortense Hot Springs and the fumaroles in the cliffs. A lesser low occurs across Cottonwood Canyon at its Hot Spring.

A persistent high noise level appears throughout the spectrum around Station 15 on Raspberry Gulch. Another persistent high occurs in the center of the survey around Station 7. The diagonal linear high extending parallel to the highway at the 1 and 2 Hz plots might be interpretated as cultural in origin; however, it is not sustained as well in the higher frequencies.

Origin of the Groundnoise Pattern

In their discussion of Imperial Valley groundnoise, Douze & Sorrells hypothesized a model of a noise generator at depth resulting from timewise pressure variations in a thermal reservoir. From their calculations a system 500X3000m, 300m-thick, whose top lay 1500m below the surface produced an anomaly about 4 km across (1/2-power width). The anomaly at Station 36 appears limited to about one section and hence must be due to a smaller, shallower source. Senturion's explanation of a fault-controlled thermal cell feeding the adjacent springs is reasonable. Because the station was on rock, I doubt that the high noise level can be attributed to local ground amplification of the low frequencies, since this usually occurs over valley fill.

Low-frequency amplification might account for the anomalies in the valley; their distribution would have to be explained by facies changes in the sediments, or variations in depth to basement. On the other hand, they may be attributable to geothermal sources at depth.

The anomalous low along Chalk Creek is of particular interest, since it seems to express a structural feature extending from beneath the cliffs out across the valley. If we assume that geothermal sources are producing the highs in the remainder of the valley, Chalk Creek would overlie a zone lacking geothermal noise sources. On the other hand, if the valleys highs are due to low-frequency amplification by the sediments, then Chalk Creek would represent a zone of different lithology absorbing the energy. Our station spacing was really not adequate in the valley to define the various anomalies well.

Recommendations

If additional groundnoise monitoring is contracted for Mt. Princeton, the following improvements in procedure should be adopted:

1) Closer station spacing (1-section to 1Km) in the valley and more coverage along the base of the range are needed. The survey should be extended to the south to delineate the southern anomaly.

2) A reference station should be established for continuous monitoring of background noise, somewhere outside of possible anomalous zones.

3) A 4-or 5-station small array (about 1 km across) should be operated near an anomalous high to attempt to compute a vector from noise bursts. Two three-station arrays may be substituted to locate the sources.

4) Other types of surveys, particularly electrical, should focus on the anomalous zones in order to determine whether they are related to geothermal sources.

These suggestions apply as well to surveys in other areas.

Conclusions

1) Anomalously high noise levels at low frequencies occur locally in the valley. These are due either to ground amplification of microseisms and local cultural noise, or deep geothermal noise sources.

2) A local high noise level occurs on bedrock at or adjacent to the frontal fault and within a kilometer of Hortense Hot Springs. It is probably due to a thermal source situated along the fault.

3) An anomalous noise low extends from the Chalk Cliffs eastward under Chalk Creek where it flows across the valley. A structural or lithologic zone that absorbs ambient seismic energy is indicated. This low embraces the hot springs and fumaroles in Chalk Creek.

4) A very local groundnoise low appears around Cottonwood Hot Spring in Cottonwood Canyon.

5) Electrical and other types of surveys should focus on the anomalous ground noise localities in order to identify their cause(s).

6) Additional groundnoise work (if scheduled) should be designed to better resolve and define the anomalies, extend coverage to the south, and attempt to make epicenter and depth determination of discrete noise bursts using small arrays.

References

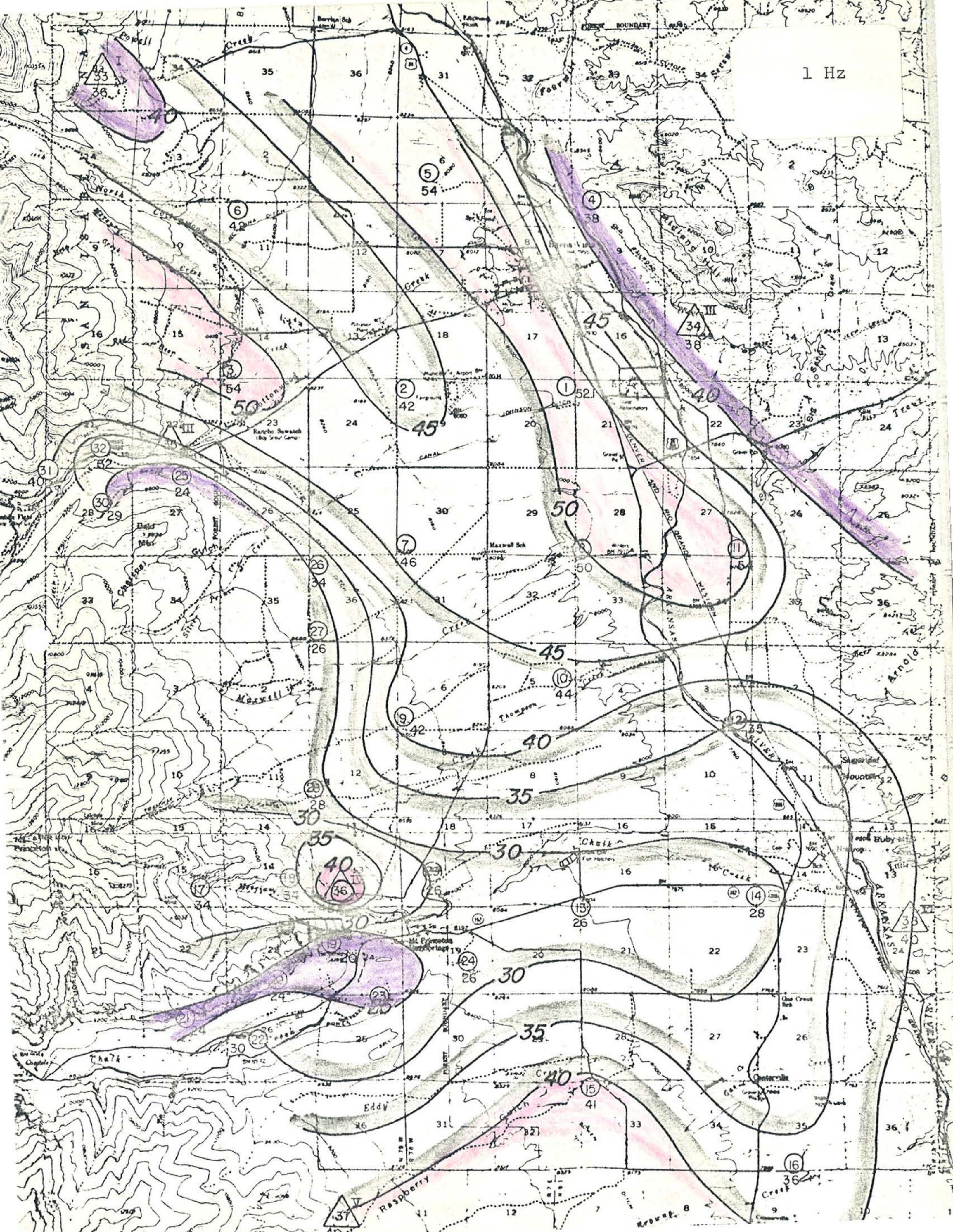
DOUZE, E.J. & G.G. SORRELLS (1972). Geothermal groundnoise surveys.
Geophysics 37: 813-824.

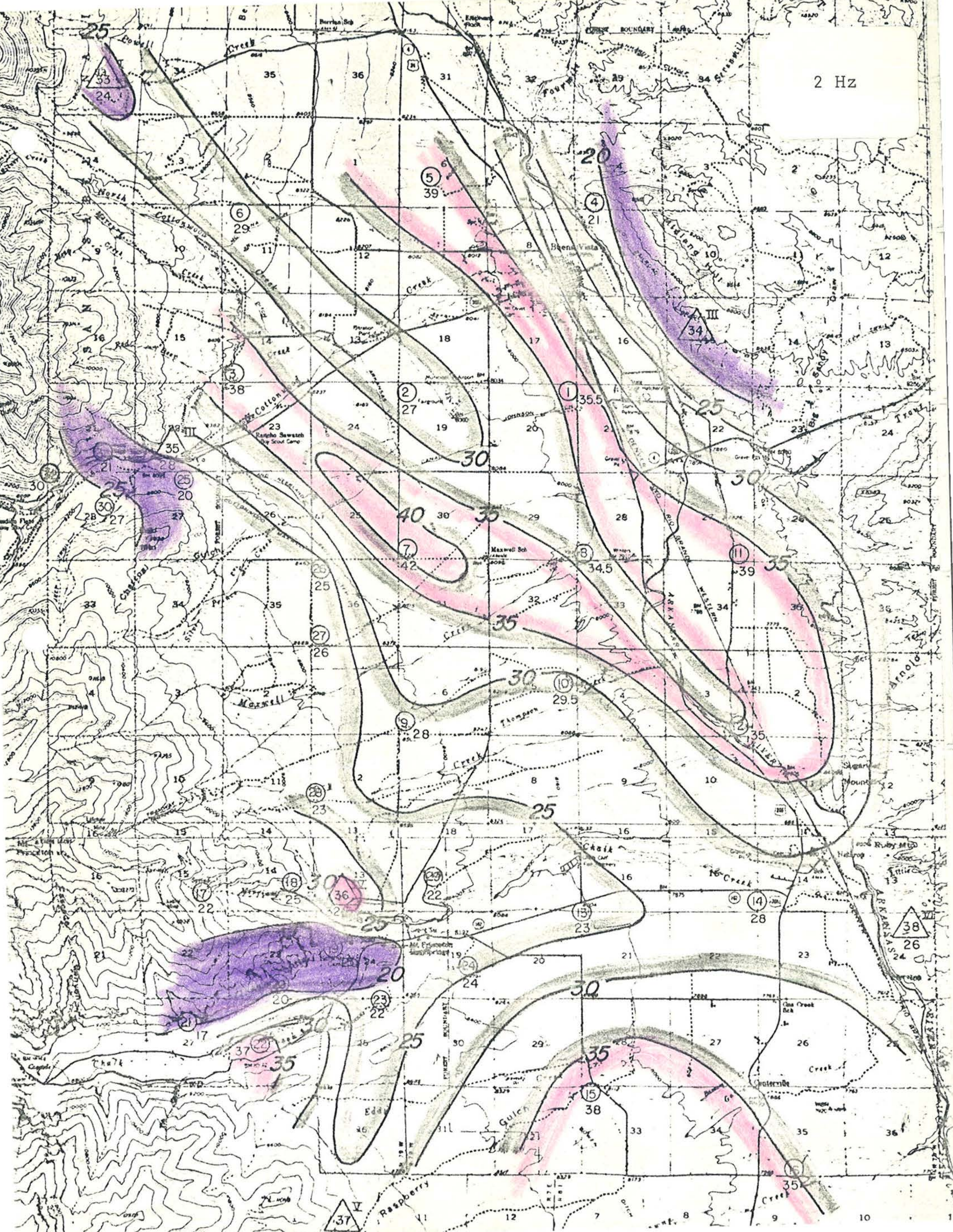
GOFORTH, T.T., E.J. DOUZE, & G.G. SORRELLS (1972). Seismic noise measurements in a geothermal area.
Geophysical Prospecting 20: 76-82.

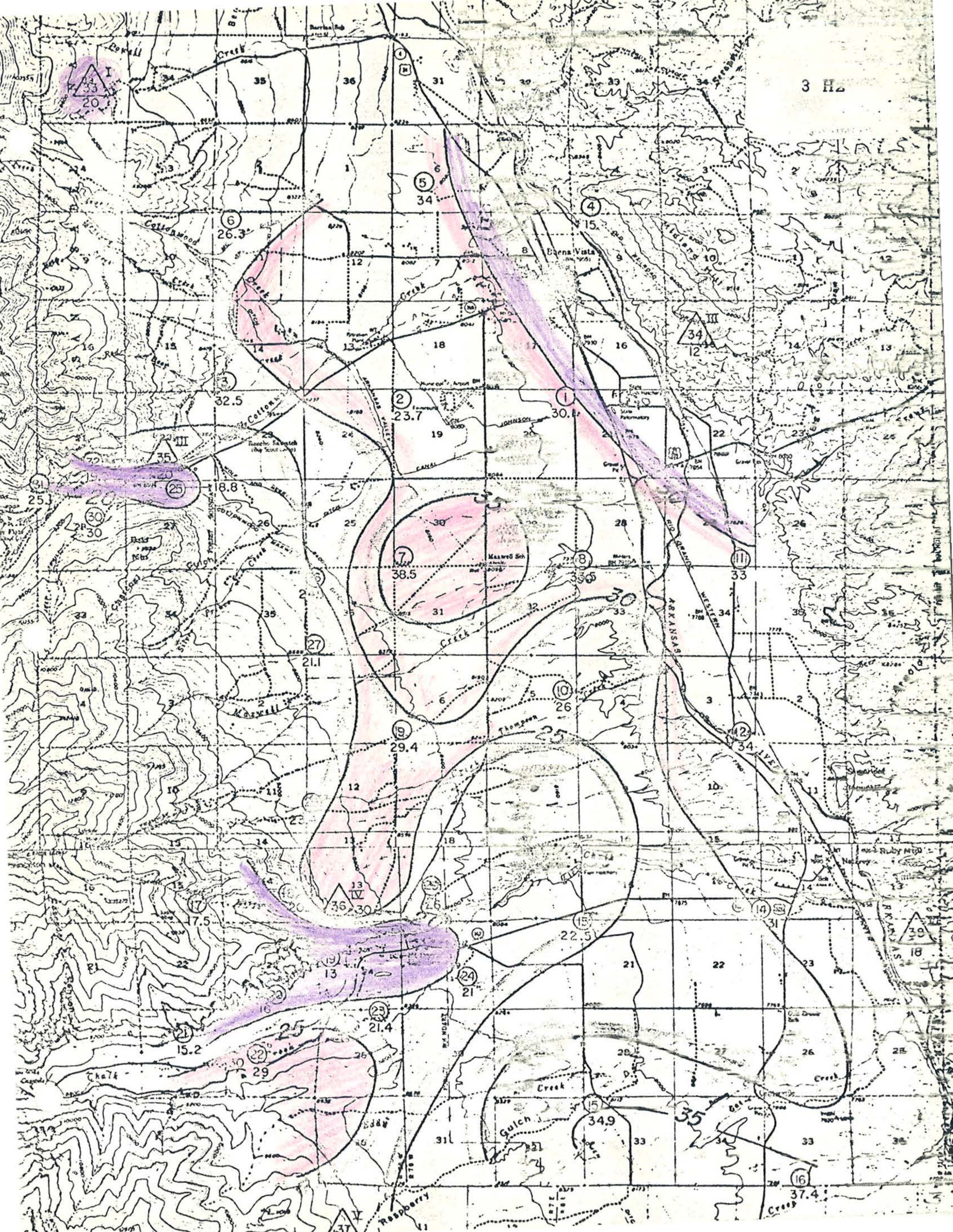
IYER, H.M. (1972). Analysis of Seismic Noise at the Geysers Geothermal Area, California. U.S.G.S. Open File Report, 21p.

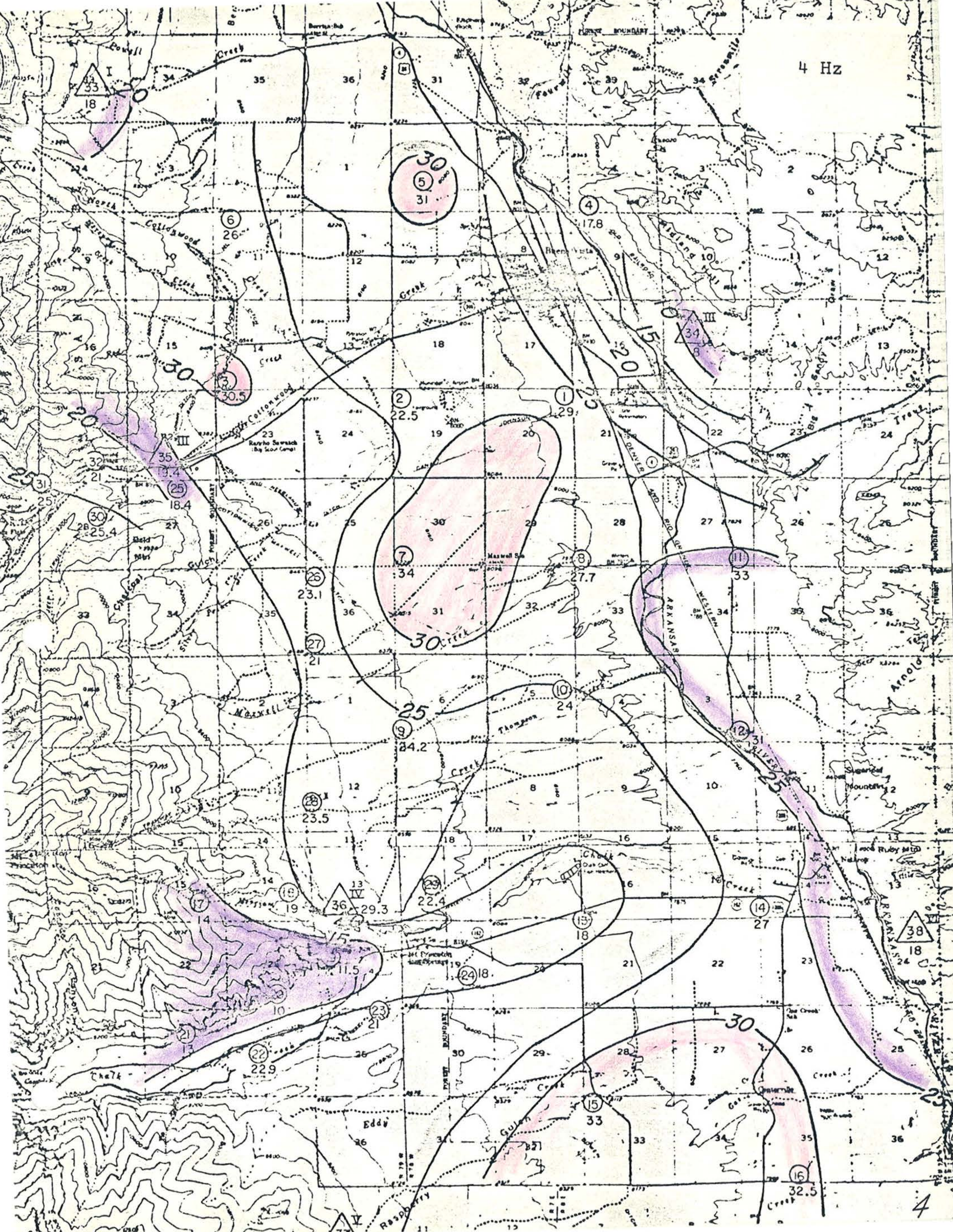
SENTURION SCIENCES, INC. (1974). Seismic Groundnoise Survey in the Mt. Princeton, Colo. Area. Report for Amax Exploration 5 pages plus data section and maps.

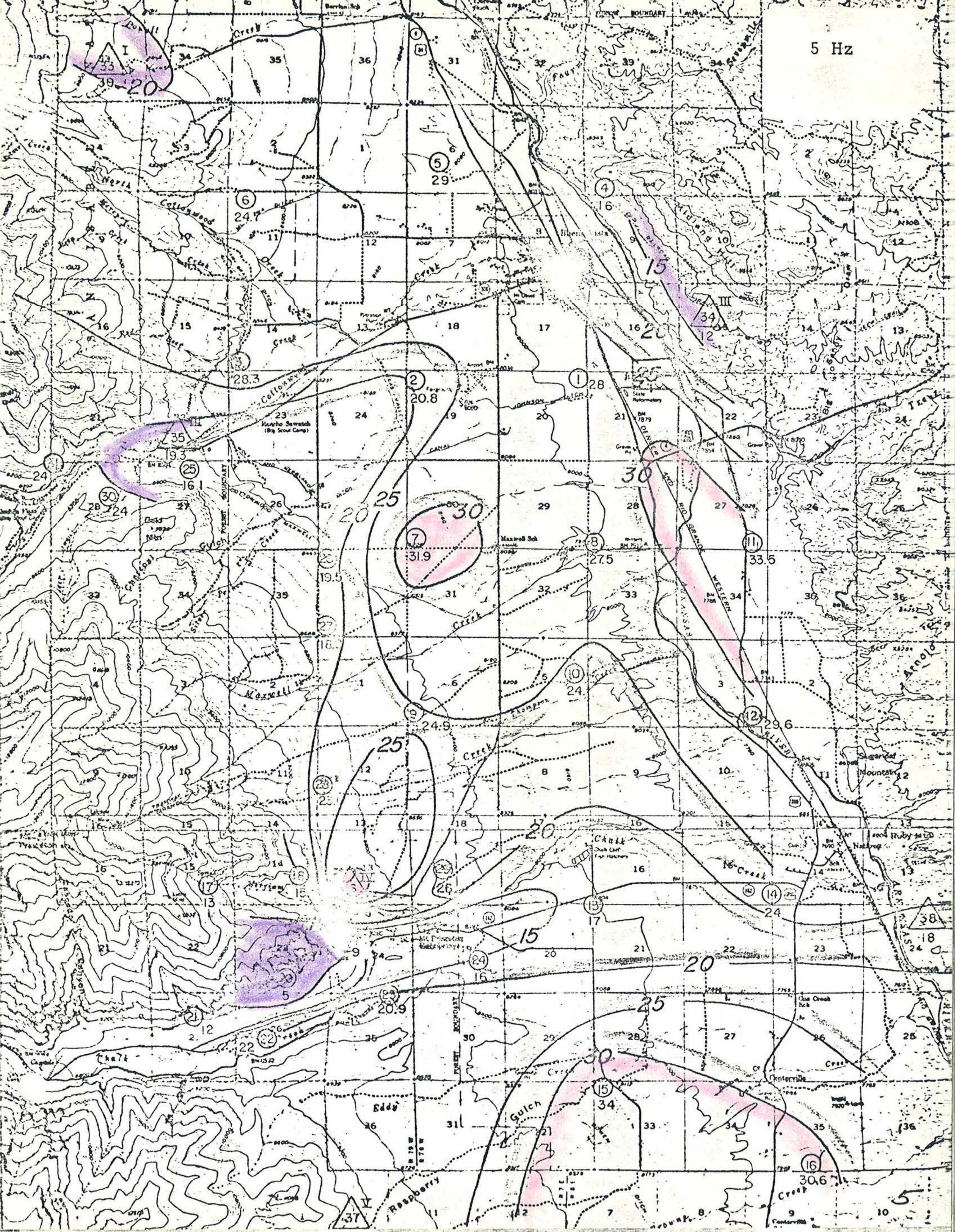
Figures 7 through 13. Groundnoise response in Mt. Princeton area for particular frequencies and bands, as marked. Anomalous high responses shown in red; lows in violet. Downsides of contours are shaded. Same scale as Figure 3.

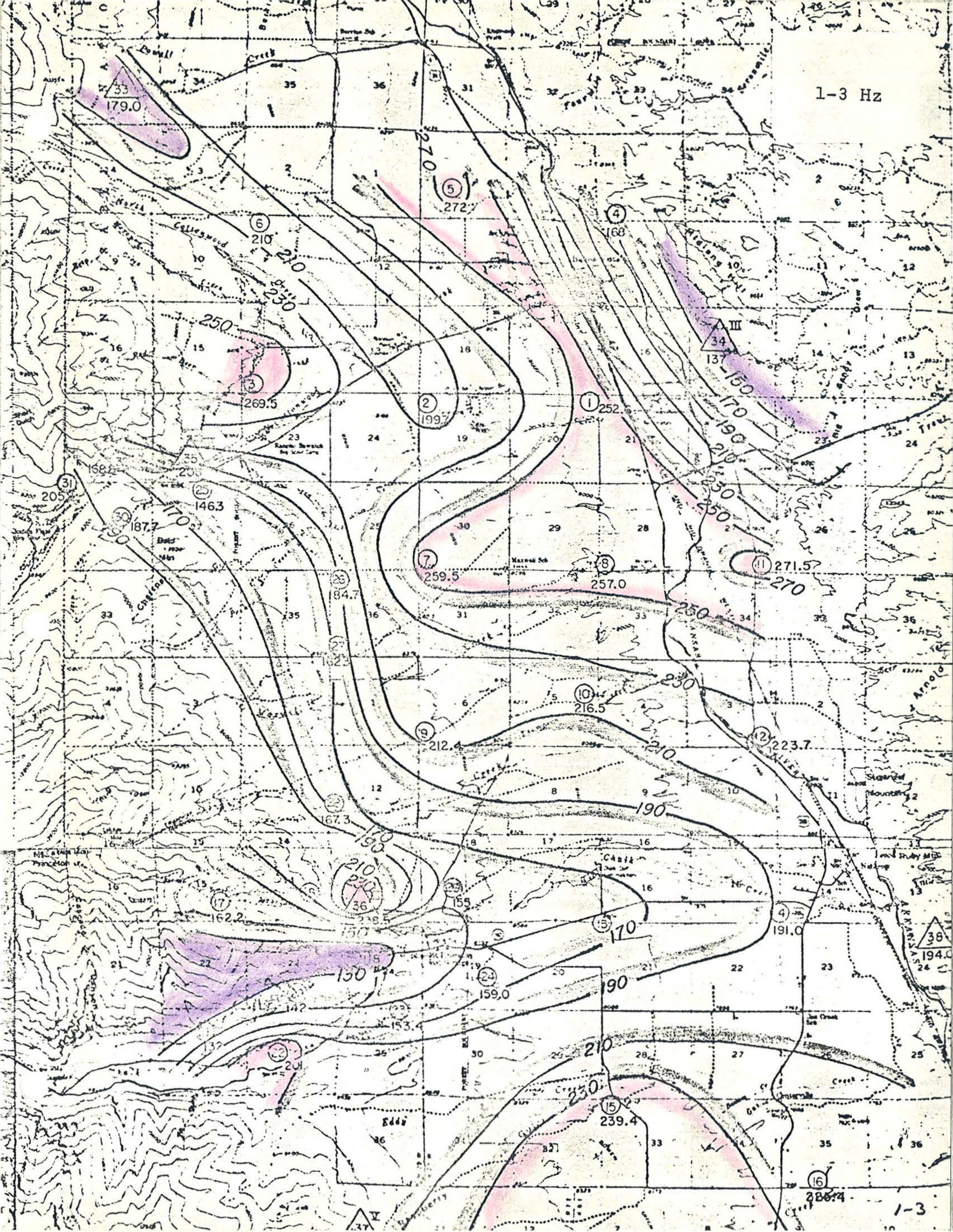

1 Hz
Rancho Sawatch (Boy Scout Camp)
Maxwell Sch
Raspberry
Thompson
Arnold
Trout
Eddy

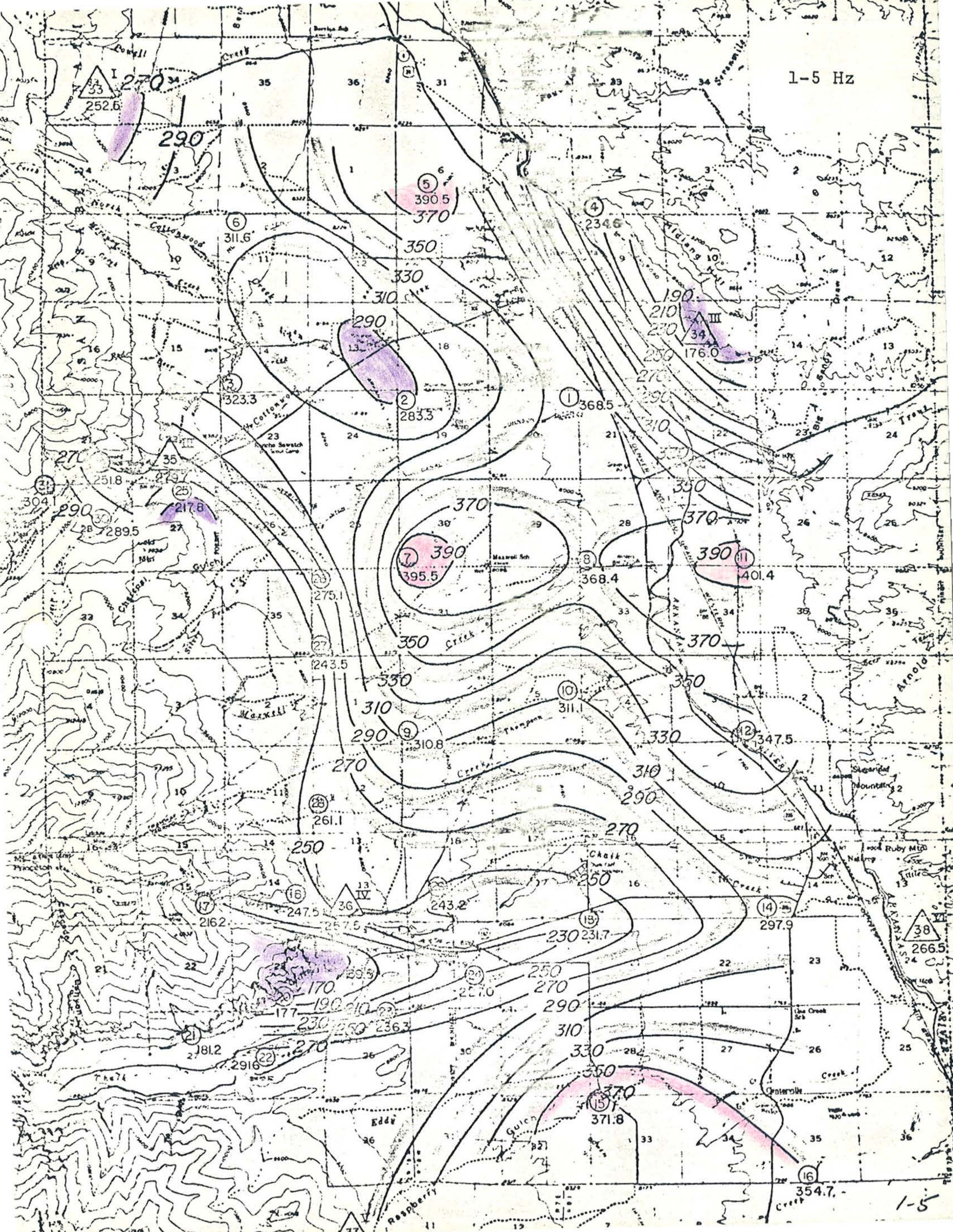

2 Hz
Buena Vista
Rancho Sawatch Boy Scout Camp
Maxwell Sch
North
Cottonwood
Creek
Powell
Charcoal
Gulch
Maxwell
Thompson
Chalk
Arkansas
River
Trout
Arnold
Ruby Mtn
Nathrop
Raspberry
Midland Hill
Mt. Princeton Hot Springs
20
25
30
35
40


3 H2
Buena Vista
Cottonwood
Creek
Maxwell Sch
Thompson
Johnson
Canal
Arkansas
Rio Grande Western
Chalk
Creek
Gulch
Raspberry
Midland Hill
30.1
23.7
32.5
26.3
34
15
38.5
33.6
33
29.4
26
21.1
18.8
25
30
35
34
12
39
18
22.5
31
21
13
15.2
29
21.4
34.9
37.4
17.5


4 Hz
Powell
Creek
North Cottonwood Creek
Ranch o Sawatch (Big Scout Camp)
Cottonwood
Maxwell
Thompson
Creek
Chalk
Chalk Creek
Mission
Eddy
Raspberry
Gulch
Buena Vista
Midland Hill
Trout
Arnold
Arkansas
River
Ruby Mtn
Nathrop
Maxwell Sch
Sugarloaf Mountain
Denver and Rio Grande Western


5 Hz
North Cottonwood Creek
Cottonwood Creek
Johnson
Maxwell Sch
Maxwell Creek
Denver and Rio Grande Western
Arkansas River
Chalk Creek
Fish Hatchery
Chalk Creek
Raspberry Creek
Eddy
Gulch
Centerville
Nathrop
Sugarloaf Mountain
Forest Boundary
Four Mile Creek
Big Trout Creek
Arnold
Rahn Sawatch (Big Scout Camp)
Charcoal Gulch
State Reformatory


1-3 Hz
1-3



1-5 Hz
Powell
Creek
Cottonwood
Maxwell
Thompson
Chalk
Eddy
Raspberry
Gulch
Sugarloaf Mountain
Ruby Mtn
Arkansas
Hidden Trail
370
350
330
310
290
270
250
230
210
190
170
390
390.5
311.6
323.3
283.3
368.5
234.6
176.0
252.6
251.8
304.1
289.5
217.8
275.1
243.5
395.5
368.4
401.4
311.1
310.8
347.5
261.1
247.5
216.2
243.2
231.7
297.9
266.5
227.0
236.3
181.2
291.6
371.8
354.7
177
1-5

MT. PRI. ETON
GROUNDNOISE CROSS SECTION A - A'

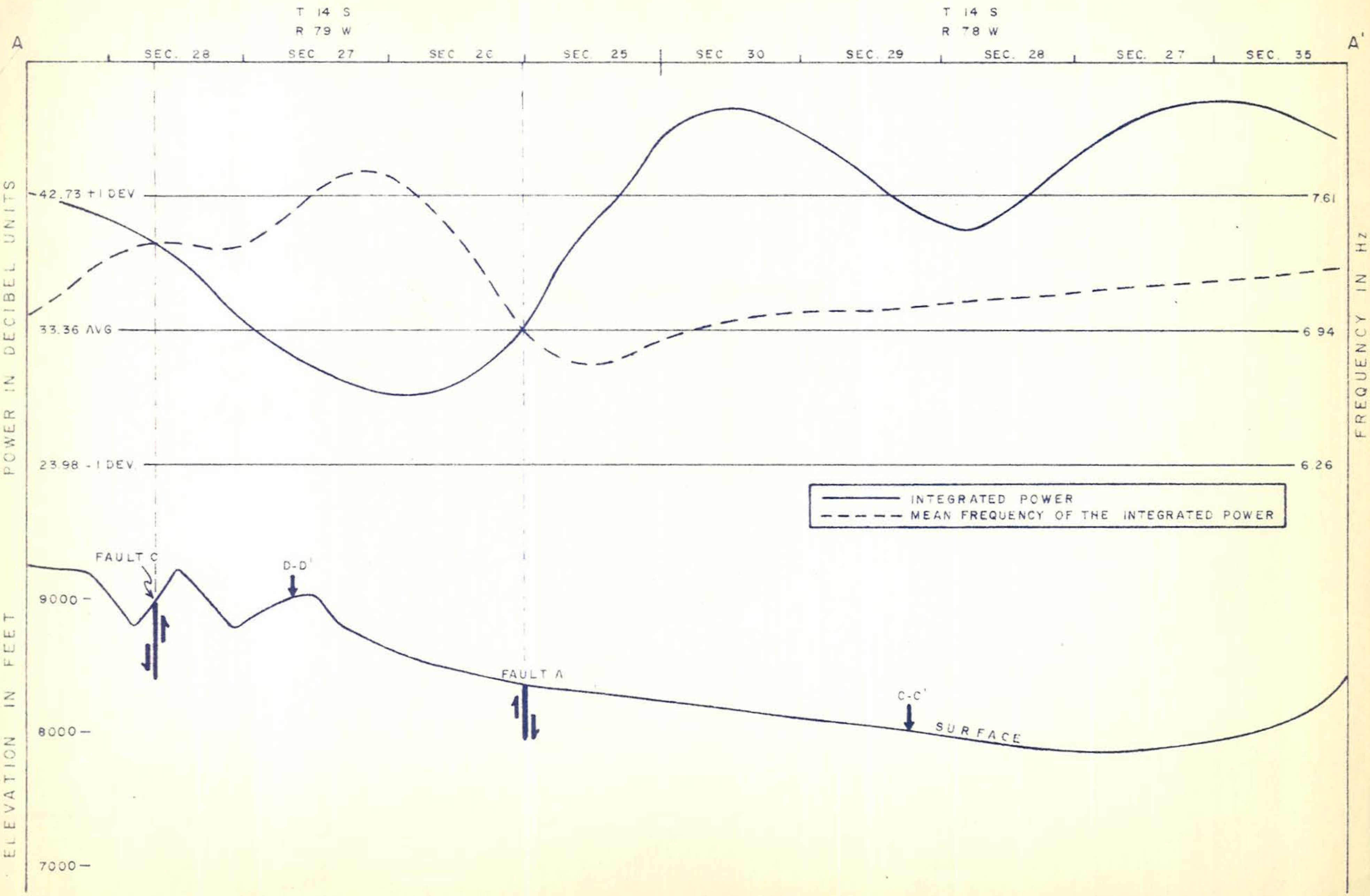


FIGURE 4
SENTURION SCIENCES, INC.

MT. PRIN TON
GROUNDNOISE CROSS SECTION B - B'

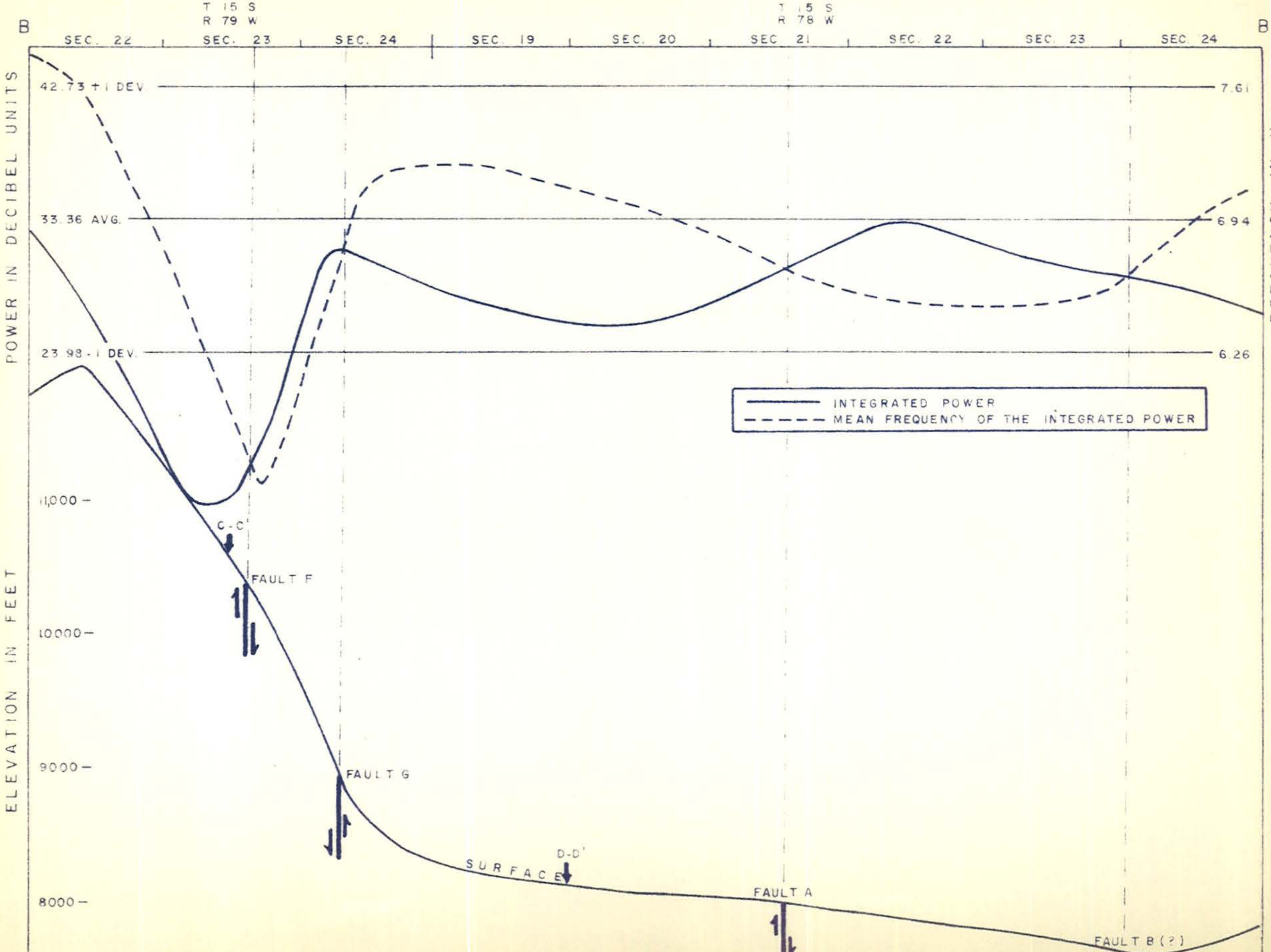


FIGURE 5

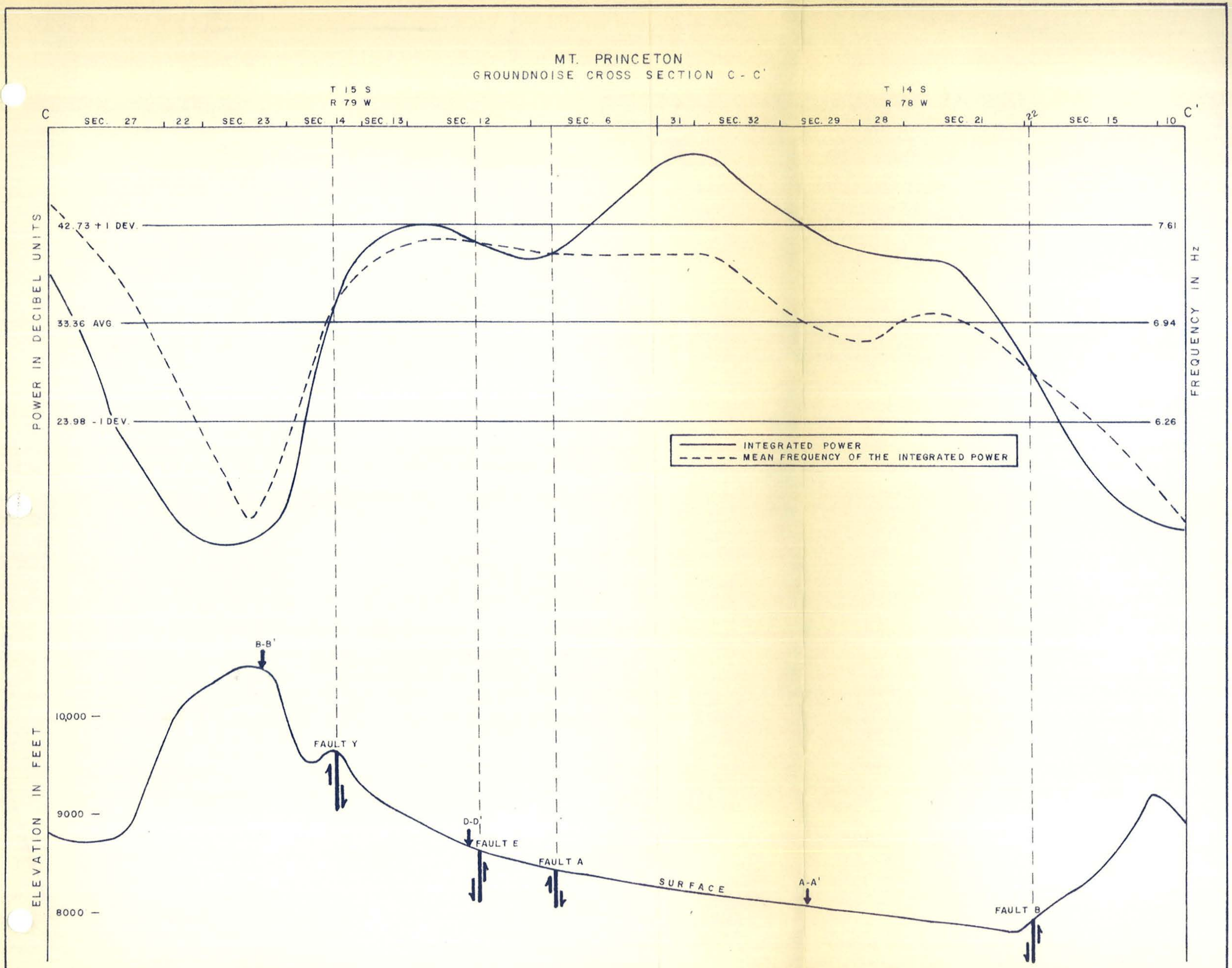


FIGURE 6
SENTURION SCIENCES, INC.

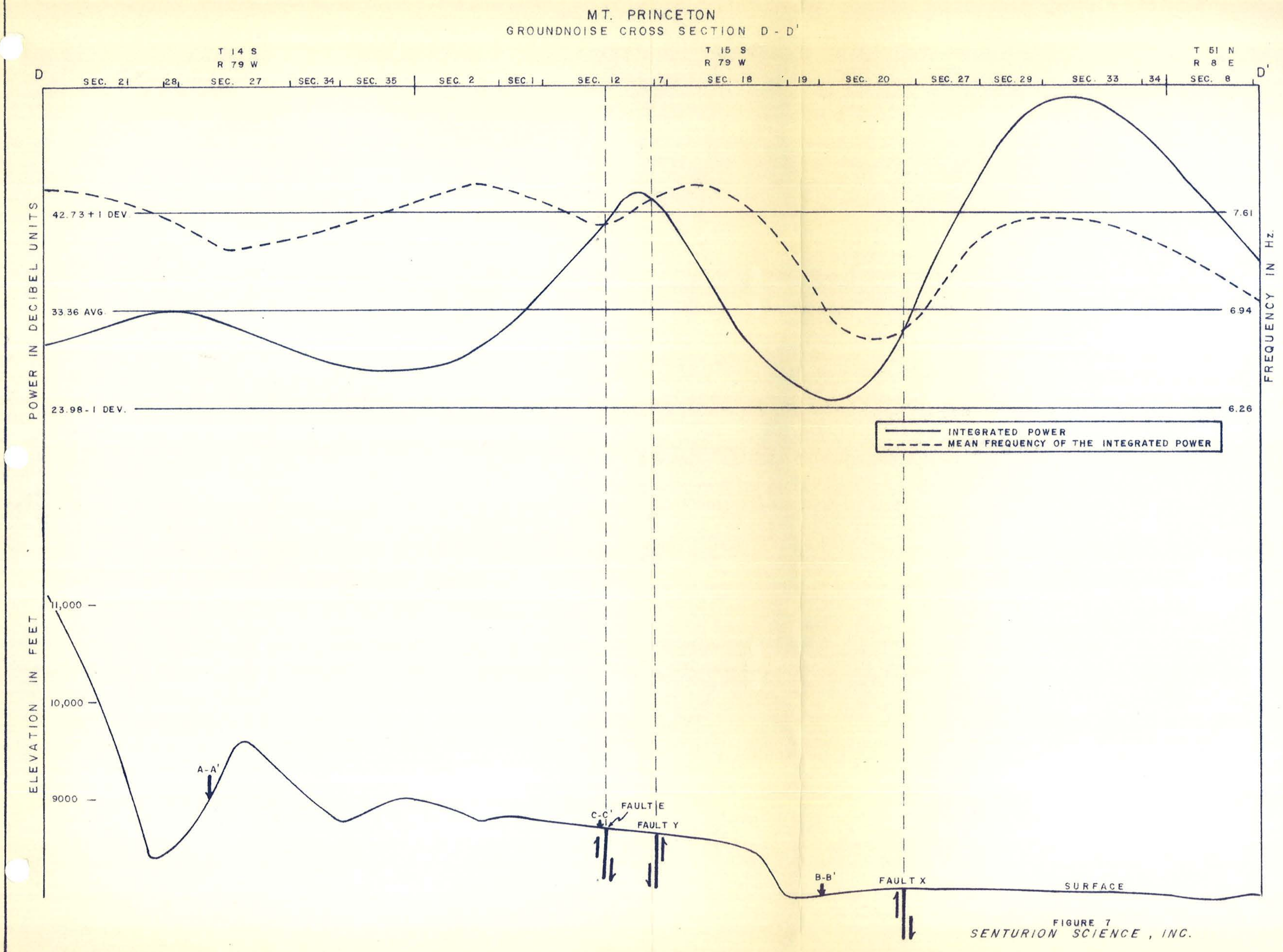
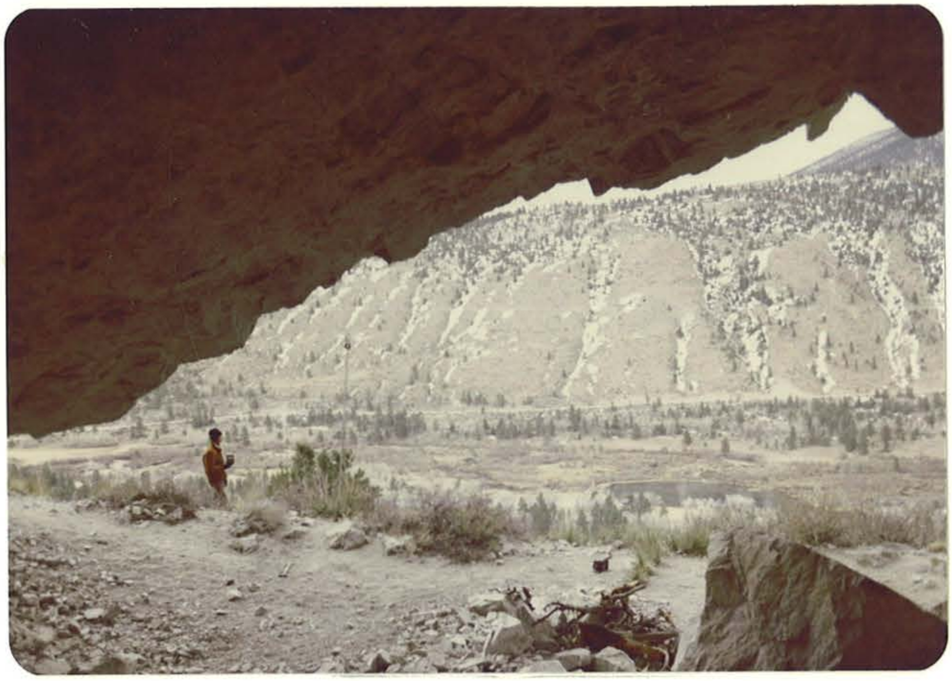


FIGURE 7
SENTURION SCIENCE, INC.

Groundnoise Survey
Mt. Princeton



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Groundnoise Survey
Mt. Princeton

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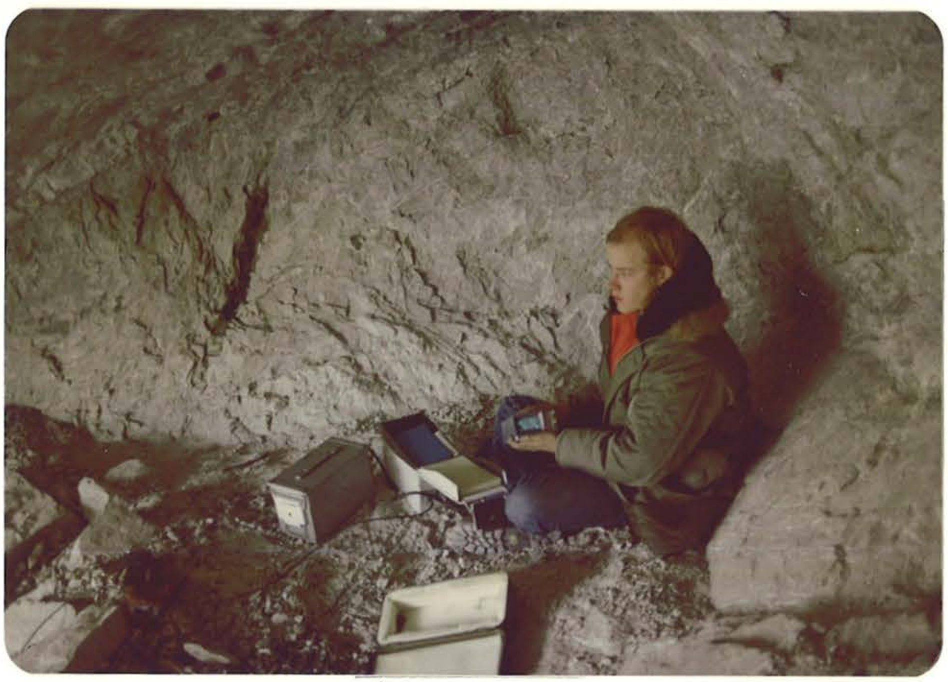
74-4-20

74-4-16



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Groundnoise Survey
Mt. Princeton

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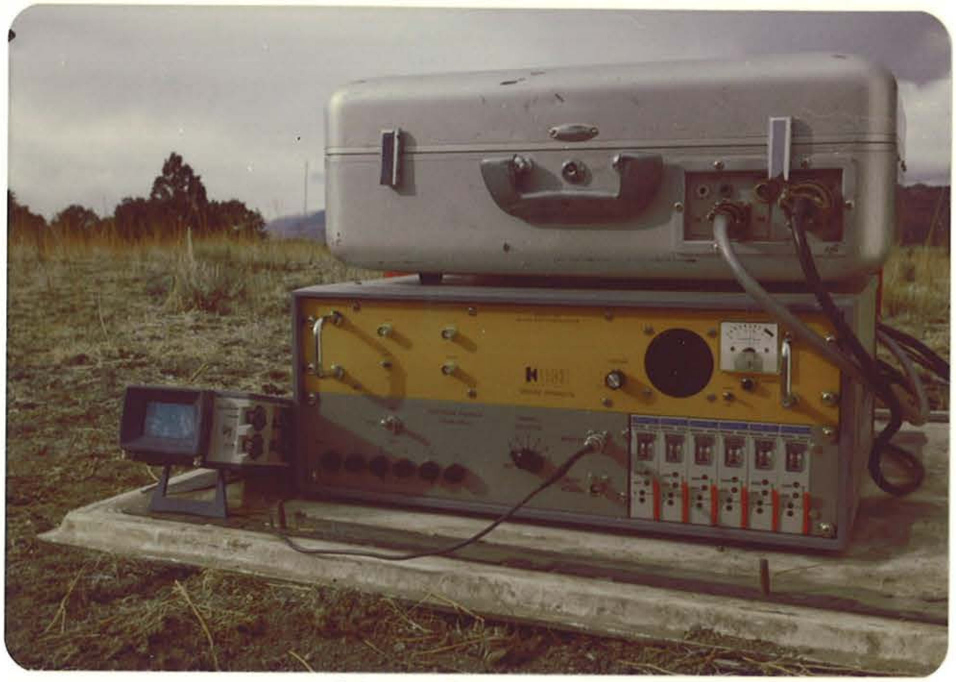
Mt. Princeton



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