Open-File Report # NM/Baca-27

BACA PROJECT

DATA AND REPORTS

GEOLOGY

No.	Transfer Date	Release Date	Title
1.	B	B	Hydrothermal Geology of the Valles Caldera, New Mexico by R.F. Dondanville - 1971.
2.	B	B	Airborne Infrared Geothermal Exploration--Valles Caldera, New Mexico Earth Resources Operations, North American Rockwell Corp.-1972.
3.	B	B	Electrical Resistivity Survey in Valles Caldera, New Mexico by Group Seven, Inc. - 1972.
4.	B	B	Additional Data--Electrical Resistivity Survey in the Valles Caldera, New Mexico by Group Seven, Inc. - 1972.
5.	B	B	Reconnaissance Resistivity Survey Baca Property, McPhar - 1973.
6.	B	B	Supplemental Report--Reconnaissance Resistivity and Schlumberger Depth Sounding Surveys Baca Property - McPhar - 1973.
7.	B	B	Quantitative Gravity Interpretation Valles Caldera Area, New Mexico by R.L. Segar - 1974.
8.	B	B	Mercury Soil Gas Survey Baca Prospect by Allied Geophysics Inc. - 1974.
9.	A	A	Mercury analysis - 1974 gradient holes.
10.	B	B	Geothermal Geology of the Redondo Creek Area Baca Location by T.R. Slodowski - 1976.
11.	B	B	Magnetotelluric--Telluric Profile Survey, Valles Caldera Prospect by Geonomics - 1976 as reprocessed by QEB Inc. - 1978.
12.	B	B	Geological Resume of the Valles Caldera by T.R. Slodowski - 1977.

Union Oil Company of California

In Reply Give No.

union 76

Los Angeles, California
April 2, 1974

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Geothermal

Quantitative Gravity Interpretation
Valles Caldera Area, Sandoval and
Rio Arriba Counties, New Mexico

INTRODUCTION

A gravity survey was recently performed in the Valles Caldera of north-central New Mexico. The caldera is approximately 60 miles due north of Albuquerque, 10 miles due west of Los Alamos, and is located in the Jemez Mountains. (Figure 3). It is very rough topographically, ranging in elevation from 7,000 to 11,250 feet (Redondo Peak). The survey area covers the Baca ranch (shown in yellow outline on enclosures) an area of 100,000 acres under lease by Union.

PRIOR INVESTIGATIONS

The first question one might ask is: "how do you know gravity will help in exploration of this area?". This can be answered by examination of the surface geology and reconnaissance gravity data available from the USGS. From surface geology, it is known that the Valles Caldera is a negative area, filled with various types of rock materials that are all less dense that a normal granite or limestone (2.7 g/cc). Theorically, this situation would produce a large negative gravity anomaly coincident with the collapsed area. This certainly is the case as shown by the USGS reconnaissance gravity work. After establishing that the gravity in a broad sense agrees with the surface geology and is not influenced to a great extent by other extraneous sources, it is then only necessary to understand the density contrasts and its variation with depth in order to give a good structural picture of the collapsed area.

Unfortunately, there are no suitable density analysis or logs for this area, therefore, one must make gross approximations of the density variations from past experience or data from similar areas. Realizing that the lack of density information would be a limiting factor in the accuracy of interpretation, it was still decided to proceed with the survey. The goal was to map the ring fault system and obtain some estimate as to the shape and depth of the deeper rocks (Paleozoic and Pre-Cambrian).

GRAVITY SURVEY

The gravity survey was started on October 1, 1973 and completed on November 9, 1973. The gravity field crew consisted of two surveying crews, gravity meter operator, computer and a party chief. Elevations were kept to less than 2 feet vertical adjusted error and 200 feet adjusted horizontal error. Gravity station misties were kept to less than 0.2 milligals. A base loop network was double run and tied to the USGS network. Approximately 650 stations were surveyed at a cost of $15,327 or $22.45 per station. These data were tied with the previous profile work (80 stations) performed last year. The high cost is due primarily to some bad weather and rough working conditions in addition to quite a few stations that needed to be double run. The field data were reduced to a Bouguer map (see Enclosure I) using a surface density of 2.45 g/cc for the Bouguer and terrain corrections. All values are tied to the International Datum and computed with respect to the International Gravity Formula.

GEOLOGICAL SETTING

An excellent geological investigation by Griggs (1964) and a geological map by Smith, Bailey, and Ross (1970) are basic ingredients to this geophysical report. A small geologic map (Figure 1) and a diagram (Figure 2) showing the evolution of the Valles Caldera have been reproduced from Smith, Bailey and Ross, 1961.

The center of the Valles Caldera is located about 14 miles due west of Los Alamos, New Mexico. It is in the heart of the Jemez Mountains, a broad uplift composed of late Tertiary and Quaternary volcanic rocks that rest on igneous, metamorphic, and sedimentary rocks of Pre-Cambrian through Tertiary. These rocks are probably related to the Rio Grande structural depression and its associated volcanism. The major structural features are the Nacimiento Mountains to the west, Albuquerque Basin to the south, and the Espanola Basin to the east.

The Rio Grande depression is a series of basins bounded by a series of uplifts which resulted from Laramide deformation first, and then later graben faulting which caused its general depression. The basins are situated en-echelon and are probably part of a general rift belt. (see Figure 3).

In this geophysical investigation, our primary concern will be the present structural configuration of the caldera floor that resulted from events that took place in Pleistocene times. After a large accumulation of volcanic rocks from eruptions during the Pliocene and after a period of quiescence and erosion, a series of catastrophic eruptions broke out near the center of the volcanic pile. Nearly 50* cubic miles of rhyolitic pyroclastic material in the form of ash flows poured over the area. These welded tuffs attained at

* This estimate by Smith and Bailey, 1968, should be revised upward to about 100 cubic miles based upon our well information.

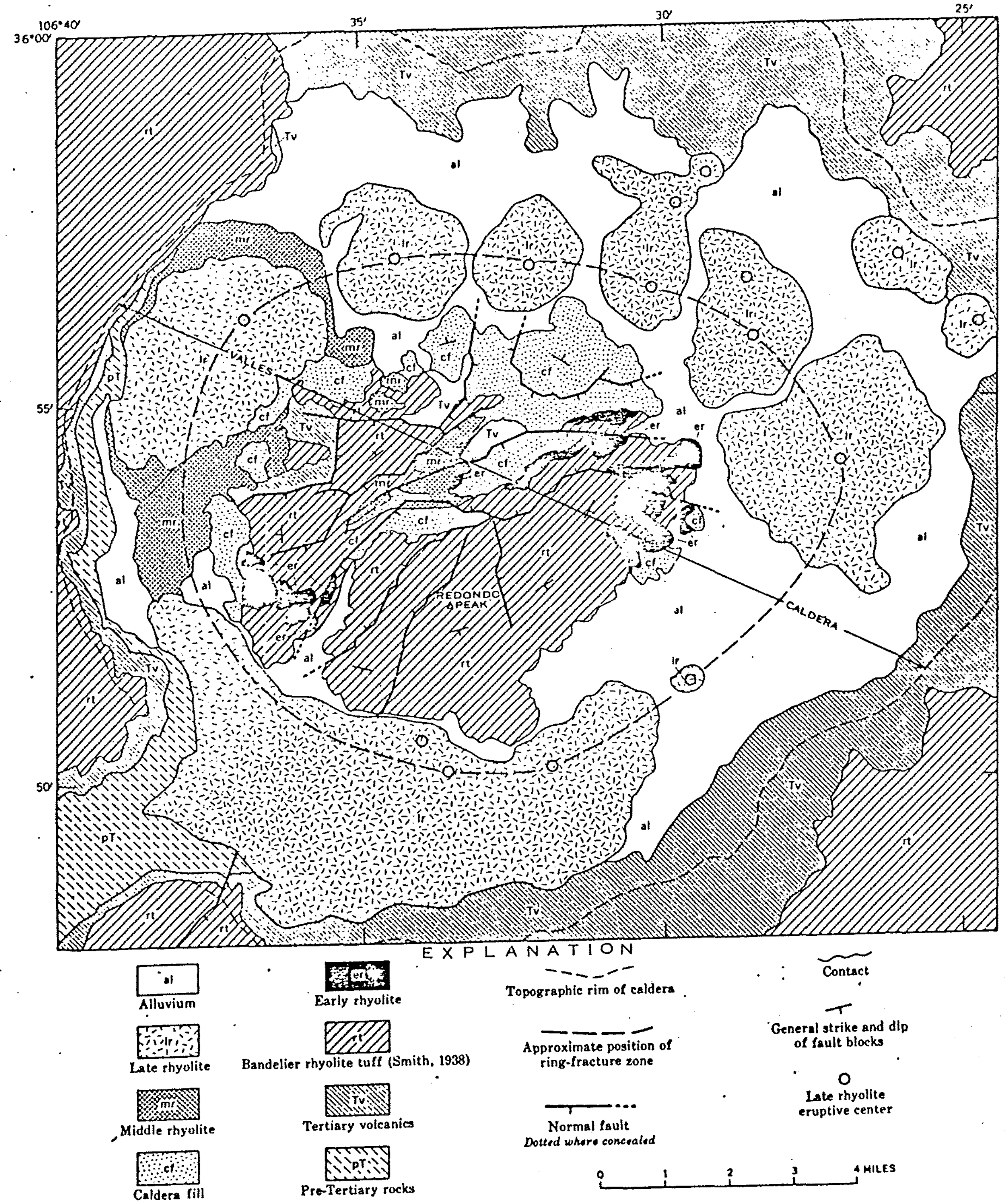

FIGURE 340.1.—Generalized geologic map of the Valles caldera, Jemez Mountains, N. Mex.

FIG. 1

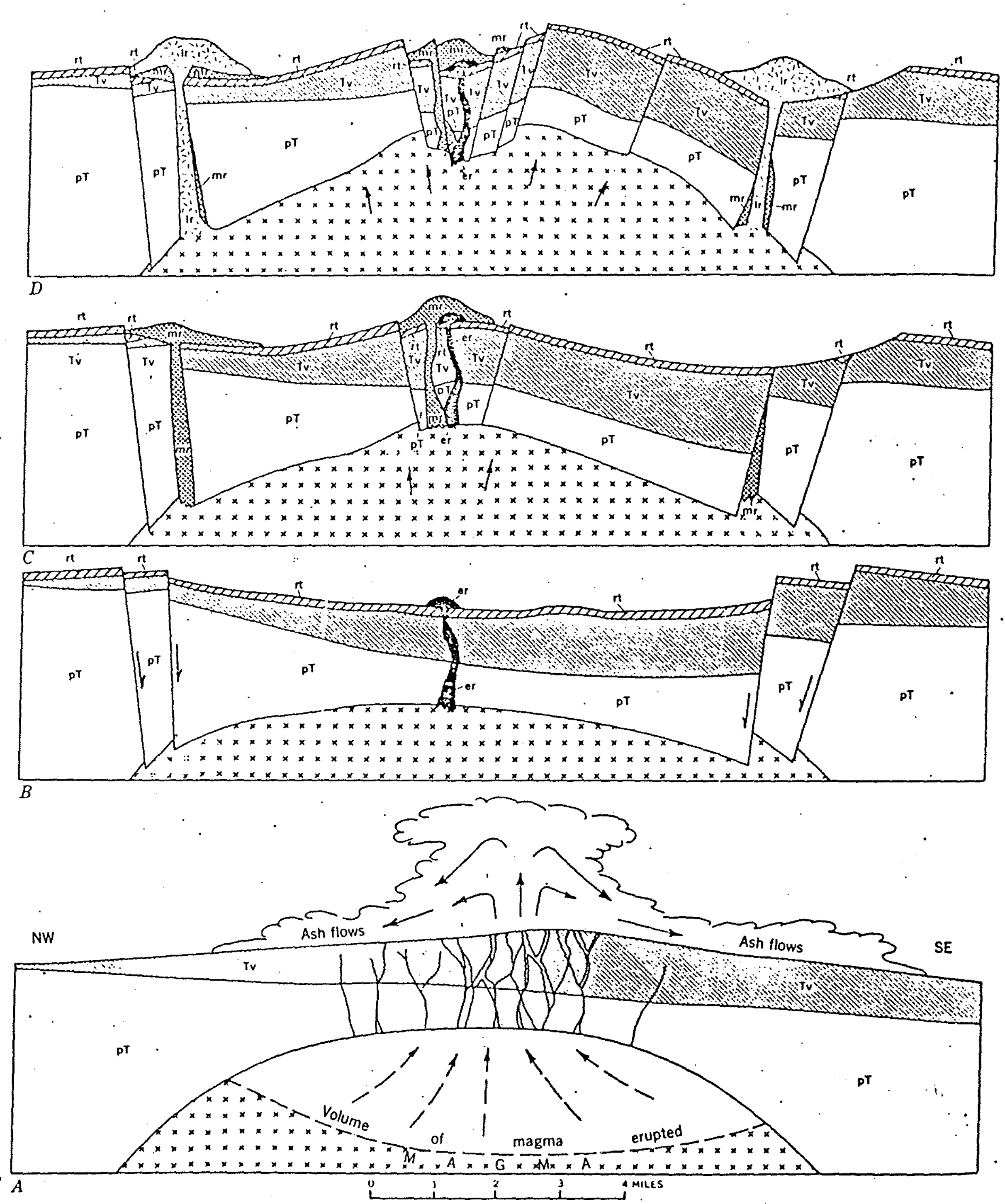

FIGURE 340.2.—Schematic sections showing the evolution of the Valles caldera (no vertical exaggeration). Patterns and symbols are the same as for figure 340.1 Caldera fill omitted for simplicity.

FIG. 2

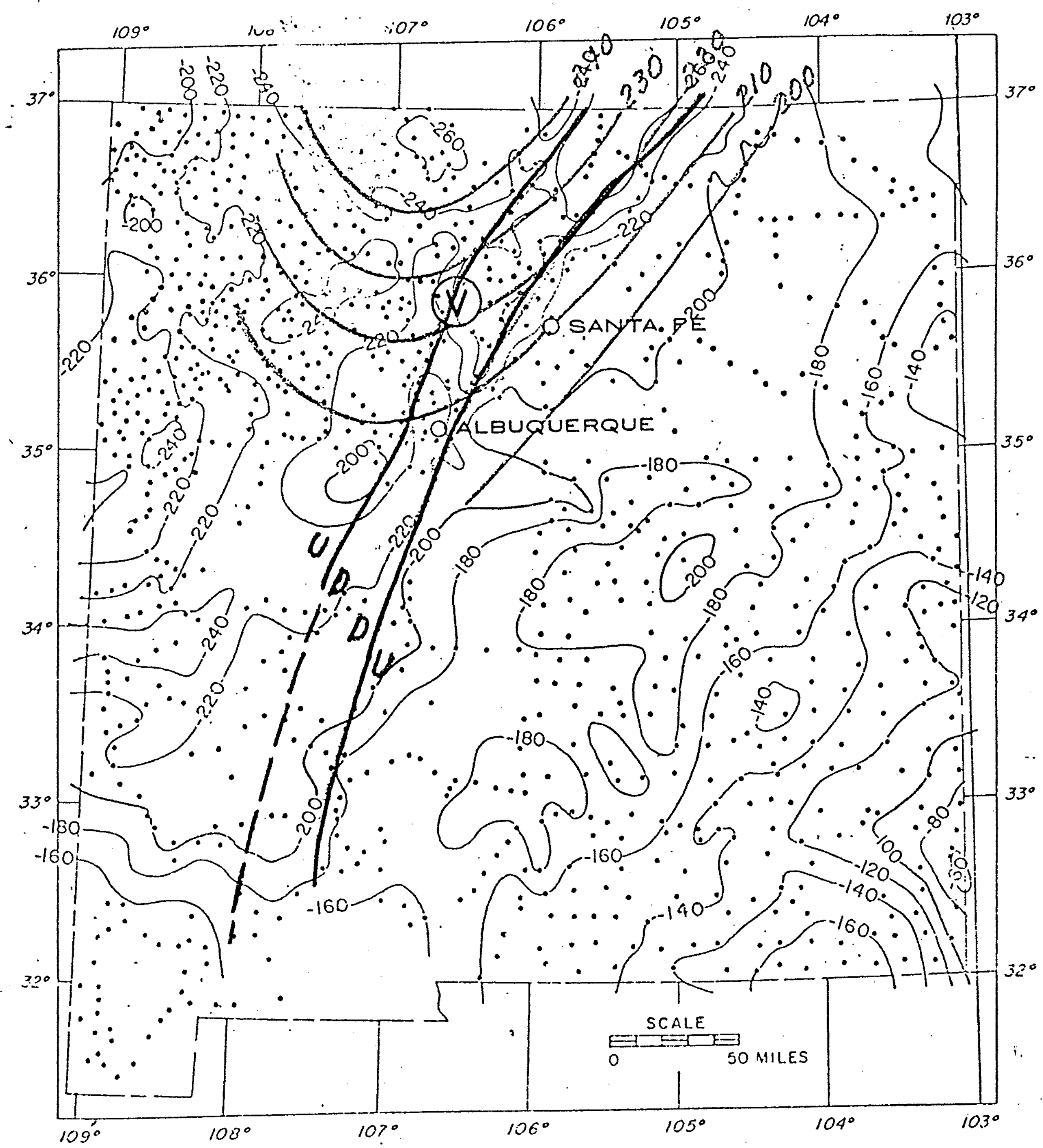

Fig. 7.25. NEW MEXICO Gravity Control and Regional Bouguer Anomaly Map.

(V) VALLES AREA

U/D FAULT

240 —— ISOSTATIC ANOMALY LINES

FIG. 3

least a thickness of 5,000 feet (based upon recent well information) and constitute the Bandelier rhyolitic tuff. As a result of this tremendous outburst, the roof of the eviscerated magma chamber collapsed to form the Valles Caldera. Subsequent activity has been mainly confined to the caldera itself. Minor eruptions of rhyolitic flows and pyroclastics, structural doming (resurgent cauldrons of Smith and Bailey, 1968) and extrusion of a ring of rhyolite domes near the periphery of the caldera were the final events in the caldera formation. Many hot springs remain in the area as evidence of its past thermal history. All of these events have been studied in detail according to lithology (Smith, et al., 1970 and Griggs, 1964) and magnetic properties (Doell, et al, 1968). The first major eruption of Bandelier Tuff took place about 1.4 MM years ago; the second eruption about 1.0 MM years ago. The rhyolitic domes were erupted since then, the oldest being Cerro del Medio, 1.0 MM years and the youngest being Banco Bonito, 0.1 MM years.

REGIONAL GRAVITY MAP OF NEW MEXICO

Figure 3 illustrates the regional gravity map (Woolland and Rose, 1963) of New Mexico which was used to obtain some estimate of the regional gradient (green lines) in the Jemez Mountains area. This regional is primarily due to isostatic condition of the earth's crust in the Rocky Mountains. Superimposed upon this isostatic anomaly are the more pronounced and regional geologic features. The primary ones of interest are two steep gradient zones (marked in red) which are interpreted as being caused by a long narrow graben approximately coincident with the Rio Grande. The westernmost fault cuts through the center of Valles area and probably represents the necessary weakness in the earth's crust for the initiation of volcanic activity.

GRAVITY INTERPRETATION

A quantitative gravity analysis was performed primarily through the use of computer programs available at the Union Research Center. Before receiving the final interpretation, it was necessary to solve or limit several problems that exist in almost every quantitative interpretation. Essentially, the problem is to isolate the gravity effect of the geological surface that is to be mapped.

Enclosure I is the fully corrected Bouguer gravity map from hand contouring. Enclosure II illustrates the same data done by computer contouring. The difference is essentially one of smoothing. The computer must grid the data (2,000' grid for all the Baca processing) by extrapolation from the observed stations. During this process the data does become somewhat smoother than the hand version.

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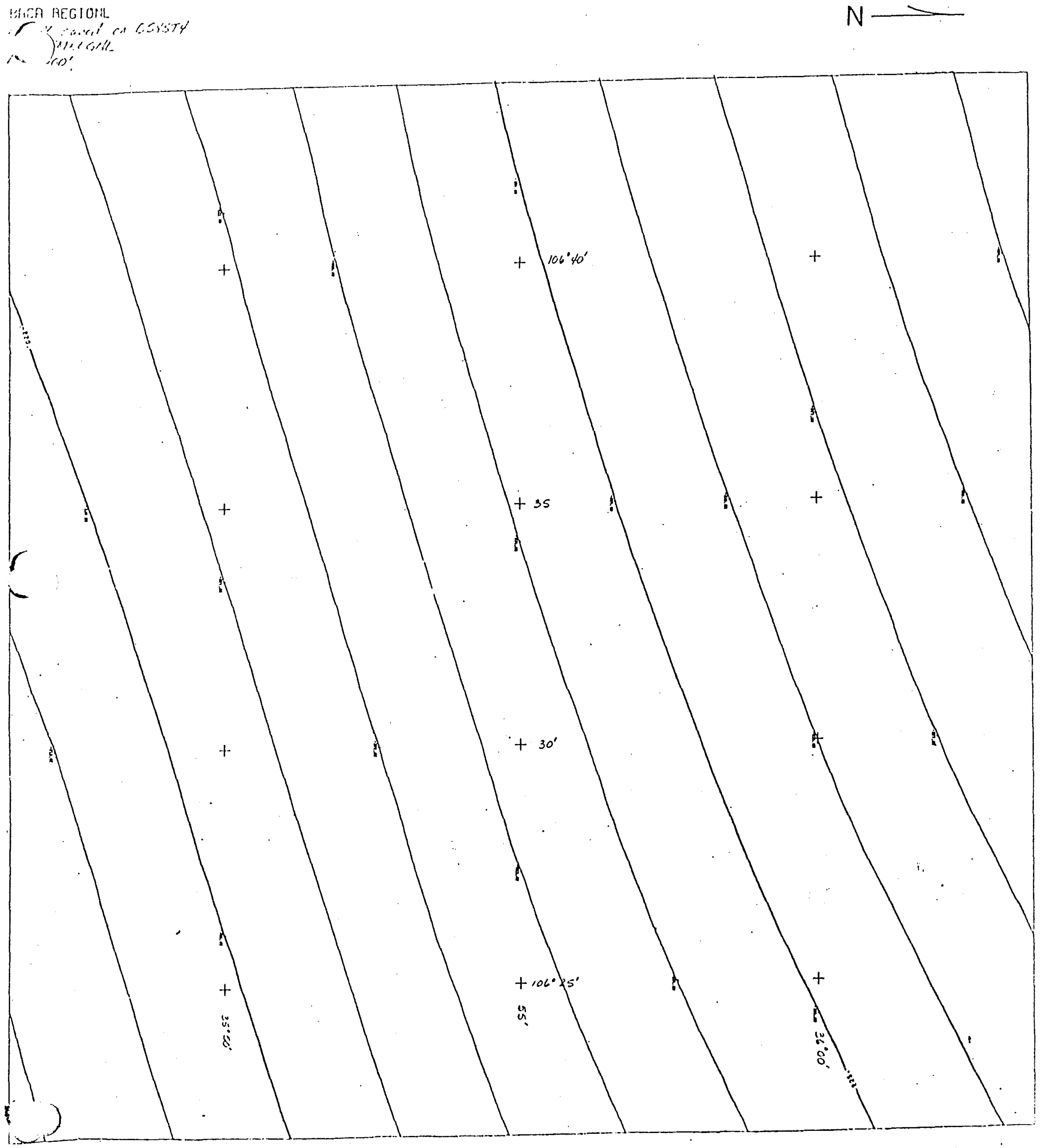

ISOSTATIC EFFECT REMOVED FROM DATA

FIG 4

Next the regional gravity (discussed earlier) caused by isostatic conditions most be removed from observed data. The smooth effect removed is illustrated on Figure 4. The resultant is shown on Enclosure III. On closer examination it was found that most of the Paleozoic outcrop area has a value of about +15 milligals. A constant correction throughout the area of -15 milligals was used in order to bring everything to a "zero" datum. A more complex datum adjustment is often justified, but not in this area since no geological control was available for the east side. The resulting map is shown on Enclosure IV. This map, often called the "First Order Residual", is the interpreter's best idea of the gravity effect from geological features in the shallow portion of the earth's crust. As can be observed, there is little apparent difference in Enclosure I and IV, which means that the data has not been warped or modified sufficiently to distort the geological effect of interest.

The next obstacle was the apparent high frequency component present in the data. The sharper anomalies can only be related to some density change very close to the ground surface. Wavelength filtering was employed here to remove most of the near-surface effect. The resulting filtered map using a 12,000' to 10,000' cut off wavelength is shown on Enclosure V.

Because of the large amount of computer time for 3-D analysis, a profile across the central portion of Enclosure V was generated to determine an order of magnitude for the density contrast. This was determined to be 0.35 g/cc.

The various parameters were then combined to allow the computer to iterate in three dimensions on the data shown on Enclosure V. Fifteen iterations usually gave a good statistical tie which suggested that additional iterations would not significantly improve the model. However, in order to investigate the parameters more fully, other filters and density contrast were used in the overall process. From the various solutions offered by the computer, Enclosure VI represents a "hand" edited interpretation. It most closely resembles the computer model from the 0.35 g/cc density contrast. No effort was made to map the minor features such as: slump along ring fracture, jagged nature of caldera rim, minor faults, and/or local deeps along volcanic necks.

One of more interesting features on this map is the location of the "ring fracture" system. Apparently the fracture does not follow the series of inner rhyolitic domes on the northern and western edges of the caldera. The trace of the fault (ring fracture) would align itself more closely with the Warm Spring and Cerros del Trasquilar features. The series of domes that includes San Antonio Mountain, Cerro Seco, Cerro San Luis and Cerro Santa Rosa and Cerros del Abrigo represent an inner lineament to the dominant ring fracture system. This group of domes also forms a very restricted age group from 0.89 MM years ago to 0.69 MM years ago from potassium-argon studies (Doell, et al., 1968). The Warm Spring and Cerro del Medio form an older age group (1.04 MM years ago to 1.22 MM years ago).

The ring fracture in the southern and eastern areas has good correspondence with the domes. This is particularly true where South Mountain, Cerro La Jara, Cerro del Medio, the east dome of Cerros de Los Posos and Cerro Rubio are located. The trace of the fracture in this vicinity corresponds roughly to the location of the Jemez River which is inward a considerable distance from the topographic rim (see Enclosure VI). The far northeastern section consist of a large negative area one mile east of Cerros del Abrigo. The large negative area is probably the location of the main collapsed area of the Toledo disturbance. There is no evidence that the Valles disturbance had an appreciable effect in this area. The ring fracture apparently does not cross the Toledo minimum.

There is some evidence of major faulting within the interior of the caldera. The major northeast-southwest fault running from Sec.31 of T21N-R5E southwest to Redondo Creek may in actuality be part of a large graben system. To the northeast it appears to be part of the Toledo collapse.

The evidence for the resurgency hypothesis is somewhat obscure from the gravity data. There is a definite positive anomaly associated with the Redondo Peak area; however, the central high does not fall upon Redondo Peak. This may be partially explained by inadequate terrain corrections, but the present interpretation suggests a structural high of some 2,000 feet of relief and confined to the area of outcrop of Bandelier Tuff to the northeast of Redondo Peak. The gravity does not suggest a resurgent dome of the magnitude suggested by Smith, et al., (1970). This may be explained in that some of the positive gravity effect of the dome may be canceled by the overall negative effect of the caldera.

A negative graben area is suggested by the gravity for the area between Redondo Peak and Redondo Creek. Although surface structure suggests a graben, the negative may also be the location of the central vent of the caldera. It is centrally located to the series of rhyolitic domes and the ring fracture system. Also the substantial thickening of the Bandelier Tuff towards this area could be an indication of closeness to the primary vent.

The Second Order Residual map shown as Enclosure VIII represents the unresolved gravity effect. This map was computed by subtracting the gravity effect of the structure on Enclosure VI from the First Order Residual Gravity Map (Enclosure IV). A 0.35 g/cc density contrast was used to compute the gravity effect shown in Enclosure VII. Shown on Enclosure VIII are the interpreted reasons for the remaining anomalies, most of which are related to near-surface effects. Some of the reasons are unresolved terrain effects, variations in the thickness of caldera and/or lake fill, subsurface vents, intrusions, domes and faults. These are indicated by the legend and the appropriate map symbol. One of the more outstanding anomalies is at the El Cajete vent (Sec.31, T19N. R4E). On Enclosure I the vent is shown by the large circular minimum. Within the minimum is a central maximum which is probably a volcanic neck surrounded by the lighter density infill of volcanics and caldera fill.

There are three distinct trends that are apparent on Enclosure VIII. The first is in the Sulphur Creek and Redondo Creek area. This negative is probably due to the caldera fill in the area causing a higher density contrast than 0.35 g/cc. The second is the Redondo Creek, Redondo Peak and Jaramillo Creek area where a large positive residual is present. The positive corresponds to the approximate outcrop pattern of the Bandelier Tuff which could mean that the anomaly could have been generated by an incorrect Bouguer correction. In this case it would be an underestimate for the tuff (2.45 g/cc). It could also be caused by too deep a Paleozoic surface. The other negative trend along the east edge of the caldera is probably caused by the presence of substantial amounts of lake beds or caldera fill. This negative means that there is a larger density contrast than 0.35 g/cc.

CONCLUSIONS AND RECOMMENDATIONS

This investigation has shown that the large negative gravity anomaly is caused primarily by a collapsed volcano. It has also shown that there is an apparent density contrast of 0.35 g/cc and that a Top Paleozoic map structure could be generated by computer processing at Research Center. This work indicated that there is as much as 15,000 feet of lighter density material within the caldera. Also this map has shown that the ring dike system is not always coincident with the ring fracture system, and that the ring fracture is located at a considerable distance inward from the topographic rim. The concept of "resurgent" doming was neither enhanced or disproved, however, the gravity does indicate that the effect of resurgent doming is much more localized than envisioned by Smith and Bailey (1968).

It is recommended that this interpretation be combined with the geological and geophysical data to form a more complete understanding of the physical nature of this caldera. A specific recommendation on areas of exploration interest within the caldera cannot be made at this time. This should be done by persons with more knowledge of the electrical and thermal properties of the near-surface rocks.

Respectfully submitted,

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Robert L. Segar

RLS:jml

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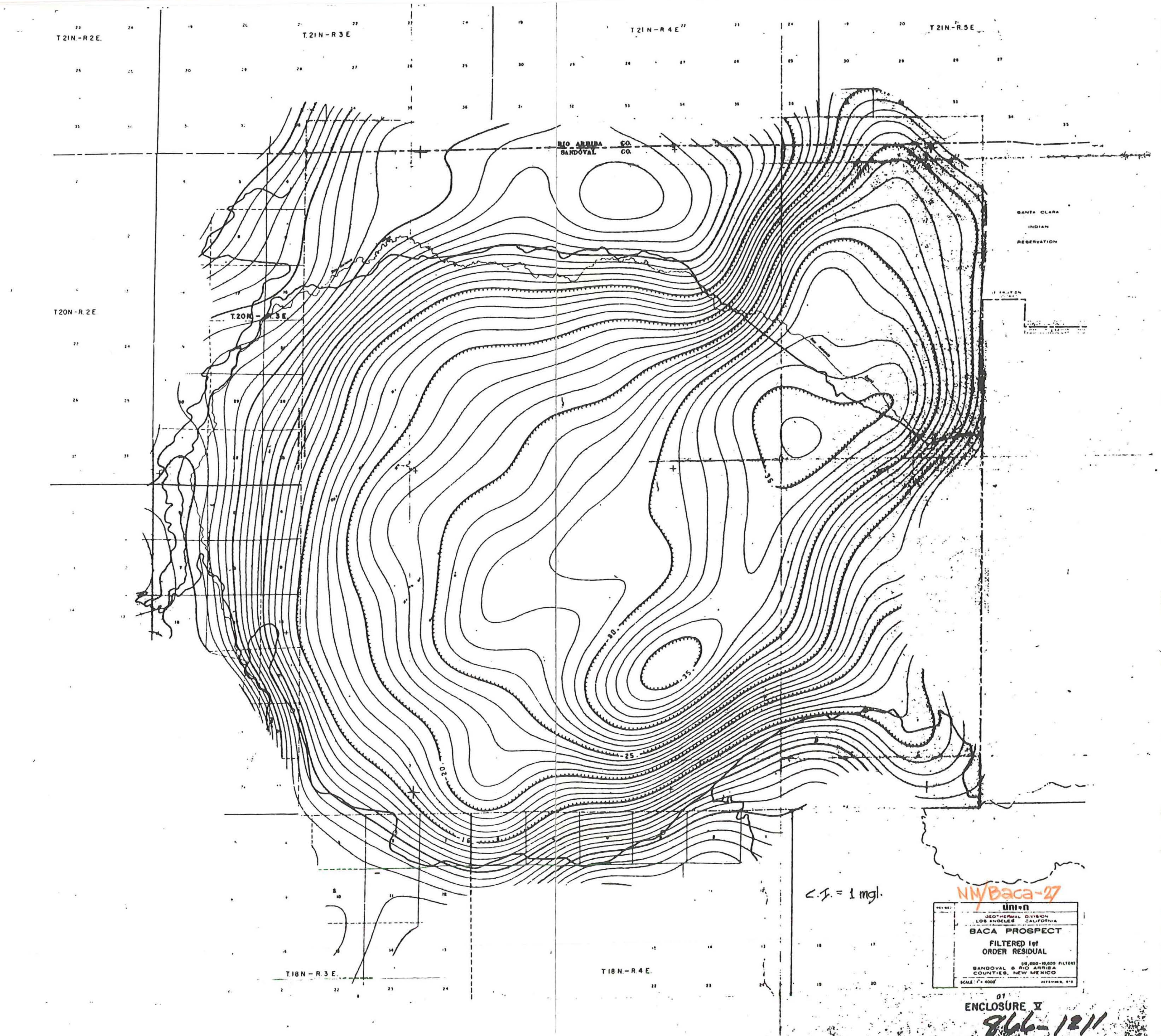
T21N-R2E.
T21N-R3E
T21N-R4E
T21N-R5E
RIO ARRIBA CO.
SANDOVAL CO.
SANTA CLARA
INDIAN
RESERVATION
T20N-R2E
T18N-R3E.
T18N-R4E.
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C.I. = 1 mgl.
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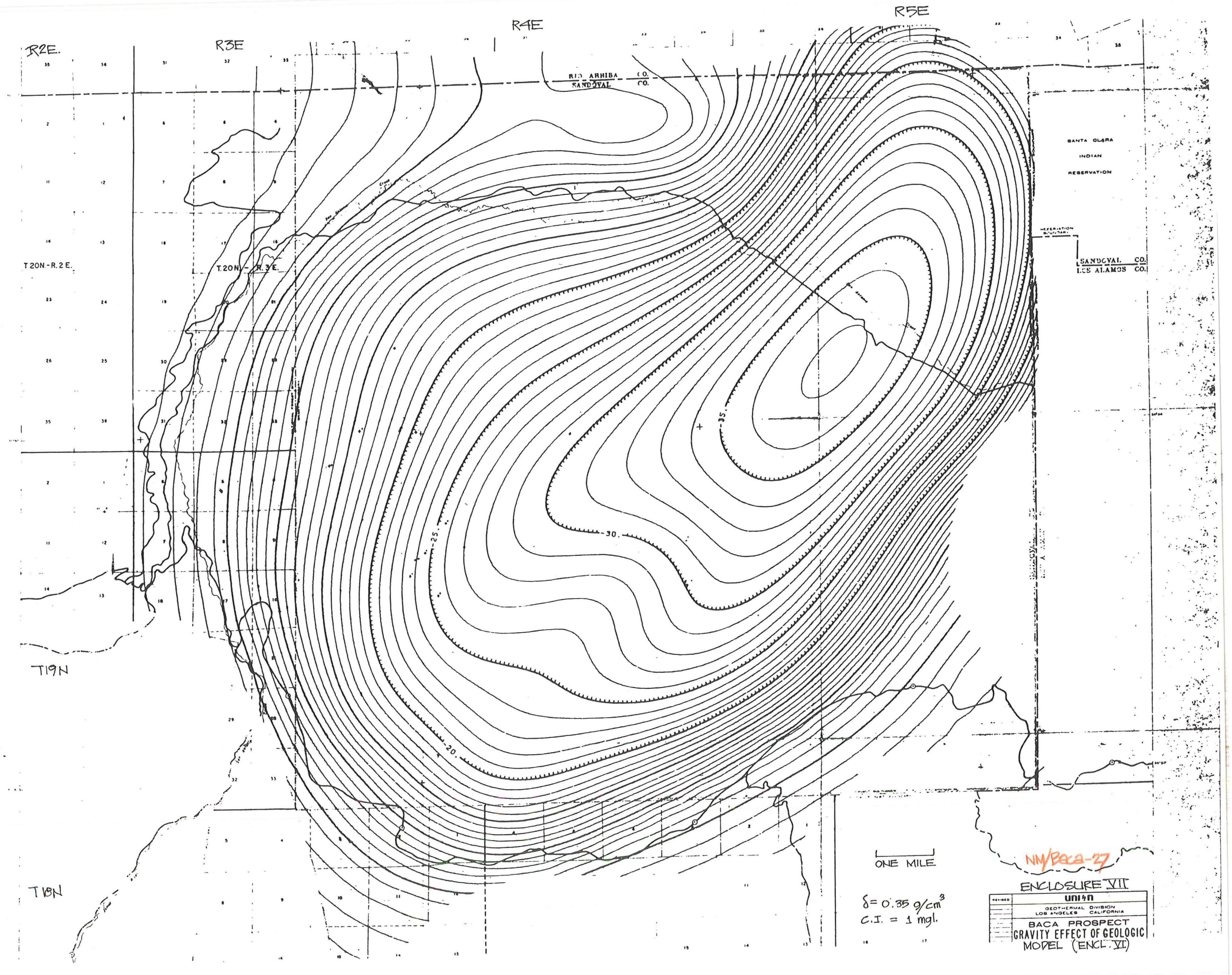
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ENCLOSURE VII
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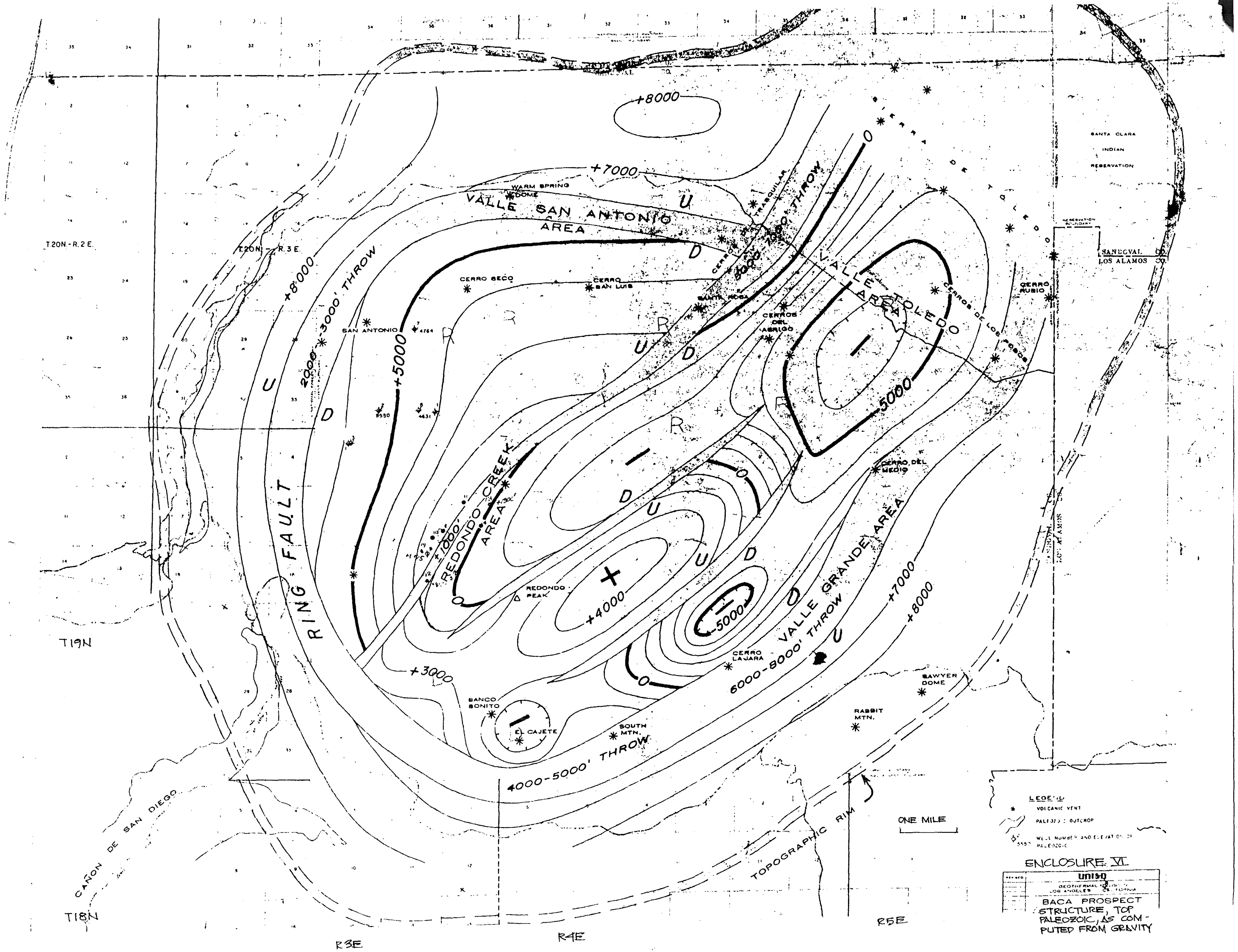
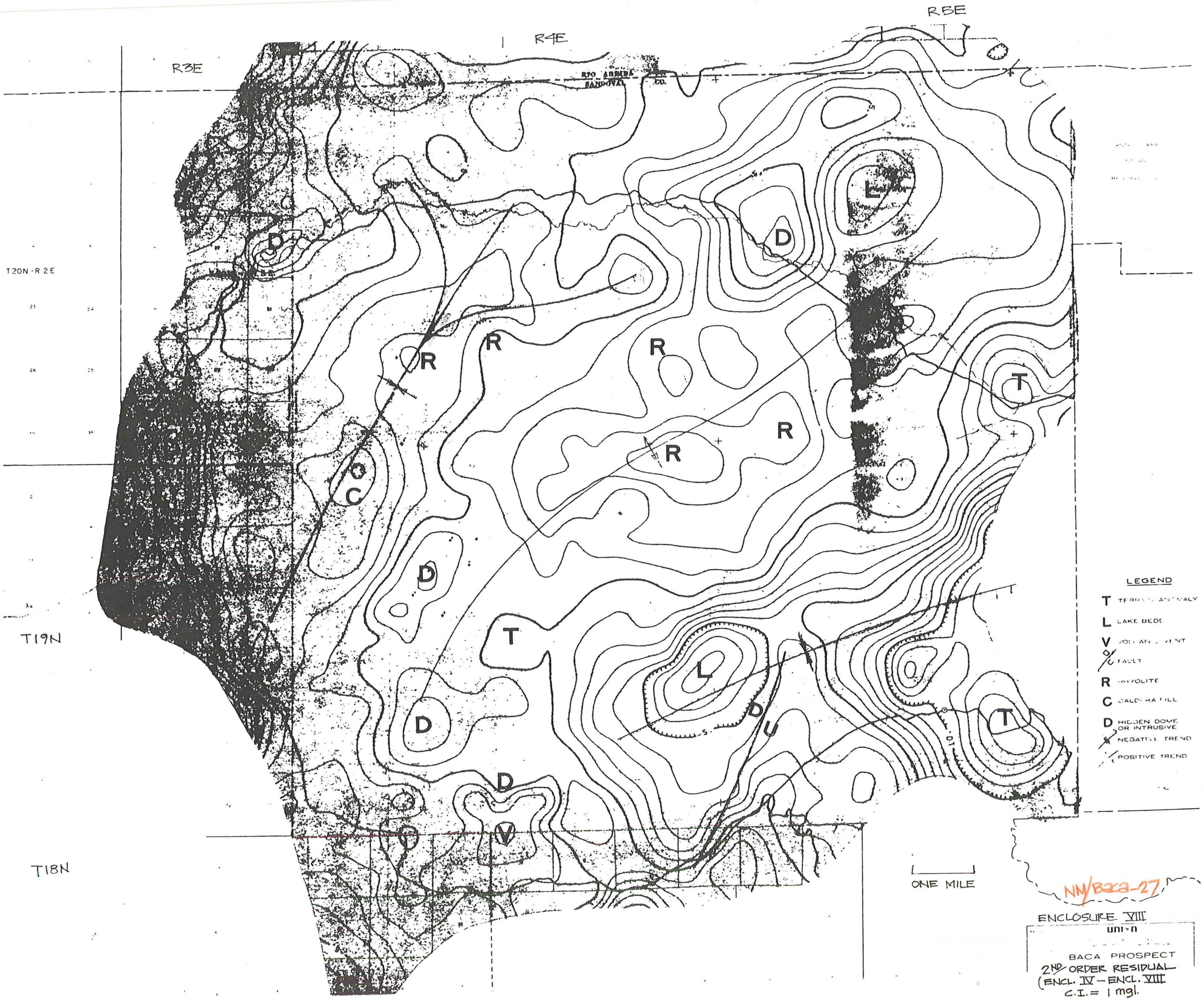
LOS ANGELES CALIFORNIA
BACA PROSPECT
GRAVITY EFFECT OF GEOLOGIC MODEL (ENCL. VI)



ENCLOSURE VI

BACA PROSPECT STRUCTURE, TOP PALEOZOIC, AS COMPUTED FROM GRAVITY


R3E
R4E
R5E
RIO ARRIBA
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ENCLOSURE VIII
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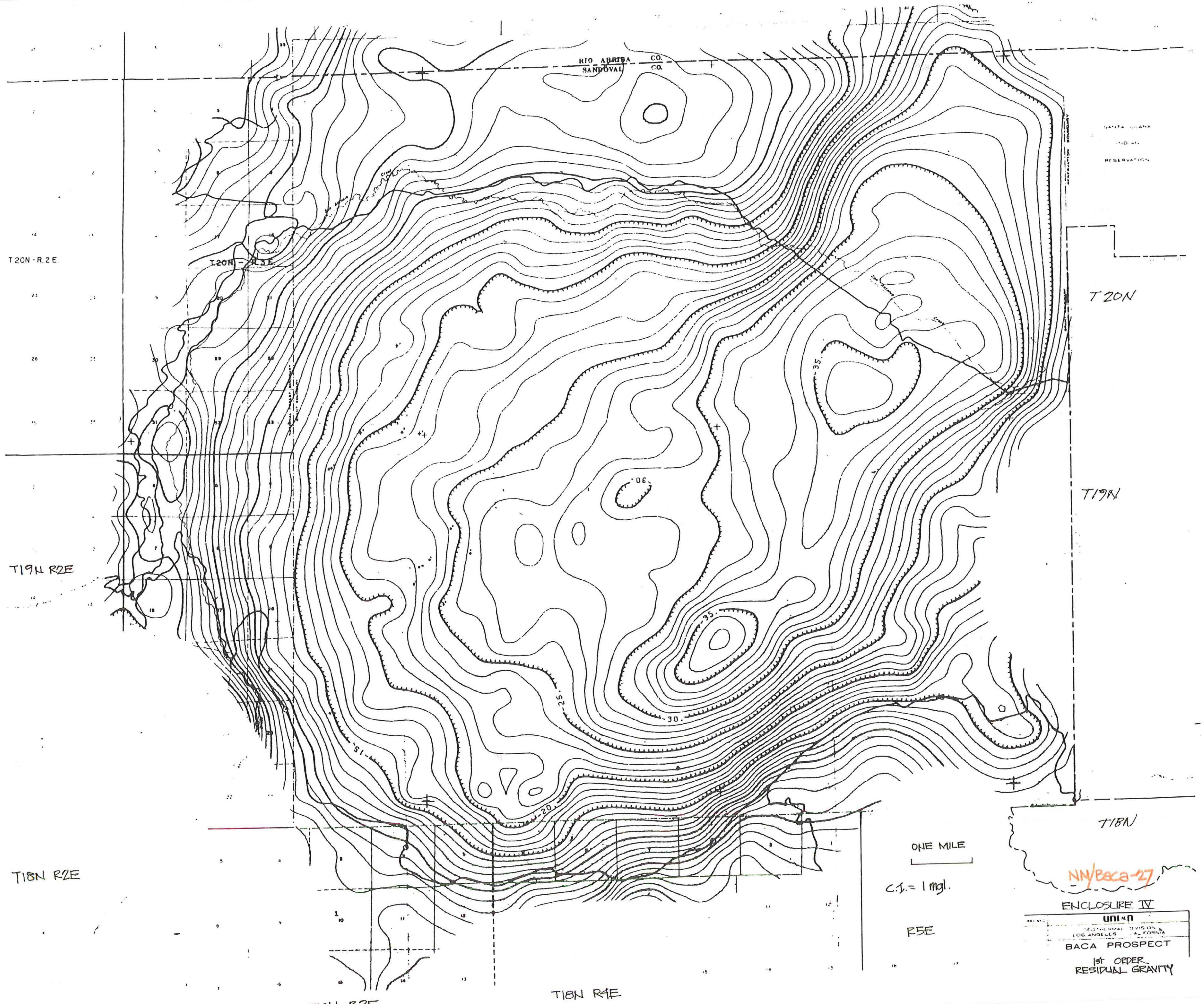
C.I. = 1 mgl.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