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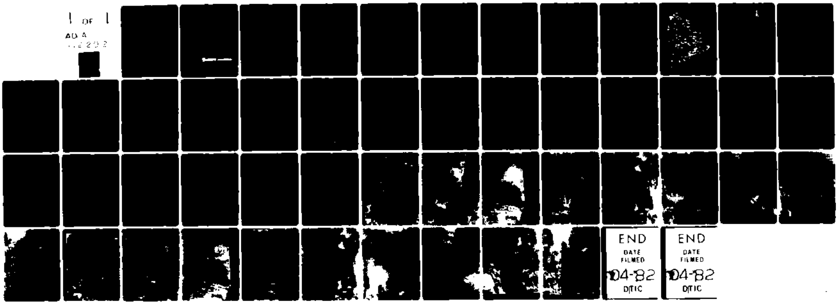

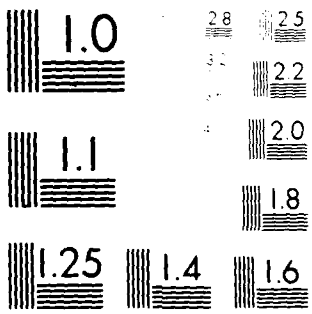
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MX SITING INVESTIGATION

GRAVITY SURVEY - BIG SMOKY VALLEY

NEVADA

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office (BMO)
Norton Air Force Base, California 92409

Prepared by:

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Long Beach, California 90807

28 November 1980

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Results of a gravity survey of the Big Smoky Valley in west-central Nevada suggest that there are major range-bounding normal fault systems along the full length of the valley on both sides. The maximum depth calculated in the valley is 4000 feet.

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FOREWORD

Methodology and Characterization studies during fiscal years 1977 and 1978 (FY 77 and 78) included gravity surveys in ten valleys in Arizona (five), Nevada (two), New Mexico (two), and California (one). The gravity data were obtained for the purpose of estimating the gross structure and shape of the basins and the thickness of the valley fill. There was also the possibility of detecting shallow rock in areas between boring locations. Generalized interpretations from these surveys were included in Fugro National's Characterization Reports (FN-TR-26a through e).

During the FY 77 surveys, measurements were made to form an approximate 1-mile grid over the study areas and contour maps showing interpreted depth to bedrock were made. In FY 79, the decision was made to concentrate on verifying and refining suitable area boundaries. This decision resulted in a reduction in the gravity program. Instead of obtaining gravity data on a grid, the reduced program consisted of obtaining gravity measurements along profiles across the valleys where Verification studies were also performed.

The Defense Mapping Agency (DMA), St. Louis, was requested to provide gravity data from their library to supplement the gravity profiles. For Big Smoky, Hot Creek, and Big Sand Springs valleys, a sufficient density of library data are available to permit construction of interpreted contour maps instead of just two-dimensional cross sections.

In late summer of FY 79, supplementary funds became available to begin data reduction. At that time, inner zone terrain corrections were begun on the library data and the profiles from Big Smoky Valley, Nevada, and Butler and La Posa valleys, Arizona. The profile data from Whirlwind, Hamlin, Snake East, White River, Garden, and Coal valleys, Nevada, became available from the field in early October 1979.

A continuation of gravity interpretations has been incorporated into the FY 80 program, and the results are being summarized in a series of valley reports. Reports covering Nevada-Utah gravity studies will be numbered "FN-TR-33-" followed by the abbreviation for the subject valley. In addition, more detailed reports of the results of FY 77 surveys in Dry Lake and Ralston valleys, Nevada, are being prepared. Verification studies are continuing in FY 80, and gravity studies are included in the program. DMA will continue to obtain the field measurements, and it is planned to return to the grid pattern. The interpretation of the grid data will allow the production of contour maps which will be valuable in the deep basin structural analysis needed for computer modeling in the water resources program.

The gravity interpretations will also be useful in Nuclear Hardness and Survivability (NH&S) evaluations.

The basic decisions governing the gravity program are made by BMO following consultation with TRW, Inc., Fugro National, and the DMA. Conduct of the gravity studies is a joint effort between DMA and Fugro National. The field work, including planning, logistics, surveying, and meter operation is done by the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC), headquartered in Cheyenne, Wyoming. DMAHTC reduces the data to Simple Bouguer Anomaly (see Section A1.4, Appendix A1.0). The Defense Mapping Agency Aerospace Center (DMAAC), St. Louis, Missouri, calculates outer zone terrain corrections.

Fugro National provides DMA with schedules showing the valleys with the highest priorities. Fugro National also recommended locations for the profiles in the FY 79 studies with the provision that they should follow existing roads or trails. Any required inner zone terrain corrections are calculated by Fugro National prior to making geologic interpretations.

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1.0 INTRODUCTION

1.1 OBJECTIVE

Gravity measurements were made in Big Smoky Valley for the purpose of estimating the overall shape of the structural basin, the thickness of alluvial fill, and the location of concealed faults. The estimates will be useful in modeling the dynamic response of ground motion in the basin and in evaluating groundwater resources.

1.2 LOCATION

Big Smoky Valley is in northeastern Esmeralda and northwestern Nye counties, Nevada. The town of Tonopah, Nevada, (Figure 1) is near the southeast corner of the valley on highways 6 and 95. Access throughout the valley is good due to an extensive network of well maintained, unpaved roads. The valley area is principally used for rangeland, but effects of extensive mining operations are apparent around the valley edge.

Big Smoky Valley (Figure 2) is bounded on the east by the San Antonio mountains and the Toquima Range, on the west by Royston Hills and Monte Cristo Range, on the south by Lone Mountain and Tonopah, Nevada, and on the north by the Toiyabe Range. The area covered by this report lies between latitudes 38°00' and 38°45' and longitudes 117°00' and 117°40'. It is approximately 40 miles by 51 miles (64 km by 81 km).

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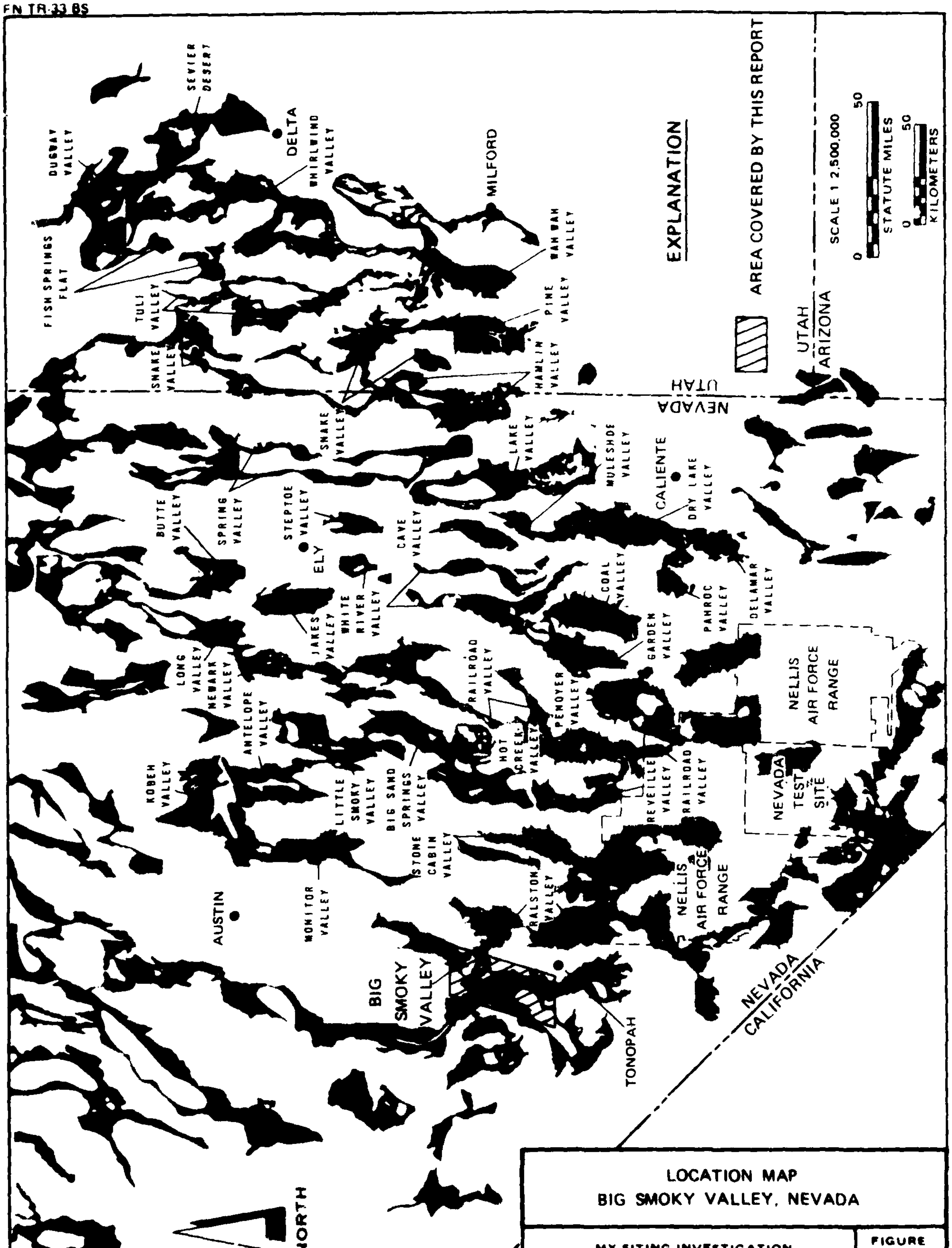

LOCATION MAP
BIG SMOKY VALLEY, NEVADA

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE 1

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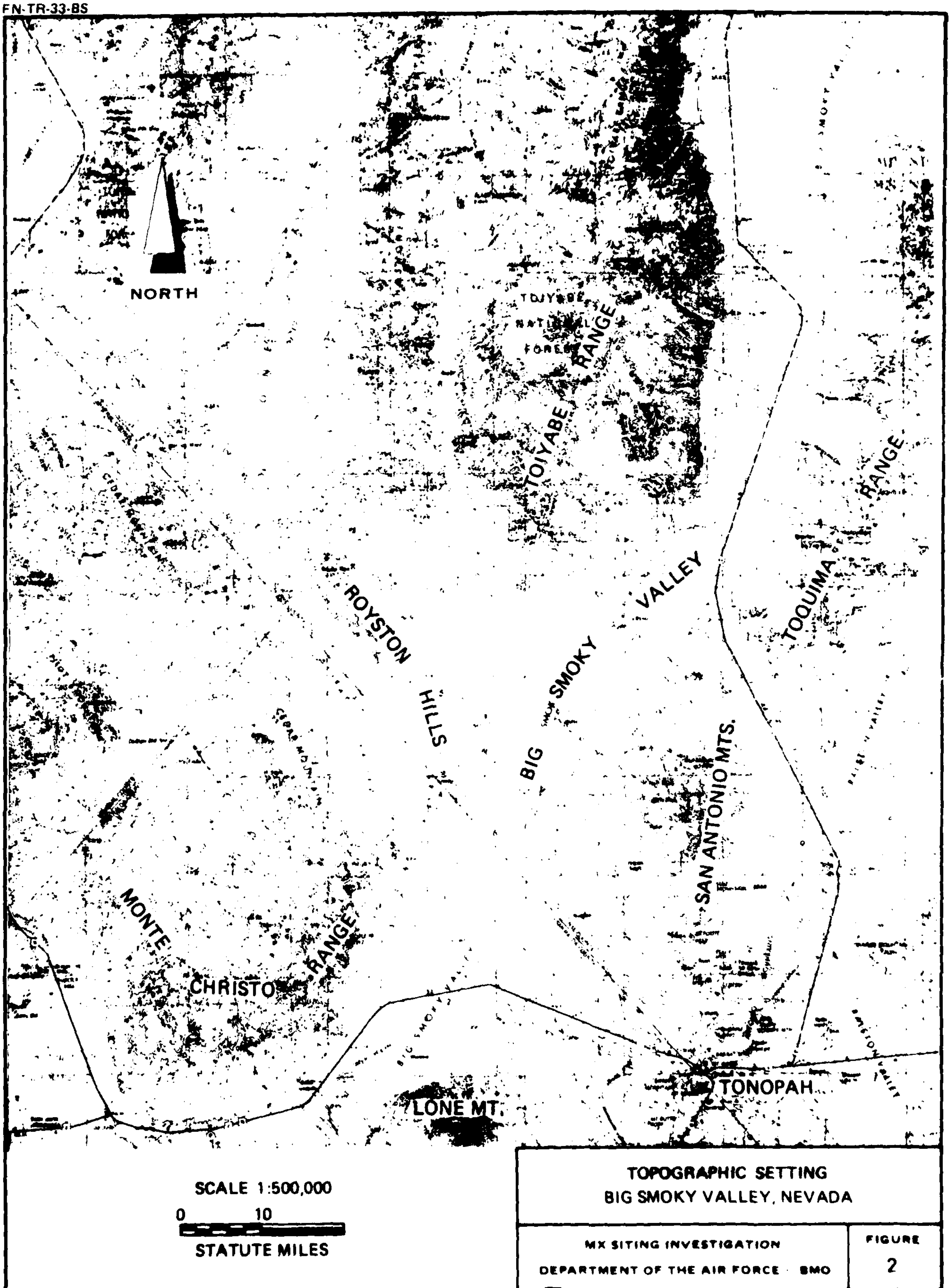

TOPOGRAPHIC SETTING
BIG SMOKY VALLEY, NEVADA

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FIGURE 2

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1.3 SCOPE OF WORK

A total of 1386 gravity stations were used in this report. The Defense Mapping Agency Aerospace Center (DMAAC) supplied 1157 gravity stations from their library and 229 new gravity station measurements were made by the Defense Mapping Agency Hydrographic-Topographic Center/Geodetic Survey Squadron (DMAHTC/GSS).

2.0 GRAVITY DATA REDUCTION

DMAHTC/GSS obtained the basic observations for the new stations and reduced them to Simple Bouguer Anomalies (SBA) as described in Appendix A1.0. Up to three levels of terrain corrections were applied to the new stations to convert the SBA to the Complete Bouguer Anomaly (CBA). Only the first two levels of terrain corrections described below were applied to the library stations.

First, the DMAAC, St.Louis, Missouri, used its library of digitized terrain data and a computer program to calculate corrections out to 104 miles (167 km) from each station. When the program could not calculate the terrain effects near a station, a ring template was used to estimate the effect of terrain within approximately 3000 feet (914 m) of the station. The third level of terrain corrections was applied to those stations where 10 feet (3 m) or more of relief was observed within 130 feet (40 m). In these cases, the elevation differences were measured in the field at a distance of 130 feet along six directions from the stations. These data were used to calculate the effect of the very near relief.

3.0 GEOLOGIC SUMMARY

Big Smoky Valley and the general vicinity lies in an area considered to be within the upper plate of the Roberts Mountain thrust sheet along the western limit of the miogeosynclinal belt. The combination of this older allochthonous sequence with Tertiary volcanic rocks and tectonic events result in complex geologic structure and extremely diverse rock types in the mountains surrounding Big Smoky Valley. To the east, the western flank of the San Antonio Mountains is composed of Tertiary volcanic flows (rhyolites, andesites, and basalts) and tuffs with some sediments, predominantly of the Esmeralda Formation (sandstones, siltstones, and mudstones) (Kleinhampl and Ziony, 1967). The southern Toquima Range, at the northeastern boundary of Big Smoky Valley, consists of Cretaceous (granites) and Tertiary rhyolite, basalt, and tuffs with some metamorphic and sedimentary rock (Ferguson and Cathcart, 1954; Kleinhampl and Ziony, 1967).

The Toiyabe Range at the northern end of the site is chiefly Tertiary air-fall and ash-flow tuff with minor outcrops of Paleozoic shale and limestone along the eastern flank. Rocks along the western side of Big Smoky Valley (Royston Hills and Monte Cristo Range) are chiefly Tertiary tuffs, rhyolites, andesites, and basalts.

Basin-fill deposits within the valley reach combined thicknesses of about 3000 feet (915 m) (Rush and Schroer, 1970). Younger alluvial fans, commonly in association with fluvial, eolian, and playa deposits, occur throughout the central valley, locally extending to the mountain fronts. Deposits consist predominantly of sand with increasing gravel content near steep mountain fronts. Intermediate-level alluvial fans are restricted to mountain front areas and are rarely exposed along the valley axis. Stream channel and playa deposits occur in northern and central Big Smoky Valley along major south flowing drainages.

Prominant north to northeast trending range-bounding faults occur on the steep eastern side of the Toiyabe Range and on the western side of the San Antonio Mountains. Evidence of late Quaternary faulting is seen in the form of fault scarps in alluvium along the southwestern edge of Lone Mountain, along the entire eastern side of the valley, and at scattered localities throughout the valley. The faults exhibiting greatest apparent displacement occur along the west side of the San Antonio Mountains where scarps are 75 feet (23 m) or more in height. Many faults previously mapped along the eastern side (Rush and Schroer, 1979) do not show displacement of the alluvium but may be represented as tonal and vegetation lineaments.

4.0 INTERPRETATION

The basis of interpretation is the Complete Bouguer Anomaly (CBA) shown in Drawing 1. The CBA is defined in Appendix A1.4.

The CBA data are reduced to a set of values at the points of a uniformly-spaced geographic array, or grid. This facilitates the mathematical treatment of irregularly spaced data. Gravity stations are numerous along roads and areas where access is easy. The grid-process is done using an algorithm which computes a value at each grid point from the gravity station data within a circular area around the grid point. A bell-shaped weighting function assigns greater weight to the nearer data points. The grid-point spacing is chosen to match the average data spacing. A 1.2 mile (2 km) grid spacing was used for this analysis.

4.1 REGIONAL-RESIDUAL SEPARATION

A fundamental step in gravity interpretation is isolation of the part of the CBA which represents the geologic feature of interest, in this case the valley fill. The valley fill has a lower density than the bedrock and, therefore, creates a negative gravity anomaly. The portion of the CBA which corresponds to this alluvial material is called the "residual anomaly."

The CBA contains long-wave-length components from deep and broad geologic structures extending far beyond the valley. These long-wave-length components, called the regional gravity, have been approximated by a second-degree trend surface. The trend surface is a least-squares fit to the CBA values at the bedrock stations of the region. This regional trend is subtracted from the CBA to obtain the residual anomaly. The residual anomaly is used to calculate a simple geologic model which fits the gravity data and is consistent with geologic knowledge from other sources.

4.2 DENSITY SELECTION

The construction of a geologic model from the residual anomaly requires selection of density values representative of the alluvial fill and of the underlying rock. Since only very generalized density information is available, the geologic interpretation of the gravity data can only be a coarse approximation. Average in situ density of the fill material was measured in six shallow borings (Table 1) at a depth of 161 feet (49 m). The observed density range for the soil was 1.7 to 2.3 g/cm^3. The largest measured density value was used in the modeling process, instead of the average, because the overall alluvium density is expected to increase due to compaction with depth (compaction with depth and age is discussed by Woollard, 1962 and Grant and West, 1965).

The basement material underlying the Big Smoky basin is thought to be the Paleozoic carbonate rocks which are found sparsely in the surrounding mountain ranges. Published values for carbonate rocks typically range between 2.6 and 2.8 g/cm^3. The Paleozoic carbonate rocks in Nevada are generally reported to be relatively high in density, on the order of 2.8 g/cm^3. This value was

VERIFICATION BORING RESULTS			
BORING NUMBER	TOTAL HOLE DEPTH feet (meters)	DENSITY g/cm^3	REMARKS
BS–B–1	162/(49)	1.7	NO ROCK ENCOUNTERED
BS–B–2	160/(49)	2.1	NO ROCK ENCOUNTERED
BS–B–3	161/(49)	2.2	NO ROCK ENCOUNTERED
BS–B–4	161/(49)	2.2	NO ROCK ENCOUNTERED
BS–B–5	161/(49)	2.1	NO ROCK ENCOUNTERED
BS–B–6	161/(49)	2.3	NO ROCK ENCOUNTERED

SELECTED VERIFICATION SEISMIC REFRACTION RESULTS *			
LINE NUMBER	DEEPEST LAYER fps (mps)	@	feet (meters)
BS–S -3	8050 (2454)	@	36 (11)
BS–S–11	8450 (2576)	@	52 (16)
BS–S–18	9100 (2774)	@	76 (23)

BORINGS FROM LITERATURE *			
I.D.	COMPANY	LOCATION	REMARKS
BORING (A)	ANACONDA	NE¼, NE¼; SEC. 2; T5N - R41E; NYE COUNTY, NEVADA	1499 FT (457m) VOLCANICS
BORING (B)	ANACONDA	SW¼, SW¼; SEC. 34; T6N - R41E; NYE COUNTY, NEVADA	1435 FT. (437m) VOLCANICS

* LOCATIONS MARKED ON DRAWING 2.

BIG SMOKY GEOTECHNICAL DATA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	TABLE 1
FUGRO NATIONAL, INC.	

selected to represent the density of the basement rock. The density contrast used for modeling was -0.50 g/cm^3.

4.3 MODELING

Modeling was done with the aid of a computer program which iteratively calculates a three-dimensional solution of gravity anomaly data (Cordell, 1970). The gravity anomaly is represented by discrete values on a two-dimensional grid. The source of the anomaly (the volume of low-density valley fill) is represented by a set of vertical prism elements. The tops of the prisms lie in a common horizontal plane. The bottoms of the prisms collectively represent the bottom of the valley fill. Each prism has a cross-sectional area equal to one grid square and a uniform density. A grid square of 1.2 miles by 1.2 miles (2 km by 2 km) was selected as representative of the gravity station distribution. Computations were made for five iterations of mutually interactive prism adjustment. The root-mean-square error for the entire grid was less than 0.5 milligal.

The calculated thickness of the valley fill depends upon the accuracy of the -0.50 g/cm^3 density contrast (i.e., fill density minus rock density) used. Since neither density is perfectly known, nor even uniform, the calculated thickness should be expected to contain a corresponding degree of uncertainty. Table 1 lists three seismic refraction lines and two deeper borings which were used as constraints in the modeling process. The seismic refraction lines located near the mountain flanks recorded high velocities which may represent the basement material. The alluvial fill material in the center of the valley is approximately 1400 to 1500 feet (427 to 457 m) thick according to the two literature borings (Table 1). The calculated thickness of fill or interpreted depth to rock is contoured in Drawing 2.

4.4 DISCUSSION OF RESULTS

The depth-to-rock contours (Drawing 2) depict a long north-south graben with multiple normal faults. The interpretation was aided by regional geologic information from published reports, aerial photographs, and field reconnaissance which located the surface expression of faults. The second vertical derivative of the CBA field was calculated to guide the placement of the faults shown. Because the zero contour of the second vertical derivative marks the steepest part of the input CBA field, the faults were placed along the zero contour.

The fault system on the west side of the San Antonio Mountains and Toquima Range is generally close to the mountain front. The fault system is also close to the mountain front on the east side of the Toiyabe Range. However, there appears to be a pediment several miles wide east of Royston Hills and Monte Cristo Range. At the southern end where the valley bifurcates, faults are interpreted to be near both flanks of Lone Mountain.

Several northwest-southwest trending fault zones are transverse to the major faults. There is no indication in regional or local geologic data or in this gravity data that these features are related to through-going tectonic systems. They appear to represent zones of differential movement within the central down-dropped block.

The northwest trending grabens between the Toiyabe Range and the Royston Hills and between the Toquima Range and San Antonio Mountains, however, may represent fundamental crustal fracture systems but their role in the regional tectonic framework is not understood at this time and is beyond the scope of this report.

In summary, central Big Smoky Valley appears to comprise a junction of several, variously oriented horsts and grabens. The central area is a small graben which is distinct from grabens in northeastern Big Smoky Valley and those to the south on both sides of Lone Mountain. This northeast-trending major graben system is disrupted by northwest-trending minor grabens.

5.0 CONCLUSIONS

The interpretation of Big Smoky Valley gravity data indicates that there are major range-bounding normal fault systems extending the full length of the valley on both sides. The maximum depth calculated in the valley is 4000 feet (1219 m).

The calculated bedrock depths are only approximations because little is known about the actual density distribution in and around the valley and the residual gravity anomaly is necessarily based on an interpreted regional field. An average density contrast of 0.50 g/cm^3 between the alluvium and bedrock was used to calculate the thickness of the valley-fill material. Future studies that acquire better density data or measure actual depths to bedrock in deep parts of the valley can be used to refine the gravity interprepation.

BIBLIOGRAPHY

Cordell, Lindreth, 1970, Iterative solution of three-dimensional gravity anomaly data, Geol. Survey Computer Contr. No. 10: U.S. Geol. Survey, Washington, D.C.

Ferguson, H. G. and Cathcart, S. H. (1954) Geology of the Round Mountain quadrangle, Nevada: U. S. Geol. Survey, Geol. Quad. Map GQ-40, scale 1:125,000.

Fugro National, Inc. 1979, MX siting Investigation geotechnical evaluation, Verification studies, v. 1B, FN-TR-27.

___________, 1979, Verification study data of Big Smoky CDP, Nevada, v. VIII, FN-TR-27.

Kleinhampl, F. J., and Ziony, J. I. 1967, Preliminary geologic map of northern Nye County, Nevada: U. S. Geol. Survey, Open file map, scale 1:200,000.

Rush, F. E., and Schroer, C. V., 1979, Water resources of Big Smoky Valley, Landu, Nye and Esmeralda counties, Nevada: Nev. Dept. of Conserv. and Nat. Resources Bull. No. 41, 84 p.

Stewart, John H. 1980, Geology of Nevada: Nevada Bureau of Mines and Geology, Special Pub. 4.

Stewart, John H. and Carlson, John E. 1978, Geology of Nevada: Nevada Bureau of Mines and Geology.

APPENDIX A1.0

GENERAL PRINCIPLES OF THE GRAVITY EXPLORATION METHOD

A1.0 GENERAL PRINCIPLES OF THE GRAVITY EXPLORATION METHOD

A1.1 GENERAL

A gravity survey involves measurement of differences in the gravitational field between various points on the earth's surface. The gravitational field values being measured are the same as those influencing all objects on the surface of the earth. They are generally associated with the force which causes a 1 gm mass to be accelerated at 980 cm/sec^2. This force is normally referred to as a 1-g force.

Even though in many applications the gravitational field at the earth's surface is assumed to be constant, small but distinguishable differences in gravity occur from point to point. In a gravity survey, the variations are measured in terms of milligals. A milligal is equal to 0.001 cm/second^2 or 0.00000102 g. The differences in gravity are caused by geometrical effects, such as differences in elevation and latitude, and by lateral variations in density within the earth. The lateral density variations are a result of changes in geologic conditions. For measurements at the surface of the earth, the largest factor influencing the pull of gravity is the density of all materials between the center of the earth and the point of measurement.

To detect changes produced by differing geological conditions, it is necessary to detect differences in the gravitational field as small as a few milligals. To recognize changes due to geological conditions, the measurements are "corrected" to account for changes due to differences in elevation and latitude.

Given this background, the basic concept of the gravitational exploration method, the anomaly, can be introduced. If, instead of being an oblate spheroid characterized by complex density variations, the earth were made up of concentric, homogeneous shells, the gravitational field would be the same at all points on the surface of the earth. The complexities in the earth's shape and material distribution are the reason that the pull of gravity is not the same from place to place. A difference in gravity between two points which is not caused by the effects of known geometrical differences, such as in elevation, latitude, and surrounding terrain, is referred to as an "anomaly."

An anomaly reflects lateral differences in material densities. The gravitational attraction is smaller at a place underlain by relatively low density material than it is at a place underlain by a relatively high density material. The term "negative gravity anomaly" describes a situation in which the pull of gravity within a prescribed area is small compared to the area surrounding it. Low-density alluvial deposits in basins such as those in the Nevada-Utah region produce negative gravity anomalies in relation to the gravity values in the surrounding mountains which are formed by more dense rocks.

The objective of gravity exploration is to deduce the variations in geologic conditions that produce the gravity anomalies identified during a gravity survey.

A1.2 INSTRUMENTS

The sensing element of a LaCoste and Romberg gravimeter is a mass suspended by a zero-length spring. Deflections of the mass from a null position are proportional to changes in gravitational attraction. These instruments are sealed and compensated for atmospheric pressure changes. They are maintained at a constant temperature by an internal heater element and thermostat. The absolute value of gravity is not measured directly by a gravimeter. It measures relative values of gravity between one point and the next. Gravitational differences as small as 0.01 milligal can be measured.

A1.3 FIELD PROCEDURES

The gravimeter readings were calibrated in terms of absolute gravity by taking readings twice daily at nearby USGS gravity base stations. Gravimeter readings fluctuate because of small time-related deviations due to the effect of earth tides and instrument drift. Field readings were corrected to account for these deviations. The magnitude of the tidal correction was calculated using an equation suggested by Goguel (1954):

$$C = P + N\cos\phi\,(\cos\phi + \sin\phi) + S\cos\phi\,(\cos\phi - \sin\phi)$$

where C is the tidal correction factor, P, N, and S are time-related variables, and ϕ is the latitude of the observation point. Tables giving the values of P, N, and S are published annually by the European Association of Exploration Geophysicists.

The meter drift correction was based on readings taken at a designated base station at the start and end of each day. Any difference between these two readings after they were corrected for tidal effects was considered to have been the result of instrumental drift. It was assumed that this drift occurred at a uniform rate between the two readings. Corrections for drift were typically only a few hundredths of a milligal. Readings corrected for tidal effects and instrumental drift represented the observed gravity at each station. The observed gravity values represent the total gravitational pull of the entire earth at the measurement stations.

A1.4 DATA REDUCTION

Several corrections or reductions are made to the observed gravity to isolate the portion of the gravitational pull which is due to the crustal and near-surface materials. The gravity remaining after these reductions is called the "Bouguer Anomaly." Bouguer Anomaly values are the basis for geologic interpretation. To obtain the Bouguer Anomaly, the observed gravity is adjusted to the value it would have had if it had been measured at the geoid, a theoretically defined surface which approximates the surface of mean sea level. The difference between the "adjusted" observed gravity and the gravity at the geoid calculated for a theoretically homogeneous earth is the Bouguer Anomaly.

Four separate reductions, to account for four geometrical effects, are made to the observed gravity at each station to arrive at its Bouguer Anomaly value.

a. Free-Air Effect: Gravitational attraction varies inversely as the square of the distance from the center of the earth. Thus, corrections must be applied for elevation. Observed gravity levels are corrected for elevation using the normal vertical gradient of:

$$FA = -0.09406 \text{ mg/ft } (-0.3086 \text{ milligals/meter})$$

where FA is the free-air effect (the rate of change of gravity with distance from the center of the earth). The free-air correction is positive in sign since the correction is opposite the effect.

b. Bouguer Effect: Like the free-air effect, the Bouguer effect is a function of the elevation of the station, but it considers the influence of a slab of earth materials between the observation point on the surface of the earth and the corresponding point on the geoid (sea level). Normal practice, which is to assume that the density of the slab is 2.67 grams per cubic centimeter was followed in these studies. The Bouguer correction (B_c), which is opposite in sign to the free-air correction, was defined according to the following formula.

$$B_c = 0.01276\ (2.67)\ h_f \text{ (milligals per foot)}$$

$$B_c = 0.04185\ (2.67)\ h_m \text{ (milligals per meter)}$$

where h_f is the height above sea level in feet and h_m is the height in meters.

c. Latitude Effect: Points at different latitudes will have different "gravities" for two reasons. The earth (and the geoid) is spheroidal, or flattened at the poles. Since points at higher latitudes are closer to the center of the earth than points near the equator, the gravity at the higher latitudes is larger. As the earth spins, the centrifugal acceleration causes a slight decrease in gravity. At the higher latitudes where the earth's radii are smaller, the centrifugal acceleration diminishes. The gravity formula for the Geodetic Reference System, 1967, gives the theoretical value of gravity at the geoid as a function of latitude. It is:

$$g = 978.0381\ (1 + 0.0053204 \sin^2 \phi - 0.0000058 \sin^2 2\phi) \text{ gals}$$

where g is the theoretical acceleration of gravity and ϕ is the latitude in degrees. The positive term accounts for the spheroidal shape of the earth. The negative term adjusts for the centrifugal acceleration.

The previous two corrections (free air and Bouguer) have adjusted the observed gravity to the value it would have had at the geoid (sea level). The theoretical value at the geoid for the latitude of the station is then subtracted from the adjusted observed gravity. The remainder is called the Simple Bouguer Anomaly (SBA). Most of this gravity represents the effect of material beneath the station, but part of it may be due to irregularities in terrain (upper part of the Bouguer slab) away from the station.

d. Terrain Effect: Topographic relief around the station has a negative effect on the gravitational force at the station. A nearby hill has upward gravitational pull and a nearby valley contributes less downward attraction than a nearby material would have. Therefore, the corrections are always positive. Corrections are made to the SBA when the terrain effects were 0.1 milligal or larger. Terrain corrected Bouguer values are called the Complete Bouguer Anomaly (CBA). When the CBA is obtained, the reduction of gravity at individual measurement points (stations) is complete.

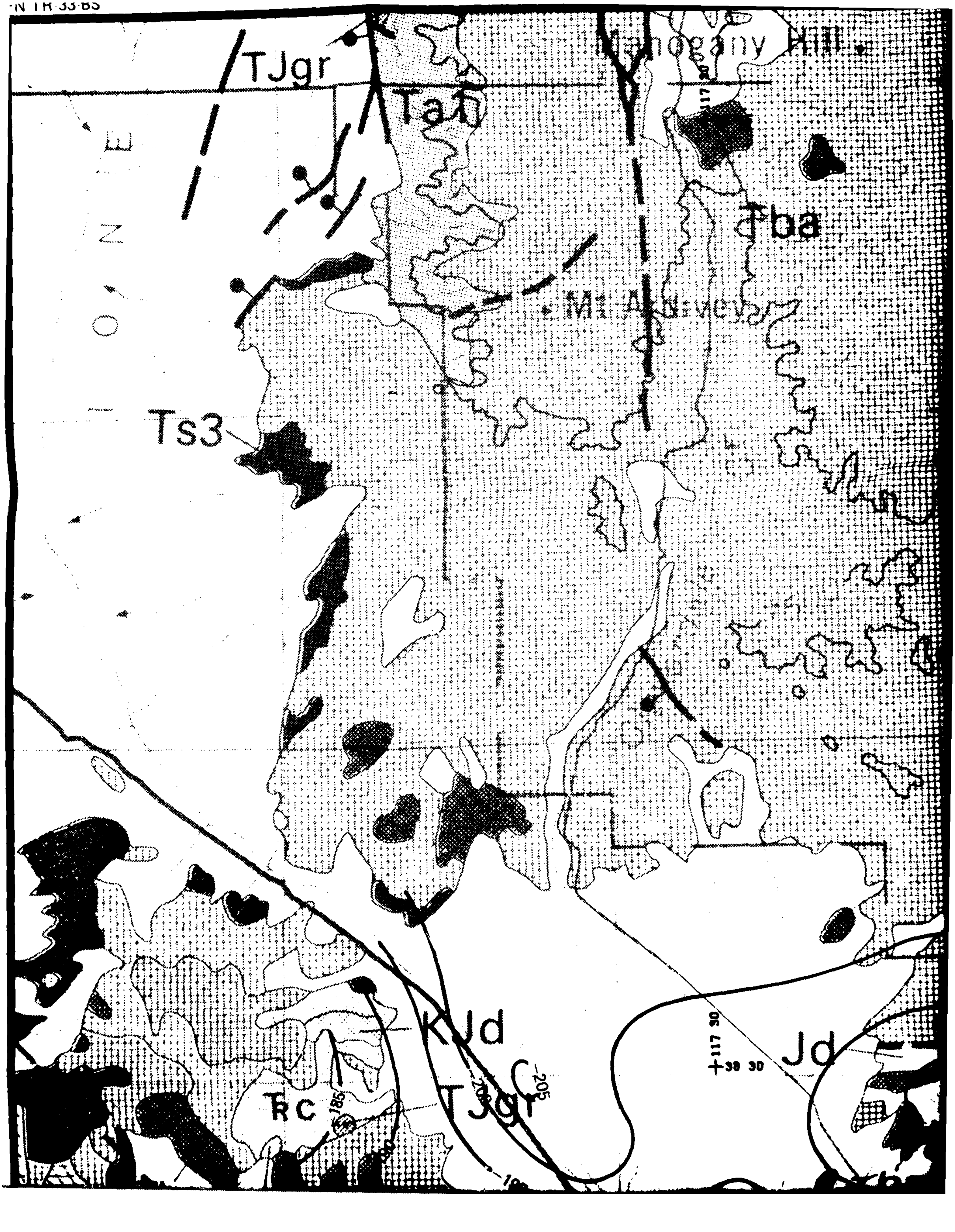
A1.5 INTERPRETATION

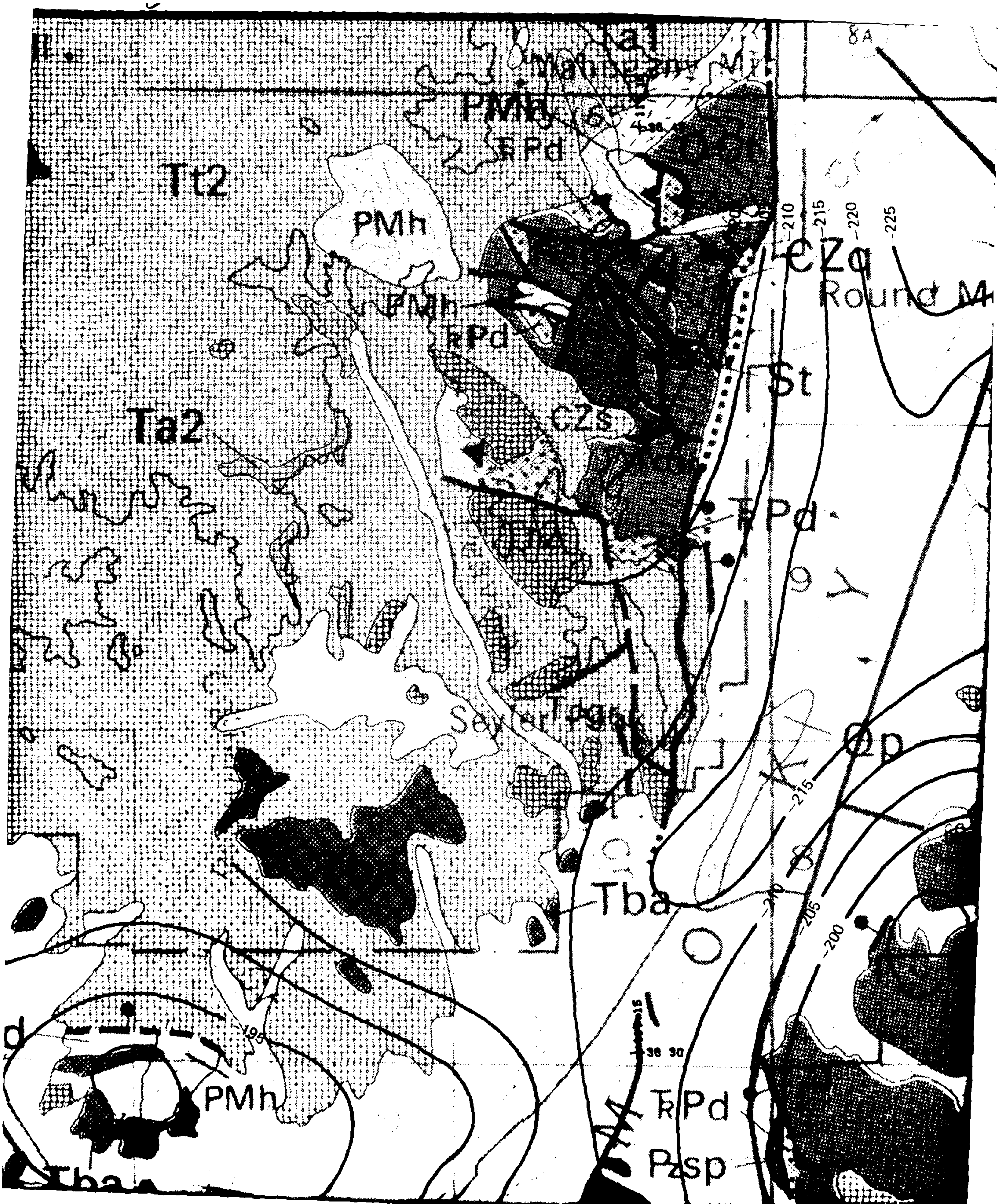
The first step in interpretation is to separate the portion of the CBA that might be caused by the light-weight, basin-fill material overlying the heavier bedrock material which forms the surrounding mountains and presumably the basin floor. Since the valley-fill sediments are absent at the stations read in the mountains, the CBA values at these bedrock stations are used as the basis for constructing a regional field over the valley. A regional field is an estimation of the values the CBA would have had if the light-weight sediments (the anomaly) had not been there.

The difference between the CBA and the regional field is called the "residual" field or residual anomaly. The residual field is the interpreter's estimation of the gravitational effect of the geologic anomaly. The zero value of the residual anomaly is not exactly at the rock outcrop line but at some distance on the "rock" side of the contact. The reason for this is found in the explanation of the terrain effect. There is a component of gravitational attraction from material which is not directly beneath a point.

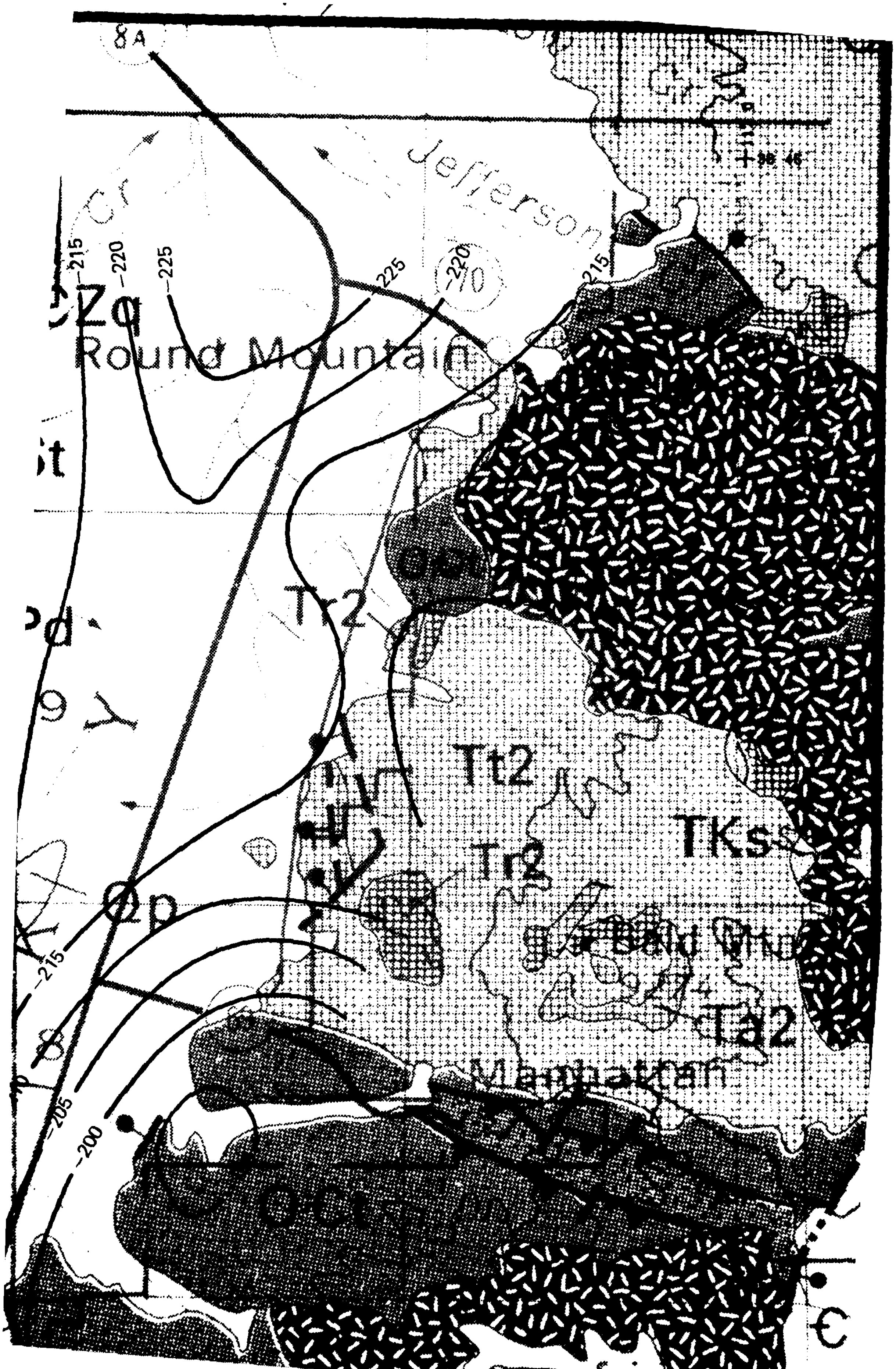
If the "regional" is well chosen, the magnitude of the residual anomaly is a function of the thickness of the anomalous (fill) material and the density contrast. The density contrast is the difference in density between the alluvial and bedrock material. If this contrast were known, an accurate calculation of the thickness could be made. In most cases, the densities are not well known and they also vary within the study area. In these cases, it is necessary to use typical densities for materials similar to those in the study area.

If the selected average density contrast is smaller than the actual density contrast, the computed depth to bedrock will be greater than the actual depth and vice-versa. The computed depth is inversely proportional to the density contrast. A ten percent error in density contrast produces a ten percent error in computed depth. An iterative computer program is used to calculate a subsurface model which will yield a gravitational field to match (approximately) the residual gravity anomaly.

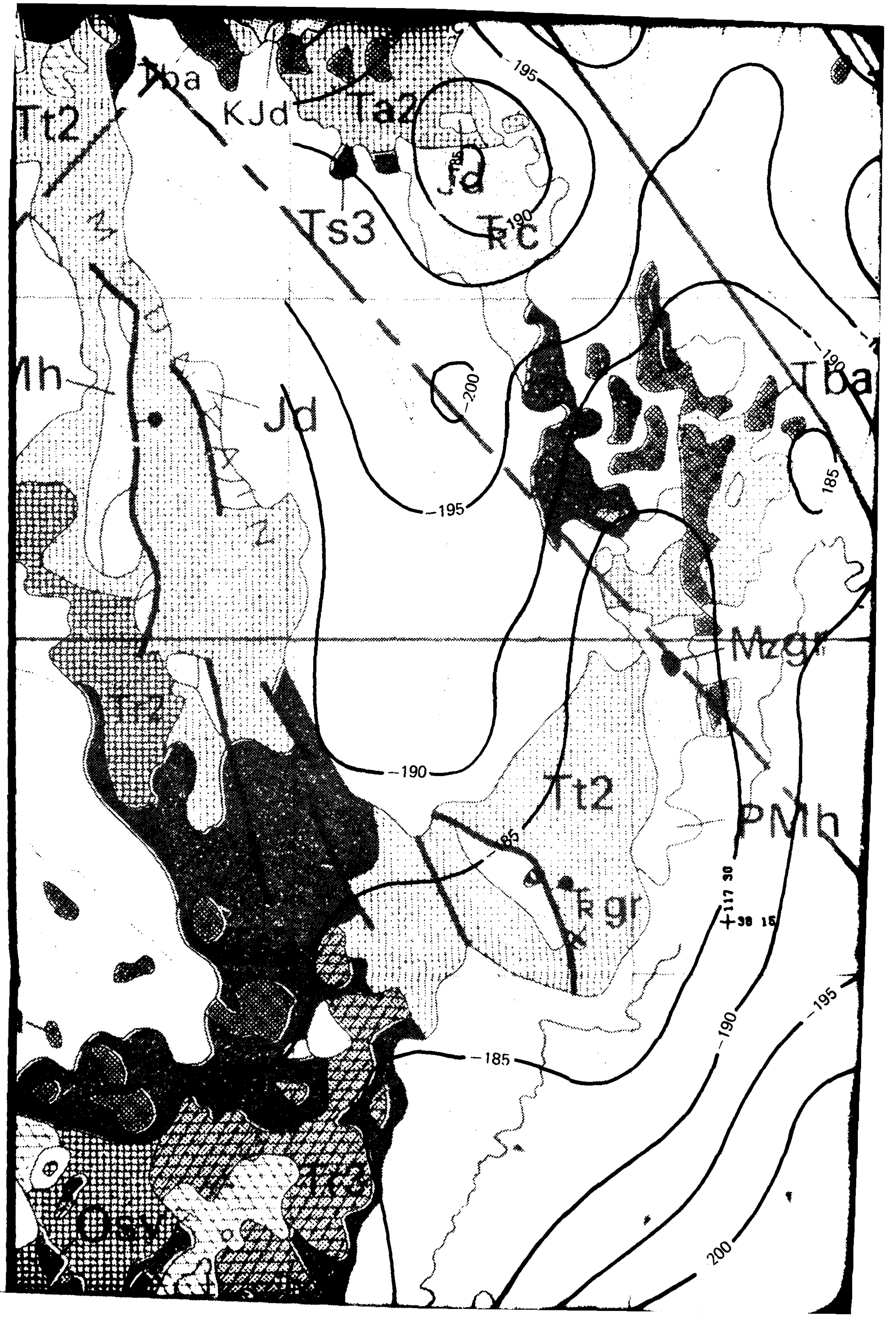

TJgr
Ta
Mahogany Hill
117 30
Tba
Mt. Andrew
Ts3
KJd
Jd
117 30
38 30
Tc
185
205
TJgr



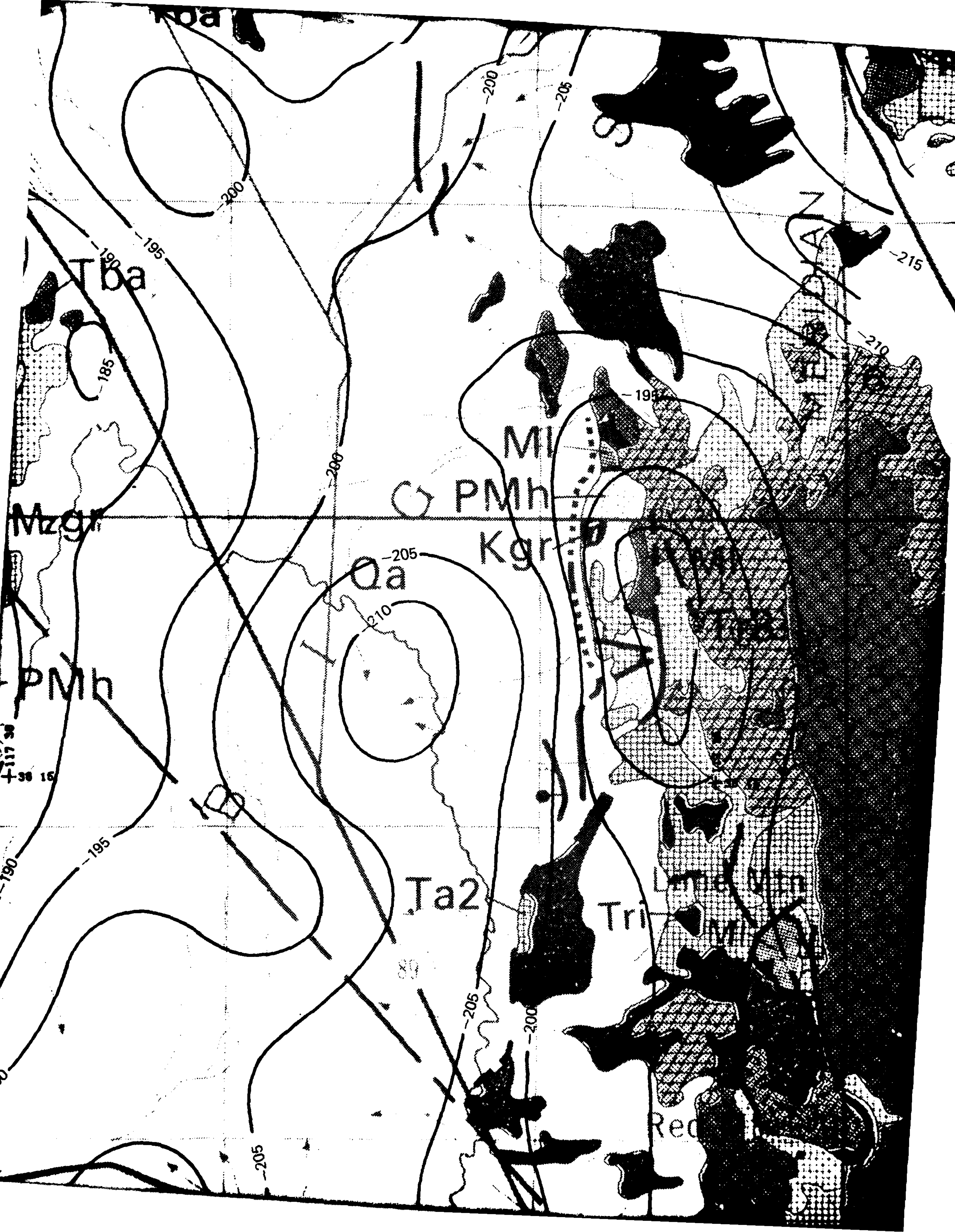
Tt2
PMh
TRPd
Ta2
CZq
Round M
St
CZs
Tba
Qp
PMh
TRPd
Pzsp
-210
-215
-220
-225
-215
-205
-200
-195



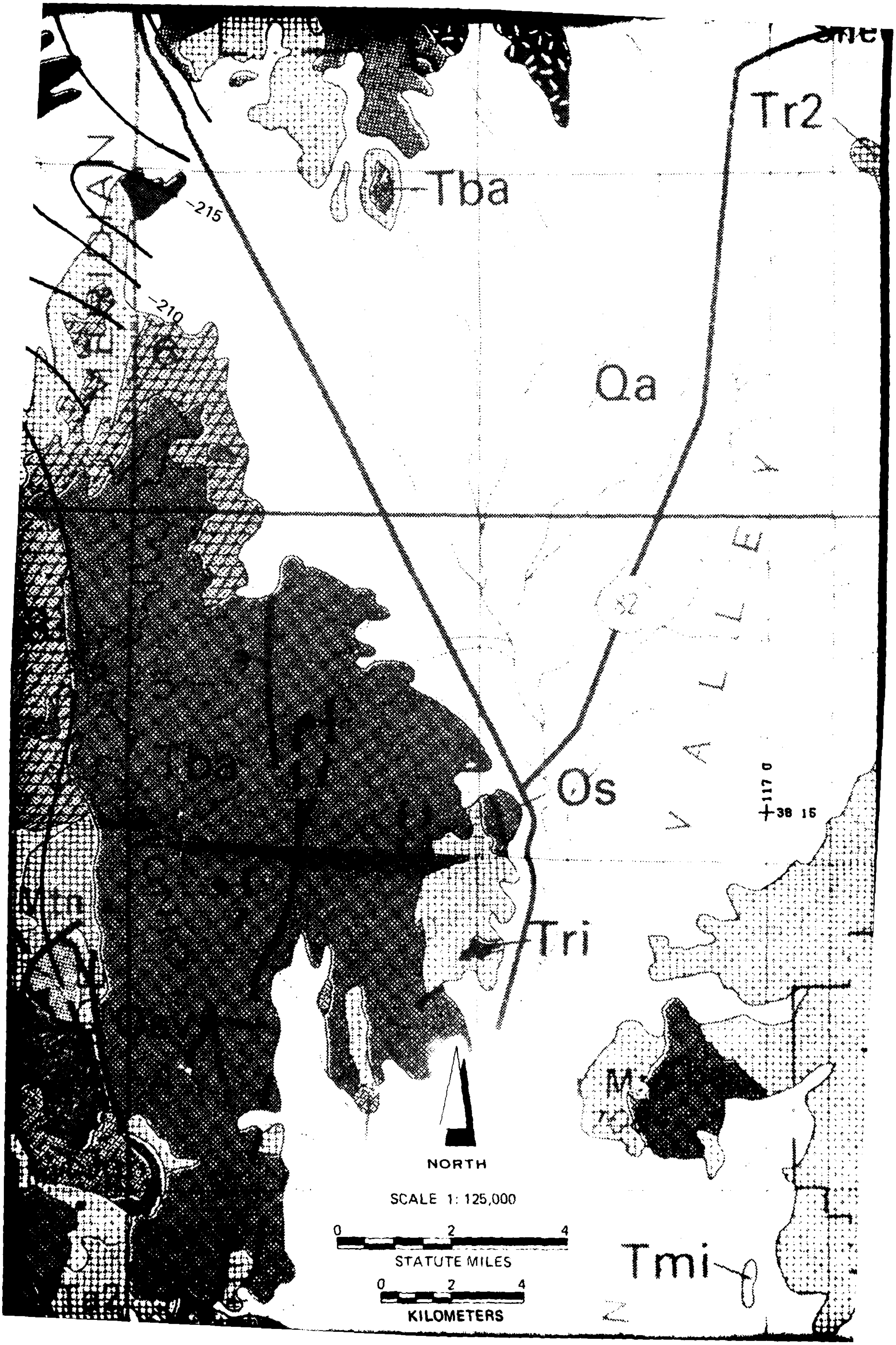
8A
Jefferson
Cr
-215
-220
-225
225
-220
215
Zq
Round Mountain
Tr2
Tt2
TKs
Tr2
Qp
-215
Bald Mtn
Ta2
Manhattan
-205
-200



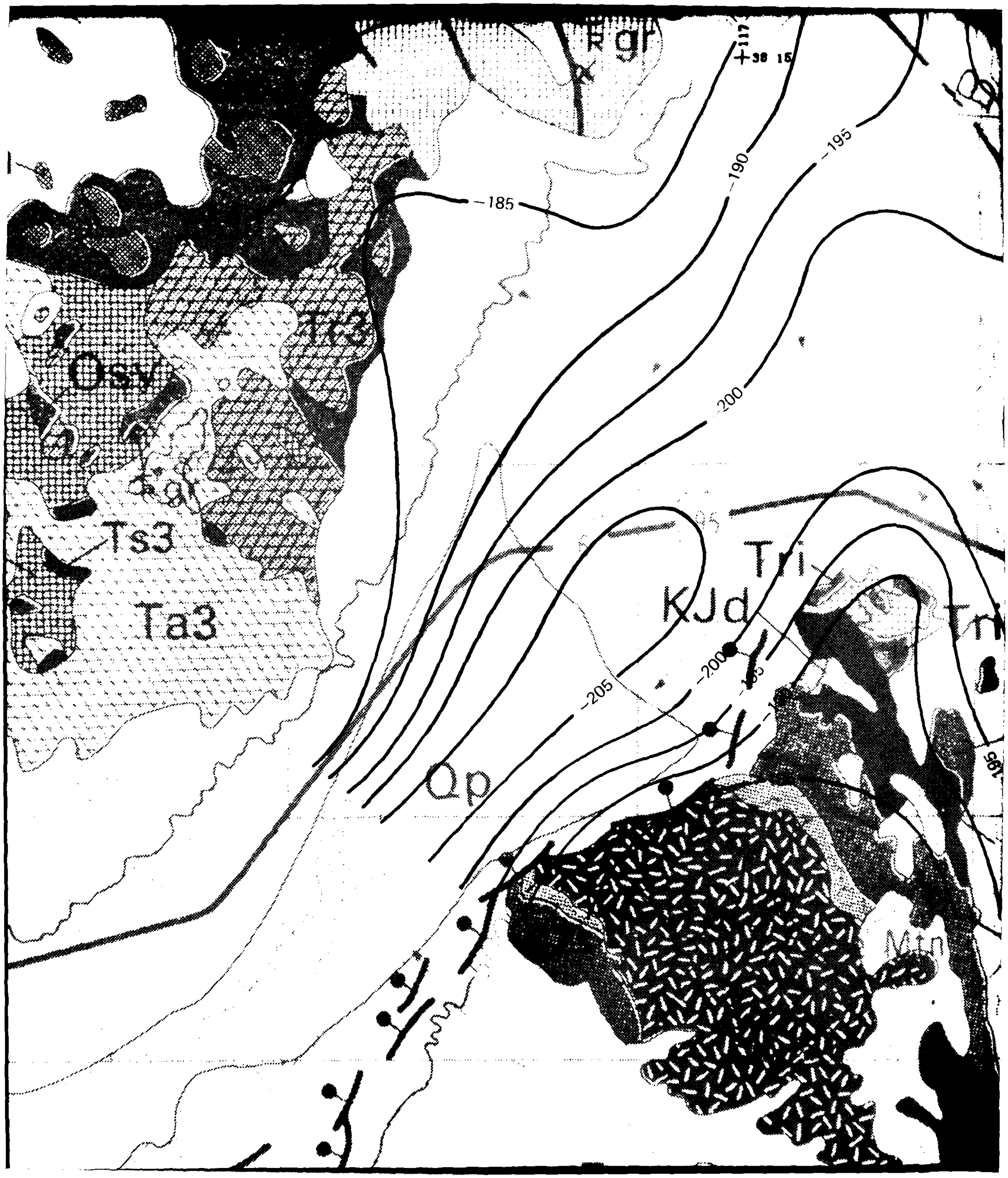
Tba
Tt2
KJd
Ta2
Jd
Ts3
Mh
Jd
195
200
190
185
Tba
Mzgr
Tt2
PMh
185
117 30
38 15
190
195
185
190
200
Tc3



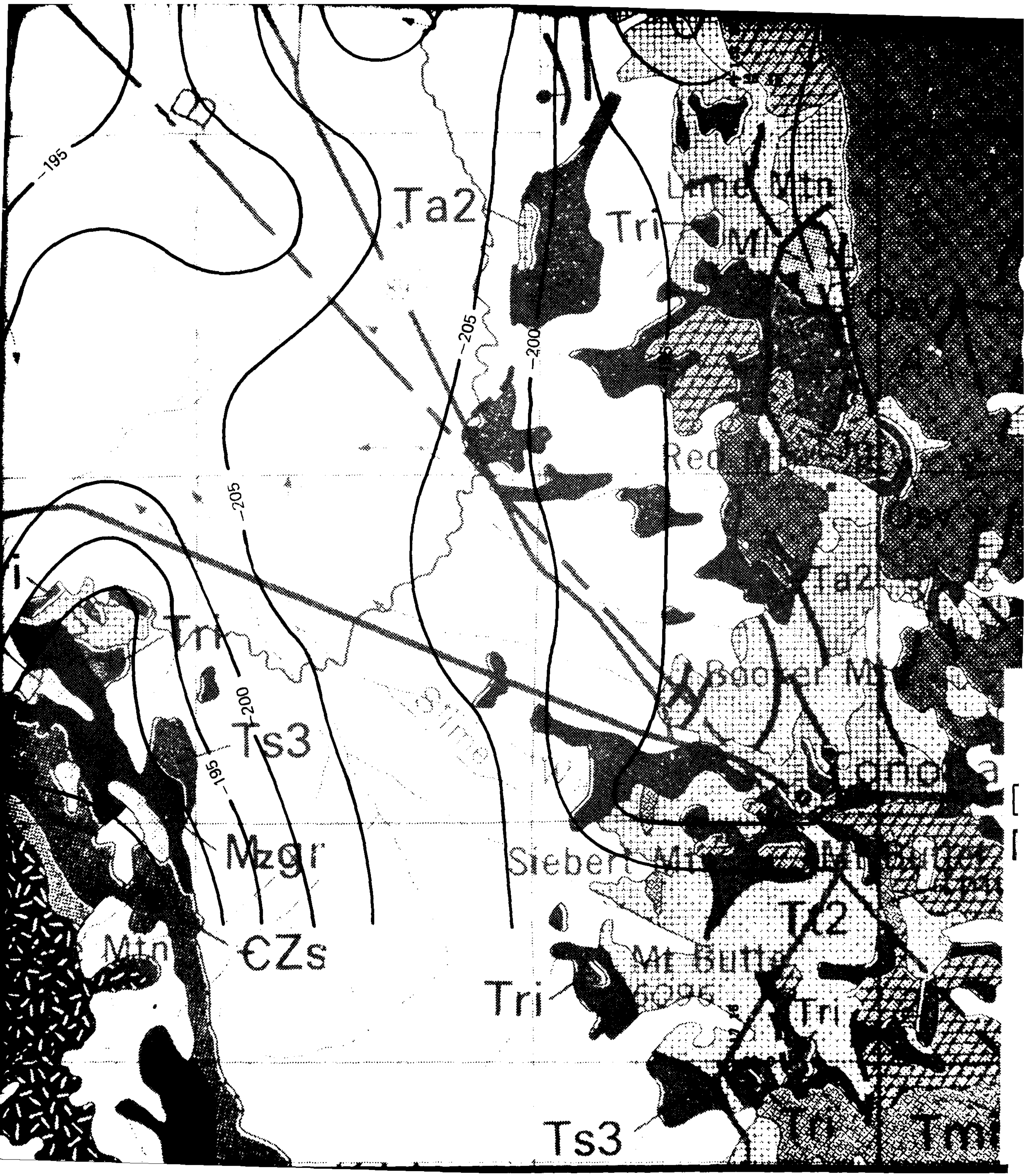
Tba
Mzgr
PMh
Mi
PMh
Kgr
Qa
Ta2
Tri
-185
-190
-195
-200
-205
-210
-215



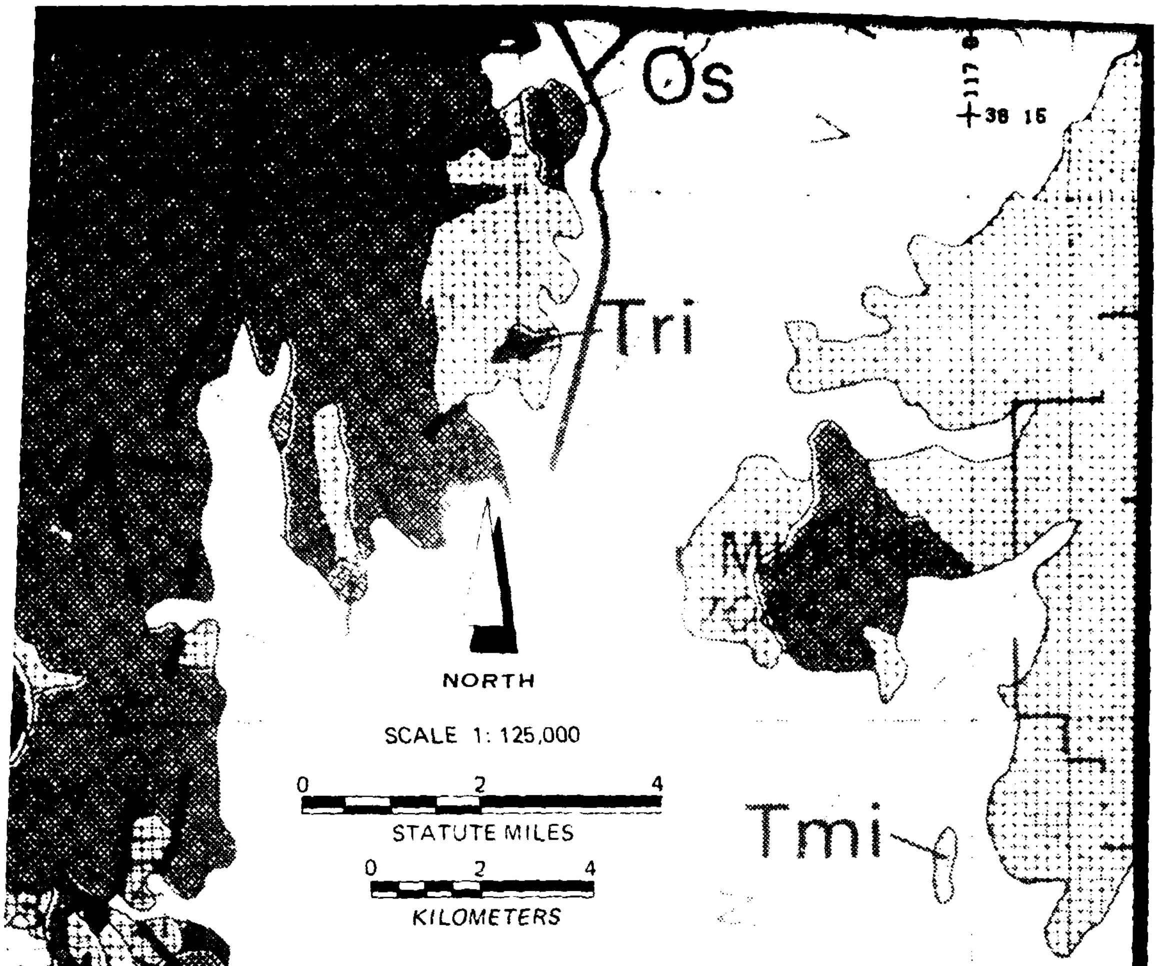
Tr2
Tba
215
210
Qa
Tba
Os
Tri
117 0
38 15
VALLEY
Tmi
NORTH
SCALE 1: 125,000
0
2
4
STATUTE MILES
0
2
4
KILOMETERS



Rgr
117
38 15
185
190
195
200
205
Osv
Ts3
Ta3
KJd
Tri
Qp
Mtn



-195
Ta2
Tri
-205
-200
-205
Tri
-200
Ts3
-195
Mzgr
Siebert
ЄZs
Mtn
Tri
Ta2
Tri
Ts3



EXPLANATION

FAULTS SHOWN ON GEOLOGIC BASE MAP

ALLUVIAL MATERIAL

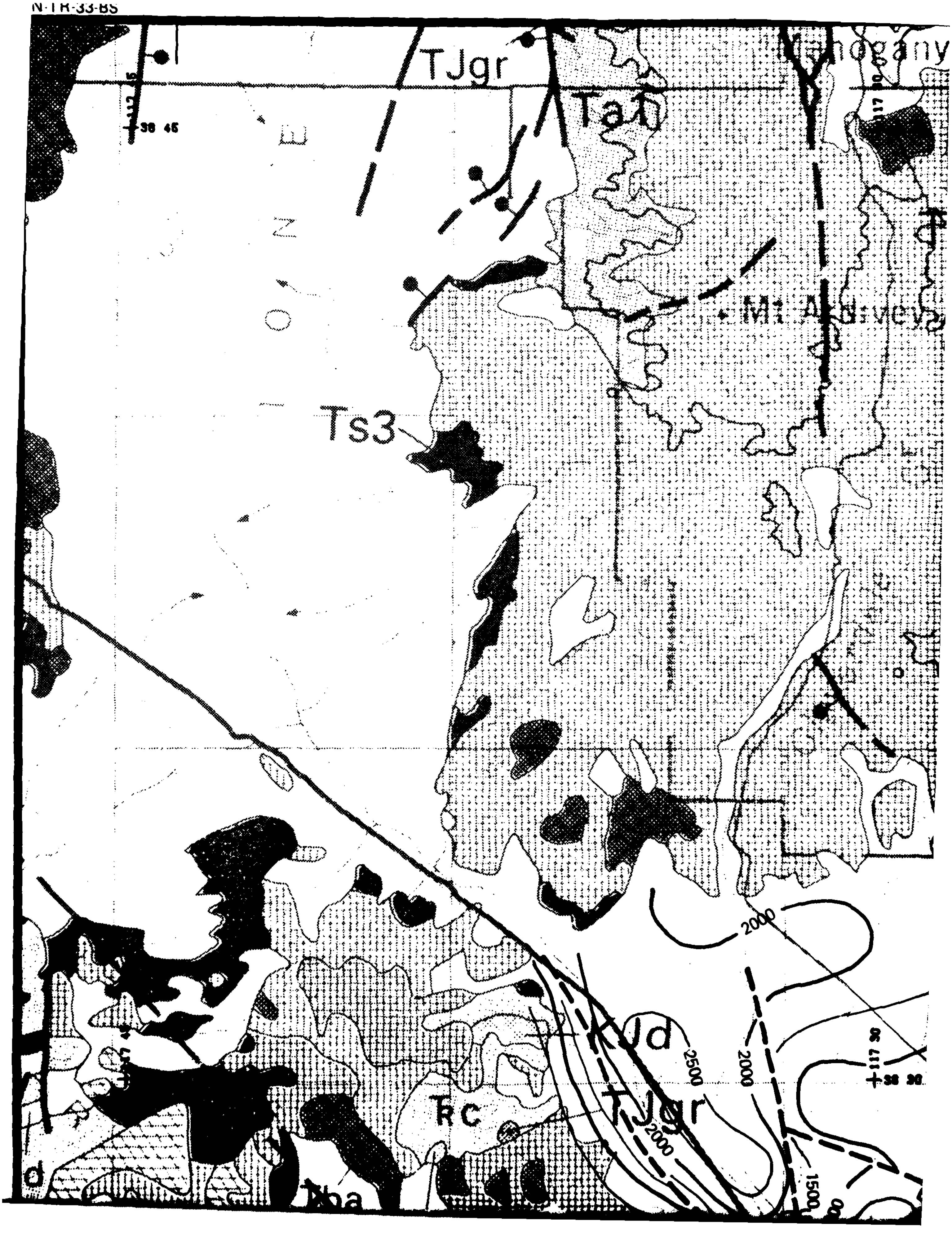
ROCK (ALL PATTERNS)

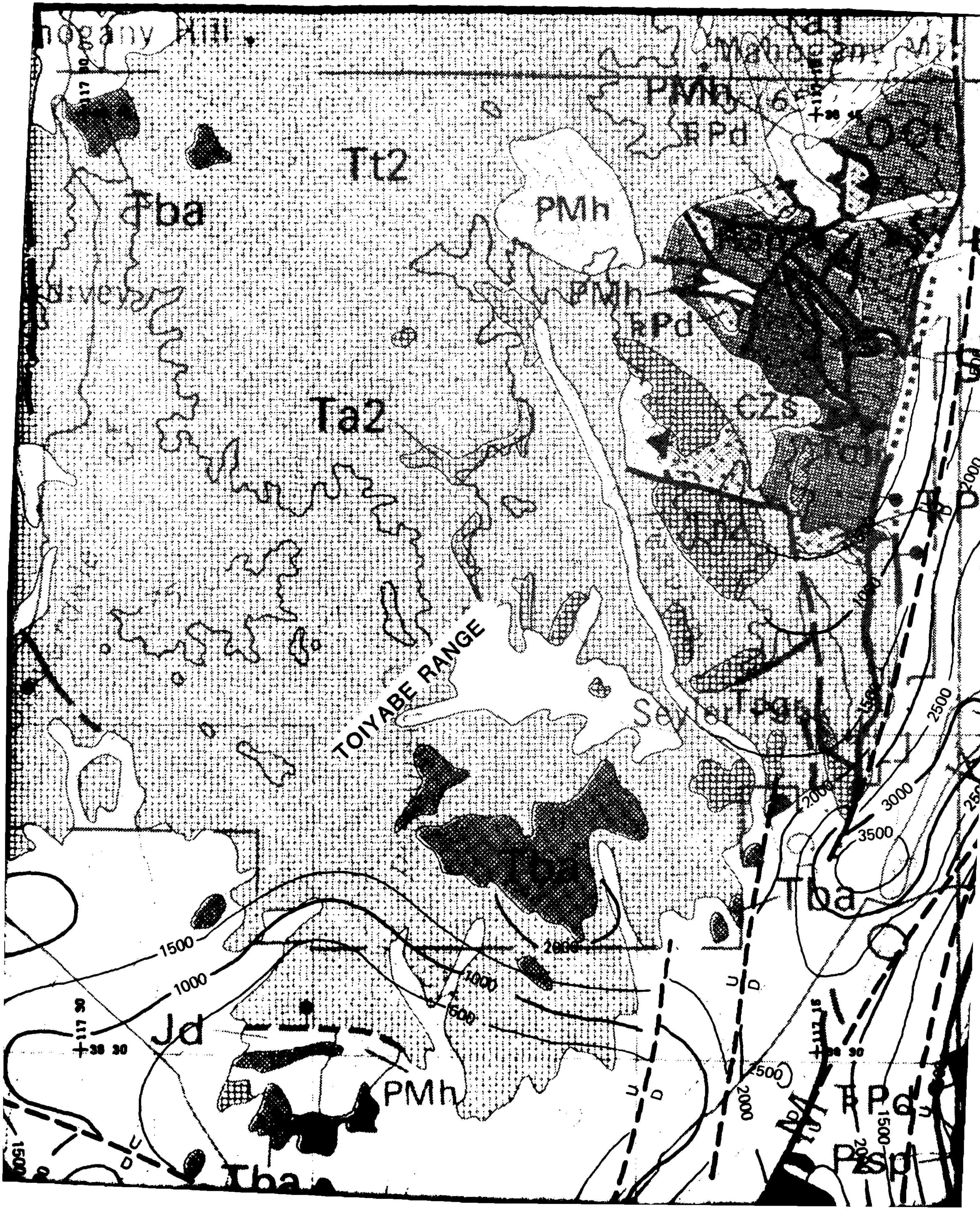
CONTOUR INTERVAL = 5 MILLIGALS

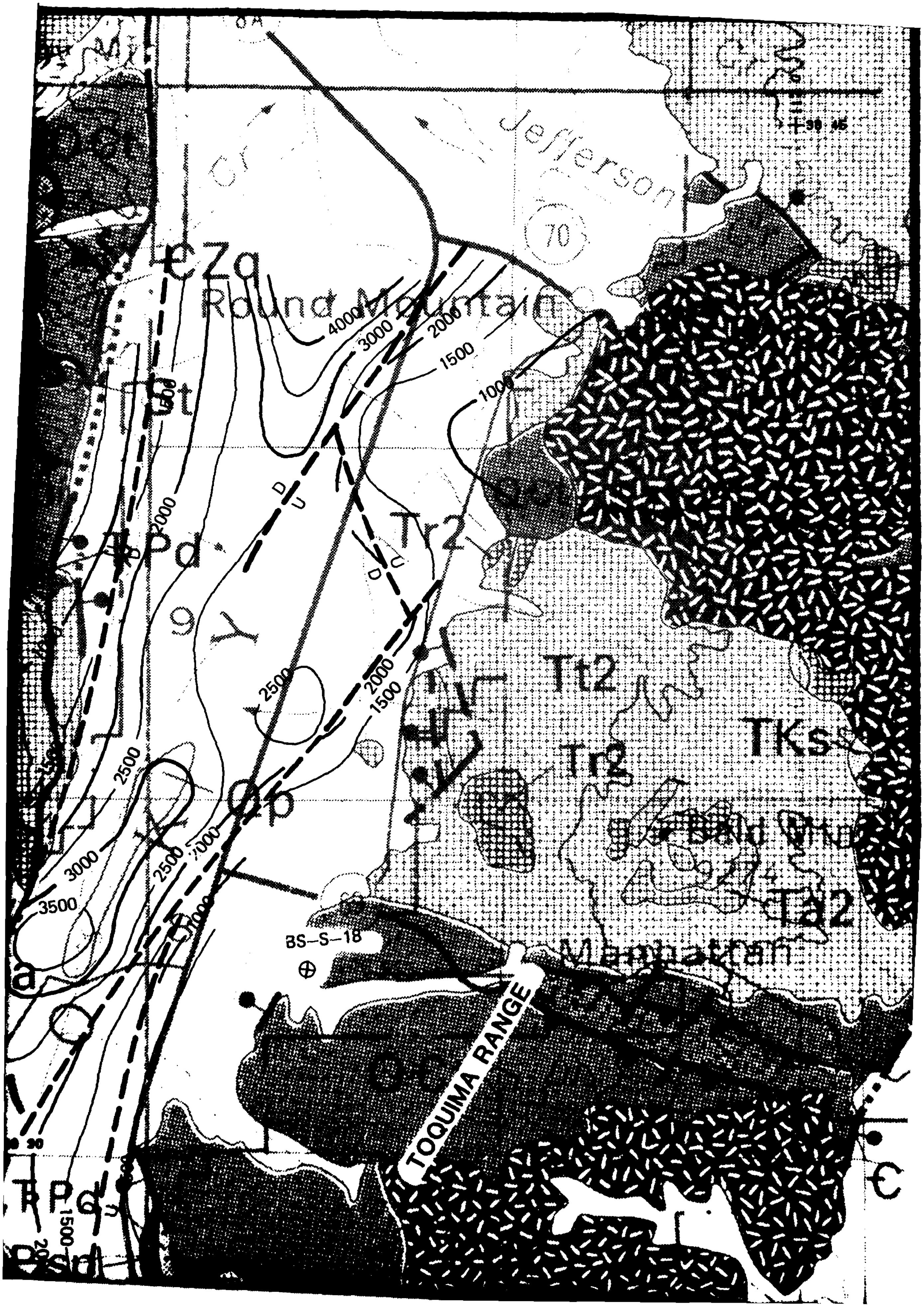
GEOLOGIC BASE MAP: STEWART & CARLSON (1978)

COMPLETE BOUGUER ANOMALY CONTOURS BIG SMOKY VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	DRAWING 1

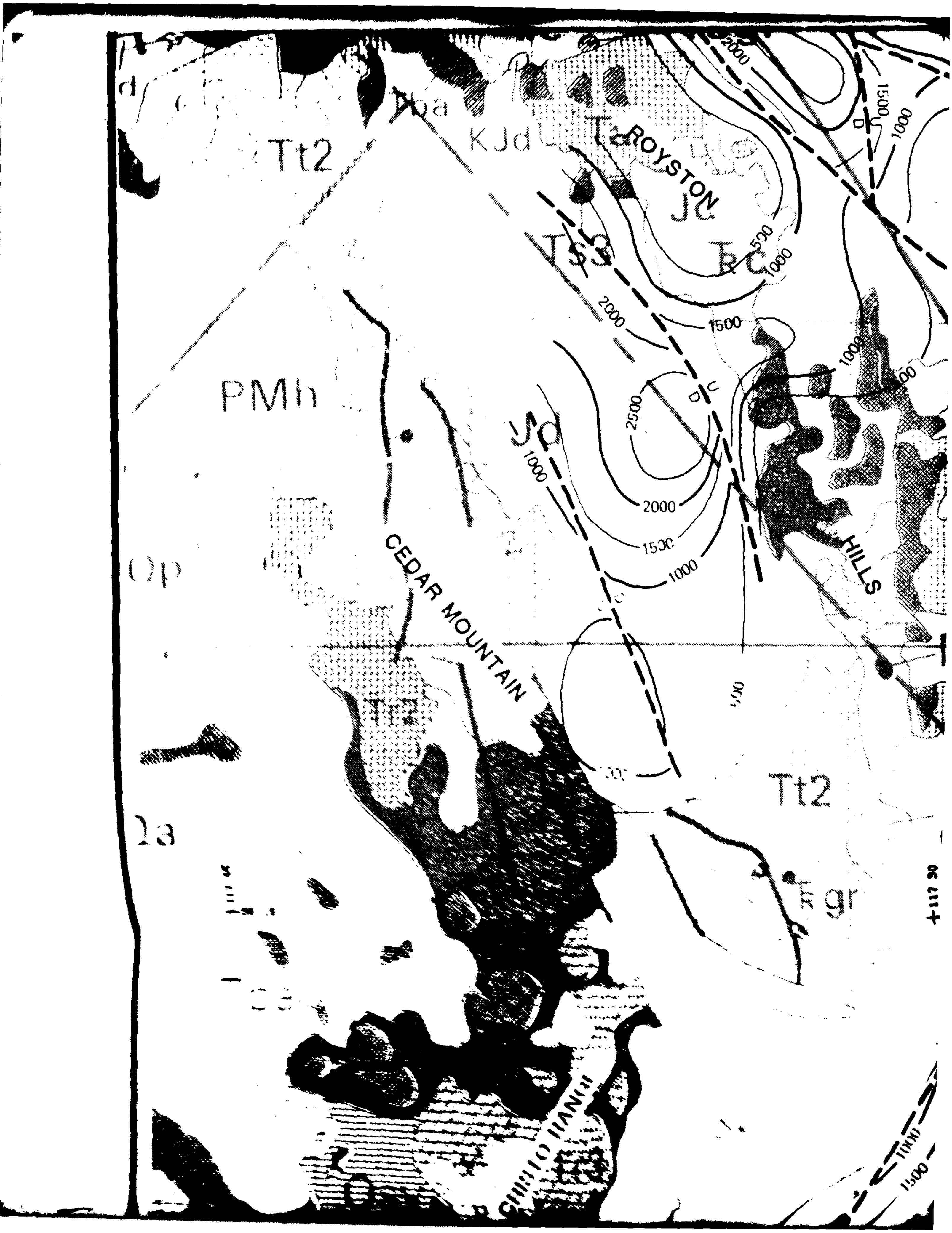
FUGRO NATIONAL, INC.


TJgr
Ta
Mahogany
Mt Aldivey
Ts3
Kjd
Kjgr
Tc
Tba
2000
2500
2000
2000
1500
38 45
38 30
117 30

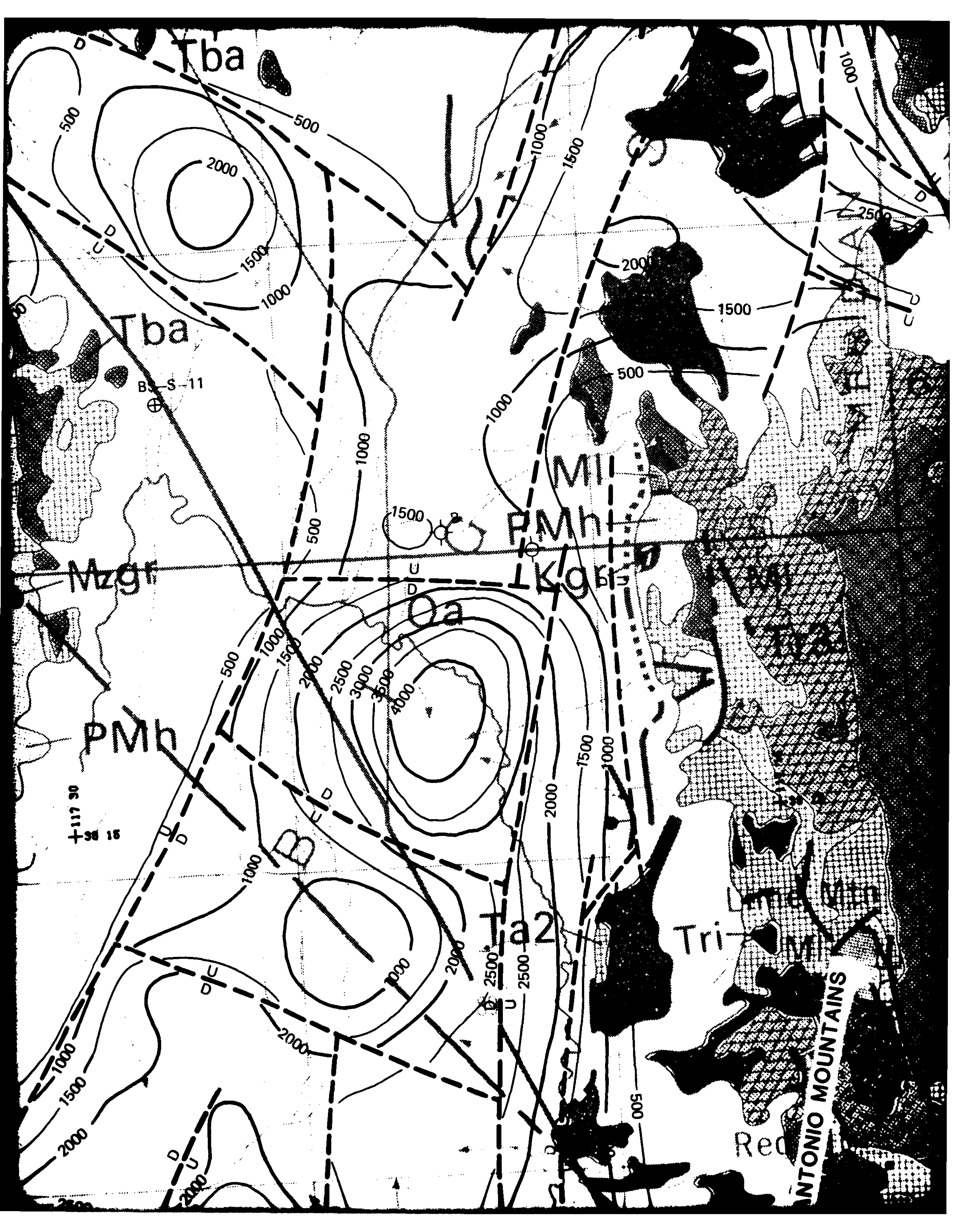

Mahogany Hill
Mahogany Hill
PMh
TRPd
Tt2
PMh
Tba
PMh
TRPd
Ta2
CZs
TOIYABE RANGE
Tba
1500
1000
500
1000
2000
Jd
PMh
Tba
2000
2500
3000
3500
2000
1500
TRPd
Psp
U
D

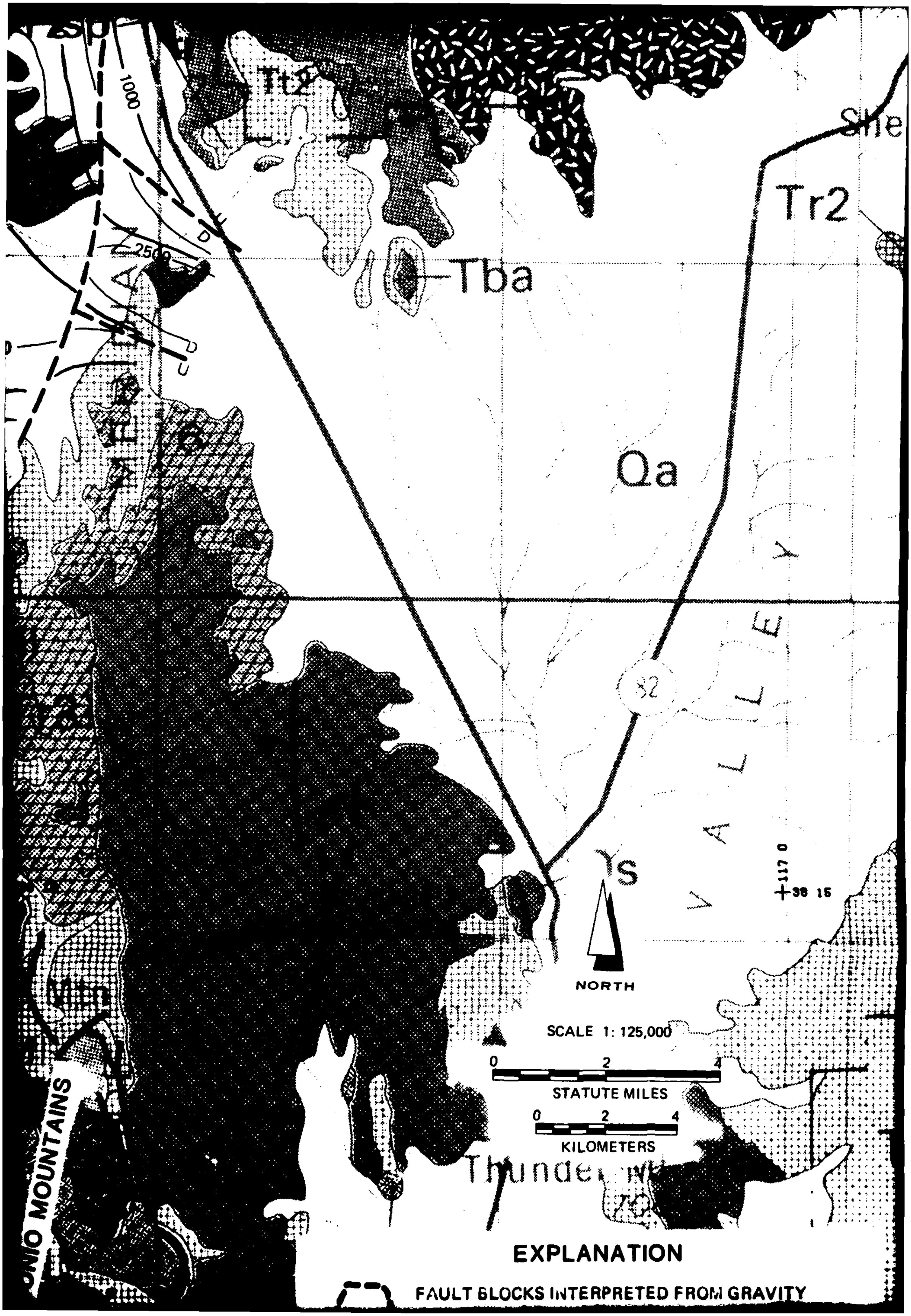


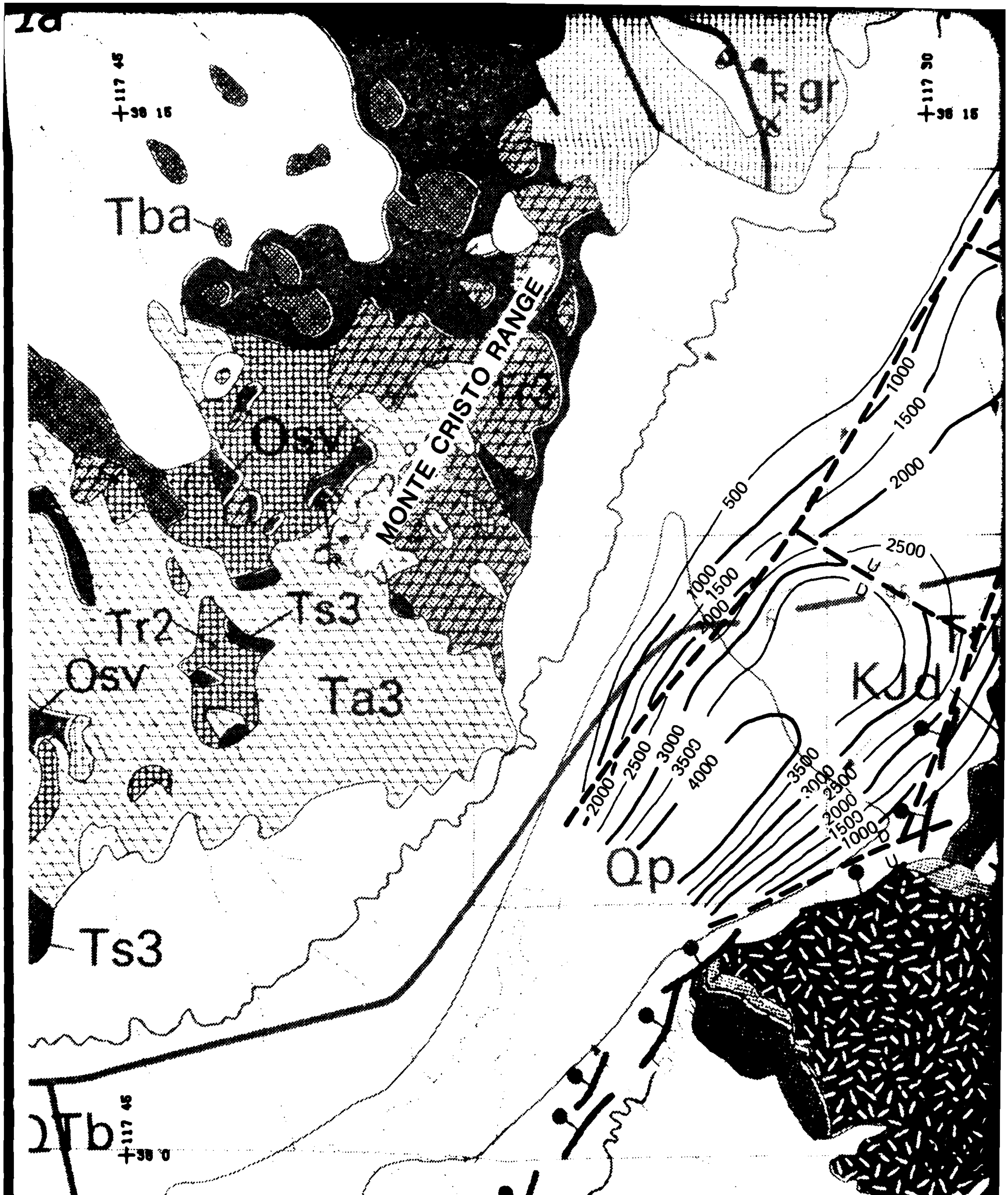
Jefferson
70
Round Mountain
4000
3000
2000
1500
1000
Tr2
Tt2
TKs
Tr2
Ta2
Manhattan
BS-S-18
TOQUIMA RANGE
2500
2000
1500
3500
3000
2500

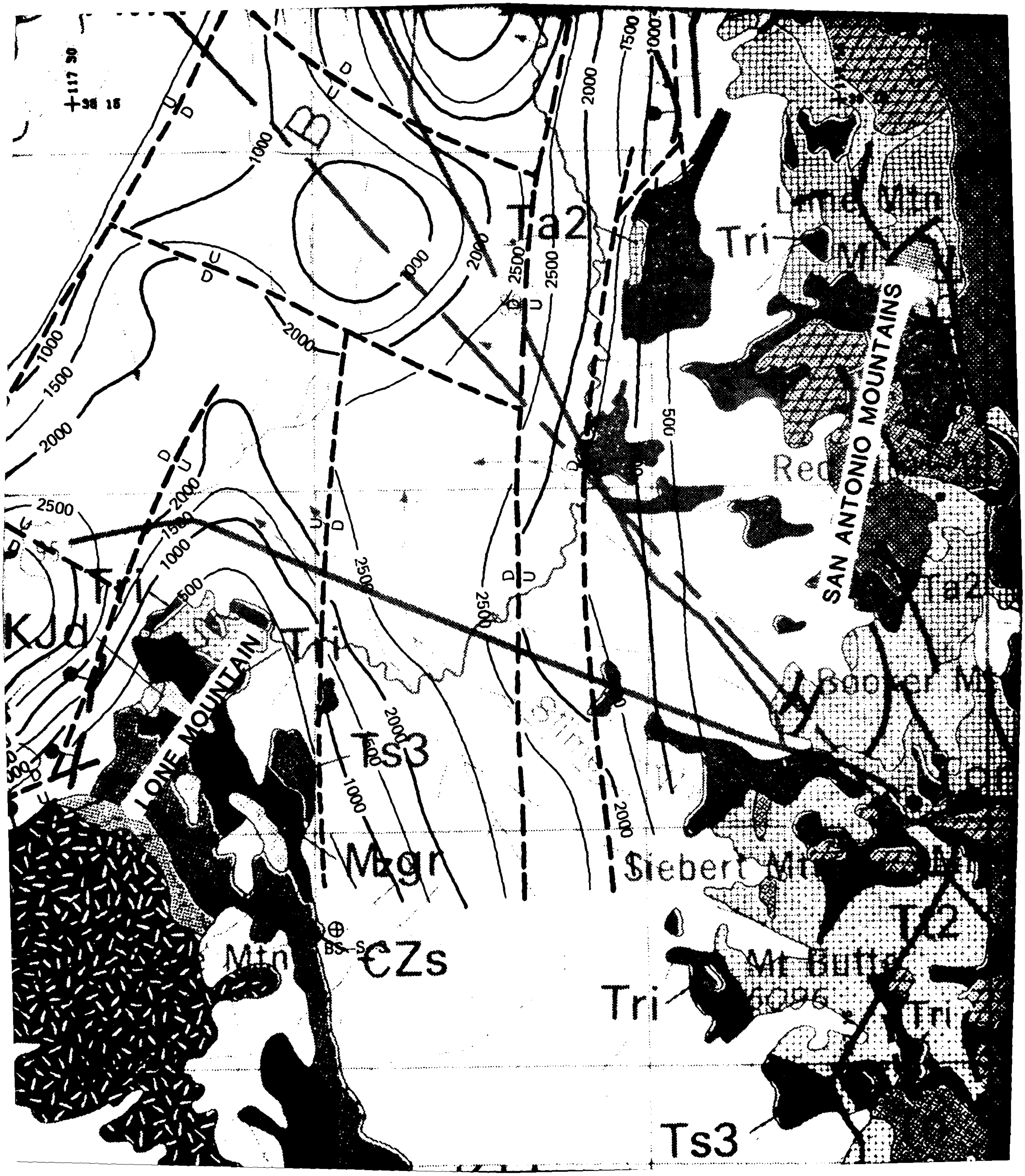


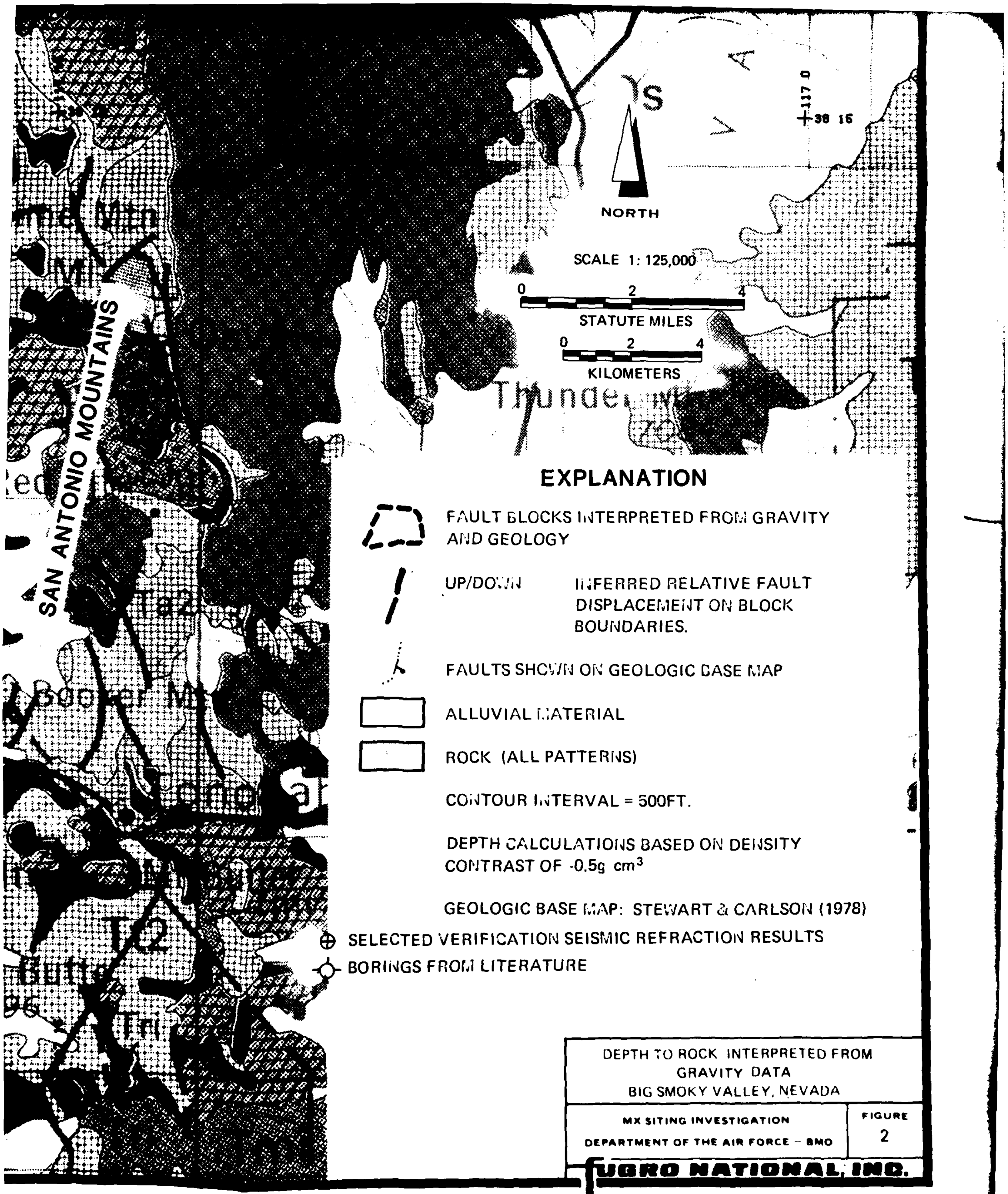
Tt2
Tba
KJd
ROYSTON
Jc
TS3
Rc
PMh
Jc
CEDAR MOUNTAIN
HILLS
Op
Tt2
Tt2
Rgr
2000
1500
1000
500
1000
2000
1500
1000
2500
2000
1500
1000
1000
U
D


Tba
Tba
BS-S-11
Mzgr
PMh
PMh
Ml
Kg
Qa
Ta2
Tri
ANTONIO MOUNTAINS
Red
117 30
38 15
500
1000
1500
2000
2500
3000
3500
4000


Tt2
1000
She
Tr2
2500
Tba
Qa
82
VALLEY
S
117 0
38 15
NORTH
SCALE 1: 125,000
0 2 4
STATUTE MILES
0 2 4
KILOMETERS
MOUNTAINS
EXPLANATION
FAULT BLOCKS INTERPRETED FROM GRAVITY


1a
117 45
38 15
117 30
38 15
Tba
Osv
Tr3
MONTE CRISTO RANGE
Tr2
Ts3
Ta3
Osv
Ts3
Qp
KJd
Trgr
QTb
117 45
38 0
500
1000
1500
2000
2500
3000
3500
4000


117 30
36 15
Ta2
Tri
SAN ANTONIO MOUNTAINS
LONE MOUNTAIN
Kjd
Ts3
Mzgr
€Zs
Siebert Mtn
Mt Butler
Tri
Ts3
Ta2
Tri
1000
1500
2000
2500
500



DEPTH TO ROCK INTERPRETED FROM GRAVITY DATA
BIG SMOKY VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 2

FUGRO NATIONAL, INC.

DAT
FILM
4-

DAT

FILM

4-