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ENTITLED Interpretation of Gravity Data for the Southern End of the Leinster Granite in Southern Ireland

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Interpretation of Gravity Data for the Southern End of the Leinster Granite in Southern Ireland

By

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Abstract

Gravity Data from the southern end of the Leinster Granite shows a pronounced low, and to the east of it there is a sharp gradient to an anomalous high near the coast. The low corresponds well to a granite batholith with a basal depth to base of less than 9 km. The eastern high and large gravity gradient can both be modeled by a sharp rise of more than 5 km in the level the Precambrian basement to a level between 2 and 3 km.

TABLE OF CONTENTS

Introduction

In this project I am attempting to interpret, by modeling, the available gravity data over the area covered by the 1/2" gravity sheet number 19. The area is located on the East coast of Ireland south of Dublin, and it extends inland to include a large portion of the Southern Leinster Granite. It includes parts of Counties Kilkenny, Carlow, Wexford and Wiklow (see fig. I).

I have compared the gravity data for this area with the known geology by compiling, from various sources, a 1/2" geologic map of the area. After a comparison of these two maps I took gravity profiles and geologic cross sections from what appeared to be the most interesting areas with the most continuous gravity data along the profile. I then attempted to create 2 dimensional model gravity profiles, using the geologic cross sections as model guides, to match those obtained from field data. In doing this I have attempted to delineate the shape of the Leinster Granite and to roughly define the Regional Geological setting. For this I used an Apple II microcomputer and a program written by Martin Critchley for a similar project by McGuinness(1984) which I modified for easier use. The program uses Talwani's method for calculating the gravity potential produced from polygonal parallel pipes.

METHODS AND MATERIALS

There were several individual steps involved in this interpretation:

I) Contouring of the Bouguer anomaly map.

II) Compilation of a 1/2" to 1 mile scale geologic map.

III) Preliminary analysis to select gravity profiles and geologic cross sections.

IV) Modification of the existing computer program.

V) Computer modelling.

VI) Error analysis.

I. THE GRAVITY MAP

The first step after receiving the Bouguer anomaly map was to contour it. This was done by hand using a rough 'in the head' linear interpolation for the position of the isograds when they went between data stations. The Bouguer readings for this area varied from a high of 40.6 mGals along the coast near Cahore Point to a low of -28.0 mGals near the western boundary of the main granite body to the southeast of Carlow (see fig. II). Because of this large spread of values a contour interval of 5 mGals was used to obtain the overall

gravity trend in this area. This may have the effect of cutting out some high frequency variations but will give a smoother general pattern.

II. THE GEOLOGIC MAP

To compile a geologic map of the area I used several sources. The main sources were the 1" sheets 137-139, 147-149, and 157-159 published by the Irish Geological Survey. I reduced these to 1/2" scale and compiled a large sheet. Because these maps are out of date, published in the late 1850's, I supplemented them with other sources. These included a general geologic map of Ireland - Tectosat Exploration System Study Map 4 (1978), a map of the Lower Palaeozoic rocks in SE Ireland - Bruck (1979). From these maps I compiled a general map of the area showing only the main geologic units with an overlay of the gravity isograds.

III. PRELIMINARY ANALYSIS

Before I could begin the computer modelling I had to do an overall analysis of the gravity and the geology.

III.1) The gravity map shows a generally ovoid low that trends in a NE - SW direction (see fig. II). This low generally ranges from -10 mGals to a central low of -28.0 mGals. In the SW quadrant of the map is another prominent feature. A rectangular minor high. This rectangle has a NW - SE orientation with a local high of 4.3 mGals. This anomaly's shape definition disappears between the -5 and -10 mgal isograds.To the east of these two features is the main gravity gradient. It has a strike of roughly 40° and runs subparallel to the coast except in the south where it turns sharply west. It shows a maximum gradient of 7.6 mGals/km. To the east of this gradient is a continued, but much more gradual, increase in the gravity values. The two minor exceptions to this are two lows in the southeast.

III.2) The geology of the area is comprised of several distinct elements (fig. I). In the SE just north of Wexford there is a thin slice of Carboniferous rocks lying unconformably on Late Precambrian metasediments. This Precambrian unit is the Cullenstown Group which is composed of lbite-chlorite schists, quartzites and psammitic greywackes. This group is thought to be resting on a high grade metamorphic basement with an age of 1600 MY. The depth to this basement complex is a subject for debate. Moving northwest from here we cross into the fairly narrow band of the Bray Group. This is a group of Cambrian greywackes, slates and quartzites that also young to the northwest. Moving upsection to the northwest again we go into the Ribband Group. Here the contact is not clear and has been changed several times. This contact may or may not be conformable, but the difficulty in establishing its position would suggest that it is. These Ordovician rocks are a series of mudstones, siltstones, greywackes and fine sandstones which extend from the Bray Group to the eastern edge of the Leinster granite. Overlying these Lower Ordovician sediments unconformably is the Duncannon Group. These volcanic rocks are present at the core of a large syncline that has a NE - SW trend that intersects the coast between Courtown and Arklow in the northeast. The group is mainly composed of calc-alkaline volcanics which become progressively more acid as you go up section. It should also be noted that the group tends to thin out as you move northeast.

To the west of the Ribband Group the Leinster Granite intrudes. This is a compound batholith that has several distinct domes which show chemical variation. These intrusions have followed very closely the trend of a pre-granite anticline. This anticline explains the possible presence of Cambrian rocks at the southeast end of the granite. To the west of the Leinster Granite and the Cambro-Ordovician rocks to the south there are Carboniferous limestones and coal measures. These rest unconformably upon the Lower Palaeozoic rocks and form a third unit to be considered when doing the gravity modelling.

III.3) My decision on where to draw my cross sections for computer modelling was based mainly on the gravity data. I tried to transect the areas that showed features that were not consistent with the general trend on the rest of the map. This resulted in my drawing six lines of section. Three of these; I, II, and III transect the low (fig. III and IV). Line IV transects the two smaller lows in the southeast (fig. V) and lines V and VI are orthogonal through the minor high in the southwest quadrant (fig. VI and VII). This was done with the possibility of gaining some ideas of the 3-dimensional structure instead of simply a 2-dimensional one.

Following this gravity profiles were drawn for lines II through VI and rough geologic sketch sections were drawn preparatory to computer modelling.

IV. THE COMPUTER PROGRAM

When I began to work on the computer I realized that the modelling program could be made more efficient than it currently was. At the time the gravity profile was stored in a text file but the geologic models had to be input each time a change was made to them. It is apparent that two improvements could be easily made. The first would allow the user to change a single element or elements of a model without re-entering the whole model. This idea turned out to be more complicated than I had first imagined because of the programs structure; this resulted in the modified program not being able to print the graphical results of a test model. Later, while working with the new program which was still more efficient, I also became aware that it did not always give me the correct model profile for my input data changes.

Because of these problems, as well as a lack of time, I was unable to program the second change which would have stored a model on disk for later use and modification. For these modifications to be made it would require a general rewriting of the source code. I feel that it would be worth doing if this program were going to be used further.

V. COMPUTER MODELLING

In doing the computer modelling I used 2-dimensional polygonal bodies to approximate the geologic features I was representing. The modelling process occurred in several steps:

I) Input of the gravity profiles.

II) Determining the general features to be used in the model and their relative densities.

III) A trial and error process of matching known and computed gravity profiles.

The first step is to input the gravity profiles into the computer and to store them on disk. When the program is run this data is read and plotted out as the gravity anomaly in mGals against its position in kilometers. The 'x' axis of this graph is the lowest value of the input profile.

The profiles I used have not been corrected for a regional trend. This is because the Leinster Granite creates an anomaly that could be viewed as a regional trend which is one of the major trends that I am modelling.

Before I could begin the actual modelling I had to determine the densities of the units I would be using. For this I first took average readings from Morris (1973):

Ordovician Strata : 2.671 gm/cc
Granite : 2.616 gm/cc
Carboniferous Strata : 2.694 gm/cc

These are the average densities Morris obtained from rocks collected in the areas I am studying. I then compared these to the values other people have used in the past. These are:

Murphy:

Ordovician Strata : 2.750 gm/cc
Granite: 2.650 gm/cc

Brown and Williams:

Ordovician Strata : 2.750 gm/cc
Carboniferous Strata : 2.680 gm/cc

Cassidy and Locke:

Basement Complex : 2.900 gm/cc

After observing these discrepancies I tested a theoretical density for a granite using a general mineral composition and densities.

MINERAL	VOLUME PERCENT	DENSITY	PARTIAL DENSITY
k-feldspar	46%	2.60	1.196
quartz	20%	2.65	.53
plagioclase	17%	2.67	.454
biotite	9%	3.00	.27
Hornblende	8%	3.21	.257
TOTAL	100%		2.707

From this rough estimate it would appear that Morris's densities may be incorrect. For this reason I will use the values used by the other authors.

Once these values were established I used the generalized cross sections to begin the modelling. In order to keep the models fairly simple I decided to use only four general units. The Ordovician country rock which included the Cambrian underlying it as well as some of the Precambrians, a basement complex, the Carbonferous in the east and any appropriate granite bodies.

After these decisions have been made the modelling is fairly simple. Each model is given a maximum depth, which I found was a limit only for the graphical representation of the model. Each polygon representing a geologic feature is then entered as a series of coordinates specifying distance along section and depth. It should also be noted that due to the structure of the algorithm used to compute the gravity anomalies, all polygons in the model must be input with a clockwise sense of rotation of the data or else an anomaly is computed using an inverse density. After each polygon is entered it is assigned a density contrast. This is given with respect to the Ordovician rocks which have been assigned a neutral density (ie. this makes granite -.1 gm/cc). The gravity profile for this model is then computed and displayed on the same graph as the actual profile. Using a trial and error process a model can be built to approximate a given profile.

Due to time restrictions I was only able to do modelling on lines II and IV.

RESULTS

When I began using the modelling program I realized that there were features of the program that would affect the models I used. The first of these was the fact that if I ended the basement layer at the edge of the section the program would assume the 'basement' ended there and would use a neutral density material to infinity from both ends of the model. This caused a dip in the profile at the edges (fig. VIII). To eliminate this effect I found it necessary to continue any continuous layer to ±20 km off section to approximate an infinite sheet (fig. IX). Another variable I had to deal with was the depth of the model. To gauge this I tried to use a single polygon to represent the basement. I then set an upper limit of 3 km on this layer. This may not be realistic, but it was a working model that agreed in general principle with Murphy (1987) as well as Cassidy and Locke (1982). To determine the depth of the model I then extended it downward until the profile gave a height that was comparable to the measured profile. In practice this turned out to be a depth of about 9 km to give an anomaly of about +35 mGals.

Once these preliminaries were complete I began modelling.

LINE II

This section extends from the Carboniferous in the northwest, crosses the main bulk of the Southern Leinster Granite and ends on the coast to the southeast.

The first model I used was a two body model with the main granite pluton abutting the upraised basement, to a 3 km depth, on its eastern edge and a much lower basement on its western edge, at 7.5 km (fig. X). This was modified to show the pluton spreading laterally below the surface and going quite deep. This model has discrepancies at both ends. These were taken care of by raising the depth to basement in the east to 2 km and adding the lower density Carboniferous layer in the west (fig. XI).

A second model was created by starting with a single polygon (fig. XII), this is the Leinster batholith. To this was then added a basement layer (fig. XIII). In this case the basement is then represented only as the uplifted block to the east and it would be continuous below 9 km. In this model the Carboniferous layer was not added but would be necessary to get a closer fit to the profile.

This example shows that more than one model can fit the known geology of an area to produce equivalent gravity profiles. The main feature incorporated by both models is the subsurface extension of the Leinster Granite westwards and the lower depth to basement in the east.

LINE IV

This section runs NW - SE from within the southern end of the granite to the northern tip of the Carboniferous in the southeast.

In this model the depth to the basement is again set to 3 km with a 9 km base. In the firs model (fig. XIV) the granite extends 3 km beyond the edge of the model. This gives a good profile but it is not realistic because the granite extends much farther than 3 km past the end of the section. To take this into account the second model (fig. XV) extends to -13 km which is the surface distance past the end of the section. This raises the depth of the batholiths base to 7.1 km to get a similar profile.

ERRORS

In doing this modelling there are several areas in which errors could occur that would affect the models.

The least significant errors would occur because of inaccuracies in the geologic map. This would change the positions of the geologic units relative to their corresponding gravity isograds. Since the features I am mainly concerned with are large in scale these inaccuracies are probably of minor importance.

Much more important are the relative densities of the units. For these I used accepted values from other papers but these values very much control the size and shape of features and could very easily be incorrect for these rocks at depth. This is an error I can not judge in magnitude but it must be considered.

The other main source for error is the modelling program itself. As was seen in figs. XIV and XV the proximity of the boundary of a unit, in this case the granite, plays a large role in its effect on the gravity anomaly. The program uses a model that has infinite depth of field. In other words any units modelled extend to infinity into and out of the page. This would change the gravity anomaly caused by a small pluton as it would be modeled as an infinite strip.

For these reasons it would be useless and incorrect to create models that follow the known gravity profiles exactly. A model profile that follows the general outline of the known profile is as accurate as can be obtained from my data and gives us a basis upon which to draw conclusions.

CONCLUSIONS

I believe that the only conclusion that can be drawn from these models is that a granite body with a fairly steep eastern edge and a western edge that is hidden beneath the Carboniferous exists and that it sits adjacent to an uplift in the basement to the east.

This agrees generally with the conclusions drawn by Murphy (1987) but he also points out that there is a thinning of the crust by about 1 km to the east of the Leinster Granite. This is not responsible for the full gravity gradient seen but it is probably a contributing factor. Exactly where the upraised basement occurs can not be determined from these models. It may abut the granite or it may be further to the east.

On a finer scale the geology and the gravity profiles generally agree. The Duncannon Group has a slight negative effect on the gravity profile which can be seen in figs. III, IV and V. In fig. V the two minor eastern lows are probably a combined effect of the volcanics, the known granite pluton and a hypothetical one within or underlying the volcanics. The small low to the east has no surface geologic expression and can only be assumed to be another granite body below surface.

In fig. VI and VII the pregranite anticline can be seen to cause the small local high in the area of the Cambrian strata. Overall the geology in this area fits very well with the gravity data of the area.

I would like to thank Professor T. Murphy for supplying the Bouguer anomaly map and advice; Martin Critchley, Andrew Rolands and Environmental Resources Analysis Limited for their support, advice and the computer and software necessary for doing the modelling. I would also like to thank Dr. W.E.A. Phillips for his help and guidance while I worked on this project.

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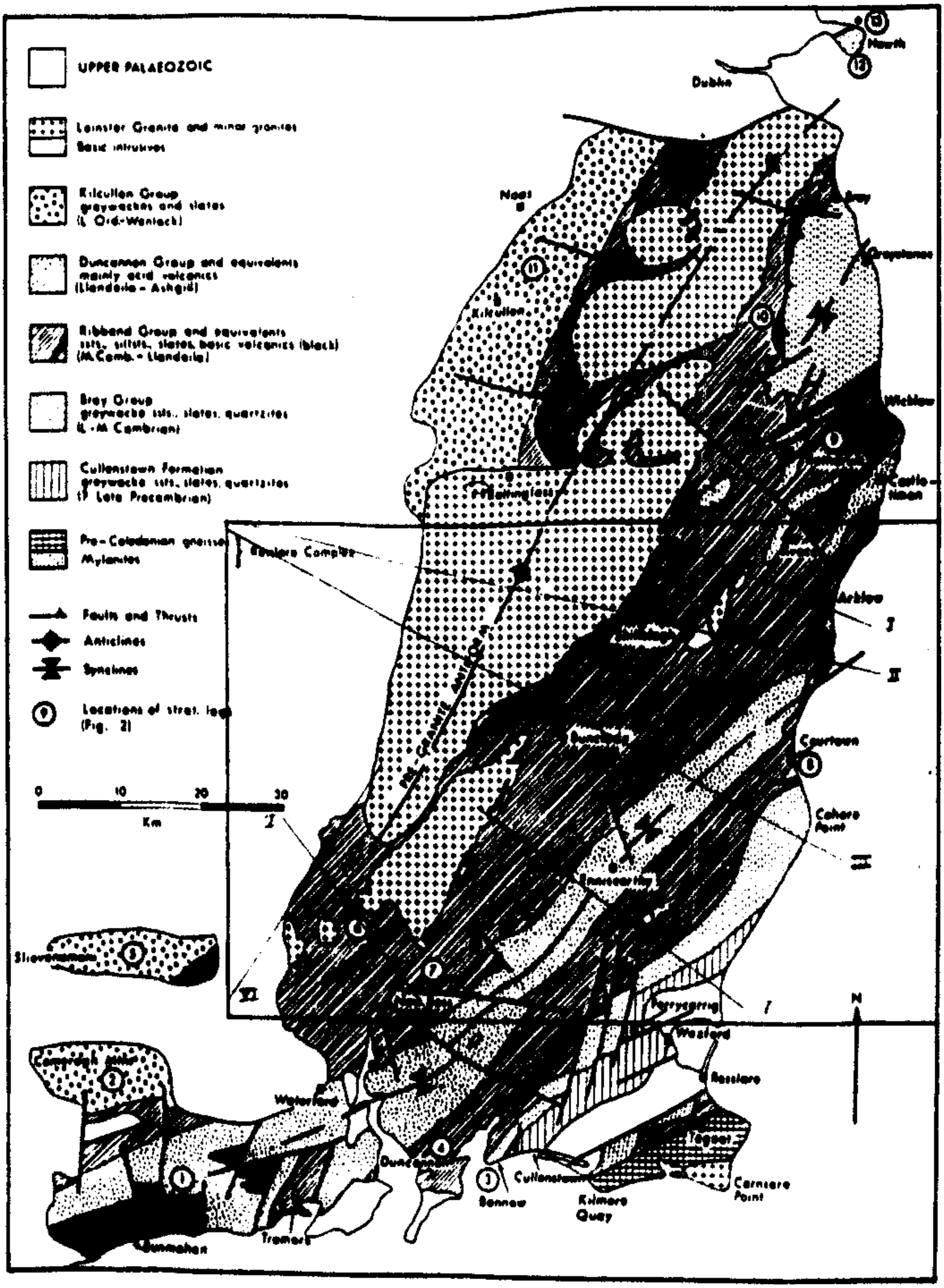
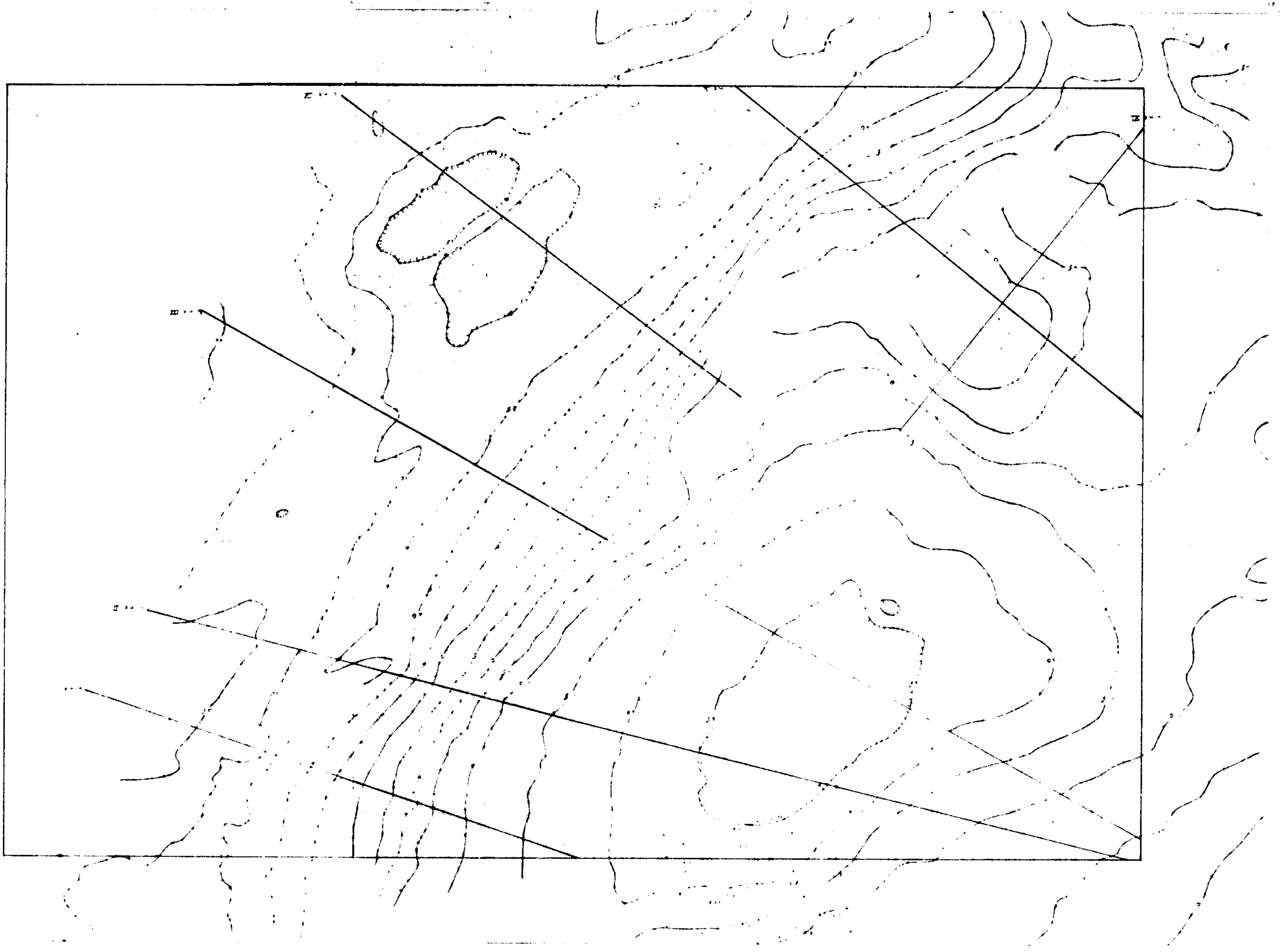


Fig. I General geologic map of the study area.
From Bruck (1979)



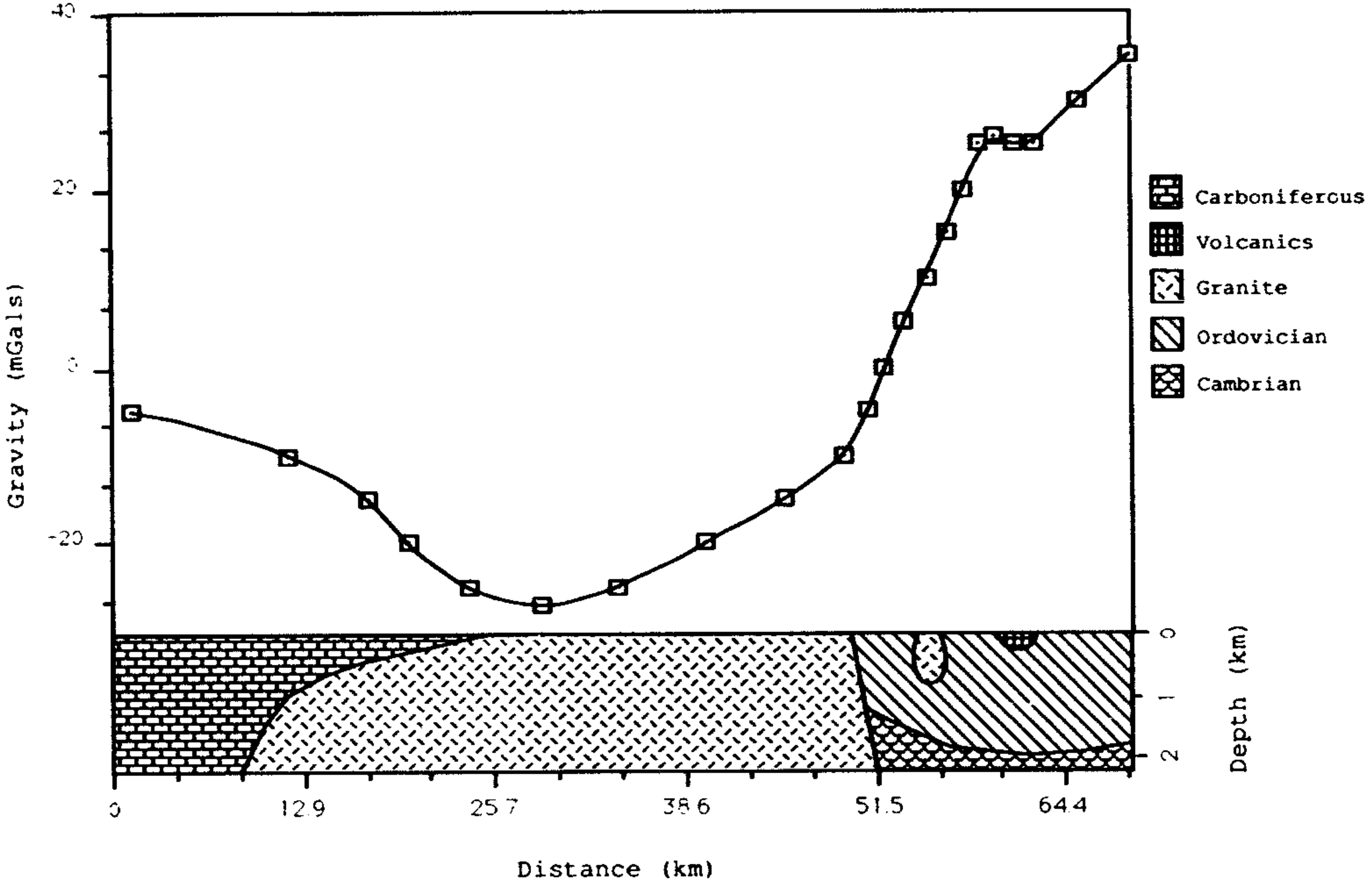


Fig. III Gravity profile and geologic sketch section for Line 2

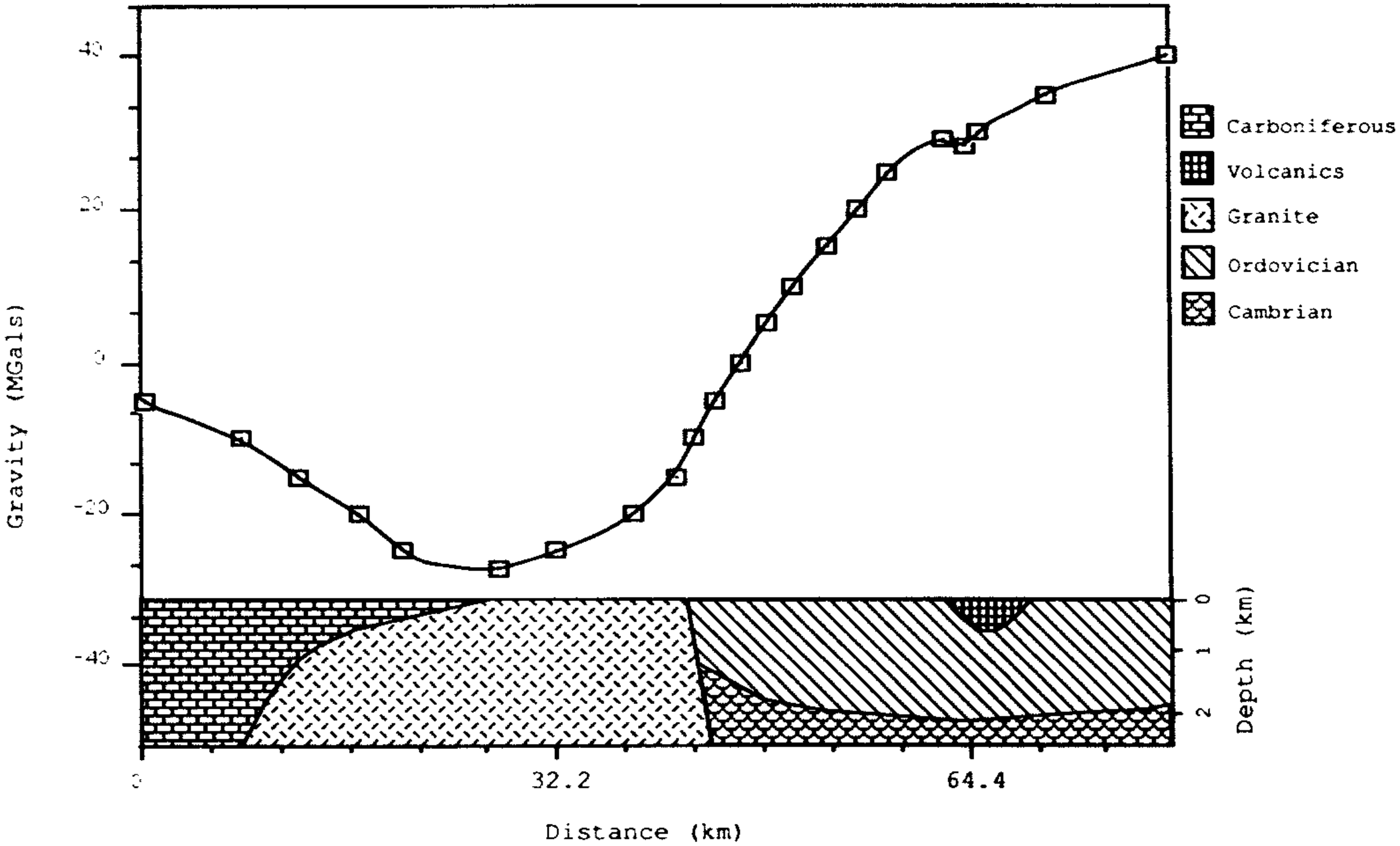


Fig. IV Gravity profile and geologic sketch section for Line 3

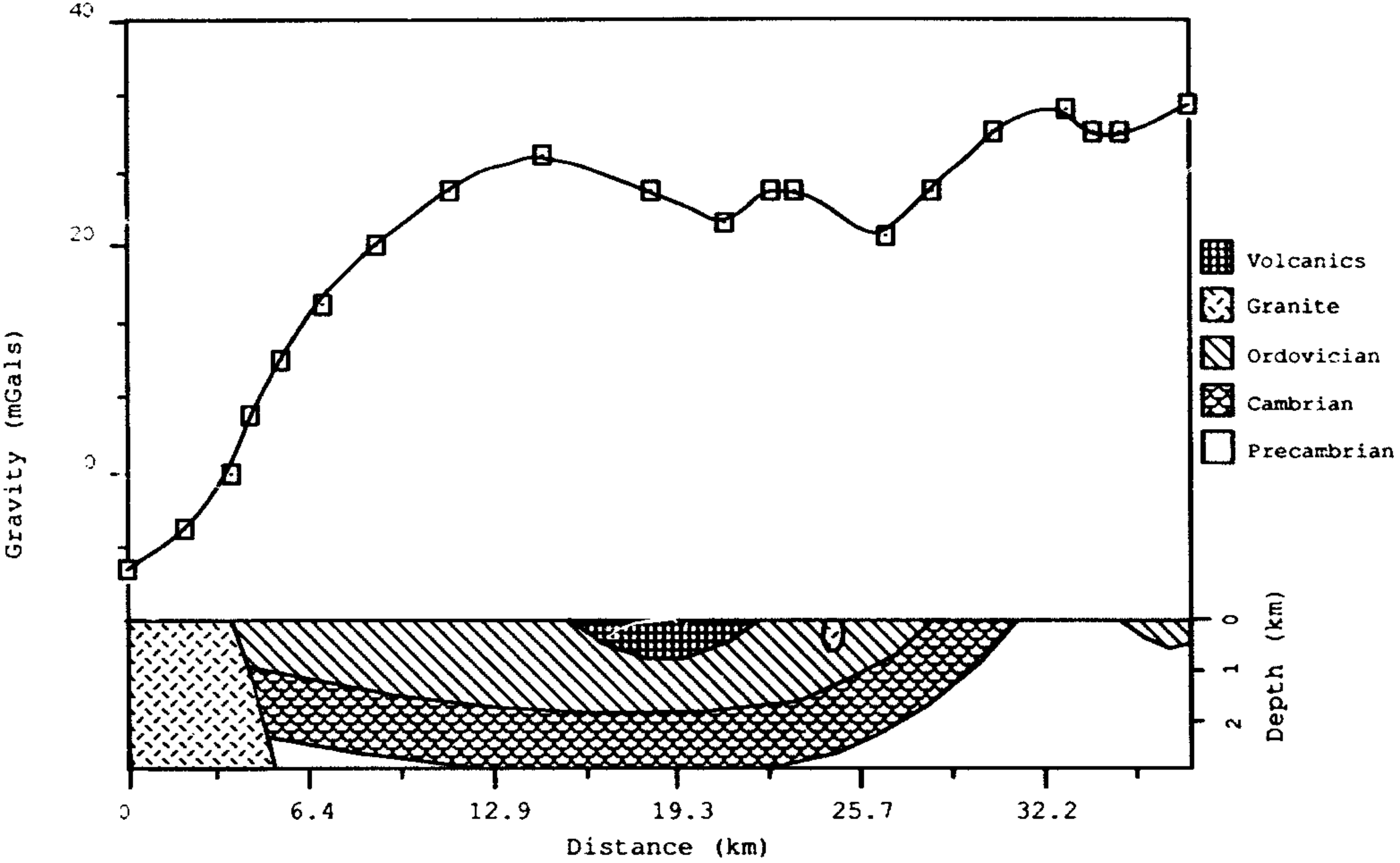


Fig. V Gravity profile and geologic sketch section for Line 4

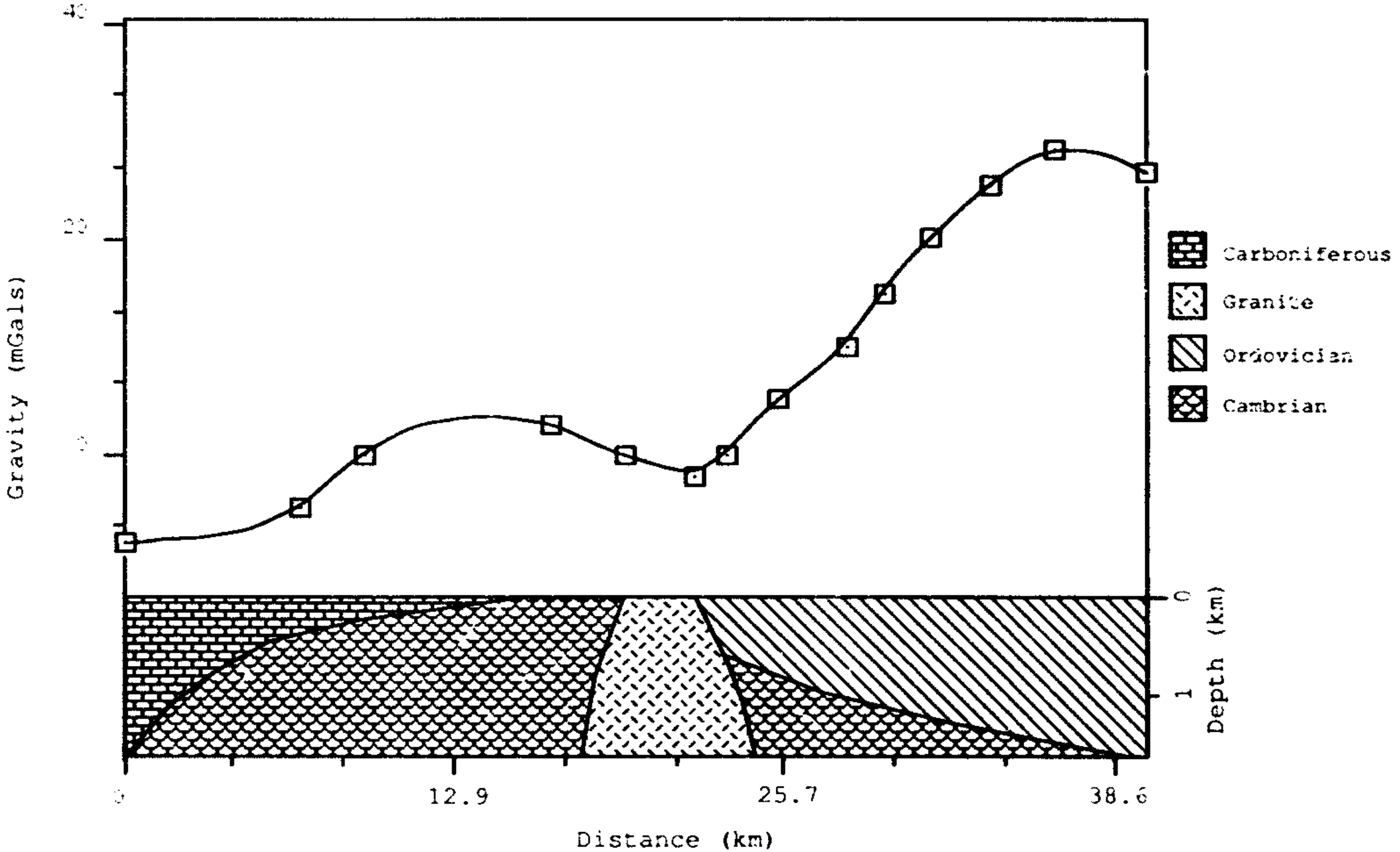


Fig. VI Gravity profile and geologic sketch section for Line 5

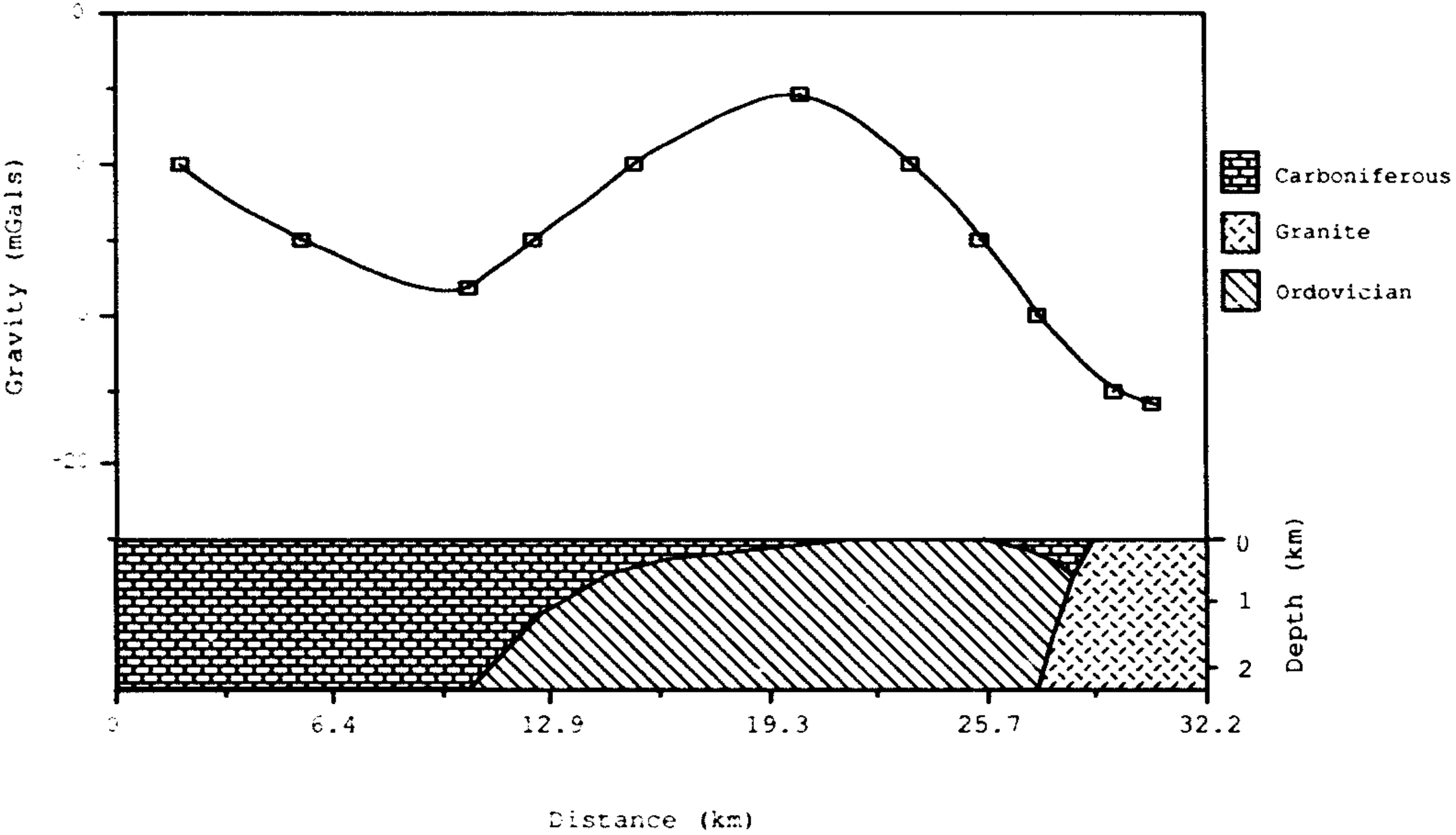
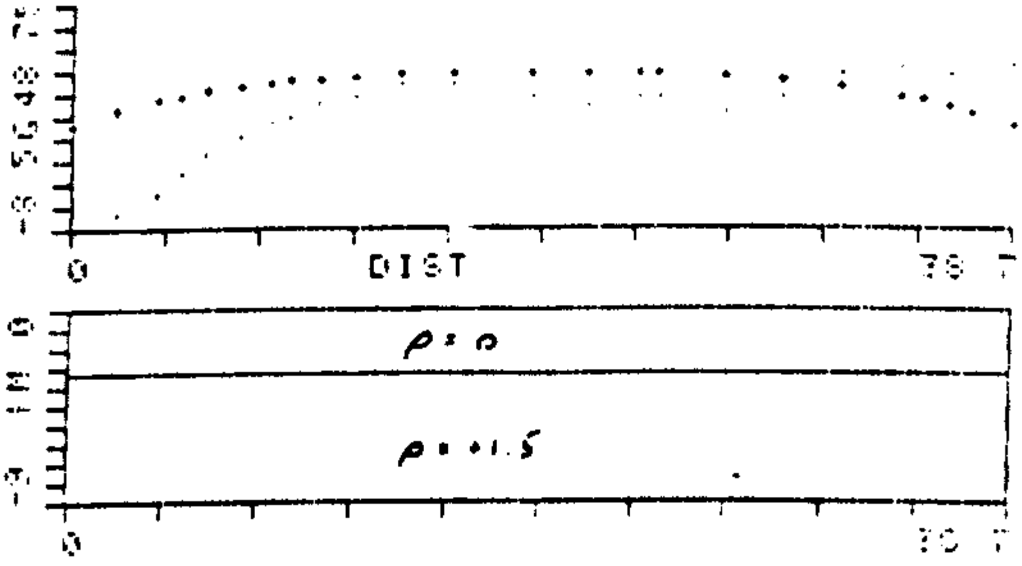


Fig. VII Gravity profile and geologic sketch section for Line 6

Fig. VIII (Test)



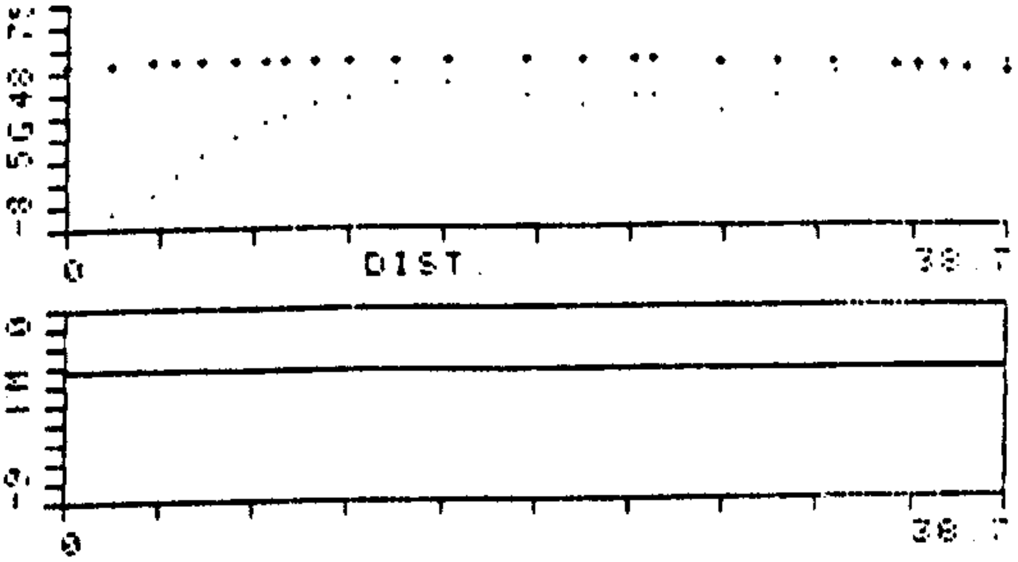
Basement

Dist. (km)	Depth (km)
0	3
38.7	3
38.7	9
0	9

. = Data Profile
\+ = Model Profile

Observed and computer generated
gravity profiles

Fig. IX (Test)

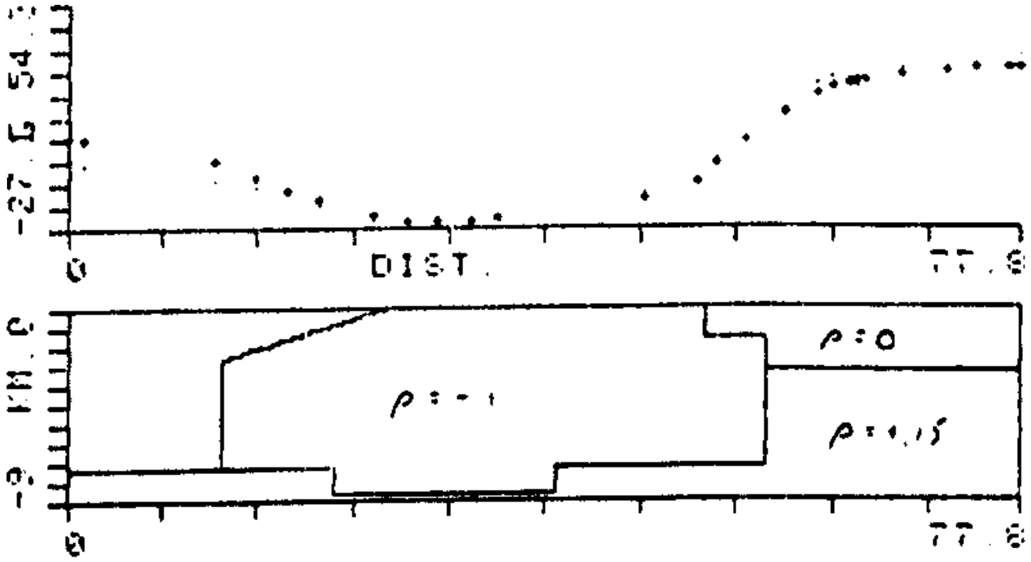


Basement

Dist. (km)	Depth (km)
-20	3
50	3
50	9
-20	9

Observed and computer generated
gravity profiles

Fig. X (Line II, Model I)



Observed and computer generated
gravity profiles

Granite

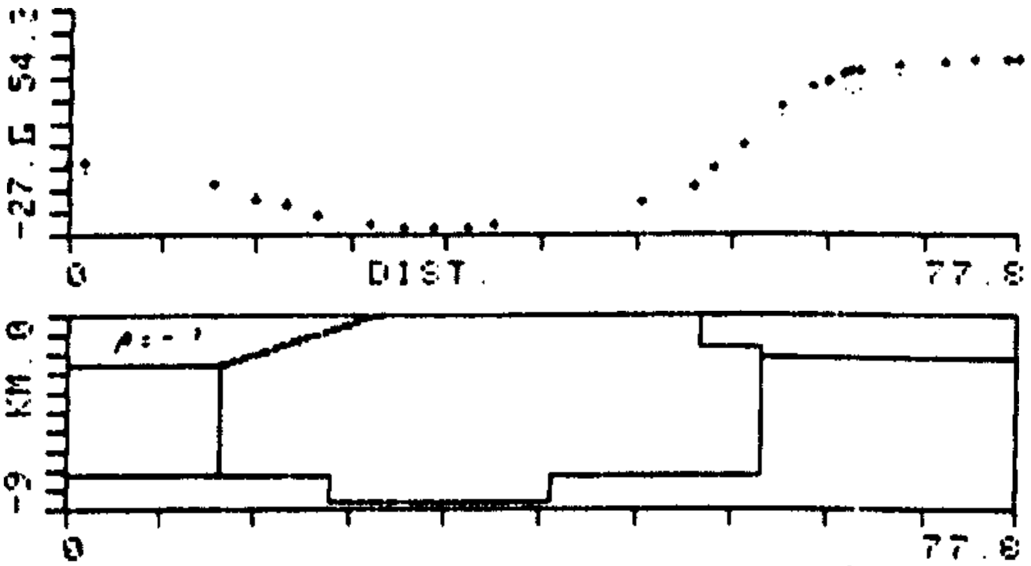
Dist. (km)	Depth (km)
26	0
52	0
52	1.5
57	1.5
57	7.5
40	7.5
40	8.8
22	8.8
22	7.5
13	7.5
13	2.5

Basement

Dist. (km)	Depth (km)
57	3
100	3
100	9
-20	9
-20	7.5
22	7.5
22	8.8
40	8.8
40	7.5
57	7.5

. = Data Profile
\+ + Model Profile

Fig. XI (Line II, Model I)



Observed and computer generated gravity profiles

Granite

Dist. (km)	Depth (km)
26	0
52	0
52	1.5
57	1.5
57	7.5
40	7.5
40	8.8
22	8.8
22	7.5
13	7.5
13	2.5

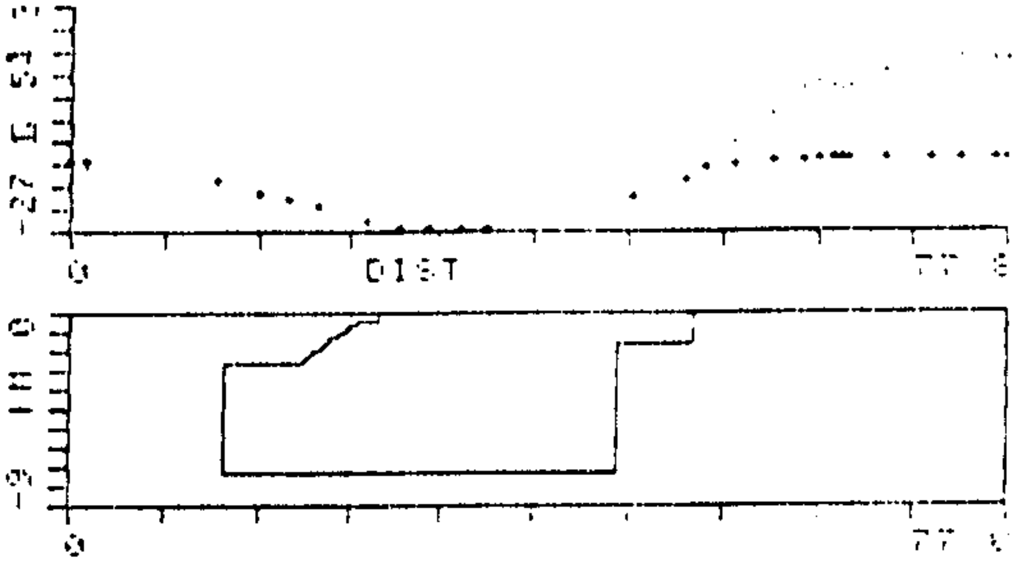
Basement

Dist. (km)	Depth (km)
57	2
100	2
100	9
-20	9
-20	7.5
22	7.5
22	8.8
40	8.8
40	7.5
57	7.5

Carboniferous

Dist. (km)	Depth (km)
26	0
13	2.5
-20	2.5
-20	0

Fig. XII (Line II, Model II)

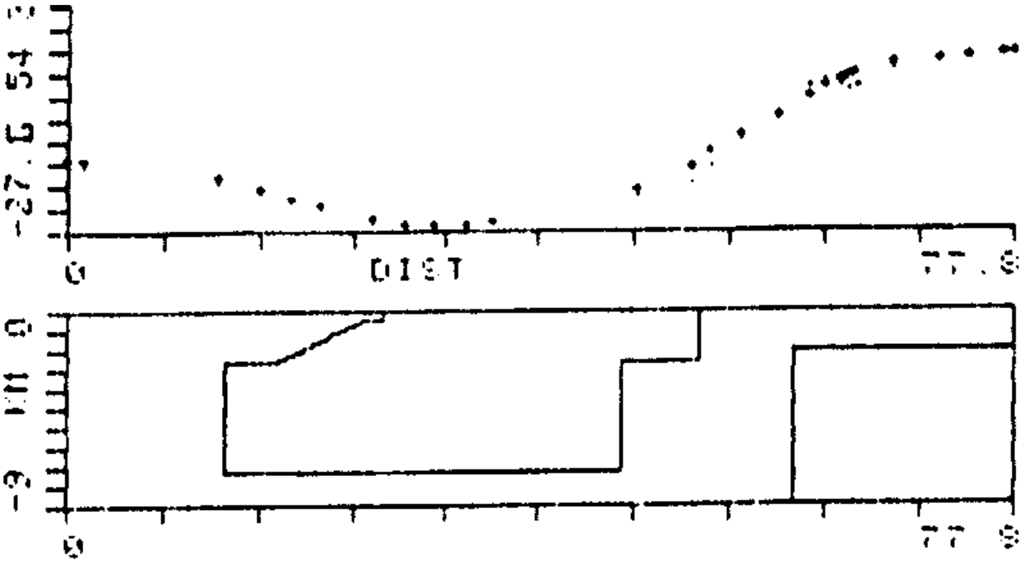


Observed and computer generated gravity profiles

Granite

Dist. (km)	Depth (km)
26	0
52	0
52	1.5
46	1.5
46	7.5
13	7.5
13	2.5
19	2.5
24	0.5
26	0.5

Fig. XIII (Line II, Model II)



Observed and computer generated
gravity profiles

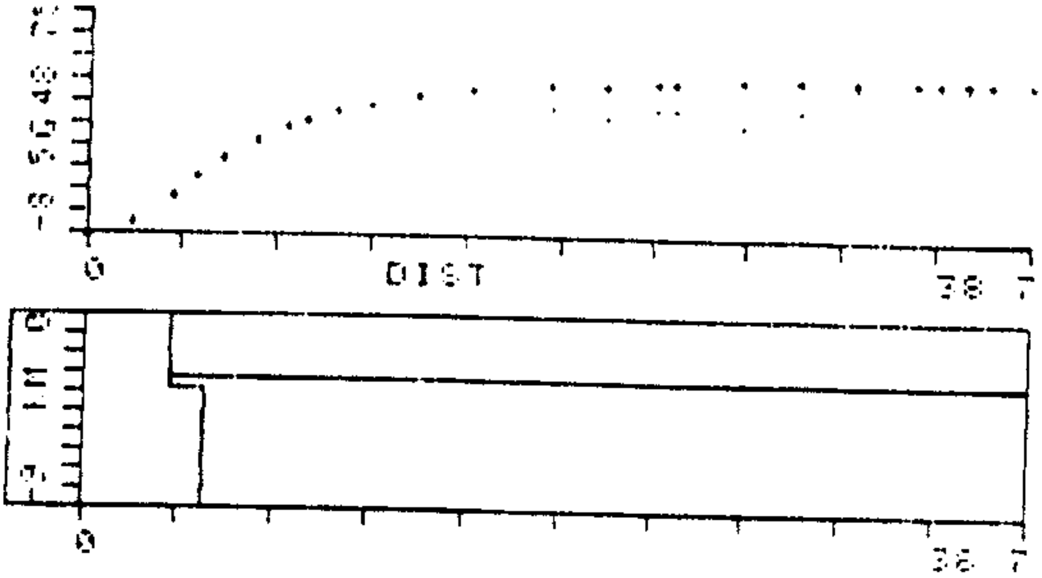
Granite

Dist. (km)	Depth (km)
26	0
52	0
52	2.5
46	2.5
46	7.5
13	7.5
13	2.5
17	2.5
24	0.5
26	0.5

Basement

Dist. (km)	Depth (km)
60	2
100	2
100	9
60	9

Fig. XIV (Line IV)



Observed and computer generated
gravity profiles

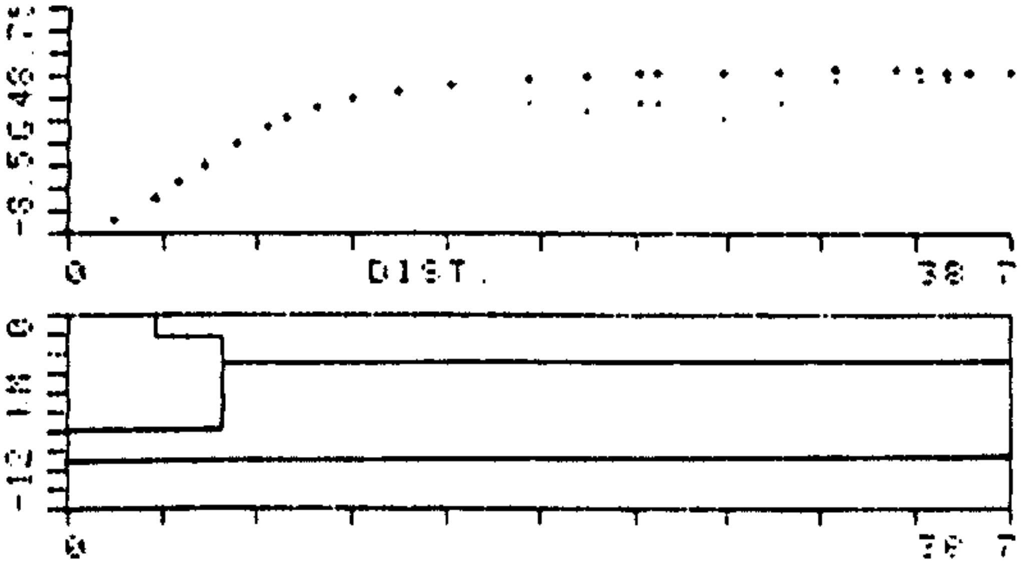
Granite

Dist. (km)	Depth (km)
-3	0
3.7	0
3.7	3.5
5	3.5
5	9
-3	9

Basement

Dist. (km)	Depth (km)
3.7	3
60	3
60	9
5	9
5	3.5
3.7	3.5

Fig. XV (Line IV)



Observed and computer generated gravity profiles

Granite

Dist. (km)	Depth (km)
-13	0
3.7	0
3.7	1.5
6.3	1.5
6.3	7.1
-13	7.1

Basement

Dist. (km)	Depth (km)
6.3	3
60	3
60	9
-13	9
-13	7.1
6.3	7.1