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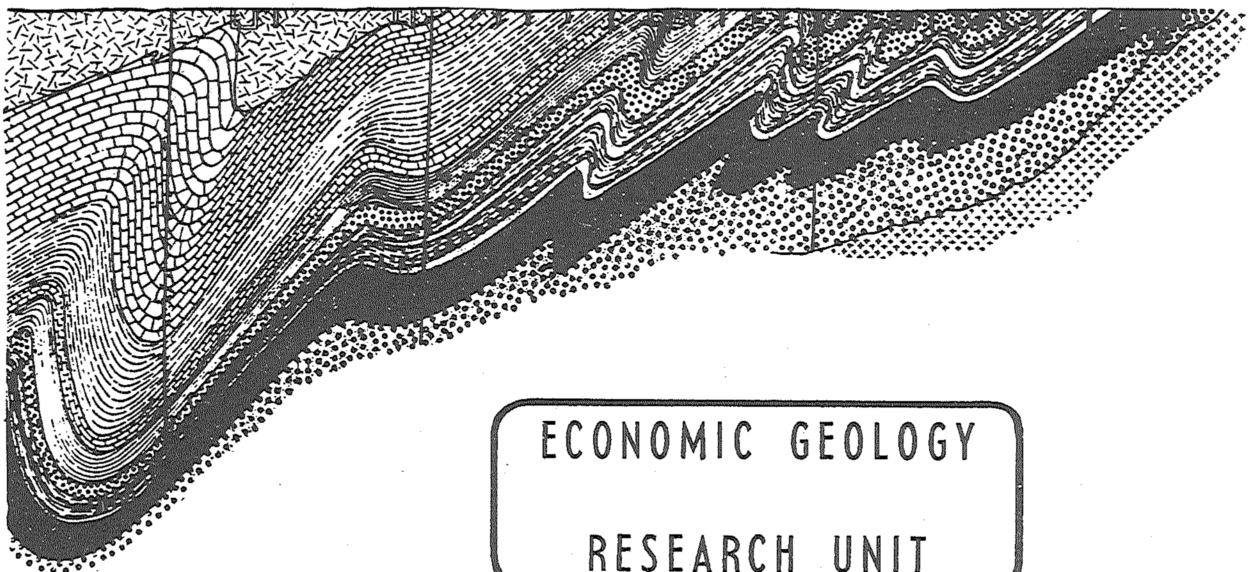

ECONOMIC GEOLOGY

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SEDIMENTOLOGICAL CONTROL OF GOLD MINERALIZATION IN THE KIMBERLEY REEFS OF THE EAST RAND GOLDFIELD

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by

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ABSTRACT

The investigation comprised a detailed sedimentological study of the U.K. 9 Zone of sediments in East Daggafontein Mines Limited, Daggafontein Mines Limited, and the northeastern portion of Springs Mines Limited. Numerous macroscopic sedimentological parameters were measured in this zone, in an attempt to establish the environment and nature of deposition of these sediments. The results obtained were used to guide predictions of further payable U.K. 9 A Reef in the mines studied and in other East Rand mines.

In this area, the general direction of current flow was towards the east-southeast during the time of deposition of the U.K. 9 Zone. This direction is believed to define the prevailing attitude of the depositional surface. Mud-cracks in, and directly above and below, the U.K. 9 A Reef favour the sub-aerial exposure of the U.K. 9 Zone sediments. Pebble orientation, typical of a fluviatile environment, was observed in the U.K. 9 A Reef. The presence of both oscillation ripple-marks and mud-cracks in the U.K. 9 A Marker favour the existence of shallow water conditions during the deposition of this zone. This information was taken collectively to indicate a continental and essentially fluviatile environment of deposition for the sediments of the U.K. 9 Zone. A distinct relationship exists between the orientation of the U.K. 9 A Reef bodies, the attitude of the depositional slope, and the paleotopography of the floor, which is considered to be largely portrayed by the pattern of U.K. 9 A Reef structural deformation.

It would seem that the bulk of the material constituting the U.K. 9 A Reef was derived from the U.K. 9 B Reefs. The erosion products were distributed east-southeastwards from this local source area to produce a series of U.K. 9 A Reef bodies trending parallel to the depositional dip in the western portion of the area studied. Towards the east, generally north-south-trending footwall folds, situated at approximately right-angles to the dip of the depositional surface, locally influenced the degree of dip of the depositional surface and the distribution of the U.K. 9 A Reef. In areas of reduced depositional dip, dumping of U.K. 9 A Reef material took place, due to a reduction in current velocities, while, in areas of relatively steep depositional dip, higher current velocities prevented appreciable reef deposition. In this eastern area, additional U.K. 9 A Reef material was derived locally from the sub-outcropping footwall conglomerates of the M.K. 1, M.K. 2, and M.K. 3 Zones.

The gold of the U.K. 9 A Reef was derived by erosion and reworking of the footwall reefs, namely, the gold-bearing U.K. 9 B Reefs and the M.K. 2 Zone.

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SEDIMENTOLOGICAL CONTROL OF GOLD MINERALIZATION IN THE KIMBERLEY REEFS OF THE EAST RAND GOLDFIELD

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SEDIMENTOLOGICAL CONTROL OF GOLD MINERALIZATION IN THE KIMBERLEY REEFS OF THE EAST RAND GOLDFIELD

INTRODUCTION

A. REASONS FOR RESEARCH

The aim of this study was to determine to what extent a sedimentological investigation of the U.K. 9 A Reef, also known as the May Reef or Kimberley Reef, would aid East Daggafontein Mines Limited and Daggafontein Mines Limited in exploiting known areas of payable U.K. 9 A Reef, and in predicting the existence of payable U.K. 9 A Reef in unexplored areas.

The orientation and extent of the U.K. 9 A Reef bodies have, in the past, been predicted by visual inspection of inch-pennyweight value trends and also by underground location of the marginal boundaries of the reef bodies (Antrobus and Whiteside, 1964, p. 146). This procedure proved successful in areas where the reef bodies were well-defined and showed fairly consistent inch-pennyweight values, but was less reliable in areas of sporadic reef development. The main drawback of this method was that, in most cases, a considerable amount of underground development and stoping was required before the reef bodies could be accurately defined. A technique which would enable prediction to be made from less extensive underground development would be of great value, as this would allow further underground work to be restricted largely to areas of payable reef. It was considered that this could possibly be achieved by ascertaining, from the measurement of cross-bedding in those parts of the mines well exposed by mining operations, the relationship between the direction of sediment transport during the time of formation of the U.K. 9 A Reef and the orientation of the reef bodies. Cross-bedding could then be used in areas of limited underground development to predict the orientation of reef bodies. This information, in conjunction with available underground sampling values, would then facilitate the prediction of the extent of payable areas from limited underground exposures.

In addition, it was considered that a comprehensive sedimentological study of the exposed U.K. 9 A Reef and adjacent sediments would reveal the environment and mode of deposition of this reef. This information would then aid in predicting the most favourable unexplored areas for further prospecting.

B. LOCALITY

The area studied comprises East Daggafontein Mines Limited, Daggafontein Mines Limited, and the northeastern portion of Springs Mines Limited. These mines are situated to the south of Springs township, and occupy the east-central portion of the East Rand Basin. The area studied has an areal extent of approximately 30 square miles, and measures some eight miles from west to east by four miles from north to south (Map 1).

C. THE DETAILED SUCCESSION OF THE KIMBERLEY STAGE

The divisions of the Witwatersrand System, accepted by geologists representing East Rand mines and presented by Antrobus (1964, pp. 113-123), are given in Figure 1. Only the Kimberley Stage, which is of major importance in this study, is treated in detail. The following description of the succession of this group has been taken from the writings of Sharpe (1942 - 1945, pp. 859-863), Whiteside (1950, pp. 24-30), and de Jager (1957, pp. 140-143), as well as of Antrobus (1964).

The accepted divisions of the Kimberley Stage are those proposed by Sharpe (1942-1945, pp. 859-863), namely, the Middle Kimberley and the Upper Kimberley. These are further divided, in ascending succession, into the zones M.K.3 to M.K.1, and U.K.9 to U.K.1. The abbreviations "M.K." and "U.K." designate "Middle Kimberley" and "Upper Kimberley", respectively.

(a) Middle Kimberley, M.K.3 to M.K.1

M.K.3 This zone contains greenish quartzites with scattered angular chert and occasional rounded quartz pebbles. The pebbles may be sufficiently concentrated to form lenticular conglomerates at various horizons. An inconsistent pebble band, containing quartz, chert, and yellow shale pebbles, occurs at the base of the zone.

M.K.2 This is a zone of well-developed conglomerates and interbedded quartzites. The conglomerates are characterized by large quartz and chert pebbles, up to three inches in diameter. The largest pebbles usually occur near the base of the zone, where pebble diameters of up to nine inches have been recorded.

M.K.1 The M.K.1 beds consist of chloritoid shale, shale, argillaceous and glassy quartzites, conglomerates, and puddingstones. Channel deposits are common, and the succession shows considerable local variation. Gold values are erratic, and isolated payable values have been encountered.

(b) Upper Kimberley, U.K.9 to U.K.1

In the Upper Kimberley, the odd-numbered zones represent conglomerates and the even-numbered zones represent quartzites. The U.K.9 Zone is economically the most important of the Kimberley Group, and the following divisions of this zone are accepted for the East Rand.

U.K.9C Reefs This group contains one to three narrow conglomerates. The conglomerates are characterized by the presence of large, well-rounded, quartz pebbles, up to four inches in diameter, angular shaly inclusions, and boulders of various footwall rock-types.

U.K.9B Reefs This zone contains interbedded conglomerates and quartzites. The conglomerates are up to 15 feet thick, and contain closely packed, well-rounded, quartz pebbles, up to three inches in diameter. Isolated gold values occur, but the reefs are seldom payable.

U.K.9A Reefs This reef is economically the most important member of the U.K.9 Zone. It generally has a dark grey matrix, where well mineralized, and a much lighter matrix, where poorly mineralized. The pebbles are predominantly of quartz, except in the eastern East Rand where chert pebbles are of local significance.

U.K.9A Marker This is a fine-grained, light-grey, glassy quartzite which may display a greenish tinge.

The remaining odd-numbered zones of the Upper Kimberley, namely the U.K.7 to the U.K.1, contain generally well-developed conglomerate horizons with subordinate coarse quartzite partings. The even-numbered zones, i.e. U.K.8 to U.K.2, consist dominantly of coarse quartzites, with occasional scattered-pebble horizons.

D. NATURE OF RESEARCH

An extensive macroscopic examination of sedimentary features was carried out in the underground exposures of the mines studied. The U.K.9 Zone was investigated in detail, and a limited amount of work was done on the footwall beds. Sedimentary structures, such as cross-bedding, ripple-marks, and sand-waves, were measured to determine the direction of transport. The properties of the U.K.9A Zone conglomerates, namely, pebble size, pebble composition, pebble orientation, and the degree of conglomerate pebble sorting, were studied. A detailed map of the U.K.9A Reef footwall was compiled, and used in conjunction with pebble size and pebble composition patterns, to establish the relation between the U.K.9A Reef and the footwall beds.

An inch/dwt. plan of the U.K.9A Reef was compiled from mine records, to illustrate the size, shape, and orientation of reef bodies, and to obtain a rough pattern of gold distribution. This plan was compared with the pattern obtained from sedimentary structures, to establish the relation between the direction of transport and the orientation of U.K.9A Reef payshoots.

Isopach maps of the various sedimentary units from the top of the Transvaal System to the top of the Main Reef Leader were compiled. These maps were compared with the structure contour plan of the U.K.9A Reef, to determine the relation between structure and sedimentation.

The information from the various aspects of this study was used to decipher the environment and mode of deposition of the U.K.9 Zone, and then the results were considered with regard to their economic application to the area studied and to other mines on the East Rand.

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THE SEDIMENTOLOGICAL CHARACTERISTICS OF THE U.K.9 ZONE

A. EXTERNAL SEDIMENTARY STRUCTURES OF THE ROCK UNITS COMPRISING THE U.K.9 ZONE

(a) Size and Shape of Sedimentary Bodies

The U.K.9B Reefs are limited in their distribution to the western portion of Daggafontein Mine (Map 3). They occur as a blanket deposit which is 15 feet thick at No. 3 Shaft, and which thins out to disappear towards the east. On three occasions, the lower portions of this zone were observed to occur in the form of southeast-trending channel deposits.

On Map 2, it is seen that the U.K.9A Reef occurs as a series of elongated, tabular and blanket bodies showing variation in orientation. The following areas on this map include U.K.9A Reef bodies of essentially the same size, shape, and orientation :

Area 1 : a series of generally east-southeast-trending tabular bodies.

Area 2 : a south-trending zone of tabular and blanket deposits.

Area 3 : tabular bodies trending northeast.

Area 4 : two southeast-trending tabular bodies.

Area 5 : a number of east-southeast-trending tabular bodies.

The U.K.9A Pebbly Quartzite Zone, which is described by de Jager (1957, p. 143), occurs as a blanket deposit on Daggafontein Mine. It is generally limited to the area which is underlain by the U.K.9B Reefs, where it invariably rests directly on the U.K.9B Reefs or the U.K.9A Reef.

The U.K.9A Marker occurs as a blanket deposit in most of the area investigated.

(b) Nature of Boundaries

An unconformity, or, to be more specific, an angular unconformity, exists between the base of the U.K.9 Zone and the underlying beds (Plate 1 and Map 3). In the area studied, the base of the U.K.9 Zone is the base of the U.K.9B Reefs, the base of the U.K.9A Reef, or the base of the U.K.9A Marker, due to total non-deposition of the U.K.9C Reefs and non-deposition of the U.K.9B and A Reefs over large areas. A disconformity occurs between the U.K.9A Reef and the underlying U.K.9B Reefs. The channel-like nature of the U.K.9A Reef was observed on several occasions, particularly in the area to the west of No. 3 Shaft. From underground observations, the U.K.9A Reef, U.K.9A Pebbly Quartzite, and U.K.9A Marker zones appear to be perfectly conformable.

B. INTERNAL SEDIMENTARY STRUCTURES OF THE U.K.9 ZONE

(a) Planar Cross-bedding

The attitudes of 890 foresets were measured on 348 cross-bedded units. The corrected cross-bedding directions are represented by arrows of unit length on Map 4, where a distinction is made between cross-bedding directions in the U.K.9B Reefs, in the U.K.9A Reef, and in the U.K.9A Marker. The mean directions of transport obtained for the various areas and zones investigated are given by the rose diagrams on Map 5. The results of the analysis of cross-bedding data on a 2000 foot-grid for the U.K.9B Reefs and the U.K.9A Marker are presented graphically on the same map. Histograms illustrating the distribution of foreset dip, and cross-bedding thickness, values, for the total area investigated are presented on Map 4.

Planar cross-bedding is well developed in the interbedded quartzites of the U.K.9B Reefs. It is poorly developed in the U.K.9A Reef, where it invariably occurs in quartzite or pebbly quartzite partings within the reef (Plate 2). It occurs most frequently in the U.K.9A Marker where it is often a characteristic feature of this zone (Plate 3).

The analysis of cross-bedding directions in the U.K.9B Reefs revealed a mean direction of transport of 114°. Cross-bedding directions in the U.K.9A Reef were too few in number to calculate a confident mean direction of transport. The few readings obtained indicate an approximate mean direction of transport from the northwest to the southeast (Map 4). The analysis of cross-bedding directions in the U.K.9A Marker gave a mean direction of transport at 111°. These results indicate that the direction of transport and, hence, the attitude of the depositional surface remained constant during the deposition of the U.K.9B Reefs, the U.K.9A Reef, and the U.K.9A Marker.

On considering the relationship between the orientation of the U.K.9 Zone reef bodies and the depositional strike, it is of importance to note the general principles outlined by Potter and Pettijohn (1963, p. 186). They mention that fluvial sand bodies tend to be oriented parallel to the depositional dip, while beach deposits commonly lie perpendicular to the depositional dip. The three observed southeast-trending channel-like deposits of the U.K.9B Reefs are oriented at right-angles to the depositional strike which is indicated by cross-bedding directions in the U.K.9B Reefs. This zone of reefs is therefore considered to be of fluvial origin.

Since there is parallelism of cross-bedding directions throughout the U.K.9 Zone, the depositional strike of the U.K.9A Reef, in the case of each of the five areas outlined on Map 4, was determined from cross-bedding directions in the U.K.9A Marker. In these areas, a definite relationship exists between the orientation of the long axes of the U.K.9A Reef bodies and the orientation of the depositional dip. In Areas 1, 4, and 5, the long axes of the U.K.9A Reef bodies are oriented parallel to the depositional dip, while in Areas 2 and 3 the long axes of the U.K.9A Reef bodies are at right angles to the depositional dip. Following the previously mentioned general principles set out by Potter and Pettijohn (1963, p. 186), it is seen that the U.K.9A Reef bodies of Area 1 were probably deposited in fluvial channels, since their long axes are oriented parallel to the depositional dip. The reef bodies of Areas 2 and 3 were presumably formed as beach deposits, since their long axes lie at approximately right-angles to the depositional dip. The reef bodies of Areas 4 and 5 were possibly deposited in original fluvial channels prior to the development of the postulated shoreline. Alternatively, the U.K.9A Reef of the entire area investigated was deposited under fluvial conditions. In Areas 1, 4, and 5, the reef bodies trending parallel to the depositional dip follow the general rule for fluvial deposits and are considered as such. In Areas 2 and 3, however, the topographical shape of the footwall possibly controlled the orientation of the U.K.9A Reef bodies (Antrobus and Whiteside, 1964, p. 146). Map 2 illustrates a number of south-trending areas of poor, or non-reef, deposition in Area 2. These areas can be considered as representing original topographic highs or island-like features which were separated by topographic lows to form a series of south-trending riffles. These riffles possibly controlled the distribution of the reef in Areas 2 and 3 where reef deposition dominantly took place in the "riffle troughs", to give rise to south-trending reef bodies in Area 2 and northeast-trending reef bodies in Area 3.

The mean cross-bedding directions calculated for each square of a 2000-foot grid serve as an additional illustration of the above-mentioned relationships between depositional strike and orientation of U.K.9A Reef bodies (Map 5). A limited number of 2000-foot squares studied contain more than ten cross-bedding directions. Visual inspection of the U.K.9A Marker cross-bedding directions in these areas reveal unimodal, bimodal, and polymodal distributions of cross-bedding vectors. The following relationships emerged when comparing the U.K.9A Marker modal direction(s) of transport with the U.K.9A Reef body orientation(s) for each of these areas (Fig. 3):

(i) The unimodal transport direction in Areas 14H and 15J is essentially parallel to the single orientation of the U.K.9A Reef body.

(ii) In the case of the individual Areas 14I, 15I, 7J, and 2D, the bimodal directions of transport are each approximately parallel to one of the two reef body orientations.

(iii) In Area 8F, the polymodal directions of transport and the complex pattern of the reef body are considered to have been caused by the effect of a locally elevated footwall feature. This island-like feature deflected the depositing currents of the U.K.9A Reef and the U.K.9A Marker, causing a divergence from the general trends. The above-mentioned "island" was identified as such by Antrobus and Whiteside (1964, p. 144) who considered it to be a small pre-U.K.9A Reef anticline.

The following explanation is offered as to the cause of the parallel relationship between the modal vectors in the U.K.9A Marker and the orientations of the U.K.9A Reef bodies : (1) currents trending down-slope scoured shallow channels in the footwall, which were partially filled by coarse U.K.9A Reef material; (2) during the initial stages of sedimentation of the U.K.9A Marker, the depositing currents were controlled to a certain extent by the partially filled channels.

(b) Trough Cross-Bedding Structures

The orientations of the axes of casts of trough cross-bedded units are illustrated on Map 4. The basal portions of trough cross-bedded units were observed only in the U.K.9A Marker. The long axes of these structures are oriented parallel to the general direction of transport obtained from the measurement of planar cross-bedding in the U.K.9A Marker. In the area studied, where planar cross-bedding is well developed in the U.K.9A Marker, trough cross-bedding was not relied on to indicate the direction of sediment transport.

(c) Ripple-Marks

Ripple-marks occur in sets which are limited to areas from less than one square foot to a few square yards. They all have relatively straight sub-parallel crests. Both the crests and the troughs are well rounded.

Eighty-four per cent of the ripple-marks measured are symmetrical in cross-section (Plate 4). The average strike of ripple axes, for each set of symmetrical ripples measured, is shown on Map 4. The rose diagrams on this map illustrate the spread, and the mean strike, of ripple axes for each of the Areas 1, 3, and 5. Histograms on Map 4 illustrate the graphical distribution of average amplitude, wave-length, and ripple index values. For each of the Areas 1, 3, and 5, the mean orientation of symmetrical ripple axes is parallel to the mean direction of transport obtained from the measurement of cross-bedding (see rose diagrams on Map 4).

According to Twenhofel (1961, p. 650), symmetrical ripple-marks are formed by the action of waves. The wave action causes an oscillatory movement of water, which agitates the bottom and throws up granular sediment into ripple ridges. The axes of these ridges coincide with the axial trend of the waves. The symmetrical ripple-marks of the area investigated are considered to have formed in this manner, where the direction of wave movement, which produced the ripple-marks, was normal to the direction of current movement, which gave rise to the planar cross-bedding. The waves possibly originated in isolated bodies of water due to winds blowing dominantly in a direction parallel to the general depositional strike (Twenhofel, 1961, p. 668; Pettijohn, 1957, p. 186; and Hargraves, 1961, p. 25). Alternatively, the waves and, consequently, the ripples were formed along the margins of streams by secondary oscillatory currents acting at right angles to the major stream currents which paralleled the depositional dip (A.O. Fuller, personal discussion).

Nine per cent of the ripple-marks measured are asymmetrical in cross-section. The average strikes of these ripple sets and their indicated directions of transport are given on Map 4. The mean ripple amplitude, ripple wavelength, and ripple index values are 4 mm., 49 mm., and 12 respectively.

Asymmetrical ripples are the product of a unidirectional current (Pettijohn, 1957, p. 186). From the writings of Twenhofel (1961, pp. 644-660), it is seen that these ripples are considered to form when the current velocity attains "the first critical point", and sand particles are set in motion. With an increase in the velocity of the current, "a second critical point" is reached when ripples disappear and the sand surface becomes smooth. On further increase of the current velocity, "a third critical point" is reached when sand-waves first appear. The current velocities of the first, second, and third critical points are dependent on the coarseness of material moved. Forbes, cited by Nassen (1904, p. 139), found a current velocity of 0.7 feet/second sufficient to set sand particles in motion, i.e. "the first critical point". The current velocity required for the formation of sand-waves, i.e. "the third critical point", was reported as 2.2 feet/second. The asymmetrical ripples of the area studied are considered to indicate the prevalence of relatively low-velocity currents during the formation of the U.K.9A Marker. These ripples were possibly formed by currents responsible for the formation of cross-bedding, i.e. currents flowing at right angles to the depositional strike.

Interference ripples constitute seven per cent of the ripple-marks observed in the U.K.9A Marker (Plate 5). These ripples are combinations of two sets of symmetrical ripples, two sets of asymmetrical ripples, or a set of each type, where the ripple axes are superimposed at approximately right angles to each other. They were presumably formed by a combination of two wave systems, two current systems, or a wave and a current system, acting at right angles to each other.

Symmetrical ripple-marks form only under water (Twenhofel, 1961, p. 667). Asymmetrical ripple-marks with a ripple index of 4 to 10 indicate water-formed ripples, while a ripple index of 20 to 50 is characteristic of wind-formed ripples (Twenhofel, 1961, p. 667). The calculated ripple index of 12.4 for the area studied indicates water-formed, rather than wind-formed ripples. In addition, it is doubtful whether aeolian ripples can be preserved (Pettijohn, 1957, p. 185). Ripple-marks are most abundant in relatively shallow-water deposits, but have been reported at depth in the ocean. The latter ripples have been observed only in very fine-grained materials. The ripple-marks of the relatively coarse U.K.9A Marker are therefore considered to have formed under shallow-water conditions.

(d) <u>Sand-Waves</u>

The orientations of sand-wave axes are presented on Map 4. The average sand-wave amplitude, wavelength, and ripple index values are 13 cm., 78 cm., and 6, respectively. These structures were observed only in the U.K.9A Marker (Plate 6). Their long axes are oriented at right angles to the general direction of transport, obtained by the measurement of planar cross-bedding which distinguishes them from the similar-appearing trough cross-bedding structures of the U.K.9A Marker. The calculated average sand-wave ripple index of six is close to the value of five obtained by Steyn (1963, p. 81) for sand-waves in the underground workings on the Livingstone Reefs of the West Rand.

Sand-waves are generally formed by relatively high-velocity currents. The scarcity of these structures, i.e. two observed in the total area studied, appears to indicate that relatively high-velocity currents were of minor importance during the deposition of the U.K.9A Marker.

(e) Mud-Cracks

The localities at which mud-cracks were observed are plotted on Map 4. They occur at the following stratigraphic positions :

Mud-cracks 1 : in the M.K.1 shale immediately below the U.K.9A Reef.

Mud-cracks 2 : in an argillaceous parting within the U.K.9A Reef.

Mud-cracks 3 : eighteen inches above the U.K.9A Reef in the U.K.9A Marker (Plate 7).

These mud-cracks are considered to be due to the sub-aerial drying of the sediments concerned.

C. PROPERTIES OF CONGLOMERATE PEBBLES

(a) Pebble Composition

The areal distribution of chert pebble percentages is given on Map 3 for the various horizons investigated.

Five pebble composition measurements, at two localities, gave an average value of 16 per cent chert pebbles for the M.K.2 conglomerate. The remaining pebbles were of quartz. The presence of a significant proportion of chert pebbles in this zone is supported by the findings of previous writers. Whiteside (1950, p. 250) described the predominance of chert pebbles near the base of the M.K.2 Zone. Towards the top of this zone, he observed a decrease in the percentage of chert, resulting in the predominance of quartz pebbles. Thirteen pebble composition measurements at five localities showed the M.K.1 conglomerate to contain an average of 26 per cent chert pebbles. Chert pebbles are also common in the M.K.1 puddingstone and the M.K.3 pebbly quartzite. Pebble composition measurements were not taken in these zones. The results obtained from 45 U.K.9B Reef pebble composition determinations, at 16 localities, support the findings of previous writers, namely, that the U.K.9B Reef consists almost exclusively of quartz pebbles. Chert pebbles were found to occur in trace amounts only, i.e. less than one per cent.

On East Daggafontein Mine, the U.K.9A Reef contains significant quantities of chert pebbles, where it overlies, or is in close proximity to, the sub-outcropping footwall beds containing chert pebbles (Plate 8). In the remaining areas, the pebbles of the reef consist predominantly of quartz, with trace amounts of chert (Plate 9). The above-mentioned relationship indicates that U.K.9A Reef material was definitely derived from the footwall in areas where it occurs in close proximity to the sub-outcropping chert-pebble conglomerates. This points to the origin of the U.K.9A Reef as being derived from the footwall beds, a conclusion also drawn by previous investigators. On Daggafontein Mine, the similarity in pebble composition between the U.K.9B Reefs and the overlying, or related, U.K.9A Reef neither proves nor disproves that the U.K.9A Reef was derived from the footwall U.K.9B Reefs, as both horizons contain a predominance of quartz pebbles.

(b) Pebble Size

Pebble size values are plotted on Map 3. Where a single sample was measured at a particular locality, the pebble size is given in millimetres. For the majority of localities, more than one sample was taken to test the local variation in pebble size. In these cases, the average pebble size, obtained by combining the individual measurements, was plotted. Histograms showing the pebble size distribution and the mean pebble size values, for each of the various areas investigated, are presented on Map 3. There is little local variation in pebble size between samples taken at the same locality.

In Area 5B, and in the area to the south of No. 1 Shaft of Daggafontein Mine, the pebble size values of the U.K.9A Reef are larger than average. Here the U.K.9A Reef is in close proximity to the sub-outcropping footwall reefs which invariably show the largest pebble size values recorded. These U.K.9A Reef pebble size anomalies, which coincide with the abnormal presence of chert pebbles in the reef, supply additional evidence that U.K.9A Reef material was derived by erosion of the footwall in these areas.

In Area 1 of Daggafontein Mine, the U.K.9A Reef pebble size values are consistently slightly smaller than those of the underlying, or closely situated, U.K.9B Reefs. This fact, on its own, neither proves nor disproves that the U.K.9A Reef was derived from its footwall in this area, as pebbles of a slightly smaller size and similar composition to those of the U.K.9B Reefs could have veen derived from a remote source area. However, it must be taken into account that the southeast-trending U.K.9A Reef bodies of Area 1 have narrow plan widths, as shown on Map 2, and that the vertical thickness of the reef seldom exceeds 24 inches. These reef bodies have been proved, by stoping and underground development, to be continuous from the eastern boundary of Area 1 to where they terminate at points which lie from one to several miles towards the west (Map 2). It is thought that post-U.K.9A Reef erosion of any consequence would have destroyed this remarkable continuity of the U.K.9A Reef bodies, and therefore the positions of termination of the reef bodies are considered to be original depositional features, i.e. the original points of origin of these reef bodies, and not the results of subsequent erosion. It is therefore apparent that the U.K.9A Reef bodies of Area 1 have their points of origin overlying, or in an immediate downcurrent direction from, the U.K.9B Reefs which strongly suggests that the U.K.9A Reef was derived from the associated U.K.9B Reefs in this area. The consistently smaller pebble size values of the U.K.9A Reef, as compared to those of the U.K.9B Reef in Area 1, are considered to be due to the following process. Erosion of the U.K.9B Reefs would generally be expected to result in the smaller size-grades of these reefs being more readily removed and transported than the larger size-grades. Thus, the products of erosion, i.e. the U.K.9A Reef material, would show slightly smaller pebble-size values than the residual, or non-eroded, U.K.9B Reefs.

Previous authors have produced no evidence that the U.K.9A Reef could have been derived, even in part, from a source area marginal to the East Rand Basin. They are, without exception, in favour of a local origin of the U.K.9A Reef due to erosion of coarse footwall horizons. The present study has revealed evidence only that the U.K.9A Reef was derived from the footwall. It is therefore the opinion of the author that, in the area studied, the U.K.9A Reef was entirely derived by erosion of the coarse footwall horizons. The bulk of the material constituting the U.K.9A Reef is considered to have been derived from the U.K.9B Reefs in the western portion of Daggafontein Mine. The erosion products were distributed southeastwards from this local source area. On East Daggafontein Mine, further material was added to the U.K.9A Reef due to erosion of the sub-outcropping coarse footwall horizons of the M.K.1, M.K.2, and M.K.3 zones.

Excluding the U.K.9A Reef pebble size values of the previously-mentioned areas containing pebble-size and chert pebble anomalies, a sharp difference in pebble-size values is apparent between Area 1 and the areas to the east (Areas 2, 3, 4, and 5A). This difference is somewhat obscured by a limited southeasterly-trending area of fluctuating pebble size values which traverses Areas 2 and 4. The pebble size values of this area range between the consistent values of Area 1 and the consistent values of the areas to the east.

The sudden decrease in pebble size between Area 1 and the areas to the east is considered to be due to an abrupt decrease in current energy between these two areas. This decrease in current energy can be accounted for by a sudden decrease in the slope of the depositional surface, where the U.K.9A Reef of the entire area investigated was deposited under fluvial conditions. Alternatively, the decrease in current energy can be explained by a change in environment of deposition, where the streams of Area 1 entered a limited body of water in Area 2, such that the transporting power of the streams was greater than that of the waves operating along the margin of the body of water. In either case, it is considered that, of the material transported in the Area 1 fluvial channels, the coarse fraction transported by traction would largely be retained in the fluvial channels. The finer material, being moved at a faster rate, by saltation and in suspension, would more readily find its way to Area 2 where, due to the decrease in current energy, it would be dumped, while some of the finer material would be transported further eastwards. This would result in the generally smaller pebble-size values and more poorly packed conglomerate of the areas situated to the east of Area 1, as compared to the larger pebble-size values and better packed conglomerate of Area 1.

A change in environment of deposition from that of fluvial in Area 1 to that of beach in Area 2, where the wave energy of the shoreline was relatively greater than that of the Area 1 streams is not considered probable. Under these conditions, the fluvial material entering the shoreline would be reworked by wave action, resulting in the larger pebbles being concentrated along the beach and the finer material being transported and deposited offshore. This process would result in the U.K.9A Reef conglomerates of Area 2 showing larger pebble-size values and better packing than the fluvial channel material of Area 1, which is not the case.

A decrease in current energy due to a reduction in the depositional slope does not account for the parallel relationship between the orientation of the elongated U.K.9A Reef bodies and the depositional strike in Areas 2 and 3. This relationship is considered to be due to the effect of smaller-scale topographical features of the footwall, i.e. riffle structures, which had their long axes trending at right-angles to the direction of transport. These structures resulted in the U.K.9A Reef being deposited mainly in the riffle troughs, so that the reef bodies are now seen to trend at right-angles to the direction of transport in these areas.

It is considered that the action of relatively low-energy waves operating along the shoreline of a restricted body of water would not entirely account for the relationship between the orientation of U.K.9A Reef bodies and the depositional strike, although it could quite possibly have been a contributing factor.

The southeast-trending area of intermediate pebble-size values, which traverses Areas 2 and 4, appears to be an extension of the largest reef body of Area 1. The intermediate pebble-size values recorded in this area might be accounted for by the following explanation. The major Area 1 fluvial channel is substantially larger than any of the other Area 1 fluvial channels, and it is therefore considered that its transporting power was greater than that of the smaller channels. This resulted in a certain amount of the coarse material, which was transported and generally retained in the Area 1 fluvial channels, being transported to a limited extent towards the southeast, across the locality of reduced current energy, i.e. through Area 2 and, to a limited extent, across Area 4, before the relatively high velocity currents related to the major Area 1 fluvial channel lost their transporting power.

(c) Pebble Orientation

Sampling stations are plotted on Map 4. In Area 1, preferred pebble orientation was observed at Stations 1 and 2, while the elongated pebbles of Stations 3 and 4 showed random orientation. At the former two stations, there is a preferred dip towards the west, i.e. upstream, where the mean angles of inclination are 30 degrees at Station 1 and 26 degrees at Station 2. In modern streams, the overwhelming majority of disc-like and ellipsoidal particles have their maximum projection plane dipping up-current, where angles of inclination vary between 10 and 30 degrees (Potter and Pettijohn, 1963, p. 36). The preferred pebble orientation observed is therefore considered to confirm a fluvial environment of deposition for the U.K.9A Reef in Area 1. Stations 1 and 2 were each located in the centre of a reef body, while Stations 3 and 4 were situated close to the outer margin of a reef body. It therefore appears possible that the consistent, central currents of the reef channels were capable of orientating the reef pebbles, as observed at Stations 1 and 2, while marginal, inconsistent currents gave rise to the random pebble orientation observed at Stations 3 and 4.

In Area 2, preferred pebble orientation was observed at Stations 5 and 6, and random pebble orientation was observed at Station 7. At Stations 5 and 6, pebbles showed a preferred dip towards the east. On detailed examination of the reef body, it is apparent that the proposed direction of U.K.9A Reef transport in this area is supported by the occurrence of abnormally large pebble-size values and significant percentages of chert pebbles in the reef to the west of the anticlinal feature. This material could have been derived only from the coarse sub-outcropping footwall beds of the anticline to the east. With the local direction of U.K.9A Reef transport being from east to west in this area, the pebbles therefore dip upcurrent, and are indicative of a fluvial environment of deposition for the U.K.9A Reef. At Station 7, the small reef-pebble size and the lack of elongated pebbles account for the absence of preferred pebble orientation. As the pebble size of the U.K.9A Reef in Area 2 is generally small and the reef bodies have largely been mined out, further stations were not available for study.

Sampling Stations 8 to 10, situated to the east of Area 2, were located along the margins of reef bodies. Random pebble orientation was observed at each of these stations.

(d) Sorting of the U.K.9A Reef Pebbles

The positions of stations from which samples were taken for investigation are indicated on Map 3. The results obtained for each of the various methods of determining sorting and median size are presented graphically, with median size-values being plotted against the appropriate sorting values (Figures 4, 5, 6).

When comparing the sorting values calculated from the number frequency data, it is seen that the samples studied in Area 1 (Samples A-F) are consistently more poorly sorted than those of the areas to the east (Samples H-L) (Figures 4 and 5, and Map 4). This difference is equally apparent when inspecting the sorting values calculated from the corrected weight percentage data (Figure 6). On considering only the difference in sorting values between Area 1 and the areas to the east, it appears possible that these results could be due to a change in environment of U.K.9A Reef deposition from that of fluvial in Area 1 to that of marine- or lake-beach in the areas to the east, where the fluvial deposits would generally be more poorly sorted than the beach deposits (Pettijohn, 1949, pp. 197-201; Emery, 1955, pp. 47-48).

When the sorting results are considered in conjunction with the difference in pebble size, which exists between Area 1 and the areas to the east, the following difficulty arises with regard to the above explanation. As previously explained, fluvial material entering a shoreline would be reworked, with the removal of fines to deeper water, and the accumulation of the coarse size-grades on the beach, resulting in a residue with a higher average size than before (Pettijohn, 1949, p. 542). This process would also result in better sorted material occurring in the beach area. In the area studied, however, the opposite is true concerning U.K.9A Reef pebble-size values, i.e. the pebble-size values in the areas to the east of Area 1 are consistently smaller than those of Area 1, and therefore an explanation, other than that of the considered change in environment of deposition, must be sought which will explain both the difference in pebble size and sorting values between these two areas.

It is thought that the following argument, previously advanced to account for the sudden decrease in pebble-size values between Area 1 and the areas to the east, also adequately explains the difference in sorting between these two areas. The material transported and retained in the Area 1 fluvial channels ranged from the coarse size-grades, transported by traction, to finer size-grades which were moved by saltation and in suspension. This relatively large range of size-grades, occurring above the selected 4 mm. = 2φ pebble population truncation point, naturally resulted in both the relatively poor reef sorting and the relatively large pebble-size values of this area. During transportation of the material in the Area 1 fluvial channels, the larger particles tended to lag behind, while the finer sizes bypassed the coarser in a down-current direction (Pettijohn, 1957, p. 541). This resulted in a larger proportion of fine material reaching Area 2 than was retained in the Area 1 fluvial channel.. On reaching Area 2, the decline in competency of the currents, due to the postulated reduction in dip of the depositional slope, caused the dumping of this relatively fine material. The resulting relatively limited range of small size-grades occurring above the selected 4 mm. = 2φ pebble population truncation point gave rise to both the relatively better reef sorting and the associated relatively smaller pebble-size values in this area, as opposed to those of Area 1. The difference in sorting values between Area 1 and the areas to the east is thus considered to be directly due to the decrease in pebble size between these two areas, coupled with the use of an arbitrary 4 mm. = 2φ pebble population truncation point when measuring pebble diameters, and not to be due to any change in environment of deposition which caused greater reworking of the U.K.9A Reef material and, hence, better sorting values in the area east of Area 1.

Similarly, the poor sorting value recorded in Area 4 (Sample G) is considered to be directly related to the relatively large pebble-size values of this area, and the use of a 4 mm. truncation point. The large range in pebble-size values resulted from the limited continuation of the major Area 1 channel and from the restricted transportation of a certain amount of coarse material beyond the postulated reduction in the inclination of the paleoslope.

D. STRUCTURE AND SEDIMENTATION

(a) The Distribution of the U.K.9A Reef in Relation to Folding

Map 6 illustrates the relation between the distribution of the U.K.9A Reef bodies and the pattern of U.K.9A Reef folding for Daggafontein and East Daggafontein mines.

In Area 1, the U.K.9A Reef bodies lie approximately parallel to the axial plane traces of a southeast-trending anticline and syncline. These structural features do not appear to have affected the general attitude of the depositional surface, and therefore the distribution or orientation of the U.K.9A Reef bodies, as these bodies show neither preferred development over the synclinal area nor preferred absence over the anticlinal area. The pattern of cross-bedding directions in the U.K.9 Zone indicates that, for the entire area investigated, the U.K.9A Reef depositional surface was a plane which dipped fairly consistently towards the east-southeast, with local variations in the direction of dip, which ranged from southeast to east between Areas 1 to 5, as illustrated on Maps 4 and 5. The general attitude of this plane is considered to have been due to regional tectonics, such as relative uplift in the northwestern marginal area of the present East Rand Basin. In Area 1, the orientation of the generally east-southeast-trending U.K.9A Reef bodies is believed to have been mainly controlled by the attitude of this regional depositional surface, where the reef bodies trending down-slope paralleled the depositional dip.

In the case of Area 4, the U.K.9A Reef horizon has been faulted to such an extent that the positions of the U.K.9A Reef contours, and hence the prediction of any structural trends in this area, are considered to be suspect.

In Areas 2, 3, and 4, a series of generally north-south-trending axial plane traces of a second group of anticlines and synclines strike roughly at 45 degrees to the axial plane traces of the Area 1 folds. In these areas, the axial plane traces of the north-south-trending folds lie approximately perpendicular to the local depositional dip. Here the major development of the U.K.9A Reef is confined to the areas lying between the axial plane trace of a syncline and the axial plane trace of the anticline immediately to the east. It is equally apparent that the U.K.9A Reef is poorly developed in the areas lying between the crest of an anticline and the trough of the next syncline towards the east. The relationship is considered to indicate the influence of the north-south-trending folds on the degree of dip of the regional depositional surface, and consequently on the distribution of the U.K.9A Reef bodies, and can be explained as follows. It is firstly assumed that the U.K.9A Reef footwall was deformed to give rise to a topographical pattern similar to the pattern of U.K.9A Reef folding. It is known, from U.K.9 Zone cross-bedding directions, that the depositional slope, whether steep or shallow, generally dipped in an east-southeasterly direction. With the axial plane traces of the generally north-south-trending anticlines and synclines lying approximately perpendicular to the depositional dip, the eastern limbs of the anticlines would be areas of relatively steep depositional dip. Under these conditions, with the U.K.9A Reef material generally being transported from west-northwest to east-southeast, U.K.9A Reef deposition would be limited where the relatively steep depositional slope supported relatively high velocity currents. On the other hand, reef material would be more freely deposited on the western limbs of the anticlines, i.e. also the eastern limbs of the synclines, where a reduction in the dip of the depositional surface caused a reduction in current velocities and a dumping of the transported material.

This relationship is also apparent on the mines to the north of the area studied. Here, the mined areas of U.K.9A Reef and the areas of known U.K.9A Reef ore reserves occur, for the most part, immediately to the east of the axial plane trace of the major north-south-trending synclinal feature which traverses the East Rand Basin.

In the case of the mines to the south of the area investigated, the above relationship is not apparent. Here, the main development of the U.K.9A Reef occurs immediately to the west of the major synclinal feature which traverses the East Rand Basin. In the case of Vogelstruisbult Mine, de Jager (1957, Plate VI) showed the relation between local eroded anticlines and the occurrence of the U.K.9A Reef in the adjacent synclinal areas. Here erosion penetrated the M.K.1 beds, with exposure of the underlying formations, to make these structures easy to detect. This relationship can also be seen in the southern portions of Areas 2 and 4 of Daggafontein and East Daggafontein mines, where the U.K.9A Reef is generally absent over the eroded anticline, but occurs in the immediately adjacent area (Maps 2 and 3). A similar pre-U.K.9A Reef anticline of relatively small dimensions occurs to the immediate southeast of No. 4 Shaft, Daggafontein Mine, where an area characterized by the general absence of U.K.9A Reef over an anticline is surrounded by payable U.K.9A Reef (Antrobus and Whiteside, 1964, p. 144). In this case, erosion of the anticline has not penetrated the M.K.1 sediments, which makes the identification of this structure difficult. In the northwestern section of Marievale Mine, the area characterized by the general absence of U.K.9A Reef, and surrounded by payable reef, is considered to be similar to the local footwall structure to the southeast of No. 4 Shaft on Daggafontein Mine. The close relationship between these relatively small footwall structures and the occurrence of payable U.K.9A Reef in the mines to the south of the area studied appears to indicate that these footwall structures, and not the larger-scale pattern of folding, as depicted by structure contour plans of the U.K.9A Reef, were responsible for the distribution of the U.K.9A Reef in this particular area.

(b) The Relation between Sedimentary Parameters and the Pattern of Folding

The areal variation in cross-bedding directions (Map 4) and the areal variation in pebble size (Map 3) in Daggafontein and East Daggafontein mines show a relation to the pattern of U.K.9A Reef folding (Map 6).

The cross-bedding directions indicate a marked change in the direction of dip of the depositional surface from that of east-southeast in Area 1 to that of east in Area 2. The line along which this change takes place, i.e. the boundary line between Areas 1 and 2, corresponds closely to the axial plane trace of the previously mentioned major north-south-trending syncline which traverses the East Rand Basin (Maps 4, 5, and 6). This relationship can be explained by considering that a generally east-southeast-dipping depositional slope was deformed by a north-south-trending syncline. This resulted in a local change in direction of depositional dip, and, consequently, in the direction of transport from east-southeast in Area 1 to east in Area 2. In addition, the eastern limb of this north-south-trending syncline was an area of reduced depositional dip, as compared to the western limb. As previously explained, such a reduction in the dip of the depositional surface between Areas 1 and 2 best explains the sudden reduction in U.K.9A Reef pebble-size values between these two areas.

From the preceding relationships between structure and sedimentation, it is seen that the known distribution of the U.K.9A Reef bodies, over the greater portion of the East Rand and the known areal variation of U.K.9A Marker cross-bedding directions and U.K.9A Reef pebble-size values on Daggafontein and East Daggafontein mines is related to the pattern of U.K.9A Reef folding, and can be accounted for through the pattern of folding having influenced the topography of the U.K.9A Reef footwall.

(c) Evidence of Pre-U.K.9A Reef Folding

Isopach maps (Maps 7 to 13), a structure contour plan of the U.K.9A Reef (Map 14), a footwall map of the U.K.9A Reef (Map 3), and paleogeological sections at the time of the U.K.7 Zone (Figure 2) are presented for interpretation of the effect of folding on the deposition of the selected groups of sediments overlying the Main Reef Leader.

It was not possible, by comparing the isopach maps representing pre-U.K.9A Reef sediments to the general pattern of Witwatersrand System folding, as depicted by the structure contour plan of the U.K.9A Reef, to determine whether this pattern of folding was in progress prior to the formation of the U.K.9A Reef, as erosion has removed large quantities of the post-Main Reef Leader, pre-U.K.9A Reef sediments. Pre-M.K.1 erosion which penetrated down to the Bird Amygdaloid has removed large portions of the Bird Quartzite, Kimberley Shale, M.K.3 and M.K.2 sediments (Figure 2). Post-M.K.1 erosion, which produced a marked angular unconformity below the U.K.9 Zone in this area, also removed previously deposited sediments (Map 3).

The above-mentioned pre-M.K.1 erosion does not appear to be related to the general pattern of Witwatersrand System folding in which maximum erosion coincides with areas of maximum uplift, i.e. anticlinal areas. A comparison between Maps 11, 12, and 14 illustrates that the east-southeast-trending area of maximum pre-M.K.1 erosion lies to the north of the anticline which trends southeastwards through Daggafontein Mine.

A limit was placed on the number of isopach maps, representing the post-Main Reef Leader, pre-U.K.9A Reef sediments, which could be compiled for comparison with the structure contour plan of the U.K.9A Reef. Lack of underground intersections in the case of the post-Main Reef Leader, pre-M.K.3 sediments made it impossible to construct separate isopach maps of the Bird Quartzite, Bird Amygdaloid, and Kimberley Shale. Only a single isopach map, representing these sediments, could be compiled by using the Main Reef Leader and U.K.9A Reef structure contour plans and the borehole and shaft intersections of the M.K. Zone. In the case of the M.K. sediments, it was considered that the presentation of separate isopach maps for each of the divisions of this zone would not reveal the presence of pre-U.K.9A Reef folding any more clearly than a combined isopach map, due to the limited distribution of the M.K.2 and 3 zones, caused mainly by pre-M.K.1 erosion. The combined isopach map of the post-Main Reef Leader, pre-U.K.9A Reef sediments was compiled to investigate any cumulative effect of folding on sedimentation, which might not have been revealed by the individual isopach maps. The possibility exists that the presence of pre-U.K.9A Reef folding was not indicated simply because isopach maps were not drawn of the appropriate sedimentary units. This applies particularly in the case of the Bird Quartzite which was not affected by pre-M.K.1 erosion.

The presence of pre-U.K.9A Reef eroded anticlines (Map 3, and de Jager, 1957, Plate VI) illustrates that the U.K.9A Reef footwall sediments were definitely subjected to rather small-scale folding, while the consistent attitude of the sub-outcropping M.K.1 beds across East Daggafontein Mine (Map 3) indicates larger-scale deformation prior to the formation of the U.K.9A Reef.

A distinct relationship exists between the pattern of Witwatersrand System folding, as depicted by the structure contour plan of the U.K.9A Reef, and the variation in thickness of the selected groups of sediments occurring between the U.K.9A Reef and the base of the Transvaal System (Maps 6 to 10). In each case, the sediments show a thinning over the U.K.9A Reef anticlinal features and a thickening over the U.K.9A Reef synclinal features. This relationship indicates that the general pattern of Witwatersrand System folding was in progress during the deposition of each of these groups of sediments.

In the area studied, the upper sediments of the Transvaal System have been eroded, and this system is represented by only the Black Reef and a portion of the Dolomite Series. Thus, a comparison between the isopach map of the Transvaal System (Map 7) and the general pattern of Witwatersrand System folding, as depicted by the structure contour plan of the U.K.9A Reef, will not reveal whether the variation in thickness of the Transvaal System sediments of this area was caused by deposition on an already folded Witwatersrand System floor, or whether the variation in sediment thickness was the result of contemporaneous post-Transvaal System folding, followed by erosion. When considering, however, only the isopach map of the Black Reef Series (Whiteside, 1950, Plate 3), it is seen that the variation in thickness of this series is not related to the general pattern of Witwatersrand System folding in the area studied. This indicates that the Black Reef and, hence, the Transvaal System were not deposited on a folded Witwatersrand System foot-wall. The variation in thickness of the Black Reef Series is possibly related to the topography of its floor caused by pre-Black Reef erosion. The almost identical relationship between the variation in thickness of the Dolomite Series (Whiteside, 1950, Plate 3; also see Map 7 which is virtually an isopach map of the Dolomite Series, since the Black Reef Series of the area concerned ranges in thickness from 0 - 20 feet) and the general pattern of Witwatersrand System folding, as depicted by the structure contour plan of the U.K.9A Reef, points to the major deformation of the pre-Dolomite Series formations of the area studied during and/or after the deposition of the Dolomite Series.

(d) The Effect of Erosion on the U.K.9A Reef Footwall

De Jager (1957, p. 164-167) clearly shows the relation between eroded footwall anticlines and the distribution of the U.K.9A Reef, where the reef was occasionally deposited as a veneer of lag gravel on the crests of the truncated anticlines, more frequently on the flanks of these features, and largely in the sub-U.K.9A Reef synclines. The topographical effect of the folded footwall on the distribution of the U.K.9A Reef bodies is also apparent to the southwest of No. 1 Shaft, Daggafontein Mine, where erosion of a footwall anticlinal feature has locally produced reef bodies which trend in the opposite direction to the general dip of the depositional surface, due to the local topography produced by this anticline. These observations indicate that post-M.K. 1 erosion was not sufficiently severe to neutralize the topographical effect of the folded footwall on the deposition of the U.K.9A Reef.

(e) Conclusions

From the above information, it is concluded that relatively small-scale folding, as shown by the eroded footwall anticlines, definitely took place prior to the deposition of the U.K.9A Reef. Larger-scale footwall folding, of the pattern and scale illustrated by the U.K.9A Reef structure contour plan, cannot be proved, or disproved, in this area, due to the effect of erosion on the post-Main Reef Leader, pre-U.K.9A Reef sediments. Folding of this type, however, is known to have taken place during the deposition of the sediments immediately above the reef, and to have been active at least until the deposition of the Dolomite Series of the Transvaal System. Pre-U.K.9A Reef erosion was not severe enough to obliterate the topographical effect of relatively small-scale footwall folding which controlled the distribution of the reef in certain areas. It is therefore considered that pre-U.K.9A Reef erosion did not neutralize the topographical effect of the large-scale footwall folding.

The presence of major pre-U.K.9A Reef folding, of the pattern and scale depicted by the U.K.9A Reef structure contour plan, and its topographical effect on the sedimentation of the U.K.9A Reef enables a reasonable explanation to be put forward in accounting for the distribution of the U.K.9A Reef bodies, and the areal variation of cross-bedding directions and pebble-size values, under the indicated fluvial conditions.

E. GOLD DISTRIBUTION

An investigation of the underground sampling records on Daggafontein Mine revealed that the U.K.9B Reefs contain a fairly even distribution of gold, at an average of about 1.0 dwt./ton, while isolated values of up to 6.0 dwts./ton over a few inches have been occasionally encountered. The M.K.2 Zone of the area studied contains erratic, but significant, gold values at an approximate average of 0.5 dwts./ton. Payable values have been intersected in boreholes, and very limited stoping has been carried out in this zone. The coarse sediments of the M.K.1 and 3 zones contain negligible quantities of gold.

From the above, it is seen that certain of the U.K.9A Reef footwall conglomerates, particularly the U.K.9B Reefs, do contain gold. As these sub-outcropping footwall beds show a decrease in thickness and a decrease in grain size towards the southeast, it is considered that they, together with the gold they contain, were derived from a source area situated to the northwest of the present East Rand Basin. In the case of the U.K.9A Reef, however, the local occurrence of the reef bodies within the sedimentary basin and the information gained from pebble size and pebble composition investigations point to the local origin of the U.K.9A Reef material. It is therefore considered that the U.K.9A Reef gold was also derived by erosion and reworking of the footwall reefs, with the U.K.9B Reefs being the chief source of both the U.K.9A Reef gold and the coarse reef material.

THE DEPOSITIONAL ENVIRONMENT OF THE U.K.9 ZONE SEDIMENTS

A. ENVIRONMENT OF DEPOSITION

The following factors indicate a continental and essentially fluviatile environment of deposition for the U.K.9 Zone sediments of the area studied :

(a) the observed channel-like nature of the basal contact of the U.K.9B Reef zone and the parallel orientation of these channels to the direction of depositional dip;

(b) the channel-like nature of the U.K.9A Reef bodies to the west of No. 3 Shaft, Daggafontein Mine;

(c) the orientation of the U.K.9A Reef bodies parallel to the direction of depositional dip in Areas 1, 4, and 5; (the parallel orientation of the reef bodies to the direction of the depositional strike in Areas 2 and 3 can be explained as being due to the local control of footwall topography on reef deposition under essentially fluviatile conditions);

(d) the characteristic fluvial pebble orientation of the U.K.9A Reef pebbles in both Areas 1 and 2;

(e) the presence of mud-cracks, immediately below the U.K.9A Reef in Area 4, in the reef in Area 2, and above the reef in Area 3;

(f) the presence in the U.K.9A Marker of both oscillation ripple-marks, indicating sub-aqueous deposition, and mud-cracks, pointing to sub-aerial exposure.

The following evidence indicates an originally southeasterly-dipping depositional surface, with minor local variations in the direction of dip, during the deposition of the Upper Witwatersrand System sediments, including those of the U.K.9 Zone :

(i) the easterly and southeasterly thinning, and decrease in grain-size, in the case of the Upper Witwatersrand System sediments (Antrobus, 1964, p. 113);

(ii) the direction of sediment transport in the Main-Bird Series quartzites, which ranges between east and south, with an average southeasterly trend (Hargraves, 1961, Figure 3);

(iii) the generally east-southeast direction of transport in the U.K.9 Zone which ranges between east and southeast for Daggafontein Mine and East Daggafontein Mine (Maps 4 and 5).

When inspecting the known distribution of the U.K.9 Zone sediments of the East Rand Basin, it is seen that the area studied includes the most southeasterly exposures of this zone (Map 6, and de Jager, 1957, Plate VII). The sediments of the area investigated are thought to be fluviatile, and, considering a generally southeasterly-dipping depositional surface for the greater part of the present East Rand Basin, it follows that the U.K.9 Zone sediments occurring in an up-dip position, with reference to the depositional surface, are also fluviatile.

The regional continental setting envisaged is that of an extensive subsiding pediplain where subsidence and fluviatile accumulation of sediments on the pediplain were generally synchronous with uplift and erosion of the source area, situated to the northwest of the present East Rand Basin. It is considered that rather special conditions, characterized by a lack of vegetation and a high rainfall, prevailed during the deposition of these sediments. The existence of such conditions during Witwatersrand times has previously been proposed by Brock (1954, p. 8).

B. NATURE OF DEPOSITION

Pettijohn (1957, p. 638) points out that diastrophism is the ultimate cause of sedimentation, where tectonics directly affects the rate of erosion and sedimentation, and thereby controls the kinds of sediments deposited.

It is put forward that the following sequence of events controlled the nature of sedimentation and the type of sediments deposited during the formation of the U.K.9 Zone. Subsequent to the deposition of the M.K.1 sediments over the pediplain, relatively rapid uplift of the source area, situated in the northwestern marginal area of the present East Rand Basin, took place. This caused substantial sheet erosion of the rather gently folded sediments of the pediplain, which initiated the truncation of folded structures and the exposure of the Kimberley Shale, M.K.3, and M.K.2 sediments, in addition to the already exposed sediments of the M.K.1 Zone. The erosion of the pediplain sediments was accompanied by the deposition of the U.K.9C Reefs in close proximity to the highlands of the source area, as shown by the restricted occurrence of these reefs in the northwestern portion of the East Rand Basin (Map 6). This deposit, with its large variation in thickness, particle size, particle type, and particle roundness is considered to closely represent a true pediment deposit (see descriptions of the U.K.9C Reefs by Sharpe, 1942-45, p. 862; and by Papenfus, 1957, p. 26; also see the general nature of pediment deposits by Twenhofel, 1961, p. 803).

With the reduction in the relief, and in the rate of erosion of the source area, and the progression towards more stable conditions of sedimentation, the interlensing conglomerates and quartzites of the U.K.9B Reef Zone were deposited over a large extent of the pediplain, i.e. in the western half of the East Rand Basin. The sediments of this zone, which are limited to the extreme western portion of the area studied, are considered to have been transported mainly by sheetflood and/or aggrading streams to give rise to a blanket deposit with the local development of channels. This deposit is not directly comparable with the deposits of a pediment, as it contains both conglomerates and quartzites, where the particles of each are restricted in size, shape, and composition. It is considered, however, that this zone bears a general relationship to the sediments of a valley-flat environment (see the general nature of valley-flat deposits by Twenhofel, 1961, pp. 807-808).

With further reduction in elevation of the source area, the deposition of sediments on the pediplain was reduced to a minimum, and finally replaced by erosion. The previously deposited coarse sediments of the pediplain, particularly the zone of U.K.9B Reefs with its relatively high gold values and its greater areal extent, as compared to the other coarse sediments exposed on the pediplain, were reworked by the action of streams, to produce payable U.K.9A Reef bodies. Stream erosion of the U.K.9B Reefs in the eastern portion of Springs Mine and on Daggafontein Mine resulted in the fluviatile transportation of the eroded material in the general direction of the depositional dip to produce a series of generally east-southeast-trending U.K.9A Reef bodies on these mines. The approximately east-southeast-trending U.K.9A Reef bodies of Government Gold Mining Areas, which possibly extend through East Geduld and Geduld mines and which are considered to parallel the local depositional dip, are also thought to have originated in the above manner.

In the area bordering Daggafontein and East Daggafontein mines, where the generally east-southeast-trending streams of Daggafontein Mine intersected the postulated north-south-trending footwall synclinal feature, dumping of the transported material took place on the eastern limb of this synclinal feature. Here, the depositional dip was significantly reduced, to produce a major north-south-trending zone of reef bodies situated parallel to the local north-south depositional strike of this particular area, i.e. Area 2. The U.K.9A Reef material deposited here is considered to have been further influenced by a series of minor north-south-trending riffles, which resulted in individual reef bodies generally showing the same orientation as the major north-south-trending zone. This major zone of reef bodies is known to extend southwards through Vogelstruisbult Mine into Marievale Mine where it sub-outcrops. In addition, it is thought to extend northwards through Grootvlei and East Geduld mines, and, possibly, also Modderfontein East Mine, as indicated by the ore reserves on the shareholders' plans of the two first-mentioned mines.

On East Daggafontein Mine, a certain amount of U.K.9A Reef material was transported and deposited to the east of this major north-south-trending zone of reef bodies. In Area 4, the southeast-trending reef body is considered to represent an extension of the main east-southeast-trending stream deposit of Area 1. In this case, a restricted amount of relatively coarse material is thought to have been transported by the relatively strong currents of this major fluvial channel for a limited distance beyond the area of reduced dip of depositional slope. In Areas 3 and 5, as in the case of Area 2, the deposition of U.K.9A Reef material is thought to have been largely controlled by the steepness of the depositional slope which varied areally due to the structure of the footwall. In areas of relatively steep depositional slope, such as on the eastern limbs of the north-south-trending footwall anticlines, reef deposition was poor due to the action of relatively high velocity currents. On the other hand, in the areas of less steep depositional slope, which occurred on the western limbs of the footwall anticlines, lower velocity currents allowed the deposition of the transported material and the formation of significant bodies of U.K.9A Reef. This process produced the generally north-south-trending zones of reef bodies in Areas 3 and 5. In Area 3, the parallel orientation of the individual reef bodies to the depositional strike is considered to be due to the influence on reef deposition of northeast-trending footwall undulations or riffles similar to those of Area 2. In Area 5, the influence of such footwall structures appears to have been negligible, as the orientation of the individual reef bodies, which trend parallel to the depositional dip, appears to have been dominantly controlled by the regional attitude of the depositional surface.

In certain portions of the area studied, the U.K.9A Reef has been derived to a greater or lesser extent by erosion of the coarse M.K.1, 2, and 3 sediments. This is particularly apparent in Area 5 and in the area to the southwest of No. 1 Shaft, Daggafontein Mine from the study of pebble size and pebble composition in the U.K.9A Reef and in the footwall reefs. De Jager (1957, Plate VI) clearly illustrates this relationship on Vogelstruisbult Mine where the U.K.9A Reef is distributed in relation to the truncated footwall anticlinal features which appear to have been the main source of the reef in this area.

The formation of the U.K.9 Zone was completed by the deposition of the U.K.9A Marker. This zone is also considered to have been deposited under essentially fluvial conditions, possibly during relatively slow elevation of the source area which resulted in rather quiet conditions of sedimentation over the pediplain.

SEDIMENTOLOGICAL GUIDES TO ORE

Payable gold values in the U.K.9A Reef are invariably associated with well-developed reef, low gold values with poor reef development, and a general absence of gold values where the reef is not developed. Therefore, regardless of the theory favoured for the origin of the gold, the search for payable U.K.9A Reef is essentially the search for well-developed bodies of U.K.9A conglomerate.

A. DAGGAFONTEIN MINE

In Area 1, the five major elongated reef bodies are oriented parallel to the general direction of cross-bedding. These reef bodies are considered to be fluvial deposits which were formed by streams flowing in the direction of dip of the depositional slope. The majority of these reef bodies have local points of origin, and are continuous until they meet the major north-south-trending reef zone of Area 2. It is considered that the presence of further major reef bodies in Area 1, if they exist, would be revealed by payable values extending northwestwards from the boundary between Areas 1 and 2. As the almost complete removal of the Area 2 reef bodies has not revealed further extensions of payable reef towards the northwest, it is considered that all the major reef bodies of Area 1 have been discovered. This conclusion has been confirmed by a limited amount of underground development between the Area 1 reef bodies.

Further underground development in Area 1 of Daggafontein Mine should therefore be restricted to following the existing major reef bodies to their sources, utilizing the fact that these reef bodies lie parallel to the general direction of cross-bedding. Attention should be paid to the possibility of minor tributaries entering the major channels. These would be indicated by the extension of a zone of payable values trending at an angle to the main reef body and by the modal distribution of cross-bedding directions in the areas concerned, i.e. Map 5, Areas 2D and 7 J.

B. EAST DAGGAFONTEIN MINE

On East Daggafontein Mine, a distinct relationship exists between the distribution of the U.K.9A Reef bodies and the pattern of U.K.9A Reef folding which, in turn, is considered to reflect the pre-existing structure of the U.K.9A Reef footwall. This relationship indicates that the eastern limbs of the postulated north-south-trending footwall synclinal features were areas most favourable for reef deposition (Maps 2 and 15).

In the case of the westernmost of these areas, i.e. Area 2, the reef has largely been mined out. Here, the reef lies immediately to the east of the synclinal axial trace, and has been followed continuously across Daggafontein and East Daggafontein mines. In Area 3, the extent of the U.K.9A Reef bodies, occurring on the eastern limb of the syncline, has largely been determined by underground development. In Area 5, the zone of U.K.9A Reef payability, lying to the east of the synclinal axial trace, possibly extends to the north and to the south, parallel to the axial trace of the syncline. The extent of the major reef body of Area 4, which is thought to be a limited extension of the relatively coarse fluvial deposit of Area 1, has largely been delineated by underground development and stoping. The occurrence of further payable U.K.9A Reef bodies to the southeast, i.e. in a down-current direction, of the exposed Area 4 reef bodies cannot be reliably predicted due to the apparent absence of fold axes trending approximately normal to the direction of sediment transport in this area.

The study of cross-bedding has established that the general direction of transport of U.K.9A Reef material was to the southeast in the area investigated. This information leads to the assumption that some reef material was transported and deposited to the east of the Area 5 zone of reef bodies, in the same way as reef material is known to have been transported and deposited to the east of Area 2. Map 2 reveals that the volume of reef material deposited in Area 2 exceeds that deposited in Area 5. A further decrease in the amount of material deposited can thus be expected to the east of Area 5. The structure of the U.K.9A Reef horizon to the east of the Area 5 zone of reef bodies is not known. Therefore, the position of further deposits of U.K.9A Reef, in relation to the inferred structure of the pre-U.K.9A Reef surface, cannot be predicted in this area.

The relation between structure and U.K.9A Reef sedimentation indicates that the western limbs of the synclinal features were areas of poor reef deposition. Further underground development is therefore not recommended in these areas.

C. OTHER MINES ON THE EAST RAND

The axial trace of the major north-south-trending synclinal feature which traverses Area 2 of Daggafontein Mine can be extended northwards by means of the Main Reef Leader structure contour plans and southwards by means of U.K.9A Reef structure contour plans. The eastern limb of this syncline should represent an area favourable for U.K.9A Reef deposition, due to the reduced dip of the depositional slope. To the north of the area studied, on Grootvlei Mine and on East Geduld Mine, this appears to be the case, as substantial U.K.9A Reef ore reserves have been blocked out where underground development has been carried out to the east of the synclinal axial trace.

To the south of the area studied, the major north-south-trending zone of U.K.9A Reef bodies has been followed through Vogelstruisbult Mine and into Marievale Mine where the U.K.9A Reef horizon sub-outcrops. Here, the development of the U.K.9A Reef is not restricted to the area immediately east of the axial trace of the U.K.9A Reef syncline, but occurs mainly to the west of it. This appears to be due to the control of U.K.9A Reef deposition by locally elevated footwall structures.

The generally east-southeast-trending reef bodies of Government Gold Mining Areas, East Geduld Mine, and possibly also Grootvlei Mine are considered to be of the same type as those of Area 1 in Daggafontein Mine, i.e. deposits occupying fluvial channels which paralleled the dip of the depositional slope. The possibility exists of further east-southeast-trending reef bodies intersecting the major north-south-trending reef zone on Grootvlei Mine and East Geduld Mine. The extent to which U.K.9A Reef material was transported and deposited to the east of the north-south-trending zone of payability on Grootvlei Mine, and the possibility of such material having accumulated on the eastern flanks of footwall synclines is considered to be worth investigating.

* *

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KEY TO MAPS

Map 1 : Locality map, showing the location of the area studied in relation to the northwestern portion of the known extent of the Witwatersrand Basin.

Map 2 : Map of U.K.9A Reef payshoots.

Map 3 : Footwall map of the U.K.9A Reef, showing the pebble size and pebble composition of the U.K.9A Reef and the footwall reefs. Also shown are histograms of pebble size and composition.

Map 4 : Sedimentary structures in the U.K.9 Zone. Also shown are histograms and rose diagrams of ripple-mark data.

Map 5 : Analysis of cross-bedding data. Also shown are rose diagrams of cross-bedding data.

Map 6 : Structure contour map of the U.K.9A Reef.

Map 7 : Isopach map of a portion of the Transvaal System, viz. the Black Reef Series and part of the Dolomite Series.

Map 8 : Isopach map of the strata between the top of the U.K.3 Zone and the base of the Transvaal System.

Map 9 : Isopach map of the zones U.K.7 to U.K.3.

Map 10 : Isopach map of the strata between the top of the U.K.9A Reef and the top of the U.K.7 Zone.

Map 11 : Isopach map of the zones M.K.3 to M.K.1.

Map 12 : Isopach map of the strata between the top of the Main Reef Leader and the base of the U.K.3 Zone.

Map 13 : Isopach map of the strata between the top of the Main Reef Leader and the top of the U.K.9A Reef.

Map 14 : Underground development and stoping on the U.K.9A Reef, in relation to major structural trends.

* *

KEY TO FIGURES

Figure 1 : Generalised geological section of the East Rand.

Figure 2 : Paleogeological sections at the time of the U.K.7.

Figure 3 : Histograms of U.K.9A Marker cross-bedding data, showing modal directions of transport, for comparison with orientations of U.K.9A Reef bodies (shown by arrows).

Figure 4 : A comparison between the uncorrected number frequency sorting (standard deviation) and median size values of the samples studied.

Figure 5 : A comparison between the uncorrected number frequency sorting (graphic standard deviation) and median size values of the samples studied.

Figure 6 : A comparison between the corrected volume frequency sorting (graphic standard deviation) and median size values of the samples studied.

* *

KEY TO PLATES

Plate 1 : Gently- to moderately-dipping Kimberley shale, M.K.1 conglomerate, and M.K.1 puddingstone, forming an angular unconformity with the overlying horizontally-bedded U.K.9A Marker quartzite. A feature of additional interest is the restriction of most of the quartz veining to the M.K.1 conglomerate.

Plate 2 : Cross-bedding in a quartzite parting within the U.K.9A Reef.

Plate 3 : Planar cross-bedded unit characterized by an essentially planar basal contact and straight foresets. The cross-bedded unit is in quartzites of the U.K.9A Marker which is underlain by M.K.1 chloritoid shale.

Plate 4 : Casts of symmetrical (oscillation) ripple-marks in the U.K.9A Marker.

Plate 5 : Interference ripple-marks in the U.K.9A Marker.

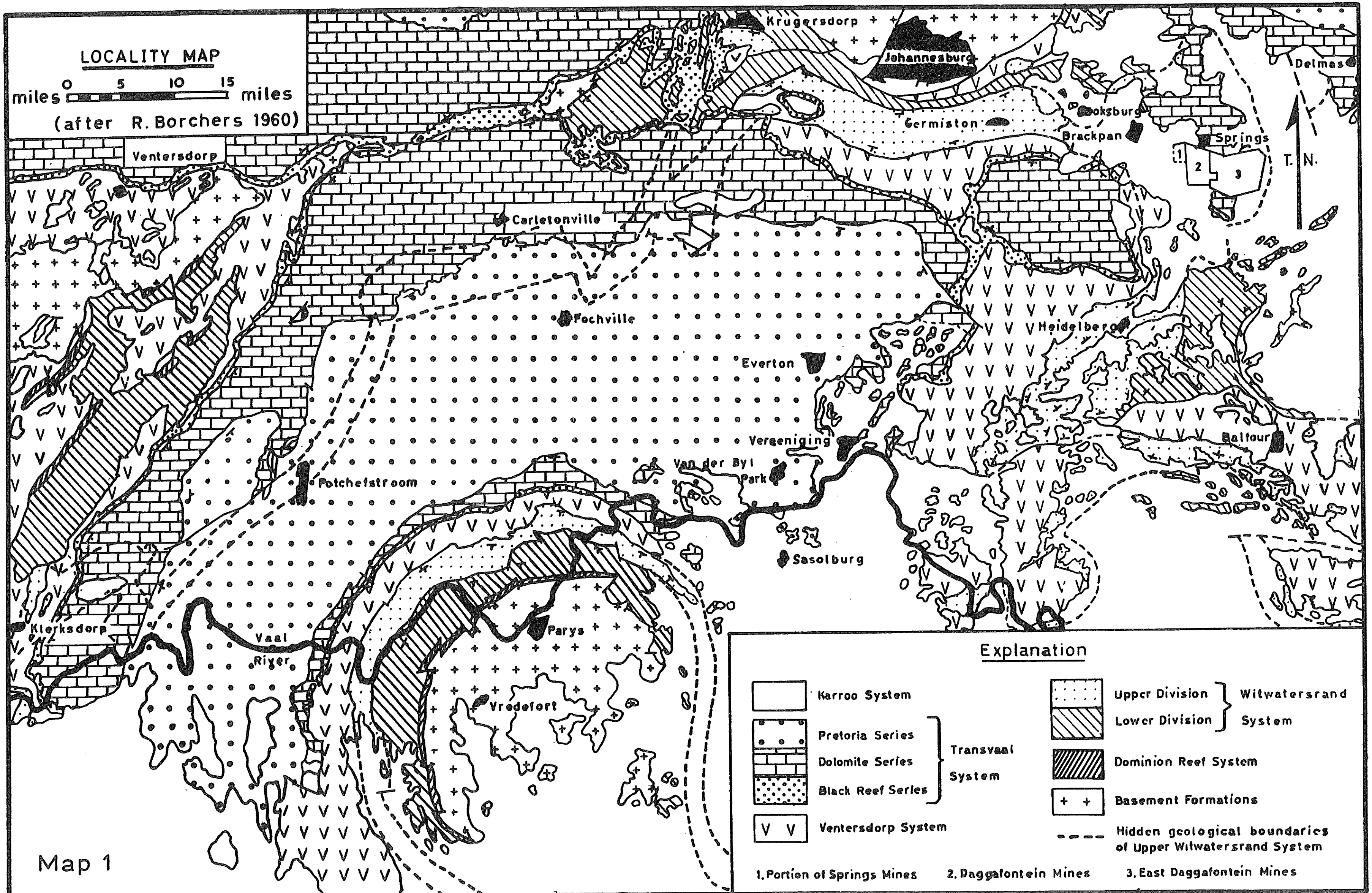
Plate 6 : A sand-wave in the U.K.9A Marker.

Plate 7 : Mud-cracks in the U.K.9A Marker.

Plate 8 : The presence of large quartz and chert pebbles in the U.K.9A Reef where it occurs in close proximity to the sub-outcropping footwall reefs.

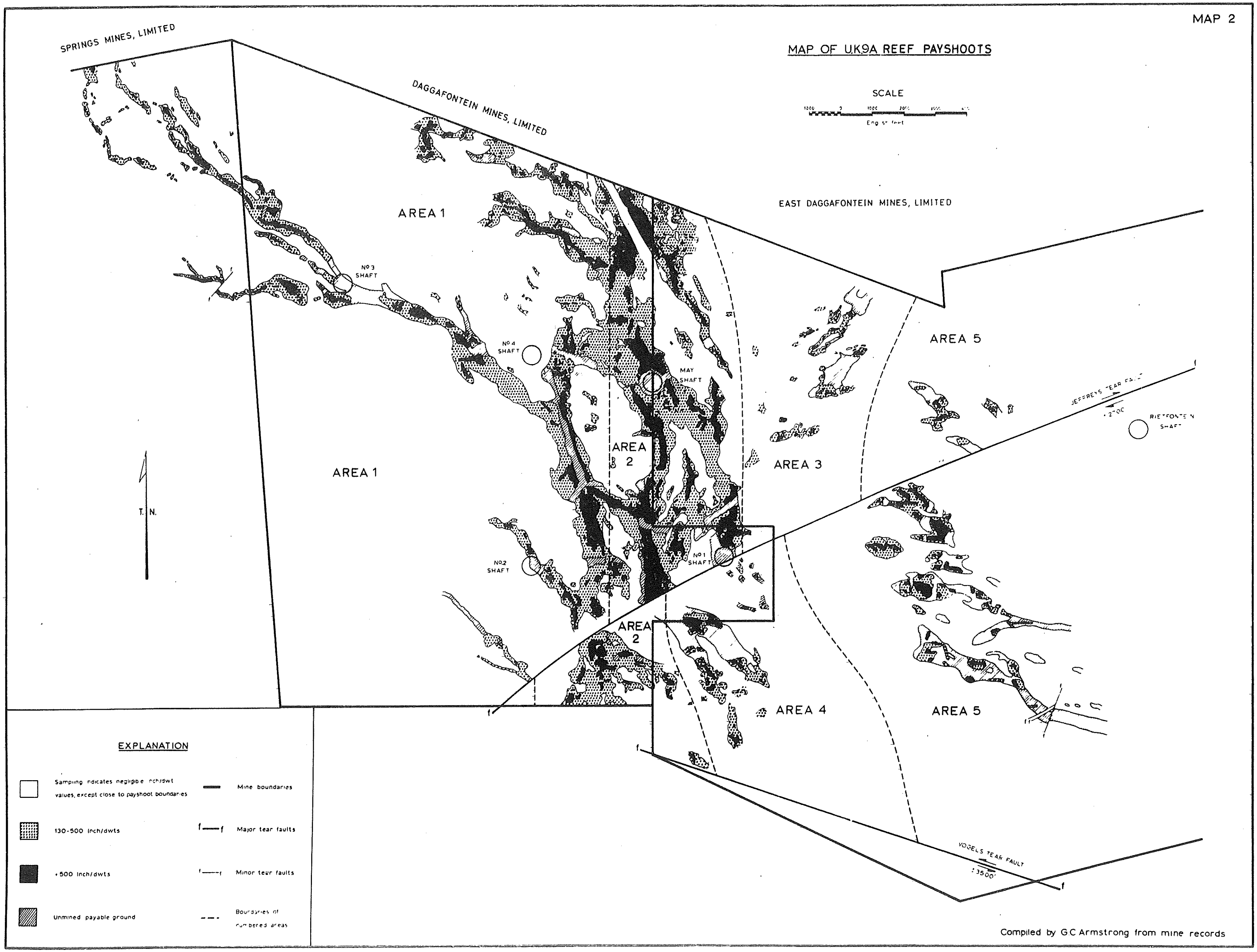
Plate 9 : U.K.9A Reef of Area 2, which straddles the common boundary of Daggafontein and East Daggafontein mines, showing the relatively small size of the almost exclusively quartz pebbles, the relatively poor pebble packing, and the relatively good sorting, in comparison with the U.K.9A Reef of Area 1 (see Plate 8).

* *

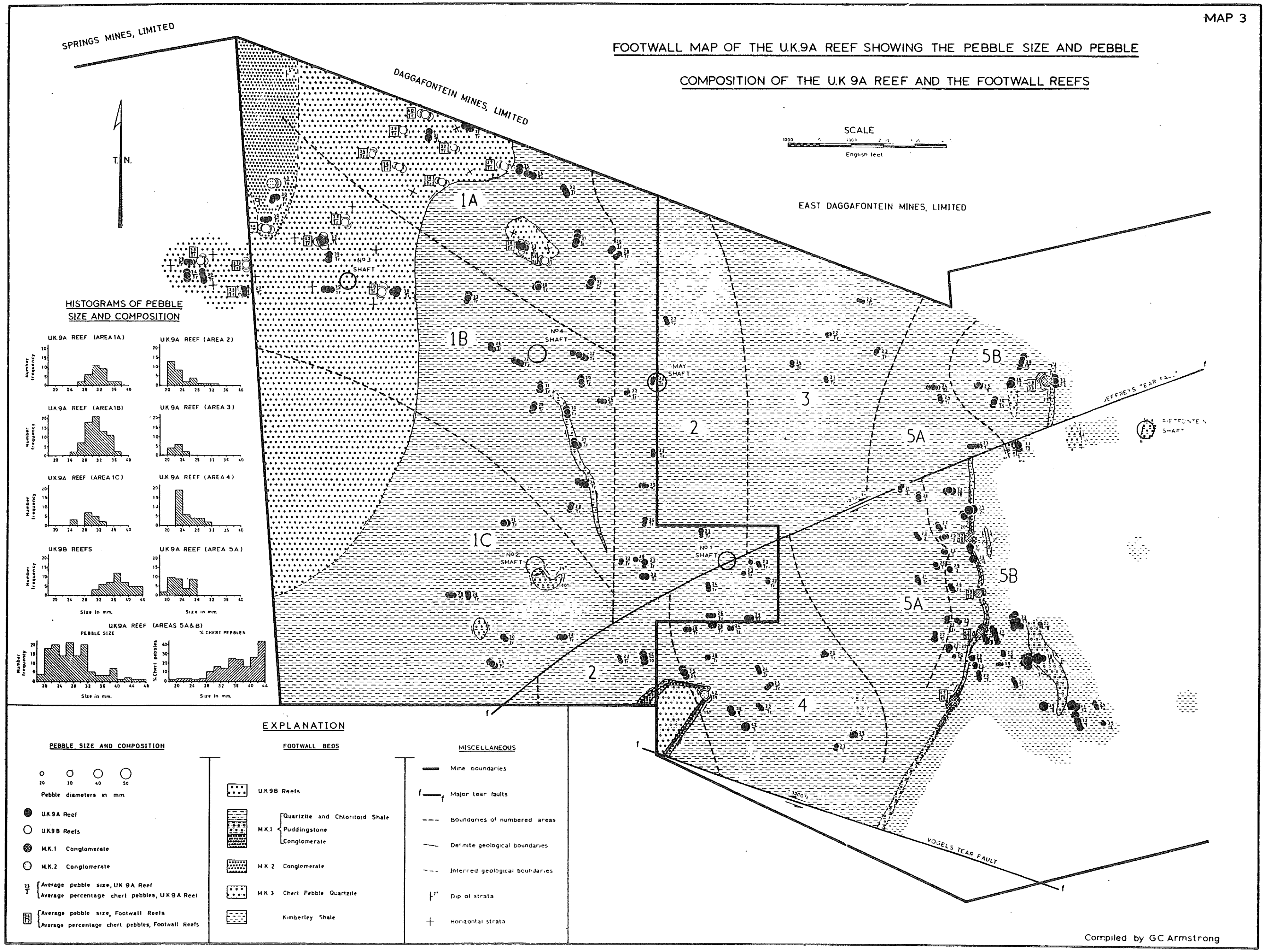


LOCALITY MAP
miles 0 5 10 15 miles
(after R. Borchers 1960)
Ventersdorp
Krugersdorp
Johannesburg
Germiston
Boksburg
Brakpan
Springs
1
2
3
Delmas
T. N.
Carletonville
Fochville
Heidelberg
Everton
Vereeniging
Van der Byl Park
Balfour
Potchefstroom
Sasolburg
Klerksdorp
Vaal River
Parys
Vredefort
Explanation
Karroo System
Pretoria Series
Dolomite Series
Black Reef Series
Transvaal System
Ventersdorp System
Upper Division
Lower Division
Witwatersrand System
Dominion Reef System
Basement Formations
Hidden geological boundaries of Upper Witwatersrand System
1. Portion of Springs Mines
2. Daggafontein Mines
3. East Daggafontein Mines

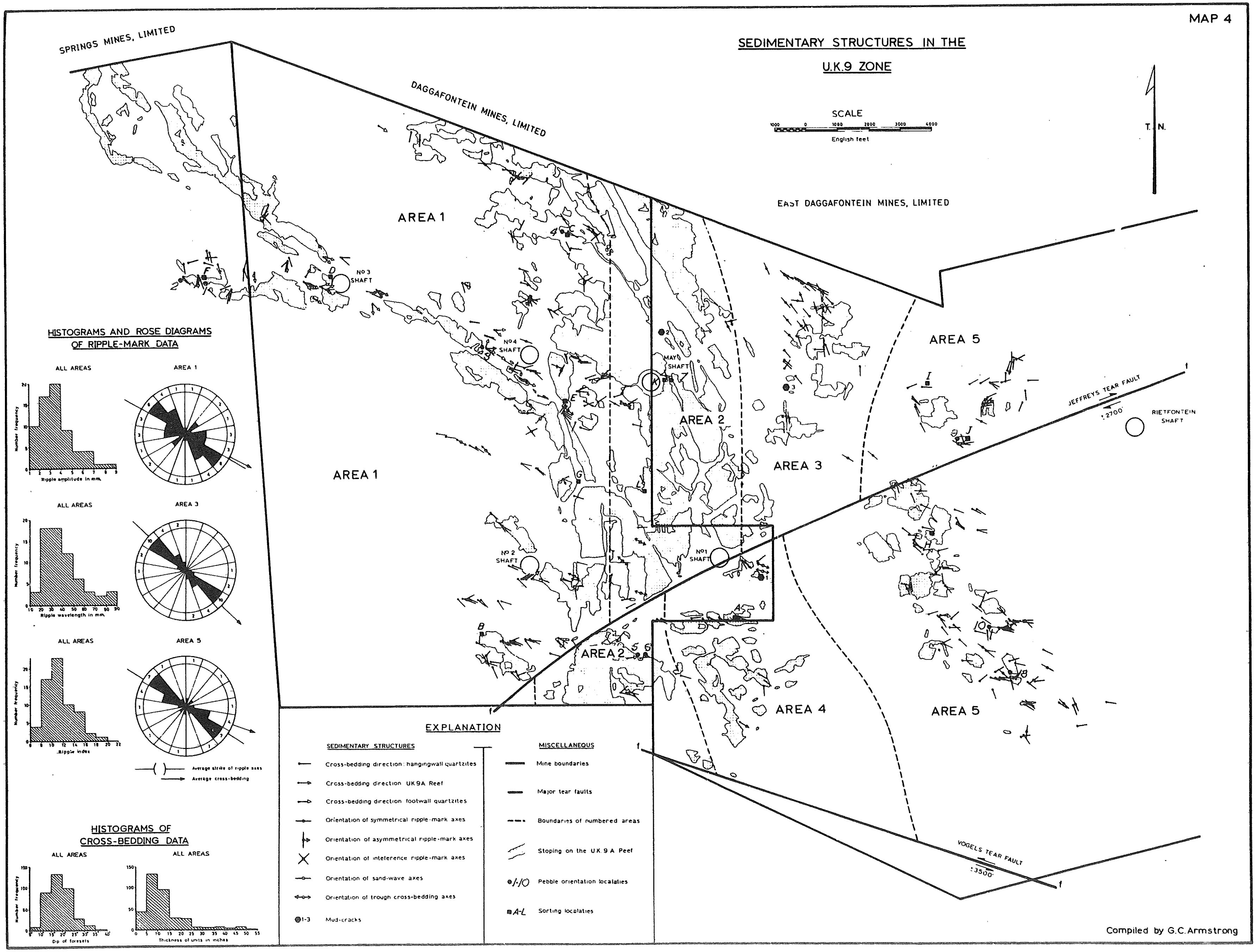
Map 1

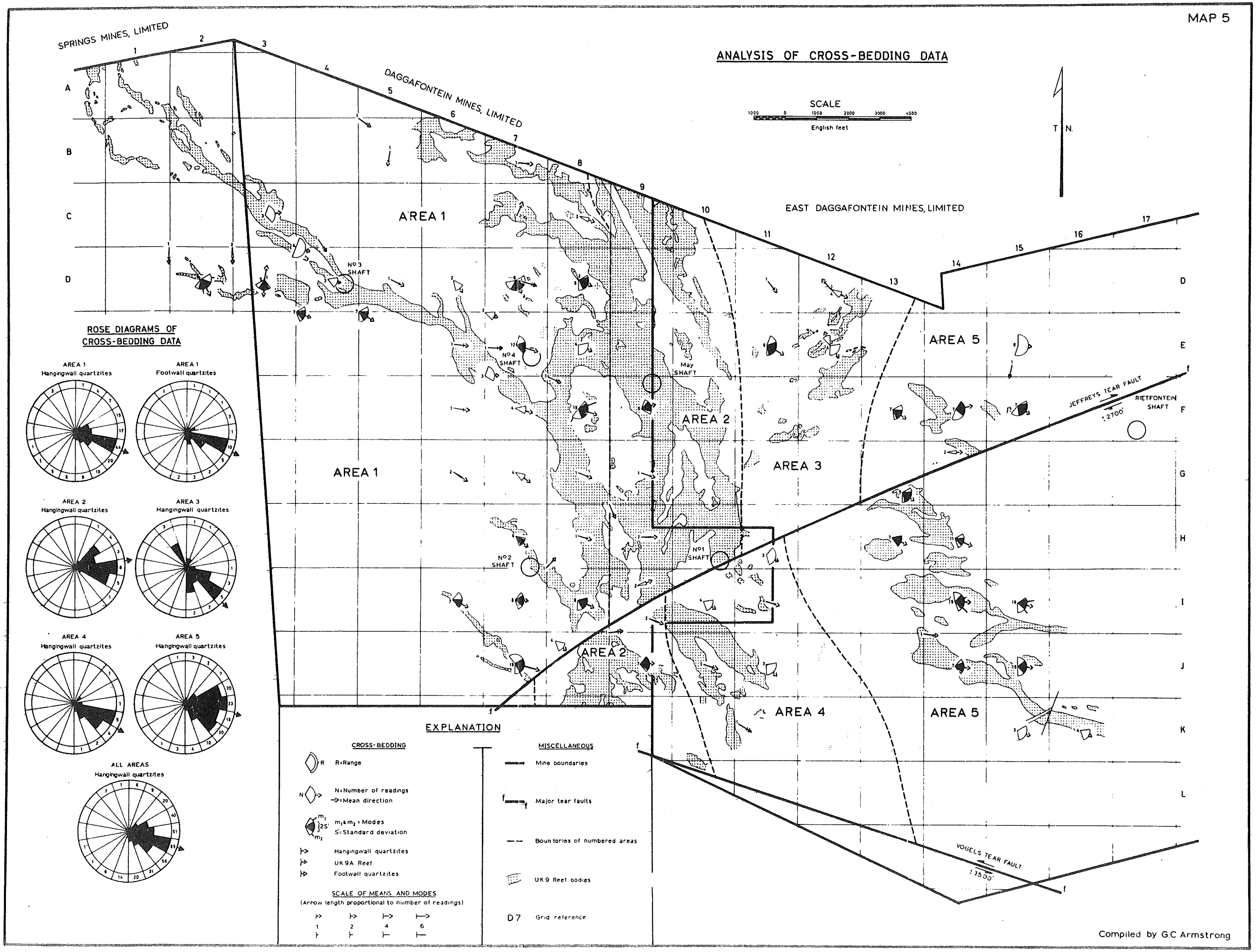


MAP 2
MAP OF U.K.9A REEF PAYSHOOTS
SCALE
SPRINGS MINES, LIMITED
DAGGAFONTEIN MINES, LIMITED
EAST DAGGAFONTEIN MINES, LIMITED
AREA 1
AREA 1
AREA 2
AREA 2
AREA 3
AREA 4
AREA 5
AREA 5
No 3 SHAFT
No 4 SHAFT
MAY SHAFT
No 2 SHAFT
No 1 SHAFT
T. N.
EXPLANATION
Sampling indicates negligible inch/dwt values, except close to payshoot boundaries
130-500 inch/dwts
+500 inch/dwts
Unmined payable ground
Mine boundaries
Major tear faults
Minor tear faults
Boundaries of numbered areas
VOGELS TEAR FAULT
Compiled by G C Armstrong from mine records



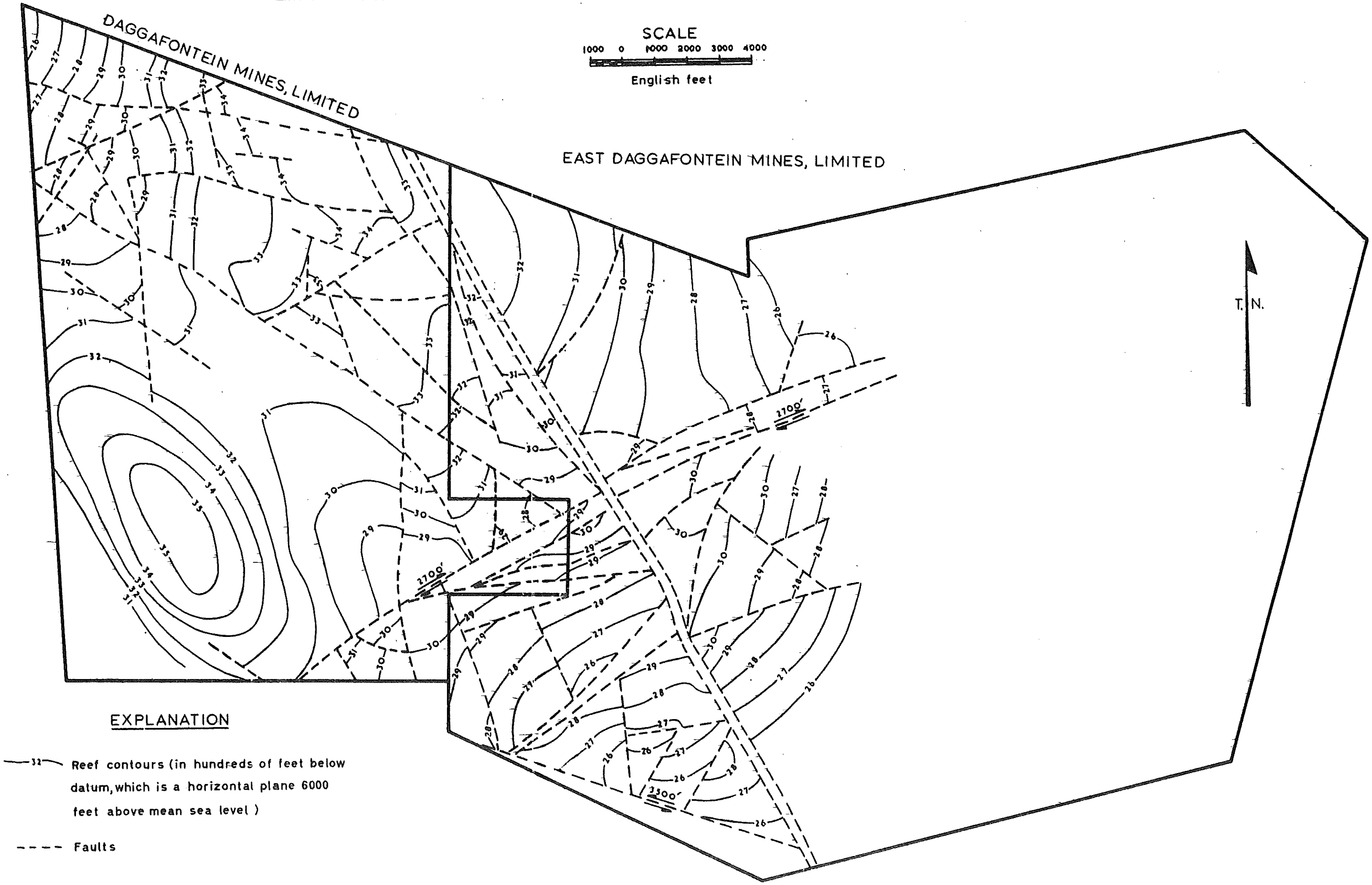
MAP 3
FOOTWALL MAP OF THE U.K.9A REEF SHOWING THE PEBBLE SIZE AND PEBBLE
COMPOSITION OF THE U.K 9A REEF AND THE FOOTWALL REEFS
SPRINGS MINES, LIMITED
DAGGAFONTEIN MINES, LIMITED
EAST DAGGAFONTEIN MINES, LIMITED
SCALE
English feet
T.N.
No 3 SHAFT
No 4 SHAFT
No 2 SHAFT
MAY SHAFT
No 1 SHAFT
1A
1B
1C
2
3
4
5A
5B
JEFFREYS TEAR FAULT
VOGELS TEAR FAULT
HISTOGRAMS OF PEBBLE SIZE AND COMPOSITION
UK9A REEF (AREA 1A)
UK9A REEF (AREA 2)
UK9A REEF (AREA 1B)
UK9A REEF (AREA 3)
UK9A REEF (AREA 1C)
UK9A REEF (AREA 4)
UK9B REEFS
UK9A REEF (AREA 5A)
UK9A REEF (AREAS 5A&B)
PEBBLE SIZE
% CHERT PEBBLES
Number frequency
% Chert pebbles
Size in mm.
EXPLANATION
PEBBLE SIZE AND COMPOSITION
Pebble diameters in mm
UK9A Reef
UK9B Reefs
M.K.1 Conglomerate
M.K.2 Conglomerate
Average pebble size, UK 9A Reef
Average percentage chert pebbles, UK9A Reef
Average pebble size, Footwall Reefs
Average percentage chert pebbles, Footwall Reefs
FOOTWALL BEDS
UK9B Reefs
M.K.1
Quartzite and Chloritoid Shale
Puddingstone
Conglomerate
M.K 2 Conglomerate
M.K 3 Chert Pebble Quartzite
Kimberley Shale
MISCELLANEOUS
Mine boundaries
Major tear faults
Boundaries of numbered areas
Definite geological boundaries
Inferred geological boundaries
Dip of strata
Horizontal strata
Compiled by G C Armstrong


MAP 4
SEDIMENTARY STRUCTURES IN THE
U.K.9 ZONE
SCALE
English feet
T. N.
SPRINGS MINES, LIMITED
DAGGAFONTEIN MINES, LIMITED
EAST DAGGAFONTEIN MINES, LIMITED
AREA 1
AREA 2
AREA 3
AREA 4
AREA 5
No 3 SHAFT
No 4 SHAFT
No 2 SHAFT
MAY SHAFT
No 1 SHAFT
RIETFONTEIN SHAFT
JEFFREYS TEAR FAULT
2700'
VOGELS TEAR FAULT
3500'
HISTOGRAMS AND ROSE DIAGRAMS OF RIPPLE-MARK DATA
ALL AREAS
AREA 1
AREA 3
AREA 5
Number frequency
Ripple amplitude in mm.
Ripple wavelength in mm.
Ripple index
Average strike of ripple axes
Average cross-bedding
HISTOGRAMS OF CROSS-BEDDING DATA
Dip of foresets
Thickness of units in inches
EXPLANATION
SEDIMENTARY STRUCTURES
Cross-bedding direction: hangingwall quartzites
Cross-bedding direction UK9A Reef
Cross-bedding direction footwall quartzites
Orientation of symmetrical ripple-mark axes
Orientation of asymmetrical ripple-mark axes
Orientation of interference ripple-mark axes
Orientation of sand-wave axes
Orientation of trough cross-bedding axes
1-3 Mud-cracks
MISCELLANEOUS
Mine boundaries
Major tear faults
Boundaries of numbered areas
Stoping on the UK 9 A Reef
Pebble orientation localities
A-L Sorting localities
Compiled by G.C.Armstrong


MAP 5
ANALYSIS OF CROSS-BEDDING DATA
SCALE
1000 0 1000 2000 3000 4000
English feet
T.N.
SPRINGS MINES, LIMITED
DAGGAFONTEIN MINES, LIMITED
EAST DAGGAFONTEIN MINES, LIMITED
AREA 1
AREA 1
AREA 2
AREA 2
AREA 3
AREA 4
AREA 5
AREA 5
No 3 SHAFT
No 4 SHAFT
No 2 SHAFT
No 1 SHAFT
May SHAFT
RIETFONTEIN SHAFT
JEFFREYS TEAR FAULT
± 2700'
VOGELS TEAR FAULT
± 3500'
ROSE DIAGRAMS OF CROSS-BEDDING DATA
AREA 1 Hangingwall quartzites
AREA 1 Footwall quartzites
AREA 2 Hangingwall quartzites
AREA 3 Hangingwall quartzites
AREA 4 Hangingwall quartzites
AREA 5 Hangingwall quartzites
ALL AREAS Hangingwall quartzites
EXPLANATION
CROSS-BEDDING
R=Range
N=Number of readings
→=Mean direction
m1 & m2 = Modes
S=Standard deviation
Hangingwall quartzites
UK9A Reef
Footwall quartzites
SCALE OF MEANS AND MODES
(Arrow length proportional to number of readings)
1 2 4 6
MISCELLANEOUS
Mine boundaries
Major tear faults
Boundaries of numbered areas
UK9 Reef bodies
D7 Grid reference
Compiled by G.C Armstrong

MAP 6

STRUCTURE CONTOUR MAP OF THE U.K.9A REEF



EXPLANATION

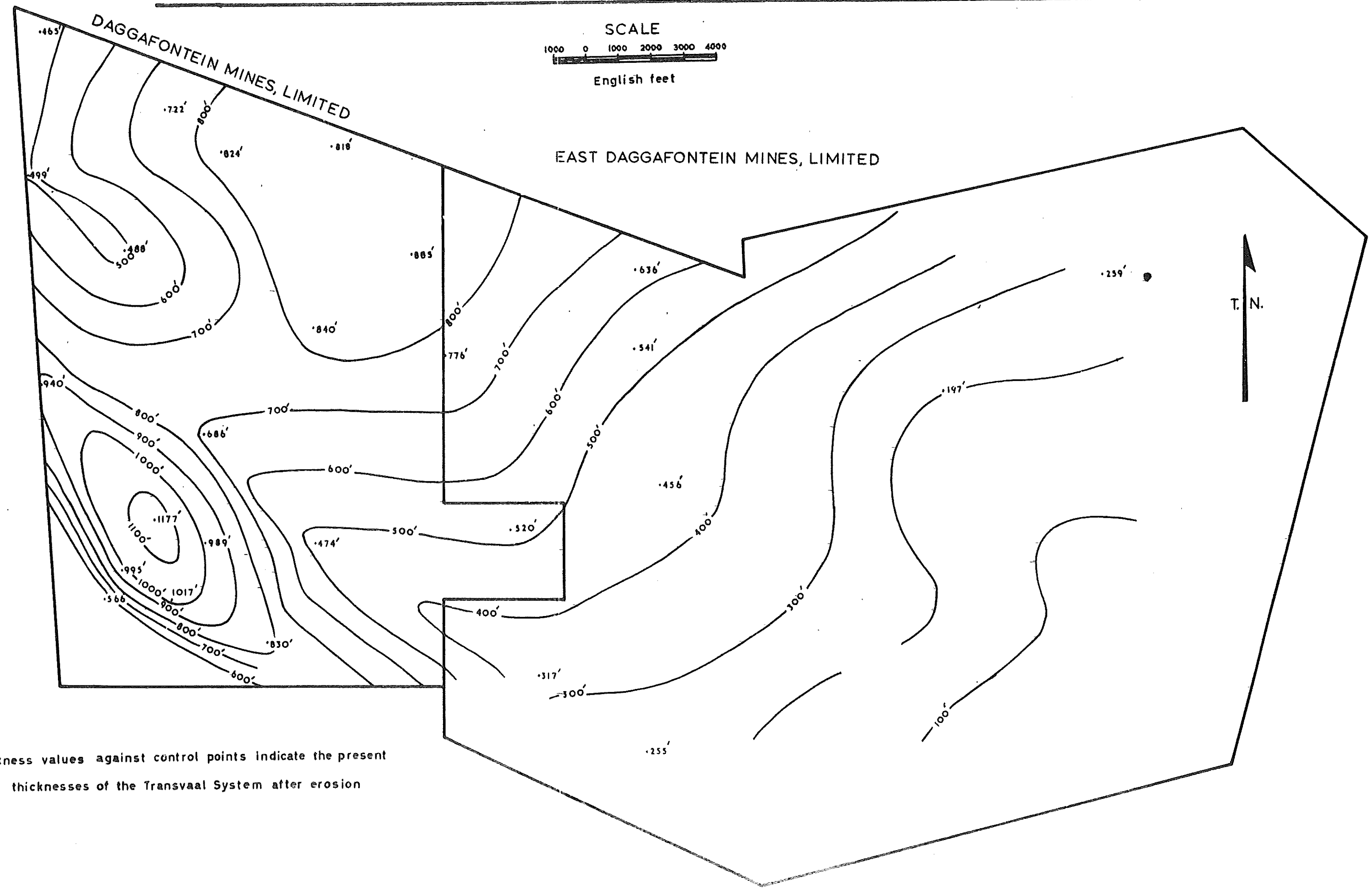
—32— Reef contours (in hundreds of feet below datum, which is a horizontal plane 6000 feet above mean sea level)

- - - - Faults

Data from mine plans.

MAP 7

ISOPACH MAP OF A PORTION OF THE TRANSVAAL SYSTEM, NAMELY, THE BLACK REEF SERIES AND PART OF THE DOLOMITE SERIES

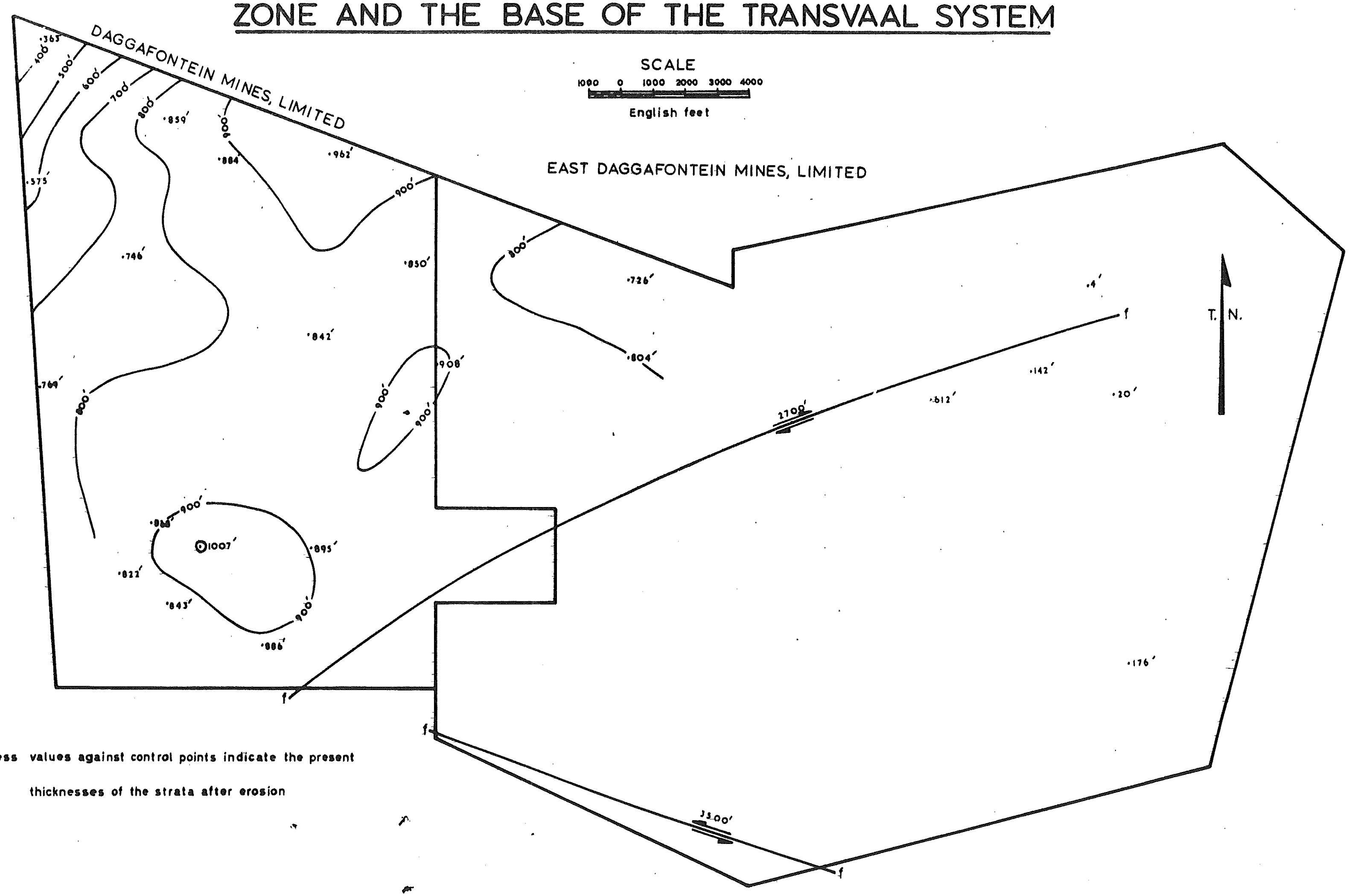


Thickness values against control points indicate the present thicknesses of the Transvaal System after erosion

Compiled by G.C. Armstrong from mine records.

MAP 8

ISOPACH MAP OF THE STRATA BETWEEN THE TOP OF THE U.K.3 ZONE AND THE BASE OF THE TRANSVAAL SYSTEM

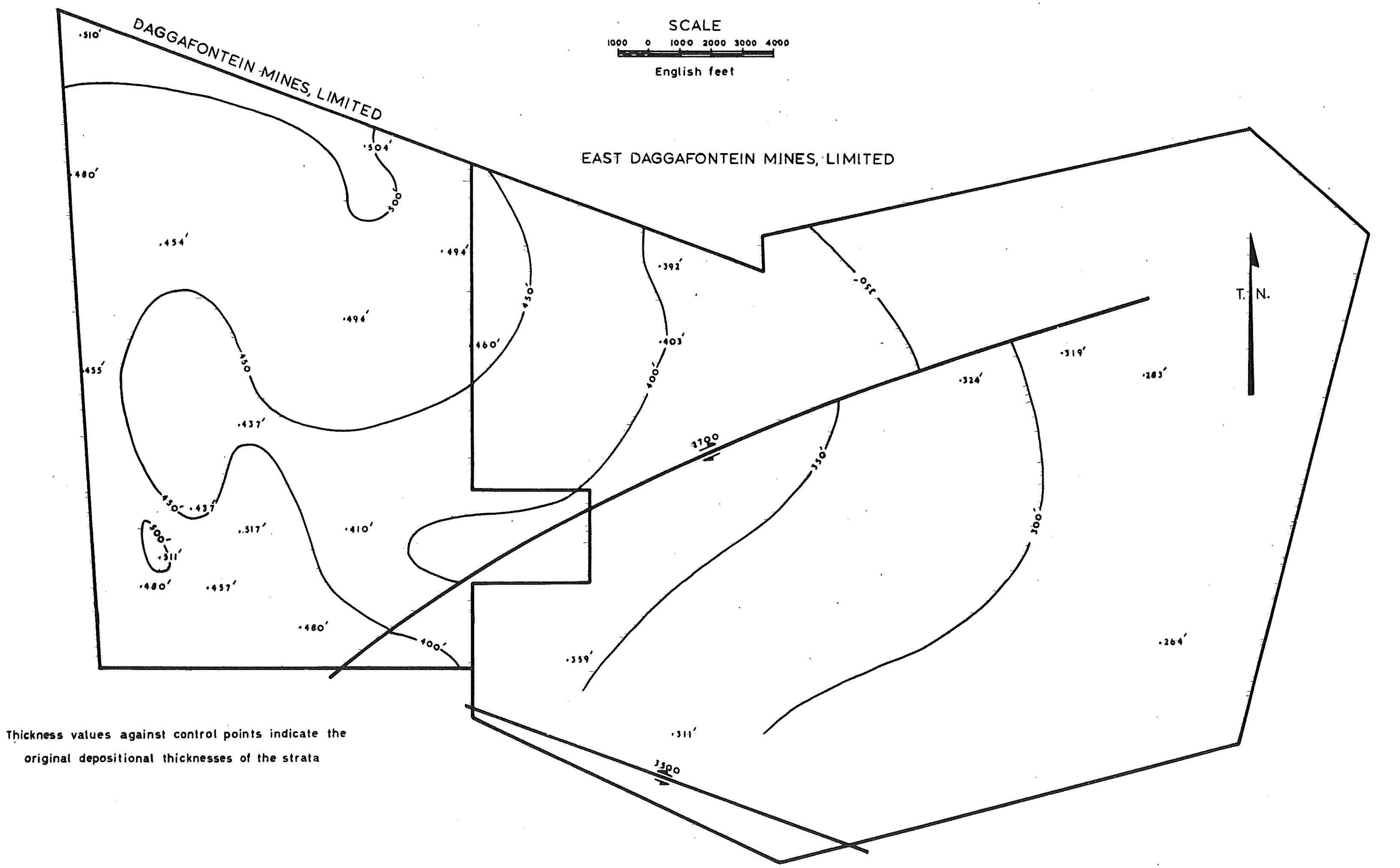


Thickness values against control points indicate the present thicknesses of the strata after erosion

Compiled by G.C. Armstrong from mine records.

MAP 9

ISOPACH MAP OF THE ZONES U.K.7 TO U.K.3

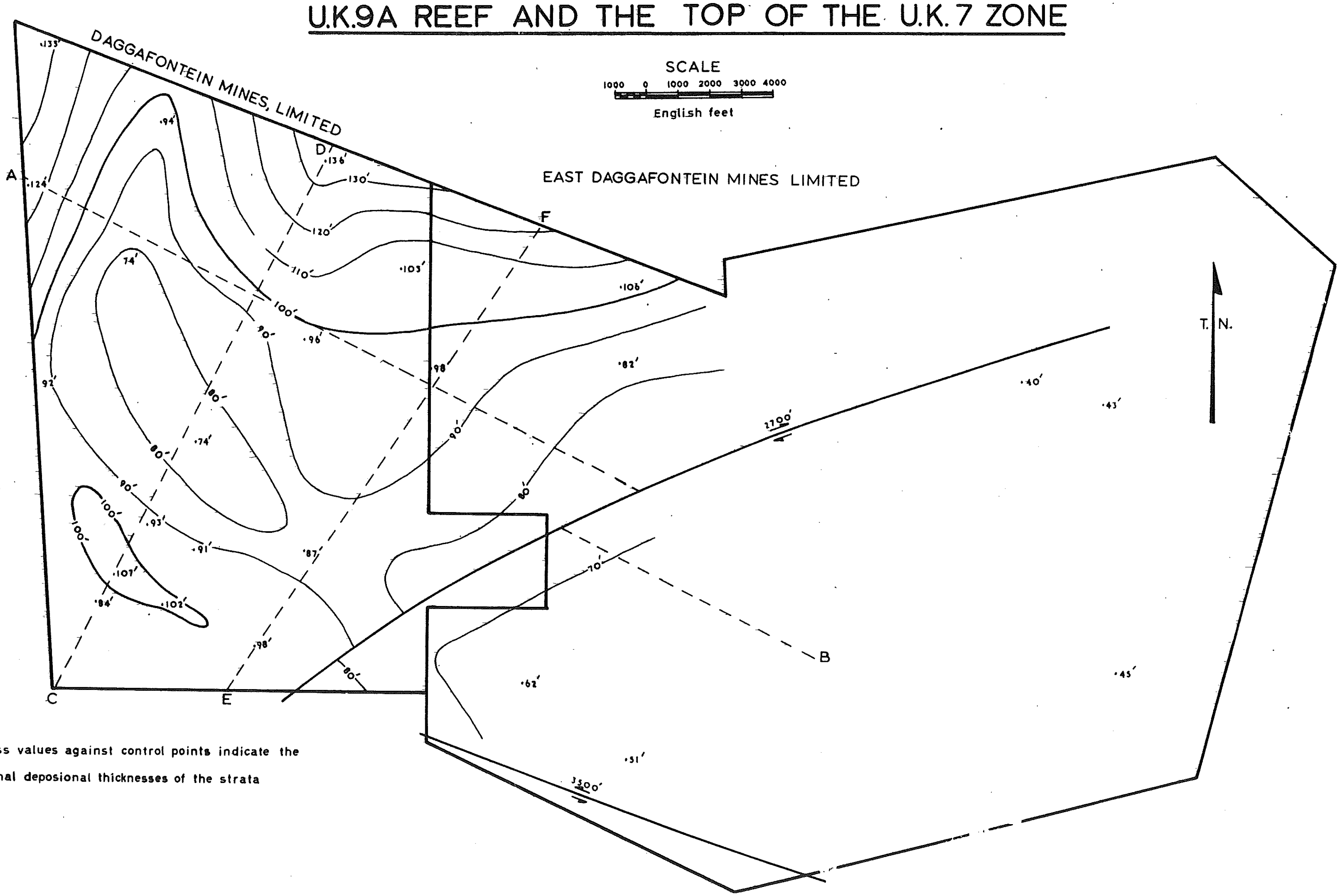


Thickness values against control points indicate the original depositional thicknesses of the strata

Compiled by G.C.Armstrong from mine records.

MAP 10

ISOPACH MAP OF THE STRATA BETWEEN THE TOP OF THE U.K.9A REEF AND THE TOP OF THE U.K. 7 ZONE

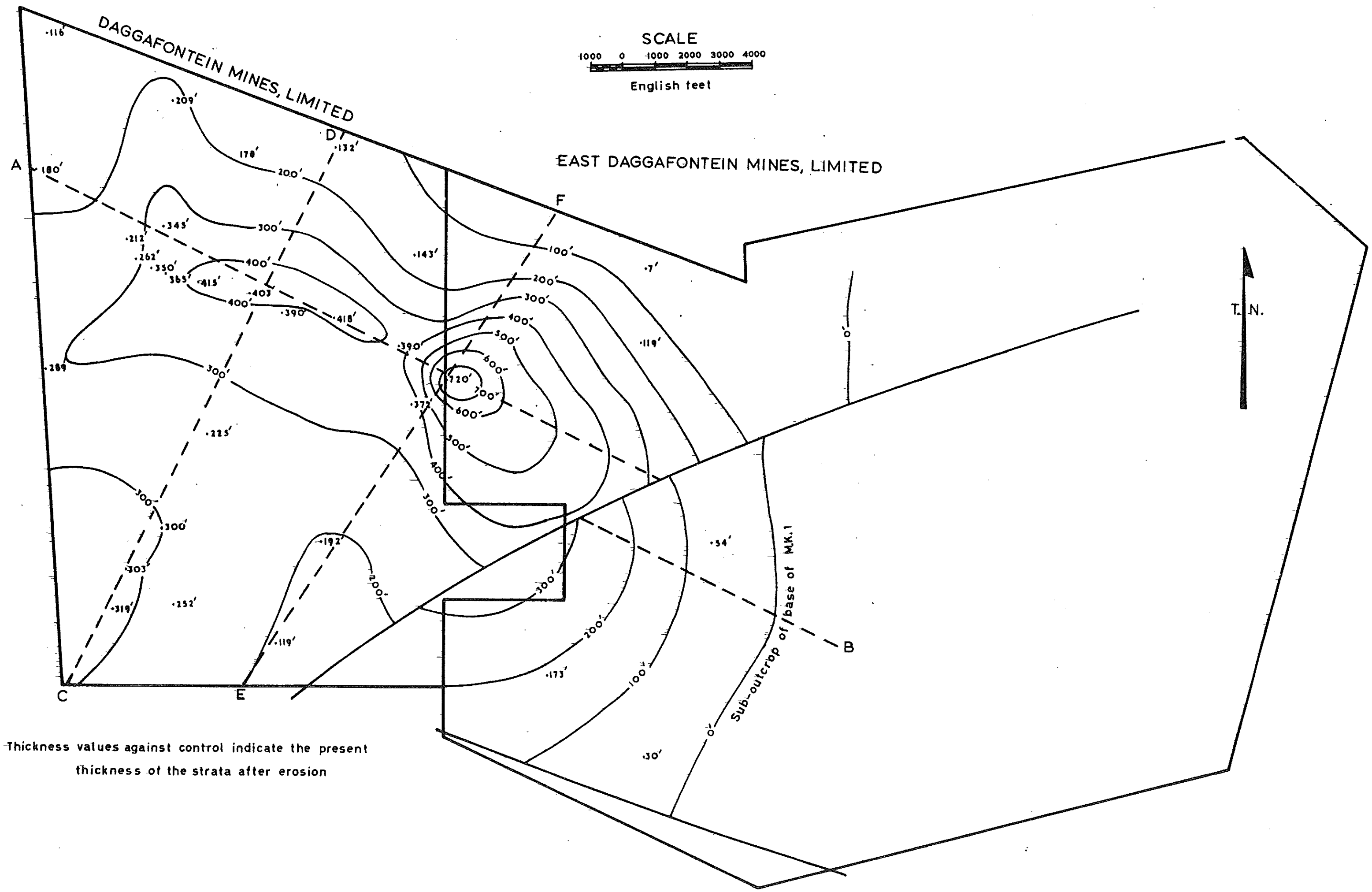


Thickness values against control points indicate the original depositional thicknesses of the strata

Compiled by G.C. Armstrong from mine records.

MAP 11

ISOPACH MAP OF THE ZONES M.K.3 TO M.K.1

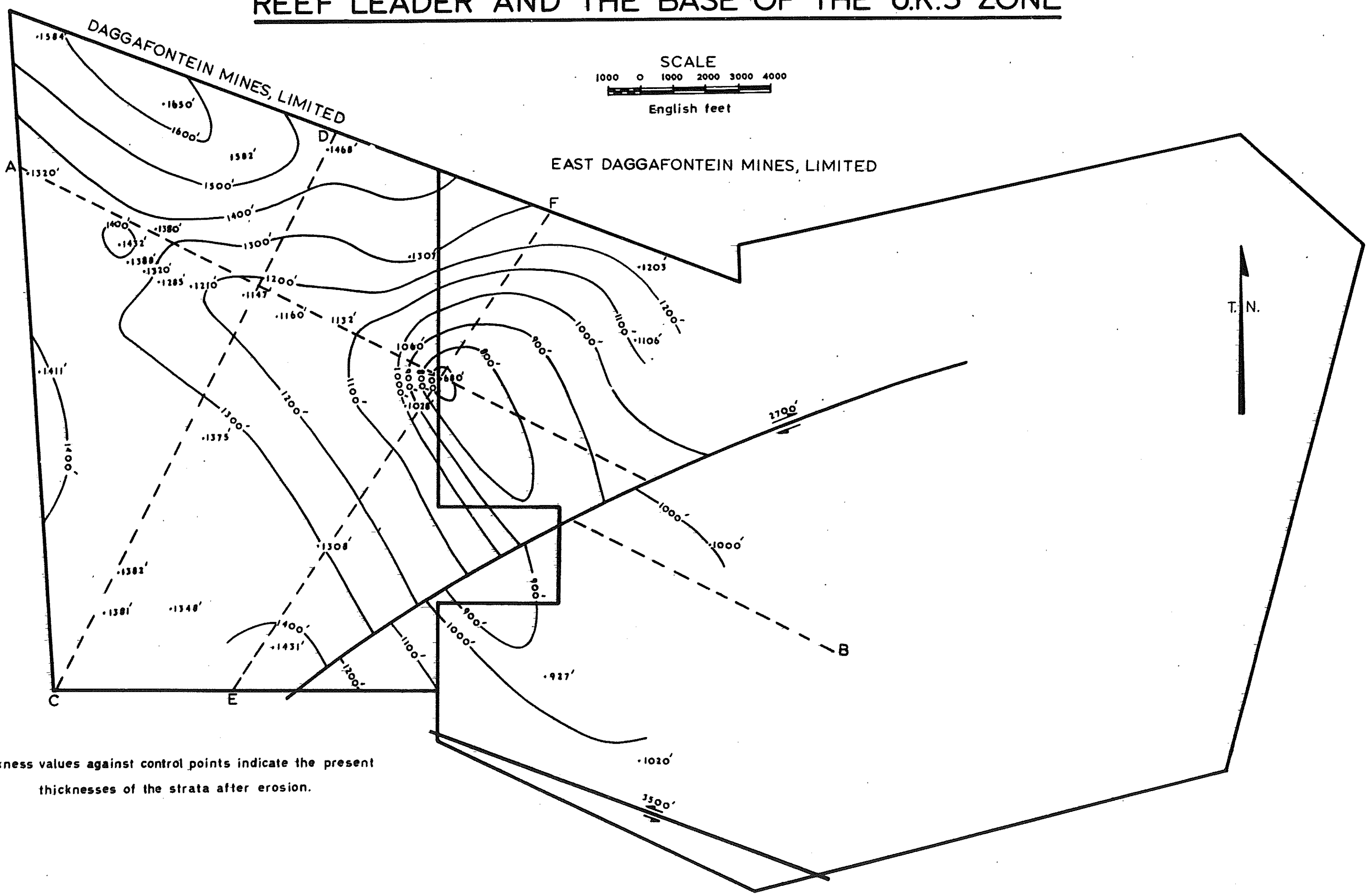


Thickness values against control indicate the present thickness of the strata after erosion

Compiled by G.C.Armstrong from mine records.

MAP 12

ISOPACH MAP OF THE STRATA BETWEEN THE TOP OF THE MAIN REEF LEADER AND THE BASE OF THE U.K.3 ZONE

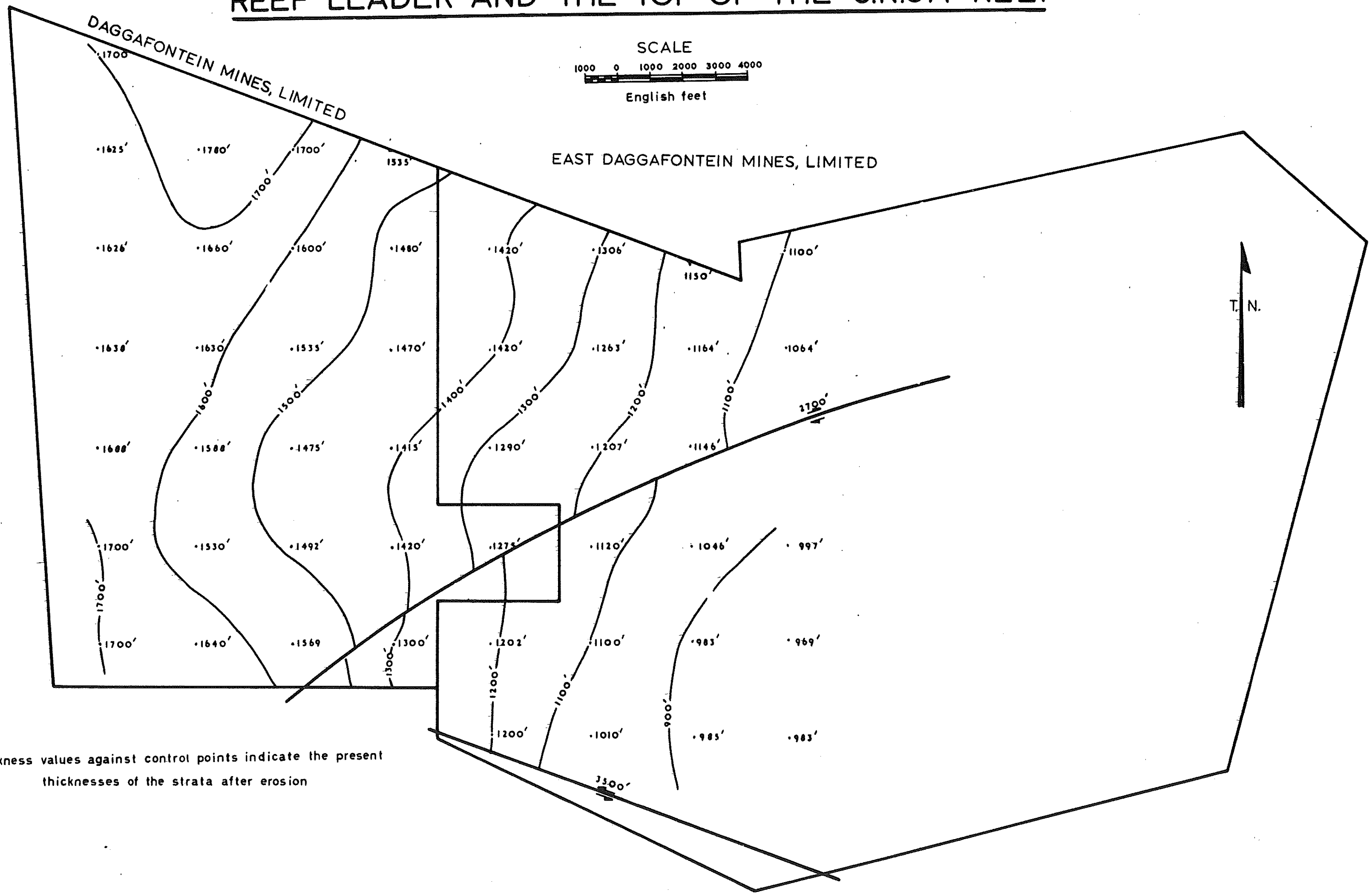


Thickness values against control points indicate the present thicknesses of the strata after erosion.

Compiled by G.C.Armstrong from mine plans.

MAP 13

ISOPACH MAP OF THE STRATA BETWEEN THE TOP OF THE MAIN REEF LEADER AND THE TOP OF THE U.K.9A REEF

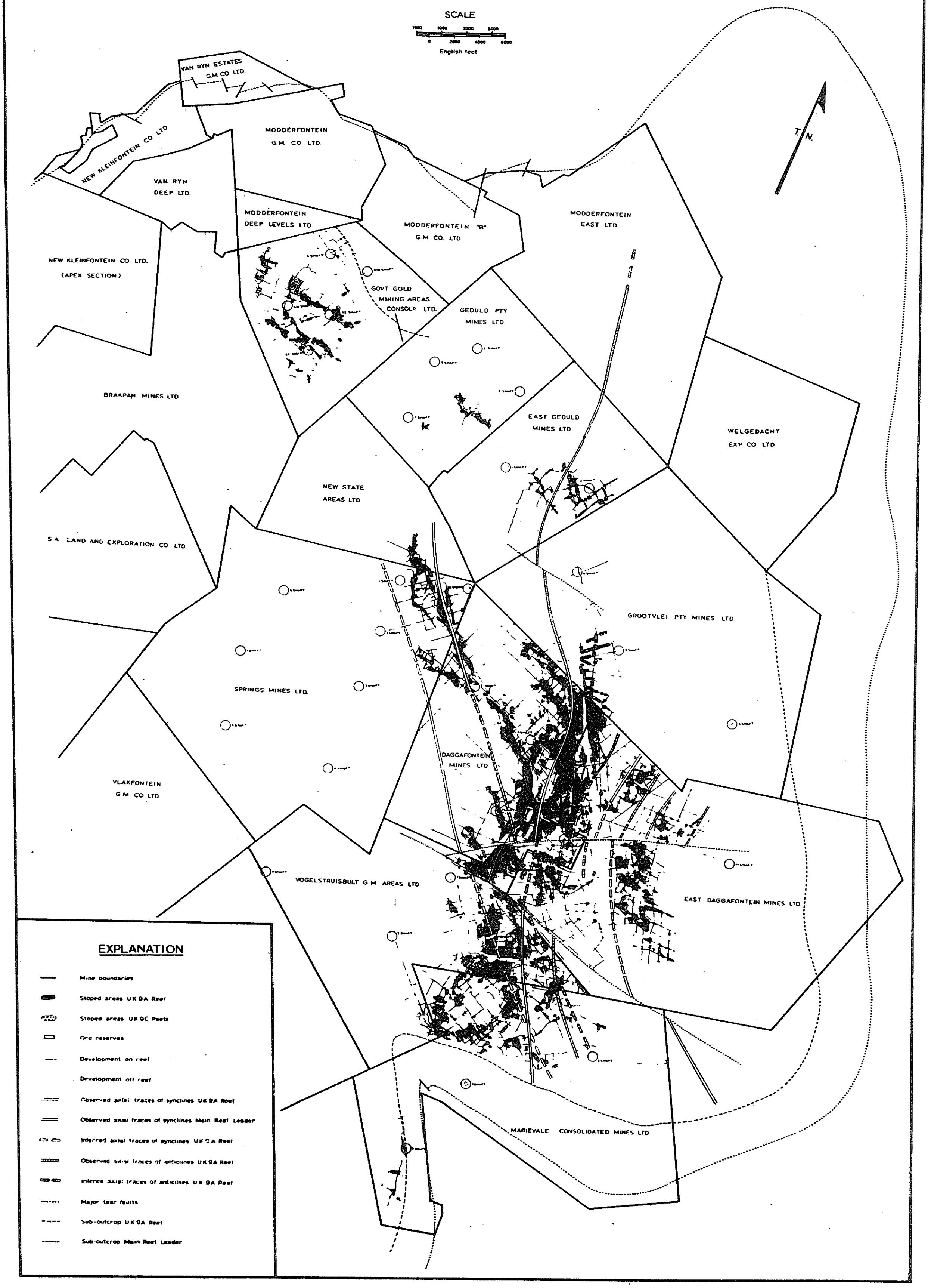


Thickness values against control points indicate the present thicknesses of the strata after erosion

Compiled by G.C.Armstrong from mine data

MAP 14

UNDERGROUND DEVELOPMENT AND STOPING ON THE U.K.9A REEF IN RELATION TO MAJOR STRUCTURAL TRENDS



GENERALISED GEOLOGICAL SECTION OF THE EAST RAND

(after Antrobus 1964)

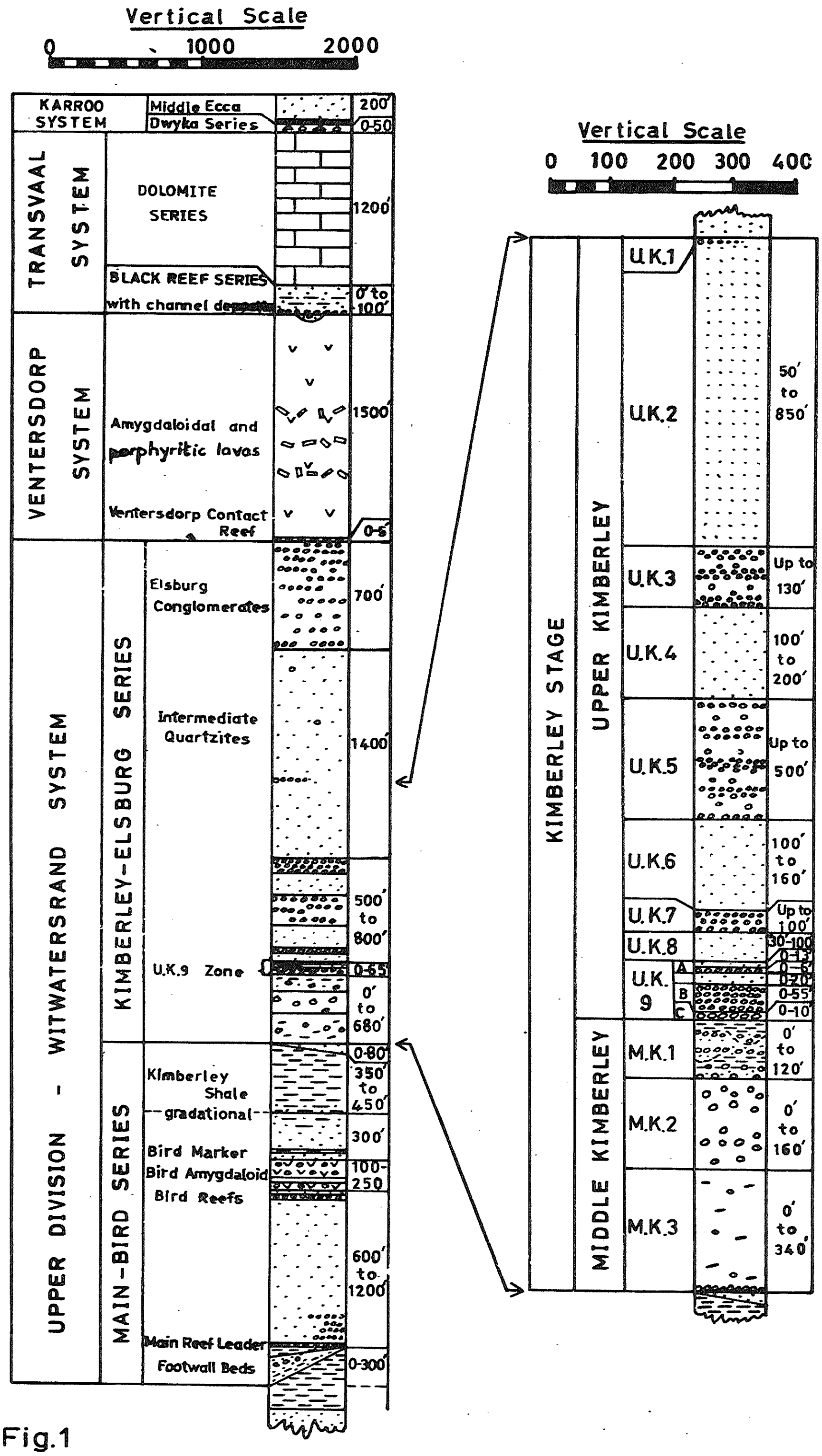
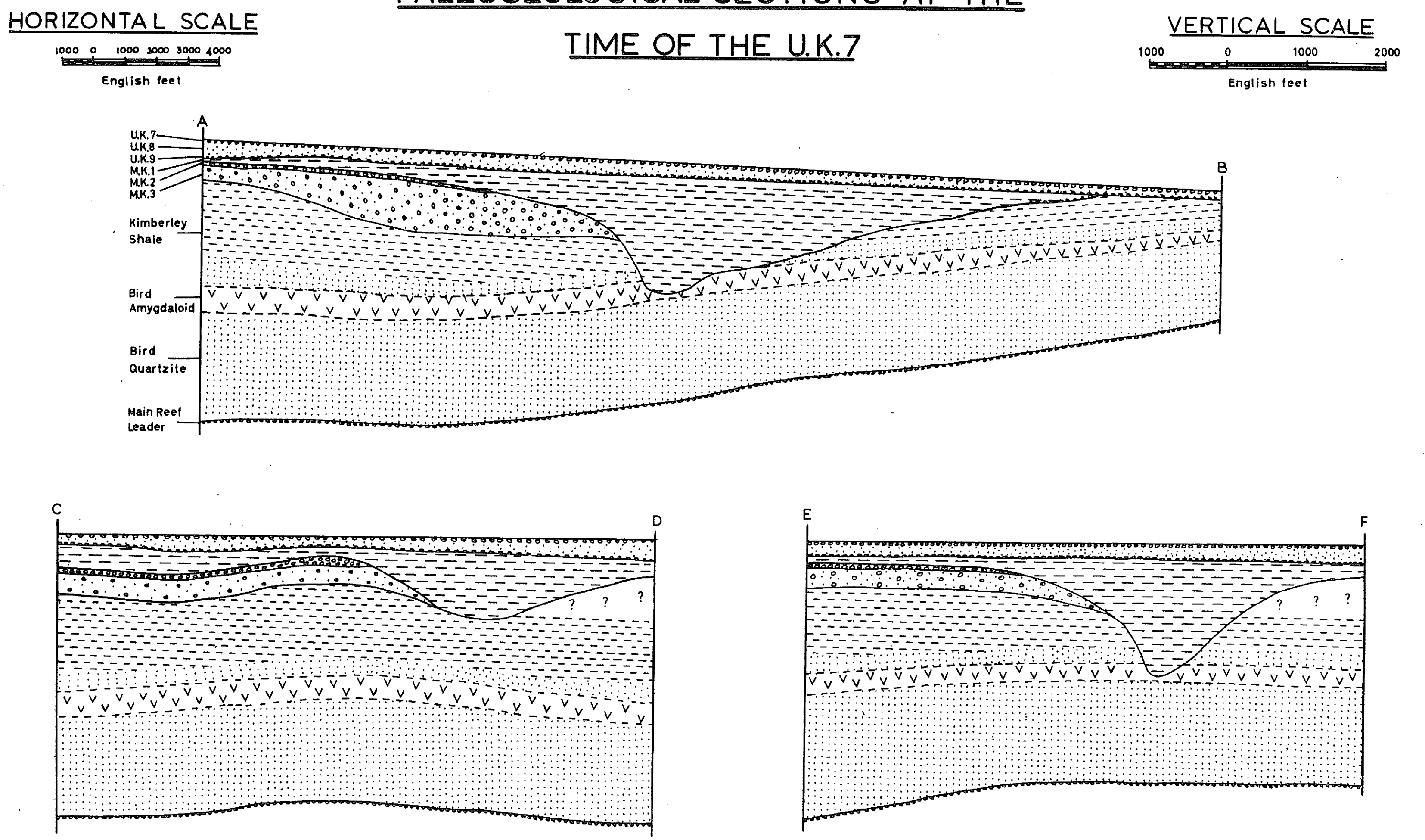


Fig.1

Fig. 2

PALEOGEOLOGICAL SECTIONS AT THE TIME OF THE U.K.7



Compiled by G.C.Armstrong
from isopach maps 10 - 12

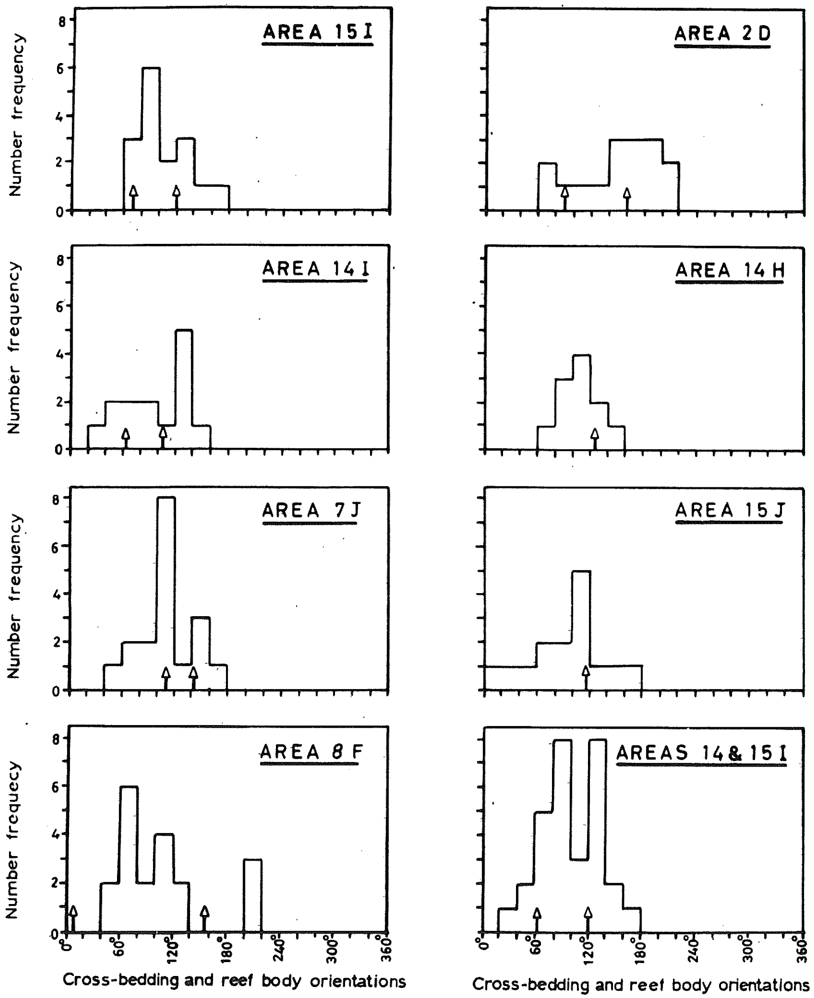


Fig. 3 Histograms of U.K.9A Marker cross-bedding data, showing modal directions of transport, for comparison with orientations of U.K.9 A Reef bodies shown by arrows.

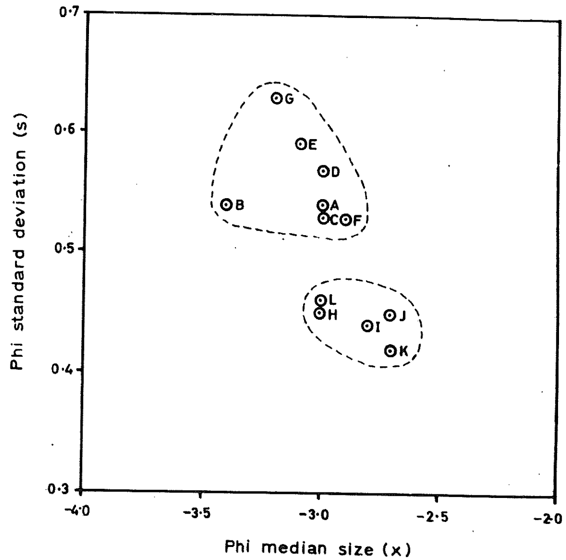


Fig. 4 A comparison between the uncorrected number frequency sorting and median size values of the samples studied.

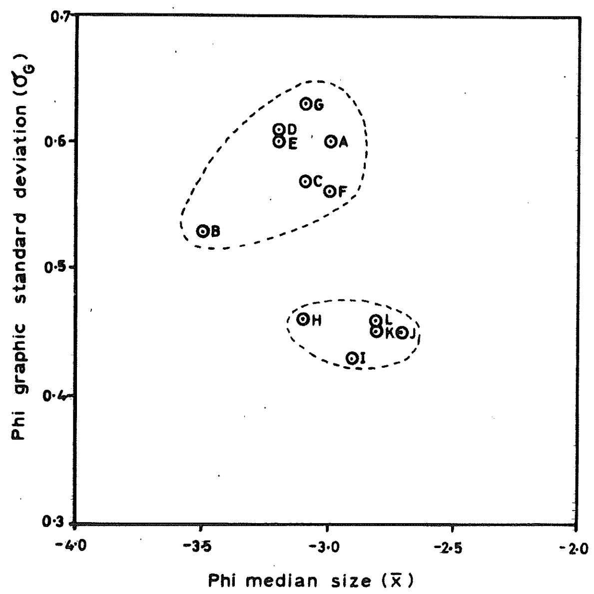


Fig. 5 A comparison between the uncorrected number frequency sorting and median size values of the samples studied.

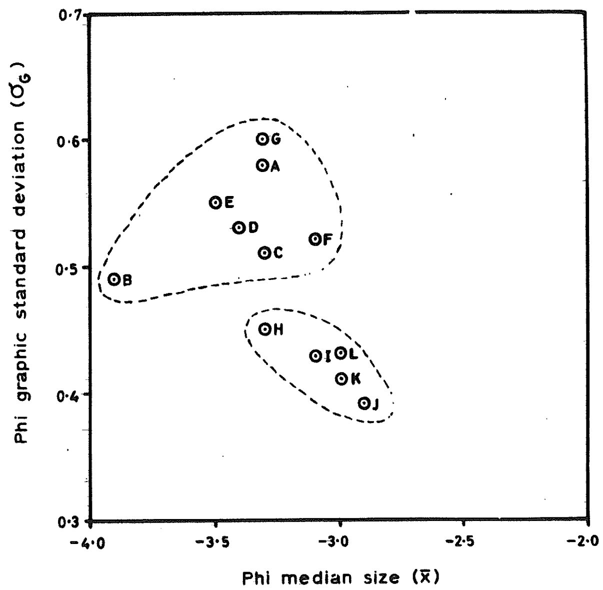


Fig. 6 A comparison between the corrected volume frequency sorting and median size values of the samples studied.

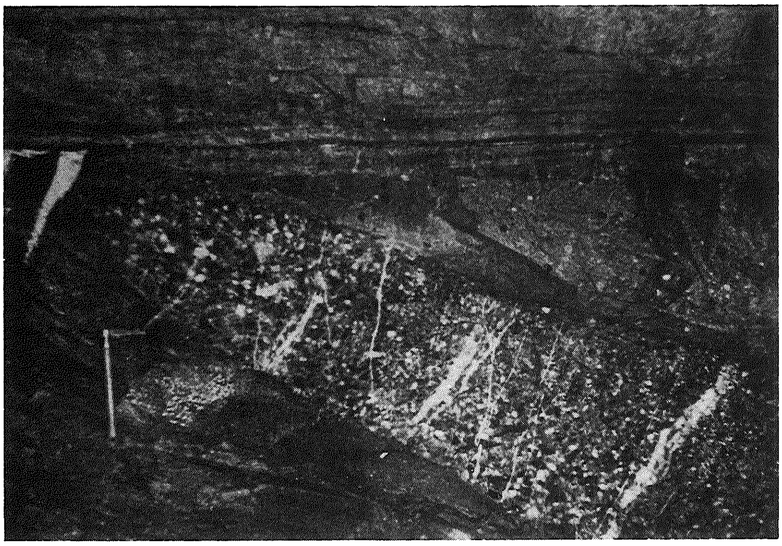


PLATE 1

PLATE 2

PLATE 3

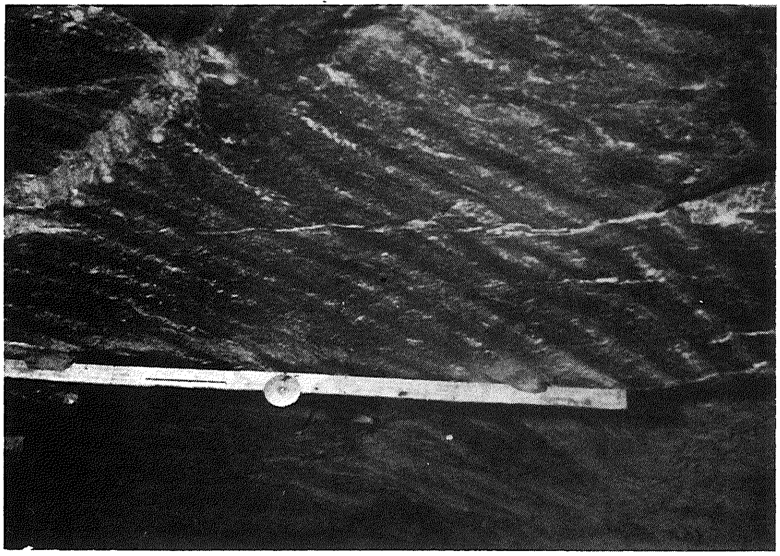
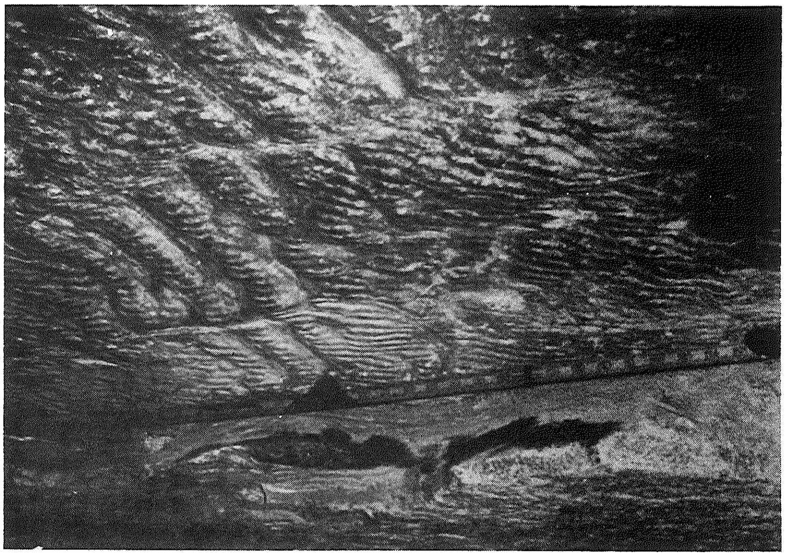


PLATE 4

PLATE 5



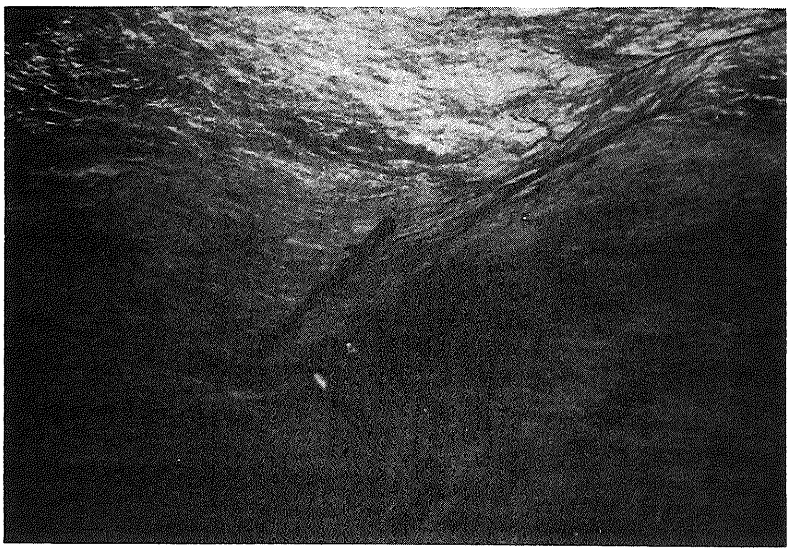
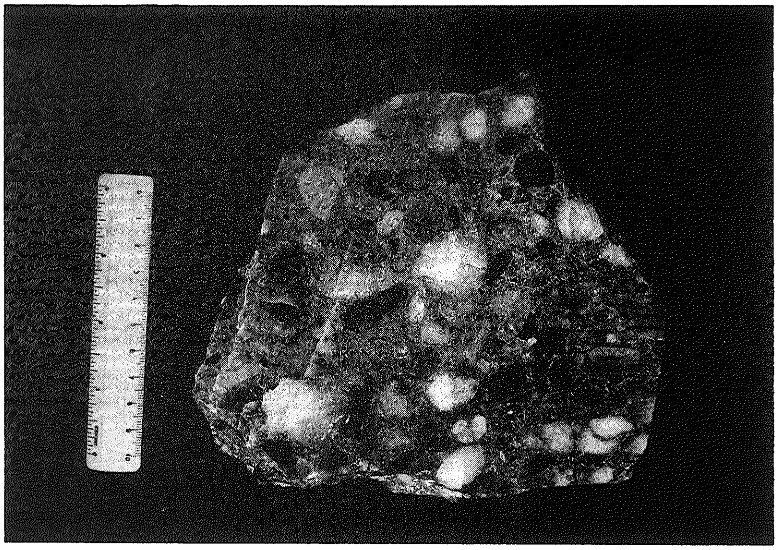


PLATE 6

PLATE 7

PLATE 8



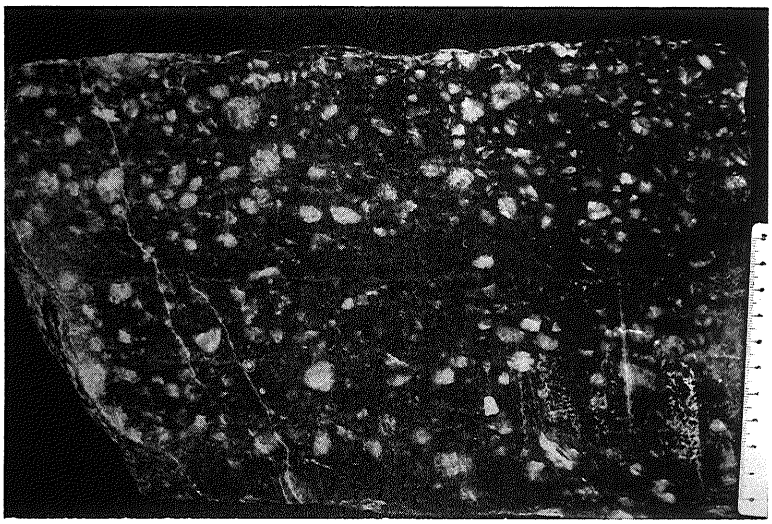


PLATE 9