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A SEDIMENTOLOGICAL STUDY OF THE CONGLOMERATES IN THE ELSBURG STAGE ON THE WELKOM AND WESTERN HOLDINGS GOLD MINES.

by

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ABSTRACT

A sedimentological description of the layers of conglomerate in the Elsburg Stage of the Witwatersrand System, as disclosed by 23 boreholes and underground development on the Welkom and Western Holdings Gold Mines in the Orange Free State Goldfield, is given.

The palaeocurrents in the Elsburg Stage as inferred from pebble-size distribution and preferred pebble orientation, were from two different directions. On Western Holdings Limited and the Welkom Mine area west of the Arrarat Fault, the layers of conglomerate were derived from the north-west. On the Welkom Mine area east of the Arrarat Fault, the direction of transport was from the south-west.

These two different palaeocurrent directions can be explained by lateral movement along the Arrarat Fault. Thus, the eastern block of the lease area of the Welkom Gold Mining Company, which was formerly situated on the north-eastern flank of a delta fan, was displaced along the strike of the Arrarat Fault for a distance of approximately 6 000 m towards the south, while the western block (Welkom No. 3 Shaft and Western Holdings Limited), was displaced towards the north.

A detailed analysis regarding the composition, roundness, shape, orientation and sorting of the pebbles in the layers of conglomerate was undertaken. The sorting and roundness of the pebbles increase towards the centre of the basin, while the majority are orientated with their long axes parallel to the palaeocurrent direction. The percentage of non-durable pebble types also decreases in a down-current direction, while the durable types remain constant. The pebbles are mostly spheroidal, although certain types show a strong tendency to disc shaped. These features indicate that the layers of conglomerate were probably deposited on an alluvial fan bordering an inland lake or sea.

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I. INTRODUCTION

During the years 1933 to 1949, a successful exploration campaign for gold in the Orange Free State, revealed a tremendous amount of stratigraphical data which are being recorded and safe-kept in the form of borehole core. Geological data from this borehole core disclosed a sequence of sedimentary rocks below the Ventersdorp System which has been correlated with the Witwatersrand System.

The layers of conglomerate in the Elsburg Stage of the Witwatersrand System on which this investigation was focussed, were discovered in the deep boreholes drilled for the locating of the gold-bearing Basal Reef. The cores from all the surface boreholes are stored in the core-shed of the Anglo American Corporation at Western Holdings Limited, or have been safe-kept in the core yards of the other gold mines in the Anglo Group.

With the kind approval of the Consulting Geologist in the Gold Section of the Anglo American Corporation, Dr. H.C.M. Whiteside, and the Managements of the Welkom and Western Holdings Gold Mines, the author was able to submit a thesis on the sedimentation of the Elsburg Stage in the Witwatersrand System in the area embracing the Welkom and Western Holdings Gold Mines.

A. HISTORICAL REVIEW

Almost 37 years have passed since the first borehole was drilled for the exploration of gold in the Orange Free State. This historical borehole, W.E. 1, which was drilled in 1933 on the farm Aandenk, near Loraine, proved the presence of gold-bearing conglomerates of the Witwatersrand System below the overlying rocks of the Ventersdorp and Karroo Systems.

In 1937, borehole W.E. 4 intersected sedimentary rocks which were recorded as "Upper Witwatersrand Quartzites, presumably of the Elsburg Series" (Coetzee, 1960, p. 57).

Diamond drilling commenced to radiate from Aandenk and was located on relatively low gravity areas where it was anticipated that the Ventersdorp lava below the Karroo System would be thin. The African and European Investment Company Limited, commenced drilling in 1938 in such an area of low gravity. This area comprises the present Welkom, President Steyn and President Brand Gold Mines.

Up to that stage, conglomerates yielding only very low values were intersected. After World War II, drilling activities increased, until such a wealth of geological information regarding the gold-bearing reefs has been obtained, that mining activities could be commenced in 1946.

B. PREVIOUS GEOLOGICAL WORK

Since the Basal Reef has been encountered in surface borehole No. 7 on St. Helena, in April 1939, many authors have made contributions regarding the geology of the Orange Free State Goldfield. There have been different opinions as to the mode of deposition of the great thickness of sediments in the Witwatersrand System. Strong arguments have been submitted in favour or against the theories regarding the proposed sedimentary environments.

Whereas this research is mainly focussed on the palaeocurrent analysis of the conglomerates in the Elsburg Stage, it would be of great importance to discuss some of the theories closely related to the sedimentation and structure of the Witwatersrand Basin in the Free State Goldfield.

Sharpe (1949) recognised a cyclic periodicity in the deposition of the Witwatersrand rocks, each cycle ending with a diastrophic culmination.

Borchers (1950) describes the formation of a border fault parallel to the western margin of the Witwatersrand Basin, which was contemperaneous with deposition of the sediments east of the fault scarp. According to Borchers, it appears that sediments had been discharged into the basin from the north, north-west and west. The layers of conglomerate in the Upper Division of the Witwatersrand System are coarser in these directions with a thickening of the sediments towards the centre of the basin. Borchers visualised the deposition of the sediments as follows:-

At the outset of the Witwatersrand period, the Archaean land surface in the vicinity of the present goldfield consisted of a barren peneplane of rocks of the Primitive System and granite. Rivers from distant mountains north and west of the Witwatersrand basin, discharged fine sediments into this inland sea. A change in climate, combined possibly with slight elevation of the surrounding country, caused the rivers to transport coarser sediments which were deposited in the basin as layers of conglomerate interbedded with quartzites.

Simpson (1951) supported the theory of Borchers. He found that the sediments of the Witwatersrand System are characterised by a series of uraniferous cycles which are separated by periods of lesser activity. These cycles proved helpful in problems of correlation.

Brock (Coetzee, 1960) postulated that in the western sector of the Orange Free State Goldfield, the auriferous reefs have been preserved in a graben. According to Brock, the sediments of the Upper Division of the Witwatersrand System were deposited in a continental basin. The periphery of this basin was surrounded by elliptical faults along which the source rocks were uplifted, while the basin itself was not affected by the faulting.

Antrobus (1956) is of the opinion that the sediments of the Witwatersrand System are the result of deposition in a continental basin surrounded by land surfaces. The whole sequence maintains the same lithological character. According to Antrobus, two types of conglomerate can be recognised in the

Upper Division of the Witwatersrand System. Normal conglomerates possess a polymictic pebble assemblage and are characterised by drab matrix material. Auriferous conglomerates are composed of well rounded chemical stable pebbles, usually set in a clean matrix of orthoquartzite.

Coetzee (1960) is of the opinion that the Witwatersrand System as found in the Orange Free State Goldfield, is part of a marine sequence laid down in a shrinking basin. Coetzee stated: "Many of the conglomerates probably are deposited on a transgressive beach over a surface of low relief" (Coetzee, 1960, p. 51).

Winter (1964) postulates that the formation was deposited in a marginal synclinal trough formed by prominent folding along an axis parallel to the elongation of the Witwatersrand Basin. The folding continued during the deposition of the beds and was particularly prominent when the Elsburg Stage was laid down. The shoreline was not far distant from the present position of the suboutcrop of the Basal Reef. The rising of the source area to the west had a profound influence on the sedimentation in the basin, and as the source area advanced eastwards, the removal and redeposition of previously accumulated sediments took place.

In studying the Elsburg Reefs in the Loraine area of the Orange Free State Goldfield, Olivier (South African Mining and Engineering Journal, 1960) felt that Winter's idea of a synclinal trough is somewhat over-emphasised. Olivier describes the pre-Ventersdorp structure as a steep marginal limb and a relatively flat area eastwards towards the centre of the basin.

In the area investigated, however, there is evidence of regular sedimentation during the deposition of the Bird, Kimberley and Elsburg Stages in the Witwatersrand Basin. The results obtained by Sims (1969) in his study of the stratigraphy and palaeocurrent history of the Upper Division of the Witwatersrand System on President Steyn Mine and adjacent areas, strongly suggest the arrangement of a fan delta about at the point of entry of a fluvial system into the marginal environment of a continental sea.

C. PRESENT INVESTIGATION

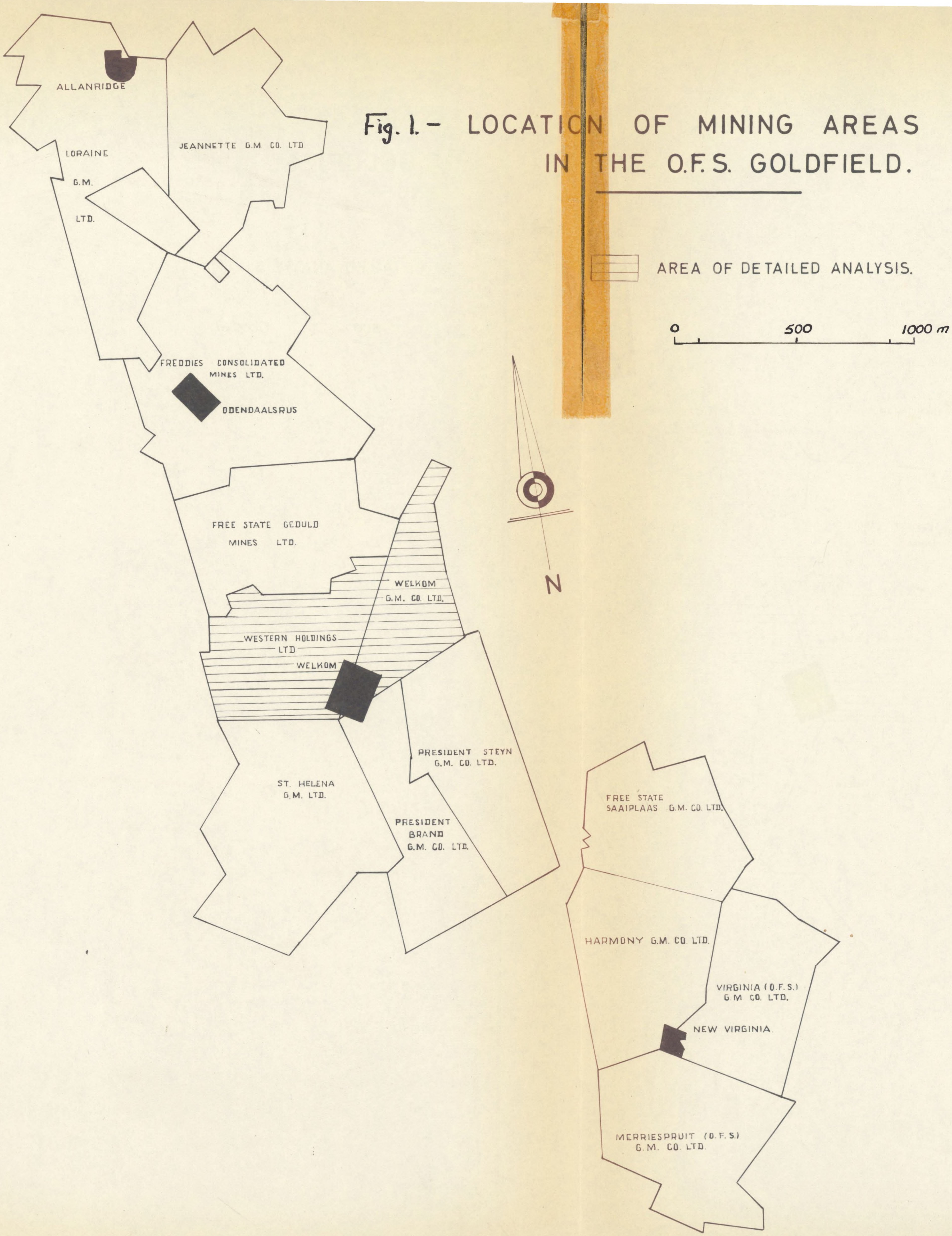
The study of sediments, both present day deposits as well as ancient sedimentary processes, has grown enormously during the past few years. Today, much sedimentological research is just a refinement of previous work already done. In a study of the sedimentology and palaeocurrents of the conglomerates in the Elsburg Stage, the author benefitted from the results obtained and techniques used during research done by his predecessors.

Encouraged by the successful results obtained by similar projects (Winter, 1957; Coetzee, 1960, Steyn, 1963; Knowles, 1966; Hodgson, 1967; Pienaar, 1969 and Sims, 1969), this investigation was undertaken to assemble and integrate some sedimentological information with the wish that the results might be a useful contribution to the study of the Elsburg Stage.

All the work done by the author was on a macroscopic scale. The investigation commenced at the beginning of 1968 and consisted of detailed geological logging of some 23 boreholes, the measuring of the pebble sizes on the borehole core, and the determination of pebble parameters such as pebble composition, roundness, shape, orientation, etc., during observations and measurements underground.

The area of detailed analysis covered by this treatise comprises the Welkom and Western Holdings Gold Mines which are situated in the centre of the Welkom section of the Orange Free State Goldfield. The area is bounded on the south by the lease areas of President Steyn, President Brand and St. Helena Gold Mines and in the north by the Free State Geduld Mine (Fig. 1).

Fig. 1.- LOCATION OF MINING AREAS IN THE O.F.S. GOLDFIELD.



II. GENERAL GEOLOGY

The stratigraphical succession in the Orange Free State Goldfield is interpreted in the geological column as recognised by the Anglo American Group Mines (Table I and Fig. 2).

The description, subdivision and correlation of the Witwatersrand System and other formations in the Orange Free State Goldfield, as described in this treatise, are based on contributions by Borchers (1950), Van der Vyver (1956), Antrobus (1956), Coetzee (1960), Winter (1964), McKinney et al. (1964) and Sims (1969). These authors provided comprehensive descriptions of the geological column in this area.

A. PRE-WITWATERSRAND ROCKS

Surface boreholes which penetrated the rocks of the Witwatersrand System proved the presence of granite, diorite, rhyolite and andesite below the Witwatersrand System. The lavas probably belong to the Dominion Reef System (Coetzee, 1960, p. 25 - 27).

B. WITWATERSRAND SYSTEM

1. Lower Division

The sediments of the Lower Division of the Witwatersrand System consist mainly of shale and quartzites belonging to the Jeppestown, Government Reef and Hospital Hill Series (Coetzee, 1960, p. 50 - 53).

2. Upper Division

(a) Main-Bird Series

The rocks stratigraphically underlying the Basal Reef are referred to as the footwall beds. Lithologically these rocks are quite variable. Conglomerates and quartzites with pebble bands are subordinate to a wide variety of quartzite types belonging to the Livingstone and Main Reef Stages.

TABLE I

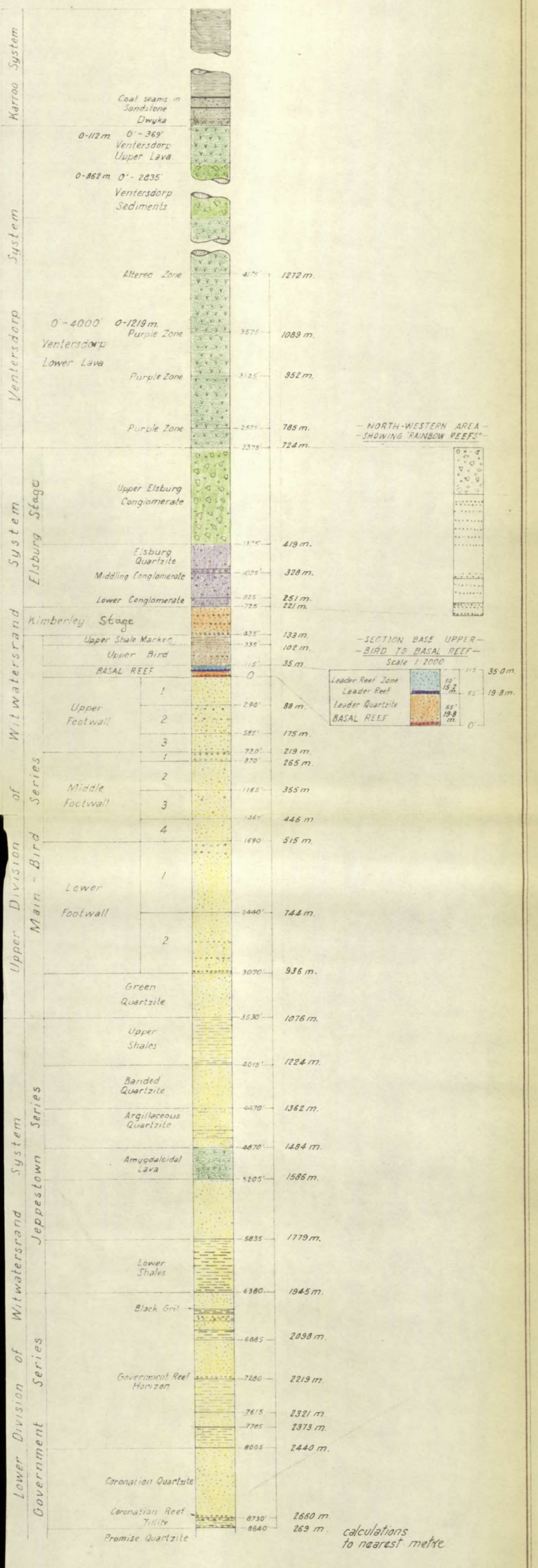
MAIN SCHEMES OF CORRELATION & TERMINOLOGY OF THE UPPER DIVISION OF THE WITWATERSRAND SYSTEM. (AFTER SIMS 1969)

BORCHERS (1950) AND BAUMBACH		SIMPSON (1951-52) RADIOMETRIC CYCLES.				FERINGA (1954)			WINTER (1957)			GEOLOGICAL SURVEY (1960) COETZEE			SIMS (1968) – EXTENSIVE REVISION OF MC.KINNEY ET ALIA (1964)					
	ZONE SYMBOLS		CYCLE	SUB – CYCLE	INNER CYCLE			ZONE SYMBOLS.			ZONE SYMBOLS			ZONE SYMBOLS		SERIES	STAGE	SUB – STAGE	ZONE	SUB ZONE
KIMBERLEY ELSBURG SERIES	V S 1	SEDIMENTS OF THE UPPER WITWATERSRAND SYSTEN	R 1			ELSBURG SERIES		V S 1	KIMBERLEY ELSBURG SERIES	ELSBURG STAGE	V S 1	KIMBERLEY ELSBURG SERIES	ELSBURG STAGE VS 1 – VS 5	V S 1	UPPER DIVISION OF THE WITWATERSRAND SYSTEM	KIMBERLEY ELSBURG SERIES	ELSBURG	UPPER	UPPER CONGLOMERATE	PROBABLY NUMEROUS DISCONFORMITIES AND UNCONFORMITIES.
	V S 2										V S 2									
	V S 3		R 2					V S 2 – 4			V S 3			V S 2 – 3				MIDDLE	MIDDLING QUARTZITE	
	V S 4										V S 4								MIDDLING CONGLOMERATE	
	V S 5										V S 5			V S 3 – 4				LOWER	LOWER QUARTZITE	
			R 3	R 3A (HIGH)	R3 A1			V S 5											LOWER CONGLOMERATE	
	T 1 E C 1				R3 A2	KIMBERLEY SERIES		U K 1 U K 2 U K 3		UK STAGE	U K 1 U K 2 U K 3		KIMBERLEY STAGE T 1 – E S 1	UPPER KIMBERLEY T1 – EC 1			KIMBERLEY STAGE (GOLD ESTATES)	UPPER	"A" REEF ZONE	UNCONF.
	E C 2				R3 A3			M K 1 M K 2 M K 3		MK STAGE	M K 1 M K 2 M K 3			MIDDLE KIMBERLEY E C 2				MIDDLE	BIG PEBBLE ZONE	UNCONF.
	E C 3 E C 4				R3 A4			L K 1 L K 2 L K 3		LK STAGE	L K 1 L K 2 L K 3			LOWER KIMBERLEY E C 3 – 4				LOWER	"B" REEF ZONE	UNCONF.
	E S 1			R3B (BARREN)	R3 B1			KIMBERLEY SHALE			E S 1			KIMBERLEY SHALE ES 1		MAIN BIRD SERIES	BIRD REEF STAGE	UPPER BIRD	UPPER SHALE MARKER	ARBITRARY
MAIN BIRD SERIES	E S 2				R3 B2	BIRD SERIES	UPPER BIRD GROUP		MAIN BIRD SERIES		E S 2	MAIN BIRD SERIES	BIRD STAGE – E S 2 – U F 4	E S 2					UPPER BIRD QUARTZITE	ARBITRARY
	E S 3			R 3C (HIGH)	R3 C1						E S 3			E S 3 LEADER REEF AT BASE					LEADER REEF ZONE	UNCONF.
	E.L 1				R3 C2						E L 1			LEADER QUARTZITE (E L 1)				LOWER BIRD	LEADER QUARTZITE	DIASTEM UNCONF.
	E L 2										E L 2			KHAKI SHALE (E L 2)					KHAKI SHALE	DIASTEM
	E L 3										E L 3			BASAL REEF (E L 3)					BASAL REEF	
	U F 1		R 4				LOWER BIRD GROUP			UPPER FOOTWALL BEDS	U F 1			U F 1			LIVING-STONE REEF STAGE	UPPER FOOTWAL 1 (U F 4)	ZONE 4	UPPER SPECKLED MIDDLE GRITTY LOWER SILICIFIED
																			ZONE 2	
																			ZONE 3	
																			ZONE 4	
																			ZONE 5	
	U F 2		R 5								U F 2			U F 2				UPPER FOOTWALL 2 (U F 2)		
	U F 3		R 6								U F 3			U F 3				UPPER FOOTWALL 3 (U F 3)	UPPER U F 3	
			R 7																LOWER U F 3	
	U F 4										U F 4			U F 4				UPPER FOOTWALL 4 (U F 4)		UPPER INTERMEDIATE REEFS
																				MAIN BAND INTER MEDIATE REEF
																	MAIN REEF STAGE.			UNCONFORMITY

FIG. 2

-GENERALISED GEOLOGICAL SECTION-
-OF O.F.S GOLDFIELDS-

-SCALE 1 : 10,000-



calculations
to nearest metre

figure 2

(i) Bird Group

This group comprises the Basal Reef and Leader Reef Formations.

The Basal Reef is characterised by an intermittent thin carbon seam at its base with one or more layers of small pebbles varying in thickness from 25 to 50 mm or from 0.3 to 1 m. This is the most important gold-bearing conglomerate in the Free State Goldfield. The reef usually contains much pyrite in a finely disseminated form or as crystalline nodules and also carbon in the form of scattered fine granules. The Basal Reef is overlain by a thin layer of Basal Quartzite.

The Khaki Shale overlying the Basal Quartzite and Basal Reef ranges in thickness from less than 30 cm in the north-eastern portion of the area, to more than 150 cm in the extreme south-west of the area.

The Leader Reef Formation rests unconformably upon the Leader Quartzites. These quartzites consist of several layers of conglomerate and quartzite and attain an average thickness of approximately 18 m. The Leader Reef is a fairly compact small pebble conglomerate about 30 cm in thickness. Mineralisation of pyrite occur quite often, but the carbon content is normally low compared with the Basal Reef. The Leader Reef has consistantly low gold values.

The quartzites of the Upper Main-Bird Stage are described as coarse-grained impure argillaceous rocks overlying the yellow grey micaceous quartzites of the Leader Reef Zone.

The Upper Shale Marker, unconformably overlain by the Kimberley-Elsburg Series, overlies the quartzites of the Upper Main-Bird Stage and attains a thickness of a few metres to approximately 30 m. The composition of this member in the Leader Reef Formation varies slightly, but is commonly described as a dark grey arenaceous shale.

(b) Kimberley-Elsburg Series

The Kimberley-Elsburg Series is subdivided into the Kimberley and Elsburg Stages.

(i) Kimberley Stage

The stratigraphic break between the Kimberley-and Elsburg Stages is based on a sharp sedimentary change, i.g. where the Lower Elsburg Conglomerate (Zone VS 5) is overlying the relatively even-grained sediments of the Upper Shale Marker. The stage comprises three horizons of conglomerates intercalated with varying thicknesses of impure quartzite. These conglomerates are the so-called "Gold Estates Reefs" ("A" Reef, Big Pebble Conglomerate and "B" Reef respectively) which attain a thickness of approximately 120 m.

(ii) Elsburg Stage

This upper group of sediments in the Witwatersrand System, which is overlain by the Lower Volcanic Stage of the Ventersdorp System, consists of a succession of conglomerates and quartzites with an average thickness of approximately 500 m. This thickness is mainly based on intersections in surface boreholes, and faulting might therefore influence the thicknesses.

Plan 1 is a map of the pre-Karroo surface showing the suboutcrop of the Elsburg Stage in the central part of the Welkom Gold Mine and the western portion of Western Holdings Limited.

In the area investigated, Borchers and White (1943, p. 137 - 143) have subdivided the sediments of the Elsburg Stage into a number of zones which are indicated by symbols.

Zone VS 1

Zone VS 2

Zone VS 3

Zone VS 4

Zone VS 5.

A subdivision of the Elsburg Stage into three substages based on genetic and cyclic affinities is described by Sims (1969, p. 138) (Table II).

TABLE II. - A subdivision of the Elsburg Stage after Sims (1969)

ZONE SYMBOL	LITHOLOGIC COMPONENT	AVERAGE THICKNESS AT WELKOM AND WESTERN HOLDINGS GOLD MINES	SUBSTAGES
VS 1	Upper Elsburg Conglomerate	300 m ±	Upper Elsburg
VS 2	Middle Elsburg Quartzite	75 m ±	Middle Elsburg
VS 3	Middle Elsburg Conglomerate	15 m ±	
VS 4	Lower Elsburg Quartzite	75 m ±	Lower Elsburg
VS 5	Lower Elsburg Conglomerate	30 m ±	

The Elsburg Stage is unconformably overlain by the Lower Volcanic Stage of the Ventersdorp System with further probable unconformities at the base of the Upper Elsburg Conglomerate (VS 1), the Middle Elsburg Conglomerate [Middling Conglomerate (VS 3a)], as well as, at the base of the Lower Elsburg Conglomerate (VS 5).

The rocks of the Elsburg Stage are subject to pronounced changes in facies in the area investigated. The one extreme occurs near the western sector of Western Holdings Limited, where the VS Zones are represented by layers of conglomerate with occasional thin intercalations of quartzite. In the central area, the succession is represented by variable amounts of quartzite and conglomerate. Further to the east and north-east, the layers of conglomerate become subordinate and the succession is largely represented by dark and light grey quartzites. Only a few layers of conglomerate are invariably developed at the top of Zone VS 1 and in Zone VS 5.

The layers of conglomerate in the Elsburg Stage differ strikingly from other conglomerates within the Upper Division of the Witwatersrand System. The conglomerates are of a very mixed, ill-sorted type, which gave rise to the term "agglomerate - conglomerate" to distinguish them from the cleaner more typical types of conglomerate encountered lower down in the Witwatersrand System.

Pettijohn (1957, p. 254 - 259) has described a genetic classification of conglomerates, according to which they are divided into the following types:

Olimictic conglomerate

Polymictic conglomerate

Intraformational conglomerate.

The principle features of a polymictic conglomerate are:-

(a) A high range of pebble sizes with poor sorting.

(b) Subrounded to subangular pebbles.

(c) Varied lithology with many rock types represented.

(d) Crude bedding of the coarsest phases.

(e) Subordinate matrix.

(f) The great thickness of the deposits.

The layers of conglomerate in the Elsburg Stage are not ideal polymictic conglomerates, but could be regarded as a variety of that type.

Lower Elsburg Substage (VS 5 - VS 4):- This substage consists of a basal member of conglomerate followed by a phase of quartzite. The conglomerate occurs as a polymictic ill-sorted type which forms a distinctive marker and normally ranges between 10 and 20 m in thickness, but may, together with the intervening quartzite, attain a thickness of about 30 m.

The rock varies from a small pebble to a boulder conglomerate. It is poor to well packed, while the pebbles are usually fairly well rounded to rounded. In order of predominence, the pebbles of Zone VS 5 consist of white and smoky quartz, massive black chert, green and grey quartzites, pale yellow sericitic silicified shale, blue and blue-grey slate, buff and banded chert, and decomposed porphyry. The presence of such a variety of pebbles caused a colourful effect (Pl. I). The matrix of the conglomerate in Zone VS 5 consists of dirty, black and yellow speckled quartzite which is typically ill-sorted and generally dark grey in colour.

This conglomerate (VS 5) grades upwards into a sequence of quartzites (VS 4), which range in thickness from an average of 3 m on Western Holdings Limited to 70 m on Welkom Gold Mine. These quartzites are usually medium to fine-grained, grey to dark grey in colour and subglassy, with fine-grained argillaceous intercalations.

Middle Elsburg Substage (VS 3 - VS 2):- This substage is mostly composed of quartzites with an average thickness of 20 m on Western Holdings Limited and 110 m on Welkom Gold Mine. A conglomerate consisting of small pebbles occurs often at the base of this substage with a thickness of about 10 to 30 m and has been designated as Zone VS 3a. This zone consists of a persistent development of typical conglomerates of the Elsburg type.

The coarse facies grades upwards into a sequence of dark grey quartzite (VS 3) which passes through a transition zone of alternating light grey (almost whitish bleached), coarse-grained glassy quartzite. Towards the west lenticular and wedge-shaped layers of conglomerate increase rapidly so that almost the entire sequence on the western portion of Western Holdings Limited consists of conglomerate.

Upper Elsburg Substage (VS 1):- The base of the Upper Elsburg Substage is often gradational, thus causing miscalculations in estimating the thickness of this zone. This, combined with faulting and subsequent erosion causes thicknesses to be erratic.

Zone VS 1 constitutes the upper 220 m of the succession; it is characterised by a thick conglomerate interbedded to a variable extent with dark grey impure quartzites. The composition of the Upper Elsburg Conglomerate is eventually similar to that of the Lower Elsburg Conglomerate. The same range of pebble types occurs and a dark grey often pyritic matrix is typical.

Although there is a good resemblance between Zones VS 1 and VS 5, Zone VS 1 can be distinguished from the lower conglomerate by the presence of a higher proportion of well rounded pebbles of milky quartz in a dark grey groundmass consisting of impure yellow speckled quartzite.

The colour of the sediments in Zone VS 1 changes from dark green in the upper portion, to dark grey and light grey shades lower down. The greenish colour of the upper portion is thought to be the result of metamorphism caused by the lavas of the Ventersdorp System which directly overlie Zone VS 1 of the Elsburg Stage (Pl. II and III).

C. VENTERSDORP SYSTEM

There is no apparent unconformity between the Witwatersrand System and the overlying Ventersdorp System. The Ventersdorp System is represented by an Upper and a Lower Volcanic Stage separated by a sedimentary sequence.

The lava of the Lower Volcanic Stage ranges in thickness from 200 to 650 m and consists of a thick series of dark green, decomposed, intermediate to basic amygdaloidal and non-amygdaloidal types.

The sediments of the Ventersdorp System are poorly sorted, with well rounded to subangular pebbles in a matrix of dark grey, green to almost black quartzites. Pebbles of igneous rocks are relatively rare, whereas pebbles of black and dark grey shale and chert are numerous with an abundance of dark grey pebbles of quartzite.

Fairly fine-grained grey-green andesitic lava of the Upper Volcanic Stage overlies the Ventersdorp sediments. Generally this lava is not distinguishable from that of the Lower Volcanic Stage.

D. KARROO SYSTEM

The Karroo beds are fairly flat lying in this area and vary in thickness between 300 and 350 m. Although sandstones in the lower portion of the Beaufort Series are found to the south-east of Welkom, the Karroo System is mainly represented by the Ecca and Dwyka Series, which are the two lowest sequences in the Karroo System. The Ecca Series is composed of blue-black soft arenaceous shales and some gritty sandstones, while the Dwyka Series is represented by tillite. The tillite consists of an unsorted assemblage of pebbles and boulders in a groundmass of sandstone or mudstone. The Dwyka tillite occurs intermittently at the base of the Ecca Series.

E. INTRUSIVE BODIES

Locally discordant sheets of intrusives are common on Welkom Gold Mine and Western Holdings Limited. These transgressive sills have considerable economic significance. Difficult mining conditions are encountered when the plane of the intrusion is along the basal roof parting.

Antrobus (1956) describes Karroo dolerites and lamprophyres of post-Ventersdorp age. The dykes of Ventersdorp age are subdivided by him in yellow porphyries and acicular lava.

III. STRUCTURAL GEOLOGY

A. GENERAL

From the interpretation of the succession of rock types found in boreholes as well as the analysis of structural problems encountered in underground mining operations, the general structure of the Welkom Gold Mine and Western Holdings Limited can be represented by an east-west geological section (Fig. 3).

It is advisable to compare Plan 2 with this figure so that the reader can easily interpret the influence of faulting in this area. Comparing these two diagrams, a number of interesting points arise from the discussion of the different aspects of faulting in this area.

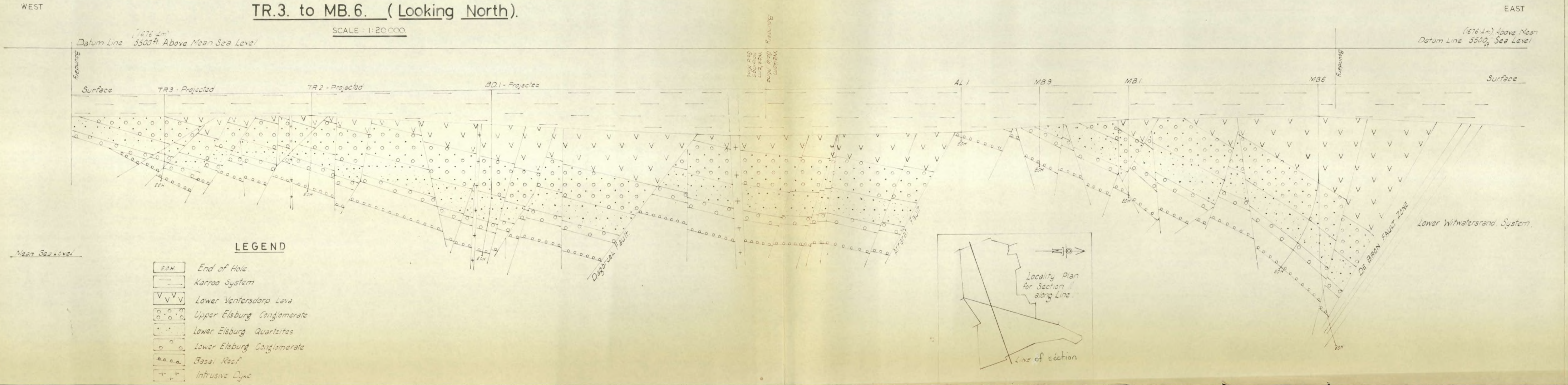
B. STRUCTURE OF THE PRE-KARROO SURFACE

Previously it was assumed that the Karroo System was laid down on a smooth peneplaned surface. Boreholes afterwards proved that this statement is not true. Borchers (1950, diagram 10) indicates that the pre-Karroo surface in the Orange Free State Goldfield was fairly deeply dissected. Fig. 3 illustrates that the sediments of the Karroo System were deposited on an undulating surface after the Lower Volcanic Stage of the Ventersdorp System has been eroded.

The sedimentary layers of the Upper Division of the Witwatersrand System were deposited on a surface with a gentle gradient. The strata in the central part of Western Holdings Limited and Welkom Gold Mine have an average dip of 15 to 22 degrees to the east, whilst the sedimentary layers near the western boundary of Western Holdings Limited and east of the Arrarat Fault on Welkom Gold Mine have dips of 25 to 52 degrees. This can be attributed to the intensive faulting near the margin of the basin and the influence of the De Bron Fault immediately east of the lease area of the Welkom Gold Mine.

FIG. 3. - East-West Geological Section Through Surface Boreholes TR.3. to MB.6. (Looking North).

SCALE : 1:20.000



C. FAULTING

To interpret the influence of faulting on the sedimentary rocks of the Witwatersrand System in the area under investigation, a brief discussion on the major fault systems is necessary.

From the structural plan of Welkom Mine and Western Holdings Limited (Plan 2), it is evident that the Witwatersrand Basin in this area has been subjected to considerable faulting. Only faults with vertical displacements of more than 20 m are shown on the structural plan. There is direct evidence of a long and complicated fault history.

Borchers (1950, p. 83) summarised the fault history as follows:-

During the deposition of the Upper Division of the Witwatersrand System some marginal faulting took place. These faults, associated with relative uplift around the edges of the basin, were possibly formed during the process of the maintenance of isostatic equilibrium between coastal areas and the great mass of sediments being deposited in the basin. There is evidence of faulting during the period of effusion of the Lower Volcanic Stage of the Ventersdorp System, but immediately thereafter, and before the commencement of the Upper Volcanic Stage, a considerable period of intensive faulting must have taken place.

In some parts of the area the faulting is excessive in magnitude as well as in frequency, whereas in other parts, faulting is less. The major faults encountered in boreholes and underground mining operations are:-

(1) Normal faults of various ages, which trend north-south. The majority of these are step-faults associated with regional tilting and with downthrows either to the east or west, depending on the regional tilt. These faults displace the thrust-faults trending east-west.

(2) Thrust-faults which trend north-south. These faults are found more frequently near the western boundary

of Western Holdings Limited with only occasional small thrust-faults in the Welkom Gold Mining area.

(3) Transverse tear-faults trending east-west. They displace faults which trend north-south.

From these fault systems, the following are of major importance:-

The three major faults recognised on Welkom Gold Mine and Western Holdings Limited, are the De Bron Fault, Arrarat Fault and the Dagbreek Fault. These three faults are all normal gravity faults with dips varying from 55 to 70 degrees and they trend roughly north-north-west (Plan 2).

The De Bron Fault cuts across the horizon of the Basal Reef near the eastern boundary of Welkom Mine. In a deflection of borehole MB 6 and in borehole U 3 the position of the De Bron Fault was located as a fracture zone of intensive faulted rocks associated with magnetic shales of the Jeppestown Series. According to Coetzee (1960, p. 122) two phases of faulting exist. During the first phase of faulting (about 2 400 m to the west), the eastern block was elevated and subjected to erosion which removed in places the Lower Stage of the Ventersdorp System as well as sediments of the Upper Division of the Witwatersrand System down to below the horizon of the Basal Reef. The second phase had a downthrow of about 600 m to the east.

The Arrarat Fault is one of the major features against which the sediments of the Witwatersrand System have been downthrown on Welkom Gold Mine. This fault is situated near the central part of Welkom Gold Mine and the north-eastern portion of Western Holdings Limited. It has a vertical downthrow of approximately 950 m in the Welkom Mining Area, but the amount of displacement increases to 1 500 to 2 000 m towards the north. Near the northern boundary of the Welkom Gold Mine, the Arrarat Fault is displaced to the east by an east-west trending tear fault.

The results obtained from pebble-size distribution and pebble orientations, proved that the Arrarat Fault is associated with a north-south tear action. The block of ground to the east of the fault has a lateral displacement of approximately 6 000 m to the south.

The Dagbreek Fault occurs in the eastern portion of Western Holdings Limited and is also encountered in the south-western corner of the Welkom Gold Mine. It has an average vertical displacement of 400 m with a downthrow to the west.

The minor faults which appear crosswise over the area, can be tentatively joined up with the major faults.

The structural implications of the many intrusives encountered in the surface boreholes are not thought to be of great geological significance as far as the layers of conglomerate in the Elsburg Stage are concerned, but these intrusive bodies have constituted a hazard in the mining of the Basal Reef when the plane of the intrusion is along the Basal Reef parting.

IV. SEDIMENTOLOGY

A. GENERAL

Sedimentation refers to the process responsible for the formation of sedimentary rocks, including the transportation and deposition of the rock-forming materials, their diagenesis and lithification. Commonly implied, sedimentation comprises sedimentary petrology and sedimentary petrography, which together cover the study, description, classification and interpretation of sedimentary rocks.

The study of sediments and sedimentary processes has made great strides in the recent years. New techniques have been developed for the analysis of the behaviour of sedimentary materials during transport and after deposition. These advances have been paralleled by the refinement of methods for the investigation of a wide variety of physical and chemical attributes of sediments. The investigation and analysis of a stratigraphic unit, thus, begin with the systematic observation of the basic components of the object, which in this case, are the properties of the layers of conglomerate in the Elsburg Stage.

The nature of the conglomerate layers was macroscopically examined regarding the composition, size, sorting and orientation of the pebbles in order to compile an analytical treatise on the palaeocurrent history of the rocks. The area investigated covers 57 km^2 bounded by the lease areas of Western Holdings Limited and the Welkom Gold Mining Company (Fig. 1). Within the above-mentioned area, the author had to make use of the information obtained from 23 surface boreholes. The research has largely been carried out by means of detailed logging and measurements on the borehole core as well as measurements and observations underground.

When selecting the 23 boreholes, the author has kept in mind that certain restrictions would be inevitable, i.e. distances between the boreholes and the tremendous amount of faulting in the area. The boreholes were chosen in order to give a regularly spaced grid when determining the properties of the conglomerates and comparing their relationships to one another. Bearing in mind that very little is known about the differences between the conglomerates of the Upper Elsburg Substage (Zone VS 1) and those of the Lower Elsburg Substage (Zone VS 5), the boreholes were selected in such a way that the complete succession of the Elsburg Stage is represented in the core.

Underground observations and measurements have been carried out on both mines where conglomerates of the Elsburg Stage are exposed. The surface boreholes and underground localities are indicated in Fig. 4.

B. PEBBLE LITHOLOGY

1. Description

A wide range of pebble types constitutes the pebble assemblage of the conglomerates, which can be divided in durable and non-durable types. These are:

Durable types	White milky quartz Smoky quartz Massive black chert Banded chert Red jasper
Non-durable types	Yellow silicified shale Slate (blue, grey, olive green and purple) Quartzite (grey and light green) Quartz porphyry

(a) Durable Types

(i) Pebbles of Quartz

The pebbles of quartz present in the layers of conglomerate consist mainly of the following types:-

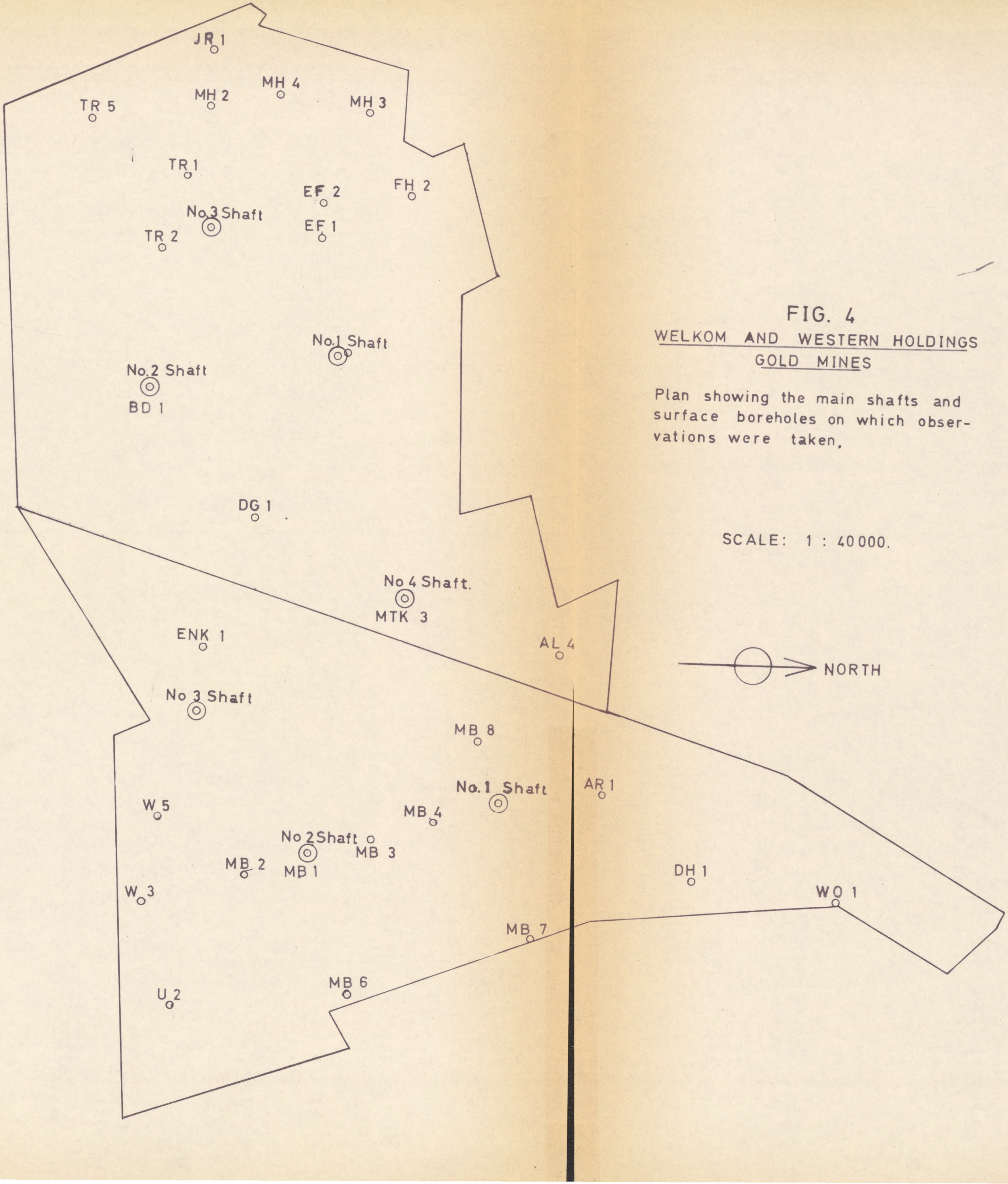


FIG. 4

WELKOM AND WESTERN HOLDINGS
GOLD MINES

Plan showing the main shafts and surface boreholes on which observations were taken.

SCALE: 1 : 40000.

(1) Milky white pebbles are the most abundant.

(2) Clear transparent glassy pebbles.

(3) Smoky quartz - these pebbles are rare.

The pebbles of quartz which have been intersected in the boreholes on Welkom Gold Mine and the central portion of Western Holdings Limited, are mainly of the clear transparent variety, while pebbles of milky quartz are the most abundant near the western and north-western boundary of Western Holdings Limited. A definite increase in the milky type towards the margin of the basin is noticeable.

Pebbles of the milky type are frequently fractured. Fracturing in two or three directions is quite common, while intense fracturing on the edges causes that these pebbles have a pseudo-quartzite appearance. The fractures are sometimes filled with red iron oxide which might have entered the cracks during the weathering of the source rock. If the fractures are very well developed towards the centre of the pebble, a pinkish tinge is observed. These have previously been described as pebbles of rose-quartz.

The fracturing has also been observed by Steyn (1963, p. 14) in pebbles of quartz present in the Livingstone Reefs on the West Rand. He found that the fracturing is only limited to certain zones on the pebble surfaces revealing a homogeneous interior.

(ii) Pebbles of Chert

The following varieties are present:

(1) Very well rounded, oval-shaped, massive black chert.

(2) Rounded to subrounded yellow-grey chert.

(3) Badly rounded banded chert which occurs as pebbles with rectangular to triangular shapes.

(4) Apart from the common types, other varieties such as olive green and purple coloured pebbles of chert are present in the conglomerates, though in small quantities.

From the logging done by previous geologists of several borehole core, the author noticed that the term "maroon cherts" was quite often used to describe the purple coloured pebbles of slate which occur near the margin of the basin. Characteristic red pebbles of jasper are also described as "maroon cherts". The author wishes to emphasize that this term has no congeniality with chert nor jasper, but refers to purple coloured slates.

(iii) Pebbles of Jasper

Pebbles of red jasper occur very seldom in the layers of conglomerate, but an interesting feature is the occurrence of these pebbles in definite zones. Typical examples of these zones are found in the 33 Haulage East at No. 2 Shaft on Western Holdings Limited (Pl. IV). The pebbles are very poorly rounded with rectangular and triangular shapes.

(b) Non-durable Types

(i) Pebbles of Quartzite

Pebbles of this type occur quite frequently in the layers of conglomerate. Three types are present:-

(1) A light green, even-grained quartzite with a sugary texture. This is the most common type.

(2) A whitish grey, somewhat bleached, fine-grained quartzite.

(3) Dark grey, coarse-grained pebbles of quartzite with a mottled appearance and sago texture do occur often.

The first two types are easily recognisable amongst the dark grey matrix of the conglomerate, whereas the pebbles of quartzite with a dark grey colour can only be distinguished with difficulty.

(ii) Pebbles of Slate

Pebbles of this type occur very seldom in the layers of conglomerate which have been intersected in boreholes drilled on the lease area of the Welkom Gold Mining Company, but a definite increase in abundance towards the margin of the basin is observed. The pebbles are usually well rounded with oval shapes and are often elongated. The colour of the slate varies from shades of blue to olive green. Pebbles of purple slate are often found, but they increase in number towards the margin of the basin. The pebbles of purple slate also show the tendency to occur in separate zones.

(iii) Pebbles of Yellow Silicified Shale

The pebbles of shale are the most common type amongs the non-durable pebbles. They are always present in the layers of conglomerate and vary in quantity from moderate to abundant. The pebbles have angular to subrounded edges and irregular or flattened shapes. Pettijohn (1957, p. 193) postulates that pebbles of shale are deposited as soft clay galls and diagenetic response determines the flattened shape of these particles.

(iv) Pebbles of Quartz Porphyry

This type is a rare constituent and occurs usually as well rounded pebbles.

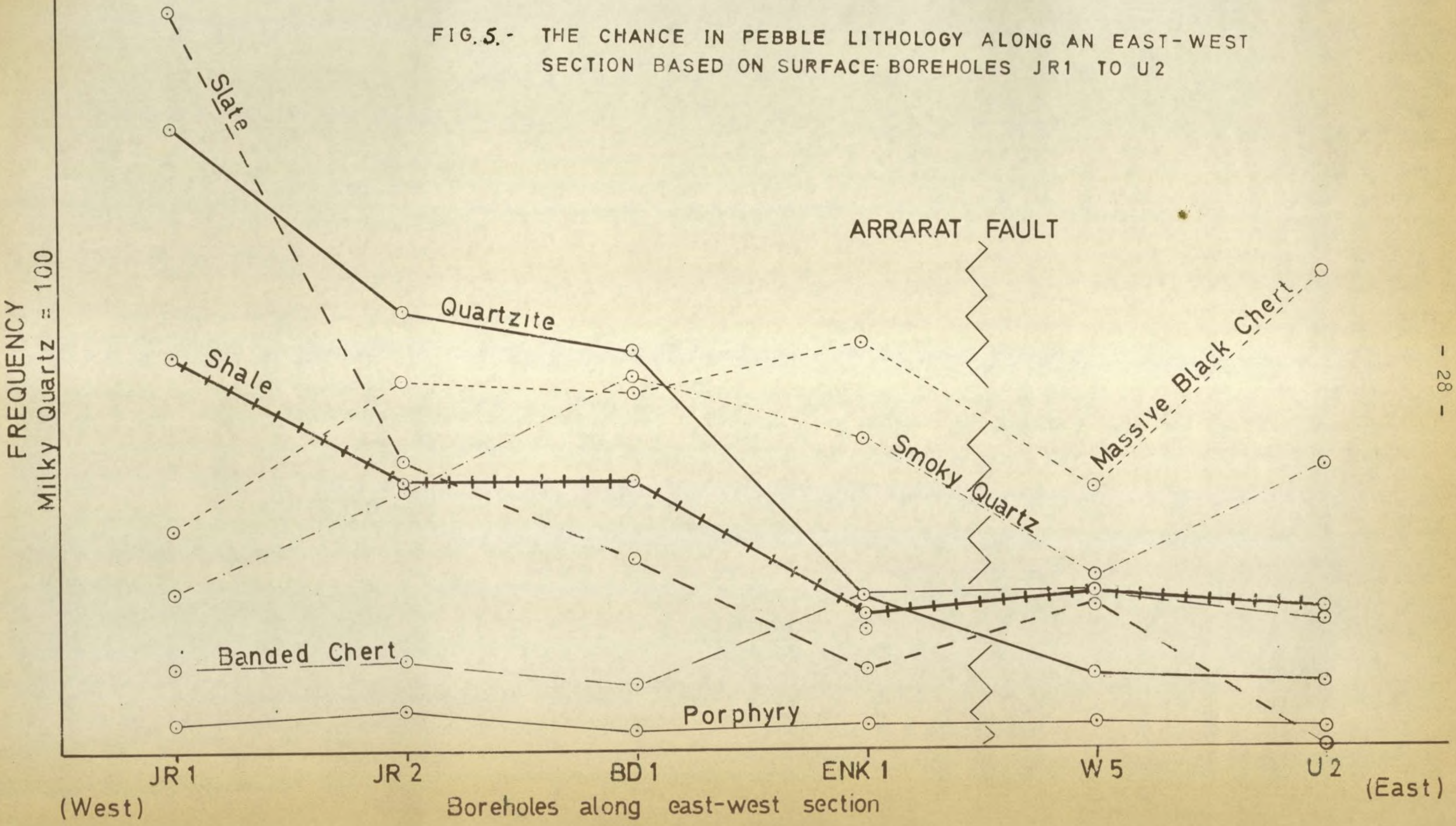
(v) Other Pebble Types

Pebbles of granite and of some greenish grey igneous rock were occasionally observed.

2. Ratios

The relative amount of the various pebble types was determined by counting the number of each type present in the borehole cores. Comparing the different boreholes it is significant that there is a definite decrease in the non-durable types towards the east (Fig. 5). This might be the result of the more rapid abrasion of the least resistant particles in the down-current direction.

FIG. 5. - THE CHANCE IN PEBBLE LITHOLOGY ALONG AN EAST-WEST SECTION BASED ON SURFACE BOREHOLES JR1 TO U2



C. PEBBLE-SIZE DISTRIBUTION

1. Size Variation

One of the most reliable and easily measured indices of palaeocurrent and dispersal in sedimentary rocks is the scalar property of pebble size.

Several studies have been done on the pebble-size variation in conglomerates with special reference to the relation between pebble sizes and gold distribution (Steyn, 1963; Knowles, 1966; Hodgson, 1967 and Sims, 1969). These authors made use of the maximum pebble sizes and all came to the conclusion that the sizes diminishes in a down-current direction.

A similar study was carried out by the author on the pebble-size variation in the conglomerates of the Elsburg Stage as observed within the boundaries of Western Holdings Limited and Welkom Gold Mine.

The object of this investigation was to determine:

(1) The possible inwash direction of the sediments.

(2) The competency of the streams during the deposition of the conglomerates.

(3) The approximate distance along which the pebbles were transported.

(a) Method Applied

The study of the pebble-size variation is based on the measurement of pebble sizes on the core of surface boreholes, because very little of the layers of conglomerate is exposed during underground mining operations. It is, however, impossible to measure the size of every pebble exposed on these borehole cores - a sampling problem common in geology.

In boreholes drilled on the lease area of the Welkom Gold Mining Company, the author has chosen a sample of about 30 cm within every 2 m of core. The sizes of all the pebbles which were exposed in the sample, were determined. The mean pebble size in the layers of conglomerate within the lease area of the Welkom Gold Mine is relatively small and in every sample between 70 and 100 pebbles were exposed. These samples could thus be considered as representative of the interval not measured. With an increase in pebble size towards the margin of the basin, a total of 1 m within every 5 m of core was measured.

This method of determining the size of pebbles differs entirely from the more conventional techniques in which at least the longest axis is directly measured. No measurements could be done on either of the three apparent axes of the pebbles found in the borehole core, therefore the square area of each pebble was determined directly on the surface of the borehole core. The following technique was applied in the determination of the square area of the pebbles:

A grid of 5 mm x 5 mm was engraved in a small sheet of transparent perspex, thus obtaining a grid pattern, each square representing 25 mm^2. Every four of these little squares were then combined to give a grid pattern of 10 mm x 10 mm - thus 100 mm^2. This sheet of perspex was then curved by means of a hot iron rod which had the same circumference as the borehole core. By sliding the curved perspex over the borehole core, a direct reading of the square area of each pebble could be done (Fig. 6; Pl. V).

The author is well aware of the mean error caused by the rounded surface of the borehole core, but this error remains constant throughout the measuring of all the pebbles, and may therefore be neglected. (In the case of only one borehole, MTK 3, the author had to construct a curved perspex with a larger circumference because this hole was drilled with an NX crown. In the case of borehole MB 2, the core was splitted, so pebble areas were measured with a flat piece of grid perspex.)

One disadvantage in this method of the determination of pebble area is, however, when the size of the pebbles exceeds the diameter of the borehole core (Pl. VI). To overcome this

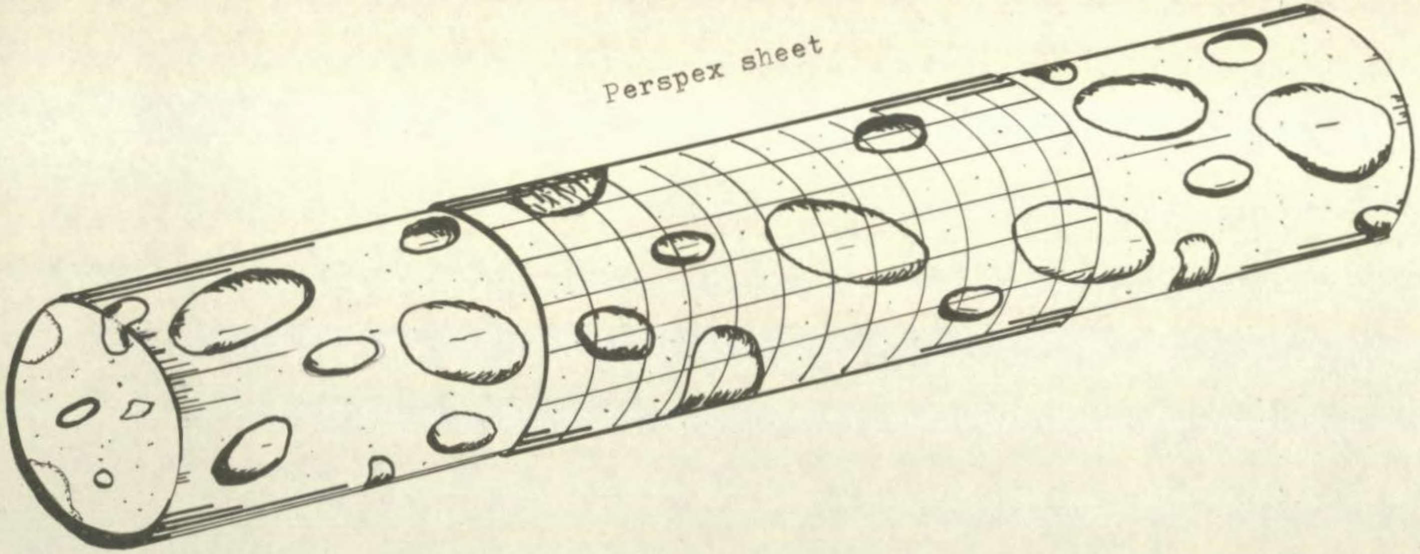


Fig. 6. - Illustration of the method applied in determining the pebble area on the borehole core.

problem, the author applied the following technique from which a fair amount of accuracy could be obtained: It has been proved by underground observations that large pebbles were laid down with their a- and b-axes parallel to the plane of deposition and the c-axis at right angles to the bedding-planes (Pl. VII and VIII). Surveying of the surface boreholes indicated that these boreholes tend to deflect from the vertical position into a direction almost perpendicular to the bedding planes. When a drill-crown penetrates a pebble larger than the diameter of the bit, it can therefore be assumed that a cut almost parallel to the apparent c-axis is seen on the core (Pl. VI). In the case of spheroids, this axis would not differ much from the actual c-axis.

Measurements at different underground localities to determine the ratio between the c-axis and the square area of a pebble have been carried out. Measurements of the apparent a- and c-axes of approximately 1 600 pebbles of different sizes were taken. A scattergram of the c-axis versus the pebble area is then constructed for each pebble type. A straight line (regression line) can then be fitted onto these diagrams (Fig. 7, 8, 9, 10, 11 and 12).

(b) Determination of the Regression Lines

The regression line for every specific type of pebble can be determined either mathematically or by means of a computer. By using any one of these two methods, the regression line for estimating the pebble area for a certain length of the c-axis of each pebble, is then calculated and plotted on the scattergram. The pebble area can thus be read off from the graph for a given length of the c-axis. The X co-ordinate represents the length of the c-axis, while the square area of the pebble is represented by the Y co-ordinate.

FIG. 8 **QUARTZITE**

Scattergram showing C-Axis versus Pebble Area with the regression line defined by means of a computer.

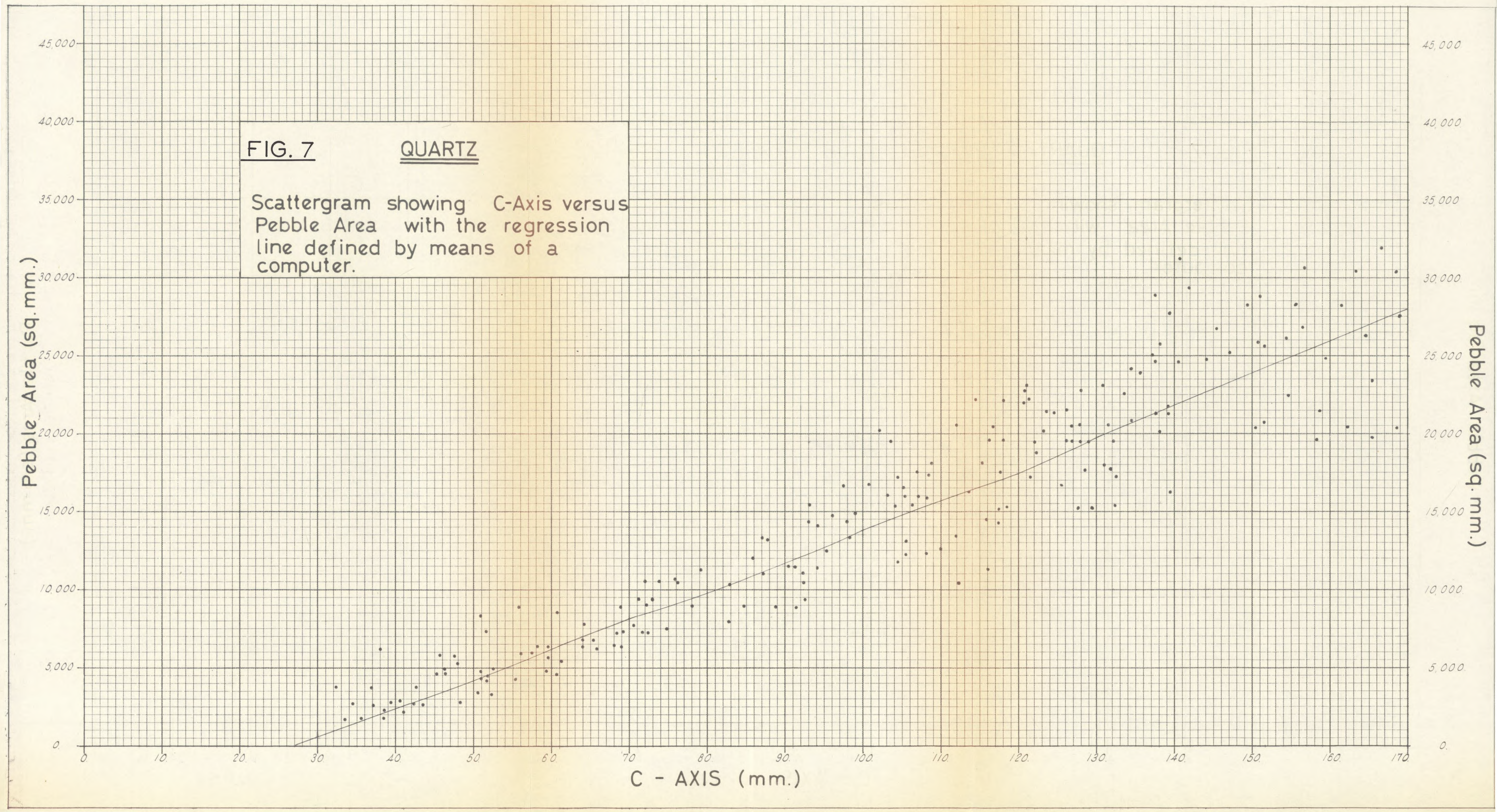


FIG. 7 QUARTZ

Scattergram showing C-Axis versus Pebble Area with the regression line defined by means of a computer.

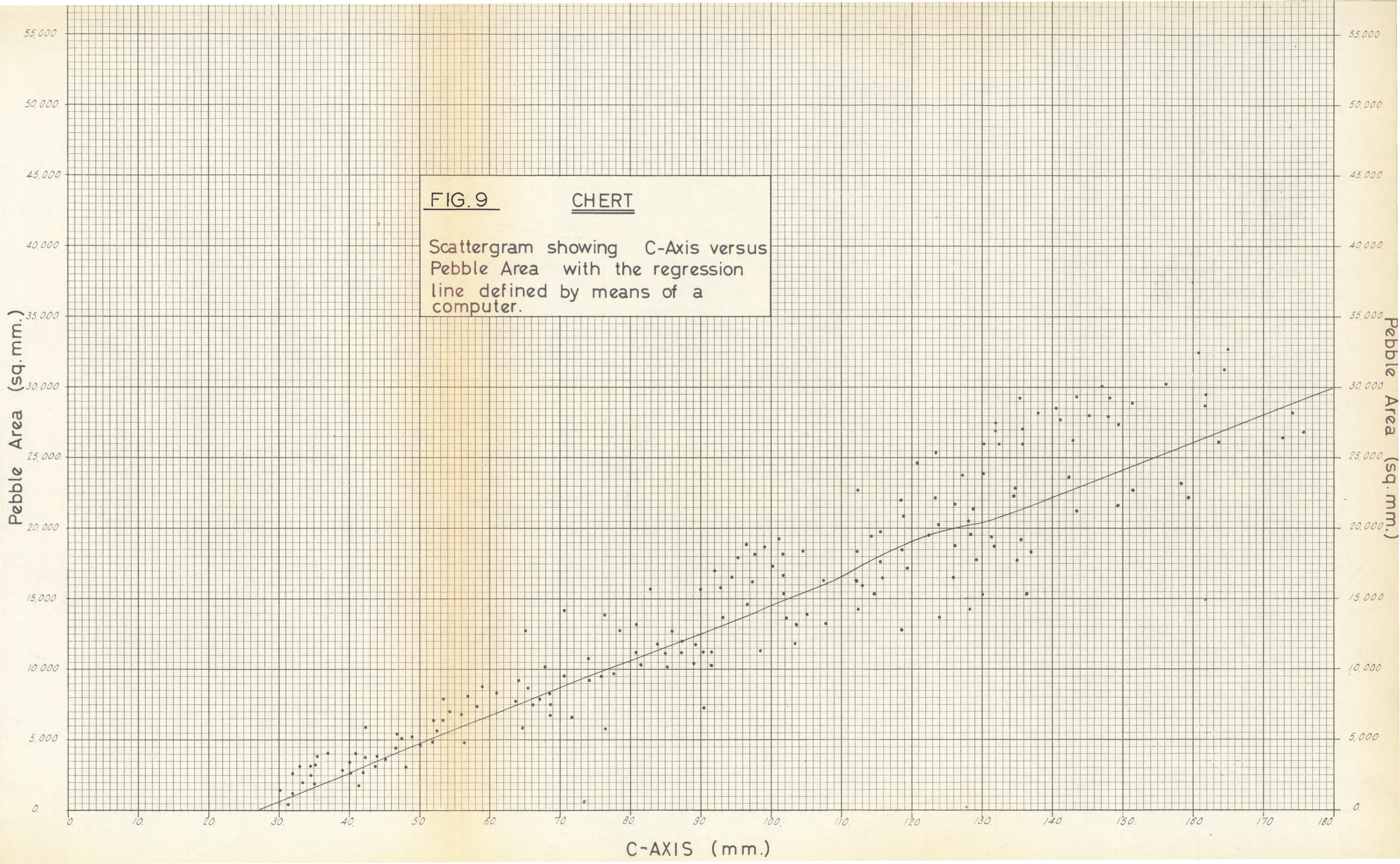


FIG. 9 CHERT

Scattergram showing C-Axis versus Pebble Area with the regression line defined by means of a computer.

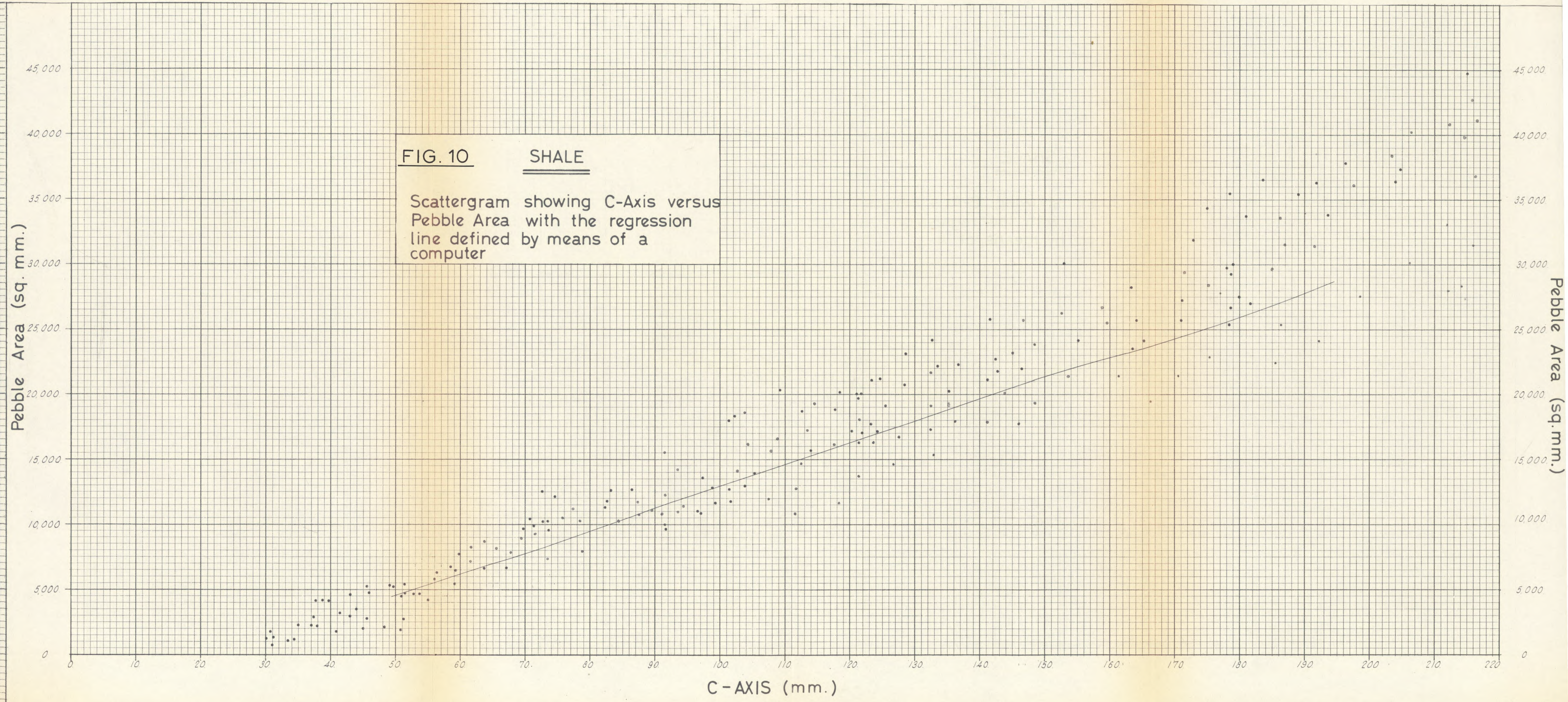


FIG. 10 SHALE

Scattergram showing C-Axis versus Pebble Area with the regression line defined by means of a computer

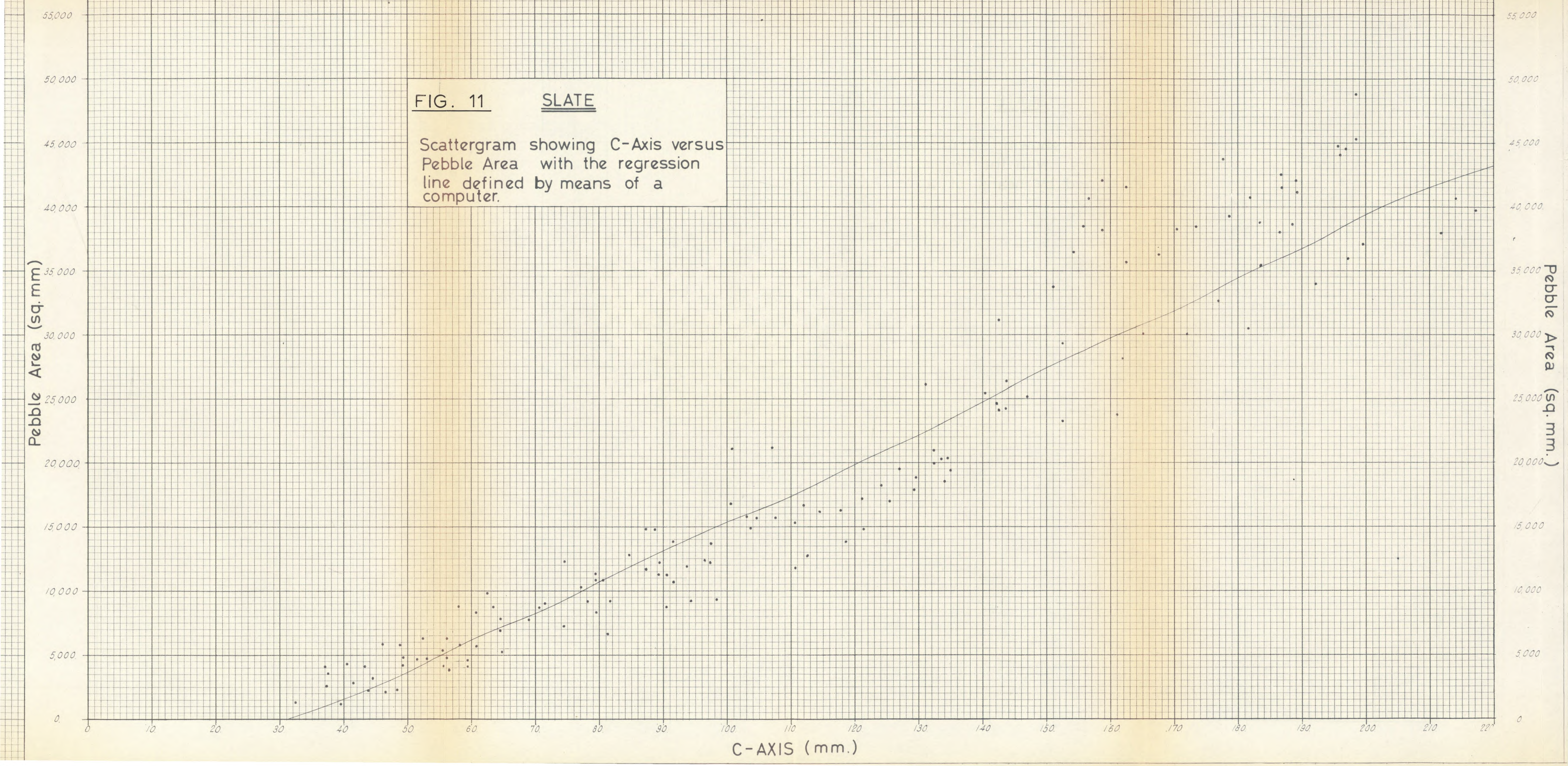


FIG. 11 SLATE

Scattergram showing C-Axis versus Pebble Area with the regression line defined by means of a computer.

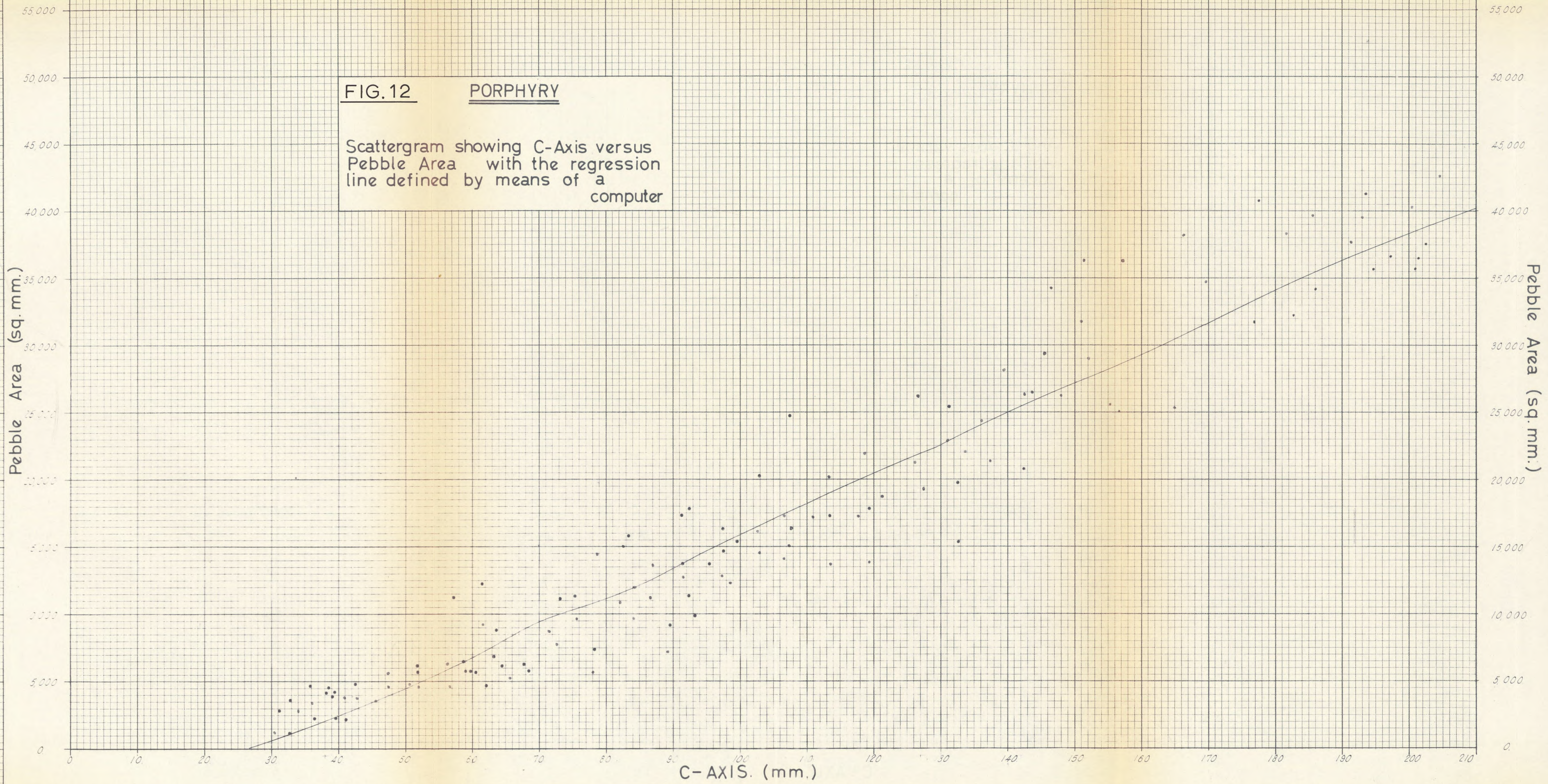


FIG.12 PORPHYRY

Scattergram showing C-Axis versus Pebble Area with the regression line defined by means of a computer

(i) Mathematical Method

The regression line is given as an equation in the form:

$$\hat{y} = \bar{y} + b\ (x - \bar{x})$$

where $\hat{y}$ = area of the pebble

x = c-axis

$\bar{y} = \frac{\Sigma\hat{y}}{N}$ = mean pebble area

N = amount of pebbles

$\bar{x} = \frac{\Sigma x}{N}$ = mean c-axis

$$\therefore \qquad b = \frac{\Sigma x\hat{y} - N\bar{x}\bar{y}}{\Sigma x^2 - N\bar{x}^2}$$

(ii) Determination by means of a computer:

A detailed write-up of the program used by a computer in the calculation of the regression line is given in the Addendum. The results are summarised below:

DETERMINATION OF THE REGRESSION LINE FOR PEBBLES OF QUARTZ (FIG. 7).

Regression line to estimate Y for a given value of X

$Y = -4712.59 + 183.26X$

Regression line to estimate X for a given value of Y

$X = 40.57 + 0.00Y$

Correlation coefficient = 0.854

DETERMINATION OF THE REGRESSION LINE FOR PEBBLES OF QUARTZITE (FIG. 8).

1. For pebbles with c-axis from 30 - 140 mm.

Regression line to estimate Y for a given value of X

$Y = -9934.47 + 255.37X$

Regression line to estimate X for a given value of Y

$X = 45.45 + 0.00Y$

Correlation coefficient = 0.923

2. For pebbles with c-axis from 140 - 240 mm.

Regression line to estimate Y for a given value of X

$Y = -30208.08 + 422.16X$

Regression line to estimate X for a given value of Y

$X = 7.94 + 0.002Y$

Correlation coefficient = 0.968

DETERMINATION OF THE REGRESSION LINE FOR PEBBLES OF CHERT (FIG. 9).

Regression line to estimate Y for a given value of X

$$Y = -4851.09 + 194.36X$$

Regression line to estimate X for a given value of Y

$$X = 40.15 + 0.00Y$$

Correlation coefficient = 0.803

DETERMINATION OF THE REGRESSION LINE FOR PEBBLES OF SHALE (FIG. 10).

Regression line to estimate Y for a given value of X

$$Y = -3586.03 + 165.35X$$

Regression line to estimate X for a given value of Y

$$X = 28.50 + 0.01Y$$

Correlation coefficient = 0.917

DETERMINATION OF THE REGRESSION LINE FOR PEBBLES OF SLATE (FIG. 11).

Regression line to estimate Y for a given value of X

$$Y = -8080.95 + 235.02X$$

Regression line to estimate X for a given value of Y

$$X = 37.93 + 0.00Y$$

Correlation coefficient = 0.960

DETERMINATION OF THE REGRESSION LINE FOR PEBBLES OF PORPHYRY (FIG.12).

Regression line to estimate Y for a given value of X

$$Y = -6495.22 + 224.14X$$

Regression line to estimate X for a given value of Y

$$X = 39.88 + 00.00Y$$

Correlation coefficient = 0.904

(c) Mean Size and Its Significance

To determine the mean pebble size for each borehole, the data are calculated by means of a computer, which gave values for various pebble-size parameters and printed a report for each sample submitted. Two sets of parameters are calculated, using the formulae of Inman (1952) and Folk and Ward (Folk, 1966, p. 81).

These formulae are somewhat modified from their usual form, in that the size in square millimetres is used instead of phi sizes. The method of moment measures is used to calculate the mean size and mean deviation. A detailed write-up of the program used by the computer is given in the Addendum. The formulae used are:

Inman:

$$\text{Mean size} = \frac{(MM_{16} + MM_{84})}{2}$$

Folk and Ward:

$$\text{Mean size} = \frac{(MM_{16} + MM_{50} + MM_{34})}{3}$$

where e.g. MM_{16} = average mm^2 at a cumulative percentage of 16.

Method of moments:

$$\text{Mean size} = \frac{\sum(\text{percentage pebbles in each group})(\text{mean size } (mm^2)}{100}$$

$$\text{Mean deviation} = \frac{\left[\sum(\text{percentage pebbles})(\text{mean size} - \text{average size})^2\right]^{\frac{1}{2}}}{100}$$

According to Krumbein and Sloss (1963, p. 101), the analysis of the grain size of a sediment can give some idea of the conditions under which clastic sediments were deposited. Mean size is proportional to the competency of the current that transported the material to the site of deposition.

The layers of conglomerate in the Elsburg Stage differ strikingly from one another regarding their mean pebble size. This feature is most prominent in the conglomerates near the margin of the basin. It has been found that in the boreholes drilled on the lease area of Western Holdings Limited, the different layers of conglomerate consist of alternating horizons of big cobbles and small pebbles.

Tables III and IV illustrate the variation in mean pebble-size in the different layers of conglomerate. Table III represents the results obtained from surface borehole MH 5, while Table IV illustrates the differences in mean pebble size as observed at Western Holdings No. 2 Shaft on the 33 Haulage East. Observations in this haulage have been done at intervals of approximately 75 to 150 m in an easterly direction. An average of approximately 120 pebbles were measured at each station. From the results in Tables III and IV it can be recognised that a large variation in mean pebble size exists. In the Welkom Mining Area, however, almost no difference in mean pebble sizes could be observed in the different layers of conglomerate.

TABLE III. - The difference in mean pebble size in the layers of conglomerate intersected in borehole MH 5.

Layer No.	Depth intersected (m)	Mean pebble size (mm^2)
1.	377.6 - 389.5	340.6
2.	389.5 - 413.3	718.0
3.	413.3 - 436.2	983.7
4.	438.9 - 444.4	1 709.4
5.	444.4 - 505.9	5 166.7
6.	505.9 - 560.8	2 871.6
7.	560.8 - 538.9	6 402.4
8.	538.9 - 603.5	605.2
9.	603.5 - 622.7	375.3
10.	626.1 - 651.0	874.1
11.	651.0 - 660.5	3 324.5
12.	662.6 - 748.9	898.0
13.	762.3 - 801.3	365.5

TABLE IV. - The differences in mean pebble size at several underground localities on Western Holdings No. 2 Shaft, 33 Haulage East.

Number of Station	Distance to nearest peg	Distance to previous station (m)	Mean pebble size (mm^2)
1	A4676 + 22 m		3 418
2	A3999 - 7 m	175	4 234
3	A3574 + 5 m	166	9 063
4	A3149 + 24 m	170	2 153
5	A2603 + 9 m	128	987
6	F9117 + 3 m	110	738
7	F9778 + 21 m	77	1 843
8	H 379 + 6 m	119	12 076
9	H 744 - 3 m	170	1 416

(d) Conclusions

(1) The mean pebble sizes in the layers of conglomerate vary slightly from borehole to borehole, but a general decrease in the mean size can be observed in mainly two directions.

West of the Arrarat Fault a definite decrease in a south-easterly direction is evident, while in the area east of the Arrarat Fault, the pebble sizes show a decrease in a north-easterly direction.

The dispersal pattern for the conglomerates (Plan 3) indicates that a sudden change in the direction in which the mean pebble size decreases, takes place along the strike of the Arrarat Fault. It is thus obvious that this fault must have an enormous structural influence after the deposition of the sedimentary layers of the Elsburg Stage. Fig. 13 illustrates the suggested transport directions of the sediments during the deposition of the Elsburg Stage. The sediments are deposited on a deltaic fan spreading from west to east. The areas surrounded by dotted lines represent the lease areas of the different mining properties as they are visualised before the Arrarat Fault. The result is that Western Holdings Limited was situated on the south-western flank of the delta fan whilst the area, representing the Welkom Gold Mine, lay on the north-eastern flank of the fan.

Shearing stress then caused the downthrow along the Arrarat Fault with a vertical displacement of 1 200 to 2 100 m to the west. Simultaneously, lateral displacement took place along the fault-plane with the western block moving towards the north and the eastern one towards the south (Fig. 13). A lateral displacement of approximately 6 000 m in a direction north-south could therefore be postulated on the Arrarat Fault.

Sims (1969) observed a similar displacement on the Brand Fault which trends in the same direction as the Arrarat Fault and coincides with the latter near the

Fig. 13. - Suggested transport directions of the sediments during the deposition of the Elsburg Stage and their lateral displacement by the later Arrarat Fault. Dotted lines represent the lease areas as postulated before the Arrarat Fault, while their present positions are shown on the overlay.

1. Western Holdings Ltd.
2. Welkom Gold Mining Co.

southern boundary of the Welkom Mine. The lateral displacement, however, was less than that along the Ararat Fault, but the movement was similar.

In a description of the palaeocurrent analysis of the Elsburg Stage on President Steyn Mine, Sims (1969, p. 140) stated that "the direction of sediment transport during the Elsburg Stage was essentially from west to east". From Fig. 13 it is obvious that the President Steyn Gold Mine must have been situated in the middle of the delta fan where the palaeocurrent directions were essentially from west to east.

Although this research was focussed on the sedimentological aspects of the layers of conglomerate in the Elsburg Stage, the author is of the opinion that, by using the present results, more light might probably be thrown on the palaeocurrent directions of the Basal Reef on the Welkom and Western Holdings Gold Mines.

In a palaeocurrent study of the Basal Reef on President Steyn Mine, Sims (1969) described transport of the sediments from south to north. A sedimentological project carried out by the Geological Department of the University of the Orange Free State on the Welkom, Free State Geduld, Western Holdings, President Brand and President Steyn Gold Mines during 1966 to 1967, indicated the following palaeocurrent directions in the Basal Reef:

Free State Geduld Mines Ltd. :- From west to east.
Western Holdings Ltd. :- From north-west to south-east.
President Brand G.M. Co. Ltd. :- From south to north.
President Steyn G.M. Co. Ltd. :- From south to north.
Welkom Gold Mining Co. Ltd. :- In the south-eastern portion the direction was from the south, but the western and north-western part showed transport from west to east.

From the above measurements the major part of the Basal

Reef shows an identical palaeocurrent direction to that of the Elsburg Stage. Fig. 13 can thus be divided into two zones: the one, south of line RR^1, can be described as a "gold-rich zone" with a highly payable Basal Reef, while the zone north of this line yields low gold values. It is then obvious that Freddies Consolidated Mines and the eastern portion of the Welkom Gold Mine must have been situated in the zone of low gold values, while the rest of the mines are situated in the highly payable zone. On the Welkom Gold Mine lateral displacement along the Arrarat Fault would therefore probably explain the area of low gold values (No. 1 and 2 Shafts) adjacent to the richer area on which the No. 3 Shaft is situated.

(2) From the pebble-size distribution alternating zones of high and low stream velocities can be recognised. These zones are very well defined near the margin of the basin, but become less obvious eastward and northeastward as the pebbles decrease in size towards the centre of the basin.

(3) Analysis of the pebble sizes shows that the various pebble types in the layers of conglomerate have different mean diameters (Table V).

TABLE V. - The mean diameters of the different types of pebbles at randomly selected stations.

Number of Station	Mean pebble size in mm^2						
	Milky quartz	Opalescent quartz	Chert	Slate	Shale	Quartzite	Porphyry
W.H.No.1 Shaft	960.8	724.6	921.3	783.7	421.3	1274.6	-
W.H.No.2 Shaft	7833.7	981.2	2482.0	965.4	613.2	9727.0	2117.3
W.H.No.3 Shaft	8214.6	3796.9	4248.3	1207.3	879.0	28303.8	6453.7
W.H.No.4 Shaft	423.0	571.0	738.2	211.8	304.7	827.1	-
W.G.M.No.3 Shaft	478.5	423.7	387.4	241.4	283.1	473.9	-

The 25 largest pebbles of each type have been measured at each station. Comparing the mean pebble sizes of the different types (Table V) the following deductions can be made:

Near the margin of the basin the pebbles of chert, slate and shale are always much smaller than those of milky and opalescent quartz, quartzite and porphyry (Pl. IX and X). The pebbles of quartzite are very large in comparison to the other pebble types, while those of chert and milky quartz have approximately the same size.

According to Sneed and Folk (1958, p. 126) pebbles of milky quartz and chert appear to abrade at equal rates and will therefore remain in the same size ratio during transportation. Thus, in the layers of conglomerate of the Elsburg Stage, these two types must have covered the same distance during transportation.

Pettijohn (1957, p. 554) found that pebbles of quartzite abrade four times faster than that of quartz and chert. The fact that the pebbles of quartzite are very large in comparison to those of quartz and chert indicates that their source area was much closer to the basin than that of either quartz or chert. Borchers (1950, p. 116) described considerable erosion of the Lower Division of the Witwatersrand System during the deposition of the Upper Division due to a retreating shore-line. According to the hypothesis of Borchers, fragments of quartzite were weathered from the exposed formations (Lower Division) and were thus subjected to a second cycle of deposition without long distance transportation.

The author does not wish to elaborate on the rate of abrasion of pebbles in this research, but it can, however, be said that the abrasion appears to become less towards the centre of the basin, where the different pebble types have almost the same mean size (Table V, W.G.M. No. 3 Shaft).

2. Sorting

The sorting of a sediment can be of great importance when problems regarding the transportation and distribution of the particles have to be solved. Pettijohn (1957, p. 36) defined the term "sorting" as the spread of the particle sizes of a sediment. Analysis of the sorting of particle sizes may possibly indicate the transporting agent of the particle.

Udden, in his pioneering work on sediments, made use of the ratio between successive classes on a histogram, as well as the total spread of the histogram as a measure of sorting (Folk, 1966, p. 82).

Trask in 1930 suggested a measure, which he defined as the sorting coefficient, and this remained the most widely used parameter for sorting of sediments until recent years. In 1932 he defined the sorting coefficient (So) as the square root of the ratio of the larger quartile (the 25 per cent value - Q_1) to the smaller quartile (the 75 per cent value - Q_3) (Pettijohn, 1957, p. 57).

Therefore: $So = \sqrt{Q_1/Q_3}$

If the values for these two quartiles are nearly equal, the sorting coefficient approaches 1. As this formula covers only 50 per cent of a cumulative curve, it has a low efficiency and should therefore be used only in the case of well sorted sediments.

Griffiths developed a more comprehensive measure, the percentile deviation (PD_ϕ), covering the central 80 per cent of the size distribution (Folk, 1966, p. 82). Inman (1952) proposed a phi analogue to Trask's sorting coefficient ($PD_\phi = \frac{\phi_{84} - \phi_{16}}{2}$) which is being a closer approach to the percentile deviation in natural sediments of the overall presence of poorly-sorted tail fractions.

Folk and Ward (Folk, 1966, p. 83) found these measures inadequate for bimodal or skewed distributions and developed the measure of "Inclusive Graphic Standard Deviation".

$$\sigma = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

Another method to calculate the sorting of a sediment is that of standard deviation.

standard deviation $S = \sqrt{\frac{1}{n-1} \times \frac{n}{(xy - \bar{x})^2}}$

where n = the number of observations

xy = the individual azimuths

$\bar{x}$ = the mean value of all the observations.

Due to the many calculations involved in this method, it is thought to be impractical when the sorting of a large number of samples have to be determined.

The sorting of the pebbles in the conglomerates of the Elsburg Stage was calculated by means of a computer and the formulae of Inman and that of Folk and Ward were used. As the program written for the computer was based on measurements in mm^2, the calculation for sorting, skewness and kurtosis were all done by the computer on this basis. In Fig. 14 a graph for the conversion of these calculations to values for sorting as defined by Inman and Folk and Ward is given.

The sorting values vary from about 1.10 to 0.55, but their distribution is strongly influenced by the Arrarat Fault. The average values to the west of the Arrarat Fault show a considerable decrease in the direction of transport (south-east) which is in accordance with the results obtained by the pebble-size distribution. The sorting is moderately poor (So = 0.8 ±) which could possibly be representative of a transition between a fluvial and a beach environment. To the east of the Arrarat Fault the layers of conglomerate are better sorted (So = 0.6 ±) and probably indicate a beach environment. The sorting values also show a tendency to decrease in a north-eastern direction, indicating an increase in sorting down-stream.

3. Skewness and Kurtosis

The formulae for the calculation of skewness and kurtosis were part of the program written for the computer and the values were thus calculated on the basis of square millimetres. These values were, however, not used because an interpretation for skewness and kurtosis based on them was considered not reliable.

Sorting.

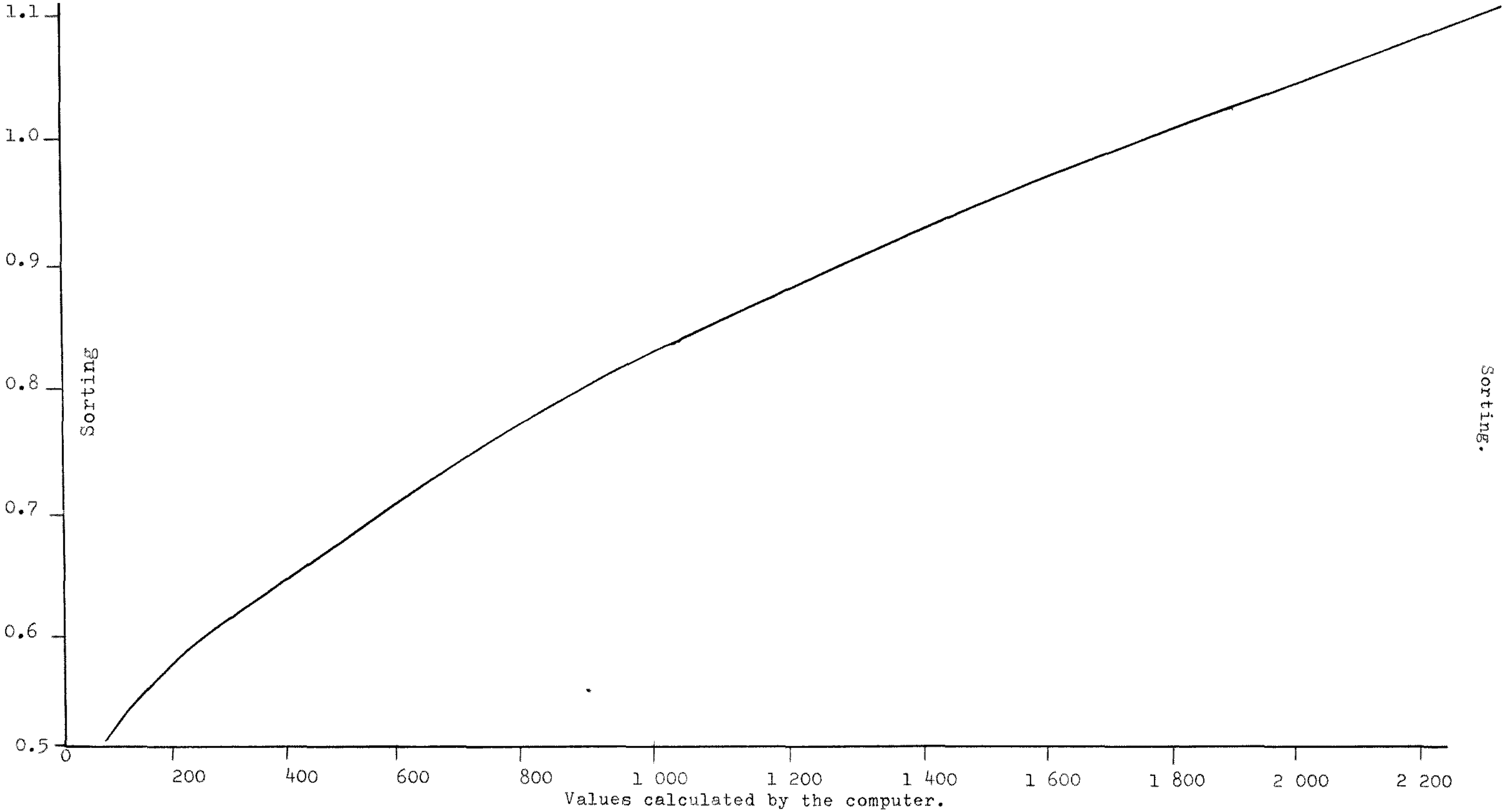


Fig. 14. - Graph for the conversion of values calculated by the computer to sorting values after Inman (1952) and Folk and Ward (Folk, 1966).

D. FABRIC

The determination of particle orientation is largely confined to pebbles because of difficulties in measuring the orientation of very small grains, and it is a powerful tool in interpreting the transport direction of the material.

When pebbles are transported in a stream, they will assume the position of minimum resistance to the water. During flood stages the movement of large pebbles is mainly by rolling and sliding, medium-sized pebbles are transported by saltation, whilst small pebbles are carried in suspension. During transportation large rod-shaped pebbles will therefore be rolled like a cylinder. After deposition they reorientate themselves with their long axes parallel to the stream direction (Reinecke, 1930, p. 122). In the case of medium-sized rod-shaped pebbles, reorientation might take place during transportation and they will also be laid down with their longest axes (a-axes) parallel to the direction of the stream. The extend to which this reorientation of the pebbles will take place, will depend on the rate of deposition.

1. Method of Determination

Five underground localities which are equally spread over the area investigated, were selected, viz. the four shafts of Western Holdings Limited and the No. 3 Shaft of the Welkom Gold Mining Company (Fig. 4). (The only other locality where conglomerates of the Elsburg Stage are exposed in underground development on Welkom Gold Mine, is at No. 2 Shaft, but this specific locality is inaccessible.) Stations were selected where pebbles are exposed in at least one horizontal and two vertical planes, thus viewing the pebbles from the bottom (exposures on the hanging-wall) as well as from two sides almost at right angles to one another. Cubby breakaways and substation often satisfy these conditions. The reason being that the author would always be ascertained of the position of each of the three axes of the pebbles, as illustrated in Fig. 15.

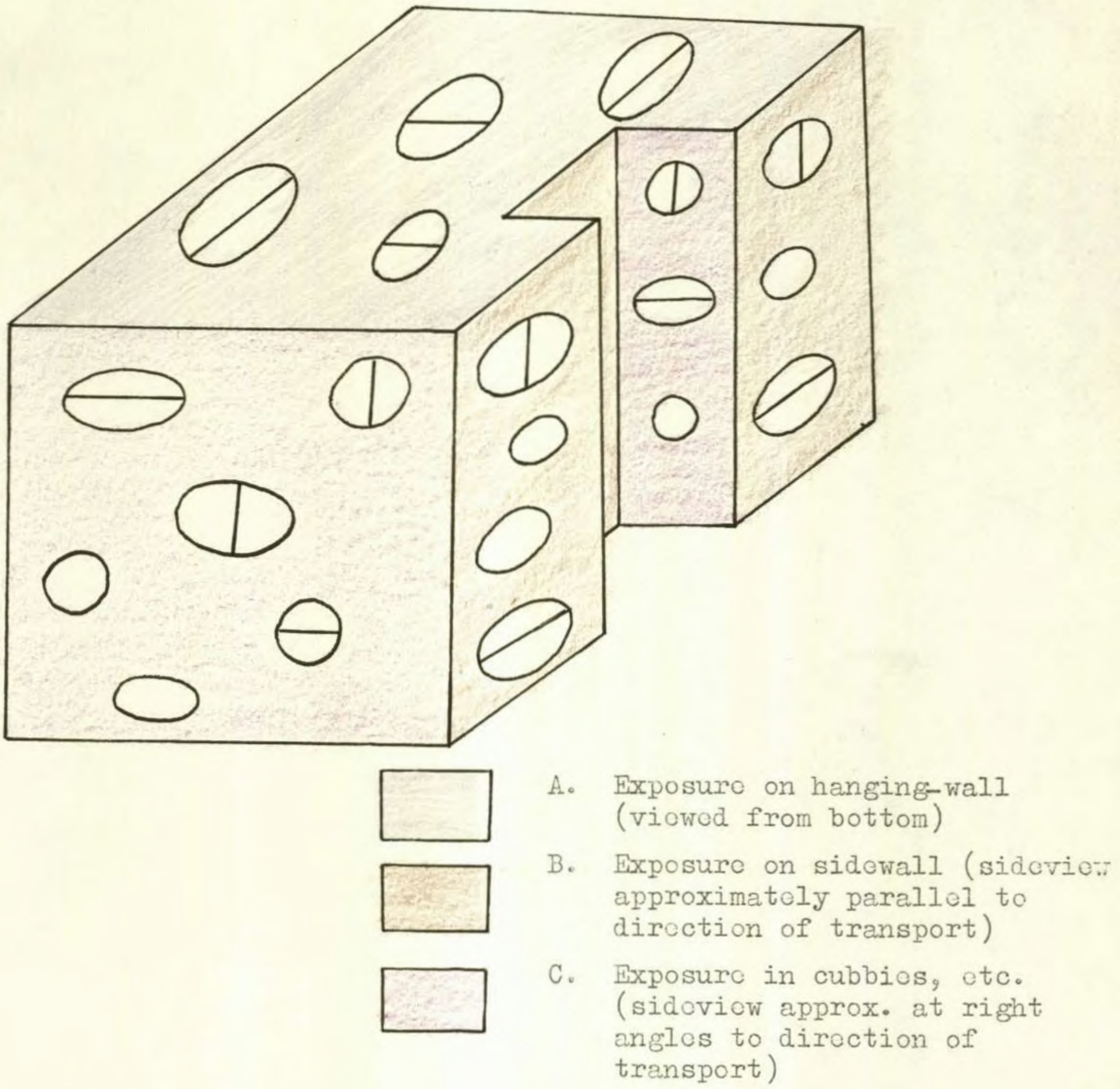


Fig. 15. - Block diagram illustrating the positions of the three axes of pebbles viewed from different angles.

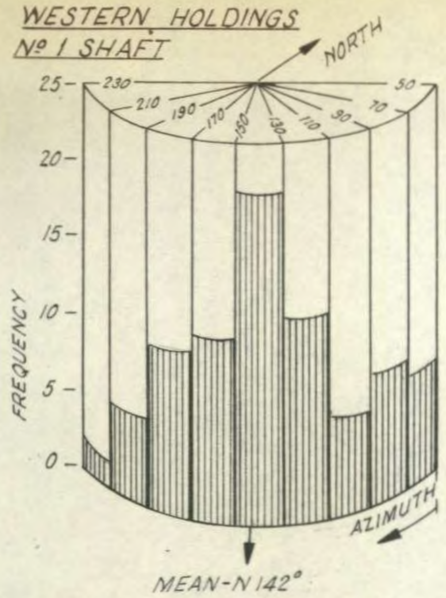
Fifty rod-shaped pebbles (bottom view) were selected at each of the localities. The author recorded only the largest pebbles (mainly quartz and quartzite), which were marked along the direction of their longest axes. This direction was determined by using a Brunton Compass (Pl. XI). At the same locality, 40 pebbles were selected on the sidewall from which the apparent dip of the longest axes was measured. The true strike and dip of the bedding-planes in the near vicinity of the stations were also measured.

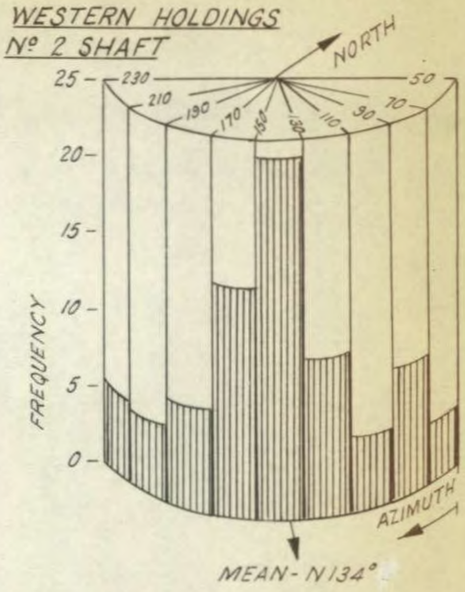
2. Statistical Analysis

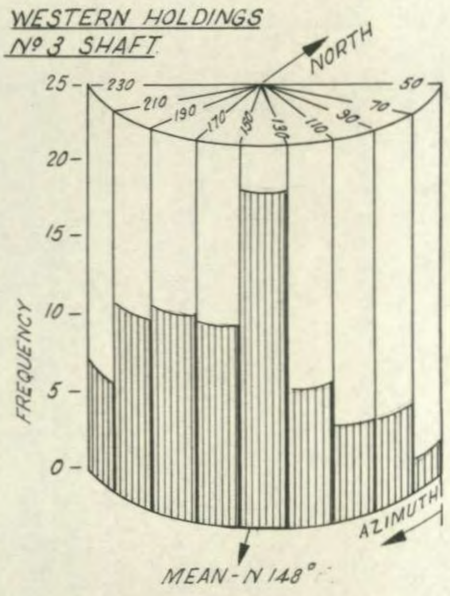
Knopf and Ingerson (Pettijohn, 1957, p. 75) described a petrofabric diagram on which both the azimuth and the inclination of a fabric element can be plotted. Knowles (1966) and Sims (1969) also used pebble imbrication as an index of the original depositional environment and of palaeocurrent direction. In the conglomerates investigated, the angles between the long axes of the pebbles and the horizontal were extremely small. These values were considered not reliable enough so that therefore only the strike of the long axes was plotted on rose diagrams. Fig. 16 shows histograms of the orientation of the long axes of the pebbles arranged on a half cylinder over an interval of 180°, as measured at the five different shafts.

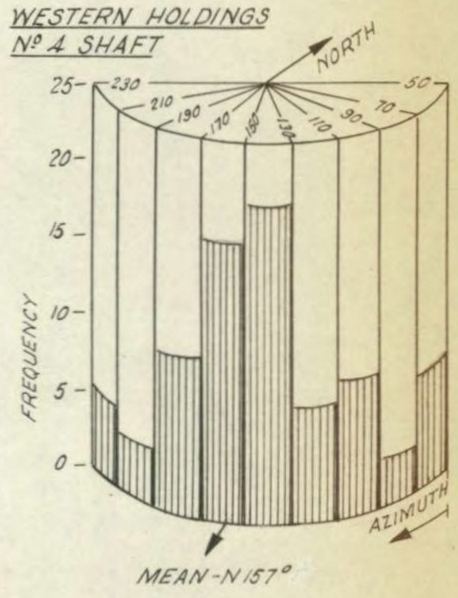
Preferred orientation of the rod-shaped pebbles in the layers of conglomerate of the Elsburg Stage could be observed at all the localities investigated by the author. A major orientation of the pebbles in a direction almost parallel to that of the palaeocurrents as indicated by the pebble-size distribution is predominant. Apart from this, a minority of pebbles were orientated with their longest axes at right angles to the direction of preferred orientation. Roberts and Kransdorf (1938, p. 243 - 244) found that the majority of pebbles in the conglomerates of the Witwatersrand System at the Central Rand, are orientated with their longest axes at right angles to the stream direction. According to them this phenomenon is typical of beach deposits.

Hodgson (1967) found a bimodal distribution of pebble orientations in the Basal Reef conglomerate at Harmony Gold Mine. He explained this phenomenon as follows:
Large rod-shaped pebbles will tend to roll like a cylinder. When deposited, these pebbles will reorientate themselves with the longest axes parallel to the stream direction. The pebbles that were not reorientated, were cemented, or captured by surrounding grains before reorientation could take place.









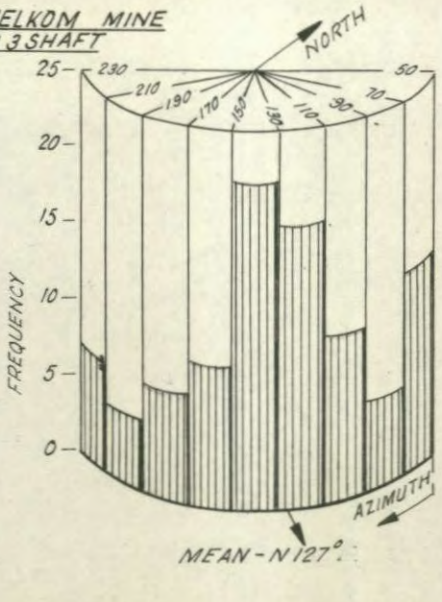


Fig. 16. - Histograms illustrating the orientation of long axes of the pebbles.

The pebbles in the conglomerates of the Elsburg Stage are closely packed with almost no matrix. This might be the reason for the small amount of pebbles orientated perpendicular to the palaeocurrent direction.

3. Pebble Clusters

In a horizontal plane structures of the type shown in Fig. 17 are commonly found at localities where there are little sorting in coarse, fluvial deposits. In these structures, cobbles or boulders on the one side give rise to a wake or tail of coarse elements, concentrated and leaning against each other. This kind of structure resembles a wedge or a bunch of grapes, and is therefore termed "pebble cluster" (Dal Cin, 1968, p. 233 - 241).

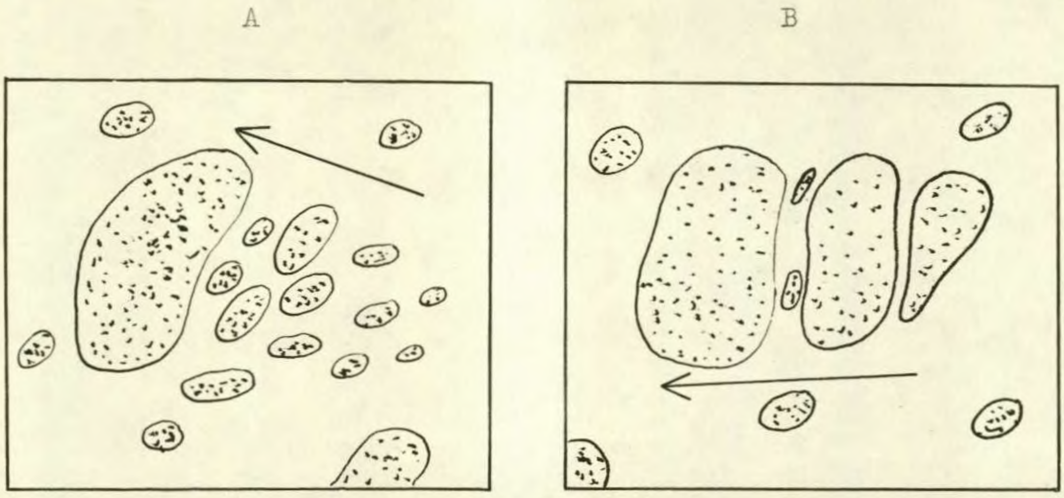


Fig. 17. - Illustrations of pebble clusters in a horizontal plane.

A. The wake formed by many pebbles.

B. The wake consisting of only two or three elements.

The arrows indicate the direction of the current.

Large cobbles or boulders protruding from the surface of the river bed, hinder the movement of smaller sized particles, which pile up in front of them, forming a kind of wake. Not all pebbles are stopped by these cobbles and boulders, as the smaller ones moved in suspension and easily by-passed the obstruction. In general, the length is directly proportional to the height of the boulder in respect to the plane of deposition.

Viewed in cross-section, pebble clusters most commonly appear as drawn in Fig. 18. The indication of the current direction as deduced from sectional views of these structures is less reliable because the orientation of the section relative to the pebble cluster is unknown. Therefore only exposures of pebble clusters in a horizontal plane (hanging-wall views) were measured. (Pl. XII).

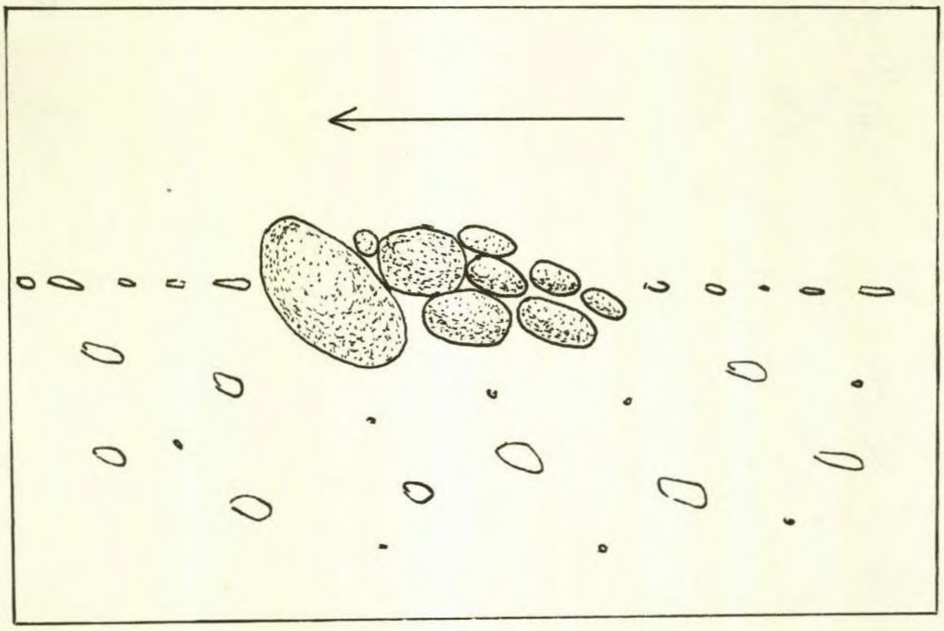


Fig. 18. - Section through a pebble cluster.

Measurements taken on 34 clearly defined structures of this type, show that the direction of the wake of coarse material, as represented by the axis which bisects the wake, is almost parallel with the palaeocurrent direction (Fig. 19). The greatest angle between the direction of the wake and that of the depositing current, in no place exceeds 35°. The greatest divergence occurred mainly in the less evident structures.

The presence of pebble clusters in layers of conglomerate offers evidence of unidirectional transport. In environments such as beaches, characterised by the back-and-forth movement of waves, structures of this kind are unlikely to last. The presence of pebble clusters in the conglomerates of the Elsburg Stage probably points to deposition in a fluvial environment.

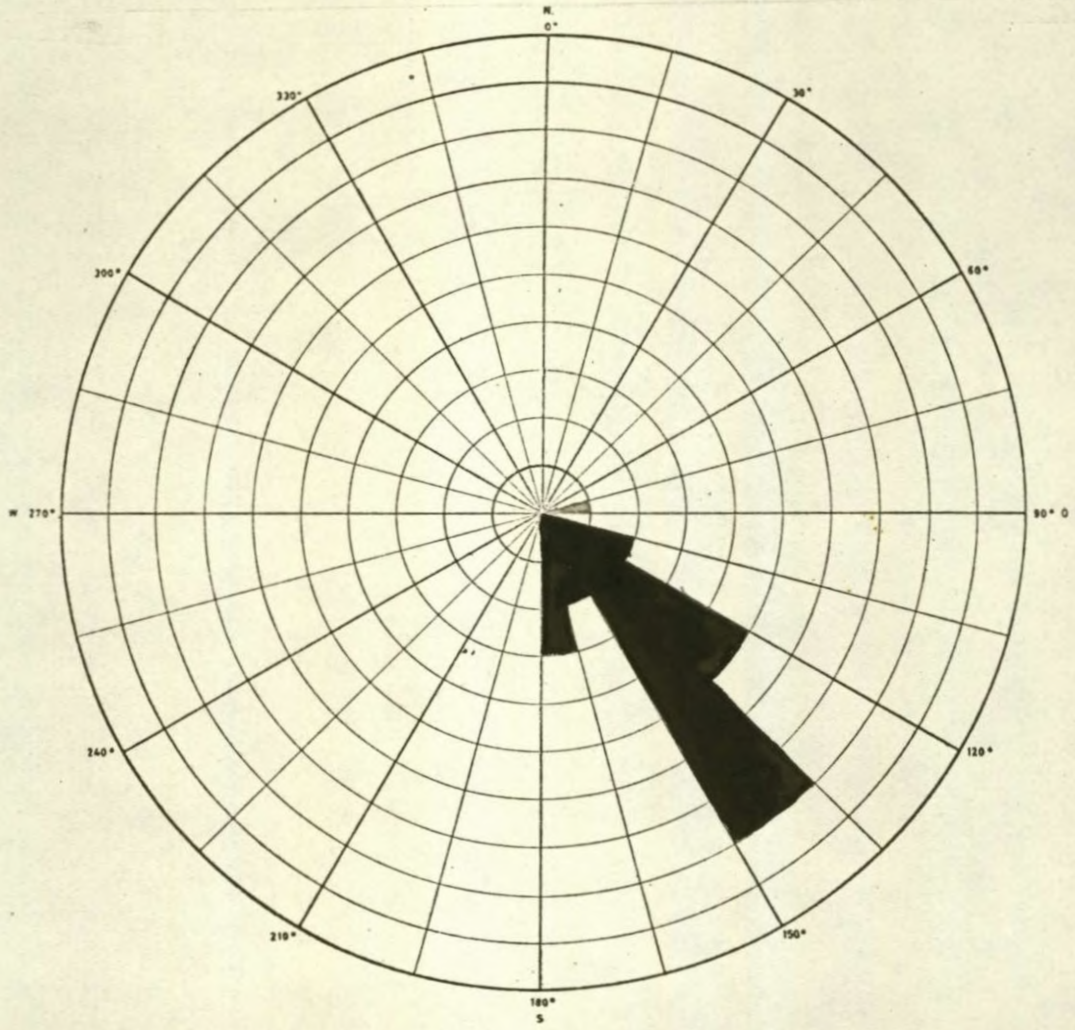


Fig. 19.- Rose diagram showing the orientation of pebble clusters.

E. PEBBLE SHAPE

The shape of a sedimentary particle is its geometric form and is generally described by certain parameters, viz. sphericity and roundness. Sphericity defines the general shape of the particle, while roundness describes the sharpness of the edges and corners of a clastic fragment.

Quantitative descriptions of the shape of a sedimentary particle appear to have first been given by Wentworth in 1922 (Krumbein and Pettijohn, 1938). He used two parameters for this purpose, viz. a roundness ratio and a flatness ratio.

Wadell differentiated between shape and roundness in 1933 (Krumbein and Pettijohn, 1938). Shape was described by him in terms of sphericity. He defined true sphericity as "the ratio of the surface area of a sphere of the same volume as the particle to the actual surface area of the particle" (Krumbein and Pettijohn, 1938, p. 283 - 284).

The shape of a pebble has a strong influence on its behaviour during transportation and deposition. The ease with which pebbles can be rolled or transported in suspension, their settling velocities in fluids and their packing arrangements, are all determined by the shape of the particular pebbles.

Several studies of pebbles under natural and experimental conditions have demonstrated changes in pebble shape as a function of distance of transport (Krumbein, 1941; Sneed and Folk, 1958). The shape of pebbles, however, is almost entirely controlled by:

1. Roundness. 2. Sphericity. 3. Source rock characteristics.

1. Roundness

Wadell (Krumbein and Pettijohn, 1938) expressed the roundness of a particle as:

$$\text{Roundness} = \frac{\text{Average radius of corner and edges}}{\text{Radius of maximum inscribed circle}}$$

When the corners and edges are sharp, the average radius is small and the roundness accordingly low. When the average radius of the corners approaches that of the inscribed circle, the roundness value approaches 1.0.

Krumbein (1941) developed a chart for the visual estimation of roundness of pebbles between 16 and 32 mm in diameter (Fig. 20). The sizes of the pebbles in the Elsburg Stage on which the research was focussed, are extremely large in comparison with the pebble sizes Krumbein used for his chart. The roundness was determined therefore by visual comparison of the silhouette of the pebbles with an enlargement of the set of images developed by Krumbein.

When different observers make visual estimates of particle roundness, some variation can be expected. This effect, known as operator variation, has been studied by Rosenfeld Griffiths (1953), who found that although estimates of individual particles may vary significantly, the average values based on 50 or more particles, tend to be similar, because the errors of estimation are largely compensating in absence of strong operator bias.

Roundness is defined by Pettijohn (1957, p. 57) as:

$$P\ (\text{rho}) = \left(\frac{ry}{R}\right) / N$$

Where ry = The individual radii of the corners.

N = The number of corners.

R = The radius of the maximum inscribed circle.

Sames (1966) developed a method according to which the roundness (rho) is expressed as the percentage of the convex parts of a pebble along its periphery (Fig. 21). The following six grades of roundness are distinguished by Sames (1966, p. 127 - 128).

Angular:- 0 - 10% rho. In this case not the slightest rounding of an edge or corner is visible.

Subangular:- 15 - 25% rho. Some edges are slightly rounded but secondary corners are still present.

Subrounded:- 30 - 40% rho. In this case secondary corners begin to disappear and the convex parts cover at least one third of the circumference.

Rounded:- 45 - 60% rho. Secondary corners are almost absent, whilst concave parts are smoothed.

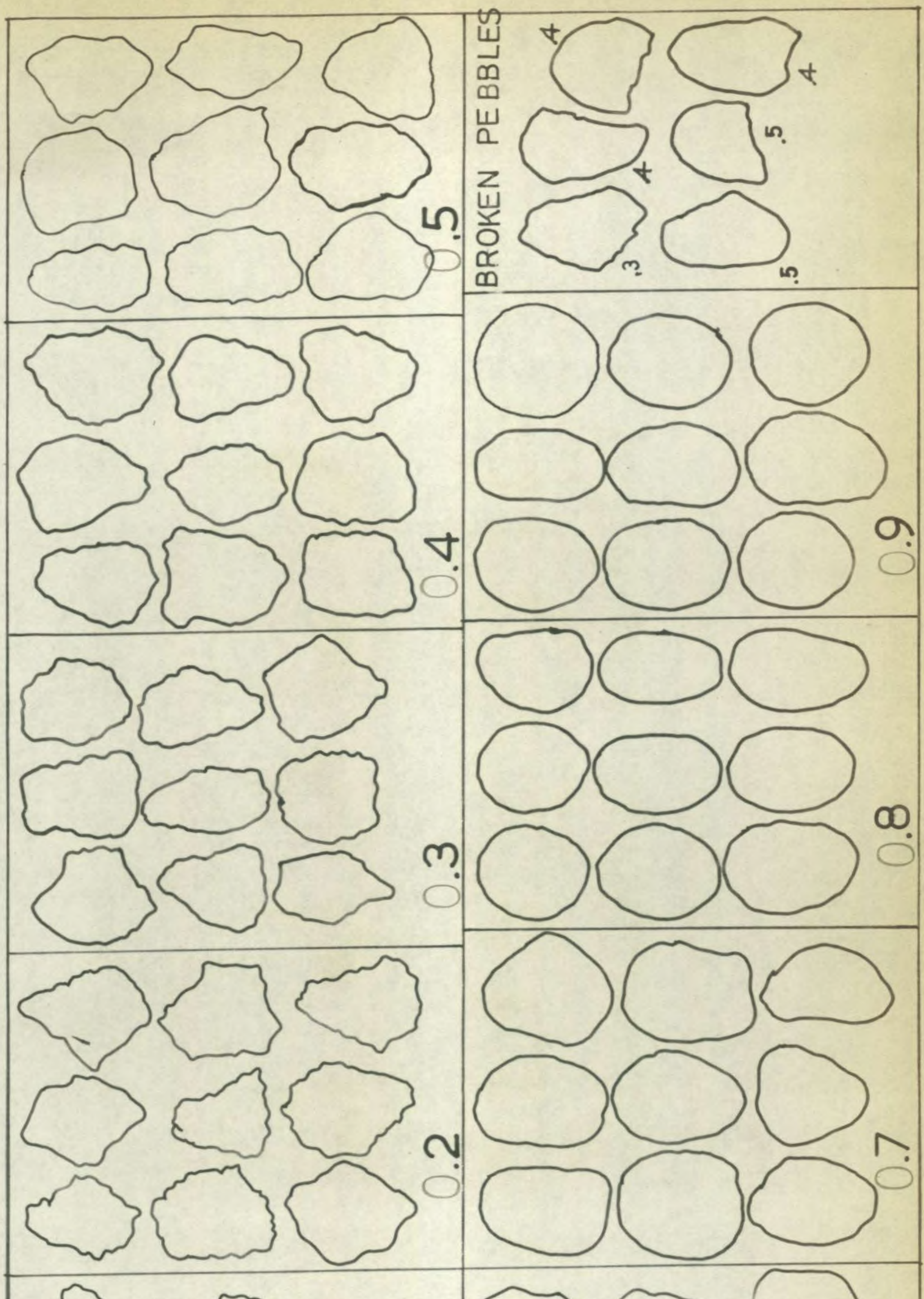


Fig. 20. - Roundness chart for 16 - 32 mm pebbles (after Krumbein, 1941).

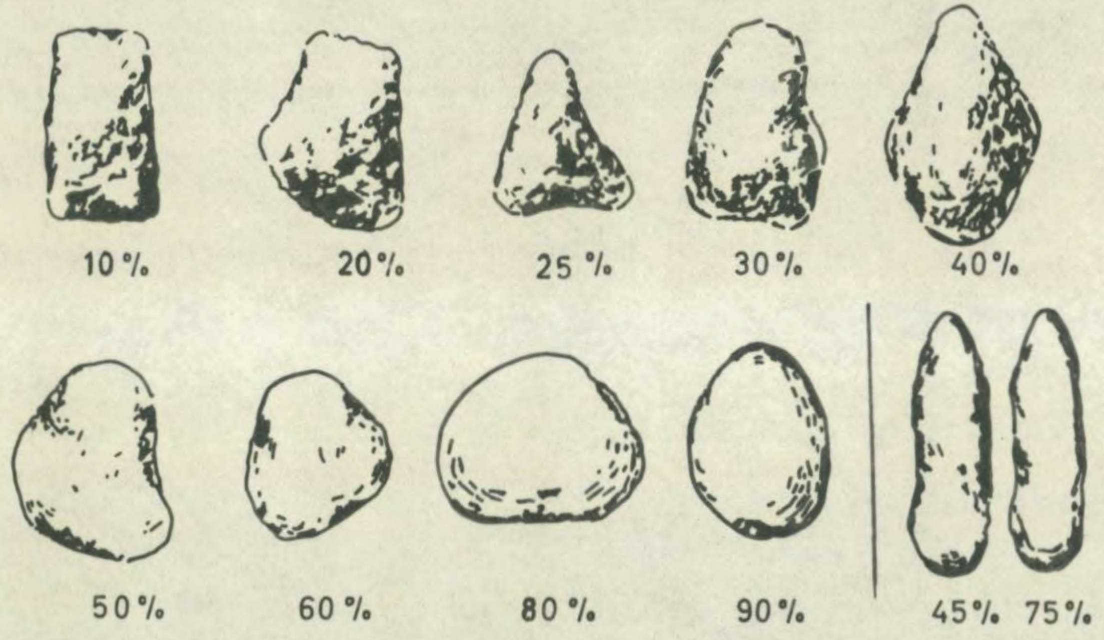


Fig. 21. - Roundness grades (after Sames, 1966).

Well rounded:- 65 - 80% rho. All parts are smoothed and secondary corners have disappeared.

Extremely well rounded:- 85 - 100% rho. This degree of roundness can probably only be achieved on beaches.

This method described by Sames is probably not suitable for particles smaller than 20 mm but will give accurate results for larger particles.

From studies of the roundness of pebbles, the following can be derived:

The roundness of a particle is increased by wear and reflects the distance transported and the mode of transportation. Apart from the mode of transportation, the roundness increases in the direction of transport in the absence of severe breakage. Large angular pebbles tend to round more rapidly than small ones. The rate of roundness depends, in part, on the hardness of the pebble.

A study of the roundness of the pebbles in the Elsburg Stage gives the following results:

(a) Durable Types

(i) Quartz

The larger pebbles of quartz, when compared to Krumbein's visual comparison chart, are subrounded to rounded, yielding a value of 0.59 to 0.63.

A distinctive difference can be made between the rounding of the pebbles of quartz in the small size range (200 - 500 mm^2) on Welkom Mine and those on Western Holdings Limited. In the Welkom Mining Area the pebbles of quartz are all rounded to well rounded (0.65 to 0.73), whilst those in the same size range found near the eastern portion of Western Holdings Limited and westwards, are almost entirely angular, yielding values of 0.3 to 0.4 according to Krumbein's chart.

It would be obvious to conclude that the rounding of the pebbles of quartz in the small size range increases eastwards, but apart from this phenomenon, no difference could be observed between the rounding of pebbles of quartz in the larger size range between these two areas. This can possibly be explained by the fact that some larger well-rounded pebbles broke up during the process of transportation. The majority of the larger pebbles show fractures filled with impurities, which would promote the above-mentioned process. These angular fragments were rounded during further transportation into the basin and would increase the number of smaller rounded pebbles towards the east.

(ii) Chert

According to Sneed and Folk (1958, p. 126; Plumley 1948), chert and milky quartz appear to abrade at equal rates. All the pebbles of massive black chert are very well rounded. This indicates that the pebbles of massive black chert are being transported over a relatively longer distance than the pebbles of quartz, which means that the source area of the chert was quite remote.

In the case of the yellow and banded types, a very low grade of rounding is observed. These varieties of chert have the tendency to weather into square to equant blocks, controlled by joints. These two types of chert are in fact highly susceptible to splitting and tend to chip or break during transport with the result that badly rounded surfaces are common.

(b) Non-durable Types

(i) Quartzite

Pettijohn (1957, p. 554) postulates that pebbles of quartzite abrade four times faster than quartz. He quoted an example where pebbles of quartzite have attained a roundness of 0.59 after being transported for a maximum distance of 72 km (Pettijohn, 1957, p. 553). The pebbles of quartzite found in the conglomerate layers of the Elsburg Stage are well rounded to extremely well rounded, which might indicate that these pebbles were transported at least 72 km. The well rounded pebbles of quartzite could also be the result that many of them have been subjected to more than one cycle of sedimentation. According to Borchers (1950) the Lower Division of the Witwatersrand System was exposed during the deposition of the Upper Division as the shoreline retreated into the basin, and could have suffered considerable erosion. It is, however, doubtful whether pebbles of quartzite derived from the erosion of the Lower Division would attain such a high grade of roundness in the absence of long distance transportation.

(ii) Slate and Shale

Pebbles of slate and shale are composed of clay, with the result that they are structurally weak and will disintegrate easily when transportation takes place in fast flowing streams. These particles are markedly flattened and somewhat rounded to subangular in outline.

(iii) Porphyry

All the pebbles of quartz porphyry present in the layers of conglomerate are always subrounded to rounded, which indicates that the degree of abrasion amongst these pebbles was moderate.

2. Sphericity

Krumbein and Sloss (1963, p. 106) postulate that the relation of the particle intercepts to each other may be expressed as the sphericity of that particle. This was defined by Wadell in 1932 (Krumbein and Pettijohn, 1938) as:

$$\text{True sphericity} = \frac{\text{Surface area of the particle}}{\text{Surface area of a sphere of the same volume}}$$

The measurement of true sphericity of an irregular particle is not practically feasible, therefore the fundamental equation for measuring sphericity, as defined by Wadell, is:-

$$\text{Optional sphericity} = \frac{\text{Volume of particle}}{\text{Volume of the circumscribing sphere}}$$

The sphericity of a pebble partly controls its behaviour during transportation and deposition. Although sphericity is increased by rounding, it is dependent to a large extend on the original shape of the particle.

Zingg in 1935 classified particles according to their shape (Krumbein and Sloss, 1963, p. 106). He showed that if the ratio of the intermediate to the maximum intercept $(\frac{b}{a})$ of a particle is plotted against the ratio of the shortest to the intermediate intercept $(\frac{c}{b})$, the particle may fall in one of four classes. A diagram of Zingg's classification is shown in Fig. 22 (Krumbein and Sloss, 1963, p. 107).

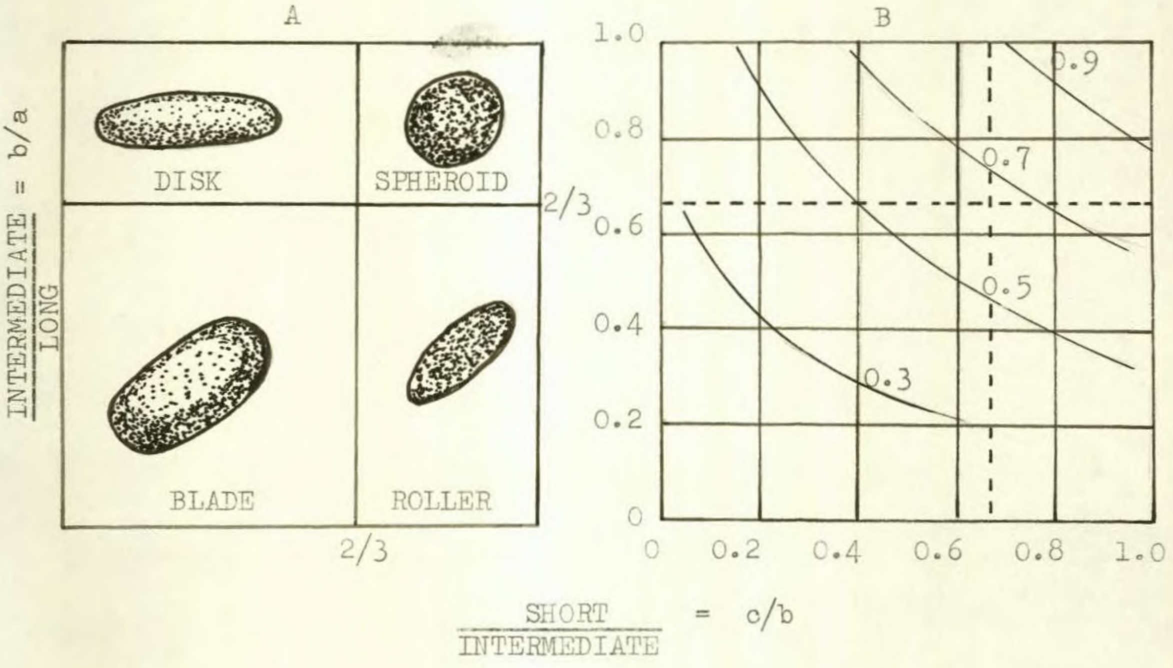


Fig. 22. - Shape classification of pebbles (after Zingg).

A. Classification of pebble shapes, based on ratios of intercepts.

B. Relation of intercept sphericity to Zingg's classification of pebble shapes.

Fig. 22B indicates the relation between sphericity and Zingg's shape indices. The curves represent lines of equal sphericity, and the fact that these lines are curved, indicates that particles of different appearance to the naked eye, may have the same numerical value of sphericity. Comparison of Fig. A and B shows that the 0.5 line sweeps through the disk, blade and roller classes.

Sphericity is important in particle dynamic behaviour and particles with the same sphericity behave in similar manner under given conditions if their diameters and densities are the same. Due to the high degree of lithification, it was not possible to extract complete pebbles underground; hence pebbles could not be studied separately for determining their physical properties. Since the diagram of Zingg is based on the ratios of the three axes and not on their actual lengths, it could also be used to determine the shape of pebbles when the apparent a-, b- and c-axes are known.

The shape of each of the three pebble types, viz. quartz, massive black chert and quartzite, was determined separately. Twelve localities at Western Holdings No. 2 Shaft were selected for measuring the three apparent axes. The results obtained from these measurements, were used for the calculation of both the $\frac{b}{a}$ and $\frac{c}{b}$ ratios.

The measurements were taken on the 33 Haulage East, because the strike of this development end is almost parallel to the direction of the palaeocurrents as determined by the pebble-size distribution and preferred pebble orientation.

The following procedure was used in measuring the three apparent axes:

All measurements were carried out in places where <u>both</u> vertical as well as horizontal exposures of pebbles were found at the same location. The reason being, that either on a vertical or horizontal surface, the pebbles are seen in two dimensions only. By following this procedure, the parameters of the apparent a- and b-axes of the pebbles were obtained in the horizontal exposures (the operator was always dealing with pebbles on the hanging-wall or roof of the haulage), while the apparent a- and c-axes of the pebbles were obtained in vertical exposures.

Indications of pebbles orientated in preferred directions were observed. No indications of pebble imbrication, however, are evident, and it may be assumed that the pebbles were thus deposited with their apparent a- and b-axes parallel to the depositional plane. While only the apparent a- and b-axes of a pebble could be measured in a horizontal plane and the apparent a- and c-axes along a vertical section, the operator had to select pebbles with approximately the same length of the a-axis on both planes. Thus, the length of the b-axis of a pebble of quartz as measured in the horizontal plane was then used to calculate the a:b:c ratios of that pebble with the same a-axis as measured in a vertical plane. The apparent a-, b- and c-axes of only the largest pebbles possible were measured so that the amount of error in measuring the a-axis in two different planes (horizontal and vertical planes) will be negligible small.

The arithmetic mean of the apparent longest, intermediate and shortest axes of the three pebble types (quartz, quartzite and massive black chert) were calculated for each station, and then compared and classified according to Zingg. Since the investigation was restricted to pebbles of approximately the same size (based on the length of the a-axis) this method is believed to yield fairly reliable results.

The ratios between the longest, intermediate and shortest intercepts of each pebble type, as well as the classification of its shape are shown in Tables VI, VII and VIII and in Fig. 23.

From Fig. 23 it is evident that the average shape of the pebbles of quartz is spheroidal, that of massive black chert also spheroidal, though some tend to be disk shaped, while that of quartzite have a tendency to be both spheroidal and disk shaped.

TABLE VI. - The ratios between the longest, intermediate and shortest intercepts of the pebbles of quartz.
(Western Holdings Limited No. 2 Shaft, 33 Haulage West).

Number of station	Bottom view a-axis x b-axis (mm)	Side view a-axis x c-axis (mm)	Ratio a : b : c
Peg A4676	168.3 x 138.0	181.3 x 123.8	1 : 0.76 : 0.68
"	128.7 x 91.4	121.6 x 64.4	1 : 0.75 : 0.53
"	140.5 x 87.6	138.2 x 66.1	1 : 0.63 : 0.47
"	106.3 x 79.1	117.0 x 64.7	1 : 0.72 : 0.58
"	251.5 x 179.3	247.3 x 109.0	1 : 0.71 : 0.44
"	149.4 x 113.7	157.4 x 97.8	1 : 0.75 : 0.65
"	194.7 x 124.2	172.5 x 103.4	1 : 0.72 : 0.60
"	267.4 x 151.0	253.6 x 107.9	1 : 0.59 : 0.42
"	153.5 x 123.6	168.9 x 97.4	1 : 0.73 : 0.58
"	203.7 x 107.5	193.0 x 83.6	1 : 0.56 : 0.43
Peg H379	144.3 x 89.3	138.8 x 74.3	1 : 0.64 : 0.53
"	203.3 x 149.7	205.7 x 123.1	1 : 0.73 : 0.60
"	194.1 x 121.2	170.3 x 109.8	1 : 0.72 : 0.65
"	227.2 x 163.6	219.7 x 128.8	1 : 0.75 : 0.59
"	186.5 x 161.5	193.5 x 109.0	1 : 0.84 : 0.56
"	111.3 x 76.5	114.6 x 58.7	1 : 0.67 : 0.51
"	128.8 x 97.4	130.4 x 79.3	1 : 0.75 : 0.61
"	221.7 x 151.1	217.6 x 129.3	1 : 0.70 : 0.60
"	124.6 x 112.2	127.8 x 93.6	1 : 0.88 : 0.73
"	129.0 x 103.1	144.9 x 87.5	1 : 0.71 : 0.61

TABLE VII. - The ratios between the longest, intermediate and shortest intercepts of the pebbles of quartzite (Western Holdings Limited No. 2 Shaft, 33 Haulage West).

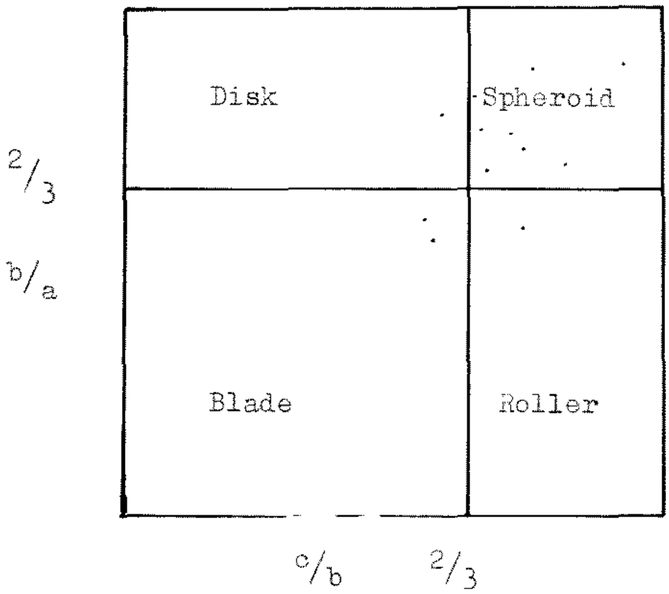
Number of station	Bottom view a-axis x b-axis (mm)	Side view a-axis x c-axis (mm)	Ratio a : b : c
Peg A4676	131.4 x 106.3	136.3 x 86.7	1 : 0.78 : 0.63
"	187.5 x 127.1	172.4 x 98.4	1 : 0.74 : 0.57
"	274.2 x 168.7	259.5 x 104.5	1 : 0.65 : 0.40
"	143.7 x 102.9	151.0 x 74.3	1 : 0.68 : 0.49
"	197.3 x 149.8	189.1 x 113.2	1 : 0.79 : 0.60
"	203.5 x 169.4	211.5 x 121.1	1 : 0.80 : 0.57
"	154.0 x 123.7	161.3 x 94.5	1 : 0.77 : 0.59
"	129.2 x 97.0	140.7 x 78.7	1 : 0.69 : 0.56
"	217.5 x 178.3	204.2 x 114.9	1 : 0.87 : 0.56
"	301.1 x 204.7	284.1 x 164.1	1 : 0.72 : 0.58
"	241.7 x 194.2	223.1 x 109.0	1 : 0.87 : 0.49
"	164.3 x 107.5	158.5 x 89.5	1 : 0.68 : 0.56
"	138.4 x 112.0	143.9 x 84.0	1 : 0.78 : 0.58
Peg H744	179.5 x 124.5	161.6 x 96.0	1 : 0.77 : 0.59
"	102.6 x 89.9	113.1 x 61.5	1 : 0.79 : 0.54
"	157.1 x 101.7	162.2 x 79.3	1 : 0.63 : 0.49
"	123.0 x 97.1	119.5 x 53.2	1 : 0.81 : 0.45
"	218.5 x 153.5	207.1 x 105.5	1 : 0.74 : 0.51
"	269.9 x 179.1	281.7 x 127.1	1 : 0.64 : 0.45
"	129.2 x 86.0	132.1 x 73.7	1 : 0.65 : 0.56

TABLE VIII. - The ratios between the longest, intermediate and shortest intercepts of the pebbles of chert (Western Holdings Limited, No. 2 Shaft, 33 Haulage West).

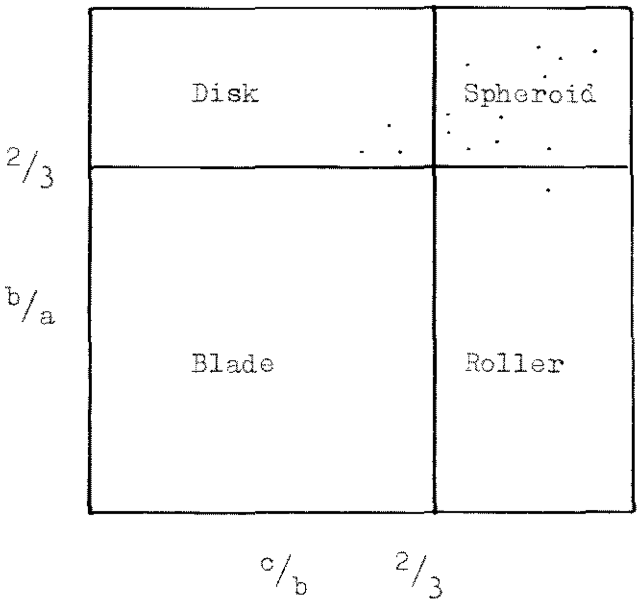
Number of station	Bottom view a-axis x b-axis (mm)	Side view a-axis x c-axis (mm)	Ratio a	:	b	:	c
Peg A4676	102.2 x 80.0	104.4 x 58.0	1	:	0.77	:	0.56
"	138.5 x 98.5	143.7 x 53.7	1	:	0.69	:	0.37
"	97.0 x 62.0	99.1 x 51.2	1	:	0.63	:	0.52
"	156.3 x 123.3	149.2 x 102.1	1	:	0.83	:	0.68
"	112.5 x 79.7	107.3 x 61.6	1	:	0.74	:	0.57
"	84.2 x 61.2	89.5 x 53.5	1	:	0.68	:	0.60
"	123.7 x 109.5	119.7 x 83.4	1	:	0.91	:	0.70
"	141.2 x 112.3	143.1 x 76.7	1	:	0.78	:	0.54
"	107.3 x 83.8	105.2 x 68.9	1	:	0.80	:	0.65
"	113.0 x 98.2	110.0 x 67.3	1	:	0.89	:	0.61
"	161.4 x 130.5	157.5 x 102.0	1	:	0.83	:	0.65
"	143.1 x 114.9	139.8 x 97.0	1	:	0.82	:	0.69
"	131.2 x 102.5	132.5 x 79.2	1	:	0.77	:	0.60
"	91.1 x 73.3	94.5 x 61.5	1	:	0.76	:	0.65
"	101.7 x 89.7	103.0 x 69.0	1	:	0.87	:	0.67
"	112.2 x 84.2	109.5 x 61.3	1	:	0.77	:	0.56
"	139.3 x 102.5	137.3 x 78.5	1	:	0.75	:	0.57
"	170.9 x 134.2	161.7 x 101.2	1	:	0.83	:	0.63
"	119.1 x 103.1	123.2 x 73.1	1	:	0.84	:	0.59
"	105.0 x 74.3	102.1 x 59.4	1	:	0.73	:	0.58

FIG. 23. - Shape classification of the pebbles of quartz, quartzite and chert according to calculated parameters.

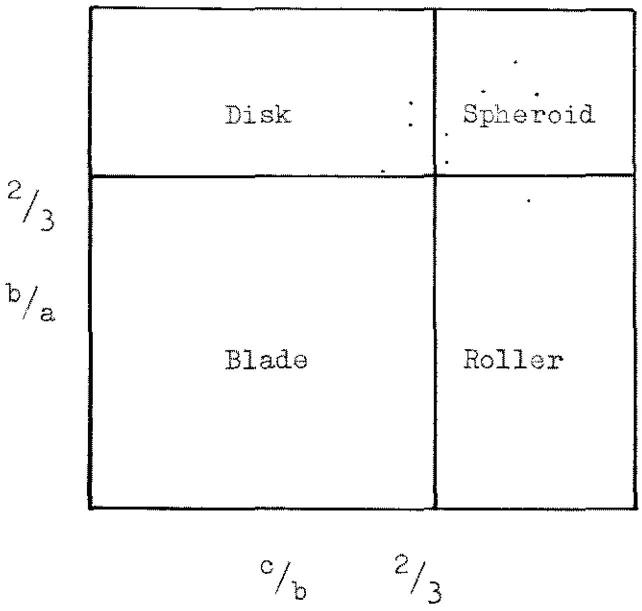
QUARTZ



QUARTZITE



CHERT



F. MORPHOLOGY OF THE PEBBLES

The purpose of the study of pebble morphology is to bring the effect of pebble sizes in connection with pebble shape. This practice, shown by Sneed and Folk (1958), illustrates interesting effects within certain particle size ranges in a sedimentary rock. As Sneed and Folk (1958, p. 115) point out, pebble morphology is affected by numerous variables such as the

(1) initial shape when released from the parent rock;
(2) internal characteristics of the pebbles such as hardness, brittleness, bedding, cleavage, etc.;
(3) original size;
(4) transport distance;
(5) transport agent; and
(6) other obscure factors.

In the study of the shape, roundness, sphericity and orientation of pebbles during underground observations, the author noticed that a fairly high percentage of pebbles of the durable types (quartz and chert) as well as those of quartzite, are cracked or broken. Pebbles which are chipped, are also quite common. In the borehole core examined, broken pebbles were rare, but chipped ones were frequently observed.

The tendency in pebbles to break or chip is controlled by (1) physical property (hardness), (2) energy (stream velocity and mass of the pebble) and (3) mode of transport (traction, saltation and suspension). The many pebbles of chert and quartz that were chipped can be ascribed to the hardness and homogeneity of the rock. The broken pebbles may be the result of processes operating during transportation.

There are three modes of stream transport which have a fundamental effect on particle size and particle behaviour. The first is traction, in which particles roll, slide or tumble along the bottom. During saltation the particles bounce along the stream-bed in a series of short interrupted leaps, while in suspension the particles are swept along entirely free from the stream-bed (Krumbein and Sloss, 1963, p.203). According to Gilbert (Pittman and Ovenshine, 1968), particles being moved by traction have a considerable lower velocity than the stream itself because of frictional loss of energy to the stream-bed. During saltation, the particles moved with a velocity nearly the same as that of the flowing water, while particles in suspension have a velocity almost equal to that of the stream.

Pittman and Ovenshine (1968) have found in the Merced River, U.S.A., that the critical factor in the breakage of pebbles is probably momentum [mass times velocity (MV)] and during the transportation of the pebbles, it can be suggested that the saltating intermediate sized pebbles might have attained the necessary velocity-mass product to break when they collide with stationary boulders in the stream-bed. Breakage of the pebbles occur if the energy of collision exceeds the fracture-strength of the pebble. The energy of collision will be a function of the momentum of the pebble at the moment of impact. Thus, for breakage to occur, there must be a critical value of the mass-velocity product.

Small pebbles that collide with a boulder may not possess sufficient mass, nor momentum, to fracture. A larger pebble, although moving at essentially the same velocity as the smaller pebbles, may fracture because of the larger mass which yields a greater momentum. Pebbles in the intermediate size therefore, will have the greatest momentum during the process of saltation and should be most subject to breakage.

During high flood stages, the movement of small pebbles is by suspension where these particles are swept along free from the stream-bed or stationary boulders. The pebbles in this size range also have not a sufficient mass or momentum to break during collision with each other.

They advanced a hypothesis to explain the relationship between pebble size and breakage of pebbles during transportation. To express this relationship mathematically, they assume:

Collision energy = kmv

where m = mass of the pebble

v = its velocity

and k = a constant of proportionality.

These authors further assume that the fracture strength of the pebble may be expressed in terms of the collision energy required for the fracturing of the pebble. Thus:

Fracture strength = $(kmv)_c$

where $(kmv)_c$ = the collision energy at which rock rupture occurs.

The relationship between collision energy (kmv) and size of the pebbles is illustrated in Fig. 24.

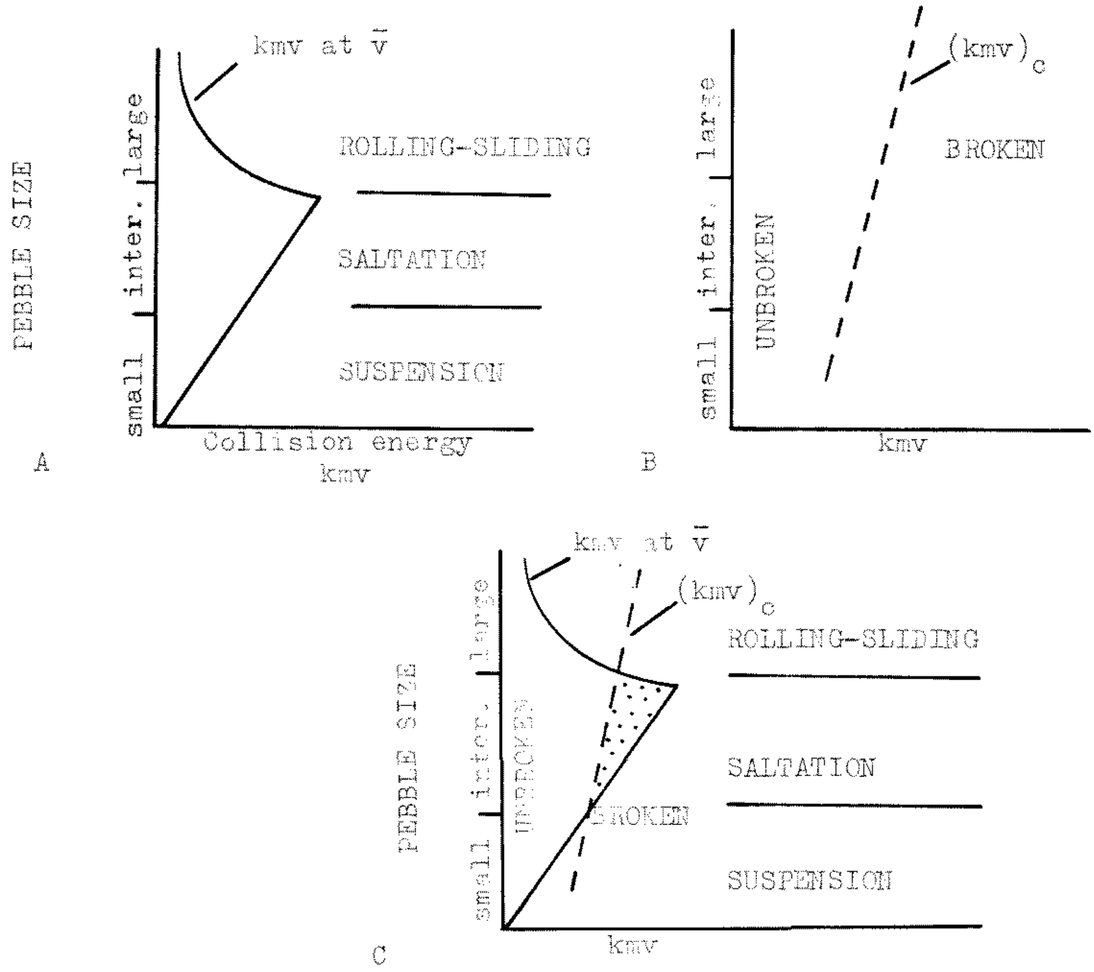


Fig. 24. - Model illustrating the relationship between broken rounds and pebble size (after Pittman and Ovenshine, 1968).

A. Distribution of collision energy (kmv) between moving clasts and stationary boulders as a function of size.

B. Collision energy at which rock rupture occurs, $(kmv)_c$ defines fields of broken and unbroken pebbles.

C. A combination of plots A and B. The distribution of kmv versus clast size at some average stream velocity $(\bar{v})$, exceeds $(kmv)_c$ only for intermediate sized pebbles during saltation. Thus, intermediate sized pebbles break whereas larger and smaller pebbles with comparable physical properties do not break.

If the theory of Pittman and Ovenshine (1968) is valid it can be concluded that the broken pebbles in the conglomerates of the Elsburg Stage could be ascribed to saltation movement in rapid flowing streams. This would apply that deposition took place in a high energy fluvial environment. The large pebbles (≮ 128 mm in diameter) were moved by rolling and sliding along the bottom with the result that very little fracturing took place. The smaller pebbles were mainly transported in suspension and their momentum was not sufficient to affect fracturing, but chipping of the pebbles took place.

G. VARIATION IN THE PERCENTAGE OF CONGLOMERATE

The percentage of conglomerate in the Elsburg Stage shows a definite down-current decrease. On Western Holdings Limited, a progressive change in the conglomerate-quartzite ratio in a south-easterly direction is observed. On the lease area of the Welkom Gold Mining Company a decrease in the ratio towards the north-east is evident (Plan 4). Abnormal conglomerate-quartzite ratios were obtained at several localities, but as this information was gathered from the intersections in surface boreholes, faulting might have influenced the data.

V. CONCLUSIONS

The most important concepts that have emerged from this investigation are:-

1. The transport direction of the sediments of the Elsburg Stage is dominantly from the northwest towards the southeast on Western Holdings Limited, and from the southwest towards the northeast on Welkom Mine east of the Arrarat Fault.
2. A general decrease in the average pebble-size in these directions are observed. These directions are emphasized by the sorting of the conglomerates which also improves in a down-current direction. A study of the preferred orientation of large rod-shaped pebbles indicates that these particles are laid down with their long axes parallel to the palaeocurrent direction. Pebble clusters, a feature previously not recognised in the Witwatersrand System, were also used to indicate the direction of transport.
3. A study of the pebble lithology proved that the presence of non-durable types show a definite decrease in the downstream direction - porphyry, however, proves to be an exception, while the percentage of the durable types (quartz and chert) remains constant.
4. No clear picture of the environment of deposition can be postulated. The sorting which varies between 1.10 and 0.55 can be indicative of the transitional zone between a fluvial and a beach environment. Deposition in a beach environment is also stressed by the tendency of the pebbles to be spheroidal to disk-shape. The presence of pebble clusters and an abundance of broken pebbles point to deposition in fast-flowing streams. The distribution pattern of the conglomerates also favours deposition in a fluvial environment. It seems most likely that deposition took place on an alluvial fan bordering an inland lake or sea and that some resorting by wave action took place.

5. A very important factor brought out by this investigation is the strike-slip movement along the Arrarat Fault. Various factors indicate that horizontal movement in the order of 6 000 m along the Arrarat Fault took place. The eastern part of the lease area of Welkom Mine originally lay next to Freddies Consolidated Mines where it formed part of the northern flank of a delta. Evidence in this connection is borne out by the palaeocurrent directions, sorting of the conglomerates, pebble lithology, percentage of conglomerate and the distribution of gold values in the Basal Reef.

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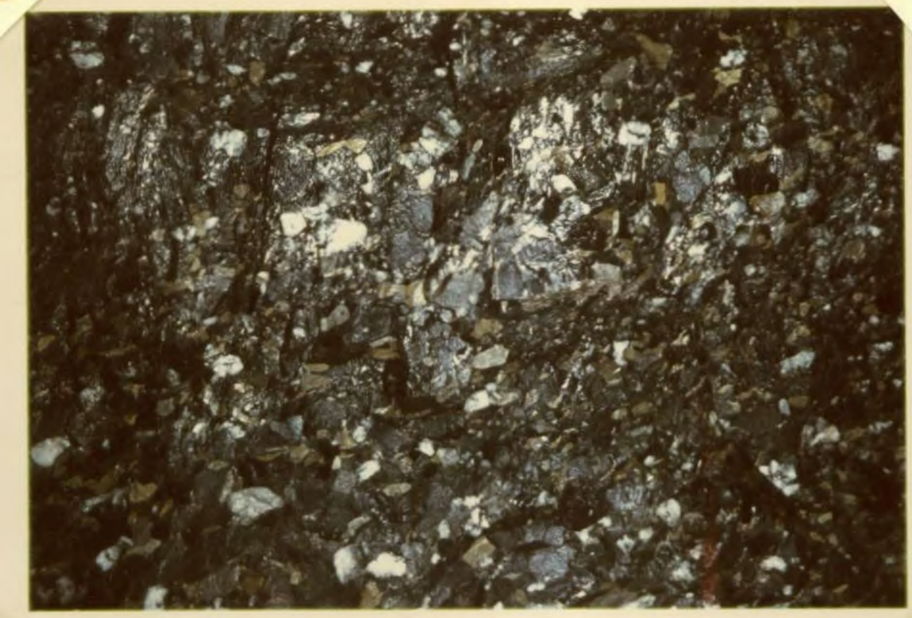

Plate I. - Specimen of typical Elsburg conglomerate (long axes of pebbles = 50 mm).

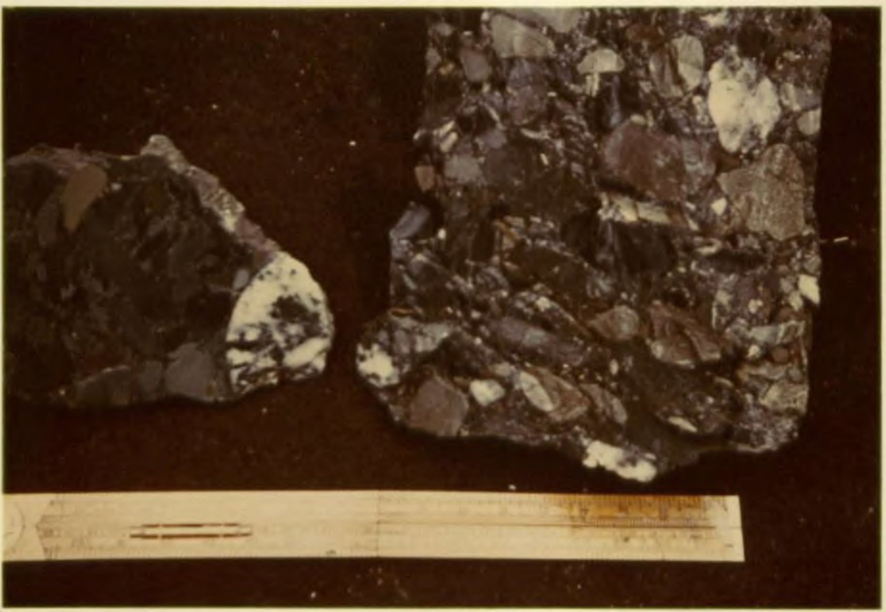

Plate II. - Specimens of Elsburg conglomerate with one sample showing the greenish tinge due to metamorphism.

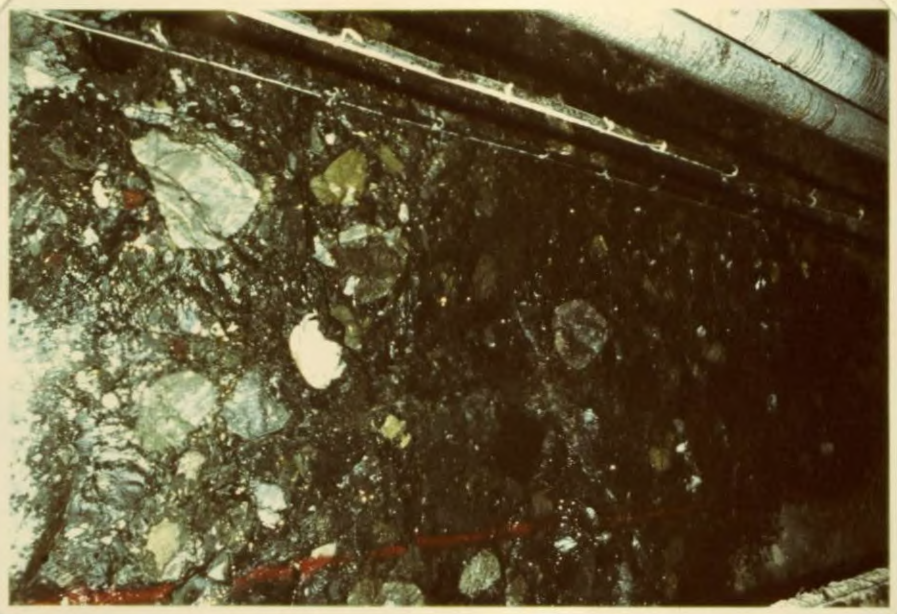

Plate III. - Greenish coloured conglomerate near the top of Zone VS 1.

Plate IV. - Specimen showing pebbles of red jasper present in the conglomerates.

Plate V. - Method applied in the determination of pebble sizes on a borehole core.

Plate VI. - Specimens of borehole core with large pebbles showing cuts parallel to the apparent c-axis.

Plate VII. - Large pebbles of milky quartz orientated with their long axes parallel to the bedding-plane.

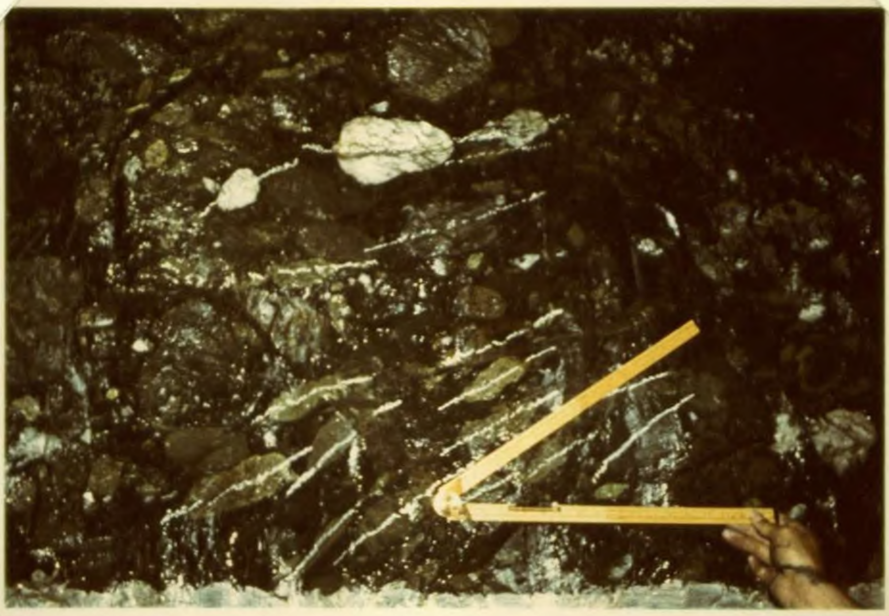

Plate VIII. - Pebbles deposited with their a-axes parallel to the bedding-plane.

Plate IX. - Specimen showing large pebbles of quartz and quartzite.

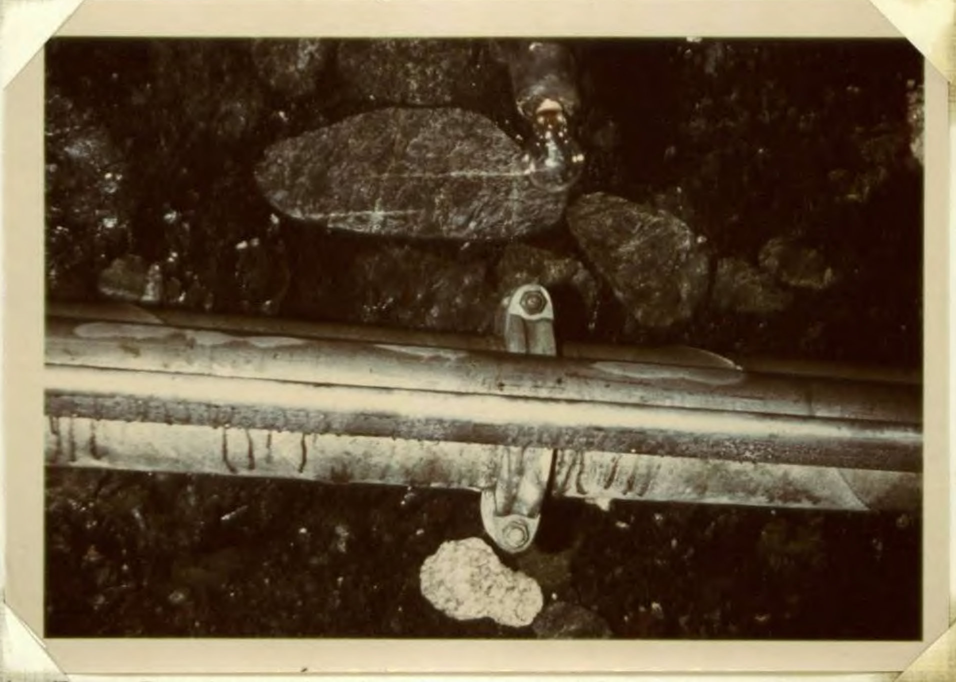

Plate X. - Specimen showing large pebbles of quartzite in comparison to other pebble types.

Plate XI. - Preferred orientation of rod-shaped pebbles (bottom view).

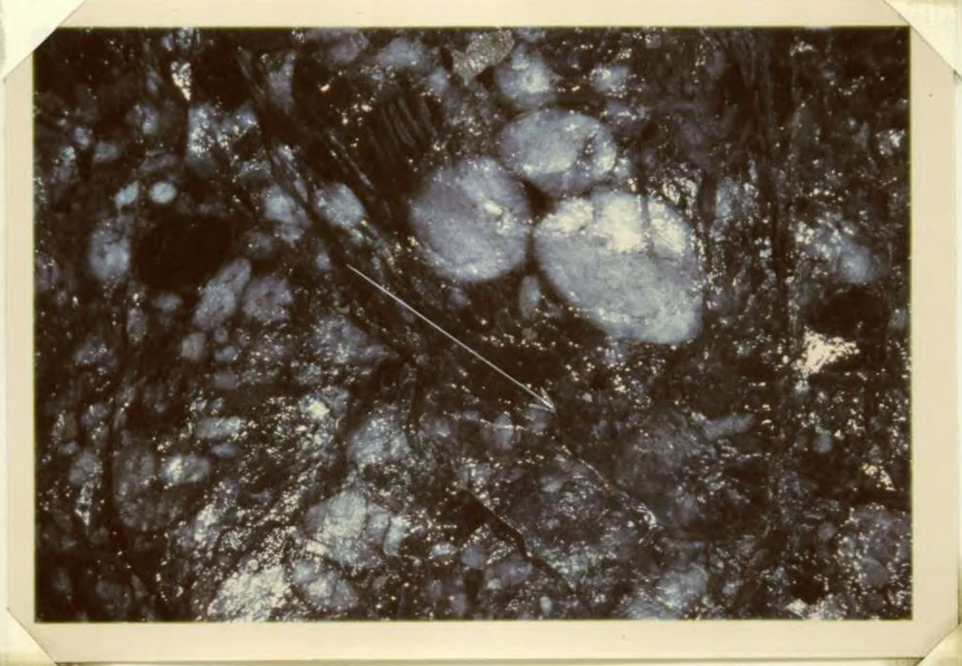

Plate XII. - Example of a pebble cluster with the arrow indicating the direction of the current.

ADDENDUM

PROGRAMS FOR I.B.M. COMPUTER

A. RUNNING OF THE PROGRAM

B. REGRESSION LINES

1. Outline of Program
2. Input to the Program
3. Processing
4. Calculations
5. Output
6. Interpretation of Results
7. Running the Program.

C. PEBBLE-SIZE DISTRIBUTION

1. Outline
2. Input
3. Calculations
4. Output
5. Interpretation of Results
6. Running the Program.

A. RUNNING OF THE PROGRAM

1. The program is coded in a computer language called FORTRAN. This code is read off punched cards by the machine and coded into FORTRAN. The calculations are then performed.

2. The data are punched onto cards, which are read by the machine. The computer then uses the above program, does the calculations and prints the results.

3. The computer has a printer which produces many hundred lines per second - 132 characters per line can be printed.

Running Times

Regression lines : 25 seconds per 120 sets of data.
Pebble sizes : 18 seconds for each complete calculation.

B. REGRESSION LINES

1. Outline of Program

The program has been written to read in a large number of ordered pairs (e.g. X and Y co-ordinates) and to fit, by the method of least squares, the two most probable straight lines, that could be used to predict one element of a pair, given the other. These lines are known as the regression lines

The correlation coefficient, showing the degree of correlation between the two lines, is also calculated.

This program has been written with geological data specifically in mind, but may be adapted, with relatively few changes, to any application requiring regression line techniques.

2. Input to the Program

In order to use the program, the user must submit the data on punched cards. This data must be punched in a specific format.

Six different classes of pebbles will be dealt with, viz. quartz, shale, quartzite, black chert, porphyry and slate. For each pebble, the X co-ordinate is the length of the longest axis (in mm) perpendicular to the bedding-plane and the $^a/_c$ ratio is the Y co-ordinate.

A large number of pebbles in each group is dealt with. Each class is processed separately.

3. Processing

If the above sets of points were plotted on graph paper, a scatter diagram will be obtained. The program will fit a straight line by least squares to the dots on the scatter diagram.

The equations of two regression lines are calculated; firstly, to minimize the sum of the squares of the distances parallel to the Y-axis, from the dots to the line, and so to obtain the regression line of Y on X; the second line will be just the opposite, that of X on Y.

The user data consist of a large number of X and Y co-ordinates, which, if plotted onto squared paper, would yield a scatter diagram. Such a collection of data will be referred to as a "set" of data.

As many sets of data as required may be submitted to the computer. Each set is then punched onto cards which are fed into the computer.

4. Calculations

For each data set, the program goes through the following steps.

(a) Reads in all data cards pertaining to the data set in question.

(b) Counts up the total number of ordered pairs in the set, i.e. the total number of points that would be plotted on the scatter diagram.

(c) Performs the following totalling operations:

Total of all X co-ordinates

Total of all Y co-ordinates

Total of the squares of each X co-ordinate

Total of the squares of each Y co-ordinate

Total of the product of each X co-ordinate with its corresponding Y co-ordinate.

(d) Two regression lines equations are calculated and printed out in the form:

$Y = bx+a$ and $X = b'y+a'$

(e) b is calculated from the formula:

$$b = \frac{N\sum_{i}^{N} x_iy_i - \sum_{i}^{N} x_i \sum y_i}{N\sum_{i}^{N} x^2_i - (\sum_{i}^{N} x_i)^2}$$

Where x_i = the X co-ordinate

y_i = the Y co-ordinate

N = total number of pairs of co-ordinates.

(f) $a = (\sum_{i}^{N} y_i - b \sum_{i}^{N} x_i) \div N$

(g) Inserting these values for a and b into $y = bx + a$ will yield the equation of the regression line of Y on X.

(h) b' is calculated from the formula:

$$b' = \frac{N \sum_{i}^{N} x_iy_i - \sum_{i}^{N} x_i \sum_{i}^{N} y_i}{N \sum_{i}^{N} y_i^2 - (\sum_{i}^{N} y_i)^2}$$

and

$$a' = (\sum_{i}^{N} x_i - b' \sum_{i}^{N} y_i) \div N$$

(i) Inserting these values for a a' and b' into $y = b'x + a'$ will yield the equation of the regression line of X on Y.

(j) Pearson's correlation coefficient is calculated to give a measure to the degree of correlation between the two lines. (R = correlation coefficient)

$$R = \frac{N\sum x\,y - \sum x \sum y}{(N\sum x^2 - (\sum x)^2)^{\frac{1}{2}} \quad (k)}$$

$$k = (N\sum y^2 - (\sum y)^2)^{\frac{1}{2}}$$

5. Output

Two reports are printed out by the computer.

(a) Input Listing

A list of pairs of X and Y co-ordinates, as read from the punched cards is printed out on this report. Six pairs of co-ordinates appear on each line. Decimal points are punched in their correct places. This enables the users to check that the correct information has been punched on the cards, and is being used in the calculations.

It is suggested that the user check this input data thoroughly before making actual use of the final results.

The Input Listing Report is headed with the description, as punched on Card 1.

The column under which the X co-ordinates are printed, is headed "C-AXIS", and the column under which the Y co-ordinates are printed, is headed "PEB AREA".

Six pairs of co-ordinates are printed per line, and there are 50 lines per page.

Since each line corresponds to a punch card, any incorrect data can readily be corrected, and the cards can, then be resubmitted.

(b) Regression Results

This report gives the following results:

1. The regression line of Y on X.
2. The regression line of X on Y.
3. The correlation coefficient.

The report is headed with the description as punched on Card 1.

The first result is the regression line of Y on X, printed in the form $y = a + bx$. Then the regression line of X on Y, printed in the form $x = a' + b'y$ appears.

Pearson's correlation coefficient, rounded to three decimal places, is given to measure the degree of correlation between the two straight line equations.

The number of points (i.e. pairs of X and Y co-ordinates) is printed at the end of the report. This also serves as a check on the correctness of the data used.

6. Interpretation of Results

(a) Regression Lines

The first regression line equation, i.e. the line of Y on X, will be used for estimating the value of Y, given X. Thus, with regard to this geological problem, this equation would be used to predict the corresponding PEB. AREA, given the length of the C-AXIS.

The second line, that of X on Y, would be used for predicting the value of X, given Y.

With a fairly large sample, the probability of the predicted value being accurate, becomes very high (approximately 95%).

(b) Correlation Coefficient

The accuracy of the predictions made from the regression lines is bound up with the value of the correlation coefficient.

The quantity, called the "standard error of estimate" may be calculated to give the error to be expected in estimating Y for a given value of X.

When the correlation coefficient is zero, the "error estimate" becomes maximum, and thus, knowledge of X is of no value in predicting Y. As the modulus of the coefficient increases, i.e. as the coefficient approaches +1 or -1, the "error estimate" decreases.

For completeness, the deviation of the "standard error estimate" is given below. This formula may be used with the computer to estimate the errors likely to occur from use of the regression lines.

$di = (y_i - Y_i)$

From the scatter diagram above, the following definition can be made:

The average concentration of the points about the regression line is measured by $(\sum d_i^{\ 2})/N$ where d_i is the difference between an observed Y_i and a calculated Y_i from the regression line. This variance of the Y values about the regression line can be denoted by Sey^2.

Therefore $NSey^2 = \sum d_i^{\ 2}$ (from definition)

$$= \sum (y_i - Y_i)^2$$

Before continuing, the theory of regression lines must be reconsidered.

If a large number of X values are available, the average value may be denoted by $\bar{x}$ and the <u>variance of X values</u> defined as:

$$N\ S_x^{\ 2} = \sum (x - \bar{x})^2$$

$\bar{x}$ is merely the arithmetic average

viz. $\bar{x} = (\sum x) / N$

Similarly:

$$N\ S\ y^2 = \sum (y - \bar{y})^2 \quad \text{and}$$

$$\bar{y} = (\sum y) / N$$

However, in the scatter diagram, pairs of X and Y values are present, and therefore the covariance of X and Y may be defined as:

$$N\ S\ x\ y = \sum (x - \bar{x}) \quad (y - \bar{y})$$

Multiply out $= \sum (xy - \bar{x}y - \bar{x}y + \overline{xy})$

Simplify $= \sum xy - \dfrac{\sum}{N} x \sum y - \sum x \dfrac{\sum y}{N} + \dfrac{\sum xy}{N}$

$$= \sum xy - \frac{\sum x}{N} \sum y - \sum x \frac{\sum y}{N} + \frac{\sum x \sum y}{N}$$

$$= \sum xy - \frac{\sum x \sum y}{N} \qquad \text{also}$$

$$N\ S_x^{\ 2} = \sum x^2 - 2\ x\bar{x} + \sum \overline{xx}$$

[multiply out (2)]

$$= \sum x^2 - 2 \sum x \frac{\sum x}{N} + \sum x \frac{\sum x}{N}$$

$$= \sum x^2 - (\sum x)^2 / N$$

Now refer back to the equations in 3(e) for b. It will be seen that

$$b = \frac{S\,xy}{S\,x^2}$$

and in section 3(f) an equation is given for a, viz.

$$a = \left(\sum y - b \sum x \right) / N$$

$$= \frac{\sum y}{N} - b \frac{\sum x}{N}$$

$$a = \bar{y} - b\,\bar{x}$$

Therefore the equation of the regression line becomes: $y = a + b\,x$

$$= y = \left(\bar{y} - \frac{S\,xy}{S\,x^2}\,\bar{x}\right) + \frac{S\,xy}{S\,x^2}\,x$$

i.e. $y - \bar{y} = \frac{S\,xy}{S\,x^2}(x - \bar{x})$

Now return to equation (1)

From the above

$$y = \bar{y} + b\,(x - \bar{x})$$

Substituting in $N\,S\,ey^2 = \sum (y_i - Y_i)^2$

$$= \sum (y_i - \bar{y} - b\,(x_i - \bar{x})\,)^2$$

$$= \sum (y_i - \bar{y})^2 + b^2 \sum (x_i - \bar{x})^2 - 2\,b \sum (x_i - \bar{x})\,(y_i - \bar{y})$$

$$= N\,sy^2 = b^2\,N\,S_x^2 - 2\,b\,N\,S\,x\,y$$

from (3) $b^2\,S_x^2 = b\,S\,xy.$

Further, it may be proved that the correlation coefficient $r = \frac{S\,xy}{Sx\,Sy}$

$$\therefore \quad r^2\,S_y^2 = \frac{S\,xy^2}{Sx^2} = b\,S\,xy$$

i.e. $b^2\,S_x^2 = b\,S\,xy = r^2\,S\,y^2$

Substitute in (4)

$$S\,ey^2 = S\,y^2 + r^2\,Sy^2 - 2\,r^2\,Sy^2$$

$$= Sy^2 - r^2\,Sy^2$$

$$= Sy^2\,(1 - r^2)$$

and this may be used to calculate the standard error of estimate.

7. Running the Program

The program will be run off the object deck. The user must supply the data cards, sorted into correct order.

The following Job Control Cards will be used to run the program.

b̸ denotes a blank. $ denotes a dollar sign.

```
*b̸$$JOBGEOLI
*b̸$$PRTD
//b̸JOBb̸GEOL1
//b̸OPTIONb̸LINK
 INCLUDE
 Object Deck
/*
//b̸EXECb̸LNKEDT
//b̸EXEC
 Data Cards
/*
/&
*b̸$$EOJ
```

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft
33 West Haulage Peg: A.4676

Co-ordinates : X + 30590.50 Y + 35249.17 ft.
X + 9323.98 Y + 10743.95 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Quartz	Spherical	81.3	52.6	3,356
Quartz	Spherical	71.0	48.8	2,719
Shale	Elongated	63.2	48.1	2,385
Quartzite	Spherical	82.8	37.4	2,430
Black Chert	Oval	71.2	43.7	2,442
Quartz	Oval	123.6	91.4	8,866
Quartzite	Spherical	92.1	62.0	4,482
Quartzite	Oval	93.6	48.3	3,548
Quartz	Oval	116.3	92.6	8,453
Quartzite	Oval	134.4	128.6	13,567
Quartzite	Oval	91.0	73.7	5,264
Quartz	Spherical	133.0	98.4	10,372
Quartzite	Oval	87.3	71.6	4,906
Quartzite	Oval	138.4	86.1	9,354
Black Chert	Oval	117.0	64.7	5,941
Quartz	Spherical	247.0	183.6	35,598
Quartz	Spherical	87.1	61.7	4,218
Quartz	Spherical	97.4	69.0	5,275
Quartzite	Spherical	153.8	107.0	12,851
Quartzite	Oval	148.3	111.0	12,921
Quartz	Spherical	109.8	92.1	7,938
Quartzite	Spherical	131.0	58.3	5,993
Quartz	Spherical	183.9	138.6	20,008
Shale	Elongated	105.0	36.3	2,991
Porphyry	Spherical	103.1	89.9	7,267
Quartz	Spherical	172.3	131.1	17,731
Quartz	Spherical	118.2	112.3	10,419
Quartz	Spherical	147.3	98.6	11,400
Quartzite	Spherical	141.0	87.2	9,651
Quartzite	Spherical	116.3	98.7	9,010
Shale	Elongated	107.3	43.2	3,638
Quartz	Spherical	186.3	121.3	17,739
Quartz	Spherical	97.4	64.1	4,900
Quartz	Spherical	283.3	141.0	31,356
Quartz	Spherical	157.3	105.7	13,050
Quartz	Spherical	102.1	85.4	6,844
Quartzite	Oval	75.0	49.3	2,902

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft
33 West Haulage Peg: A 4676
Co-ordinates : X + 30590.50 Y + 35249.17 ft.
X + 9323.98 Y + 10743.95 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	AXES		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}$A x $\frac{1}{2}$C x 3.14 (mm^2)
Black Chert	Oval	86.1	41.0	2,771
Black Chert	Oval	149.3	97.2	11,391
Black Chert	Oval	97.1	33.5	2,552
Banded Chert	Rectangular	58.2	47.1	2,151
Black Chert	Spherical	72.1	46.3	2,620
Quartz	Spherical	148.3	105.6	12,293
Black Chert	Spherical	76.0	45.0	2,684
Shale	Oval	56.3	31.0	1,369
Shale	Rectangular	55.6	45.3	1,976
Quartz	Oval	163.9	93.7	12,055
Quartzite	Oval	137.2	57.0	6,138
Quartz	Spherical	158.1	108.6	13,477
Black Chert	Spherical	91.7	49.5	3,563
Quartzite	Spherical	126.3	83.5	8,278
Quartzite	Oval	174.5	64.9	8,890
Quartz	Spherical	193.2	103.6	15,711
Shale	Elongated	157.9	74.5	9,231
Black Chert	Oval	87.5	43.4	2,980
Porphyry	Oval	139.2	63.8	6,970
Quartz	Spherical	164.0	118.3	15,191
Quartzite	Oval	111.3	56.0	4,879
Quartz	Spherical	138.8	79.7	8,683
Quartzite	Spherical	361.8	225.3	63,987
Quartzite	Oval	158.6	34.3	4,269
Quartz	Oval	181.2	64.9	9,094
Quartz	Spherical	153.0	103.2	12,394
Black Chert	Oval	59.4	41.0	1,911
Quartzite	Spherical	84.1	52.1	3,439
Shale	Oval	107.8	38.6	3,266
Quartzite	Spherical	134.4	112.4	11,858
Black Chert	Spherical	97.2	76.7	5,852
Black Chert	Spherical	139.6	124.0	13,588
Quartzite	Spherical	387.2	193.4	58,783
Quartz	Spherical	184.5	113.2	16,394
Porphyry	Spherical	152.6	75.2	9,007
Quartzite	Spherical	103.2	91.5	7,411
Quartz	Spherical	79.0	42.6	2,641

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft
33 West Haulage Reg: A 4676
Co-ordinates : X + 30590.50 Y + 35249.17 ft.
X + 9323.98 Y + 10743.95 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}$A x $\frac{1}{2}$C x 3.14 (mm^2)
Quartz	Oval	143.3	67.1	7,547
Quartzite	Oval	204.6	143.7	21,998
Shale	Oval	104.5	51.3	4,207
Black Chert	Oval	119.7	36.2	3,401
Quartz	Spherical	143.1	108.8	12,221
Black Chert	Oval	119.0	46.5	4,343
Quartz	Spherical	98.9	71.7	5,566
Quartz	Spherical	79.3	38.1	2,364
Quartzite	Oval	293.6	161.4	37,603
Porphyry	Spherical	271.3	193.8	41,258
Quartz	Spherical	121.6	116.0	11,072
Shale	Oval	107.0	59.4	4,988
Slate	Oval	113.2	56.1	4,984
Quartzite	Oval	86.2	36.7	2,482
Quartz	Spherical	98.3	75.3	5,809
Quartzite	Spherical	153.0	128.1	15,385
Black Chert	Spherical	78.2	49.9	3,063
Quartz	Oval	152.6	87.5	10,481
Quartz	Oval	97.5	31.3	2,395
Shale	Spherical	172.1	121.5	16,414
Quartzite	Spherical	269.3	237.1	48,139
Quartz	Spherical	241.7	103.6	19,656
Quartzite	Spherical	98.2	79.0	6,089
Quartz	Spherical	79.9	41.2	2,583
Quartzite	Oval	163.1	114.3	14,633
Quartz	Spherical	97.3	68.0	5,193
Quartzite	Spherical	149.0	91.5	10,701
Shale	Oval	104.4	63.7	5,220
Black Chert	Spherical	67.4	42.9	2,340
Quartzite	Spherical	171.3	127.1	17,091
Quartz	Oval	123.3	94.3	9,127
Quartz	Oval	113.0	67.2	5,960
Porphyry	Spherical	151.5	113.6	13,509
Slate	Spherical	104.3	79.8	6,531
Quartzite	Spherical	343.1	213.7	57,556
Black Chert	Spherical	93.6	54.9	4,033

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft
33 West Haulage Peg: A 3574
Co-ordinates : X + 30618.56 Y + 34188.15 ft.
X + 9332.54 Y + 10420.55 m

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	AXES		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Quartz	Spherical	102.3	57.8	4,640
Black Chert	Spherical	191.2	151.3	22,713
Shale	Spherical	73.1	31.0	1,778
Black Chert	Spherical	196.3	143.7	22,143
Quartzite	Spherical	195.8	156.8	24,100
Quartzite	Spherical	102.4	68.3	5,489
Quartz	Spherical	146.3	132.7	15,239
Quartzite	Spherical	191.6	166.3	25,012
Banded Chert	Oval	123.4	68.3	6,615
Porphyry	Spherical	94.1	78.4	5,790
Quartzite	Spherical	94.3	68.7	5,085
Black Chert	Oval	188.6	93.8	13,886
Quartzite	Spherical	91.4	58.6	4,204
Quartz	Spherical	80.6	34.9	2,207
Black Chert	Oval	162.4	81.7	10,415
Quartzite	Oval	126.0	69.3	6,853
Quartz	Spherical	174.9	128.4	17,628
Quartz	Spherical	191.6	114.8	17,266
Slate	Spherical	122.8	97.9	9,437
Quartzite	Spherical	184.3	126.7	18,329
Shale	Spherical	79.0	55.3	3,428
Slate	Spherical	92.6	43.8	3,183
Quartz	Spherical	153.1	139.6	16,777
Black Chert	Oval	181.3	51.2	7,286
Quartzite	Spherical	163.7	120.4	15,471
Quartz	Spherical	168.9	154.3	20,459
Shale	Elongated	110.3	37.9	3,281
Black Chert	Oval	138.1	71.4	7,740
Quartzite	Oval	118.3	91.7	8,515
Quartzite	Oval	121.7	89.5	8,620
Quartz	Oval	102.0	56.3	4,507
Porphyry	Spherical	92.4	67.8	4,917
Quartzite	Spherical	91.1	72.9	5,213
Quartzite	Oval	119.3	84.6	7,922
Black Chert	Oval	105.7	49.6	4,114
Quartzite	Spherical	86.8	71.2	4,851
Quartzite	Spherical	166.3	128.4	16,761

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft
33 West Haulage Peg: A 3574
Co-ordinates : X + 30618.56 Y + 34188.15 ft.
X + 9332.54 Y + 10420.55 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A \times \frac{1}{2}C \times 3.14$ (mm^2)
Shale	Spherical	170.8	121.4	16,276
Black Chert	Oval	169.1	114.8	15,238
Black Chert	Oval	103.0	54.7	4,422
Shale	Oval	76.3	45.9	2,749
Black Chert	Spherical	183.9	149.3	21,552
Quartzite	Oval	120.1	62.8	5,920
Quartz	Oval	107.4	47.9	4,038
Shale	Spherical	168.3	112.5	14,862
Black Chert	Oval	163.1	49.3	63,114
Porphyry	Spherical	83.7	39.6	2,601
Quartzite	Oval	114.3	52.8	4,737
Slate	Spherical	71.2	43.1	2,408
Quartz	Oval	105.3	56.1	4,636
Porphyry	Spherical	87.4	68.3	4,685
Black Chert	Oval	121.4	49.1	4,678
Quartzite	Spherical	94.6	43.7	3,245
Quartzite	Oval	117.2	38.6	3,550
Shale	Oval	107.4	56.2	4,737
Chert	Oval	98.3	46.7	3,603
Quartzite	Oval	107.2	42.9	3,609
Quartz	Oval	92.4	56.8	4,119
Quartz	Spherical	79.3	51.2	3,187
Quartzite	Oval	84.8	34.2	2,276
Porphyry	Oval	111.8	58.9	5,169
Black Chert	Oval	161.0	79.0	9,982
Porphyry	Spherical	75.3	41.0	2,423
Quartz	Spherical	97.5	64.2	4,913
Quartzite	Oval	121.3	56.2	5,351
Chert	Oval	93.4	48.3	3,541
Quartz	Oval	117.2	46.8	4,304
Quartzite	Oval	107.3	49.2	4,144
Quartzite	Oval	102.7	57.8	4,659
Shale	Spherical	91.2	59.5	4,261
Quartzite	Oval	102.3	47.8	3,838
Quartzite	Spherical	89.2	53.4	3,669
Quartzite	Oval	112.6	47.8	4,233
Shale	Elongated	131.0	71.4	7,339

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft
33 West Haulage Peg: A 3574
Co-ordinates : X + 30618.56 Y + 34188.15 ft.
X + 9332.54 Y + 10420.55 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Shale	Oval	131.3	59.7	6,148
Quartzite	Oval	196.2	87.4	13,460
Black Chert	Oval	127.4	59.8	5,980
Quartzite	Spherical	99.1	64.7	5,032
Black Chert	Oval	93.7	38.6	2,838
Quartz	Oval	103.2	59.6	4,827
Banded Chert	Spherical	58.7	32.9	1,515
Black Chert	Spherical	147.2	103.5	11,959
Porphyry	Spherical	73.1	32.7	18,761
Shale	Oval	105.2	58.6	4,837
Quartz	Spherical	148.2	129.4	15,053
Quartzite	Spherical	187.2	163.4	24,011
Quartzite	Oval	123.9	62.0	6,029
Shale	Spherical	94.4	62.7	4,645
Quartzite	Oval	180.4	97.8	13,849
Quartz	Spherical	91.3	52.9	3,790
Black Chert	Oval	156.2	69.6	8,533
Slate	Oval	128.2	93.4	9,398
Quartzite	Spherical	168.4	126.4	16,708
Quartz	Spherical	153.2	127.1	15,284
Black Chert	Oval	182.4	59.6	8,533
Quartzite	Oval	162.8	119.4	15,258
Quartz	Spherical	169.2	151.3	20,095
Shale	Spherical	110.5	49.2	4,267
Black Chert	Oval	135.6	91.2	11,139
Quartzite	Spherical	128.1	96.8	9,734
Quartzite	Oval	126.4	89.8	8,909
Quartz	Oval	102.0	64.4	5,155
Porphyry	Spherical	96.8	59.6	4,528
Quartzite	Spherical	91.8	76.7	5,527
Quartzite	Oval	120.3	86.4	8,158
Quartz	Oval	106.8	46.4	3,889
Black Chert	Oval	163.3	79.1	10,137
Quartzite	Spherical	162.1	123.7	15,740
Shale	Spherical	173.8	123.4	16,835
Black Chert	Oval	169.3	102.1	13,568

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft
33 West Haulage Peg A.3787
Co-ordinates : X + 30,541.20 Y + 34,637.17 ft.
X + 9308.96 Y + 10557.41 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A \times \frac{1}{2}C \times 3.14$ (mm^2)
Quartz	Spherical	151.2	126.8	15,050
Quartzite	Oval	80.6	40.1	2,522
Shale	Spherical	161.1	128.4	16,233
Quartzite	Oval	95.2	51.6	3,840
Quartzite	Spherical	136.5	114.9	12,311
Shale	Spherical	129.1	56.3	5,685
Shale	Spherical	142.6	121.8	13,555
Quartz	Spherical	83.7	56.1	3,697
Quartzite	Oval	141.8	58.2	6,378
Quartzite	Spherical	163.3	137.1	17,568
Black Chert	Oval	109.6	51.3	4,255
Quartz	Oval	172.4	126.5	17,119
Quartz	Oval	105.1	37.3	3,077
Quartz	Spherical	144.3	128.7	14,491
Quartz	Spherical	66.1	41.9	21,344
Quartzite	Oval	161.3	127.1	16,093
Quartz	Oval	104.8	52.9	4,269
Shale	Oval	92.8	31.4	2,779
Black Chert	Spherical	149.7	130.0	15,275
Quartzite	Spherical	160.5	123.8	15,597
Shale	Oval	117.4	64.9	5,958
Shale	Oval	102.3	58.6	4,695
Quartzite	Spherical	149.2	121.0	12,047
Quartz	Spherical	158.1	122.3	15,190
Quartz	Oval	141.6	97.3	11,436
Shale	Oval	139.4	57.0	6,311
Quartz	Spherical	146.2	117.3	13,461
Quartz	Spherical	178.1	132.4	17,517
Black Chert	Spherical	143.2	136.5	15,343
Quartz	Oval	152.4	91.6	10,934
Quartz	Spherical	154.3	137.2	16,617
Black Chert	Oval	109.9	58.4	4,881
Quartz	Spherical	123.3	102.1	9,517
Quartzite	Spherical	158.0	126.7	15,813
Black Chert	Oval	126.1	59.7	5,990
Black Chert	Oval	146.3	62.3	7,151

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 West Haulage	Peg: A 3787
Co-ordinates :	X + 30541.20	Y + 34637.17 ft.
	X + 9308.96	Y + 10557.41 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}$A x $\frac{1}{2}$C x 3.14 (mm^2)
Quartz	Spherical	187.1	149.2	21,913
Quartz	Oval	148.1	68.3	7,940
Quartz	Spherical	123.7	101.4	9,859
Quartz	Oval	102.8	59.3	5,607
Quartz	Oval	176.1	69.2	9,201
Quartz	Spherical	151.7	122.6	14,599
Quartzite	Oval	102.8	49.1	3,705
Quartz	Oval	118.4	94.6	8,724
Black Chert	Spherical	166.9	135.7	17,778
Black Chert	Oval	132.6	85.4	9,905
Shale	Oval	91.3	45.7	3,509
Porphyry	Spherical	93.8	61.2	4,467
Quartzite	Spherical	63.9	49.4	2,448
Quartz	Spherical	153.0	130.3	15,648
Quartzite	Spherical	172.8	116.1	15,748
Porphyry	Spherical	148.1	132.6	15,446
Black Chert	Spherical	169.5	137.1	18,241
Quartzite	Oval	126.1	97.4	9,550
Quartzite	Oval	118.4	66.7	6,140
Shale	Spherical	164.8	132.6	17,395
Porphyry	Spherical	149.6	119.1	13,986
Slate	Oval	137.1	61.0	6,249
Quartzite	Oval	158.6	41.4	4,641
Quartz	Oval	106.4	39.7	3,368
Quartz	Spherical	146.2	118.9	13,645
Black Chert	Spherical	184.3	112.4	16,276
Black Chert	Oval	119.7	47.3	4,410
Shale	Oval	206.3	141.2	21,912
Porphyry	Spherical	98.1	64.4	5,017
Black Chert	Oval	114.0	69.5	6,147
Quartz	Spherical	151.7	142.9	17,016
Shale	Oval	104.3	82.7	6,682
Quartzite	Spherical	162.3	121.0	15,364
Quartzite	Oval	101.1	53.7	4,260
Quartz	Oval	144.2	48.6	5,440
Quartz	Spherical	163.2	129.7	16,623

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft.
33 West Haulage Peg: A 3787

Co-ordinates : X + 30541.20 Y + 34637.17 ft.
X + 9308.96 Y + 10557.41 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Porphyry	Spherical	98.3	51.8	4,807
Slate	Spherical	86.4	56.1	3,910
Quartz	Spherical	112.7	101.3	9,200
Quartz	Spherical	143.6	106.3	12,016
Black Chert	Oval	113.7	43.2	3,821
Quartzite	Oval	119.4	59.9	5,611
Quartz	Spherical	99.1	88.7	7,010
Quartzite	Oval	108.3	64.3	5,482
Quartzite	Oval	129.2	56.4	5,093
Black Chert	Spherical	99.8	71.4	5,609
Quartzite	Oval	140.0	59.6	6,377
Quartzite	Spherical	163.8	129.4	17,064

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 East Haulage	Peg: F 9144 + 500'
Co-ordinates :	X + 30457.11	Y + 33162.96 ft.
	X + 9283.33	Y + 10108.07 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	AXES		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm²)
Quartz	Spherical	80.6	43.8	2,771
Shale	Spherical	47.1	31.0	1,146
Quartzite	Spherical	65.2	32.6	1,668
Quartzite	Spherical	90.1	51.8	3,663
Quartz	Spherical	95.3	40.7	3,044
Quartz	Spherical	85.2	33.6	2,246
Porphyry	Spherical	75.0	62.1	3,655
Quartzite	Spherical	88.2	43.7	3,025
Quartz	Spherical	102.3	68.9	5,532
Shale	Spherical	91.1	51.4	3,675
Quartzite	Spherical	72.8	51.9	2,965
Black Chert	Oval	78.1	30.3	1,857
Black Chert	Oval	127.4	56.3	5,630
Slate	Oval	79.1	32.4	2,011
Quartzite	Oval	101.1	53.8	4,269
Shale	Spherical	180.2	102.3	14,470
Black Chert	Oval	123.6	78.1	7,577
Black Chert	Oval	142.0	91.1	10,154
Shale	Spherical	112.2	41.1	3,621
Quartzite	Oval	107.1	43.9	3,696
Quartzite	Spherical	81.0	61.0	3,878
Quartz	Oval	95.6	39.4	2,956
Quartzite	Oval	97.0	59.3	4,515
Black Chert	Oval	69.1	33.8	1,832
Quartzite	Oval	100.2	47.0	3,696
Quartz	Spherical	78.3	59.6	3,662
Quartz	Oval	83.1	42.7	2,785
Black Chert	Oval	114.3	89.8	8,057
Shale	Oval	91.2	51.1	3,658
Quartz	Oval	107.0	34.3	2,880
Quartz	Oval	88.0	40.0	2,763
Quartzite	Spherical	71.2	51.0	2,850
Black Chert	Oval	115.5	53.8	4,879
Porphyry	Oval	131.0	35.7	3,648
Shale	Oval	82.3	36.9	2,383
Quartz	Spherical	87.1	62.3	4,259
Black Chert	Oval	102.7	37.1	2,990

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft.
33 East Haulage Peg: F 9144 + 500'

Co-ordinates : X + 30457.11 Y + 33162.96 ft.
X + 9283.33 Y + 10108.07 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Quartzite	Oval	96.9	31.0	2,357
Shale	Spherical	68.5	41.7	2,241
Black Chert	Oval	112.8	30.4	2,691
Black Chert	Oval	97.8	32.3	2,479
Quartz	Oval	107.2	58.8	4,947
Quartzite	Spherical	78.6	58.2	3,467
Black Chert	Oval	104.4	41.3	3,384
Porphyry	Spherical	69.3	36.0	1,957
Quartzite	Spherical	97.1	52.7	4,016
Quartzite	Spherical	93.4	54.2	3,973
Black Chert	Oval	80.8	36.8	2,333
Quartz	Spherical	94.9	52.4	3,903
Quartz	Oval	121.2	24.7	2,349
Shale	Oval	92.7	30.2	2,197
Quartz	Oval	76.0	48.9	2,917
Quartzite	Oval	126.3	42.0	4,163
Quartzite	Oval	148.5	34.1	4,079
Quartz	Spherical	68.0	54.5	2,909
Black Chert	Oval	97.7	29.4	2,254
Quartzite	Oval	86.9	62.2	4,242
Quartzite	Oval	102.1	26.7	2,139
Shale	Spherical	69.5	51.1	2,787
Quartzite	Oval	80.0	36.5	2,292
Quartz	Oval	103.2	49.1	3,977
Slate	Oval	126.3	37.1	3,677
Shale	Oval	90.7	43.0	3,061
Quartzite	Spherical	94.6	59.3	4,432
Quartz	Spherical	84.5	40.7	2,699
Black Chert	Oval	79.2	47.2	2,934
Quartzite	Oval	104.8	45.9	3,775
Porphyry	Oval	91.7	31.1	2,238
Quartz	Spherical	87.3	63.7	4,365
Quartzite	Oval	126.9	59.5	5,926
Black Chert	Oval	114.1	39.0	3,492
Quartzite	Oval	84.0	31.3	2,063
Quartzite	Oval	104.0	30.7	2,505
Quartz	Spherical	78.4	46.2	2,843
Quartzite	Spherical	92.6	54.8	3,983

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 East Haulage	Peg: F 9144 + 500'
Co-ordinates :	X + 30457.11	Y + 33162.96 ft.
	X + 9283.33	Y + 10108.07 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Black Chert	Oval	89.4	33.6	2,357
Quartzite	Oval	102.2	64.9	5,199
Shale	Spherical	107.3	43.3	3,646
Quartz	Oval	121.9	46.7	4,468
Black Chert	Oval	84.2	38.1	2,518
Black Chert	Oval	97.3	27.0	2,062
Quartzite	Oval	110.7	35.3	3,066
Quartz	Spherical	84.4	51.9	3,438
Shale	Oval	97.7	26.8	2,055
Black Chert	Oval	101.3	23.6	1,876
Quartzite	Spherical	89.9	56.2	3,965
Quartzite	Spherical	76.5	62.5	3,753
Quartzite	Oval	103.4	51.0	4,139
Quartzite	Spherical	92.0	57.7	4,166
Shale	Oval	112.7	45.9	4,060
Black Chert	Oval	97.1	34.2	2,606
Porphyry	Oval	109.2	32.7	2,802
Quartzite	Spherical	88.7	62.3	4,337
Quartz	Spherical	76.3	38.7	2,317
Black Chert	Oval	195.0	39.9	6,107
Quartz	Spherical	63.4	42.8	3,131
Quartzite	Oval	113.7	46.0	4,105
Quartz	Spherical	97.3	51.8	4,055
Quartzite	Spherical	88.8	56.2	3,917
Slate	Spherical	67.1	46.7	2,459
Quartzite	Oval	121.0	24.3	2,307
Quartzite	Spherical	89.7	52.4	3,689
Slate	Spherical	78.2	61.7	3,786
Black Chert	Oval	123.9	56.9	5,533
Black Chert	Oval	171.3	93.2	12,532
Quartz	Oval	79.6	36.1	2,255
Quartz	Oval	108.6	43.0	3,665
Black Chert	Oval	114.1	49.3	4,414
Shale	Oval	84.5	36.0	2,387
Porphyry	Oval	107.0	39.5	3,317
Quartzite	Spherical	79.0	64.9	4,024
Quartzite	Oval	117.3	36.2	3,333

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 East Haulage	Peg: F.9117
Co-ordinates :	X + 30457.17	Y + 32926.42 ft.
	X + 9283.34	Y + 10035.97 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A \times \frac{1}{2}C \times 3.14$ (mm^2)
Quartz	Spherical	217.4	130.0	22,185
Porphyry	Oval	143.6	95.4	10,753
Quartzite	Oval	127.2	93.3	9,315
Quartzite	Spherical	170.8	123.7	16,584
Quartzite	Oval	153.0	72.6	8,718
Quartzite	Spherical	93.3	56.6	4,144
Quartzite	Oval	135.5	93.2	9,912
Black Chert	Spherical	89.9	51.0	3,598
Quartzite	Oval	197.2	86.9	13,451
Quartzite	Oval	114.1	88.0	7,881
Black Chert	Spherical	144.1	81.1	9,175
Black Chert	Spherical	110.5	83.5	7,242
Shale	Spherical	87.4	54.3	3,724
Shale	Oval	103.3	56.5	4,581
Quartzite	Oval	134.2	91.7	9,660
Porphyry	Oval	173.6	82.1	11,187
Shale	Oval	112.5	67.7	5,978
Quartzite	Oval	219.9	114.2	19,712
Quartz	Oval	124.8	87.9	8,610
Porphyry	Oval	190.1	83.3	12,430
Black Chert	Oval	103.4	48.6	3,944
Quartz	Spherical	92.2	51.2	3,705
Quartzite	Oval	102.5	56.3	4,529
Quartz	Oval	88.3	38.8	2,689
Slate	Oval	82.8	49.1	3,191
Quartzite	Oval	134.2	52.2	5,498
Quartzite	Oval	196.5	41.9	6,462
Black Chert	Oval	92.9	38.9	2,836
Quartz	Spherical	87.0	52.4	3,578
Porphyry	Oval	107.4	38.3	3,228
Quartzite	Oval	94.7	43.8	3,255
Quartzite	Oval	116.3	54.5	4,975
Slate	Oval	85.8	56.2	3,784
Quartzite	Oval	72.5	36.6	2,082
Shale	Oval	101.2	39.7	3,153
Quartz	Spherical	74.7	60.9	3,570
Black Chert	Oval	97.9	42.1	3,234

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft.
33 East Haulage Peg: F.9117
Co-ordinates : X + 30457.17 Y + 32926.42 ft.
X + 9283.34 Y + 10035.97 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A \times \frac{1}{2}C \times 3.14$ (mm^2)
Black Chert	Oval	107.1	38.4	3,227
Quartzite	Oval	142.0	63.4	7,066
Black Chert	Oval	93.3	48.2	3,530
Black Chert	Oval	114.8	51.4	4,631
Shale	Spherical	69.2	30.6	1,661
Quartzite	Spherical	98.0	31.1	2,391
Quartz	Oval	119.4	36.3	3,402
Quartzite	Spherical	73.6	68.5	3,957
Porphyry	Oval	102.9	42.2	3,408
Shale	Elongated	93.2	35.9	2,625
Black Chert	Oval	192.1	43.1	6,499
Quartz	Oval	102.5	49.7	3,998
Quartz	Oval	84.3	36.3	2,402
Black Chert	Oval	172.8	48.5	6,578
Black Chert	Oval	123.7	23.4	2,271
Slate	Oval	121.2	52.7	5,012
Quartzite	Spherical	89.4	61.2	4,294
Quartzite	Oval	121.3	24.1	2,294
Slate	Oval	132.0	46.5	4,818
Quartzite	Oval	180.5	51.3	7,268
Quartz	Oval	93.2	59.9	4,381
Black Chert	Oval	112.0	41.8	3,674
Quartz	Spherical	92.6	66.1	4,804
Black Chert	Oval	102.5	32.5	2,614
Quartz	Oval	176.5	38.0	5,264
Slate	Spherical	88.3	53.0	3,673
Porphyry	Oval	106.4	39.4	3,290
Quartz	Spherical	99.3	46.5	3,624
Porphyry	Oval	114.9	42.3	3,815
Black Chert	Spherical	93.2	51.8	3,789
Porphyry	Oval	107.4	51.9	4,373
Quartzite	Spherical	76.1	68.0	4,061
Quartz	Spherical	89.0	61.3	4,282
Quartzite	Oval	121.9	47.1	4,506
Black Chert	Oval	109.8	39.5	3,404
Slate	Spherical	89.0	51.4	3,590
Slate	Oval	100.0	36.3	2,849

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft.
33 East Haulage Peg: F.9117
Co-ordinates : X + 30457.17 Y + 32926.42 ft.
X + 9283.34 Y + 10035.97 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2).
Black Chert	Oval	123.4	29.7	2,876
Quartz	Spherical	98.5	45.2	3,549
Quartzite	Spherical	141.2	112.1	12,424
Quartzite	Oval	92.5	36.1	2,621
Slate	Oval	98.6	49.2	3,808
Black Chert	Spherical	117.0	73.7	6,768
Porphyry	Spherical	148.3	91.3	10,628
Quartz	Oval	279.9	137.9	30,299
Quartzite	Spherical	98.1	60.0	4,620
Black Chert	Spherical	183.4	119.3	17,175
Quartz	Oval	159.5	56.0	7,011
Black Chert	Oval	130.6	89.5	10,578
Shale	Elongated	189.1	53.5	7,941
Quartz	Oval	127.4	73.3	7,330
Quartzite	Oval	183.5	62.2	8,959
Quartzite	Oval	104.7	78.9	4,847
Shale	Oval	112.0	44.0	3,868
Slate	Spherical	98.9	58.3	4,525
Quartz	Spherical	94.0	83.5	6,161
Porphyry	Oval	195.1	57.2	8,759
Black Chert	Oval	124.6	63.0	6,159
Black Chert	Spherical	96.7	62.5	4,743
Quartzite	Spherical	112.2	71.7	6,317
Shale	Oval	123.2	69.7	6,740
Quartzite	Oval	114.5	88.3	7,936
Shale	Spherical	105.0	92.8	7,649
Quartz	Oval	123.3	72.6	7,026
Porphyry	Oval	195.9	61.5	9,456
Black Chert	Spherical	120.8	81.0	7,680
Quartz	Spherical	150.4	96.3	11,391
Quartzite	Oval	193.2	104.6	15,863

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 East Haulage	Peg: H. 379
Co-ordinates :	X + 30194.04	Y + 32305.60 ft.
	X + 9203.14	Y + 9846.75 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A \times \frac{1}{2}C \times 3.14$ (mm^2)
Quartz	Spherical	170.4	125.3	16,760
Shale	Spherical	130.7	98.7	10,126
Quartzite	Spherical	205.2	140.2	22,583
Quartzite	Spherical	219.9	163.9	28,290
Quartzite	Oval	190.0	88.8	13,242
Quartz	Oval	150.3	80.1	9,450
Shale	Oval	140.8	73.5	8,123
Quartz	Spherical	145.2	120.4	13,723
Quartzite	Spherical	168.5	98.2	12,988
Quartzite	Spherical	114.7	80.6	7,256
Quartz	Spherical	132.3	90.5	9,398
Quartzite	Spherical	121.2	100.9	9,599
Porphyry	Spherical	193.5	131.2	19,928
Quartzite	Spherical	150.8	105.0	12,429
Quartz	Spherical	120.4	84.3	7,967
Black Chert	Oval	195.3	65.7	9,979
Porphyry	Oval	123.2	78.8	15,470
Quartz	Spherical	105.5	69.5	5,755
Shale	Spherical	114.9	83.4	7,521
Quartzite	Oval	123.7	56.6	5,496
Shale	Spherical	112.2	97.5	8,587
Quartzite	Spherical	93.8	56.3	4,144
Black Chert	Oval	107.5	44.2	3,729
Black Chert	Oval	195.7	71.9	11,044
Porphyry	Spherical	94.0	52.1	3,844
Slate	Spherical	98.2	55.5	4,278
Shale	Spherical	130.3	73.4	7,507
Quartzite	Spherical	104.8	71.6	5,889
Quartzite	Oval	183.5	73.6	10,601
Quartz	Spherical	128.2	71.2	7,164
Shale	Spherical	88.7	53.9	3,752
Black Chert	Oval	193.1	66.0	10,004
Quartz	Oval	107.7	48.2	4,074
Black Chert	Spherical	184.6	120.7	17,490
Quartzite	Spherical	92.0	61.0	4,405
Quartz	Oval	281.1	140.3	30,958
Porphyry	Oval	153.8	99.8	12,048

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 East Haulage	Peg: H. 379
Co-ordinates :	X + 30194.04	Y + 32305.60 ft.
	X + 9203.14	Y + 9846.75 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A \times \frac{1}{2}C \times 3.14$ (mm^2)
Black Chert	Oval	101.4	85.2	6,781
Slate	Spherical	95.2	41.6	3,108
Black Chert	Oval	121.3	41.4	3,941
Shale	Oval	106.4	49.4	4,167
Quartzite	Spherical	271.2	136.2	29,019
Quartz	Oval	144.0	72.4	8,183
Quartz	Spherical	81.5	51.8	3,313
Quartzite	Spherical	107.7	89.4	7,558
Porphyry	Spherical	151.1	73.1	8,670
Quartz	Spherical	183.3	104.3	15,007
Quartzite	Spherical	281.2	181.3	40,020
Black Chert	Spherical	137.5	118.7	12,811
Black Chert	Spherical	91.9	72.2	5,208
Quartzite	Spherical	134.1	104.8	11,031
Shale	Oval	107.1	46.0	3,866
Quartzite	Spherical	92.5	51.4	3,731
Black Chert	Spherical	53.2	49.4	2,062
Quartz	Spherical	161.0	107.6	13,598
Quartz	Spherical	182.4	66.3	9,493
Quartz	Oval	158.3	38.1	4,734
Quartzite	Spherical	361.7	217.7	61,798
Quartzite	Spherical	133.2	72.4	7,569
Quartz	Spherical	138.1	81.3	8,813
Quartzite	Oval	101.3	52.8	4,198
Quartz	Spherical	163.7	108.9	13,993
Quartz	Oval	138.0	61.1	1,618
Black Chert	Spherical	89.1	46.0	3,216
Quartzite	Oval	140.0	71.4	7,803
Shale	Oval	187.3	109.0	16,025
Quartzite	Oval	122.9	61.0	5,884
Black Chert	Oval	131.2	86.3	8,887
Black Chert	Oval	92.6	48.9	3,554
Quartzite	Spherical	151.5	112.0	13,319
Quartz	Oval	139.0	52.1	5,684
Porphyry	Oval	168.0	97.5	12,866
Quartzite	Spherical	55.4	43.5	1,891
Porphyry	Spherical	58.7	36.2	1,667

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Western Holdings Ltd. - No. 2 Shaft.
33 East Haulage Peg: E. 379

Co-ordinates : X + 30194.04 Y + 32305.60 ft.
X + 9203.14 Y + 9846.75 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm²)
Slate	Spherical	72.1	48.3	2,733
Quartz	Spherical	143.2	106.9	12,016
Slate	Spherical	70.3	44.0	2,428
Slate	Spherical	56.8	39.6	1,765
Quartzite	Oval	123.3	92.7	8,971
Quartzite	Oval	146.0	91.0	10,429
Quartz	Oval	151.0	87.3	10,347
Quartz	Spherical	112.3	110.3	9,723
Quartz	Spherical	171.2	127.5	17,134
Porphyry	Spherical	106.0	93.2	7,755
Porphyry	Oval	108.5	38.5	3,278
Shale	Spherical	181.7	132.8	18,941
Quartzite	Spherical	123.6	64.3	6,238
Quartzite	Oval	119.5	59.8	5,609
Slate	Oval	137.5	89.3	9,638
Quartzite	Spherical	326.5	120.6	30,909
Slate	Oval	110.5	56.5	4,899
Quartz	Spherical	99.6	89.0	6,958
Quartzite	Oval	153.3	53.2	6,401
Black Chert	Spherical	179.0	131.9	18,533
Quartzite	Oval	158.5	69.1	8,597
Black Chert	Oval	92.2	42.4	3,068
Quartzite	Oval	84.7	59.5	3,955
Slate	Oval	108.3	64.6	5,491
Shale	Spherical	119.8	112.6	10,588
Quartz	Oval	123.9	87.5	8,510
Porphyry	Spherical	270.1	156.0	33,075
Porphyry	Oval	298.1	146.2	34,211
Quartzite	Oval	78.3	39.5	2,427
Quartz	Spherical	99.8	72.0	5,640
Quartzite	Oval	117.2	59.0	5,427

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd. - No. 2 Shaft.	
	33 East Haulage	Peg: N. 744
Co-ordinates:	X + 29847.07	Y + 31886.07 ft.
	X + 9097.39	Y + 9718.87 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}$A x $\frac{1}{2}$C x 3.14 (mm^2)
Quartzite	Oval	218.8	160.0	27,475
Quartz	Oval	240.4	112.5	21,230
Quartzite	Oval	173.7	143.4	19,420
Black Chert	Oval	128.0	98.3	9,876
Quartz	Spherical	191.2	173.8	26,085
Black Chert	Spherical	117.8	69.9	6,463
Quartz	Spherical	205.4	93.2	15,027
Maroon Slate	Spherical	193.1	152.4	23,100
Quartzite	Spherical	216.0	184.6	31,300
Porphyry	Spherical	107.5	63.3	5,341
Maroon Slate	Spherical	219.2	58.0	9,971
Quartz	Spherical	284.9	168.5	32,922
Black Chert	Spherical	159.8	103.5	12,986
Shale	Spherical	169.3	64.2	8,532
Quartzite	Spherical	209.5	147.0	24,174
Quartz	Spherical	327.6	69.1	17,770
Black Chert	Spherical	96.4	52.1	3,942
Slate	Spherical	135.3	79.4	8,430
Maroon Slate	Spherical	109.0	81.5	6,973
Maroon Slate	Spherical	124.1	93.2	9,079
Quartzite	Spherical	154.9	150.6	18,317
Black Chert	Spherical	402.6	123.3	35,296
Quartz	Spherical	373.8	104.8	30,751
Quartzite	Spherical	281.0	160.5	35,403
Slate	Spherical	171.3	87.2	11,725
Quartzite	Spherical	190.5	93.7	13,870
Quartzite	Spherical	400.2	214.3	67,323
Porphyry	Spherical	191.5	92.2	14,016
Quartz	Spherical	174.5	161.5	22,122
Quartzite	Spherical	211.0	84.0	13,913
Slate	Spherical	134.0	63.9	6,721
Quartzite	Spherical	193.3	151.5	22,987
Quartzite	Spherical	128.2	46.6	4,689
Quartz	Spherical	310.8	72.7	17,737
Maroon Slate	Spherical	268.1	100.8	21,046
Quartzite	Spherical	194.0	167.9	25,569
Shale	Spherical	155.1	146.6	17,846

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 East Haulage	Peg: H. 744
Co-ordinates :	X + 29847.07	Y + 31886.07 ft.
	X + 9097.39	Y + 9718.87 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Quartz	Spherical	271.6	52.1	15,197
Quartz	Spherical	214.6	56.4	9,500
Quartzite	Spherical	116.3	92.8	8,471
Black Chert	Spherical	134.4	128.6	13,567
Quartz	Spherical	138.3	86.1	9,346
Quartz	Oval	117.4	64.7	5,962
Maroon Slate	Oval	247.3	183.6	35,642
Maroon Slate	Oval	253.6	107.1	21,320
Porphyry	Oval	149.6	97.3	11,426
Black Chert	Oval	102.3	58.6	4,695
Quartzite	Spherical	157.3	102.6	12,668
Maroon Chert	Oval	286.1	163.2	36,652
Quartzite	Spherical	180.4	114.3	16,185
Quartzite	Oval	107.3	56.2	4,733
Porphyry	Oval	144.2	59.2	4,581
Maroon Slate	Oval	218.4	142.7	24,464
Porphyry	Spherical	183.3	143.9	20,705
Quartzite	Spherical	109.2	89.0	7,628
Quartz	Spherical	136.8	74.2	8,064
Quartz	Spherical	164.0	118.4	15,242
Quartzite	Spherical	119.6	103.2	9,688
Quartzite	Oval	176.3	64.9	8,981
Black Chert	Oval	139.4	57.0	6,302
Quartz	Spherical	148.3	107.2	12,465
Shale	Spherical	161.4	141.7	17,951
Quartzite	Spherical	184.0	113.2	16,349
Slate	Spherical	136.4	110.5	11,831
Quartzite	Oval	181.2	63.9	9,086
Porphyry	Spherical	153.0	121.1	14,544
Quartzite	Oval	152.3	81.4	9,731
Slate	Oval	144.6	103.0	11,692
Maroon Slate	Spherical	123.3	90.2	8,729
Quartzite	Spherical	147.2	98.1	11,335
Quartz	Oval	244.0	103.2	19,766
Slate	Oval	152.4	91.4	10,934
Porphyry	Spherical	193.2	102.6	15,813
Quartzite	Spherical	204.7	114.2	18,350

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Western Holdings Ltd.	- No. 2 Shaft.
	33 East Haulage	Peg: H. 744
Co-ordinates :	X + 29847.07	Y + 31886.07 ft.
	X + 9097.39	Y + 9718.87 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A$ x $\frac{1}{2}C$ x 3.14 (mm^2)
Quartz	Spherical	276.3	121.3	26,309
Quartzite	Spherical	303.1	210.2	50,013
Porphyry	Oval	191.2	91.4	13,717
Slate	Oval	122.5	121.4	11,676
Black Chert	Oval	191.1	126.3	18,945
Quartzite	Oval	142.0	89.3	9,953
Quartz	Spherical	133.4	77.2	8,083
Slate	Spherical	126.0	89.3	8,832
Quartzite	Oval	102.6	59.3	4,775
Shale	Spherical	181.4	103.0	14,666
Quartz	Oval	147.0	94.3	10,865
Quartzite	Spherical	164.3	112.8	14,548
Maroon Slate	Oval	110.2	61.3	5,302
Porphyry	Oval	269.0	126.2	26,648
Quartzite	Spherical	134.0	101.6	10,686
Quartzite	Oval	153.6	52.4	6,317
Slate	Oval	118.0	49.0	4,538
Quartzite	Oval	191.7	100.5	15,123
Black Chert	Oval	163.0	112.6	14,407
Quartz	Oval	152.3	93.2	11,142
Quartzite	Spherical	171.0	123.7	16,604

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Welkom G.M. Co. Ltd. - No. 3 Shaft.
30 Level Connection to J.V.S.

Co-ordinates : X + 28329.87 Y + 22133.56 ft.
X + 8634.94 Y + 6746.31 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm²)
Black Chert	Oval	90.1	41.3	2,920
Black Chert	Spherical	33.6	32.5	1,406
Quartzite	Oval	74.0	34.3	1,876
Quartzite	Oval	74.4	48.6	2,837
Shale	Spherical	42.0	34.8	1,133
Black Chert	Oval	110.1	55.6	4,806
Shale	Oval	73.7	43.0	2,488
Chert	Oval	103.3	47.5	3,852
Shale	Oval	74.8	39.9	2,342
Quartz	Spherical	118.2	50.3	4,667
Quartzite	Oval	85.2	50.0	3,352
Chert	Oval	92.8	38.9	2,834
Shale	Oval	77.4	49.0	2,978
Quartzite	Oval	106.1	35.8	2,981
Shale	Oval	107.2	67.3	5,662
Shale	Oval	113.7	61.0	5,446
Black Chert	Oval	77.5	47.8	2,907
Black Chert	Oval	78.5	42.6	2,590
Shale	Oval	86.4	31.4	2,130
Black Chert	Spherical	76.1	54.0	3,227
Shale	Oval	85.3	47.2	3,160
Black Chert	Oval	72.8	40.4	2,308
Quartzite	Spherical	87.6	49.8	3,391
Black Chert	Spherical	60.9	45.0	2,151
Black Chert	Oval	102.4	31.4	2,521
Black Chert	Spherical	89.1	57.7	4,037
Black Chert	Oval	95.5	51.2	3,848
Black Chert	Oval	85.0	43.8	2,920
Quartzite	Oval	60.8	33.2	1,584
Quartz	Spherical	109.8	58.5	5,044
Black Chert	Spherical	37.2	30.0	876
Black Chert	Oval	80.1	38.6	2,679
Quartzite	Oval	118.4	61.2	5,686
Black Chert	Spherical	79.9	63.0	3,950
Shale	Oval	80.8	30.8	1,953
Shale	Oval	87.1	47.4	3,239
Shale	Spherical	54.0	30.5	1,292

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Welkom G.M. Co. Ltd. - No. 3 Shaft. 30 Level Connection to J.V.S.	
Co-ordinates :	X + 28329.87	Y + 22133.56 ft.
	X + 8634.94	Y + 6746.31 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Black Chert	Spherical	83.9	59.9	3,943
Black Chert	Oval	92.8	33.6	2,448
Quartzite	Spherical	41.7	34.6	1,131
Black Chert	Oval	92.8	53.7	3,862
Shale	Rectangular	58.4	38.7	1,774
Shale	Rectangular	95.4	40.3	2,995
Quartzite	Oval	115.0	61.2	5,524
Black Chert	Oval	109.2	55.5	4,713
Black Chert	Oval	97.7	51.5	3,910
Black Chert	Oval	82.0	38.0	2,446
Shale	Spherical	79.6	44.0	2,749
Shale	Spherical	118.4	69.9	6,415
Shale	Oval	60.5	32.5	1,526
Black Chert	Spherical	76.9	53.1	3,154
Black Chert	Spherical	76.8	51.2	3,074
Shale	Spherical	69.3	41.3	2,230
Shale	Spherical	89.5	47.7	2,565
Black Chert	Oval	120.7	60.4	5,686
Shale	Spherical	79.7	51.0	3,189
Black Chert	Oval	98.1	47.6	4,006
Shale	Spherical	55.3	45.5	1,975
Quartzite	Oval	90.0	33.0	2,332
Shale	Oval	87.1	30.3	2,051
Black Chert	Spherical	81.6	37.7	2,370
Black Chert	Oval	106.3	49.2	4,089
Shale	Oval	78.5	38.9	2,396
Quartzite	Oval	128.9	56.3	5,666
Shale	Oval	130.1	69.9	7,079
Black Chert	Oval	92.2	42.7	3,038
Black Chert	Oval	113.0	63.3	5,589
Quartz	Rectangular	98.1	38.5	2,927
Black Chert	Spherical	60.1	30.0	1,416
Shale	Rectangular	59.1	41.7	1,902
Black Chert	Oval	147.5	57.2	6,614
Quartzite	Oval	90.9	49.4	3,495
Black Chert	Spherical	82.3	33.0	2,129
Quartz	Rectangular	48.7	44.0	1,681

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Welkom G.M. Co. Ltd. -- No. 3 Shaft 30 Level Connection to J.V.S.	
Co-ordinates :	X + 28329.87	Y + 22133.56 ft.
	X + 8634.94	Y + 6746.31 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	$\frac{1}{2}A \times \frac{1}{2}C \times 3.14$ (mm^2)
Black Chert	Spherical	62.1	48.3	2,343
Quartzite	Oval	104.8	52.3	4,275
Shale	Spherical	66.0	41.0	2,122
Quartzite	Oval	92.6	39.4	2,833
Quartzite	Oval	105.1	37.3	3,077
Quartzite	Oval	81.4	31.7	2,026
Black Chert	Oval	95.1	38.1	2,844
Shale	Spherical	82.0	62.1	3,954
Black Chert	Oval	97.0	30.4	2,314
Black Chert	Oval	96.1	41.0	3,092
Black Chert	Spherical	101.1	53.7	4,260
Quartzite	Oval	102.7	46.0	3,706
Quartzite	Oval	93.9	32.3	2,381
Black Chert	Oval	141.8	59.8	6,654
Black Chert	Oval	144.2	48.0	5,432
Quartzite	Oval	99.9	34.2	2,681
Shale	Spherical	54.4	31.2	1,332
Quartzite	Spherical	53.9	34.1	1,891
Black Chert	Oval	88.4	39.5	2,742
Black Chert	Oval	146.3	62.3	7,151
Quartzite	Spherical	92.0	51.8	3,741
Quartz	Spherical	108.9	66.2	5,656
Quartz	Rectangular	82.3	47.0	3,037
Quartzite	Oval	102.8	37.1	2,993
Black Chert	Oval	89.4	32.9	2,308
Quartzite	Spherical	93.8	53.4	3,931

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality : Welkom G.M. Co. Ltd. - No. 3 Shaft.
26 Level Station

Co-ordinates : X + 28329.87 Y + 22133.56 ft.
X + 8634.94 Y + 6746.31 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Shale	Spherical	74.2	55.6	3,211
Chert	Oval	116.2	61.3	5,590
Chert	Oval	57.0	48.7	3,326
Quartzite	Spherical	86.9	59.2	4,037
Chert	Oval	75.0	38.9	2,289
Shale	Spherical	132.0	64.0	6,632
Quartzite	Oval	85.7	43.4	2,919
Quartz	Spherical	52.0	30.3	1,230
Quartz	Oval	102.4	68.6	5,515
Quartzite	Spherical	78.6	51.0	3,148
Chert	Spherical	63.0	46.1	2,279
Quartzite	Spherical	69.1	35.0	1,895
Shale	Oval	81.4	39.2	2,503
Quartz	Spherical	85.7	54.5	3,665
Chert	Oval	90.9	35.4	2,526
Quartzite	Spherical	55.3	37.8	1,620
Quartz	Rectangular	97.3	59.0	4,504
Chert	Oval	99.4	47.7	3,645
Quartz	Spherical	109.5	63.2	5,434
Quartz	Oval	108.7	68.2	5,819
Quartzite	Oval	93.2	38.1	2,787
Chert	Oval	102.1	58.9	4,721
Chert	Spherical	66.2	51.2	2,661
Shale	Spherical	83.3	56.5	3,695
Chert	Spherical	51.9	31.0	1,263
Quartzite	Oval	109.1	46.4	3,974
Quartzite	Oval	78.4	51.0	3,139
Chert	Oval	122.6	67.0	6,448
Chert	Oval	78.3	40.7	2,502
Quartz	Spherical	57.9	48.3	2,195
Chert	Oval	85.6	34.0	2,285
Shale	Spherical	117.0	63.5	5,832
Chert	Oval	131.9	69.8	7,227
Chert	Spherical	105.3	50.3	4,158
Chert	Oval	100.4	41.0	3,231
Chert	Spherical	78.8	38.1	2,357
Quartzite	Oval	86.1	31.0	2,095

DETERMINATION OF PEBBLE AREAS AT UNDERGROUND LOCALITIES.

Locality :	Welkom G.M. Co. Ltd. - No. 3 Shaft. 26 Level Station	
Co-ordinates :	X + 28329.87	Y + 22133.56 ft.
	X + 8634.94	Y + 6746.31 m.

PEBBLE TYPE	PEBBLE SHAPE Spherical Oval Rectangular Elongated	A X E S		PEBBLE AREA
		A Axis (mm)	C Axis (mm)	½A x ½C x 3.14 (mm^2)
Shale	Spherical	85.9	47.5	3,203
Chert	Spherical	84.8	58.0	3,861
Shale	Spherical	55.7	31.9	1,395
Quartz	Spherical	83.7	62.1	4,080
Shale	Spherical	37.1	30.4	885
Quartzite	Spherical	81.4	61.8	3,949
Chert	Oval	88.8	47.4	3,304
Chert	Oval	100.6	45.5	3,593
Quartz	Spherical	93.2	60.0	4,390
Quartzite	Oval	65.3	43.0	2,204
Shale	Oval	79.4	43.4	2,705
Quartzite	Spherical	108.9	56.1	4,796
Shale	Spherical	57.5	33.0	1,490
Quartzite	Spherical	89.4	53.0	3,719
Quartzite	Oval	80.4	40.0	2,525
Quartzite	Oval	115.9	61.5	5,595
Quartz	Spherical	45.7	33.0	1,184
Shale	Oval	95.4	51.3	3,842
Quartzite	Oval	80.4	39.7	2,506
Quartz	Oval	121.7	66.4	6,343
Quartzite	Oval	72.8	41.0	2,343
Quartzite	Spherical	77.2	53.5	3,242
Chert	Oval	109.6	49.5	4,259
Shale	Oval	80.9	39.0	2,477
Shale	Oval	129.1	56.1	5,685
Chert	Oval	132.7	68.9	7,177
Quartzite	Spherical	63.9	40.9	2,052
Quartzite	Spherical	67.0	46.1	2,425
Quartzite	Oval	142.6	57.0	6,381
Chert	Oval	87.5	33.5	2,301
Quartz	Oval	107.4	52.4	4,418
Shale	Oval	75.2	41.2	2,432
Quartzite	Spherical	83.7	56.1	3,686
Quartz	Spherical	38.5	33.0	997
Quartz	Oval	95.4	39.0	2,921
Quartzite	Oval	91.1	42.4	3,032
Shale	Spherical	46.2	35.1	1,273

C. PEBBLE-SIZE DISTRIBUTION

1. Outline

This program will calculate the pebble-size parameters of mean size, sorting, skewness and kurtosis, according to the number of pebbles in each of 40 size groups.

Two sets of parameters will be calculated, using the Inman and Folk and Ward formulae. These formulae will be somewhat modified from their usual form, in that size in square millimetres will be used instead of phi size. The method of moment measures will be used to calculate mean size and mean deviation.

2. Input

Input to the program is in the form of punched cards, submitted by the user.

Information pertaining to a particular SAMPLE of pebbles is required for one calculation. Basically, the input data consist of the number of pebbles, counted in each of the 40 size groups. Thus, the size (i.e. total number of pebbles) of the sample will depend entirely on the user.

Although the program does refer to 40 separate groups, the user may find that only a limited number of these groups contain pebbles in a particular sample. Only seldom (if ever), will there be a sample, with pebbles in each and every group. Thus, the actual definition of a sample is entirely up to the user; i.e. the user must decide on the size of the sample and its location.

For each sample, four punched cards must be submitted to the computer.

3. Calculations

The program goes through the following steps:

(a) The number of pebbles in each of the 40 size groups, is totalled up.

(b) The percentage of the total pebbles in each group, is calculated:

$$\text{Percentage in group} = \frac{\text{Number in group}}{\text{Total number}} \times 100$$

(c) The cumulative percentage in each group is calculated.

The cumulative percentage in the fortieth size group (group 60001 - 70000 mm^2) is the actual percentage of the total in that group. The cumulative percentage of the next group is obtained by adding the just calculated cumulative percentage of the previous group to the actual percentage of the total in the group in question. This is repeated for each of the 40 groups; the first size group, which is last calculated, will thus have a cumulative percentage of 100.

(d) The average square millimetre size of each group is now calculated. The arithmetic average is used, e.g. Group 25 - 50 mm^2, average size = $\frac{(25 + 50)}{2}$ = 37.5 mm^2

(e) A "graph" of average size versus cumulative percentage is "stored".

(f) In order to make the necessary calculations, the average sizes at seven critical percentages are required, and these are "calculated" from the "graph". The seven critical percentages are: 5, 16, 25, 50, 75, 84 and 95.

(g) Using these results, the Inman formulae are used to calculate mean size, sorting, skewness and kurtosis.

N.B. MM_5 = average mm^2 size at cumulative % 5, etc.

$$\text{Mean Size} = \frac{(MM_{16} + MM_{84})}{2}$$

$$\text{Sorting} = \frac{(MM_{84} - MM_{16})}{2}$$

$$\text{Skewness} = \frac{(MM_5 + MM_{95} - 2MM_{50})}{(MM_{84} - MM_{16})}$$

$$\text{Kurtosis} = \frac{(MM_{95} - MM_5) - (MM_{84} - MM_{16})}{(MM_{84} - MM_{16})}$$

(h) The Folk and Ward formulae are then used to calculate mean size, sorting, skewness and kurtosis.

$$\text{Mean size} = \frac{(MM_{16} + MM_{50} + MM_{84})}{3}$$

$$\text{Sorting} = \frac{MM_{84} - MM_{16}}{4} + \frac{(MM_{95} - MM_5)}{6.6}$$

$$\text{Skewness} = \frac{MM_{16} + MM_{84} - 2MM_{50}}{2(MM_{84} - MM_{16})} + \frac{MM_5 + MM_{95} - 2MM_{50}}{2(MM_{95} - MM_5)}$$

$$\text{Kurtosis} = \frac{(MM_{95} - MM_5)}{2.44\ (MM_{75} - MM_{25})}$$

(i) The Method of Moments is used to calculate the mean size, as follows:-

Mean size =

$$\frac{\sum (\%\ \text{pebbles in each group})\ (\text{mean size } (\text{mm}^2))}{100}$$

(j) The mean deviation is calculated by first totalling for each size group, the product of the percentage of pebbles in each group, with the square of the difference between mean size and average size in each group; this total is then divided by 100, and the square root is calculated to give the mean deviation.

Mean deviation =

$$\frac{(\sum (\%\ \text{pebbles})\ (\text{mean size} - \text{average size})^2)^{\frac{1}{2}}}{100}$$

4. Output

Program output consists of a two page report for each sample submitted.

Page 1

This report is headed with an identification of the sample, e.g. borehole number. Further identification in the form of the location, co-ordinates, depth and rock type is printed. Rock type is always given as 'ELSBURG CONGLOMERATE'.

Then the sizes in square millimetres, the numbers of pebbles in each group, the percentages of total pebbles and the cumulative percentages are tabulated. The size groups are listed in descending order.

This report could be used as a check on the correctness of the input, i.e. on the number of pebbles in each group.

The percentages are given, rounded to two decimal places, and the cumulative percentage for the smallest size group, should in all cases be 100.00.

Page 2

This report contains the mean size, sorting, skewness and kurtosis, as calculated by the Inman and Folk and Ward formulae. mean size and mean deviation, as calculated by the method of moment measures are also given. These results are printed alongside each other for comparison purposes.

Finally, a list of the mean square millimetre size at the critical cumulative percentages of 5, 16, 25, 50, 75, 84 and 95 is given below. All results are given correct to two decimal places.

5. Interpretation of Results

The cumulative percentages and their corresponding square millimetre sizes may be used together with the cumulative percentages on the first page to plot an accurate graph of size (mm^2) versus cumulative percentage. If the results from the first page are used in plotting the graph, the maximum and minimum sizes of the group in question should be arithmetically meaned.

The results on the second page may be used to make various deductions about the sample, e.g. grade, etc.

6. Running the Program

The program will be run off the object deck. The following Job Control Cards are required:-

(N.B. b̸ denotes a blank. $̸ denotes a dollar sign.)

```
*b̸$̸$̸JOBGEOL2

*b̸$̸$̸PRTD

//b̸JOBb̸GEOL2

//b̸OPTIONb̸LINK

b̸INCLUDE

     Object deck of program.

/*

//b̸EXECb̸LNKEDT

//b̸EXEC

     Data cards.

/*

/&

*b̸$̸$̸EOJ
```

The user need only supply the data cards.

Timing

Compilation time = 1 minute 38 seconds

Running time = 0 minutes 32 seconds

N.B. Actual running times may differ due to running under POWER.

PEBBLE-SIZE DISTRIBUTION BOREHOLE TR5.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.	
COORDINATES	Y+ 42560.13	X+ 32299.23
	Y+ 12972.3	X+ 9844.8
DEPTH	193 - 1357 ft.	(58.8 - 413.6 metre)
ROCK TYPE	ELSBURG CONGLOMERATE	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	1	0.01	0.01
8001 - 8500	4	0.04	0.05
7501 - 8000	3	0.03	0.08
7001 - 7500	0	0.0	0.08
6501 - 7000	3	0.03	0.11
6001 - 6500	5	0.05	0.16
5501 - 6000	4	0.04	0.21
5001 - 5500	17	0.17	0.38
4501 - 5000	19	0.19	0.57
4001 - 4500	56	0.57	1.15
3501 - 4000	102	1.05	2.20
3001 - 3500	83	0.85	3.05
2501 - 3000	107	1.10	4.15
2001 - 2500	312	3.20	7.35
1501 - 2000	641	6.58	13.92
1001 - 1500	924	9.48	23.40
901 - 1000	1231	12.63	36.04
801 - 900	1076	11.04	47.08
701 - 800	979	10.05	57.12
601 - 700	1286	13.20	70.32
501 - 600	872	8.95	79.26
401 - 500	526	5.40	84.66
301 - 400	444	4.56	89.22
201 - 300	321	3.29	92.51
151 - 200	286	2.93	95.44
101 - 150	217	2.23	97.67
51 - 100	103	1.06	98.73
25 - 50	124	1.27	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	1051.87	975.04	942.20
SORTING	-589.13	-662.77*	
SKEWNESS	-0.99	-0.43	
KURTOSIS	1.06	1.62	
MEAN DEV.			771.82

SIZE (SQ MM.) AT CUM. PERCENTAGES OF

5%	2617.0
16%	1641.0
25%	1212.6
50%	821.4
75%	598.1
84%	462.7
95%	186.9

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MH2.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.	
COORDINATES	Y+ 4030.12	X+ 28148.86
	Y+ 13115.5	X+ 8579.8
DEPTH	789 - 1519 ft.	(240.4 - 462.9 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL	CUMULATIVE %.
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	3	0.02	0.02
20001 - 25000	8	0.07	0.09
17501 - 20000	2	0.02	0.11
15001 - 17500	5	0.04	0.15
12501 - 15000	2	0.02	0.16
10001 - 12500	7	0.06	0.22
9501 - 10000	6	0.05	0.27
9001 - 9500	11	0.09	0.36
8501 - 9000	19	0.16	0.51
8001 - 8500	39	0.32	0.83
7501 - 8000	34	0.28	1.11
7001 - 7500	28	0.23	1.34
6501 - 7000	52	0.42	1.76
6001 - 6500	71	0.58	2.34
5501 - 6000	46	0.38	2.72
5001 - 5500	93	0.76	3.48
4501 - 5000	111	0.91	4.39
4001 - 4500	189	1.54	5.93
3501 - 4000	214	1.75	7.68
3001 - 3500	744	6.08	13.76
2501 - 3000	621	5.07	18.83
2001 - 2500	864	7.06	25.89
1501 - 2000	1087	8.88	34.77
1001 - 1500	923	7.54	42.31
901 - 1000	538	4.40	46.70
801 - 900	827	6.76	53.46
701 - 800	643	5.25	58.71
601 - 700	769	6.28	64.99
501 - 600	651	5.32	70.31
401 - 500	631	5.15	75.47
301 - 400	561	4.58	80.05
201 - 300	388	3.17	83.22
151 - 200	674	5.51	88.73
101 - 150	452	3.69	92.42
51 - 100	641	5.24	97.66
25 - 50	287	2.34	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	1634.66	1390.34	1452.43
SORTING	-1394.78	-1371.80*	
SKEWNESS	-1.02	-0.58	
KURTOSIS	0.60	0.98	
MEAN DEV.			1691.14

SIZE (SQ MM.) AT CUM. PERCENTAGES OF

5%	4551.9
16%	3029.4
25%	2313.4
50%	901.7
75%	459.6
84%	239.9
95%	100.9

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MB5.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 18780.71 Y+ 5724.3	X+ 17781.85 X+ 5419.9
DEPTH	841 - 1980 feet	(256.3 - 603.5 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	0	0.0	0.0
3501 - 4000	0	0.0	0.0
3001 - 3500	1	0.02	0.02
2501 - 3000	3	0.05	0.07
2001 - 2500	2	0.03	0.10
1501 - 2000	2	0.03	0.13
1001 - 1500	4	0.07	0.20
901 - 1000	9	0.15	0.35
801 - 900	11	0.18	0.54
701 - 800	28	0.47	1.01
601 - 700	74	1.24	2.25
501 - 600	138	2.32	4.57
401 - 500	429	7.21	11.78
301 - 400	764	12.84	24.62
201 - 300	1034	17.38	41.99
151 - 200	983	16.52	58.51
101 - 150	891	14.97	73.48
51 - 100	623	10.47	83.95
25 - 50	955	16.05	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	246.51	235.72	214.21
SORTING	-171.12	-160.59*	
SKEWNESS	-0.48	-0.26	
KURTOSIS	0.45	0.88	
MEAN DEV.			175.22

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	544.5
16%	417.6
25%	348.3
50%	214.1
75%	118.3
84%	75.4
95%	49.3

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MB4.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 18146.67 Y+ 5531.1	X+ 19991.05 X+ 6093.3
DEPTH	1522 - 2932 feet	(463.9 - 893.6 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	0	0.0	0.0
3501 - 4000	0	0.0	0.0
3001 - 3500	0	0.0	0.0
2501 - 3000	0	0.0	0.0
2001 - 2500	3	0.03	0.03
1501 - 2000	14	0.15	0.19
1001 - 1500	41	0.45	0.64
901 - 1000	71	0.78	1.42
801 - 900	193	2.12	3.54
701 - 800	289	3.18	6.72
601 - 700	406	4.47	11.19
501 - 600	597	6.57	17.75
401 - 500	842	9.26	27.02
301 - 400	1003	11.03	38.05
201 - 300	1125	12.37	50.42
151 - 200	1086	11.95	62.37
101 - 150	981	10.79	73.16
51 - 100	1256	13.82	86.98
25 - 50	1184	13.02	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	331.74	305.80	284.83
SORTING	-245.47	-236.76*	
SKEWNESS	-0.71	-0.39	
KURTOSIS	0.53	0.87	
MEAN DEV.			240.61

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	804.6
16%	577.2
25%	472.3
50%	253.9
75%	118.8
84%	86.3
95%	52.1

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MB3.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 17511.87 Y+ 5337.6	X+ 22202.91 X+ 6767.4
DEPTH	1356 - 2971 feet (413.3 - 905.6 metre)	
ROCK TYPE	ELSBURG CONGLOMERATE	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	1	0.01	0.01
3501 - 4000	2	0.02	0.03
3001 - 3500	2	0.02	0.05
2501 - 3000	4	0.04	0.10
2001 - 2500	7	0.08	0.18
1501 - 2000	21	0.23	0.41
1001 - 1500	69	0.76	1.16
901 - 1000	127	1.39	2.56
801 - 900	240	2.64	5.19
701 - 800	301	3.31	8.50
601 - 700	373	4.10	12.59
501 - 600	487	5.35	17.94
401 - 500	749	8.22	26.17
301 - 400	901	9.89	36.06
201 - 300	969	10.64	46.70
151 - 200	1246	13.68	60.38
101 - 150	1187	13.03	73.42
51 - 100	1094	12.01	85.43
25 - 50	1327	14.57	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	334.13	300.23	288.29
SORTING	-252.69	-248.66*	
SKEWNESS	-0.88	-0.48	
KURTOSIS	0.60	0.96	
MEAN DEV.			277.32

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	857.9
16%	586.8
25%	464.7
50%	232.4
75%	118.9
84%	81.4
95%	50.5

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE W3.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 15280.0	X+ 30251.0
	Y+ 4657.3	X+ 9220.5
DEPTH	954 - 2156 feet	(290.7 - 657.1 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	1	0.01	0.01
5001 - 5500	3	0.04	0.06
4501 - 5000	2	0.03	0.08
4001 - 4500	2	0.03	0.11
3501 - 4000	4	0.06	0.17
3001 - 3500	9	0.13	0.30
2501 - 3000	14	0.20	0.49
2001 - 2500	23	0.32	0.82
1501 - 2000	32	0.45	1.27
1001 - 1500	58	0.82	2.09
901 - 1000	91	1.28	3.37
801 - 900	86	1.21	4.59
701 - 800	119	1.68	6.27
601 - 700	377	5.32	11.59
501 - 600	561	7.92	19.50
401 - 500	707	9.98	29.48
301 - 400	993	14.01	43.49
201 - 300	1258	17.75	61.25
151 - 200	1123	15.85	77.10
101 - 150	672	9.48	86.58
51 - 100	437	6.17	92.75
25 - 50	514	7.25	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	366.92	349.23	341.65
SORTING	-227.83	-229.40*	
SKEWNESS	-0.57	-0.29	
KURTOSIS	0.67	1.01	
MEAN DEV.			349.63

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	825.9
16%	594.7
25%	495.4
50%	313.9
75%	185.4
84%	139.1
95%	63.7

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE U2.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 11616.31	X+ 29259.06
	Y+ 3540.6	X+ 8918.2
DEPTH	1711 - 3487 feet (521.5 - 1062.8 metre)	
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	0	0.0	0.0
3501 - 4000	0	0.0	0.0
3001 - 3500	0	0.0	0.0
2501 - 3000	3	0.04	0.04
2001 - 2500	7	0.10	0.14
1501 - 2000	11	0.15	0.29
1001 - 1500	37	0.51	0.80
901 - 1000	52	0.72	1.53
801 - 900	91	1.26	2.79
701 - 800	103	1.43	4.21
601 - 700	712	9.87	14.09
501 - 600	488	6.77	20.85
401 - 500	675	9.36	30.21
301 - 400	1023	14.18	44.39
201 - 300	981	13.60	57.99
151 - 200	917	12.71	70.71
101 - 150	750	10.40	81.10
51 - 100	569	7.89	88.99
25 - 50	794	11.01	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	364.67	346.20	313.55
SORTING	-257.53	-232.98*	
SKEWNESS	-0.35	-0.24	
KURTOSIS	0.34	0.80	
MEAN DEV.			243.94

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	742.5
16%	622.2
25%	506.2
50%	309.3
75%	154.8
84%	107.1
95%	54.8

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*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MTK3.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.
COORDINATES	Y+ 25869.18 X+ 21150.17 Y+ 7884.9 X+ 6446.5
DEPTH	2464 - 4280 feet (751.0 - 1304.5 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	3	0.03	0.03
12501 - 15000	2	0.02	0.05
10001 - 12500	1	0.01	0.06
9501 - 10000	2	0.02	0.07
9001 - 9500	7	0.06	0.14
8501 - 9000	4	0.04	0.18
8001 - 8500	0	0.0	0.18
7501 - 8000	2	0.02	0.19
7001 - 7500	4	0.04	0.23
6501 - 7000	6	0.06	0.29
6001 - 6500	5	0.05	0.33
5501 - 6000	9	0.08	0.42
5001 - 5500	11	0.10	0.52
4501 - 5000	17	0.16	0.67
4001 - 4500	29	0.27	0.94
3501 - 4000	42	0.39	1.33
3001 - 3500	84	0.77	2.10
2501 - 3000	155	1.43	3.53
2001 - 2500	224	2.07	5.60
1501 - 2000	471	4.34	9.94
1001 - 1500	460	4.24	14.18
901 - 1000	614	5.66	19.85
801 - 900	1176	10.85	30.69
701 - 800	325	3.00	33.69
601 - 700	342	3.15	36.84
501 - 600	478	4.41	41.25
401 - 500	645	5.95	47.20
301 - 400	1326	12.23	59.43
201 - 300	986	9.09	68.52
151 - 200	1068	9.85	78.37
101 - 150	781	7.20	85.58
51 - 100	912	8.41	93.99
25 - 50	652	6.01	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	645.37	572.78	654.03
SORTING	-508.93	-606.91*	
SKEWNESS	-1.58	-0.56	
KURTOSIS	1.29	1.36	
MEAN DEV.			874.64

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	2395.3
16%	1154.3
25%	903.0
50%	427.6
75%	201.2
84%	136.4
95%	69.1

*See Fig. 14.

PEBBLE_SIZE DISTRIBUTION BOREHOLE DG1.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.	
COORDINATES	Y+ 28683.92	X+ 26370.45
	Y+ 8742.5	X+ 8037.7
DEPTH	2437 - 3006 feet (742.7 - 916.2 metre)	
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	3	0.01	0.01
12501 - 15000	4	0.01	0.02
10001 - 12500	4	0.01	0.04
9501 - 10000	5	0.02	0.05
9001 - 9500	3	0.01	0.06
8501 - 9000	6	0.02	0.09
8001 - 8500	6	0.02	0.11
7501 - 8000	8	0.03	0.13
7001 - 7500	7	0.02	0.16
6501 - 7000	11	0.04	0.19
6001 - 6500	16	0.05	0.25
5501 - 6000	20	0.07	0.32
5001 - 5500	23	0.08	0.39
4501 - 5000	52	0.18	0.57
4001 - 4500	120	0.41	0.98
3501 - 4000	175	0.60	1.57
3001 - 3500	267	0.91	2.48
2501 - 3000	442	1.50	3.99
2001 - 2500	713	2.43	6.41
1501 - 2000	1387	4.72	11.13
1001 - 1500	1749	5.95	17.08
901 - 1000	1596	5.43	22.51
801 - 900	3088	10.50	33.01
701 - 800	2987	10.16	43.17
601 - 700	2615	8.89	52.07
501 - 600	3133	10.66	62.72
401 - 500	2163	7.36	70.08
301 - 400	1498	5.10	75.18
201 - 300	1826	6.21	81.39
151 - 200	1426	4.85	86.24
101 - 150	1224	4.16	90.40
51 - 100	1298	4.42	94.82
25 - 50	1524	5.18	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	775.63	741.67	778.71
SORTING	-565.54	-656.62*	
SKEWNESS	-1.12	-0.35	
KURTOSIS	1.18	1.77	
MEAN DEV.			822.45

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	2541.6
16%	1341.2
25%	926.8
50%	673.7
75%	354.0
84%	210.1
95%	74.2

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MB7.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 14070.0	X+ 16449.0
	Y+ 4288.5	X+ 5013.6
DEPTH	3038 - 4777 feet	(925.9 - 1456.0 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	0	0.0	0.0
3501 - 4000	1	0.01	0.01
3001 - 3500	1	0.01	0.03
2501 - 3000	1	0.01	0.04
2001 - 2500	0	0.0	0.04
1501 - 2000	3	0.04	0.09
1001 - 1500	0	0.0	0.09
901 - 1000	4	0.06	0.15
801 - 900	0	0.0	0.15
701 - 800	0	0.0	0.15
601 - 700	6	0.09	0.23
501 - 600	21	0.31	0.54
401 - 500	76	1.10	1.64
301 - 400	328	4.77	6.41
201 - 300	870	12.64	19.05
151 - 200	1073	15.59	34.64
101 - 150	1545	22.45	57.08
51 - 100	1716	24.93	82.01
25 - 50	1238	17.99	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	172.95	162.40	139.42
SORTING	-101.65	-101.12*	
SKEWNESS	-0.72	-0.38	
KURTOSIS	0.63	1.03	
MEAN DEV.			120.14

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	380.0
16%	274.6
25%	221.9
50%	141.3
75%	89.6
84%	71.3
95%	48.1

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE EF2.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.	
COORDINATES	Y+ 39710.24 Y+ 12103.6	X+ 24194.70 X+ 7374.5
DEPTH	1465 - 3328 feet	(446.5 - 1014.3 metre)
ROCK TYPE	ELSBURG CONGLOMERATE	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	4	0.03	0.03
25001 - 30000	3	0.02	0.05
20001 - 25000	6	0.04	0.09
17501 - 20000	9	0.06	0.16
15001 - 17500	22	0.16	0.31
12501 - 15000	31	0.22	0.53
10001 - 12500	29	0.21	0.74
9501 - 10000	14	0.10	0.84
9001 - 9500	23	0.16	1.00
8501 - 9000	40	0.28	1.28
8001 - 8500	49	0.35	1.63
7501 - 8000	77	0.55	2.17
7001 - 7500	84	0.59	2.77
6501 - 7000	73	0.52	3.29
6001 - 6500	130	0.92	4.21
5501 - 6000	139	0.98	5.19
5001 - 5500	138	0.98	6.17
4501 - 5000	208	1.47	7.64
4001 - 4500	347	2.46	10.10
3501 - 4000	462	3.27	13.37
3001 - 3500	711	5.04	18.41
2501 - 3000	1005	7.12	25.52
2001 - 2500	947	6.71	32.23
1501 - 2000	1221	8.65	40.88
1001 - 1500	1140	8.07	48.95
901 - 1000	894	6.33	55.28
801 - 900	685	4.85	60.13
701 - 800	556	3.94	64.07
601 - 700	784	5.55	69.62
501 - 600	825	5.84	75.46
401 - 500	653	4.62	80.09
301 - 400	334	2.37	82.45
201 - 300	472	3.34	85.79
151 - 200	554	3.92	89.72
101 - 150	481	3.41	93.12
51 - 100	577	4.09	97.21
25 - 50	394	2.79	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	1896.76	1664.73	1791.61
SORTING	-1592.59	-1666.73[*]	
SKEWNESS	-1.11	-0.53	
KURTOSIS	0.80	1.06	
MEAN DEV.			2133.20

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	5847.4
16%	3489.3
25%	2787.2
50%	1200.7
75%	558.4
84%	304.2
95%	102.5

[*] See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE JR1.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.	
COORDINATES	Y+ 44853.51	X+ 28145.21
	Y+ 13671.3	X+ 8578.6
DEPTH	718 - 1302 feet	(218.8 - 396.8 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	3	0.02	0.02
50001 - 60000	4	0.03	0.06
40001 - 50000	6	0.05	0.11
30001 - 40000	2	0.02	0.12
25001 - 30000	7	0.06	0.18
20001 - 25000	5	0.04	0.22
17501 - 20000	4	0.03	0.25
15001 - 17500	19	0.15	0.40
12501 - 15000	11	0.09	0.49
10001 - 12500	12	0.10	0.59
9501 - 10000	11	0.09	0.68
9001 - 9500	5	0.04	0.72
8501 - 9000	13	0.11	0.82
8001 - 8500	26	0.21	1.04
7501 - 8000	49	0.40	1.43
7001 - 7500	42	0.34	1.77
6501 - 7000	55	0.44	2.22
6001 - 6500	103	0.83	3.05
5501 - 6000	141	1.14	4.19
5001 - 5500	204	1.65	5.84
4501 - 5000	315	2.55	8.39
4001 - 4500	496	4.01	12.40
3501 - 4000	513	4.15	16.54
3001 - 3500	597	4.83	21.37
2501 - 3000	533	4.31	25.68
2001 - 2500	778	6.29	31.97
1501 - 2000	752	6.08	38.05
1001 - 1500	671	5.43	43.48
901 - 1000	526	4.25	47.73
801 - 900	508	4.11	51.84
701 - 800	406	3.28	55.12
601 - 700	561	4.54	59.66
501 - 600	752	6.08	65.74
401 - 500	880	7.12	72.86
301 - 400	1021	8.26	81.11
201 - 300	563	4.55	85.66
151 - 200	511	4.13	89.80
101 - 150	473	3.82	93.62
51 - 100	434	3.51	97.13
25 - 50	355	2.87	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	2051.55	1666.13	1757.96
SORTING	-1764.52	-1700.24*	
SKEWNESS	-1.08	-0.68	
KURTOSIS	0.53	0.92	
MEAN DEV.			2668.03

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	5504.5
16%	3816.1
25%	2829.5
50%	895.3
75%	424.5
84%	287.0
95%	105.8

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*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE TR2.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.	
COORDINATES	Y+ 38002.82	X+ 29878.32
	Y+ 11583.2	X+ 9106.9
DEPTH	823 - 2262 feet	(250.8 - 689.5 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	3	0.02	0.02
17501 - 20000	5	0.04	0.06
15001 - 17500	3	0.02	0.08
12501 - 15000	2	0.01	0.09
10001 - 12500	9	0.06	0.15
9501 - 10000	3	0.02	0.18
9001 - 9500	4	0.03	0.20
8501 - 9000	4	0.03	0.23
8001 - 8500	8	0.06	0.29
7501 - 8000	3	0.02	0.31
7001 - 7500	7	0.05	0.36
6501 - 7000	18	0.13	0.49
6001 - 6500	41	0.29	0.77
5501 - 6000	48	0.34	1.11
5001 - 5500	63	0.44	1.56
4501 - 5000	97	0.68	2.24
4001 - 4500	113	0.80	3.03
3501 - 4000	187	1.32	4.35
3001 - 3500	533	3.75	8.10
2501 - 3000	694	4.88	12.98
2001 - 2500	887	6.24	19.22
1501 - 2000	1049	7.38	26.60
1001 - 1500	1287	9.06	35.66
901 - 1000	1491	10.49	46.15
801 - 900	1304	9.18	55.33
701 - 800	1534	10.79	66.12
601 - 700	1211	8.52	74.64
501 - 600	793	5.58	80.22
401 - 500	517	3.64	83.86
301 - 400	524	3.69	87.55
201 - 300	675	4.75	92.30
151 - 200	251	1.77	94.06
101 - 150	248	1.75	95.81
51 - 100	267	1.88	97.68
25 - 50	329	2.31	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	1477.69	1287.98	1258.47
SORTING	-1031.03	-1048.09*	
SKEWNESS	-0.97	-0.56	
KURTOSIS	0.70	1.19	
MEAN DEV.			1256.70

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	3663.6
16%	2508.7
25%	1859.2
50%	908.6
75%	644.1
84%	446.7
95%	148.6

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MH5.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.
COORDINATES	Y+ 41480.82 X+ 24494.45 Y+ 12643.3 X+ 7465.9
DEPTH	1239 - 2629 feet (377.6 - 801.3 metre)
ROCK TYPE	ELSBURG CONGLOMERATE

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	1	0.01	0.01
50001 - 60000	0	0.0	0.01
40001 - 50000	3	0.02	0.03
30001 - 40000	3	0.02	0.05
25001 - 30000	2	0.01	0.06
20001 - 25000	7	0.05	0.10
17501 - 20000	16	0.10	0.21
15001 - 17500	31	0.20	0.41
12501 - 15000	67	0.44	0.85
10001 - 12500	109	0.71	1.57
9501 - 10000	130	0.85	2.42
9001 - 9500	169	1.11	3.53
8501 - 9000	211	1.38	4.91
8001 - 8500	262	1.72	6.63
7501 - 8000	221	1.45	8.08
7001 - 7500	142	0.93	9.01
6501 - 7000	157	1.03	10.04
6001 - 6500	181	1.19	11.22
5501 - 6000	208	1.36	12.59
5001 - 5500	274	1.80	14.38
4501 - 5000	234	1.53	15.92
4001 - 4500	332	2.18	18.10
3501 - 4000	261	1.71	19.81
3001 - 3500	274	1.80	21.60
2501 - 3000	289	1.89	23.50
2001 - 2500	313	2.05	25.55
1501 - 2000	327	2.14	27.69
1001 - 1500	444	2.91	30.61
901 - 1000	440	2.88	33.49
801 - 900	563	3.69	37.18
701 - 800	598	3.92	41.10
601 - 700	543	3.56	44.66
501 - 600	961	6.30	50.96
401 - 500	997	6.54	57.50
301 - 400	1430	9.38	66.88
201 - 300	1690	11.08	77.96
151 - 200	1297	8.50	86.46
101 - 150	871	5.71	92.17
51 - 100	726	4.76	96.93
25 - 50	468	3.07	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	2464.57	1831.64	1895.25
SORTING	-2267.37	-2441.07*	
SKEWNESS	-1.70	-0.86	
KURTOSIS	0.90	1.68	
MEAN DEV.			3032.42

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	8724.5
16%	4731.9
25%	2384.7
50%	565.8
75%	277.2
84%	197.2
95%	95.8

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE FH1.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.	
COORDINATES	Y+ 34292.67 Y+ 10452.4	X+ 23341.95 X+ 7114.3
DEPTH	1994 - 3803 feet	(607.7 - 1159.1 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	1	0.01	0.01
10001 - 12500	3	0.02	0.03
9501 - 10000	6	0.04	0.07
9001 - 9500	14	0.10	0.17
8501 - 9000	22	0.16	0.33
8001 - 8500	15	0.11	0.43
7501 - 8000	20	0.14	0.57
7001 - 7500	28	0.20	0.77
6501 - 7000	41	0.29	1.06
6001 - 6500	50	0.35	1.42
5501 - 6000	67	0.48	1.89
5001 - 5500	126	0.89	2.79
4501 - 5000	124	0.88	3.67
4001 - 4500	233	1.65	5.32
3501 - 4000	359	2.55	7.87
3001 - 3500	564	4.00	11.87
2501 - 3000	761	5.40	17.26
2001 - 2500	1325	9.40	26.66
1501 - 2000	1456	10.33	36.99
1001 - 1500	1277	9.06	46.04
901 - 1000	802	5.69	51.73
801 - 900	500	3.55	55.28
701 - 800	673	4.77	60.05
601 - 700	671	4.76	64.81
501 - 600	465	3.30	68.11
401 - 500	511	3.62	71.73
301 - 400	435	3.09	74.82
201 - 300	545	3.87	78.68
151 - 200	686	4.87	83.55
101 - 150	619	4.39	87.94
51 - 100	1092	7.74	95.68
25 - 50	609	4.32	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	1518.89	1359.85	1399.52
SORTING	-1348.56	-1320.82[*]	
SKEWNESS	-0.87	-0.45	
KURTOSIS	0.58	0.88	
MEAN DEV.			1426.00

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	4347.1
16%	2867.5
25%	2338.8
50%	1041.8
75%	345.7
84%	170.3
95%	79.9

[*] See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE BD1.

SAMPLE LOCATION	WESTERN HOLDINGS LTD.
COORDINATES	Y+ 33184.93 X+ 30253.18 Y+ 10114.7 X+ 9221.1
DEPTH	2149 - 3789 feet (655.0 - 1154.8 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	1	0.00	0.00
20001 - 25000	4	0.02	0.02
17501 - 20000	3	0.01	0.04
15001 - 17500	12	0.05	0.09
12501 - 15000	17	0.08	0.17
10001 - 12500	28	0.13	0.30
9501 - 10000	34	0.15	0.45
9001 - 9500	25	0.11	0.56
8501 - 9000	32	0.15	0.71
8001 - 8500	21	0.10	0.80
7501 - 8000	37	0.17	0.97
7001 - 7500	35	0.16	1.13
6501 - 7000	75	0.34	1.47
6001 - 6500	87	0.40	1.87
5501 - 6000	78	0.35	2.22
5001 - 5500	115	0.52	2.74
4501 - 5000	178	0.81	3.55
4001 - 4500	279	1.27	4.82
3501 - 4000	264	1.20	6.02
3001 - 3500	380	1.73	7.74
2501 - 3000	578	2.62	10.37
2001 - 2500	681	3.09	13.46
1501 - 2000	904	4.11	17.57
1001 - 1500	659	2.99	20.56
901 - 1000	1592	7.23	27.79
801 - 900	2128	9.66	37.45
701 - 800	2004	9.10	46.55
601 - 700	1892	8.59	55.14
501 - 600	1936	8.79	63.93
401 - 500	1628	7.39	71.33
301 - 400	1341	6.09	77.42
201 - 300	1136	5.16	82.58
151 - 200	913	4.15	86.72
101 - 150	863	3.92	90.64
51 - 100	968	4.40	95.04
25 - 50	1093	4.96	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	1082.93	958.74	1060.64
SORTING	-858.19	-1050.12*	
SKEWNESS	-1.65	-0.56	
KURTOSIS	1.39	2.49	
MEAN DEV.			1497.59

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	4174.6
16%	1941.1
25%	1066.2
50%	710.4
75%	390.2
84%	224.7
95%	75.9

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE DH1.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 16104.65	X+ 10861.92
	Y+ 4908.63	X+ 3310.71
DEPTH	1211 - 2795 feet (369.1 - 851.9 metre)	
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	0	0.0	0.0
3501 - 4000	0	0.0	0.0
3001 - 3500	2	0.03	0.03
2501 - 3000	1	0.01	0.04
2001 - 2500	0	0.0	0.04
1501 - 2000	0	0.0	0.04
1001 - 1500	3	0.04	0.09
901 - 1000	0	0.0	0.09
801 - 900	4	0.06	0.15
701 - 800	0	0.0	0.15
601 - 700	6	0.09	0.23
501 - 600	21	0.31	0.54
401 - 500	76	1.10	1.64
301 - 400	328	4.77	6.41
201 - 300	870	12.64	19.05
151 - 200	1073	15.59	34.64
101 - 150	1545	22.45	57.08
51 - 100	1716	24.93	82.01
25 - 50	1238	17.99	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	172.95	162.40	139.07
SORTING	-101.65	-101.12*	
SKEWNESS	-0.72	-0.38	
KURTOSIS	0.63	1.03	
MEAN DEV.			115.16

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	380.0
16%	274.6
25%	221.9
50%	141.3
75%	89.6
84%	71.3
95%	48.1

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MB2.

SAMPLE LOCATION	WELKOM GOLD MINING CO.
COORDINATES	Y+ 16247.60 X+ 26629.55 Y+ 4925.3 X+ 8116.7
DEPTH	1164 - 2433 feet (354.8 - 741.6 metre)
ROCK TYPE	ELSBURG CONGLOMERATE

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	1	0.01	0.01
4001 - 4500	5	0.06	0.07
3501 - 4000	7	0.08	0.15
3001 - 3500	15	0.17	0.31
2501 - 3000	19	0.21	0.52
2001 - 2500	27	0.30	0.83
1501 - 2000	39	0.44	1.26
1001 - 1500	44	0.49	1.75
901 - 1000	101	1.13	2.88
801 - 900	319	3.56	6.44
701 - 800	393	4.38	10.82
601 - 700	357	3.98	14.80
501 - 600	628	7.01	21.81
401 - 500	843	9.40	31.21
301 - 400	924	10.31	41.52
201 - 300	1339	14.94	56.46
151 - 200	1276	14.23	70.69
101 - 150	1041	11.61	82.31
51 - 100	952	10.62	92.93
25 - 50	634	7.07	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	375.48	348.23	342.13
SORTING	-257.95	-254.20*	
SKEWNESS	-0.71	-0.38	
KURTOSIS	0.60	0.94	
MEAN DEV.			351.07

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	890.9
16%	633.4
25%	516.6
50%	293.7
75%	157.0
84%	117.5
95%	64.4

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE ENK1.

SAMPLE LOCATION	WELKOM GOLD MINING CO.
COORDINATES	Y+ 24163.74 X+ 28203.97 Y+ 7365.1 X+ 8596.5
DEPTH	1751 - 3354 feet (533.7 - 1022.2 metre)
ROCK TYPE	ELSBURG CONGLOMERATE.

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	1	0.01	0.01
12501 - 15000	3	0.03	0.04
10001 - 12500	3	0.03	0.07
9501 - 10000	0	0.0	0.07
9001 - 9500	3	0.03	0.10
8501 - 9000	4	0.04	0.14
8001 - 8500	2	0.02	0.16
7501 - 8000	0	0.0	0.16
7001 - 7500	4	0.04	0.20
6501 - 7000	8	0.08	0.27
6001 - 6500	14	0.14	0.41
5501 - 6000	21	0.21	0.62
5001 - 5500	12	0.12	0.73
4501 - 5000	18	0.18	0.91
4001 - 4500	64	0.63	1.53
3501 - 4000	31	0.30	1.84
3001 - 3500	43	0.42	2.26
2501 - 3000	55	0.54	2.79
2001 - 2500	83	0.81	3.61
1501 - 2000	126	1.23	4.84
1001 - 1500	317	3.10	7.93
901 - 1000	581	5.68	13.61
801 - 900	543	5.31	18.92
701 - 800	1607	15.70	34.62
601 - 700	1023	10.00	44.62
501 - 600	893	8.73	53.34
401 - 500	671	6.56	59.90
301 - 400	837	8.18	68.08
201 - 300	1240	12.12	80.19
151 - 200	873	8.53	88.72
101 - 150	357	3.49	92.21
51 - 100	486	4.75	96.96
25 - 50	311	3.04	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	561.26	570.44	647.18
SORTING	-344.23	-418.78*	
SKEWNESS	-0.93	-0.16	
KURTOSIS	1.36	1.29	
MEAN DEV.			816.38

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	1724.2
16%	905.5
25%	811.8
50%	588.8
75%	293.4
84%	217.0
95%	96.1

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*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE WO1.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 15399.59 Y+ 4693.8	X+ 5765.99 X+ 1757.5
DEPTH	3671 - 4306 feet	(118.9 - 1312.5 metre)
ROCK TYPE	ELSBURG CONGLOMERATE	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	0	0.0	0.0
3501 - 4000	0	0.0	0.0
3001 - 3500	0	0.0	0.0
2501 - 3000	0	0.0	0.0
2001 - 2500	2	0.05	0.05
1501 - 2000	0	0.0	0.05
1001 - 1500	1	0.03	0.08
901 - 1000	1	0.03	0.10
801 - 900	0	0.0	0.10
701 - 800	4	0.10	0.21
601 - 700	3	0.08	0.28
501 - 600	8	0.21	0.49
401 - 500	48	1.24	1.73
301 - 400	111	2.87	4.60
201 - 300	341	8.81	13.41
151 - 200	526	13.59	27.00
101 - 150	710	18.35	45.35
51 - 100	942	24.34	69.69
25 - 50	1173	30.31	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	146.89	136.57	118.48
SORTING	-89.33	-90.45*	
SKEWNESS	-0.88	-0.43	
KURTOSIS	0.69	1.05	
MEAN DEV.			105.89

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	346.0
16%	236.2
25%	186.6
50%	115.9
75%	68.8
84%	57.6
95%	43.8

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE AR1.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 19202.81	X+ 14093.25
	Y+ 5853.02	X+ 4295.62
DEPTH		
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %.
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	0	0.0	0.0
4501 - 5000	0	0.0	0.0
4001 - 4500	0	0.0	0.0
3501 - 4000	0	0.0	0.0
3001 - 3500	1	0.03	0.03
2501 - 3000	1	0.03	0.05
2001 - 2500	0	0.0	0.05
1501 - 2000	0	0.0	0.05
1001 - 1500	2	0.05	0.10
901 - 1000	1	0.03	0.13
801 - 900	1	0.03	0.15
701 - 800	5	0.13	0.28
601 - 700	19	0.49	0.77
501 - 600	67	1.71	2.48
401 - 500	291	7.43	9.91
301 - 400	486	12.41	22.32
201 - 300	722	18.44	40.77
151 - 200	687	17.55	58.31
101 - 150	568	14.51	72.82
51 - 100	623	15.91	88.74
25 - 50	441	11.26	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	245.91	234.29	204.60
SORTING	-155.53	-147.80*	
SKEWNESS	-0.48	-0.27	
KURTOSIS	0.49	0.87	
MEAN DEV.			150.35

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	516.6
16%	401.4
25%	336.0
50%	211.0
75%	118.7
84%	90.4
95%	54.4

*See Fig. 14.

PEBBLE-SIZE DISTRIBUTION BOREHOLE MB6.

SAMPLE LOCATION	WELKOM GOLD MINING CO.	
COORDINATES	Y+ 12163.0	X+ 23040.0
	Y+ 3707.3	X+ 7022.6
DEPTH	2593 - 4370 feet (790.3 - 1331.9 metre)	
ROCK TYPE	ELSBURG CONGLOMERATE.	

SIZE IN SQ MM.	NO. OF PEBBLES.	% OF TOTAL.	CUMULATIVE %
60001 - 70000	0	0.0	0.0
50001 - 60000	0	0.0	0.0
40001 - 50000	0	0.0	0.0
30001 - 40000	0	0.0	0.0
25001 - 30000	0	0.0	0.0
20001 - 25000	0	0.0	0.0
17501 - 20000	0	0.0	0.0
15001 - 17500	0	0.0	0.0
12501 - 15000	0	0.0	0.0
10001 - 12500	0	0.0	0.0
9501 - 10000	0	0.0	0.0
9001 - 9500	0	0.0	0.0
8501 - 9000	0	0.0	0.0
8001 - 8500	0	0.0	0.0
7501 - 8000	0	0.0	0.0
7001 - 7500	0	0.0	0.0
6501 - 7000	0	0.0	0.0
6001 - 6500	0	0.0	0.0
5501 - 6000	0	0.0	0.0
5001 - 5500	1	0.01	0.01
4501 - 5000	2	0.03	0.04
4001 - 4500	1	0.01	0.05
3501 - 4000	4	0.05	0.11
3001 - 3500	3	0.04	0.15
2501 - 3000	6	0.08	0.23
2001 - 2500	6	0.08	0.31
1501 - 2000	9	0.12	0.44
1001 - 1500	14	0.19	0.63
901 - 1000	12	0.16	0.79
801 - 900	39	0.53	1.33
701 - 800	84	1.15	2.47
601 - 700	139	1.90	4.37
501 - 600	308	4.21	8.58
401 - 500	531	7.26	15.84
301 - 400	968	13.23	29.06
201 - 300	1486	20.30	49.36
151 - 200	1121	15.32	64.68
101 - 150	713	9.74	74.42
51 - 100	827	11.30	85.72
25 - 50	1045	14.28	100.00

	INMAN	FOLK & WARD	MOMENT MEASURES
MEAN SIZE	266.19	259.92	247.74
SORTING	-183.07	-180.14*	
SKEWNESS	-0.52	-0.22	
KURTOSIS	0.60	0.93	
MEAN DEV.			252.11

SIZE (SQ MM.) AT CUM. PERCENTAGES OF.

5%	635.6
16%	449.3
25%	381.2
50%	247.4
75%	122.9
84%	83.1
95%	50.8

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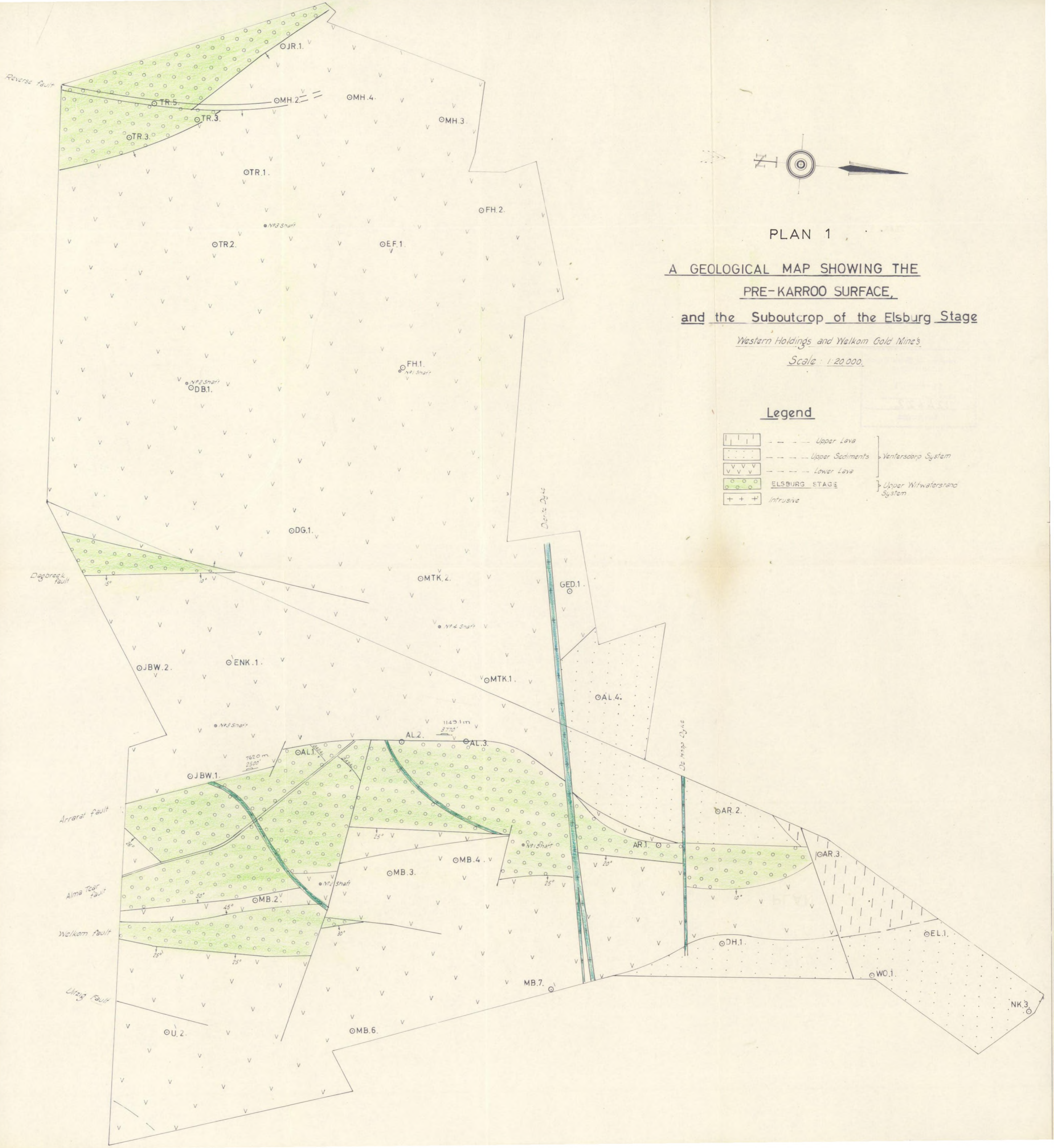
*See Fig. 14.

PLAN 1

A GEOLOGICAL MAP SHOWING THE PRE-KARROO SURFACE, and the Suboutcrop of the Elsburg Stage

Western Holdings and Welkom Gold Mine's

Scale : 1:20,000.



Legend

▥	Upper Lava	Ventersdorp System
⁘	Upper Sediments	
V V V	Lower Lava	
🟩 ○ ○ ○	ELSBURG STAGE	Upper Witwatersrand System
+ + +	Intrusive	

PLAN 2

STRUCTURAL PLAN
OF
WESTERN HOLDINGS & WELKOM GOLD MINES
Scale 1: 20,000.

legend

🟥	TEAR FAULT	ON REEF PLANE
400	DOWNTHROW FAULT (in feet)	
750	UPTHROW FAULT (in feet)	
🟩	INTRUSIVE	
41	REEF CONTOURS	

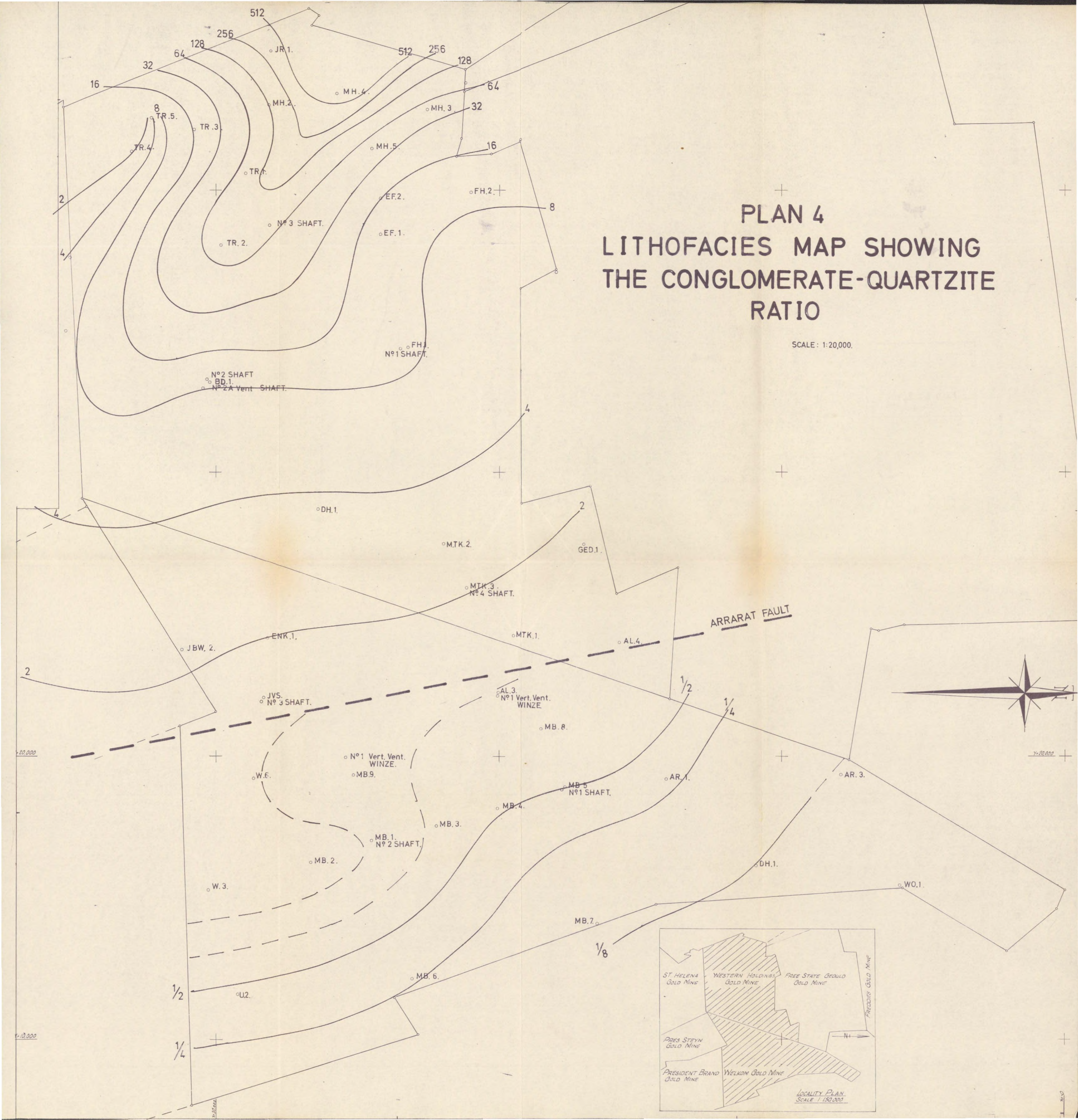
CONVERSION TABLE

10 feet	=	3·04 metre.
50 "	=	15·24 "
100 "	=	30·48 "
500 "	=	152·4 "
1000 "	=	304·8 "

PLAN 4

LITHOFACIES MAP SHOWING THE CONGLOMERATE-QUARTZITE RATIO

SCALE: 1:20,000.



PLAN 3

Welkom and Western Holdings Gold Mines

ISOPLETH MAP OF PEBBLE SIZE

SCALE: 1:20,000.