GEOPHYSICAL INVESTIGATIONS IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA

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By
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CONTENTS

ABSTRACT

Magnetic and gravimetric surveys were conducted in a portion of the Humboldt River Valley near Winnemucca, Nevada, as a preliminary phase of a geophysical program authorized under the State of Nevada's Humboldt River Research Project. The primary purpose of these surveys was to determine the possibility of delineating buried basalt flows using magnetic methods and to obtain the depth of basin sediments using gravity data. Subsequently, the gravity investigation was extended to determine whether a subsurface barrier exists across the outlet of the Humboldt River drainage in the vicinity of Rose Creek.

The magnetometric surveys show that buried basalt flows can be delineated, that qualitative depth calculations are possible, and that in a detailed survey, it is often possible to correlate subsurface structure with surface geology. A detailed magnetometer survey of the Kern Ranch suggests that the exposed basalts in those localities do not dip continuously beneath the alluvium and the "broken rock" described by the driller's log of the Kern well may not be basalt.

On the basis of gravity data, the basin sediments in Grass Valley are estimated to be over 4600 feet thick, and the sediments in the Rose Creek area at least 1200 feet thick. Variations in thickness of the valley fill, as determined by combined magnetic and gravimetric surveys, reflect the structure and configuration of the basement in the areas mentioned above.

The gravity survey south of Rose Creek gives strong evidence for a subsurface barrier across the Humboldt River drainage. A low may exist in the center of the barrier, but more geophysical data is necessary for a positive interpretation.

INTRODUCTION

In the spring of 1959, a program designated the Humboldt River Research Project was authorized by the State of Nevada to investigate the ground water resources of a section of the Humboldt River near Winnemucca, Nevada. One phase of the program provided for geophysical surveys (including magnetic and gravimetric methods) to be followed by drilling.

This first portion of the project covers the Humboldt River Valley proper and the adjacent drainage area from the Rose Creek to the Comus gauging station (see Fig. 1).

The primary purpose of the geophysical survey was to determine the possibility of delineating volcanic flows (basalt) beneath valley fill utilizing magnetometer data correlated with data from wells producing from fractured basalt and from surface exposures of basalt. Also, to provide information for other phases of the research program, a gravimetric and magnetic survey to determine the depth of the valley fill was made across Grass Valley and across the Humboldt River above its junction with Rose Creek.

Subsequently, investigators of other phases of the project discovered a spring and outcrops west of Rose Creek. This evidence, plus the fact that the Rose Creek gauging station shows more water than the upstream Comus station, indicates a possible barrier across the outlet for the Humboldt River drainage. The geophysical survey was extended to include this area in the hopes of determining the structure and configuration of the basement.

Field work was begun in May, 1959 and completed in September, 1959. There has been no previous (published) geophysical work in the area, but the geology and ground water have been investigated.

Figure 1 - Index map showing approximate location of area investigated

This report describes the geophysical work accomplished under this program in the first year and presents the geophysical data and the geological interpretation thereof.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Professor J. I. Gimlett, Geophysicist, Nevada Bureau of Mines, for advice, criticism and field assistance during the course of the geophysical investigation and the preparation of this report. Credit is due also to the members of the staff of the Nevada Bureau of Mines for their aid and cooperation, in particular to Delbert Brix, Field Assistant; and to Keros Cartwright and Emil Onuschak, graduate students at the University of Nevada, for detailed geologic data and valuable assistance in the field.

PHYSIOGRAPHY AND DRAINAGE

The area studied includes parts of Paradise and Grass Valleys, lying north and south of the Humboldt River, respectively, and an adjacent portion of the Humboldt River Valley. These north-south trending depressions are bounded almost entirely by mountains that are typical of the block-faulted ranges found in the Basin and Range province of Nevada.

The highest range in the area, the Santa Rosa Range, (maximum altitude 9754 feet above mean sea level) borders the west side of the area and extends northward to the Nevada-Oregon boundary, broken occasionally by low passes. Winnemucca mountain, in the southern portion of this range, has been subjected to an uninterrupted cycle of erosion and is rounded and subdued, characteristic of a mature mountain. Northward, in the highest parts of the range, there is evidence that Pleistocene glaciers have superimposed alpine features on the mature stage.

To the east of Grass Valley is the Sonoma Range (highest altitude 9421 feet above mean sea level), a fault block also in the state of maturity, with a greater amount of faulting on the western front. Pleistocene glaciation again has brought about local changes in the higher reaches (Robinson, Loeltz, and Phoenix, unpublished manuscript).

South of the area the East Range separates Grass Valley from Buena Vista Valley and the northeast portion of the Humboldt River Valley. The highest peak in the vicinity is Dun Glen Peak (7430 feet above mean sea level).

Most of the ranges have a very thin soil mantle and vegetation is sparse. They are drained by small perennial and intermittent streams. The Little Humboldt River drains Paradise Valley but even during years of high run-off the channel is dry beyond an area of sand dunes at the south end of the valley. In Grass Valley, which is tributary to the Humboldt River Valley, water never reaches the Humboldt River as surface flow, although an incised channel indicates that it did in the past.

The Humboldt River drains the entire area from northeast to southwest. It is a mature river with meander scrolls, cut-offs and ox-bow lakes within the confines of its flood plain, which is bordered by terraces as high as 50 feet. The river has reached grade but has sufficient energy to transport its load (gradient 2 feet per mile)(Robinson, et al, unpublished manuscript).

Large alluvial fans have been deposited at the base of the ranges opposite canyon mouths and extend several miles toward the valley floor. Level lines for gravimetric surveys indicate gradients as high as 300 feet per mile (base of the Sonoma Range) but the average is about 200 feet per mile. The fans have rolling surfaces near the mountain fronts with concave profiles grading smoothly into the valley troughs. They are locally marked by shore-line terraces of the Pleistocene Lake Lahontan.

A 15 foot high fan scarp borders the floor of Grass Valley near the base of the Sonoma Range north of Sonoma Canyon. Farther north, opposite Thomas Canyon, a pediment lies at the foot of the range and is capped by basalt at its most western extension.

Low volcanic mesas are found near the water gap of the Little Humboldt River at its confluence with the Humboldt River. Lake terraces adjoin the basalt mesas and extend north along the Little Humboldt River until they disappear beneath a belt of sand dunes that have migrated across the channel, filling it with sand (Robinson, et al, 1949).

GEOLOGY

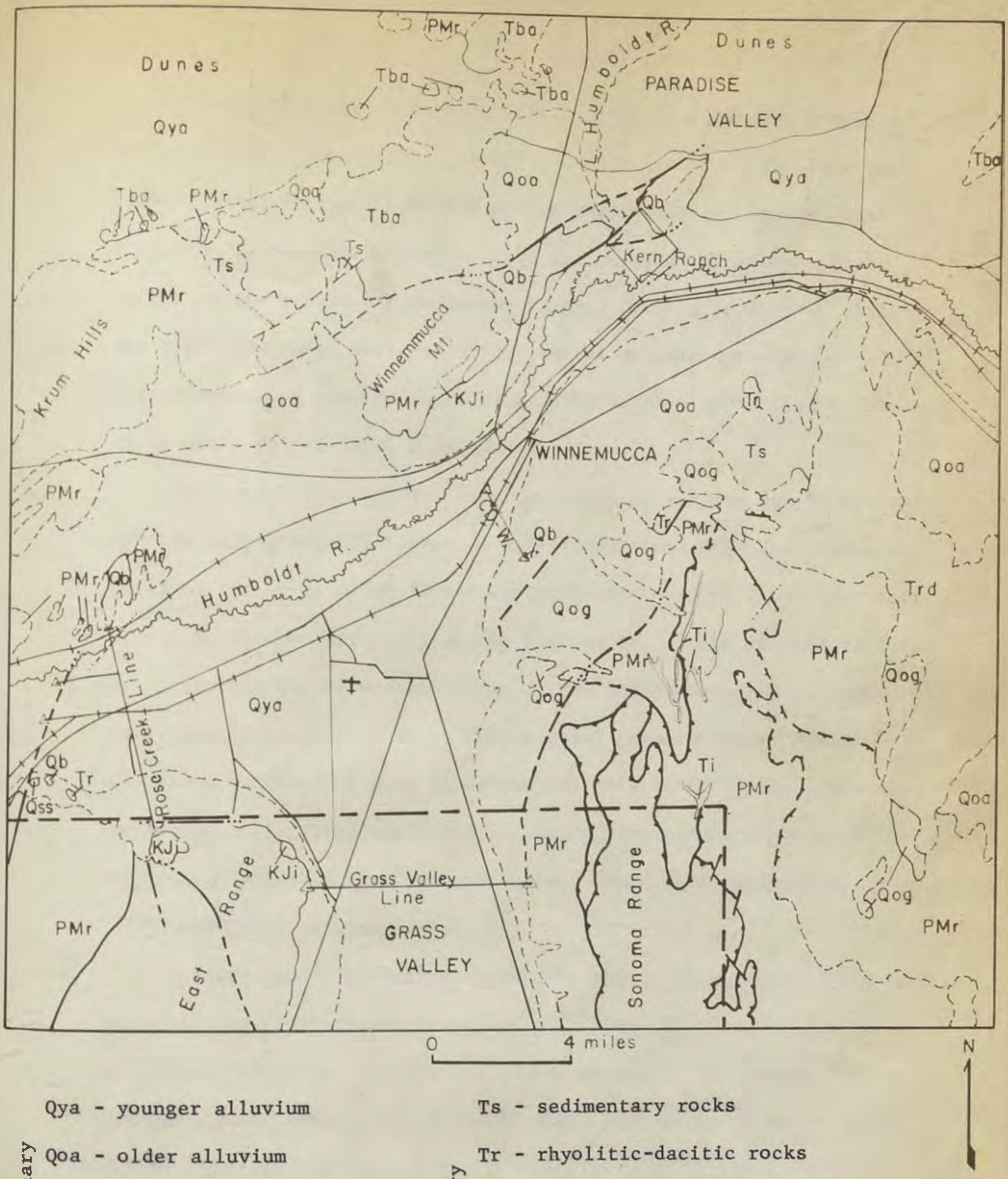
Introduction

The geology of the Winnemucca quadrangle has been mapped by Ferguson, Muller, and Roberts (1951) and R. Willden (in preparation). Interpretations have been drawn largely from their reports and from detailed work by investigators of other phases of the Humboldt River Research Project.

Since the detailed geology of the ranges bordering the area is not within the scope of this report, only a general summary is presented. The rock units have been divided into sections based on physiographic rather than stratigraphic grounds. Structural and stratigraphic relationships are incorporated in these sections commensurate with their importance to the report.

The rocks exposed in the area range in age from Cambrian to Recent (see Fig. 2). In general, the older Paleozoic and Mesozoic rocks form the ranges which are typical tilted fault blocks of the Basin and Range Province. Tertiary and Quaternary flows flank the ranges and overlie Tertiary sediments at the bases of the mountains. The valleys are floored and underlain by poorly consolidated, continental sediments of Tertiary and Quaternary age. The basement, it is believed, consists of indurated sediments and crystalline igneous rocks similar to those exposed on the bordering mountain ranges (Robinson, et al, unpublished manuscript).

The older sedimentary rocks have been highly folded and their relationships complicated by repeated overthrusts of large displacement. Local emplacement of Jurassic (?) and Cretaceous granitic rocks was followed by normal faulting which has continued to the present time.



Quaternary
Qya - younger alluvium
Qoa - older alluvium
Qog - older gravel deposits
Qb - vesicular olivine basalt

Tertiary
Ts - sedimentary rocks
Tr - rhyolitic-dacitic rocks
Tba - basaltic-andesitic rocks
Ti - intrusive rocks

KJi - Jurassic(?) and Cretaceous intrusive rocks

PMr - Paleozoic and/or Mesozoic rocks

Figure 2 Geologic map with locations of geophysical surveys.

Older Rocks

The pre-plutonic rocks have been strongly deformed by a series of large thrust faults which brought together rocks of the same age but different facies. Cambrian grits, sandstones and shales, with limestone lenses (Harmony formation) are exposed in a thrust plate in the northern part of the Sonoma Range. Ordovician cherts, slates, and argillites with interbedded quartzites are also present, as are undifferentiated Permian rocks consisting of altered siliceous volcanic rocks and a coarse local fanglomerate.

Triassic rocks crop out near the bases of all the ranges bordering the area. A small klippe of undifferentiated dolomite lies upon rocks of the lower plate facies (shallow-water deposits) of the Tobin thrust in the northern part of the East Range. Rocks of this facies also crop out on the western flank of the Sonoma Range in an overturned syncline plunging east, where they consist principally of shale and sandstone interbedded with limestone and massive dolomite. Only the uppermost units (Winnemucca and Raspberry formations) are exposed on Winnemucca Mountain and under the basalt louderback (defined by Davis, 1930) southeast of Winnemucca.

The Winnemucca formation exposed in the northern part of the East Range is mostly slate and quartzite with some limestone and is intruded by several masses of granite and quartz monzonite of Jurassic (?) or younger age. At Winnemucca Mountain, the upper Triassic units are intruded by Jurassic (?) diorite.

Tertiary Rocks

Eroded remnants of thick flows of rhyolitic lavas are exposed in Water Canyon and south of Harmony Canyon. Several miles southeast, dikes of rhyolite porphyry cut through Paleozoic sediments (some dikes following thrust fault planes) and are associated with irregular pebble dikes consisting mainly of quartzite pebbles in a matrix of rhyolite (Ferguson, et al, 1951).

Tertiary sedimentary rocks are exposed on the pediment bordering the Sonoma Range east of Winnemucca. They consist principally of poorly consolidated conglomerates and sandstones and are overlain by volcanic flows of rhyolitic to dacitic composition. Northwest across the valley, tuffaceous sediments reportedly dip 30° southeast and underlie less steeply-dipping Quaternary basalt flows. Similar relationships were mapped in Grass Valley by Ferguson, Muller, and Roberts (1951). This evidence correlated with well data suggests that most of the valley floor may be underlain by Tertiary sediments. These include fairly thick sections of pre-Lahontan silts and clays, possibly of the Pliocene (?) Humboldt formation (Wilmarth, 1938).

Basalts

Basalt flows are important to this report because of their magnetite content. Tertiary basalt flows are quite extensive north of the area on the flanks of the mountains bordering Paradise Valley. On the west side of the valley, they dip 10° to 15° northeast and pass beneath the alluvium of the valley floor. On the east side the lava flows are flat-lying or dipping west. It is believed that the flows on the west may be the same as those appearing on the east (Robinson, et al, 1949).

No well data could be correlated with these flows so the geophysical investigation was directed toward the Quaternary basalts, although one magnetic line that was run from a flow north of Winnemucca Mountain (see Fig. 5B) indicates that Tertiary flows may be delineated beneath the valley fill.

Quaternary basalt flows form louderbacks north of Winnemucca at the confluence of the Little Humboldt River with the Humboldt River (near the Kern Ranch) and opposite the mouth of Grass Valley just north of the Hillyer Ranch on the Humboldt River. A small basalt cap is exposed directly east of the city dump and west of an old gravel terrace two miles south of Winnemucca. The basalt flows are cut by normal faults and most of them have been tilted by Basin and Range faulting. The basalt mesa northwest of the Kern Ranch is essentially flat-lying but dips slightly southeast at its eastern extremity. The flow northeast of the Kern Ranch dips 10° southeast and passes beneath the alluvium. The basalt flow north of the Hillyer Ranch dips 10° to 15° south, passing beneath the Humboldt River (magnetic and drill data, Hawley, J., personal communication).

The age of these basalts has not yet been determined but their relationships with Tertiary sediments and Lake Lahontan (Pleistocene) and younger sediments indicate a Quaternary, pre-Lahontan age.

Textures and structures of different basalt samples vary but the mineralogical composition is approximately the same. Thin-section study shows that the basalt is a vesicular olivine basalt. Abundant large phenocrysts of zoned olivine (altering to iddingsite and enclosing magnetite) are contained in an intergranular matrix of plagioclase laths, pyroxene and magnetite with subordinate amounts of granular olivine, ilmenite, apatite, and dark glass. Textures vary from porphyritic to vesicular, with amygdule fillings of zeolites and opal. The orientation of the plagioclase laths in some specimens shows flow lineation.

Valley Fill

The lower part of the valley fill probably consists of tilted, semi-consolidated Tertiary sediments with associated basalt flows.

The domestic and irrigation wells of the City of Winnemucca (36/38-19D1, 36/38-30CD1)[1] and a well (36/38-2B1) drilled on the Kern Ranch have penetrated subsurface flows within or near the terrace margin of the Recent flood plain of the Humboldt River. The well logs (see Table I) of the city wells show that fractured basalt was encountered approximately 490 feet below the land surface and that drilling stopped when basalt was penetrated. The Kern well continued drilling through "broken, brown rock" (251 feet) and stopped in "brown" rock (304-314 feet). No well data was available on sediments underlying the subsurface flows.

Silts and clays penetrated by well 39/39-24B2 in Paradise Valley from 294 to 800 feet were tentatively assigned to the Pliocene (?) Humboldt formation by Robinson, Loeltz, and Phoenix (1949). Well data from Grass Valley (see Table I) indicate similar silts and clays with occasional beds of sand and gravel. These sediments probably also represent the Humboldt formation (Robinson, et al, unpublished manuscript).

The data further show that the overlying material consists of Quaternary lake sediments (including the Pleistocene Lahontan sediments), except within the margins of the flood plain, where the upper 200-250 feet of sediments consists of stream or delta sands and gravels interbedded with some silts and clays.

Beach lines along the edges of alluvial fans indicate that alluvial material was deposited before the latest stage of the Pleistocene lake and has been accumulating up to the present time. The sediments in the alluvial fans are coarse and poorly sorted near the apex and finer and more evenly sorted near the lower edges.

[1] See Appendix for explanation of well numbers.

Lake Lahontan covered the valley floor during late Quaternary time and deposited a thin layer of silt and clay. Sections as thick as 60 feet have been exposed in some terraces (Cartwright, K., personal communication).

Geologic History (Late Tertiary and Quaternary)

The following sequence of geologic events has been suggested by Robinson, Loeltz, and Phoenix (1949) and modified by the author:

1. Miocene vulcanism resulting in the widespread distribution of rhyolite and other flow rocks (including basalt) with partly contemporaneous deposition of Tertiary sediments.

2. Tilting of the volcanic flows and sediments by Basin and Range faulting followed by the accumulation of the Humboldt (?) formation (probably Miocene-Pliocene) up to 2000 feet in some basins, accompanied by some vulcanism (Tertiary and Quaternary basalt). Climatic change or faulting indicated by thin beds of gravel in preponderance of clay, which may include pre-Lahontan Pleistocene lake sediments.

3. Change to an arid climate and dessication of lakes prior to Lake Lahontan--major development of the Humboldt River drainage system; continued Basin and Range faulting and tilting of the basin sediments; antecedent down cutting by the Humboldt River through the Osgood Range and by the Little Humboldt River through the Hot Springs Range and the Quaternary basalt flows, continued downcutting into basin deposits; beginning of alluvial fans (earlier deposited as pre-Lahontan shoreline sediments).

4. First major cycle advance of Lake Lahontan, accompanied by deposition of sediments (mostly sand and gravel in the Humboldt and Little Humboldt River channels. Deposition of small amounts of lake

sediments in the floor of Grass Valley and lower Paradise Valley, cutting of lake shore lines, continued alluvial fan deposition and probably local Basin and Range faulting.

5. Retreat and dessication of Lake Lahontan, continued alluvial fan deposition.

6. Second major cycle advance, aggradation of the Humboldt and Little Humboldt Rivers; some lake sediments deposited.

7. Retreat of Lake Lahontan, development of meander scrolls and oxbow lakes in the Humboldt River flood plain; sand dunes; late Basin and Range faulting (fan scarps); continued deposition of alluvial fan debris.

GEOPHYSICAL PROGRAM

In a bulletin on the ground water resources in Paradise Valley (Robinson, et al, 1949), the authors reported that several wells were producing from fractured lava rock (basalt) and suggested that the basalts beneath the valley fill are related to slightly dipping surface flows. The flows could be expected to follow the pre-Lahontan drainage and occupy the low areas of the former topography.

Basalts possess a magnetic susceptibility considerably greater than that of the valley fill, disturbing the normal distribution of the earth's magnetic field. The resulting anomalies may possibly be correlated with underlying basalt masses. Polarization effects, igneous intrusions and mineralized zones, of course, can complicate the magnetic data and hence the interpretation.

Initially, it was decided to try to trace the basalt from surface exposures to wells that were producing from basalt using a magnetometer. Only two such wells were isolated enough from extraneous (artificial) magnetic fields (produced by power lines, pipes, fences, railroad tracks, etc.) to permit surveying. The proximity to surface basalts of the well (36/38-2B1) at the Kern Ranch offered a good test site for detailed work. A line was run from a basalt flow to the city well (36/38-30CD1) near the cemetary and from the basalt louderback at the Hillyer Ranch 10 miles southeast of Winnemucca.

The difference between the densities of the valley fill sediments and the underlying indurated Paleozoic and Tertiary rocks is enough to be able to distinguish their effects on the earth's gravitational field. Any variation should reflect the topography of the basement rocks. Combined gravimeter and magnetometer lines were established across Grass Valley and across the Humboldt River near Rose Creek to determine basement structures and to obtain depth estimates for use in determining the size of ground water reservoirs.

Gauging stations at Rose Creek and Imlay on the Humboldt River measured an increase in flow compared to data from the Comus gauging station, 35 miles upstream. It was suspected that the increase was caused by underground flow from the Grass Valley drainage or from a subsurface constriction above the Rose Creek station. Field evidence supported the barrier hypothesis, so the gravimetric survey was extended to determine the structure and configuration of the basement in that area.

Instrumentation

The magnetic observations were made with a standard Askania torsion magnetometer and a Sharpe dip needle. The magnetometer has a temperature-compensated system adjusted to a sensitivity of 232.1 gammas per degree. (100,000 gammas = 1 oersted, the C.G.S. unit of magnetic field intensity). The mean error of the observations was of the order of magnitude of 2.5 gammas, well within the accuracy of the corrections which had to be applied in the reduction of the field data. The dip needle was "zeroed" and the reading taken on the swing. The sensitivity of the dip needle as determined from a calibration curve was approximately 80 gammas per degree. Readings could be repeated to one degree.

The gravimetric observations were made with a portable Worden "Educator" gravity meter with a sensitivity of 0.4657 milligal per division. (1000 milligals = 1 cm. per second per second). The average error of the observations was ± 0.1 mgal. A Zeiss self-leveling level was used to measure elevation changes and the error at any station should be less than 0.5 foot.

Field Procedure

Base stations were selected and a base line established by transit and tape. Stakes were placed at 500 foot intervals and side lines established for the magnetic survey at the Kern Ranch. Magnetic readings were taken at paced intervals of 100 feet, except on part of the Grass Valley line, where the regularity of the magnetic data permitted readings at 500 foot intervals.

All gravity observations were taken at 500 foot intervals. A rapid and efficient method of survey on relatively flat ground was to take gravity readings while running the level lines. Vertical control was established from bench marks along railroads and highways and usually dictated where gravity lines were to start, as time and field assistance were limited. Wherever possible, gravity lines were run in an east-west direction to eliminate corrections for latitude.

Maps made by the Army Map Service and the U. S. Geological Survey, as well as aerial photographs, were available for all of the area surveyed. In a total of 90 days actually spent in field work, 2793 magnetic and 141 gravity observations were made.

Reduction of field data

The earth's magnetic field intensity varies from hour to hour at any given point (diurnal variation). This variation, though roughly repeated daily, is not regular or predictable with any degree of accuracy. The magnetometer, though temperature-compensated, would also drift due to the high temperature range (a 50° daily temperature range was not uncommon). Both of these variations may be determined by repeating observations at a base station at intervals not exceeding 2 hours and plotting a combined drift-diurnal curve from the data. After this correction was applied, all readings were made relative to one base station and converted to units of magnetic intensity (gamma) by multiplying by the calibration constant. (All secondary base stations were tied to one base by the method of "loops").

The gravimetric data were corrected for tidal variation, instrument drift, elevation, latitude and terrain departures. The tidal variation and instrument drift were incorporated into a single drift curve and determined in the same manner as for the magnetometer. The Worden gravimeter used on this survey was exceptionally drift free.

The gravitational force at any point varies with the distance of that point from the center of the earth. Therefore, the elevation of the point has a definite influence on the observed value of gravity (other factors remaining constant). This elevation correction consists of two parts, the free-air and Bouguer corrections. The free-air correction treats the station as though it were a point in space at a given elevation above sea level (or any local datum) and assumes a theoretical decrease in gravity of 0.09406 milligal for each foot increase in elevation (Nettleton, 1940). The Bouguer correction accounts for the additional downward pull of the rock material between the station and sea level. It assumes that this material can be approximated by an infinite homogeneous horizontal slab whose thickness is the difference between the elevation of the station and the datum. With this assumption the Bouguer correction per foot of elevation (always negative) is given by 0.01276 milligal times the density of the rocks. Assuming an average density for crustal rocks of 2.67 gm/cm^3 (Thompson, 1958), the Bouguer correction becomes (-)0.03407 milligal per foot. Combining the free-air and Bouguer corrections (since both are directly proportional to elevation), the final elevation correction is 0.06 milligal times the change in elevation in feet. For this survey the datum plane used was not mean sea level but equal to the elevation of the base station (USC&GS bench mark C-7). Since the probable error in elevation of the stations is 0.5 foot, error due to elevation inaccuracies is on the order of 0.03 milligal, which is smaller than the reading error.

Due to the rotation and to the spheriodal shape of the earth, gravity gradually increases (by 5.17 gals.) from the equator to the poles. The latitude correction accounts for any change in gravity due to horizontal displacement in a north-south direction. For the latitude of this survey ($\phi = 41°$) the variation is 0.12 milligal per 500 feet.

In areas of reasonably level topography, the Bouguer correction gives a sufficiently accurate approximation of the included mass effect. But a correction is needed to compensate for local relief at the ends of the Grass Valley line. This correction, called the terrain correction, accounts for departures of the topography from the horizontal slab of infinite extent assumed in the Bouguer correction.

The terrain correction was computed out to zone L for various stations by using a Hammer (1939) terrain correction chart (constructed to the proper scale). Interpolated values were used for correcting intermediate stations.

All corrections applied to readings (magnetic and gravity) reduce the geophysical data to an arbitrary geophysical datum. Any variations in intensity are classed as anomalies and indicate (ideally) changes in the structure, configuration or character of the subsurface rocks.

RESULTS OF THE GEOPHYSICAL SURVEY

The results of the corrected geophysical data are presented in the form of profiles and plan maps to facilitate interpretation. Fig. 2 illustrates the general geology and geographical location of the geophysical profiles. Combined magnetic and gravimetric profiles of the Rose Creek and Grass Valley lines were plotted for the purpose of comparing the results of the different methods.

In both methods the instruments measure relative changes in the vertical intensity of the natural force investigated. In either case, the effect of a unit mass (gravity) or unit pole (magnetic) varies inversely as the square of its distance from the observation point and directly as the cosine of the vertical angle between the point and the unit mass or pole. The measured intensity at any station represents the sum of the effects of all the unit masses or poles below and around the station. Thus, it can be seen that small, near-surface masses may produce anomalies equal in magnitude to those caused by much larger masses at greater depth. However, the sharpness of the anomaly and its areal extent are good indications as to the nature and depth of the masses. A sharp, local anomaly indicates a small, shallow mass. Good examples are the anomalies between stations 41 and 43 and stations 45 and 48 (Fig. 3K). Magnetite stringers in the underlying basalts (depth < 200 feet) are a possible cause of these anomalies (Heiland, 1946).

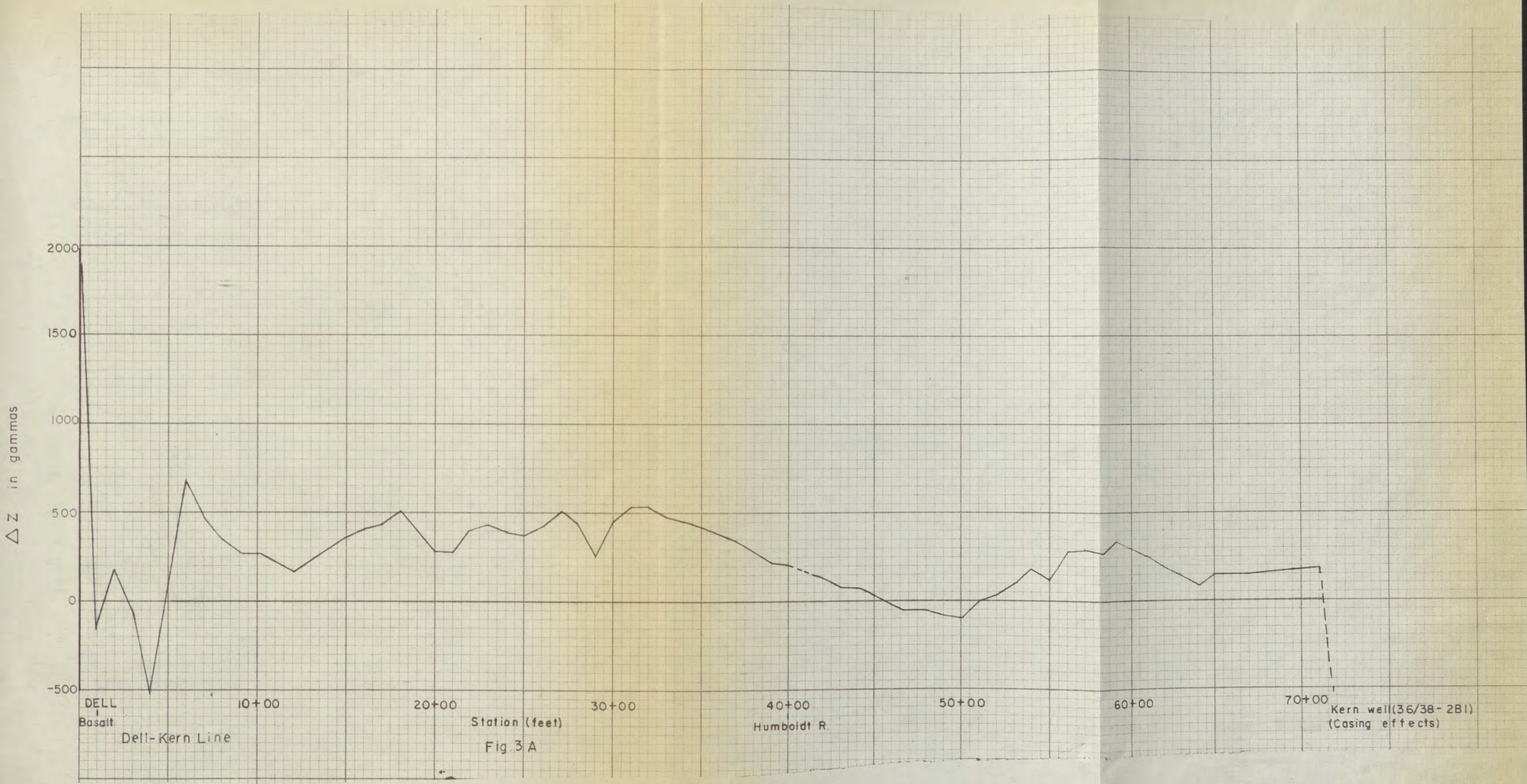
Magnetic Interpretation

The interpretation of magnetic data is inherently more complicated than that of gravimetric data because the property of a rock (polarization) which determines its magnetic effects has magnitude and direction, unlike the corresponding property that affects the gravitational field, the density, which has magnitude only. In addition to the polarization induced by the earth's present magnetic field, many rocks exhibit a remanent or residual magnetism that may have a direction quite different from that of this field. Ordinarily, a knowledge of the susceptibility and remanent magnetization of the rocks would be necessary in the interpretation of magnetic data, but because of the high susceptibility contrast between basalt and valley fill, it is not important in this case.

For the purpose of this report, it is assumed that the polarization is in the same direction as the earth's magnetic field, although reversals of polarity do occur over some basalt flows (see Figs. 3K and 4B). The magnetic profiles have not been corrected for any regional anomaly because the local anomalies were so intense as to make elimination of the regional effect of secondary importance. The magnetic profiles over thick valley fill (Figs. 4A and 5A) are fairly smooth and have a value of about 150 gammas for the arbitrary datum used in this report. Figs. 4B and 3K are typical profiles over surface flows of basalt.

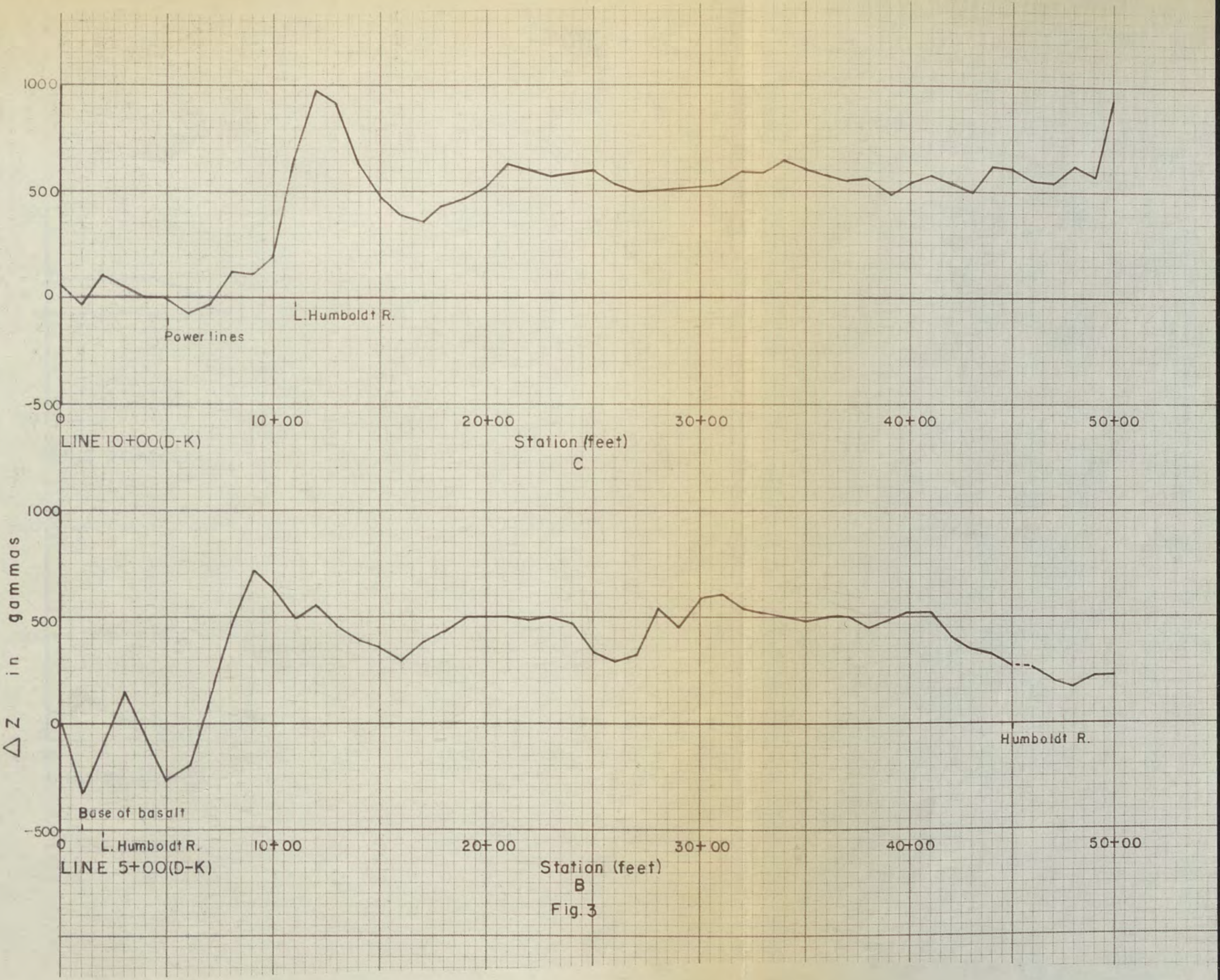
Fig. 5B is a profile of a preliminary dip needle survey that was run from a Tertiary basalt flow across the valley fill to Highway 95 (see Fig. 2). The positive anomaly east of the surface flow probably represents the continuation beneath the alluvium of the easterly-dipping basalt. This line demonstrates the fact that buried basalt flows may be detected even by an instrument of low sensitivity such as the dip needle.

Kern Ranch Area The delineation of buried lava flows by magnetic methods is most graphically illustrated by the magnetic iso-anomaly map (Plate I). A study of the map reveals a broad, positive anomaly



Dell-Kern Line

Fig. 3 A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-500
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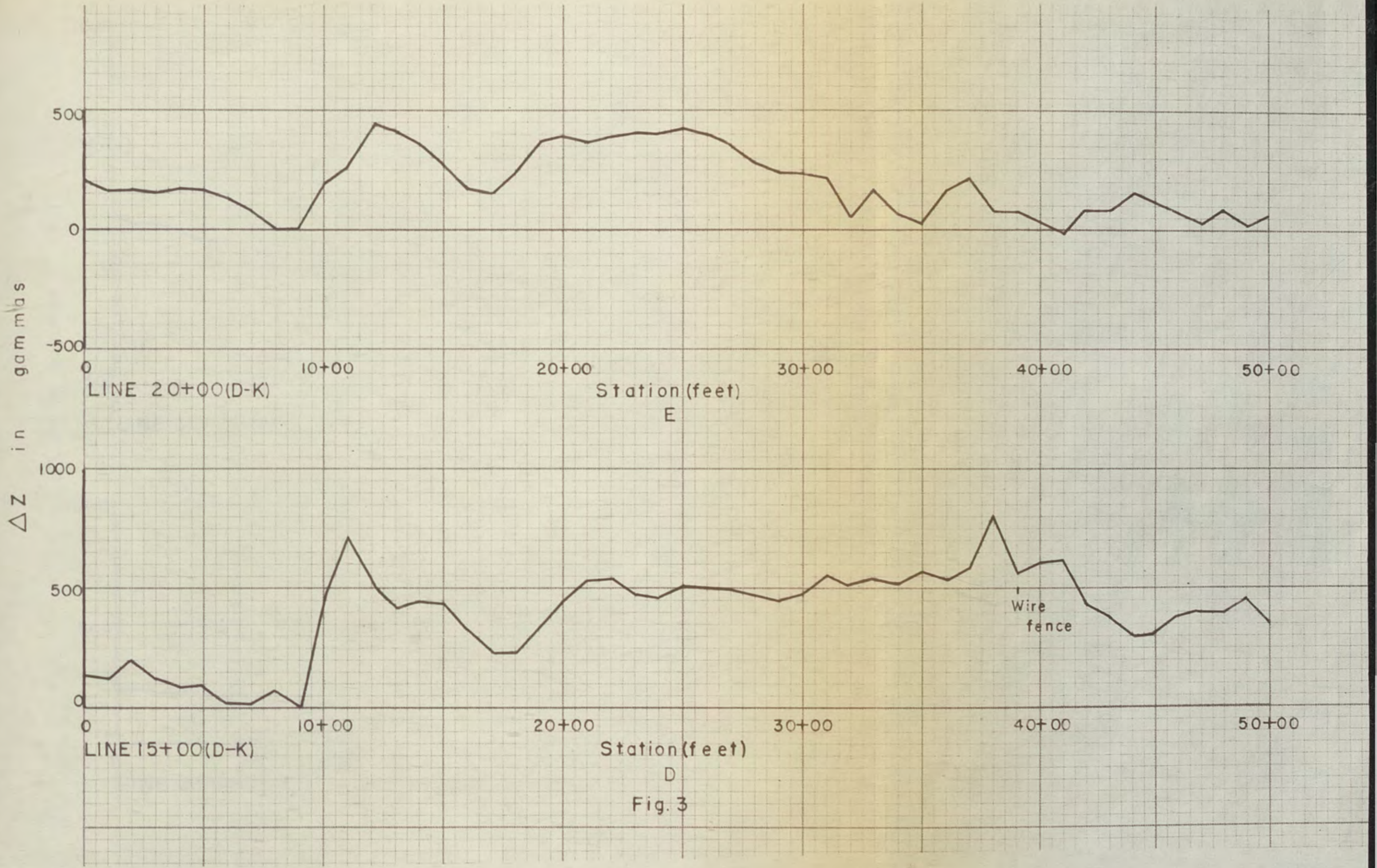
10+00
20+00
30+00
40+00
50+00
Power lines
L. Humboldt R.
LINE 10+00(D-K)
Station (feet)
C
ΔZ in gammas
1000
500
0
-500
0
10+00
20+00
30+00
40+00
50+00
Base of basalt
L. Humboldt R.
Humboldt R.
LINE 5+00(D-K)
Station (feet)
B

Fig. 3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0
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10+00
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50+00
LINE 20+00(D-K)
Station (feet)
E
ΔZ in gammas
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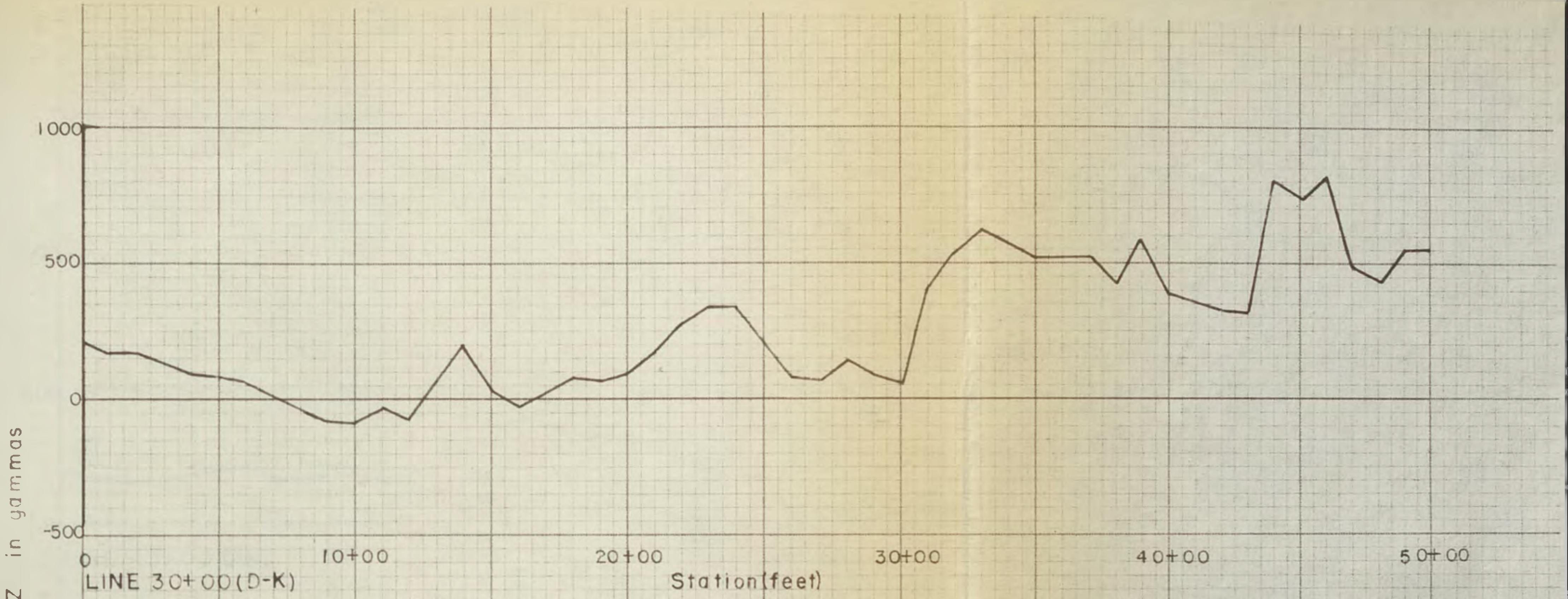
10+00
20+00
30+00
40+00
50+00
Wire fence
LINE 15+00(D-K)
Station (feet)
D

Fig. 3


△ Z in gammas
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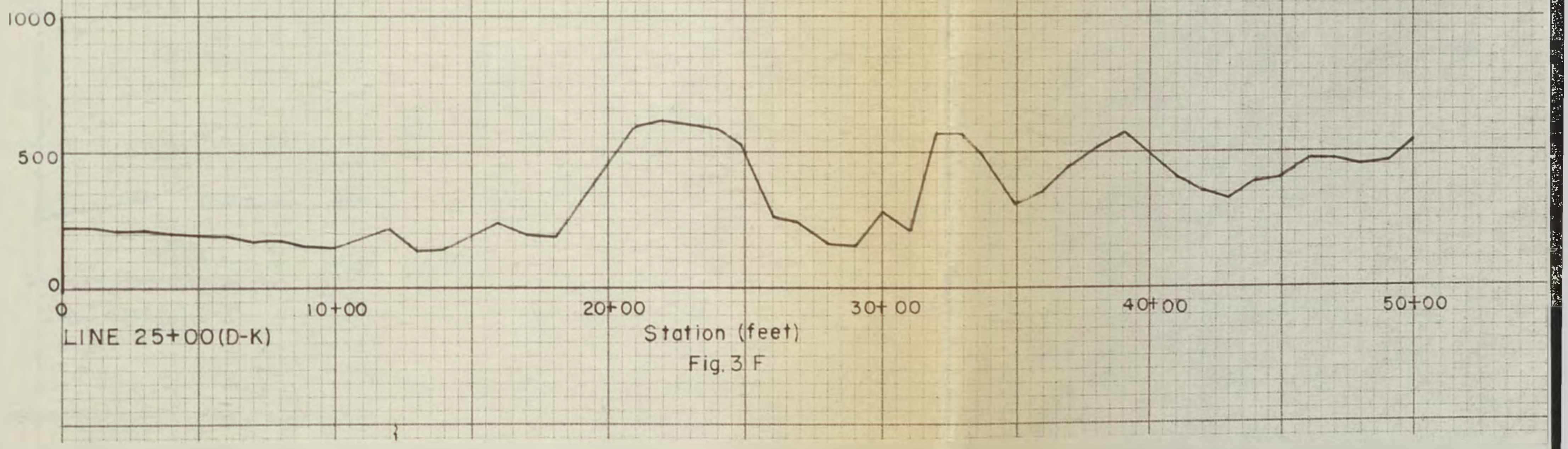
40+00
50+00
LINE 30+00 (D-K)
Station (feet)

G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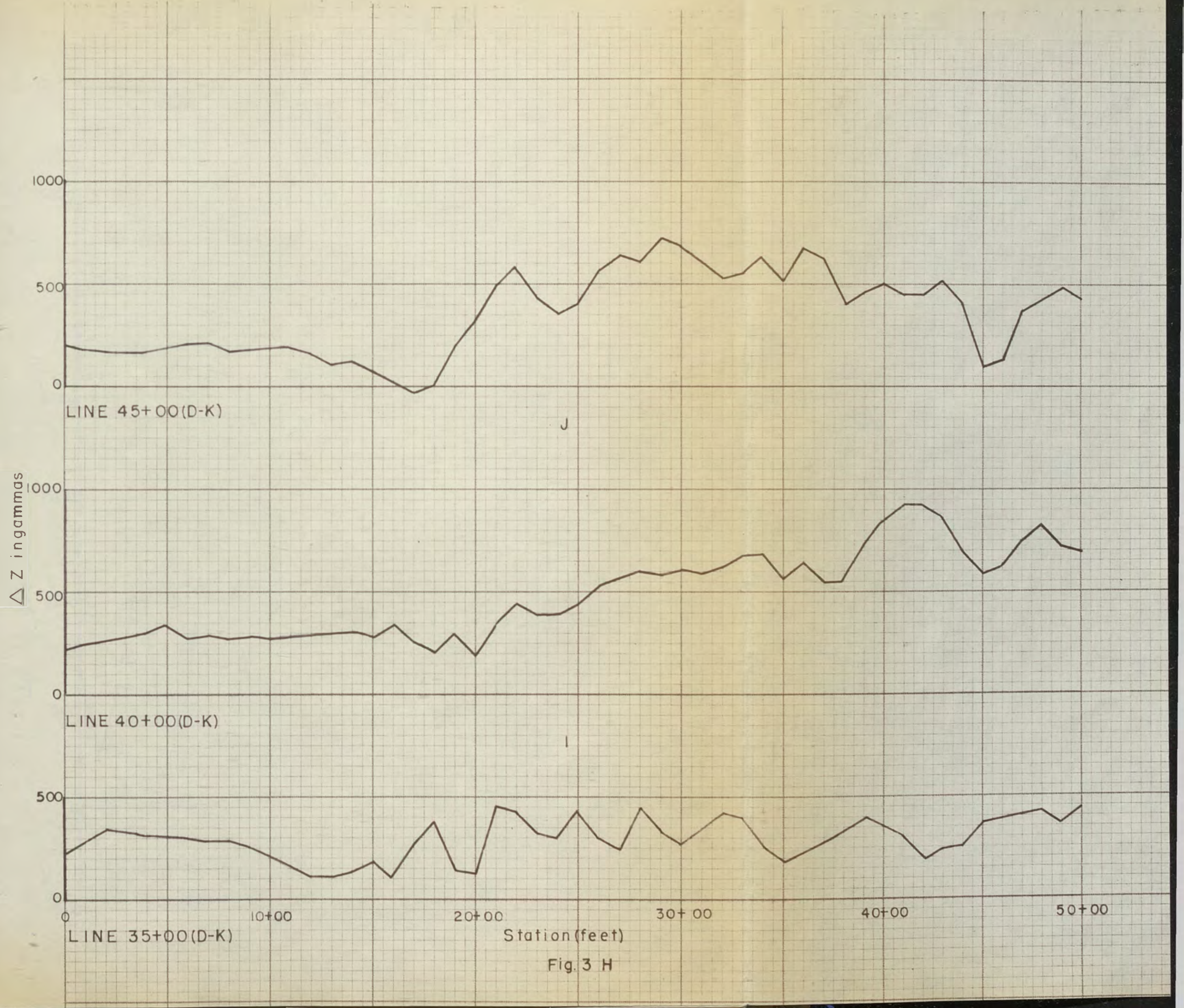
LINE 25+00 (D-K)
Station (feet)

Fig. 3 F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500
0
LINE 45+00(D-K)
J
1000
500
0
LINE 40+00(D-K)
I
500
0
0
10+00
20+00
30+00
40+00
50+00
LINE 35+00(D-K)
Station (feet)
△ Z ingammas

Fig. 3 H

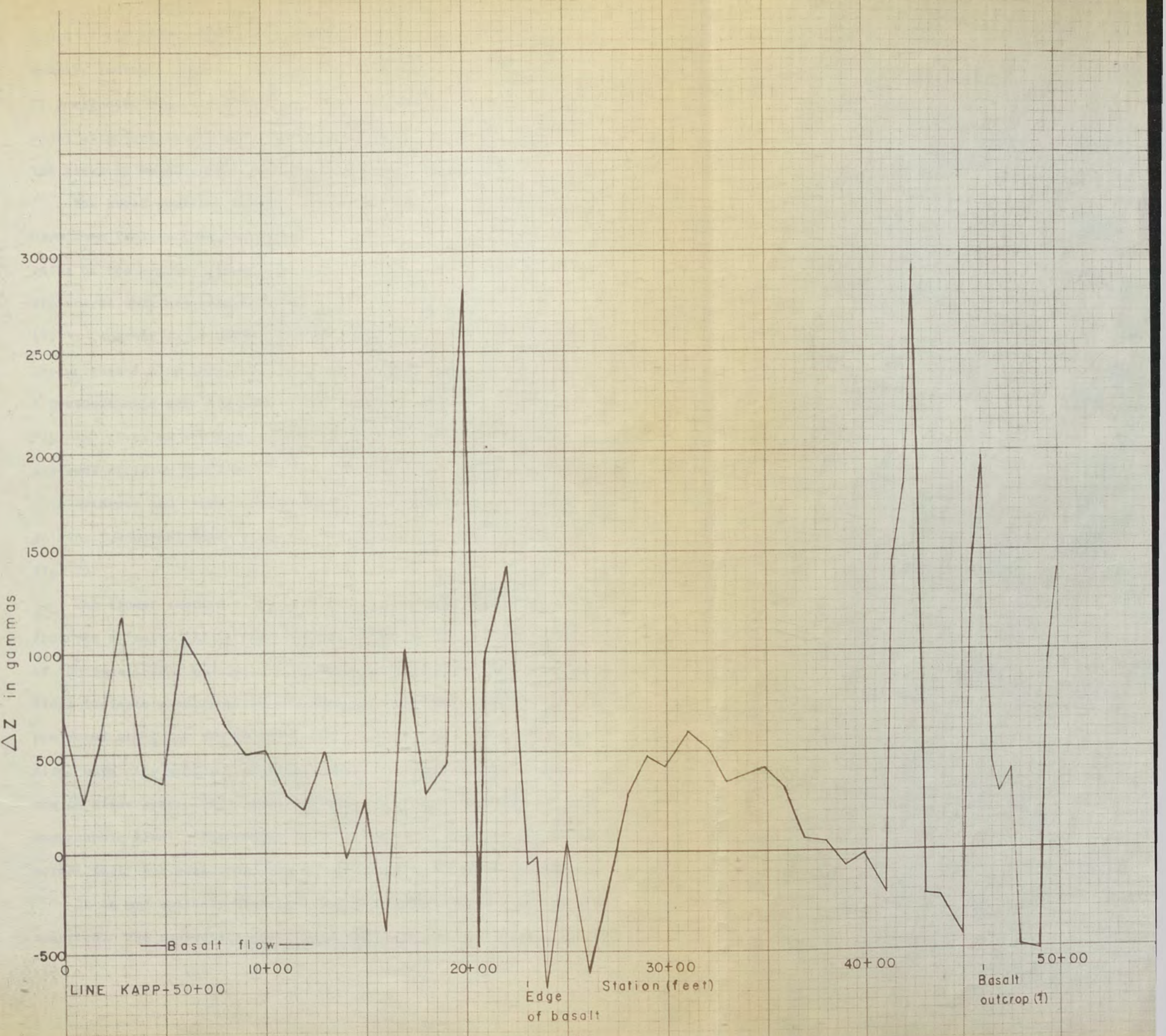

3000
2500
2000
1500
1000
500
0
-500
ΔZ in gammas
Basalt flow
0
10+00
20+00
30+00
40+00
50+00
LINE KAPP-50+00
Edge of basalt
Station (feet)
Basalt outcrop (?)

Fig. 3K

south of the basalt flows. The contours on the north side of this anomaly indicate a fairly linear feature having a magnetic low north of a magnetic high. This is more clearly seen in the profiles (Fig. 3A-K) attendant to the map. North of this feature, the area between the flows is magnetically fairly low and featureless.

The broad positive anomaly represents buried basalt flows that have been faulted into the positions shown on the map. Field relationships of the surface flows indicate a normal fault along their northern scarps that has been obscured by the alluvium (Robinson, et al, 1951). Another major fault is required to account for the tilting of the northeast flow relative to the flat-lying flow to the northwest. A prospect hole near the base of the latter (station 9, Dell-Kapp line, Fig. 4A) revealed a 4 foot zone of fault breccia and gouge, with fault surfaces striking N40°E and dipping 85° southeast. On the basis of this evidence and field relationships, a major fault is postulated, joining the normal fault along the northern scarps of the flows (see Fig. 2).

The linear feature on the iso-anomaly map does not necessarily indicate a fault. It is strictly due to the contrasting susceptibility of the basalt-fill contact. But the magnetic contours over the buried flows indicate a tilting surface that does not correspond to the plane projected along the top of the dipping basalt flow to the northeast. Also, both city wells (8 miles southwest of the Kern Ranch), which are 1½ miles apart, have penetrated basalt at approximately the same topographic level. Therefore, it is likely that an east-west trending normal fault has positioned the buried flows as shown on the map.

It is not unlikely that faulting within the buried flow has also occurred. The contours suggest parallel fractures that have slightly

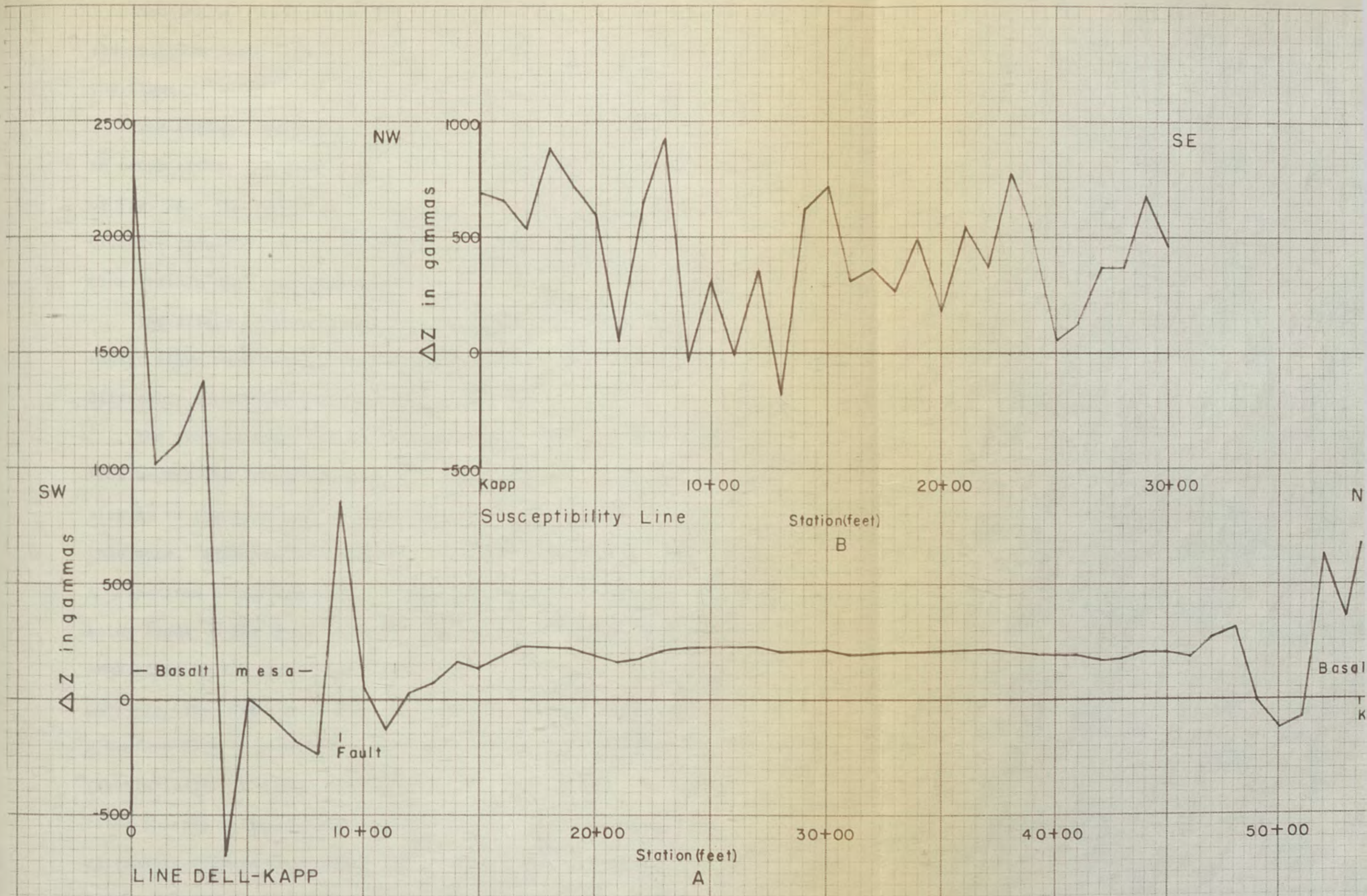

NW
SE
1000
500
0
-500
ΔZ in gammas
Kapp
10+00
20+00
30+00
Susceptibility Line
Station(feet)
B
SW
2500
2000
1500
1000
500
0
-500
ΔZ in gammas
— Basalt mesa —
Fault
0
10+00
20+00
30+00
40+00
50+00
Station (feet)
A
LINE DELL-KAPP
N
Basal
K

Fig. 4

displaced the flows, tilting each segment to the southwest in a ste-like manner.

Erosion by the Little Humboldt River has removed the basalt from the upthrown fault, resulting in the magnetically low area between the flows.

The maximum disturbance of the earth's magnetic field was found to occur within the area covered by the magnetic map along the profile of Fig. 3K. The anomalies are quite local, and as mentioned previously, possibly due to the effects of shallow magnetite concentrations within the underlying basalt.

Insufficient data, the irregularity and multipolar nature of the basalt flows, and edge effects make theoretical calculations very difficult, so estimates of depth were not made.

The profile along the Dell-Kern line (Fig. 3A) indicates a buried flow beyond the border of the map centered over station 60. From station 65 to the Kern well the data give no indication of a buried anomalous mass. (The negative anomaly at the well is due to the casing). A comparison of this profile with the profile of Line CD-Wentz mentioned below leads to the conclusion that the "broken rock" (see Table I) penetrated by the well is not basalt.

<u>CD-Wentz Line</u> Fig. 5A is a magnetic profile of Line CD-Wentz, from a surface flow to a well (36/38-30CD1) that has penetrated basalt (see Table I). The characteristic negative anomaly north of the flow rises sharply to the magnetic level of the valley fill. After the extraneous effects of buried metal in dumps, buried pipe, railroad tracks and power lines (Heiland, 1940) are removed, the profile is smooth, indicating the absence of any buried basalt masses. In the vicinity of the well the polarization effects of the edge of the buried basalt are evident, despite the distortion due to artificial sources.

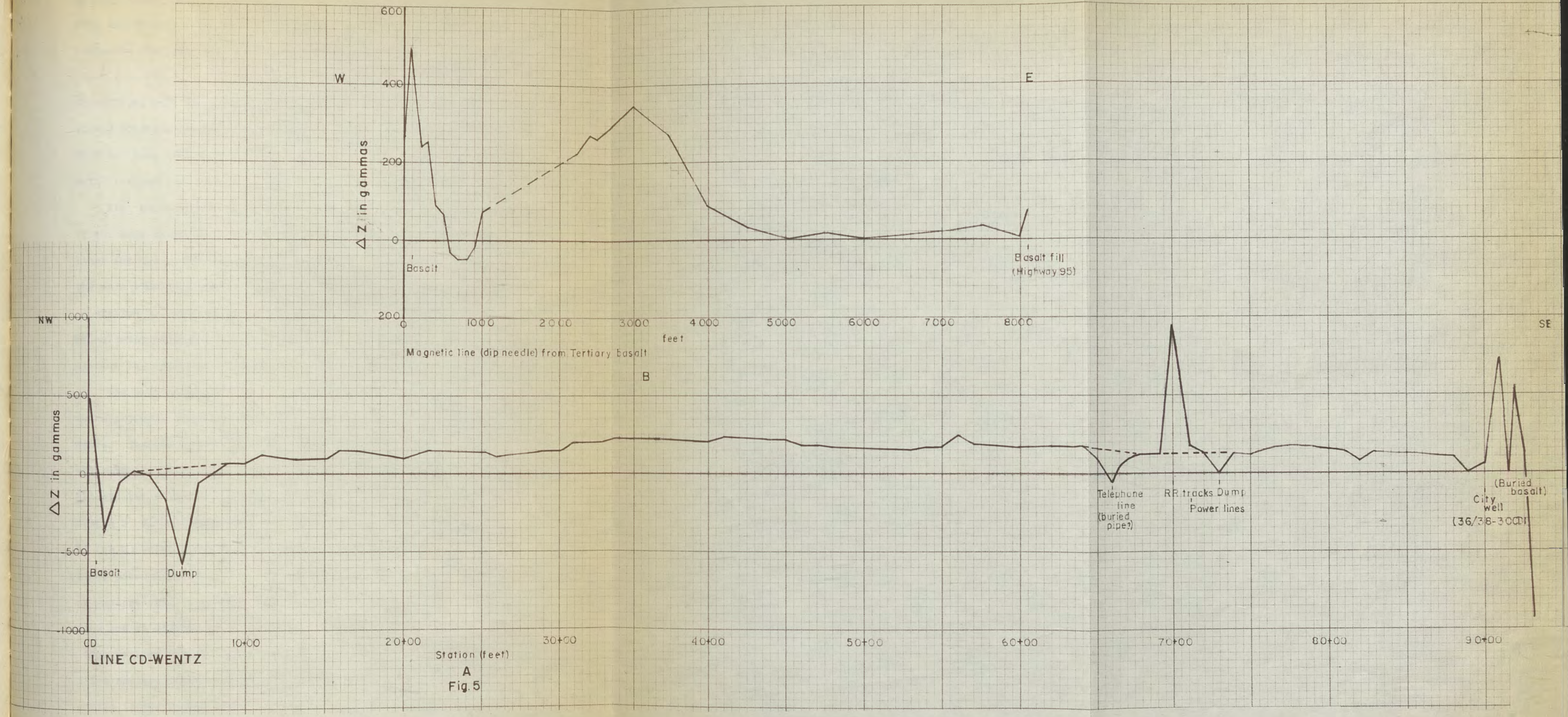

W
E
600
400
200
0
200
ΔZ in gammas
Basalt
Basalt fill
(Highway 95)
0
1000
2000
3000
4000
5000
6000
7000
8000
feet
Magnetic line (dip needle) from Tertiary basalt
B
NW
SE
1000
500
0
-500
-1000
ΔZ in gammas
Basalt
Dump
Telephone line (buried pipe?)
RR tracks
Dump
Power lines
City well
(36/38-30CD1)
(Buried basalt)
0D
10+00
20+00
30+00
40+00
50+00
60+00
70+00
80+00
90+00
Station (feet)
LINE CD-WENTZ
A

Fig. 5

Hillyer Ranch Area Although there were no well data at the time of this survey pertaining to buried flows on the Hillyer Ranch, it was suspected that the southerly-dipping louderback west of the Humboldt River (see Fig. 2) continued beneath the alluvium. A survey (Rose Creek line, Fig. 6A) from the East Range to the louderback revealed strong polarity changes some distance before the base of the dipping flow had been reached. Additional lines were run parallel to the main line and 500 feet on either side, from station 73 to the river.

Fig. 6B shows the profiles of the parallel side lines and part of the Rose Creek line, which was enlarged to the scale of the side lines for the purpose of comparison. Inspection of the profile of the main line (Fig. 6A) reveals a broad positive anomaly (station 32 to station 74) with an extended low to the north. There is a reversal of polarity at station 90 and again in a more pronounced manner at station 96, near the southern end of the louderback.

The pronounced polarity reversal at station 96 is typical of the curve produced at the contact of surface flows with valley fill sediments. The sharp, positive anomaly centered over station 91 + 50 (Fig. 6D) probably represents the southern extension of the louderback beneath the alluvium. This interpretation is supported by the fact that a U. S. Geological Survey test well recently drilled at the edge of the Humboldt River flood plain (two miles west of the Rose Creek line) encountered basalt at a depth of 50 feet (Hawley, J., personal communication). A fault is indicated at station 91 of the Rose Creek line and at station 86 of Line RR-100W (Fig. 6C). The magnetic data shown by Line RR-100E (Fig. 6B) does not match any of the other profiles and the broad negative anomaly may be due to changes in polarization in the buried flow.

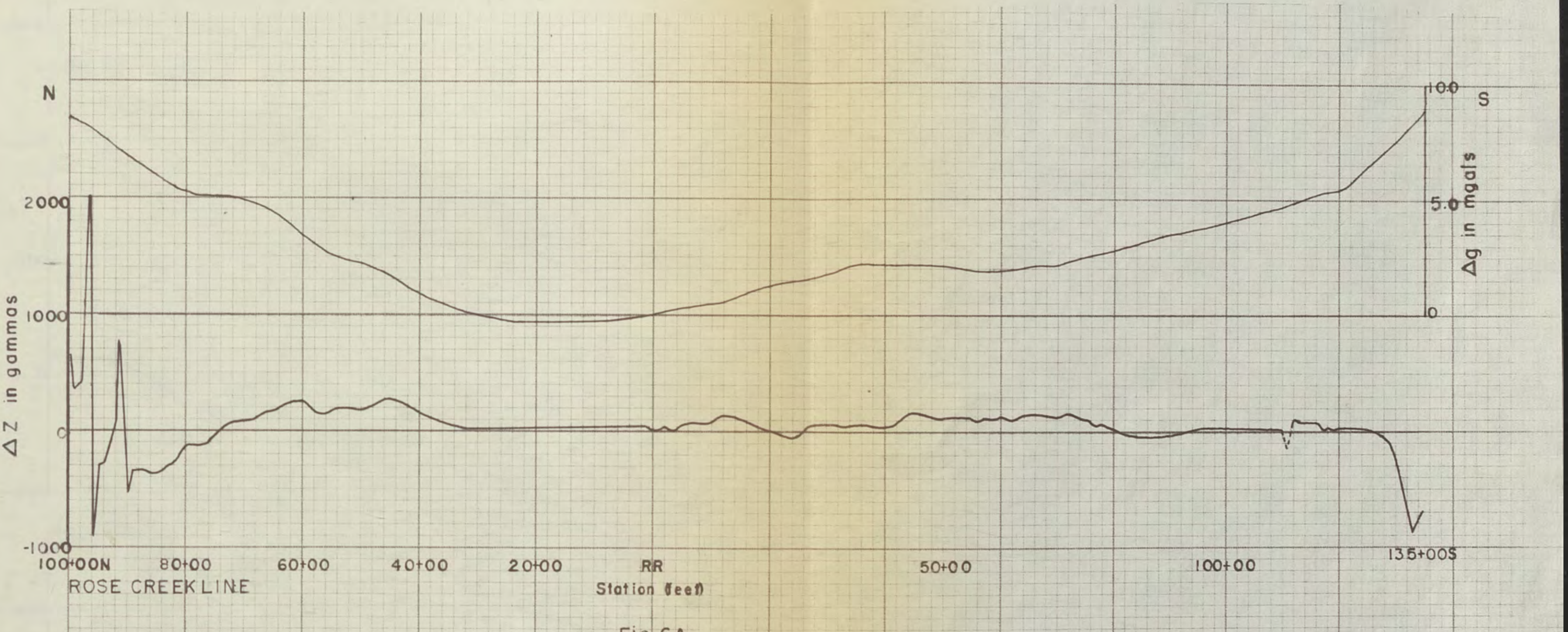

N
S
2000
1000
0
-1000
ΔZ in gammas
10.0
5.0
0
Δg in mgals
100+00N
80+00
60+00
40+00
20+00
RR
50+00
100+00
135+00S
ROSE CREEK LINE
Station (feet)

Fig. 6A

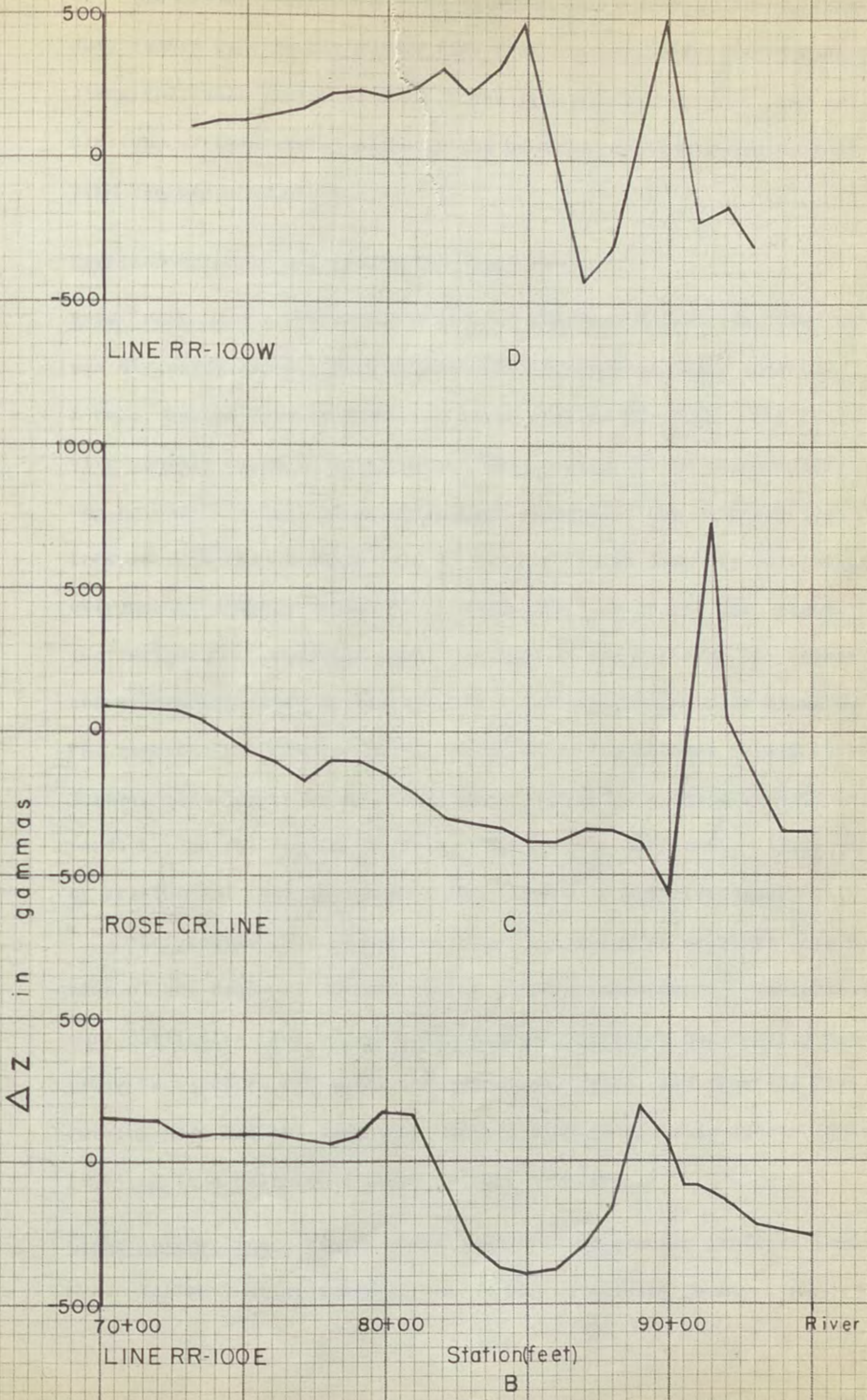

500
0
-500
LINE RR-100W
D
1000
500
0
-500
ROSE CR.LINE
C
500
0
-500
Δz in gammas
70+00
80+00
90+00
River
LINE RR-100E
Station(feet)
B

Fig. 6

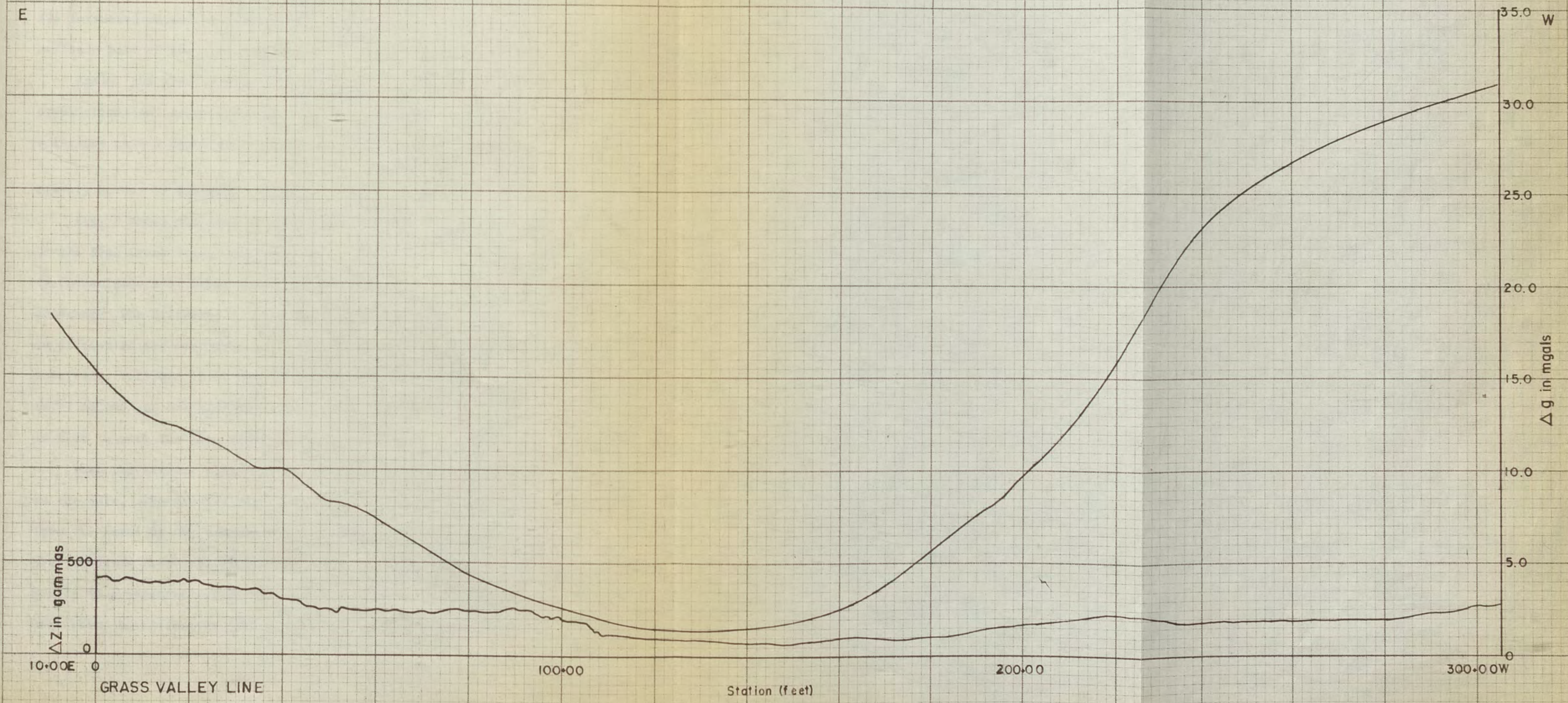
The broad, positive anomaly (station 32 to station 74) is probably caused by a deeply buried flow that has been displaced downward along the fault indicated above. The gravity data support this conclusion, as the gravity highs in the profile coincide quite closely with the magnetic highs.

Combined Magnetic and Gravimetric Surveys

Rose Creek Line   The northern part of the Rose Creek line (Fig. 6A) was discussed above. Both magnetic and gravimetric data indicate a deep, buried flow from station RR to station 70 south. The positive anomaly shown by both curves from station 110 to station 117 may be due to a dike of granitic rock related to the Jurassic (?) intrusive in the northern part of the East Range (see Fig. 2). Field evidence of a major normal fault along the base of the East Range (Cartwright, K., personal communication) is supported by the magnetic and gravimetric data at station 130. The negative anomaly shown by the magnetic profile may be due to polarization effects caused by the Jurassic (?) intrusive mentioned above, which is exposed several hundred yards beyond the end of the line. The profile indicates a sharp rise at station 134 that undoubtedly continues to a positive value.

The gravity data is not complete enough for an accurate determination of the regional anomaly, which in turn makes depth calculations more difficult. But close approximations, assuming the density contrast is equal to 0.5 grams/cm^3 (Thompson, 1958), and that the disturbing body has the form of a faulted slab of infinite extent (Dobrin, 1956), give a calculated depth of over 1200 feet.

Grass Valley Line   Fig. 7 shows magnetic and gravity profiles across Grass Valley 2 miles south of the Humboldt-Pershing County line. The



E
W
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
Δ g in mgals
500
0
ΔZ in gammas
10+0.0E
0
100+00
200+00
300+0.0W
GRASS VALLEY LINE
Station (feet)

Fig. 7

magnetic profile east of station 115 is very irregular and subdued compared to that over the center of the valley and is probably due to a buried lava flow at a considerable depth (2000-3000 feet). The gravity data coincide with the magnetic data over this area and support the interpretation. A broad magnetic anomaly from station 190 to station 210 is also mirrored slightly by the gravity data and may be due to a granitic intrusion in the basement related to the Jurassic (?) intrusive mapped by Ferguson, Muller, and Roberts (1951) in the northern part of the East Range.

Again, the gravity data is incomplete, but with the same approximations and assumptions as above for the Rose Creek line, calculations give a depth of at least 4600 feet.

Gravity Survey of Suspected Barrier

Fig. 8 shows the results of the gravity survey in the area west of the Rose Creek line, where a subsurface barrier has been postulated by investigators of other phases of the project on the basis of field evidence. The distances in Line East-West No. 1 from station U-343 to station RR are not exact, as the gravity readings were taken along a curving, railroad level line (see map, Fig. 2). Line East-West No. 2 is two and one half miles long, but not in a straight line and is tied in with the Rose Creek line at station 65N.

That the barrier exists is immediately apparent from a study of the data. The gravity curve of Line East-West No. 1 (Fig. 8) rises from the level of the basement at station RR and reaches a high several thousand feet west of station U-343, where it drops steeply and evenly to a negative value. The steep gradient of the profile at that point is indicative of a major normal fault that may be an

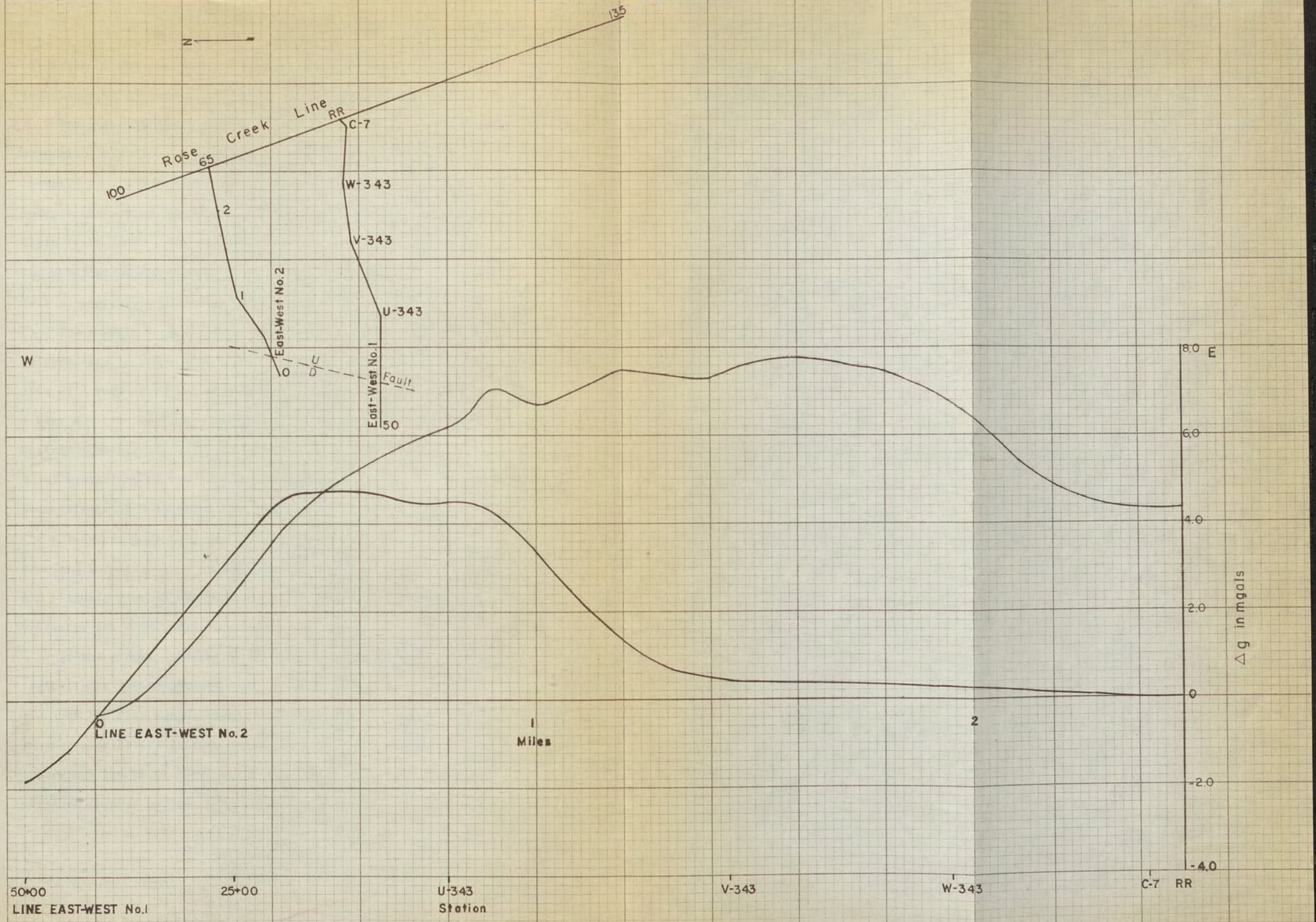

N
135
Rose Creek Line
RR
C-7
65
100
2
W-343
V-343
1
U-343
East-West No. 2
East-West No. 1
U
D
0
Fault
50
W
E
8.0
6.0
4.0
2.0
0
-2.0
-4.0
Δ g in mgals
0
LINE EAST-WEST No. 2
1
Miles
2
50+00
25+00
U-343
V-343
W-343
C-7 RR
LINE EAST-WEST No. 1
Station

Fig. 8

extension of the normal fault mapped along the western front of the East Range by Ferguson, Muller, and Roberts (1951) (see Fig. 2).

The curve of Line East-West No. 2 is yet more indicative of a subsurface barrier. From the level of station 65, it rises fairly abruptly to a value almost as high as the gravity observation at the bedrock contact of the Rose Creek line, indicating a very shallow depth (<100 feet). The gradient is steep to the west, approximating the gradient of the western part of Line East-West No. 1 and may indicate a continuation of the fault proposed above.

The gravity high outlined by the profile of Line East-West No. 1 is considerably lower than that of the profile to the north. The presence of a seep or spring at the surface (station 25) could indicate a very shallow depth to bedrock, a hypothesis incongruous with one derived from gravity data at that point. The profile from station U-343 to station 50 was tied in to the base station on the basis of observations on a single point, which is certainly subject to error. The survey was made late in the season and time did not allow for a complete investigation. Another line, parallel to the Rose Creek line and slightly east of the spring, would provide the additional data necessary for a more reliable interpretation.

If the gravity picture is reliable as presented, the spring could logically be assumed due to water derived from drainage on the north flank of the East Range, moving along a fault zone in the valley fill. Another possibility is that the displacement of gravel lenses against impervious layers of clay has allowed the water under hydrostatic pressure to move upward along a fault zone to the surface.

Conclusions

The geophysical surveys have produced sufficient evidence that buried basalt flows may be delineated by magnetic methods of investigation and that qualitative assumptions may be made on their depth using magnetic data. In addition, these preliminary surveys demonstrate that in some instances it is possible to correlate subsurface structures with the surface geology.

The detailed magnetic survey at the Kern Ranch indicates that the "broken rock" described in the driller's log of the Kern well is not related to buried flows north of the well and may not be basalt.

Gravity data indicates that basin sediments in Grass Valley are at least 4600 feet thick and over 1200 feet thick beneath the Rose Creek line. Combined magnetic and gravimetric surveys agree quite closely in outlining the structure and configuration of the basement in both areas.

Gravity investigations west of the junction of Rose Creek and the Humboldt River give conclusive proof of a subsurface barrier that may or may not have a low divide beneath Line East-West No. 1. More geophysical data are necessary for a complete picture of the configuration of the basement in that area.

APPENDIX

Explanation of Well Numbers

The wells in the following table are identified by a numbering system based on the network of surveys established by the General Land Office. This system serves to locate each well in the township, range and section. The township is represented by the first unit. The unit between the diagonal line and the dash is the range and is followed by a unit representing the section, quarter section and individual well number. The quarter sections are lettered in a counterclockwise direction, beginning with the northeast quarter (A). Thus, the well number 36/38-2B1 means that the well is located in the northwest quarter of section 2, township 36N., range 38E., and that it is the first well in that quarter.

TABLE 1

Logs and casing records of wells in Paradise and Grass Valleys, Nevada

36/38-2B1. Jack Kearns. Drilled by Mel Meter. Casing diameter 12 inches to a depth of 304 feet, open hole below. Land-surface altitude 4,301 feet above mean sea level.(Robinson, et al, 1949).

Material	Thickness (feet)	Depth (feet)
Sand, fine, to grit, gray; 30% of sample greater than ¼ inch in diameter	6	6
Sand, fine, to grit, gray, subrounded to subangular; 10% of sample larger than ¼ inch in diameter; silt, less than 5% of volume	24	30
Sand, medium, to fine gravel, rounded to subrounded; reddish clay, less than 5% of volume	10	40
Sand, medium, to grit, rounded to subrounded; reddish silt and clay, less than 10% of volume	35	75
Sand, medium, to medium gravel, rounded to subrounded; light-brown silt, less than 10% of volume	50	125
Sand, coarse, to fine gravel, rounded to subrounded; light-brown silt, less than 10% of volume	35	160
Sand, coarse, to fine gravel, rounded to subangular; brown silt and clay, about 30% of volume	40	200
Sand, coarse, to medium gravel, rounded to subangular; light-brown silt and clay, less than 4% of volume	51	251
Rock, broken, brown	13	264
Rock, broken; gray clay	12	276
Rock, broken; brown clay	8	284
Rock, broken; green clay	20	304
Rock, brown; main water	10	314
Total depth	--	314

36/38-19D1. City Well. In the City of Winnemucca on the road to the Western Pacific Railroad depot. Flow measured 1200 gpm with a 10-foot head (artesian)(1936). Elevation: 4273 feet (approx.) (Robinson, et al, 1949).

Material	Depth (feet)
Sand, clay, gravel, and cong	150
Cemented gravel	204
Clay, sand, gravel	
Sand and artesian water	475
Cemented cap	494
"Fissured lava", gravel	499
Lava	525
Total depth	525

TABLE 1 - Continued

36/38-30CD1. City Well. In the cemetery of the City of Winnemucca.

Material	Depth (feet)
Sand and soil	25
Gravel	115
Clay and gravel	180
Gravel	195
Clay	250
Gravel	257
Clay	490
Gravel	495
Lava	500
Total depth	500

39/39-24B2. Bennett and Biltz. Well bored in 1889 by a group of Paradise Valley ranchers. Casing diameter 3 inches, measured depth in 1947, 61 feet. Land-surface altitude 4,334 feet above mean sea level. Log compiled from daily editions of The Silver State, Winnemucca, Nevada, newspaper, during the period June 8, 1889, to July 29, 1889.(Robinson, et al, 1949)

Material	Depth (feet)
Loam, topsoil	9
Gravel, hard and cemented, water level at 84 feet, 2 feet above land surface	89
Gravel and sand	103
Gravel, cemented. Gravel sample consists of quartz and slate worn smooth. Some of the specimens forced up by the pump were flat and smooth and nearly as large as a dime	153
Unknown	274
Sandstone, hard	294
Ground, soft, drilling 10 feet an hour	294
Ground, soft	450
Clay, drilling 85 feet a day	540
Clay, drilling 75 feet a day	700
Unknown, drill rod broken, well abandoned	800
Total depth	800+

BIBLIOGRAPHY

Davis, W. M., 1930, The Peacock Range, Arizona: Bull. Geol. Soc. of Amer. v. 41, p. 293-313.

Dobrin, M. B., 1952, Introduction to geophysical prospecting: New York and London, McGraw-Hill Book Company, Inc.

Ferguson, H. G., Muller, S. W., and Roberts, R. J., 1951, Geology of the Winnemucca quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map.

Hammer, S., 1939, Terrian corrections for gravity meter stations: Geophysics, v. 4, p. 184-194.

Heiland, C. A., 1940, Geophysical exploration: New York, Prentice-Hall, Inc.

Hinze, W. J., 1959, A gravity investigation of the Baraboo syncline region: Jour. Geology, v. 67, no. 4, p. 417-446.

Mabey, D. R., 1956, Geophysical studies in southern California basins: Geophysics, v. 21, p. 839-853.

Malamphy, M. C., 1940, Geophysical-geological study of the Sao Pedro area, Brazil: Trans. AIME (Geophysics), v. 138, p. 110-132.

Nettleton, L. L., 1940, Geophysical prospecting for oil: New York and London, McGraw-Hill Book Company, Inc.

Robinson, T. W., Loeltz, O. J., and Phoenix, D. A., Groundwater in Grass Valley and adjacent portions of the Humboldt River Valley, Pershing and Humboldt Counties, Nev.: Nevada State Engineer Water Resources Bull. (in preparation).

_______________, 1949, Groundwater in Paradise Valley, Humboldt County, Nev.: Nevada State Engineer Water Resources Bull. No. 10, 61 p.

Romberg, F., and Barnes, V. E., 1954, A geological and geophysical study of Pilot Knob (south), Travis County, Texas: Geophysics, v. 19, no. 3, p. 438-454.

Skeels, D. C., 1940, Gravity in sedimentary basins: Trans. Am. Geophys. Union, v. 21, p. 187-202.

Thompson, G. A., and Sandberg, C. H., 1958, Structural significance of gravity surveys in the Virginia City-Mount Rose area, Nevada and California: Geol. Soc. American Bull., v. 69, p. 1269-1282.

Willden, C. R., Geology and mineral resources of Humboldt County, Nevada: Nevada Bur. of Mines Bull. (in preparation).

Wilmarth, M. G., 1938, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, p. 994.

Worzell, J. Lamar, and Shubert, G. Lynn, 1955, Gravity: crust of the earth: Geol. Soc. American Special Paper 62, p. 87-101.