A GEOPHYSICAL INVESTIGATION AND GEOLOGICAL INTERPRETATION OF PART OF THE DIAMONDIFEROUS GRAVELS ON THE FARM GRASFONTEIN (356 JP), WEST OF BAKERVILLE

by

MICHIEL CORNELIS JAN de WIT B.Sc. (Hons.)

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ABSTRACT

The results of a gravity and magnetic study comprising 2911 and 14 650 stations respectively over a small portion of the diamondiferous gravels north of Lichtenburg and immediately west of Bakerville, are described.

The magnetic survey precisely located the Grasfontein dyke which crosses the area.

Two major trends of gravity lows averaging -0,6 mgal are recognised; (i) a main WSW-ENE trend and (ii) a less prominent nearly N-S trend. Geological observations and drilling indicate that the more pronounced WSW-ENE gravity anomaly trend is associated with the major direction of diamond-bearing gravel runs, whilst the N-S trend is more often associated with leached zones in the dolomite, which may be covered with shallow gravels only. These surface geological trends are shown to have developed from a similarly orientated joint pattern in the underlying dolomite of the Chuniespoort Group by differential weathering and erosion. The preferential development of the WSW-ENE joints is reflected in the orientation of the palaeo-drainage pattern and was thought to have some influence on it.

The success of the gravity survey in locating subsurface karst topography and gravels can be mainly attributed to the significant density contrast between the dolomite and chert on the one hand and the wad and residual chert in the leached zones and superficial deposits on the other.

Sampling results indicate that the diamonds, following their separation from the primary source may reflect a polycyclic sedimentological history in which the Dwyka tillite is thought to have

been of great importance. The primary source of the diamonds is thought to lie a considerable distance from the Lichtenburg-Ventersdorp region in a north-easterly direction.

SAMEVATTING

Die resultate van gravitasie en magnetiese opnames van 2911 en 14 650 stasies onderskeidelik oor 'n klein gedeelte van die diamanthoudende gruise noord van Lichtenburg, en wes van Bakerville, word beskryf.

Twee hoof rigtings van gravitasie minima, gemiddeld 0,6 mgal elk, is waargeneem; (i) 'n hoof WSW-ONO rigting, en (ii) 'n minder prominente amper N-S rigting.

Geologiese waarnemings en boorwerk toon dat die prominente WSW-ONO gravitasieneiging geassosiëer word met die hoofrigting van voorkoms van die diamanthoudende gruisafsettings, terwyl die N-S neiging meesal geassosiëer word met geloogde sones in die dolomiet. Hierdie sones mag bedek wees met vlak gruisafsettings. Hierdie oppervlakkige geologiese kenmerke het skynbaar ontwikkel vanuit 'n ooreenstemmende patroon van nate in die onderliggende dolomiet van die Groep Chuniespoort waar differensiele verwesing en erosie plaasgevind het.

Die voorkeurontwikkeling van die WSW-ONO tensiebreuke word gereflekteer in die orientasie van die paleo-dreineringspatroon en het vermoedelik 'n invloed daarop gehad.

Die sukses van die gravitasie-ondersoek in die opspoor van ondergrondse karsttopografie en gruise kan grootliks toegeskryf word aan die beduidende digtheidsverskil tussen die dolomiet en chert aan die een kant en die mangaanaarde en verweerde chert in die geloogde sones, en oppervlakkige afsettings aan die ander kant.

Toetse op grondmonsters van die gruise dui aan dat die geskiedenis van diamante, na hulle skeiding van die primêre bron, gekompliseerd is deur die rol wat die Dwyka tilliet gespeel het, 'n polisikliese sedi-

mentologiese geskiedenis reflekteer waarin die Dwyka tilliet ŉ belangrike rol gespeel het. Die primêre bron van die diamante is vermoedelik in ŉ noordoostelike riging ver van die Lichtenburg-Ventersdorp gebied.

I. INTRODUCTION

The first diamond discovery in the Lichtenburg area took place in 1921 on Klipbankfontein 26 IP (near Manana) while in 1926 economic quantities of diamonds were located on the farm Grasfontein 356 JP.

The diamondiferous gravels occur over an area approximately 60 kilometres long and some 50 kilometres wide (fig. 1) and are concentrated in so-called runs usually about 150 to 200 metres wide. However, gravels are also found in potholes, pans and larger surface depressions. Very high concentrations of diamonds were commonly found in potholes. (The term pothole applies throughout the text to structures that represent palaeo-sinkholes and yama's subsequently filled with gravel).

Between 1926 and 1947 the production of the Lichtenburg diggings amounted to 7 220 847 carats which was then valued at £16 006 832 (Du Toit, 1951). As the price of diamonds during this period was very much influenced by (a), the enormous quantities which reached the market, (b) the 1930 depression and (c) the events which led to World War II, it would be very difficult to estimate the value of the total diamond production at present prices, but it would obviously be significantly more in view of subsequent price increases. The annual output at present is only a few hundred carats and is minimal compared with the early years when digging operations were in full swing.

The proclamation of these diamond fields in 1926 led to one of the biggest diamond rushes in South Africa. It was estimated that nearly 50 000 white diggers and some 90 000 black helpers were concentrated in the Bakerville area at the beginning of 1929 (Von Backström and others, 1953, p.36).

At present only a handful of diggers are exploiting the gravel by means of very simple mining methods and they generally lack the scientific knowledge and financial resources to make a proper assessment of the remaining potential of the gravels.

In view of the great economic potential of further discoveries of gravel-filled potholes, it was decided to do an intensive investigation of the diamondiferous gravels of the Lichtenburg district. The Lichtenburg area has already been extensively studied geologically by Draper (1927), Du Toit (1951), Retief (1960) and Darracott (1973, 1974). In order to extend the existing geological information a detailed geophysical investigation of the area was planned. Initially two test areas on the farms Grasfontein 356 JP and Ruigtelaagte 353 JP measuring 7 and 7,5 km² respectively, were investigated (fig.1). The test areas are 10 kilometres apart and potholes, famed for their high diamond content are known to occur in both. The former area was investigated by the author and the latter by Stettler (1979) (fig. 1).

Detailed gravity and magnetic surveys were conducted on a 50-metre grid on the farm Grasfontein 356 JP. This was later followed by a drilling programme. Special attention was given to the existence of potholes. The field work was started in February 1977 and was completed one year later, apart from electromagnetic surveys conducted by Stettler (1979).

The Grasfontein area includes King's and Malan's potholes, both famous for their richness in diamonds. According to Du Toit (1951), of the 7 220 847 carats which were extracted from all the gravels around Lichtenburg between 1926 and 1947, a total of 2 309 156 carats (nearly 32 per cent) then worth £4 981 950, was found on Grasfontein 356 JP only.

The author wishes to express his sincere thanks to the Director of the Geological Survey of South Africa for permission to use the information obtained during the investigation for this thesis.

Thanks are due to Prof. C.P. Snyman and Dr R.J. Kleywegt for their supervision and guidance during the course of this work.

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Lastly I would like to thank my wife Cheryl for the patience she had during the late nights which were necessary for the completion of this thesis.

2. GEOLOGY

2.1 Stratigraphy and field relationships

The alluvial gravels in the Bakerville district were deposited on a peneplain of quasi-horizontally bedded dolomite. The dolomite forms part of the Chuniespoort Group which attains a thickness of almost 1 200 metres in the Lichtenburg area (Du Toit, 1951). This group is divided into several formations on the basis of their chert content (Table 1).

The bedrock in the Grasfontein area is the Monte Christo Formation (figs. 1 and 2), which corresponds with the upper chert-rich zone of Du Toit (1951).

The dolomite is a fine-grained, blue to blue-greyish rock with a characteristic "elephant-skin" surface due to preferential weathering along abundant joints. Pale-coloured chert occurs in layers and lenses up to 500 mm thick. Stromatolites are abundant in the dolomite.

Nodules of manganese oxides, which form during the weathering of the dolomite, constitute a significant proportion of the gravels. They are important in the recovery of the diamonds because they facilitate the separation of diamonds from the lighter gravel fraction during washing. In places these nodules are also exploited as an ore of manganese.

Two sets of dykes, (probably dolerite, Mr R. Day, personal communication) which strike NNW and ENE cut the dolomite of the Lichtenburg-Zeerust area. They are generally deeply weathered and outcrops are sporadic so that most of them have been mapped with the aid of photogeological, aeromagnetic and electromagnetic surveys (Wilson, 1977; Richards and Day, 1975; Day, 1976; Hauger, 1973). One of these dykes, the Grasfontein dyke, crosses the area investigated, but only outcrops further to the east (Mr R Day, personal communication).

TABLE 1

SEQUENCE	GROUP		FORMATION	LITHOLOGY
TRANSVAAL	PRETORIA			
	CHUNIESPOORT		PENGE	BANDED IRON FORMATION
		MALMANI SUBGROUP	FRISCO	CHERT-FREE DOLOMITE
			ECCLES	CHERT-RICH DOLOMITE
			LYTTELTON	CHERT-FREE DOLOMITE
			MONTE CHRISTO	CHERT-RICH DOLOMITE
			OAKTREE	DARK COLOURED DOLOMITE
			BLACK REEF	QUARTZITE

Stratigraphical subdivision of Transvaal sequence.
(South African committee for stratigraphy, Feb 1979, unpubl)

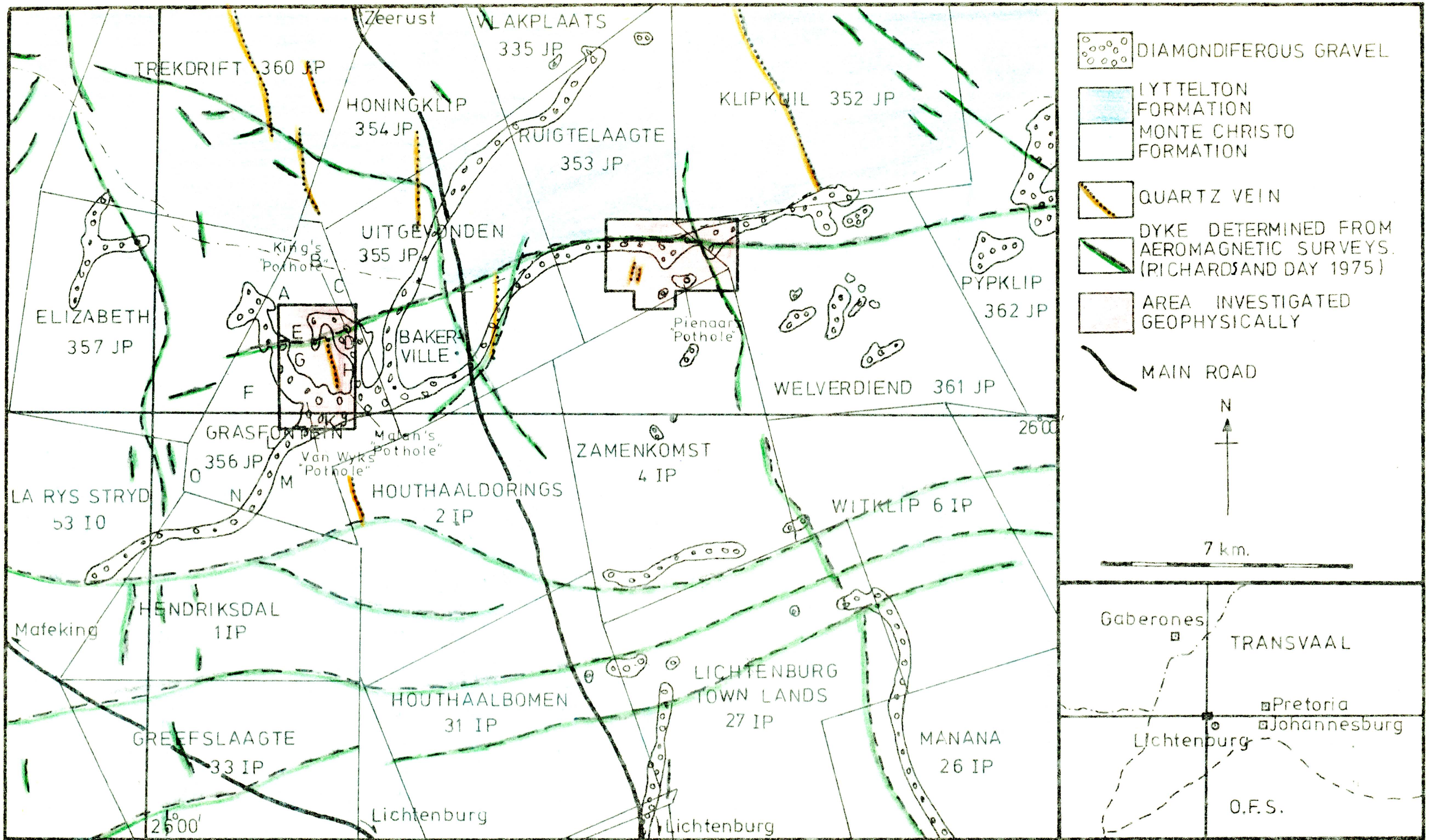


FIGURE 1: THE GEOLOGY AND DISTRIBUTION OF THE DIAMONDIFEROUS GRAVEL IN THE AREA SURROUNDING BAKERVILLE.

Additionally several quartz veins, striking north-south cross the area and delineate well-defined ridges from 5 to 10 metres in width (fig.1).

2.2 Geomorphology

The surface features developed on the dolomite throughout the Lichtenburg area are manifestations of typical karst topography. Regional features include numerous depressions and sinkholes which vary considerably in size and depth.

Other well developed, smaller scale karst features in the study area are the following :

(1) LAPIES

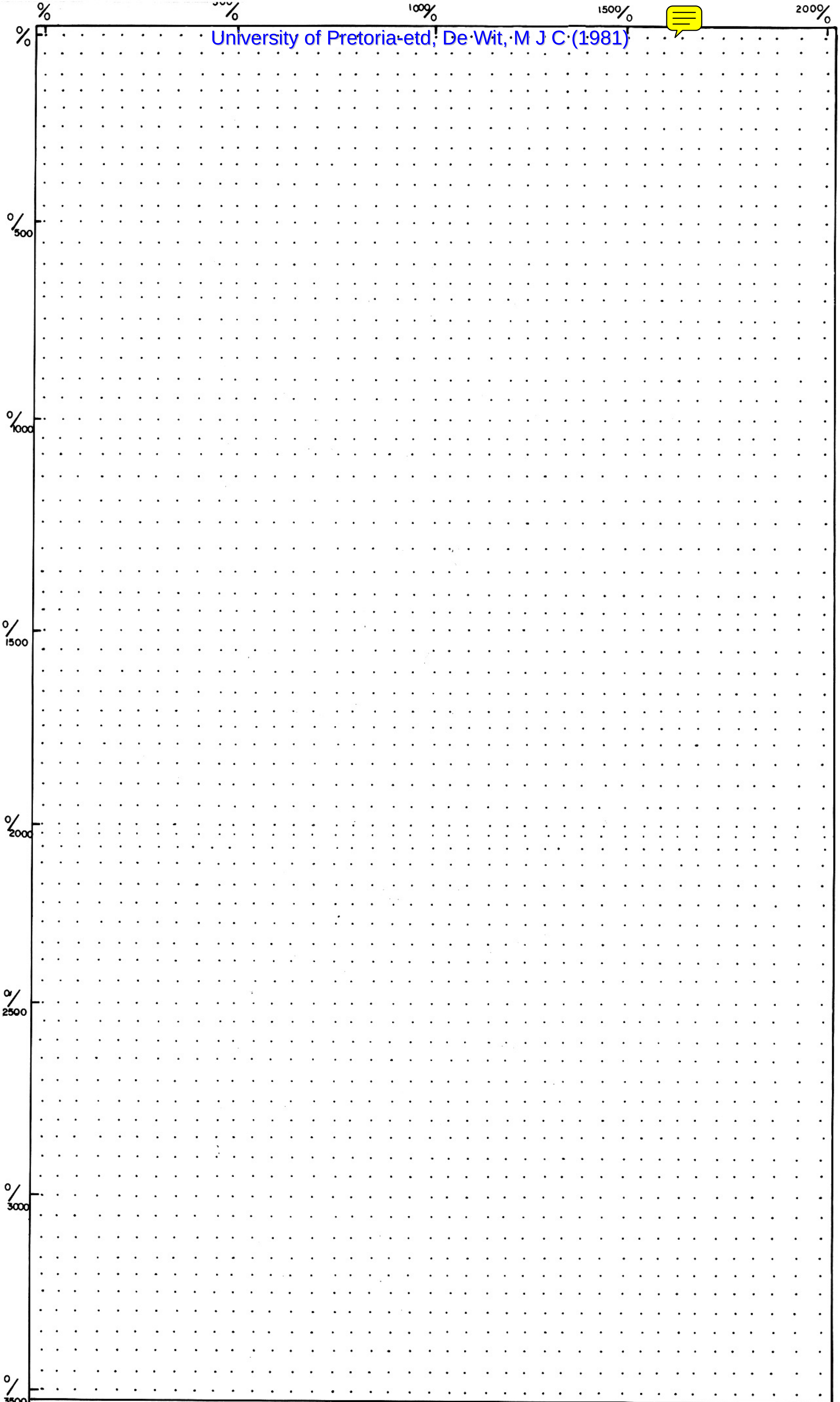
These are V-shaped solution channels. They vary in depth from 2 to 10 metres and range in length from one to fifteen metres. These structures are best exposed on the farms Uitgevonden 355 JP and Welverdiend 361 JP.

A number of solution channels are invariably associated with the gravel runs. The majority of these have been excavated and their entire contents removed by prospecting.

(2) YAMAS

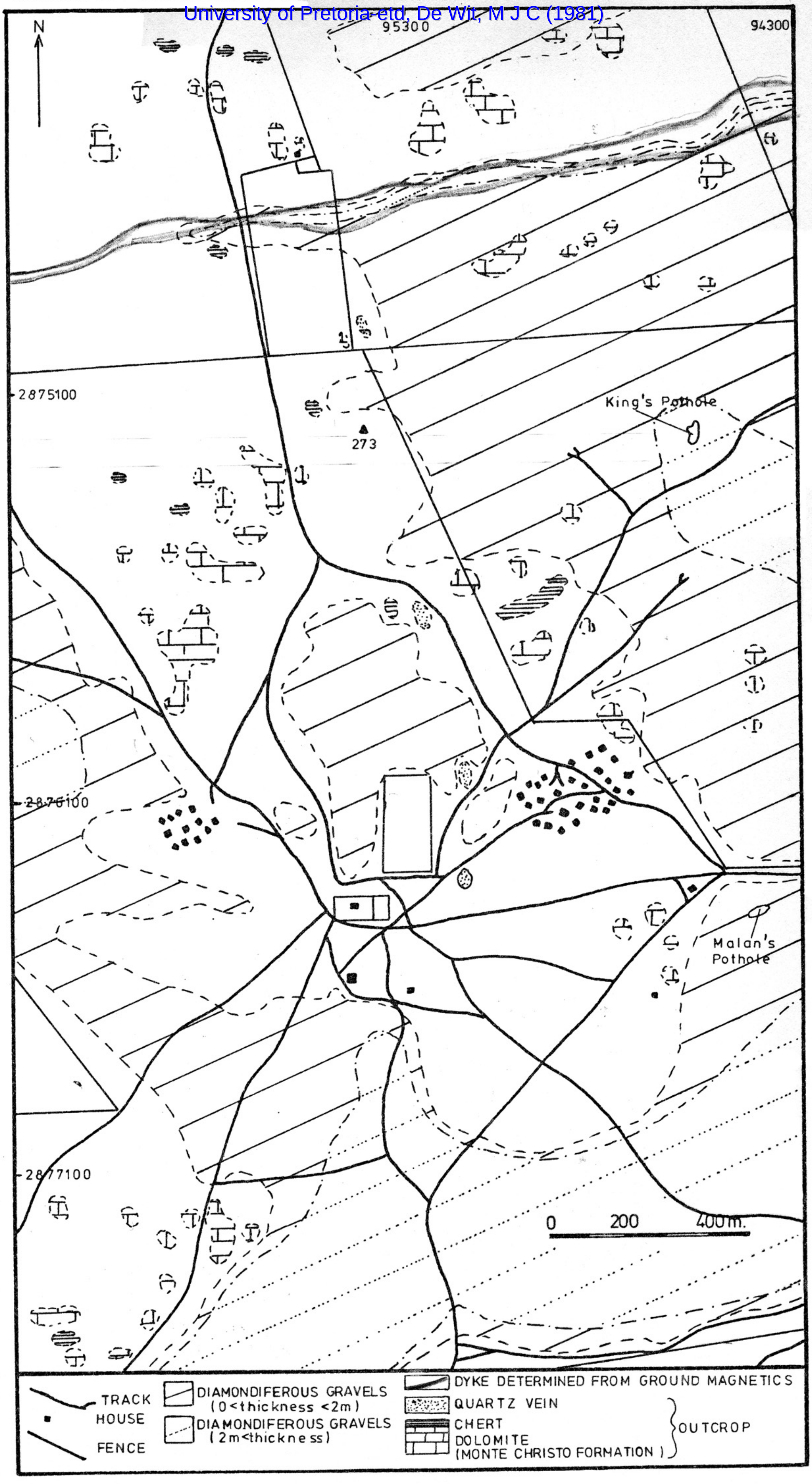
These are vertical shafts of up to 15 metres in diameter and they normally merge into caves at depth. Both King's and Malan's potholes are good examples (fig. 7).

According to Cvijic (1924), joints, fissures, rock texture and composition, surface slope and precipitation are the main factors controlling the formation of lapies. Cvijic (1924) also observed that lapies form only on exposed rock surfaces. This implies that, at least in the Lichtenburg area, the formation of the dolomite peneplain had already reached an advanced state before the gravels were deposited (Harger,1922).



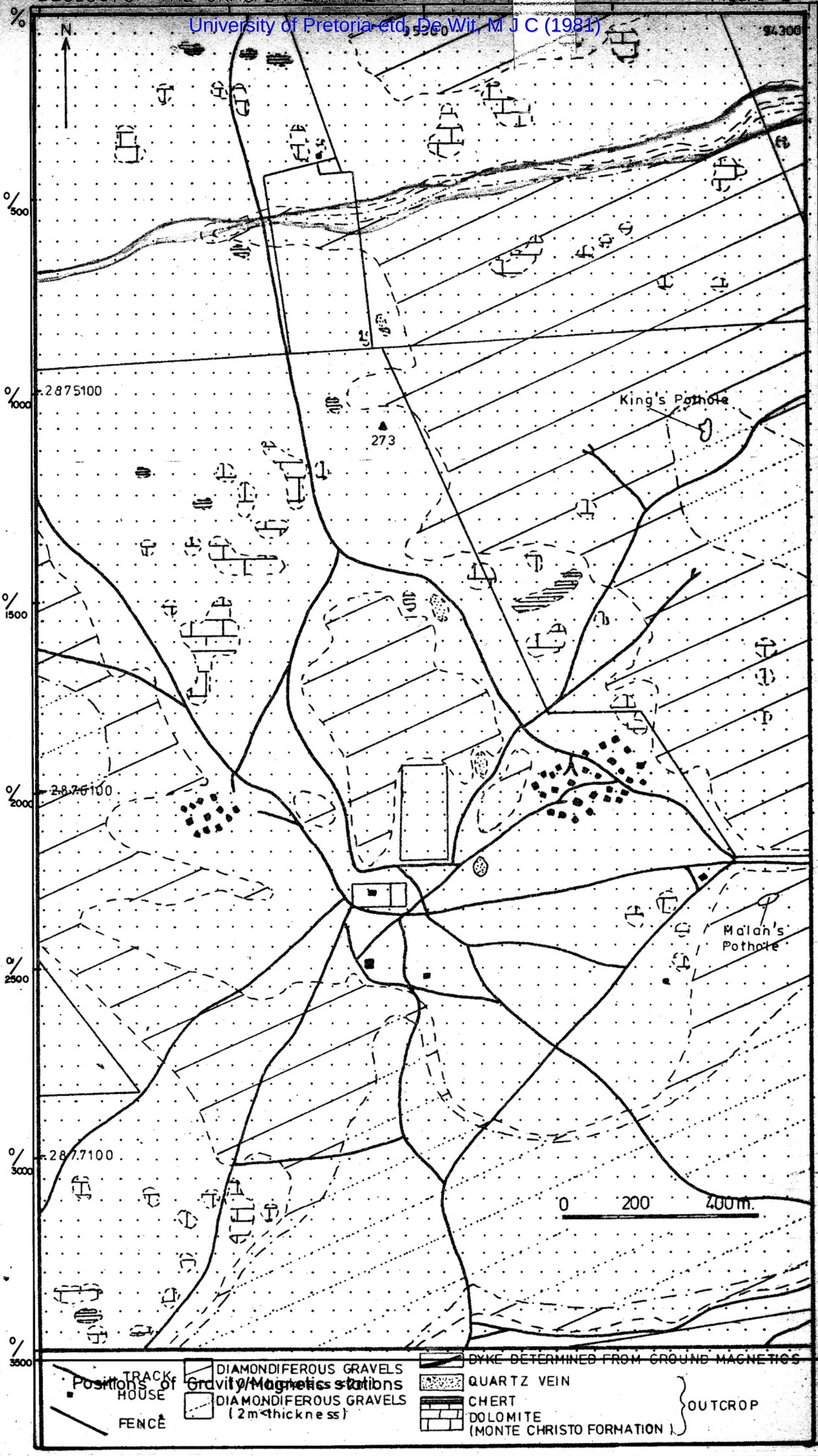
· Positions of Gravity/Magnetic stations

GEOLOGY OF THE GRASFONTEIN AREA (Outcrop map) Figure 2



GEOLOGY OF THE GRASFONTEIN AREA (Outcrop map)

Figure 2



The direction of the solution channels is usually controlled by joint patterns (Cvijic 1924, Moneymaker 1941).

Cvijic (1924) recognised that different forms of lapies delineate various stages of the erosion cycle and classified them accordingly :

(i) Young - characterised by shallow channels separated by sharp and irregular ridges.

(ii) Mature - characterised by deep irregular channels separated by rounded ridges.

(iii) Old - characterised by deep smooth channels separating low rounded dolomitic buttresses or monoliths.

Lapies of the mature and old stages predominate in the Lichtenburg area. Lapies of the young stage are only preserved below the gravel cover, as seen in cross-section close to King's pothole.

Harger (1922) was one of the first workers to realise the full economic implications of the geomorphological evolution of the Lichtenburg karst terrain. In particular he emphasised the importance of underground erosion integrated with the structural control of joints during the deposition of the diamondiferous gravels.

Harger (1922) argued that during Karoo sedimentation waters which percolated into the dolomite basement initiated chemical erosion. Subsequently the basement was gradually stripped of its cover of Karoo sediments, leaving only remnants of Dwyka tillite trapped in sinkholes.

The dolomite has undergone chemical erosion by percolating waters probably since pre-Karoo times. This is confirmed by the regional hydrogeology; there is a virtual absence of any flow of surface water due to numerous underground cavities and joints. Springs emerge only locally from the formation, where dykes, acting as barriers force the water flow to change direction.

2.3 Areal distribution and lithology of the gravels

The gravels in the Lichtenburg area are preserved in zones over an area covering approximately 3 000 km² and may be up to 20 metres thick. Significant variations in both thickness and lateral extent are known to occur. According to Du Toit (1951) all gravels were deposited in mid-late Tertiary.

The alluvial runs presently stand out in the landscape as positive topographical ridges due to chemical weathering of the dolomite following the deposition of the gravels (Du Toit, 1951).

The Welverdiend-Grasfontein run which constitutes the main alluvial run crosses the southern part of the study area in a northeast-southwest direction and can be traced from Welverdiend 361 JP, Hendriksdal 1 IP, to La Rys Stryd 53 IO (fig. 1). A secondary NW-SE run is present between Grasfontein 356 JP and Elizabeth 357 JO.

The central and eastern parts of the study area are covered by thin gravel, varying in thickness between one and two metres. In the northern part of the investigated area a deeper and major east-west run of younger gravels is referred to as the "Rooisloot" (Beetz, 1927; Du Toit, 1951) but this run is not manifested as a positive feature in the landscape.

The runs contain two types of gravel, namely (1) alluvial and (2) eluvial.

The contact of the alluvial gravel with the dolomite walls is often sharp and distinct although slumping is evident in several places. The eluvial material generally overlies the alluvial gravel but in places can also be found in weathered zones in the dolomite where no alluvial gravel exists.

2.3.1 Alluvial gravel

Two separate diamond-bearing alluvial gravel deposits have been recognized (Beetz , 1927).

(a) The older or high level gravels, of which the main Welverdiend-Grasfontein run forms part, are confined to the above-mentioned well-defined ridges (fig. 8). Clasts are predominantly chert and have a wide range in both roundness and size. These gravels have been interpreted as reworked gravel (Beetz 1927, Retief 1960), and are enriched in diamonds, but the content is variable. The gravels of the main Welverdiend-Grasfontein run were very rich on the farm portions D, H, K, L and M (fig. 1) of Grasfontein 356 JP, for example, but from M towards La Rys Stryd 53 IO diamond contents decreased significantly. Concomitantly the width of the run narrows down to 200 metres and the deposit thins considerably.

(b) The younger gravels were deposited in local hollows and channels of variable size. The "Rooisloot" which forms part of these gravels, consists of infilling of laterite, lateritic soil and sporadic layers of water-worn pebbles. Bedding can often be recognized in the "Rooisloot" and diamonds, although not in the quantities as found in the high level gravels, have been recovered from it (figs. 3 & 4).

The high level gravels can be further subdivided into the following four subdivisions (based on sections from deep workings and potholes; slightly modified after Du Toit, 1951).

(1) Basal white layer

This consists mainly of a white clay with abundant angular and weathered clasts of chert, dolomite and vein quartz. Sporadic rounded clasts have been encountered. Slump structures are evident in places. This layer normally directly overlies the dolomite. Infrequently it is underlain by wad, which as the drilling results have indicated, contain many cavities (up to 3 metres in diameter) or highly weathered dolomite still in situ. No diamonds are known to occur in this layer.

0,5m

0

Fig. 3. Section through Rooisloot.

0,5m

0

Fig. 4. Grading in the Rooisloot gravels. Diagonal across is the contact with the weathered dolomite.

(2) Productive lower red zone

This gravel, which has a high diamond content, generally consists of well-rounded pebbles of agate, chert, vein quartz, sandstone and dolomite. These well-rounded, water-worn pebbles may constitute nearly 90 per cent of the gravel in which instance it is referred to as "potato gravel" (fig. 5). Large boulders of chert and less frequently of sandstone, up to 700 mm in diameter are reasonably common.

The matrix varies in colour from off-white to shades of pink, red, brown and black. It consists mainly of argillaceous detritus probably derived from dolomite, sandstone and volcanics (Du Toit, 1951).

A point of interest is the origin of the volcanic detritus and associated agates. The agates range in colour from a bluish or deep green through greenish to yellow and even smokey-brown. A wine-red colour or even a darker tint, approaching that of almandine garnet, is especially common in agates from the deeper levels. According to Du Toit (1951) these peculiar wine-coloured agates are unknown elsewhere in South Africa.

Agates attain a size of several tens of millimetres in diameter but bigger agates are not uncommon. The smaller ones are all usually well rounded and even polished, but the bigger specimens may be angular, cylindrical to slab-shaped.

It has been claimed that most of the agates found in the Bakerville gravels are similar to the agates found on the Springbok Flats which were derived from the Bushveld basalt (Du Toit 1951, Retief 1960).

(3) Poor intermediate zone

The lithology of this zone is similar to that of the productive lower zone, but despite scattered agates and even sporadic diamonds, this zone is generally uneconomic. The zone is not always clearly

Fig. 5. Potato gravel.

Fig. 6. Potato gravel lying on weathered chert and dolomite.

developed and the transition from the productive lower red zone to the overlying productive upper layer may be gradual.

Du Toit (1951) believed the interface between the productive upper and the lower gravels to represent an unconformity which he recognized [illegible] in a number of places. Unfortunately lack of exposure, due to infilling of tailings in most of the excavations, prevented the verification of such an unconformity.

(4) Productive upper layer

The upper layer is mainly composed of rounded pebbles, although angular chert clasts are present. The matrix is generally pale-grey in colour (compared with that of the lower productive layer), probably due to more extensive leaching. Diamonds are as abundant as in the lower productive zone. Retief (1960) described the occurrence of reworked gravels composed of chert fragments with a wide range in degree of rounding and in size. These reworked gravels occur at a depth of no more than 1-1½ metres and are usually found in the vicinity of the alluvial gravels, commonly flanking the runs (Retief,1960). A common feature of these deposits is that the pebbles are usually in an advanced state of weathering. The thickness of this productive upper zone can be as much as seven metres.

2.3.2 Eluvial gravel

It appears that solution of the basement dolomite with interbedded chert has left the chert as a residue of insoluble silica clasts. These angular clasts vary in size from millimetres to metres in diameter. They are very poorly sorted and are densely packed. There is no field evidence to suggest that these gravels have been transported horizontally.

The field relation suggests that this gravel accumulated on the dolomite surface and within the depressions of the chemically weathered dolomite. Previously deposited alluvial gravel may be completely covered by this eluvial material. In many instances there is a clear break between the alluvial and eluvial material on top. Elsewhere the deposits consist entirely of eluvial chert.

2.4 Sinkholes

The three major potholes in the area are known as King's, Malan's and Van Wyk's potholes. The former two are in fact two deep gorge-like features, and thus should strictly speaking be called yamas (see section 2.2). Van Wyk's Pothole (situated on the main run near peg no. 900/3200, fig. 2), merely a large depression and also famous for the diamond production, is now completely filled with tailings.

The water table in King's Pothole is approximately 30 metres below the ground level, with approximately another 4 metres to the bottom of the hole. The pothole is nearly 15 metres wide. Its long axis strikes nearly in a north-south direction (fig. 7). At right angles to this, following an east-west joint in the dolomite, is a diamond-rich gravel run, erroneously referred to as a fissure by some local diggers. On both sides of the pothole, the diamondiferous gravel is covered by a thick layer of angular, weathered chert.

The long axis of Malan's Pothole is nearly east-west parallel to the "fissure" in King's Pothole and also parallel to the trends of the runs. The diamondiferous gravel here is also covered by about 5 to 10 metres of angular chert and weathered dolomite fragments. Fractures are perpendicular to the long axis of Malan's Pothole.

The dimensions of both potholes are similar. It is interesting to note that neither of these two potholes is situated along the main run.

A.

B.

Fig. 7A & B.
King's Pothole
(Facing south).

2.5 Chert ridges

Several small ridges of chert are present in the study area. They are thought to be the remnants of the weathered chert/dolomite sequence. According to local diggers who have been working on Manana 261 IP, some of the long channels in the run are truncated by the chert bars. These bars evidently acted as weirs across the channel. Large concentrations of diamonds were found on the northern and western sides of these barriers depending on the direction of the channel. They have apparently acted as trap sites and diamond concentrations are probably due to changes in current direction and velocity (turbulence) at these obstructions within the channels.

Although these bars have not been observed within the main run of the investigated area, they are present in the more central part of the study area. Here only thinner gravels exist, with thicknesses of between 1 and 2 metres and containing smaller and fewer pebbles than the main run.

3. GRAVITY SURVEY

3.1 Introduction

The magnitude of gravity at any point on the earth's surface depends on five factors namely elevation, latitude, topography of the surrounding terrain, earth tides and variations in density of the sub-surface. It is the last factor that is important in gravity exploration, but because its effect is generally very much smaller than that of the other four combined, accurate corrections are necessary to eliminate the others.

The change in gravity from the equator (978 049 mgal) to the poles (983 221 mgal) amounts to about 5000 mgal which is about 0,5 per cent of the average gravity value. The effect of elevation can in some cases be as much as 100 mgal or 0,01 per cent of gravity. A large local gravity anomaly can be as much as 10 mgal (0,0001 per cent of gravity), but usually much less, down to one or more tenths of a mgal. Thus variations in gravity which are significant in prospecting are not only minute in comparison with the average value of gravity but also in comparison with the effects of large changes in latitude and elevation.

The corrected gravity values which are measured relative to a base station, give information about subsurface density differences over an investigated area.

The main purpose of the present gravity survey was to produce a Bouguer and a residual gravity anomaly map. Since the density difference between the dolomite and the leached dolomite and overlying gravels is sufficiently large, it was estimated that subsurface potholes and gravel-filled structures should be readily detected by the application of a detailed gravity survey. This would be particularly relevant for major potholes not situated on the main runs, that might be further explored for diamondiferous gravels.

A 50-metre grid was set up over a rectangular area covering 3,5 kilometres in a north-south direction and 2 kilometres in an east-west direction on Grasfontein 356 JP (figs. 1 and 2) and comprised a total of 2911 stations. The dimensions of the known potholes and gravel runs (generally larger than 50-60 metres) justified a 50 metre spacing of stations to identify these major structures.

3.2 Field Procedure

3.2.1 Surveying

(a) Latitude and longitude

The correct co-ordinates of stations were determined by Blunt's method (Richardus, 1966) using beacon 273 (y= 95 384,37 x= 2 875,41; found on 1:50 000 topographical map 2526 CC), which is situated in the centre of the area, together with beacons in the immediate vicinity.

The co-ordinate system in South Africa is based on the Gauss conform projection. It consists of belts (Lo) running north-south, 2° of longitude in width, the central meridian being the odd meridian, e.g. 15°, 17°, 21° etc.

On Grasfontein 356 JP Lo 17 was used. The most north-westerly point of the grid was used as a local co-ordinate reference point with co-ordinates y= 0,00 and x= 0,00 (actual co-ordinates y= 96 300,00 and x= 2 874 100,00).

A computer programme, developed by Mr C.P. Venter of the Geological Survey of South Africa, for use on a Hewlett-Packard 9825A calculator, was used for the conversion of longitude and latitude to x and y co-ordinates (in metres).

The remaining stations were laid out relative to the reference point, and hence the absolute co-ordinates of every point can be calculated, i.e. station y= 250,00; x= 650,00 has absolute co-ordinates of;

y= 96 300,00 - 250,00 = 96 050,00

x= 2 874 100,00 + 650,00 = 2 874 750,00

In a Lo system y is positive to the west of the central meridian.

A Wild T_2 theodolite was used to accurately position each corner of every square kilometre of the test area.

To maintain the required accuracy, four beacons were used to obtain three comparable co-ordinated values for each corner point by resection (Richardus, 1966). Following the location of the corner stations (15 in total), a 50-metre cable was used to lay out the rest of the stations.

(b) Elevation (fig. 8 and map 2)

Using a Zeiss automatic level, the four boundary lines of each square kilometre were levelled at least twice to within 0,005 metre per kilometre. Thus a total of 10 x 1 and 2 x 0,5 kilometre lines were levelled four times. Subsequently, each line of 20 stations (i.e. 1 kilometre) was levelled to an accuracy of 0,005 metres. Due to the repeated levelling of the outer kilometre lines, a high degree of accuracy was obtained. The Wild T_2 theodolite was used in a tachymetric method to establish the height of the reference point (y= 0,00, x= 0,00) from beacon 273 (topographical map 2526 CC). It has a height of 1522,3 metres. The height of the other stations were tied in from this reference base. A successful check was made by measuring the heights of several other corner points using the same method. Levelling results of the point furthest away from the reference point, i.e. station number 2000/3500, were well within the maximum acceptable error of 0,028 metres. The results of the levelling are shown as map 2 and fig. 8.

3.2.2 Gravity

(a) Gravity meters

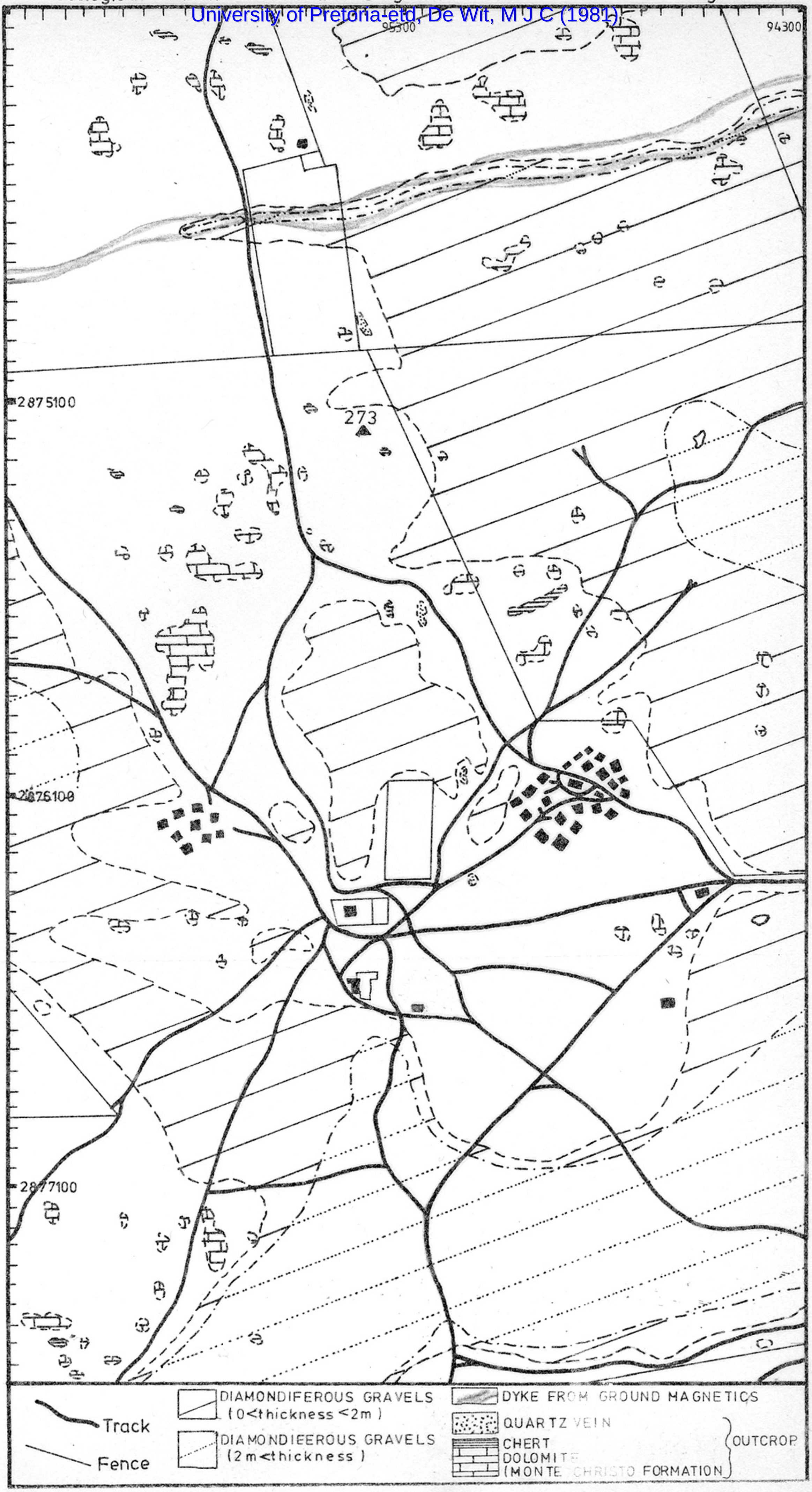
A temperature stabilised geodetic La Coste-Romberg gravimeter (no.

Elevation map (1 contour=1metre)

Figure 8

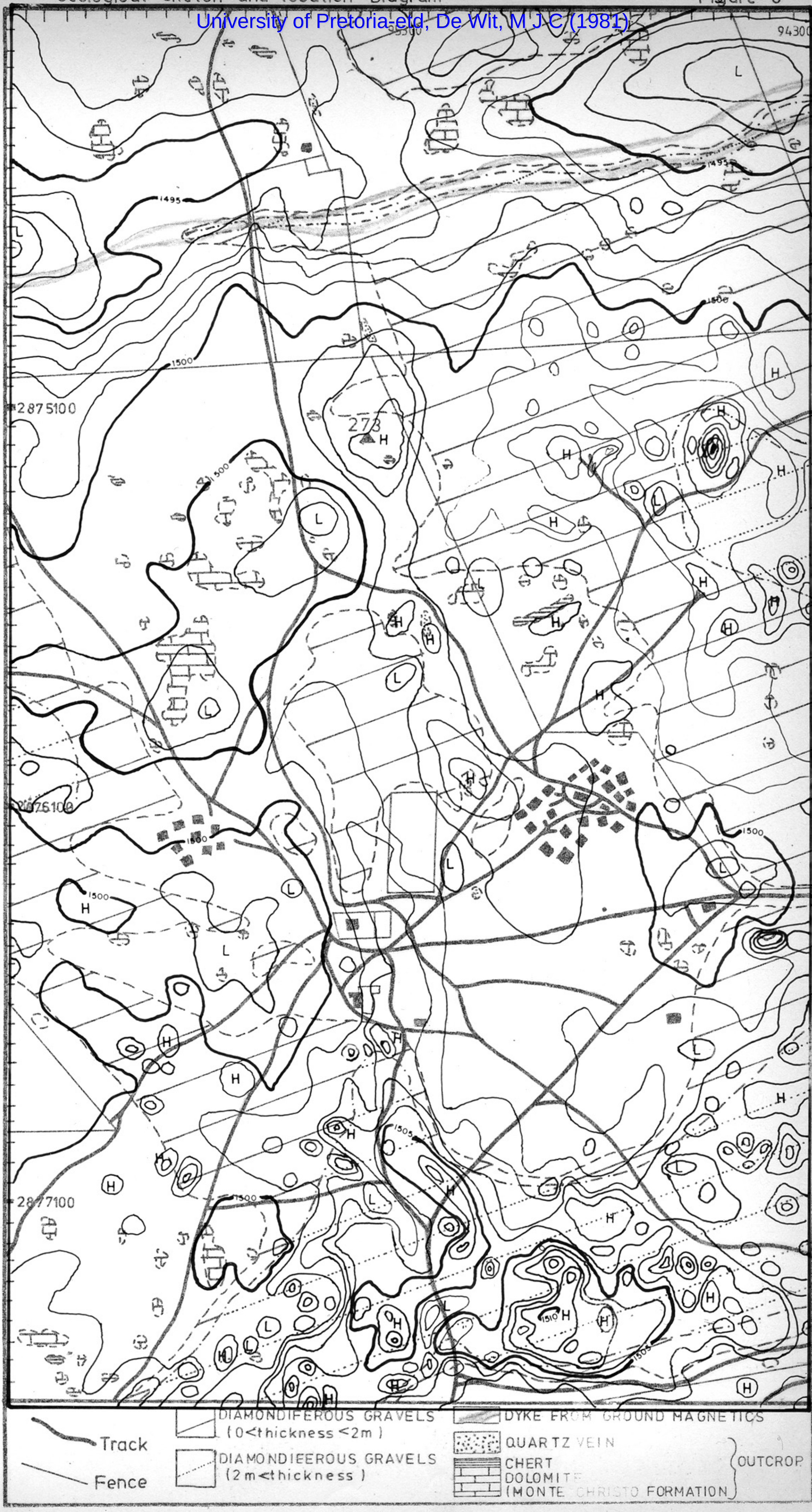
Geological sketch and location Diagram

Figure 8



Elevation map (1 contour = 1 metre) Figure 8

Geological sketch and location Diagram Figure 8



397) was used for all base stations, allowing an accuracy of 0,01 mgal per station. For the remaining 2831 stations a Sodin gravimeter (no. 102) (see illustration on front page) was used with a dial constant of 0,1017 mgal per division. A plot of the daily drift (fig. 9) does not follow a smooth curve. Constant use of the Sodin gravimeter over a period of eight months and its transport on dirt roads are thought to have contributed to the irregularities.

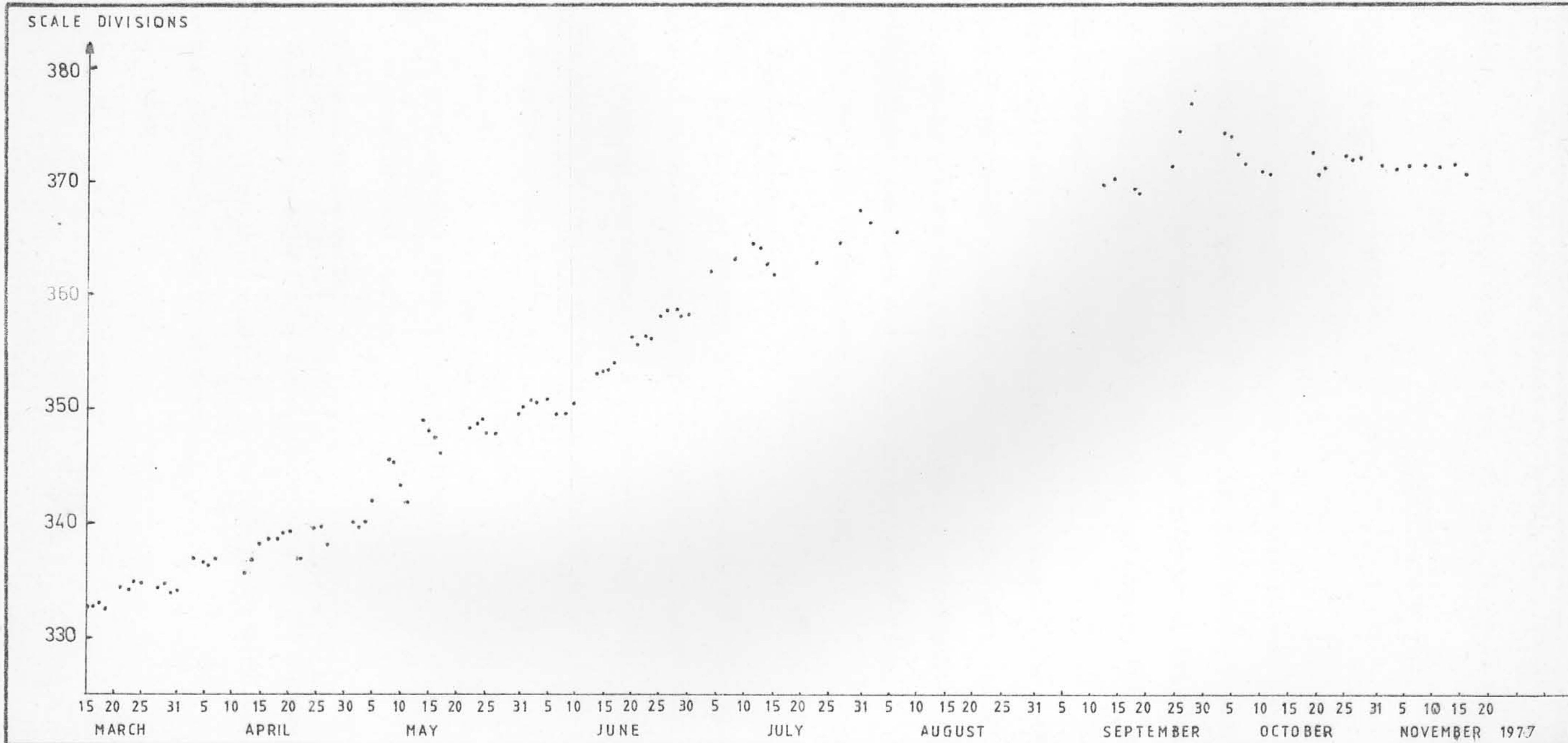
(b) Gravity base stations

A second order base station was established at Rooigrond (Cape Province), 47 kilometres from Lichtenburg on the main Lichtenburg-Mafikeng road, in 1976 using a La Coste-Romberg Gravimeter (Palmer, 1978). It was tied to the Pretoria Old Landbank base station (978 616,22 mgal), which itself has been tied to the Transvaal Museum pendulum site on IGSN-71 International base in Pretoria (Maher, 1979).

The absolute gravity value of the Rooigrond base station was determined as 978 602,05 ± 0,01 mgal (Palmer, 1978).

From Rooigrond (approximately 50 kilometres west of Bakerville) a main third order base was established at the junction of the Greefslaagte turn-off from the main Lichtenburg-Zeerust road close to Bakerville by Mr E.H. Stettler and the author (978 585,65 ± 0,01 mgal, Appendix B). This base station was used to tie in four main base stations on the Grasfontein test area, again using the La Coste-Romberg gravimeter. Each of these stations was tied in to the Greefslaagte turnoff base station at least three times to ensure an accuracy of ± 0,01 mgal. The remaining 78 base stations in the survey area were tied in with similar accuracy using the same gravimeter (Appendix B).

The 82 subordinate base stations on Grasfontein 356 JP were used to tie-in the main survey which was carried out using a Sodin gravimeter. The base stations were spaced in such a way that the calculation of the



Drift curve for Sodin gravimeter (no. 102) for period 15-3-1977 —— 15-11-1977.
(Scale value = 0,1017 mgal per division).

Drift curve gravimeter

Figure 9

hourly drift of the gravimeter needed for primary calculations was facilitated. Gravity stations were read at least twice to keep within limit of 0,02 mgal.

3.3 Corrections

3.3.1 Gravimeter drift

Gravimeters are very sensitive and can measure changes in gravity caused by the relative movement of the sun and moon which is amplified by the elasticity of the earth. These changes known as the tidal effect, can be as large as 0,3 mgal (Telford and others, 1976) and must be corrected.

The total drift of the gravimeter, i.e. the quasi-linear drift due to creep of the quartz spring and handling and other more random effects was obtained by reading the gravimeter at the base stations at hourly intervals between the start and the end of each working day. Corrections for each station were made accordingly.

3.3.2 Free-air correction

Since the force of attraction varies inversely with the square of distance, it is necessary to correct for changes in elevation so that all field readings are reduced to a common elevation datum.

The gravity attraction of the earth on a unit mass a distance r from the centre of the earth is,

$$g = kM/r^2$$

where g = gravitational attraction per unit mass

k = gravitational constant

M = mass of the earth

The vertical gradient of g due to variations in the distance from the centre of the earth is expressed by the derivative with respect to the radial distance in the above formula,

$$\frac{\partial g}{\partial r} = \frac{-2kM}{r^3} = \frac{-2g}{r}$$

At sea level this value of the gradient is -0,3086 mgal per metre (Telford and others, 1976 ; Darracott,1974; Parasnis,1962). The correction of 0,3086 mgal per metre of elevation must be added to a measured gravity difference if the station lies above the datum level and subtracted if it lies below it. This free-air correction takes no account of the rock material between the station and the datum plane.

3.3.3 Bouguer correction

The Bouguer correction takes into account the vertical attraction exerted on a unit mass by the slab of material between the station and the datum plane, which is ignored in the above free-air calculations. If the topography above sea level (datum plane) is regarded as a horizontal infinite plate with density of 2,67 g/cm³ it follows that the reduction for this mass will be

$\partial g = 2 \pi G \rho h$ (Heiskanen and Vening Meinesz 1958)

where ρ = density

h = height above sea level

G = the universal gravitational constant

$= 6{,}670 \times 10^{11}$ m³/kg s²

then $\Delta g = 0{,}04191\ \rho$ mgal/m and for $\rho = 2{,}67$ g/cm³

$\Delta g = 0{,}1118$ mgal/m

the correction must be subtracted from the measured gravity difference if a station lies above the datum level.

The combined free-air and Bouguer correction for a density of 2,67 g/cm³ is,

$B_k = 0{,}3086 - 0{,}1118$

$= 0{,}1968$ mgal/m

Two assumptions are made in deriving the Bouguer correction, namely that the slab is of uniform density and of infinite horizontal extent. To modify this one needs considerable knowledge of (1) the local geology in terms of rock type, its actual density and the geometry of the rock sequences, and (2) an accurate knowledge of the topography.

As the Bakerville terrain is relatively flat no terrain corrections were required in the survey. When an occasional hollow or elevation was encountered, due to the activities of the diggers, the station was removed far enough away to eliminate its local influence.

The Bouguer anomaly (Ervin, 1977) is calculated as follows :-

$$g_B = g_{obs} - (g_{theo} - B_{com}) = g_{obs} + B_{com} - g_{theo}$$

where g_{obs} = observed gravity value

B_{com} = combined free-air and Bouguer reduction

g_{theo} = theoretical gravity value

3.3.4 Theoretical gravity

As the earth is not a perfect sphere, the absolute value of the theoretical gravity at sea level will change from point to point, in such a way that for each station at sea level the calculation for its theoretical gravity value is as follows :-

$$g_{theo} = 978\ 031{,}8\ (1+0{,}0053204\ \sin^2 L - 0{,}0000058\ \sin^2 2L)\ \text{mgal}$$

where L = the latitude

978 031,8 mgal = the gravity value at the equator

These are the figures as set by the International Gravity Standardisation Net 1971 (IGSN 71; Darracott, 1974).

The theoretical gravity of each corner point of the grid was calculated from which the intermediate observation points were interpolated. The theoretical gravity will change by approximately 0,01 mgal per 15 metre change in latitude.

3.4 Bouguer anomaly map

Because of the large amount of field data and the many calculations for the reduction of the 2911 gravity observation points, it was decided to present the results in map form only. Field data and calculations are contained in the technical report of the Geological Survey of South Africa (Filmalter, 1978). The elevation, the Bouguer anomaly and the residual gravity are shown as maps 2, 3 and 4.

The Bouguer anomaly and residual gravity maps are contoured at 0,1 mgal interval.

3.5 Regional and residual gravity maps

Seventeen evenly distributed gravity stations at which the depth to the dolomite was accurately known (usually dolomite outcrop), were used to calculate a regional gravity field for the area (fig. 10). These stations were all situated over so-called gravity highs, (i.e. areas with a relatively shallow bedrock). The data for these points are given in Table 2.

Polynomial trend surfaces of various degrees were fitted to the data and the most satisfactory fit, a first order one, (i.e. a sloping plane), was chosen. The calculations were done using a Fortran program available at the Geological Survey of South Africa. In this way a regional gravity field was calculated that would have been observed if dolomite cropped out everywhere.

The calculated regional gravity field is shown on map 4.

The regional gravity value at each station was subtracted from the observed Bouguer anomaly at that station to produce the residual gravity value. Values were plotted and contoured (fig. 11 and map 4).

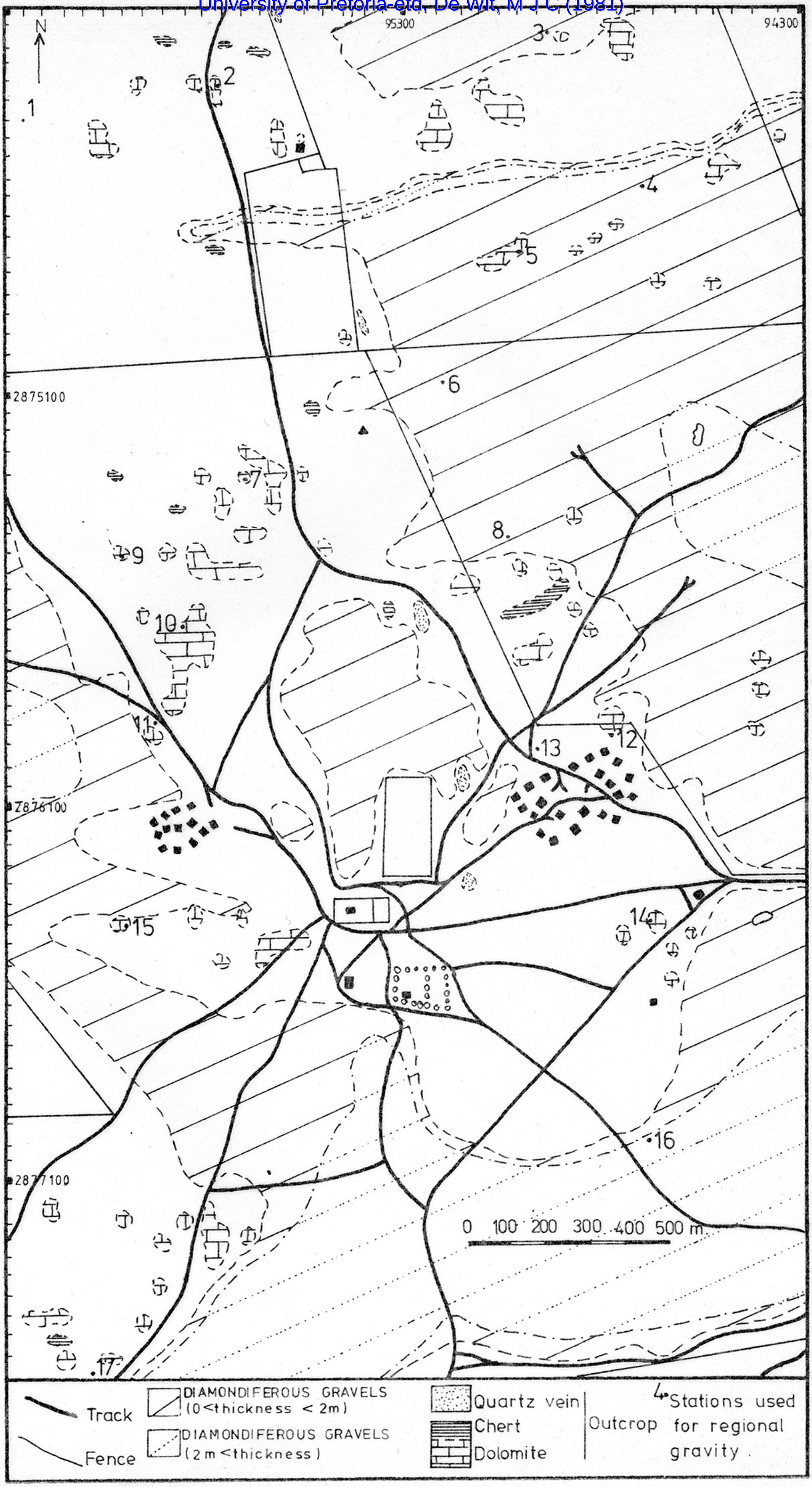
3.6 Results and interpretation

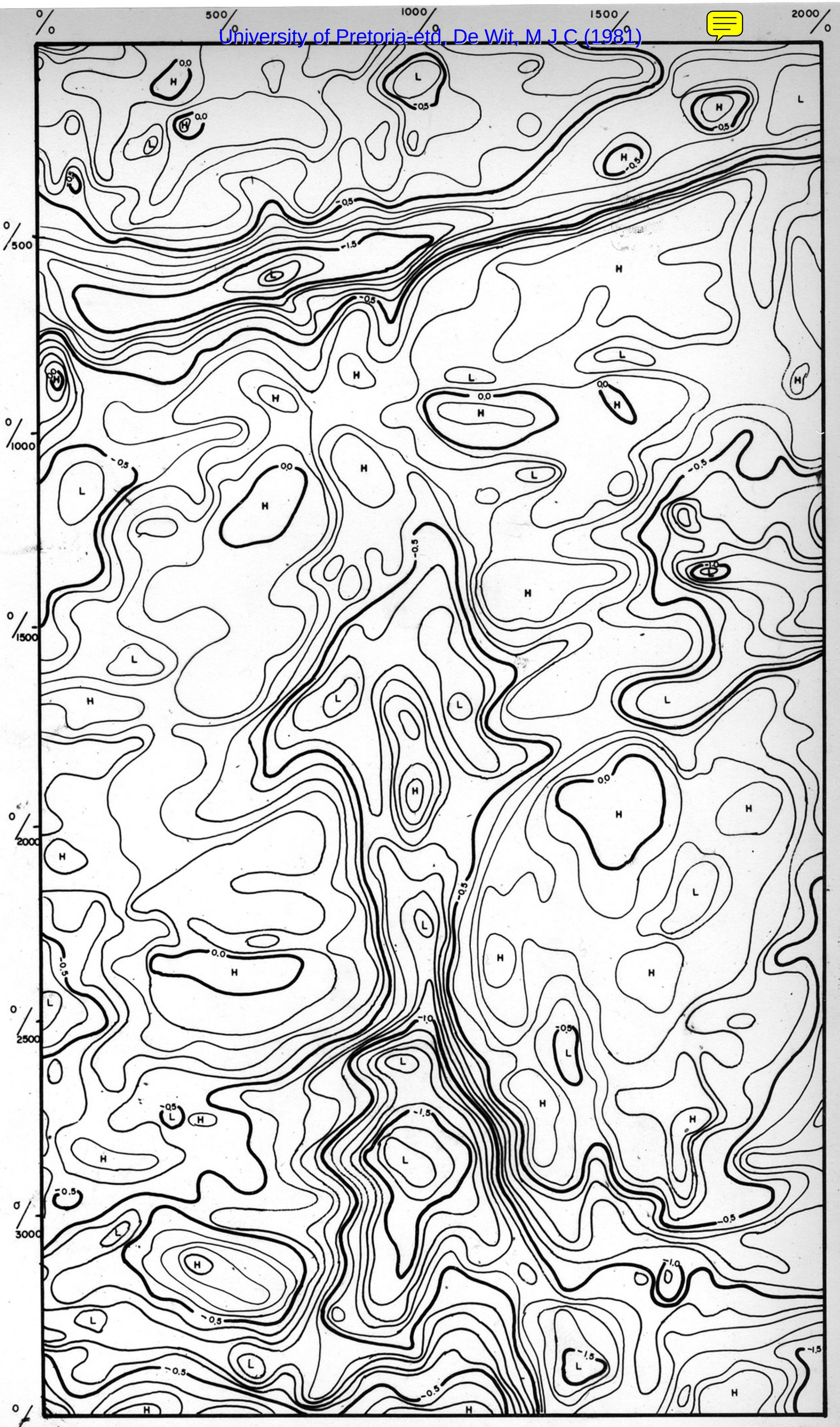
The density of dolomite varies with composition. Density determinations were done on fresh dolomite and gave a mean value of 2,85 g/cm^3. This agrees with the values used by Kleywegt and Enslin (1973).

In considering the density of the gravel and leached zones, factors

Gravity stations used for regional gravity field

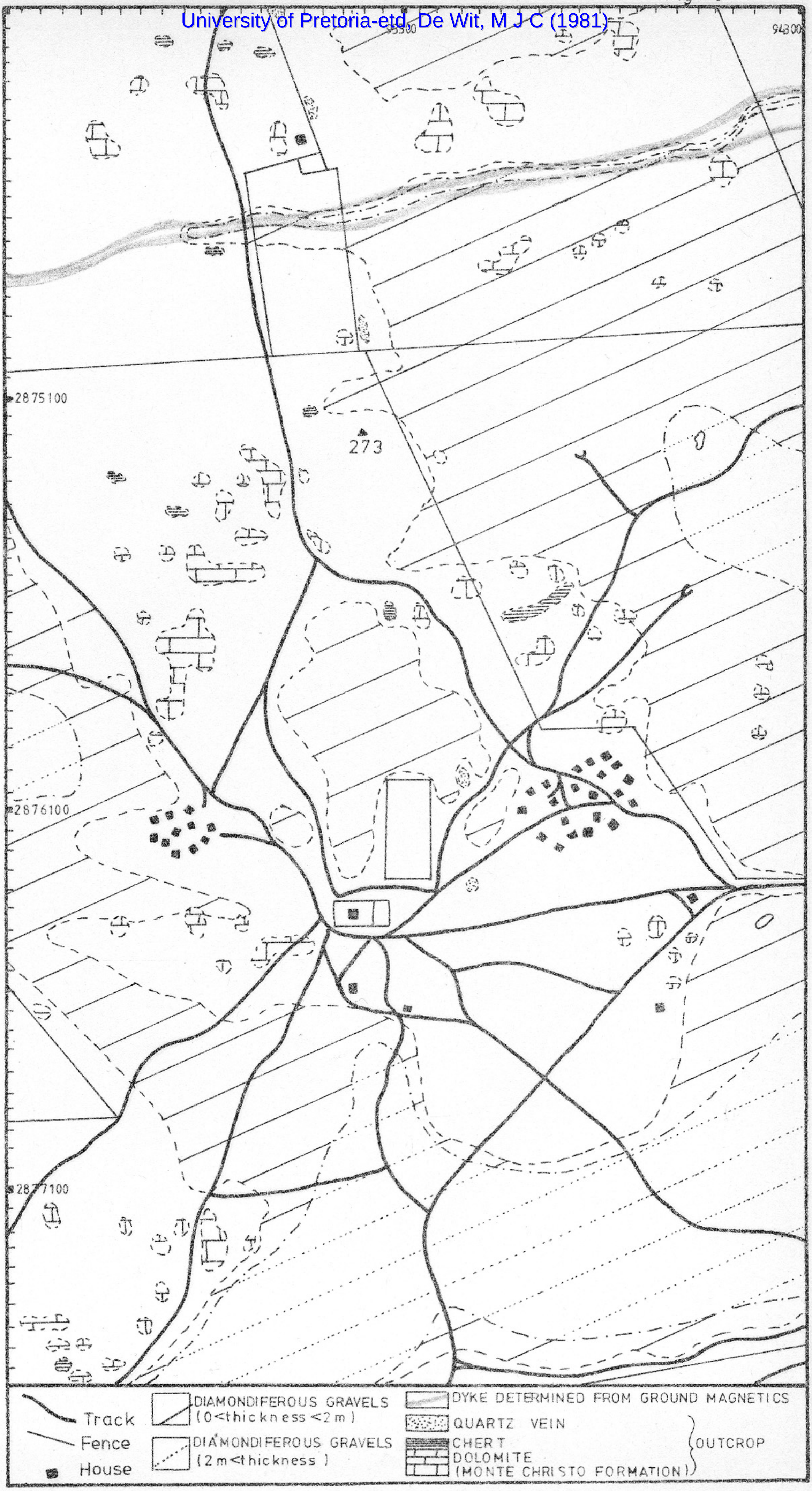
Figure 10

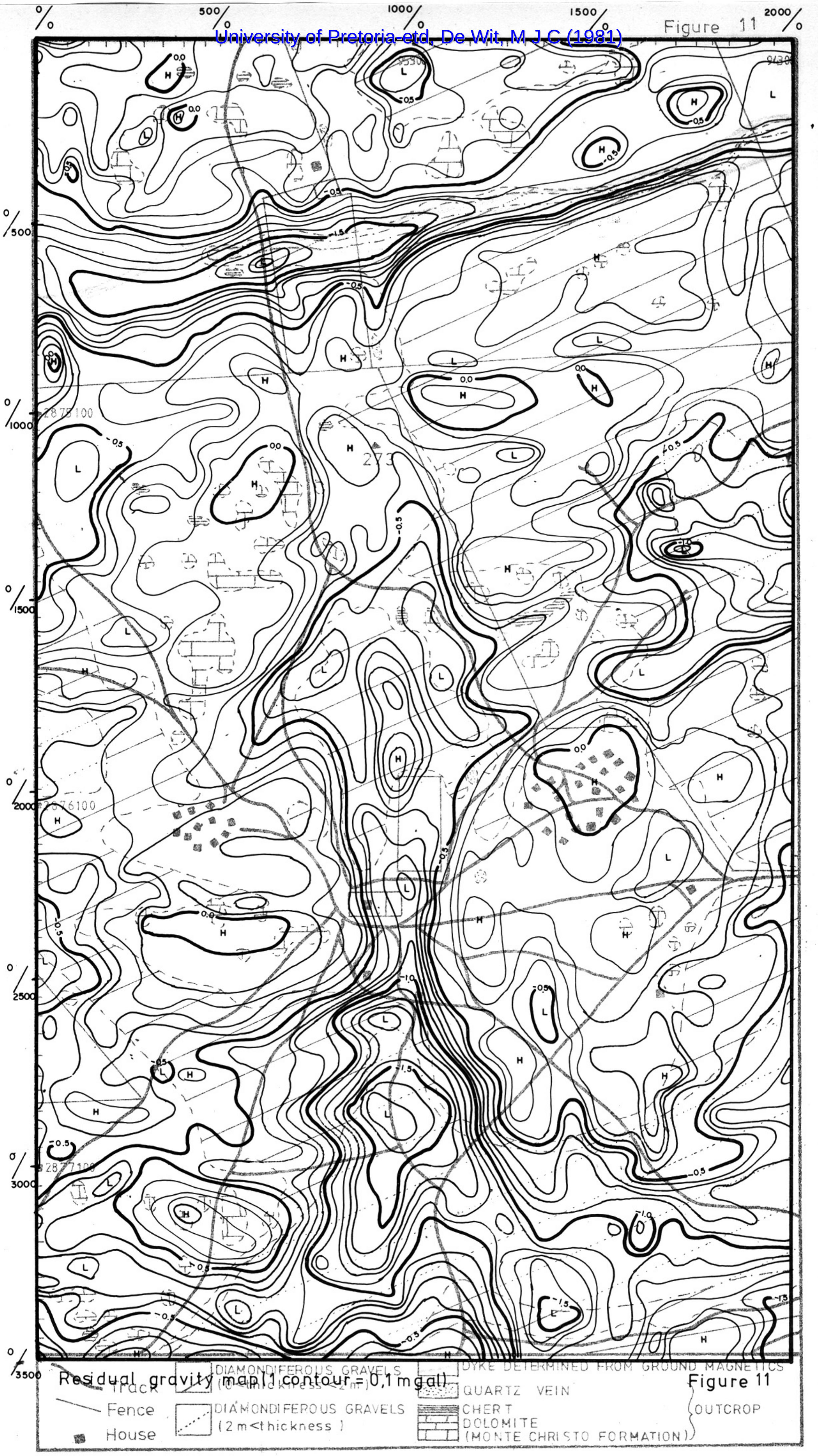




Residual gravity map (1 contour = 0,1 mgal)

Figure 11


94300
2875100
273
2876100
2877100
Track
Fence
House
DIAMONDIFEROUS GRAVELS (0<thickness<2m)
DIAMONDIFEROUS GRAVELS (2m<thickness)
DYKE DETERMINED FROM GROUND MAGNETICS
QUARTZ VEIN
CHERT
DOLOMITE
(MONTE CHRISTO FORMATION)
OUTCROP



Residual gravity map (1 contour = 0,1 mgal)

Figure 11

TABLE 2 Data for 17 stations used in calculating the regional and residual gravity fields.

STATION NO.	CO-ORDINATES	BOUGUER ANOMALY (Observed)	BOUGUER ANOMALY (Calculated)	RESIDUAL VALUE
1	50/ 300	-140,08	-140,16	0,08
2	550/ 200	-140,30	-140,30	0,00
3	1350/ 50	-140,69	-140/47	-0,22
4	1600/ 450	-140,84	-140,78	-0,06
5	1300/ 600	-140,82	-140,77	-0,05
6	1100/ 950	-140,84	-140,91	0,07
7	600/1200	-140,80	-140,85	0,05
8	1250/1250	-141,18	-141,19	0,01
9	300/1400	-140,95	-140,90	-0,05
10	450/1600	-141,01	-141,03	0,02
11	350/1800	-141,24	-141,21	-0,03
12	1500/1900	-141,57	-141,56	-0,01
13	1350/1900	-141,56	-141,54	-0,02
14	1600/2350	-141,92	-141,87	-0,05
15	300/2750	-141,45	-141,47	0,02
16	1650/2900	-142,11	-142,22	0,11
17	250/3500	-142,30	-142,12	-0,18

Locations of these 17 stations are illustrated on Figure 10.

such as increasing compaction with depth, the variable types of material present and the influence of the water table have to be taken into account.

Wad and even cavities which exist in highly leached dolomite will also affect the average density of material in leached zones.

Fourteen density determinations on gravel and on weathered dolomite gave an average value of 2,07 g/cm³. However, taking the presence of cavities and layers of wad into account a density contrast of -1,0 g/cm³ between fresh dolomite and the superficial deposits was used for modelling purposes. Drilling results showed the models to be reasonably accurate so that this density contrast appears to be of the correct magnitude.

It is impossible to reach a unique solution through the interpretation of anomalies in any of the potential field methods. This is due to two factors, namely: (i) the characteristics of the unknown body which causes the anomaly are given only by insufficient limits, and (ii), an infinite number of forms and positions of the body remain for any particular characteristic. However, the best possible fit after some geological constraints have been applied, of the models calculated over the gravity anomalies will be used.

The regional gravity field should theoretically always be equal to or larger than the observed Bouguer gravity values in this type of application and the residual will therefore either be zero or negative. As outcropping dolomitic bedrock in this particular area is representative of the regional field, the areas with zero residual anomaly are those with no density contrast.

The areas of zero or small residual gravity values are referred to as gravity "highs". The "lows" are the areas where the residual gravity has relatively high negative values (as low as -2,5 mgal) because of the density contrast and a large thickness of overburden. These areas are of most interest in this particular study.

Two major orientation trends dominate the areas of negative anomalies on the residual map (fig. 11, map 4). In addition to these two major orientation trends, the dyke in the northern part of the area causes a major gravity anomaly in a north-easterly direction. The negative anomaly which is associated with the dyke, is due to its deep weathering and the associated material which was deposited in the channel to form the so-called "Rooisloot".

Dr R.J. Kleywegt of the Geological Survey of South Africa developed a programme which was translated for the Hewlett-Packard 9825A by Mr C.P. Venter, which computes two-dimensional models using residual gravity data and a fixed density contrast. In this instance the upper surface of the anomalous mass is assumed to be horizontal and to coincide with the ground surface. The method is based on the iterative method of Bott (1960). Using the residual gravity data and a density contrast of -1,0 g/cm^3 several models over specific areas were calculated. These are illustrated in fig. 35. These two-dimensional models give an indication of the depth and width of the structures involved. Boreholes which were drilled confirmed the parameters calculated for the models.

Three models have been calculated for the Grasfontein dyke and are shown in fig. 35, models 1, 2 and 3. The width of the weathered zone along the dyke varies from approximately 100 m in the west to nearly 200 m in the east of the area, and variations in depth of unweathered dyke material range from between 12 and 40 m. The Rooisloot fault (Day, 1980) is picked up as a linear leached zone (fig. 12) and coincided with the displacement of the dyke indicated by this magnetic survey (map 4). The actual gravel runs situated over the gravity low are, however, much shallower and the maximum depth recorded is approximately 6 m. They merely contribute to the total anomaly.

Most of the negative anomalies are, however, caused by deep leached zones in the dolomite which contain no gravel. These zones occur on both the ENE and the nearly N directional trends. The anomalies associated with these zones are narrow, generally between 50-100 m wide and are between 500-1000 m in length before disappearing or being intersected by anomalies of the alternate trend. These residual gravity anomalies can be as large as -0,5 mgal but are usually less.

The material intersected in these zones by boreholes ranges from fresh chert, usually at the top, through highly leached dolomite/chert and wad into solid dolomite. Cavities in the wad close to the solid dolomite are not unusual. (Figs. 19-23, p.58).

A major negative gravity anomaly trends north-south in the southern half of the area (fig. 12) which branches off the main major channel zone. A negative gravity low occupies the centre of the belt in the south (- 1,7 mgal). Here a depth of nearly 50 m to bedrock was recorded (figs. 12 & 21, borehole 9).

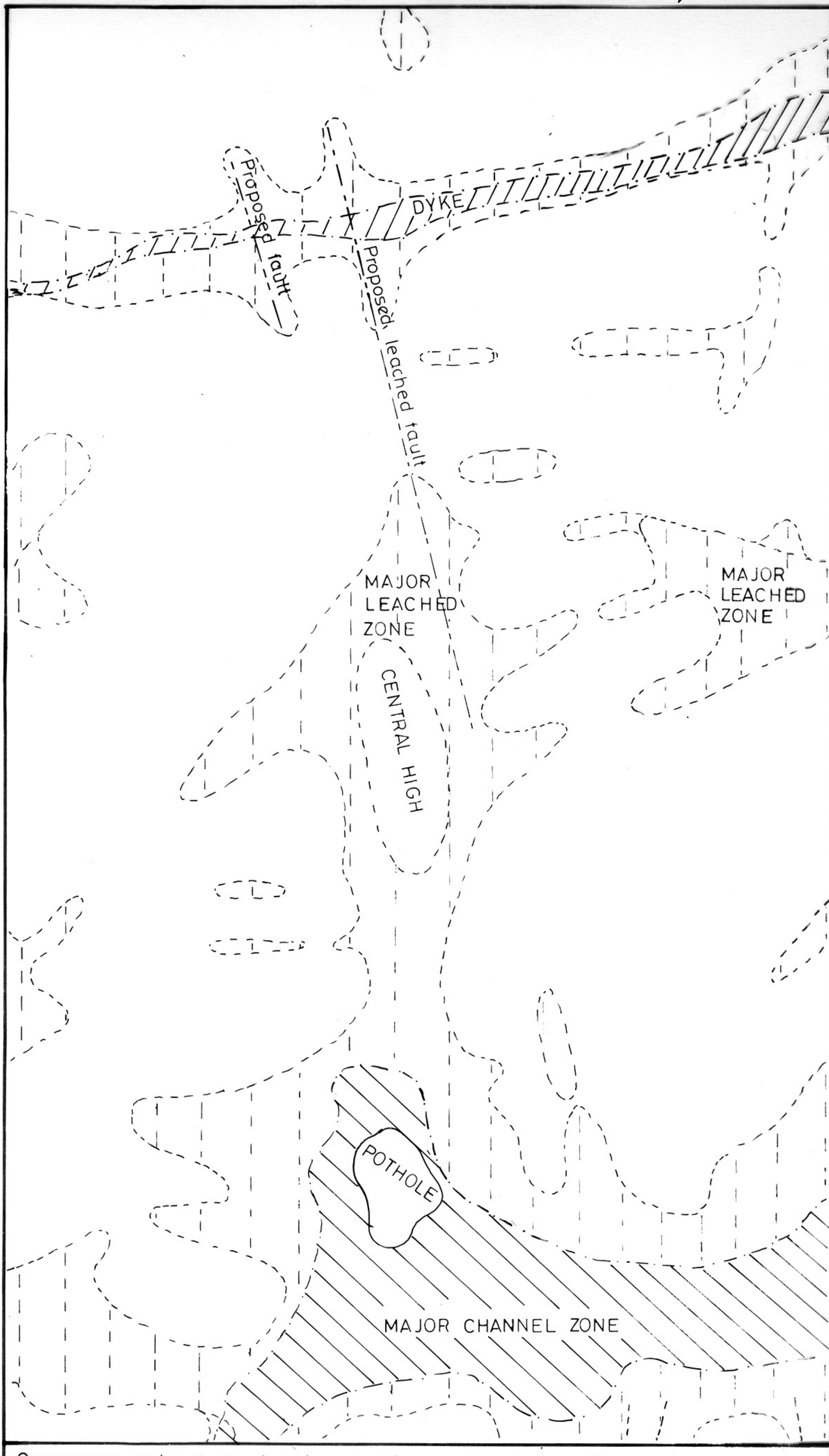
In the middle of the survey area (around peg 1000/1900), an isolated positive gravity anomaly (fig. 12, central high) occurs within this negative anomaly. A weathered zone of chert and dolomite was found (figs. 20 & 22, boreholes 2 and 5) on the eastern side of this positive anomaly. On the western side (around peg 800/1650) five to eight metres of gravel were found. Three holes drilled with a pneumatic drill (fig. 22, boreholes 10, 13 and 14) penetrated the small basin of shallow gravels and at the position of borehole 10, a hole with a diameter of 1,8 m was drilled with the Masserenti drill to a depth of 7 m. Two diamonds totalling 0,115 carats were recovered from this hole. The gravels overlying this anomaly were apparently deposited by river floods, as it does not lie on any of the major gravel runs. The depth to dolomitic bedrock was found to be 5 m less (Masserenti hole 1) on the eastern side of the central high (fig. 12). The maximum thickness of the weathered zones here reached approximately 15 m. On the western side, depths of similar magnitude are common (fig. 35, model 7). Model 9 also indicates that this major structure increases in depth and width towards the south and grades into the major gravity low in the south-central part of this area (fig. 12).

A model over this large negative anomaly in the south (fig. 35, model 10) gives an indication of the size and depth of the structure which has a steep eastern side and a gentler sloping western side. Calculations indicate a depth of more than 50 m over this circular anomaly which has a diameter of nearly 350 m. This structure is the cause of the largest gravity anomaly in the test area (- 1,7 mgal). Results of borehole 9 indicate nearly 20 m of agate-rich gravel. The economic potential of this circular structure must be seriously considered.

In the northern and eastern parts of the area, the gravels were found to be deposited in thin sheets as a thin veneer (up to 1 m) as overflow sediments. These are underlain by dolomite and weathered chert is regularly encountered.

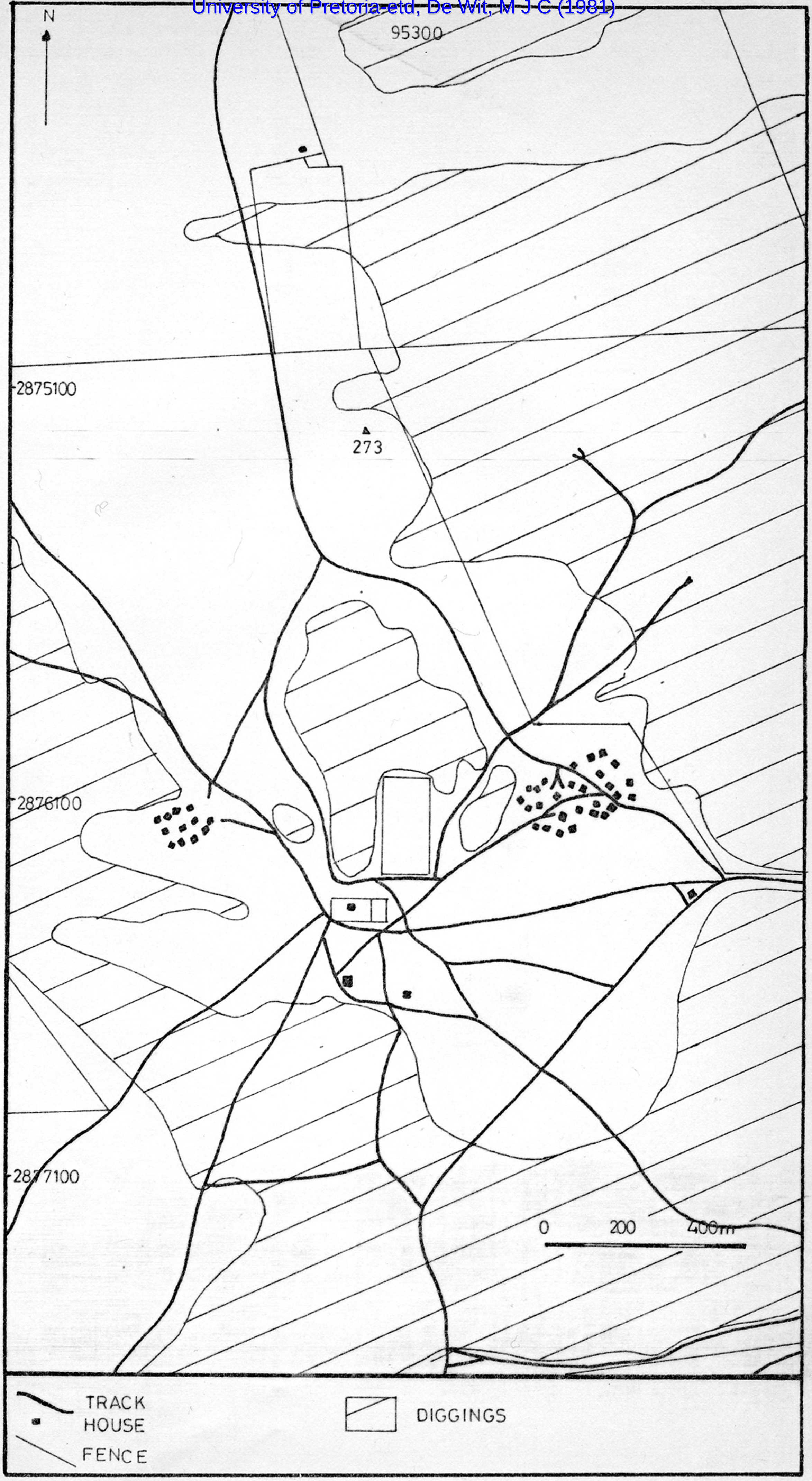
Exceptions to these sheet deposits were both King's and Malan's potholes. A thin channel filled with diamondiferous gravels was found to have extended to a depth of over 30 metres in the former pothole and agate-rich gravels were found to have been deposited between the steep dolomitic cliffs of the latter pothole (Mr E. Bredenkamp, personal communication). Both potholes were famous for their diamond content. No records exist concerning the quantity and quality of those diamonds.

Thus, as drilling results have shown, anomalies can be loosely categorised into two groups; (1) those which are usually 200 m or less in width and 500 to 700 m or less in length (i.e. anomalies which are

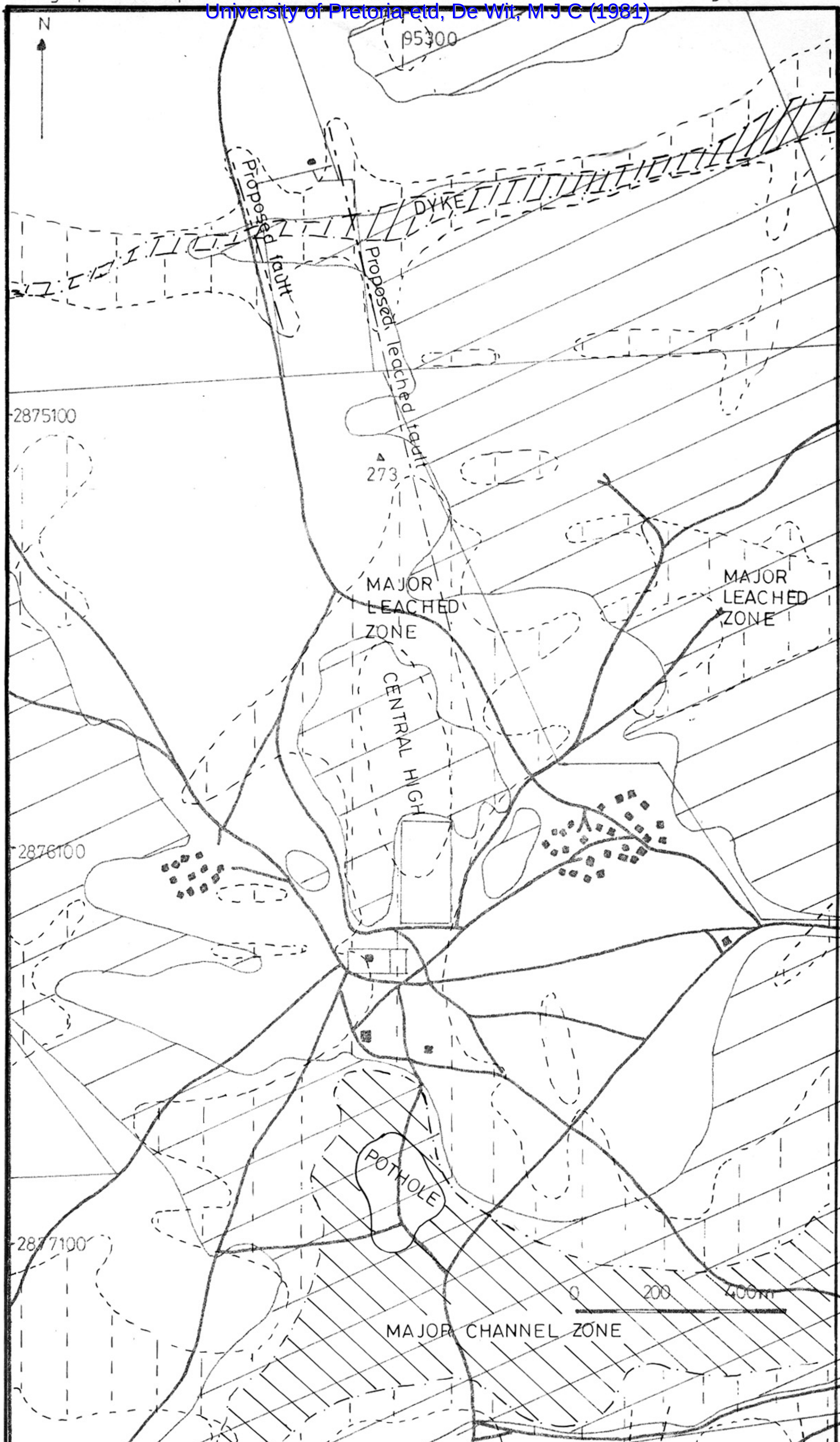


Occurrence and nature of major negative residual anomalies.

Leached zones.



N
95300
2875100
273
2876100
2877100
0
200
400m
TRACK
HOUSE
FENCE
DIGGINGS



Occurrence and nature of major negative residual anomalies.

TRACK
HOUSE
FENCE
DIGGINGS
Leached zones.

short and narrow) and which are due to leaching, and (2) the wider anomalies of greater aerial extent often associated with gravel runs.

Most of the gravel deposits are however associated with gorge structures and are "hidden" and require geophysical techniques to locate them. Gravity anomalies do not appear to be of sufficient amplitude to outline the position of the thin gravel sheets over the central-eastern part of the area.

In conclusion, the gravity work has shown that apart from the obvious major gravel runs, there are subsurface alluvial gravels that may be hidden by eluvial material such as weathered chert and residual dolomite. This weathered material can obscure any potholes to the extent that it would be impossible to locate them without the use of geophysics. The anomaly in the southern part of the area (- 1,7 mgal) is a prime example. Only a small portion of the gravity lows represents gravel-filled structures. Most can be ascribed to deep leaching of the dolomite, along certain directional trends, indicating that the jointing of the dolomite was a major controlling factor in the formation of the karst topography and therefore indirectly in the deposition of the gravels which were deposited either in already existing gorge structures or later slumped into sinkholes.

The gravity results had to be followed up by drilling (section 5) to determine the nature of the gravity anomalies - first of all to establish whether a negative anomaly contained gravels or whether it was solely due to leaching and secondly where gravels were found, to establish whether they were diamondiferous or not.

4. MAGNETIC SURVEY

4.1 Introduction

Following completion of the gravity survey, a ground magnetic survey was carried out over the same area (i) to ascertain the exact position of the east-west striking dyke in the northern part of the area and (ii) to locate any other magnetic body that may have been present, e.g. kimberlite pipes or fissures.

4.2 Field work

Two Chemtron proton magnetometers (models G2) were used for the survey. Initially the sensor was mounted on a 3-metre staff but later it was decided to place the sensor in a backpack, because the wind caused slight swaying of the staff and because of dense bush in places. Readings and systematic checks were made every 10 m and a total of 14 650 readings were taken, including those necessary for the establishment of the 40 base stations.

The survey was carried out in north-south traverses but where anomalies were found, east-west traverses were added. Across the anomaly caused by the dyke, several traverses perpendicular to its strike were done (map 5).

A contour map (map 5) is used to present part of the data. Because the anomaly caused by the dyke is the only significant feature in the area, only the northern section of the area is shown.

The amplitude of the anomaly over the dyke varies between 100 and 500 nanoTesla (nT) against the background noise with a maximum range of 20 to 30 nT. The position of the dyke is therefore easily determined.

Like the majority of magnetic anomalies over thin dykes in South Africa, the anomaly has a positive component on the northern side of the dyke, which is larger than the negative component on its southern side (Richards , 1977; T. Hattingh, University of the Orange Free State, personal communication).

Using the available aeromagnetic data and aerial photographs the anomaly has been recognised as that being caused by a nearly vertical dyke and was called the Grasfontein dyke (Richards, 1973).

4.3 Calculations

Using the Koulomzine method (Koulomzine et al., 1970) the estimates of the centre of the dyke, the width and the depth to the top of the dyke were calculated. This method is based on the decomposition of the field curve $F_k = F(x)$ into its symmetrical and antisymmetrical components. The function $F_k = F(x)$ thus consists of the sum of two functions which can be expressed as follows ;

$$\Delta F_k = S(x) + A(x)$$

where $S(x) = \frac{1}{2}[\Delta F_k(x) + \Delta F_k(-x)]$

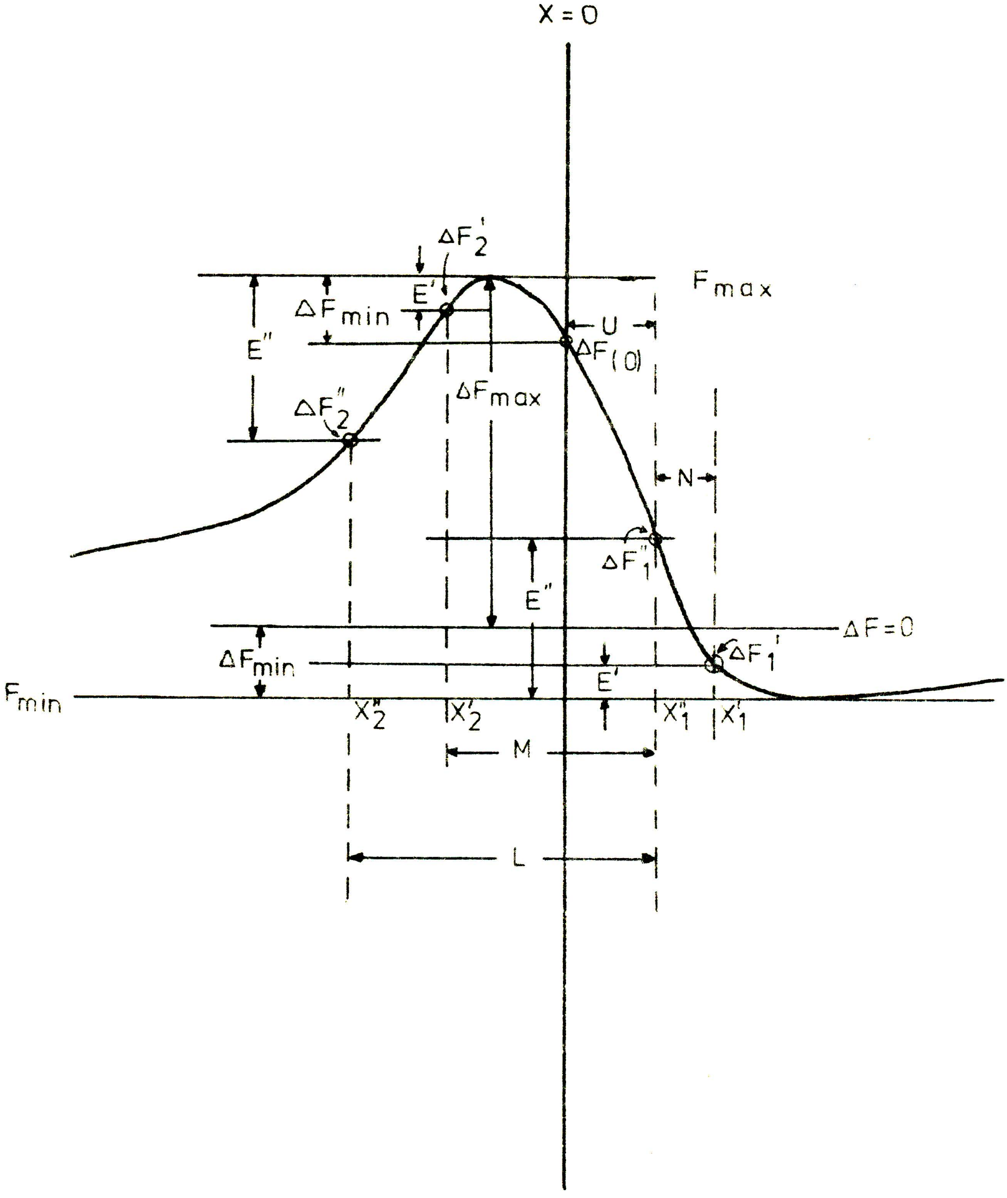
and $A(x) = \frac{1}{2}[\Delta F_k(x) - \Delta F_k(-x)]$

The x=0 position on the field curve, which corresponds to the centre of the dyke, is essential for separating the field curve into correct symmetrical and antisymmetrical components (Koulomzine et al., 1970). The point x=0 was graphically fixed using the Lamontagne method (Koulomzine et al., 1970) by calculating :

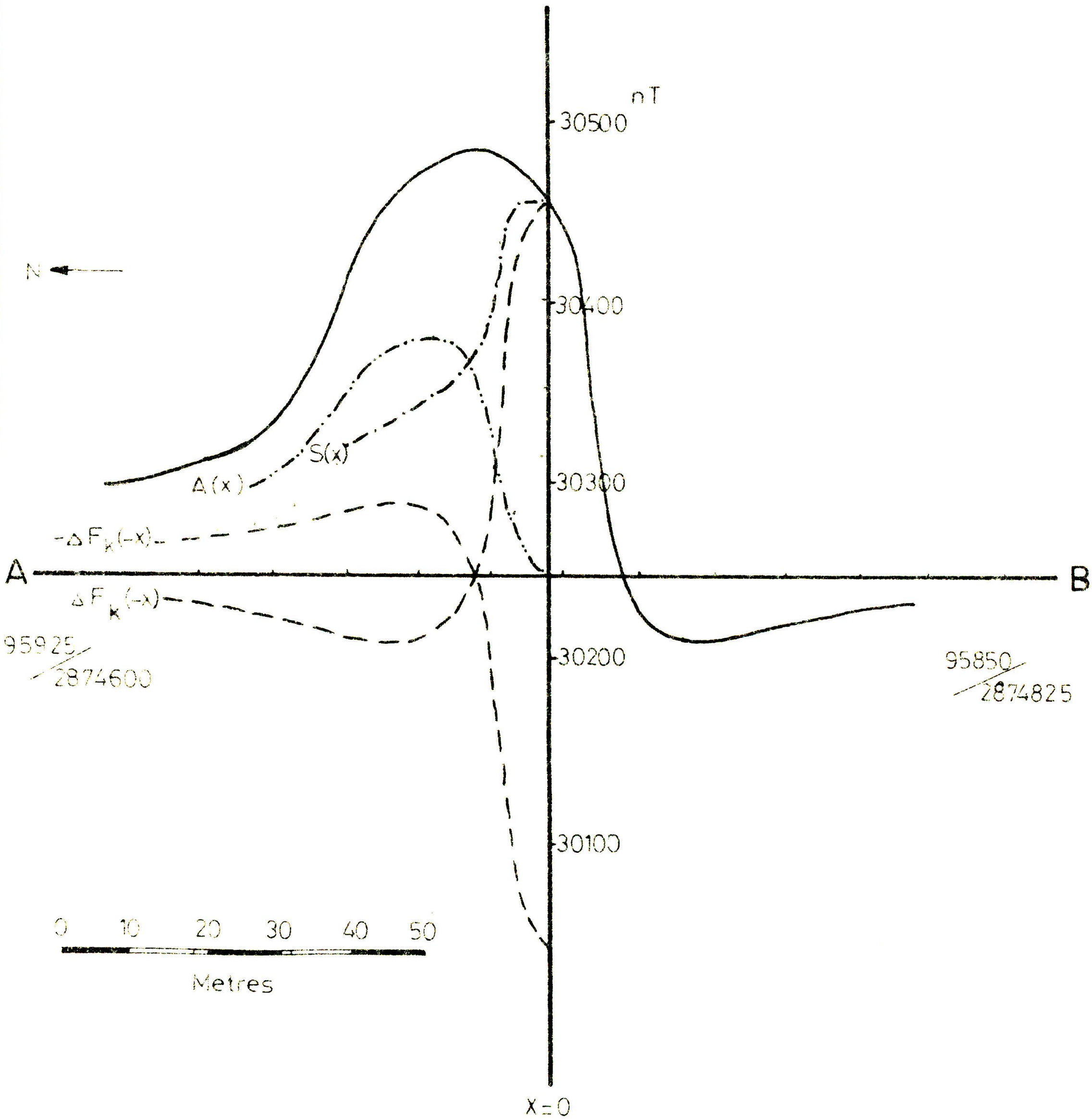
$$U = \frac{M\ .\ N}{L-M+N} \qquad \text{(Fig. 13)}$$

Two sets of conjugate points, $\Delta F_1'$ and $\Delta F_2'$ and $\Delta F_1''$ and $\Delta F_2''$ (fig. 13) were located on the field curve in such a way that the differences between their ordinates and the maximum and minimum are equal. This procedure was repeated four times on each of the three curves (figs. 14, 15 and 16) until the position where x=0 was satisfactorily determined on each of the curves.

Due to the lack of information concerning the regional field the F=0 axis was simply determined perpendicular to the x=0 axis. The



Determination of the midpoint position of a dyke and the datum level from a total field magnetic profile by construction.


nT
30500
30400
30300
30200
30100
N
A(x)
S(x)
$-\Delta F_k(-x)$
$\Delta F_k(-x)$
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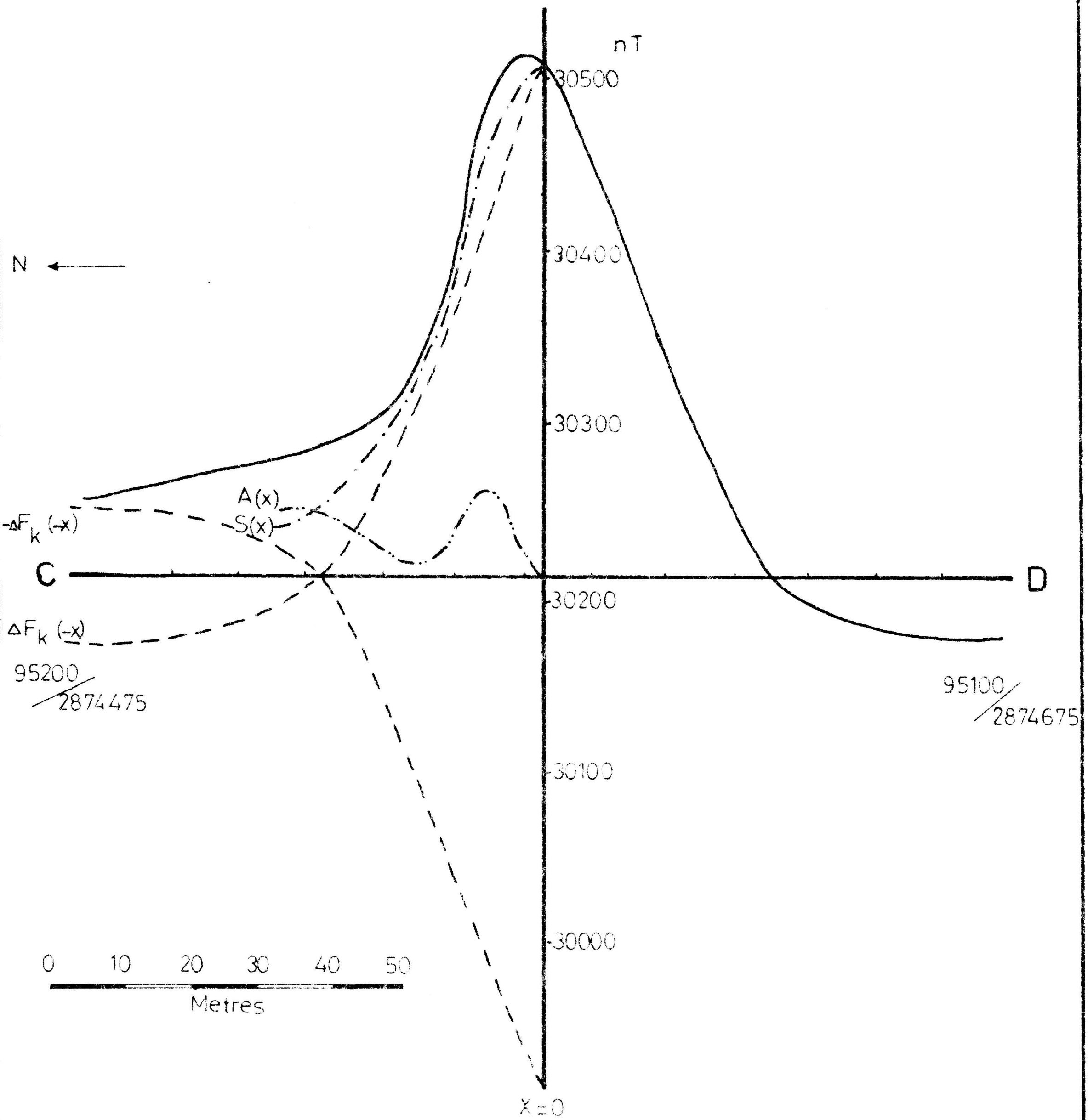
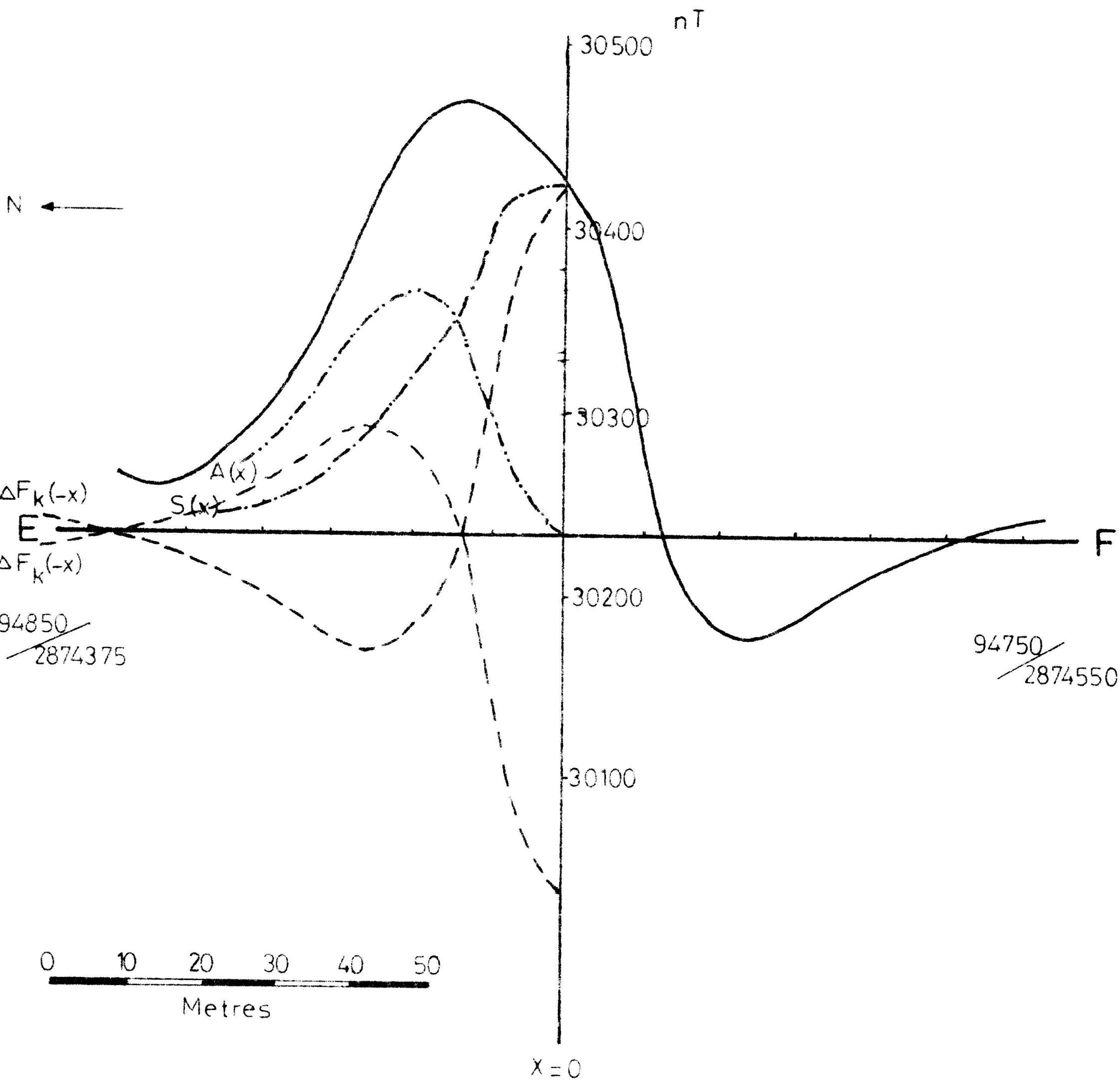
B
95925
2874600
95850
2874825
0 10 20 30 40 50
Metres
X=0



nT
30500
30400
30300
30200
30100
30000
N
A(x)
S(x)
-ΔF k (-x)
ΔF k (-x)
C
D
95200/2874475
95100/2874675
0 10 20 30 40 50
Metres
X = 0


nT
30500
30400
30300
30200
30100
N
A(x)
S(x)
ΔFk(-x)
E
F
ΔFk(-x)
94850
2874375
94750
2874550
0
10
20
30
40
50
Metres
X=0

symmetrical and antisymmetrical components were then constructed. The former is the locus of the midpoints between F_k (x) and F_k (-x) and the latter is the locus of the midpoints between F_k (x) and $-F_k$ (-x) (figs. 14, 15 and 16).

Four master curves (from Koulomzine and others, 1970) were used to calculate the width and depth of the top of the dyke. Table 3 gives the values obtained from these calculations;

TABLE 3 Calculated width and depth of Grasfontein dyke.

	S (x)		A (x)		AVERAGE	
	WIDTH	DEPTH	WIDTH	DEPTH	WIDTH	DEPTH
Profile 1	16,1	10,4	20,8	7,8	18,5	9,1
Profile 2	18,0	5,9	19,1	5,2	18,6	5,6
Profile 3	29,2	8,5	27,9	9,5	28,6	9,0

The average values for the width of the dyke range from approximately 18 to 28 m for the three profiles; while the depth varies from about 5,6 to 9,1 m. Depths obtained from models of the gravity survey over the dyke varied from 12 to 40 m. However that is down to unweathered dyke material. Drilling has shown that a clay consisting of decomposed basic material was present above unweathered dyke material on Ruigtelaagte (Stettler, 1979) and that magnetic material in the clay could have been responsible for the difference (Stettler, 1979) Variations between the three profiles probably reflect the uneven geometry of the dyke such as different erosion levels to the top of the dyke and non-parallelism of its margins.

The above values for the width are slightly lower than those obtained in rough calculations using the maximum-minimum distance, the half-peak width and the half-slope distance methods used by Richards (1973). Values for the depth of the dyke for the profiles 1, 2 and 3 using the latter method are 16, 12 and 14 m respectively. These methods are however only applicable to very thin dykes (Richards, 1973).

Using available curves for estimating dip (Richards, 1977) the following results were obtained for the dip of the dyke along profiles 1, 2 and 3, viz., ∿ 100-105°, ∿ 90° and ∿ 90° from North respectively.

From the general trend of the contours of the total magnetic intensity map, it appears that the dyke has been displaced by dextral wrench faults (around peg 1300/400 and 750/550, Map 5) and has been interpreted as the Rooisloot fault (Day, 1980). Similar faults affecting the Grasfontein dyke have been described by Day (1976) just west of the study area.

In conclusion it appears that the position of the dyke had a considerable influence on the deposition of the gravels of the "Rooisloot". These gravels can be seen to be closely associated with the dyke over a considerable strike distance (figs. 1 and 2).

It seems likely that preferential weathering has occurred along the zones where dykes have intruded the country rock and these have been likely areas for river drainage. The area overlying the Grasfontein dyke, in the study area at least, is in fact a geographical valley (fig. 8).

5. DRILLING AND TRENCHING

To evaluate the gravity results, some of the negative anomalies were drilled. The first stage of the drilling programme was to try to locate gravel deposits associated with gravity low features. Once gravel deposits had been located, the second step was to determine whether they were diamond-bearing.

Two different types of drill were used. To identify the nature of the negative gravity anomalies a 165 millimetre air drill was used and to obtain samples of gravel large enough to acquire a reasonable indication of its diamond content a Masserenti Jumper drill with a drill-head diameter of 1,8 metres was used.

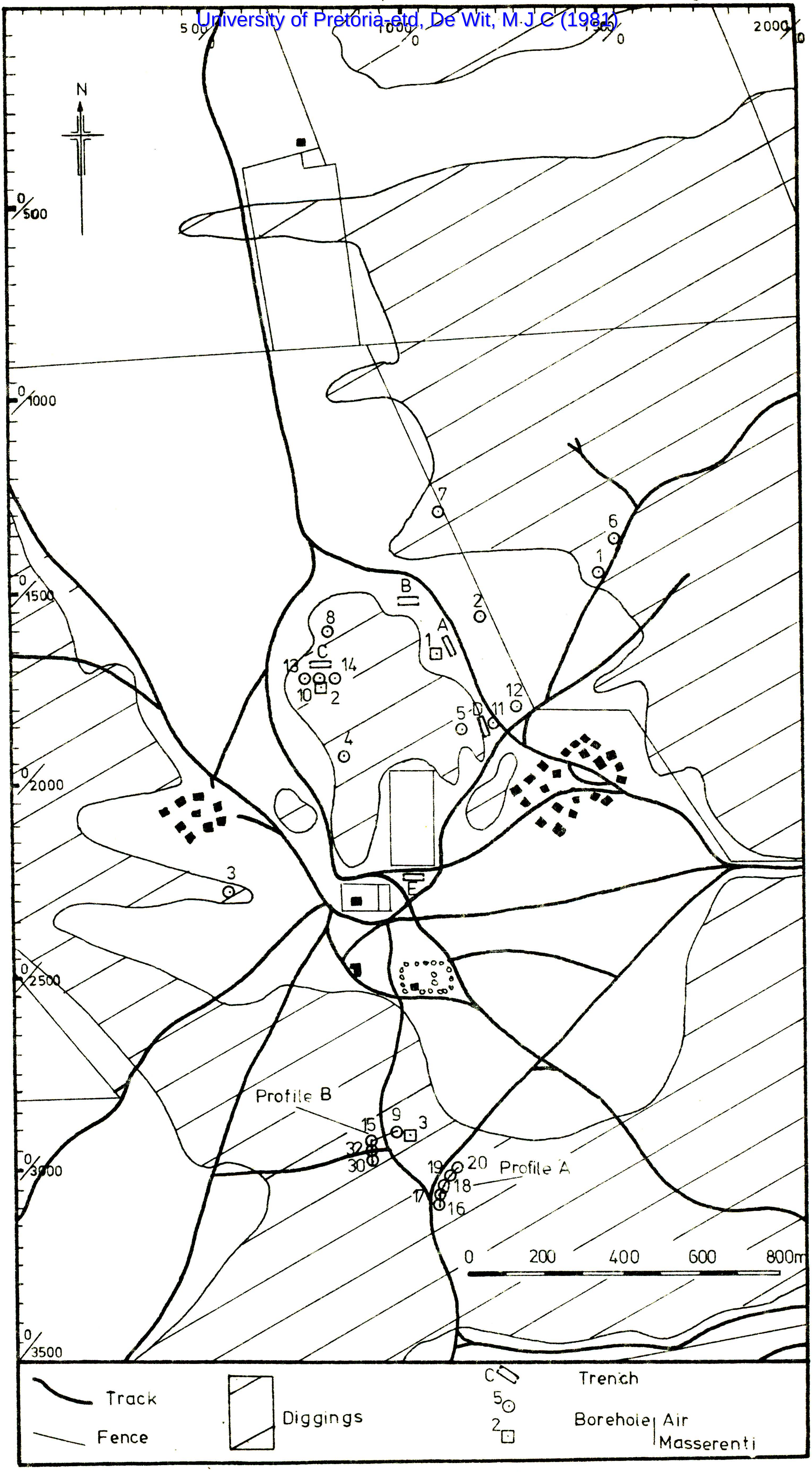
All the logs of the air drill holes are given in the figs. 21 to 25 (boreholes I-V). Interesting thick gravels were obtained in the vicinity of 800/1650 (boreholes 10, 13 and 14) and around 900/2875 (borehole 9) (figs. 21 and 22).

Success with the Masserenti drill was obtained only in one of the three holes drilled with it (fig. 17, hole 2). Other holes drilled with this drill had to be abandoned when relatively consolidated material, such as weathered chert and dolomite which had only been transported vertically over a very short distance, was encountered. From the one successful hole two diamonds with a total mass of 0,115 carats were recovered.

Prior to the drilling several trenches were dug to guide the drilling operation (fig. 17). Trenches A and B both reached weathered chert after a thin soil cover of 0,15 m. A well-developed gravel was found in trench C below a cover of manganese-rich soil of 0,25 metres. It was in this gravel that the above-mentioned diamonds were found. Boreholes 10, 13 and 14 (figs. 17 and 22) proved that the gravel in this area was deposited in a small, isolated depression with a diameter of approximately 250 m and a maximum depth of about 5 m. It does not

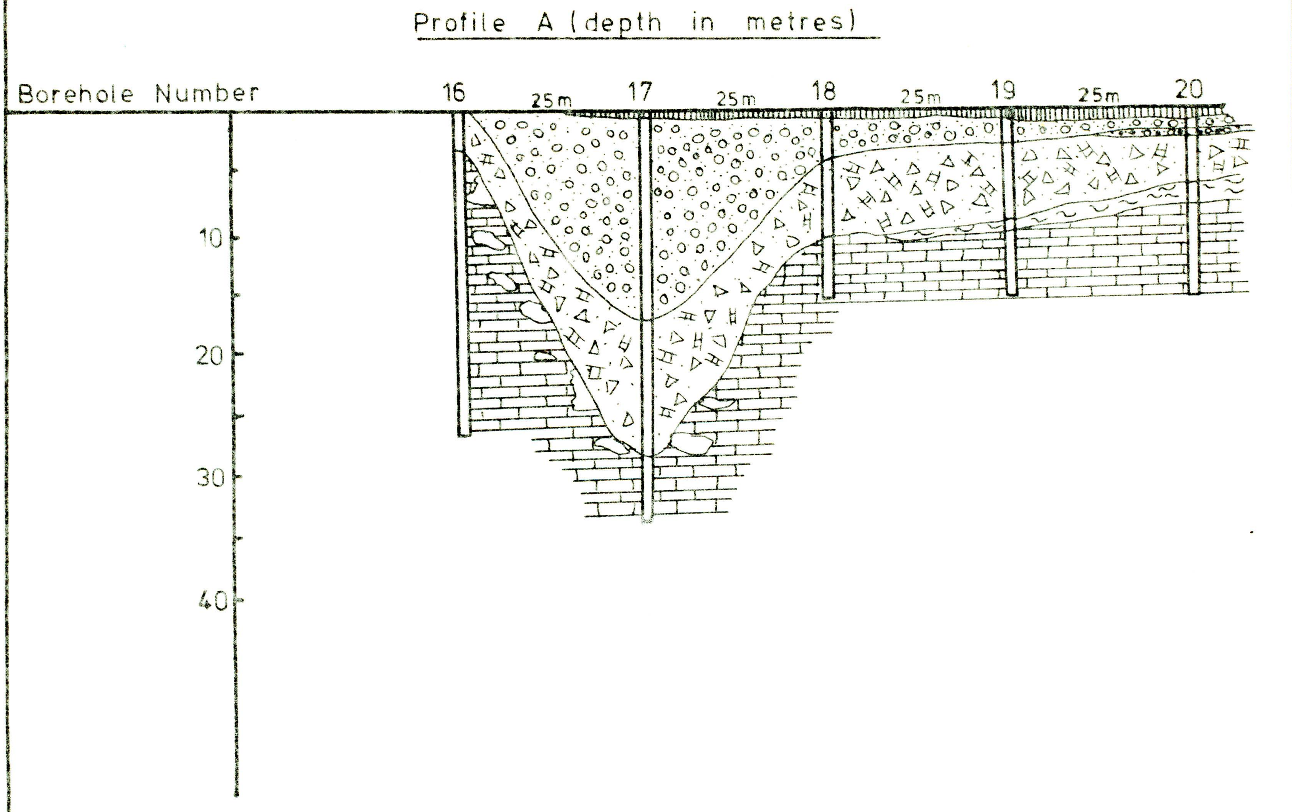
Borehole and Trench location map

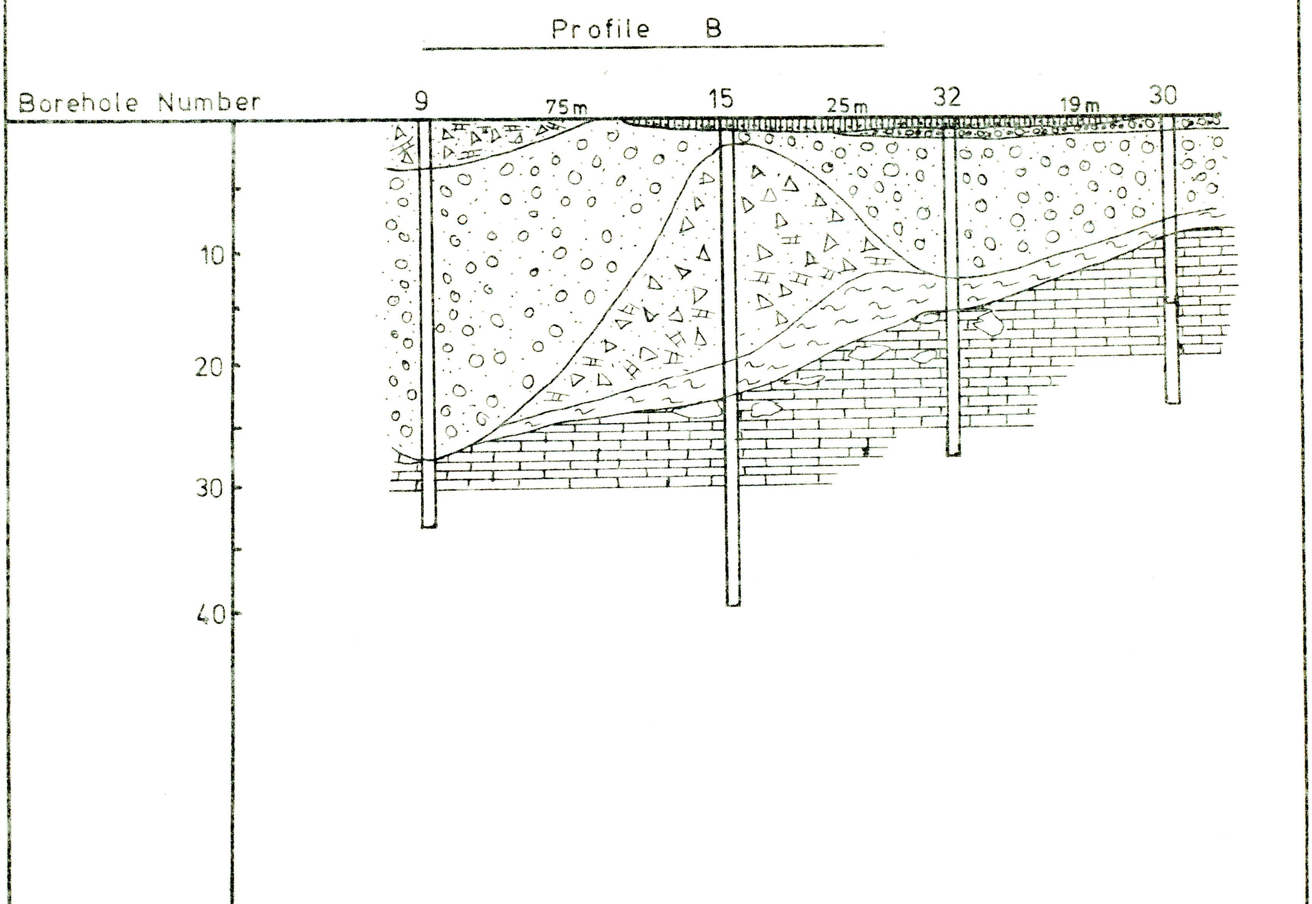
Figure 17



Drilling Profiles

Figure 18

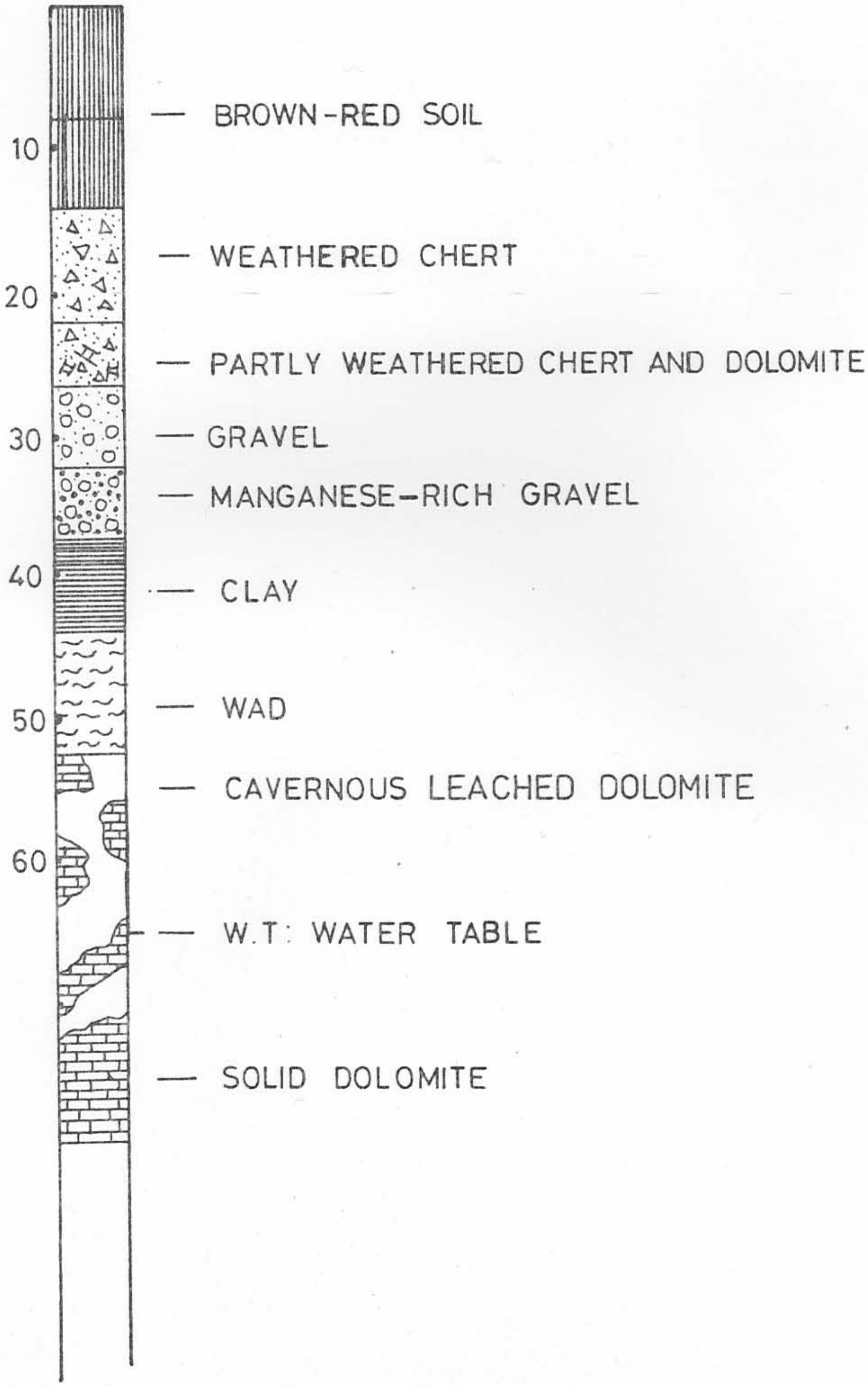




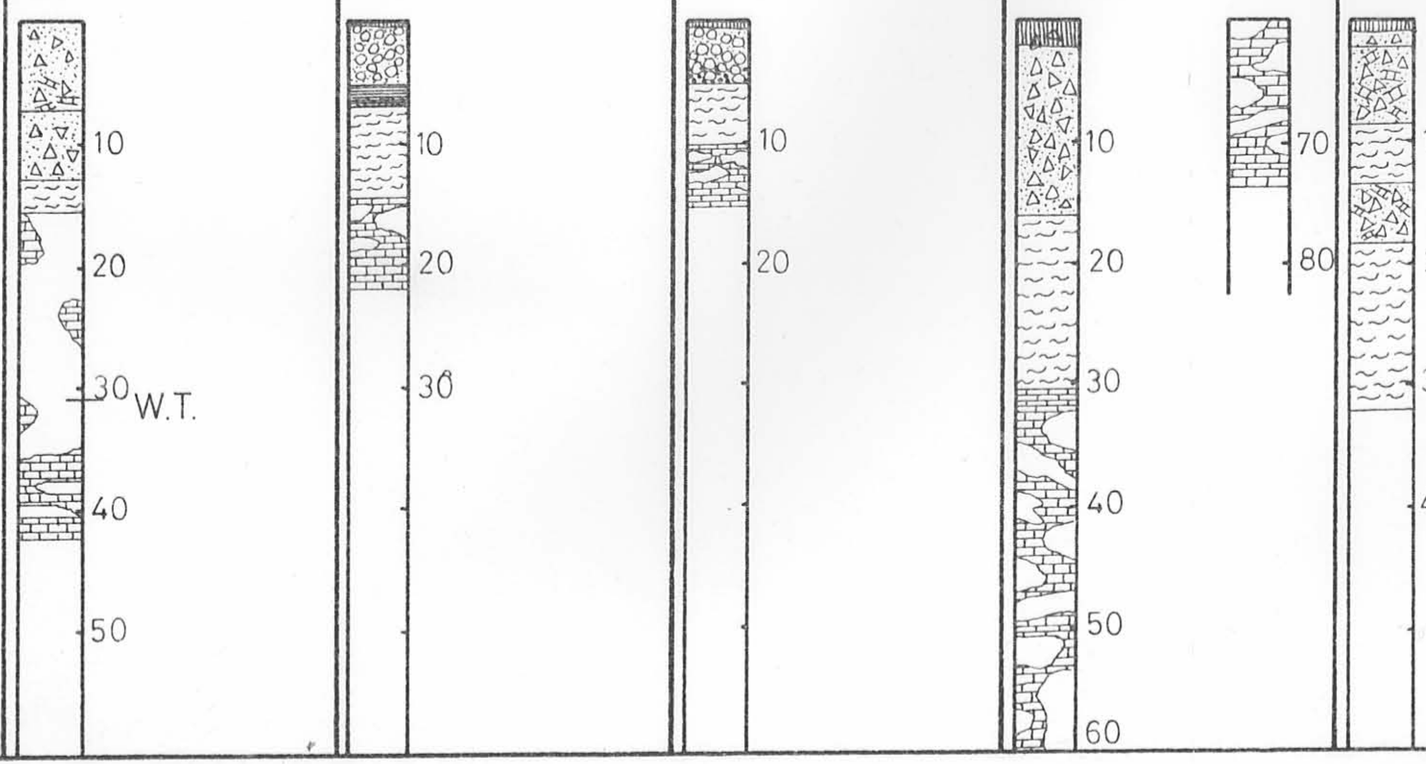
See figure 18 for the legend and figure 16 for the location of the above profiles.

LEGEND TO BOREHOLES AND PROFILES (FIG. 17)

(Depth in metres)



BOREHOLE NUMBER	8	12	11	5	4
COORDINATES: X / Y	790 / 1565	1300 / 1800	1240 / 1820	1150 / 1850	850 / 1925
COLLAR ELEVATION	1500 m	1499 m	1499 m	1502 m	1502 m



BOREHOLE LOGS I

FIGURE 20

BOREHOLE LOGS II

BOREHOLE NUMBER	3	9	15	7	6
COORDINATES: X	550	925	890	1100	1575
COORDINATES: Y	2300	2875	2925	1300	1350
COLLAR ELEVATION	1499m	1502 m	1502 m	1501 m	1501 m

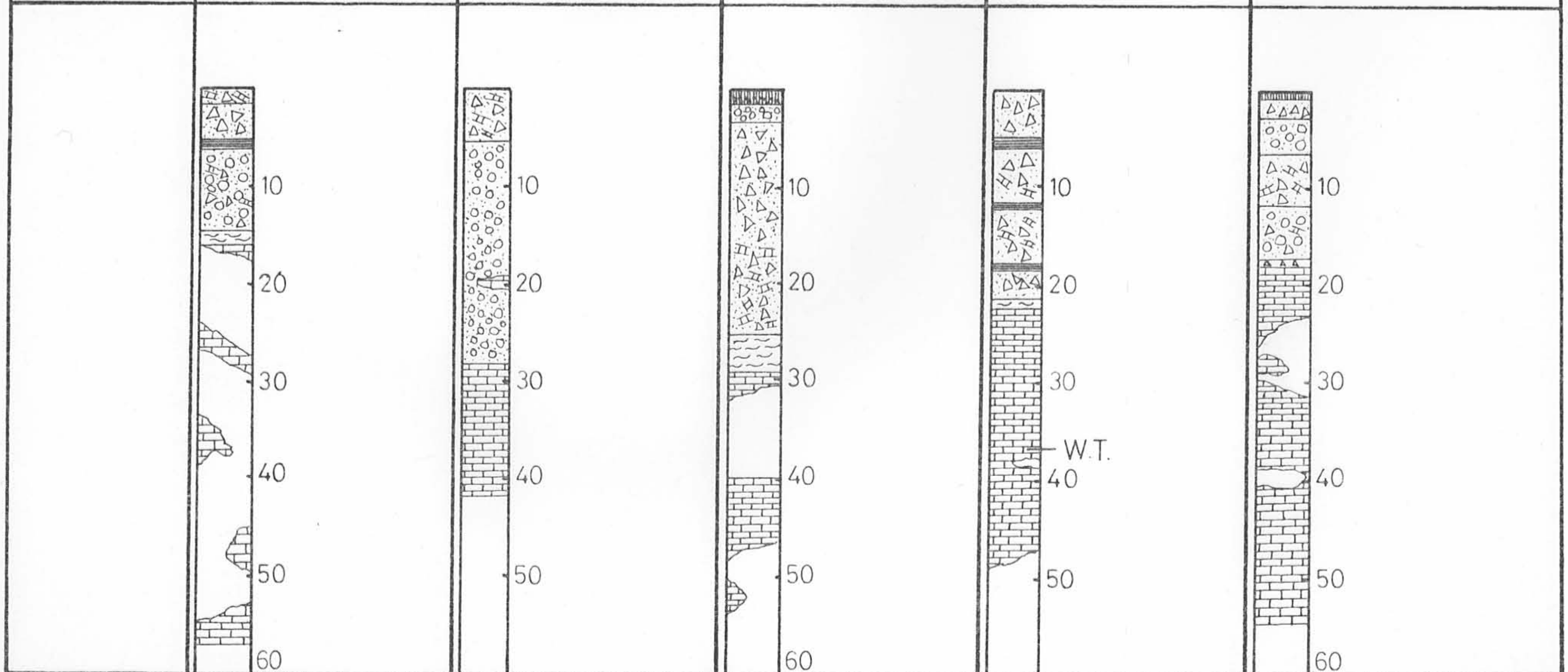
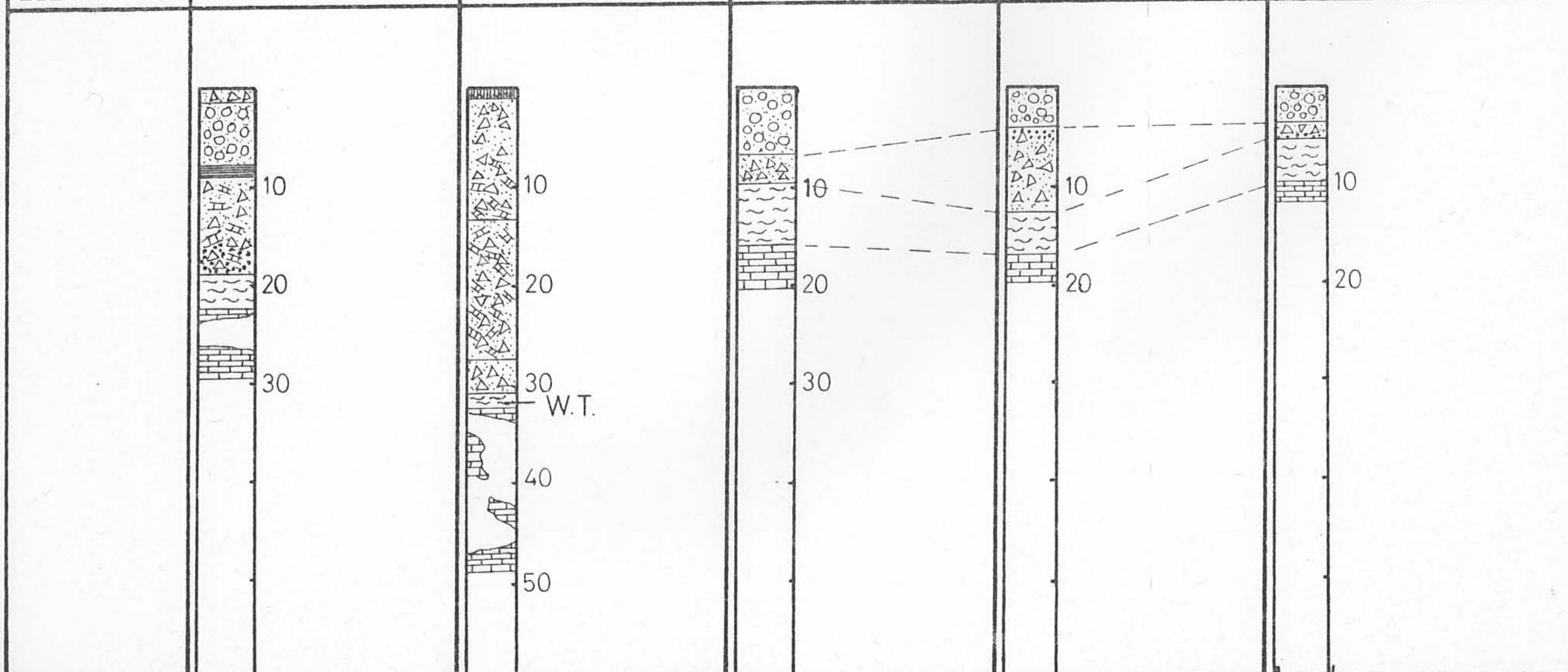


FIGURE 21

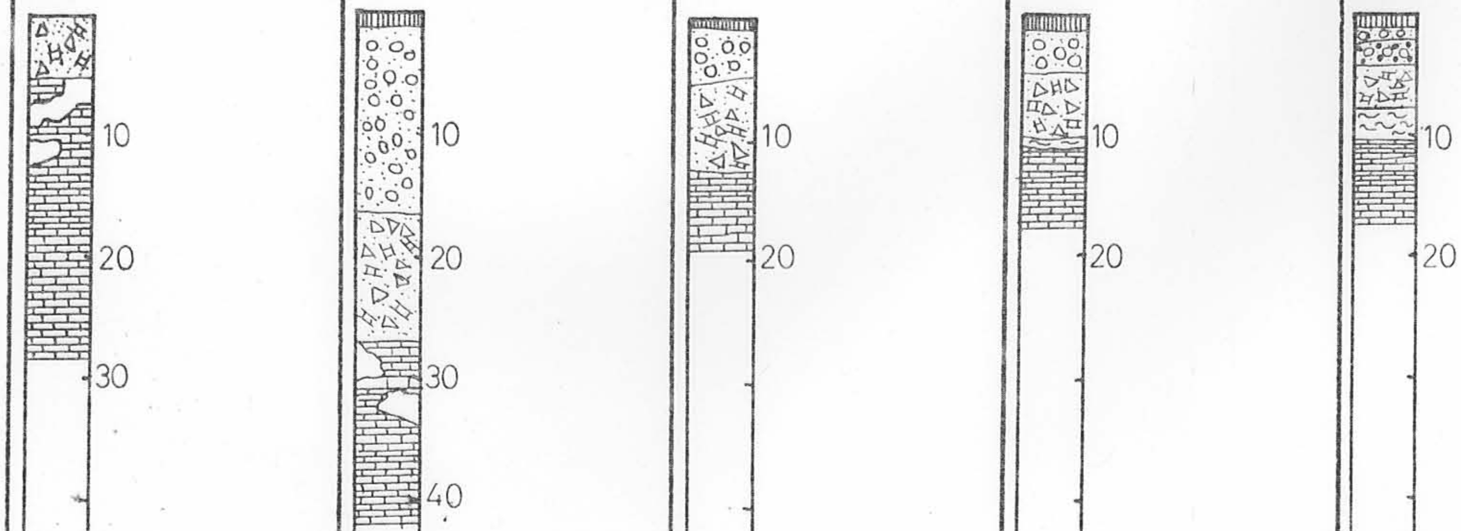
BOREHOLE NUMBER.	1	2	14	10	13
COORDINATES: X	1500	1200	820	800	780
COORDINATES: Y	1475	1625	1665	1665	1665
COLLAR ELEVATION.	1500m	1500m	1500m	1500m	1500m



BOREHOLE LOGS III

FIGURE 22

BOREHOLE NOMBER	16	17	18	19	20
COORINATES X	1040	1045	1055	1060	1070
COORINATES Y	3090	3070	3050	3030	3010
COLLAR ELEVATION	1503m	1503m	1504m	1504m	1504m

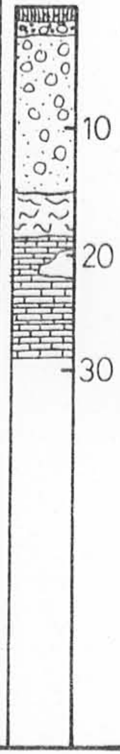


BOREHOLE LOGS IV

FIGURE 23

BOREHOLE LOGS V

BOREHOLE NUMBER	32	30			
COORDINATES: X	880	870			
COORDINATES: Y	2950	2970			
COLLAR ELEVATION	1501 m	1502 m			



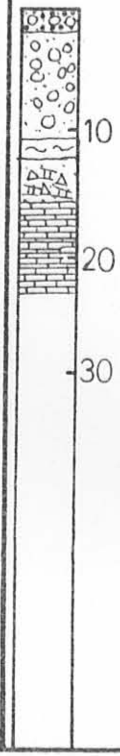


FIGURE 24

form part of any gravel run, and has not been exploited by any diggers.

Two holes (holes 11 and 12, figs. 17 and 20 respectively) were drilled and a trench (D) was dug just north-west of the main black village in the study area, around peg 1250/1800 - 1250/1830 (fig. 17). Water-worn pebbles were found in a red-brown soil approximately four metres thick which was probably deposited on a flood plain. This soil is underlain by wad and weathered chert before solid dolomite is encountered.

A place of great interest is in the south-eastern part of the area (around peg 925/2875, fig. 11, map 4) where thick gravels were found in a circular structure (fig. 21, borehole 9). Profiles A and B (fig. 18) give an indication of the volume of unworked gravel in this area under a cover of weathered chert and dolomite (which have only been transported vertically over a short distance) and finally manganese-rich soil. The Masserenti drill failed to penetrate the top 5 m of weathered chert, so that no indication of the diamond content of the underlying gravels could be obtained.

The two profiles A and B and the large gravity anomaly (around peg 925/2875), which was interpreted as a circular pothole (fig. 35, model 10), prove that large amounts of unworked gravel are still present. However, these buried gravels are usually inaccessible to the underequipped individual digger.

6. SAMPLING

To get an indication of the minerals present and whether any of these minerals are of kimberlitic origin, several samples of the surface gravels and previously concentrated material were taken for heavy mineral analysis.

Initially 15 fifty-kilogram samples were taken from the study area; from the main run in the southern part, the shallow gravels of the central area and from the Rooisloot in the northern part of the area (fig. 25). These were washed, concentrated and divided into a coarse, medium and fine fraction defined as follows ;

Coarse	1 - 2 mm
Medium	0,5 - 1 mm
Fine	0,3 - 0,5 mm

Most of the samples were taken from unworked gravels. However, sample numbers 3, 9, 14 and 15 (fig. 25) were taken from wash concentrates left by diggers during their exploitation for diamonds. The latter concentrates thus represent large volumes of gravels which enhances the possibility of finding kimberlitic minerals such as garnet, ilmenite and chrome-diopside in them. Samples 14 and 15 were in fact taken from the famous King's and Malan's potholes.

Following the initial gravity concentration of the samples the heavy minerals were separated in bromoform. Not one kimberlitic mineral grain was identified. Consequently a further 9 samples (fig. 25 A-I) were analyzed. The minimum size of the initial 15 samples was 0,3 mm or about 45 mesh, whereas only the -60 mesh fraction was used in the second series of samples. The nine samples were analyzed by Mr E. Peters of the Geological Survey of South Africa using X-ray diffraction techniques. The results are listed in Table 4.

Magnetite, hematite, hydrated iron oxides and iron hydroxide (lepidocrocite, limonite and goethite), manganese oxides (pyrolusite)

Sample location map

Figure 25

and the andalusite are all thought to have been derived either from the sedimentary rocks of the Pretoria group or from the dolomite itself. Barite is known to be associated with the fluorite in the dolomite (Wilson, 1977).

Zircon, tourmaline, sphene and chlorite are ubiquitous and could have been derived from the granite of the Bushveld Complex or from the Archaean granite.

Olivine, enstatite and ilmenite are the only minerals which can be related to basic and ultrabasic rocks, of which kimberlite is a member. However, mafic and ultramafic rocks of the Bushveld Complex and dolerite dykes could equally have contributed these minerals.

A microprobe analysis of the ilmenites, using the SEMQ electron microprobe at the Anglo American Research Laboratories classified these minerals as non-kimberlitic (AARL geology laboratory reference no. M/79/487).

Several samples were examined by the author from the Orange River terraces near Hopetown (De Wit, 1980). These samples were treated and washed in the same way as the Bakerville samples using the same fractions, and proved to contain abundant kimberlitic mineral grains, up to 2 mm in size. Most of them are only slightly abraded. Eighty per cent of these minerals were found to be derived from a known kimberlite occurrence north of Philipstown, a distance of at least 130 km from the Hopetown terrace (De Wit, 1980). These terraces contain gravels similar to those in the Lichtenburg area and appear to have been deposited under similar environmental conditions. Although direct comparison between the heavy mineral contents of gravels and the distance between the gravel and the primary source of the heavy minerals in the two areas may not be entirely justified, it appears anomalous that no evidence of kimberlitic minerals other than diamonds was found in the Bakerville gravels, even from the concentrate of the two famous potholes.

TABLE 4 Minerals in Samples A - I (-60 mesh)

MINERALS	A	B	C	D	E	F	G	H	I
Secondary manganese oxides	X	X	X	X	X	X	X	X	X
Secondary iron oxides	X	X	X	X	X	X	X	X	X
Magnetite	X	X	X	X	X	X	X	X	X
Andalusite	X		X	X				X	
Barite				X			X	X	X
Tourmaline		X							
Zircon			X	X					
Chlorite		X	X	X					
Sphene									X
Anatase									X
Ilmenite	X	X	X	X	X	X	X	X	X
Enstatite	X								
Olivine		X							

7. PALAEOGEOGRAPHY, GRAVEL DEPOSITION AND ORIGIN OF DIAMONDS

7.1 Palaeogeography and gravel deposition

Sedimentation of the diamondiferous gravel runs of Bakerville was greatly influenced by the karst topography of the underlying dolomite basement. Erosion and karstification of the dolomitic bedrock was evidently well advanced prior to the onset of deposition of the oldest gravels which are of Tertiary age according to Du Toit (1951). Features formed during four recognised periods of karstification (Martini and Kavelieris, 1976) were predominantly structurally controlled.

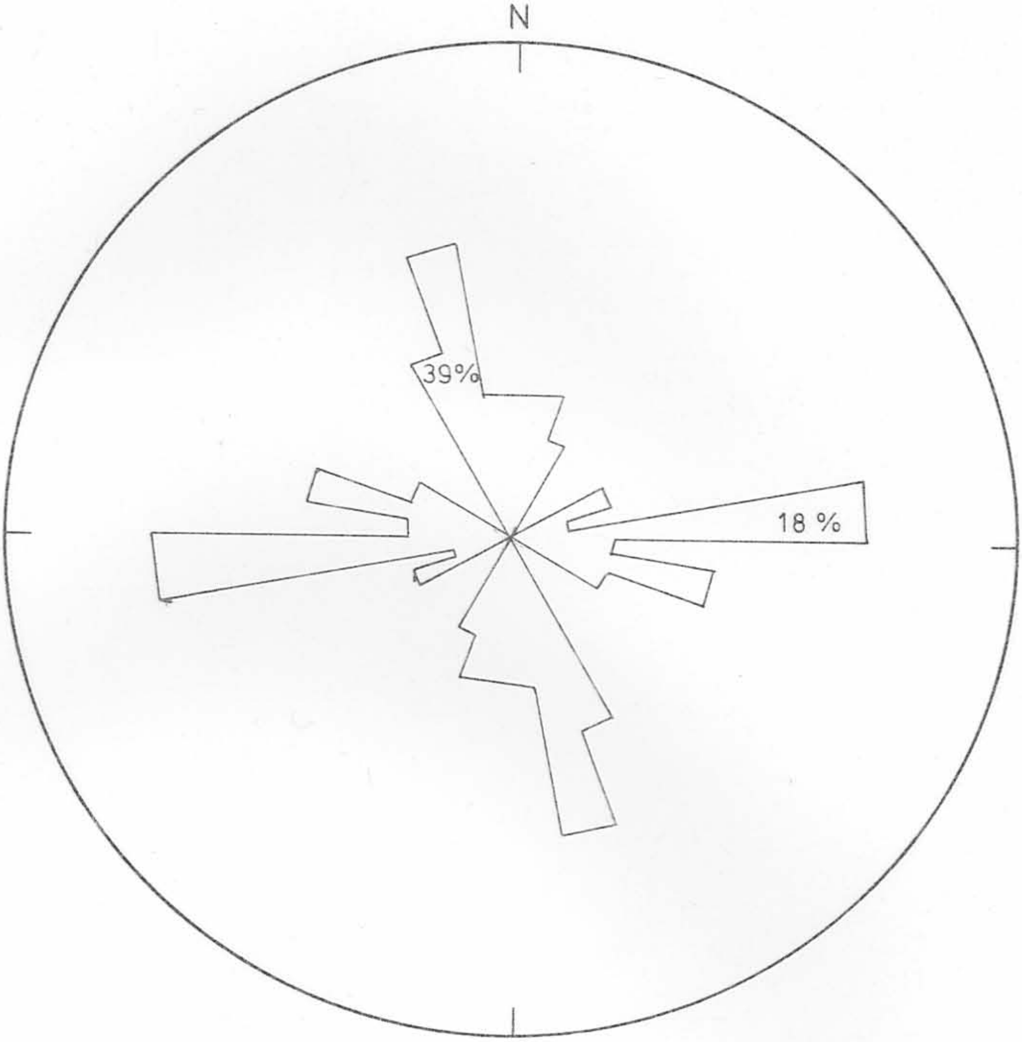
Jointing is the only macroscopic manifestation of tectonism on the dolomites. Bedding is nearly horizontal and faulting of any kind is rarely observed. Two major joint directions, one just west of north (350°) and the other just north of east (080°), are evident (fig. 26). These directions are comparable on a regional scale with the two major structural trends of the Archaean complex as discussed by Wilson (1977).

There is a significant coincidence between the joint orientation and that of the dykes and quartz veins (figs. 27 and 28) (Day, 1980), suggesting preferential intrusion along these planes of structural weakness although the quartz veins are only found in the northerly trend. Similarly, a statistical concurrence between the orientation of the dykes and joints, and that of the gravel runs and the gravity anomalies (figs. 26, 27, 29 and 30) indicates a causal connection.

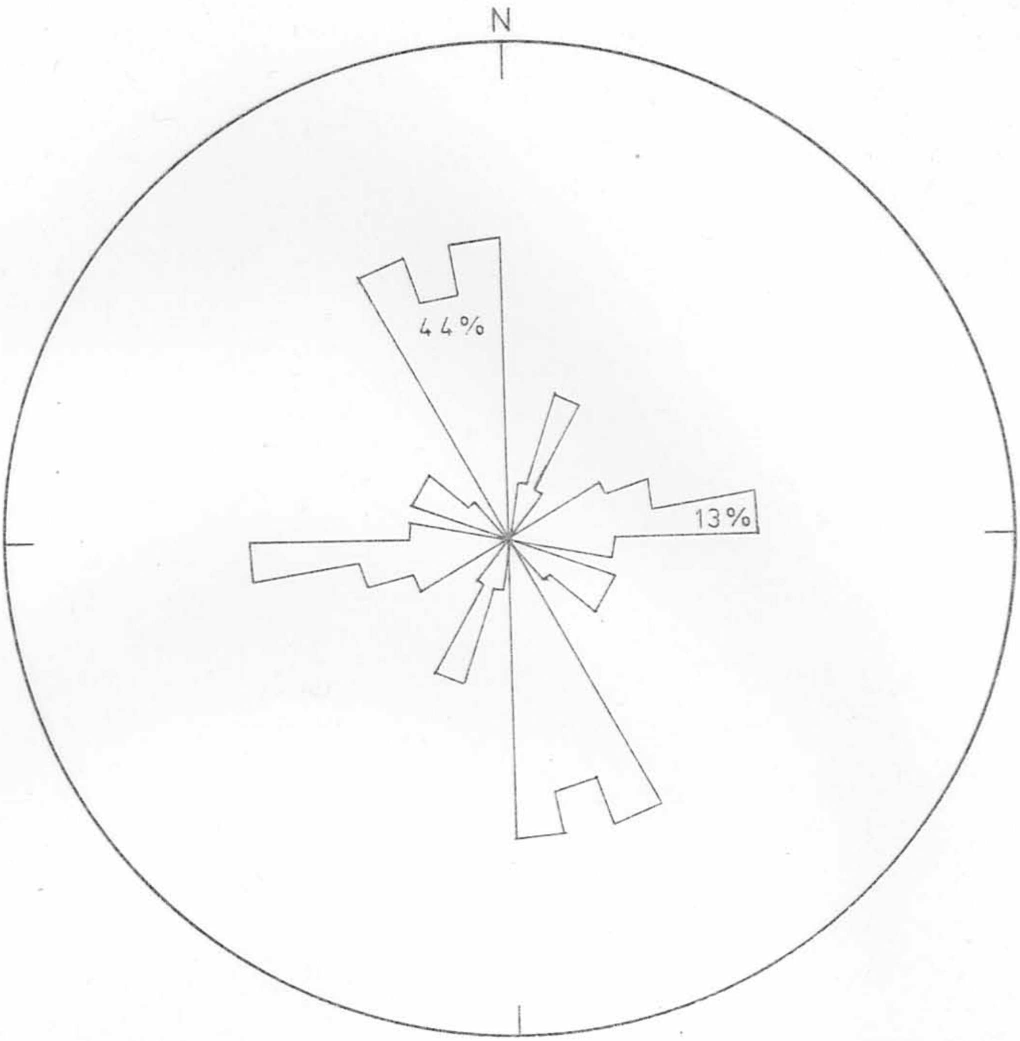
The long axes of the King's and Malan's potholes are also aligned along these main regional joint trends.

The development of caves in the Bakerville area by dissolution at joint planes followed a two stage process involving (1) the random formation of wall pockets (cavities) through differential solution of the dolomite and (2) the collapse of pocket partitions through further chemical and mechanical erosion causing cavity coalescence.

Wall pockets or solution indentations are common along cave walls,

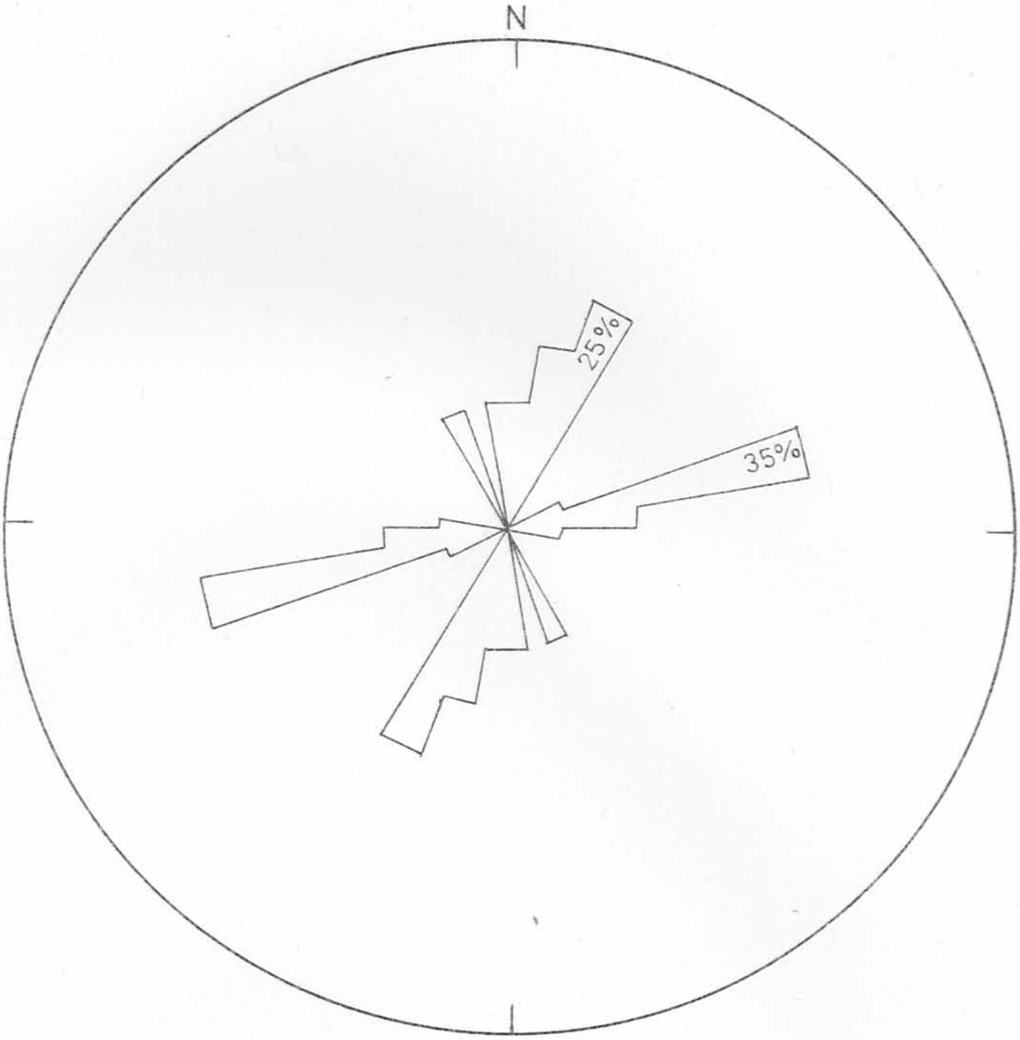


ORIENTATION DIAGRAM: JOINTING (39)

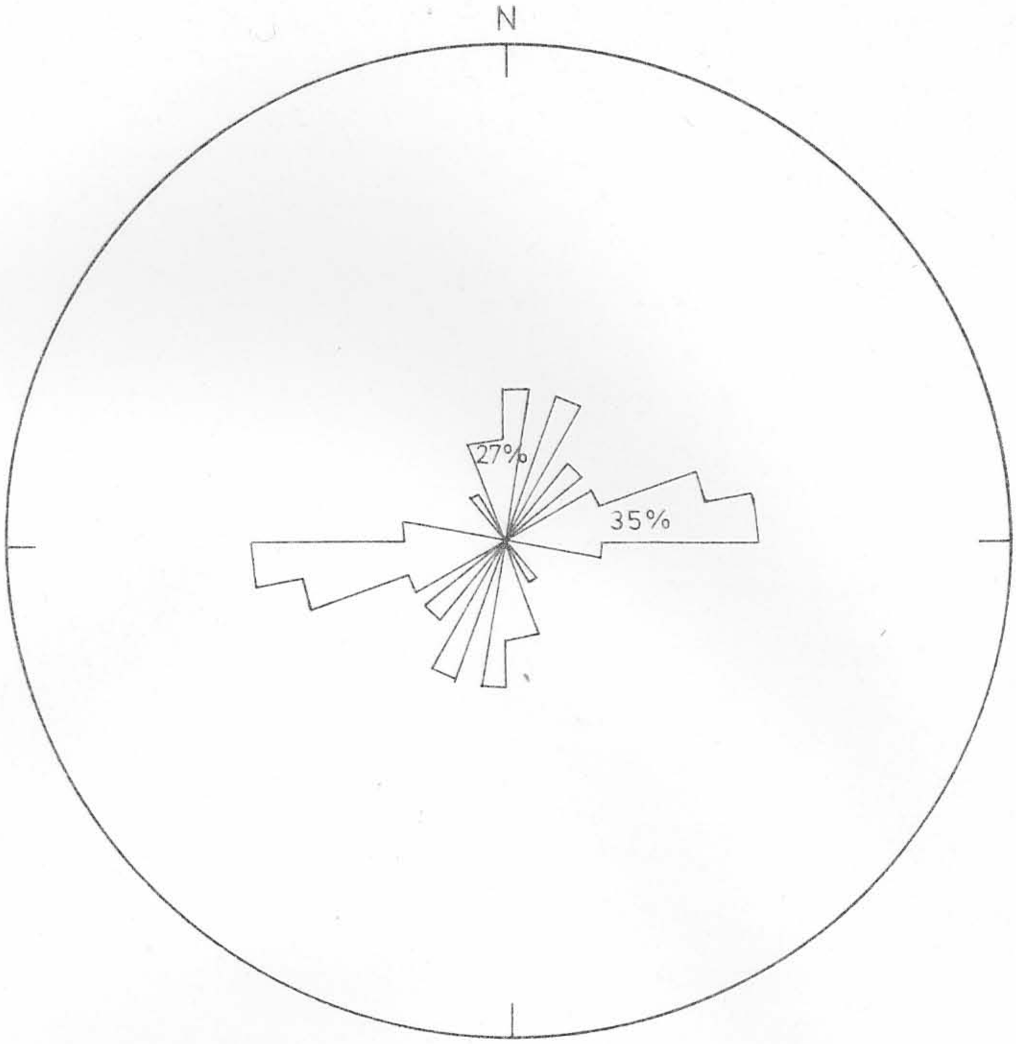


ORIENTATION DIAGRAM: DYKES (39)

ORIENTATION DIAGRAM: QUARTZ VEINS (9)



ORIENTATION DIAGRAM: GRAVEL RUNS (28)



ORIENTATION DIAGRAM: GRAVITY ANOMALIES (26) and it has been suggested that these structures are phreatic in nature and are formed below the water table (Bretz, 1942). Wall pockets are well developed in the dolomite cliffs of King's Pothole. They are roughly circular and range from 0,2 m to 1,5 m in diameter. One of the larger wall pockets displays a prominent arched column of remnant dolomite, 2,5 m in length and with an average inclination of 60°. Similar structures are to be found at Malan's Pothole and in a cave which was discovered between Bakerville and the main Lichtenburg-Zeerust road. The preservation of such features within these wall pockets would indicate that dissolution occurred during weak current activity in such water-filled cavities.

Moneymaker (1942) described solution cavities both below and above the water table in the Tennessee valley. Although the development might have started under the water table, a major portion of the enlargement was done above.

In his studies of the Transvaal caverns Brain (1958) recognised two definite types, viz., solutional and subsidence caves. In both cases irregularly shaped chambers are dissolved out by phreatic waters immediately below the water table. Structural weakness in the dolomite aided the development of caverns. Through lowering the water table by surface erosion and climatic change the caverns are elevated into the vadose zone. In this zone the chamber is enlarged by the dissolving action of water seeping through the joints and the ultimate collapse of the roof-developed sinkholes.

Retief (1960) describes the pre-Karoo surface as a peneplain formed by partially denuded Transvaal rocks presumably covered only by outliers of rocks of the Waterberg Group. Dwyka glaciation probably removed all the arenaceous rocks and laid bare the dolomite and solution of the dolomitic limestone was then in progress. Tillite was deposited on the dolomite covering the erosion surface of the pre-Karoo peneplain.

Harger (1922) visualised that whilst deposition of the Karoo beds occurred percolating waters were already finding their way downwards and developing caverns in the dolomite.

In post-Karoo times denudation set in and river systems started to develop and incised deeply into the Karoo bedrock, the prominent drainage direction being south-westerly. That little of the dolomite has been stripped since its exposure by the removal of the Karoo cover and that the existing peneplain is not very different from the pre-Karoo erosional surface can be deduced from the following observations; (1) Karoo rocks still exist at Pienaar's Pothole (Du Toit, 1951; Stettler, 1979) and, (2) other outliers of Karoo rocks also exist in the area especially around Lichtenburg. The dolomite is nearly horizontal so that the area has been very stable since post-dolomite deposition. There is very little change in elevation between Lichtenburg and Bakerville so that the actual contact between the dolomite and the overlying Karoo rocks was not far from the existing peneplain.

As the denudation of the Karoo sediments progressed dolomite was laid bare again and karstic surface features developed on the exhumed former peneplain. In addition to these erosional forms a honeycombed subsurface pattern existed in the dolomite. The water table was still relatively high. A further development of the underground solution cavities would tend to be concentrated in the areas underlying the valleys as it is these regions where the dolomite was first laid bare.

Denudation of the sediments progressed at such a rapid pace that the load of the rivers was out of proportion to their capacity and during severe floods debris was moved over considerable distances.

Many present-day braided rivers are found on piedmont fans along the flanks of highlands from which discharge is often seasonal, e.g. as from the Rocky Mountains into the hot desert of the mid-western United States, and along the periglacial mountains in Canada (Blissenbach, 1954; Williams and Rust, 1969). Although flanks of highlands were not all round, certainly the mountainous divide between the dolomite and the Pretoria series was much further south and closer to the Lichtenburg gravels, than presently. In these regions mechanical erosion is rapid, discharge sporadic, but volumetrically vast and there is little vegetation to hinder runoff. Rivers are generally overloaded with sediment. Repeated bar formation and channel branching generates a network of braided channels over the whole depositional area. Therefore the alluvium of the braided rivers is typically composed of sand and gravel deposits, similar to those found in the Bakerville district. Due to repeated channel switching and a fluctuating discharge there is generally an absence of laterally extensive cyclic sequences, such as those produced by meandering streams (Selly, 1969).

During severe flood conditions, overflow would cause finer material to be deposited outside the main river channels to form thin and finer gravels whose ratio of matrix to pebbles is much higher than that of the main runs (fig. 31).

The dendritic shape of the morphology of the gravel run, the width of the major gravel runs and the size of some of the boulders indicate that the rivers were large and that the initial capacity to move and remove material at flood conditions was great.

Potholes developed in or alongside the riverbed. Those which occurred near enough to the channel were filled with finer gravel in times of severe floods when the rivers were overloaded with sediment. The influx of gravel in these sinkholes was very gradual and the churning action of the currents in the potholes caused the concentration of diamonds in the basal layers of each cycle.

The relative lowering of the water table caused the rivers to lose their capacity to transport material further as the drainage changed from subaerial to underground as the result of the development of karst

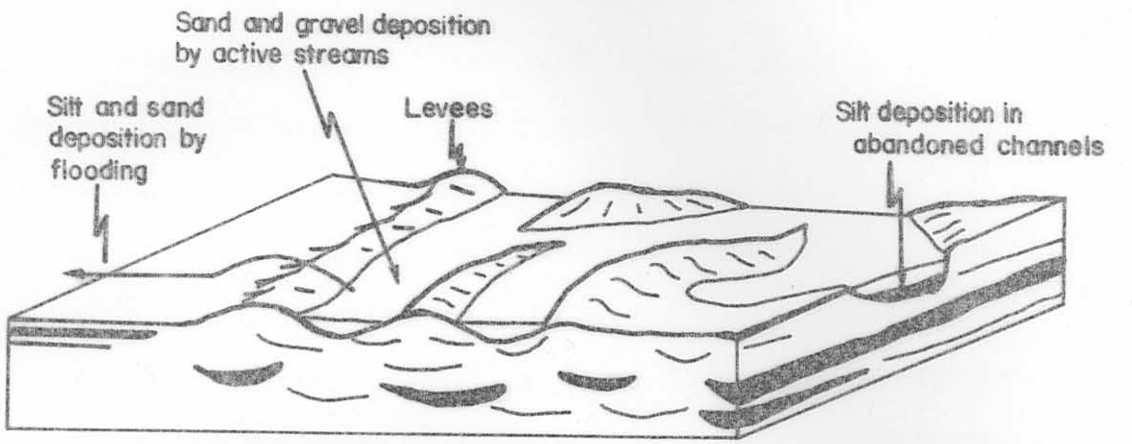


Figure 31 Origin of alluvial sub-facies deposited by braided rivers(after Selly 1969).

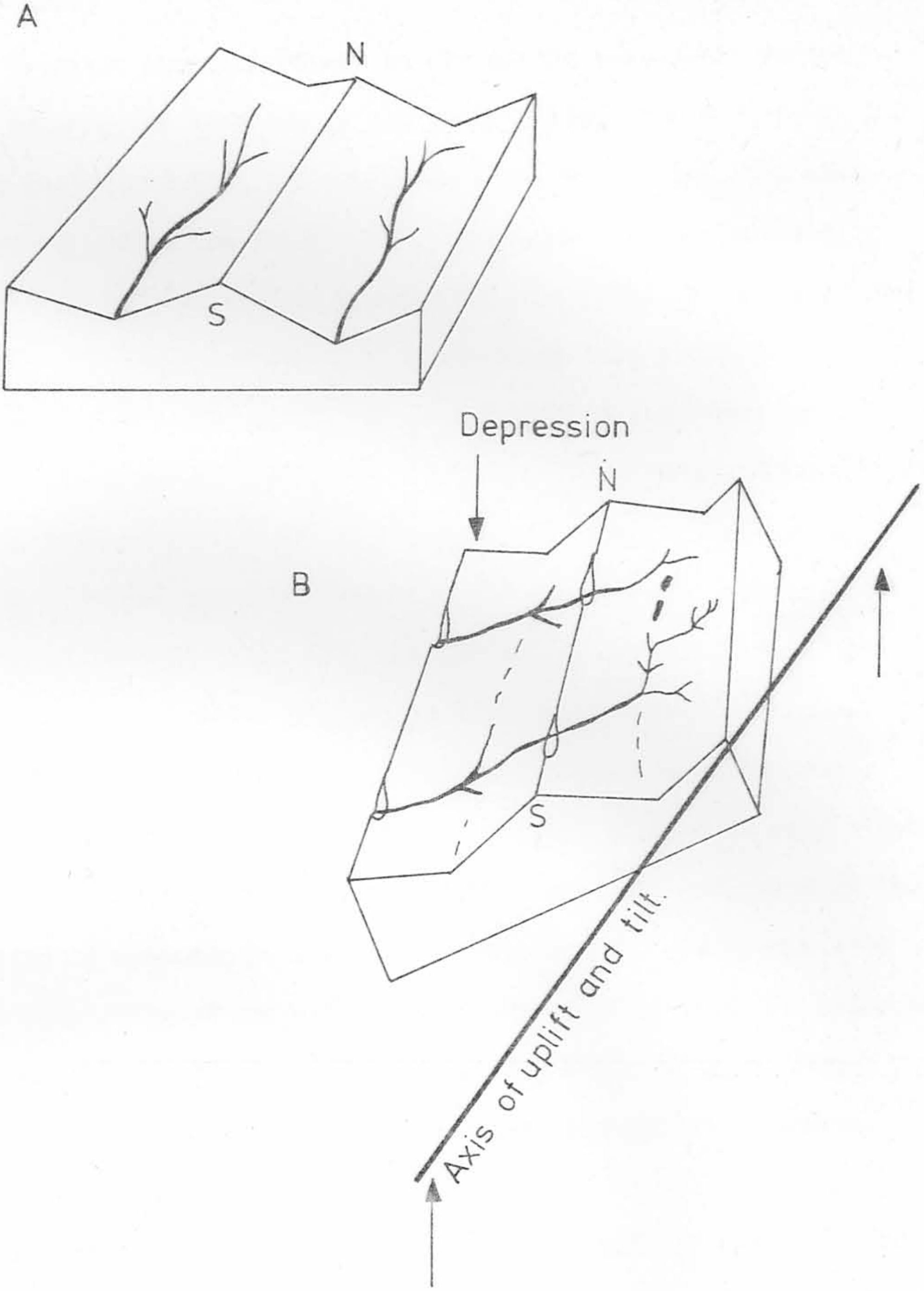
topography.

Two unrelated forces are thought to have instigated the relative lowering of the water table namely climatic fluctuation and late-Tertiary crustal uplift.

It is generally agreed that periods of both wetter and drier climatic conditions have occurred during this period in Southern Africa (Marker, 1972). During the wetter periods water would have been available for dissolution under high water table conditions. In the intervening dry periods the water table would have been lower and flash floods common (Bond, 1967). Late Tertiary crustal uplift along the Griqualand-Transvaal axis would cause a dramatic change in the drainage system (Mayer, 1973; Du Toit, 1933) and in the regional hydraulic head of both the surface and underground waters (fig. 32). Mayer (1973) proposed that the Welverdiend-Grasfontein run during its mature stage formed a tributary of the Harts River. Due to the uplift of the Griqualand-Transvaal axis, tributaries of the Molopo River cut off the headwater of the palaeo-Harts River so that the Welverdiend-Grasfontein-La Rys Stryd tributary was directed towards the north-west.

On the map accompanying Du Toit's paper (1933) the Griqualand-Transvaal axis of uplift is shown as passing through Lichtenburg. For geological as well as geomorphological reasons it is expedient to move this line further south and Mayer (1973) suggests that it coincides with the present divide of the Harts and Vaal rivers.

The dykes which cut the dolomite have a significant influence on the water table. They act as barriers and divide the dolomite into compartments. However due to the tilting of the area which was caused by the axial uplift, the axis of which is to the south of the study



THE UPLIFT ALONG THE GRIQUALAND-TRANSVAAL AXIS CAUSING A DRAMATIC CHANGE IN DRAINAGE DIRECTION (After MAYER 1973) area, a relative lowering of the water table will be experienced in each compartment.

Every climatic change from wet to dry during the uplift period would also enhance the lowering of the water table.

In the Bakerville area the sharp outlines of the runs, the absence of any slumping within the gravels or of collapse features where a potato gravel is resting against a dolomite wall (figs. 6 and 7, around peg 800/2900) all suggest that little subsidence took place in the river courses, except where potholes were formed in the river bed.

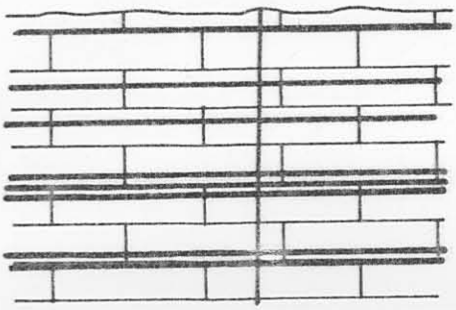
Some of the gravels found their way into the already existing sink-holes at the time of deposition (e.g. King's Pothole). Collapse of the dolomite walls of such a pothole burying the gravels under a thick layer of dolomite/chert (fig. 33), can be clearly observed around peg 1000/2850 (fig. 21, borehole 9), and at King's and Malan's potholes.

It has been suggested (Retief, 1960) that some reworking took place at the edges of the runs. This is in fact evident in many places, and indicates that reworking probably had an important influence on the concentrating of diamonds in the runs. The last cycle of deposition before the completion of the axial uplift was manifested by the sediments of the "Rooisloot" which cuts obliquely across older drainage lines. The change in gravel morphology suggests that this cycle represents change in climate.

A final comment is justified on the preservation of the gravels. Both to the north and the south of Bakerville their traces vanish. It is most likely that the actual physical characteristics of the karst area was responsible for the preservation. Would the bedrock have been granitic for instance, then the remaining gravel would probably be less extensive in aerial distribution or perhaps non-existent.

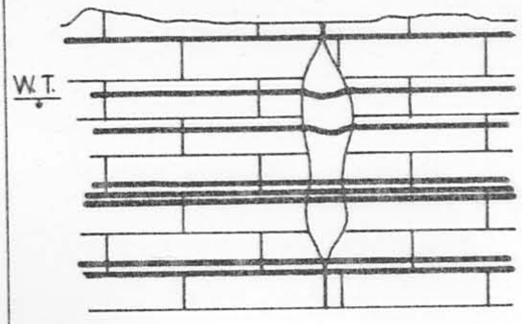
The above scenario and sequence of events is thought to best explain the features of the Bakerville gravels as well as their stratigraphic

A



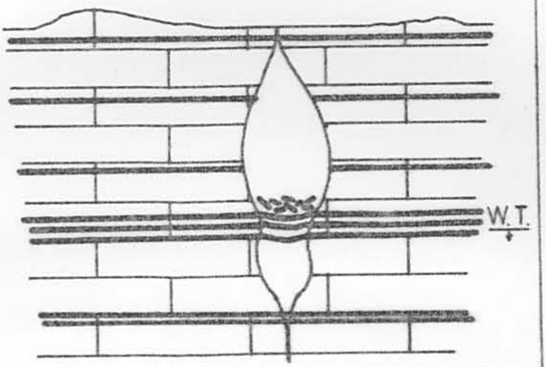
Jointing in the impure dolomite.
(dark thick horizontal lines represent chert bands)

B



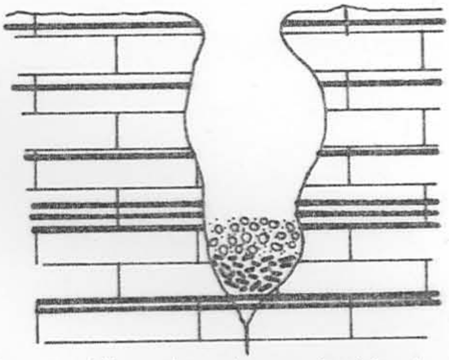
Initial cavity development along joint plane mainly below the watertable.

C



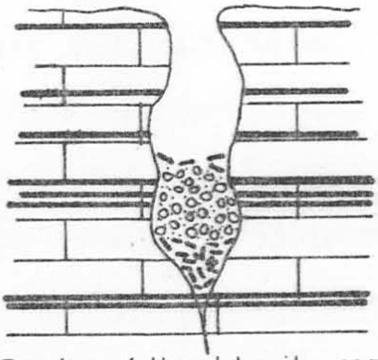
Drop of watertable and further development of the cave can cause collapsing of chert bands.

D



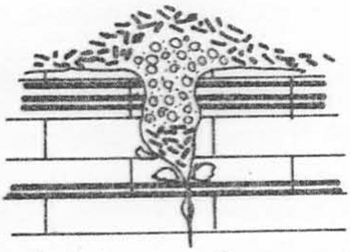
Canyon-like structures areideal coursesfor rivers.

E



Erosion of the dolomite continuous until locally residually derived ....

F



...material cover the gravels sometimes completely.

DEVELOPMENT OF A CAVE IN ANIMPURE DOLOMITE AND THE SUBSEQUENT DEPOSITION OF THE GRAVELS.

setting.

7.2 Origin of gravel and diamonds

On the basis of lithological variations in the gravels, coupled with palaeocurrent directions Stratten (1979) concluded that there are three distinct source areas for the gravels of the south-western Transvaal. The first and most prominent, is situated north of Swartruggens. This is the source area for the Lichtenburg/Ventersdorp gravels (Stratten, 1979). Other source areas such as south-eastern Botswana, which were supposedly responsible for the gravels near Mafikeng and Schweizer-Reneke were less influential (Stratten, 1979). Prior to the Tertiary upwarping in this area, the watershed was located further to the north. Thus eroding streams flowed southwards, with a tendency to radiate from the source area (Stratten, 1979). This is in agreement with the work of Mayer (1974) from which Stratten argued that tectonic movement during the Tertiary disrupted the south-eastern drainage tributaries in the Swartruggens-Lichtenburg area of the Vaal catchment area.

Judging from the roundness of the quartzite pebbles, which are believed to have been derived from the Waterberg Group, Stratten (1979) estimated that they could only have travelled approximately 60 km. The nearest Waterberg quartzite outcrop is nearly 110 km away (in the central Transvaal), so Stratten (1979) concluded that the only medium that could have transported these pebbles and diamonds from pre-Karoo kimberlites in that area to the Lichtenburg area was the Transvaal ice sheet of the Dwyka period radiating from the central Transvaal. Subsequent erosion of the tillite released the clasts to be transported by fluviatile forces.

Du Toit (1952) mentions the presence of pebbles of Dwyka tillite in the Bakerville gravels and reports the sporadic occurrence of silicified wood on Grasfontein 356 JP both of which must have been derived from the Karoo sequence.

If the source area of the Bakerville gravels was identified correctly as being just north of Swartruggens (Stratten, 1979) one must conclude that the source of the diamonds, be it primary or secondary, is somewhere between Swartruggens and Bakerville, a distance of approximately 100 km. However, samples taken from the gravel runs at Bakerville failed to produce any kimberlitic minerals which could be identified beyond doubt. The samples also include concentrates from King's and Malan's potholes (see section 6).

It is unlikely that the diamonds were derived from the Swartruggens kimberlite dykes as the physical characteristics of the diamonds of the two areas differ distinctly, even if the dykes were part of a system of kimberlitic diatremes which are now eroded away (Dawson,1972).

It has been suggested (Stettler, 1979) that a yet unidentified diamondiferous kimberlitic source exists in the immediate vicinity to the east or north of Lichtenburg. The lack of abrasion of the diamonds and the presence of cleavage "chips" are supposed to be in support of this idea. However, diamonds with such physical characteristics are also found in the beach deposits at Oranjemund (J.B. Hawthorne personal communication).

Detailed loam sampling for heavy minerals in the immediate area of the gravels and in the Lichtenburg district, by the prospecting group of the De Beers Consolidated Mines, failed to even pick up any kimberlitic grains (Mr J.B. Hawthorne, personal communication).

Examples of diamondiferous sediments close to a primary source such as Swartruggens (Transvaal), Premier (Transvaal), Lethlakane (Botswana), Orapa (Botswana), all yield large quantities of kimberlitic minerals such as garnets, ilmenites and chrome-diopsides, which are lacking in the Bakerville gravels.

The author finds it highly unlikely that a primary diamond source is either in or close to the Lichtenburg diamond fields.

It thus seems reasonable to conclude from the abundance of diamonds and the lack of other kimberlitic minerals in the gravels that the history of the diamonds after liberation from their primary source, is more complicated than the formation of the gravels themselves.

As the Dwyka tillite is being considered a likely source for the foreign clasts in the Bakerville gravels, (Stratten, 1979) the tillite must surely be considered a likely source for the diamonds in these gravels. This was first suggested by Harger (1914).

The Transvaal highland area was one of the major ice producing centres in Southern Africa during the Dwyka glaciation (Stratten, 1977). The south-western Transvaal was invaded by the massive Transvaal ice sheet which radiated outwards from the Transvaal highlands. In the south-western Transvaal the main direction of flow was towards the south-west at the close of the glacial period (Stratten, 1967). The primary source of the diamonds must therefore have been to the north-east of the Lichtenburg-Swartruggens area. It is postulated that the pre-Karoo kimberlites were eroded by the advancing ice sheets and that the kimberlite debris became incorporated in the tillite.

Studies made on the chemical stability of garnet have provided a variety of results. The general consensus, however, is that garnet is only moderately stable under soil-forming processes but once buried shows a high resistance to further weathering by intra-stratal solution (Pettijohn, 1941; Gravenor, 1954).

It was found that a large percentage of chattermarked garnets, taken from the late-Palaeozoic glaciogenic deposits in the Kimberley area, was the result of a much longer distance of transport probably because of continuous recycling (Gravenor, 1979). Gravenor (1979) concluded that the concentration of heavy minerals and the loss of unstable minerals is in large measure due to mechanical abrasion, which took place during interglacial periods when the heavy minerals were subjected to reworking in lacustrine and fluvial environments.

As the ice vacated the depressed basin, the sediment in the basin was reworked (Gravenor, 1979). Under these conditions the less mechanically stable minerals were broken down, leaving concentrates of diamonds and to a lesser extent, garnets. As the ice re-advanced heavy mineral concentrates were picked up by the ice, reworked and redeposited. After many cycles of this nature, the heavy minerals in the glacial deposits became enriched, (Gravenor, 1979).

Once liberated from the tillite, these minerals became exposed to different chemical and mechanical weathering processes. After transport to and deposition in the Lichtenburg area diamonds, being the most stable of kimberlitic minerals, will eventually occur in largest concentration.

Although the occurrence of small garnets in very small quantities and only found in some of the major potholes (e.g. Pienaar's Pothole) has been reported (Du Toit, 1951; Stettler, 1979) it appears that the diamonds from the Bakerville gravels are the only remains of the primary source.

It would be a rewarding experiment to analyse these garnets for chattermarks and other surface features.

8. SUMMARY AND CONCLUSIONS

The gravity survey indicated a clear regional pattern of gravity highs and lows. Geological field evidence indicated that gravity highs are always associated with outcropping dolomite or dolomite under a thin cover.

Drilling results have shown that most of the narrower and shallower gravity lows are usually related to leached zones, whilst the major gravity anomalies, at least in the test area are often caused by leached zones which have been filled with alluvial gravel.

The aim of the survey,to establish the presence of leached zones and palaeosinkholes in which gravel deposits may be present,was successfully reached. Although time-consuming and therefore expensive it is the only method which has thus far been proved to be of use in the search for these subsurface structures.

Because of the dimensions of the structures involved, the 50 m spacing of stations was sufficiently close. A closer grid would not have provided sufficient additional information to justify the expense. A larger station spacing might have missed several structures.

The success of the gravity survey can mainly be attributed to the significant density contrast between the dolomite and chert on the one hand and the material in the leached zones (wad and residual chert) and superficial deposits on the other.

The position of the Grasfontein dyke was accurately located by means of the magnetic survey. No other magnetic bodies were detected.

From the unsuccessful search for kimberlitic minerals in the gravels, which are otherwise so rich in diamonds, and from the abundance of Waterberg quartzite pebbles which were partially transported to the Lichtenburg area by the ice flows of the Dwyka glaciation, it is felt that the diamonds went through a polycyclic sedimentological history. The palaeorivers of which the gravel runs at Bakerville are remnants must have been eroding the Dwyka tillite which was locally rich in diamonds. The kimberlitic minerals, not being as stable as diamonds, were eventually broken down by mechanical and chemical weathering in glacial and fluvial environments, and environments that existed before the Dwyka glaciation. Few garnets and ilmenites were saved from this destruction and these were deposited in small quantities in some of the major potholes.

From glacial directions and the location of the source area of the gravels it was concluded that the pre-Karoo kimberlite intrusions that were responsible for the diamonds in Bakerville are situated a considerable distance in north-easterly direction from the Lichtenburg-Ventersdorp area.

It might thus be desirable to sample some of the outliers of Dwyka tillite between Swartruggens and Lichtenburg to establish the possible diamond content in order to verify this proposed hypothesis.

Finally, a more accurate correlation of the gravels from different localities appears to be important. This might be done by a magnetic susceptibility survey. This method proved to be successful in Canada to distinguish between different surface tills (Gravenor and Stupavsky, 1974).

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APPENDIX A

Co-ordinates of beacons used in resection and co-ordinates and theoretical gravity values of corner points.

1. Co-ordinates of the beacons used in the Grasfontein area of map 2526 CC and 2626 AA;

BEACONS	Y	X
273	95 384,37	2 875 173,34
18	92 674,56	2 869 706,80
26	99 072,14	2 878 216,07
248	98 129,66	2 874 121,94
480	92 464,71	2 878 488,18

2. Co-ordinates and theoretical gravity values of the corner points of the grid;

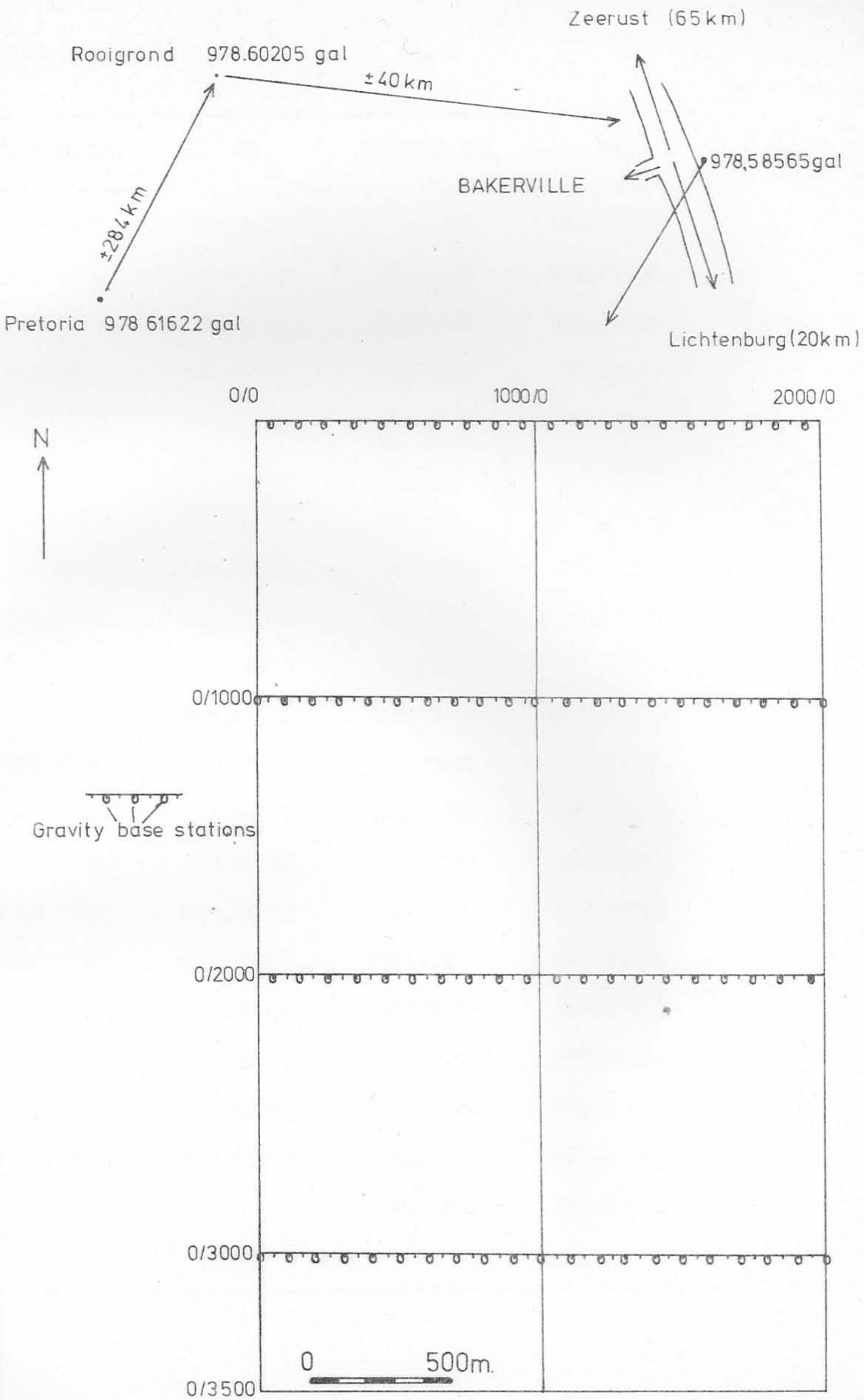
POINT	Y	X	G_t
0/0	96 300,00	2 874 100,00	979,023019
1000/0	95 300,00	2 874 100,00	979,023019
2000/0	94 300,00	2 874 100,00	979,023019
0/1000	96 300,00	2 875 100,00	979,023661
1000/1000	95 300,00	2 875 100,00	979,023661
2000/1000	94 300,00	2 875 100,00	979,023661
0/2000	96 300,00	2 876 100,00	979,024303
1000/2000	95 300,00	2 876 100,00	979,024303
2000/2000	94 300,00	2 876 100,00	979,024303
0/3000	96 300,00	2 877 100,00	979,024977
1000/3000	95 300,00	2 877 100,00	979,024977
2000/3000	94 300,00	2 877 100,00	979,024977
0/3500	96 300,00	2 877 600,00	979,025266
1000/3500	95 300,00	2 877 600,00	979,025266
2000/3500	94 300,00	2 877 600,00	979,025266

APPENDIX B

Gravity base stations: co-ordinates and values

Gravity values and station numbers of the gravity bases on Grasfontein 356 JP derived from the Bakerville base (978,58565 gal.)

STATION NO.	G. OBS.	STATION NO.	G. OBS.
50/0	978,58768	0/1000	978,58772
150/0	978,58779	100/1000	978,58755
250/0	978,58808	200/1000	978,58753
350/0	978,58803	300/1000	978,58723
450/0	978,58771	400/1000	978,58703
550/0	978,58801	500/1000	978,58710
650/0	978,58804	600/1000	978,58720
750/0	978,58800	700/1000	978,58707
850/0	978,58788	800/1000	978,58654
950/0	978,58727	900/1000	978,58669
1050/0	978,58729	1000/1000	978,58687
1150/0	978,58746	1100/1000	978,58741
1250/0	978,58733	1200/1000	978,58722
1350/0	978,58742	1300/1000	978,58673
1450/0	978,58732	1400/1000	978,58702
1550/0	978,58727	1500/1000	978,58675
1650/0	978,58761	1600/1000	978,58677
1750/0	978,58768	1700/1000	978,58604
1850/0	978,58774	1800/1000	978,58569
1950/0	978,58727	1900/1000	978,58661
		2000/1000	978,58671



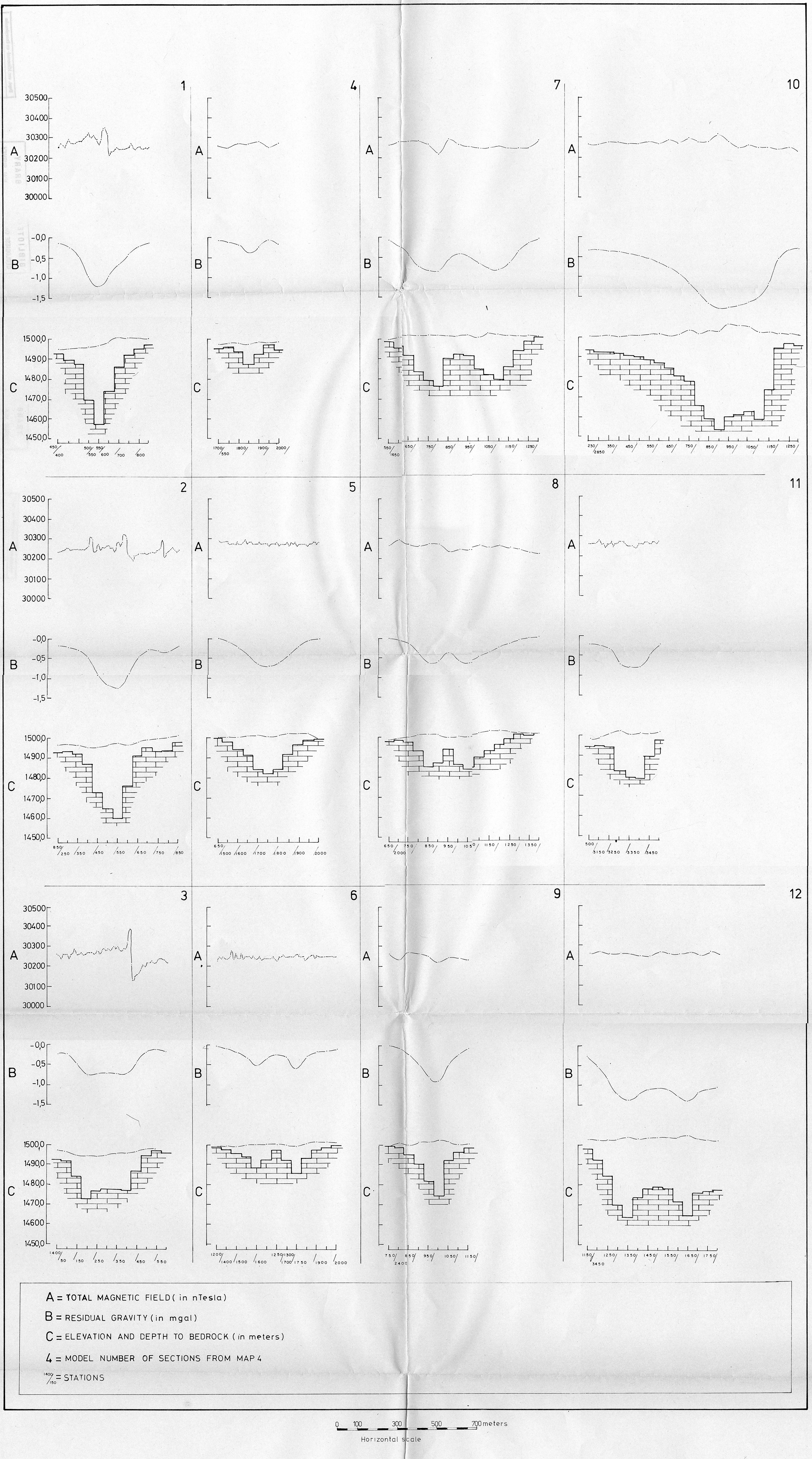
GRAVITY BASE STATIONS ON GRASFONTEIN 356 JP

APPENDIX B (contd.)

STATION NO.	G OBS.	STATION NO.	G OBS.
50/2000	978,58720	0/3000	978,58740
150/2000	978,58723	100/3000	978,58730
250/2000	978,58751	200/3000	978,58714
350/2000	978,58731	300/3000	978,58713
450/2000	978,58716	400/3000	978,58696
550/2000	978,58739	500/3000	978,58697
650/2000	978,58793	600/3000	978,58714
750/2000	978,58736	700/3000	978,58692
850/2000	978,58662	800/3000	978,58624
950/2000	978,58723	900/3000	978,58576
1050/2000	978,58672	1000/3000	978,58546
1150/2000	978,58640	1100/3000	978,58520
1250/2000	978,58673	1200/3000	978,58573
1350/2000	978,58700	1300/3000	978,58607
1450/2000	978,58723	1400/3000	978,58596
1550/2000	978,58728	1500/3000	978,58576
1650/2000	978,58686	1600/3000	978,58643
1750/2000	978,58722	1700/3000	978/58654
1850/2000	978,58708	1800/3000	978,58653
1950/2000	978,58670	1900/3000	978,58564
		2000/3000	978,58533

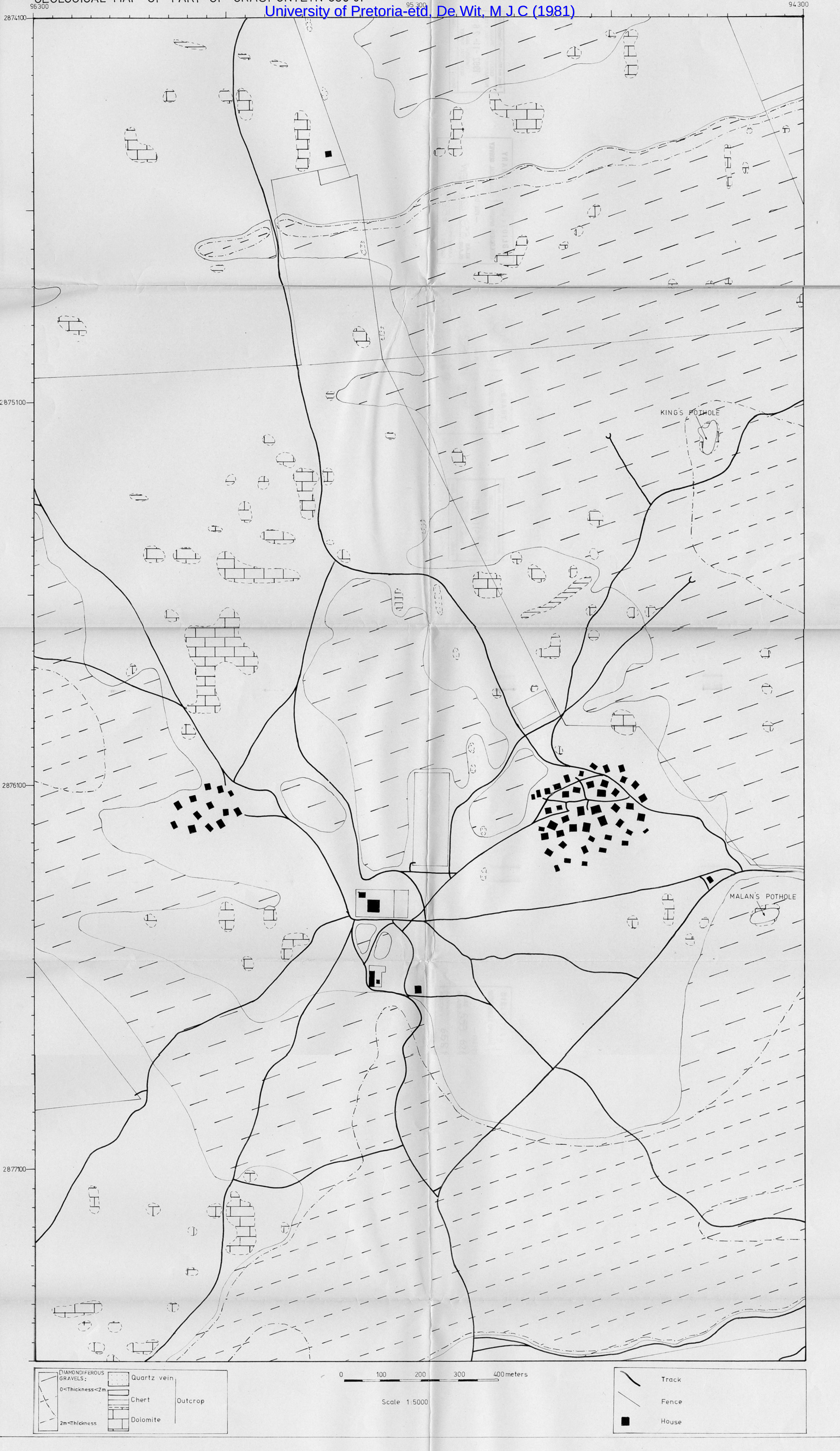
TWO-DIMENSIONAL MODELS BASED ON RESIDUAL GRAVITY OF PART OF GRASFONTEIN 356 JP

FIGURE 35



GEOLOGICAL MAP OF PART OF GRASFONTEIN 356 JP

MAP 1



ELEVATION MAP OF PART OF GRASFONTEIN 356 JP

MAP 2

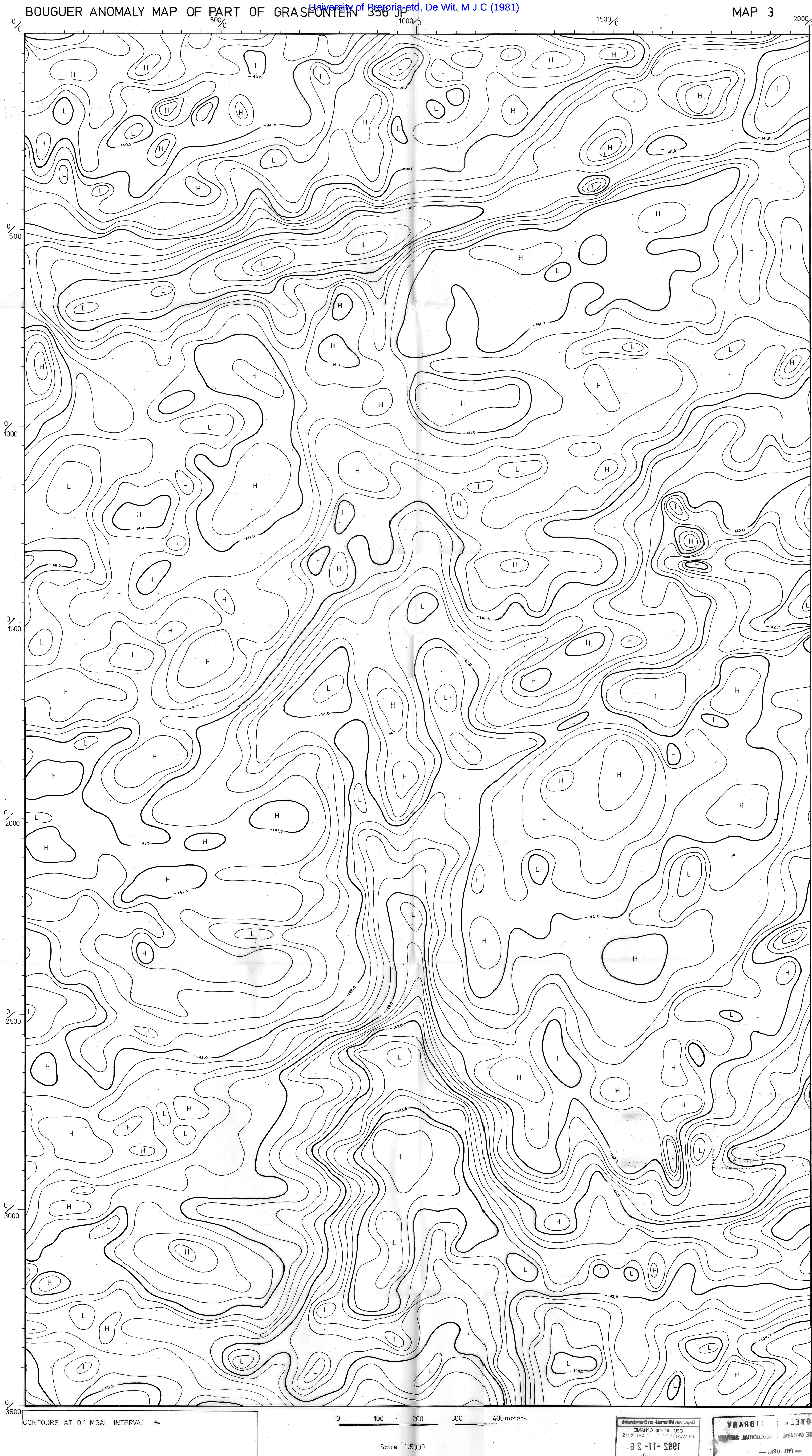
Contours at 1 metre intervals

0 100 200 300 400 meters

Scale 1:5000

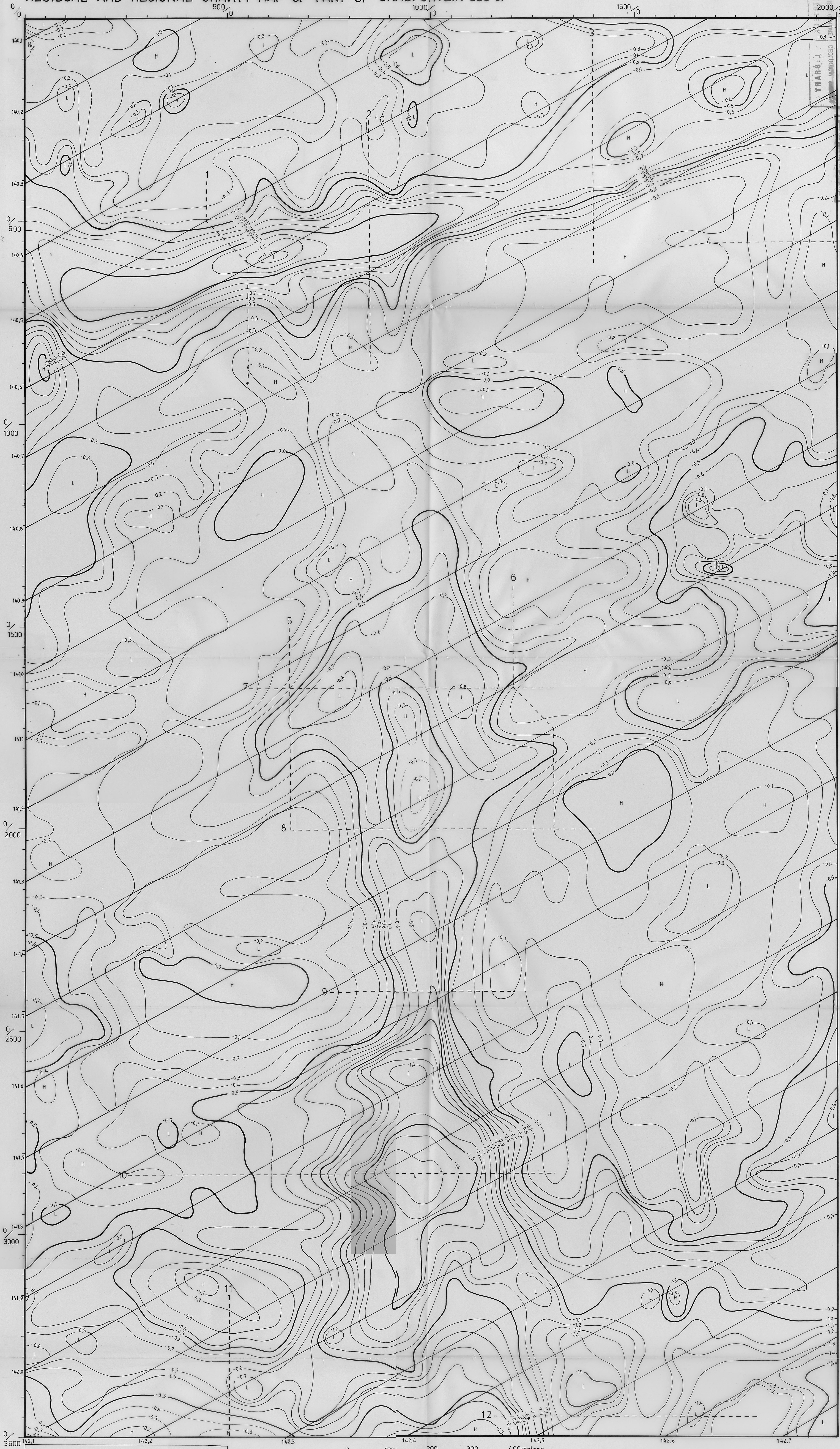
BOUGUER ANOMALY MAP OF PART OF GRASFONTEIN 356 JP

MAP 3



RESIDUAL AND REGIONAL GRAVITY MAP OF PART OF GRASFONTEIN 356 JP

MAP 4



Scale 1:5000

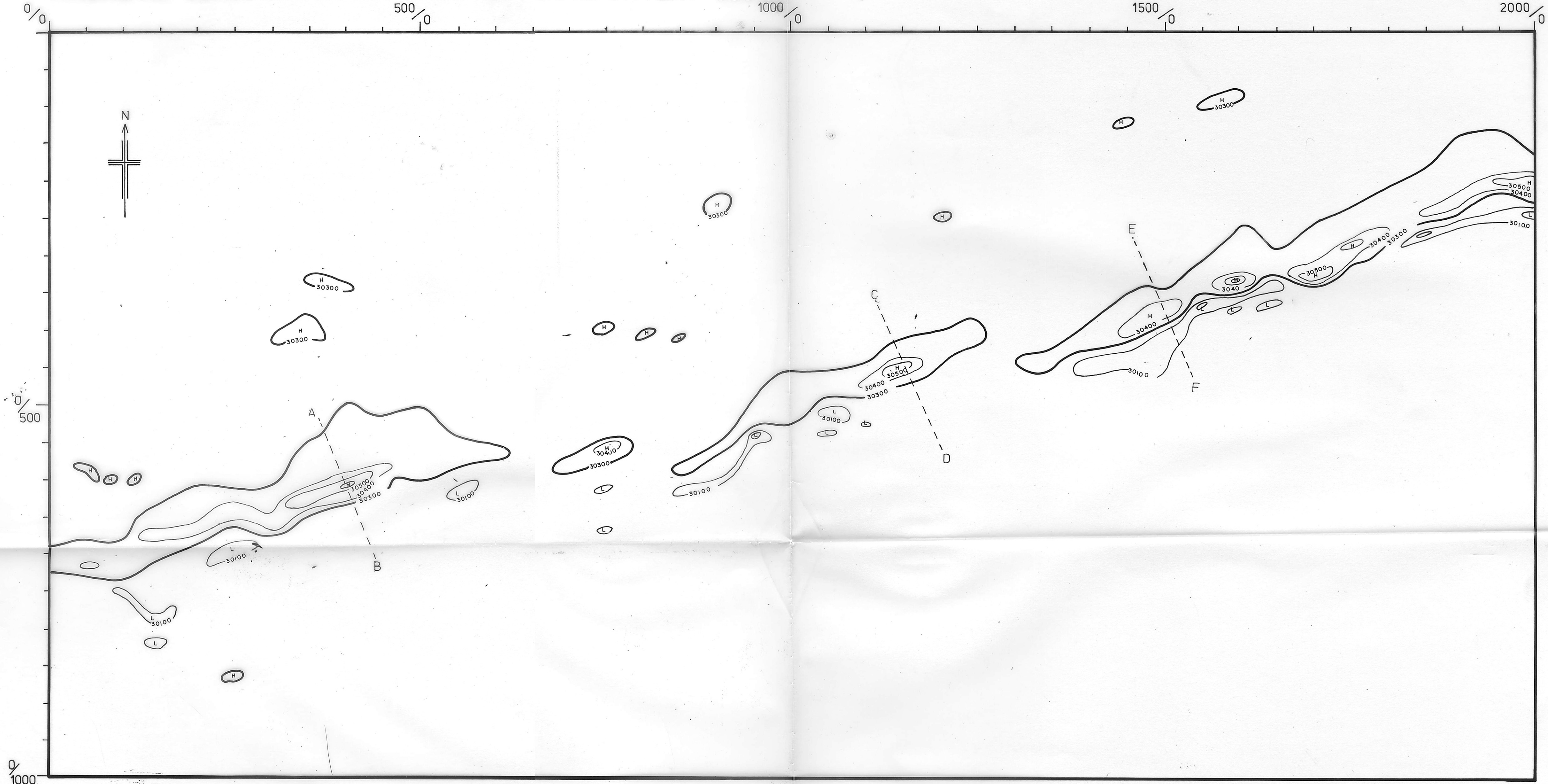
0,3 RESIDUAL GRAVITY (contours at 0,1 mgal)

141,2 REGIONAL GRAVITY FIELD (in mgal)

6 - - - - SECTIONS OF MODELS (Fig. 34)

MAGNETIC CONTOUR MAP OF PART OF GRASFONTEIN 356 JP

MAP 5



TOTAL MAGNETIC FIELD (Contours every 100 nT)

SECTIONS ACROSS DYKE

Scale 1:5000

0 100 200 300 400 meters