THE STRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER JOHANNESBURG AND TURFFONTEIN SUBGROUPS IN THE SOUTHWESTERN PORTION OF THE WELKOM GOLDFIELD

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ABSTRACT

This study documents and interprets the stratigraphy and sedimentary environments of the upper Johannesburg and Turffontein Subgroups of the Witwatersrand Supergroup on St. Helena Gold Mine. These data are used to construct a tectono-stratigraphic framework and determine the general distribution of economic mineralization.

Data from borehole cores and underground exposures are utilized to compile cross-sections and isopach maps of formations and reefs. Using this information facies arrangements and associations as well as evidence of syn-sedimentary tectonics are determined.

The Basal Reef constitutes the basal unit of the Harmony Formation and both the Basal- and Steyn facies of the Basal Reef are present on St. Helena Gold Mine. In the overlying Dagbreek Formation the Alma and Bedelia facies of the Leader Reef occur on St. Helena Gold Mine. The Aandenk Channel on St. Helena Gold Mine is a multi-stage erosive scour-and-fill channelized feature, the orientation of which is an indication of a tectonic control. The Eldorado Formation coarsens-upward on St. Helena Gold Mine and also contains lateral facies variations.

Deposition of conglomerates and arenites of the Harmony, Dagbreek, Spes Bona and Aandenk Formations occurred on the distal portion of a braid-plain in unconfined channels. Swash-stratification during localised transgressions resulted in the deposition of horizontal laminations in the Top of Reef quartzite. Pebbly arenites, massive wackes and diamictites resulted from mass-emplacement by gravity-flow deposition. Deposition of argillites and diamictites in the Aandenk Channel

occurred subaqueously following a major transgression. Deposition of the Eldorado Formation occurred on an alluvial fan which prograded as a fan delta into a marine body of water.

Angular unconformities along the western margin of the Welkom Goldfield and variations in the thickness of sediments indicate that tectonic uplift occurred during sedimentation. The intensity of tectonic activity affecting the sedimentation increased with time and the locus of this tectonic activity moved progressively inwards towards the basin centre.

Unconformity-bound oligomict conglomerates contain the majority of gold mineralization on St. Helena Gold Mine. Increased gold grades are related to occurrences of carbon and rounded pyrite in the conglomerate matrix. Further gold mineralization in the vicinity of St. Helena Gold Mine may occur to the west of the present-day basin margin where the Basal Reef, Leader Reef and "B" Reef may be preserved.

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

ABailey

20th day of March 1991

To my wife, Jean

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1 INTRODUCTION

1.1 PREAMBLE

Since the discovery in 1886 of gold in the Witwatersrand Supergroup the origin of this unique sedimentary sequence, and the abundant gold mineralisation contained therein, has been debated. Depositional environments proposed include rivers, lakes oceans and even glaciers, although opinion in the current literature generally favours fluvial deposition of the sediments. The gold mineralisation has traditionally been viewed as having either a sedimentary or a hydrothermal origin and current mineralisation models vary from a "modified placer" theory to an epigenetic origin of the gold.

The discovery of the Welkom Goldfield in the 1940's emphasised the great extent and lateral continuity of the sediments and mineralisation of the Witwatersrand Supergroup. Research carried out in the Welkom Goldfield to date has dealt primarily with the Basal and Leader Reefs and to a lessor extent with the overlying auriferous reefs. Although specific formations have been studied, no studies have encompassed a wide interval of the stratigraphy. For this reason a sedimentological and stratigraphic investigation was undertaken of the sedimentary sequence from the base of the Harmony Formation to the top of the Eldorado Formation.

1.2 LOCATION

This study was undertaken in the Welkom Goldfield primarily on St. Helena Gold Mine and to a lessor extent on Unisel Gold Mine (Fig. 1). The stratigraphy studied

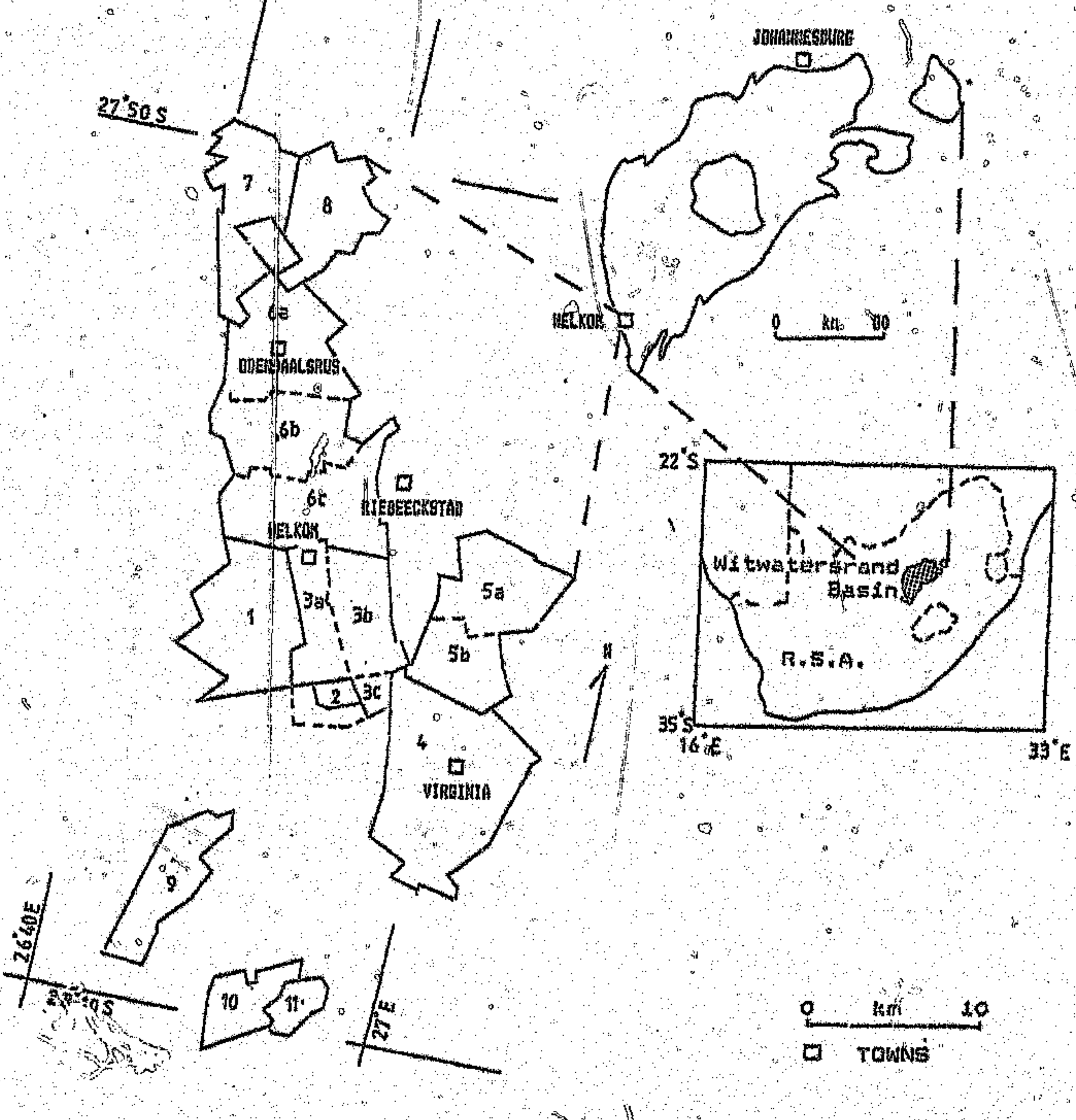


Figure 1 : Location of the Welkom Goldfield in relation to the Witwatersrand Basin. Mines are 1) St. Helena, 2) Unisel, 3) Freegold South, 4) Harmony, 5) Freegold (Saaiplaats and Erfdeel), 6) Freegold North, 7) Loraine, 8) Jeanette, 9) Beisa (Oryx), 10) Beatrix, 11) Joel.

encompasses the upper portion of the Johannesburg Subgroup and the Turffontein Subgroup which are together composed of the Harmony, Dagbreek, Spes Bona, Aanderk and Eldorado Formations. These formations contain the Basal, Middle, Leader, "B", Big Pebble Marker, "A", and VS 5 Reefs. On both St. Helena and Unisel Gold Mines the Basal Reef is the principle producer of ore and the remaining 15 percent of the ore mined is derived from the Leader Reef.

1.3 AIMS

The aim of this study is to document and interpret the stratigraphy and sedimentary environments, from the base of the Harmony Formation in the Johannesburg Subgroup to the top of the Turffontein Subgroup. Within this framework there are several secondary objectives;

a) To reconstruct a tectono-stratigraphic framework for the upper Johannesburg and Turffontein Subgroups. This reconstruction includes determining the extent to which syn-sedimentary tectonics have influenced sedimentation.

b) To determine depositional environments and to reconstruct the palaeogeography of the upper Johannesburg and Turffontein Subgroups.

c) To determine the general distribution of gold, uranium, pyrite and carbon with respect to the sedimentary facies in specific reefs.

1.4 DATA

Data for this study were collected over a twelve month period. The logs of more than 10 000 short underground boreholes drilled on St. Helena Gold Mine were used together with 20 surface boreholes which contain representative intersections of the stratigraphy.

In addition, underground observations were made at 60 localities on both St. Helena and Unisel Gold Mines. Observations were made in Basal and Leader Reef stopes and at other intersections of the Harmony, Dagbreek, Spes Bona, Aandenk and Eldorado Formations. Underground studies of the Basal and Leader Reefs were limited to the area of underground development (Fig. 2).

The thickness data of formations and reefs were compiled using an IBM-compatible personal computer. Computer generated isopachs of corrected data were then plotted (Appendix 1), using standard base plans (Figs. 3 and 4). Cross-sections of the stratigraphy were constructed from borehole logs, underground sections and isopach maps. Borehole logs were compiled using an IBM mainframe computer logging programme and the logs of boreholes with representative intersections of the stratigraphy have been plotted (Appendix 2). Depositional environments have been constructed from vertical and lateral facies arrangements and associations. Cross-sections constructed from thickness information have been used to determine the amount and location of syn-sedimentary thickness anomalies present in the stratigraphy.

Fifty-four thin sections, representing the entire stratigraphic interval studied, have also been examined together with hand specimens from both underground

Figure 2 : Plan of the underground development on St. Helena Gold Mine (development on the Basal Reef only).

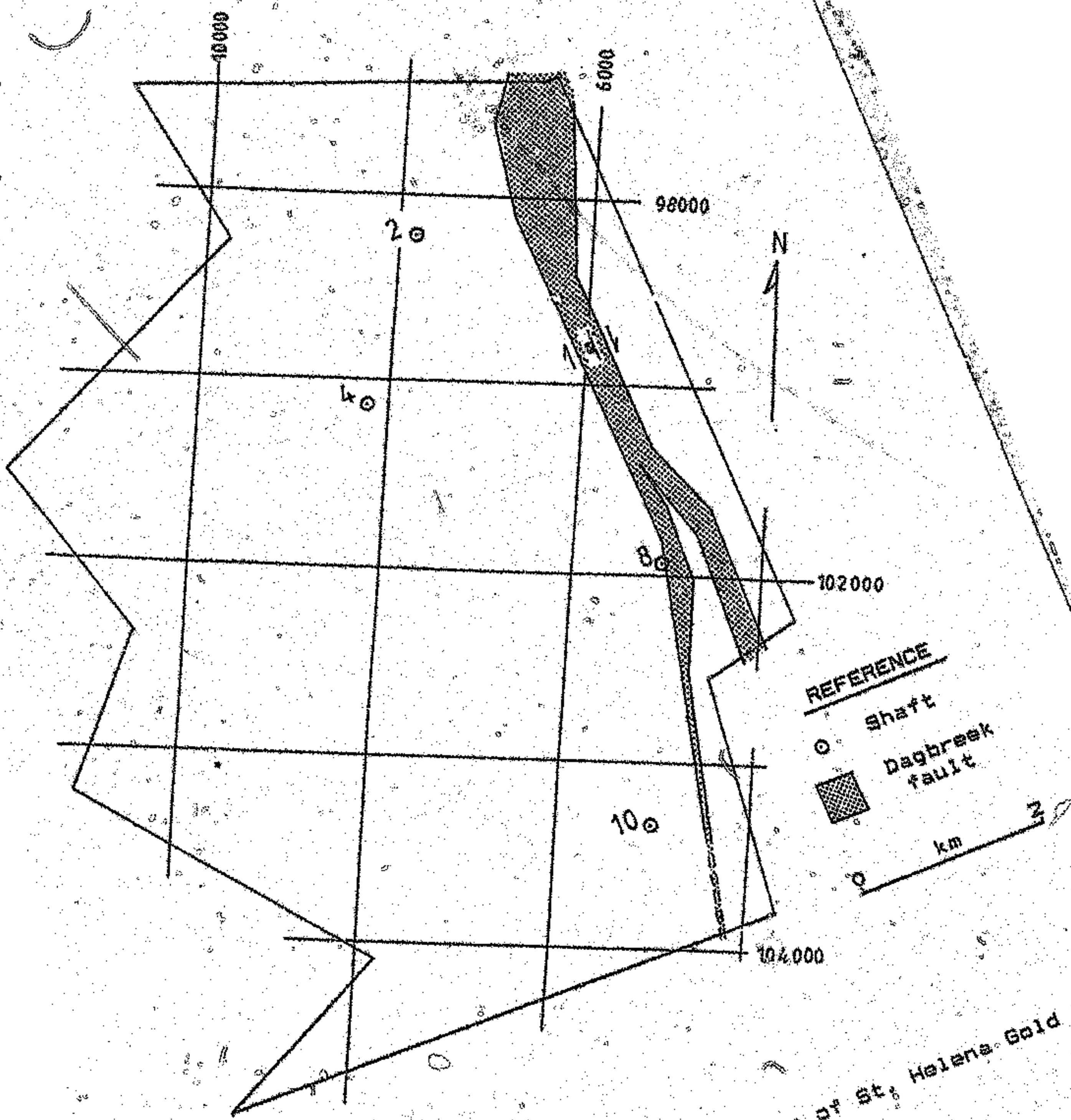


Figure 3 : Base plan and grid reference of St. Helena Gold Mine.

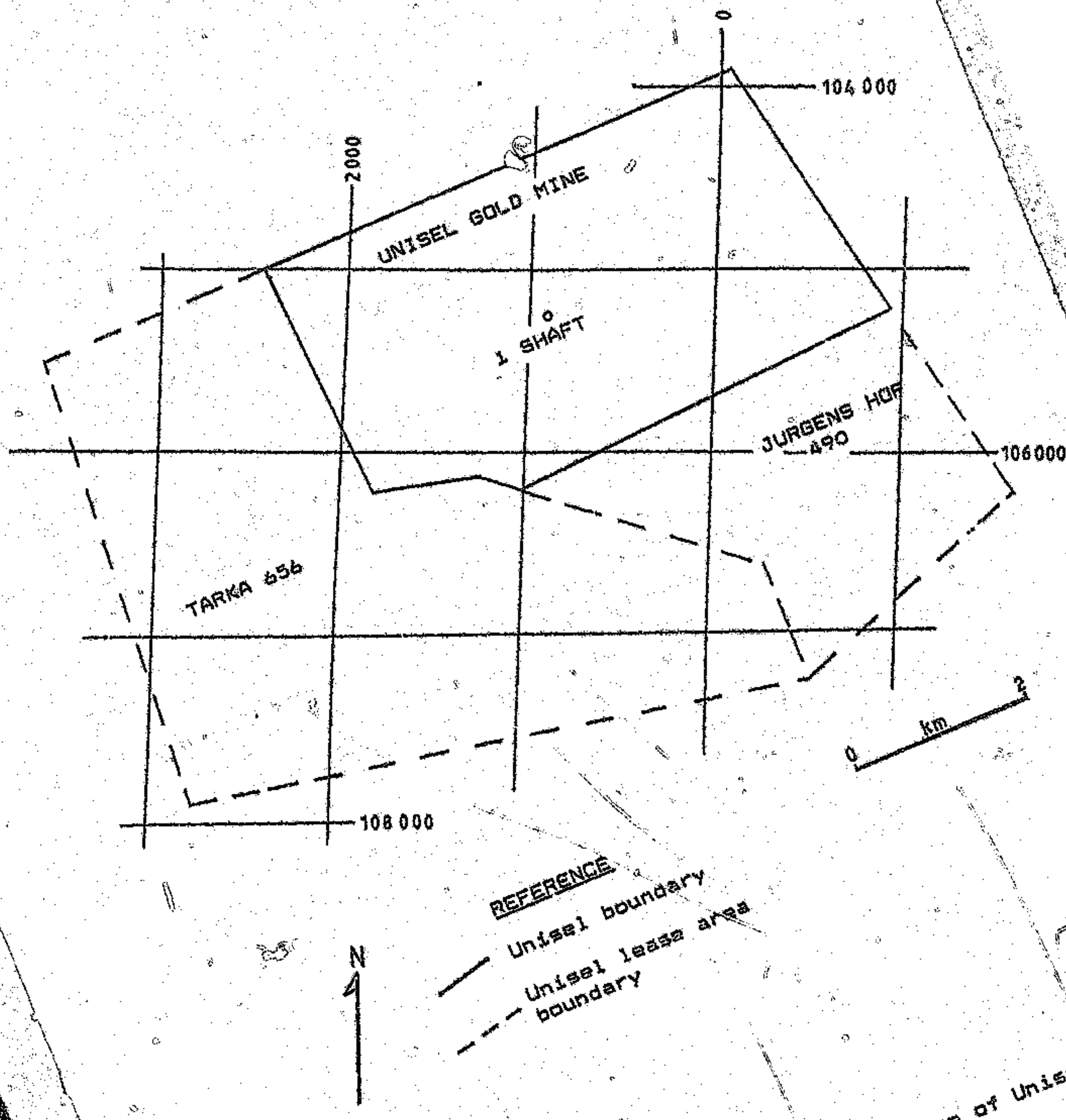


Figure 4 : Base plan and grid reference of Unisel Gold Mine and its lease areas.

localities and boreholes. Additional mineralogical data were obtained from XRD and XRF analyses.

1.5 PREVIOUS WORK

1.5.1 The Welkom Goldfield

The first published studies of a specific portion of the Welkom Goldfield were undertaken by Winter (1957, 1964a), who studied the geology of the mines in the Virginia area. Winter (1957, 1964a) identified disconformities and concluded that most reefs were formed in a neritic environment associated with marginal unconformities and disconformities. Winter (1964b) concluded that subsidence due to folding occurred during Witwatersrand depositional times. Minter et al. (1986) summarised the general geology of the Welkom Goldfield and concluded that eight major fluvial-fan formations were deposited in response to local folding and that the fans were not affected by the major faulting in the Welkom Goldfield.

In the first sedimentological study of the Welkom Goldfield Antrobus (1956) documented the Basal Reef as consisting of two principal facies, namely an oligomict Basal Placer and an overlying polymict Steyn Placer. Sims (1969) studied the detailed sedimentology of the main auriferous conglomerates of President Brand and President Steyn Gold Mines, concluding that deposition occurred with a fluvial system entering a land-locked sea. Kingsley (1984) proposed a detailed model for the deposition of the Leader Reef and the overlying Doornkreek Formation, with deposition by a fan-delta. Kingsley (1987) was the first to publish a detailed model for the Eldorado Formation, proposing that the Eldorado Formation resulted from cyclic alluvial fan sedimentation and acknowledging that synsedimentary tectonics had occurred during deposition of the Eldorado Formation.

Very few structural studies of the Welkom Goldfield have been undertaken. Dell (1982) studied the Dagbreek fault on Western Holdings Limited Gold Mine. He concluded that the fault was a complex system which formed as a tear fault under a compressive stress regime, with later re-activation and vertical movement.

1.5.2 St. Helena and Unisel Gold Mines

The sedimentation and large-scale soft-sediment deformation features of the Middle Reefs on Unisel Gold Mines were documented by Ellis (1988). Reynolds (1986) concluded that two coalescing alluvial fans deposited the facies of the Leader Reef on St. Helena Gold Mine, with deposition of the northern fan from the west and deposition of the southern fan from the southwest. The chemical composition and the regionally persistent mineralogy of the southwestern portion of the Welkom Goldfield was documented by Law et al. (1988a, b, 1990) and Law (1990). Numerous Gencor unpublished internal bulletins dealing with the localised geology of St. Helena and Unisel Gold Mines have also been compiled (Appendix 3).

1.6 REGIONAL GEOLOGY

1.6.1 Introduction

The Witwatersrand Supergroup consists of a 5km thick arenaceous and argillaceous sedimentary sequence termed the West Rand Group and an overlying 3km thick arenaceous and conglomeratic sedimentary sequence termed the Central Rand Group. Deposition of this epi-continental sedimentary sequence took place between 3060Ma and 2700Ma (Armstrong et al., 1990), following deposition of the sedimentary and volcanic Dominion Reef Sequence on granites and greenstones of the Kaapvaal craton. Witwatersrand Supergroup sedimentation was followed by deposition of volcanics and sediments of the Ventersdorp Supergroup.

1.6.2 Structure

The Welkom Goldfield comprises the structurally preserved southwestern portion of the Witwatersrand basin which occurs as a north / south trending synform. The rocks of the Welkom Goldfield contain a complex tectonic history, with both syn- and post-depositional deformation recorded. The tectonic style of the Welkom Goldfield and that the northern portion of the Witwatersrand basin are [illegible]ably similar, with marginal monoclines and associated reverse faulting characterising both these areas during Central Rand Group depositional times (Myers et al., 1990). Faulting in the Welkom Goldfield is predominantly dextral oblique-slip with down-throw to the west.

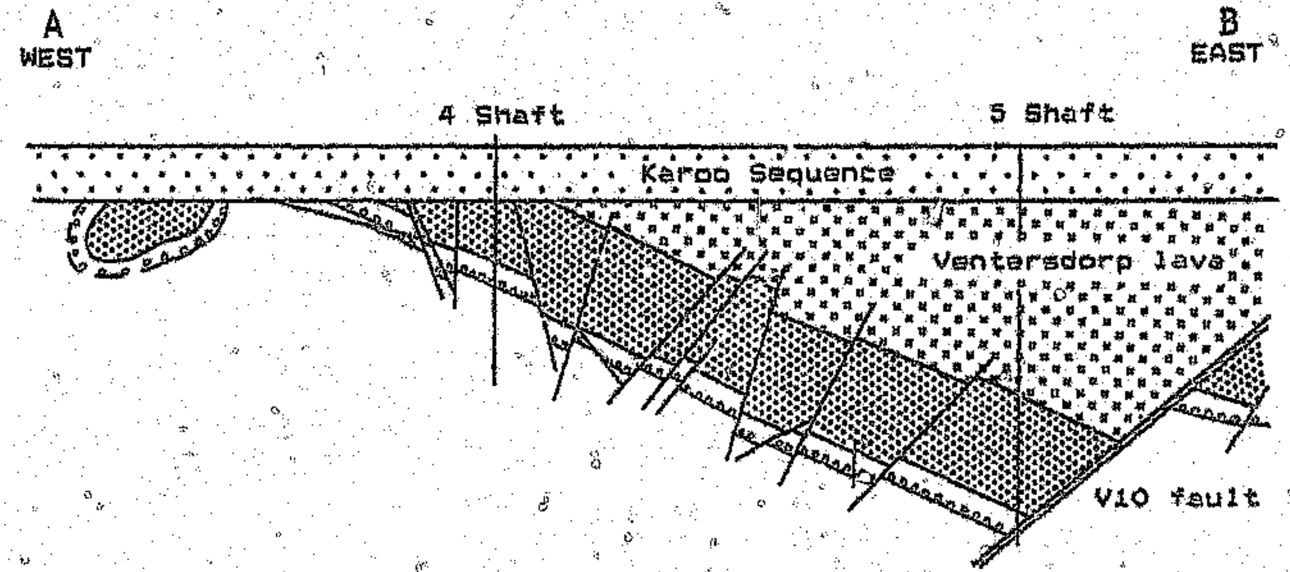
Three major phases of structural deformation are recorded in the Welkom Goldfield. The first phase of deformation occurred during Witwatersrand and pre-Ventersdorp times when compressional tectonics resulted in folding and faulting occurring on the western, southern and eastern margins of the Welkom Goldfield (Callow and Myers, 1986). The second phase of deformation began with the outpouring of the Klipriviersberg lava during extensional Ventersdorp-age tectonics. This Ventersdorp extensional tectonic regime also resulted in horst- and graben formation in the Welkom Goldfield (Buck, 1980). The formation of the Dagbreek, Arrarat, Stuirmanspan, Homestead, De Bron and Virginia fault systems occurred during and after this Ventersdorp extensional tectonic period. The third major phase of deformation is post-Ventersdorp in age, with re-activation the large oblique-slip fault systems with minor reverse faulting occurring (Minter et al., 1986).

The structure of St. Helena Gold Mine is dominated by a syncline and anticline as well as north / south striking normal and oblique-slip faults parallel to the western margin structure (Figs. 5 and 6). The dip of the Witwatersrand Supergroup on St. Helena Gold Mine is generally between 20° and 40° east. The largest fault is the oblique-slip Dagbreek Fault which has a downthrow to the west of approximately 450m in the northern portion of St. Helena Gold Mine and of 200 to 250m in the southern portion of the mine, where the fault splits. The dextral displacement changes along strike but the average movement is 1150m, calculated from thickness data of formations and conglomerates across the fault.

The Welkom Goldfield has undergone lower greenschist facies metamorphism with temperatures of 350°C ± 50°C and pressures of 1-2 kilobars recorded (Phillips, 1987a).

1.6.3 Pre-Witwatersrand stratigraphy

The basement to the east and west of the Witwatersrand Supergroup in the Welkom area consists of Archaean granitoids (Drennan et al., 1988). The Dominion Group disconformably overlies the basement granitoids below the Witwatersrand Supergroup to the north and west of Welkom



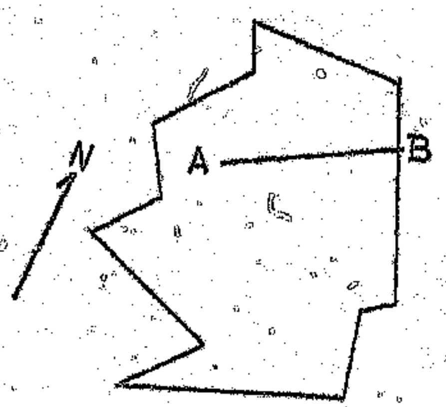


Figure 5 : West / east structural section A-B across St. Helena Gold Mine. Note the western syncline and the easterly dip.

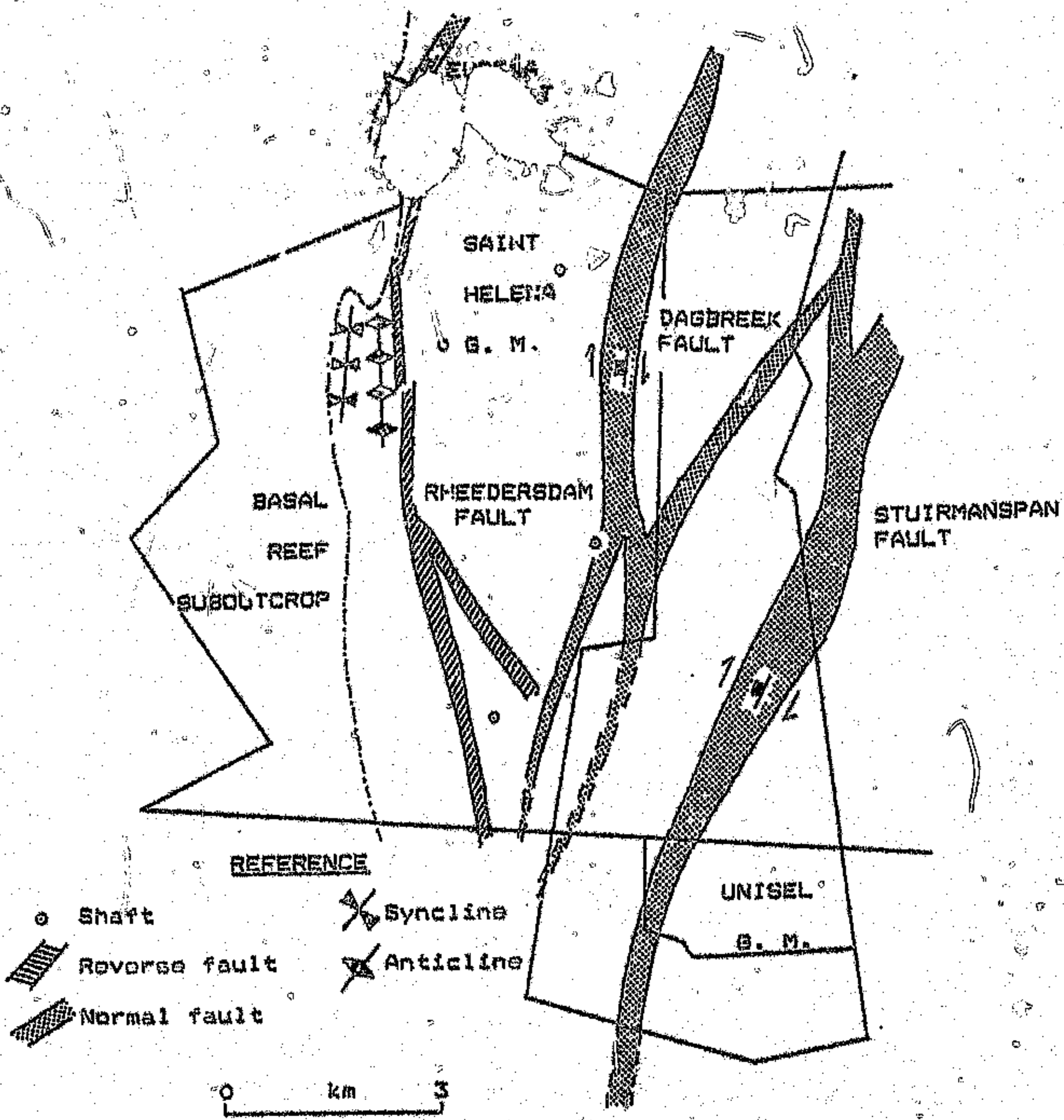


Figure 6 : Major structures of the south-western portion of the Welkom Goldfield. Also shown is the suboutcrop position of the Basal Reef along the western part of St. Helena Gold Mine. NOTE : The suboutcrop of the Basal Reef is a result of uplift and truncation by a north-south trending structure known as the "western margin structure".

and in the Klerksdorp area. The general stratigraphy of the study area is shown in Fig. 7.

1.6.4 Witwatersrand Supergroup

1.6.4.1 West Rand Group

In the western portion of St. Helena Gold Mine the West Rand Group has been intersected in 6 boreholes, all located to the west of the suboutcrop of the Witwatersrand Supergroup. The sediments intersected comprise arenaceous and argillaceous components of the Hospital Hill, Government and Jeppestown Subgroups which overlie the basement lithologies, although the basal contact of the West Rand Group has not been exposed in the Welkom area to date.

1.6.4.2 Central Rand Group

1.6.4.2.1 Johannesburg Subgroup

The Johannesburg Subgroup in the Welkom Goldfield is subdivided into 5 formations (Fig. 8). The lowermost subdivision is the Virginia Formation (Lower Footwall, LF 1-6) which consists of sublithic arenites with rare matrix-supported conglomerates and the unconformable Ada May (Beisa) Reef at the base. The Ada May Reef is an oligomict small pebble conglomerate containing crystalline pyrite mineralisation and gold and uranium values of uneconomic importance.

Overlying the Virginia Formation is the unconformity-based St. Helena Formation (Middle Footwall, MF 1-4) which comprises predominantly sublithic- to quartz arenites and scattered pebbly sandstones. Near the top of

FORMATION	SUBGROUP	GROUP	
	Adelaide	Beaufort (40m)	KAROO SEQUENCE
Volksrust		Ecca (450m)	
Vryheid			
Dwyka (50m)			
Klippan		Platberg (190m)	VENTERSDORP SUPERGROUP
Orkney(?)		Klipriviersberg (350m)	
	Turffontein (465m)	Central Rand (1860m)	WITWATERSRAND SUPERGROUP
	Johannesburg (1395m)		
	Government	West Rand (±4650m)	
	Jeppestown		
	Hospital Hill		
Basement			

Figure 7 : Generalized stratigraphic column for the Welkom Goldfield.

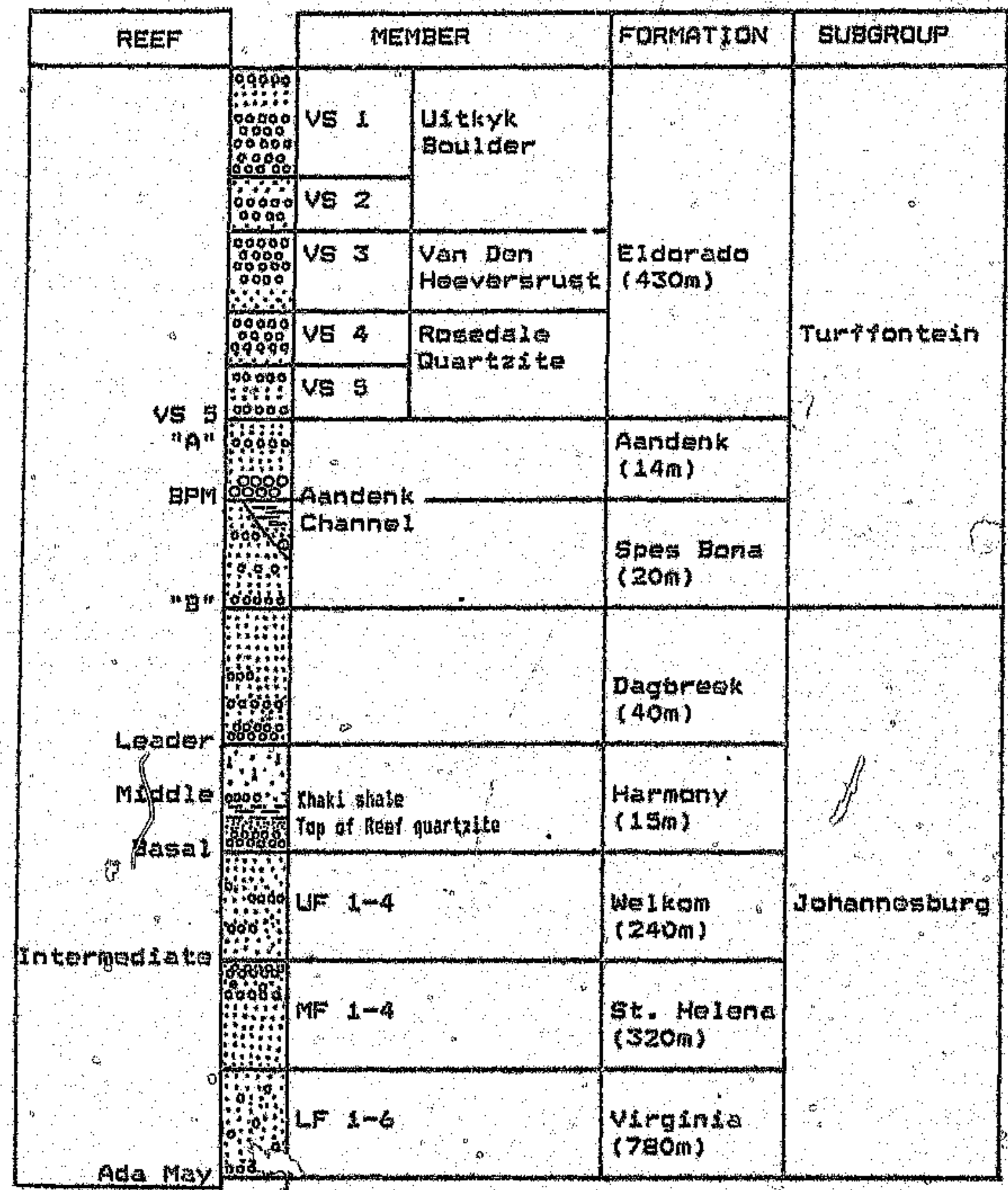


Figure 8 : Detailed stratigraphic column for the Central Rand Group in the south-western portion of the Welkom Goldfield.

the St. Helena Formation is the Intermediate (Frost) Reef in the conglomeratic MF 1 zone. The Intermediate Reef is an oligomict small pebble conglomerate which is generally thin and contains no mineralisation of economic importance.

The Welkom Formation (Upper Footwall, UF 1-4) unconformably overlies the St. Helena Formation and is composed of planar- and trough crossbedded, fine- to coarse-grained lithic- and sublithic arenites with a characteristic speckling of yellow metapelite and black chert grains. Disseminated pyrite on bedding planes, interbedded quartz arenites and scattered polymict pebbly sandtones also occur in the Welkom Goldfield.

The Harmony Formation unconformably overlies the Welkom Formation and has at its base the Basal Reef which has yielded >80% of the gold mined in the Welkom Goldfield to date. The Basal Reef is unconformity-based and laterally persistent, and is overlain by characteristic wackes and arenites of the Harmony Formation.

The unconformity-based Dagbreek Formation is the uppermost formation of the Johannesburg Subgroup. At its base is the Leader Reef which has yielded approximately 15% of the gold mined in the Welkom Goldfield.

1.6.4.2.2 Turffontein Subgroup

The lowermost of the three formations comprising the Turffontein Subgroup is the unconformity-based Spes Bona Formation which contains the "B" Reef at its base. The "B" Reef contains sporadic but generally low gold values.

The Spes Bona Formation is eroded in the southern portion of St. Helena Gold Mine by the Aandenk Channel. Where the Aandenk Channel is not present the Big Pebble Marker forms the unconformable base of the Aandenk Formation. To the south of St. Helena Gold Mine the Aandenk Channel contains mineralised conglomerates. The Big Pebble Marker is poorly mineralised in the Welkom Goldfield.

The unconformity-based Eldorado Formation is the uppermost unit of the Central Rand Group in the Welkom Goldfield and is equivalent to the Mondeor and Elsburg Formations. Numerous unconformity-based conglomerates occur in the Eldorado Formation but to date no conglomerates of economic importance have been located on St. Helena Gold Mine.

1.6.4.3 Ventersdorp Supergroup

The Ventersdorp Supergroup on St. Helena Gold Mine is relatively thin and is represented by the Klipriviersberg Group (Orkney Formation) of dark-green amygdaloidal lava and tuff. The thickness of the Klipriviersberg lava decreases rapidly in a westerly direction across St. Helena Gold Mine to a point where the Karoo Sequence rests unconformably on the Witwatersrand Supergroup. Unisel Gold Mine has lava of the Klipriviersberg Formation and clastic and carbonate sediments of the overlying Klippan Formation of the Platberg Group preserved.

1.6.4.4 Karoo Sequence

On both St. Helena and Unisel Gold Mines the Karoo Sequence of age 300-150 Ma (SACS, 1980) is preserved. Shale and diamictite of the Dwyka Formation form the base of the Karoo Sequence and Dwyka Formation is overlain by

Ecca and Beaufort Group sediments. The Vryheid Formation of the Ecca Group comprises sandstones and thin coal seams, while the overlying Beaufort Group comprises sandstones and siltstones of the Adelaide Subgroup.

1.6.4.5 Intrusives

Intr[illegible]s of early Ventersdorp age occur throughout the Welk[illegible] [illegible]oldfield and are related to extrusions of the Klipriviersberg lava. Late-Ventersdorp age intrusives, Karoo dolerites and kimberlites also occur sporadically throughout the Welkom Goldfield.

1.7 MINERALISATION

The general consensus as to the origin of the gold mineralisation in the Witwatersrand Supergroup in the literature over the last twenty years is one of predominantly placer or modified placer origin. Reasons for the consensus are the close relationship between gold distribution and sedimentary features, the inferred lack of alteration in the deposit, the lack of permeability to allow post-depositional fluid movement, the lack of vertical zoning, and the inability of fluids to transport gold (Hallbauer and von Gehlen, 1983).

A post-depositional origin for the mineralisation of the Witwatersrand Supergroup has been re-emphasised in recent work by Phillips (1986a, b, 1987a, b, 1988), Phillips et al. (1987), Law et al. (1988a, b, 1990), Law (1990) and Phillips and Myers (1990). The above workers identified problems with the placer model such as the lack of iron oxides but abundance of pyrite, unusual sulphides in the reefs, detrital transport of uraninite grains, the inference of hydraulic equivalence of reef minerals, basinwide chemical associations, and the source of the gold itself (Phillips et al., 1987).

Economic mineralisation in the Welkom Goldfield is generally confined to unconformity-based conglomerates. Gold and uranium mineralisation contained in the Basal Reef on St. Helena Gold Mine is associated with the abundance of porous round pyrite and the carbon (kerogen) content of the host-conglomerate. Although small-scale anomalies in value may occur across faults, neither regional nor systematic trends of gold mineralisation related to fault structures are detected on St. Helena Gold Mine.

2 STRATIGRAPHY

2.1 STRATIGRAPHIC CONCEPTS

Stratigraphic classification is the systematic arrangement of rock strata into units with reference to any of the properties that the rocks may possess (SACS, 1987). One of the accepted methods of stratigraphic classification is lithostratigraphic classification (SACS, 1980). A lithostratigraphic unit is one which is unified by consisting predominantly of either a certain rock type or other significant lithological features. Sequence stratigraphy and tectonostratigraphy are alternatives to lithostratigraphy which are necessary to reflect the tectonic development of a depository and the genetic relationship of different lithostratigraphic units. Sequence stratigraphy is based on sequences, which are bounded by unconformities and correlative conformities (Von Wagoner et al., 1988). Tectonostratigraphy is defined as the relationship between tectonics, sedimentation and erosion (Brink, 1986).

A lithostratigraphic subdivision over an area the size of the Welkom Goldfield only provides partial stratigraphic data, as a lithostratigraphic subdivision does not reflect the tectonic development of the depository adequately (Winter, 1985). This is because of the presence of large lateral lithofacies variations (e.g. intertonguing units) in the depository cannot be adequately presented in a lithostratigraphic column. The use of lithostratigraphy over a smaller area, and specifically that of St. Helena Gold Mine, is possible because large lateral lithofacies variations do not occur in the Harmony, Dagbreek, Spes Bona and Aandenk Formations. In the case of the Eldorado Formation lateral lithofacies variations do occur and sequence stratigraphy is applicable.

2.1 UNCONFORMITIES

An unconformity is a surface separating younger from older strata, along which there is evidence of either erosional truncation or subaerial exposure, with a significant hiatus indicated (Von Wagoner et al., 1988). Unconformities are fundamental for determining genetic packages of rocks and subsequently for stratigraphic classification. Unconformities underlie the major auriferous conglomerates of the Witwatersrand Supergroup and are characterised by their flat or slightly undulatory nature and vertical facies changes from arenite below the unconformity to conglomerate above the unconformity. The conglomerates overlying unconformities generally contain above-average gold, uranium and pyrite mineralisation and the unconformities also form the base of commonly upward-fining units termed para-sequences or sequences (Von Wagoner et al., 1988).

The angle of an unconformity depends on the rate of uplift, erosion, basin subsidence and sedimentation, with repeated pulses of uplift producing superimposed unconformities (Miall, 1978). On unconformity surfaces sediment is generally removed and heavy minerals and durable clastic material accumulates (Beater, 1982).

Low-angle unconformities (<2°) of the Central Rand Group converge towards the basin edges, indicating that pulses of uplift occurred either during or following periods of sedimentation. Uplift was more intense at the basin margin, compared to the basin interior. Rapid erosion of the uplifted stratigraphy took place and relief was subsequently reduced, after which the depositional cycle began again.

Unconformities are common to sedimentary basins which undergo uplift and erosion together with deposition. The unconformities which occur in the Witwatersrand Supergroup are similar to those described by Riba (1976) and Anadon et al. (1986) from the Spanish Pyrenees and to unconformities which commonly form in Molasse basins (Miall, 1978). Detailed descriptions of the unconformities on St. Helena Gold Mine are presented in Chapter 5.

2.3 STRATIGRAPHY OF THE STUDY AREA

2.3.1 Introduction

The stratigraphy studied in detail is from the upper portion of the Johannesburg Subgroup and the entire Turffontein Subgroup. This encompasses the Harmony, Dagbreek, Spes Bona, Aandenk and Eldorado Formations, each of which are described in detail below.

The stratigraphic nomenclature utilised in this study is that which is in use in the current literature and on many of the mines in the Welkom Goldfield. Minor differences between the nomenclature used in this study and that of SACS (1980, Fig. 3.2.3.) and Minter et al. (1986) do occur. The differences in nomenclature and the lack of communication between mines have resulted in correlation on a goldfield-scale remaining uncertain (Winter, 1985).

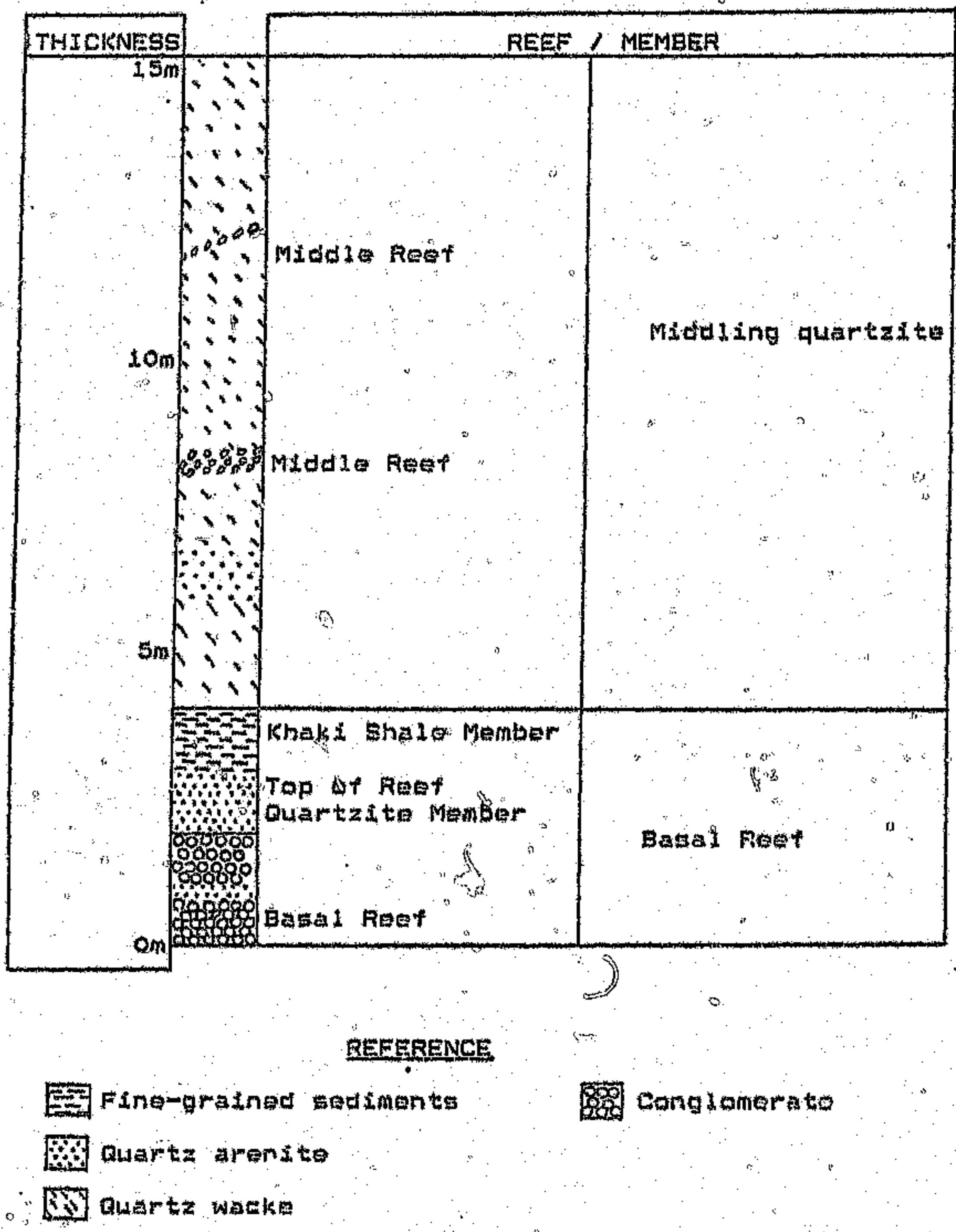
The stratigraphy of the study area was constructed from the examination of borehole cores (Fig. 8) and the thickness of sedimentary intervals calculated from isopach maps. The isopach maps constructed for each sedimentary interval show the western margin suboutcrop position, the position of which is well constrained only in the central and northern portions of St. Helena Gold Mine. The stratigraphy preserved towards the centre of the Welkom Goldfield (e.g. President Steyn Gold Mine) is in places twice as thick as that present on St. Helena Gold Mine.

In the description of conglomerates the term oligomict refers to a conglomerate containing >95 percent of either durable or non-durable clasts. Durable clasts are defined as consisting of either quartz or chert, and non-durable clasts consist of either metapelite, quartzite, igneous or volcanic material.

2.3.2 Johannesburg Subgroup

2.3.2.1 Harmony Formation

The Harmony Formation is defined in this study as including the Basal Reef as the lowermost unit of the Harmony Formation (Fig. 9). The Basal Reef is included at the top of the Welkom Formation by SACS (1980) and Minter et al. (1986), but this author and others (McKinney et al., 1964; Winter, 1964a, b; Sims, 1969; Catlow and Myers, 1986; C.S. Kingsley, pers. comm, 1988; A.R. King, pers. comm, 1989) have found no justification for doing so, as the Basal Reef overlies a major unconformity. Thus in terms of the principles of sequence stratigraphy the Basal Reef logically forms the basal unit of the genetic package termed the Harmony Formation.



<u>Figure 9</u> : Idealised stratigraphic column of the Harmony Formation, St. Helena Gold Mine.

To the south of Unisel Gold Mine the lithologies of the Welkom and Harmony Formations are similar, making distinction based solely on lithology difficult, particularly when there is no Basal Reef development. The Harmony Formation present to the south of Unisel Gold Mine and in places in the southern portion of St. Helena Gold Mine is distinguished from the Welkom Formation by the presence of porous round pyrite nodules in the Harmony Formation.

The isopach map of the Harmony Formation on St. Helena Gold Mine (Fig. 10) includes the combined thickness of the Basal Reef, Top of Reef quartzite, Khaki shale and the Middling quartzite. The Harmony Formation thickens from 0m in the west to over 20m in the east of St. Helena Gold Mine. The Harmony Formation thins to the east of the Dagbreek fault (section A'-A; Figs. 11 and 12). The thickness of the Harmony Formation increases sl ht1 in a northerly direction across St. Helena Gold Mine.

East / west oriented sections through St. Helena Gold Mine are characterised by the overall thinning and truncation of formations in a westerly direction (sections B'-B and C'-C; Figs. 13 and 14). In the more southerly section (Fig. 13) the Basal Reef sub-outcrops against the Leader Reef but to the north of this (section C'-C, Fig. 14) the Basal and Leader Reefs suboutcrop against the "B" Reef.

2.3.2.1.1 Basal Reef

The Basal Reef, a the base of the Harmony Formation, is subdivided in t Welkom Goldfield into two major coalescing facies (Antrobus, 1956). These are a northern,

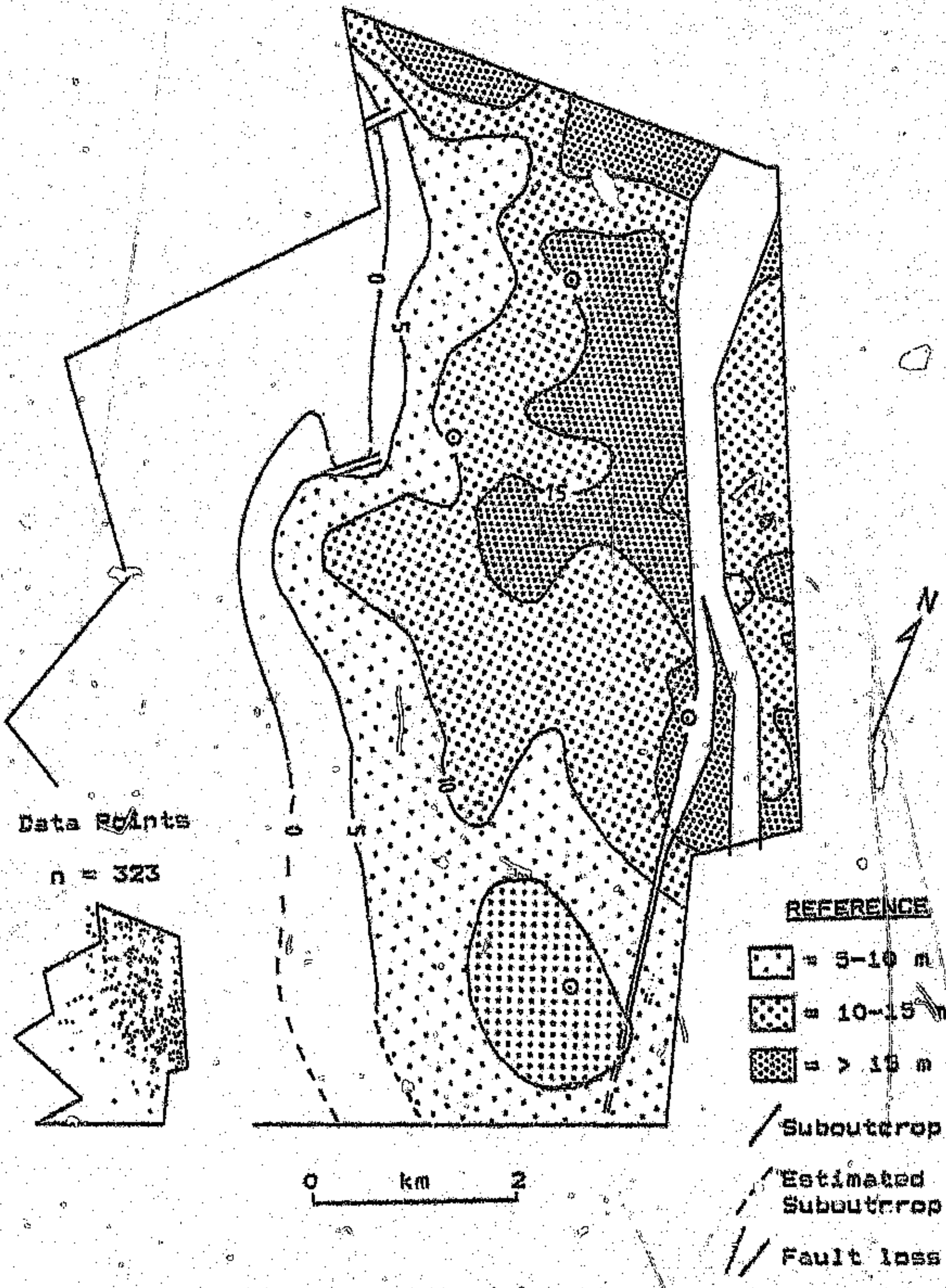


Figure 10 : Isopach map of the Harmony Formation. Contour interval = 5m.

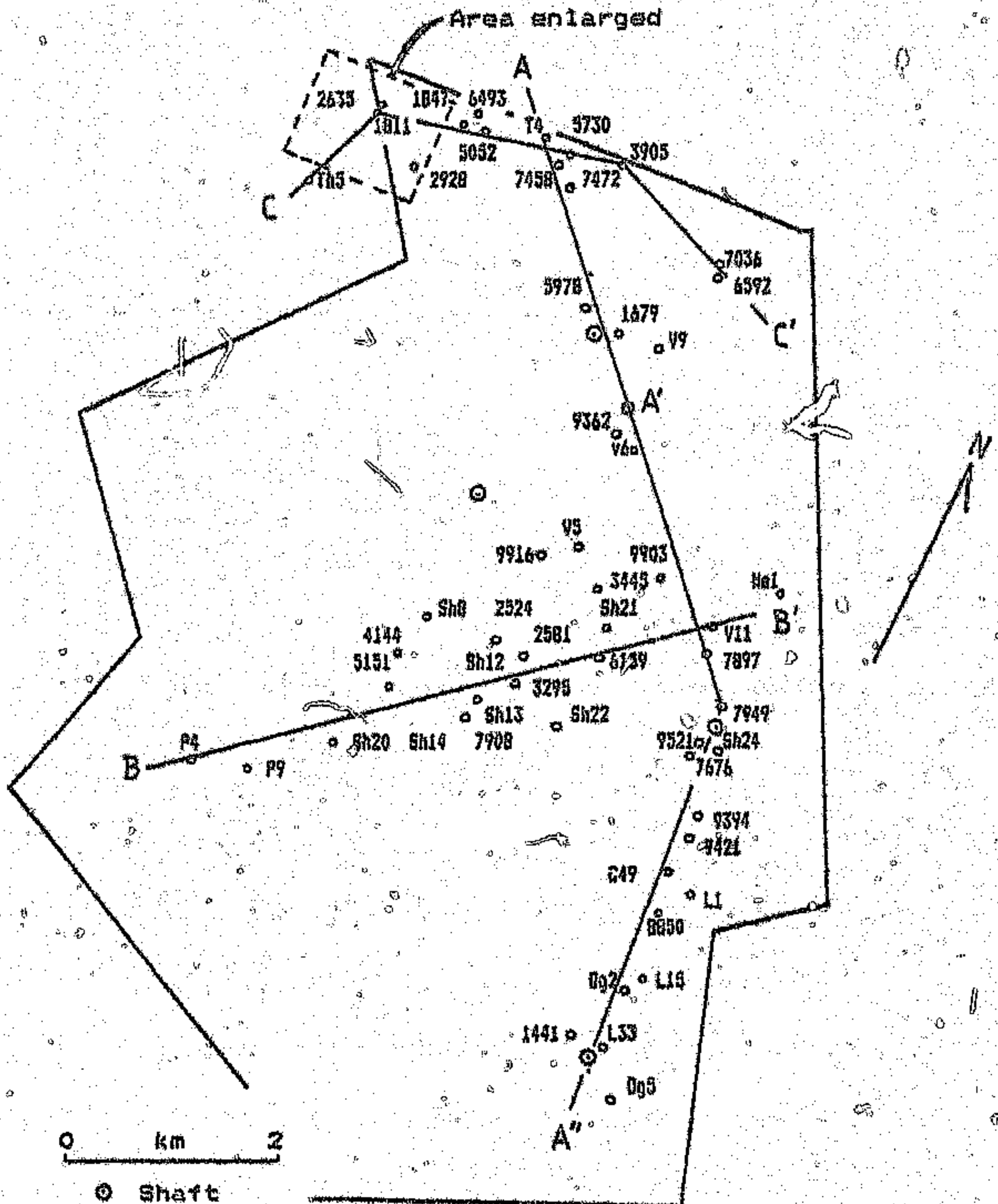


Figure 11 : Plan showing the location of sections A-A", A'-A", B-B' and C-C' and the boreholes and underground locations used in their construction. The northwestern portion of St. Helena Gold Mine is enlarged in Fig.62.

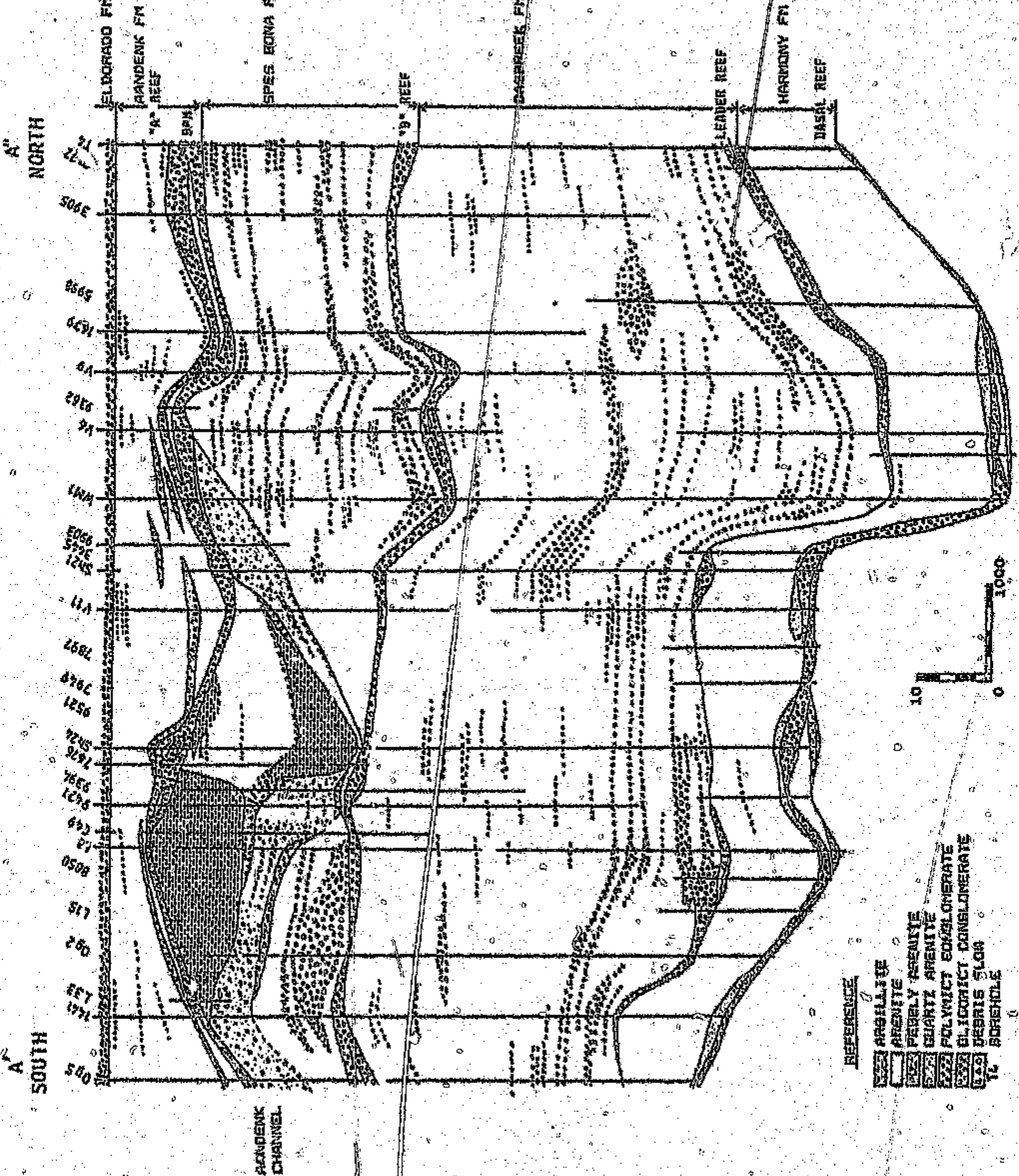


Figure 12 : North / south strike section A-A" of the Harmony to Aandenk Formations. The base of the Eldorado Formation has been used as datum. Location is shown in Fig. 11. Note vertical exaggeration.

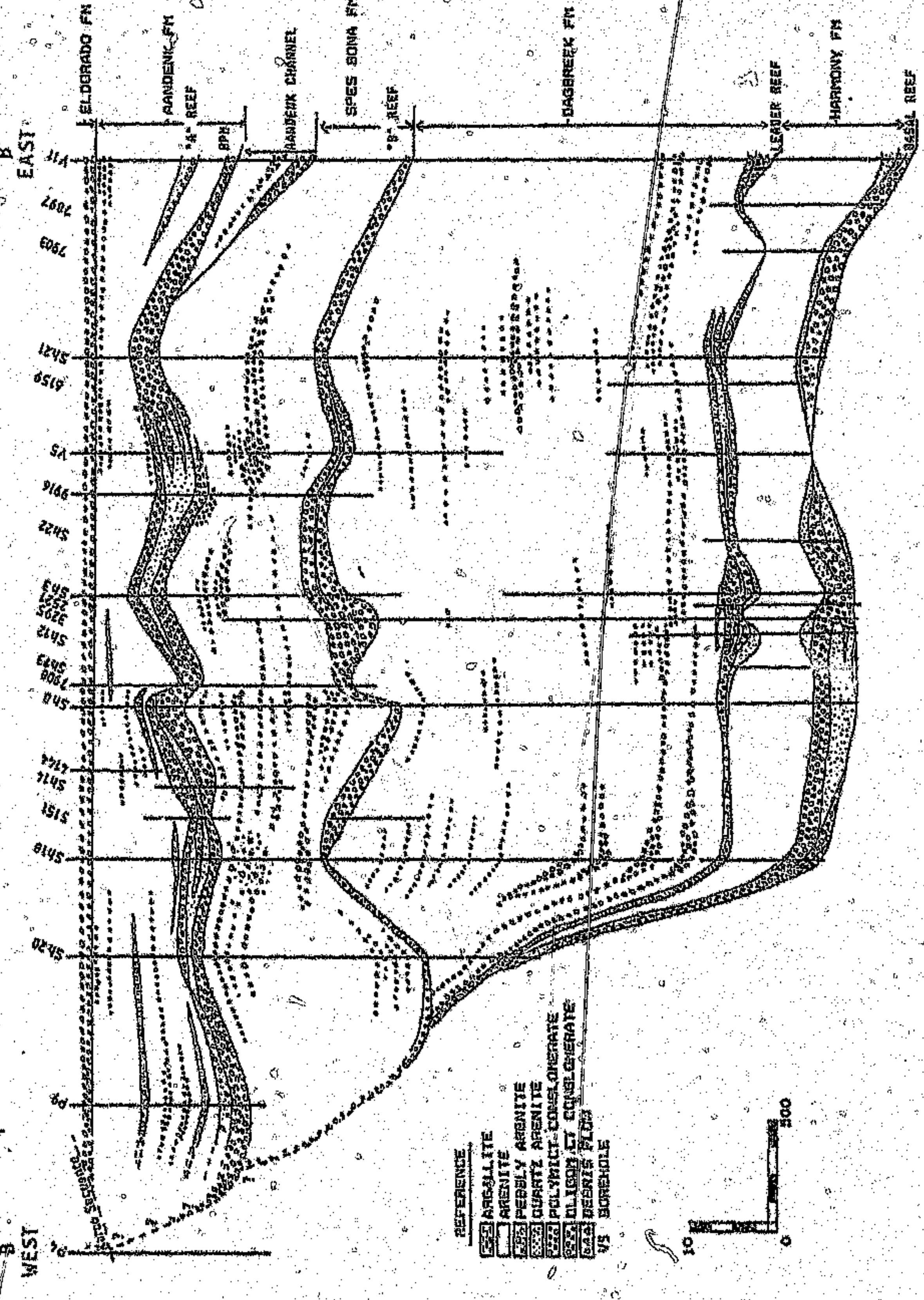
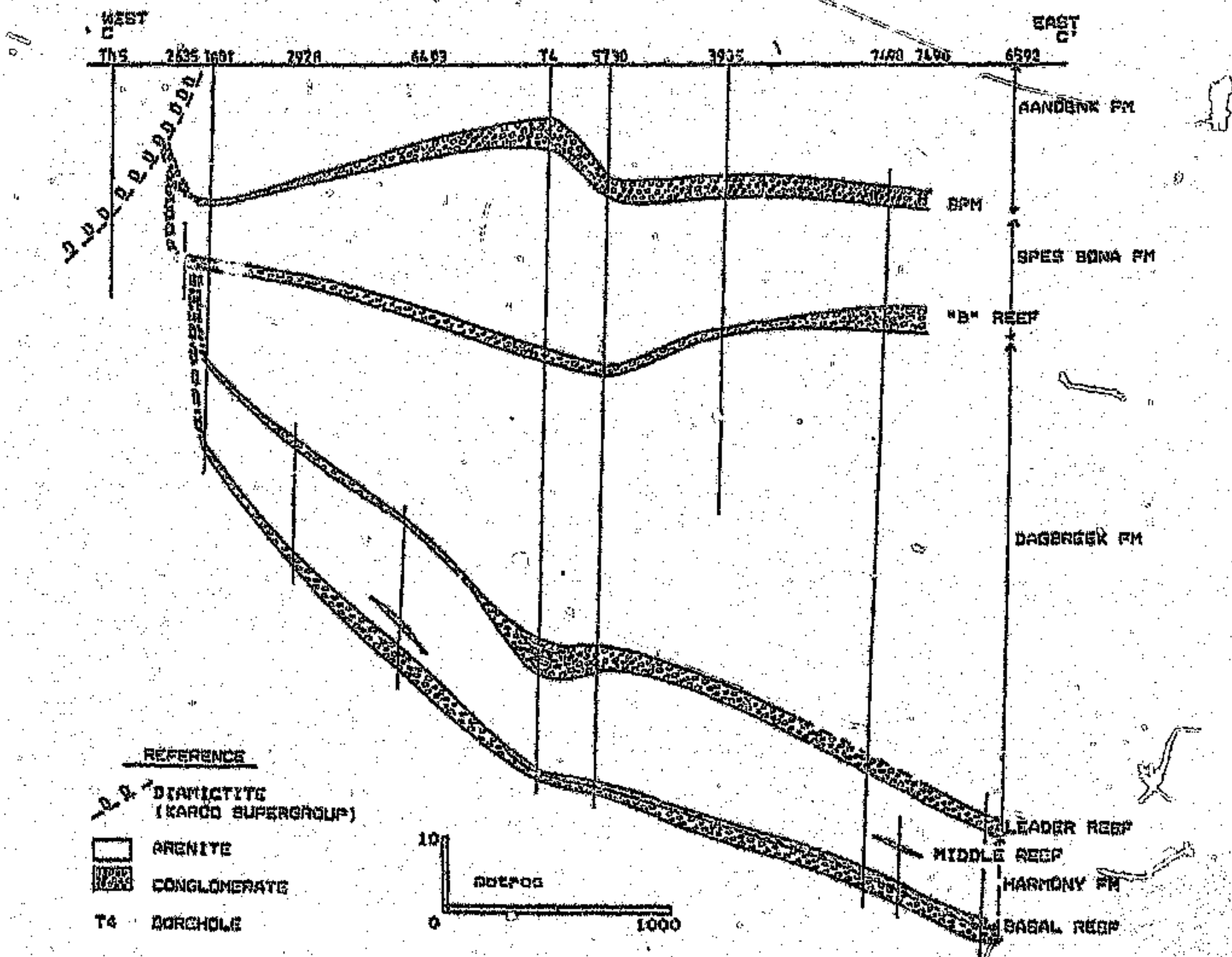


Figure 13 : West / east dip section B-B' of the Harmony to Aandenk Formations. The base of the Eldorado Formation has been used as datum. Location is shown in Fig. 11. Note vertical exaggeration.



<u>Figure 14</u> : West / east dip section C-C' of the Harmony to Aandenk Formations. The base of the Eldorado Formation has been used as datum. Location is shown in Fig. 11. Note vertical exaggeration.

generally oligomict Basal facies and the southern polymict Steyn facies, the boundary between which occurs in the northern portion of St. Helena Gold Mine (Minter, 1978). The Basal facies on St. Helena Gold Mine is further divided into the oligomict and carbon seam reef types. The polymict Steyn facies is divided into the polymict southern reef, the mixed reef and the arenite reef on St. Helena Gold Mine (Figs. 15 and 16).

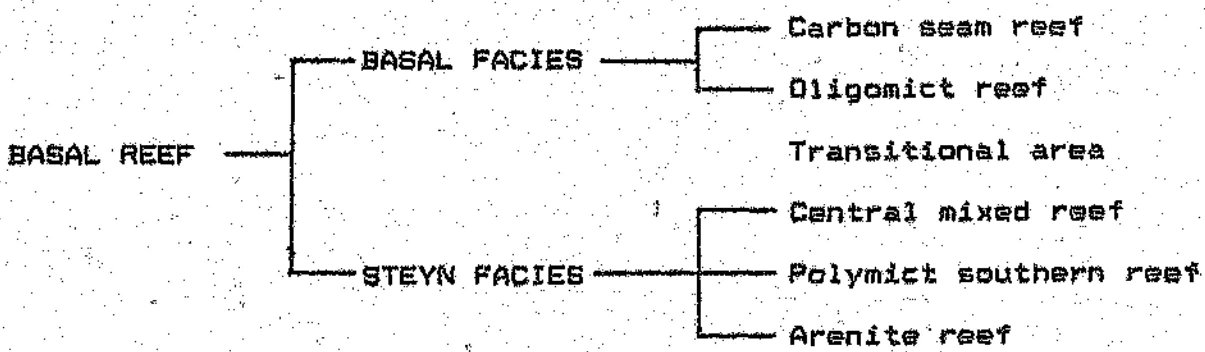


Figure 15: Basal Reef subdivisions, St. Helena Gold Mine.

The facies distribution of sub-divisions of the Basal Reef bears no relation to the suboutcrop position of the Basal Reef, with four of the five facies abutting against the westerly suboutcrop line of the Basal Reef on St. Helena Gold Mine. The facies of the Basal Reef also show no relation to the syncline and adjacent anticline present in the western portion of St. Helena Gold Mine. The Basal Reef subdivisions on St. Helena Gold Mine are compared (Table 1) and are described below:

a) Oligomict reef. The oligomict reef is the thinnest reef type and occurs in the northwestern portion of St. Helena Gold Mine. The oligomict clasts and porous round pyrites (Fig. 17) occur primarily in shallow undulatory depressions below a thin layer of sublithic- and quartz arenite. Areas with no conglomerate

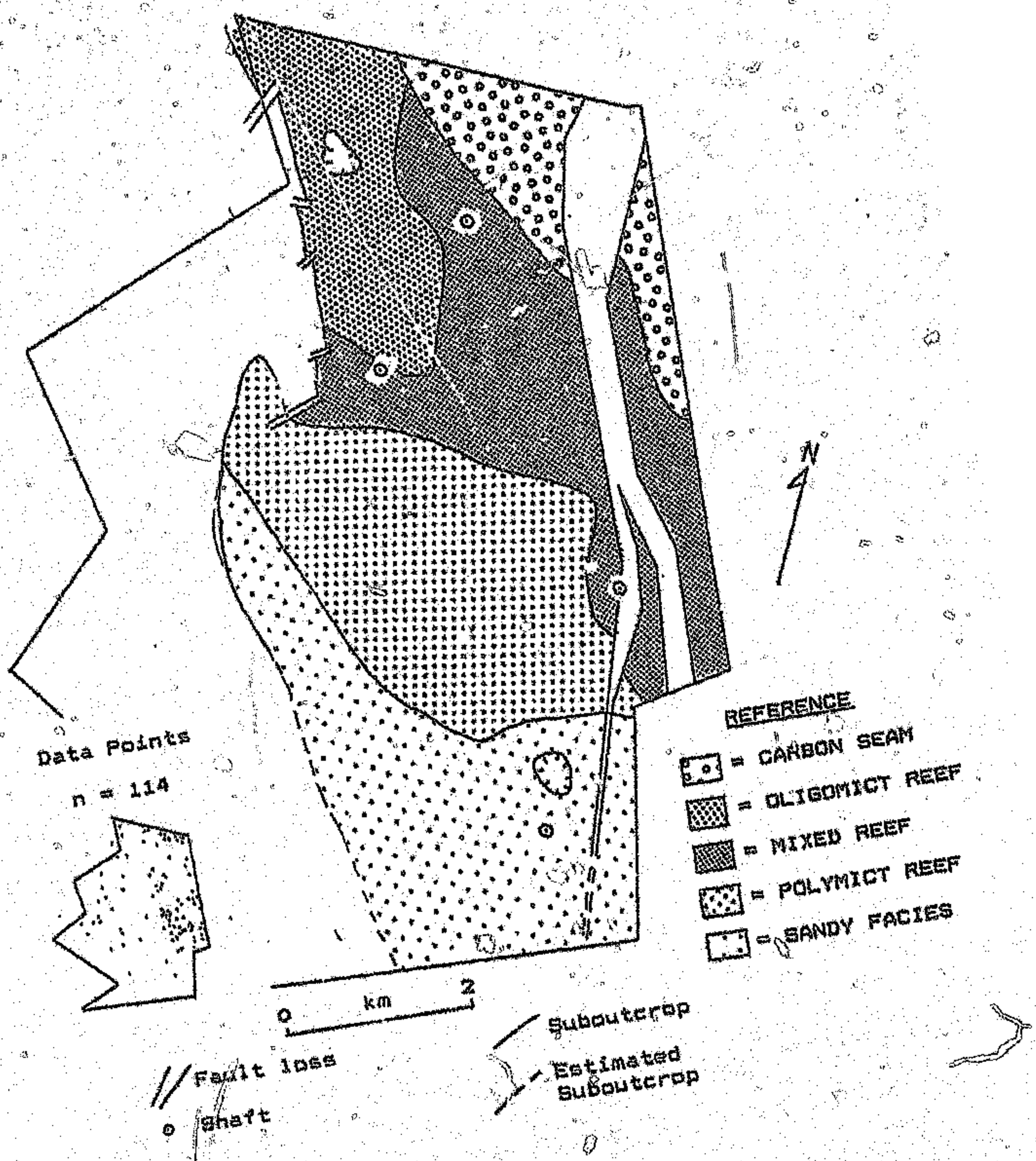


Figure 16 : Basal Reef facies distribution.

REEF	THICK-NESS	SORTING	
BASAL REEF (ARENITE REEF)	0-4m	poor	ad
BASAL REEF (POLYMICT SOUTHERN REEF)	0.5-7m upper	poor	cl
	2-35cm lower	poor-good	cl
BASAL REEF (EAST/CENTRAL MIXED REEF)	0-1.8m	moderate	ma
BASAL REEF (CARBON SEAM)	<50cm	good	cl sy
BASAL REEF (OLIGOMICT)	0-40cm max 1m	good	cl

REFERENCE

Q ARENITE = QUARTZ ARENITE — SPC

SL ARENITE = SUBLITHIC ARENITE — MPC

L ARENITE = LITHIC ARENITE — LPC

MIN = MINERALIZATION — X-B

VEIN Q = VEIN QUARTZ

Table 1 : Comparis
facies o

REEF	THICK-NESS	SORTING	PACKING	PEBBLE SIZE	CLAST TYPES	MATRIX	PYRITE MINERALIZATION	ECONOMIC MINERALIZATION	LATERAL CONTINUITY	INTERNAL PARTINGS	COMMENTS
BASAL REEF (ARENITE REEF)	0-4m	poor	matrix supported	spc-mpc	metapelite, vein q., chert, rare volcanic	sl-l arenite, rare q wackes	rare rounded, dissem-inated, stringers	poor	?	conglomerate, granulestone	rare spc-lpc, siltstone lag at base
BASAL REEF (POLYMICT SOUTHERN REEF)	0.5-7m upper	poor	clast supported	mpc-lpc	metapelite, vein q., chert, rare igneous, volcanic and arenite	sl-q arenite	crystalline and rare rounded pyrite	variable	channelized	trough x-bedded sl-q arenite,	interbedded conglom-erate and arenite, rapid facies changes Fig.
	2-25cm lower	poor-good	clast supported	spc-lpc	vein quartz, chert	sl-q arenite	rounded and crystalline	moderate-good	discontin-uous	trough x-bedded sl-q arenite,	basal conglomerate
BASAL REEF (EAST/CENTRAL MIXED REEF)	0-1.8m	moderate	matrix supported	mpc	vein q., chert, meta-pelite, rare arenite, volcanic and igneous	sl-q arenite	moderate-good rounded and crystalline	moderate Au and U	channelized in places	trough x-bedded arenite, rare granulestones	rare disseminated carbon near base
BASAL REEF (CARBON SEAM)	<50cm	good	clast - matrix supported	spc-mpc	vein quartz, rare chert	q arenite	abundant rounded	high Au and U	continuous	rare, q. arenite	disseminated and seam carbon, up to 4cm thick
BASAL REEF (OLIGOMICT)	0-40cm max 1m	good	clast supported	spc-mpc	vein quartz, rare chert	q arenite	abundant, rounded	high Au and U	continuous	rare, q. arenite	Fig.

REFERENCE

Q ARENITE = QUARTZ ARENITE

SL ARENITE = SUBLITHIC ARENITE

L ARENITE = LITHIC ARENITE

MIN = MINERALIZATION

VEIN Q = VEIN QUARTZ

SPC = SMALL PEBBLE CONGLOMERATE

MPC = MEDIUM PEBBLE CONGLOMERATE

LPC = LARGE PEBBLE CONGLOMERATE

X-BEDDED = CROSSBEDDED

Table 1 : Comparison of conglomerate characteristics of the facies of the Basal Reef, St. Helena Gold Mine.

Figure 17 : Oligomict Basal Reef. Note abundant porous rounded pyrite. Coin diameter = 20mm.

have the base of the Harmony Formation defined by either a scattered granuleconglomerate or a discontinuous layer of porous round pyrite. Increased gold values in the oligomict reef are associated with porous round pyrite and also with the presence of pyrite on foresets and set surfaces of associated quartz arenites.

b) Carbon seam reef. This consists of either single or multiple carbon (kerogen) seams or flyspeck (disseminated) carbon, overlain by either an oligomict reef or by scattered oligomict pebbles in a sublithic arenite, fining-up to a quartz arenite. Carbon abundance decreases in a southwesterly direction across St. Helena Gold Mine (Fig. 18). High gold and uranium values are commonly associated with occurrences of both carbon and porous round pyrite grains. The transition between the carbon and oligomict reef subdivisions of the Basal Reef is gradational, with disseminated carbon occurring in areas of oligomict reef.

c) East / central mixed reef. The mixed reef is transitional in character and thickness between the oligomict and carbon reefs in the north and the polymict reef in the south. Disseminated carbon occurs in places in the mixed reef.

d) Polymict southern reef. The polymict conglomerate reef has a sharp upper contact and is generally overlain by the un-mineralised Top of Reef quartzite and a narrow 5cm thick khaki-coloured siltstone unit in places (Fig. 19). To the south of the main development of the polymict southern reef the basal oligomict conglomerate is frequently absent and the conglomerate thins in a southerly direction.

e) Arenite reef. This facies comprises sublithic- and lithic arenites with minor interbedded polymict conglomerates. The arenite reef facies is restricted to

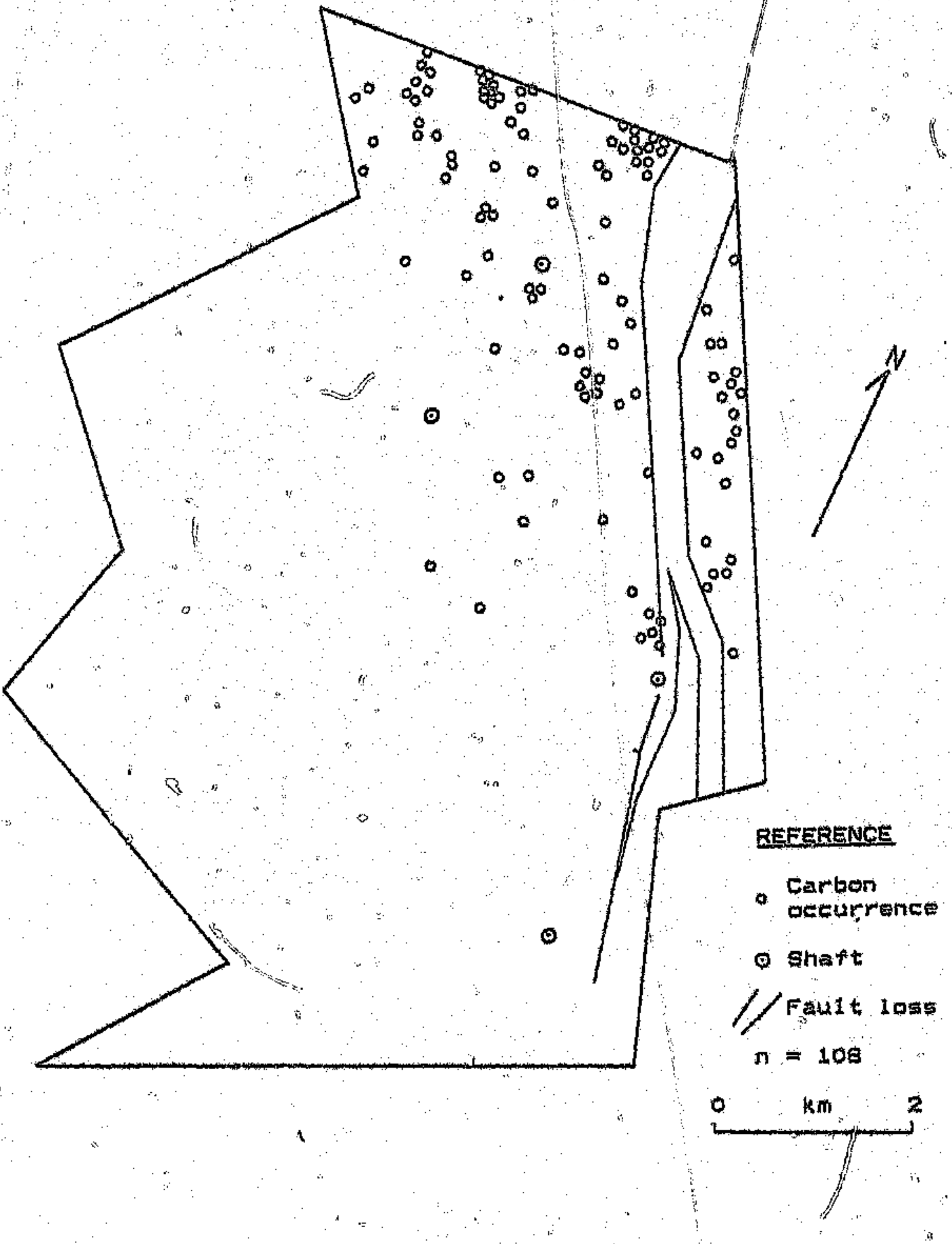


Figure 18 : Distribution of carbon (kerogen). Data are from underground borehole logs and includes both carbon seams and disseminated carbon.

Figure 19 : Polymict Southern Basal Reef overlain by the Khaki shale, southern part of St. Helena Gold Mine. Coin diameter = 17mm.

the southern and southwestern portion of St. Helena Gold Mine and is the least known of the Basal Reef subdivisions of St. Helena Gold Mine.

f) Transitional areas. The mixed reef is a transitional form which occurs between the Basal and Steyn facies of the Basal Reef and no sharp contact between the Basal and Steyn Reefs has been recorded to date in underground exposure on St. Helena Gold Mine. A transitional area also occurs between the polymict southern reef and the arenite reef in the southern part of St. Helena Gold Mine. Transition areas have characteristics of the adjoining reef types and are similar to the transition areas described on President Steyn Gold Mine by Sims (1969). Channelling, which is a feature of the mixed, southern and arenite reef types also results in the juxtaposition of differing conglomerate facies making the precise transition point between facies unclear.

Concentrations of detrital minerals appear to be related to gold mineralisation in the Basal Reef on St. Helena Gold Mine. Detrital minerals include chromite, zircon, leucoxene, certain forms of pyrite and possibly detrital gold. In general the amount of mineralisation of the unconformity-based conglomerates on St. Helena Gold Mine decreases with increasing height up the stratigraphy, from the Basal Reef upwards.

The isopach map of the Basal Reef (Fig. 20) does not include thickness data for either the Top of Reef quartzite or the Khaki Shale. The Basal Reef is thickest in the central portion of St. Helena Gold Mine and suboutcrops in the western portion of the mine. The isopach map of the Basal Reef corresponds to the facies distribution of the Basal Reef (Fig. 15) with areas of thin reef

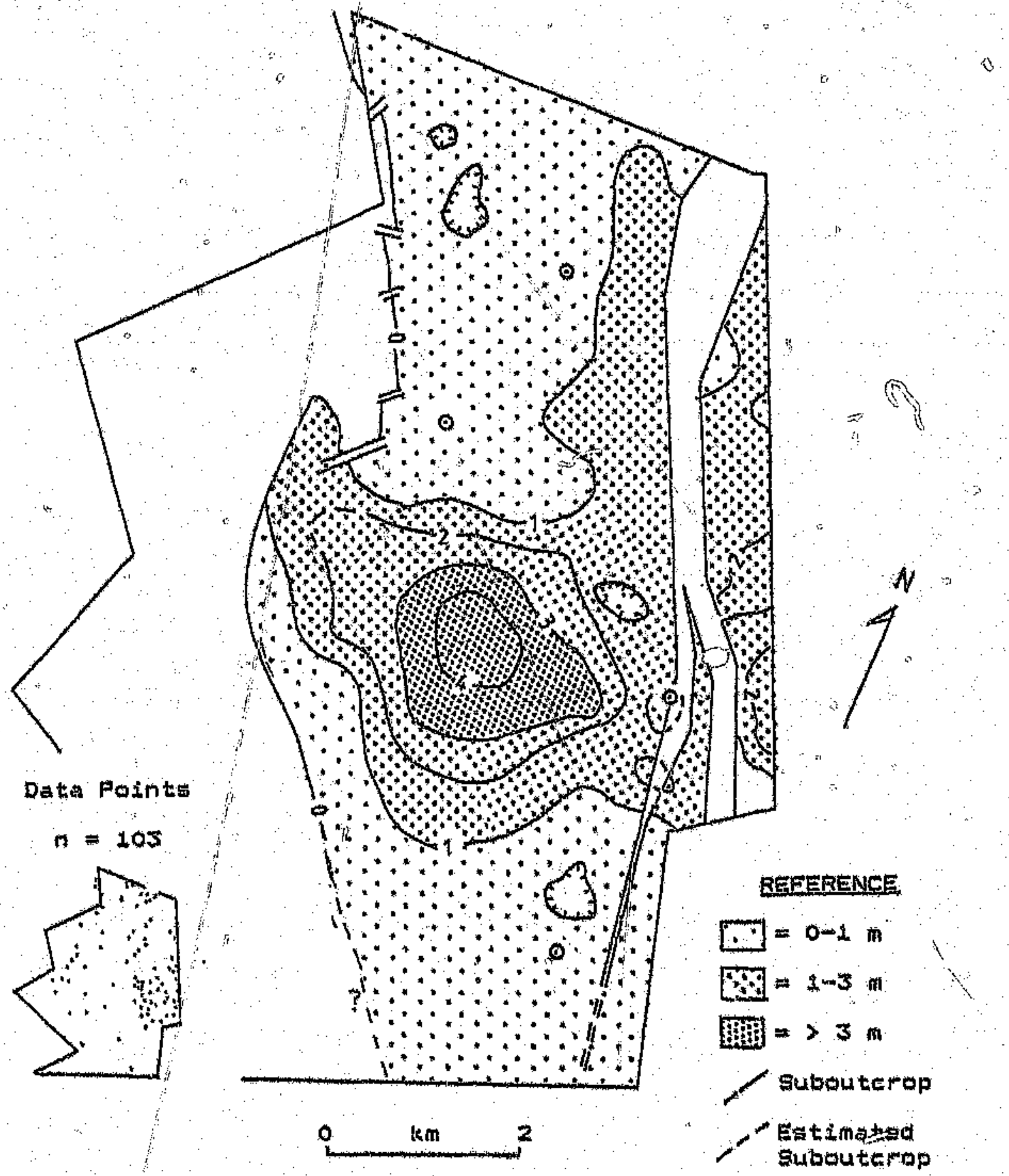


Figure 20 : Isopach map of the Basal Reef. (Excluding the Top of Reef quartzite and the Khaki shale). Contour interval = 1m.

corresponding to occurrences of the carbon and oligomict reef types and the area of thickest reef coinciding with the polymict southern reef type. In the western syncline area of St. Helena Gold Mine the Basal Reef is >1m thick up to the point of suboutcrop, but the thickness is not affected by the western syncline.

2.3.2.1.2 Top of Reef Quartzite Member

The Top of Reef quartzite is known locally as the Clean Bar, White Bar or Middling Quartzite and overlies the Basal Reef in the central and southern portions of St. Helena Gold Mine. The Top of Reef quartzite is a fine-grained sublithic- to quartz arenite of maximum 1m thick (Fig. 21). Bedding varies from horizontal laminations (Fig. 22) through asymptotically based trough crossbeds to small-scale (5-20cm) trough crossbeds. Foresets are defined by argillaceous material and disseminated and crystalline pyrite. The Top of Reef quartzite contains rare scattered pebbles and occasional pyrite stringers on foresets but has no gold or uranium mineralisation of economic importance. Brecciation occurs in places, with a breccia-fill of chlorite and pyrite.

The contact between the Top of Reef quartzite and the Basal Reef on St. Helena Gold Mine is sharp. The upper contact of the Top of Reef quartzite with the Khaki shale is variable, ranging from a gradational contact, in the northern portions of St. Helena Gold Mine and on President Brand Gold Mine (A.R. King, pers. comm., 1988), through interlaminations of arenite and Khaki shale, to a sharp contact in the northeastern area of St. Helena Gold Mine (Minter et al., 1986). Where there is no Khaki shale development the contact between the Top of Reef quartzite

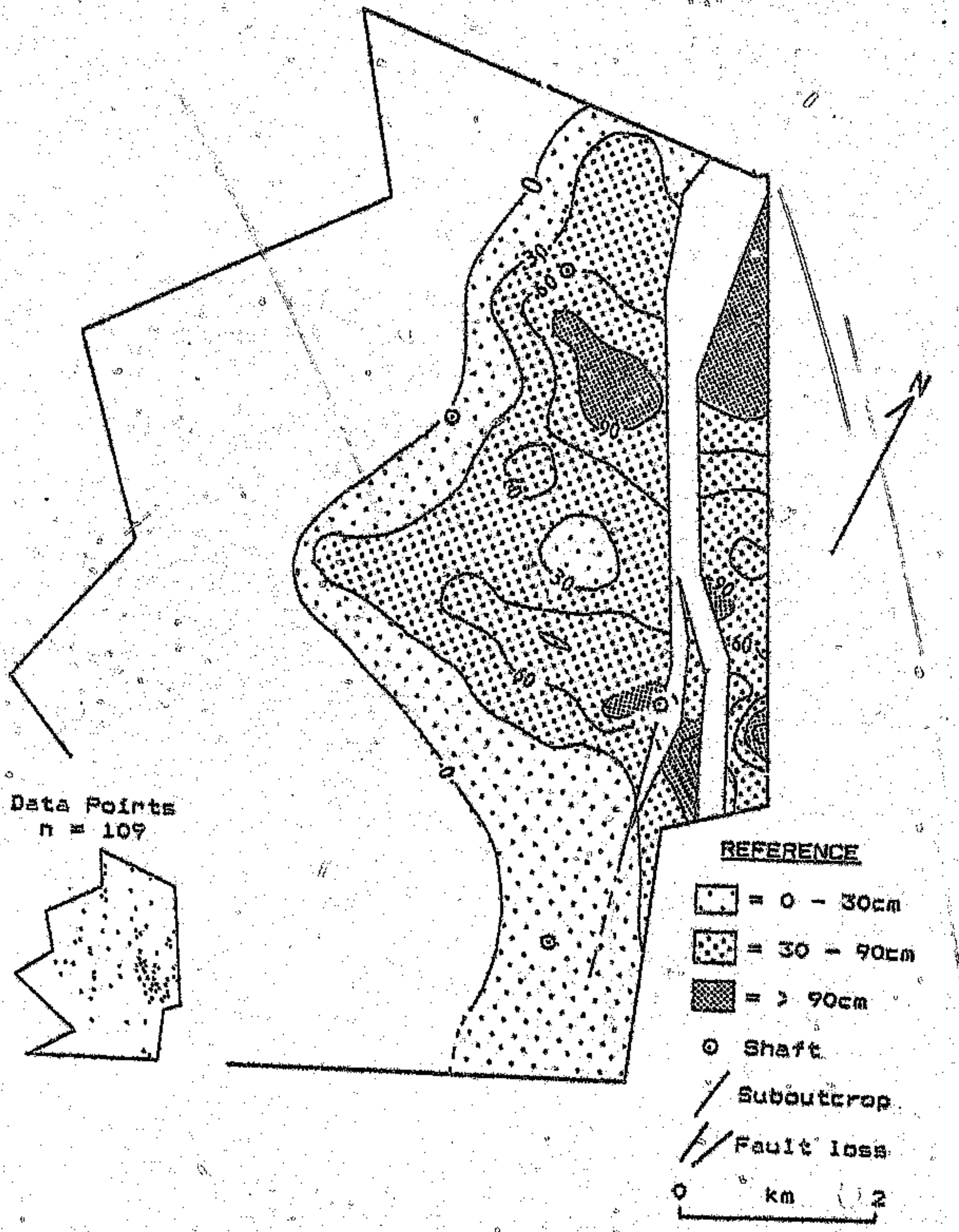


Figure 21 : Isopach map of the Top of Reef quartzite. Contour interval = 30cm.

Figure 22 : Horizontally laminated Top of Reef quartzite overlain by quartz wackes of the Middling quartzite which contain scattered pebbles. Coin diameter = 17mm.

and the Middling quartzite is erosive, e.g. in the western area of St. Helena Gold Mine (Fig. 21).

2.3.2.1.3 Khaki Shale Member

The Khaki shale is a yellow- to khaki-coloured claystone which is phyllitic in places. In the southern and western portions of St. Helena Gold Mine the Khaki shale is a coarse-grained grey siltstone. Bedding is rarely preserved in the Khaki shale because of overprinting by a pervasive foliation, although symmetrical ripples and horizontal laminations occur in places. The thickness of the Khaki shale ranges from 0-2m, with the thickest areas occurring in the northern portion of St. Helena Gold Mine (Fig. 23). The upper contact with the Middling quartzite is unconformable.

2.3.2.1.4 Middling Quartzite Member

The Middling Quartzite Member on St. Helena Gold Mine consists of quartz wackes (the Middling quartzite) with interbedded laterally impersistent conglomerates (the Middle Reefs) and rare quartz arenite interbeds.

a) Middling quartzite. This consists of a characteristic drab brown-grey quartz wacke containing scattered angular chert and quartz grains and pebbles on St. Helena Gold Mine. The Middling quartzite exhibits similar thickness trends to those of the Harmony Formation, thickening in a northerly and easterly direction and thinning to the southwest of St. Helena Gold Mine (Fig. 24).

Thin impersistent siltstone drapes are common in the Middling quartzite and light-grey fine-grained sub-

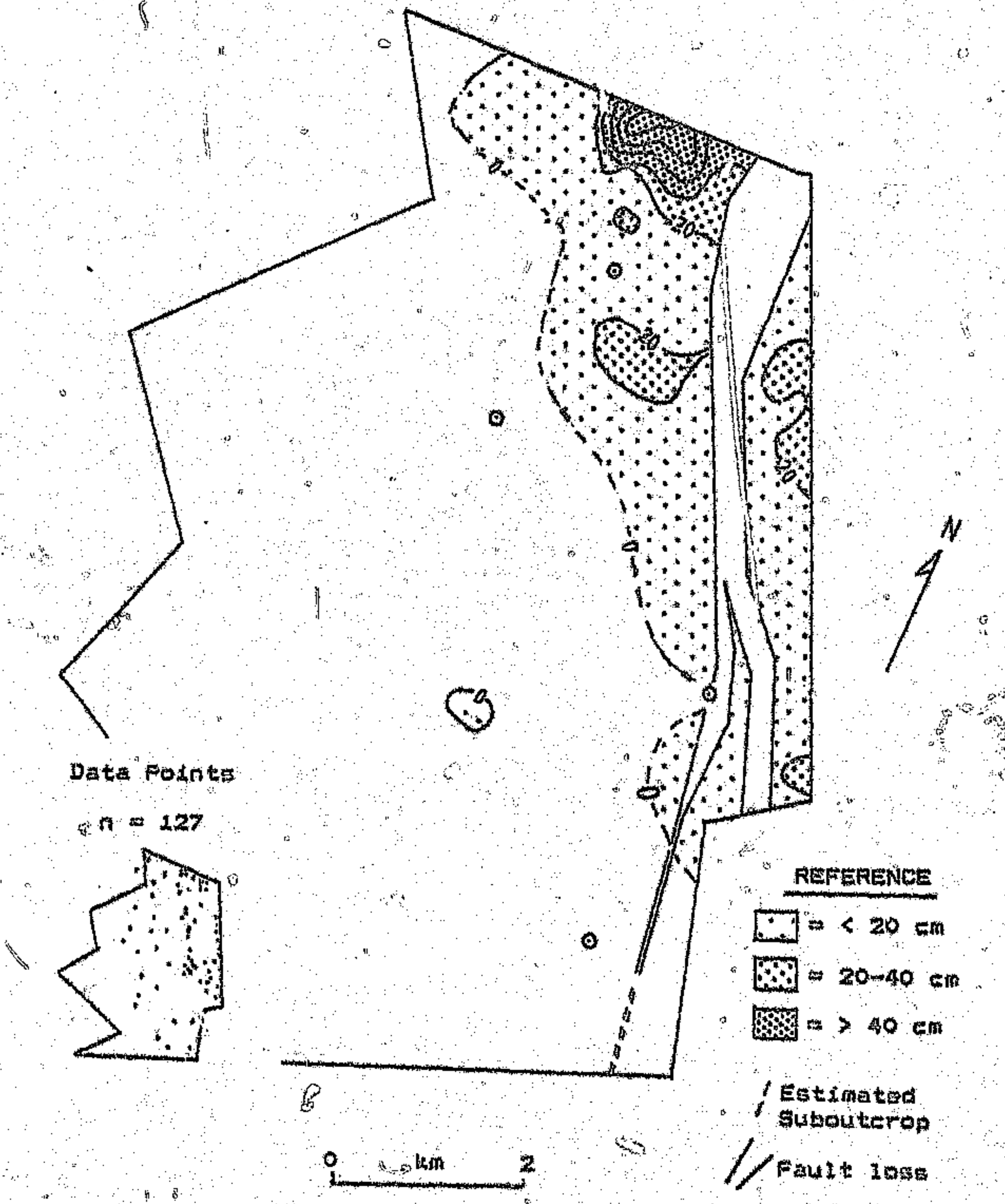


Figure 2. 1 Isopach map of the Khaki shale. Contour interval = 20cm.

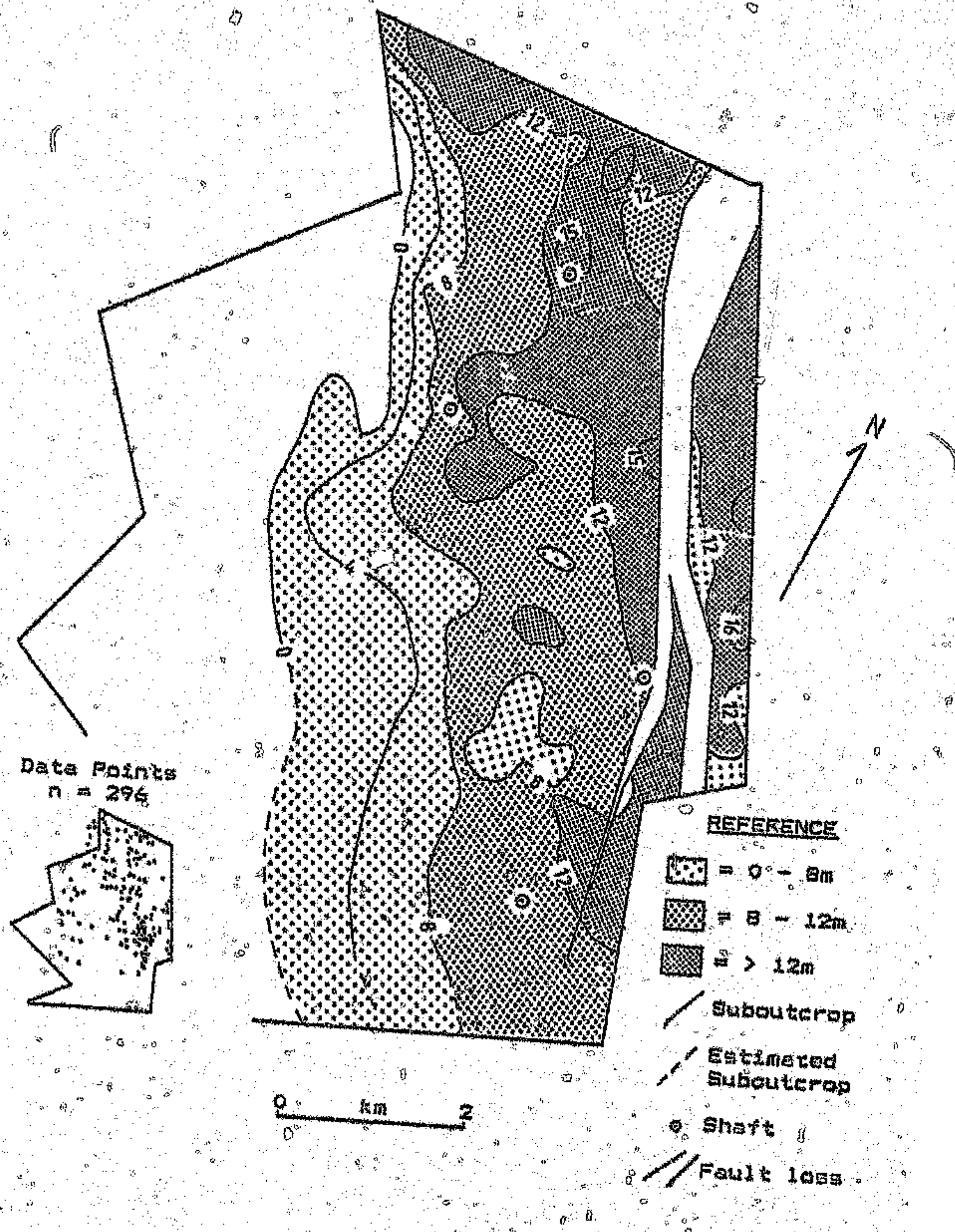


Figure 24 : Isopach map of the Middling Quartzite. Contour interval = 3m.

lithic- to quartz arenite interbeds occur in places. The arenites display both trough- and planar cross-bedding and fine upward in grain size from coarse- to fine-grained. Horizontal laminations also occur in places. On Unisel Gold Mine typical quartz wackes are less abundant in the upper portion of the Middling quartzite, being replaced by a highly variable sediment association ranging from texturally mature, light-grey fine-grained crossbedded quartz arenites to texturally immature wackes. Evidence of soft sediment deformation occurs throughout the Middling quartzite (Ellis, 1988). Soft sediment deformation features include load casts, dish structures, large- and small-scale flame structures and dewatering features.

b) Middle Reefs (Saaiplaats placer). The Middle Reefs are generally thin and poorly developed on St. Helena Gold Mine. The Middle Reefs are sub-divisible into chert-rich, quartz-rich and narrow carbon seam reef types (Table 2). The Middle Reefs occur sporadically in the northern and eastern portion of St. Helena Gold Mine (Fig. 25) and in a broad area across Unisel Gold Mine (Ellis, 1988). Occurrences of the Middle Reefs on St. Helena Gold Mine are generally near the base of the Middling quartzite (Fig. 26).

On Unisel Gold Mine the Middle Reefs are overlain by distinctive horizontally laminated and crossbedded quartz arenites. In general, economic mineralisation of the Middle Reefs occur where the reefs are situated in the lower 4m of the Harmony Formation, close to the Basal Reef (Buck, 1983). In the southern portion of Unisel Gold Mine conglomerates of the Middle Reef and the underlying Basal Reef are similar in composition,

REEF	THICK-NESS	SORTING	PACKING	PEBBLE SIZE	CLAST TYPES	MATRIX	PYRITE MINERALIZATION	ECONOMIC MINERALIZATION	LATERAL CONTINUITY	INTERNAL PARTINGS	COMMENTS
VS 5 (BEATRIX?)	0-2.8m	moderate	clast supported	spc-mpc	vein q and chert, rare metapelite and arenite	dark chloritic sl arenite	rare rounded and crystalline	very low	lenticular	rarely two sl arenites	scattered occurrences
"A" REEFS	0-1.2m	moderate	clast supported	spc-mpc	vein q and chert	sl arenite	rare rounded	very low	lenticular	rare	normally graded, commonly quartz arenite top
BPM	0-6m	moderate	clast supported	lpc	vein q, rare chert, metapelite, igneous and arenite	sl-q arenite	moderate roudoed	low	?	commonly two sl arenites	normally graded
"B" REEF	0-3m	poor	clast supported	mpc-lpc	metapelite, vein q, volcanic, igneous, chert and arenite	l-sl arenite	abundant rounded	erratic, low	?	rare	base inversely graded rare carbon specks
LEADER REEF ZONE	0-16m	poor-moderate	clast supported	spc-mpc	metapelite, vein q, chert, rare igneous and volcanic	l-sl arenite	moderate rounded and crystalline	moderate	lenticular	common, sl arenite rare q arenite	laterally variable
LEADER REEF	0-1.7m	moderate-good	clast supported	spc-mpc	vein q and chert, rare arenite	sl-q arenite	rounded and crystalline	moderate-high	channelized	rare, q arenite	not always preserved, generally fines up
MIDDLE REEFS (UNISEL G.M.)	0-3m	poor-moderate	clast supported	mpc	vein q and chert, rare arenite	q arenite	rounded and crystalline	erratic, high	lenticular, complex	----	soft sediment deformation common (Fig. 27)
MIDDLE REEFS (S.H.G.M.)	0-60cm	moderate-good	clast supported	spc-lpc	vein q and chert, rare arenite and metapelite	q arenite	rare rounded and crystalline	erratic, low	lenticular, complex	----	rare carbon

REFERENCE

Q ARENITE = QUARTZ ARENITE

SL ARENITE = SUBLITHIC ARENITE

L ARENITE = LITHIC ARENITE

MIN = MINERALIZATION

VEIN Q = VEIN QUARTZ

SPC = SMALL PEBBLE CONGLOMERATE

MPC = MEDIUM PEBBLE CONGLOMERATE

LPC = LARGE PEBBLE CONGLOMERATE

X-BEDDED = CROSSBEDDED

Table 2 : Comparison of conglomerate characteristics of the Middle- to VS 5 Reefs, St. Helena Gold Mine.

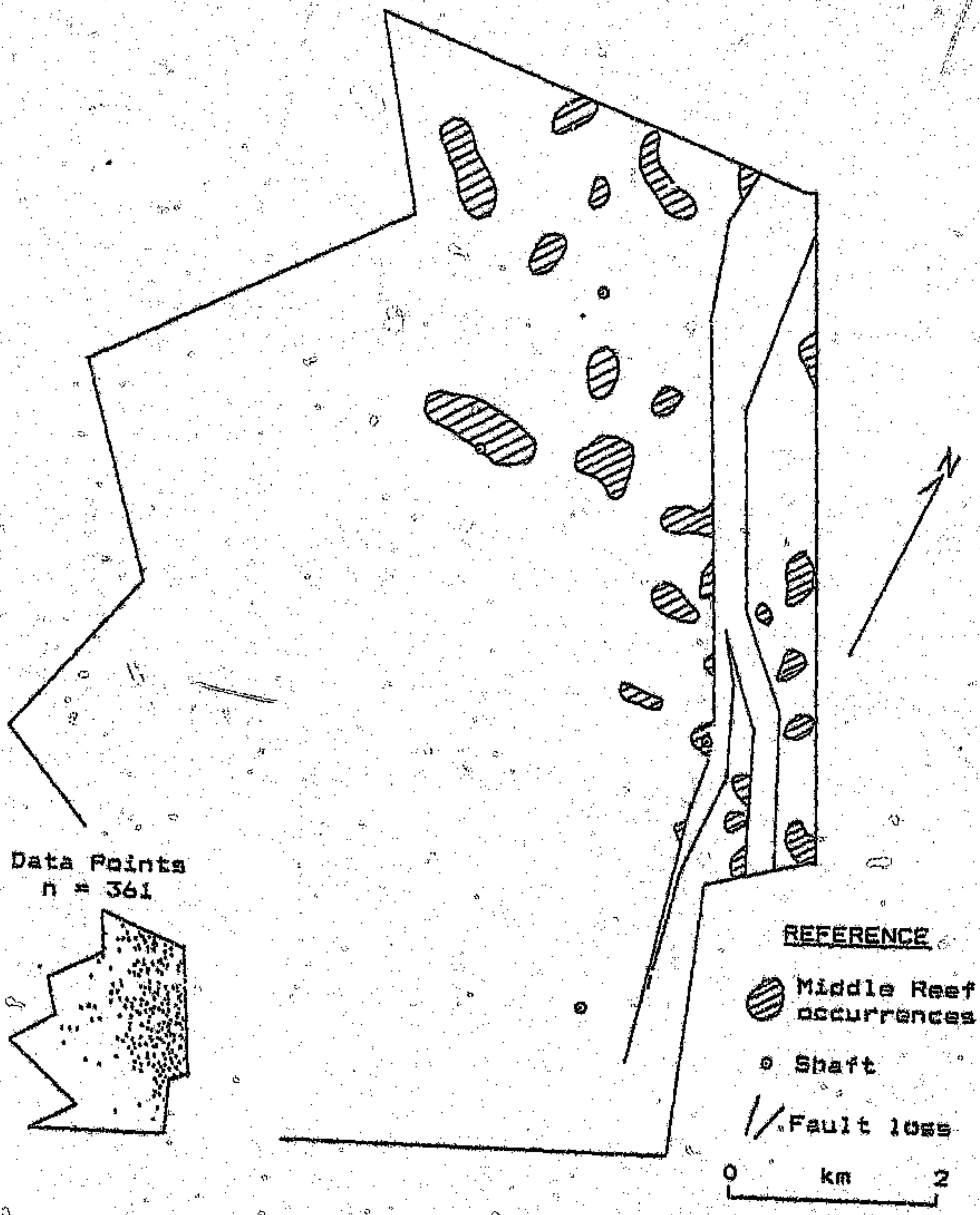


Figure 25 : Plan of occurrences of the Middle Reef.

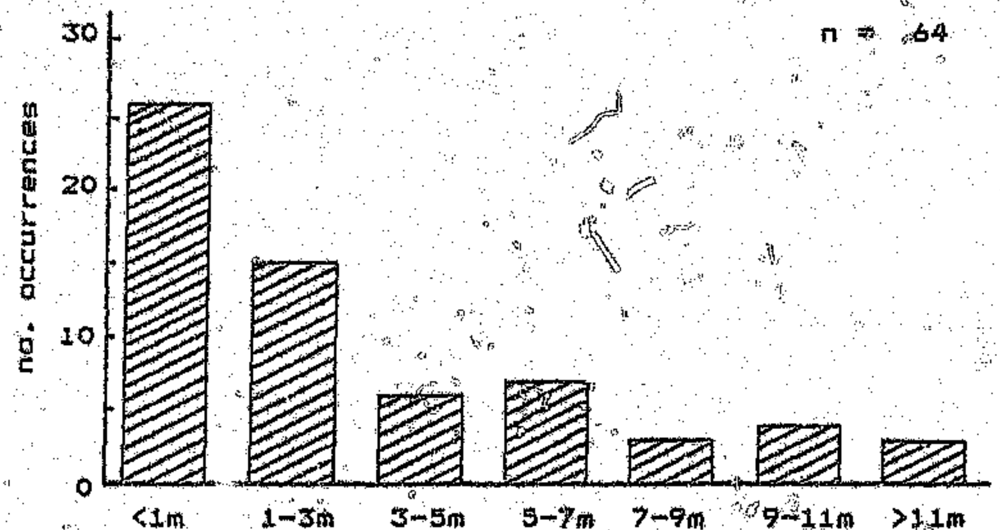


Figure 26 : Height (in metres) of occurrences of the Middle Reefs above the top of the Basal Reef.

particularly where the interval between the two reefs is less than 3m.

The Middle Reefs are characterised by soft sediment deformation structures (Fig. 27). The deformation structures range from small-scale undulations to large-scale diapiric structures which have led to duplication of the conglomerate in places, (Ellis, 1988). The Middle Reefs are generally too narrow and laterally impersistent to be of economic significance on St. Helena Gold Mine. On Unisel Gold Mine the laterally extensive Middle Reefs are widely exploited.

2.3.2.2 Dagbreek Formation

The Dagbreek Formation on St. Helena Gold Mine consists of the Leader Reef and Leader Reef Zone at the base overlain by the Dagbreek Quartzite (Fig. 28). The Upper Shale Marker, which forms the uppermost zone of the Dagbreek Formation to the east of St. Helena Gold Mine, is not developed on St. Helena Gold Mine. The Dagbreek Formation thickens in an easterly direction from the westerly suboutcrop to over 50m thick in the northeastern portion of St. Helena Gold Mine (Fig. 29). Areas of thick Dagbreek Formation occur in the northeast and south-central portion of St. Helena Gold Mine. Sections through the Dagbreek Formation indicate that the Leader Reef is laterally impersistent and of varying thickness making correlation between boreholes tentative (Figs. 12 and 14). Conglomerates higher up in the Dagbreek Formation are also laterally discontinuous. The angle of unconformity between the top of the Dagbreek Formation the base of the overlying "B" Reef along the western margin of St. Helena Gold Mine increases in a northerly direction.

Figure 27 : Slumped Middle Reef of vein quartz clasts, chert clasts and rounded pyrite grains in the Middling quartzite (quartz wacke) of Unisel Gold Mine. The core is drilled vertically, perpendicular to bedding.

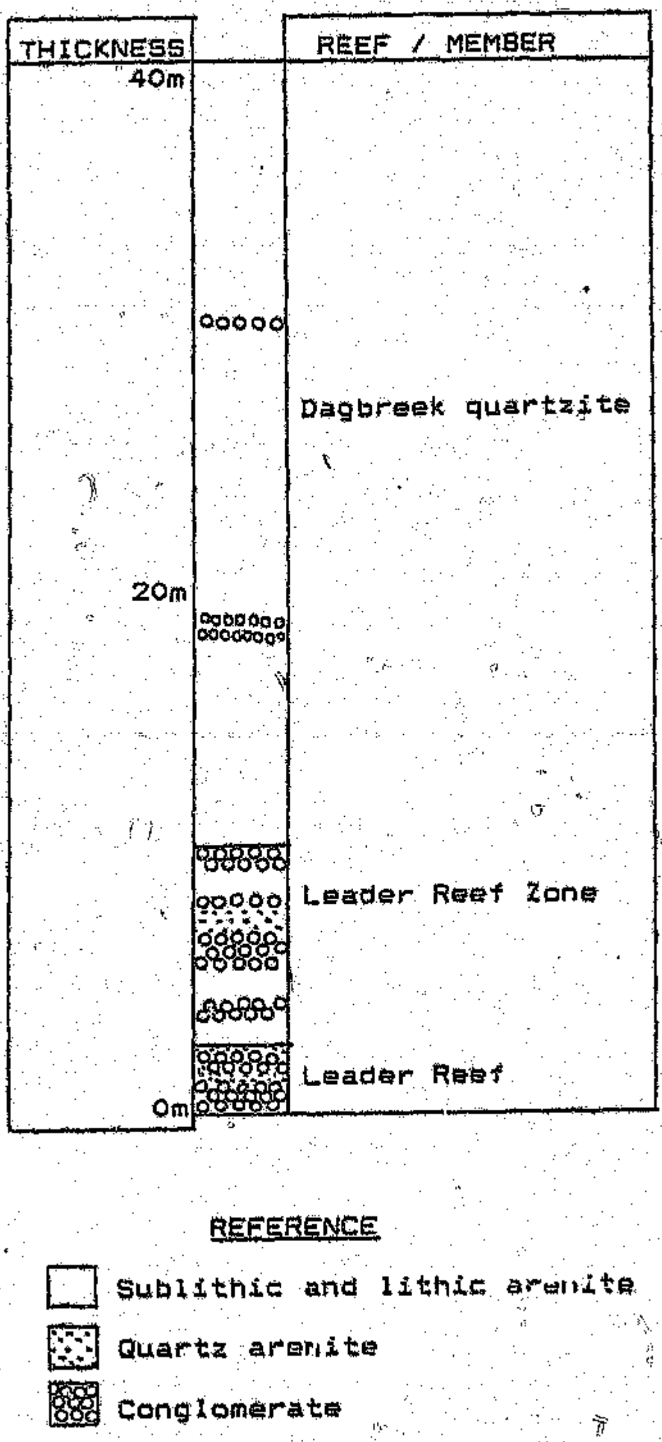


Figure 28 : Idealised stratigraphic column of the Dagbreek Formation, St. Helena Gold Mine.

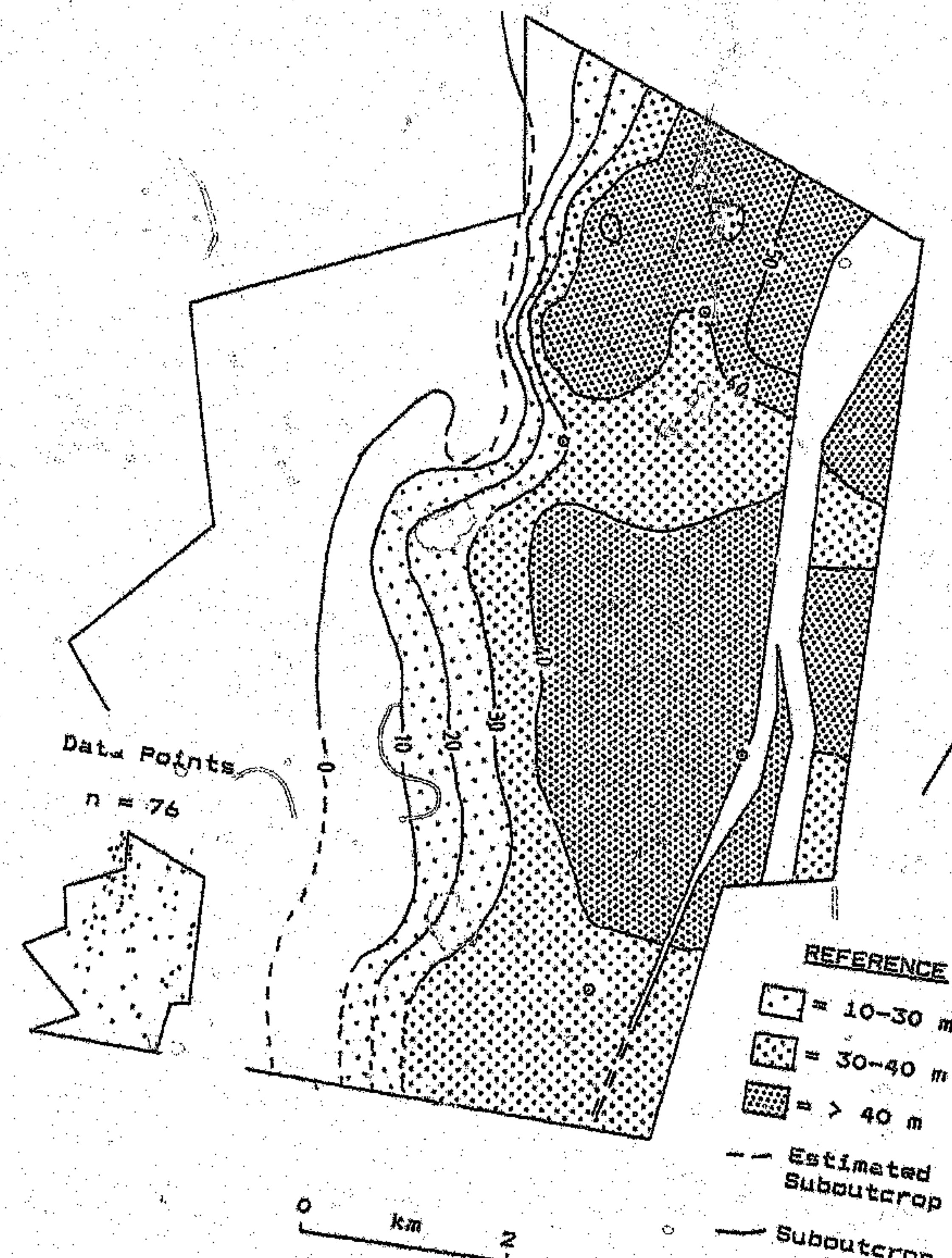


Figure 29 : Isopach map of the Dagbreek Formation. Contour interval = 10m.

2.3.2.2.1 Leader Reef and Leader Reef Zone

The basal conglomerates and arenites of the Dagbreek Formation on St. Helena Gold Mine unconformably overlie the Harmony Formation and are subdivided into the oligomict Alma facies (referred to as the Leader Reef) and the overlying polymict Bedelia facies (referred to as the Leader Reef Zone) (Fig. 30). The basal Alma facies is a pyritic oligomict conglomerate which is overlain by a quartz arenite. The Alma facies is eroded in places by the younger Bedelia facies, with channelised occurrences of the Bedelia facies of 200m wide and 3m deep (Kingsley, 1984). The Leader Reef on St. Helena Gold Mine occurs as two separate north-northeast / south-southwest trending areas and thickens to the east of the Dagbreek fault (Fig. 31).

Where the Leader Reef is not developed either polymict conglomerates or arenites of the Leader Reef Zone (Bedelia facies) rest unconformably on the Harmony Formation. The Leader Reef Zone consists of a maximum of 16m of alternating trough- and planar crossbedded sublithic arenites and small- to medium-pebble massive polymict conglomerates which are frequently channelised. Thin (<50cm) upward-fining oligomict conglomerates and quartz arenite partings also occur. There is a decrease in the textural maturity of the arenites vertically from quartz- to lithic arenite. This textural variation is accompanied by subtle colour changes, from a light- to dark-grey colour at the base to yellow-brown and brown-grey towards the top of the arenite.

The Leader Reef and overlying Leader Reef Zone on St. Helena Gold Mine accounts for approximately 15 percent of gold production. Gold mineralisation of the Leader Reef

Figure 30 : Polymict Leader Reef. Coin diameter = 20mm.

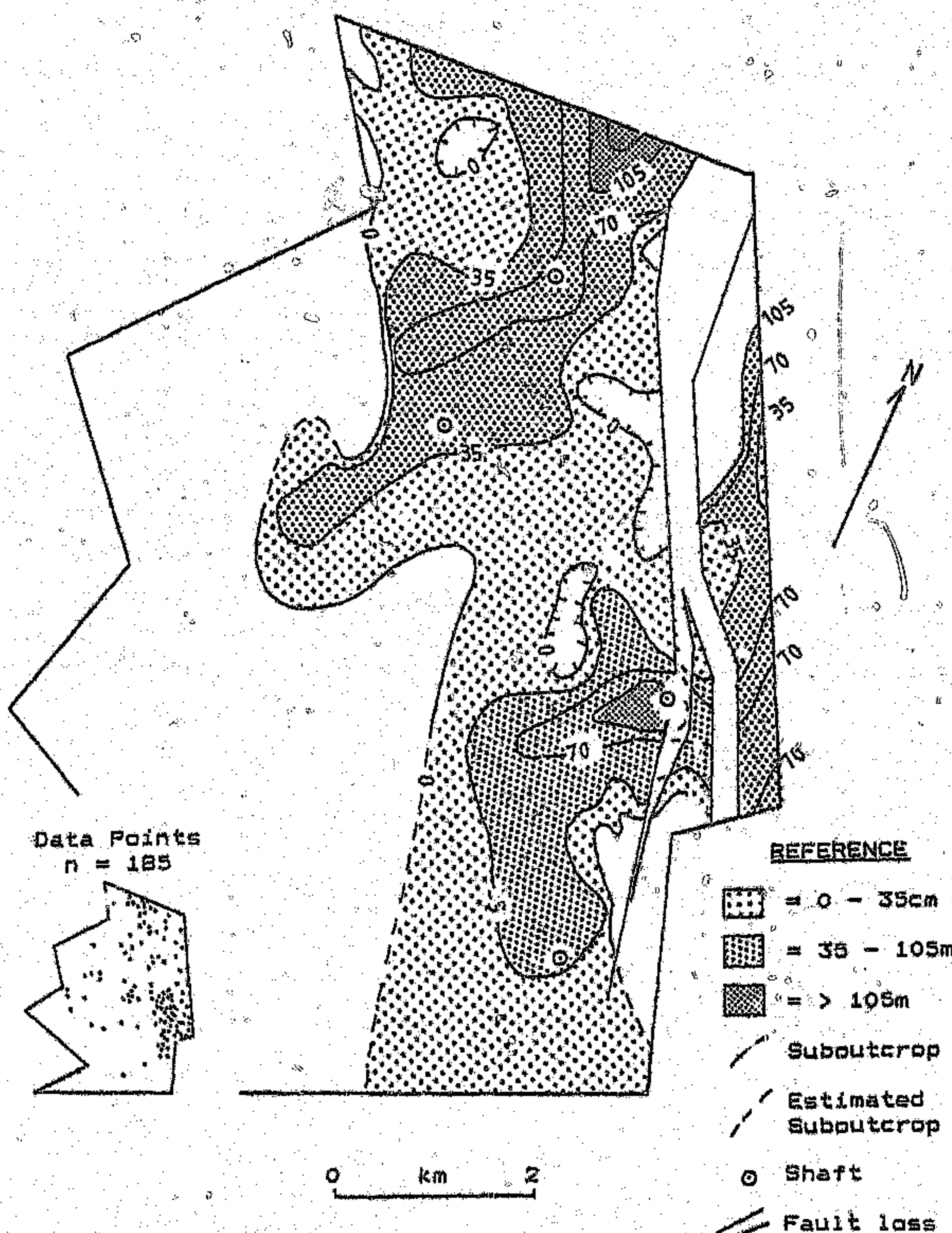


Figure 31: Isopach map of Leader Reef thicknesses. Contour interval = 35cm.

is erratic with scattered values frequently occurring vertically over more than 3m of conglomerate. Increased gold grades are associated with oligomict conglomerates, although gold mineralisation and increased quantities of porous pyrite occur in places in the polymict Leader Reef Zone conglomerates and on foresets in interbedded arenites.

2.3.2.2.2 Dagbreek Quartzite Member

The Dagbreek quartzite is defined as overlying the Leader Reef Zone conglomerates (Kingsley 1984). The Dagbreek quartzite is a yellow-grey lithic- to sublithic arenite containing scattered, impersistent, polymict granule- to medium pebble conglomerates. Clast compositions are similar to those of the Leader Reef. Coarse-grained arenites are texturally more mature and lighter coloured than the yellow-coloured fine-grained arenites. Conglomerate clasts decrease in size and frequency towards the top of the Dagbreek Formation with the upper 5m of the Dagbreek Formation devoid of pebbles. Trough cross-beds with set thicknesses of 5-25cm are common and rare planar crossbed sets of 30cm thick also occur.

2.3.3 Turffontein Subgroup

The Turffontein Subgroup in the western portion of the Welkom Goldfield is a coarsening-upward arenite and conglomerate sequence. The basal predominantly arenitic Spes Bona and Aandenk Formations are collectively known as the Kimberley conglomerates (Jordaan, 1986). Unconformably overlying the Kimberley conglomerates is the conglomeratic Eldorado Formation.

2.3.3.1 Spes Bona Formation

The Spes Bona Formation occurs at the base of the Turffontein Subgroup and has at its base the "B" Reef (Fig. 32). The "B" Reef is characterised by large porous pyrite nodules and a polymict clast composition containing characteristic igneous clasts which are rare in the underlying Johannesburg Subgroup (Table 2). The "B" Reef contains increased gold grades in the vicinity of the Basal Reef suboutcrop in the northwestern portion of St. Helena Gold Mine (J.R.F. Handley, pers. comm.).

The remainder of the Spes Bona Formation comprises yellow- and brown-grey massive and trough crossbedded sublithic- to lithic arenites. The arenites are interbedded with laterally impersistent medium-pebble polymict conglomerates. The Spes Bona Formation coarsens upwards above the "B" Reef, with the ratio of conglomerate to quartzite also increasing upwards (Jordaan, 1986). Pebbly arenites of scattered polymict pebbles with a sublithic arenite matrix are well developed in places in the Spes Bona Formation.

The thickness of the Spes Bona Formation on St. Helena Gold Mine increases erratically in an easterly direction to a maximum of 26m (Fig. 33). The thickness is calculated from the base of the "B" Reef to the base of the Big Pebble Marker, irrespective of the development of the Aandenk Channel. The thickness of the "B" Reef is erratic with the thickest conglomerate development occurring in the central and northern portion of St. Helena Gold Mine (Fig. 34). The "B" Reef is laterally persistent and relatively easy to correlate although the overlying conglomerates within the Spes Bona Formation are

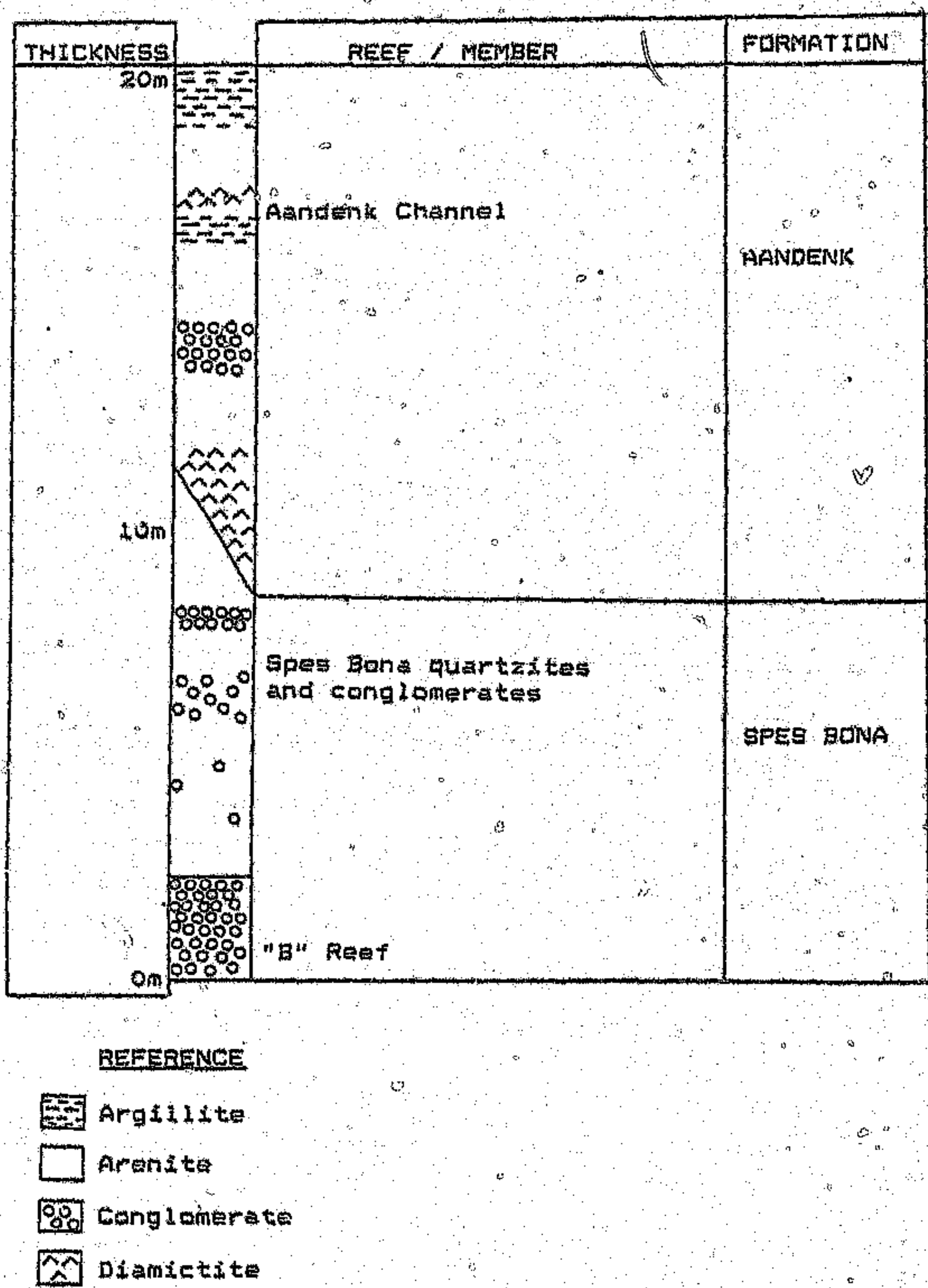


Figure 32 : Idealised stratigraphic column of the Spes Bona Formation and Aandenk Channel, St. Helena Gold Mine.

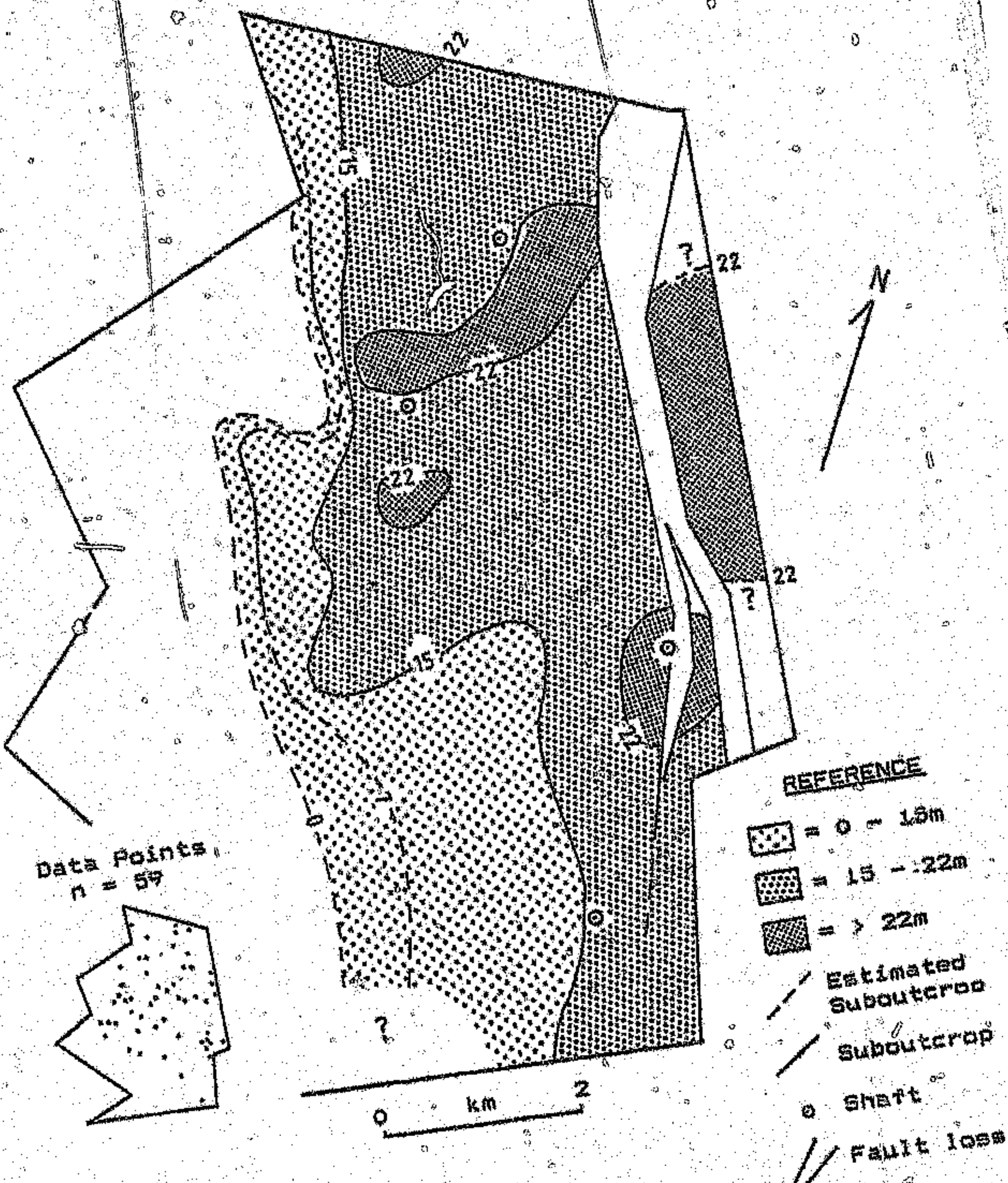


Figure 33 : Isopach map of the Spes Bona Formation. Contours in metres.

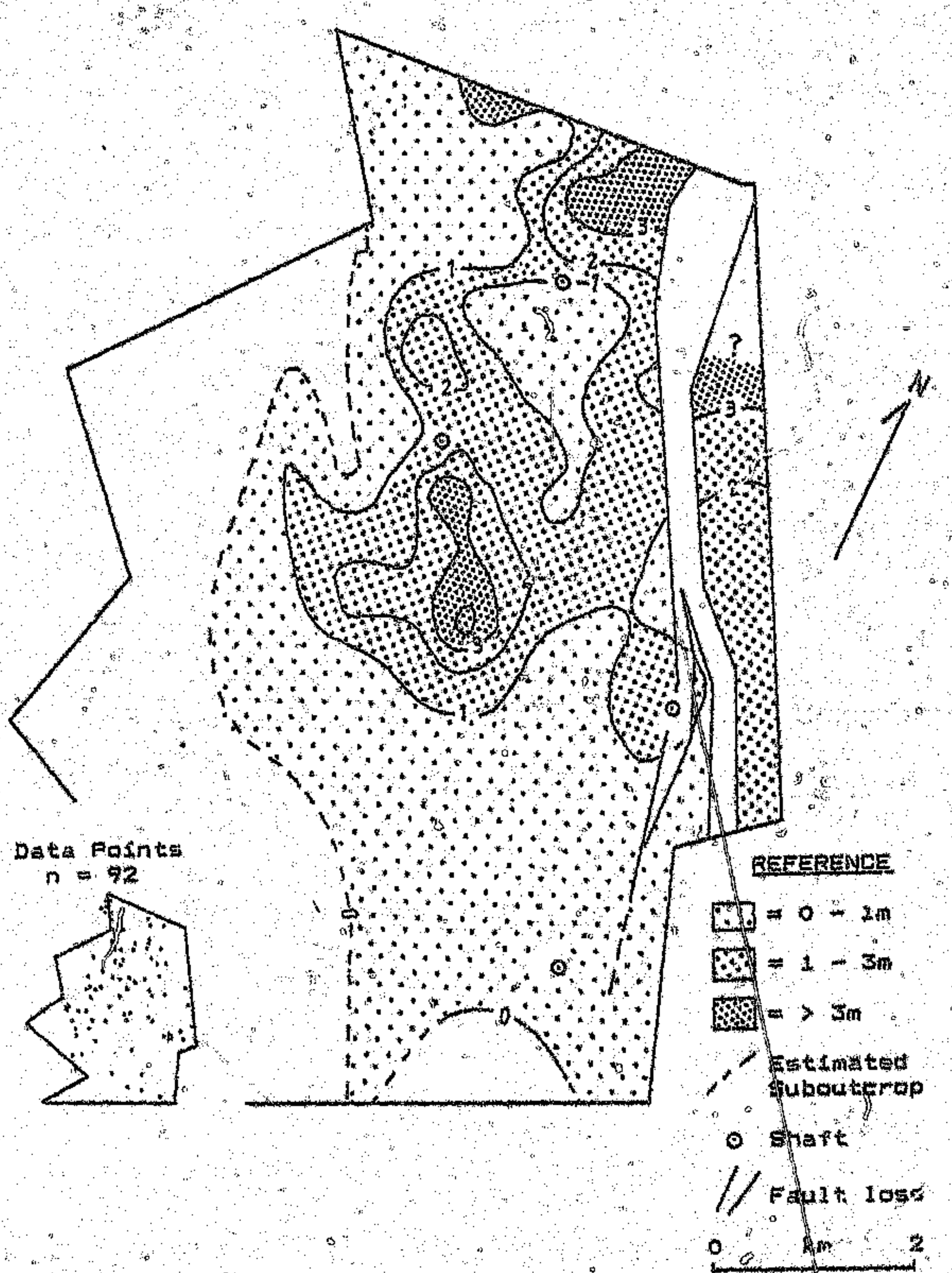


Figure 34: Isopach map of the "B" Reef. Contour Interval = 1m.

laterally impersistent, making correlation of these Spes Bona conglomerates tentative (Figs. 12 and 13).

2.3.3.2 Aandenk Formation

The Aandenk Formation constitutes an overall fining-up sedimentary succession which comprises the lenticular Aandenk Channel at the base overlain by the laterally persistent Big Pebble Marker (Figs. 32 and 35). Overlying the Big Pebble Marker are the Aandenk arenites which contain sporadically developed "A" Reefs (Figs. 12 and 13).

2.3.3.2.1 Aandenk Channel

The Aandenk Channel (K4 Reef, Kimberley channel) is an erosive scour-and-fill channelised feature consisting of conglomerate, arenite, argillite, pebbly mudstones and pebbly arenite. The channel-fill generally comprises a conglomerate at the base overlain by pebbly sublithic arenites, scattered diamictites and argillites. The base of the argillite in the Aandenk Channel is characterised by a diamictite which varies between 10cm to 7m in thickness. The diamictite comprises poorly- sorted small- to large- polymictic pebbles in an argillaceous matrix. The upper portion of the channel- fill comprises interlaminated argillites and rare medium- grained sub-lithic arenites. The argillites consist of interlaminated claystone and siltstone which are tectonically disturbed, containing soft-sediment deformation features such as dewatering and ball-and-pillow structures (Fig. 36).

The geometry of the Aandenk Channel is best illustrated when the Big Pebble Marker is used as datum (section A'-A"; Fig. 37). The Aandenk Channel consists of a series of scour-and-fill features with scattered conglomerates,

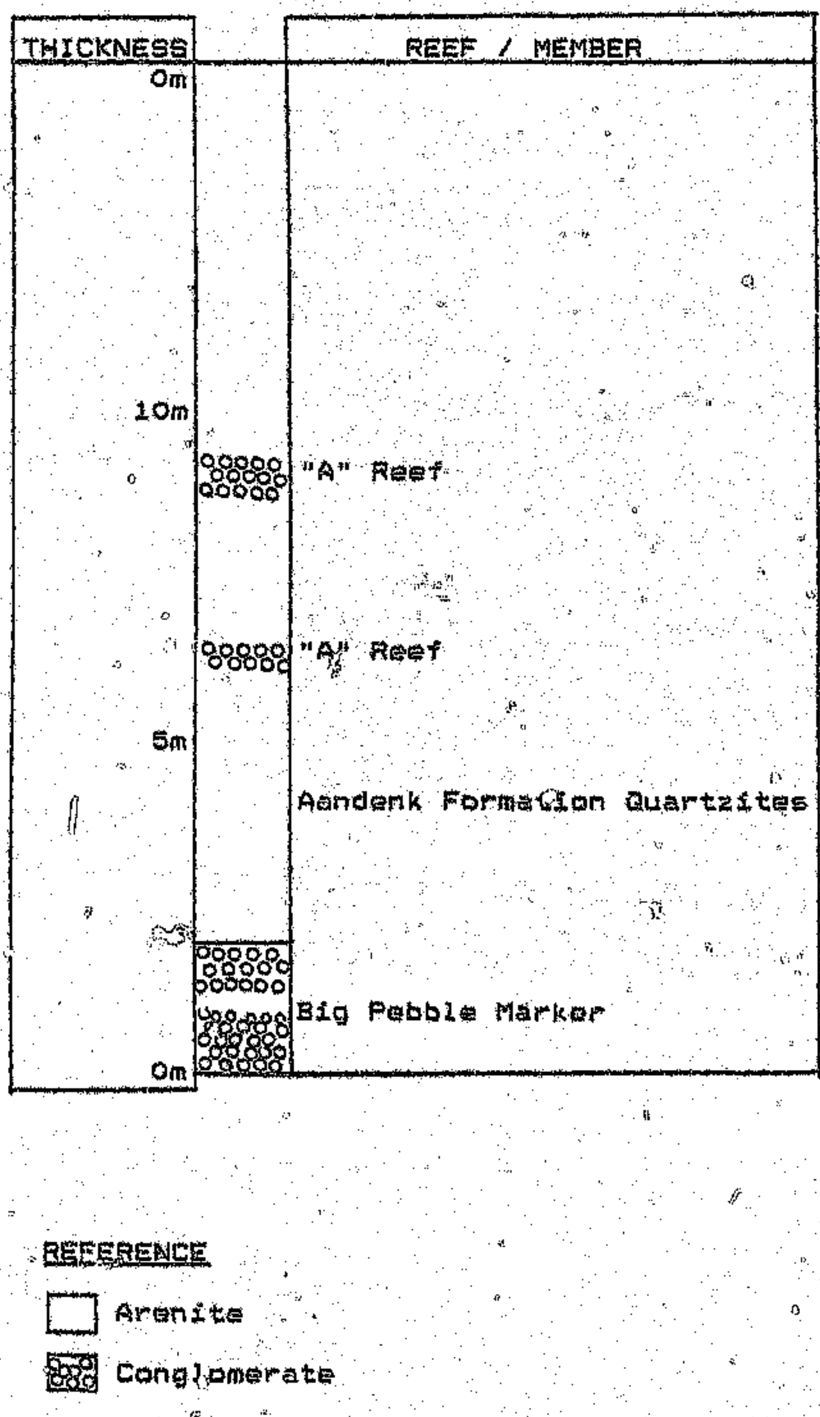


Figure35 : Idealised stratigraphic column of the Aandenk Formation, St. Helena Gold Mine.

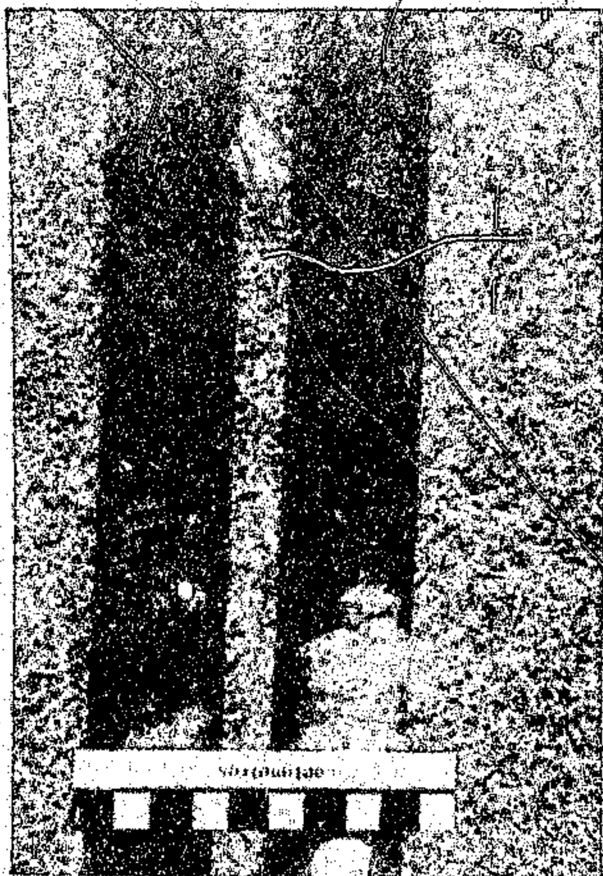


Figure 36 : Slumped siltstone / mudstone interbeds, Aandenk Channel.

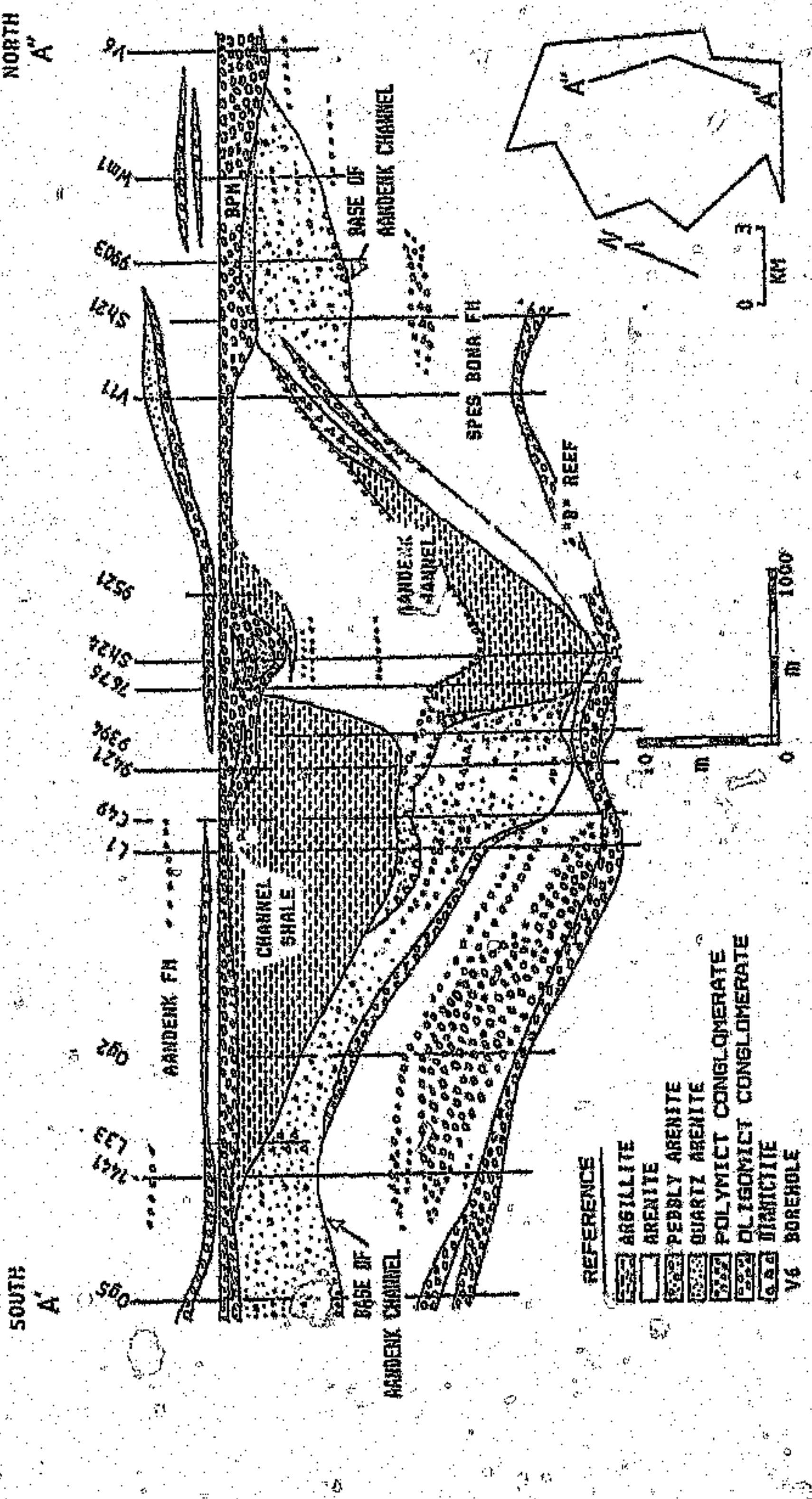


Figure 37 : South / north strike section A'–A" of the AanDenk Channel in the 8 shaft area of St. Helena Gold Mine. The top of the Big Pebble Marker has been used as datum. Note the vertical exaggeration.

diamictites and at least three periods of mudstone channel-fill.

Erosion associated with the Aandenk Channel on St. Helena Gold Mine has removed a maximum of 25m of the Spes Bona Formation. On Unisel Gold Mine the Aandenk Channel is a maximum of 23m deep, and the "B" Reef is removed in places because of Aandenk Channel erosion. The Aandenk Channel occurs in the southern portion of St. Helena Gold Mine, where it is about 4km wide, and over most of Unisel Gold Mine (Fig. 38). To the north of Unisel Gold Mine the Aandenk Channel has also been documented (Sims, 1969). Minor shale-filled channelling in the Aandenk Formation (the Carbonaceous Shale) was documented on President Brand and Western Holdings Gold Mines (Borrego, 1986). On Harmony Gold Mine (formerly Merriespruit), Winter (1957, 1964a) described the Aandenk Channel as a 2km wide and 75m deep linear scour feature which has removed the Big Pebble Marker. Uncertain correlation across the Welkom Goldfield may mean that the Big Pebble Marker on Harmony Gold Mine is incorrectly correlated to Spes Bona Formation conglomerates on St. Helena Gold Mine.

A palinspathic reconstruction of channel in the St. Helena, Unisel and Harmony Gold Mine areas, restoring the right-lateral displacement of the north / south trending Dagbreek, Stuirmanspan and De Bron faults, shows the location of the channel as forming a linear feature across the southern portion of the Welkom Goldfield (Figs. 39 and 40).

On St. Helena Gold Mine no gold or uranium grades of economic importance occur in the Aandenk Channel although

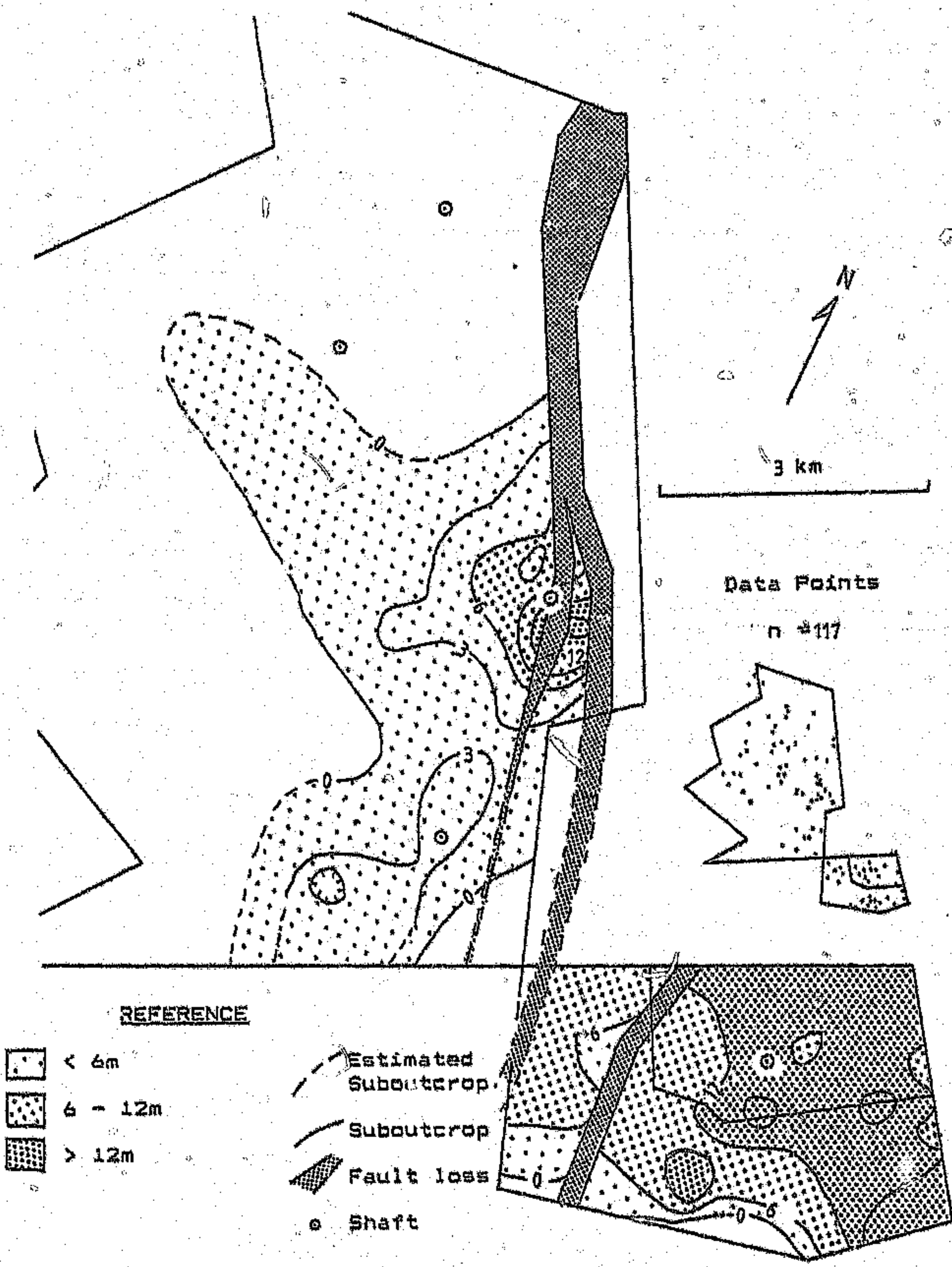


Figure 38 : Isopach map of the Aandonk Channel on St. Helena Gold Mine and Unisel Gold Mine. Contour interval = 3m.

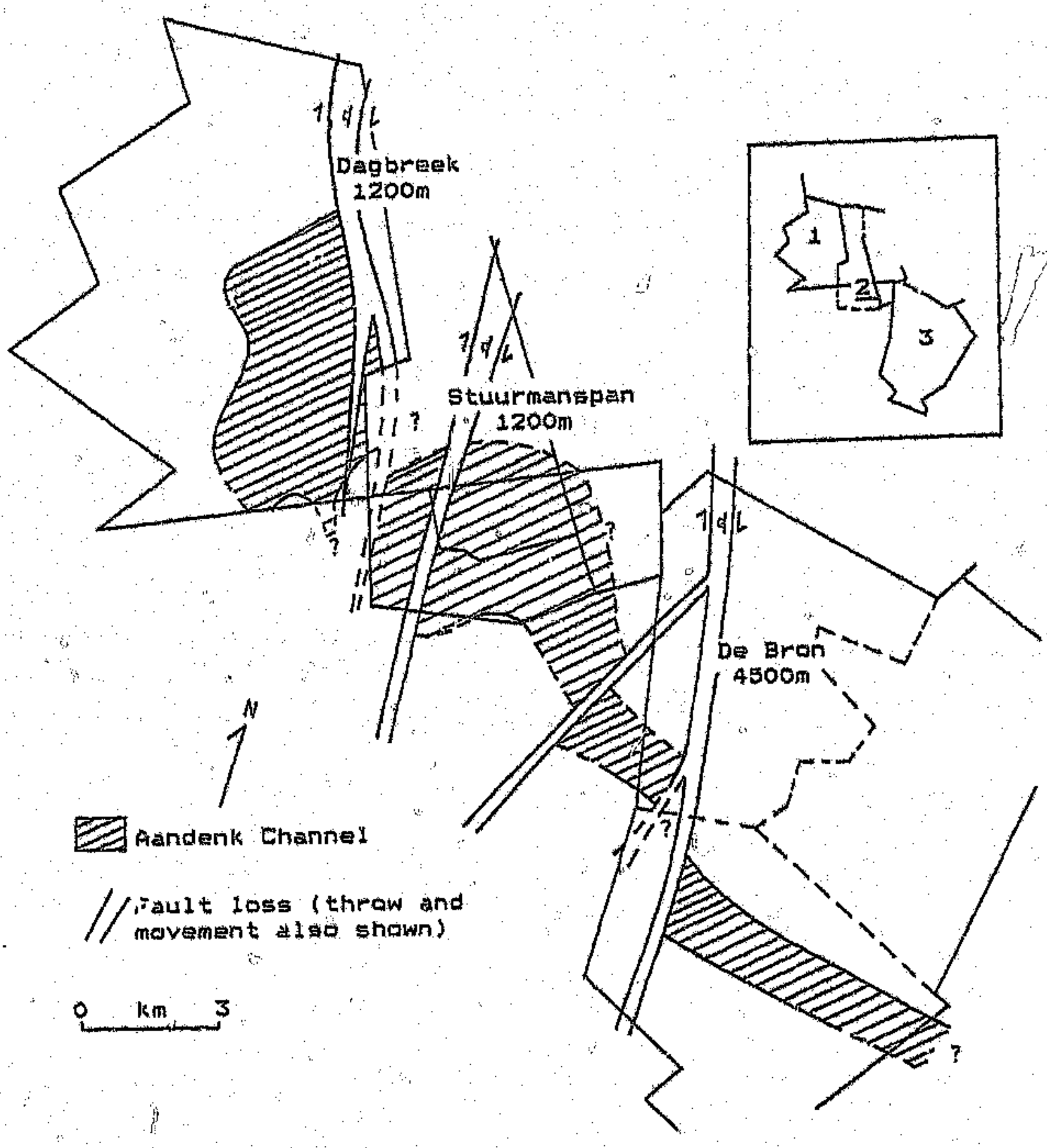


Figure 39 : Location of the Aandenk Channel in the southern part of the Welkom Goldfield. 1) St Helena Gold Mine, 2) Unisel Gold Mine, 3) Harmony Gold Mine. Data from Harmony Gold Mine are from Winter (1957, 1964b).

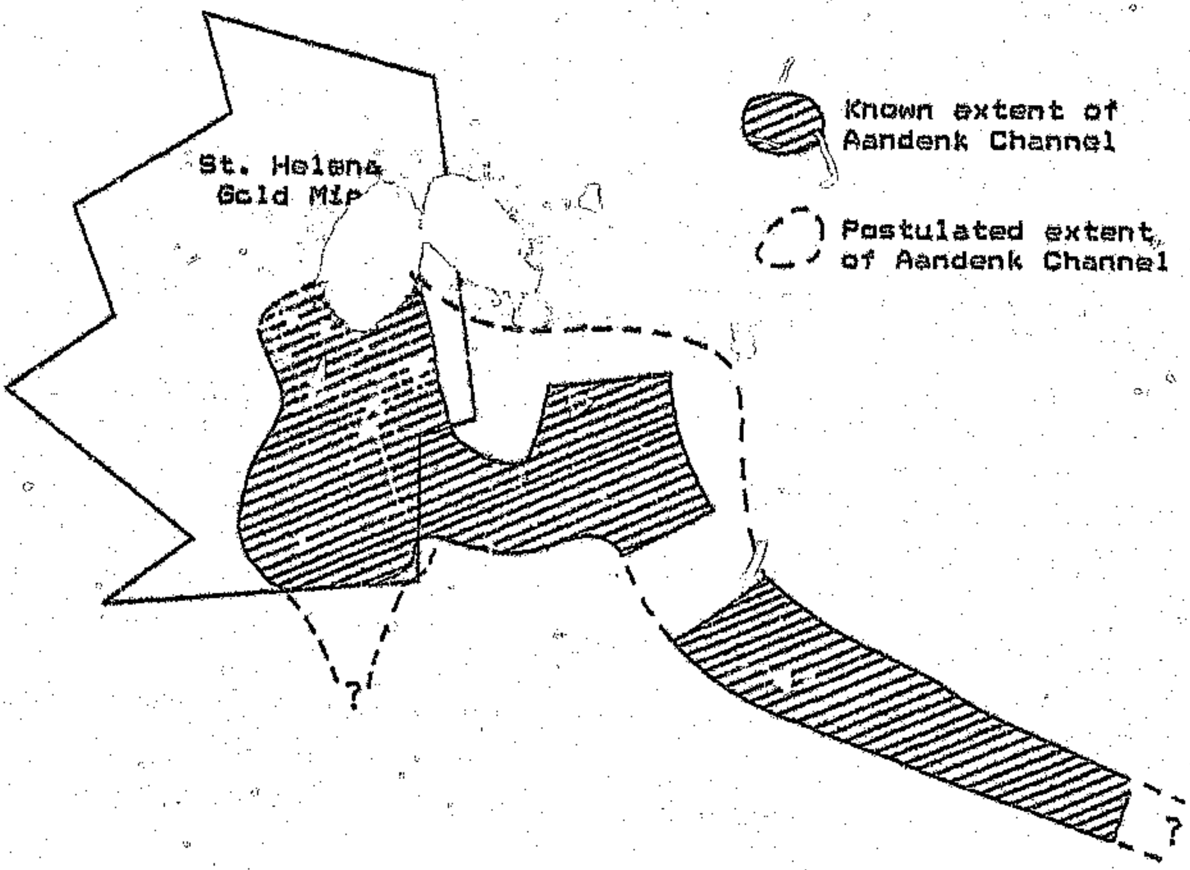


Figure 40 : Palinspathic reconstruction of Aandenk and Spes Bona age channels in the southern part of the Welkom Goldfield (Data are from Fig. 39).

both round pyrite and oligomict conglomerates do occur in the channel.

2.3.3.2.2 Big Pebble Marker

The oligomict Big Pebble Marker (Big Pebble Conglomerate or BPC) overlies an unconformity at the base of the Aandenk Formation. Underlying the unconformity are either arenites of the Spes Bona Formation or interbedded sublithic arenites and argillites of the Aandenk Channel. The Big Pebble Marker is < 2.5m thick over most of St. Helena Gold Mine with the thickest occurrences in the northern portion of the mine (Fig. 41). To the east of the Dagbreek fault on St. Helena Gold Mine the Big Pebble Marker thickens, with occurrences further east on President Brand Mine being polymict and up to 17m in thickness (King, 1986).

2.3.3.2.3 Aandenk arenites

The remainder of the Aandenk Formation comprises massive and trough crossbedded sublithic- to lithic arenites and rare, laterally impersistent, small- to medium-pebble polymict conglomerates. The conglomerates fine upwards in clast size and occur predominantly near the base of the Aandenk Formation, resulting in a generally fining-up sequence. Rare occurrences of interlaminated siltstone and claystone in the Aandenk arenites occurs in the northwestern portion of St. Helena Gold Mine, together with a locally-developed 30cm thick diamictite. A pebbly arenite also occurs in the vicinity of the "A" Reef.

The isopach map of the Aandenk Formation comprises the stratigraphic interval from the base of the Big Pebble Marker to the base of the Eldorado Formation (Fig. 42).

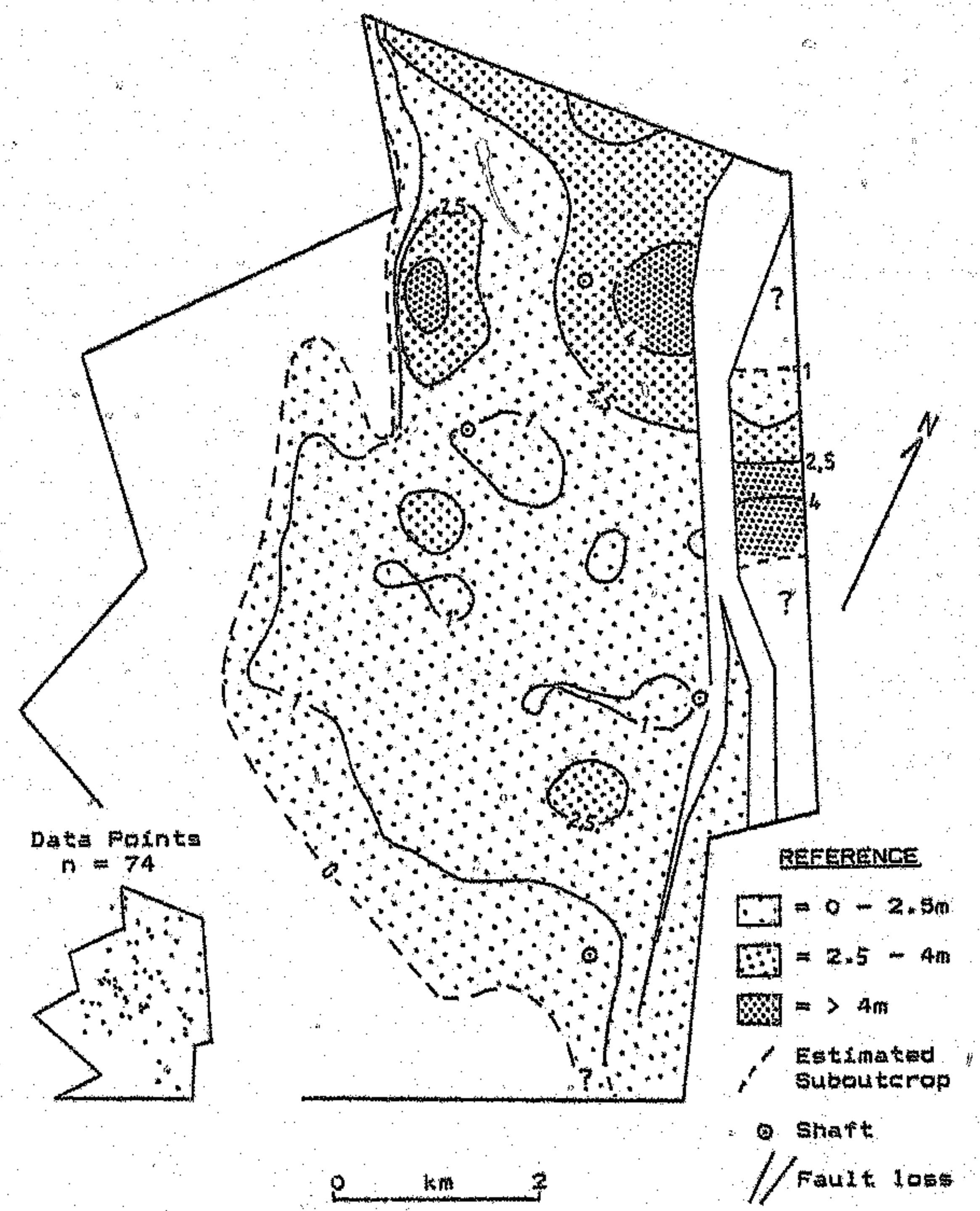


Figure 41 : Isopach map of the Big Pebble Marker (BPM). Contours in metres.

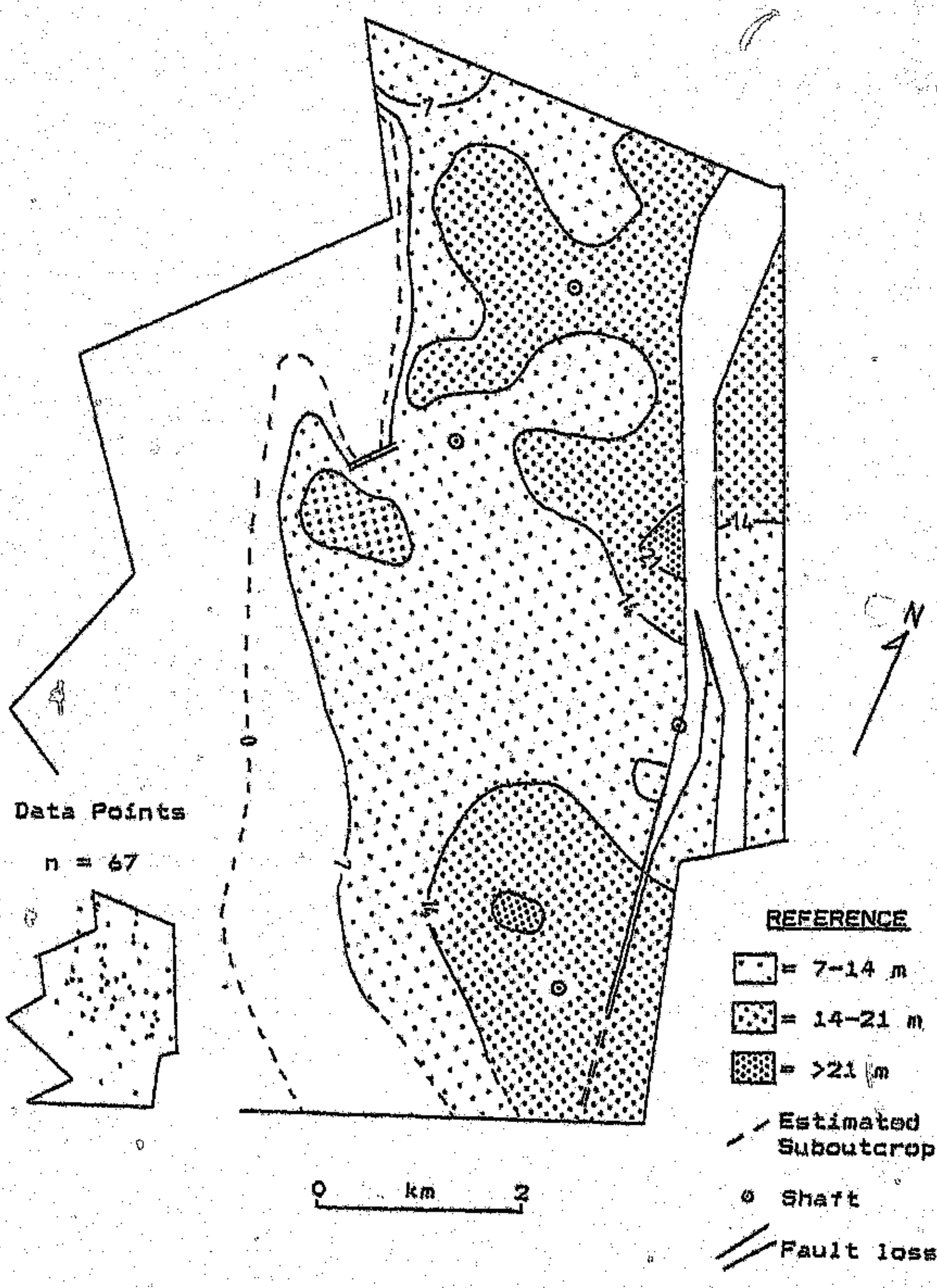


Figure 42 : Isopach map of the Aandenk Formation. Contour interval = 7m.

The Aandenk Formation thickens in a northerly and easterly direction to a maximum of 22m.

2.3.3.2.4 "A" Reefs

The Aandenk Formation contains three impersistent oligomict conglomerates in places in the Welkom Goldfield, classified by Jordaan (1986) as the Lower, Middle and Upper "A" Reef placers. These are laterally equivalent to the Witpan and Uitsig placers identified by Karpeta (1984). On St. Helena Gold Mine the oligomict "A" Reef conglomerates are laterally impersistent and vary in stratigraphic position from above the Big Pebble Marker to 30cm below the contact with the Eldorado Formation. No correlation of the "A" Reefs on St. Helena Gold Mine with those occurring in other parts of the Welkom Goldfield has been possible. The majority of borehole intersections of the "A" Reefs occur within 3m of the top of the Big Pebble Marker with occurrences of conglomerate higher than 6m above the Big Pebble Marker being rare (Fig. 43). The occurrence of conglomerates at varying stratigraphic heights suggests that the "A" Reefs comprise several lenticular units, the distribution of which have been plotted (Fig. 44).

The "A" Reefs are exploited in various areas of the Welkom Goldfield, however on St. Helena Gold Mine the "A" Reefs are not exploited as they contain low gold and uranium values. Higher gold grades are contained in the "A" Reefs on St. Helena Gold Mine only where the "A" Reefs closely overlie the Big Pebble Marker.

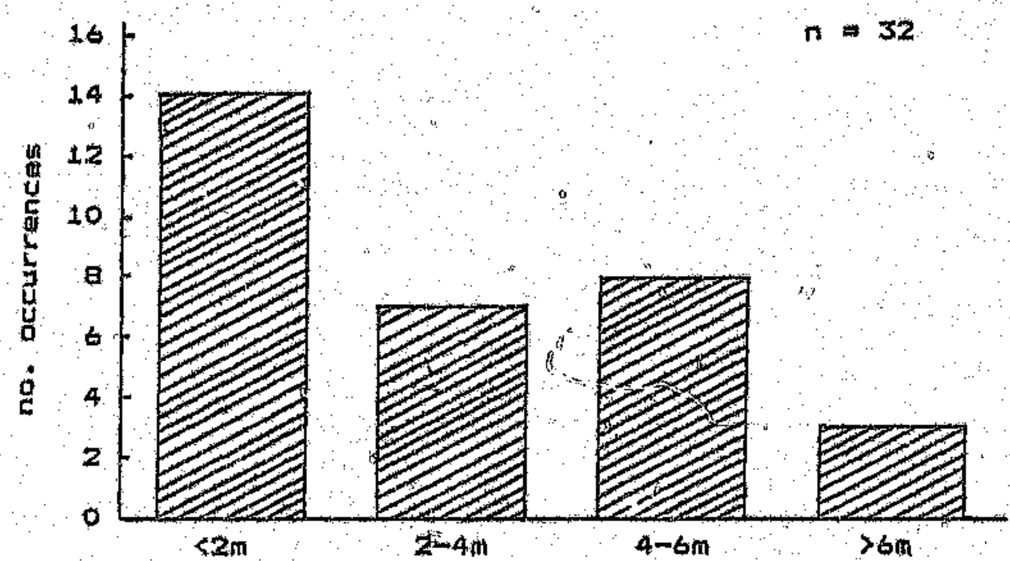


Figure 43 : Height (in metres) of occurrences of the "A" Reefs above the top of the BPM.

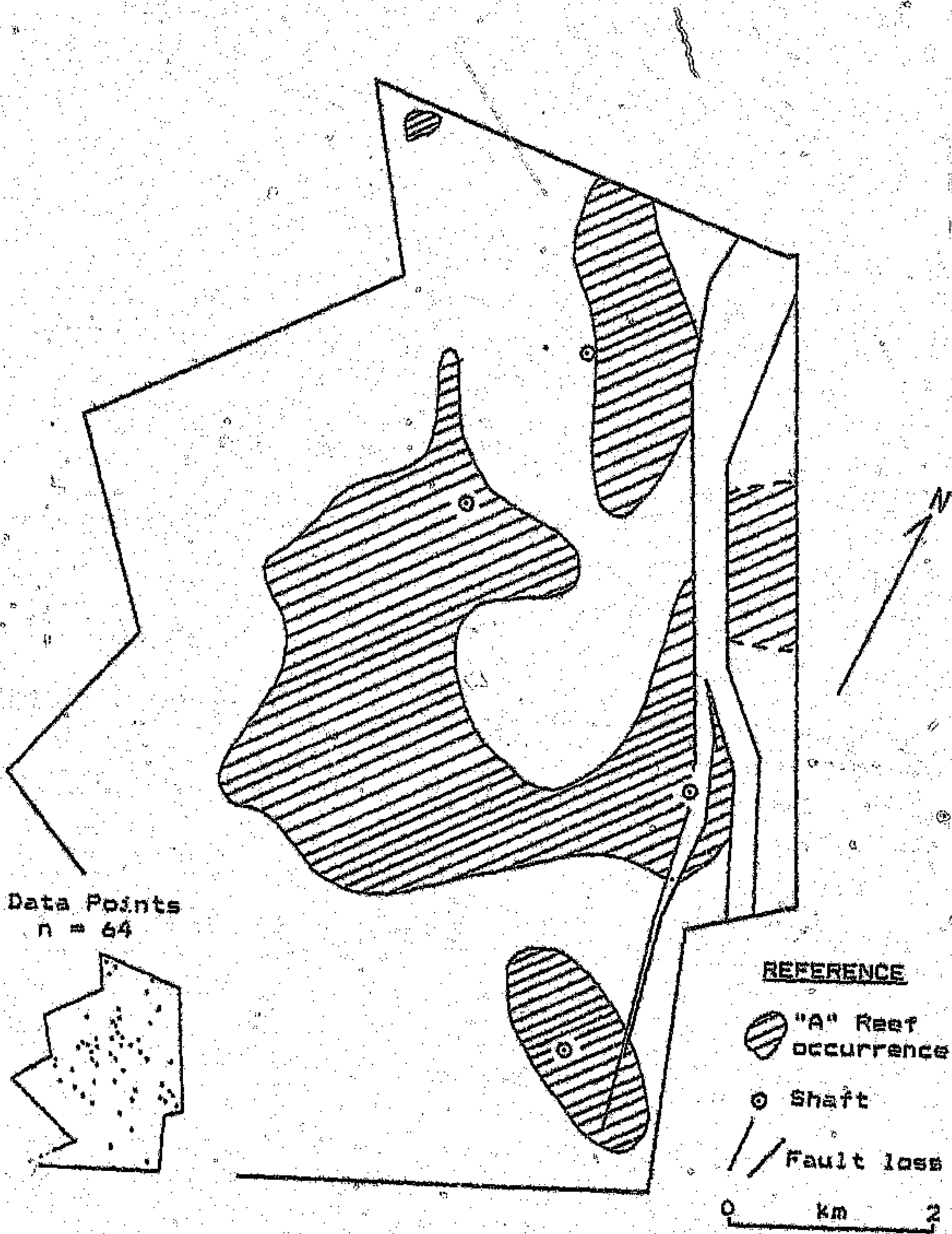


Figure 44 : Plan of occurrences of the "A" Reef.

2.3.3 Eldorado Formation

The Eldorado Formation (historically referred to as the Ventersdorp Sediments) unconformably overlie the Aandenk Formation. The Eldorado Formation in the Welkom Goldfield consists of two distinct facies (Kingsley, 1987):

a) The Loraine (northern) facies of predominantly quartz arenite and oligomict conglomerates.
b) The Welkom (southern) facies of predominantly polymict conglomerates and lithic- and sublithic arenites. The Welkom facies occurs on Western Holdings Gold Mine, St. Helena Gold Mine and the area to the south and east of St. Helena Gold Mine.

Both the Loraine and Welkom facies of the Eldorado Formation are characterised by rapid lateral facies variations from cobble sized conglomerates to arenites over only 5km down the depositional slope. The nomenclature used for the Welkom facies of the Eldorado Formation on St. Helena Gold Mine is restricted to the unconformity-based VS 1, VS 2-4 and VS 5 zones (Table 3).

The Eldorado Formation thins in a westerly direction across St. Helena Gold Mine from over 300m thick in the east to a position where post-Ventersdorp erosion has removed the entire Eldorado Formation (Fig. 45). A southeast / northwest cross-section of the Eldorado Formation (section B-B'; Fig. 46) illustrates the general thinning of the Eldorado Formation in the northern portion of St. Helena Gold Mine. Despite the rapid lateral facies variations which occur, particularly in the VS 1 to VS 4 zones, lithostratigraphic subdivision and the correlation of conglomerates on a broad scale are possible.

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Borchers and White (1943)	Winter (1957)	Winter (1964b)	SACS (1980)	Minter et al. (1986)	Kingsley (1987)	This work; St Helena Gold Mine
VS 1	Boulder Beds	Boulder Beds	Uitkyk Member	Uitkyk Boulder Member	Uitkyk Member	VS 1 (240m)
	EA Zone	EA Zone			EA Zone	
VS 2	EB	EB ?——?		Van Den Heeversrust Member	Van Den Heeversrust Member	VS 2-4 (145m)
VS 3		EC	Van Den Heeversrust Member			
VS 4	EC	ED	Rosedale Member	Rosedale Member	Rosedale Member	
	ED					
VS 5						VS 5 (15m)

<u>Table 3</u>: Stratigraphic correlation and nomenclature used for the Eldorado Formation in various parts of the Welkom Goldfield. The table also shows the average thickness of sediments in the study area (not to scale).

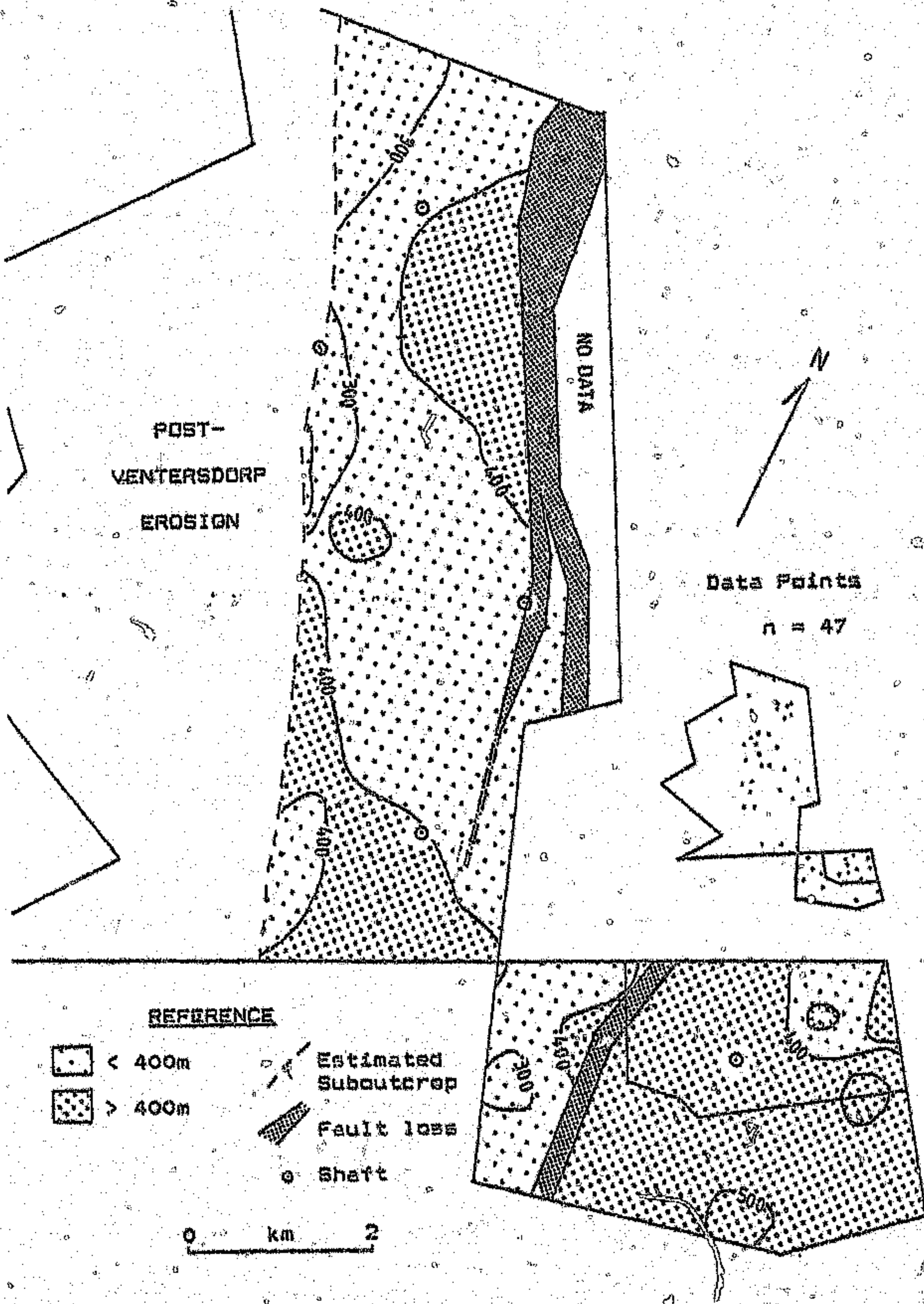
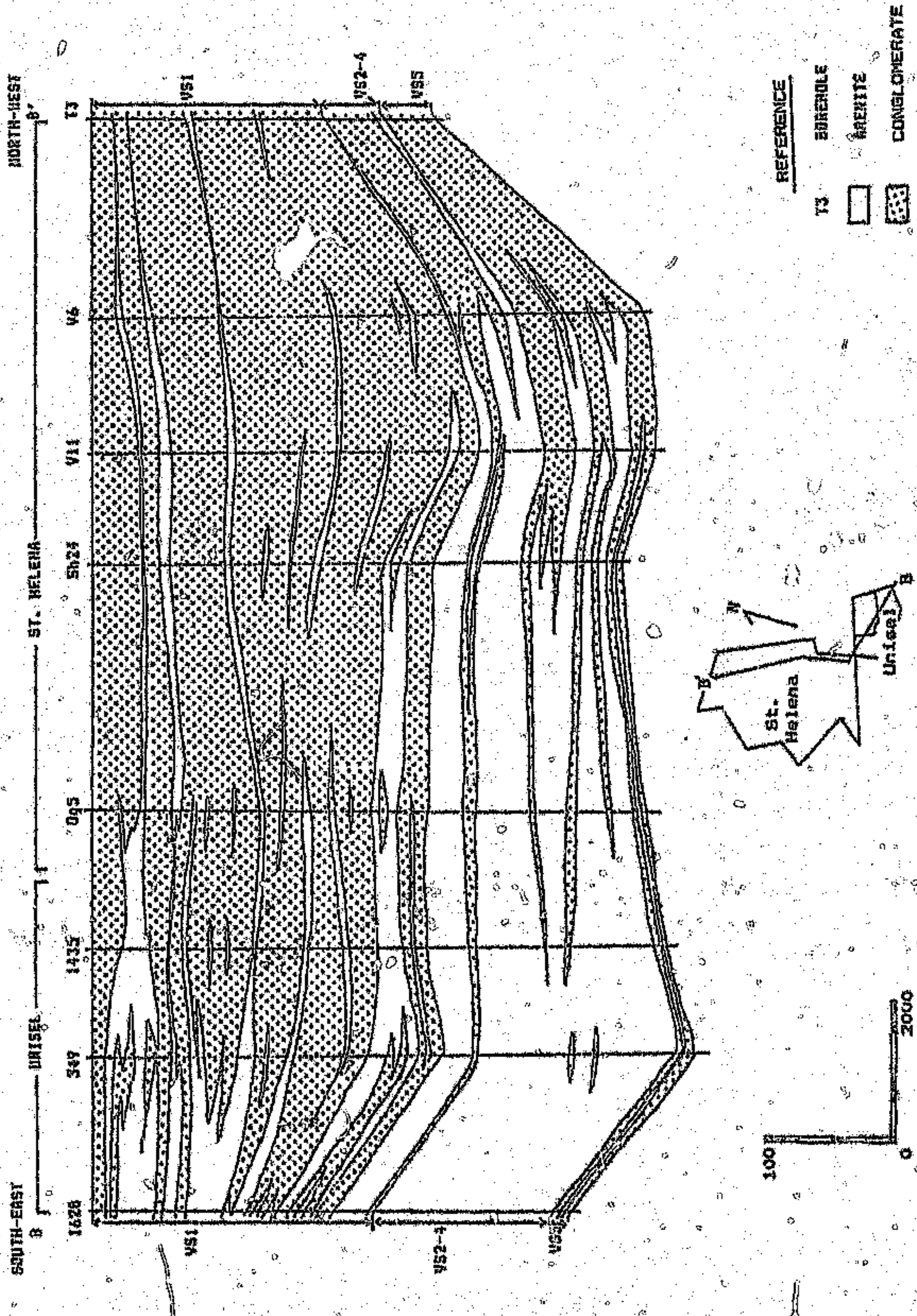


Figure 46 : Isopach map of the Eldorado Formation. Contour interval = 100m.



<u>Figure 46</u> : South-east / north-west section B-B' of the Eldorado Formation. The top of the Eldorado Formation has been used as datum. Note vertical exaggeration.

The Eldorado Formation changes from comprising of >95 percent conglomerate in the northwestern portion of St. Helena Gold Mine to <40 percent conglomerate in the southeastern portion of Unisel Gold Mine (Fig. 47). On St. Helena Gold Mine the Eldorado Formation also has a broadly upward-coarsening motif, from intercalated arenites and conglomerates in the VS 5 and VS 2-4 zones to the large-pebble conglomerates of the VS 1 zone. On a smaller scale, however, both normally- and inversely-graded conglomerates occur throughout the Eldorado Formation on St. Helena Gold Mine. The Eldorado Formation is characterised by a distinct dark-green to black matrix and colourful polymict clast assemblage, primarily of yellow and black metapelite clasts and white vein quartz clasts. On Unisel Gold Mine the Eldorado Formation is lighter green in colour than on St. Helena Gold Mine.

The Eldorado Formation in the Welkom Goldfield generally contains low gold values but on Loraine Gold Mine as many as 18 of the oligomict Rainbow Reefs are locally exploited (Minter et al., 1986). The texturally immature nature of the Eldorado Formation and the lack of major erosional unconformities in the vicinity of St. Helena Gold Mine make the prospect of economic mineralisation poor. On both St. Helena and Unisel Gold Mines low gold grades occur throughout the Eldorado Formation (< 1g/t) with anomalous values occurring only in the VS 5 Reef at the base of the VS 5 zone.

2.3.3.3.1 Zone VS 5

The VS 5 zone is the lowest stratigraphic unit of the Eldorado Formation and has at its base, in places, the VS 5 Reef (Rosedale placer, EBC, Beatrix Reef). The oligomict VS 5 Reef is 0-3m thick and is separated from

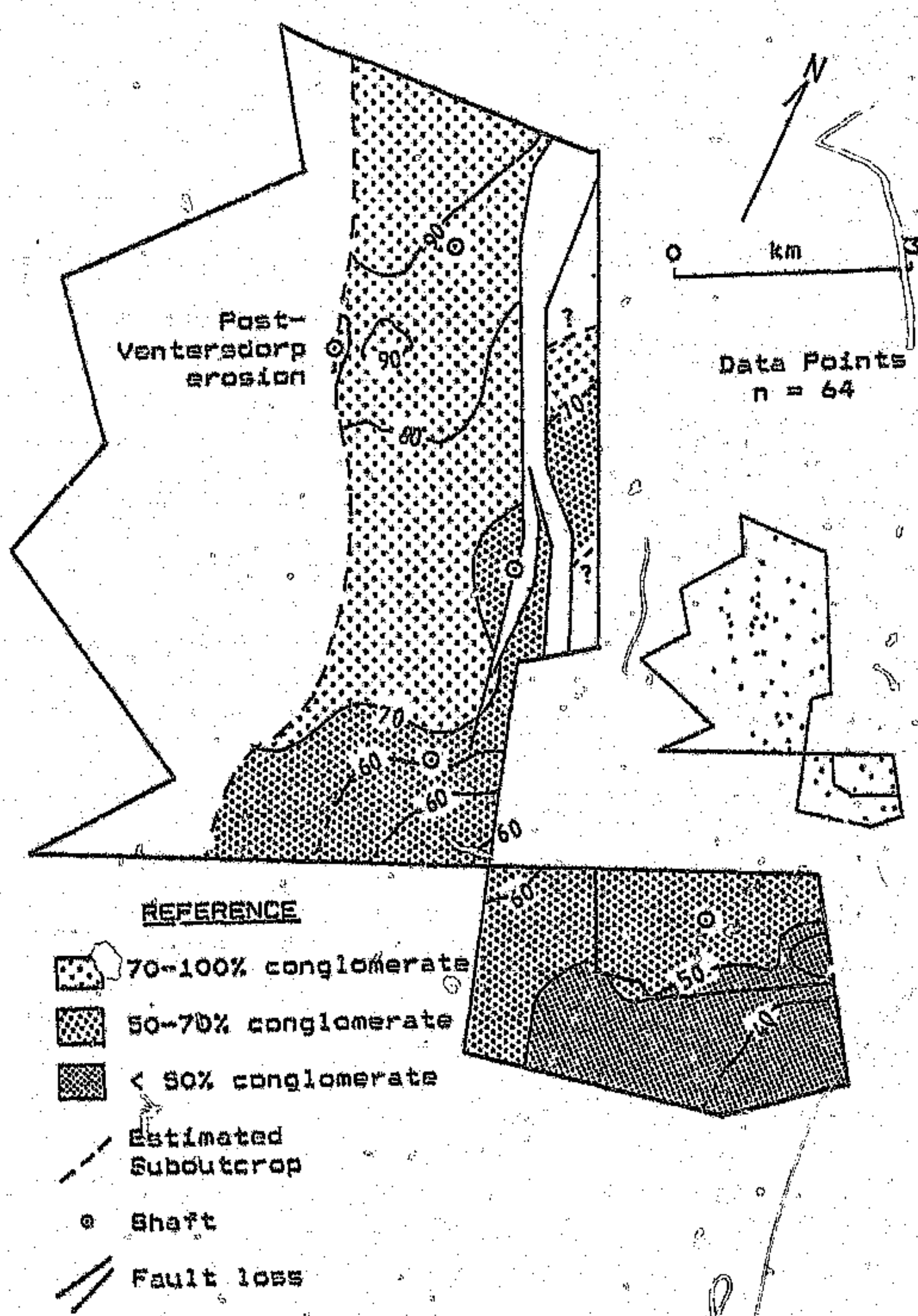


Figure 47 : Conglomerate / arenite ratio (in %) of the Eldorado Formation. Contour interval 10%.

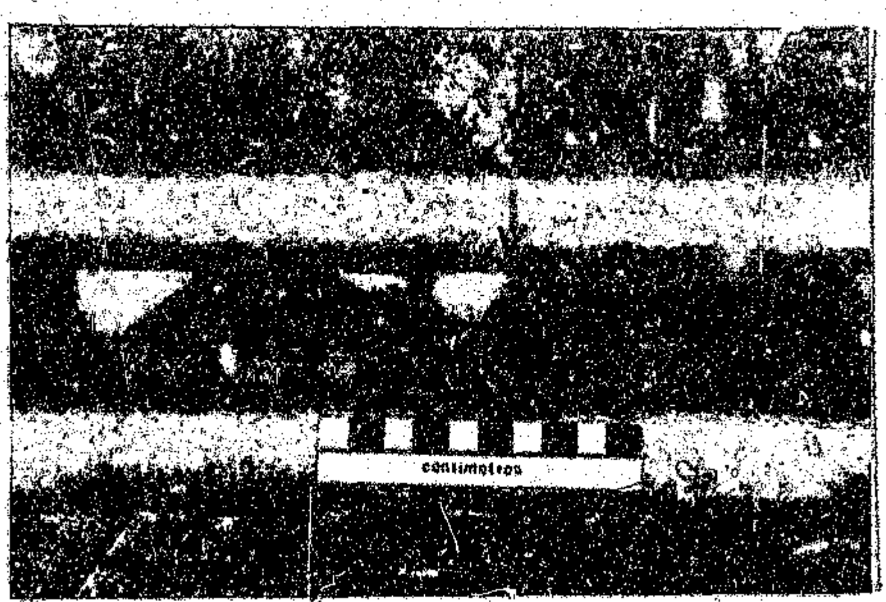
the overlying Eldorado Formation by an unconformity (Kingsley, 1987, J.H. Genis, pers. comm., 1989). The contact of the VS 5 zone with the underlying Aandenk Formation is unconformable on a basin-wide scale.

The VS 5 zone on St. Helena Gold Mine is dark-grey in colour, compared to the yellow-grey arenites of the underlying formations (Fig. 48). Clast types are colourful and the clast assemblage is polymict (Fig. 49a). The VS 5 is texturally more immature, has larger pebbles and a greater proportion of quartz and chert clasts than the overlying VS 2-4 zone (Fig. 50). The VS 5 zone is overlain by the first major arenite of the VS 2-4 zone. In the northern portion of St. Helena Gold Mine the conglomeratic nature of the entire Eldorado Formation makes the subdivision of the VS 5 and VS 2-4 zones difficult.

2.3.3.3.2 Zone VS 2-4

The VS 2-4 zone consists of alternating arenites and conglomerates over much of St. Helena Gold Mine. In the northern portion of St. Helena Gold Mine the zone is a dark-grey poorly-sorted medium- to large-pebble polymict conglomerate (Fig. 51). In the Unisel area the VS 2-4 zone is predominantly a light-grey, crossbedded coarse-grained arenite with rare conglomerates. Trough cross-bedded sets of 5-30cm thick with cosets of 60-80cm thick and planar sets 5-50cm thick occur. Fining-upward arenite to siltstone units of 1-4cm thick, diamictites of 3-10cm thick and slumped siltstones are also present.

Texturally, the VS 2-4 zone is the most mature of the three Eldorado Formation subdivisions in the study area, with a higher percentage of chert and quartz clasts but



<u>Figure 48</u> : Unconformable contact between the conglomeratic VS 5 zone of the Eldorado Formation (dark-grey) and the the arenitic Aandenk Formation (yellow-grey). Note the abrupt colour change from dark-grey to yellow-grey across the unconformity (arrowed).

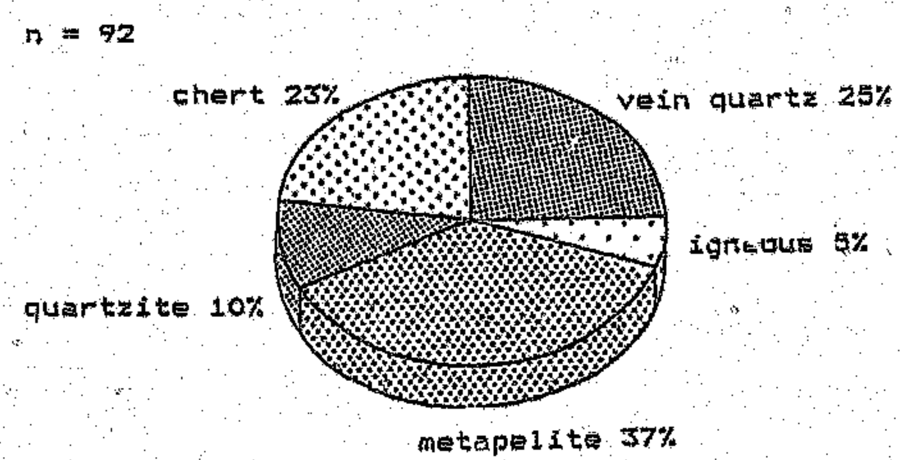


Figure 49 a

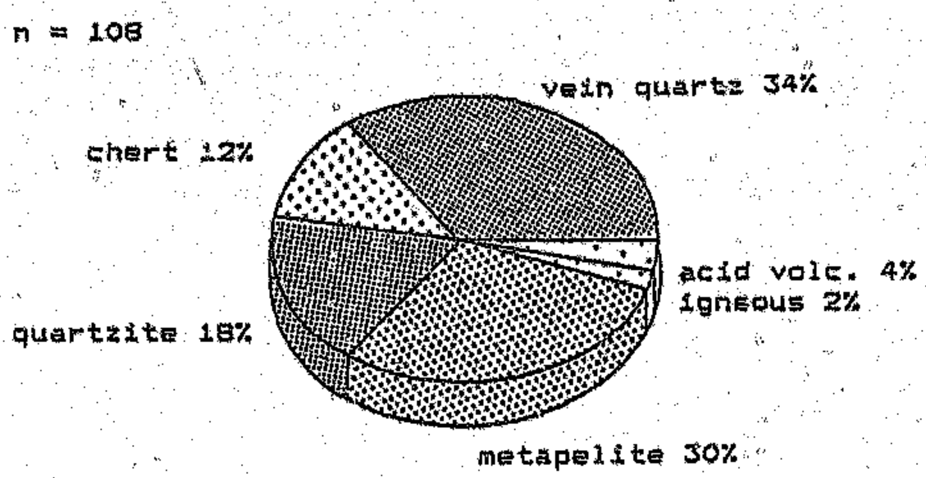


Figure 49 b

Figure 49 : Pie chart of clast compositions, Eldorado Formation. a) VS 5 zone. b) VS 2-4 zone.

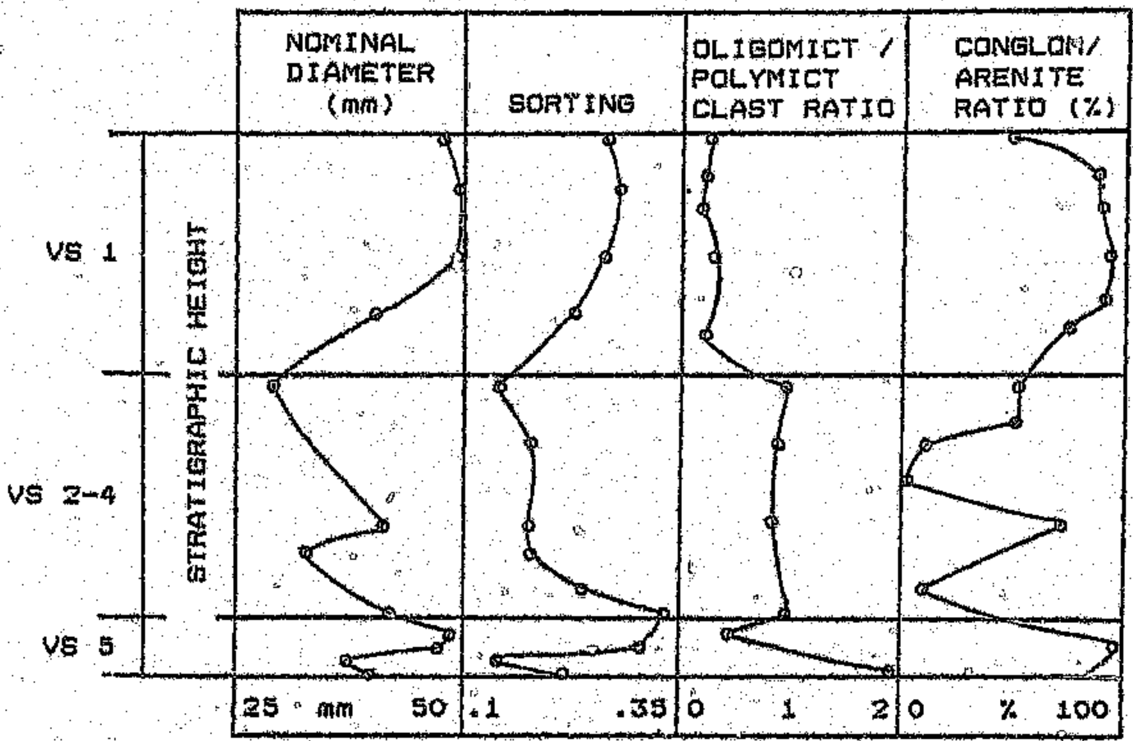


Figure 50 : Statistical parameters for clasts of the Eldorado Formation. Nominal diameter = (long axis x intermediate axis)½. Sorting (c) = standard deviation/ mean of clast size. Data from boreholes Sh24 and 1476.

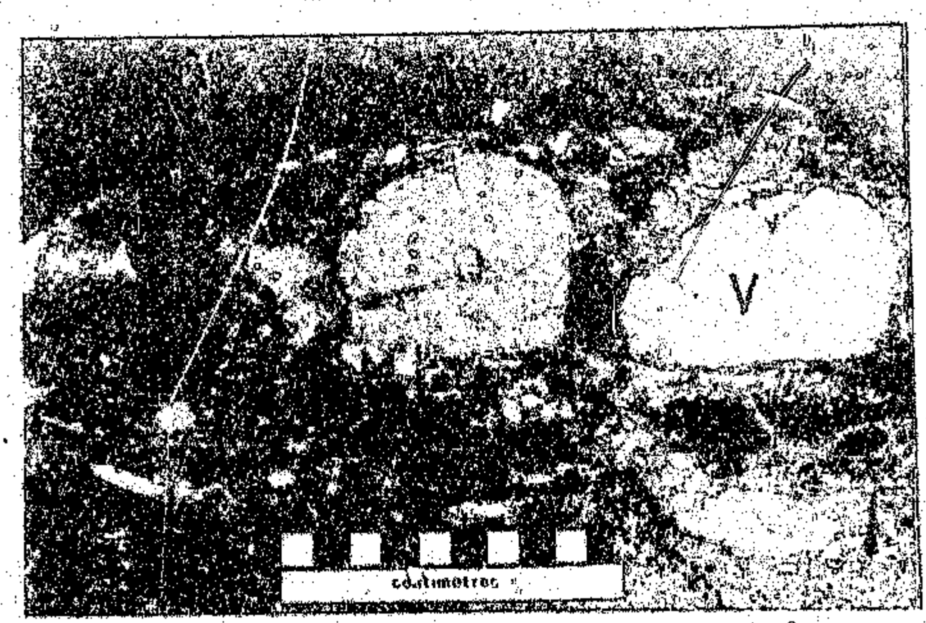


Figure 51 : Poorly sorted VS 4 conglomerate of the Eldorado Formation, southern area of St. Helena Gold Mine. Clast types are quartz arenite (Q), vein quartz (V), black and white chert (C) and yellow and black metapelite (M).

with similar clast compositions to the under- and overlying areas (Fig. 49b). Smaller pebbles, increased sorting and a greater proportion of arenites than either the VS 1 or VS 5 zones occur (Fig. 50).

A persistent polymict conglomerate and overlying sub-lithic arenite form a marker of local significance at the top of the VS 2-4 zone. The overlying VS 1 zone comprises a thick succession of distinctive robust polymict conglomerates at the base.

2.3.3.3.3 Zone VS 1

The VS 1 is texturally and mineralogically less mature than the underlying arenite-rich VS 2-4 zone (Fig. 50) but also consists of a polymict pebble assemblage (Fig. 52). The VS 1 is a massive, large-pebble to cobble conglomerate with occasional sublithic- to lithic arenite partings. Poorly sorted matrix-supported diamictites occur in the VS 1 zone in the northwestern portion of St. Helena Gold Mine.

Two sublithic- to quartz arenite markers occur at 40m and 100m below the top of the Eldorado Formation, respectively. The 40m arenite marker is generally better developed than the 100m arenite marker and displays trough crossbedding. The 100m arenite marker frequently coarsens up from a fine- to coarse-grained arenite and is separated from the 40m marker by a laterally persistent medium- to large-pebble polymict conglomerate consisting of vein quartz, metapelite and igneous clasts of 2-6cm in size.

Clast size increases upwards in the VS 1 zone, although smaller-scale coarsening- and fining-up sedimentary

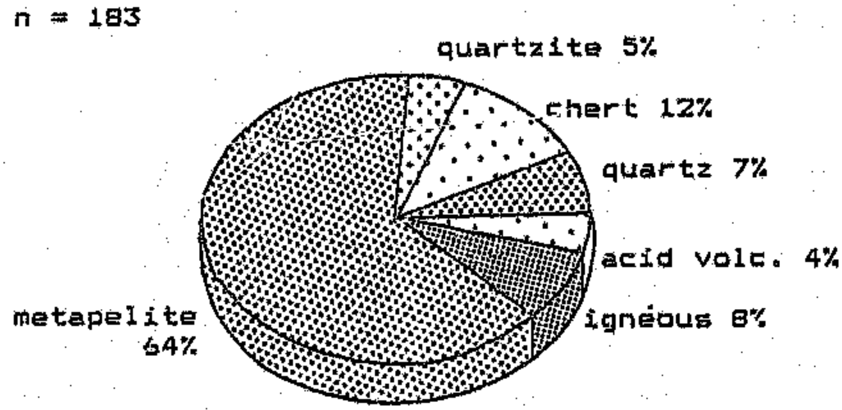


Figure 52 : Pie chart of clast compositions in the VS 1 zone, Eldorado Formation.

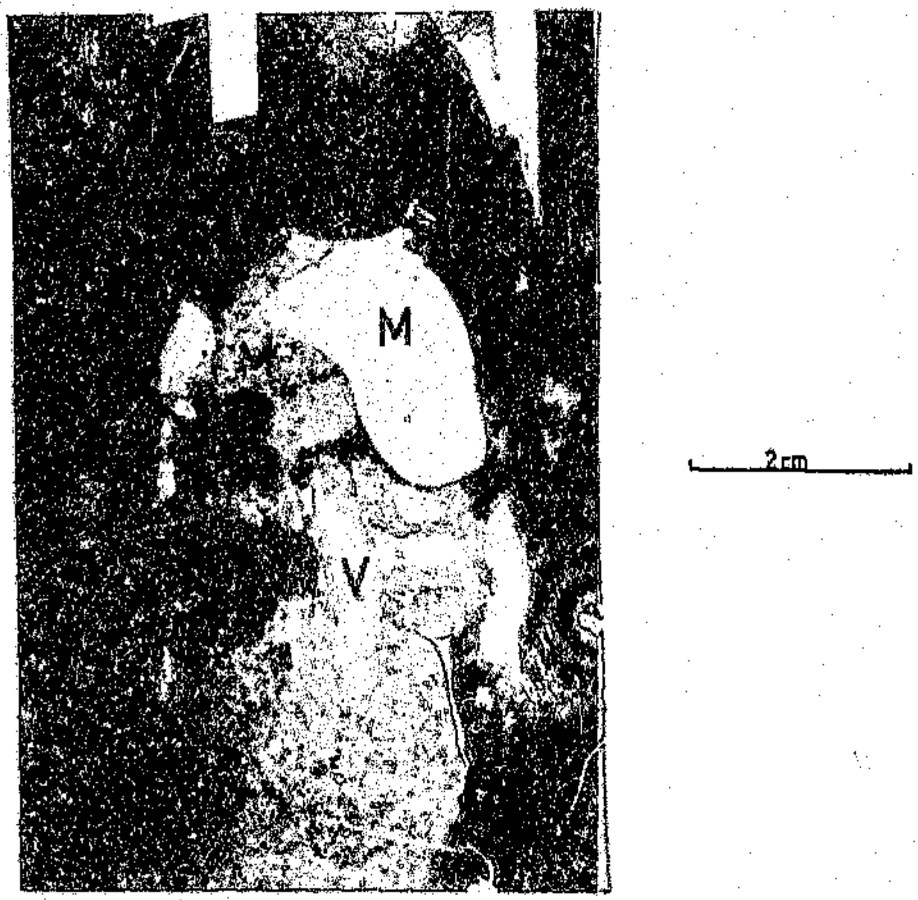


Figure 53 : Polymict VS 1 clasts of the Eldorado Formation, St. Helena Gold Mine. Note the extreme induration and lack of matrix material. Clast types are vein quartz (V), metapelite (M) and igneous (I).

cycles also occur. In places the conglomerate is extremely well packed, containing <20 percent matrix material. Compaction and apparent loss of matrix material has resulted in numerous indurated clasts (Fig. 53). Induration occurs between varying types of clasts, with both durable and non-durable clast types affected. The intensity of the induration and lack of matrix material in places indicates that the amount of compaction which has occurred is substantial. When seen in borehole intersections the compaction and flattening of pebbles gives the incorrect impression that the clasts are imbricated. Poorly defined imbrication does occur and is best seen in underground exposure. At the top of the Eldorado Formation interbedded conglomerates and lava of the overlying Ventersdorp Supergroup occur in places.

2.4 SUMMARY OF STRATIGRAPHY

The Basal Reef is included in this study as constituting the basal unit of the Harmony Formation because the Basal Reef overlies a regional unconformity and constitutes a major lithological change. The Basal Reef in the Welkom Goldfield consists of the Basal and Steyn facies, the boundary between which occurs in the northern portion of St. Helena Gold Mine.

The Basal facies of the Basal Reef is sub-divided into the oligomict- and carbon seam reef types on St. Helena Gold Mine. The Steyn facies of the Basal Reef is subdivided into the polymict southern reef, the mixed reef and the arenite reef. The distribution of the above facies bears no relation to the suboutcrop position of the Basal Reef, with four of the five facies abutting against the westerly suboutcrop line of the Basal Reef on St. Helena Gold Mine.

The Leader Reef on St. Helena Gold Mine consists of the oligomict Alma facies, referred to as the Leader Reef, and the polymict Bedelia facies, referred to as the Leader Reef Zone. The laterally persistent "B" Reef at the base of the Spes Bona Formation has a polymict clast composition characterised by large porous pyrite nodules and igneous clasts.

The Aandenk Channel on St. Helena Gold Mine is a multi-stage erosive scour-and-fill channelised feature. The channel-fill comprises diamictites, polymict conglomerates, pebbly sands and argillites. The Big Pebble Marker occurs at the base of the Aandenk Formation and overlies the Aandenk Channel, where the Aandenk Channel is developed.

Laterally discontinuous oligomict conglomerates are present at varying stratigraphic heights in both the Harmony Formation and the Aandenk Formation. The Middle Reefs, which occur in the Harmony Formation, contain sporadic gold mineralisation whilst the "A" Reefs, which occur in the Aandenk Formation, are poorly mineralised.

On St. Helena Gold Mine only the Welkom (southern) facies of the Eldorado Formation is present and this is subdivided into the unconformity-based VS 1, VS 2-4 and VS 5 zones. On St. Helena Gold Mine the Eldorado Formation coarsens-upward and rapid facies changes, from >95% conglomerate to <40% conglomerate, occur laterally across the mine.

3 SEDIMENTOLOGY

3.1 PETROLOGY

3.1.1 Classification of "quartzites"

The quartzite classification scheme used in this study is that of Law et al., (1990) who modified the schemes of Dott (1964) and Pettijohn et al., (1972); (Fig. 54). Law's classification scheme is applicable to the secondary mineral assemblages of the quartzites of the Witwatersrand Supergroup. This secondary assemblage which resulted from pervasive fluid alteration, and in particular destruction of the labile phase, is related to diagenesis and metamorphism of the original detrital assemblage (Law. et al., 1988a, 1990). The classification system subdivides the quartzites of the Witwatersrand Supergroup into "arenites" and "wackes", based on original matrix content, stratification and sorting. The quartzites are separated into four groups on the basis of their appearance:

a) Quartz arenites, of >95 percent quartz. The Top of Reef quartzite is the most common example, although quartz arenites are not abundant.
b) Sublabile arenites, comprising 75-95 percent quartz. The remaining percentage of unstable (labile) fragments are no longer distinguishable as either feldspathic or as lithic fragments. Recognisable lithic fragments are predominantly metapelite- and rare igneous grains. As these metapelite and igneous grains are more abundant than feldspathic grains in the study area the term "lithic" rather than "labile" is used. Sublithic arenites comprise the

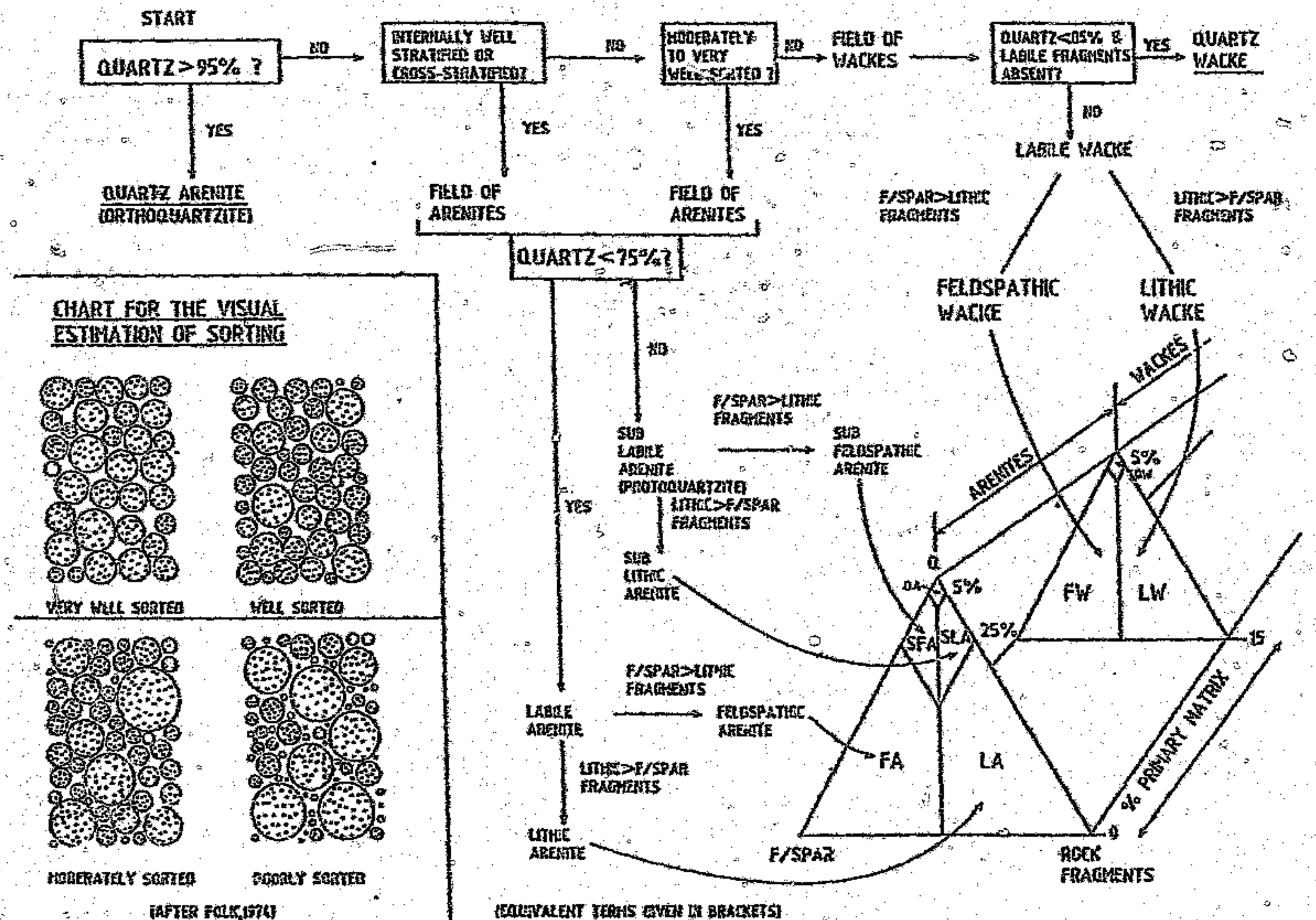


Figure 54: Classification diagram of quartzites (Lew et al., 1990).

dominant arenite group, constituting approximately 70 percent of the quartzites studied.

c) Labile arenites, of <75 percent quartz with the remaining percentage of grains comprising labile fragments. As in the case of sublabile arenites the labile fragments are recognisable as metapelite- and rare igneous grains and therefore the term "lithic" rather than "labile" is used. Lithic arenites may be well bedded and well sorted.

d) Quartz wackes, containing quartz grains in a fine-grained matrix. Matrix material comprises >15 percent of the rock, althoug sublithic- and lithic arenites commonly contain 10 percent matrix material. The quartz wackes generally overlie an erosive base and are poorly sorted.

3.1.2 General mineralogy

The mineralogy of the quartzites is simple and regionally persistent with quartz - muscovite - pyrophyllite - chlorite - chloritoid and pyrite ubiquitous, irrespective of rock texture and sedimentary characteristics. Less common components are rutile, tourmaline, chromite, zircon and leucoxene. Feldspar has not been detected in thin section or by XRD analysis of 60 samples (Law et al., 1990). Colour variations which occur are attributed to variations in the pe, abundance and grainsize of matrix minerals.

The quartzites studied are separated into two distinct groups, based on both colour and composition:

a) Muscovite- and pyrophyllite-rich light coloured meta-sediments, which occur throughout the upper Johannesburg Subgroup and the Spes Bona and Aandenk Formations of the Turffontein Subgroup. Colours range from grey /

white through various shades of grey. The mineralogy of this group remains constant theoughout all the formations, being dominated by quartz and pyrophyllite.

b) Chlorite-rich dark-grey meta-sediments, which comprise the Eldorado Formation on St. Helena Gold Mine. The mineralogy is dominated by a quartz - muscovite - chlorite - chloritoid assemblage and colours range from grey to dark-grey or black.

3.2 FACIES

3.2.1 Introduction

Facies are used to describe the sum total of features which characterise a sediment as having been deposited in a given environment. Fundamental to the use of facies for the interpretation of a sequence of sedimentary rocks is Walther's Law of Facies which states: "A conformable vertical sequence of facies was generated by a lateral sequence of environments" (Middleton, 1973), although Walther's law applies only to successions without major breaks. Parameters for facies definition are lithology, sedimentary structures, palaeontology, geometry and palaeocurrent patterns. These features are applicable to areas of extensive outcrop but data from borehole core and limited outcrop leaves lithological data to play the key role for facies definition (Selley, 1976).

In this study the description of facies types is limited to traditional names (e.g. massive, matrix-supported gravel) for ease of reading, rather than using appended facies codes following the terminology of Miall (1977); e.g. Gms. Three basic criteria exist for the reconstruction of depositional environments; facies definition, facies contacts and facies associations or sequences (Cairncross, 1986). A facies model can thus be constructed which is a general summary of a specific sedimentary environment.

3.2.2 Conglomerate facies

3.2.2.1 Introduction

The term oligomict refers to a conglomerate containing >95 percent of either durable or non-durable clasts. Durable clasts are defined as consisting of quartz and chert while non-durable clasts consist of either meta-pelite, quartzite, igneous or volcanic material. In the study area both oligomict and polymict clast-supported conglomerates and polymict matrix-supported conglomerates occur.

3.2.2.2 Oligomict conglomerate facies

Oligomict conglomerates in the study area are clast-supported, massive and contain >95 percent quartz and/or chert clasts. The oligomict conglomerates are generally well packed with 2-4cm diameter clasts, an erosive base, a sharp upper contact and they commonly overlie either unconformities or erosion surfaces. Oligomict conglomerates are generally between 5cm and 1m thick, although the Big Pebble Marker is >2m thick in places and consists solely of vein quartz clasts of 4-8cm diameter. Thin oligomict conglomerates are referred to as either sheet conglomerates or lag deposits. Oligomict clast-supported conglomerates have a well sorted (bimodal) sandstone matrix and are generally laterally extensive. Oligomict conglomerates are often interbedded with, and overlain by, trough- and planar crossbedded sublithic- and quartz arenites. The Basal facies of the Basal Reef is oligomict although both the Steyn facies of the Basal Reef and the Leader Reef are comprised of an oligomict conglomerate at the base overlain by polymict conglomerates.

3.2.2.3. Polymict clast-supported conglomerate facies

The polymict conglomerate facies contains massive clast-supported conglomerates with >5 percent metapelite, quartz arenite, igneous and acid volcanic clasts. Polymict conglomerates are generally not as well packed as oligomict conglomerates and are usually >30cm thick. The sorting of sandstone matrix material tends to be poor (poly-modal) and the clast size is variable, from <1cm to >6cm diameter. Polymict conglomerates commonly display a fining-upward clast-size motif although coarsening-upward in clast size does occ in the massive polymict conglomerates of the Eldorado Formation. Partings of sublithic- and quartz arenite commonly occur within the conglomerates. Thin, laterally impersistent polymict conglomerate lags commonly have a gradational basal contact with the underlying arenites. The upper contact of the conglomerate is variable, but frequently gradational, particularly in the case of the polymict conglomerates of the Dagbreek, Spes Bona and Aandenk Formations. Polymict conglomerates are generally horizontally laminated and lack imbrication. The presence of porous round pyrite is an indicator of increased gold grades although areas containing little pyrite but moderate gold grades do occur. Polymict conglomerates display either an erosive or a flat base.

3.2.2.4 Interpretation of the conglomerate facies

Massive, crudely bedded and horizontally-bedded polymictic clast-supported conglomerates formed from the migration of longitudinal bars, diagonal bars and sieve deposits under conditions of traction currents and low sediment supply. Deposition of polymict conglomerates occurred in coarse-grained proximal braided river- and braid-plain settings. In this fluvial environment cross-stratified gravels are rare compared to massive gravels (Rust, 1975). The stratification of the conglomerates, defined by compositional, sorting and fabric changes, is a result of foreset accretion in a down-current direction (Harms et al., 1982). The channelised base of the polymict conglomerates is a common feature in alluvial fan settings (Miall, 1977). Well-packed conglomerates also resulted from the deflation, winnowing and reworking of earlier pebbly sandstone deposits as a result of low sediment supply.

Well-packed oligomict conglomerates result from the re-working of pebbly sandstones and polymict conglomerates and therefore have complex histories. The re-working of distal portions of a braid-plain in a beach or fore-shore environment following progradation of alluvial fan and braid-plain sediments into a standing body of water also occurred. Oligomict conglomerates do not possess a well-developed grading and do not have scoured bases because high-energy sheet floods spread gravel over the fan surface as a sheet conglomerate (Allen, 1985; Friend, 1978; Rust, 1978). Oligomict lag deposits result from deposition from the short-lived transport of pebbles on channel beds to produce diffuse gravel sheets (Hein, 1974; Hein and Walker, 1977).

3.2.3 Quartzite facies

3.2.3.1 Introduction

In the classification of quartzites the terms "siliceous", describing a quartz arenite and "argillaceous", describing a lithic arenite, are avoided. The term quartzite includes both arenites and wackes. The term granuleconglomerate has been used for grains of 2-4mm in size and is a size classification equivalent to "grit". In the study area trough- and planar crossbedded, planar bedded, massive- and pebbly arenites occur as well as quartz wackes.

3.2.3.2 Trough crossbedded arenite facies

Trough crossbedded fine- to very coarse-grained sublithic- to quartz arenites contain scattered pebbles in places. Crossbed sets vary from 10cm to 50cm in thickness, commonly fine-upwards in grain size, and are characterised by round and euhedral pyrite and chlorite concentrations on foresets, together with small pebbles of maximum 2cm diameter. Sets are laterally extensive (>4m) and erosively based. Trough crossbedding is the most common sedimentary structure in the arenite facies, occurring as asymptotically-based sets of variable thickness in all the formations of the Central Rand Group. Trough crossbedded arenites occur interbedded with both polymict- and oligomict conglomerates.

3.2.3.3 Planar crossbedded arenite facies

The planar crossbedded arenite facies comprises medium- to very coarse-grained sublithic arenites which contain scattered pebbles. Crossbedding is [illegible] to 60cm thick although smaller scale (+\-20cm) crossbeds are common. Planar crossbed sets are >3m in length parallel to flow. Planar crossbedded arenites are not abundant but do occur in all the formations studied. Chlorite and pyrite concentrations on planar foresets are rare.

3.2.3.4 Plane bedded arenite facies

Plane beds are comprised of fine- to very coarse-grained lithic- to sublithic arenites separated by thin argillaceous laminations up to 2cm thick. Horizontal laminations and low angle stratification are common in the Top of Reef quartzite. Scattered small pebbles occur on bedding surfaces.

3.2.3.5 Massive arenite facies

The massive arenite facies comprise fine- to very coarse-grained lithic- to sublithic arenites which contain no discernible bedding and up to 50 percent scattered pebbles. Massive arenites containing scattered pebbles are a characteristic of the Spes Bona Formation and occur in both the Aandenk Channel and the Eldorado Formation.

3.2.3.6 Pebbly arenite facies

Clasts are not in contact with one another and this facies contains >50 percent sandstone. The sandstone is fine- to medium-grained and is moderately- to poorly-sorted. Bedding is commonly absent and the fabric is random. Thickness of this facies varies from 3cm to over 5m and the clasts are of moderate- to poorly-sorted chert, vein quartz, quartzite, metapelite and igneous material. The pebbles are moderately- to well-rounded and range in size from <1cm to 15cm diameter. Pebbly arenites are characteristic of the Spes Bona Formation and also occur in the Aandenk Channel, where the intermediate sandstone is a sublithic- to quartz arenite.

3.2.3.7 Quartz wacke facies

The Quartz wacke facies comprises wackes containing >15% matrix material, no discernible bedding and up to 50 percent scattered pebbles. The Middling quartzite on St. Helena Gold Mine is a 12m thick quartz wacke containing chert and vein quartz pebbles.

3.2.3.8 Interpretation of the quartzite facies

Planar- and trough crossbedded arenite facies are formed by the migration of sandwaves and dunes (mega-ripples), respectively. Sand waves are 2-dimensional straight-crested bedforms which have a long wavelength compared to their height, whereas dunes are 3-dimensional sinuous-crested bedforms. These bedforms are well documented from shallow-water flume studies (e.g. Harms et al., 1982).

The crossbedded quartz- and sublithic arenites which occur in the study area were deposited on a braided alluvial plain (braid- plain) of a bajada as sheet-like deposits. Re-working of distal portions of the braid-plain in a beach or fore-shore environment following progradation into a standing body of water resulted in the formation of horizontally laminated quartz arenites with sub- parallel laminae. Horizontal laminations form in a wide range of sediment sizes and with varying current velocities.

Fluvial deposition of moderately- to well-sorted pebbly arenites also occurred in this braid-plain setting, resulting in deposits with a stratified matrix. Pebbly arenites with an un-stratified matrix and with no preferred clast orientation resulted from the deposition of clasts together with the arenaceous matrix material in a debris-flow environment (e.g. Harms et al., 1982).

Massive wackes of the Middling quartzite and massive arenites lack traction current features such as cross-laminations. The lack of textural variation in wackes is due to mass emplacement by gravity flow of highly concentrated sediment dispersions in a debris-flow environment. Mass emplacement deposition by gravity flow may occur on variable slopes, depending on the intensity of dispersive grain pressures (Middleton and Hampton, 1976).

3.2.4 Argillite facies

3.2.4.1 Introduction

Argillite is the general term for a mudstone (mudrock) hardened by incipient metamorphism and showing a slaty cleavage (Blatt et al., 1980). The term mudstone includes claystone and siltstone, with a maximum grainsize of 1/16mm. Use of the term shale is entrenched in the literature and shale refers to all argillites, irrespective of either grainsize or texture. The lamination and grading of an argillite is often overprinted by a foliation (e.g. in the Khaki shale), due mainly to the ductile nature of the argillite.

3.2.4.2 Mudstone facies

Laminated and massive mudstone drapes occur in the Eldorado Formation and fining-up units from arenite to mudstone are common in both the Aandenk Channel and the Eldorado Formation. Both laminated and massive mudstone units occur sporadically throughout the Middling quartzite and in distal depositional settings the Eldorado Formation. The Khaki shale grades from a siltstone in the southern portion of St. Helena Gold Mine to a claystone in the northeastern portion of the Welkom Goldfield. Siltstone and claystone occur as narrow interbeds in both polymict conglomerates and sublithic- and lithic arenites.

Interlaminated siltstone and claystone (laminated mudrock) is abundant in the upper portion of the Aandenk Channel and contains soft-sediment deformation features such as dish- and ball-and- pillow structures. The contact between laminations is sharp. Interlaminated siltstone and claystone is associated with sublithic- and lithic arenites as well as pebbly arenites.

3.2.4.3 Diamictite facies

Diamictites are massive matrix-supported conglomerates which contain a matrix of mudstone comprising >50 percent of the rock. The fabric of a diamictite is random and thickness ranges from 3cm to over 3m in places. The clast assemblage consists of poorly-sorted and poorly-packed chert, vein quartz, quartzite, metapelite and igneous material with clasts of <1cm to 10cm diameter. Rare porous pyrite clasts of 1cm diameter occur in diamictites contained within the Aandenk Channel. Diamictites characterise the Aandenk Channel and diamictites of <30cm thick occur in the Eldorado Formation. The diamictites are associated with both the conglomerate and arenite facies.

3.2.4.4 Interpretation of the argillite facies

Argillite deposition occurred by means of suspension deposition in low energy environments. Narrow mudstone drapes contained in conglomerates and arenites were deposited during periods of stillstand following energetic flow conditions. The Aandenk Channel contains interlaminated siltstone and claystone which results from alternating episodes of bedload deposition and suspension settling (Blatt et al., 1980). Laminated mudstone is indicative of cyclic sedimentation and each lamination may be the product of fine-grained density underflows, classified by Stow and Shanmugam (1980) as fine-grained turbidity current laminae (T3-T6), similar to the 'D' and 'E' sequence turbidite classification for coarser-grained turbidites (Bouma, 1964).

Diamictites are emplaced as mass-flow deposits either subaerially or subaqueously with deposition by downslope movement and subsequent "freezing" of material (Middleton and Hampton, 1976). The movement is episodic and occurs in response to gravity on slopes with varying gradients. The diamictites of the Aandenk Channel, which are associated to mudstones of up to 2m thick, were deposited subaqueously. The diamictites of the Eldorado Formation were deposited subaerially by debris flows. Such debris flows are promoted by steep slopes, short periods of abundant water supply and a source providing debris with a muddy matrix (Bull, 1977).

3.3 PALAEOCURRENTS

Trough crossbedding axes are the most re''able palaeocurrent indicator and these were measured wherever possible. Palaeocurrent measurements for conglomerates are confined to crossbedding contained in interbedded and overlying arenites of the same depositional cycle as the conglomerates. All palaeocurrent measurements are presented in section 4.2 (Sedimentary sequences).

Palaeocurrent trends of the Harmony, Dagbreek, Spes Bona and Aandenk Formations are towards the northeast in the vicinity of St. Helena Gold Mine and the trends show no relationship to the western margin structure of St. Helena Gold Mine. Palaeocurrents of the Eldorado Formation in the St. Helena Gold Mine area illustrate a palaeoflow direction towards the southeast.

4 DEPOSITIONAL ENVIRONMENTS

4.1 INTRODUCTION

Interpretation of depositional environments for Proterozoic sediments using equivalent modern environments is problematic, due mainly to the lack of pre-Devonian vegetation. No environment can be identified using individual parameters but rather combinations of parameters are necessary. Depositional environments postulated for the Central Rand Group include marine, lacustrine, a marine-fluvial interface and fluvial and alluvial fan settings. A comparison of various parameters associated with these environments is made (Table 4). Based on the parameters used and on previous work, deposition of the Witwatersrand Supergroup is interpreted in this study to be predominantly fluvial in a braided alluvial plain (braid-plain) setting on a bajada. Minor marine influences did occur and alluvial-fan deposition is evidenced in the upper portion of the stratigraphy.

The stratigraphy of the study area is subdivided into five sedimentary sequences, termed sequences 1 to 5. Between periods of deposition, uplift and erosion took place which resulted in the widespread development of unconformities which are fundamental to the identification and definition of each sedimentary sequence.

4.2 SEDIMENTARY SEQUENCES

4.2.1 Introduction

The detailed depositional environments of each of the formations in the study area have been described with the

PARAMETER	ALLUVIAL FAN GRAVELS	FLUVIAL GRAVELS	OFFSHORE GRAVEL BARS AND GRADED STORM LAYERS
THICKNESS	10's-100's metres	0-30 metres	0-5m, generally <70cm
BASAL CONTACT	Sharp, channelled	Sharp with grooves, channelled	Sharp, planar?, lack of channelling
CLAST SIZE	<300cm	< 20cm	Average 2-3cm, maximum 6cm
CLAST ROUNDNESS	Poor rounding	Variable rounding	Well rounded clasts
MATRIX MATERIAL	Poorly sorted	Moderately sorted	Well sorted
STATISTICAL PARAMETERS	Maturity and rounding increases, clast size decreases downslope	Maturity and rounding increases, clast size decreases downslope	Variable
LATERAL EXTENT	Limited (10's metres)	Limited (100's metres)	Laterally extensive
NATURE OF BEDFORMS	Continuous in radial downfan direction, complex in cross-fan section, with cut-and-fill structures. Lenticular bedforms predominate	Complex conglomerate bars, through numerous erosional and depositional events after initial formation. Indistinct and lenticular gravel bedforms result	Elongate, low relief conglomerate bars Discrete conglomerates present
VERTICAL PACKING	Variable	Variable	Generally increases upwards, with winnowing important
TEXTURE	Clast to matrix supported, variable sorting and matrix	Clast supported, sandy matrix	Clast to matrix supported, sandy matrix
FACIES ASSOCIATION	Variable arenites, limited fines	Arenites, limited fines	Arenites and extensive fines
TOP CONTACT	Generally sharp	Sharp or gradational	Sharp
	ALLUVIAL FAN SANDS	FLUVIAL SANDS	MARINE SANDS
TEXTURAL AND MIN. MATURITY	Immature	Immature to mature	Mature to very mature
MUD DRAPES	Laterally inextensive	Laterally inextensive	Laterally extensive
BEDFORMS	Variable, from massive sheet-like deposits to dunes and ripples	Laterally inextensive, of transverse sandwaves	Laterally extensive and vertically stacked sandwaves (amplitude >1m) and dunes (10-200cm sets)
EROSIONAL SCOURS	Variable (0-10's metres deep) from fanhead incision	Variable (0-10's metres deep)	Low relief, <1m
OVERALL MORPHOLOGY	Wedge shaped, thinning markedly away from source	Thickens from source	Little thickness variation
PALAEOCURRENTS	Unimodal, small spread (<90°), but radial pattern	Unimodal, commonly 180° spread	Unimodal or bipolar
OVERALL SIZE	Generally <10km²	10-100's km²	10-100's km²
	ALLUVIAL FAN DEPOSITS	FLUVIAL DEPOSITS	MARINE DEPOSITS
GRADIENT	1-5°	< 1°	<< 1°
GENERAL PARAMETERS	Change rapidly downslope	Change less rapidly downslope	Show few lateral changes

Table 4 : Comparison of various characteristics of alluvial fan, fluvial and marine deposits. Data are from Bailey et al. (1990), McCave (1975), Johnson and Baldwin (1986), Leckie and Walker (1982), Balazs and Klein (1972), Banks (1973) and Boersma and Terwindt (1981).

aid of characteristic depositional sequences. The sequences and the stratigraphy described are illustrated in Fig. 35.

4.2.2 Sequence 1

a) Description. Sequence 1 consists of the oligomict and carbon seam reef-types of the Basal Reef and overlying arenite- and argillite units. The Basal Reef in the northern portion of St. Helena Gold Mine is an unconformity-based laterally continuous 2-50cm thick, well- sorted medium-pebble clast- supported oligomict conglomerate. The matrix material comprises quartz arenite and the conglomerate contains 5-50cm thick quartz- and sublithic arenite interbeds. Carbonaceous material (kerogen) occurs predominantly at the base of conglomerate. Unconformably overlying the conglomerate is the Top of Reef quartzite, a plane-bedded quartz arenite of 5-150cm thickness which contains rare trough crossbedding and scattered small-pebble oligomict clasts. The Top of Reef quartzite is in turn overlain by the Khaki shale, a mudstone which has a sharp upper contact and which is up to 1.8m thick in the northern portion of St. Helena Gold Mine.

b) Interpretation. The oligomict Basal Reef conglomerates were deposited by a braided stream on a braid-plain of a bajada subsequent to the development of an extensive, flat, unconformity surface. Very low gradients on the depositional surface led to frequent channel switching and deposition of texturally- and mineralogically mature conglomerates over a large area. Reworking and low rates of deposition resulted

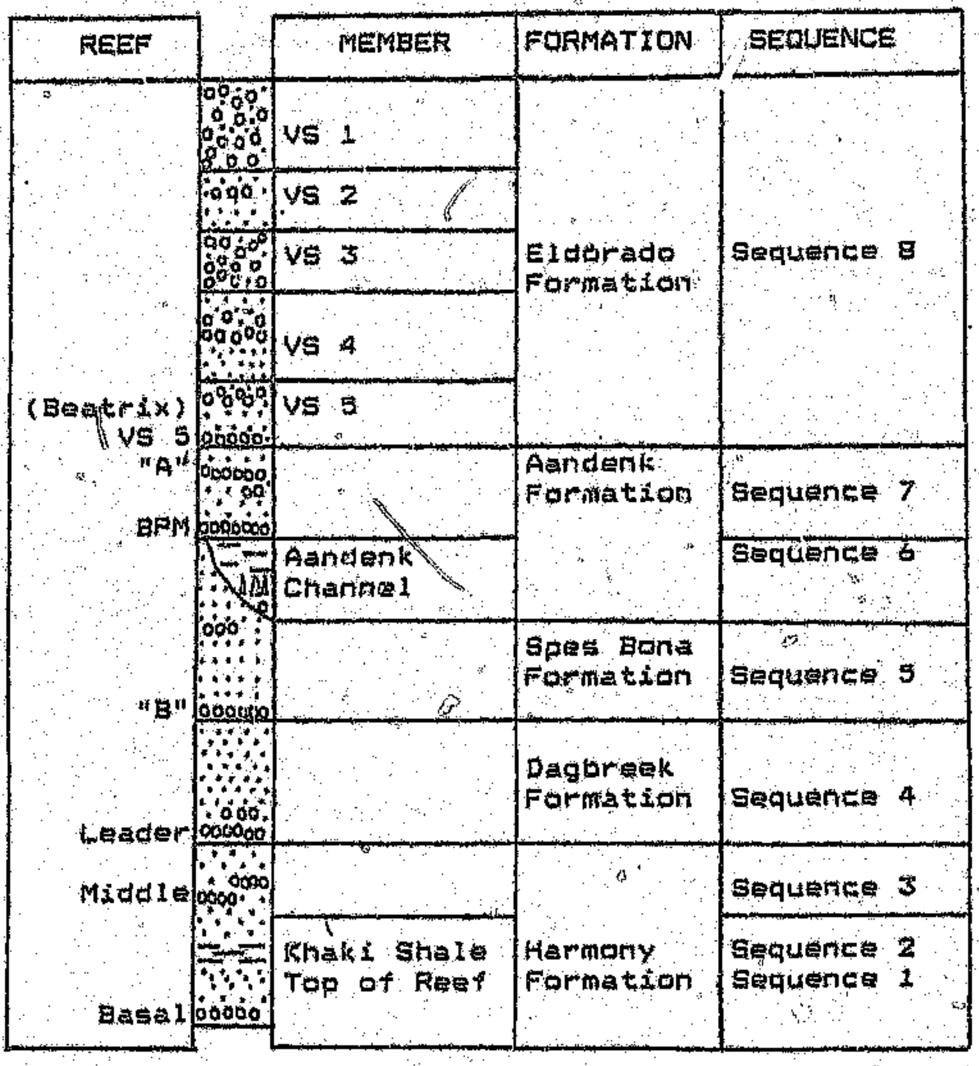


Figure 55 : Sedimentary sequences in the upper Johannesburg and Turffontein Subgroups.

in the deposition of durable clast types and quartz arenites.

Textural and mineralogical maturity of the system was further enhanced by modification of distal portions of the braid- plain in a beach or foreshore environment with the formation of a braid delta from progradation into a standing body of water (c.f. McPherson et al., 1987, p.33; Clifton et al., 1971). This marine modification resulted in deposition of the plane-bedded quartz arenite of the Top of Reef quartzite. Similar modern-day modification of coastal alluvial fans (fan deltas) by wave action and long-shore drift occurs in the Gulf of Aquaba (Hayward, 1985). Continued transgression resulted in the deposition of argillites of the Khaki shale, which are the distal equivalents of the underlying Top of Reef quartz arenite.

Palaeocurrent measurements of trough crossbedding for the Basal Reef on St. Helena Gold Mine indicate a north- northeasterly transport direction (Fig. 56). Pebbles of the Basal Reef also decrease in size in a northeasterly direction across St. Helena Gold Mine. Limited measurements of trough crossbedding in the Top of Reef quartzite and ripple strikes of symmetrical ripples from the Khaki shale indicate that post-Basal Reef transport was in a northeasterly direction. The Khaki shale also fines from a siltstone to a claystone in a northeasterly direction across St. Helena Gold Mine and across the Welkom Goldfield in general (Sims, 1969).

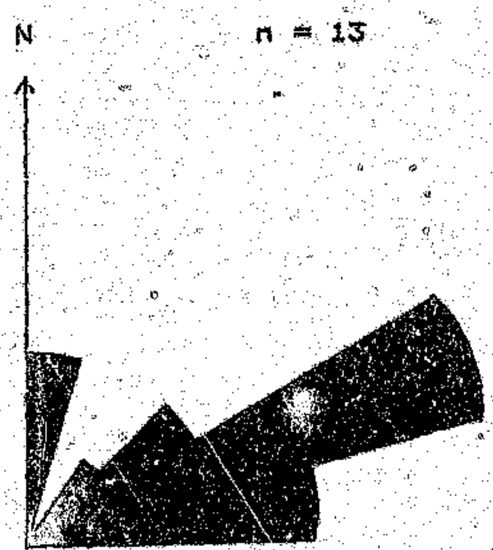


Figure 56 : Trough-crossbed readings in arenites within and overlying the Basal Reef, St. Helena Gold Mine.

4.2.3 Sequence 2

a) Description. Sequence 2 consists of unconformity-based Basal Reef conglomerates from the southern- and central portions of St. Helena Gold Mine. The Basal Reef in this area is a polymict moderately-sorted small- to large-pebble conglomerate of between 10cm and 2m thick. Preserved remnants of a basal oligomict conglomerate of up to 20cm thick are present in places. The overlying polymict conglomerates are interbedded with trough- and planar crossbedded sublithic- and quartz arenites of 5-70cm thick. Overlying the conglomerate is the plane-bedded Top of Reef quartz arenite of 5-150cm thickness which contains rare trough crossbedding and scattered small- pebble oligomict clasts. A poorly-developed mudstone of up to 15cm thick (the Khaki shale) overlies by the Middling quartzite in places.

b) Interpretation. Sequence 2 resulted from deposition of polymict conglomerates on a braid-plain of a bajada following source area re-juvination and an increase in energy of the depositional system. The oligomict clasts which underlie sequence 2 conglomerates are preserved remnants of sequence 1 oligomict conglomerates which were deposited over a large area. Gravel and sand were deposited by longitudinal and transverse bars on the braid-plain as sheet- like deposits. Periods of rapid deposition resulted in the lateral switching of channels and the formation of channelised laterally discontinuous polymict conglomerates. The intensity and duration of erosion associated with sequence 2 determined the extent to which underlying sequence 1 oligomict conglomerates and quartz arenites were preserved.

4.2.4 Sequence 3

a) Description. Sequence 3 consists of massive wackes, scattered granules and small pebbles of the Middling quartzite. Interbedded with the wackes are channelised sublithic- and quartz arenites and lensoid small- to medium- pebble oligomict clast-supported conglomerates of the Middle Reefs. The Middle Reefs contain soft-sediment deformation features.

b) Interpretation. Sequence 3 resulted from regressional deposition by either a mud flow deposit or fine-grained diamictite in an alluvial fan setting (c.f. Bull, 1972). The interbedded mineralogically mature Middle Reefs and associated quartz arenites formed from the localised reworking of the wackes by channelised fluvial streams and the subsequent removal of argillaceous matrix material.

4.2.5 Sequence 4

a) Description. Sequence 4 comprises sediments of the unconformity-based Dagbreek Formation. The sporadically developed Leader Reef at the base of the Dagbreek Formation is up to 1.5m thick and is a small- to medium pebble oligomict conglomerate with overlying- and interbedded quartz arenites. Either overlying the Leader Reef or occurring on the Harmony Formation where the Leader Reef is not developed are the polymict conglomerates and interbedded sublithic- and lithic arenites of the Leader Reef Zone which are a maximum of 15m thick. The predominantly lithic arenites of the Dagbreek Formation overlie the Leader Reef Zone conglomerates and contain laterally impersistent polymict conglomerates.

b) Interpretation. Sequence 4 deposition resulted from unconformity development followed by the deposition of laterally extensive oligomict conglomerates in an environment similar to that responsible for sequence 1 deposition. Deposition of the overlying polymict conglomerates then followed in a braid-plain environment similar to that responsible for sequence 2 deposition. Sporadic erosion of the basal oligomict conglomerates occurred. Following deposition of the polymict Leader Reef Zone conglomerates continued regression resulted in the fluvial deposition of sublithic- and lithic arenites and rare interbedded conglomerates on the braid-plain.

Palaeocurrent measurements of trough- and planar crossbedding from the Leader Reef Zone indicate transport in an easterly directions with a 180° spread of readings (Fig. 57). Pebble sizes also decrease in an easterly direction across St. Helena Gold Mine (Reynolds, 1986)

4.2.6 Sequence 5

a) Description. Sequence 5 consists of the unconformity-based polymict "B" Reef at the base overlain by laterally discontinuous polymict conglomerates and pebbly arenites.

b) Interpretation. Deposition of the "B" Reef occurred following unconformity development on a braid-plain with depositional conditions similar those of sequence 2. Following deposition of the "B" Reef, an overall coarsening-up unit of sequence 2 arenites and

<u>Figure 57</u> : Palaeocurrent readings in arenites within and overlying the Leader Reef, St. Helena Gold Mine. Data from this work and Reynolds (1986) and include both trough- and planar-crossbed measurements.

interbedded laterally impersistent polymict conglomerates was deposited on a braid- plain.

Palaeocurrent directions for the "B" Reef, derived from the orientation of channels and limited palaeocurrent data, indicate transport in a northeasterly direction (Minter, 1982). The clast sizes of the "B" Reef also decrease in a northeasterly direction.

4.2.7 Sequence 6

a) Description. Sequence 6 is the Aandenk Channel, an erosive scour-and-fill channelised feature containing polymict clast- supported conglomerates at the base overlain by pebbly arenites, scattered diamictites and sublithic arenites. The diamictite, of 10cm to 7m thick, comprises poorly-sorted small- to large-pebbles in an argillaceous matrix. The upper portion of the channel-fill comprises interlaminated fine-grained arenite, siltstone and claystone and rare medium- grained sublithic arenites.

b) Interpretation. Erosion of the underlying Spes Bona Formation occurred prior to sequence 6 deposition and resulted from uplift and fanhead incision in a tectonically unstable environment (c.f. Hooke, 1967). Small-scale alluvial fan sedimentation of conglomerates, diamictites and pebbly arenites of the Aandenk Channel then filled the eroded area and local reworking of deposits led to the development of complex cut-and-fill structures of laterally impersistent oligomict conglomerates. Continued transgression resulted in the subaqueous deposition of laminated siltstone and claystone.

The Aandenk Channel trends northwest to southeast across the southern portion of the Welkom Goldfield. Erosional features similar in size and sediment-fill characteristics and with similar orientations to the Aandenk Channel in the southern portion of the Welkom Goldfield also occur in other parts of the Witwatersrand Supergroup. These channel-like erosion features overly argillaceous units and occur at various stratigraphic heights (e.g. Stanistreet et al., 1988; Camden- Smith et al., 1986; Brouwer, 1986; Martin and Stanistreet, 1988; Riley and Viring, 1986).

4.2.8 Sequence 7

a) Description. The Big Pebble Marker at the base of the Aandenk Formation unconformably overlies either the Aandenk Channel, where the Aandenk Channel occurs, or alternatively the Spes Bona Formation. Polymict and oligomict occurrences of the Big Pebble Marker occur with thicknesses ranging from 0m to 2.5m. Overlying the Big Pebble Marker are lithic arenites of the Aandenk Formation which contain the sporadically developed "A" Reefs. The "A" Reefs are comprised of laterally-impersistant oligomict small-pebble conglomerates which occur at varying heights above the Big Pebble Marker.

b) Interpretation. The Big Pebble Marker resulted from deposition on a braid-plain with depositional conditions similar to that for sequence 2 deposition. Following deposition of the Big Pebble Marker deposition of the arenites and laterally impersistant polymict "A" Reef conglomerates occurred. The "A" Reefs resulted from periods of stability when the reworking of previously deposited braid-plain conglomerates occurred. The "A" Reefs are similar in appearance and composition to the Middle Reefs which formed during sequence 3 deposition.

Palaeocurrent measurements for the Big Pebble Marker are to the northeast and east (King, 1986) and for the "A" Reef transport is in a south-southeasterly direction (Karpeta, 1984).

4.2.9 Sequence 8

a) Description. Sequence 8 is the unconformity-based Eldorado Formation. The Eldorado Formation is an overall upward-coarsening depositional package consisting predominantly of small- to medium-pebble polymict clast-supported conglomerate with cobble-sized clasts in proximal areas. Narrow, texturally immature sublithic- and lithic arenites occur interbedded with the conglomerates, together with 2-10cm siltstone units and rare 5-30cm thick diamictites. In more distal depositional areas trough- and planar crossbedded sublithic arenite are abundant.

b) Interpretation. Following deposition of the Aandenk Formation source area re-juvination and uplift along the western margin of the Welkom Goldfield resulted in deposition of a classic upward-coarsening alluvial fan sequence, the Eldorado Formation. Deposition of coarse conglomerates by braided high-energy flow occurred rapidly in the proximal areas of the Eldorado Formation at the northern margin of St. Helena Gold Mine and the southern portion of Western Holdings Gold Mine. The lack of an upward fining sequence at the top of the Eldorado

Formation indicates that equilibrium in the depositional sequence was not reached.

Characteristic of alluvial fan deposition is the large surface area, lack of abundant mud flow or sieve deposits and moderately sorted- and rounded clasts (Denny, 1967). The channelling, normal and inverse grading of conglomerates and basinward change from predominantly conglomerate facies to predominantly arenite facies also support an alluvial-fan interpretation (c.f. Hooke, 1967; Beaty, 1970; Schumm, 1977; Kochel and Johnson, 1984).

Lower gradients and less energetic flow resulted in braided stream deposition on a braid-plain with an increasing percentage of arenites occurring in distal areas of the Eldorado Formation to the south of Unisel Gold Mine. These distal surfaces are degradational and accumulations of durable clasts and heavy minerals occurred, with the preservation of symmetrical ripples indicating rare subaqueous deposition. The distal alluvial fan deposits prograded directly into a standing body of water to form a fan delta in places (c.f. McGowan, 1970; McPherson et al., 1987). The two laterally persistent and mineralogically mature arenaceous markers near the top of the VS 1 zone resulted from short- lived marine transgressions, although similar sheet sandstones can be produced by sheet-flood deposits on the distal portion of an alluvial fan (Collinson, 1978).

The coarsening-upward nature from arenite and small-pebble conglomerates to cobble-conglomerates in the Eldorado Formation was a result of progradation, although short-lived transgressional phases also occurred which resulted in intertonguing conglomerate and arenite facies occurring. Short- lived periods of erosion in the Eldorado Formation resulted in the formation of unconformities which separate the VS 1, VS 2-4 and VS 5 zones of the Eldorado Formation.

Transport directions for the VS 2-4 and VS 5 zones of the Eldorado Formation indicate transport in a southeasterly direction (Fig. 58a). Transport in the VS 1 zone is in an easterly direction (Fig. 58b). The southeasterly and easterly transport directions coincide with the lateral facies changes in a southeasterly direction across St. Helena and Unisel Gold Mines, with decreasing pebble sizes and an increase in the textural and mineralogical maturity of clasts also occurring in a southeasterly direction.

Sediments similar to the Eldorado Formation are preserved in the Abitibi greenstone belt, Quebec, and are interpreted as high gradient alluvial fan deposits (Mueller and Dimroth, 1987). These fan deltas are usually confined to tectonically active areas such as the margins of fault-bounded intra-cratonic seas and lakes (Ethridge, 1985) and along the margins of many active tectonic basins, e.g. the Hornelen Basin, western Norway (Gloppen and Steel, 1981).

4.3 DEPOSITIONAL MODEL

The overall sequence of events that led to the deposition of the Harmony, Dagbreek, Spes Bona and Aandenk Formations has been reconstructed (Fig. 59). The

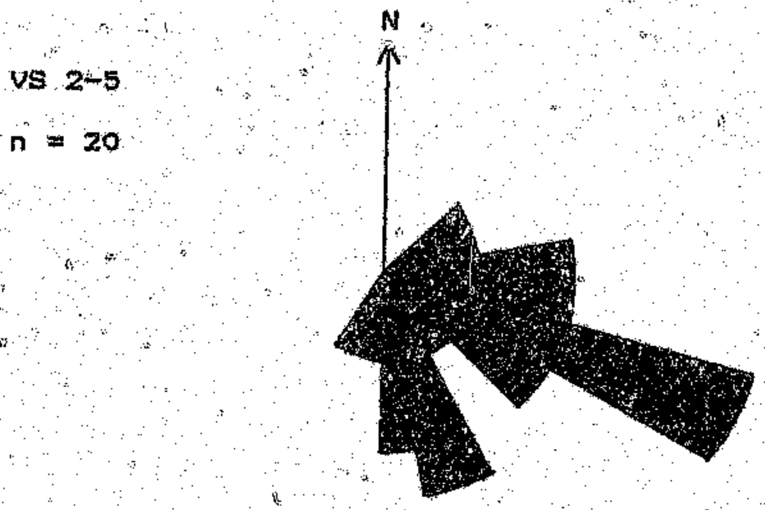


Figure 58 a

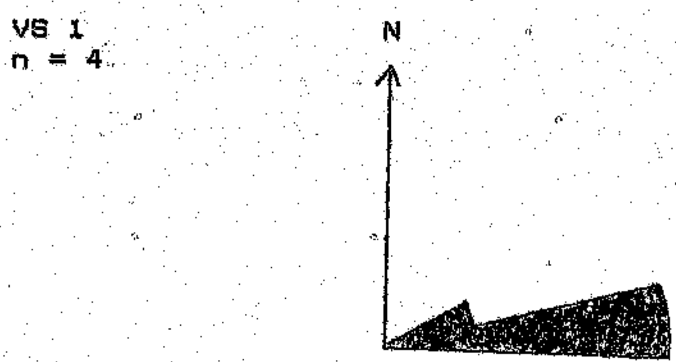


Figure 58 b

Figure 58 : Trough-crossbed readings from arenites of the Eldorado Formation, St. Helena Gold Mine. a) VS 2-5 zones. b) VS 1 zone.

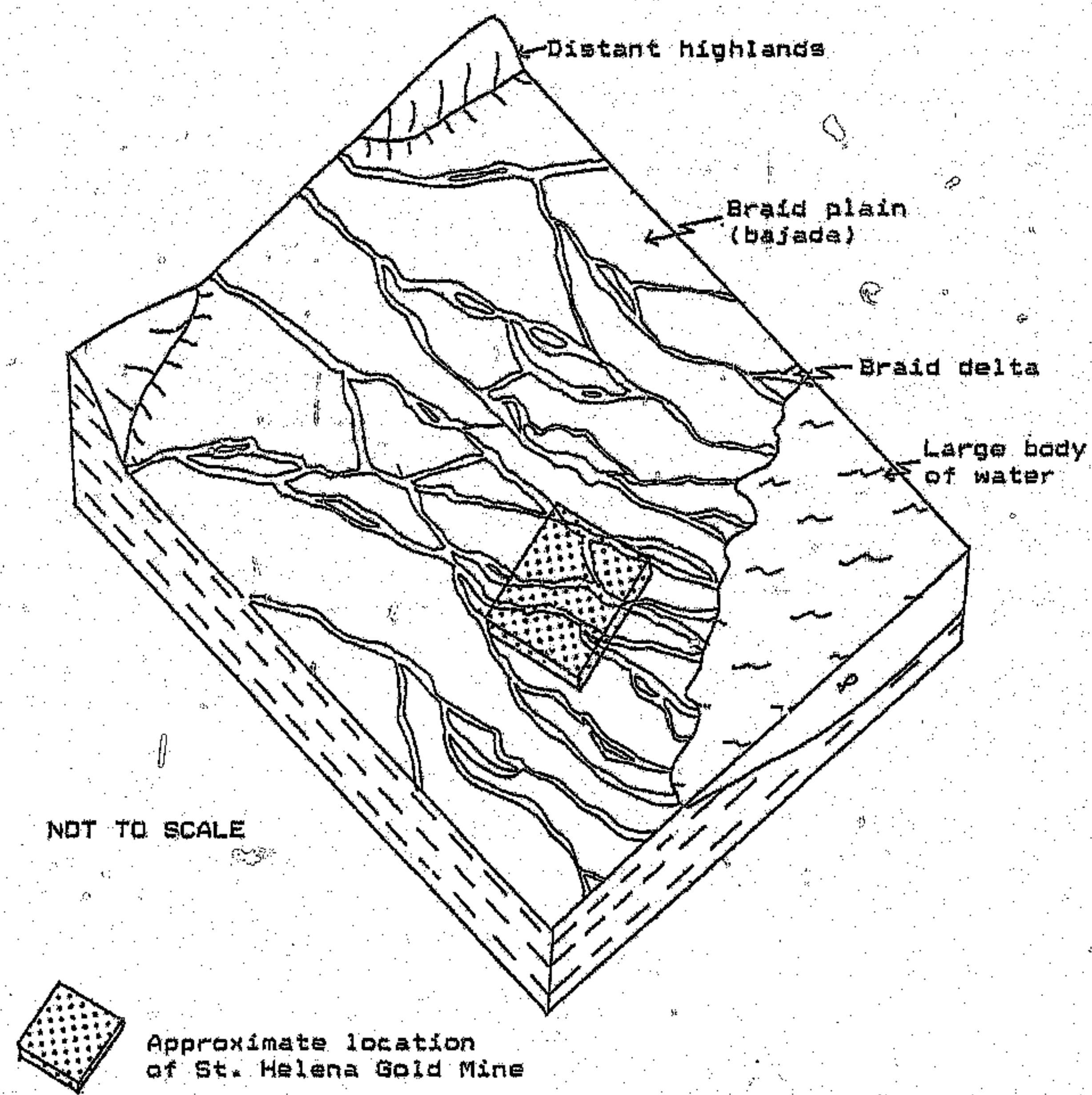


Figure 59 : Schematic reconstruction of the depositional environment of the Basal Reef.

depositional environment was on the distal portion of a braid-plain of a bajada with sediments derived from distant alluvial fan sedimentation. This braid-plain setting remained similar from the Harmony to the Aandenk Formations but the energy of the system increased with time. Deposition of the overlying Eldorado Formation was from an alluvial fan which prograded as a fan delta into a marine environment (Fig. 60).

The depositional environment proposed in this study is similar to the models of Minter (1975, 1978) and Verrezen (1987) and to aspects of the models postulated by and Smith and Minter (1980), Tucker (1980) and Kingsley (1984) for the Witwatersrand Supergroup.

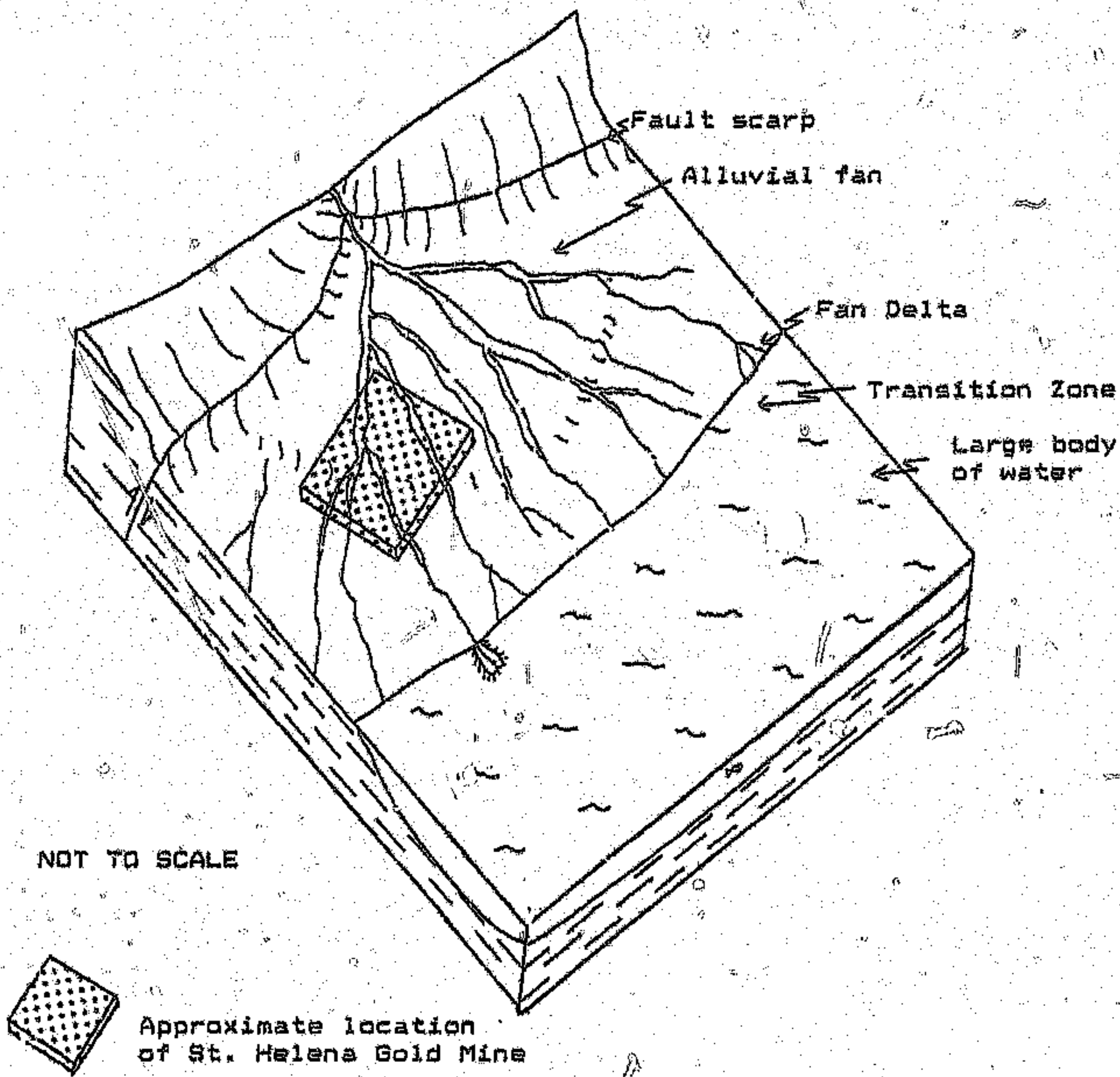


Figure 60 : Schematic reconstruction of the depositional environment of the Eldorado Formation.

5 SYNSEDIMENTARY TECTONICS

5.1 INTRODUCTION

Some of the consequences of synsedimentary tectonics, i.e. tectonic activity contemporaneous with sedimentation, are the formation of unconformities, the variation in the thickness of sediments and in some cases the development of non-uniform lateral and vertical facies associations. To assess the effect of synsedimentary tectonics the assumption is made that the depositional surface is flat at all times and variations in stratigraphic thickness reflect either subsidence or uplift within the basin. Areas which are rapidly subsiding accumulate thicker sedimentary sequences while areas which are rising relative to this accumulate thinner either sequences or experience erosion (McCarthy et al., 1987). Repeated uplift or subsidence in a specific area ...ll cause repeated anomalies in thickness in that area. ...dynamic nature of tectonics and differing causes of uplift may result in an area of repeated uplift to migrate laterally with time.

Synsedimentary uplift along the western margin of the Welkom Goldfield occurred sporadically during deposition of the upper Johannesburg and Turffontein Subgroups and continued throughout the deposition of the Eldorado Formation (Winter, 1964b; McKinney et al., 1964; Olivier, 1965; Kingsley, 1984). The thickness variations and facies relationships of sediments have been used to illustrate the nature and extent of synsedimentary tectonics which have occurred in the vicinity of St. Helena Gold Mine.

5.2 THICKNESS VARIATIONS

Synsedimentary uplift resulted in the formation of unconformities and the thinning of formations in a westerly direction across St. Helena Gold Mine. The angle of sub-outcrop between the Basal Reef and the top of the Aandenk Formation is 2.1° in the southern portion of St. Helena Gold Mine and 7.2° in the northern portion of St. Helena Gold Mine (Fig. 61).

Syn-sedimentary tectonics resulted in complex sub-outcrop positions in the northwestern portion of St. Helena Gold Mine (Figs. 62 a, b and Fig. 63). The Leader Reef is truncated by the "B" Reef in the central portion of section D-D' (Fig. 63) where uplifted Leader and Basal Reefs occur. Both the Basal and Leader Reefs are poorly developed in this area but the "B" Reef is anomalously thick. Sections E-E' and F-F' (Fig. 64 a, b) are constructed roughly perpendicular to strike. In both sections the "B" Reef truncates folded Basal and Leader Reef sediments. In the western portion of sections E-E' and F-F' the "B" Reef rests unconformably on the Welkom Formation (UF 1).

5.3 FACIES RELATIONSHIPS

The Basal Reef has both proximal facies (oligomict and disseminated carbon reef) and distal facies (polymict southern reef) occurring along the present Basal Reef suboutcrop position. The Leader Reef, Big Pebble Marker and "A" Reefs also have oligomict reef facies occurring in the vicinity of the present day basin margin and showing no spatial relationship to the basin margin.

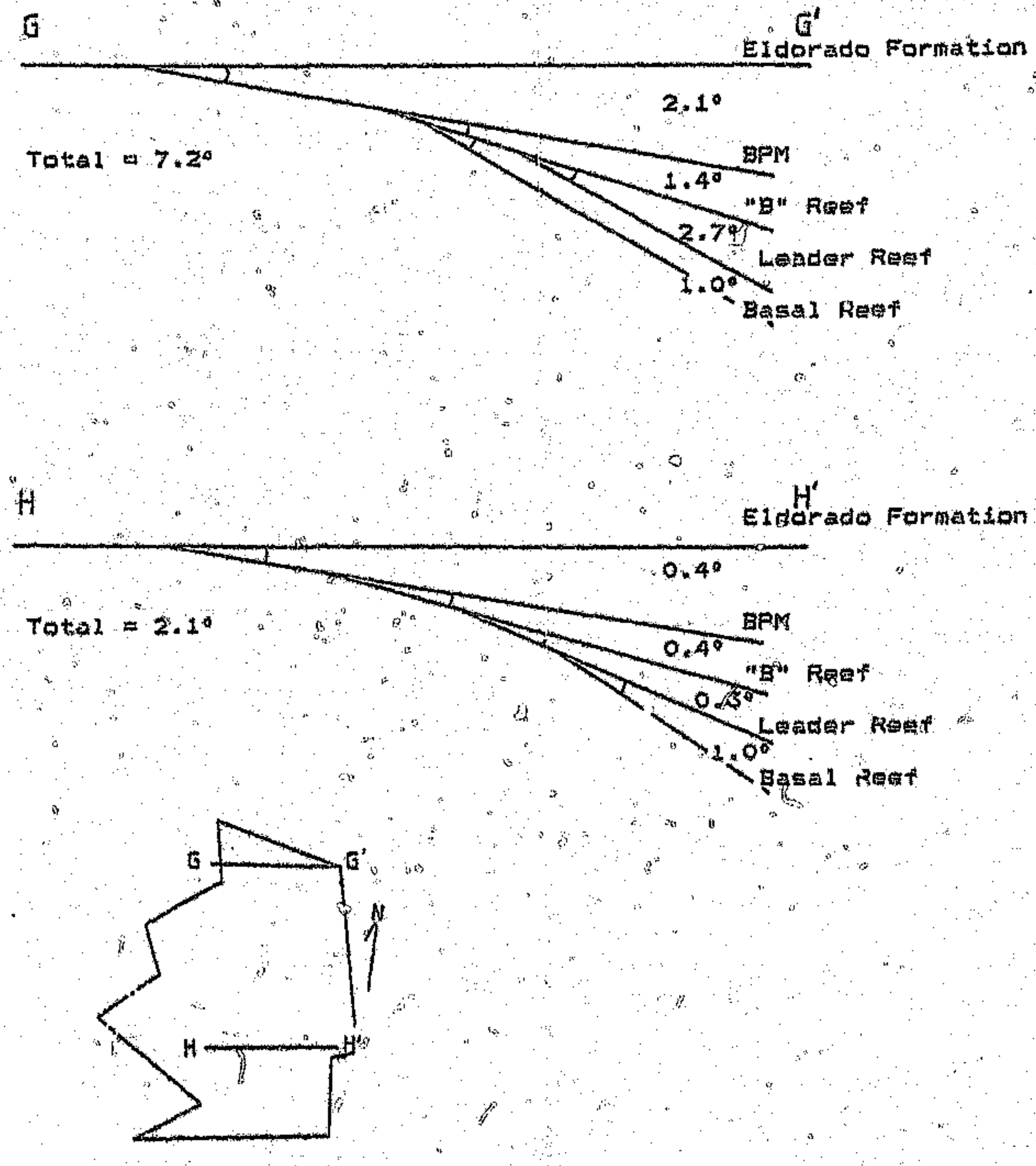


Figure 61 : Schematic east/west sections of St. Helena Gold Mine showing the onlapping nature of the formations and approximate unconformity angles.

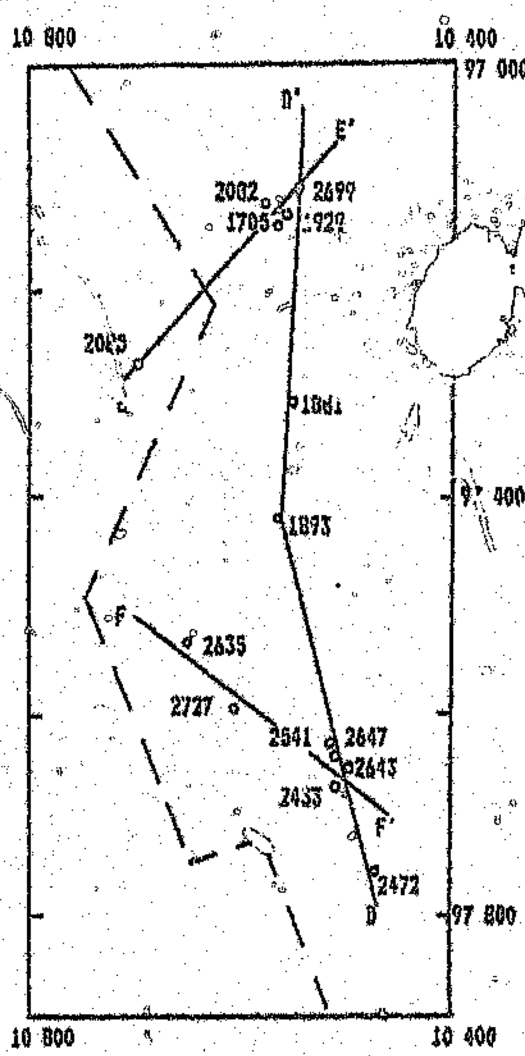


Figure 62 a

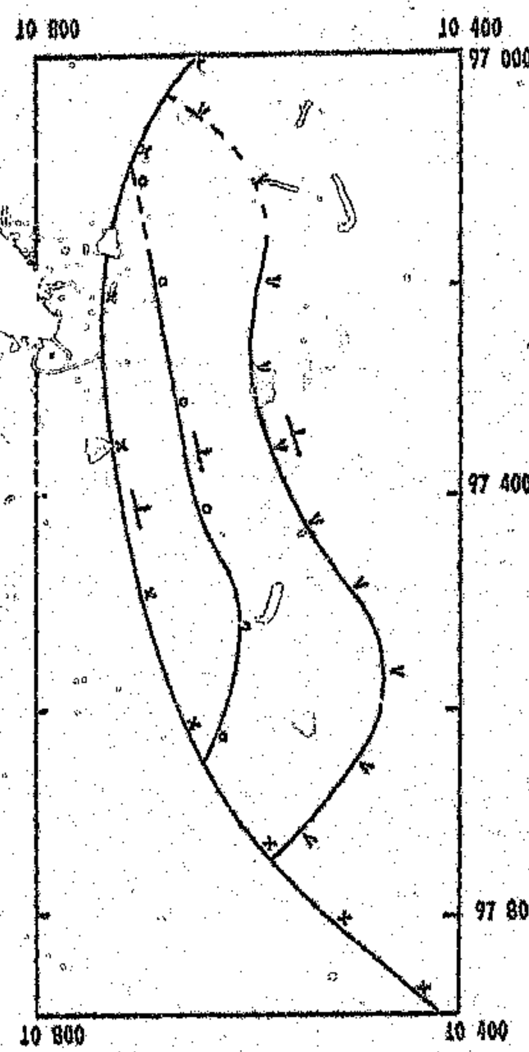


Figure 62 b

REFERENCE

E —— E' Section line

— — — Mine boundary

2035 Borehole

Dip

"B" Reef suboutcrop

Leader Reef suboutcrop

Basal Reef suboutcrop

Figure 62 : Plan of the north-western part of St. Helena Gold Mine, enlarged from Fig. 11. a) Borehole numbers and the location of sections D-D', E-E' and F-F'. b) Plan of the suboutcrop position of the Basal and Leader Reefs against the "B" Reef.

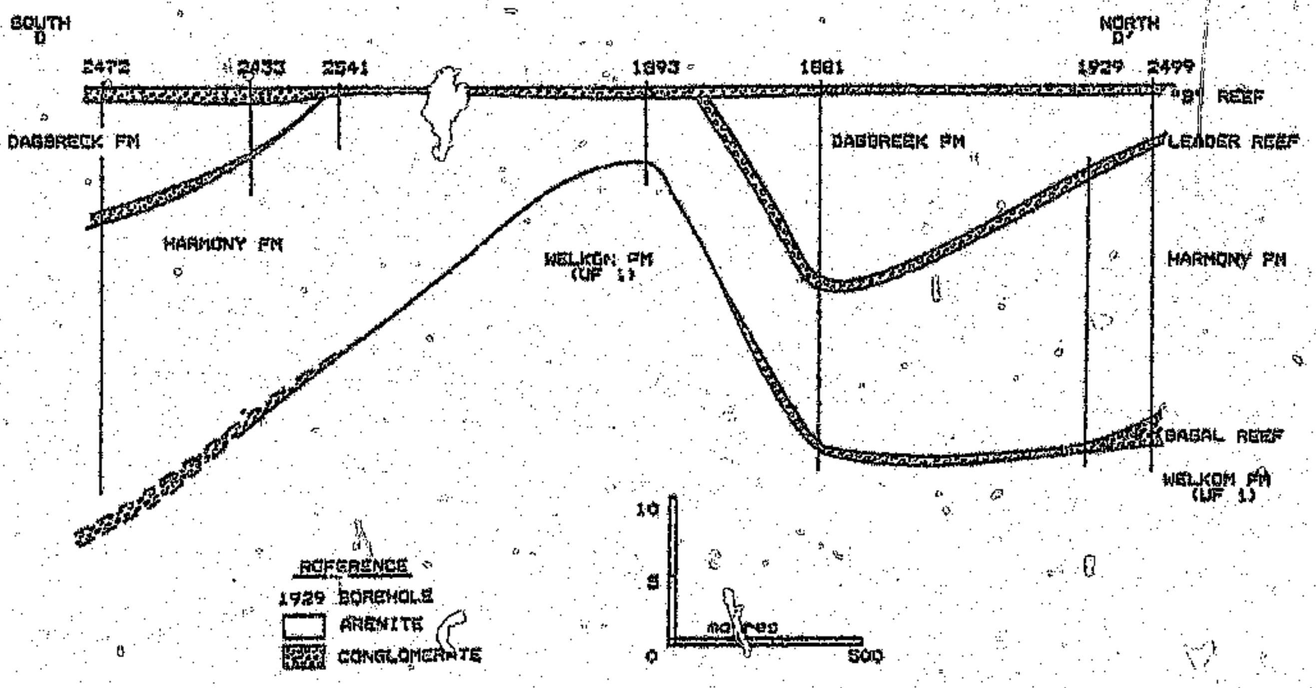


Figure 63 : North / south strike section D'-D of the Harmony Formation, Dagbreek Formation and the "B" Reef. The top of the "B" Reef has been used as datum. Location is shown in Fig. 62. (Note vertical exaggeration).

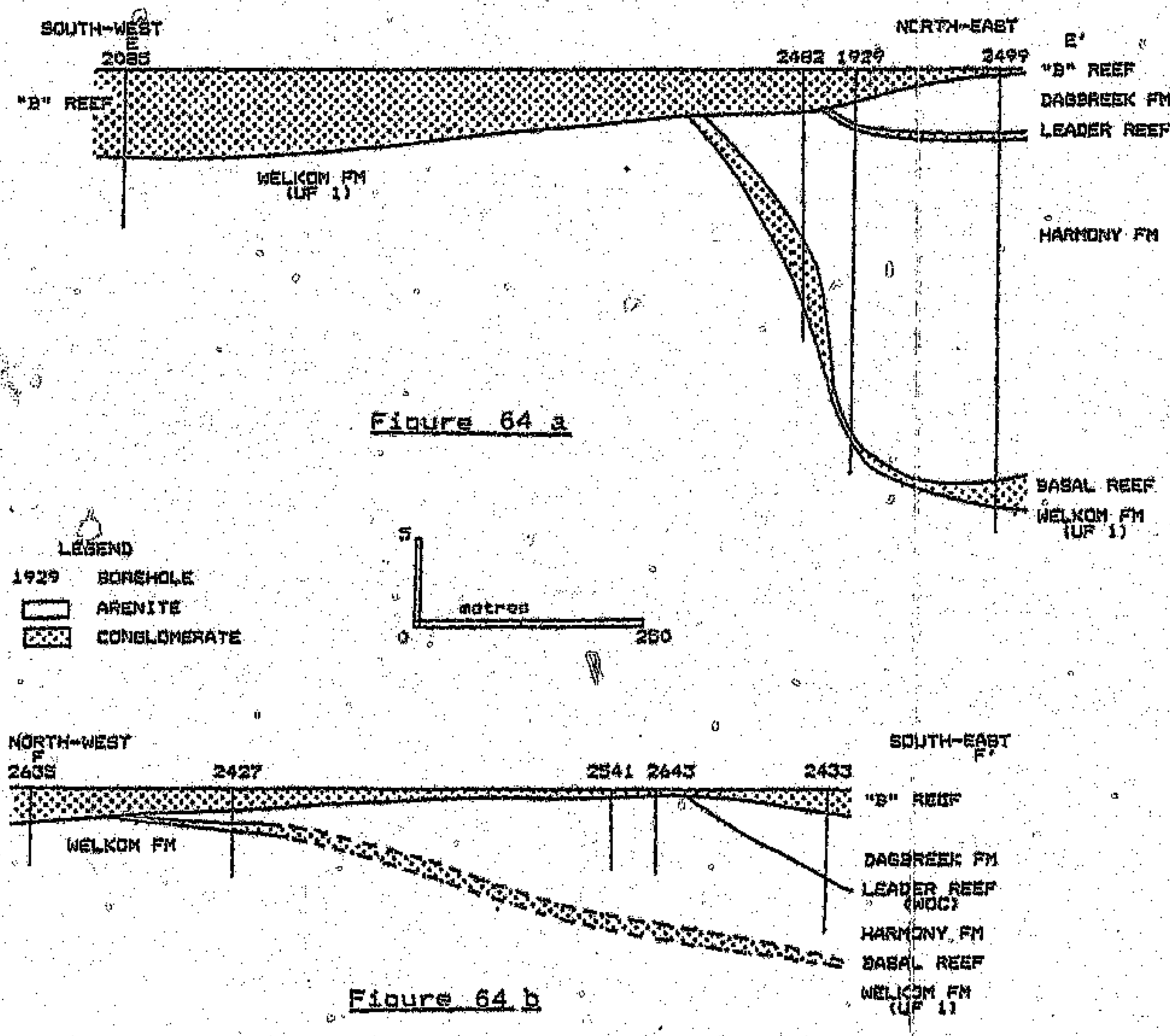


Figure 64 : Dip sections of the Harmony and Dagbreek Formations and the overlying "B" Reef unconformity. The top of the "B" Reef has been used as datum. Location of sections is shown in Fig. 62. a) South-west / north-east section E-E' b) North-west / south-east section F-F'. (Note vertical exaggeration).

Unconformity-based conglomerates on St. Helena Gold Mine show a broad decrease in textural and mineralogical maturity up the stratigraphy, from the oligomict small-pebble Basal Reef to the large-pebble polymict Eldorado Formation conglomerates. The ratio of conglomerate to arenite also increases upwards in the stratigraphy, culminating in the conglomeratic Eldorado Formation. The Eldorado Formation is a broadly upward-coarsening sequence which occurs stratigraphically at the top of the Witwatersrand Supergroup, which is also broadly upward-coarsening.

The Middle Reefs occur within the wackes of the Middling quartzite and contain large-scale soft-sediment deformation features. Diamictites occur in the Aandenk Channel as well as in the Eldorado Formation.

5.4 SYNSEDIMENTARY TECTONIC INTERPRETATION

The presence of angular unconformities along the western margin of the Welkom Goldfield, which become disconformable into the basin, indicate that uplift occurred during sedimentation. This marginal uplift occurred by rotation and upfolding which left the basin interior relatively undisturbed (e.g. Riba, 1976; Miall, 1978). Areas of repeated subsidence or uplift resulted in anomalies in thickness. The orientation and location of the Aandenk Channel, in a broad band across the southern portion of the Welkom Goldfield is an indication of a tectonic control.

The uplifted material was a source of sediments, particularly during deposition of the Eldorado Formation. Tectonic instability at the time of deposition triggered debris-flows, resulting in the formation of wackes of the

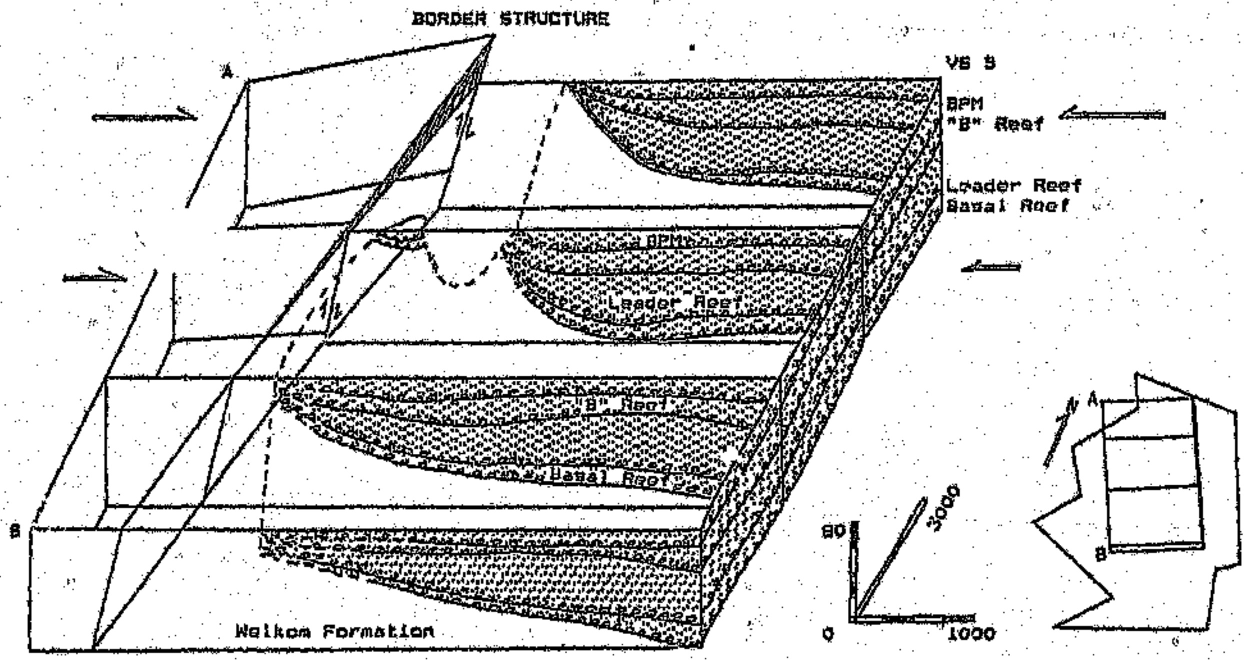
Middling quartzite and diamictites in the Aandenk Channel and Eldorado Formation. Soft-sediment deformation features also resulted from tectonic instability. On a basin-wide scale diamictites are reported form various localities and stratigraphic heights and are interpreted by Stanistreet et al., (1988) as being a response to tectonism. Deposition of specific facies was not related to the present western margin structure as there is no relationship between specific facies of the Basal Reef, the Leader Reef, Big Pebble Marker and "A" Reefs and the present day suboutcrop position of these conglomerates.

Differing angles of unconformities between formations indicate varying rates and duration of uplift occurred along the western and southern margins of the Welkom Goldfield. In the northwestern portion of St. Helena Gold Mine syn-sedimentary uplift of the basin margin was more rapid than in the south and was concentrated in a narrow area 1500m wide. This area is characterised by intense uplift and folding of the entire Johannesburg and Turffontein Subgroups, where truncation of more than 1300m of stratigraphy occurred during the deposition of the Witwatersrand Supergroup. Folding and truncation of the "B" Reef indicates that synsedimentary tectonics also occurred on a localised scale (100's metres).

A gradual increase in the tectonic activity of the Witwatersrand Supergroup occurred with time which resulted in a vertical decrease in textural maturity of the sediments. Following deposition of the Witwatersrand Supergroup, continued tectonic activity led to fracturing of the crust and the outpouring of the Klipriviersberg lavas of the Ventersdorp Supergroup. Initial lava deposition was concomitant with Eldorado Formation sedimentation.

The cause of the uplift along the western margin of the Welkom Goldfield may have been differential movement of large basement blocks which shifted under a regional compressive regime. Block movement resulted in small displacements over large areas but with the western margin representing a narrow area of complex and intense deformation. The tectonics are not simply vertical but consist of both episodic uplift and lateral movement with blocks pivoting in various directions about a fixed point (Myers et al., 1990).

Tectonics along the western margin of the Welkom Goldfield were syn-sedimentary and compressional, acting in an east-west direction in the vicinity of St. Helena Gold Mine (Fig. 65). North- south trending folding along the western margin of St. Helena Gold Mine did not affect sedimentation during upper Johannesburg- and lower Turf-fontein Subgroup depositional times. Data from this study indicates that the overall intensity of tectonic activity increased and the locus of the tectonic activity moved progressively inwards towards the basin centre with time, to give the effect of a shrinking basin.



REFERENCE

Unconformity-based conglomerate

Major stress direction

Estimated suboutcrop position

Arenite

<u>Figure 65</u> : Schematic fence diagram, St. Helena Gold Mine. The compressive tectonics, western margin structure and unconformity angles which decrease southwards, are shown. The Eldorado Formation has been used as datum and the Harmony, Dagbroek, Spes Bona and Aandenk Formations are shaded.

6 CONCLUSIONS

The Witwatersrand Supergroup, comprising both West Rand and Central Rand Group rocks, is underlain by basement granitoids and overlain by the Ventersdorp Supergroup and the Karoo Sequence, respectively, on St. Helena Gold Mine. This stratigraphic and sedimentological study is confined to the Harmony and Dagbreek Formations of the Johannesburg Subgroup and the Spes Bona, Aandenk and Eldorado Formations of the Turffontein Subgroup, which together comprise the Central Rand Group.

An understanding of the overall sedimentary and tectonic processes of the Johannesburg and Turffontein Subgroups has been gained by studying the total sedimentary succession rather than the few gold-bearing unconformity-based conglomerates. The Witwatersrand stratigraphy at St. Helena Gold Mine is incomplete and represents a preserved sequence of unconformity-bound units.

The Basal Reef has yielded more than 80% of the gold mined to date in the Welkom Goldfield and is interpreted as constituting the basal unit of the Harmony Formation and not the uppermost unit of the Welkom Formation. The Basal Reef in the Welkom Goldfield is divided into the Basal and Steyn facies. On St. Helena Gold Mine the Basal facies is in turn subdivided into the oligomict and carbon seam reef types whilst the Steyn facies is sub-divided into the polymict southern reef, the mixed reef and the arenite reef. The Harmony Formation also contains the Middle Reefs which occur at varying stratigraphic intervals above the Basal Reef. Both the Middle Reefs of the Harmony Formation and the "A" Reefs of the Aandenk Formation consist of discrete channelised oligomict conglomerates located at varying stratigraphic elevations.

The Leader Reef at the base of the Dagbreek Formation is divided into the oligomict Alma facies, referred to as the Leader Reef, and the polymict Bedelia facies, referred to as the Leader Reef Zone. The Aandenk Channel which stratigraphically overlies the Leader and "B" Reefs on St. Helena Gold Mine is a multi-stage erosive scour-and-fill channelised feature. The orientation and location of the Aandenk Channel, in a broad band across the southern portion of the Welkom Goldfield, is an indication of tectonic control.

On St. Helena Gold Mine only the Welkom (southern) facies of the Eldorado Formation is present and this is subdivided into the unconformity-based VS 1, VS 2-4 and VS 5 zones. The Eldorado Formation coarsens-upward on St. Helena Gold Mine and rapid facies changes occur across the mine, with conglomerate being replaced by arenite as the dominant facies of the Eldorado Formation in distal areas.

Deposition of Harmony, Dagbreek, Spes Bona and Aandenk Formation conglomerates and arenites occurred fluvially on the distal portion of a braid-plain in unconfined channels. The re-working of polymict conglomerates resulted in the formation of oligomict conglomerates, and the deposition of sand by traction currents resulted in trough- and planar crossbedded arenites. Swash-stratification during localised transgressions resulted in the formation of horizontal laminations in the Top of Reef quartzite. Pebbly arenites and massive wackes resulted from mass-emplacement by gravity-flow deposition and argillite-deposition occurred during periods of stillstand. Extensive transgressions are recorded by the deposition of argillites above unconformity-based conglomerates. The deposition of diamictites was a result of episodic mass-flow movements. A transgression resulted in the subaqueous deposition o argillites and diamictites of the Aandenk Channel. Deposition of the Eldorado Formation occurred subaerially on an alluvial fan which prograded as a fan delta into a marine environment. Marine incursions reworked distal portions of the fan and deposited oligomict conglomerates and laterally continuous quartz arenites.

Angular unconformities along the western margin of the Welkom Goldfield indicate that uplift occurred during sedimentation. The uplift was episodic and occurred in discrete pulses between periods of sedimentation in a narrow 1500m wide area with the intensity of uplift being greater in the north than the south of St. Helena Gold Mine. The intensity of tectonic activity increased with time which resulted in a vertical decrease in the textural and mineralogical maturity of sediments and the deposition of a generally upward-coarsening sedimentary sequence. The uplift on St. Helena Gold Mine resulted from an east-west orientated compressional tectonic regime and the locus of tectonic activity moved progressively inwards towards the basin centre to give the effect of a shrinking basin.

Synsedimentary tectonics resulted in anomalous thicknesses of sediments and the uplifted sediments were re-worked a source of further sediments. Synsedimentary tectonics also resulted in the eposition of wackes of the Middling quartzite, the tectonically disturbed sediments of the Middle Reefs and in the sedimentary facies and sedimentary deformation in the Aandenk

Channel. The formation of unconformity-based oligomict conglomerates which contain gold mineralisation resulted from syn-sedimentary tectonics. Increased gold grades are related to occurrences of carbon and round pyrite in the conglomerate matrix.

The facies distribution of the Basal Reef occurring along the western margin on St. Helena Gold Mine has no relationship to the present location of the western margin fault. The recognition that deposition of the Basal Reef and overlying unconformity-based economic conglomerates occurred to the west of the present-day basin margin of the Central Rand Group is important. The possibility exists that not all of the Witwatersrand Supergroup sediments deposited to the west of the present-day margin have been uplifted and eroded. Potential for preserved Basal Reef, Leader Reef and possibly "B" Reef sediments therefore exists in areas to the south and west of St. Helena Gold Mine. The preservation of sediments could occur either in a syncline similar to the western margin syncline of St. Helena Gold Mine or as a down-faulted block. The orientation of such a preserved feature would be north-south, parallel to the present-day structures of the Welkom Goldfield.

7 APPENDIX 1

Data input and the generating of isopach maps was done using a Personal Computer and a spreadsheet application. The isopaching package utilized creates high resolution two- and three- dimensional graphics by computing a regularly spaced grid of data points from irregularly spaced data. Computerised isopach construction has the advantage of detecting and smoothing large irregularities in thickness of formations due to faulting, and also of being unbiased. An inverse distance method of interpolation and an inverse weighting power of 2 (inverse distance squared) was used. The search method utilised the ten nearest points in each quadrant. Duplicate data points were averaged out and a grid size of 25 x 25 is created (data permitting) to form a two-dimensional contour map of variable scale and configurations. The contour lines were smoothed using spline interpolation within the grid cells.

8 APPENDIX 2

The summaries of surface boreholes were plotted using a Fortran IV computer program (McCarthy, 1981) run on the IBM mainframe of the University of the Witwatersrand, Johannesburg. This program has subsequently been modified by Mr. A.B. Cadle and Dr. B.C. Cairncross. The program provides a graphic plot of stratigraphic thickness, elevation, sedimentary structure and grainsize data and allows comments to be added. Input of data are by alpha-numeric codes, alphabetic units and numerals. The location of all boreholes logged have been plotted (Fig. 66) and the summarised logs are presented below.

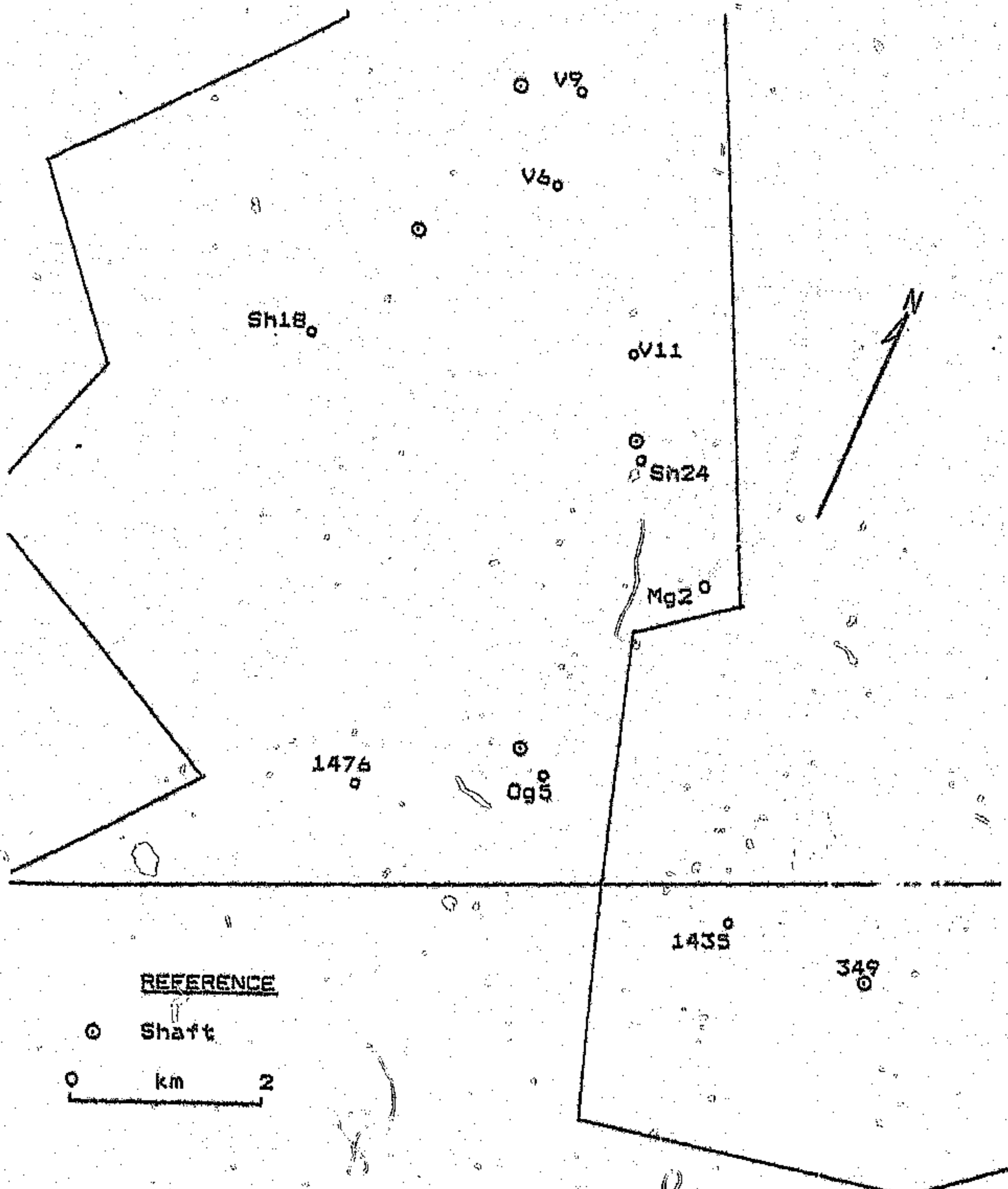
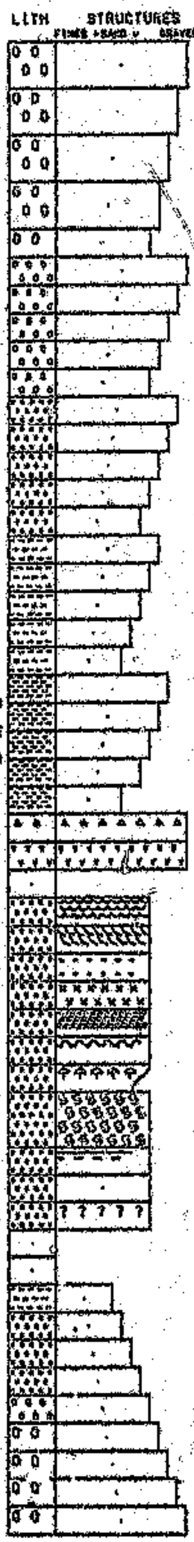


Figure 66 : Location of boreholes logged on St. Helena Gold Mine and Unisel Gold Mine (Appendix 2).

KEY TO PLOTS

X 12345634.22
Y -1234563.24

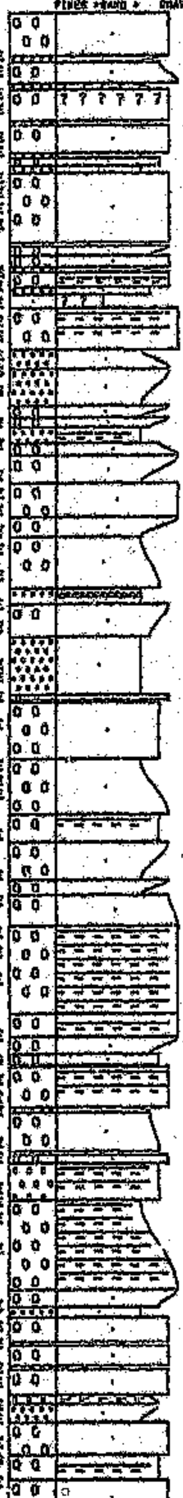
ELEV 0.00



TAG	THICK	ELEV	DEP	C			COMMENTS
1	5.00	-5.00	5.00		CU	MM	UNDIFFERENTIATED CONGLOMERATE
2	5.00	-10.00	10.00		CG	MM	GRITTY
3	5.00	-15.00	15.00		CS	MM	SANDY
4	5.00	-20.00	20.00		CF	MM	SILTY
5	3.00	-23.00	23.00		CM	MM	MUDDY
6	3.00	-26.00	26.00		GU	MM	UNDIFFERENTIATED GRANULESTONE
7	3.00	-29.00	29.00		GP	MM	PEBBLY
8	3.00	-32.00	32.00		GS	MM	SANDY
9	3.00	-35.00	35.00		GF	MM	SILTY
10	3.00	-38.00	38.00		GM	MM	MUDDY
11	3.00	-41.00	41.00		SU	MM	UNDIFFERENTIATED SANDSTONE
12	3.00	-44.00	44.00		SP	MM	PEBBLY
13	3.00	-47.00	47.00		SG	MM	GRITTY
14	3.00	-50.00	50.00		SF	MM	SILTY
15	3.00	-53.00	53.00		SM	MM	MUDDY
16	3.00	-56.00	56.00		FU	MM	UNDIFFERENTIATED SILTSTONE
17	3.00	-59.00	59.00		FP	MM	PEBBLY
18	3.00	-62.00	62.00		FG	MM	GRITTY
19	3.00	-65.00	65.00		FS	MM	SANDY
20	3.00	-68.00	68.00		FM	MM	MUDDY
21	3.00	-71.00	71.00	G	MU	MM	UNDIFFERENTIATED MUDSTONE
22	3.00	-74.00	74.00	E	MP	MM	PEBBLY, GRADATIONAL CONTACT
23	3.00	-77.00	77.00	S	MG	MM	GRITTY, EROSIVE CONTACT
24	3.00	-80.00	80.00		MS	MM	SILTY, SHARP (FAULTED) CONTACT
25	3.00	-83.00	83.00		MF	MM	MUDDY
26	3.00	-86.00	86.00		DD	DD	DIAMICTITE
27	3.00	-89.00	89.00		DO	DO	DOLERITE
28	3.00	-92.00	92.00		UU		CORE LOSS (FAULT)
29	3.00	-95.00	95.00		SU	BT	TROUGH CROSS-BEDDING
30	3.00	-98.00	98.00		SU	BP	PLANAR CROSS-BEDDING
31	3.00	-101.00	101.00		SU	BH	HORIZONTAL BEDDING
32	3.00	-104.00	104.00		SU	BU	CROSS-BEDDING (UNDIFFERENTIATED)
33	3.00	-107.00	107.00		SU	LR	RIPPLE DRIFT LAMINATION
34	3.00	-110.00	110.00		SU	LW	WAVY LAMINATION
35	3.00	-113.00	113.00		SM	LG	GRADED LAMINATION
36	6.00	-119.00	119.00		SM	DU	DEFORMATION STRUCTURES (SLUMP, BALL AND PILLOW
37	3.00	-122.00	122.00		SP	II	INTERBEDDED LITHOLOGIES
38	3.00	-125.00	125.00		SU	MM	MASSIVE
39	3.00	-128.00	128.00		SU	?	UNDIFFERENTIATED
40	3.00	-131.00	131.00		UU		
41	3.00	-134.00	134.00		UU		GRAIN SIZE OFFSETS
42	3.00	-137.00	137.00		FU	MM	MUDSTONE (M/S) 5 PHI
43	3.00	-140.00	140.00		SF	MM	FINE SANDSTONE (S/G) 3-4 PHI
44	3.00	-143.00	143.00		SU	MM	MEDIUM SANDSTONE 1-2 PHI
45	3.00	-146.00	146.00		SU	MM	COARSE SANDSTONE 0-1 PHI
46	3.00	-149.00	149.00		GU	MM	GRANULESTONE (GR/S) -1--2PHI
47	3.00	-152.00	152.00		CU	MM	SMALL PEBBLE CONGLOM (SPC) 4-20MM
48	3.00	-155.00	155.00		CU	MM	MEDIUM PEBBLE CONGLOM (MPC) 21-40MM
49	3.00	-158.00	158.00		CU	MM	LARGE PEBBLE CONGLOM (LPC) 41-60MM
50	3.00	-161.00	161.00		CU	MM	VERY LARGE PEBBLE CONGLOM >60MM

BH 349 ELDORADO FORMATION

X 20899.96
Y 3105190.80 ELEV 0.00



TAG	THICK	ELEV	DEP	G	CODES	COMMENTS	
1	7.42				CU MM	POLY, CS	VS 1
		-7.42	7.42	E			
2	1.11	-8.53	8.53	E	SP MM		
3	3.58				CU MM		
		-12.00	12.00	E			
4	1.00	-13.16	13.16	E	SP II		
5	5.40				CS II	SILT BANDS	
		-18.50	18.50	E			
6	0.77	-19.33	19.33	E	SU MM		
7	4.71				CU MM	POLY	
		-24.04	24.04	E			
8	0.85	-24.89	24.89	E	SP MM		
9	1.31	-26.20	26.20	E	CU MM		
10	1.24	-27.44	27.44	E	SG MM		
11	11.91				CS MM	POLY, W.PACKED	
		-39.35	39.35	E			
12	0.61	-39.96	39.96	E	SG MM	MARKER 1	
13	1.58	-41.54	41.54	E	CG MM		
14	1.97	-43.51	43.51	E	SU MM		
15	0.92	-44.43	44.43	E	SU MM		
16	2.49	-46.92	46.92	E	CO II	POLY, GR/S BANDS	
17	1.29	-48.21	48.21	S	SG MM		
18	2.30	-50.51	50.51	S	UU CD	LOSS	
19	7.12				CO II	GR/S BANDS	
		-57.63	57.63	E			
20	3.37	-61.00	61.00	E	SP MM		
21	6.34				SP MM		
		-67.34	67.34	E			
22	2.05	-69.39	69.39	E	CG MM	POLY	
23	1.73	-71.12	71.12	E	CG MM	POLY	
24	2.74	-73.86	73.86	E	SP II	SILT BAND	
25	2.14	-76.00	76.00	E	CU MM	POLY	
26	4.73				CU MM		
		-80.73	80.73	E			
27	5.27				CU MM	POLY	
		-86.00	86.00	E			
28	3.40	-90.00	90.00	E	CU MM		
29	0.79				CS MM		
		-90.79	90.79	E			
30	0.13	-90.92	90.92	E	MU II		
31	10.62	-101.54	101.54	E	SU LU		
32	5.56				CU MM	POLY, OCC. PYRITE	
		-107.10	107.10	E			
33	9.90				SG MM	MARKER 2 ?	
		-117.00	117.00	E			
34	0.92	-118.00	118.00	E	CU MM	POLY	
35	0.40	-118.40	118.40	E	GP MM		
36	9.88				CG MM		
		-128.28	128.28	E			
37	9.52				CG MM		
		-137.80	137.80	E			
38	4.75				CS II	SILT AND CONGLOM BANDS	
		-142.55	142.55	E			
39	6.50				CG MM		
		-149.05	149.05	E			
40	2.03	-151.08	151.08	E	CG MM	POLY, PYRITIC	
41	5.92				CU MM		
		-157.00	157.00	E			
42	15.00				CU II	OCC THIN GR/S BANDS	
		-172.00	172.00	E			
43	4.00	-176.00	176.00	E	CO II		
44	3.00	-179.00	179.00	E	CG MM		
45	1.09	-180.09	180.09	E	CG MM		
46	1.14	-181.23	181.23	E	SG II		
47	6.99				CG II	THIN GR/S BANDS	
		-188.22	188.22	E			
48	0.94	-189.16	189.16	E	SG MM		
49	5.89				CG MM		
		-195.05	195.05	E			
50	1.45	-196.50	196.50	E	SU II	SI/S AND M/S	
51	1.47	-197.97	197.97	E	CU MM	POLY	
52	6.53				GP II	CONGLOM AND GR/S BANDS	
		-204.50	204.50	E			
53	15.75				CG II	POLY, PACKING INCREASES DOWN	
		-220.25	220.25	E			
54	2.96	-223.21	223.21	E	CU MM		
55	1.78	-224.99	224.99	E	SG MM		
56	4.30				CU MM	POLY, GOOD SORT	
		-229.29	229.29	E			
57	0.56	-229.85	229.85	E	SU MM		
58	3.52				CU MM	POLY	
		-233.37	233.37	E			
59	0.63	-234.00	234.00	E	GG II		
60	4.31				CU MM	POLY	
		-238.31	238.31	E			
61	1.74	-240.05	240.05	G	GP II		
62	3.34				SU MM		
		-243.00	243.00	E			
63	5.70				CU MM	POLY	
		-248.70	248.70	E			
					CS II	POLY CONGLOM. AND SILT BANDS	
					CU MM	POLY	VS 1

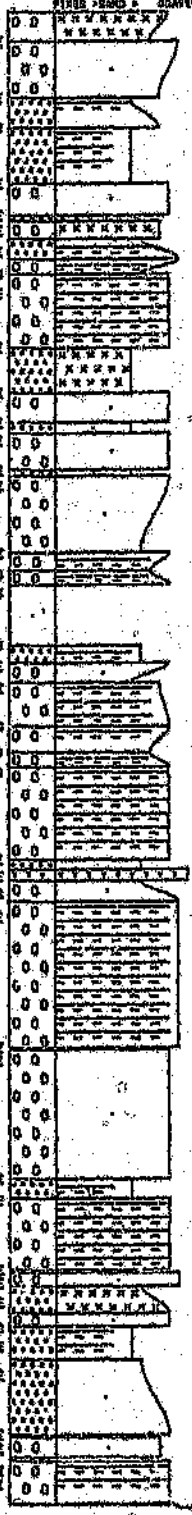
CONTINUED

BH 349 CONTINUED

64	4.21	-253.00 253.00 E					
65	6.37	-259.37 259.37 E					
66	5.63	-265.00 265.00 G	SB	DU	SCAT PEBS, COARSE AND FINE BANDS	VS 2-4
67	5.00	-270.00 270.00 G	SP	DU	GR/G AND PEBBLES	
68	16.00		SP	GU		
69	2.15	-286.00 286.00 D	SP	II	POLY	
70	2.41	-288.15 288.15 S	CU	HH		
71	4.09	-290.50 290.50 S	SP	HH		
72	0.00	-295.22 295.22 S	HU	HH		
73	7.81	-295.30 295.30 G	SP	HH		
		-303.11 303.11 G				
74	15.04		SO	CU		
		-318.15 318.15 D				
75	6.85	-325.00 325.00 G	GH	II		
76	3.87	-328.87 328.87 S	SH	II	SCAT. GRITS	
77	6.33		GO	II		
		-335.00 335.00 S				
78	0.10	-335.10 335.10 E	HU	HH		
79	6.90		SU	GU		
		-342.00 342.00 G				
80	10.04		SP	II		
		-352.04 352.04 E				
81	5.26		SO	DU	SCHISTOSE BANDS	
		-358.10 358.10 G				
82	1.26	-359.36 359.36 E	GP	HH		
83	1.49	-360.85 360.85 E	SP	HH		
84	0.10		SP	II	COARSE AND FINE BANDS	
		-368.03 368.03 G				
85	3.97		SU	II		
		-373.00 373.00 E				
86	0.10	-373.10 373.10 E	HU	HH		
87	0.15	-373.25 373.25 E	SP	HH		
88	4.24		SU	HH		
		-377.49 377.49 E				
89	0.21	-377.70 377.70 E	CU	HH		
90	2.00	-379.70 379.70 E	SP	HH		
91	0.01	-380.00 380.00 E	CU	HH		
92	10.50		SP	II		
		-391.10 391.10 E				
93	1.88	-393.00 393.00 G	GS	II		
94	5.00	-396.00 396.00 D	SU	II		
95	15.54		SP	DU	OCC. SCAT GR/G. PEBBLES AND SL ARGN BANDS	
		-411.54 411.54 E				
96	0.10	-411.70 411.70 G	CU	HH		
97	15.01		SU	DU	OCC. SPECKLED BANDS	VS 2-4
		-426.71 426.71 E				
98	6.00		CO	HH	POLY	VXS
		-432.71 432.71 E				
99	0.54	-433.25 433.25 E	CP	HH		
100	4.03		CU	HH	POLY	
		-437.28 437.28 E				
101	0.67	-437.95 437.95 E	CO	II	LAMINATED & ARGN AND SI/S BANDS	VS 3

BH 1435 ELDORADO FORMATION

X 22458.96
Y 3105314.80   ELEV 0.00



TAG	THICK	ELEV	DEP	C			COMMENTS	
1	5.10				CU	OU	POLY. IMBRICATED	VS 1
		-5.10	5.10	E				
2	9.21				CU	MM	POLY	
		-14.01	14.01	E				
3	5.10				SP	II	PEBBLE SANDS, + X FINING UPS	
		-20.00	20.00	G				
4	3.55				SP	II	PEBBLE SANDS	
		-20.55	20.55	E				
5	5.44				CU	MM	POLY. MO	
		-34.00	34.00	E				
6	1.01	-30.06	30.00	E	CU	DU	MARKER 1	
7	2.00	-36.90	30.90	E	CS	DU	PYRITE ON FORESETS	
8	3.52	-42.50	42.50	G	SP	II		
9	2.57	-45.07	45.07	E	SS	II		
10	12.73				CS	II		
		-57.80	57.80	E				
11	7.70				SS	DU		
		-65.50	65.50	E				
12	5.11				CU	MM	POLY. W.PACKED	
		-70.67	70.67	E				
13	1.90	-72.57	72.57	E	SS	MM		
14	6.23				SU	MM	POLY	
		-78.80	78.80	E				
15	1.00	-79.88	79.88	E	SP	MM		
16	13.19				CU	MM		
		-93.07	93.07	E				
17	3.06	-96.15	96.15	G	CS	II	IMBRICATED	
18	2.44	-98.59	98.59	E	CS	II		
19	10.41				UU		CORE LOSS: FAULT	
		-109.00	109.00	E				
20	3.00	-112.00	112.00	E	SP	II	PEBBLE SANDS MARKER 2 ?	
21	3.30	-115.35	115.35	E	SS	MM		
22	7.62				CS	II	OCC. GR/S SANDS	
		-123.00	123.00	G				
23	4.80				CS	II		
		-127.80	127.80	G				
24	2.30	-130.00	130.00	G	CS	II		
25	16.01				CU	II	POOR IMBRICATION	
		-146.01	146.01	E				
26	1.07	-147.08	147.08	E	SS	MM		
27	1.06	-148.84	148.84	E	DD	DD	INTRUSIVE	
28	3.66	-153.30	153.30	E	CS	MM		
29	25.21				CS	II	IMBRICATED (?), POLY, GR/S SANDS, POOR CROSS-BEDDING	
		-178.51	178.51	E				
30	0.30	-178.80	178.80	E	SS	MM	TALC: FAULT (?)	
31	22.40				SS	MM	GRITTY MATRIX, OCC. PYRITE, FAULTED ?	
		-201.30	201.30	E				
32	3.40	-204.07	204.07	E	SP	II	SANDS OF L-DL ARGN AND CONGLOM.	
33	12.48				CS	II	IMBRICATED, OCC GR/SLT SANDS	
		-217.32	217.32	E				
34	0.43	-217.75	217.75	E	SP	MM		
35	2.37	-220.12	220.12	E	CU	MM		
36	4.60				SU	DU		
		-224.72	224.72	G				
37	2.28	-227.00	227.00	E	CU	MM		
38	5.75				SP	II	L-SL ARGN. CONGLOM AND INTRUSIVE. FAULTED?	
		-232.75	232.75	E				
39	13.02				SP	MM		
		-245.77	245.77	E				
40	0.39	-246.16	246.16	E	SU	MM		
41	3.37				CU	MM		
		-249.53	249.53	E				
42	0.63	-250.16	250.16	E	SP	MM		
43	7.36				CS	II		VS 1

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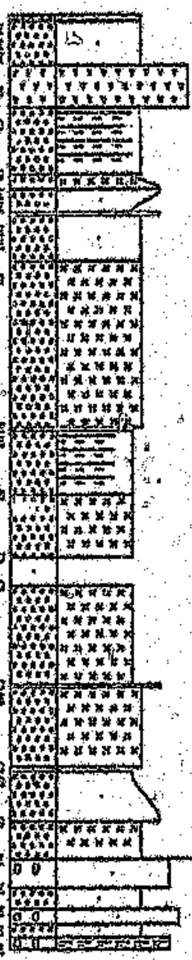
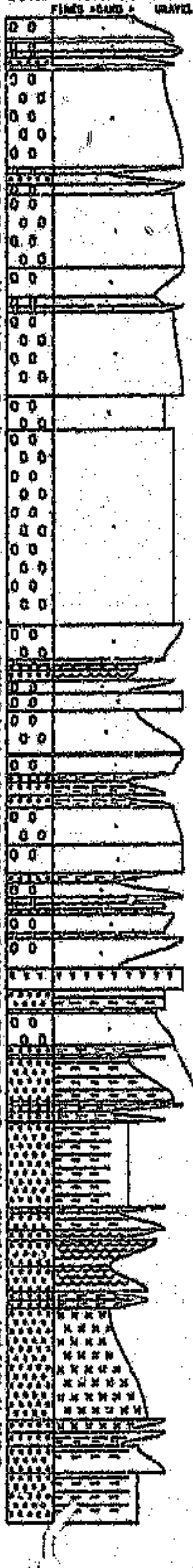
BH 1435 CONTINUED



		-257.81 257.81 E				
44	1.04	-258.85 258.85 E	SU	MM		VB 2-4
45	0.11	-258.96 258.96 E	MU	MM		
46	7.53		SU	MM		
		-266.49 266.49 D				
47	7.31		DD	DD	INTRUSIVE	
		-273.80 273.80 D				
48	11.53		SP	11	SL ARGN AND SI/S, CORE LOSS, FAULTED ??	
		-285.33 285.33 D				
49	2.45	-287.78 287.78 E	SP	DD		
50	0.10	-287.88 287.88 E	PB	MM		
51	3.64		SP	MM		
		-291.52 291.52 E				
52	0.48	-292.00 292.00 E	DU	MM		
53	8.00		SO	MM		
		-300.00 300.00 D				
54	20.43		SP	DU	OCC. THIN SHALES (SHEARS ?)	
		-320.43 320.43 E				
55	0.56	-320.99 320.99 E	PU	MM		
56	19.01		SU	11	GR/S, PEBBLE AND SI/S BANDS	
		-340.00 340.00 D				
57	10.74		SU	DU	GRITTY AND SHALE BANDS	
		-350.74 350.74 D				
58	4.34		MM		CORE LOSS	
		-355.08 355.08 D				
59	18.60		SU	DU	GR/S AND SI/S BANDS	
		-373.68 373.68 D				
60	0.14	-373.82 373.82 E	CU	MM		
61	13.02		SP	DU	PEBBLE BANDS	
		-386.71 386.71 D				
62	0.79	-387.50 387.50 E	UU		CORE LOSS	
63	0.71		SP	MM		
		-388.21 388.21 D				
64	[illegible]		SP	CU	PEBBLE, SI/S BANDS, SERICITIC, FAULTED	VS 2-4
		-402.00 402.00 E				
65	5.36		CG	MM		VS 5
		-407.36 407.36 E				
66	3.87	-411.23 411.23 E	SO	MM	+ SI/S BAND	
67	2.62	-413.85 413.85 E	CU	MM		
68	2.32	-416.17 416.17 E	SO	MM		
69	3.10	-419.27 419.27 E	DU	11	+ SL ARGN BAND	VB 3

BH 1476 ELDORADO FORMATION

X 26081.95
Y 3099149.86
ELEV 0.00



TAG	THICK	ELEV	DEP	C			COMMENTS	
1	3.09				CU	MM	GRADU. WITH V/CORP LAVA. SHEARED	VS 1
		-3.09	3.09					
2	0.35	-4.24	4.24		CU	MM		
3	1.71	-5.95	5.95		DU	MM		
4	1.01	-6.96	6.96		CU	MM	V. PACKED	
5	1.49	-8.46	8.46		SU	MM		
6	0.50	3.01	9.01		SP	MM		
7	0.21	-9.22	9.22		SP	MM		
8	16.90				CU	MM	CALCITE VEINING. FAULTED (?)	
		-26.21	26.21					
9	1.00	-27.27	27.27		CU	MM		
10	1.81	-29.00	29.00		SP	MM	MARKER 1	
11	1.80	-30.80	30.80		CU	MM		
12	12.74				CU	MM	V.PACKED BASE. POLY. FAULTED MAX CLAST = 10MM	
		-43.02	43.02					
13	5.12				CU	MM	CG-MG. DK.GY. M-C L.AREN	
		-48.74	48.74					
14	1.54	-50.30	50.30		CU	MM	CLA MATRIX	
15	0.80	-51.30	51.30		CU	MM	NOTE IGNEOUS CLASTS	
16	14.64				CU	MM	POLY. CS. INDURATED. SUX PACK. MAX CLAST = 30MM	
		-66.00	66.00					
17	6.00				CU	MM		
		-72.00	72.00					
18	34.05				CU	MM		
		-106.05	106.05					
19	6.10				CU	MM		
		-112.15	112.15					
20	0.89	-113.04	113.04		CS	MM		
21	0.96	-114.00	114.00		SU	GU		
22	1.91	-115.91	115.91		SU	GT	MARKER 2	
23	2.14	-118.05	118.05		CU	MM	V.ROUNDED	
24	3.10	-121.15	121.15		CU	MM	V.PACKED. SL. FLATTENING	
25	7.[illegible]				CS	MM		
		-128.85	128.85					
26	0.38	-129.03	129.03		DD	DD	"FLOATING" PEBBLES	
27	3.26				CU	MM	DK.GY. V.PACKED	
		-132.29	132.29					
28	1.31	-133.60	133.60		SP	II	DK.GY	
29	2.30	-135.90	135.90		SP	II		
30	2.21	-138.10	138.10		SP	II	GLASSY. GY.. SL AREN. AT TOP	
31	6.55				CU	MM	ODD. G GR. L AREN BANDS. NO IG. CLASTS. FAULTED NEAR BASE	
		-144.74	144.74					
32	4.96				CU	MM	POLY. A-R. V.PACKED. NO IG.	
		-149.70	149.70					
33	1.60	-151.30	151.30		SP	II		
34	2.62	-153.92	153.92		CU	MM	ODD. L.AREN AREAS AND SMALL COARSENING UP AREAS	
35	1.15	-155.07	155.07		CU	MM		
36	0.93	-156.00	156.00		CU	MM		
37	0.07	-156.07	156.07		SP	II	4 FINING UP UNITS	
38	3.[illegible]7				CU	MM		
		-160.14	160.14					
39	0.91	-161.05	161.05		CU	II		
40	5.32				CU	MM	POLY. V.PACKED. SA-R CLASTS	
		-166.37	166.37					
41	3.63				DD	DD	FAULTED	
		-170.00	170.00					
42	3.41				DF	II	DK.GY SL AREN LENSES	
		-173.41	173.41					
43	0.66	-174.07	174.07		SP	II		
44	5.73				CU	MM	V.PACKED. ONE L AREN GR/S LENS	VS 1?
		-179.80	179.80					
45	1.64	-181.44	181.44		SP	II		VS 2-4 ?
46	0.56	-182.00	182.00		SP	II		
47	7.63				SP	II	POLY. MAX CLAST = 30MM	
		-189.63	189.63					
48	0.66	-190.29	190.29		SP	II		
49	1.19	-191.48	191.48		SP	II		
50	1.71	-193.19	193.19		SP	II		
51	0.33	-193.52	193.52		SP	MM	LT.GY. SL-G AREN. [illegible] SPECKLING	
52	15.04				SU	II	FINE AND M-C SL AREN	
		-208.56	208.56					
53	0.90	-209.46	209.46		SP	II		
54	3.11				SP	II		
		-212.57	212.57					
55	1.84	-214.41	214.41		SU	DT	GY SL AREN. WINNOWED TOP	
56	4.71				CU	DT	WINNOWED TOP	
		-219.12	219.12					
57	4.51				SP	DT		
		-223.63	223.63					
58	1.43	-225.06	225.06		SP	II		
59	1.44	-226.50	226.50		SP	II		
60	10.00				CP	DU	INTRODUCED LITHOLOGIES	

CONTINUED...

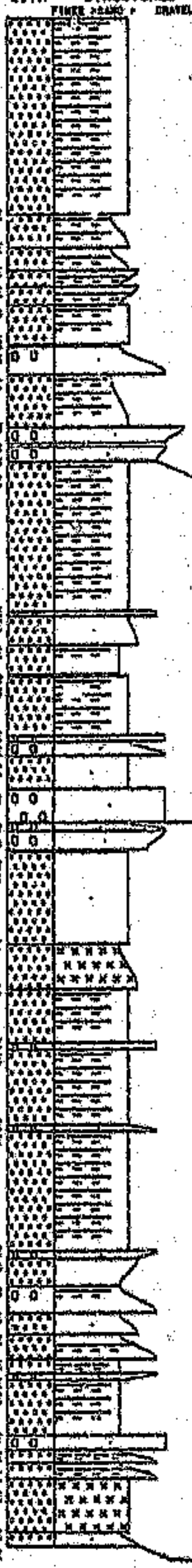
BH 1476 CONTINUED

		-240.10	240.10	E
61	2.12	-248.28	248.28	E
62	2.46	-250.74	250.74	E
63	4.71	-255.45	255.45	E
64	8.73	-264.18	264.18	E
65	22.32	-286.50	286.50	E
66	16.58	-303.08	303.08	E
67	1.23	-304.31	304.31	E
68	4.92	-309.23	309.23	E
69	0.82	-310.05	310.05	E
70	3.28	-313.33	313.33	E
71	1.03	-314.36	314.36	E
72	4.62	-319.00	319.00	E
73	6.86	-326.84	326.84	C
74	4.18	-331.02	331.02	E
75	3.60	-334.62	334.62	E
76	5.49	-340.11	340.11	E
77	5.87	-345.98	345.98	C
78	3.00	-348.98	348.98	E
79	6.53	-355.51	355.51	E
80	10.24	-365.75	365.75	E
81	4.51	-370.26	370.26	E
82	3.27	-373.53	373.53	E
83	0.09	-373.62	373.62	E
84	0.32	-373.94	373.94	E

SP GU L AREN. BURROWED AT TOP
SP II SL-L AREN. MS
SP II DK.GY. V. PACKED SPG'S. DK. MATRIX
SP II OCC. SPG'S. LENSES. TX BEDDING. L-SL AREN
GU GY SI/G ON FORESETS
SP GU 14 FINING UP CYCLES. X-BEDDED. MAX CLAST = 40MM
SP GU
SP II 5 FINING UP SEQUENCES. POLY. L-SL AREN. OCC SI/G
SP II
GU MN
SP II L AREN TO POLY M/S
SP II L AREN. POLY SPG
SU II L AREN. TX BEDDED. NEAR LAMINATED
SP GU L AREN. POLY PEBBLE BANDS
SP GU SL AREN. INTERBEDDED LITHOLOGIES
SP II 5 FINING-UPS IN AN OVERALL FINING UP SEQUENCE
GU MN POLY
GU MN POLY
SP II SLUMPED. NEAR LAM. BEDDED M/S-SPG'S. FAULTED VS 2-4
GU MN POLY. MAX CLAST = 40MM VS 5
SU II POLY GRIT BANDS. GR/G AND L AREN- SL AREN. SLUMPED
GU MN POLY. L.GY. SL AREN BAND AND MATRIX. OLIGO BASE
SU GU SL AREN
GU MN OLIGO. W.ROUND. P.SORT. OCC. SSP. D.PY VS 3

BH OG5 HARMONY - AANDFNK FORMATIONS

X 24329.95
Y 3105325.80 ELEV 0.00

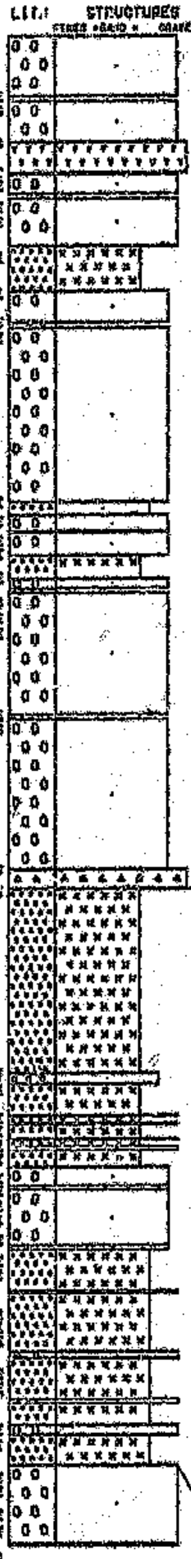


TAG	THICK	ELEV	DEP	C			COMMENTS	
1	8.49				SP	II	OCC C GR. SR/S AND PEBBLY BANDS	AANDENK FM
		-8.49	8.49	E				
2	1.45				SG	II	L-SL AREN	
		-9.94	9.94	E				
3	0.88	-10.82	10.82	E	SG	II	L-SL AREN	
4	0.66	-11.88	11.88	E	SU	II	L-SL AREN	
5	0.80	-12.40	12.40	G	SU	II		
6	1.70				SF	II	L AREN F S/S-SI/S LAMINATIONS	
		-14.10	14.10	S				
7	0.10	-14.20	14.20	S	UU		FAULT	
8	1.23				CS	MM	OLIGO BASE"A" REEF ?	
		-15.43	15.43	E				
9	2.29				SP	II	L AREN	
		-17.72	17.72	G				
10	0.68	-18.40	18.40	G	CU	MM	OLIGO, SL AREN, M GR MTRIX	
11	0.15	-18.55	18.55	G	SU	MM	L AREN PARTING	
12	0.66	-19.21	19.21	E	CU	MM	OLIGO	GPM
13	6.50				SP	II	F-C GR SL-L AREN, LAMINATIONS	SPES BONA FM
		-25.71	25.71	E				
14	0.22	-25.93	25.93	E	CU	MM	POLY	
15	1.24				SG	MM		
		-27.17	27.17	E				
16	1.26				SP	II	INTERLAM F GR S/S AND M-C GR SL AREN	
		-28.43	28.43	S				
17	0.10	-28.53	28.53	S	UU		CORE LOSS	
18	2.61				SU	II	M. C GR SL AREN LAMINATIONS	
		-31.14	31.14	E				
19	0.26	-31.40	31.40	E	SU	MM	POLY, CS	'B' REEF TOP ??
20	0.62	-32.02	32.02	E	CS	MM		
21	1.45				SP	MM	GOAT GR/S AND SPG'S, L-SL AREN, DK GY	
		-33.47	33.47	G				
22	1.46				CU	MM	POLY, MATURE BASE, SL AREN MATRIX	"B" REEF
		-34.93	34.93	S				
23	0.37	-35.30	35.30	G	CS	MM	FAULTED TOP	BABOREEK FM
24	0.84				CS	MM	POLY, FAULTED BASE	
		-36.14	36.14	S				
25	0.10	-36.24	36.24	S	UU		CORE LOSS (MAJOR FAULT)	
26	4.02				SP	MM	SL-L AREN	
		-40.26	40.26	E				
27	1.94				SP	DU	Y-GY, GR/S SPECKS 2X FINING UPS, SOFT SEDOT	
		-42.20	42.20	E				
28	2.38				SG	II	F, C GR SL-L AREN ZONES	
		-44.58	44.58	E				
29	0.30	-44.88	44.88	E	CS	MM	POLY BAND	
30	3.30				SG	II	L-SL AREN	
		-48.15	48.15	E				
31	0.29	-48.44	48.44	E	CS	MM	POLY BASE	
32	5.31				SG	II	L-SL AREN	
		-53.75	53.75	E				
33	0.35	-54.10	54.10	G	CS	MM	POLY	
34	1.21				SP	MM	1 LARGE PEBBLE	
		-55.31	55.31	G				
35	1.21				CG	II	4X FINING UPS	
		-56.52	56.52	E				
36	0.92	-57.44	57.44	E	GU	MM		
37	1.10				SU	II		
		-58.54	58.54	E				
38	0.64	-59.18	59.18	E	SP	II		
39	0.29	-59.47	59.47	E	CS	MM		
40	2.43				SP	II		
		-61.90	61.90	E				
41	0.64	-62.54	62.54	E	CU	MM	POLY, O. BSP, SL AREN MTRIX	LEADER REEF
42	0.58	-63.12	63.12	E	SP	II	OLIGO SPG TO L AREN	
43	0.68	-63.80	63.80	E	CP	II	OLIGO SPG TO L AREN	
44	2.33				SG	DU	SLUMPED ?	
		-66.13	66.13	E				
45	0.63	-66.76	66.76	E	SU	MM	2X FINING UPS, W.O.B.	

CONTINUED ...

BH MG2 ELDORADO FORMATION

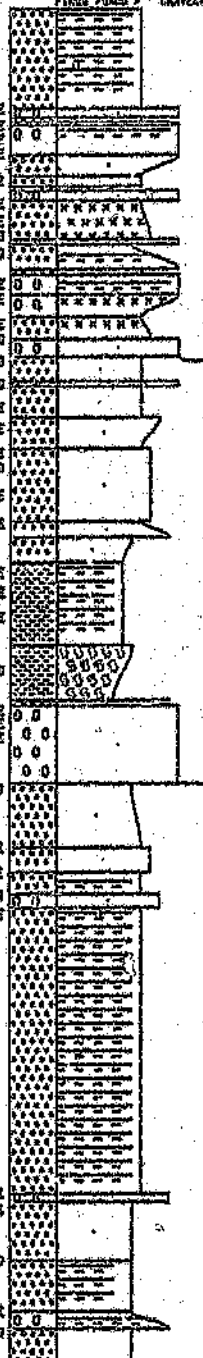
X 24244.95
Y 3102236.80 ELEV 0.00



TAO	THICK	ELEV	DEP	C			COMMENTS	
1	10.35				CU	MM	5DK GY. VG.QITE.SH.CH	VS 1
		-10.35	10.35	E				
2	0.03	-11.18	11.18	S	CS	MM		
3	7.02				CU	MM		
		-18.20	18.20	S				
4	5.31				DD	DD	LAVA	
		-23.51	23.51	E				
5	0.29	-23.80	23.80	E	BD	MM		
6	3.30				CU	MM	5 DK GY. P. PACK (1)	
		-27.10	27.10	E				
7	0.80	-27.90	27.90	E	DG	MM		
8	8.20				CU	MM	5 (1)	
		-36.10	36.10	E				
9	7.70				SP	DU	PALE GY MARKER 1	
		-43.80	43.80	E				
10	5.40				CU	MM	5 (1)	
		-49.20	49.20	E				
11	1.00	-50.20	50.20	E	DS	MM		
12	30.00				CU	MM	5 DK GY. P. SORT (2)	
		-80.20	80.23	E				
13	2.21	-82.41	82.41	E	SG	MM	PALEGY. COAT QGITE	
14	2.75	-85.16	85.16	E	CD	MM	3 (2)	
15	0.27	-85.42	85.42	E	DU	MS		
16	3.90				CU	CA	3 (2)	
		-89.40	89.40	E				
17	4.00				SO	DU	GY MARKER 2	
		-93.40	93.40	S				
18	1.60	-95.00	95.00	E	CD	MM	(2) R-SA. CH.QITE.Q.SH	
19	0.09	-95.00	95.80	E	SU	MM	L.AREN	
20	20.00				CD	MM	3 DK.GY. P.SORT. R-SA. Q.PY (3)	
		-115.70	115.70	E				
21	0.00	-117.30	117.30	S	SD	MM		
22	26.00				CD	MM	3 (3)	
		-143.30	143.30	D				
23	3.30	-146.80	146.80	E	DD	DD	LITHIC WACKE	VG 1
24	31.80				SG	DU	WITH Y AND BL SPECKS	VS 2-4
		-178.80	178.80	E				
25	1.90	-180.50	180.50	E	CS	MM	DK.GY	
26	5.50				SO	DU	WITH Y AND BL SPECKS	
		-186.00	186.00	E				
27	0.13	-186.13	186.13	E	CS	MM		
28	1.20	-187.33	187.33	E	SO	DU		
29	0.27	-187.60	187.60	E	CS	MM		
30	2.47				SO	DU		
		-190.07	190.07	E				
31	0.09	-190.16	190.16	E	CO	MM		
32	1.30	-191.44	191.44	E	SO	DU		
33	0.64	-191.90	191.90	K	CS	MM		
34	3.32				SO	DU		
		-195.00	195.06	E				
35	5.30				CO	MM	3 DK GY. P SORT. OF CH.Q.SH.QITE	
		-190.30	190.30	E				
36	0.57	-190.87	190.87	E	CO	MM		
37	9.03				CO	MM	3	
		-208.70	208.70	E				
38	0.41	-209.11	209.11	E	SU	MM	L WACKE	
39	0.41	-209.52	209.52	E	DD	MM	3	
40	7.17				DP	DU	L-DK GY (4)	
		-216.69	216.69	E				
41	0.41	-217.10	217.10	E	CU	MM		
42	10.20				SP	DU	(4)	
		-227.30	227.30	E				
43	1.10	-228.40	228.40	E	CU	MM		
44	7.15				DP	DU	(4)	
		-235.55	235.55	E				
45	0.56	-236.11	236.11	E	CU	MM		
46	3.02				DP	DU	(4)	
		-239.03	239.03	E				
47	1.97	-241.00	241.00	E	CU	MM		
48	8.20				DP	DU	(4)	VS 2-4
		-249.00	249.00	E				
49	13.80				CU	MM	5 VGS M-PACK. DK.GY. OF QITE.Q.CH.SH	VS 5
		-260.30	260.30	E				
50	0.35	-260.65	260.65	E	SU	MM	5K GY-BL L-BL AREN. + POLY SAND	
51	0.10	-260.75	260.75	E	CU	MM	POLY. PRED VG: BEATRIX REEF	VS 5

BH MG2 HARMONY-AANDENK FORMATIONS

X 24244.95
Y 3102236.80 ELEV 260.75



TAG	THICK	ELEV	DEP	G	COMMENTS	
1	4.20				SU II INTERBEDDED L AREN AND SL AREN	AANDENK FM
		256.47	4.20	E		
2	0.30	256.00	4.07	E	CU MM "A" REEF ?	
3	0.20	255.80	4.87	E	CU MM GY L AREN	
4	0.12	255.70	4.99	E	CU MM POLY, ANG, DK.GY-GL (SIMILAR TO VS)	
5	1.20				CU II GY, L-SL AREN MTRIX, WITH G OR L AREN	
		254.47	6.20	E		
6	0.90	253.57	7.10	E	SP MM CLEANS UP, L-SL AREN	
7	0.45	253.12	7.53	E	SU MM GY-DK.GY L AREN	
8	0.10	253.04	7.61	S	CU LN BLACK, FAULTED	
9	0.43	252.61	8.24	G	CU MM CLEAN, SLA GY	
10	1.07				SU BU SL AREN	
		250.67	9.60	E		
11	0.22	250.56	10.10	E	CU MM	
12	1.05				SP II POOR SORT, POLY BASE	
		249.50	11.16	E		
13	0.25	249.34	11.41	G	CU MM SLA	
14	0.04	248.80	12.25	G	CU II OLIGO, SL AREN MTRIX AND 17CM PARTING	SPM
15	0.95	247.55	13.20	G	CS BU POLY, L-SL AREN BASE	
16	0.95	246.60	14.15	E	SU BU AANDENK CHANNEL	
17	0.78	245.04	14.91	E	CU MM POLY, SH,VQ,CH,IQ, L GY L AREN MTRIX	
18	1.00				SU MM LGY-Y L AREN	
		244.76	15.99	E		
19	0.18	244.59	16.17	G	MU MM PEBBLE BAND	
20	1.35				SU MM GY L-SL AREN	
		243.23	17.52	E		
21	1.35				SP MM	
		241.88	18.87	E		
22	3.14				SP MM DK.GY, L.AREN, WITH Y. SPECKS (Y)	
		238.74	22.01	E		
23	0.07	238.67	22.60	E	SP MM 3X FINING UP OLIGO LAGS, SL AREN MTRIX	
24	1.07				SU MM L-SL AREN, SI/S INTERBEDS	
		237.60	23.75	E		
25	3.05				MS II INTERBEDDED M/S, SI/S AND F S/S	
		233.49	27.30	G		
26	2.35				MP BU	
		231.10	29.05	E		
27	0.05	231.08	29.70	E	CM MM WACKE, DEBRIS FLOW, COARSENS UP	BASE OF CHANNEL
28	0.20	230.05	30.00	E	SU MM	SPES BONA FM
29	3.35				CU MM POLY, SL AREN MTRIX, D PY, GG, GHOSTY	"G" REEF
		227.50	33.35	G		
30	2.70				SU MM SL TO LAREN AT TOP	DAGBREEK FM
		224.72	36.03	E		
31	1.06	223.80	37.00	E	SG MM	
32	0.90	222.70	38.05	G	SP II SL-L AREN, OCC PEBBLE BANDS, COLOUR CHANGES	
33	0.60	222.10	38.65	E	CG MM POLY, SL AREN PARTING	
34	12.45				SP II L-SL AREN	
		209.65	51.10	E		
35	0.35	209.30	51.45	G	CU MM POLY	
36	2.55				SU MM	
		206.75	54.00	G		
37	2.20				SP II	
		204.55	56.20	E		
38	0.75	203.80	56.95	G	G II POLY BAND AT BASE	
39	3.50				SU MM	
		200.30	60.45	E		
40	0.10	200.20	60.55	E	CS MM POLY LAG	
41	2.05				SU MM	
		197.55	63.20	E		

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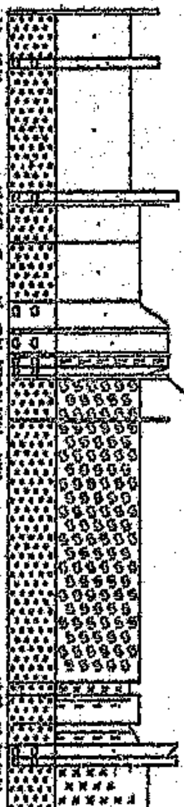
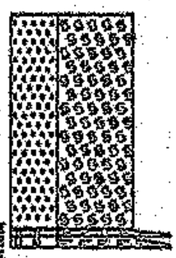
BH MG 2 CONTINUED



42	0.15	197.40	83.35	E	DS	MM	POLY LAG	
43	4.05				SU	MM		
		105.45	85.30	E				
44	0.42	105.83	85.72	E	CS	MM		
45	5.33				SU	MM		
		100.70	71.05	E				
46	0.42	180.20	71.47	E	CS	MM	BOO POLY LPB'S	
47	0.10	100.12	71.63	Q	OU	MM	LAG AT BASE	
48	1.01				SP	MM	TBY L AREN. FAULTED BANDS	
		107.81	73.24	Q				
49	2.52				SP	MM	DK.GY SL AREN, L GY-Y GY BANDS. POLY	
		104.89	75.76	E				
50	1.17				CP	MM	POLY. Y L AREN MTRIX	
		103.02	76.83	Q				
51	0.10	103.04	77.11	E	SU	MM	L AREN. Y GY	
52	0.85				CU	MM	POLY.SCAT Q AND GSP	
		102.78	77.80	E				
53	0.14	102.65	78.10	E	SU	MM		
54	0.45	102.20	78.55	E	OU	II	INTERBEDDED SL AREN BANDS	
55	0.30	101.85	78.93	E	CU	MM		
56	0.10	101.65	79.00	E	CU	MM	LQ POLY, P SORT, V PACK	LEADER REEF
57	1.70				UP	OU	OLIVE GY, DK AND L. ZONES: WACKE	
		120.80	80.79	E				
58	0.00	170.87	80.08	E	CU	MM	MIDDLE REEF. MATURE, +D.PYRAMHONY PM	
59	11.26				SU	OU	OLIVE GY. DK. AND L. ZONES: WACKE MIDDLING QUARTZITE	
		100.63	92.12	E				
60	0.88	149.00	93.07	E	SU	OU	TAR BITE. BRECCIATED. PYRITIZED	
61	1.22				SP	II	POLY	
		108.05	93.09	E				
62	0.91				SP	II		
		185.96	94.80	E				
63	0.55	103.40	95.35	E	CU	MM	POLY. P SORT, MS. M-G SL AREN MTRIX, +GSP	
64	0.30	185.04	95.71	E	OQ	MM	POLY. +GSP, MS. G GR. MTRIX	BASAL REEF
65	5.54				SU	OU	SL AREN. WITH POLY SPECKS	
		181.90	99.27	E				

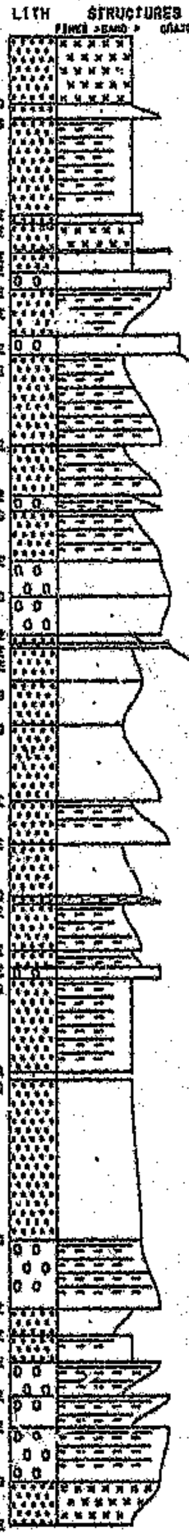
BH OG 5 CONTINUED



40	0.07				SP	DU	D WACKE	HARMONY FM
		-75.03	75.03	E				
47	0.07	-75.00	75.00	E	GU	GU	SL ADCH TOO QUARTZITE	
48	0.27	-76.17	76.17	E	CS	II	POLY. CS 100/T	
49	0.18	-76.68	76.85	E	CS	II	POLY. MS	BASAL REEF

BH SH18 HARMONY - AANDENK FORMATIONS

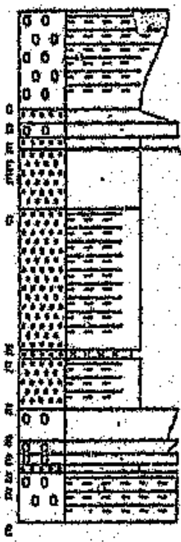
X 28196.95
Y 3101940.81
ELEV 0.00



TAG	THICK	ELEV	DEP	C	COMMENTS			
1	2.90				SU	DU	L AREN	AANDENK FM
		-2.90	2.90	G				
2	0.65				SP	MM	MS PEBBLE BAND	
		-3.55	3.55	S				
3	4.16				SP	II	OCC. F OR DARK BANDS	
		-7.71	7.71	E				
4	0.37				SU	MP	SL-G AREN	
		-8.08	8.08	E				
5	1.13				SU	DU	L AREN	
		-9.21	9.21	E				
6	0.10				CU	MM	OLIGO. M. PACK. BSP. SL AREN M GR MTRIX	'A' REEF
		-9.31	9.31	E				
7	0.84				SU	MM	DARKER AT TOP	TOP OF BPM
		-10.15	10.15	E				
8	0.75				CU	MM	POOR PACK AND SORT	
		-10.90	10.90	E				
9	1.97				SP	II	2X COARSENING UPS. DK GY L AREN TO OLIGO SPC	
		-12.87	12.87	E				
10	0.83				CU	MM	OLIGO (VO). BSP. SL AREN MTRIX	BPM
		-13.70	13.70	G				
11	3.87				SP	II	F OR L AREN TO POLY SPC. 3X FINING UPS	SPES BONA
		-17.57	17.57	G				
12	2.16				SP	II	3X FINING UPS	
		-19.73	19.73	E				
13	0.66				CS	II	MS. C GR MTRIX	
		-20.39	20.39	G				
14	2.16				SP	II		
		-22.55	22.55	E				
15	1.55				CS	MM	POLY. SL AREN MTRIX	
		-24.10	24.10	G				
16	1.65				CS	MM		
		-25.75	25.75	E				
17	0.37				SU	MM		
		-26.12	26.12	E				
18	0.19				CU	MM	POLY. C GR MTRIX	"B" REEF
		-26.31	26.31	E				
19	1.41				SU	MM	SL AREN	DAGGAFONTEIN FM
		-27.72	27.72	G				
20	1.88				SU	MM	SL AREN	
		-29.60	29.60	G				
21	3.20				SP	MM	L AREN. MS. PEBBLY BASE	
		-32.00	32.05	E				
22	1.80				SP	II	SL AREN TO POLY MPG	
		-34.77	34.77	E				
23	2.25				SU	MM		
		-37.02	37.02	G				
24	0.34				SP	II	2X FINING UPS	
		-37.36	37.36	E				
25	2.01				SP	II	Y-GY L- SL AREN	
		-39.37	39.37	E				
26	0.73				SP	II	SL AREN	
		-40.10	40.10	E				
27	0.49				CU	MM	G GR. SL AREN MTRIX	
		-40.59	40.59	R				
28	4.05				SP	II	INTERBEDDED SL-L AREN AND PEBBLE BANDS	
		-44.64	44.64	R				
29	0.36				UU		FAULT	
		-45.00	45.00	S				
30	7.00				SP	MM	L-SL AREN	
		-52.00	52.00	G				
31	2.00				CS	II	POLY SPC. OCC. SL AREN BANDS	
		-54.00	54.00	E				
32	1.15				SP	MM	DK GY L AREN	
		-55.15	55.15	E				
33	1.17				SP	II	PEBBLY. 1: FINING UP	
		-56.32	56.32	E				
34	1.46				CU	II	2X COARSENINGS	
		-57.78	57.78	E				
35	1.36				CU	II	COARSENS AND CLEANS UP	
		-59.14	59.14	E				
36	2.38				CS	II	POLY. BSP	
		-61.52	61.52	G				
37	1.92				SU	DU	L-SL AREN	
		-63.44	63.44	E				

CONTINUED..

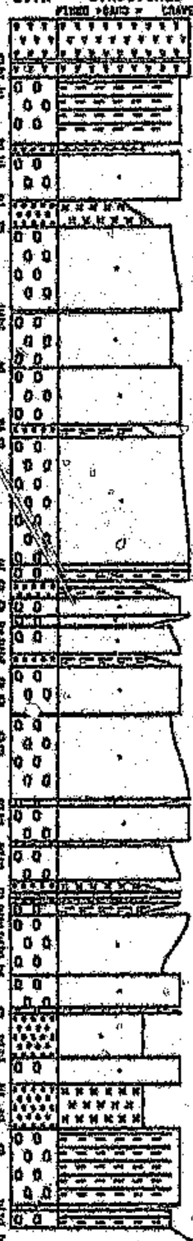
BH SH 18 CONTINUED



38	4.26				CS	II	CS, SS, POLY AREAS
		-68.70	68.70	G			
39	0.60	-69.30	69.30	B	SP	MM	
40	0.61	-69.91	69.91	E	CU	MM	OLIGO, V.PACKED, BC
41	0.49	-70.40	70.40	E	SU	MM	L AREN PARTING
42	0.04	-70.44	70.44	E	CU	MM	OLIGO, BSP — LEADER REEF
43	2.56				SU	MB	SL AREN — HARMONY FM
		-73.00	73.00	G			
44	6.02				SU	II	OCC CLEAN AND PEBBLY AREAS — MIDDLING QUARTZITE
		-79.02	79.02	E			
45	0.38	-79.40	79.40	E	SU	BU	TOP GRIT
46	2.47				SP	II	SL AREN, OLIGO PEBS, BOAT BSP, XTAL PY
		-81.87	81.87	E			
47	1.06				DS	MM	POLY, L AREN MTRIX
		-82.93	82.93	E			
48	0.57	-83.50	83.50	E	CS	MM	POLY SOUTHERN TYPE REEF
49	0.46	-83.96	83.96	B	CU	MM	OLIGO, FAULTED BASE
50	0.34	-84.30	84.30	E	SP	MM	
51	2.18				CS	II	POLY, POOR PACK, MTX, OCC BSP, PY AT BASE — BASAL REEF
		-86.48	86.48	E			

BH SH24 ELDORADO FORMATION

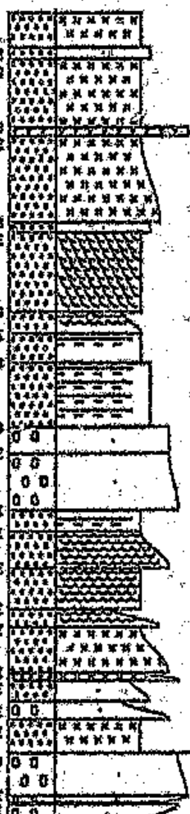
X 25040.96
Y 3101863.81
ELEV 0.00



TAG	THICK	ELEV	DEP	C	COMMENTS	
1	0.00				DD BD	VENTERSDORP LAVA
		-0.00	0.00	G		
2	0.40	-7.37	7.37	E	CU DU CONGLOMERATE BAND; VEINED TO 1 ?	
3	2.03	-10.00	10.00	E	GG GD INTRUSIVE	
4	11.02				CG II 3 POLY CONGLOM AND L AREN INTERBEDS	VS 1
		-21.02	21.02	E		
5	1.75	-23.37	23.37	E	GU GT Y-GY SL AREN MARKER (?)	
6	7.90				CU MM POLY, DK MTRIX, 2X FINING UPS	
		-31.27	31.27	E		
7	4.00				SG GU 2X FINING UP UNITS, L-SL AREN MARKER 1	
		-35.07	35.07	G		
8	14.23				CG MM GY-L GY MTRIX	
		-50.10	50.10	E		
9	0.40	-50.60	50.60	E	SP II COARSENING UP	
10	5.44				CU MM	
		-60.00	60.00	E		
11	6.05				CU MM 10 % PACKED, ANGULAR POLY PEBBLES, MAX = 160MM	
		-66.05	66.05	E		
12	2.20	-72.05	72.05	G	SP II Y-GY SL-L AREN AND CONGLOM BANDS	
13	21.02				GU MM 6 %. PACKED	
		-93.07	93.07	E		
14	2.95	-96.02	96.02	G	SG II GR/S BANDS	
15	2.80	-99.80	99.80	G	SP II DK. GITE MARKER 2	
16	3.12	-102.90	102.90	E	CU MM GY.GOOD PACK	
17	1.70	-104.50	104.50	E	CG MM	
18	0.22	-104.72	104.72	E	SP MM DK.GY SL AREN BAND	
19	4.60				CU MM	
		-109.32	109.32	G		
20	2.19	-111.51	111.51	G	GP II PACK DECR. UP	
21	0.17				GG MM V.POOR SORT MATRIX	
		-118.60	118.60	G		
22	0.30	-118.90	118.90	G	SU MM GY SL-L AREN	
23	14.40				CU MM 70%POLY, SA-R, REPEATED COARSENING AND FINING CYCLES	
		-134.44	134.44	E		
24	1.10	-135.63	135.63	G	CU MM	
25	0.74				GU MM 3 WITH A 10CM L AREN BAND	
		-141.77	141.77	E		
26	0.88	-142.65	142.65	E	SP II	
27	5.92				GU MM 10. CLASTS OFTEN WITH CHLORITIC REPLACEMENT	
		-148.57	148.57	G		
28	1.97	-150.54	150.54	E	GG GU Y-GY SL-L AREN	
29	0.16	-150.70	150.70	E	MU II BLACK SHALE DRAPE	
30	0.94	-151.64	151.64	E	CU MM	
31	0.98	-152.62	152.62	E	SU GT GY, SL AREN IN PLACES	
32	2.00	-154.60	154.60	E	CG II DK. GY. SL-L AREN AT BASE	
33	10.50				CU MM 60% DK GITE PEBBLES, W. COMPACTED, MAX CLAST = 120MM	
		-165.10	165.10	G		
34	5.61				CU MM GP GITE, G. SH. IO CLASTS	
		-170.71	170.71	E		
35	1.10	-171.81	171.81	E	CG II 3X FINING UPS	
36	7.87				SP MM DK. GY-GY. L-SL AREN, SILICEOUS	
		-179.40	179.40	E		
37	4.61				CU MM V DK GY, GR/G MATRIX, MAX CLAST = 100MM	
		-184.00	184.00	G		
38	7.70				SP GU L GY SL AREN, SOFT DURABLE LACK DIFF FROM ABOVE	
		-191.70	191.70	G		
39	13.24				CG II POLY CONGLOMS AND NARROW SL-L AREN BANDS	
		-205.00	205.00	E		
40	1.00	-206.00	206.00	E	GU MM	
41	3.00	-209.00	209.00	E	CG II DK. GITE BANDS AND ANG. POLY CONGLOMS	VS 1

CONTINUED ...

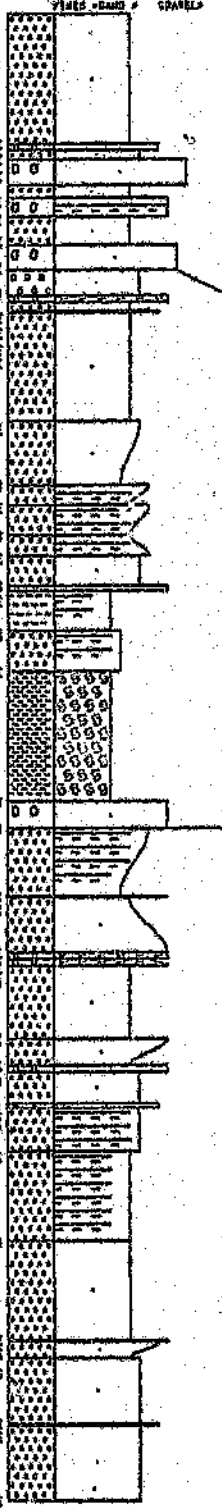
BH SH 24 CONTINUED



Unit	Thickness	Depth			Description	
42	5.92		SU	CU	LT.GY. SL-L AREN. OCC SHALE BANDS. OCC. FINING UPS	VS2-4
		-216.00 216.00 S				
43	2.00	-217.00 217.00 E	SG	MM	[?] GG/S BANDS	
44	11.02		SU	SU	SL-L AREN. RARE FINING UPS	
		-220.02 220.02 S				
45	1.50	-230.32 230.32 E	SG	GG	SAMPLE 8 CUBES PYRITE	
46	14.94		SU	SU	GY SL-L AREN	
		-245.26 245.26 S				
47	1.74	-247.00 247.00 E	SG	MM		
48	13.61		SU	SP	Y-GY. SL-L AREN. OCC SIL. SL-G AREN BANDS	
		-260.61 260.61 S				
49	3.73	-264.34 264.34 E	SU	ST	4X FINING UP SEQUENCES	
50	5.04		SF	II	SOFT SEDS. L-SL AREN. MOTTL. BP'D	
		-269.30 269.30 S				
51	10.00		SG	II	L AREN W. DK GY BANDS AND BPD'S	
		-280.34 280.34 S				
52	4.66		SU	MM	POLY. B.CH.SH.OCC SL AREN BANDS. DK MTRIX	
		-285.00 285.00 E				
53	9.01		SG	MM	S/G MUCH Y SH. OCC SL AREN BANDS	VS 3 ?
		-294.01 294.01 S				
54	3.73	-298.34 298.34 E	SF	II	SI/S BAND. LT. GY G AREN AND DK L AREN. Y SH CLASTS	
55	6.29		SF	ST	4X FINING UPS. 1X COARSENING UP. SL AREN. GY	
		-304.63 304.63 S				
56	7.10		SU	ST	Y-GY SL-G AREN. OCC. PY STRINGERS	
		-311.93 311.93 S				
57	3.07	-315.00 315.00 E	SU	ST	OCC M/G. GY	
58	7.00		SG	SU	G-L.GY SL AREN	
		-322.00 322.00 S				
59	1.30	-324.18 324.18 E	SG	SU	?	
60	3.52		SU	MM		
		-327.70 327.70 E				
61	3.07	-330.77 330.77 E	SU	MM	? DUNABLES. LESS POLY THAN VS 5 (?)	
62	8.00		SU	SU	ALTN. OF G AND F GR ZONES	VS-4
		-338.85 338.85 S				
63	7.35		SU	MM	POLY. G.CH.QTZITE.LG.TOM. DK MTRIX	VS 5
		-344.00 344.00 E				
64	1.15	-345.15 345.15 E	SU	MM	MORE NON-DUNABLES. MAX CLAST = [illegible]	
65	0.31	-345.46 345.46 S	SU	MM		
66	3.54		SS	MM	MORE DUNABLES	
		-349.00 349.00 E				
67	0.11	-349.11 349.11 E	SU	II	ROUNDED DUNABLES + PY	VS 5

BH SH24 HARMONY - AANDENK FORMATIONS

X 25040.96
Y 3101864.81
ELEV 0.00



TAG	THICK	ELEV	DEP	O	COMMENTS	
1	5.57				SP MM SCAT GR/G. SPD	AANDENK FM
		-5.57	5.57	E		
2	0.27	-5.84	5.84	E	CU MM OLIGO. POOR DSP	"A" REEF
3	0.40	-6.24	6.24	E	SU MM	
4	1.11				CU MM OLIGO. W. PACKED	TOP OF DPM
		-7.35	7.35	E		
5	0.53	-7.88	7.88	E	SU MM SL-L AREN	
6	0.82	-8.70	8.70	E	CS II DURABLE BANDS	
7	1.21				SP MM	
		-9.91	9.91	E		
8	1.05	-10.96	10.96	S	CU MM MS. POOR PACK. OLIGO	DPM
9	1.11				DS MM SCAT PEBS. CLEANS UP. SHEARED	AANDENK CHANNEL
		-12.07	12.07	E		
10	0.28	-12.35	12.35	E	CS II 2X POLY BANDS. OCC DSP	
11	0.37	-12.72	12.72	E	SU MM	
12	0.09	-12.81	12.81	E	CU MM W PACKED. WASHED. OLIGO	
13	4.65				SP MM SL AREN. VQ AND CHERT PEBS	
		-17.46	17.46	E		
14	2.80				SP MM SL AREN	
		-20.26	20.26	G		
15	0.84	-21.10	21.10	E	SG II GR/S AT TOP	
16	1.31				SG II	
		-22.41	22.41	G		
17	0.59	-23.00	23.00	E	[illegible]	
18	1.57				[illegible] SL AREN	
		-24.57	24.57	S		
19	0.22	-24.79	24.79	E	CU MM OLIGO. NO LIN. SL-G AREN MTRIX	
20	1.71				FS II	
		-26.50	26.50	G		
21	1.73				SP II	
		-28.23	28.23	E		
22	5.61				NF DB QUARTZ VEINS; FAULTED	BASE OF CHANNEL ?
		-33.84	33.84	S		
23	1.16				CU MM 'B' REEF ? SEE BH 7076	"B" REEF?
		-35.00	35.00	B		
24	2.83				SP II	DAGGREEK FM
		-37.83	37.83	S		
25	0.06	-37.89	37.89	E	CU MM	
26	2.48				SP MM	
		-40.37	40.37	E		
27	0.28	-40.65	40.65	E	CS II 2X INTERBEDDED CONGLOM. L-SL AREN	
28	0.30	-40.95	40.95	G	SD II	
29	3.19				SP MM L AREN	
		-44.14	44.14	S		
30	1.16				SP MM	
		-45.30	45.30	S		
31	0.30	-45.60	45.60	G	CS MM POLY	
32	1.38				SP MM	
		-46.98	46.98	E		
33	0.16	-47.14	47.14	S	DS MM POLY. L AREN MTRIX	
34	1.91				SP II 1X COARSENING UP	
		-49.05	49.05	S		
35	3.97				SG II L AREN AND GR/S BANDS	
		-53.02	53.02	G		
36	4.31				SP MM Y-DK L AREN. CH AND SH GR/S'S	
		-57.33	57.33	E		
37	0.07	-57.40	57.40	S	CU MM POLY	
38	0.70	-58.10	58.10	S	SP MM 2X COARSENING UPS	
39	2.84				SP MM PYROPH-SHEAR AT TOP. SL AREN	
		-60.94	60.94	S		
40	0.09	-61.03	61.03	S	CU MM	
41	3.23				SP MM SHEARED	
		-64.26	64.26	S		

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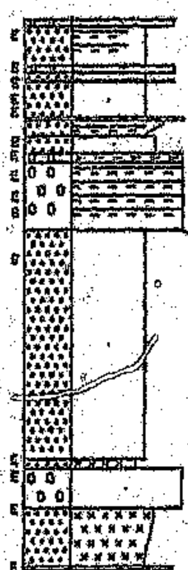
BH SH 24 CONTINUED

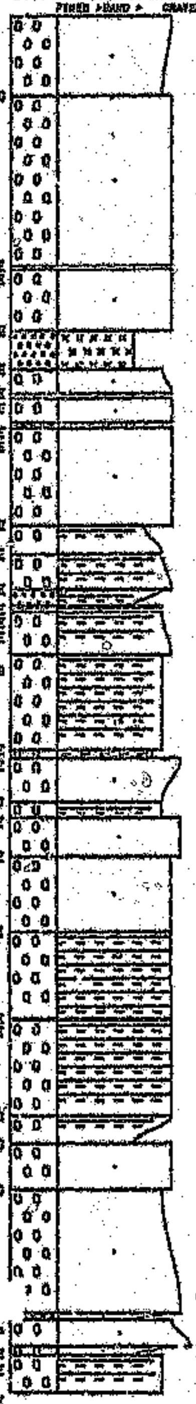


42	0.29	-64.25	64.55	E	CS	MA		
43	1.71				SP	TI	CONGLOM BANDS IN L AREN	
		-65.20	65.20	E				
44	0.30	-65.50	65.50	E	CS	MT		
45	0.34	-66.00	66.00	E	SP	MM	L-SL AREN	
46	0.05	-66.05	66.05	E	CS	MM		
47	1.53				SP	MM	L AREN	
		-68.50	68.50	E				
48	0.10	-68.60	68.60	E	CU	MM	GL100	
49	0.70	-69.30	69.30	E	SG	TI	L AREN	
50	0.75	-70.05	70.05	E	SP	SM		
51	0.38	-70.43	70.43	E	CS	TI	2% CONGLOM BANDS	
52	2.91				CS	TI	5% POLY CONGLOMS	LEADER REEF
		-73.34	73.34	E				
53	9.85				SG	MM	L AREN TO MACHR. OCC. CROSS BEDDING	HARMONY FM
		-83.19	83.19	E				
54	0.30	-83.49	83.49	E	SU	BV	TOR QUARTZITE	
55	1.73				CS	MM	POLY	
		-85.31	85.31	E				
56	2.50				SG	BV	G AREN PARTING	
		-87.81	87.81	E				
57	0.12	-87.93	87.93	E	CU	MM	GL100	BASAL REEF

BH V6 ELDORADO FORMATION

X 27111.95
Y 3099149.86
ELEV 0.00

LITH / STRUCTURES (FINED / SAND / GRAVEL)



TAG	THICK	ELEV	DEP	C			COMMENTS	
1	13.01				CU	MM	POLY, LIGHT AND DARK BANDS	VG 1
		-13.01	13.01	G				
2	29.99				CU	MM		
		-43.00	43.00	E				
3	0.65	-43.65	43.65	E	SP	MM	DK GREY	
4	10.60				CU	MM		
		-54.25	54.25	E				
5	6.06				SU	DU	MARKER 1	
		-60.31	60.31	E				
6	4.75				CU	MM	POLY	
		-65.06	65.06	E				
7	0.84	-65.90	65.90	E	CP	MM	SHALY BANDS	
8	4.15				DU	MM		
		-70.05	70.05	E				
9	0.95	-71.00	71.00	E	SP	II	SILT BANDS, SERICITIC	
10	16.07				CU	MM	DARK	
		-87.07	87.07	E				
11	5.70				CS	II	AND CLASTS, SILT BANDS	
		-92.77	92.77	E				
12	6.26				CS	II	OCC SILT BANDS	
		-99.03	99.03	E				
13	2.77	-101.80	101.80	E	SP	II	MARKER 2	
14	0.40	-102.20	102.20	E	CU	MM		
15	0.49	-102.69	102.69	E	SS	MM		
16	7.31				CS	II	OCC. SHALY SILT BANDS, VARIABLE PACKING	
		-110.00	110.00	G				
17	16.50				CS	II		
		-126.50	126.50	E				
18	1.45	-127.95	127.95	E	SS	II		
19	7.55				CS	MM		
		-135.50	135.50	G				
20	2.70	-138.20	138.20	E	CS	II	SILT BANDS	
21	6.80				CU	MM	POLY, L COLOUR	
		-145.00	145.00	E				
22	13.00				CU	MM		
		-158.00	158.00	E				
23	15.07				CS	II	OCC. SILT BANDS	
		-173.07	173.07	E				
24	0.31	-173.38	173.38	E	SS	MM	FINED UP	
25	16.62				CS	II	OCC. SILT BANDS	
		-190.00	190.00	E				
26	4.03	-194.03	194.03	G	CS	II		
27	8.67				CS	MM		
		-202.70	202.70	G				
28	21.64				CS	MM	POORLY DEFINED	
		-224.34	224.34					
29	1.18	-225.52	225.52	E	SP	MM		
30	4.62				CU	MM	FREQ. SILT CLASTS	
		-230.14	230.14	E				
31	1.57	-231.71	231.71	E	CS	MM		
32	0.69				CS	II	SILT BANDS	
		-232.40	232.40	E				

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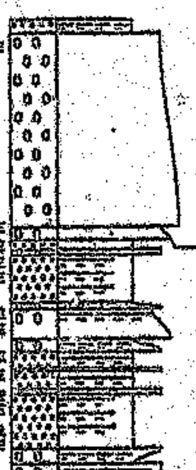
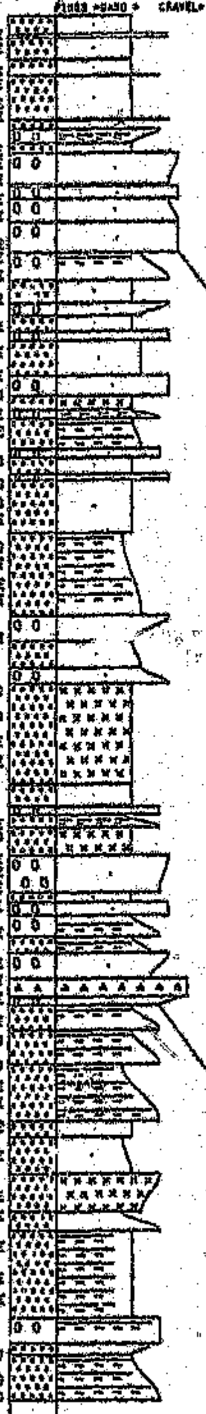


33 8.35 -240.75 240.75 E CO II ARGILL. POORLY DIVE DANDS
34 35.42 CU MR POORLY DEFINED
-274.17 274.17 E
35 2.21 -276.30 276.30 E CU MM VS 1
36 1.00 -278.04 278.04 E SP MM VSS-4
37 0.04 -279.00 279.00 E CS MM
38 0.24 SF II ZCC. PYRITE STREAKS. FAULTED
-287.22 287.22 E
39 1.10 -288.32 288.32 E CS II
40 5.14 CS II
-293.46 293.46 E
41 0.21 -293.67 293.67 E CO II
42 2.01 -298.40 298.40 E SF II GR/G. SL AREN. SHALE BANDS
43 0.44 -300.02 300.02 E CU MM
44 3.10 SU II GRIT. DIVE AND SHALE BANDS
-302.02 302.02 E
45 0.05 -302.07 302.07 E CU MR
46 9.34 CS II GR/G. SL AREN. SHALE BANDS
-312.21 312.21 E
47 2.02 -314.83 314.83 E CS II
48 2.33 -317.70 317.70 E CO II
49 0.30 -318.15 318.15 E SO II
50 2.32 -320.47 320.47 E CO II SHEARED
51 7.00 CS II CONGLOM. AND SL AREN BANDS
-327.63 327.63 E
52 16.70 CS II
-344.31 344.31 E
53 0.24 -344.55 344.55 E CS MM
54 4.46 CS II
-349.03 349.03 E
55 0.20 -349.20 349.20 E SP MM FINES UP
56 7.07 CS VF
-356.00 356.00 E
57 1.66 -358.62 358.62 E SU MM
58 3.12 -361.74 361.74 E CU MM
59 0.07 CS II COURSE FINING UP
-367.81 367.81 E
60 1.66 -369.47 369.47 E CO II
61 6.00 SG II PYRITE. POOR X-BEDDING. DCC. GR/G
-375.30 375.30 E
62 4.10 -379.65 379.65 E CU MM
63 3.10 -382.75 382.75 E SO II GR/G BANDS
64 3.85 -386.30 386.30 E SU MM
65 2.40 -388.40 388.40 E CU MM
66 1.00 -390.37 390.37 E SO II
67 0.34 CU MM VS 2-4
-395.71 395.71 E
68 2.00 -399.37 399.37 E DS MM
69 2.57 -402.24 402.24 E CO MM DK. GY. VS 3
70 12.54 CG MM PALE Y-GY
-414.70 414.70 E
71 1.05 -416.43 416.43 E CO II DIVE AND CONGLOM. BANDS
72 2.70 -419.23 419.23 E CS II VS A

BH V6 HARMONY - AANDENK FORMATIONS

X 27111.95
Y 3099149.86 ELEV 0.00

TAG THICK ELEV DPP C LITH STRUCTURES (FINES + SAND + GRAVEL+) COMMENTS



TAG	THICK	ELEV	DPP	C	COMMENTS	
1	0.70	-0.70	0.70	E	SU MM L AREN	AANDENK FM
2	0.14	-0.83	0.83	E	CU MM POLY, SL AREN MATRIX	
3	0.04				SU MM L AREN, Y-GR COLOUR	
		-1.05	1.05	S		
4	0.04	-1.09	1.09	E	FU II FAULT	
5	0.00				SP MM	
		-2.55	2.55	S		
6	0.03	-2.30	2.58	E	SS MM	
7	1.87				SU MM L AREN, OCC. SL AREN BANDS	
		-4.45	4.45	E		
8	0.08	-4.20	4.50	E	CU MM POLY	
9	0.37	-4.87	4.87	E	SU MM L-SL AREN, Y-GR COLOUR	
10	0.60	-5.47	5.47	E	SG II OLIGO. MS	A REEF ?
11	0.42	-5.89	5.89	E	SP MM L AREN, Y-GR	
12	1.34				CU MM OLIGO TOP, CLEANS UP	UPM (TOP)
		-7.23	7.23	S		
13	0.09	-7.32	7.32	E	CU MM SL AREN PARTING	
14	0.32	-7.64	7.64	S	SU MM OLIGO. VQ AND CHERT	
15	0.09				CU MM OLIGO, FINES UP, G. AREN MTRIX AT BASE	
		-8.03	8.03	S		
16	1.38				CU MM OLIGO, COARSEST AT CENTRE, CS, A-GR CLASTS	UPM
		-10.10	10.12	E		
17	1.21				CS II	
		-11.35	11.35	E		
18	0.97				SU MM SPES BONA FM	
		-12.33	12.33	E		
19	0.56	-12.89	12.89	G	CU MM OLIGO + QSP, F-GR, SLA, MATRIX	
20	0.60				SU MM	
		-13.50	13.50	E		
21	0.40	-13.90	13.90	E	SU MM POLY, L-SL MATRIX	
22	1.50				SP MM L AREN, Y-GN	
		-15.40	15.40	G		
23	0.70				CU MM F.J. L AREN	
		-16.30	16.30	G		
24	0.61	-16.97	16.97	G	SU SU	
25	0.37	-17.34	17.34	E	CS II 2X GPC'S	
26	1.30				SP II	
		-18.64	18.64	G		
27	0.37	-19.01	19.01	E	CU MM +RED JASPER CLAST	
28	0.71	-19.72	19.72	E	SU MM SL-L AREN	
29	0.26	-19.98	19.98	E	CU MM POLY	
30	2.27				SU MM SL-L AREN	
		-22.25	22.25	E		
31	3.53				SU II 4 FINING UPS	
		-25.78	25.78	G		
32	1.11				CU MM POLY (T GN AND ID.CLASTS?	
		-26.89	26.89	G		
33	1.16				SU MM	
		-28.05	28.05	E		
34	0.69	-28.74	28.74	E	SU MM POLY	
35	4.31				SP SU SL-L AREN, OCC. M/S PARTINGS, CLEAN BASE	
		-33.05	33.05	E		
36	0.05	-33.10	33.10	G	MU MM KHAKI COLOUR	
37	0.93				SU MM	
		-34.03	34.03	E		
38	0.04	-34.07	34.07	E	MU MM KHAKI COLOUR	
39	0.33	-34.40	34.40	E	CU MM	
40	0.55	-34.95	34.95	E	SP II GRADES TO LITHIC AREN	
41	1.21				SU SU MICACEOUS GP'S	
		-36.16	36.16	E		
42	1.62				CU MM POLY, 10CM S/S PARTINGS	
		-37.78	37.78	E		
43	0.42	-38.20	38.20	E	SU MM Y-GN L AREN	
44	0.53	-38.73	38.73	E	CU MM POLY	
45	0.89				CS II POLY MS 3 X FINING UPS	
		-39.62	39.62	E		
46	0.74	-40.36	40.36	G	SU II SL AREN	
47	1.11				CU MM POLY, MS	
		-41.48	41.48	G		
48	0.72				DG GG DIAMICTITE BASE ?	
		-42.20	42.20	E		
49	0.37	-42.65	42.65	E	CU MM OLIGO BASE, POLY TOP	G? REEF ?
50	1.11				SP II PEBBLY BASE, SL AREN	DAGBREEK FM
		-43.76	43.76	E		
51	1.49				SP II PEBBLY BASE, Y-GR SL AREN	
		-45.25	45.25	E		
52	2.50				SP II	
		-47.75	47.75	E		
53	0.70	-48.45	48.45	E	SP MM	
54	1.58				SU MM MS, SL AREN	
		-50.07	50.07	E		
55	1.67				SP SU PEBBLY TOP	
		-51.74	51.74	E		
56	0.83	-52.57	52.57	E	SP MM SL AREN, Y-GN	
57	3.80				SP II OCC. FINE GR. AREAS	
		-56.37	56.37	G		
58	1.12	-57.49	57.49	G	CS II POLY + L AREN PARTING	
59	0.61	-58.00	58.00	G	SG MM	
60	2.00				SP II	
		-60.00	60.00	S	UU FAULT, CORE LOSS	

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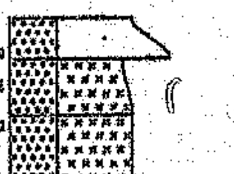
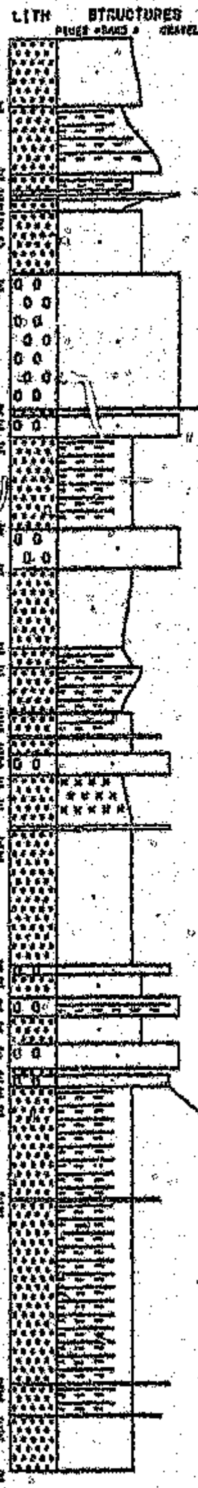
BH V 6 CONTINUED



61	0.02	-60.92	60.92	0	SD NM POLY, BASAL LAG, SL ARGN		
62	1.76	-62.60	62.60	6	SP DU		
63	2.42	-65.00	65.00	0			
64	4.08				SP CU SL ARGN, GY-F GY		
		-69.08	69.08	0			
65	1.30	-70.37	70.37	6	SP NM		
66	0.37	-70.74	70.74	6	SP NM PEBBLE LAG		
67	0.37	-71.11	71.11	6	CU NM SL-L ARGN		
68	1.21	-72.32	72.32	6	SP NM CG, POLY		
69	0.07	-72.39	72.39	6	CU NM POLY		
70	1.33	-73.02	73.02	6	SU NM		
71	0.73	-74.64	74.64	0	CG II CG, POLY	LOZ	
72	0.30	-75.05	75.05	6	CG II POLY		
73	4.10	-76.21	76.21	6	CG II POLY		
74	0.09	-76.20	76.26	6	CU NM		
75	0.07	-76.31	76.31	6	CU NM ALTON	LOWER REEF	
76	0.04	-76.35	76.35	6	SU NM	BAGGINEAR FM	
77	5.80				SP DU L.STVACHE	HARMONY FM	
		-86.23	86.23	0			
78	3.74				SP DU FAULTED		
		-89.97	89.97	6			
79	1.25	-91.22	91.22	6	SU DU PYRITE STRINGERS; TOP OF REEF QUARTZITE		
80	1.00	-92.20	92.26	6	CG NM		
81	0.48	-92.70	92.76	6	CG DU		
82	0.50	-93.34	93.34	6	SP NM DISS. PY		
83	0.03	-93.37	93.37	6	CU NM PYRITIC, OLIGO LAG	BASAL REEF	

BH V9 HARMONY - AANDENK FORMATIONS

X 27126.95
Y 3098347.86 ELEV 0.00



TAG	THICK	ELEV	DEP	C	COMMENTS	
1	2.00				SG HN Y L AREN	AANDENK FM
		-2.00	2.00	E		
2	3.00				SP II	
		-5.00	5.00	E		
3	0.70	-5.70	5.70	E	SP II SOAT SPO'S. SL AREN	
4	0.18	-5.88	5.88	E	SU GU L AREN	
5	0.22	-6.00	6.00	E	CU HM	
6	0.50	-7.40	7.40	C	SU HM	
7	2.70				SU HM SL AREN	
		-10.10	10.10	E		
8	5.00				CS HM CS. POLY. H-O SLA MTRIX AU + U	OPM
		-15.20	15.50	E		
9	0.20	-16.10	16.10	E	SU HM L AREN	SPES BONA FM
10	0.05	-17.15	17.15	E	CS HM POLY. HP	
11	3.07				SP II OCC. PEBBLE BANDS	
		-21.10	21.10	E		
12	1.70				CS HM MS. & GR. SL AREN MTRIX	
		-22.00	22.80	E		
13	3.40				SP HM	
		-26.20	26.20	E		
14	0.05	-27.05	27.05	E	SP II MIS.& L AREN. ARGILL BAND	
15	1.03				SP II	
		-28.98	29.00	E		
16	0.07	-29.05	29.05	E	SP HM	
17	0.95				SP II	
		-30.00	30.00	E		
18	0.10	-30.10	30.10	E	SU HM BAND	
19	0.70	-30.80	30.80	E	SU HM	
20	0.90	-31.70	31.70	E	CS HM H-G AR. MATRIX	
21	2.20				SP GU L AREN	
		-33.90	33.90	E		
22	0.15	-34.05	34.05	E	SU HM	
23	5.85				SU HM	
		-39.90	39.90	E		
24	0.40	-40.30	40.30	E	CS HM	
25	1.00				SU HM SL AREN. F-GT	
		-41.30	41.30	E		
26	0.80	-42.10	42.10	E	CU II POLY. + SITE BAND	
27	1.20				SP HM "OTHERS" MATRIX MATERIAL	
		-43.30	43.30	C		
28	1.10				CU HM SL AREN MATRIX. POLY. LOW AU	
		-44.40	44.40	E		
29	0.30	-44.70	44.70	E	SU HM	
30	0.50	-45.20	45.20	E	CU HM POLY. & GR MTRIX. M-LPG	"D" REEF
31	4.00				SG II L AREN. POLY GRITS	DAGGAFONTEIN FM
		-50.10	50.10	E		
32	0.10	-50.20	50.20	E	SU HM PEBBLE BANDS. REVERSE FAULT ?	
33	6.00				SG II OCC. ARGILL BANDS	
		-56.20	56.20	E		
34	0.05	-56.25	56.25	E	CU HM POLY BAND	
35	1.35				SG II OCC. F. SR	
		-58.00	58.00	E		
36	0.05	-58.05	58.05	E	GU HM POLY. & O/T	
37	2.35				SG HM	
		-60.00	60.00	E		

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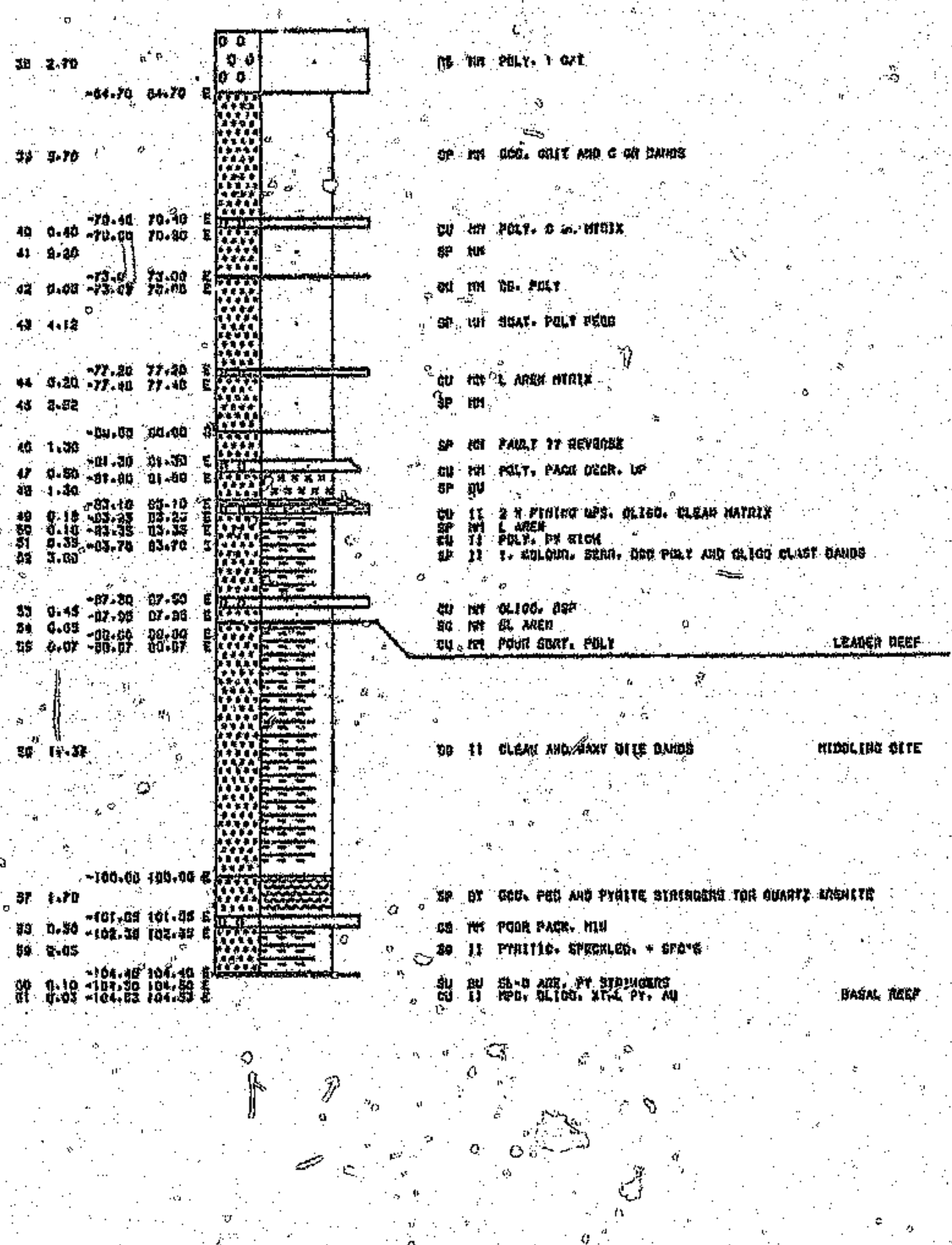
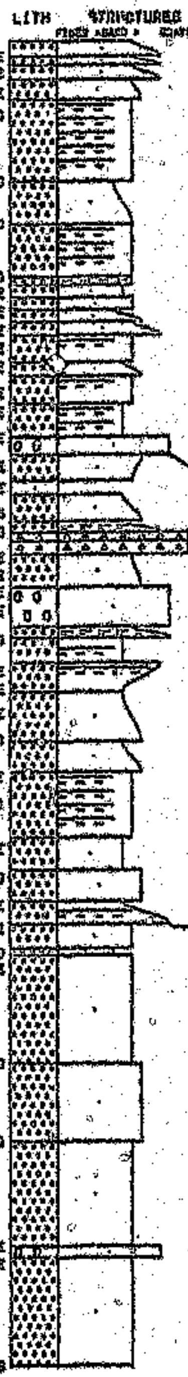
BH V 9 CONTINUED



VII HARMONY - AANDENK FORMATIONS

X 25869.96
Y 3100443.81 ELEV 0.00



TAG	THICK	ELEV	DEP	Q			COMMENTS	
1	0.66	-0.66	0.66	E	SP	MM	LAG AT BASE, L-SL AREN	AANDENK FM
2	0.37	-1.03	1.03	E	SP	MM	LAG AT BASE, L-SL AREN	
3	0.62	-1.65	1.65	E	SP	MM	LAG AT BASE, L-SL AREN	
4	0.85	-2.50	2.50	G	SP	MM		
5	3.50	-6.00	6.00	G	SP	II	F GR L AREN AND M GR SL AREN	
6	1.05	-7.05	7.05	D	SU	MM	3X FINING UPS	
7	3.05	-10.10	10.10	G	SU	II	F GR L AREN AND M GR SL AREN	
8	0.35	-10.45	10.45	E	SP	II		
9	0.54	-10.99	10.99	E	SU	MM	L AREN	
10	0.62	-11.61	11.61	E	SS	MM	C AREN SAND	
11	0.41	-12.02	12.02	E	SP	MM		
12	0.57	-12.59	12.59	E	SP	MM	TO LAG	"A" REEF ?
13	1.18	-13.77	13.77	E	SU	II	SI/S-F L AREN	
14	0.60	-14.37	14.37	E	SU	MM	SL AREN TO L AREN	
15	1.19	-15.56	15.56	E	SU	II	S. AND L AREN	
16	1.44	-17.00	17.00	E	DU	II	SI/S-M GS SL AREN	
17	0.70	-17.70	17.70	E	CU	MM	DK GY M GR SL AREN MTRIX, OLIGOMICT. C. PYRITE	DPM
18	1.11	-18.81	18.81	S	SU	MM	CLEANS AND COARSENS UP	SPES BONA FM
19	0.68	-19.49	19.49	G	MU		FAULT	
20	1.18	-20.67	20.67	E	SU	MM	GY SL AREN	
21	0.47	-21.14	21.14	E	SP	II	POLY. SPG BASE	
22	0.38	-21.52	21.52	E	SD	GG	LITHIC WACKE, ANGULAR, M/S MTRIX	
23	0.50	-22.02	22.02	E	SS	GG	COARSENS UP	
24	1.41	-23.43	23.43	G	SP	MM		
25	1.75	-25.18	25.18	E	SU	MM	POLY. PRED TO, CLEANS UP	
26	0.47	-25.65	25.65	E	SP	II	OLIGO CONG,GM, SL-M AREN MTRIX	BASE OF CHANNEL?
27	1.08	-26.73	26.73	E	SS	II	F GR L-SL AREN, GR/S BAND	
28	1.27	-28.00	28.00	G	SP	II	L-SL AREN	
29	2.18	-30.18	30.18	E	SU	MM		
30	1.22	-31.40	31.40	G	SU	MM	2X FINING UPS	
31	2.90	-34.30	34.30	E	SS	II	INTERLAM F GR L AREN, C GR SL AREN, PRED. F GR SL AREN	
32	1.41	-35.71	35.71	D	SU	MM	L AREN, GY	
33	1.36	-37.07	37.07	E	SP	MM	FAULTED TOP	
34	0.99	-38.06	38.06	G	SP	II	POLY OSP, AU, IN GR REEF	"B" REEF
35	1.04	-39.10	39.10	D	SU	MM	L-SL AREN, L GY	DAGBREEK FM
36	0.30	-39.40	39.40	E	FS	MM	USM ?? SHEARED TOP	
37	4.70	-44.10	44.10	G	SS	MM	L-SL AREN F. BL STIPPLING, GRADN. COLOUR CHANGES	
38	3.40	-47.50	47.50	G	SS	MM	L-SL AREN, F. BL STIPPLING, FAULTED	
39	4.60	-52.10	52.10	E	SP	MM	SL AREN, POLY PEBS AND BANDS	
40	0.50	-52.60	52.60	E	CS	GM	POLY	
41	4.72	-57.32	57.32	S	SP	MM		

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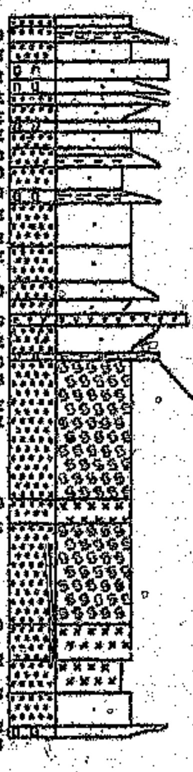
BH V 11 CONTINUED

42 0.36 -57.70 57.70 S
43 0.00 -58.36 58.36 E
44 0.94 -58.80 58.80 S
45 0.78 -59.00 59.00 E
46 0.62 -60.00 60.00 E
47 0.40 -61.00 61.00 E
48 0.71 -61.79 61.79 S
49 0.48 -62.05 62.25 S
50 0.09 -62.94 62.94 S
51 0.62 -63.70 63.70 E
52 0.99 -64.75 64.75 S
53 0.60 -65.31 65.31 E
54 1.00
-67.10 67.10 S
55 1.51
-68.70 68.70 S
56 0.77 -69.47 69.47 E
57 0.33 -70.10 70.10 S
58 0.47 -70.57 70.57 S
59 1.10
-71.75 71.75 E
60 0.50 -72.05 72.05 E
61 6.00
-78.05 78.05 S
62 1.05 -79.10 79.10 S
63 4.40
-83.50 83.50 S
64 1.54
-85.01 85.01 E
65 1.41
-86.45 86.45 S
66 1.41
-87.06 87.06 S
67 0.47 -88.33 88.33 S



SP MM FAULTED TOP
SP II POLY SPG. FAULTED TOP
SU MM
CS MM POLY
DS MM
SP MM 2X FINING UPS
DU MM
SU MM
SU MM Y BY L ARCH
SP II 2X DURABLE SPG'S
SU MM Y-GY SL-L ARCH
CS II 2 FINING UPS. UPPER 2 = POLY LOWER = OLIGO
SP MM POLY. GR/S AND SPG'S
MM SPECKLED L.GY SL ARCH
SP MM POLY BASE. SL ARCH- D ARCH MTRIX
SU MM L-SL ARCH
DD DD INTRUSIVE
SP MM
CS II 2X POLY BANDS. L GY. LOWER FINES UP LEADER REEF
SF DU SLUMPED Q WACKE. CLEAN AREAS HARMONY FM
SU DU
SP DU SLUMPED Q WACKE
SU DU
SU DU TOR OLIG BRZ
SU MM SL ARCH. POLY SPECKLING. = UP 1
CS MM POLY. PY. D ARCH MTRIX BASAL REEF

9 APPENDIX 3

Numerous Gengin unpublished internal bulletins concerning St. Helena Gold Mine have been compiled to date but little information from such bulletins has been published. The bulletins document the sedimentology and structure of St. Helena Gold Mine and the most noteworthy bulletins are outlined below.

a) Sedimentology. Properties of the Ada May Reef were documented by Kleynhans (1984a) and the Intermediate Reef by Tunnington (1986). The Basal Reef facies types on St. Helena Gold Mine were documented and described by Moubray (1950), Jeppe (1953), Bird (1954), Potgieter (1964), Tweedie (1978), Hankin (1979), Rossiter (1981) and Mount (1984). Mount (1984) completed a detailed study of the Basal Reef. The Middle Reefs were documented by Kleynhans (1984b), Reynolds (1985) and Ellis (1982). Ellis and Ridley (1988) studied the Dagbreek formation on Unisel Gold Mine. The "A" Reefs on St. Helena Gold Mine were documented by Chapman (1983).

b) Structure. The complex structure and sedimentology of the western syncline of St. Helena Gold Mine was investigated by Potgieter (1963), Algie (1974) and Tunnington (1986).

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