MX SITING INVESTIGATION

GRAVITY SURVEY - COAL VALLEY

NEVADA

FUGRO NATIONAL

CONSULTING ENGINEERS AND GEOLOGISTS

FN-TR-33-CL

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GRAVITY SURVEY - COAL VALLEY

NEVADA

Prepared for:

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

Prepared by:

Fugro National, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

30 May 1980

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Gravity measurements were made in Coal 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.

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FOREWORD

Methodology and Characterization studies during fiscal years 1977 and 1978 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 one-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, Reveille and Railroad valleys, a sufficient density of library data is 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. In 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, 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 within the constraints 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 Coal 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.

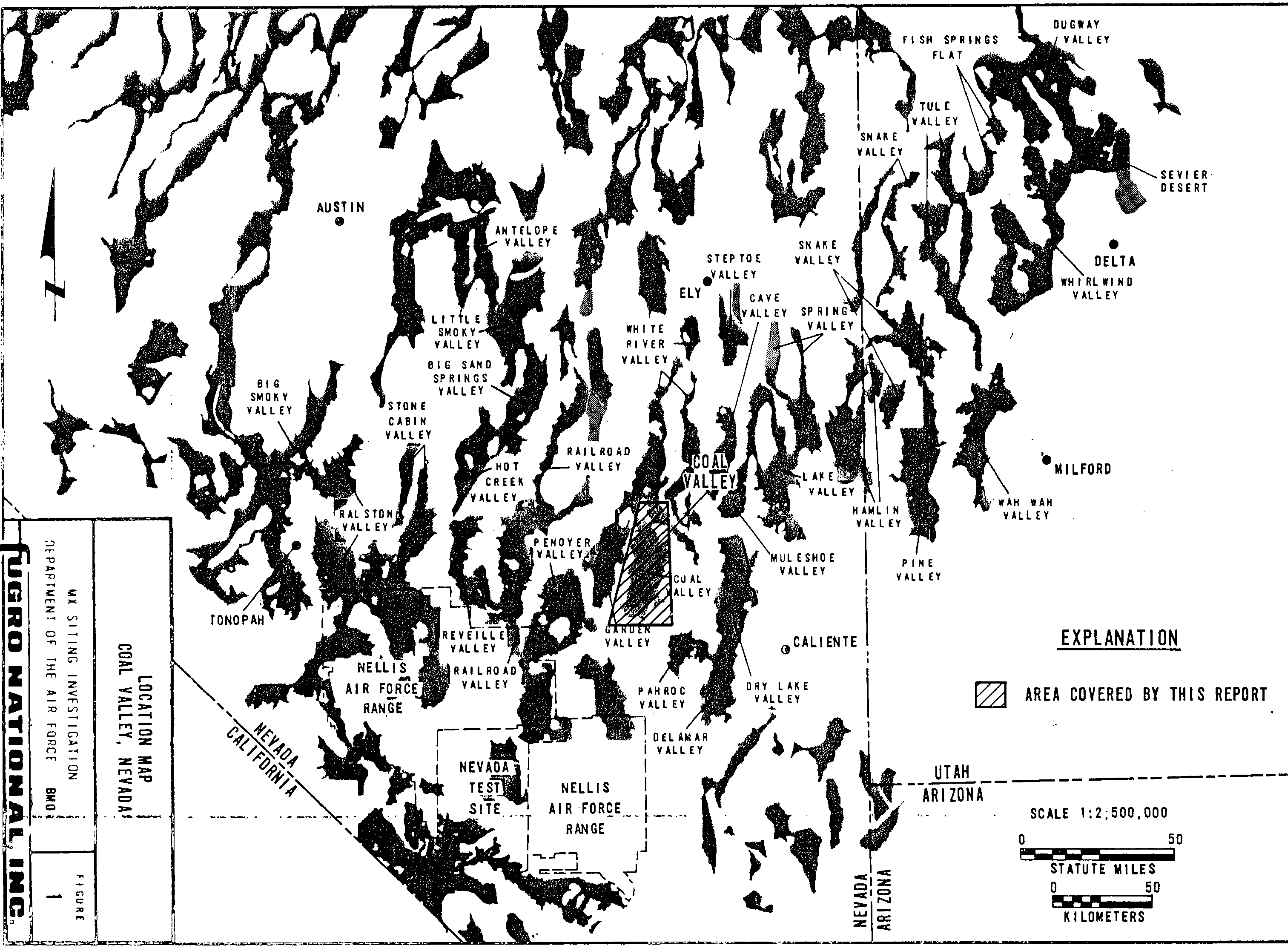
1.2 LOCATION

Coal Valley is located in central Nevada (Figure 1) and includes parts of Nye and Lincoln counties. The valley is accessible only by improved and unimproved dirt roads. Caliente, Nevada is located approximately 55 miles (89 km) east of the valley on U.S. Highway 93.

Coal Valley is bounded on the west by the Golden Gate Range, on the south by the North Pahranagat Range and on the east by the Seaman Range (Figure 2). The Seaman Range and Golden Gate Range merge together forming the northern boundary.

1.3 SCOPE OF STUDY

The Defense Mapping Agency Hydrographic-Topographic Center/ Geodetic Survey Squadron (DMAHTC/GSS) made the 74 gravity measurements for the three profiles used in this study (Appendix A2.0). Data from the DMA gravity library was also used to establish the regional gravity.



LOCATION MAP
COAL VALLEY, NEVADA

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FIGURE 1

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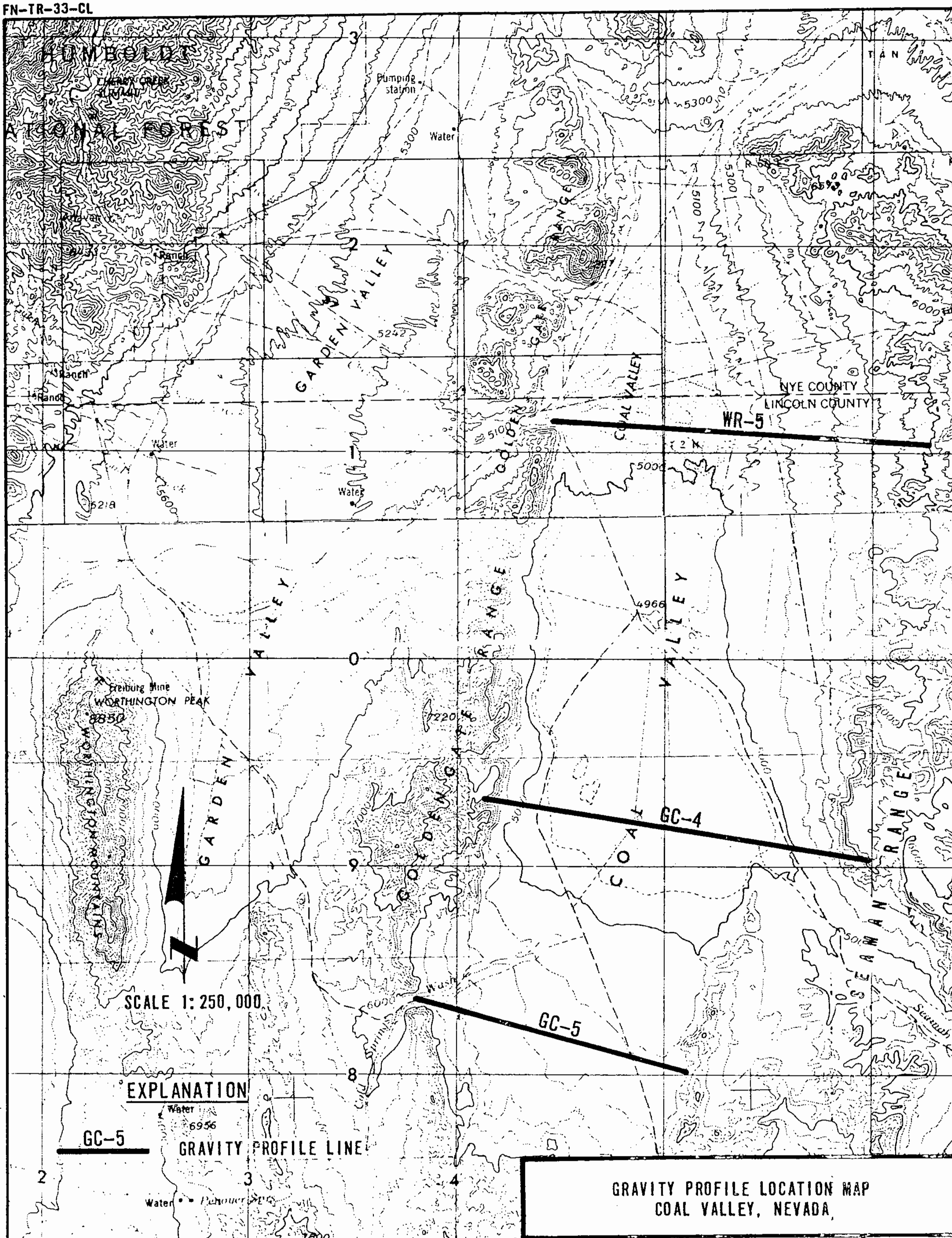

GRAVITY PROFILE LOCATION MAP
COAL VALLEY, NEVADA

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FIGURE 2

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Profile positions are shown in Figure 2 and the locations of the individual stations are shown on Drawing 1. The profile lengths range between 7 miles (11 km) and 11 miles (18 km), crossing over the valley fill from rock outcrop to rock outcrop. The gravity sampling interval is approximately 1-mile (1.6 km) in the central valley and .25 mile (0.4 km) near the valley boundaries. The denser sampling was used near the valley flanks to define any steep gravity gradients associated with boundary faults, and to resolve anomalies with high spatial frequency that could be associated with shallow bedrock.

The tolerance for establishing station elevations was 5 feet (1.5 m). This tolerance for elevation control limits the gravity precision to 0.3 milligals.

2.0 GRAVITY DATA REDUCTION

DMAHTC/GSS obtained the basic observations and reduced them to Simple Bouguer Anomalies (SBA) for each station as described in Appendix A1.0. Up to three levels of terrain corrections were applied to convert the SBA to the Complete Bouguer Anomaly (CBA). First, the Defense Mapping Agency Aerospace Center (DMAAC), St. Louis, 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 (40 m) along six directions from the stations. These data were used to calculate the effect of the very near relief. The CBA data for the Coal Valley stations are listed in Appendix A2.0.

3.0 GEOLOGY SUMMARY

Coal Valley is a typical north-south trending valley of the Basin and Range physiographic province. The Golden Gate Range separates Garden and Coal Valleys and consists of westward dipping Paleozoic limestone and dolomite overlain in the north by Tertiary ash-flow tuffs and Quaternary basalt (Howard, 1978). This block is broken by northeast trending faults. The Seaman Range, on the east side of the valley, consists of Devonian and Mississippian limestone, dolomite, and quartzite. These are overlain by a comparatively thin ash-flow tuff layer followed by a complex series of mud flows, lava flows, volcanic breccias, and tuff flows connected with an extinct volcano whose eroded remnants lie east of the center of Coal Valley (Tschanz and Pampeyan, 1970). The northern end of the Seaman Range is broken by numerous north-south and east-west trending faults, most of which appear to predate the valley sediments (Howard, 1978, Fugro National, 1979).

The MX fault study revealed that previously mapped faults (for example Howard, 1978) were lineaments due to vegetation, aeolian, and late Pleistocene-Holocene shoreline features. Gravity data tends to support such an interpretation.

The valley fill consists of 1) alluvial clay, silt, sand, and gravel units and 2) Pleistocene lake deposits ranging also from clayey to gravelly sediments but with clay predominant. The lake deposits comprise about 40 percent of the surficial geology. The alluvial fan deposits make up the remaining

60 percent of surficial deposits and generally occur above the 5100 foot level of the old shoreline (Tschanz and Pampeyan, 1970 and Fugro National FY 78 and 79 data). The lake sediments are probably only a few tens of feet thick, but the valley fill may be several hundred feet thick (although there is little well data to substantiate this) (Eakin, 1963).

4.0 INTERPRETATION

A valley filled with alluvium which has a low-density relative to the surrounding bedrock creates a negative gravity anomaly. Gravity profiles across such valleys are often U-shaped, low in the middle of the valley where the fill is thickest and high on the ends where the fill thins and bedrock emerges. Interpretation requires removal of regional trends leaving the gravity reflection of the valley fill. The gravity data and interpreted geologic models for the three profiles across Coal Valley are shown in Figures 3 through 5.

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 relatively low density valley fill. The portion of the CBA which corresponds to this alluvial material is called the "residual anomaly".

The CBA contains long-wavelength components from deep and broad geologic structures extending far beyond the valley. These long-wavelength components, called the regional gravity, have been approximated by linear interpolation between CBA values at bedrock stations on opposite ends of the profiles. Where only one end of a profile was on bedrock, the regional value on the other end was assigned a quantity consistent with the regional trend of the valley. The regional gravity was subtracted from the CBA and the resulting residual anomaly profiles were used to model the valley. This regional separation technique is only approximate. Some regional effects may still remain after the subtraction but the error is probably small compared to the large residual anomaly values of these profiles.

The CBA values and the straight line regional field for each profile is shown in the top portion of Figures 3 through 5. The residual gravity anomaly (interpolated at evenly spaced points) is shown by the crosses (x) in the second block of Figures 3 through 5.

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 be only a coarse approximation. Average in situ density of the fill material was measured between depths of 100 to 160 feet (30 to 49 m) in several shallow borings. The observed density range for the soil was 1.7 to 2.0 g/cm^3. A larger density of 2.3 g/cm^3 was used in the modeling process to approximate the expected overall alluvium density 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 Coal basin is thought to be the Paleozoic carbonate rocks which are found 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 selected to represent the density of the basement rock.

Relative to a given basement density, the calculated basin depth is inversely proportional to the density value assigned to the valley fill materials. A one percent change in the average alluvial fill density will result in a five percent change in the calculated fill thickness.

4.3 MODELING

An iterative computer program that calculates the gravitational field for two-dimensional models was used to approximate the thickness of alluvium beneath each profile. The cross-sectional models appear as a set of 0.5-km-wide blocks whose tops are at surface elevation and whose bottoms represent the alluvium-bedrock boundary. The elevations at the bottoms of the blocks were adjusted by iterative computation until the computed gravity anomaly for the valley fill differed by less than one milligal from the observed residual anomaly.

The gravity anomaly computed from the final model can be compared to the residual anomaly in the second block of Figures 3 through 5. The computed anomaly is shown as the solid line and the residual anomaly is shown by the crosses (x). The final calculated basin models are shown in the third block of Figures 3 through 5. The cross sections have a five times vertical exaggeration so that even gentle slopes appear steep. The lowest block shows a suggested geological interpretation.

All three gravity profiles indicate that Coal Valley is asymmetrical, with a dominant extremely steep fault between the outcrops and the deep basin with the largest of these being near the center of the topographic valley. On the southern profile, GC-5, a horst is indicated on the eastern side of the basin. The outcrop pattern (Figure 6) south of the profile can be construed to support this interpretation.

The calculated thickness of alluvium diminishes from approximately 6900 feet (2103 m) beneath profile WR-5 on the north to about 2900 feet (884 m) beneath profile GC-5 on the south. The deep basin floor calculates to be almost flat between profiles WR-5 and GC-4. The average rate of rise to the south between these profiles is about 50 feet per mile (9 m/km). This rate increases approximately ten times to more than 500 feet per mile (95 m/km) between profiles GC-4 and GC-5. Even this latter rate is insufficient to explain the proximity of the outcrops to the south. This may indicate that transverse faulting occurs south of profile GC-5.

5.0 CONCLUSION

There is a large well defined negative gravity anomaly associated with Coal Valley. 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.

The gravity interpretation of Coal Valley indicates that the basin is asymmetrical with a major range bounding normal fault on the western side of the valley with a series of lesser faults in the eastern half of the valley. The primary graben block lies along the Golden Gate Range and is oriented NNE-SSW. Calculated depth ranges from 6900 feet (2103 m) beneath profile WR-5 and 2900 feet (884 m) beneath profile GC-5 near the south end.

The calculated bedrock depths can only be approximations since little is known about the actual density distribution in and around the valley. Future studies that acquire better density data or actual depth to bedrock in deep parts of the valley can be used to refine the gravity interpretation.

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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. <u>Latitude Effect</u>: 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 lightweight, 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.

APPENDIX A2.0

COAL VALLEY, NEVADA

GRAVITY DATA

COAL VALLEY GRAVITY DATA

PROFILE GC-4

STATION IDENT.	LAT. DEG MIN	LONG. DEG MIN	ELEV. +CODE	TER-COR. IN/OUT	NORTH UTM	EAST UTM OBSV GRAV THEO GRAV	FAA	CBA +1000
GC0401	375267	1152334	5425B	0	357419328	64168146929198138	-156	81699
GC0402	375266	1152305	5285B	0	466419327	64211147781198137	-619	81822
GC0403	375265	1152277	5177B	0	298419326	64252148202198135	-1206	81433
GC0404	375263	1152250	5090B	0	241419323	64292148372198132	-1858	81022
GC0405	375259	1152223	5016B	0	215419316	64331148393198127	-2528	80579
GC0406	375255	1152197	4953B	0	196419309	64370148156198121	-3347	79954
GC0407	375251	1152171	4944B	0	175419302	64408147805198115	-3782	79530
GC0408	375248	1152142	4945B	0	154419298	64450147526198110	-4049	79240
GC0409	375244	1152115	4927B	0	144419291	64490147527198105	-4205	79132
GC0410	375228	1152010	4918B	0	114419264	64645147494198081	-4303	79037
GC0411	375212	1151902	4939B	0	91419237	64804147621198058	-3953	79292
GC0412	375194	1151797	4942B	0	87419207	64958147987198031	-3531	79699
GC0413	375179	1151690	4945B	0	86419182	65115148731198009	-2746	80476
GC0414	375164	1151582	4948B	0	87419157	65274149038197988	-2384	80827
GC0415	375147	1151476	4954B	0	97419129	65430149495197963	-1846	81354
GC0416	375141	1151441	4956B	0	103419118	65482149510197954	-1801	81398
GC0417	375136	1151409	4969B	0	108419110	65529149418197947	-1759	81399
GC0418	375132	1151384	4978B	0	116419103	65566149409197941	-1683	81454
GC0419	375128	1151358	5011B	0	120419097	65604149207197935	-1567	81461
GC0420	375123	1151330	5052B	0	131419088	65645148926197928	-1459	81442
GC0422	375131	1151277	5179B	0	162419105	65723148587197940	-607	81889
GC0423	375142	1151254	5252B	0	223419126	65756148590197955	59	82370
GC0424	375152	1151232	5350B	0	212419145	65788148069197970	448	82413
GC0425	375163	1151209	5476B	0	300419166	65821147209197987	761	82384

END OF LIST

COAL VALLEY GRAVITY DATA

PROFILE GC-5

STATION IDFNT.	LAT. DEG MIN	LONG. DEG MIN	ELEV. +CODE	TFR-COR. IN/OUT	NORTH UTM	EAST UTM / OBSV GRAV / THEO GRAV	FAA	CBA +1000
GC0502	374746	1152530	5718B	0	193418359	63697144526197377	966	81656
GC0503	374743	1152503	5718B	0	173418355	63937144489197373	931	81602
GC0504	374736	1152478	5685B	0	163418342	63974144749197363	888	81662
GC0505	374730	1152451	5654B	0	154418332	64014144987197354	843	81714
GC0506	374723	1152425	5618B	0	147418320	64052145064197344	594	81580
GC0507	374717	1152399	5578B	0	144418309	64091145007197335	165	81286
GC0508	374711	1152372	5536B	0	141418299	64130144846197327	-382	80878
GC0509	374705	1152346	5501B	0	134418288	64169144755197318	-789	80582
GC0510	374697	1152319	5482B	0	131418274	64209144662197306	-1051	80382
GC0511	374672	1152210	5344B	0	120418231	64369145433197270	-1545	80349
GC0512	374643	1152096	5270B	0	113418180	64538146320197227	-1225	80883
GC0513	374613	1151991	5227B	0	112418127	64693147291197184	-699	81585
GC0514	374606	1151964	5210B	0	109418115	64733147233197173	-909	81431
GC0515	374599	1151938	5206B	0	108418103	64771147197197163	-975	81379
GC0516	374593	1151911	5206B	0	108418092	64811147162197155	-995	81356
GC0517	374587	1151885	5204B	0	108418082	64849147031197145	-1143	81217
GC0518	374580	1151859	5206B	0	109418070	64888146958197135	-1181	81171
GC0519	374574	1151833	5208B	0	112418059	64926146959197127	-1155	81194
GC0520	374567	1151806	5215B	0	118418047	64966147022197116	-1017	81315
GC0521	374560	1151780	5220B	0	121418035	65004147132197106	-845	81471

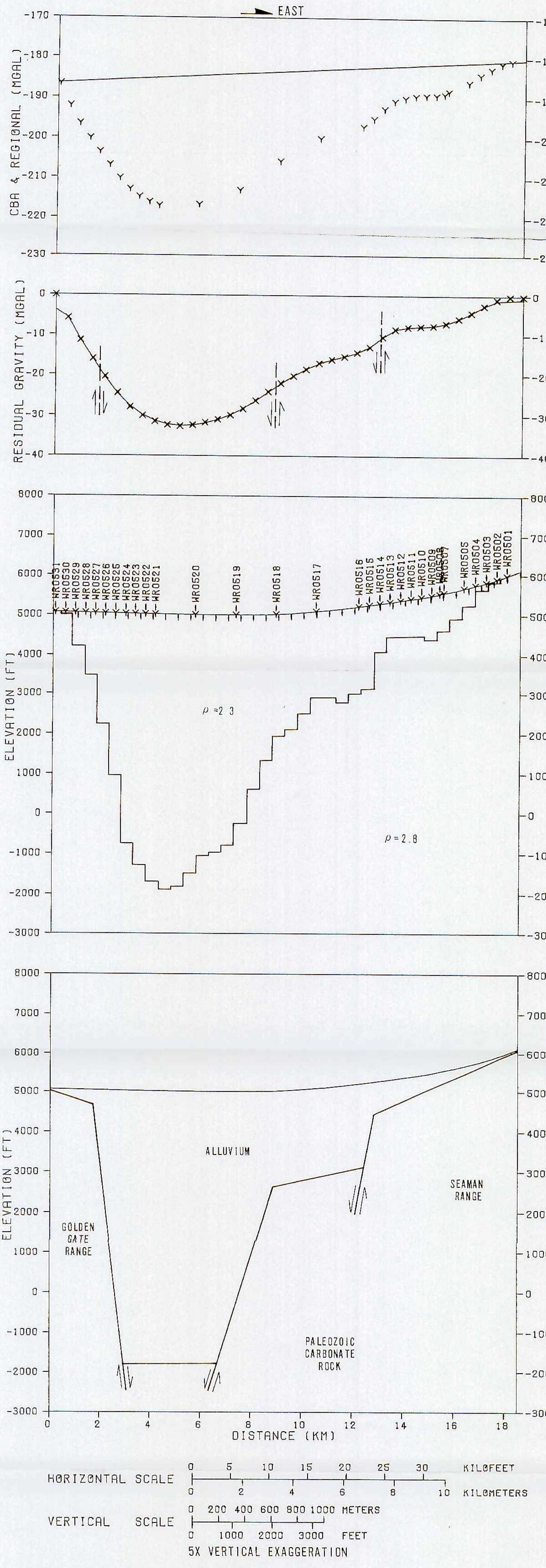
END OF LIST

COAL VALLEY GRAVITY DATA

PROFILE WR-5

STATION IDENT.	LAT. DEG	LAT. MIN	LONG. DEG	LONG. MIN	ELEV. +CODE	TER-COR. IN/OUT	NORTH UTM	EAST UTM	OBSV GRAV	THEO GRAV	FAA	CBA +1000
WR0501	38	146	115	887	5984Y	0 209	420993	66297	145223	199423	2119	81919
WR0502	38	131	115	915	5895B	0 190	420964	66217	145697	199401	1776	81860
WR0503	38	131	115	943	5809B	0 181	420963	66176	146080	199401	1359	81728
WR0504	38	134	115	972	5744B	0 169	420968	66133	146345	199405	998	81577
WR0505	38	138	115	1003	5685B	0 158	420975	66088	146651	199411	559	81394
WR0507	38	154	115	1055	5554B	0 135	421003	66011	147158	199434	-13	81178
WR0508	38	172	115	1065	5521B	0 145	421036	65996	147285	199461	-212	81101
WR0509	38	179	115	1086	5480B	0 132	421048	65965	147522	199471	-371	81069
WR0510	38	176	115	1114	5442B	0 125	421042	65924	147754	199466	-500	81065
WR0511	38	178	115	1142	5399B	0 123	421045	65883	147998	199470	-658	81049
WR0512	38	180	115	1170	5358B	0 118	421048	65842	148203	199473	-848	80997
WR0513	38	185	115	1198	5317B	0 117	421056	65801	148381	199480	-1056	80925
WR0514	38	188	115	1225	5280B	0 115	421061	65761	148423	199484	-1373	80735
WR0515	38	188	115	1254	5241B	0 114	421060	65719	148401	199484	-1756	80481
WR0516	38	185	115	1282	5206B	0 109	421054	65678	148415	199480	-2066	80285
WR0517	38	178	115	1399	5086Y	0 98	421037	65507	149840	199470	-2765	79986
WR0518	38	187	115	1506	5014B	0 94	421051	65350	148722	199483	-3577	79417
WR0519	38	197	115	1614	4998B	0 83	421067	65192	148112	199498	-4347	78689
WR0520	38	207	115	1724	5005B	0 78	421082	65031	147740	199512	-4688	78326
WR0521	38	216	115	1832	5015B	0 77	421096	64872	147648	199525	-4677	78294
WR0522	38	219	115	1859	5019B	0 77	421101	64833	147720	199530	-4579	78381
WR0523	38	222	115	1887	5022B	0 78	421106	64792	147835	199534	-4433	78515
WR0524	38	224	115	1913	5027B	0 78	421109	64754	148003	199537	-4228	78705
WR0525	38	226	115	1940	5031B	0 80	421112	64714	148257	199540	-3941	78981
WR0526	38	229	115	1968	5036B	0 81	421116	64673	148559	199545	-3593	79312
WR0527	38	231	115	1995	5041B	0 83	421119	64633	148853	199547	-3251	79638
WR0528	38	233	115	2022	5046B	0 86	421122	64594	149161	199550	-2897	79977
WR0529	38	236	115	2050	5052B	0 92	421127	64553	149493	199555	-2519	80343
WR0530	38	239	115	2076	5057B	0 97	421132	64515	149906	199559	-2064	80786
WR0531	38	241	115	2104	5065B	0 114	421135	64474	150390	199562	-1505	81334

END OF LIST



EXPLANATION

BLOCK 1 CBA (Y) & REGIONAL (————)

BLOCK 2 RESIDUAL GRAV: OBSERVED VALUES (INTERPOLATED) (X)
CALCULATED FROM MODEL ( )

BLOCK 3 ELEVATION: STATION ELEVATIONS (Y) & IDENTIFICATION (GC-0110)
INTERPOLATED SURFACE ELEVATIONS ( )
MODEL OF BEDROCK SURFACE ( )

BLOCK 4 SUGGESTED GEOLOGICAL STRUCTURE ( )
DENSITY VALUES (ρ=2.3) g cm^3
DISTANCE SCALE 1:125,000

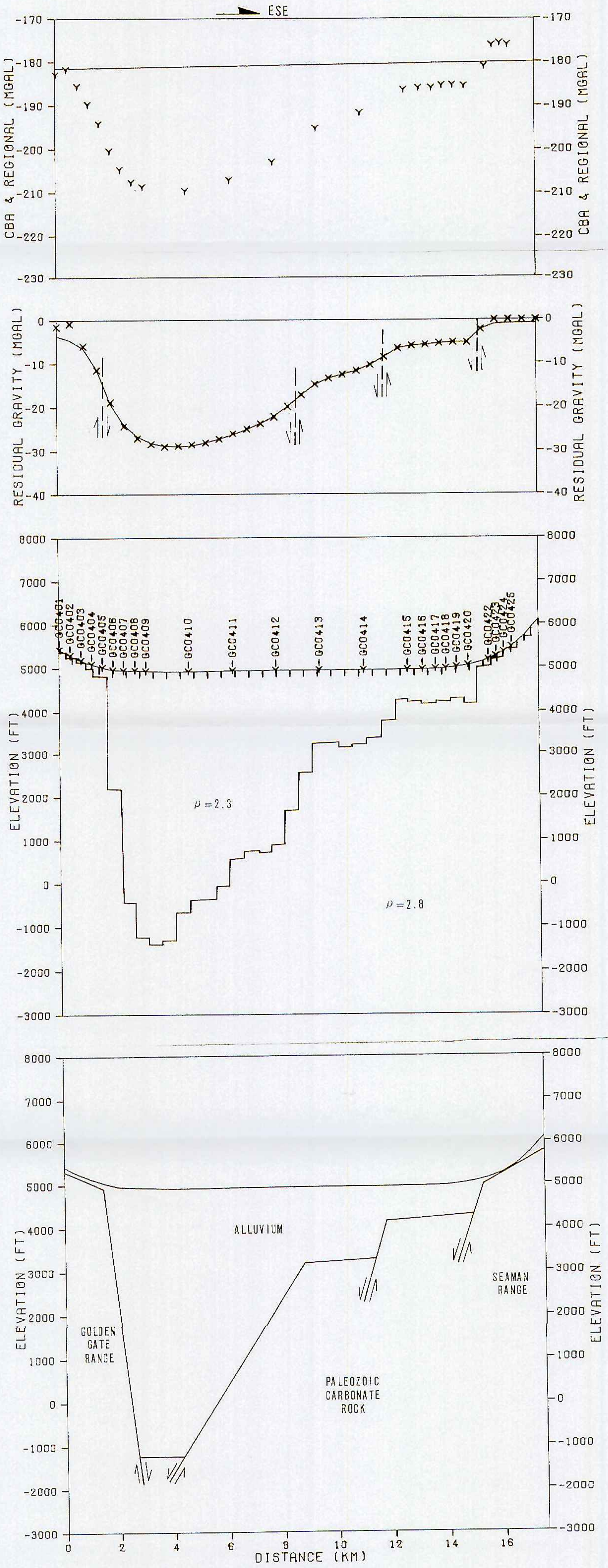
— — — GRAVITY INTERPRETED FAULT LOCATION

INTERPRETED GRAVITY PROFILE WR-5
COAL VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 3

FUGRO NATIONAL, INC.



HORIZONTAL SCALE 0 5 10 15 20 25 30 KILOFEET
0 2 4 6 8 10 KILOMETERS

VERTICAL SCALE 0 200 400 600 800 1000 METERS
0 1000 2000 3000 FEET

5X VERTICAL EXAGGERATION

EXPLANATION

BLOCK 1 CBA (Y) & REGIONAL (———)

BLOCK 2 RESIDUAL GRAV: OBSERVED VALUES (INTERPOLATED) (X)
CALCULATED FROM MODEL (———)

BLOCK 3 ELEVATION: STATION ELEVATIONS (Y) & IDENTIFICATION (GC-0110)
INTERPOLATED SURFACE ELEVATIONS (———)
MODEL OF BEDROCK SURFACE (———)

BLOCK 4 SUGGESTED GEOLOGICAL STRUCTURE (———)
DENSITY VALUES (ρ=2.3) g cm^3
DISTANCE SCALE 1:125,000

— — — GRAVITY INTERPRETED FAULT LOCATION

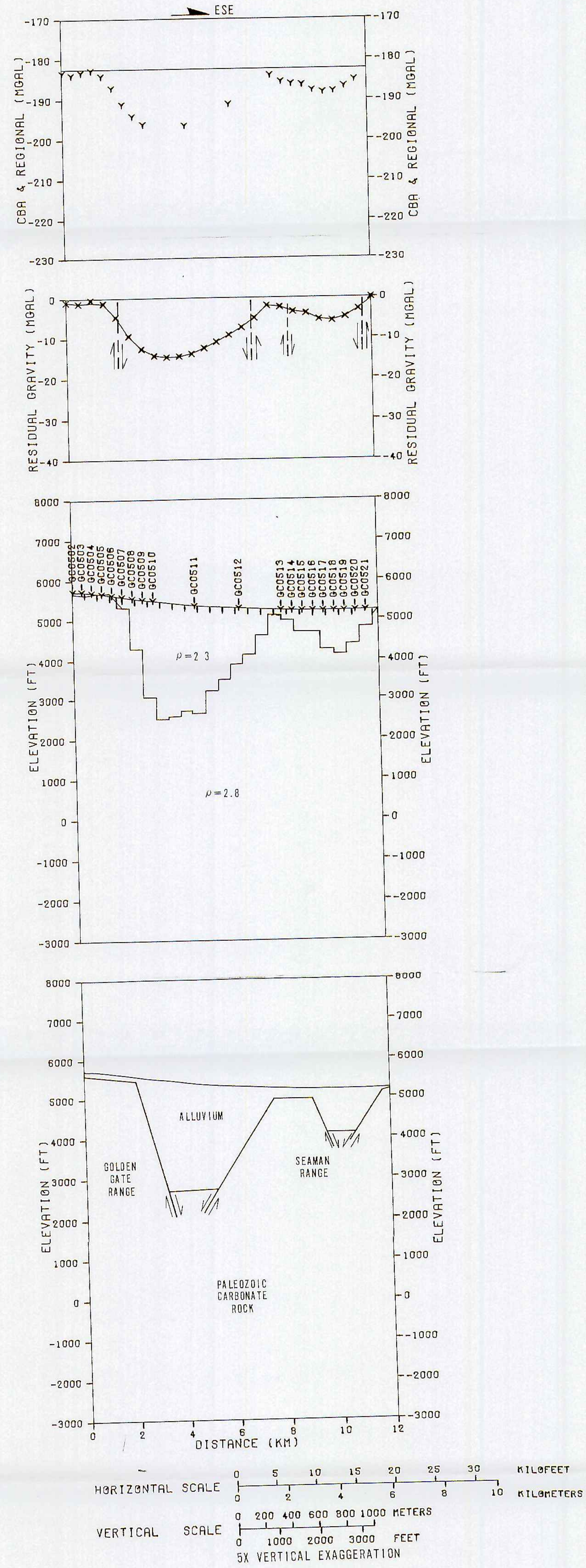
INTERPRETED GRAVITY PROFILE GC-4
COAL VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 4

FUGRO NATIONAL, INC.

30 MAY 80



EXPLANATION

BLOCK 1 CBA (Y) & REGIONAL (———)

BLOCK 2 RESIDUAL GRAV: OBSERVED VALUES (INTERPOLATED) (X)
CALCULATED FROM MODEL (———)

BLOCK 3 ELEVATION: STATION ELEVATIONS (Y) & IDENTIFICATION (GC-0110)
INTERPOLATED SURFACE ELEVATIONS (———)
MODEL OF BEDROCK SURFACE (———)

BLOCK 4 SUGGESTED GEOLOGICAL STRUCTURE (———)
DENSITY VALUES (ρ=2 3) g cm^3
DISTANCE SCALE 1:125,000

— — — GRAVITY INTERPRETED FAULT LOCATION

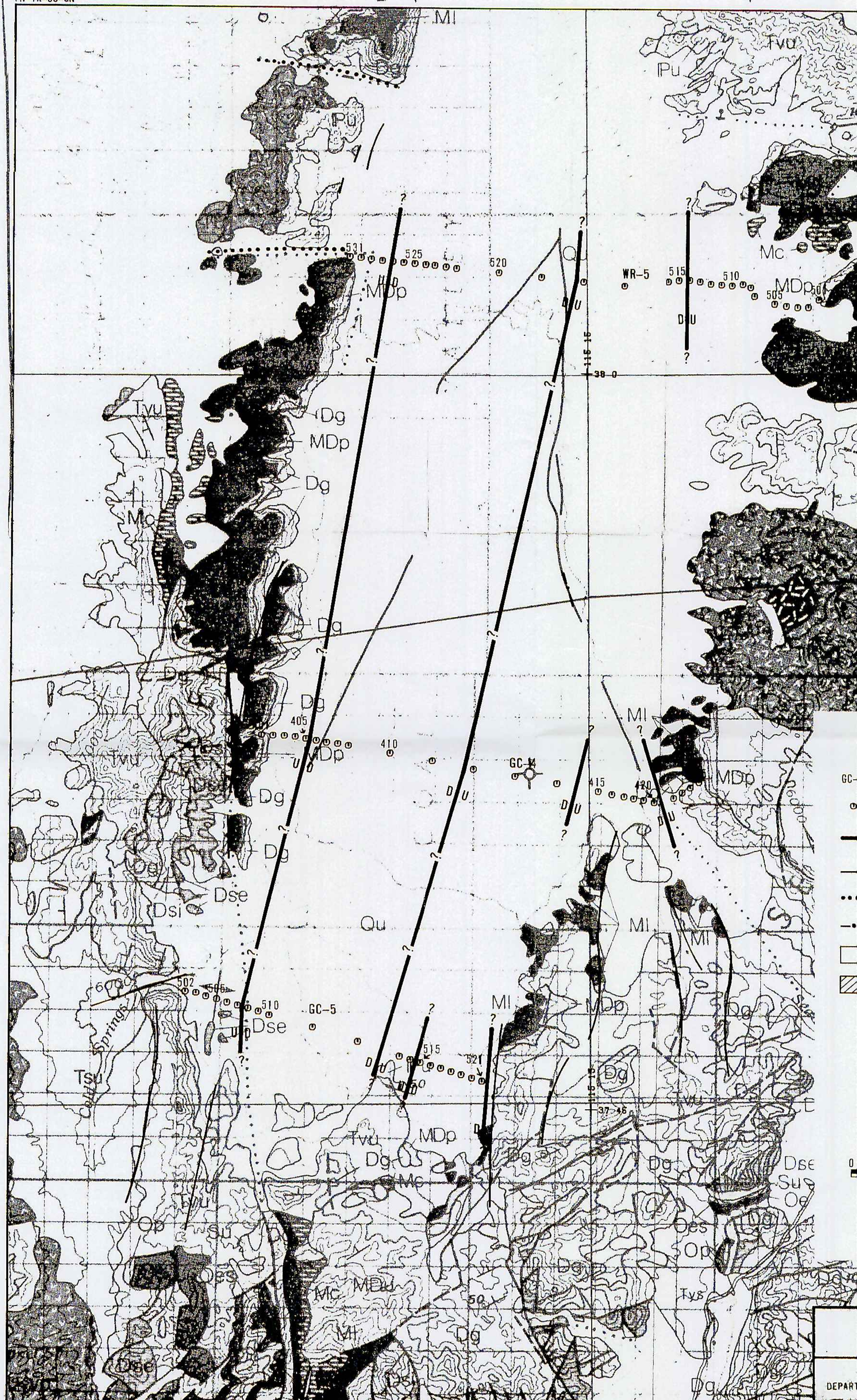
INTERPRETED GRAVITY PROFILE GC-5
COAL VALLEY NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE 5

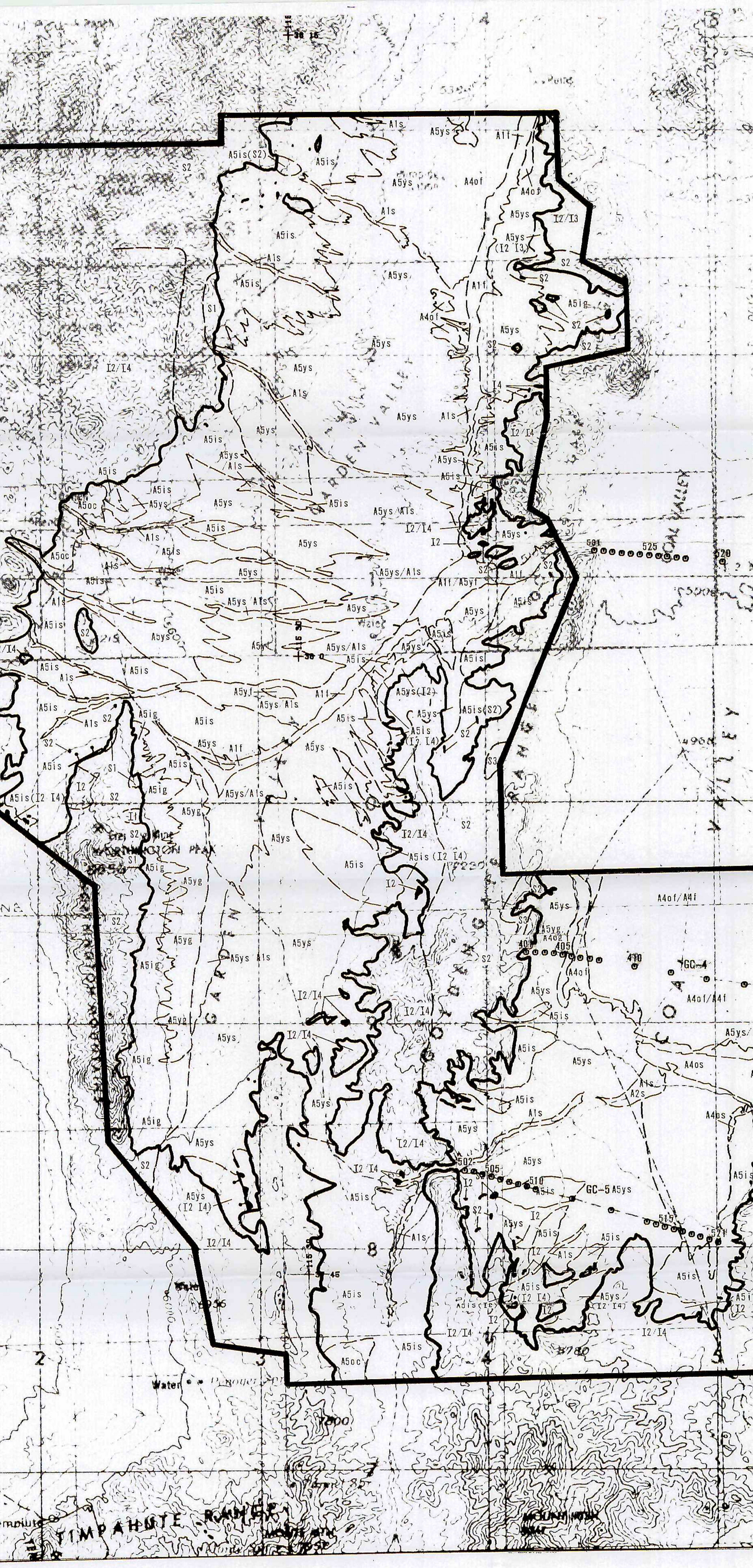
FUGRO NATIONAL, INC.

FN-TR-33-GN



30 MAY 80

3



EXPLANATION

SURFICIAL BASIN-FILL UNITS

A1f / A1s	Younger Alluvial Deposits - Modern stream channel and floodplain deposits of: A1f, clay (CL) and s silt (ML) and A1s, silty sand (SM).
A2s	Older Fluvial Deposits - Older stream channel and floodplain deposits in terraces composed of silty
A4f	Younger Playa Deposits - Active playa deposits of sandy silt (ML)
A4of / A4os / A4og	Older Playa and Lacustrine Deposits - Inactive playa, older lake bed, and abandoned shoreline depos A4of, sandy silt (ML); A4os, sand and gravelly sand (SP); and A4og, sandy gravel (GP)
A5yf / A5ys / A5yg	Younger Alluvial Fan Deposits - Active, younger alluvial fan deposits of: A5yf, sandy silt (ML); A5ys, weakly cemented silty sand and gravelly sand (SM); and A5yg, weakly cemented sandy gravel (G
A5is / A5ig	Intermediate Alluvial Fan Deposits - Inactive, intermediate-age alluvial fan deposits of: A5is, moderately cemented silty sand and gravelly sand (SM); and A5ig, sandy gravel (GM)
A5oc	Older Alluvial Fan Deposits - Older, highly eroded alluvial fan deposits of moderately cemented gravelly sand with greater than 30 percent boulders and cobbles

ROCK UNITS

Igneous (I)

I1	Granite
I2	Rhyolite, quartz latite, dacite, and andesite
I3	Basalt
I4	Tuff, tuffaceous sediment, and ignimbrite

Sedimentary (S)

S1	Orthoquartzite
S2	Limestone and dolomite, locally cherty, with interbedded shale and sandstone
S3	Shale, with interbedded limestone and sandstone

A5ys/A5is Combination of geologic unit symbols indicates a mixture of either surficial basin-fill or rock ur inseparable at map scale

A5is(I2) Parenthetic unit underlies surface unit at shallow depth.

SYMBOLS

- Contact between rock and surficial basin-fill units
- Contact between surficial basin-fill or rock units
- Fault, trace of surface rupture of faults offsetting surficial basin-fill deposits, ball on downt
- Gravity Station

NOTES:
1. Surficial basin-fill units pertain only to the upper several feet of soil Due to variability of surficial and scale of map presentation, unit descriptions refer to the predominant soil types. Varying amounts of types can be expected within each geologic unit
2. The distribution of geologic data stations is presented in Volume VI, Drawing 1. A tabulation of all stat and generalized description of all geologic units is included in Volume VI, Section 1.0
3. Geology in areas of exposed rock from: Kleinhampl and Ziony (1967), Tschanz and Pampeyan (1970).