(Maps and other support data will be brought by Baily on Monday -)

THE AIRBORNE MAGNETIC SURVEY
Using the Optically-Pumped Helium Magnetometer

OF THE BEOWAWE AREA

IN

EUREKA AND LANDER COUNTIES, NEVADA

FOR

THE GEOTHERMAL GROUP
OF
CHEVRON OIL COMPANY

SENTURION SCIENCES, INC.
TULSA, U.S.A.

REPORT ON

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BY

SENTURION SCIENCES INCORPORATED

FEBRUARY, 1976

SURVEY SPECIFICATIONS

BEOWAWE PROSPECT

Location:	Conterminous with T. 31 N., R. 47 E., Eureka and Lander Counties, Nevada
Area Covered:	30 square miles
Dates:	January, 1976
Crew:	Senturion Sciences Crew #8
Terrain:	Shoshone Range of North Central Nevada with typical Basin and Range topography possessing Tertiary volcanic rocks fractured by multiple stress patterns. Basalts and andesites make up the faulted mountains while Quaternary alluvium covers the valley floors.
Number of Miles of Singel Level Magnetics:	80
Number of Ground miles of MultiLevel Magnetics:	14
Geophysicist:	M. Darwin Quigley

SURVEY REPORT

BEOWAWE AREA,

EUREKA AND LANDER COUNTIES, NEVADA

SUMMARY

The surveying of the Beowawe area with the high sensitivity helium magnetometer reveals two magnetic lows as well as resolving in two places the attitude of the Malpais Fault. The multiLevel air magnetic profiles reveal the Malpais Fault near Chevron's well hading toward the northwest and then reversing itself and dipping to the southeast. Eastward extensions of the Malpais Fault are broken by cross faulting as well as the Malpais related blocks being tilted and rotated.

INTRODUCTION

Senturion Sciences Incorporated flew a helium magnetometer survey in January, 1976, over the Beowawe Area of Eureka and Lander Counties, Nevada. The survey was undertaken to demonstrate the applicability of highly sensitive magnetic measurements to the location of abnormal geothermal temperatures as well as its effectiveness in resolving complex geology. Specifically, the Beowawe area was flown to resolve the attitude of the Malpais fault in the vicinity of Chevron's recent geothermal well in the southwest quarter of section 13, T. 31 N., R. 47 E.

We also wished to illustrate the effect of heat on magnetic fields. If the rocks overlying or surrounding a geothermal source are above the Curie Point (478° to 670° C), the area will appear as a magnetic void enclosed by a normal magnetic field. If mineralization has occurred peripherally around a geothermal source, a magnetic halo will result. If the rocks associated with geothermal activity have had excursions through the Curie Point, they will have abnormal intensity and orientation because the rocks will assume the magnetization of the earth's geomagnetic field at the time of cooling below the Curie Point. Often the magnetic poles have become reversed such that the rocks will have polarities opposite to the earth's present geomagnetic field.

In each of the three cases stated above, the detailed highly sensitive magnetic survey, and particularly multiple level profiles, will reflect the temperatures and pressures, past and present, to which the rocks have been subjected.

FIELD PROCEDURE

Senturion surveyed a 30-square-mile area, mainly in T. 31 N., R. 48 E., just west of Beowawe, Nevada. The area, as shown in Figures 1 and 2 and the included maps*, was covered by 11 irregularly spaced northwest-southeast flight lines and five irregularly spaced northeast-southwest flight lines. All the lines were one mile or less apart. The survey was flown at a constant altitude of 6500 feet above sea level, and data was acquired on a density of 18 magnetic readings per mile.

The magnetic readings were recorded digitally in the airplane on magnetic tape along with clock times, Doppler down-track and off-track information. A 16-mm photograph of the ground was taken with every data point to firmly fix the ground position of each magnetic reading.

In addition to the single level profiles, two multiple level profiles were flown northwest-southeast over the Malpais fault. The locations of these MultiLevel profiles are shown in both the flight line map and anomaly map. Profile 1-N was flown at 5500', 6500', and 8500' above sea level. Profile 2-S was flown at 6500', 7500', and 8500' above sea level.

Mean terrain 5,000'

COMPUTER PROCESSING

After dumping and editing the data recorded on the field magnetic tape, the ground positon of each flight line was established from the 16-mm photographs. The tie points along each flight line were assigned X and Y coordinates as measured from a single point of origin on the 15-minute topographic maps at a scale of 2000 feet to the inch. These values were programmed into the computer so that each data point along the profile was given an X and Y coordinate. Then the coordinates, the total magnetic field, and the first and second horizontal derivative curves along each profile were computer printer plotted.

The peripheral profiles tied to each other without any corrections, thus indicating that there was no appreciable heading effect and no change in the diurnal variations of the earth's geomagnetic field during the time span of the survey. Subsequently, a 400-foot grid of the total field values was computed for contouring. A total field map with a contour interval of 5.0 gammas was machine contoured at a scale of 1000 feet to the inch.

In addition to the total field map, a vector gradient map was generated from the grid values. The vector gradient map is a first horizontal derivative map and compares areas of equal horizontal magnetic gradient in gammas per 1000 feet, regardless of direction. The map is beneficial in correlating fault traces and boundaries of magnetic events which occur on the individual profiles.

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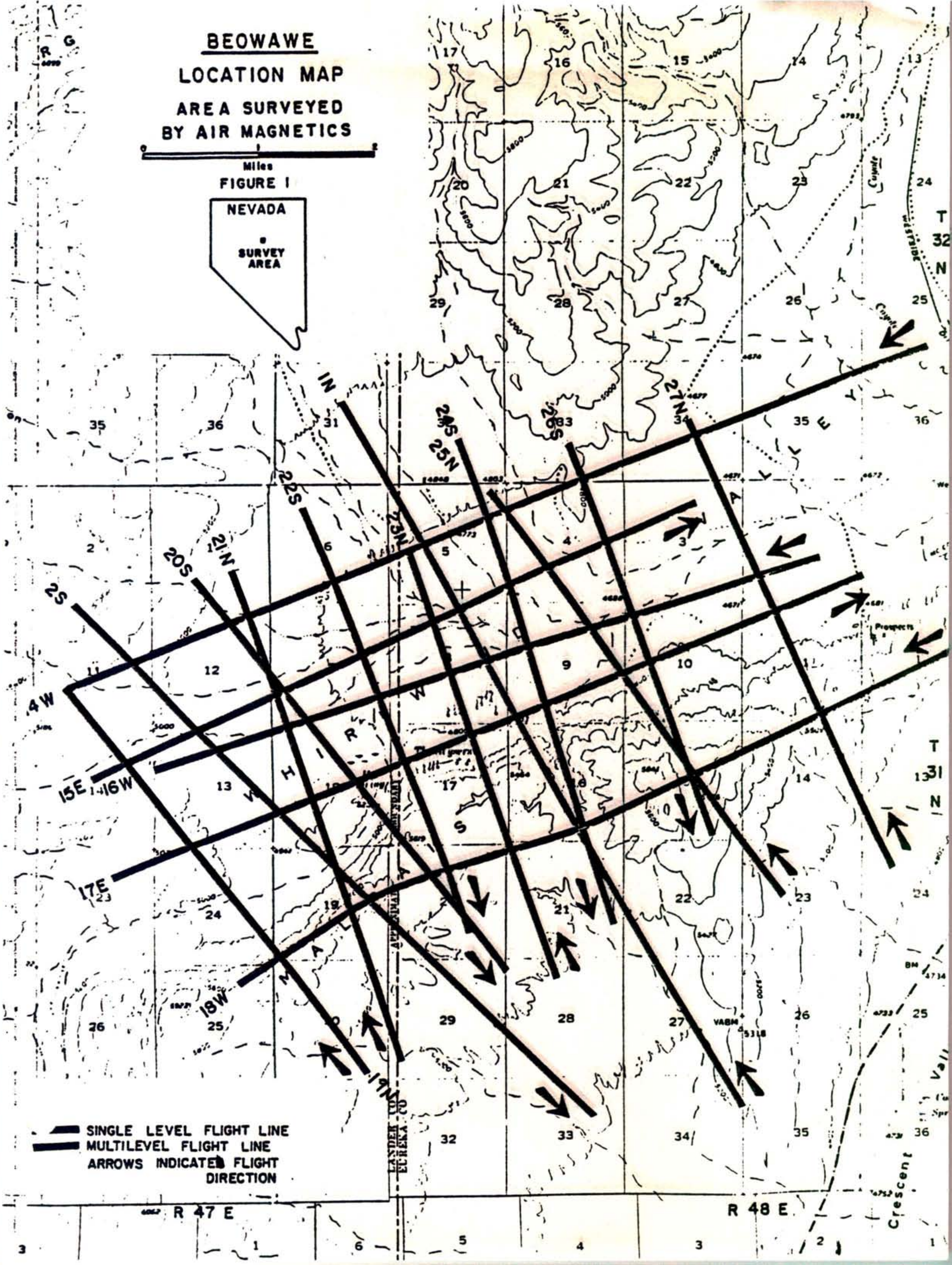
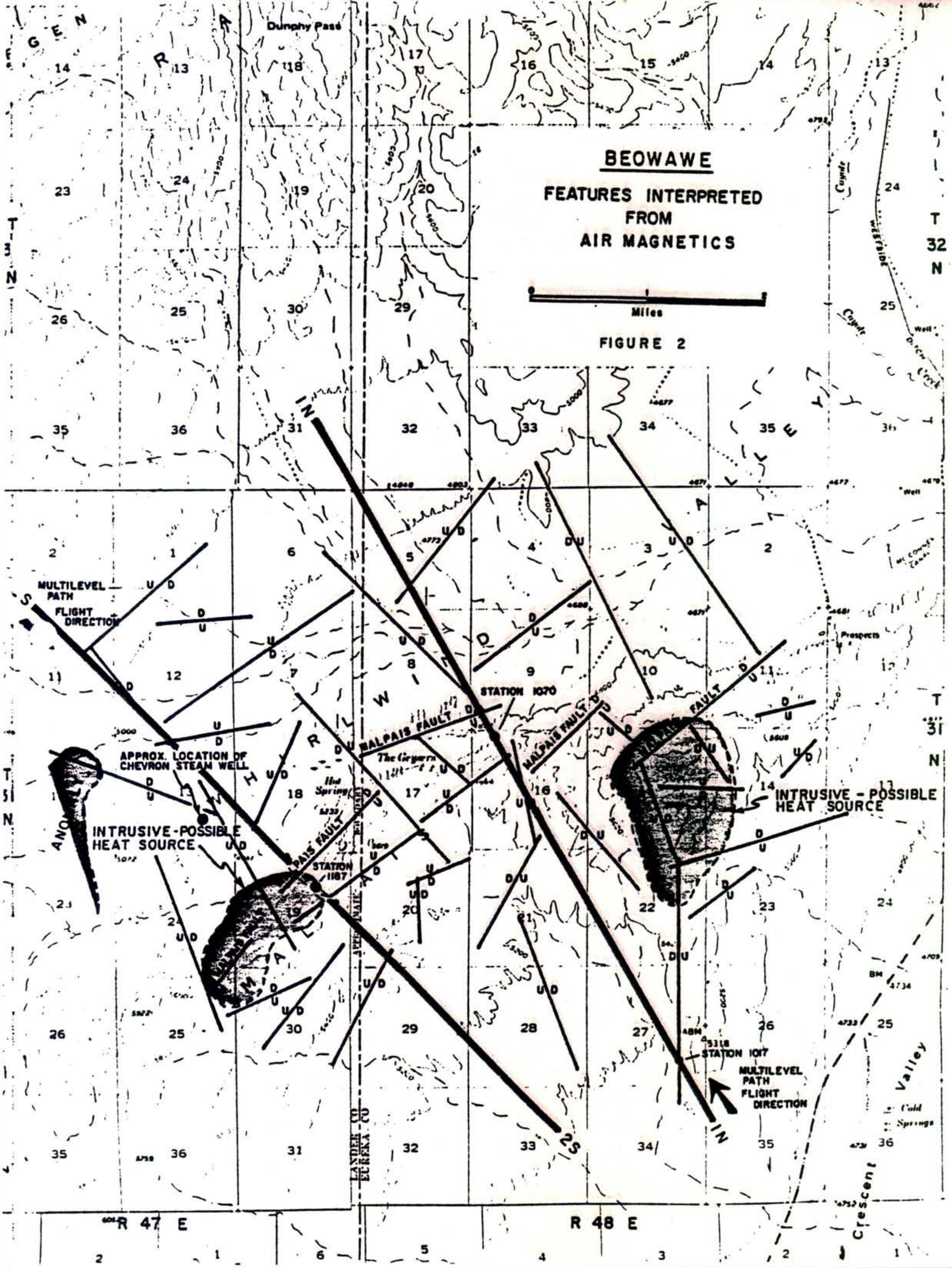
* The data (18 data points per mile) density justified a large scale (1" = 1000') mapping; therefore, reference is made by title while the included figures in the text are synopses.



BEOWAWE
LOCATION MAP
AREA SURVEYED
BY AIR MAGNETICS
Miles
FIGURE 1
NEVADA
SURVEY AREA
SINGLE LEVEL FLIGHT LINE
MULTILEVEL FLIGHT LINE
ARROWS INDICATE FLIGHT DIRECTION
R 47 E
R 48 E
T 32 N
T 31 N
WHIRLWIND VALLEY
LANDER CO
EUREKA CO
1N
2S
20S
21N
22S
23N
24S
25N
26S
27N
14W
15E
16W
17E
18W
19N
Crescent Valley



BEOWAWE

FEATURES INTERPRETED FROM AIR MAGNETICS

FIGURE 2

The MultiLevel profiles were processed to show the relative shift of magnetic events with altitude and the change in the vertical magnetic gradients. First, the total field values on each flight level were plotted one above the other to show the field relationships. Then the next higher total field was subtracted from the adjacent lower total field and the corresponding interval gradients were plotted one above the other. The higher gradient was subtracted from the lower gradient to show the change in gradient from 1000-foot flight interval to another. The curves are labeled on the attached computer printouts.

INTERPRETATION

A fault delineation map was made from the magnetic events from an analysis of the individual magnetic profiles and the correlations and trends evident on the vector gradient map. These events are the maximum slope values and step relationships on the profiles that suggest possible faulting. The faults indicated by the magnetic field changes are shown on the attached map. The upthrown and downthrown sides of the faults are indicated, but reverse polarities and sudden susceptibility changes can give an apparent magnetic relative movements on either side of several of the faults may be incorrect. The correct movement can be established only through the use of MultiLevel profiles flown perpendicular to the strikes of the faults.

The area surveyed is a small portion of a large tilted fault block west of Beowawe that is evident on the topographic maps on the aerial photographs. This fault block is intensely faulted and fractured, especially along the southern edge of the block. The Malpais fault forms the southeast boundary of the block.

The Malpais fault is not a continuous fault, but is broken frequently by cross faults as shown in Figure 1 and on the Feature Map (1" = 1000'). One of the purposes of the survey was to determine, if possible, the attitude of this fault from MultiLevel profiling. Figure 3 shows a plot of the fault face with depth as observed by the four levels over Profile 1-N (Figure 2). The fault face hades 30° to the southeast at the surface and then swings through vertical and hades 25° to the northwest with depth.

Figure 4 shows the attitude of the Malpais fault where it was crossed by Profile 2-S. Instead of a southeast hade at the surface, this section of the fault hades 45° northwest. Then at depth, it swings through vertical and hades 25° to the southeast.

The two MultiLevel profiles across the Malpais fault demonstrate that the attitude of the fault face changes along strike and depends on the realtive movements of the segmented blocks. All the blocks are tilted and rotated, but the vertical rotation differs with adjacent blocks. Even the vector gradient map clearly shows the difference in the attitudes of the fault block segments northeast and southwest of the larger cross fault in section 17, T. 31 N., R. 48 E.

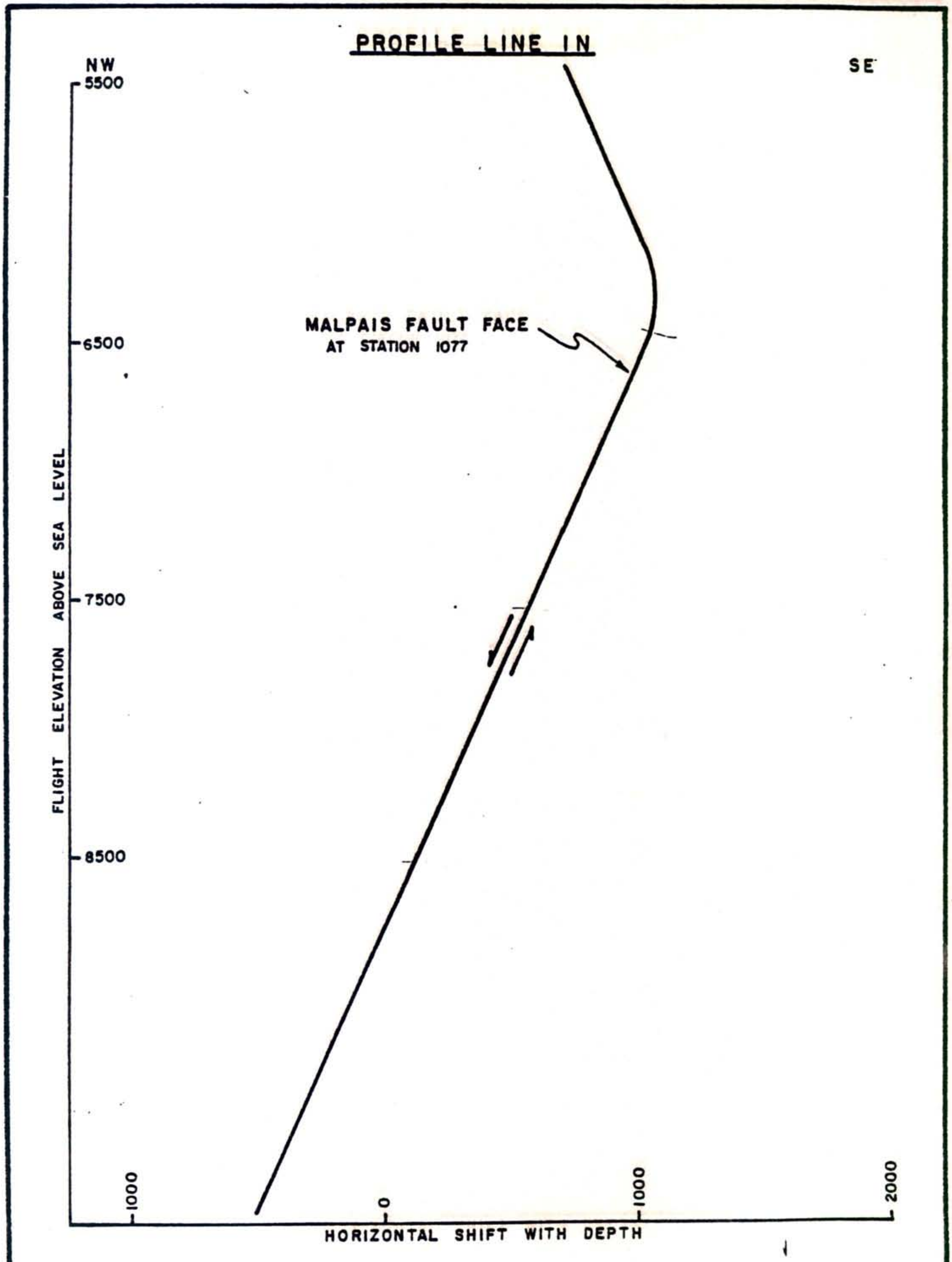


FIGURE 3

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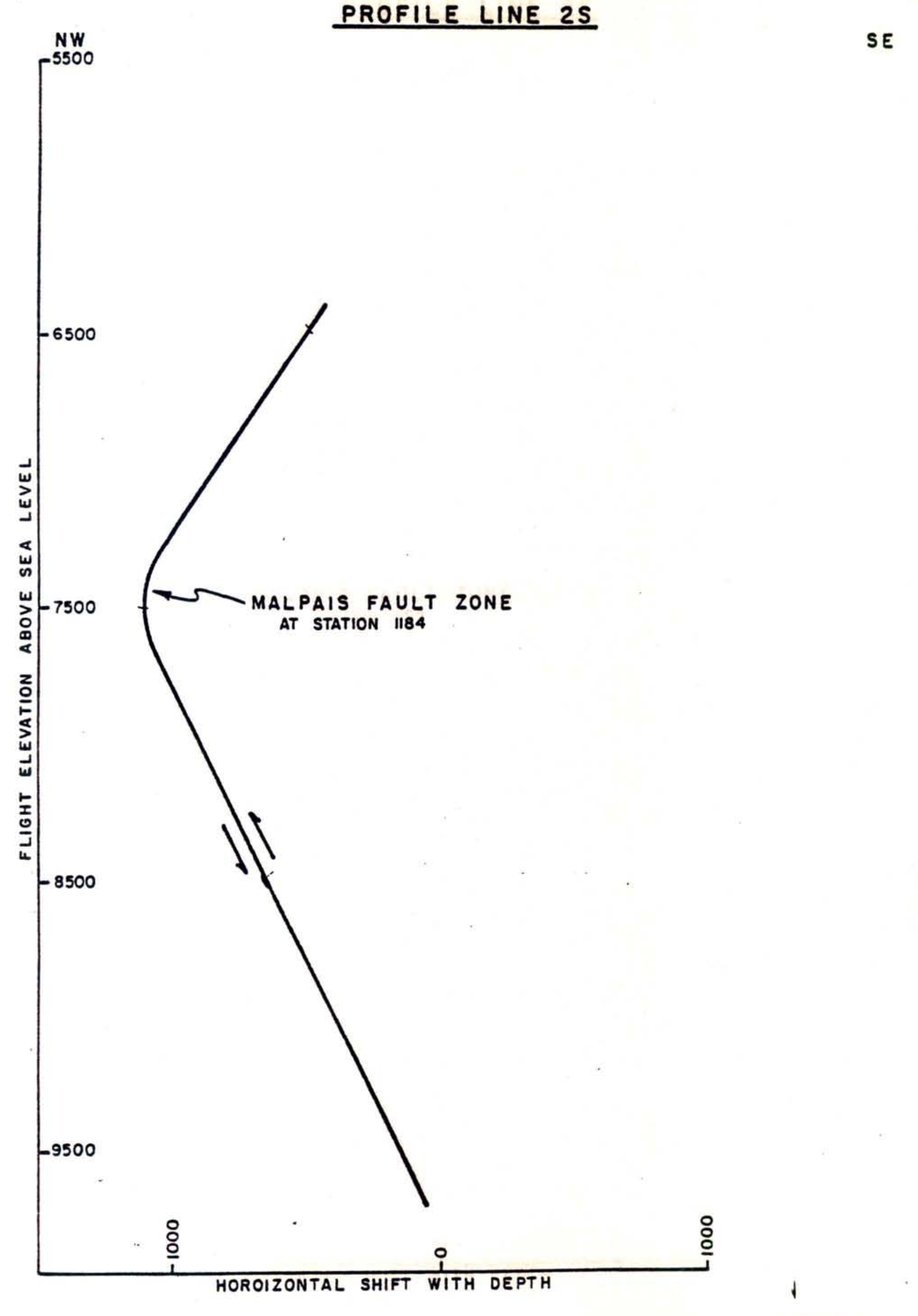

FIGURE 4
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The MultiLevel profiles also indicate that the thickness of the andesite and basalt lava flows changes drastically within the area of the survey. Figure 5 is a plat of the gradient change from one level to the next over the magnetic "high" adjacent to the Malpais fault. The curve shows the very steep gradient caused by the andesite and basalt lavas on the surface, but it also shows a change in gradient between the 7500 and 8500-foot flight levels. The increase in gradient at this point indicates a contact zone at the base of the lavas. By using an inverse proportion and the square roots of the observed gradients, the depth of this contact zone calculates to be 3950 feet above sea level. Since the surface elevation is 5450 feet, the thickness of the lavas is approximately 1500 feet.

Figure 6 shows the gradient curve constructed from the three levels over Profile 2-S. This profile is over one of the apparent igneous plugs which could be the origin for a portion of the lava flows. The nearly straight line gradient curve gives a distance of 5760 feet to the top of the plug from a reference elevation of 7000 feet above sea level. This point of inflection, which is approximately 1240 feet above sea level, or about 4360 feet below the surface, probably represents the base of the extrusives and the top of the intrusives. The figures suggest that the lavas change thickness from 4360 feet to 1500 feet in a distance of two miles.

The survey strongly suggests that there are two intrusives within the limits of the survey. The first source is in section 19. This is a positive magnetic anomaly of 150 gammas which represents an igneous plug at depth. This plug may be the heat source for Chevron's geothermal well in the southeast quarter of section 13, T. 31 N., R. 47 E.

The second anomalous area is in section 15. This is a negative anomaly of 500 to 550 gammas. The negative anomaly is represented as an area of rapid and intense changes on the vector gradient map. The negative anomaly may originate in one of two ways; in either case, extreme heat is involved. The rocks in this area currently may be above Curie Point temperatures, so as to create a magnetic void; or, the polarity of the earth's magnetic field may have been reversed during the last episode of cooling below the Curie Point temperature. Since there is an igneous plug nearby with normal magnetic polarity, two different periods of magmatic activity are implied. The Quaternary basalt in section 15 is younger and overlies the andesites in sections 16 and 22. Either the geomagnetic poles were reversed during the more recent magmatic activity or the rocks at depth are still above Curie Point temperature. At any rate, section 15 is the site of the most recent activity. The large landslide, which is composed largely of basalt boulders, indicates that disturbances are still going on.

The geysers, hot springs, and steam wells in sections 16 and 18 may originate from either of the anomalies. Both the sources are nearly equidistant. The most probable source is the igneous plug in section 19, because hot liquids could move along the Malpais fault into sections 17 and 18 to generate the steam evident in the wells, geysers, and hot springs.

PROFILE LINE IN

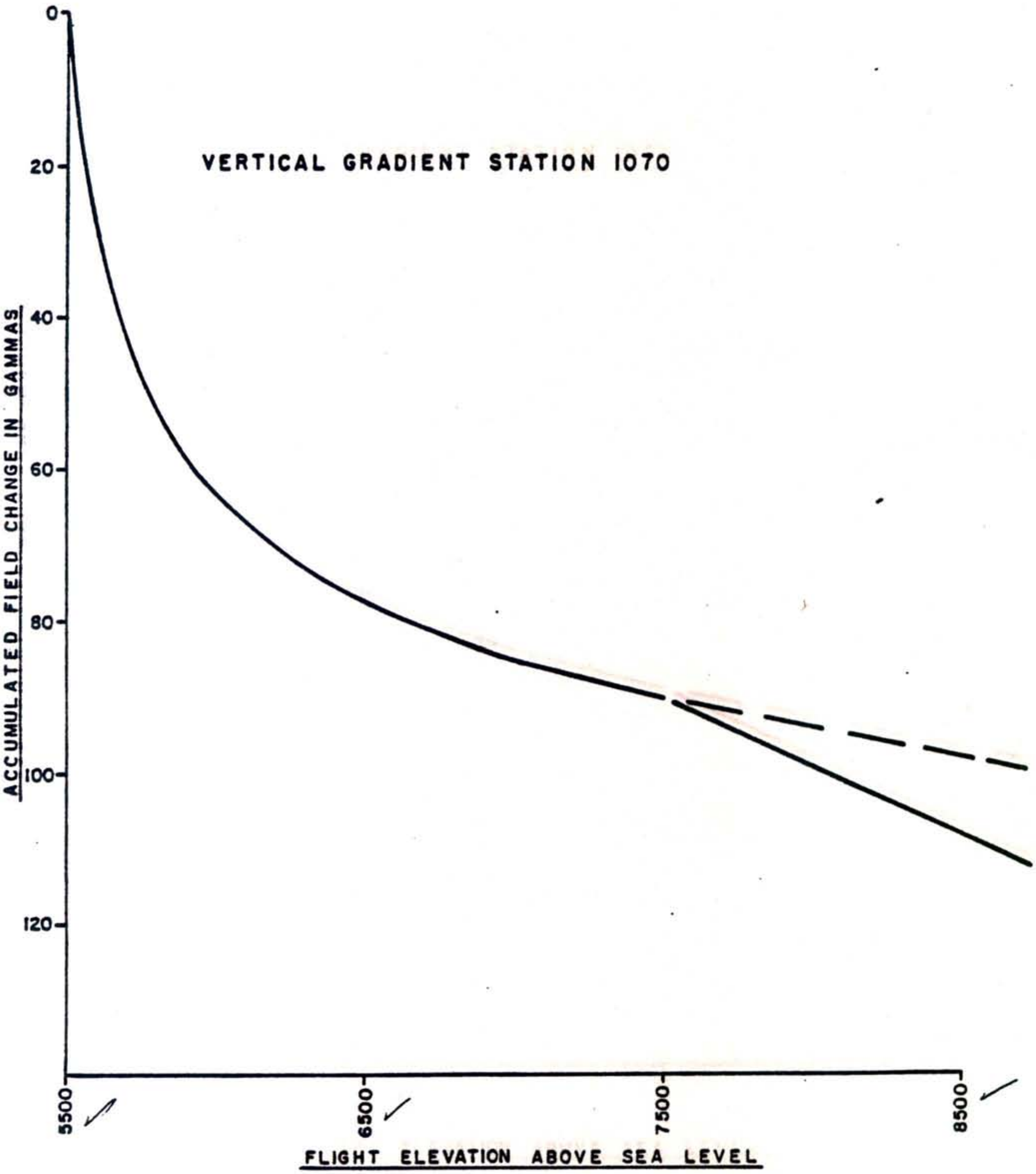

FIGURE 5
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PROFILE LINE 2S

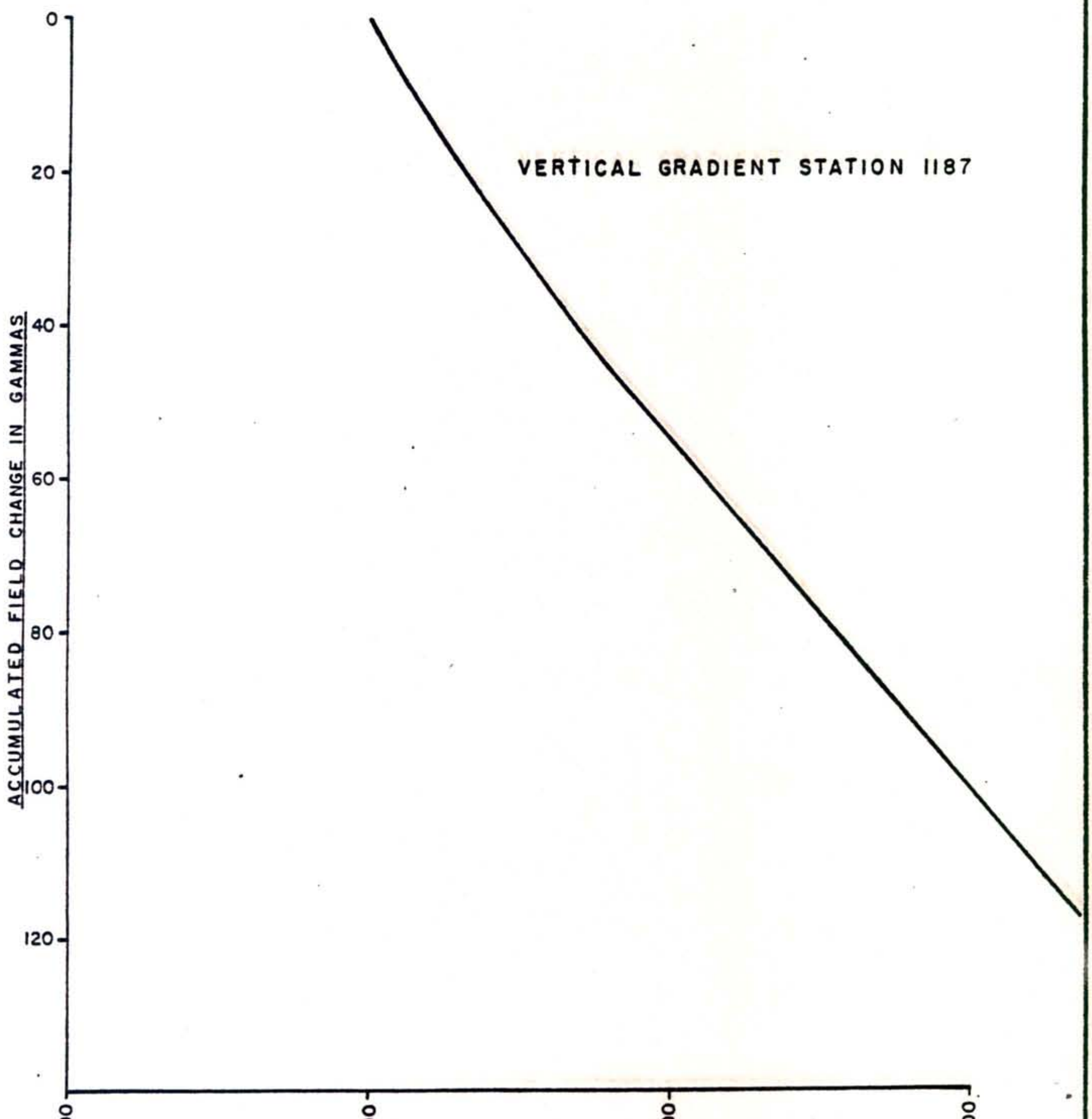

FIGURE 6
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A third anomaly is suggested along the west margin of the test survey in sections 14 and 23, T. 31 N., R. 47 E. The vector gradients suddenly intensify as in the other two source areas. Insufficient survey coverage precludes any evaluation of this suggestion of a third source. The important fact is that there is a suggestion of not just two, but three anomalous situations within a very limited area. Since this is a KGRA magnetic anomalies are expected, where they are is critical and the degree of abnormality with the region would be important.

Several significant conclusions can be stated as a result of the helium magnetometer survey.

1. Through the use of MultiLevel Profiles, the change in the attitude of faults with depth can be mapped.

2. Detailed tight grid surveys will give positive suggestion of geothermal source areas. These areas may show up as magnetic haloes, magnetic voids, or reverse magnetic polarizations.

3. Many of the areas which have geothermal potential are covered with lavas and other volcanic extrusives. The survey illustrates that multiple level profiles are an effective way to determine lave thicknesses. Once the inference of the surface rocks is removed, the underlying geology is more accurately revealed.

The survey demonstrates the applicability of highly PRECISE helium magnetometer in geothermal exploration. Ideally, a geothermal prospect should be covered initially with a low-cost helium magnetometer survey on a tight grid basis. After the total field survey is interpreted and anomalies of interest identified, then MultiLevel profiles should be flown over the specific targets, prospects, or fault zones.

RECOMMENDATIONS

A one-half mile grid survey is recommended over the Whirlwind Valley fault block in Eureka and Lander Counties, Nevada. The grid survey should be followed by MultiLevel profiles to determine the attitude of faults and thicknesses of lava flows and other volcanic extrusives.

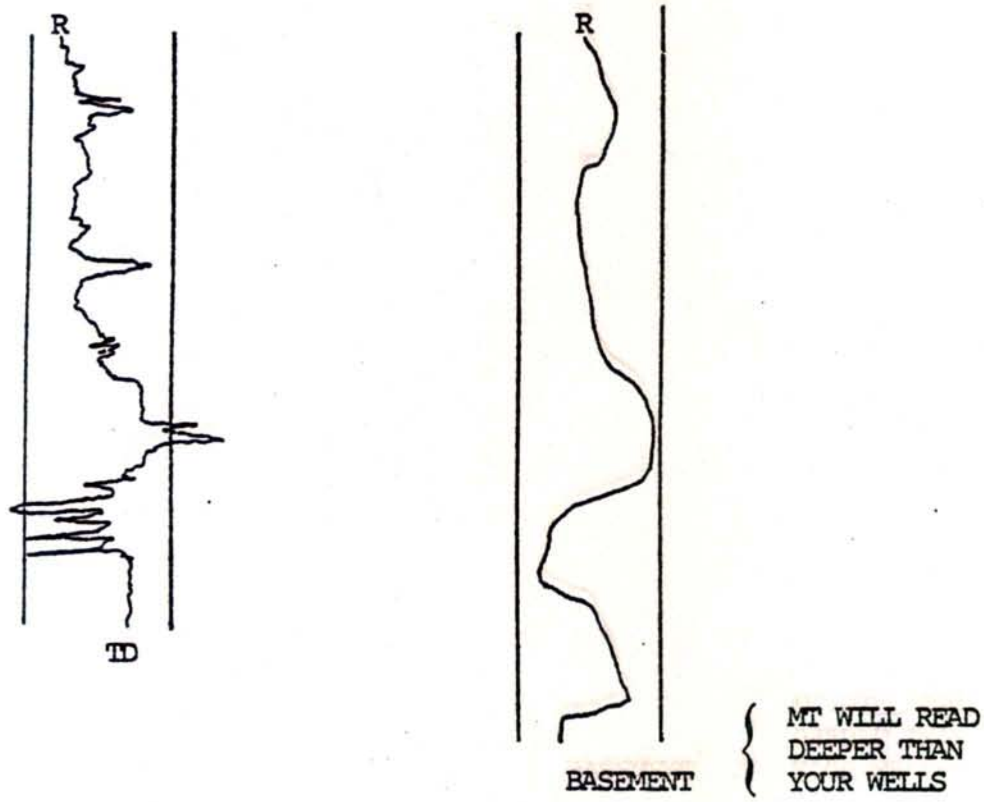
One very positive application of high sensitivity mangetic surveys is suggested by Bhattacharyya and Lei-Kuang in their paper on the *"Analysis of Magnetic Anomalies over Yellowstone National Park"*, which was published in the Journal of Geophysical Research, volume 80, number 32, November 10, 1975. The authors suggest that the Curie Point isothermal surface can be interpreted by a spectral analysis of the residual magnetic anomalies. Such a surface, if accurate, would be a direct way of mapping sources of geothermal energy. The accuracy of the mapped surface necessarily depends on the accuracy and density of the input data. The recommended one-half mile grid survey with a helium magnetometer would provide the right kind of data to generate the Curie Point isothermal surface and determine its application to a specific area. The total survey area needs to be of fair size (three to four townships) to get the true picture of the heat relationship to the magnetics.

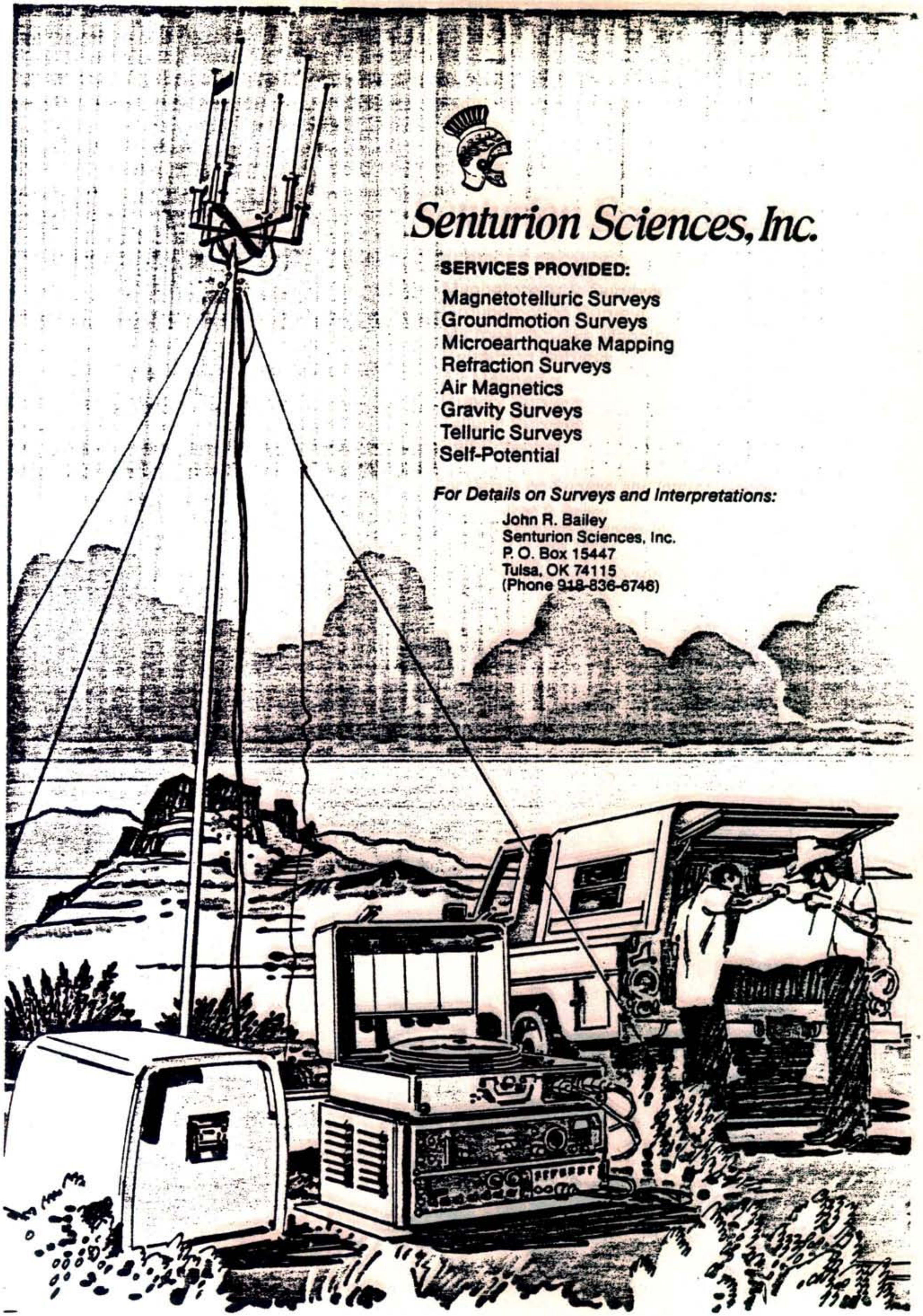
To fully utilize the high resolution magnetics, some auxiliary information is needed. Normally this is provided by well logs which can give positive control to the magnetic interpretation. Since there are virtually no deep wells in the vicinity, Senturion recommends that a magnetotelluric survey be run in the area. This will allow depths and thicknesses of the major lithologic units to be determined. This information tied to the precision magnetics will be extremely useful in mapping faults, their attitude at depth, thicknesses of extrusives, and locating intrusives which may be the source of heat for the geothermal system at Beowawe.

Not quite the case.

already planned

Optimally an MT true resistivity electric log can be compared with Chevron's well log. Understandably, our MT derived log will not reveal small lenses, but the MT derived logs can and does chart true resistivities which would mean tracing between three to six horizons. This would mean the logs (MT with respect to the well electric log) may compare as follows:

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SERVICES PROVIDED:
Magnetotelluric Surveys
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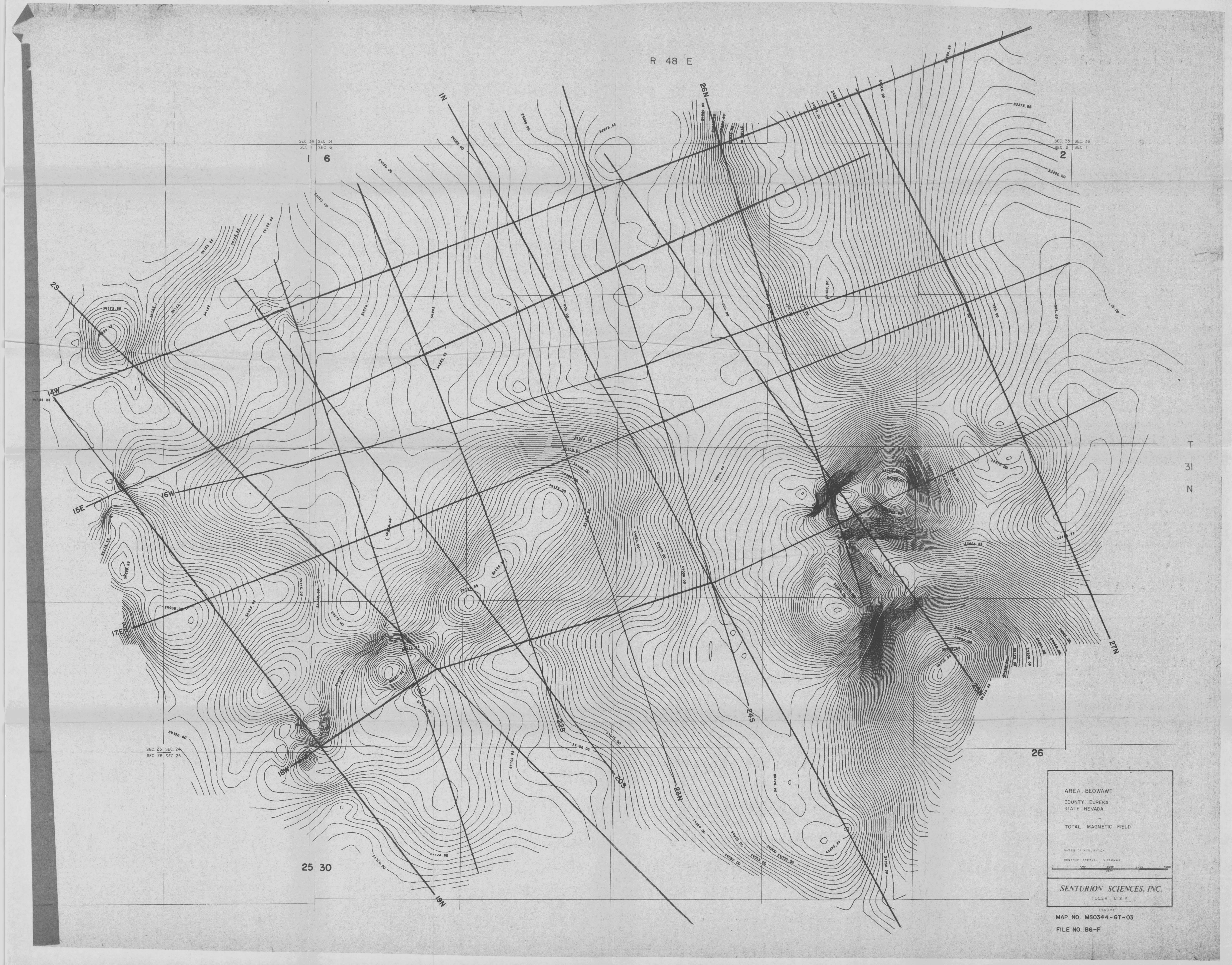
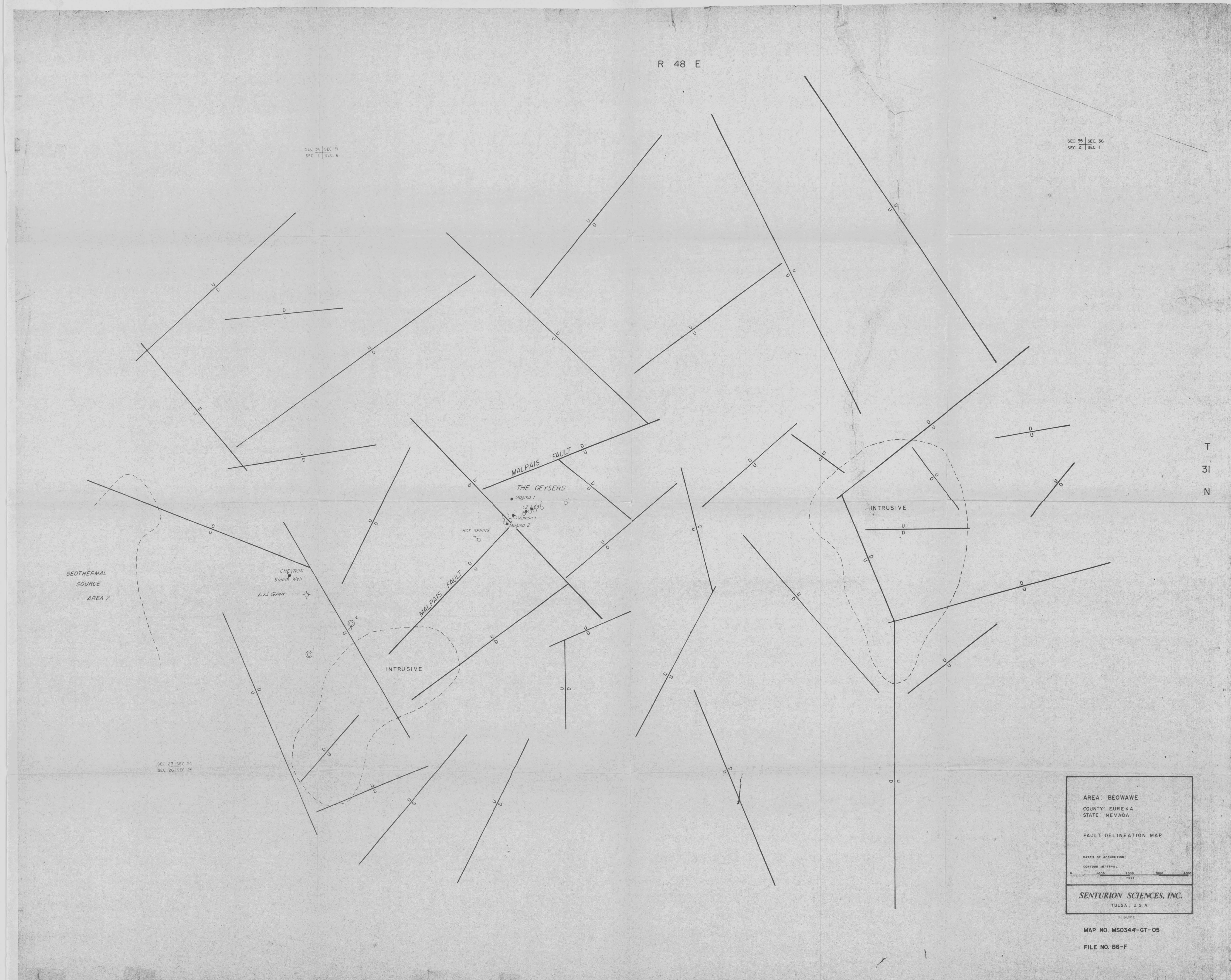
Microearthquake Mapping
Refraction Surveys
Air Magnetics
Gravity Surveys
Telluric Surveys
Self-Potential
For Details on Surveys and Interpretations:
John R. Bailey
Senturion Sciences, Inc.
P. O. Box 15447
Tulsa, OK 74115
(Phone 918-836-6746)


R 48 E
T
31
N
SEC 36 | SEC 31
SEC 1 | SEC 6
1 6
SEC 35 | SEC 36
SEC 2 | SEC 1
2
SEC 23 | SEC 24
SEC 26 | SEC 25
25 30
26
2S
14W
15E
16W
17E
18W
19N
1N
20S
22S
23N
24S
26N
27N
AREA: BEOWAWE
COUNTY: EUREKA
STATE: NEVADA
TOTAL MAGNETIC FIELD
DATES OF ACQUISITION
CONTOUR INTERVAL 5 GAMMAS
0 1000 2000 3000 4000
FEET
SENTURION SCIENCES, INC.
TULSA, U.S.A.
FIGURE
MAP NO. MS0344-GT-03
FILE NO. B6-F


R 48 E
SEC. 35 | SEC. 31
SEC. 2 | SEC. 6
SEC. 35 | SEC. 36
SEC. 2 | SEC. 1
T
31
N
MALPAIS FAULT
THE GEYSERS
Magma 1
Vulcan 1
Magma 2
HOT SPRING
MALPAIS FAULT
GEOTHERMAL
SOURCE
AREA ?
CHEVRON
Steam Well
1-13 Ginn
INTRUSIVE
INTRUSIVE
SEC. 23 | SEC. 24
SEC. 26 | SEC. 25
AREA: BEOWAWE
COUNTY: EUREKA
STATE: NEVADA
FAULT DELINEATION MAP
SENTURION SCIENCES, INC.
TULSA, U.S.A.
MAP NO. MS0344-GT-05
FILE NO. 86-F


R 48 E
SEC. 36 | SEC. 31
SEC. 1 | SEC. 6
SEC. 35 | SEC. 36
SEC. 2 | SEC. 1
SEC. 23 | SEC. 24
SEC. 26 | SEC. 25
T
31
N
10.00
AREA: BEOWAWE
COUNTY: EUREKA
STATE: NEVADA
VECTOR GRADIENT
(GAMMAS PER THOUSAND FEET)
DATES OF ACQUISITION
CONTOUR INTERVAL: 2 GAMMA
0 1000 2000 3000 4000
FEET
SENTURION SCIENCES, INC.
TULSA, U.S.A.
FIGURE
MAP NO. MS0344-GT-04
FILE NO. B6-F