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CHARACTERISTICS OF THE E9Gb (MIDDLE ELSBURG) ORE SHOOT, COOKE 1 SHAFT, RANDFONTEIN ESTATES GOLD MINE, SOUTH AFRICA

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by

M.J. VILJOEN[1] and O.N. TENNANT[2]
([1] Department of Geology, University of the Witwatersrand,
P/Bag 3, WITS 2050, South Africa
[2] Group Geological Services, JCI Limited,
James Park Complex, P.O. Box 976,
Randfontein 1760)

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ABSTRACT

The E9Gb conglomerate reef of the Witwatersrand Supergroup is one of minor economic importance that occurs within the Middle Elsburg conglomerate package on Cooke Section of Randfontein Estates Gold Mine (REGM). This conglomerate reef unit is situated between the extensively mined UE1A/E9Gb composite reef conglomerate and the E8 conglomerate which has been mined to a lesser extent. Although developed throughout Cooke Section only, a discrete, relatively small mineralized ore shoot within the E9Gb unit has been mined in its entirety within the Cooke 1 area.

Routine underground sampling information, consisting of gold grades over the total conglomerate package thickness, have been regularized and contoured to produce isopach and gold isochon maps. An east-northeast-trending region of thicker conglomerate occurs along the south flank of the area and zones of thinner conglomerate along the northern area. Best gold values are situated in an area of intermediate thickness in the western, proximal part of the study area.

A number of vertical profiles across the ore shoot have been mapped and sampled. The conglomerate unit comprises a basal and top conglomerate unit, separated by a quartzite. Most of the gold occurs in the upper part of the basal conglomerate unit.

A higher pebble density and pyrite abundance are found to correlate closely with higher gold values in the upper part of the basal conglomerate unit. While channel thickness data have a normal distribution, gold value data have a log normal distribution. The E9Gb unit provides an opportunity of relating sedimentology within the ore shoot to the gold value distribution.

It is concluded that certain relationships such as that between gold grade and reef thickness as well as pebble density, combined with facies mapping, could be used to greater effect as a predictive tool for mining operations on most Witwatersrand gold mines.

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INTRODUCTION

Cooke 1 Shaft is the oldest of three shafts operating within the Cooke Section of the Randfontein Estates Gold Mine (REGM) in the West Rand Goldfield and lies immediately south of Doornkop Section, the latest extension to REGM (Fig. 1). The geological setting and regional controls of gold mineralization in the area have recently been documented (Viljoen, 1994) and are only briefly summarized here.

Gold production from Cooke Section has been derived mainly from the Gold Estates and Elsburg Formations of the Turffontein Subgroup (Fig. 2). The UE1A/E9Gd composite reef has been extensively exploited on Cooke 1 and 2 Shafts and to a lesser extent on the newest Cooke 3 Shaft (Viljoen, 1994). The underlying E8 reef has been mined to a lesser extent, mainly at Cooke 1 and 2 shafts (Viljoen, 1994). The E9Gb reef, although forming an extensive, recognizable conglomerate unit, is only mineralized in a few discrete areas of Cooke 1 shaft where it has been mined to a limited extent (Figs. 1 & 2). The major mining has taken place on one small, but discrete, and well-defined ore shoot, some 800m long by 200m wide, which has been investigated in some detail and forms the basis for this study. Sedimentological and gold value distribution patterns of the E9Gb conglomerate, based on underground borehole sampling and borehole data have been established and are compared with gold value distribution trends for the Composite and E8 reefs.

REGIONAL GEOLOGICAL SETTING

The regional geological setting of the Gold Estates and Elsburg Formation reefs of the Turffontein Subgroup within the West Rand area and at Cooke Section has been outlined previously (Tucker & Viljoen, 1986; Viljoen, 1994). A regional east-west section through Cooke 1 Shaft portrays the major structure and stratigraphy of the area (Fig.2). The Malmani Dolomite of the Transvaal Supergroup outcrops at surface and unconformably overlies the entire area, averaging 230m in thickness. This is underlain by the Black Reef Quartzite Formation which unconformably overlies the Witwatersrand Supergroup. The Klipriviersberg lava of the Ventersdorp Supergroup subcrops against the base of the latter and unconformably overlies the Witwatersrand Supergroup as a thickening wedge to the west. The Gold Estates and Elsburg Formations dip at low angles to the east and generally thin in a westerly direction before subcropping against the base of the lava. The Panvlakte Fault occurs to the west of Cooke Section and is overlain by a thick wedge of Klipriviersberg lava (Viljoen, 1994; Fig 3). The Panvlakte Fault has an upthrow of $\pm$ 700m to the west. A major anticline running parallel to the Panvlakte Fault occurs to the west in the Cooke 2 and southern part of the Cooke 1 shafts having been eliminated by the basal Ventersdorp Supergroup unconformity in the northern part of Cooke 1 (Fig. 3). Footwall strata of the Composite reef are progressively eliminated by the UE1A/E9Gb unconformity to the west of the anticline, a feature not observed at Cooke 1 due to the Ventersdorp unconformity having truncated the stratigraphy well to the east of the anticline in this area (Viljoen, 1994; Figs.2 and 3).

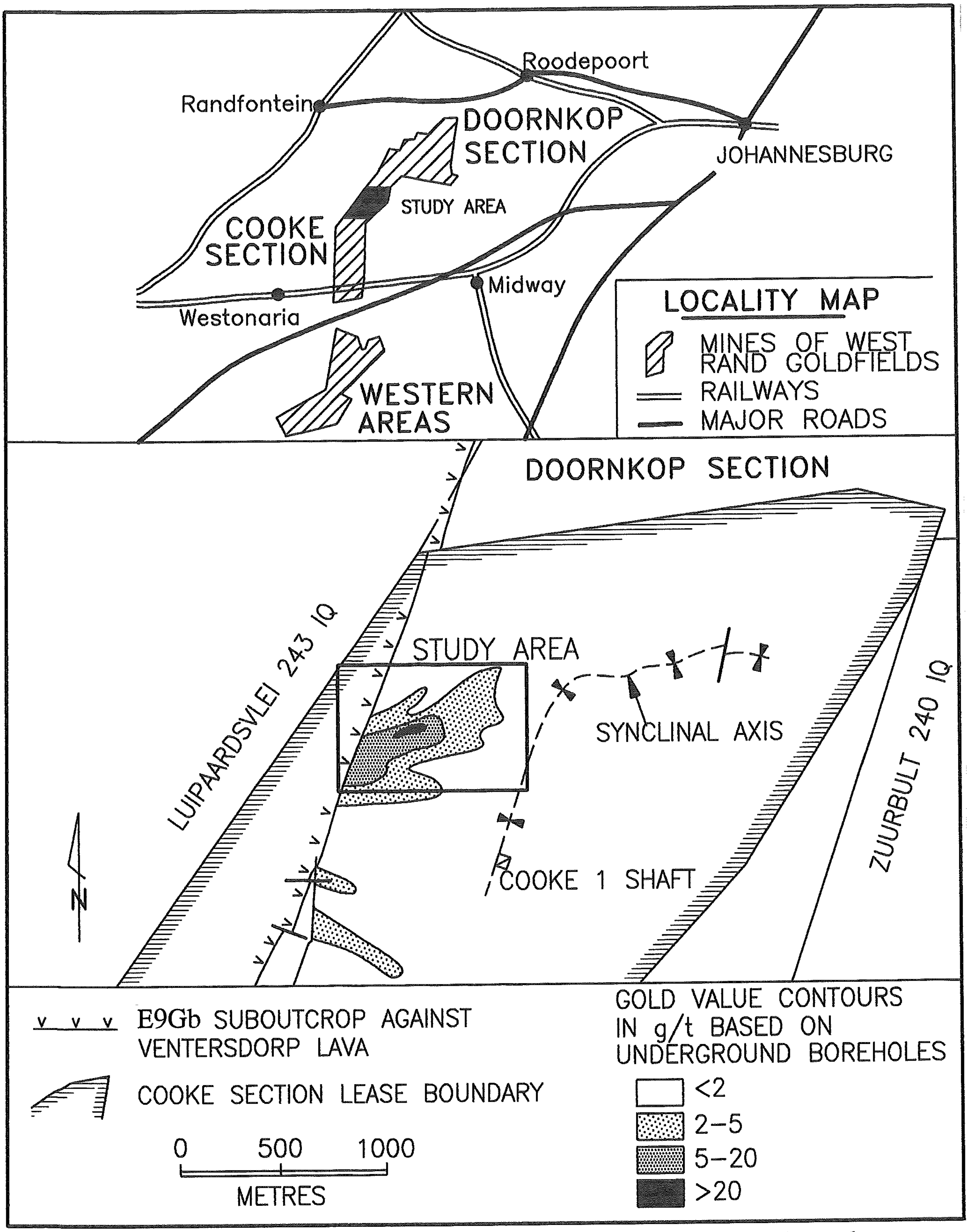

Figure 1: Locality of study area showing gold value distribution of the E9Gb conglomerate on Cooke 1 Section of Randfontein Estates Gold Mine.

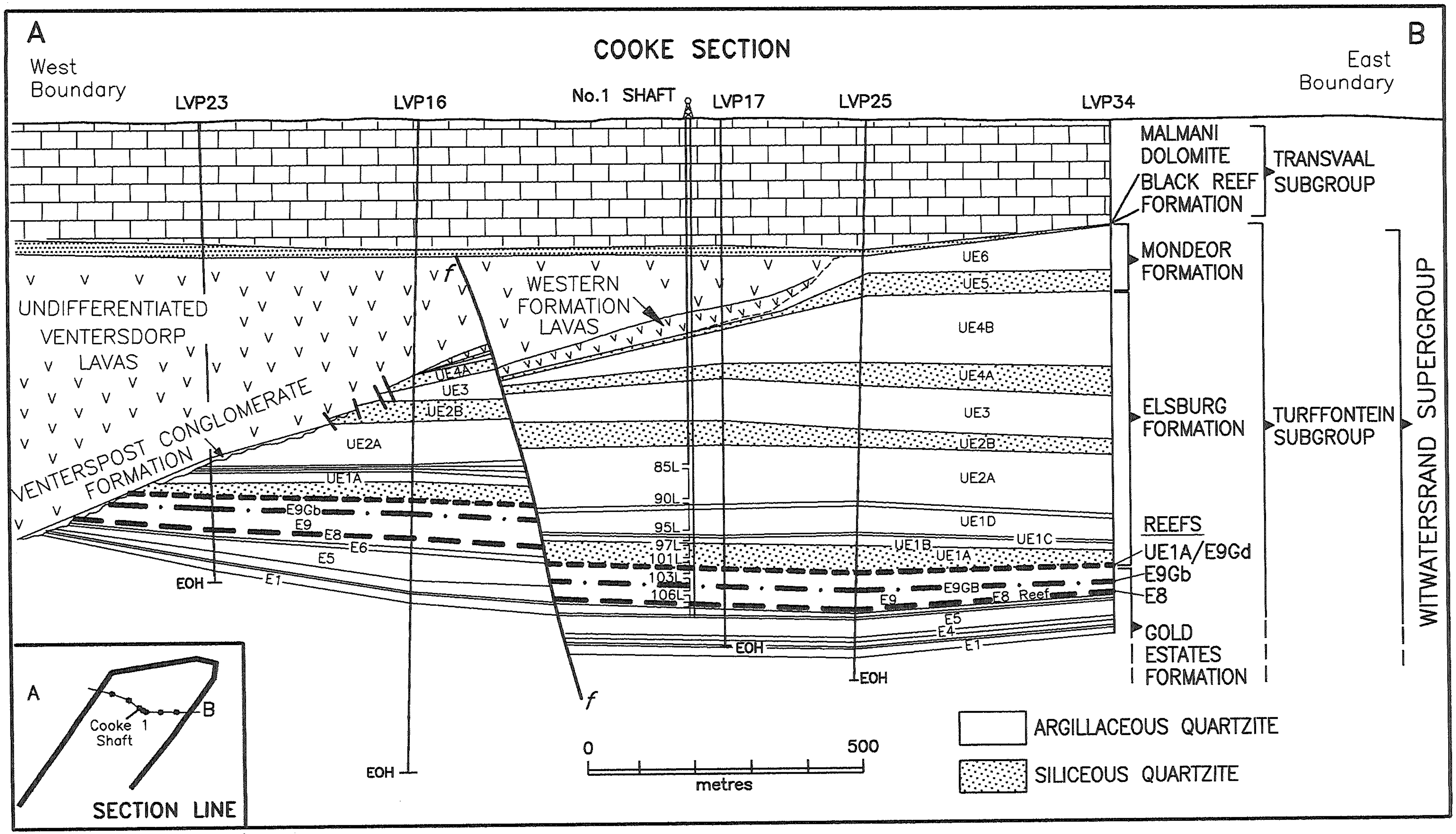

Figure 2: Geological section through Cooke 1 Shaft showing the setting of the E9Gb reef within the Gold Estates Formation.

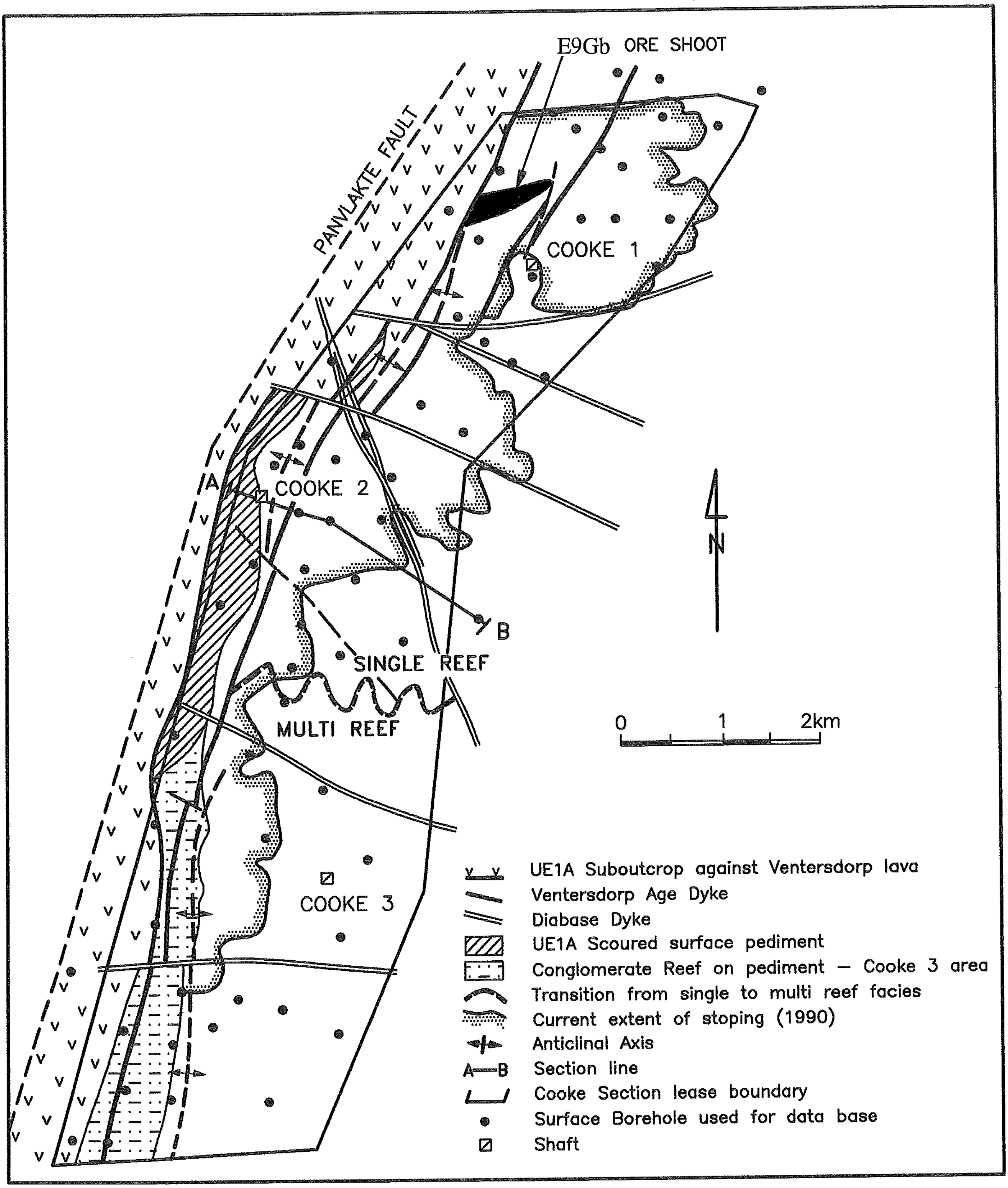

Figure 3: Major geological features of the UE1A/E9Gb composite reef at Cooke Section (from Viljoen, 1994).

A basinal structure in the Cooke 1 area has played an important role in the control of ore shoots. Virtually all of the major shoots of the UE1A/E9Gd Composite reef, as well as those of the E8 reef are confined to a basinal structure defined by the 900m above sea level structure contour of the Composite reef (Viljoen, 1994). An east-west-trending synclinal axis extends westward from the basinal structure axis north of Cooke 1 Shaft to the Ventersdorp lava unconformity (Fig.4). Major UE1A/E9Gd Composite and E8 reef ore shoots appear to be focused by this feature which also focuses the E9Gb shoot (Fig.4). This structure is considered to have been active and to have had a major influence on sedimentology and the concentration of gold throughout the deposition of the reefs of the whole Turffontein Subgroup in the Cooke 1 area (Viljoen, 1994).

STRATIGRAPHY

The detailed stratigraphy of the Turffontein Subgroup with the position of the various conglomerate reefs identified at Cooke Section are portrayed on the stratigraphic column, the broader subdivisions based on the latest stratigraphic nomenclature of the SACS Working Group on the Witwatersrand (T.S. McCarthy, pers.comm. Fig.5). The stratigraphic column as exposed by underground workings on Cooke Section includes the whole of the Turffontein Subgroup of the Central Rand Group. This has been divided into the Robinson, Gold Estates, Elsburg, and Mondeor Formations which are again subdivided into a total of 9 members. The detailed subdivision of the members into units is largely the result of the detailed studies of Mr B. Stewart (pers.comm. 1985, Fig.5). The importance of this stratigraphic classification as an indispensable part of meaningful regional stratigraphic, structural and mineralization modelling has recently been demonstrated (Viljoen, 1994). As noted, the predominant gold-bearing reefs being mined are the UE1A/E9Gd Composite and the E8, the former straddling the Gemsbokfontein and Panvlakte Members (as well as the Gold Estates and Elsburg Formations), and the latter occurring at the base of the Panvlakte Member (Fig.5). Twelve thin, and sporadically developed, unmineralized or weakly mineralized conglomerate horizons occur within the 60-70m thick E9 unit. These conglomerates can be correlated throughout Cooke Section. The E9Gb conglomerate is the third from the top and occurs some 25m below the UE1A/E9Gd composite reef (Figs.2 and 5). The immediate hanging wall of the E9Gb conglomerate comprises an argillaceous grey quartzite, whereas the footwall consists of a light-grey quartzite.

E9Gb ORE SHOOT

Structure

Structure contours and fault traces on the plane of the E9Gb reef are shown in Figure 6, together with stoped areas as at September 1990 shortly before cessation of mining operations on this shoot in 1991.

The E9Gb reef dips at about 11° in a southeasterly direction from the lava subcrop position, flattening to about 6° further into the basin. One major strike fault with a splay cuts across the ore shoot, downthrowing the reef by some 20m to the west (Fig. 6). This has had little horizontal movement and appears to have caused minimal horizontal displacement of the ore shoot. A gentle syncline trending subparallel to the fault in the west

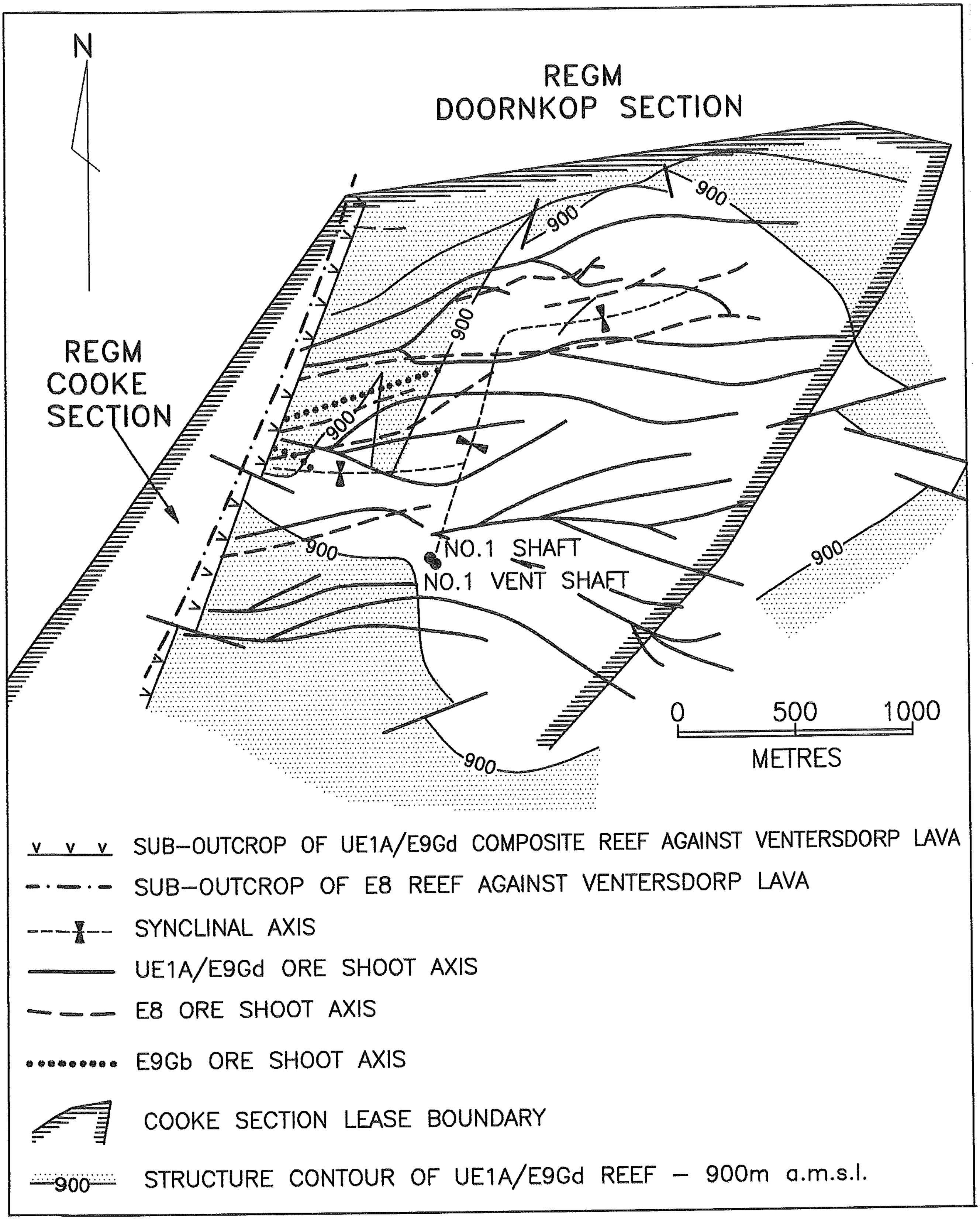

Figure 4: Axes of high-grade (> 5g/t) ore shoots for the UE1A/E9Gd composite, E8 and E9Gb reefs showing structural control (after Viljoen, 1994).

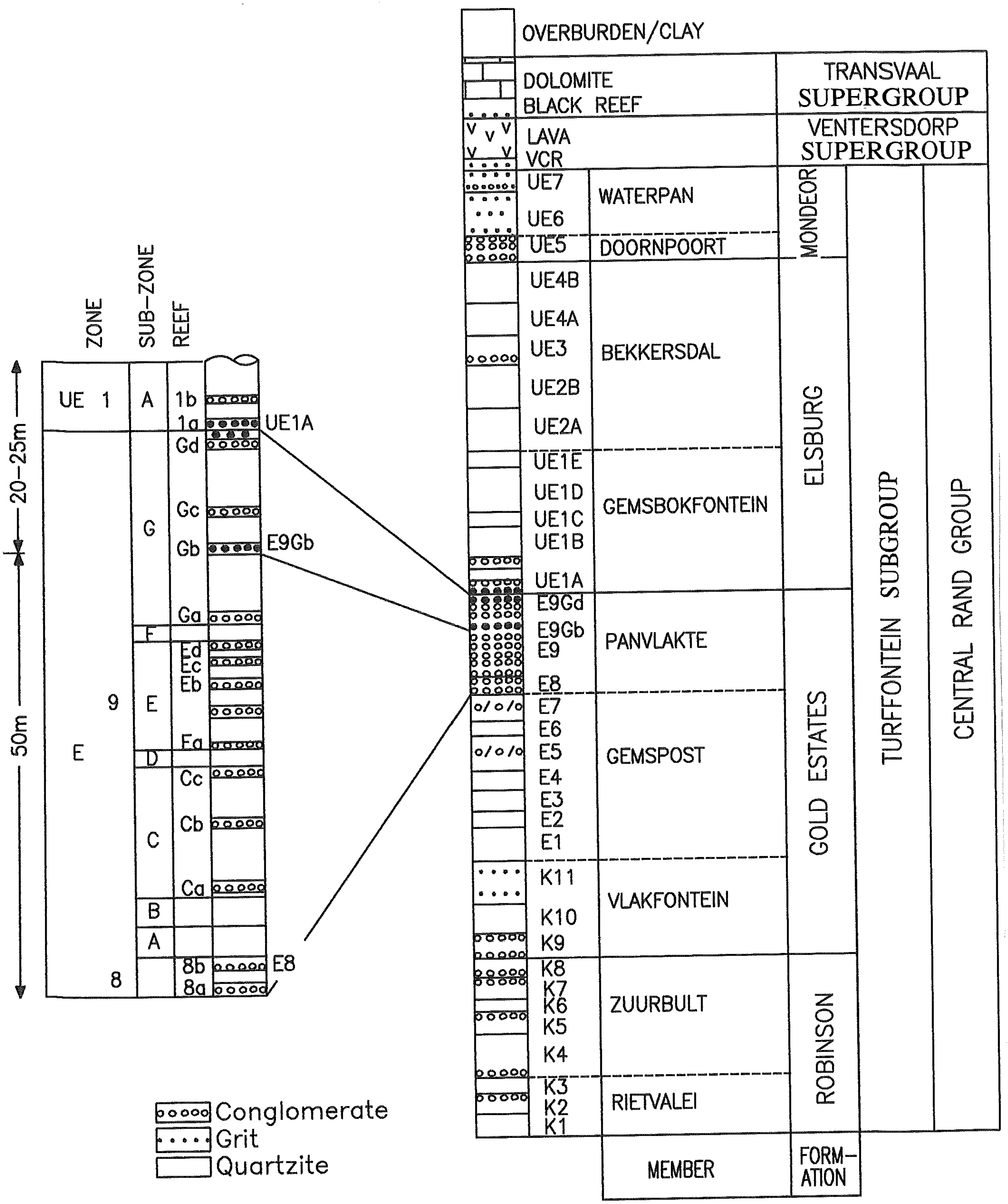

Figure 5: Stratigraphic column for the Cooke 1 and 2 areas showing the stratigraphic position of the E9Gb reef.

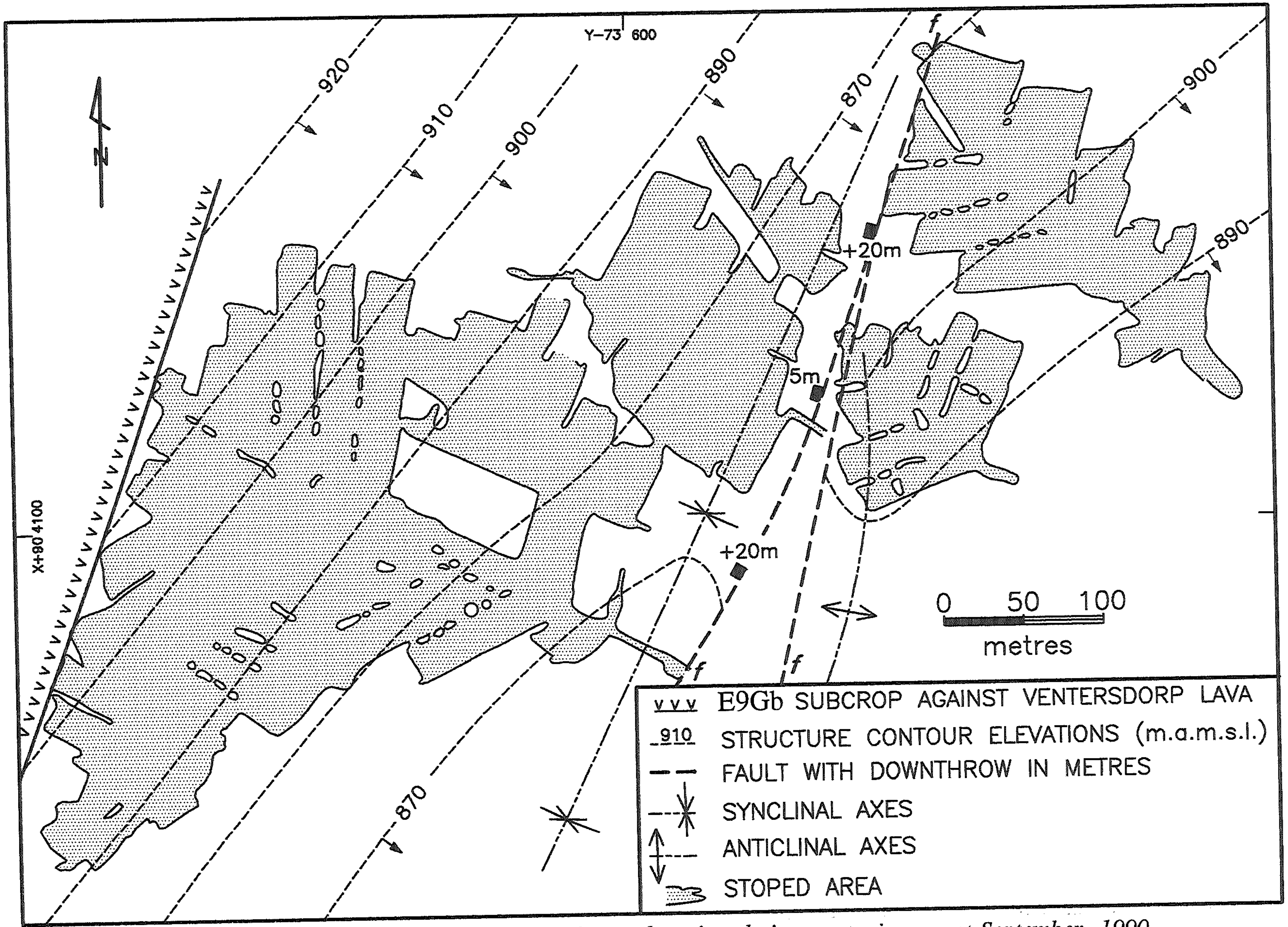

Figure 6: Structural features of the E9Gb ore shoot in relation to stoping, as at September, 1990.

and a gentle anticlinal axis trending subparallel to the fault in the east, appear to be related to the fault (Fig. 6).

Channel Morphology

The E9Gb reef is a composite body consisting of two main conglomerate zones with quartzite partings as will be described later. During mining and sampling, the full conglomerate package, together with internal quartzite, was sampled and the thickness and grade over the full channel width is quoted. These sample positions, with values for thickness and gold content, were digitised by means of the AUGES computer programme. The underground development sampling values, as well as underground borehole values, were also included in the database. A plot of average gold values and thicknesses for as many samples as occur in regularized 20m x 20m blocks was produced by the AUGES programme. The centres of regularized blocks, together with the stoped-out areas of the E9Gb reef are depicted in Figure 7.

Contouring of reef thickness was undertaken in 25cm intervals with thickness values ranging between 50cm and 300cm (Fig.8). Although somewhat irregular in detail, broad, east-northeast-trending zones of thicker and thinner reef are evident. In the southern part of the area, a well-defined thickened channel is developed in the central and eastern sectors of the area with thicknesses generally above 200cm but ranging to over 250cm (Fig. 8). This zone of thicker channelized reef probably swings northwards in the western part of the area between lines C-D and A-B, to the west of which it is truncated by the Ventersdorp lava unconformity.

A zone of reef with an intermediate thickness (between 175-200cm) occurs immediately to the north of the thick reef zone throughout the length of the area and contains a few sectors of thicker reef along the northern side of the western region between lines A-B to E-F as well as an area of thin reef between lines A-B and C-D. Areas of thinner reef (less than 150cm) occur along the northern flank of the region in the western and central parts of the area as well as in its eastern regions (Fig. 8). The broad pattern is thus one of generally thicker reef in the south, thinning significantly towards the north and less so to the south (as shown later in Fig. 13), and with an east-northeast trend. Of importance, from an economic viewpoint, is the shoulder or plateau of intermediate reef thickness immediately north of the thick reef in the western part of the area between lines A-B and E-F (Fig. 8). As will be shown, the high-grade sector of the ore shoot is largely confined to this shoulder area.

Gold Distribution

Gold content in cm.g/t ranges from less than 200 cm.g/t to greater than 5000 cm.g/t. Hand contouring of the regularized 20m x 20m block value information is depicted in Figure 9 and outlines a well-defined ore shoot. A very high grade western sector of the ore shoot core (>2000 cm.g/t) is truncated by the Ventersdorp lava subcrop to the west. It averages between 175cm and 200cm in thickness and extends over a distance of 250m from the

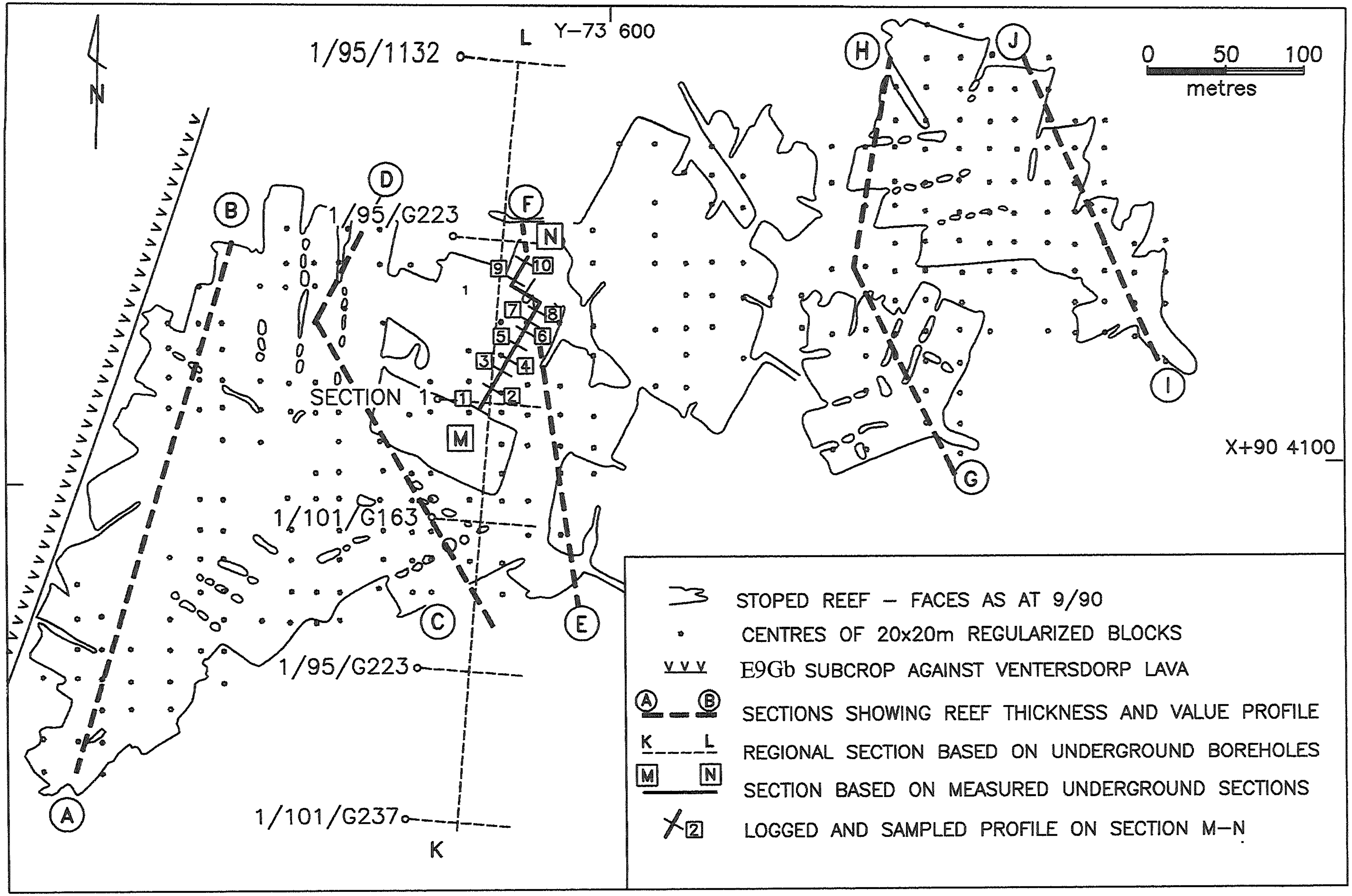

Figure 7: Centres of regularized block values on the E9Gb ore shoot used in data contouring, together with localities of various section lines.

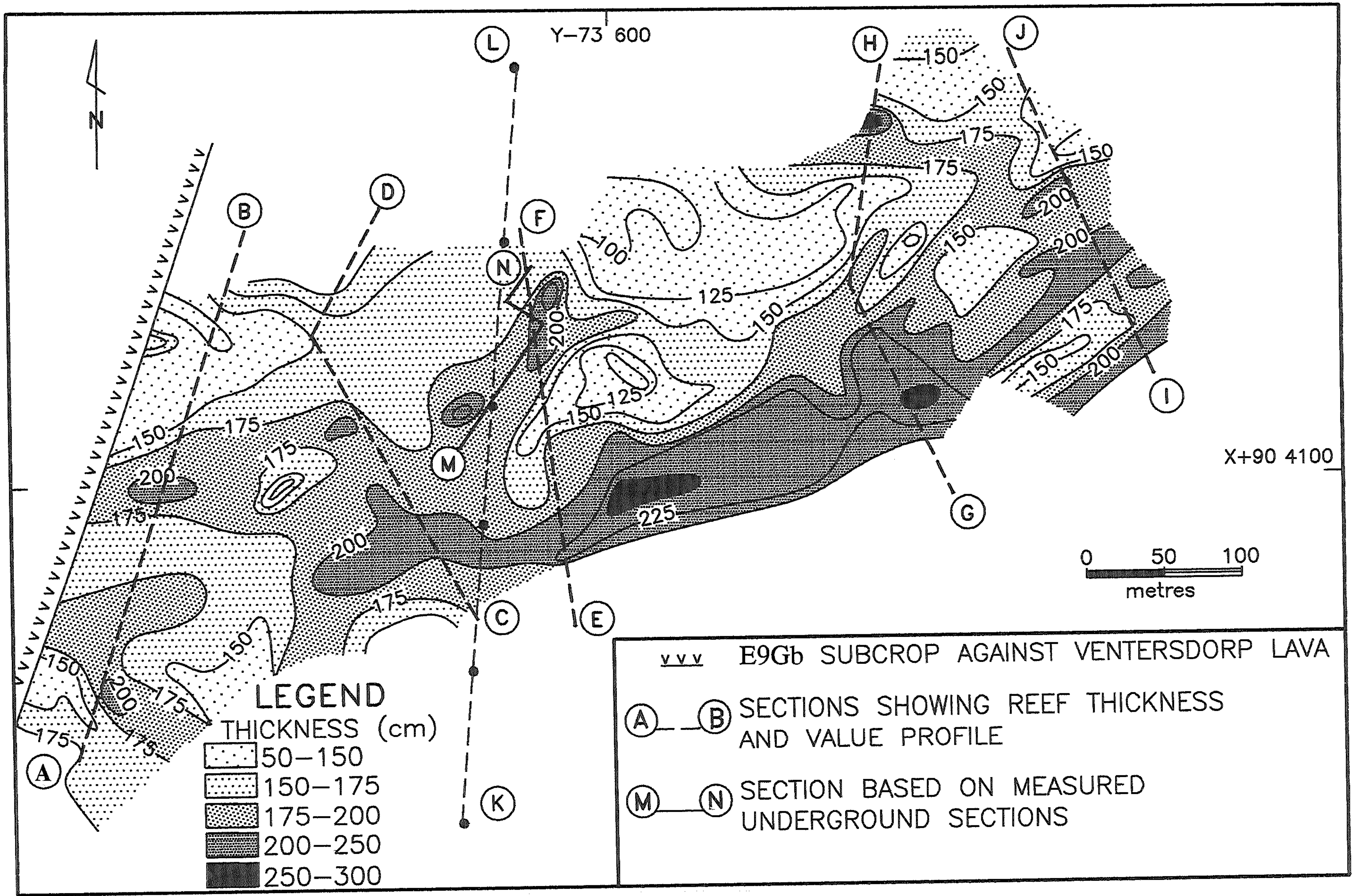

Figure 8: Plan showing E9Gb channel isopach.

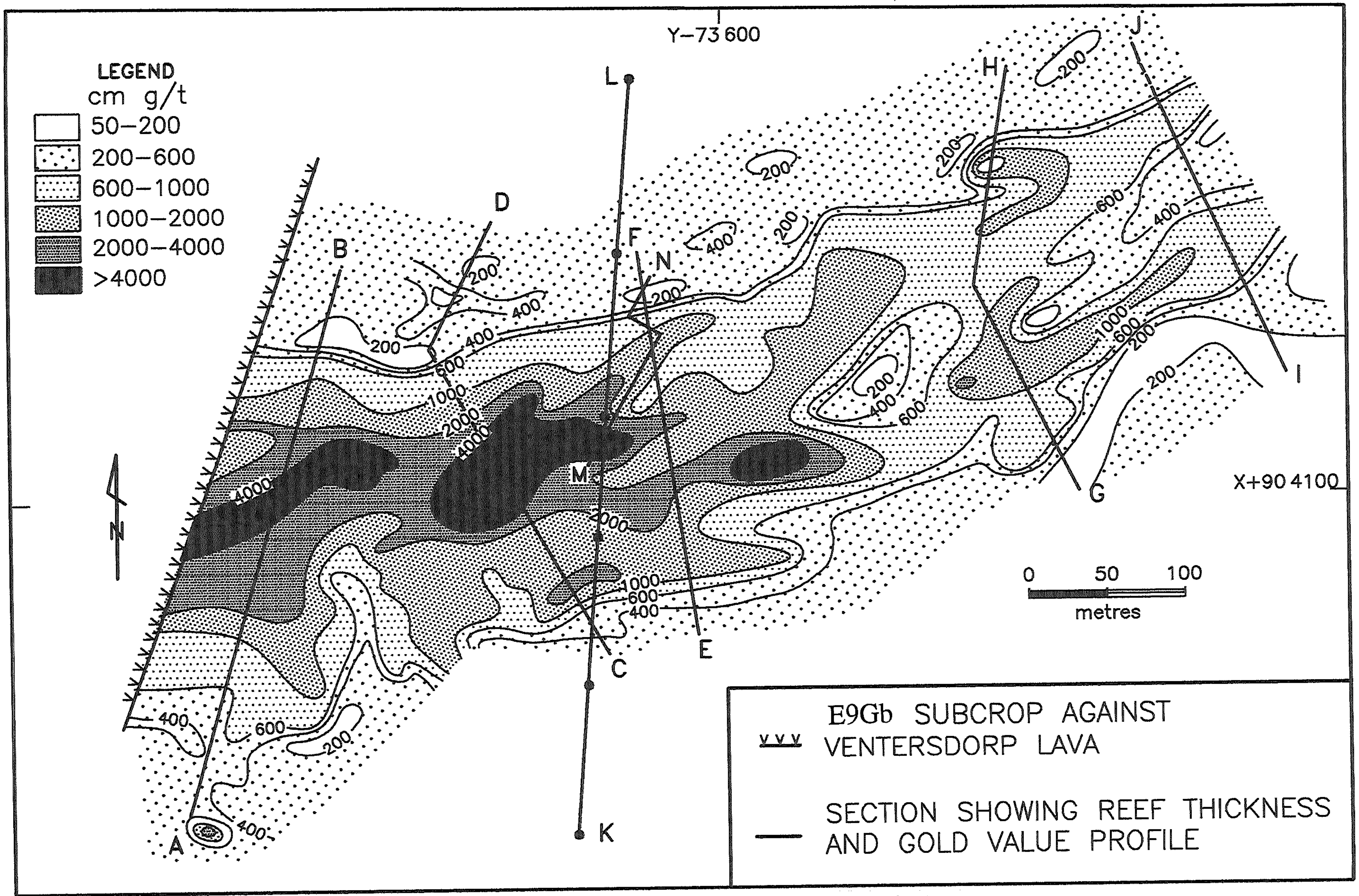

Figure 9: Plan showing E9Gb gold content distribution.

subcrop. To the east it breaks up into several tongues. Two of these tongues persist through to the far eastern border of the area with gold content generally declining from west to east (Fig.9).

The gold content in most areas declines sharply along the northern and southern flanks of the main ore shoot with values decreasing particularly rapidly beyond the 600 cm g/t contour. The 400 cm g/t contour roughly demarcates the economically viable cut off. Values up to 100m beyond the 400 cm.g/t contour are generally in the range 200-400cm g/t with numerous sectors below 200cm g/t and with grades becoming even lower beyond the limits of the data portrayed (Fig. 9). A low-grade sector also divides the two distal tongues of the ore shoot. The average horizontal extent of the E9Gb ore shoot is just over 200m while its length is of the order of 800m.

Relationship Between Reef Thickness and Gold Content

In order to analyse the relationship between channel thickness and gold content, several maps and sections were compiled. Simplified representations of channel thickness and gold content which are portrayed on Figures 8 and 9, are depicted on Figure 10. This figure also illustrates the superimposition of the southern zone of thick reef (>200 cm) and the northern zones of thinner reef (<150 cm) with the area of gold content (72 000 cm.g/t between the two. The relationship between gold value and reef thickness axes are shown in Figure 11 while in Figure 12 a series of sections depict the above relationships.

Several subparallel branches constitute the main ore shoot in the higher-grade western sector and two main, parallel, lower gold value axes with minor branches extend to the east (Fig.11). It is evident that the high value western "core" of the E9Gb ore shoot (>2000 cm.g/t, Fig.10) correlates very closely with the intermediate thickness channel "shoulder". Several high value (>2000 cm.g/t) and eastward bifurcating axes are also largely confined to this area (Fig.11). The correlation between high gold value and the channel "shoulder" is particularly clear on Section C-D of Figure 12. In the extreme western part of the ore shoot the main southern channel axis (a) appears to swing northward to correlate with the axis of highest gold content as seen on section A-B of Figure 12. Local scours in the high grade western "shoulder" have resulted in elongate patches of thicker reef containing very high gold values (Figs. 8 and 10). A patch of thinner reef to the east of the "shoulder" and to the east of line E-F, appears to have formed as the result of a substantial footwall barrier to the strong eastward continuation of the major, high grade ore shoot. The high gold value shoot fingers out eastwards from here (Figs. 8 and 10) except for the main southern channel axis (a) and ore shoot (A), as well as a northern gold content axis (B) (Figs. 11 and 12).

The relationship between the main southern channel axis (a) and the main southern ore shoot axis (A) is a close one, the two always being within 40m of each other (Figs. 10, 11 and 12). The main southern axis (A) occurs largely on the northern side of the channel axis (a) as seen on sections C-D through to I-J (Figs. 11 & 12). In the case of the northern subsidiary channel axis (b), best gold values (B) are largely associated with local thicker reef areas in the western sector (Fig. 11). In the central and eastern sectors of the area, the main northern shoot (B) is more directly correlated with local thinner reef areas occurring in the

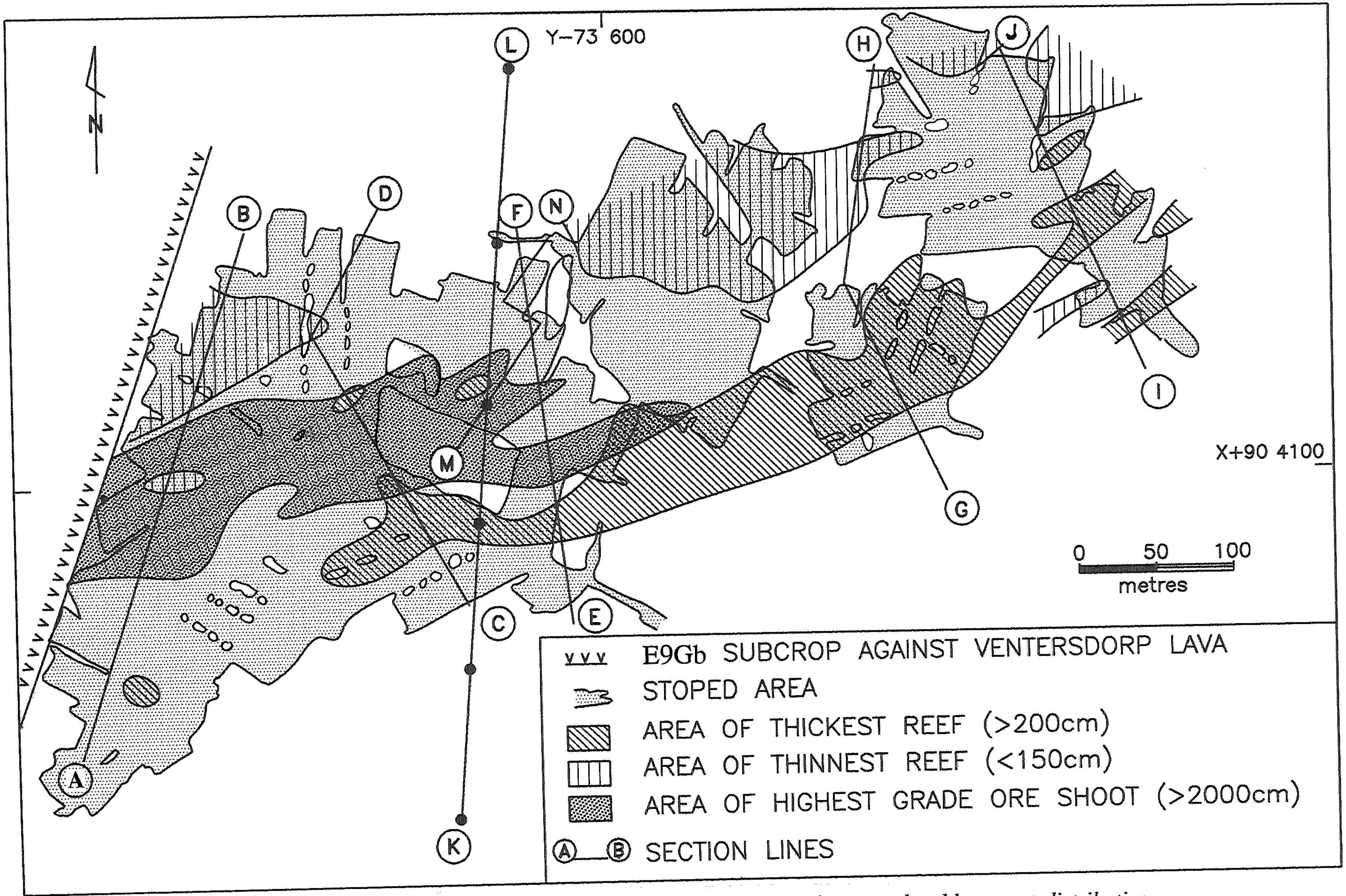

Figure 10: Plan showing relationship between channel thickness and gold content distribution.

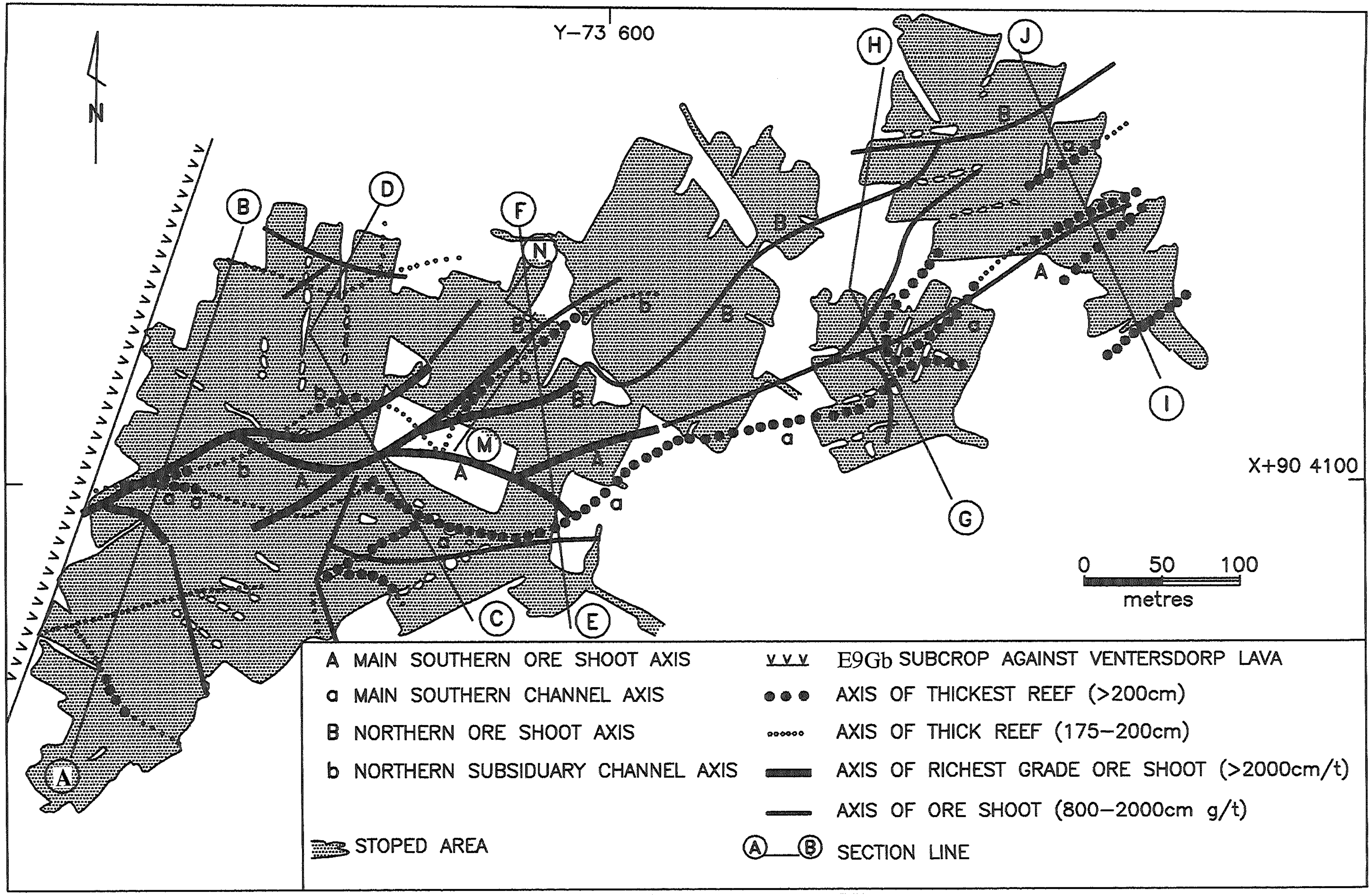

Figure 11: Plan showing relationship between channel thickness axes and gold content axes.

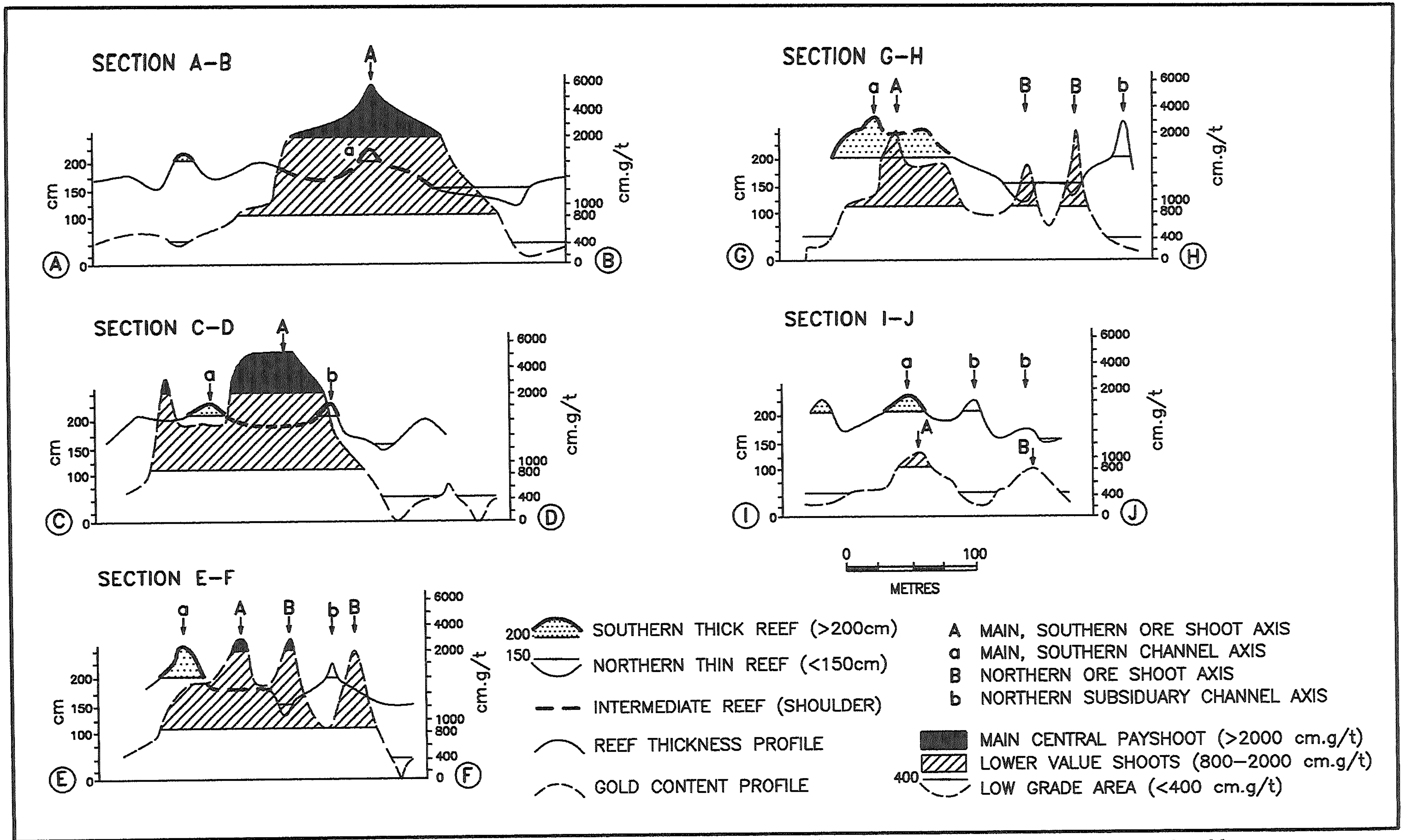

Figure 12: Profiles I-J to E-F across the E9Gb, the ore shoot depicting the relationship between reef thickness and gold content.

vicinity of a thicker reef axis (Figs. 11 and 12, sections E-F through to I-J).

Channel Profiles

Sedimentology

The sedimentology of the E9Gb placer is depicted in two north-south sections. The first is a regional section K-L constructed roughly at right angles to the trend of the E9Gb ore shoot and based on underground borehole information (Fig.13 - locality Fig.8). The second section is constructed from mapped profiles underground within the area of stoping (Section M-N, Fig.14 - locality Figs. 8-11). From the data it is evident that the E9Gb conglomerate consists of four distinguishable units, two conglomeratic and two quartzitic which can be identified in both sections.

i) Basal Conglomerate Unit

This unit forms the base of the E9Gb reef package and is laterally extensive. It is a 50-150cm thick oligomictic conglomerate consisting of well packed, medium-to-large pebbles, and containing abundant buckshot pyrite mineralization within the ore shoot of the E9Gb channel. The unit is thickest in the core of the ore shoot as is shown by sections 1 to 3 of Figure 13 and thins towards the edge. This thinning is accompanied by a smaller pebble size and less well developed packing and mineralization. Traced further, beyond the limit of the ore shoot, the basal conglomerate maintains a thickness of between 60cm and 120cm (Fig.13). This is a result of increasingly prominent quartzite partings that are developed within the unit. In such areas the conglomerate is poorly packed, contains mostly small pebbles, and has very little pyrite mineralization.

This unit can be identified far beyond the mineralized ore shoot across much of Cooke Section, but as noted, its characteristics are significantly different to its characteristics in the central part of the ore shoot.

ii) Intercalated Quartzite

A fine-grained siliceous quartzite unit occurs sporadically across the area and separates the two major conglomerate units. The unit has a definite tendency to be thicker away from the well-mineralized ore shoot (Figs. 13 and 14). The intercalated quartzite contains very little mineralization.

iii) Upper Conglomerate Unit

This conglomerate unit is matrix supported, contains small, subrounded pebbles and numerous quartzitic partings. In the core of the ore shoot it forms a minor part of the total reef package, averaging about 40cm in thickness (Figs.13 and 14). In such areas minor mineralization occurs within the unit. The upper conglomerate unit thickens up to 90cm towards the edge of the E9Gb ore shoot on section 10 of Figure

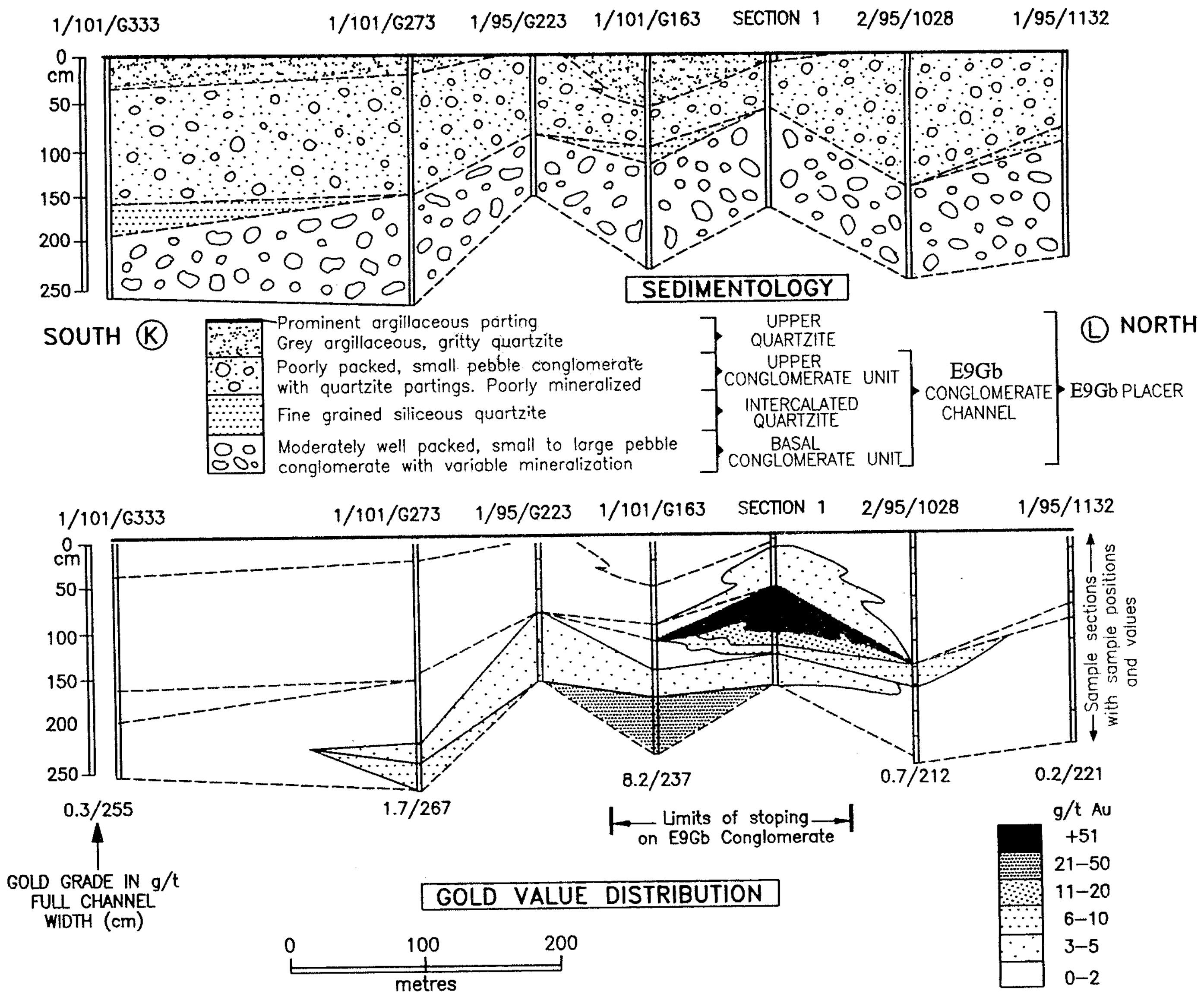

Figure 13: South/north regional section K-L across the E9Gb ore shoot based on underground boreholes.

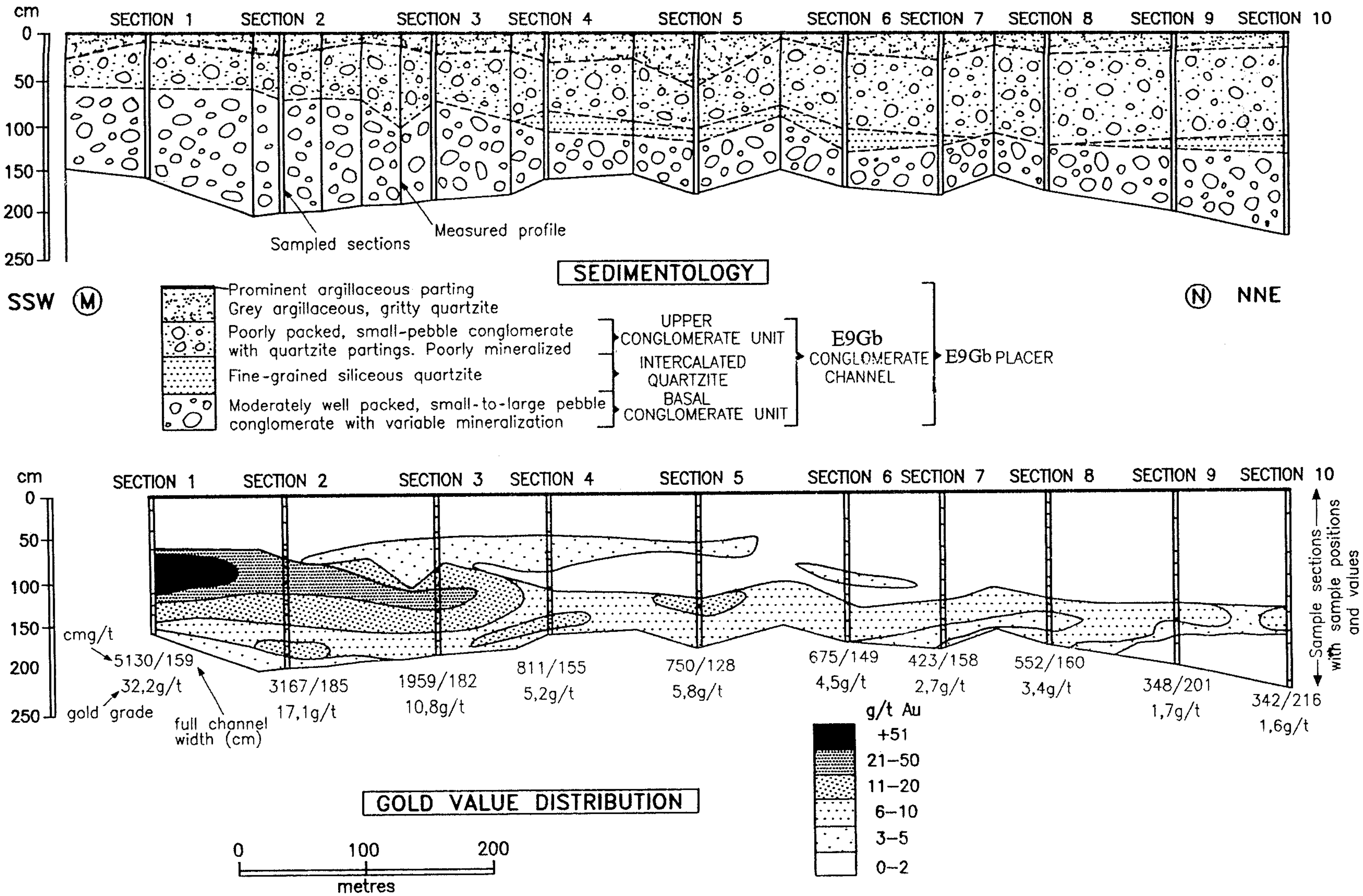

Figure 14: South/north sedimentological and gold value distribution profile M-N across the E9Gb ore shoot based on underground sections.

14. Beyond the ore shoot the upper conglomerate forms the dominant unit within the E9Gb package averaging between 90cm and 130cm (Figs. 13 and 14). Outside the ore shoot, this unit contains very little mineralization. The lateral variations of the unit pertain more to thickness than to the actual characteristics of the conglomerate.

iv) Gritty Quartzite

A grey, argillaceous, gritty quartzite is developed as a drape on top of the upper conglomerate unit. The thickness varies from 0cm to 60cm and appears to bear no relationship to the position of the ore shoot (Figs. 13 & 14). The top of this unit is overlain by a very well developed micaceous parting which can be traced over an extensive area. It forms a natural hanging wall parting plane during mining operations.

Value Distribution

Interpolated gold value profiles (g/t) are depicted below the sedimentological profiles in Figures 13 and 14. Vertical channel sampling was undertaken as close as possible to the measured vertical section lines 1 to 10 in Figure 14. The ten profiles within the E9Gb ore shoot span a range from the centre of the ore shoot to its contact and beyond (Figs. 7, 9 and 14).

It is evident that significant gold mineralization is concentrated within the basal E9Gb conglomerate unit and decreases steadily from section 1 to 10. Within the axial part of the ore shoot (sections 1 to 3) the best concentration of gold is in the upper part of the basal conglomerate (Fig.14).

Figure 15 shows the average cm.g/t per sampled section of Figure 14 and highlights the systematic drop in gold content largely of the basal mineralized conglomerate from 5000 cm.g/t in the centre of the shoot to 300 cm.g/t at the northern edge some 90m away. The drop in gold values from west to east is more gradational over a distance of 800m.

Conglomerate Packing Density

Measurements of packing density were undertaken for the basal and upper conglomerate units for sections 1 to 10 of profile M-N of Figure 14. This was accomplished by overlaying a 10cm by 10cm grid ($100cm^2$) on the conglomerate exposure and recording the number of grid intersection points covering pebbles. Figure 16 shows the variation in packing density in percentage for the basal and upper conglomerate units, for each section (Figure 14). A general decrease in packing density for both units is evident from sections 1 to 10 (Fig. 16). In the case of the mineralized basal conglomerate, the overall packing density is higher and ranges from 65% in the centre of the channel (section 1) to 21% at the edge of the ore shoot (section 10, Fig.16). In the case of the upper conglomerate, packing density ranges from 49% for section 1 to 12% for section 10. Where the upper conglomerate contains minor mineralization in the axial part of the main ore shoot, the packing density is 49%. Outside of this the packing density is evenly low at about 18% (Fig.16).

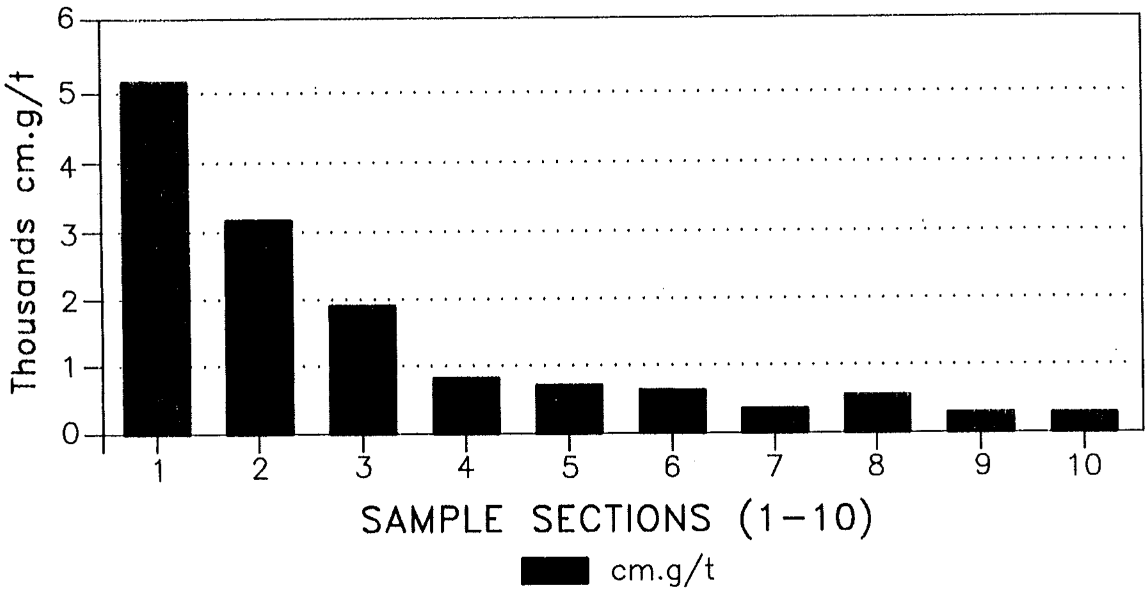

Figure 15: Cm.g/t profile for section lines 1 to 10 of section M-N.

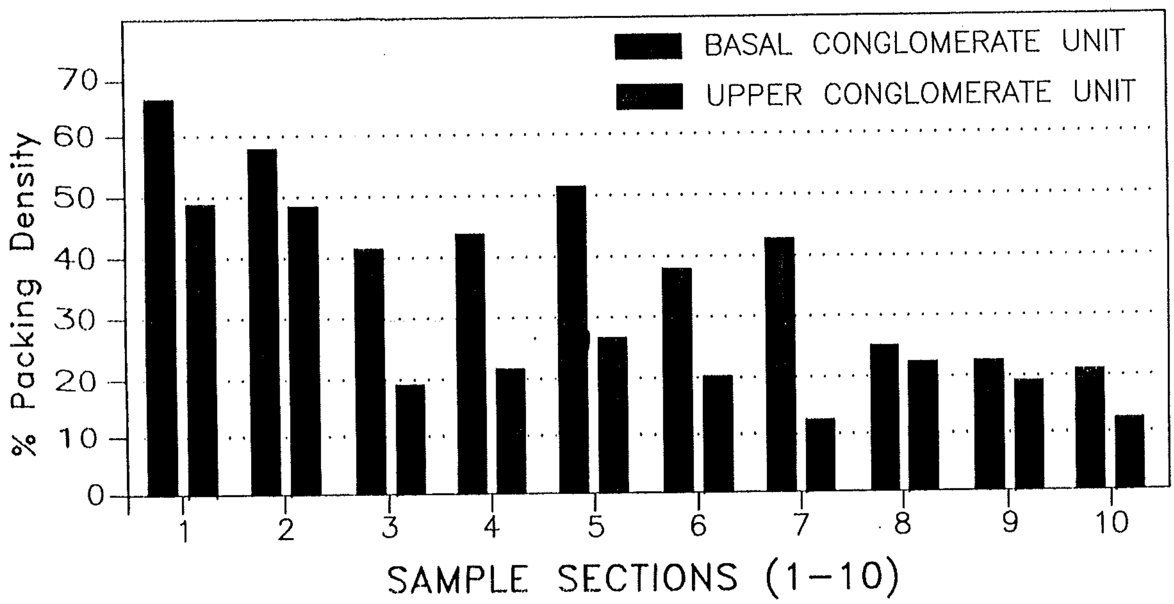

Figure 16: Packing densities for the basal and upper conglomerates along profile M-N.

In the basal conglomerate unit a clear relationship exists between packing density and grade with a systematic decrease in packing density as the grade decreases from section 1 to 10 of section M-N (Fig.14). This is portrayed in Figure 17 where packing density percentage per section is plotted against the natural log of the grams per ton gold value of the basal conglomerate. The correlation coefficient (r) for this relationship is 0,92 (Fig.17). Measurements were taken as close as possible to the positions of the sampling profiles to ensure that two variables were comparable. The result shows that measurable aspects of the conglomerate, specifically packing density in this case (as well as pyrite mineralization) can give a good indication of gold grade. To establish a consistent relationship to be used as a predictive tool, however, more extensive packing measurements would have to be made and related to sampled gold values.

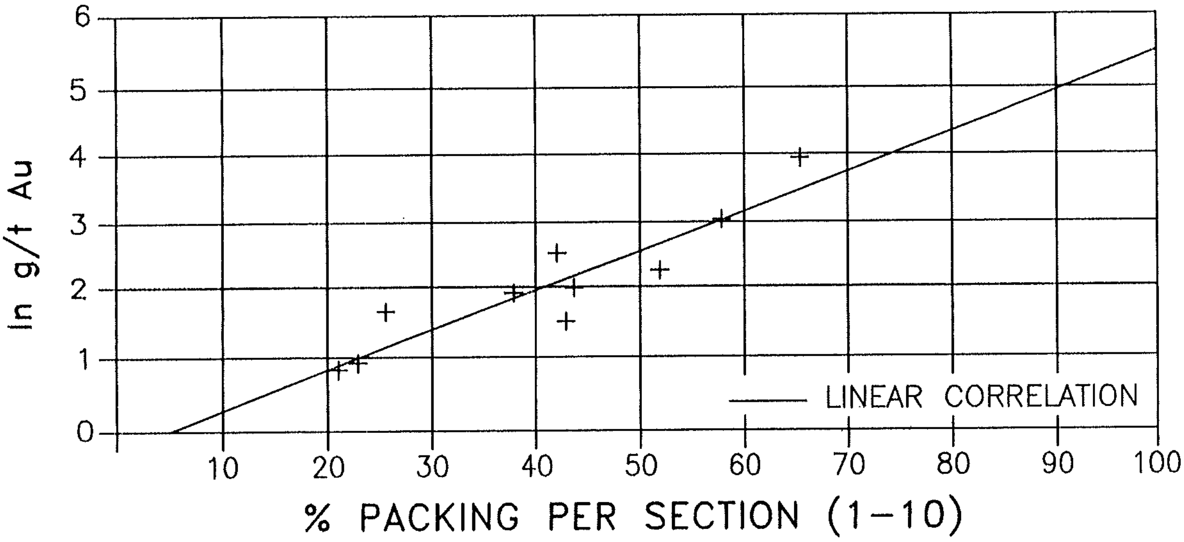

Figure 17: Percentage packing vs Au (g/t) for profile M-N in well-mineralized and poorly mineralized areas.

Statistical Distribution of Channel Thickness and Gold Content Data

Raw sampling data from the E9Gb conglomerate were used to determine the statistical characteristic of the ore body. The thickness of the total conglomerate package is shown on a histogram plot (Fig. 18) and is based on 1841 measured regularized data points. The statistical distribution is very close to the normal and has a mean of 169,5 and a standard deviation of 43,5.

The cm.g/t histogram distribution is shown in Figure 19 and is based on 1798 sampled points. The cm.g/t shows a lognormal distribution at a 0,05 level of significance. The mean value is 1131 cm.g/t and standard deviation is 46,6.

The above brings out a statistical feature of most Witwatersrand reefs, viz. that reef thickness values are normally distributed while the contained gold values are log normally distributed.

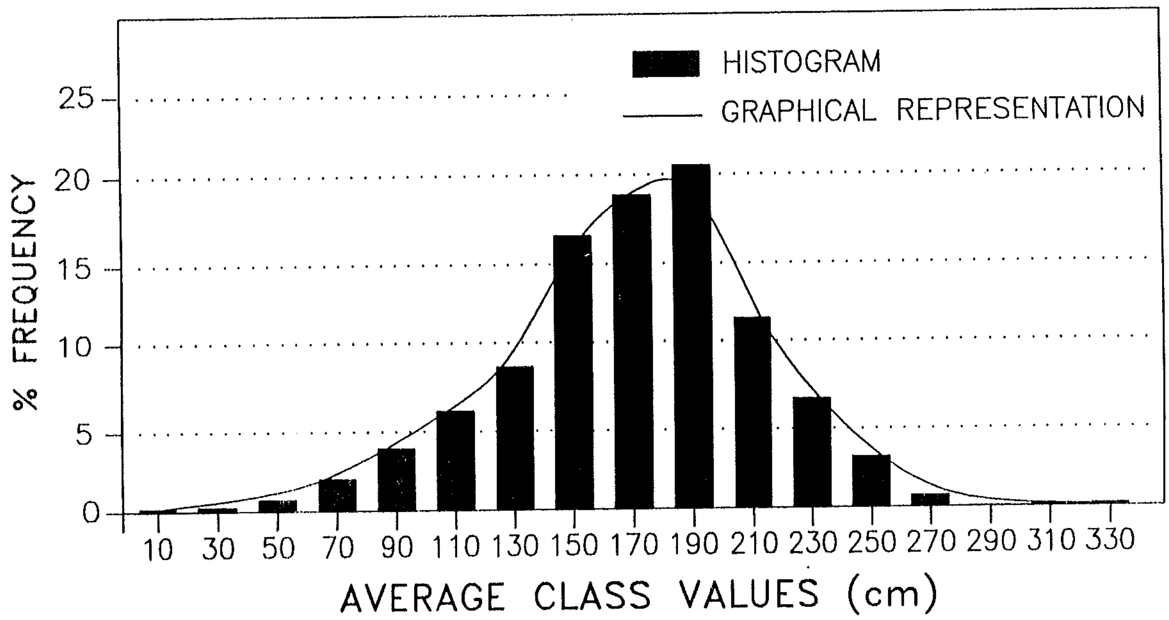

Figure 18: E9Gb histogram of channel thickness (cm).

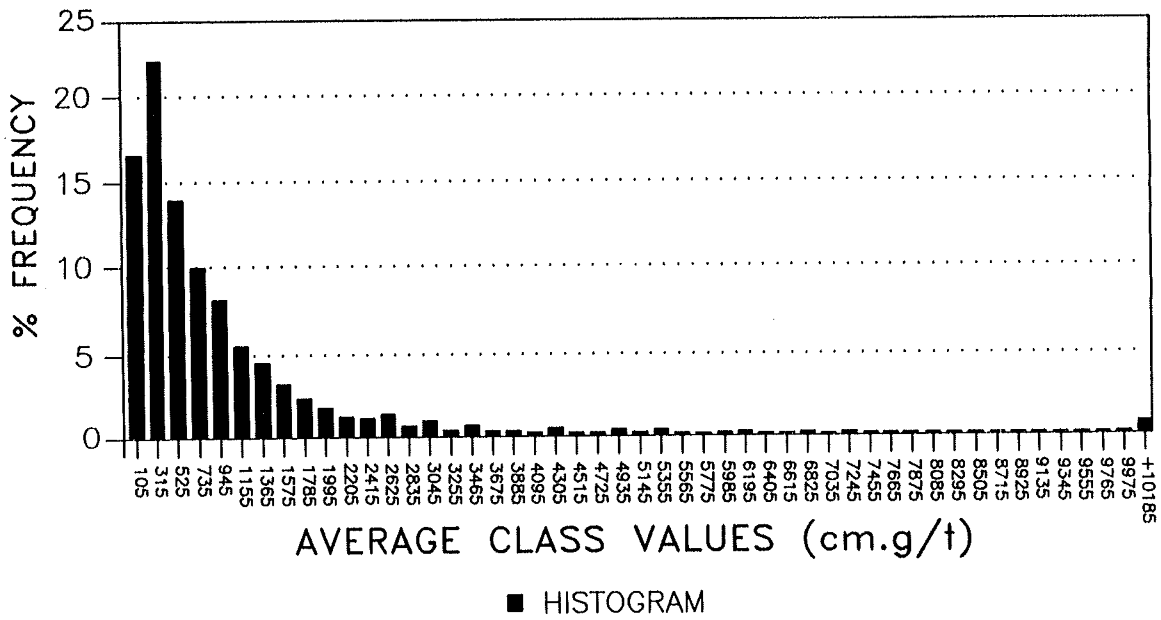

Figure 19: E9Gb histogram (cm.g/t) of gold content.

CONCLUSIONS

The aim of this study is to determine the characteristics and portray the anatomy of a typical Witwatersrand ore shoot that has been exposed and mined in its entirety. A close correlation has been shown to exist between reef thickness and reef characteristics and gold value distribution.

The major controlling feature of the ore shoot is the presence of a thick, east-northeast-trending conglomerate zone developed along the southern flank of the area and interpreted as a channel. Gold values are associated with this channel and with the highest degree of pyrite mineralization in the western part of the ore shoot, being located on the shoulder of the channel in an intermediate zone between thicker and thinner channelized conglomerate. The eastern part of the ore shoot shows a fingering effect as the grades slowly drop off in the east- northeasterly direction of transport. Grades drop off sharply in the north-south direction to the flanks of the channel. As with ore shoots in the composite and E8 reefs at Cooke Section, the characteristics described above are consistent with an ore shoot with its proximal region to the west and distal region to the east.

In a study of the Leader Reef in the Welkom Goldfield, Smith and Minter (1979) found that higher gold concentrations were evident on the edge of channels. They suggested that this was due to the migration of bank-hugger bars towards the edge of the channel. Convergent flow becomes increasingly restricted by a growing bar margin, resulting in reworking of the channel bottom sediments and so concentrating heavy minerals.

The relationships described above are also very similar to those noted for the UEIA/E9Gd composite and E8 reefs of Cooke Section, the Beatrix Reef at H.J. Joel Gold Mine and the Kimberley Reef ore shoots at Doornkop Section (Viljoen, 1990, 1994; Young and Viljoen, 1994). The results are also consistent with the determination models which use hydraulic conditions prevailing during floor formation (Nomi and James, 1987).

The highest gold grades are confined to the top of the basal conglomerate of the Composite reef channel. A relationship exists between the thickness of the basal conglomerate and gold content with local features within the shoulder appearing to have controlled the extent of mineralization within this zone.

A linear relationship exists between the higher packing density of the basal conglomerate and the high gold concentration within that unit. As with Witwatersrand conglomerate reefs elsewhere the channel width measurements have a normal distribution, while the gold content of sampled data within the E9Gb stoped area have a lognormal distribution.

The E9Gb reef has been extensively sampled during normal exploration drilling from footwall development and there does not appear to be any further potential for mining the E9Gb conglomerate on Cooke 1.

From the study the importance of geologically controlled sampling has become evident. With available sampling information only the thickness of the whole channel and its value could be contoured. With geologically controlled sampling the thickness variation and value distribution of the economically important basal conglomerate could have been assessed independently and allowed for a more selective mining operation.

Packing density shows a very good correlation with gold content and it is recommended that this feature be considered in the appraisal of the viability of Middle Elsburg Reefs at Cooke Section. The first stage of any study should firstly identify the facies within the mining horizon. Relationships between gold content within facies, and any measurable sedimentological features can then be explored.

With the need for more meticulous mining, it is strongly recommended that the approach of studying and analyzing the sedimentological anatomy of a reef and its gold value distribution be undertaken as a routine procedure on all Witwatersrand gold mines.

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