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ANALYSIS OF GRAVITY DATA IN AND AROUND A GEOTHERMAL PROSPECT IN BEAVER COUNTY, UTAH

by

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Summary

Gravity data are presented and interpreted in and near a geothermal prospect in T26S and T27S, R9W in Beaver County, Utah. A contour map of depth-to-bedrock in the Escalante Valley is presented. The northern part of the valley averages about 4000' deep while the southern part of the valley may be as deep as 7000 feet. A negative gravity anomaly in the Mineral Range may be associated with the young volcanics of the range and several heat flow determinations are recommended to investigate any thermal consequences of the gravity anomaly. Successful results of the drilling could expand the area of the geothermal prospect by several times. Gravity data do not furnish much useful evidence on the fault in section 16 associated with the geothermal anomaly, although a small positive gravity anomaly is probably related to the caprock of the reservoir, and its shape is consistent with silicification along a west dipping normal fault. Electrical resistivity data, including soundings both east and west of the fault might furnish needed evidence on the depth to basement on the west side of the geothermal anomaly and, as noted in a previous report, on the reservoir temperatures, depth, and porosities.

Introduction

The geothermal prospect in T26 and 27S, R9W, is situated between the Mineral Range to the east, and the Escalante Valley to the west. A report on the heat flow and geothermal gradients has been submitted previously (Blackwell, 1974). The geothermal anomaly appears to be related to a Basin-Range normal fault between the range and the valley. Because the earth's gravity field is affected by variations in density of near surface rocks it appeared that a gravity study of the area would be useful in delineating the structure of the valley and bounding fault. The gravity data to be discussed were obtained from two sources: a regional map of complete Bouguer gravity at a scale of 1:250,000 with a station spacing of about $1/mi^2$ (except in the crucial area of the prospect) by Petersen (1972); a detailed cross section of gravity approximately along the Nigger Mag Wash road obtained for the project (Gay, 1974) and ten scattered points to supplement the regional data obtained for the project (Gay, 1974).

Regional Gravity

A portion of the map by Petersen (1972) covering the area of interest is shown as Fig. 1 (a copy of a copy). The map includes effects arising outside the area of interest so a regional effect was removed by subtracting from the map values corresponding to a plane striking NE-SW with a value of -170 mgals (a mgal is 10^{-3} cm/sec^2) in the northwest portion of the map and -190 mgals in the southeast portion of the map. The resulting map (Fig. 2) has values near zero over the bedrock areas of the ranges and negative values (to -28 mgals) over the valleys. The extra points obtained by Gay after reduction to Simple Bouguer values (Table 1) have been included

Table 1 Supplemental Regional Gravity Data

Station	Latitude	Longitude	Obs Gravity mgal	Simple Bouguer Gravity (2.67 density)
1	38° 26.6'	112° 51.7'	979484.2	-197.8
2	38° 25.8'	112° 52.0'	979486.3	-198.6
3	38° 26.0'	112° 53.0'	979493.3	-202.4
4	38° 25.0'	112° 50.0'	979445.3	-204.7
5	38° 19.5'	112° 47.1'	979468.0	-202.5
6	38° 25.4'	112° 46.8'	979455.3	-211.3
7	38° 21.2'	112° 46.1'	979447.3	-207.8
8	38° 22.0'	112° 46.0'	979441.2	-207.4
9	38° 23.8'	112° 45.5'	979429.5	-208.0
10	38° 25.0'	112° 45.1'	979429.6	-212.5

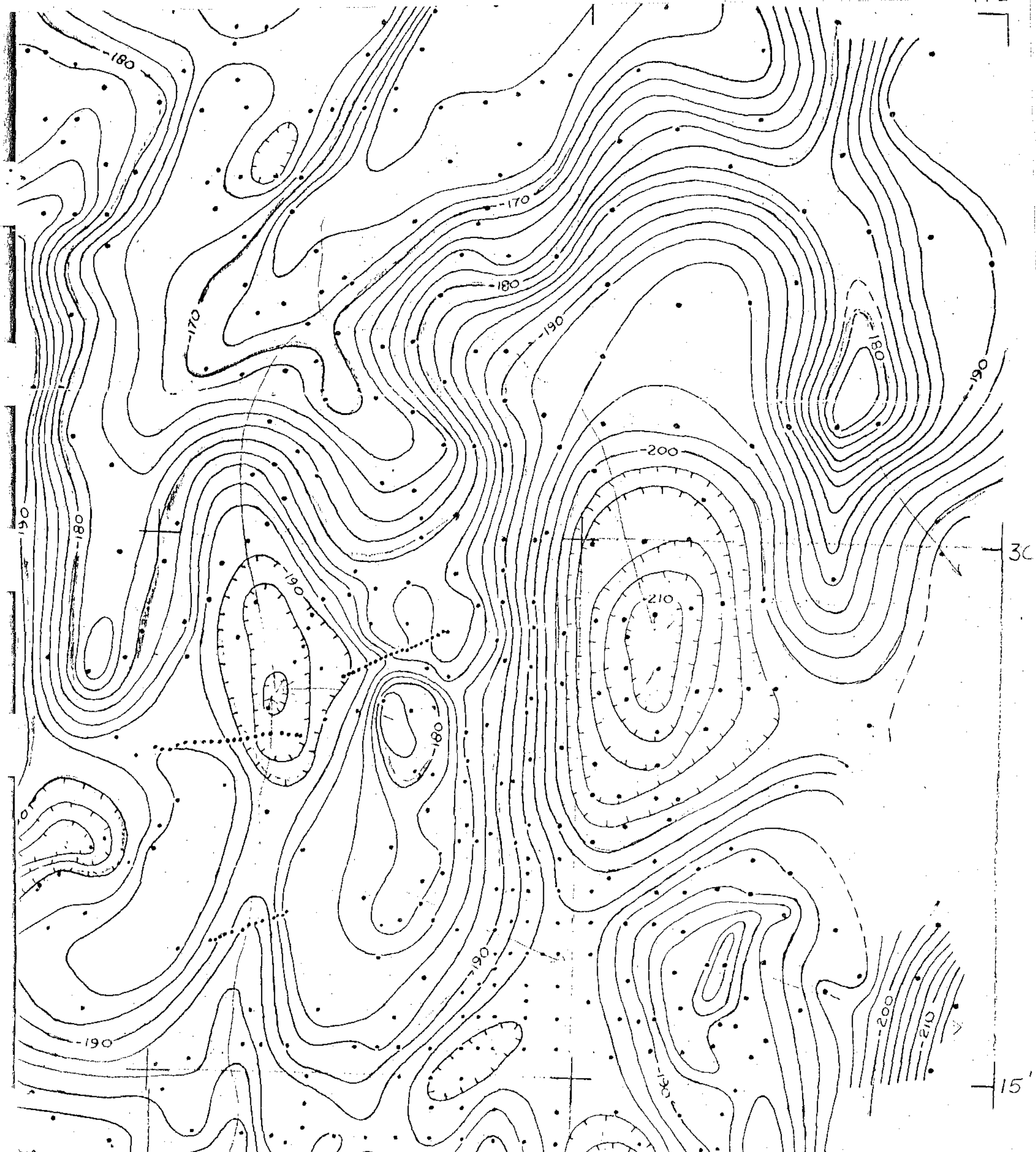
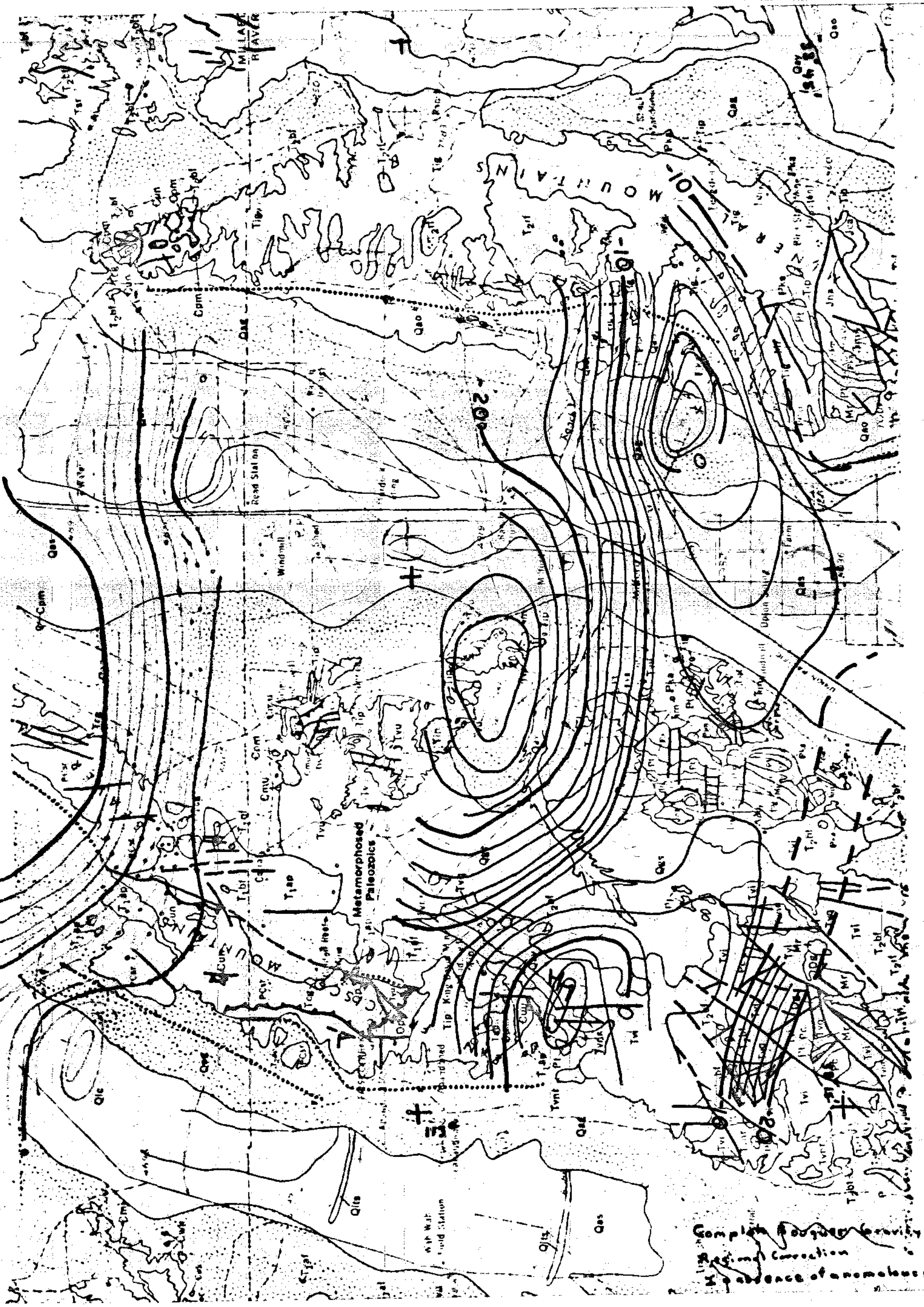
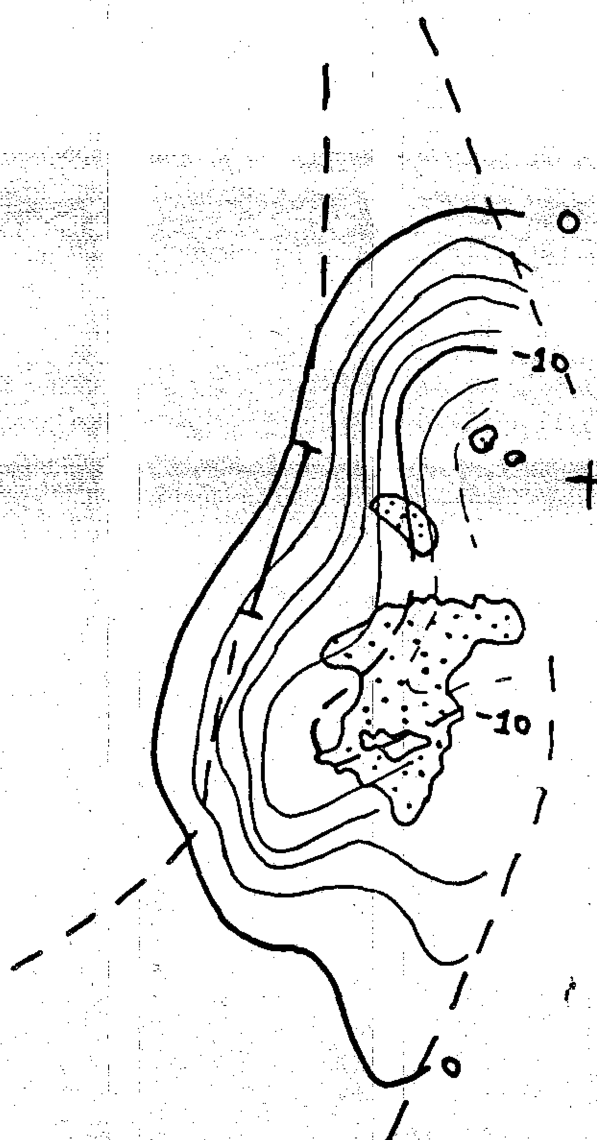


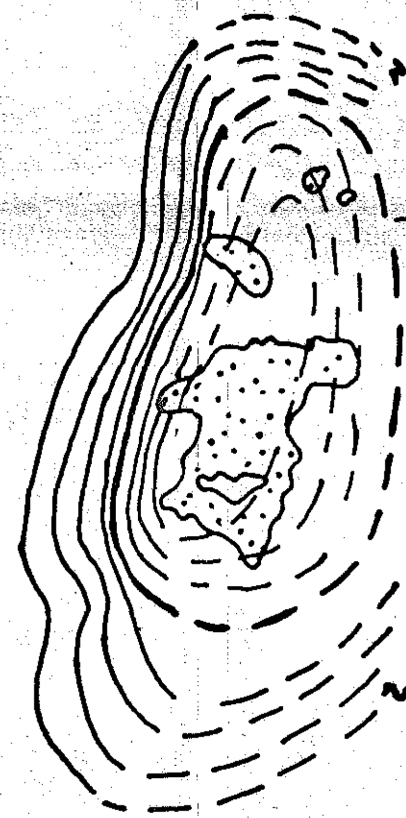
Figure 1. Regional gravity map (complete Bouguer gravity) in the region of the geothermal anomaly after Peterson (1972). The contours of all gravity maps are at 2 mgal (1 mgal = 10^{-3} cm/sec^2) intervals. Station locations are shown. Scale is 1:250,000 for all of the maps.



Complete Bouguer Gravity
Regional Correction
I = absence of anomalous mass

38°45'
0
-10
-10
-10
-20
-10
-10
-10
-20
0
-10
0
0
Fig 1
Complete Bouguer Gravity
1:250,000
Contour Interval 2 mgal


0
10
10
0


2
10
2

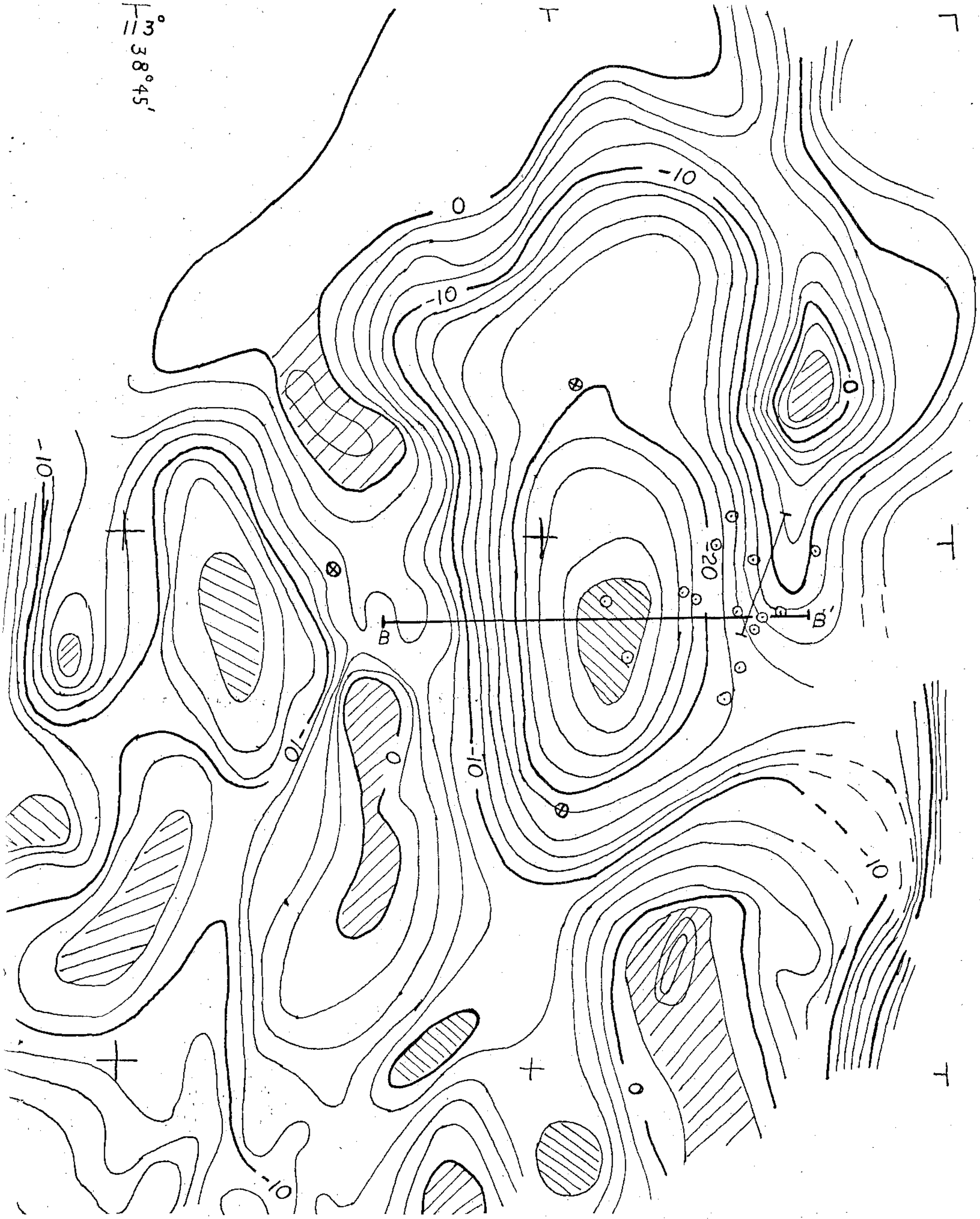


Figure 2. Residual gravity map in the region of the geothermal anomaly. Diagonal shading patterns indicate areas of high and low gravity. Location of drill holes and the surface manifestations of the geothermal anomaly are shown.

in the contouring of Fig. 2. The areas of positives and negatives are indicated on the map by opposite diagonal shading patterns.

In the Basin and Range Province,where deep downwarped or down-faulted valleys filled with low density alluvial material alternate with ranges composed of denser material, relative negative values of gravity are characteristic of the valleys as opposed to the ranges (compare Fig. 2 and Fig. 3, a generalized bedrock map of the area). The most negative values of gravity are found north of Milford in the Escalante Valley. Negative values are also found in the valleys between Star, Beaver, and San Francisco Mountains and in the valley on the east side of Mineral Range. A similar relationship of gravity to ranges and valleys is also illustrated in the study of an area just to the south by Cook and Hardman (1967). A primary feature of interest in this analysis is the large negative gravity anomaly associated with the Escalante Valley. It is clear from a consideration of Fig. 2 and 3 that the bedrock areas around the valley have near zero values of gravity making the gravity contrast approximately -18 to -28 mgals. In the southern end of the Escalante Valley a shallow alluvial trough extends southwestward toward Lund and the gravity values are on the order of only -10 mgals relative to the ranges.

Mineral Range Gravity Anomaly

An exception to the general rule of a contrast of greater than 18 mgals between the Escalante Valley and surrounding ranges occurs in the central portion of the Mineral Range, almost due west of Milford, in the area of the geothermal anomaly. Here the values in the range are as low as -16 mgals relative to values both to the north and south in the range. There is no explanation for this gravity variation obvious from surface rock exposure.

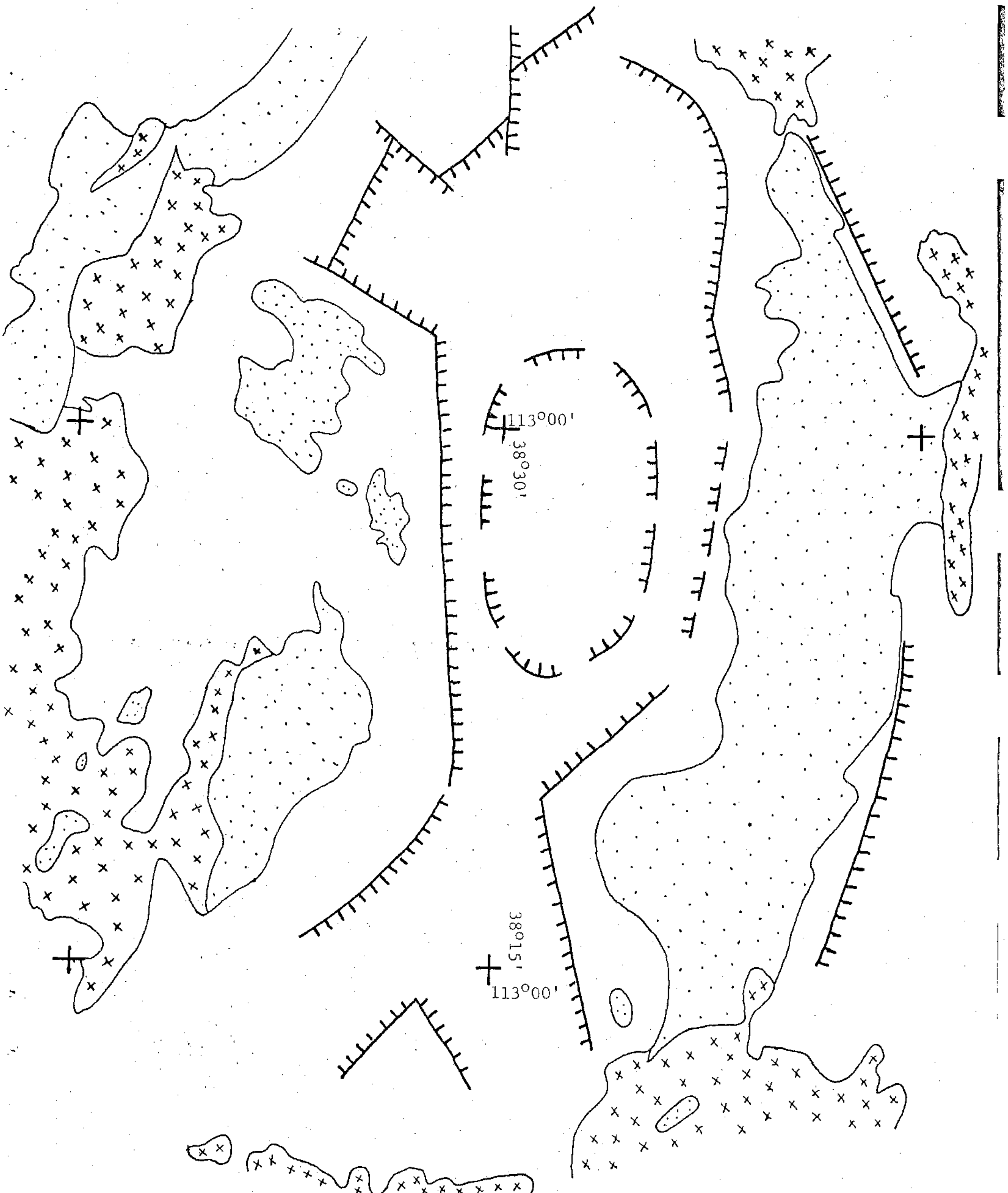
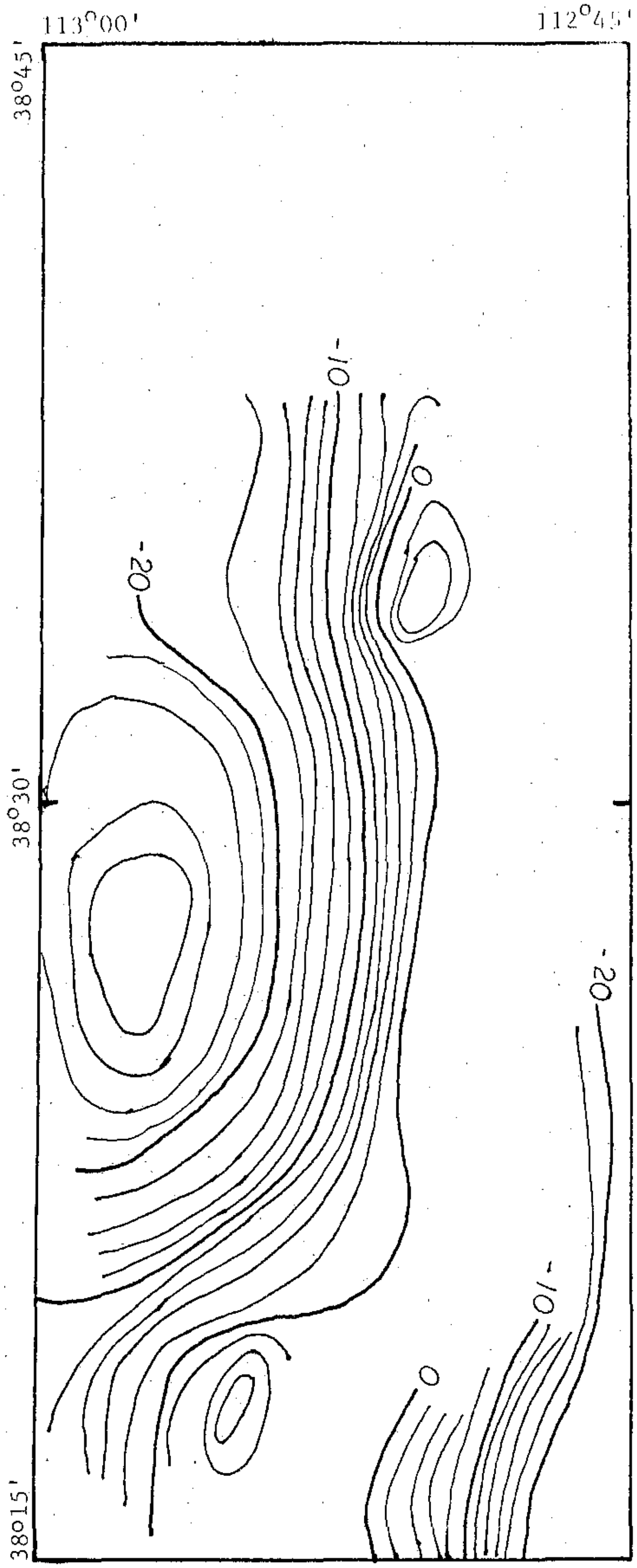


Figure 3. Bedrock map of the area. Areas of volcanic rocks are shown with X's while basement areas are shown with dots. Areas of steep gravity gradients are indicated as possible faults.

The low density volcanic rocks exposed in the area appear to be quite thin and of totally inadequate volume to explain the negative values of gravity. I must emphasize that this anomaly is an extremely unusual feature and it is very difficult to explain on the basis of the exposed surface geology. It is possible that the negative might be due to the granite of the Mineral Range pluton. Such an explanation does not seem consistent, however, with the lack of gravit y contrast between the bedrock granite of the mountains and low density gravel of the Escalante Valley. In order to estimate the implications of this negative anomaly in the Mineral Range I have prepared a hypothetical map of the gravity in the Mineral Range by analogy with the surrounding ranges (Figure 4). We can then take the difference between the gravity values shown in Figure 2 and in Figure 4 as an estimate of the gravity anomaly in the Mineral Range (Figure 5). The anomaly is elongate north-south and approximately 8 miles long, at least 4 miles wide, and has a minimum value of about -16 mgals. The minimum value of the anomaly is over the general area of volcanic rocks exposed in the central portion of the Mineral Range. It seems to me, therefore, that there is a very strong implication that the volcanics of the Mineral Range may overly a shallow pluton which was the source for the volcanics. In order for there to be a negative gravity anomaly associated with this pluton the pluton would still have to be quite hot and the low density caused by the thermal expansion of the rocks, since in general solidified granite has a density in excess of 2.5 g/cm^3 whereas the density of the fill on the basin must be equal to or less than 2.3 g/cm^3. From the anomaly we can make an estimate of the size, mass, and depth of the body although this estimate is extremely tentative as the anomaly is not well defined and many assumptions have gone into its separation from the background gravity. Nevertheless,



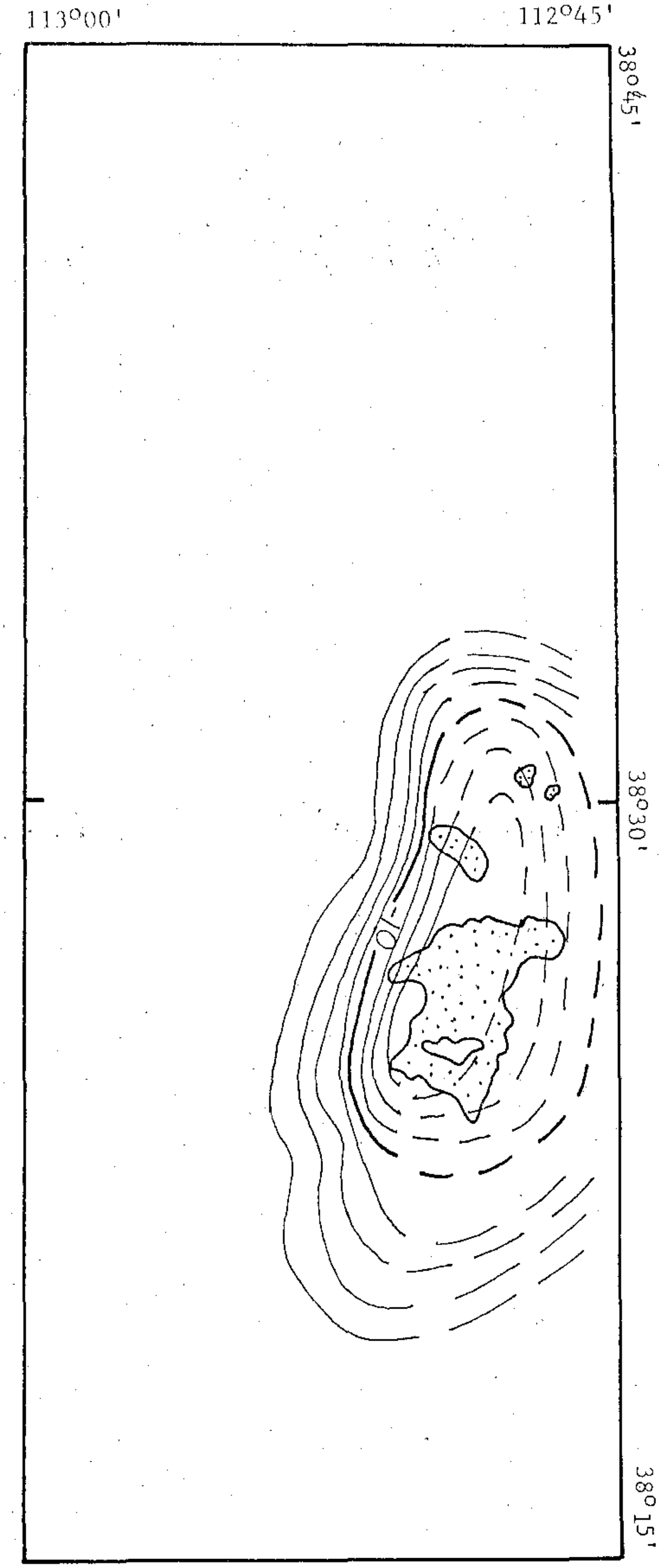


Figure 4. Reconstructed residual gravity for the Mineral Range.

Figure 5. Mineral Range gravity anomaly. The locations of the silic volcanics in the range are indicated by the dot pattern.

the general position of the anomaly and a general magnitude seem to be indisputable. If we assume a density contrast of -.2 gm/cm^3 the anomaly of Fig. 5 could be explained by a buried horizontal cylinder with a mass of 7.1 x 10^8 tons, a circular cross section with a radius of 8,000 feet, and a depth of burial to the center of the cylinder of 11,000 feet.

Escalante Valley Anomaly

Based on the reconstructed gravity map for the west side of the basin (Figure 4) and the data of Figure 2 an interpretation was made of the shape and thickness of the fill in the Escalante Valley. A density contrast of -.4 g/cm^3 was used in the interpretation. The actual density contrast might be more, but almost certainly will not be much less; therefore, the values shown for the thickness of the valley are equal to or greater than the actual values. The interpretation was done three dimensionally with a grid size of 6000 feet. Thus the details of the basin structure along the margins are not well shown. This margin structure is considered in more detail in another manner. The three-dimensional results are shown in Fig. 6 as a contour map of depth to basement. The thickness of low density material in the northern part of the valley is approximately 4000 feet, but is up to 7000 feet thick in the southern portion of the valley. This interior, deeper portion of the valley is probably blocked out by ring faults. The shallower portion of the valley would also appear to be blocked out by faults particularly along the western,northern,and southeastern margins. Interpretation of what happens along the eastern margin is difficult because of the assumptions that had to be made to reconstruct the gravity map there. A cross section across the valley is shown in Fig. 7. This cross section was interpreted in more detail in order to delineate the detailed structure

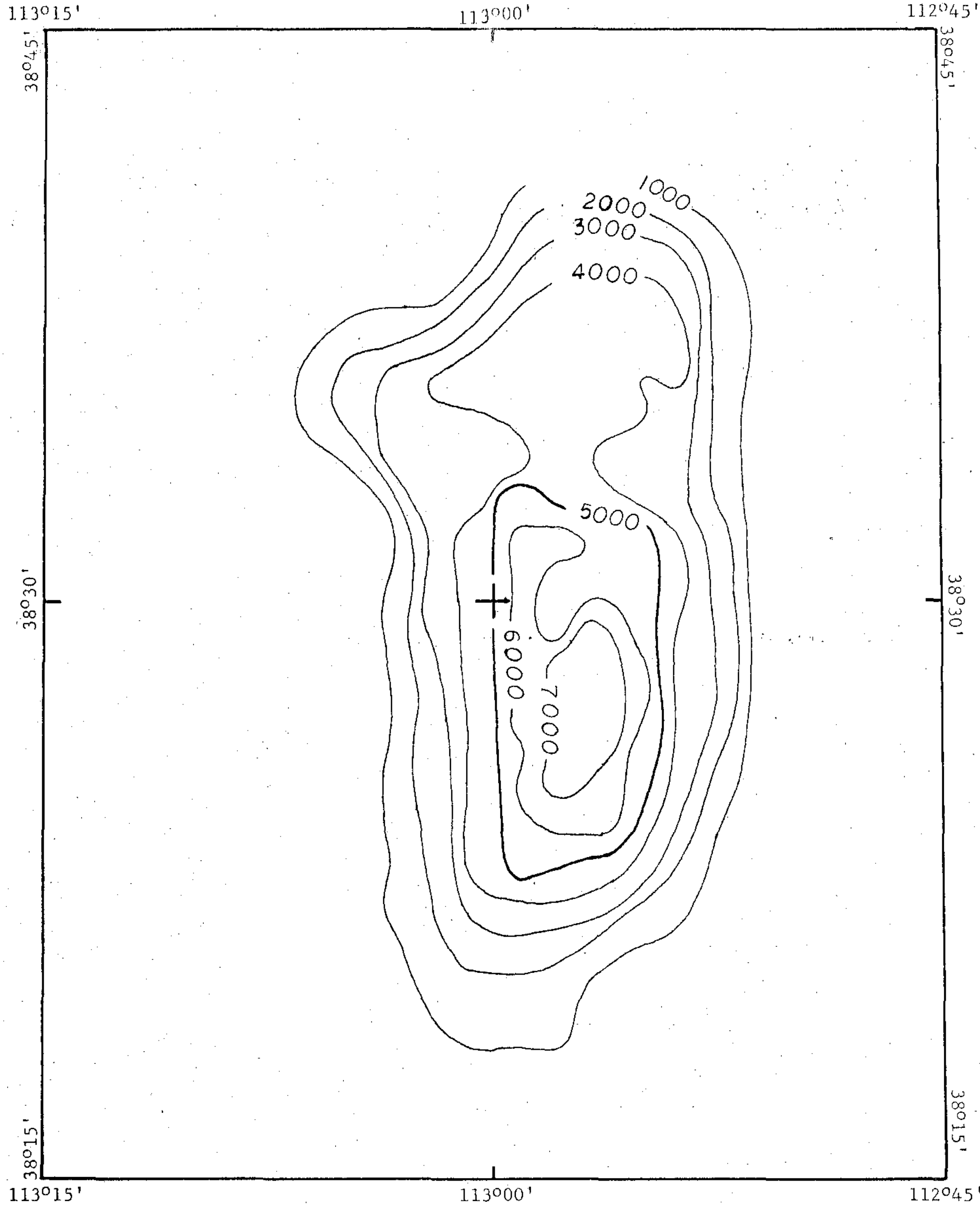


Figure 6. Contour map of depth to bedrock in the Escalante Valley, assuming a density contrast of 0.4 gm/cm^3. Contours are in units of 1000 feet.

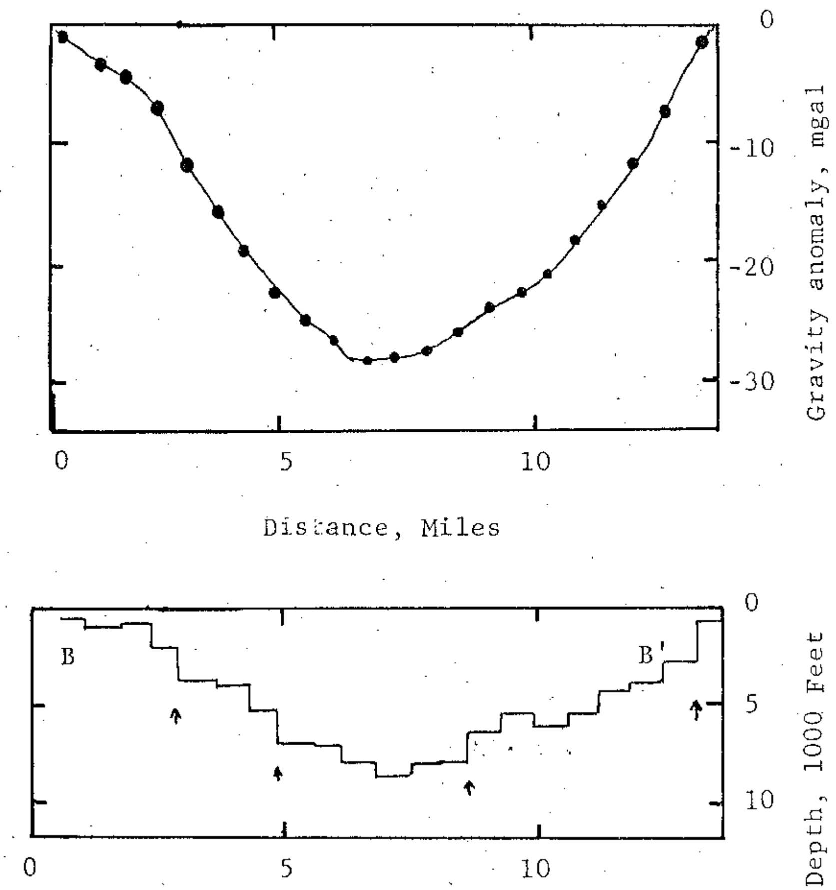


Figure 7. Residual gravity and depth to basement for cross section BB' (Figure 2). Position of possible faults indicated by arrows.

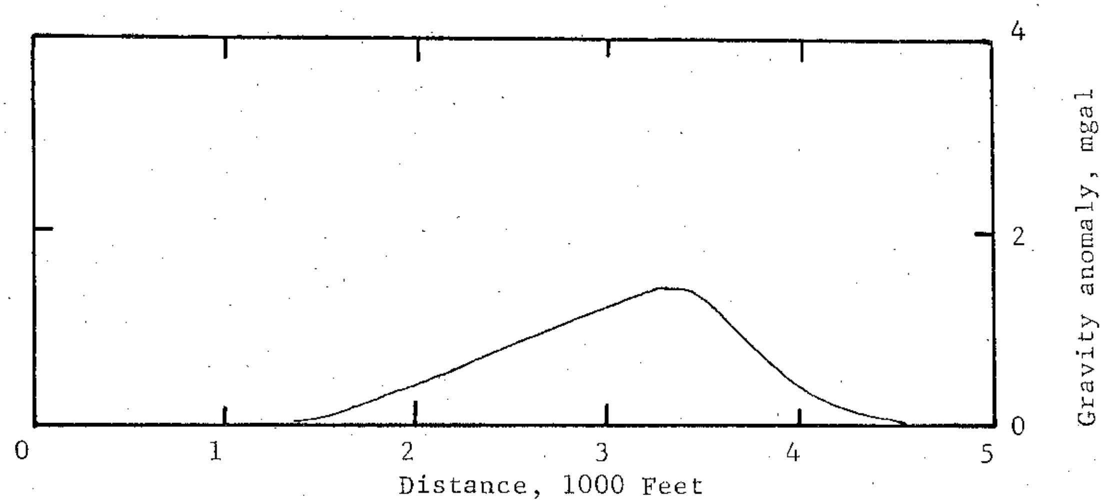


Figure 8b. Residual gravity over the silicified zone(Profile AA').

of the basin margins. The interpretation was two dimensional, but corrections were made for the finite length of the basin. There are two faults bounding the west side of the valley. There may be 2 faults on the eastern side as well, although the valley could be just steeply downwarped.

Section 16 Fault Zone Anomaly

The final part of the gravity data to be discussed is part of the detailed cross section prepared by Gay. This cross section is reproduced in reduced fashion as Fig. 8. There is a small relative positive on the gravity section near the surface expression of the fault of section 16. This small positive gravity is probably due to silicification along the fault zone, expressed at the surface as the opal deposit. From the anomaly the shape and size of the opal deposit can be inferred. The separated anomaly is consistent with silicification along a dipping zone several hundred feet wide and dipping west at $40-60^{o}$ (the anomalous mass is 78 tons).

Discussion

The regional gravity data outline two anomalies, a negative anomaly over the Escalante Valley and a negative anomaly in the Mineral Range east of the geothermal prospect. The shape and thickness of low density fill in the valley can be obtained from the gravity anomaly (Figures 2 and 4). The thickness inferred for the valley is consistent with well data. An oil well was drilled to a depth of about 3400 feet in sec 21 T25N R9W. The well remained in valley sediments to the total depth. According to the gravity data the depth to basement at that point is between 4000 and 4500 feet. The circular area in the center of the valley might be interpreted as a caldera structure; however, the low values of gradient and heat flow rule that area out as a source of the heat for the geothermal anomaly.

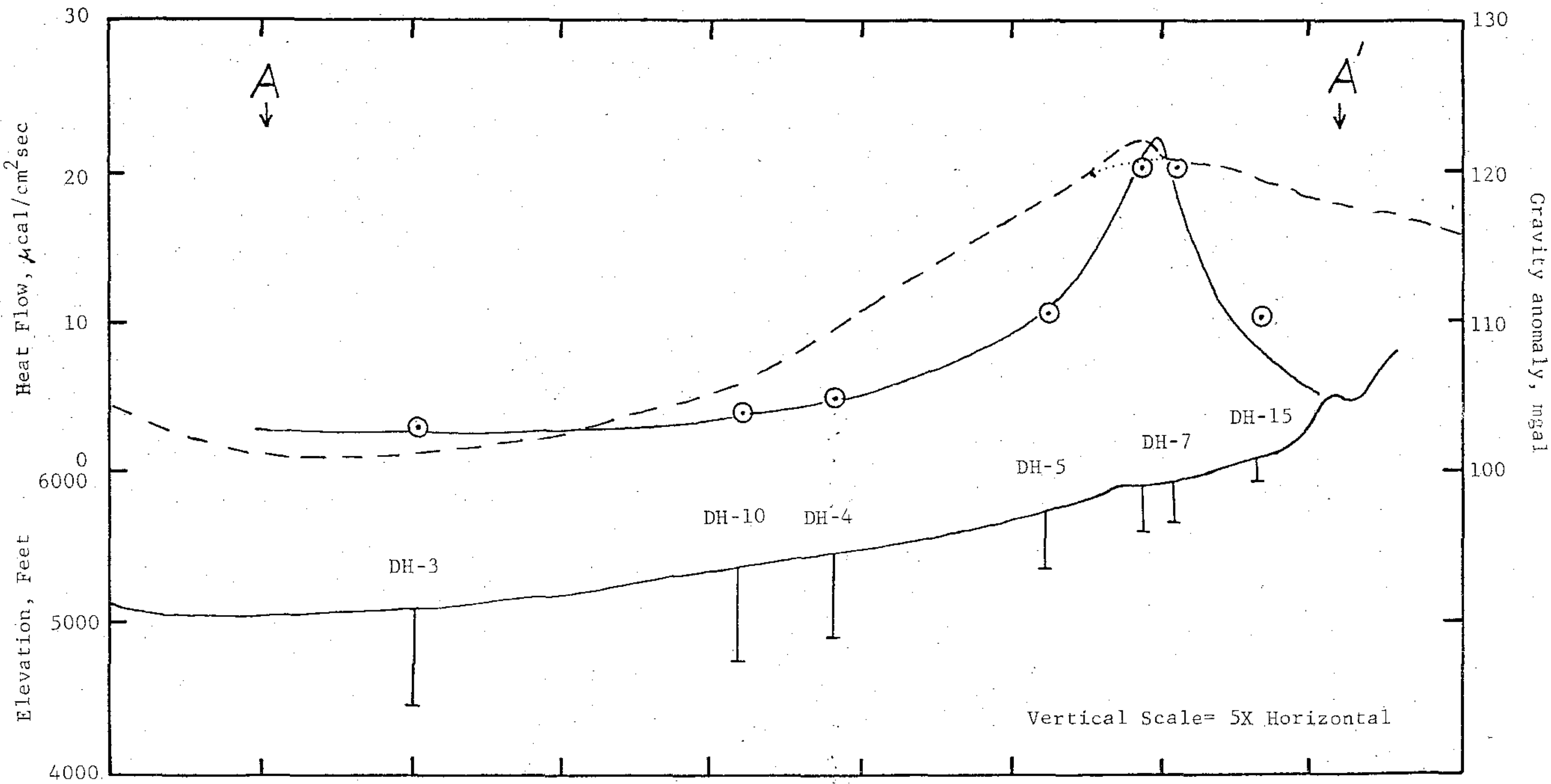


Figure 8a. Heat flow, topography and gravity. The gravity profile (dashed line) is in mgal relative to the Milford base station(Gay,1974).

The second regional anomaly, the Mineral Range anomaly, has no ready explanation on the basis of the surface geology. If it does indeed reflect a buried granite body, perhaps the source of the volcanics, then this body might be the source of heat for the geothermal anomaly. At least two exploration drill holes should be drilled for heat flow over the gravity anomaly (Figure 5) as soon as possible. The size of the anomaly is large enough to imply a huge heat source if the body is still hot. If high heat flow is observed in these drill holes then the area potentially valuable for geothermal exploration is increased tremendously. Zones of fracture porosity and permeability in the range, particularly the conduits for the volcanic rocks, might be the reservoir. Along the east side of the Mineral Range east dipping basin and range faults, similar to the one postulated for section 16, T27S, R9W on the west side of the range, might also serve as reservoirs.

Because of the interference of the Escalante Valley and Mineral Range gravity anomalies in the immediate area of the geothermal prospect, the detailed gravity cross section does not clearly outline the nature of the valley-range contact. There is a small positive gravity anomaly at the surface expression of the geothermal reservoir. The anomaly is caused by silica deposition in the alluvium and probably along the fault zone as well. Thus the gravity data do delineate the self-sealed cap of the geothermal reservoir. The gravity data furnish little evidence on the displacement along the fault in section 16. The strongest argument for its existence is still the shape of the heat flow anomaly. The thickness of the valley sediments on the west side is an important parameter for the evaluation of possible depth extent, reservoir type, and source of the geothermal fluid moving along the fault. Electrical resistivity measurements across the geothermal anomaly zone and soundings both east and west of the fault might supply more information on basement depths and reservoir conditions in the prospect. Such measurements should be carried out before deep exploration drilling in the valley block proceeds.

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