CHAPTER 3: THE BLOUBERG FORMATION.

3.1: Introduction:

This chapter includes field data collected from the Blouberg Formation, which outcrops generally on the lower southern slopes of Blouberg mountain south of the southern strand of the Melinda Fault (Appendix 1), and also approximately 25 km west of Blouberg mountain, on the farm Kranskop 278 LR (23°09'S; 28°42'E to 23°09'S; 28°41'E: Appendix 1). The siliciclastic rocks which underlie the northern foothills of Blouberg mountain and which occur on the northern side of the southern strand of the Melinda Fault (Appendix 1), named the Mositone Conglomerate, Varedig Sandstone and Semaoko Grit members by Jansen (1976) (also named the Lebu Complex by Meinster, 1977), are considered in Chapter 4 (Waterberg Group). The volcanic rocks west of Blouberg mountain, named the My Darling Trachyandesite Member of the Blouberg Formation by Jansen (1976) (also part of the Meinster's (1977) Lebu Complex), are considered in Chapter 5 (Soutpansberg Group). The correlations used during this work are presented in Table 8.1.

The outcrops of the Blouberg Formation which occur south of the southern strand of the Melinda Fault (Appendix 1) are generally less than 300m thick. In contrast, in the area between 23°09'S; 28°42'E and 23°09'S; 28°41'E (Appendix 1), on the farm Kranskop 278 LR, a 1400m-thick sequence of Blouberg sediment is preserved, consisting of vertically dipping, north-striking beds exposed in a westwards-trending streambed. This Blouberg succession can be followed from its nonconformable relationship with the basement gneiss at 23°09.01'S; 28°42.01'E, until it is unconformably overlain by the basal conglomerate beds of the Mogalakwena Formation at 23°09.12'S; 28°41.23'E (Appendix 1). This section is thought to represent the most complete record of the Blouberg strata, as it is considerably thicker than any of the outcrops of the Blouberg Formation further to the east. It is thus presented here as the provisional type section of the Blouberg Formation. The extent of the outcrop, which is generally restricted to within the bounds of the stream bed is, however, not suitable for establishing lateral dimensions of architectural elements or any lateral facies variation.

3.2: Description of Type Section of Blouberg Formation:

The Blouberg Formation at the Kranskop type locality is composed of an entirely clastic succession of sedimentary rocks, which are shown in a partially complete sedimentary profile in Figure 3.1. Figure 3.1 shows that the lower part of the Blouberg succession (0m to 675m) is dominated by medium- to coarse-grained sandstone and granulestone, according to terminology for grain size classification on the Udden-Wentworth scale (Wentworth, 1922). This nomenclature will be used to describe sedimentary rocks throughout this work, and medium-grained sandstones are defined as those composed of grains with a diameter between 250 and 500µm. Coarse-grained sandstones have grains between 500µm and 1mm, and granulestones have grains between 2 and 4mm. The upper part of the succession (from 675m to 1400m) is largely conglomeratic, with only minor sandstone and granulestone deposits. Clasts within the upper part of the Blouberg Formation are classified as pebbles and cobbles under the Udden-Wentworth scale, where pebbles are of a clast size between 4 and 64mm, cobbles between 64 and 256mm, and boulders are larger than 256mm. These sedimentary rocks of the Blouberg Formation will be described (in order from bottom to top) in the following section, in terms of architectural elements, facies associations and sedimentary facies.

3.2.1: Architectural elements:

Miall (1985) proposed a system for the classification of fluvial sediments, whereby all fluvial deposits are interpreted as being composed of varying proportions of eight *architectural elements*. This system will be used to classify all fluvial deposits considered in this work (Blouberg, Mogalakwena and Wyllies Poort Formations; Section 8.2). Other workers have broadened the application of architectural elements to other palaeoenvironments, such as shallow marine and fan-delta deposits (e.g., Tirsgaard, 1993; Eriksson *et al.*, 1995). An architectural element is defined as a three-dimensional lithosome, for which bounding surfaces, scale, internal lithofacies (and lithofacies associations), and external geometry are defined (Miall, 1985). The eight architectural elements proposed by Miall (1985) are each made up of a certain combination of facies associations, which are, in turn, made up of combinations of individual facies (Miall, 1985). The architectural elements for fluvial deposits and their symbols are shown in Table 3.1, together with the symbols for facies classification (Miall, 1978).

Of particular importance in the discrimination of architectural elements is the concept of external geometry. In order to correctly identify the external geometry of an element, its bounding surfaces must be recognised, and in order to fulfil this, outcrops must be present which are sufficiently large, so that the bounding surfaces can be traced over a distance, in order to determine the three-dimensional geometry of the element under investigation (Miall, 1985). The larger the scale of the element, then the larger the size of the outcrop necessary for satisfactory definition of the architectural element. In the Kranskop section, it was difficult to accurately determine the three-dimensional external geometry of the deposits, as only a vertical profile through the sedimentary succession (vertically dipping beds exposed in the essentially horizontal stream bed) was afforded in the area. With the absence of data from the third dimension, and with the vertical profile limited to the width of the stream bed (usually between two and five metres) it was impossible to accurately assess the type of architectural element present, although individual facies and facies associations could still be readily determined.

3.2.2: Facies and Facies Associations:

The term 'facies' as used in this work is defined as a particular set of sediment characteristics, and includes a description of attributes such as lithology, texture, colour, sedimentary structures and palaeocurrent direction. Throughout the vertical section of the Blouberg Formation at Kranskop, a variety of sedimentary facies could be identified, which could be grouped into 4 discrete facies associations within the Formation (Figure 3.1). The sedimentary rocks are usually purplish in colour (red beds), though many beds and cross-beds are creamy-white, presumably where certain horizons have been permeable to circulating reducing fluids (Figure 3.2). In general, the rocks within the Kranskop section are weathered and friable, and cannot be easily sectioned for microscopic analysis. However collected rubble from the Kranskop section can be sectioned after being set in resin.

The lowermost part of the succession consists predominantly of facies of trough and locally planar cross-bedded medium- to coarse-grained sandstone (*Sp* and *St* in Miall's [1985] scheme; Table 3.1), with wedge-shaped sets. These sets vary in set thickness between 15cm and 50cm (Figure 3.2). A third facies also present comprises pebbly granulestones, generally with clasts with long axes smaller than 7cm (Figure 3.3) which commonly occurs as a trough cross-bedded channel-fill (Facies code: Gt; Table 3.1). Channel-fills vary in size between 1.5m and 4m wide, and are generally 15-20cm deep (Figure 3.3). These three facies can be considered together as facies association 1, which reaches a thickness of approximately 300m above the basement nonconformity in the Kranskop section (Figure 3.1). Prepared sections (Figure 3.4), show that, mineralogically, the rocks of facies association 1 are immature and poorly sorted, and contain, on average (300 points from 1 thin section) 43% quartz, 33 % matrix (clays), 21% lithic fragments (mainly quartzite), and 3% muscovite. Grains are sub-rounded to sub-angular, and of generally low sphericity. Given the general immaturity of the sediment, it is likely that feldspars, now weathered, were initially also present, and are represented by areas in photomicrographs where clay patches are prevalent. Quartz pebbles in channel-fills are generally angular to sub-rounded and poorly sorted (Figure 3.3). Large sub-euhedral feldspar crystals are also present amongst the pebbly granulestones of the channel-fills (Figure 3.5). These matrix-supported pebbly granulestones have an orthoclase-rich granule-sized interclast material.

Between 300m and 650m, a second facies association is defined. Facies association 2 consists of coarse and very coarse sandstone- and granulestone-filled channel forms (Gt: Table 3.1) (Figure 3.6), within which planar and trough cross-bedding (Sp and St) of medium set thickness (c.20-30cm), and small (<20cm) set thickness occur (Figure 3.7). Planar-bedded sandstone also occurs locally (Figure 3.1). Generally the channel-fills are less granule- and pebble-rich than those in facies association 1. These facies are arranged cyclically to produce individual fining-up sequences which are typically 70cm in thickness, with the lowermost c. 30cm being composed of granulestone-fill (Figure 3.6). There is also an overall fining-upwards trend displayed by this facies association as a whole, so that towards the top, pebble lag deposits and granulestones become less common as set thicknesses decrease concomitantly upwards (Figure 3.7). Locally, evidence for soft-sediment deformation can be seen (Figure 3.8). Thin sections prepared from samples from facies association 2 show that the rock is comprised, on average (300 points from 1 thin section) 45% quartz, 24% matrix (=clay, probably replacing orthoclase), 24% lithic fragments (mainly quartzite) and 7% muscovite (Figure 3.9). Sorting and grain shapes are comparable with those of facies association 1.

Between 650 and 675m above the basement nonconformity there is a sudden change in sedimentary facies within the Blouberg Formation (Figure 3.1). The medium- to coarse-grained sandstones with small sets of cross-bedding found in the uppermost portion of facies association 2 are overlain by coarse, matrix-supported conglomerate and breccia. Unfortunately the contact between facies associations 2 and 3 is not exposed in the field (Figure 3.1).

From 675m to 925m (Figure 3.1) facies association 3 is comprised of three facies: bedded, cross-bedded and massive matrix-supported conglomerate, composed of angular feldspathic clasts (pebbles, cobbles and, rarely boulders), and sub-rounded to rounded quartz cobbles (Figures 3.10 and 3.11)(Facies code Gmg; Table 3.1). These large feldspar clasts, which generally range in size from 2cm to 25cm diameter, consist of orthoclase derived from the basement gneisses and have sub-rounded shapes with low sphericity (Figure 3.10); they occur within an arkosic granulestone matrix (Figure 3.11), and can only rarely be seen to be imbricated. Generally, conglomerates are arranged in fining-upwards cycles. Each cycle, which is typically between 50 and 100cm thick, is topped by a fourth facies, comprising small channel forms between 10 and 35cm thick, filled with trough cross-bedded coarse arkosic sandstone (Figures 3.12 and 3.13). Thin sections prepared from interclast material in the conglomerate shows that this portion of the rock is composed, on average, of 38% quartz granules, 34% matrix (=clay), 24% lithic fragments, 2% muscovite and 2% feldspar (100 points from 1 thin section)(Figure 3.14).

From 925m to the top of the succession (1400m), the fourth facies association is also composed of matrix-supported massive, bedded and cross-bedded conglomerate, and is thus similar to facies association 3, except that channel forms appear to be laterally more extensive, and may, instead, represent laterally extensive sandstone lenses or even sheets (it is generally difficult to establish the extent of this facies on account of the narrow width of river section). These wide channel forms/sandstone sheets are found between conglomerate beds, and contrast with the narrow sandstone-filled channel forms of facies association 3 (Figure 3.15). Red-coloured sandstone clasts can also be found locally in the conglomerate.

The similarity between facies associations 1 and 2 suggests that they should be considered together as an individual, lower member of the Blouberg Formation. The similarity between facies associations 3 and 4, and the dissimilarity between these and the lower facies associations, suggest that they should be considered together as a separate upper member. The lithological contrast between the Lower (sandy) and Upper (conglomeratic) members of the Blouberg Formation is strong, and each member can be readily distinguished in the field.

Having identified a general two-member stratigraphy for the Blouberg Formation from the 1400m Kranskop vertical profile, in the next section other outcrops of the Blouberg Formation from further east will be considered in terms of this apparent type stratigraphy.

3.3: Blouberg Formation in the area of Blouberg mountain:

There is a considerable distance (about 25km) between the Kranskop outcrop of the Blouberg Formation and the outcrops surrounding Blouberg mountain, in which no Blouberg strata are preserved. Nevertheless, outcrops on the southern side of the mountain, which lie south of the southern strand of the Melinda Fault, appear to correlate reasonably well with the Blouberg strata from the Kranskop section. Outcrop is more often exposed in three-dimensions in the Blouberg area than in the Kranskop area, due to the less-steeply orientated dip, and greater topographical relief (Appendix 1).

Despite the fact that three-dimensional outcrop is better in this area, the size of outcrops is, again, insufficient for establishing architectural elements. However, facies and facies associations could readily be recognised. The most westerly outcrops of the Blouberg

Formation in the Blouberg area occur around 23°08.02'S; 28°55.16'E. Generally the outcrop here is quite weathered, and the angle of dip of the bedding is matched by the south-facing slope of the hillside, so the outcrop exposes only about 10m of vertical section. The lithology is characterised by purple and cream coloured coarse sandstone and granulestone, with trough and planar cross-beds. Channel forms filled with small rounded quartz pebbles, with a maximum diameter of 3cm, and angular feldspathic clasts (5-10cm diameter) (Figure 3.16) are locally developed, and reach a maximum of 5m width, 55cm depth. The characteristics observed from this Blouberg Formation locality compare favourably with facies association 1 from the Kranskop section (Lower Member).

Between 23°06.80'S; 28°58.50'E and 23°08.00'S; 28°56.50'E (on the farm Buffelshoek 261LR) an almost continuous ridge runs approximately east-west, which is comprised of the Blouberg Formation, exposed in steeply dipping to slightly overturned rocks. The outcrop may continue further along the ridge to the west as far as 23°08.00'S; 28°55.50'E, though it is covered by talus derived from the Wyllies Poort Formation above. The approximate base of the steeply southwards-dipping Blouberg Formation can be gauged by the presence of basement rocks on the northern side of the ridge, which are nonconformably overlain by the Blouberg Formation. Often this nonconformity is marked by the presence of jasperitic, hydrothermally altered rocks (Chapter 2; Figure 2.17). The total thickness of exposed Blouberg strata along this ridge is less than 300m. The lithology consists of coarse-grained sandstone and granulestone, often with rounded quartz pebbles and cobbles, and sub-angular to angular feldspar grains up to 1cm in diameter (Figure 3.17). Locally cobbles of foliated gneiss are also present (Figure 3.18). Quartz cobbles often exceed 10cm in diameter (Figure 3.19). Generally planar and trough cross-bedded sandstones (Sp and St) are common facies in this area, though channel-fills seem to be absent.

Cross-bedding is often preserved in sets of 30-50cm (Figure 3.20), which build fining-upwards pebbly sandstone cycles. Rounded quartz cobbles often occur on the bedding plane at the base of the set, though they may also occur in foresets (Figure 3.21). Foresets are generally comprised of coarse sandstone and granulestones, which may grade up into medium-grained sandstone on top-most foresets. Point counting of thin sections of Blouberg rocks from this area show that, on average (500 points per section, 2 sections), rocks are composed of 38% quartz, 35% lithic fragments, 24% matrix (=clay), and 3% feldspar and opaques combined (Figure 3.22). Generally the lithology of the rocks seems to bear much in common with facies association 1 (Lower Member) of the Kranskop section.

Continuing eastwards, the next good outcrop of the Blouberg Formation occurs at 23°06.80'S; 28°59.40'E, on the farm Beauley 260 LR. Again, this consists of steeply dipping to overturned Blouberg strata. Trough and planar cross-bedded medium- to coarse-grained sandstone, containing some heavy mineral drapes on foresets is the common lithology, and this locally exhibits soft-sediment deformation. Pebble- and cobble-sized clasts are conspicuously absent (Figure 3.23). Towards the northern edge of this outcrop (i.e. towards the base of the Blouberg Formation), a c.1m-thick folded muddy sandstone bed is developed (Figure 3.24). The stratigraphic position within the Blouberg Formation (i.e. the height above basement) of this outcrop is unknown, as the underlying contact with the basement is not seen. Though the lithology of this outcrop is not exactly comparable with any seen in the Kranskop section, this Beauley outcrop most readily compares with facies association 2 (Lower Member). In contrast to this relatively fine-grained, steeply dipping Blouberg succession, approximately 1km S.E. of this area, at 23°07.22'S; 28°59.91'E, sub-horizontally bedded strata of coarse sandstone and granulestone are found, which locally contain beds which are conglomeratic. The latter consist of feldspathic basement clasts (Figure 3.25), similar to those found in facies associations 3 and 4 (Upper Member) in the Kranskop section.

From the latter outcrop of conglomerate eastwards until 23°07.15'S; 29°03.00'E, a poorly exposed outcrop of Blouberg strata lies beneath cliffs of the Mogalakwena Formation. Generally this outcrop is covered by talus derived from the Mogalakwena Formation above, but rare good exposures suggest that the sub-horizontal strata (of coarse sandstone and granulestone) contain trough cross-bedding, with preserved set thickness of about 50cm – 1m. Locally rounded quartz pebbles and more angular feldspathic basement clasts can also be found in these coarse sandstones and granulestones. At 23°07.22'S; 29°01.58'E a good vertical section is exposed on the South-facing hillside, of sub-horizontal Blouberg strata, which is shown in a sedimentary profile in Figure 3.26. The section is comprised of slightly less than 100m of a fairly monotonous sequence of trough cross-bedded medium- to coarse-grained sandstone, with rare channel-fills. The lithology is generally free of granules, though it locally contains quartz and feldspar-rich rock fragments, with clasts up to 8cm in diameter. Again, this facies association compares favourably with facies association 1 (Lower Member) of the Kranskop section.

At 23°06.86'S; 29°02.26'(Farm Dantzig 3LS), on a north facing slope, an outcrop of sub-horizontally bedded matrix-supported conglomerate can be found. The matrix is composed of coarse sandstone and granulestone, and the basement clasts are generally sub-angular and feldspathic, mostly c. 10cm in diameter (Figure 3.27) and commonly contain a foliation. Sub-rounded quartz cobbles of similar dimensions are also common. Bedding and trough cross-bedding is generally visible within these rocks. Locally, clasts of red-coloured sandstone are also present, which vary in diameter from 3 to 8cm. Sand-filled channel forms are developed in this matrix-supported conglomerate, typically around 6m wide, and 60cm deep. Channel forms are filled with trough cross-bedded arkose and feldspathic granulestone and locally contain quartz pebbles. This facies association bears a considerable similarity to facies association 4 (Upper Member) of the Kranskop section. The exposed conglomerates, however, are relatively thin (about 20m), and grade into coarse sandstone and granulestone (similar to the conglomerate matrix and channel-fill beneath) where large clasts are more rare; conglomerates are restricted to channel-fills (preserved channels are typically about 5m wide, 50cm deep). This coarse sandstone with local lenticular conglomerates fines upwards into medium-grained trough cross-bedded sandstone, with set thicknesses, typically, of 50cm. Both the upper and lower margins of this outcrop are marked by intrusions of dolerite sills, so the height within the Blouberg stratigraphy is difficult to determine.

The topography of the area around farm Dantzig 3LS produces an east-west trending valley, flanked to the north and south by ridges. The southern ridge is occupied by previously described sub-horizontal Blouberg sediments, overlain by sub-horizontal strata of the Mogalakwena Formation (Appendix 1). In contrast, the northern ridge of the Dantzig valley, between 23°06.20'S; 29°01.70'E and 23°06.00'S; 29°02.35'E, is underlain by steeply dipping to overturned strata of the Blouberg Formation. The S.S.E.- and N.N.W.-dipping strata are probably underlain by basement gneiss (the localised presence of jasperitic hydrothermal rocks may be diagnostic of the nonconformity), but the gneiss itself does not outcrop, the area being covered by talus derived from the Wyllies Poort Formation above. The total thickness of Blouberg sedimentary succession exposed here is less than 150m.

The lowermost part of the succession here is composed of 4-6m of reddish-purple, micaceous muddy sandstone and medium-grained sandstone beds, which rapidly grade upwards into coarse arkose, sandstone and granulestone, which dominate the remainder of the succession. Large, sub-rounded quartz pebbles and cobbles occur towards the top, and are absent in the lower parts of the stratigraphy. Rare feldspathic clasts of around 1cm diameter are also present. Generally, the 150m-thick sequence exhibits a coarsening-up character.

The dimensions and style of sedimentary structures also varies with height in the stratigraphy. The lowermost shaley sandstones and sandstones are dominated by small planar cross-bedded sets, between 5 and 10cm in height, which suggest a palaeocurrent direction from west to east. Higher up the succession, large-scale trough cross-beds dominate (Figure 3.28), with granulestone-filled channel forms preserved locally. Set thicknesses of planar cross-beds, which occur locally, are typically between 50 and 180cm (Figure 3.29). Preserved channel forms are typically 4.5m wide, and about 40cm deep, and contain clasts up to 9-10cm in diameter. Thin section analysis of Blouberg Formation rocks from Dantzig shows that, on average, the rocks are composed of 42% quartz, 36% matrix (=clay), 17% lithic fragments (=quartzite), and 4% opaques, feldspar and mica combined (averaged from 2500 counted points, in 5 sections). Palaeocurrent directions gained from trough cross-beds in this location show an average trend towards 260°, almost opposite to the current directions associated with the finer grained sedimentary rocks lower in the succession. Despite considerable differences (i.e. the presence of a muddy sandstone facies, general coarsening-up sequence, and comparably larger trough cross-bed set thicknesses), this Dantzig outcrop bears some resemblance to facies association 1 of the Kranskop sequence.

All the outcrops described above in the vicinity of Blouberg Mountain underlie areas immediately south of the southern strand of the Melinda Fault. Generally, Blouberg rocks are absent from areas north of the southern strand of the Melinda Fault, with one important exception. At 23°05.76'S; 28°53.47'E (Farm Varedig 265LR), a small outcrop of steeply-dipping and locally overturned Blouberg strata occurs unconformably beneath basal conglomerates of the Mogalakwena Formation. This lithology consists of purple, laminated to thinly bedded, fine- to medium-grained muddy arkosic sandstone (Figure 3.30). Cross-bedding is absent, and the bedding has a sheet-like geometry, though small (c.20cm deep, 70cm wide) channel forms are observed rarely (Figure 3.31). It is important to bear in mind that this is the only outcrop of Blouberg strata which occurs north of the southern strand of the Melinda Fault. Point counting of a thin section of this rock shows that it comprises 34% quartz, 35% matrix (=clay), 23% lithic fragments (=quartzite), 6% opaques and 2% muscovite. The rock from this location shows a general immaturity, which is comparable with that of the Blouberg Formation elsewhere in the Blouberg basin.

The general high percentages of matrix recorded in the Blouberg rocks indicates that they should all be classified as sub-lithic wackes or lithic wackes (after Pettijohn *et al.*, 1973). However, the generally weathered state of Blouberg rocks, and the presence of common feldspars in conglomerate beds, suggests that fresh samples of Blouberg sandstones would be more arkosic. The high proportions of matrix recorded in point counts may be due, in part, to the weathering of feldspars to clay minerals.

3.4: Palaeocurrent analysis:

Indicators for palaeocurrent direction were taken throughout the exposed Blouberg Formation. Ripplemarks are not preserved within the Formation, so dip directions of trough (and locally planar) cross-bedding foresets were used as indicators of palaeocurrent direction.

The steeply-dipping nature of the Kranskop section, and generally two-dimensional nature of the outcrop are not conducive for the accurate measurement of foreset dip-directions. Only rarely, when the stream bed possessed sufficient topography to expose vertically-dipping bedding planes and cross-bedded sets, could the orientation of foresets and bedding be measured. The original (pre-tectonic) foreset orientation was calculated by rotating bedding planes to their original horizontal orientation, and by similarly rotating foreset planes by the same amount. Only rarely was imbrication identified in the clasts of the conglomeratic Upper Member of the Kranskop section. The few foreset orientations within the vertically dipping strata at Kranskop which could be measured, were recorded with a very acute angle (<5°) with the bedding plane. With such shallow angular relationships, when rotational correction for horizontal bedding planes is carried out on a stereo net, a very small error in measurement, plotting or rotation may easily allow for 180° change in palaeocurrent direction. Such a potential error in the palaeocurrent data from the Kranskop strata should therefore be borne in mind, especially in view of the small data set that it was possible to collect. Palaeocurrent data collected from the outcrops of the Blouberg Formation in the Kranskop area are presented in Figure 3.32, and show a wide spread of palaeocurrent directions.

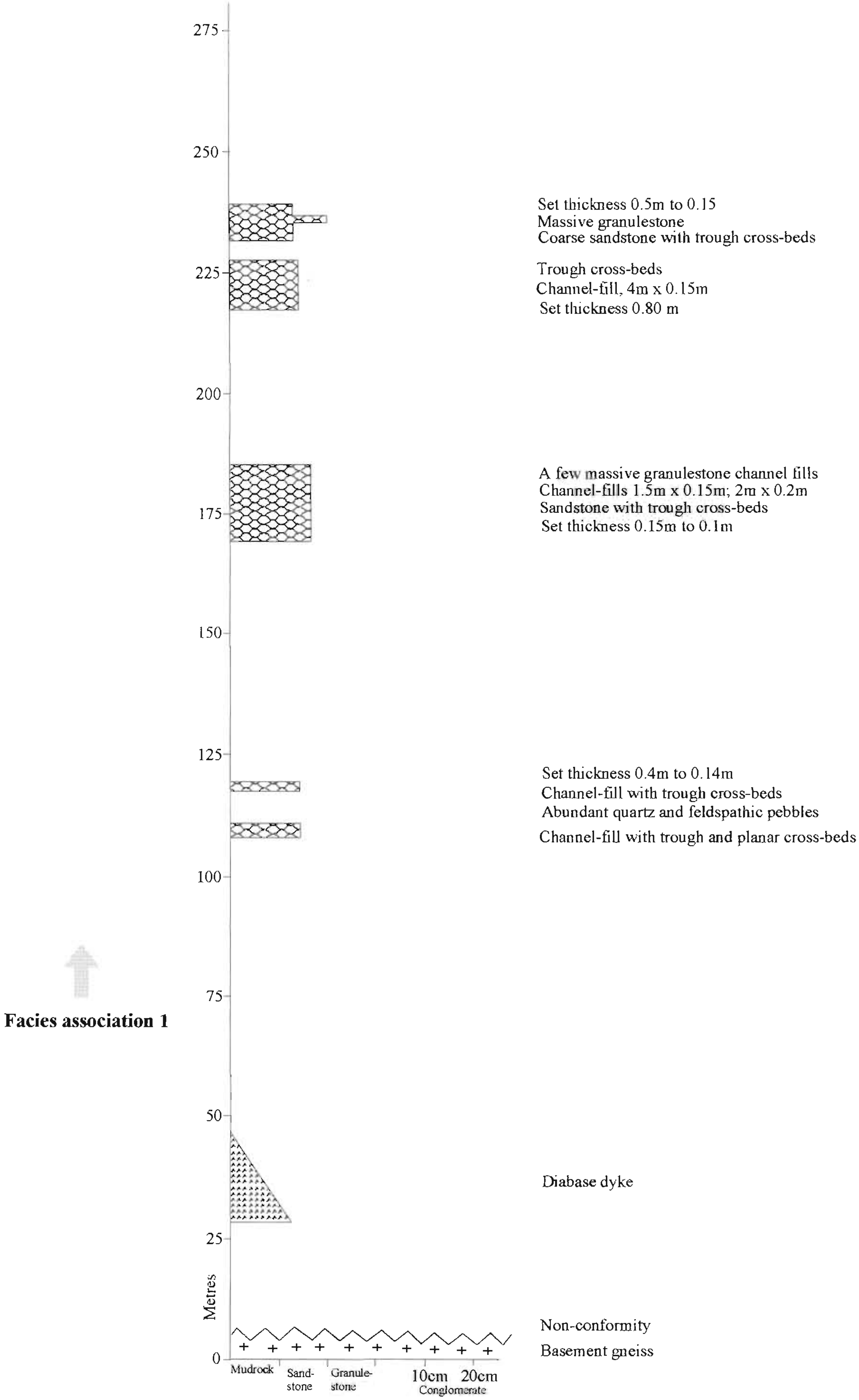
Palaeocurrent data from the Blouberg Formation around Blouberg Mountain are presented in Figure 3.33 (Lower Member) and Figure 3.34 (Upper Member), and show that palaeocurrents dominantly flowed towards the S.W. and west respectively. The geographic distribution of outcrops of the Blouberg Formation and of their palaeocurrent directions are shown in Figure 3.35. Figure 3.35 also shows the location of sites (A to F) at which measurements were taken for palaeohydraulic estimations. These calculations will be discussed in the following section.

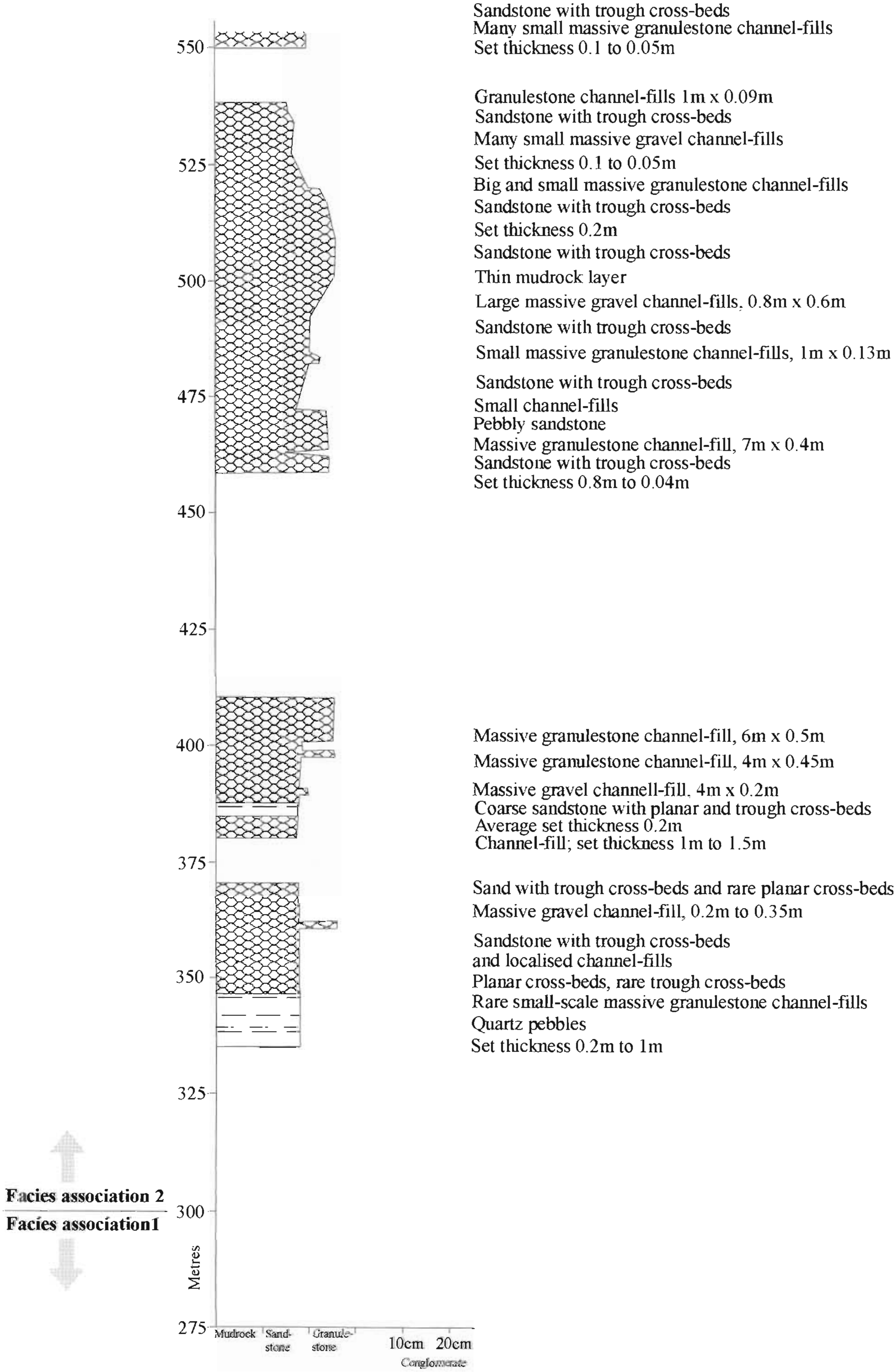
3.5: Palaeohydraulics:

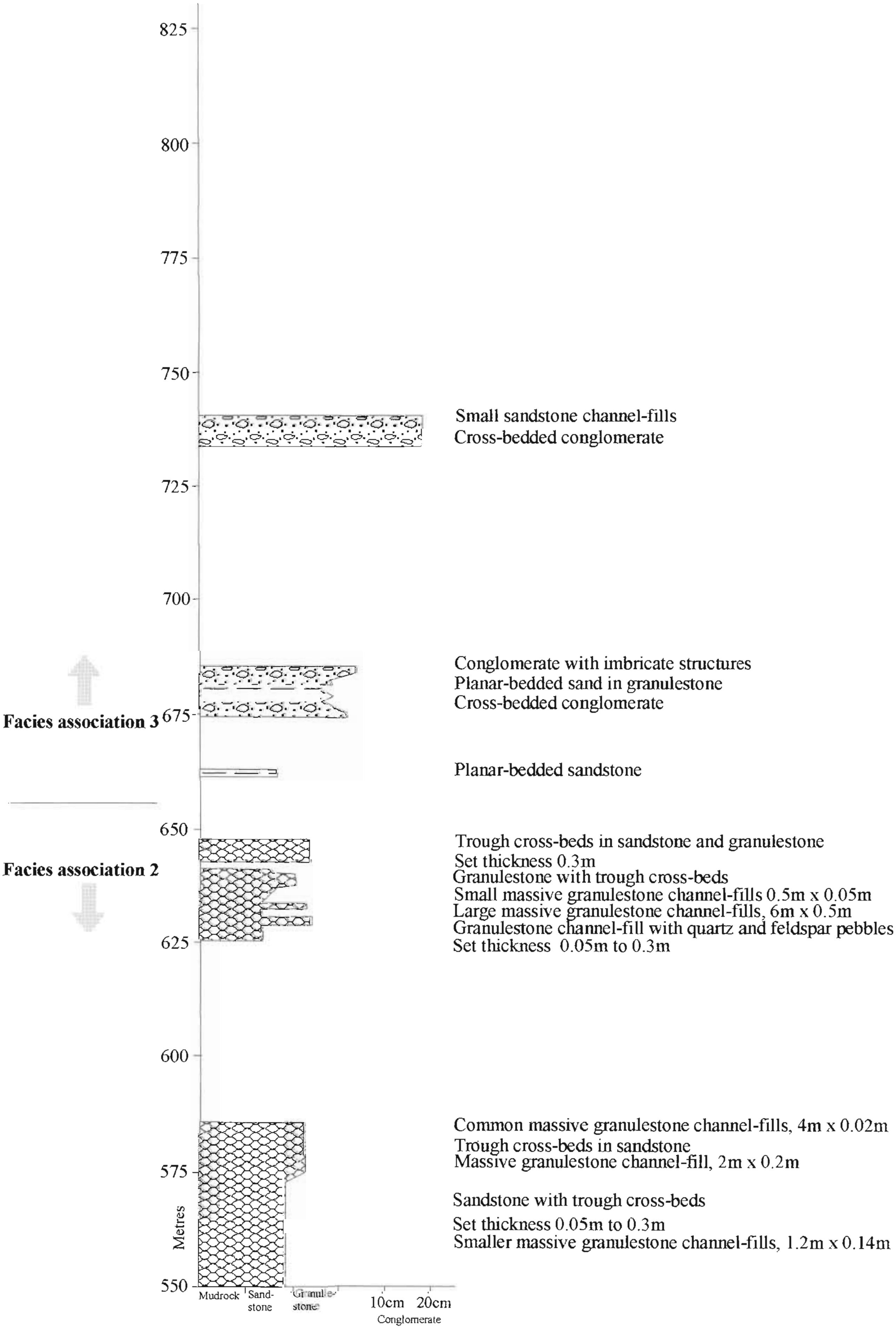
The general presence of clast-filled channels and predominance of cross-bedded strata, especially in the Lower Member of the Blouberg Formation, provided measurements from which palaeohydrological parameters can readily be calculated. Measurement of the length of the intermediate axis of clasts, channel dimensions and the set thickness of cross-bedding were recorded from outcrops throughout the Blouberg Formation, and were used for palaeohydrological modelling (as outlined in Section 1.6.3). Sites for measurement were chosen to illustrate how parameters might vary along the inferred axis of the preserved Blouberg basin. Clast-filled channels could be recorded locally (for calculation of equations 1 to 4 in Section 1.6.3.1), and these results are shown in Table 3.2, and in Figure 3.36. Measurements of the set thickness of cross-bedding could be recorded more frequently, and the calculated palaeohydrological parameters (equations 4 to 16 in Section 1.6.3.2) are shown in Table 3.3. These data are also shown as histograms in Figures 3.37 and 3.38.

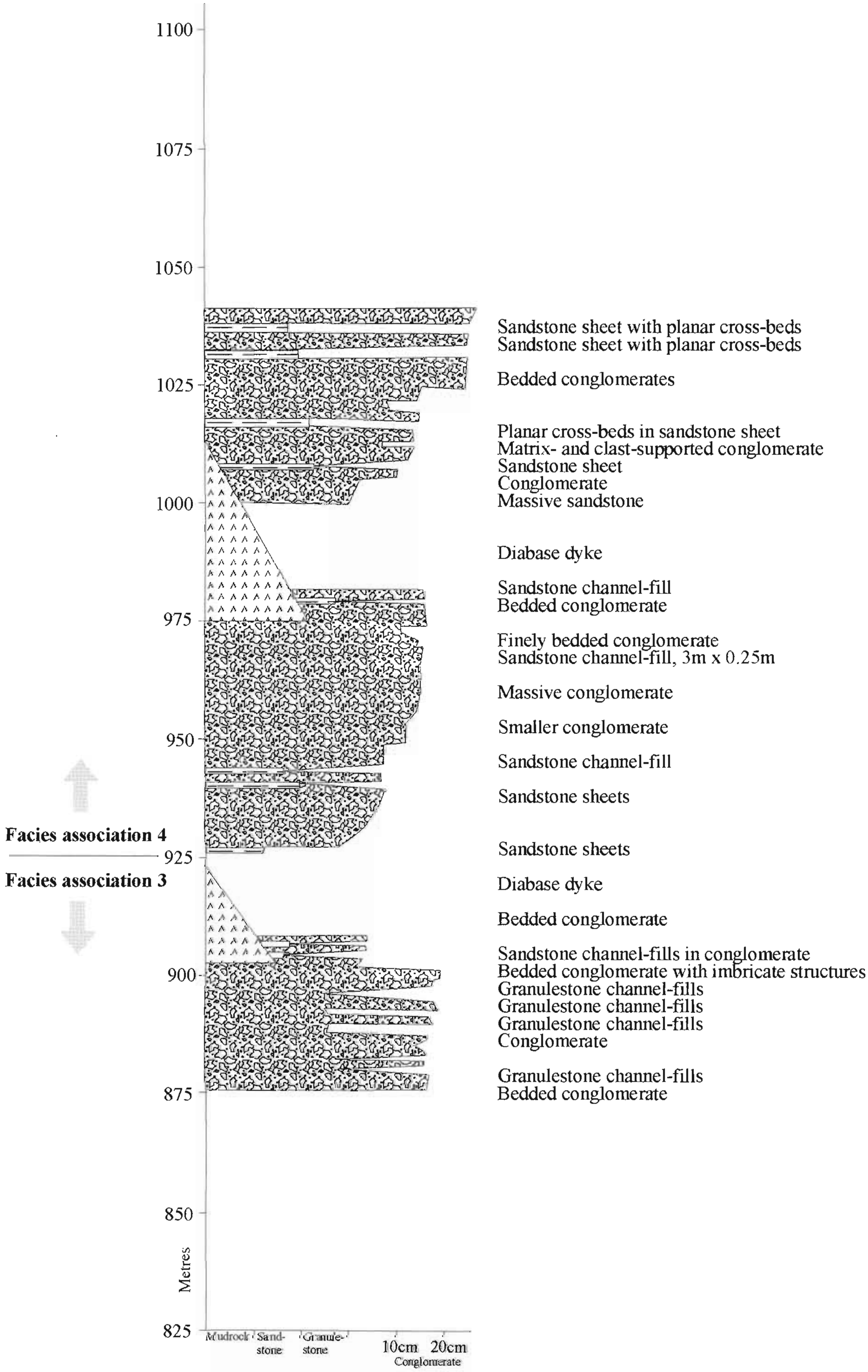
It should be stressed that the values calculated for palaeohydraulic parameters should not be considered as absolute values, but rather should be used for comparative purposes between different locations in the basin. For example, parameters calculated using the length of the intermediate axis of the largest clast within a channel of known cross-sectional area (equations 1-4 in Section 1.6.3.1) can only provide a minimum estimate of palaeohydrological parameters, as the initial (pre-erosion) cross-sectional area of the channel is not known. The columns shown in the histograms (Figures 3.36, 3.37 and 3.38) are arranged geographically, so that variation across the approximately East-West trending basin axis can be gauged.

Generally, the histograms in Figures 3.36, 3.37 and 3.38 show little systematic variation across the Blouberg basin, with the largest parameters of discharge, drainage area, and stream length being calculated for the approximate centre of the preserved basin (Location B). Palaeoslope appears to decrease towards the centre of the basin. These calculated parameters are discussed more fully in Section 8.2.1.


275
250
Set thickness 0.5m to 0.15
Massive granulestone
Coarse sandstone with trough cross-beds
225
Trough cross-beds
Channel-fill, 4m x 0.15m
Set thickness 0.80 m
200
A few massive granulestone channel fills
Channel-fills 1.5m x 0.15m; 2m x 0.2m
Sandstone with trough cross-beds
Set thickness 0.15m to 0.1m
175
150
125
Set thickness 0.4m to 0.14m
Channel-fill with trough cross-beds
Abundant quartz and feldspathic pebbles
Channel-fill with trough and planar cross-beds
100
75
Facies association 1
50
Diabase dyke
25
Metres
Non-conformity
Basement gneiss
0
Mudrock
Sand-stone
Granule-stone
10cm
20cm
Conglomerate


Sandstone with trough cross-beds
Many small massive granulestone channel-fills
Set thickness 0.1 to 0.05m
Granulestone channel-fills 1m x 0.09m
Sandstone with trough cross-beds
Many small massive gravel channel-fills
Set thickness 0.1 to 0.05m
Big and small massive granulestone channel-fills
Sandstone with trough cross-beds
Set thickness 0.2m
Sandstone with trough cross-beds
Thin mudrock layer
Large massive gravel channel-fills, 0.8m x 0.6m
Sandstone with trough cross-beds
Small massive granulestone channel-fills, 1m x 0.13m
Sandstone with trough cross-beds
Small channel-fills
Pebbly sandstone
Massive granulestone channel-fill, 7m x 0.4m
Sandstone with trough cross-beds
Set thickness 0.8m to 0.04m
Massive granulestone channel-fill, 6m x 0.5m
Massive granulestone channel-fill, 4m x 0.45m
Massive gravel channell-fill, 4m x 0.2m
Coarse sandstone with planar and trough cross-beds
Average set thickness 0.2m
Channel-fill; set thickness 1m to 1.5m
Sand with trough cross-beds and rare planar cross-beds
Massive gravel channel-fill, 0.2m to 0.35m
Sandstone with trough cross-beds
and localised channel-fills
Planar cross-beds, rare trough cross-beds
Rare small-scale massive granulestone channel-fills
Quartz pebbles
Set thickness 0.2m to 1m
550
525
500
475
450
425
400
375
350
325
300
275
Metres
Facies association 2
Facies association1
Mudrock
Sand-stone
Granule-stone
10cm
20cm
Conglomerate


825
800
775
750
Small sandstone channel-fills
Cross-bedded conglomerate
725
700
Conglomerate with imbricate structures
Planar-bedded sand in granulestone
Cross-bedded conglomerate
Facies association 3
675
Planar-bedded sandstone
650
Trough cross-beds in sandstone and granulestone
Set thickness 0.3m
Facies association 2
Granulestone with trough cross-beds
Small massive granulestone channel-fills 0.5m x 0.05m
Large massive granulestone channel-fills, 6m x 0.5m
Granulestone channel-fill with quartz and feldspar pebbles
Set thickness 0.05m to 0.3m
625
600
Common massive granulestone channel-fills, 4m x 0.02m
Trough cross-beds in sandstone
Massive granulestone channel-fill, 2m x 0.2m
575
Sandstone with trough cross-beds
Set thickness 0.05m to 0.3m
Smaller massive granulestone channel-fills, 1.2m x 0.14m
Metres
550
Mudrock
Sand-stone
Granule-stone
10cm 20cm
Conglomerate


1100
1075
1050
1025
1000
975
950
925
900
875
850
825
Metres
Facies association 4
Facies association 3
Sandstone sheet with planar cross-beds
Sandstone sheet with planar cross-beds
Bedded conglomerates
Planar cross-beds in sandstone sheet
Matrix- and clast-supported conglomerate
Sandstone sheet
Conglomerate
Massive sandstone
Diabase dyke
Sandstone channel-fill
Bedded conglomerate
Finely bedded conglomerate
Sandstone channel-fill, 3m x 0.25m
Massive conglomerate
Smaller conglomerate
Sandstone channel-fill
Sandstone sheets
Sandstone sheets
Diabase dyke
Bedded conglomerate
Sandstone channel-fills in conglomerate
Bedded conglomerate with imbricate structures
Granulestone channel-fills
Granulestone channel-fills
Granulestone channel-fills
Conglomerate
Granulestone channel-fills
Bedded conglomerate
Mudrock
Sand-stone
Granule-stone
10cm
20cm
Conglomerate

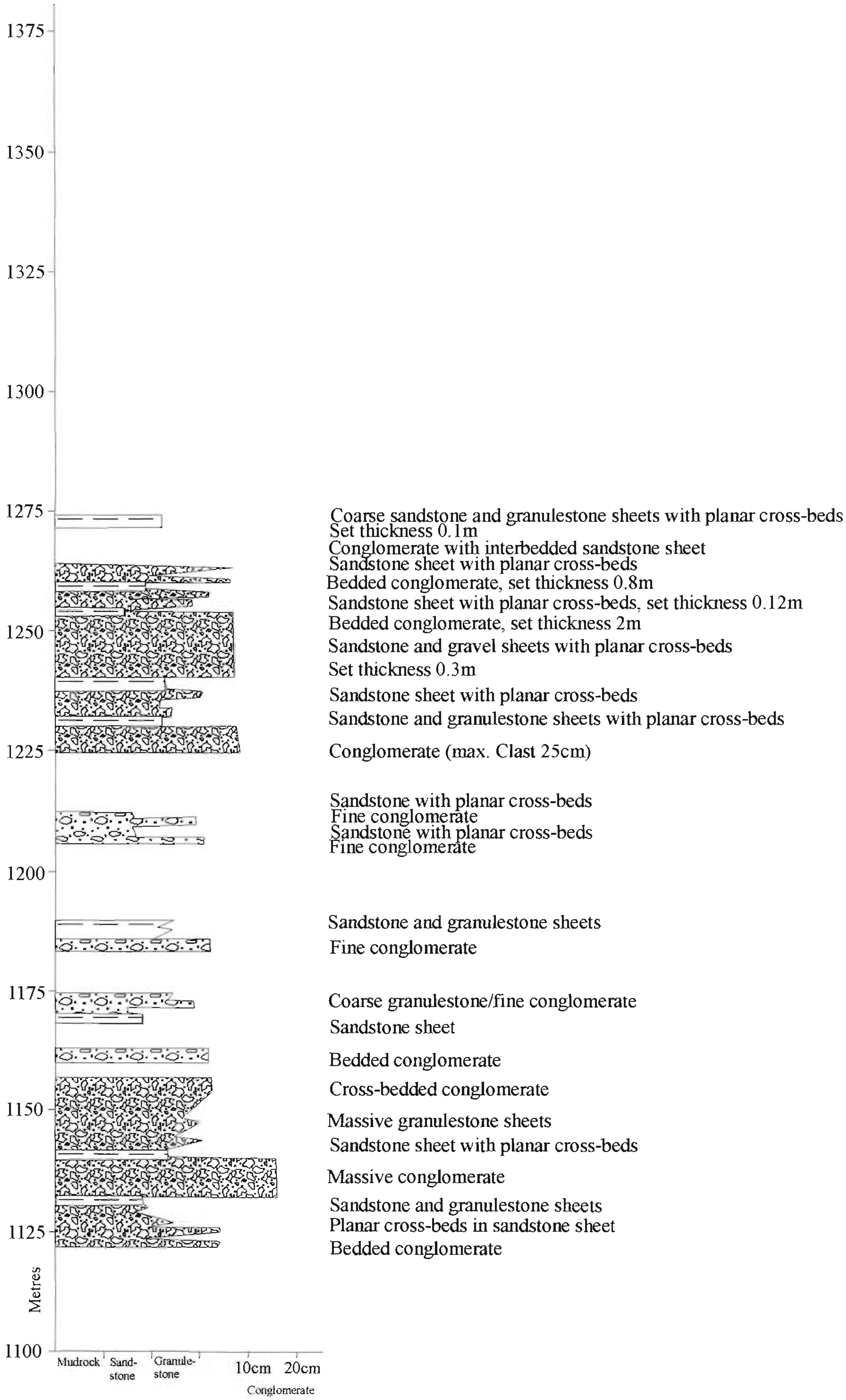

1375
1350
1325
1300
1275
1250
1225
1200
1175
1150
1125
1100
Metres
Mudrock
Sand-stone
Granule-stone
10cm
20cm
Conglomerate
Coarse sandstone and granulestone sheets with planar cross-beds
Set thickness 0.1m
Conglomerate with interbedded sandstone sheet
Sandstone sheet with planar cross-beds
Bedded conglomerate, set thickness 0.8m
Sandstone sheet with planar cross-beds, set thickness 0.12m
Bedded conglomerate, set thickness 2m
Sandstone and gravel sheets with planar cross-beds
Set thickness 0.3m
Sandstone sheet with planar cross-beds
Sandstone and granulestone sheets with planar cross-beds
Conglomerate (max. Clast 25cm)
Sandstone with planar cross-beds
Fine conglomerate
Sandstone with planar cross-beds
Fine conglomerate
Sandstone and granulestone sheets
Fine conglomerate
Coarse granulestone/fine conglomerate
Sandstone sheet
Bedded conglomerate
Cross-bedded conglomerate
Massive granulestone sheets
Sandstone sheet with planar cross-beds
Massive conglomerate
Sandstone and granulestone sheets
Planar cross-beds in sandstone sheet
Bedded conglomerate

Figure 3.1: Stratigraphic section of the Blouberg Formation in the Kranskop area.

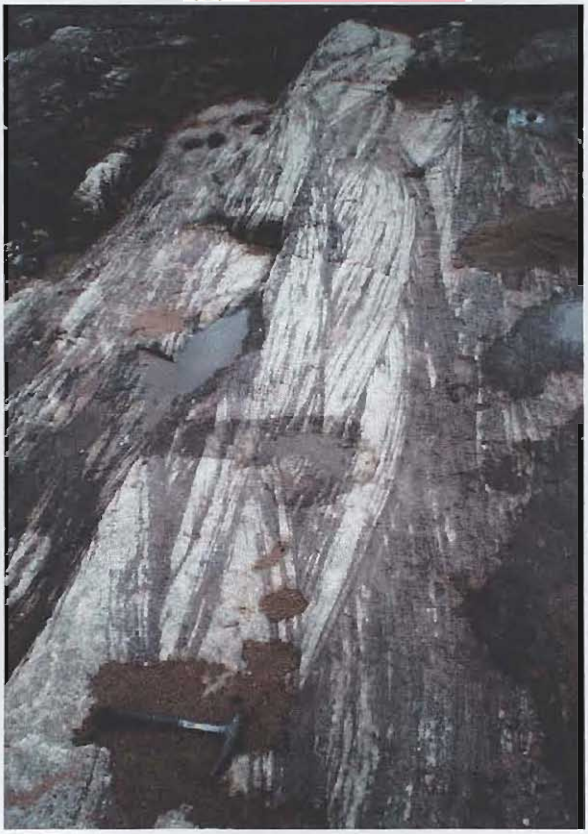


Figure 3.2: Small trough cross-bedded sets (facies association 1; Lower Member, Blouberg Formation). Recorded at 23°09.03'S; 28°41.85'E. Hammer is 30cm long.

Figure 3.3: Pebbly granulestone-filled channel with angular quartz clasts in facies association 1 (Lower Member) of the Blouberg Formation. Recorded at 23°09.03'S; 28°41.85'. Pen is 15cm long.

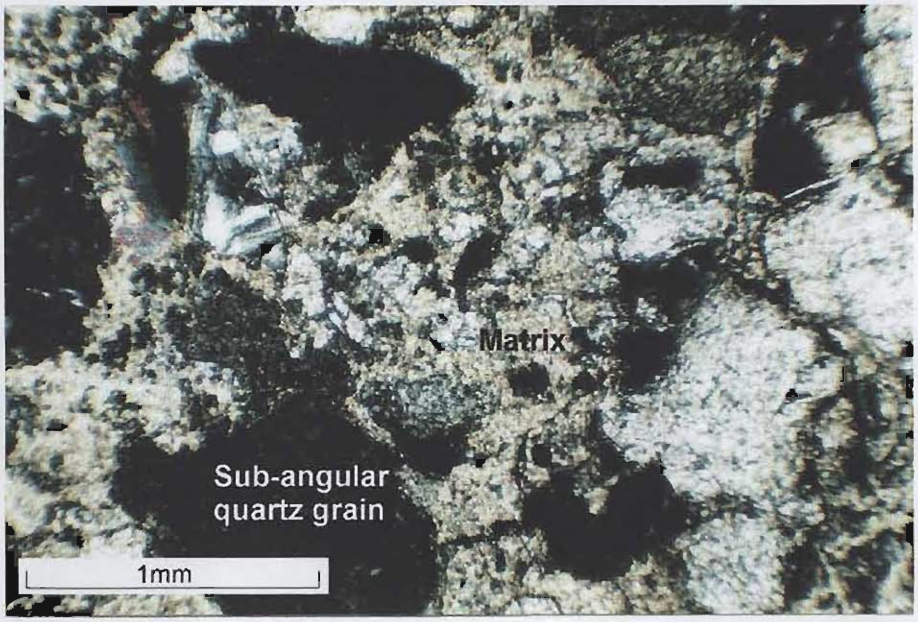


Figure 3.4: Photomicrograph of coarse sandstone from facies association 1 of the Blouberg Formation (collected at 23°09.03'S; 28°41.85'). The sediment is generally immature, with sub-angular quartz grains of low sphericity, with a high percentage of matrix, possibly reflecting weathered feldspar.

Figure 3.5: Detail of pebbly granulestone from Figure 3.3, showing that channel-fill is composed of a highly arkosic (orthoclase) granulestone with pebbles of quartz and feldspathic lithic clasts. Pen is 15cm long.

Figure 3.6: Coarse sandstone- and granulestone-filled channel forms in facies association 2 of the Lower Member of the Blouberg Formation. Recorded at 23°09.05'S; 28°41.65'E. Hammer is 30cm long.

Figure 3.7: Generally small (<10cm) sets of trough cross-bedded coarse sandstone in facies association 2 of the Lower Member of the Blouberg Formation. Recorded at 23°09.05'S; 28°41.76'. Hammer is 30cm long.

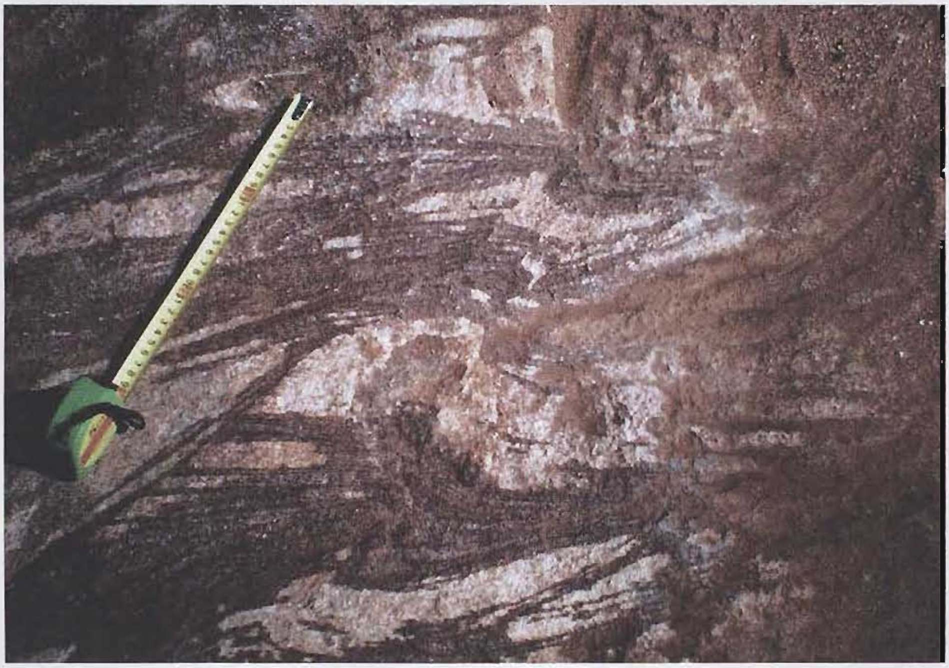


Figure 3.8: Soft sediment deformation in facies association 2 of the Lower Member of the Blouberg Formation. Scale in centimetres.

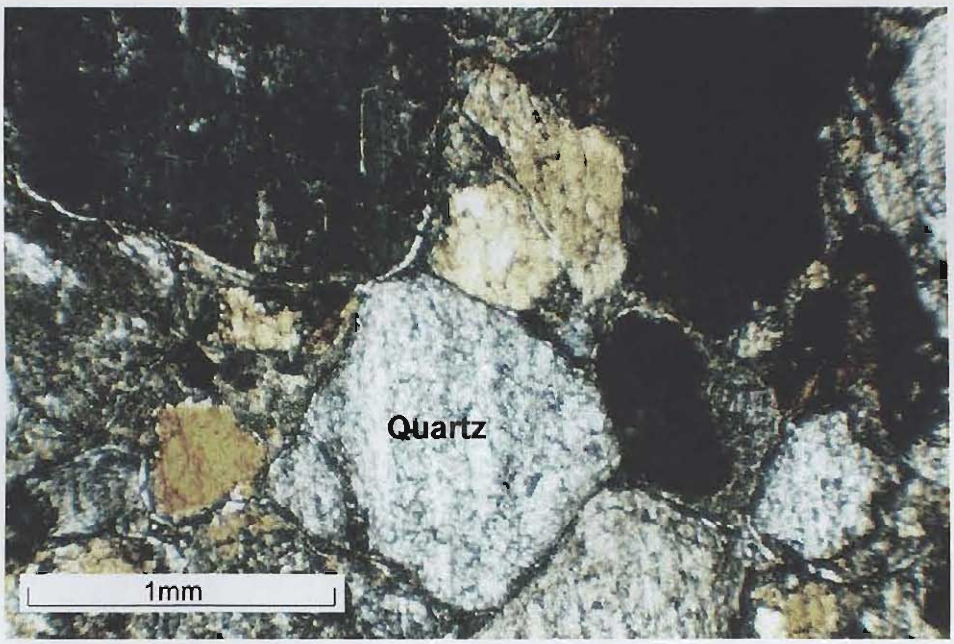


Figure 3.9: Photomicrograph of thin section of coarse sandstone from facies association 2 of the Lower Member of the Blouberg Formation. Quartz grains are sub-angular to sub-rounded, though there is generally less matrix than facies association 1 (Figure 3.4).

Figure 3.10: Facies association 3 of the Upper Member of the Blouberg Formation. Note the presence of large sub-rounded feldspathic clasts of low sphericity in a coarse arkosic matrix. Recorded at 23°09.09'S; 28°41.90'E. GPS receiver is 15cm long.

Figure 3.11: Detail of facies association 3. Note the foliation planes preserved in the cobble of feldspathic gneiss, and the coarse arkosic granulestone matrix. Hammer head is 10cm long.

Figure 3.12: Cyclicity in facies association 3. A fining-upwards massive conglomerate grades into an upper trough cross-bedded arkose. The onset of the next cycle is marked by presence of larger cobbles which, in-turn, fine upwards. Hammer is 30cm long.

Figure 3.13: Bedded, clast-supported conglomerates fine upwards into a sandstone-filled channel form, prior to the start of the next cycle, marked by the presence of larger cobbles above. Hammer is 30cm long.

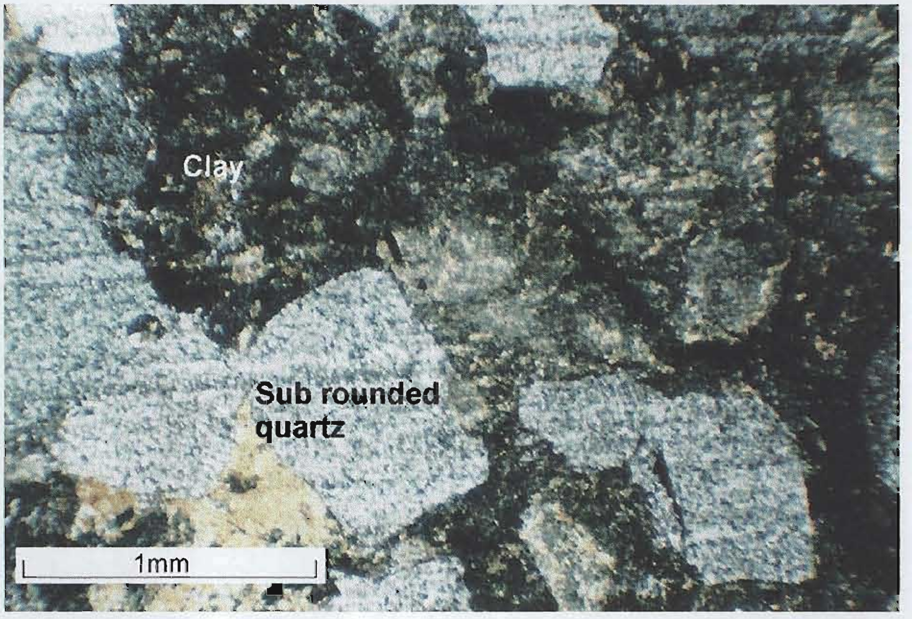


Figure 3.14: Photomicrograph of thin section of interclast material from conglomerate in facies association 3. Quartz grains are sub rounded and of low-sphericity. A high proportion of the grains consist of fine-grained, clayey material, probably reflecting weathered feldspar grains.

Figure 3.15: Facies association 4. Bedded and massive conglomerates are interbedded with trough cross-bedded sandstone sheets or wide channel forms. Recorded at 23°09.05'S; 28°41.30'E. Hammer is 30cm long.

Figure 3.16: Channel-fill in the Blouberg Formation in the Blouberg mountain area. Note the quartz and feldspar granulestone channel-fill (c.f. Figures 3.5 and 3.6 from the Kranskop area). Recorded at 23°07.96'S; 28°55.25'E. Hammer is 30cm long.

Figure 3.17: Detail of coarse, feldspathic granulestone from 23°07.47'S; 28°57.42'E. Pen is 15cm long.

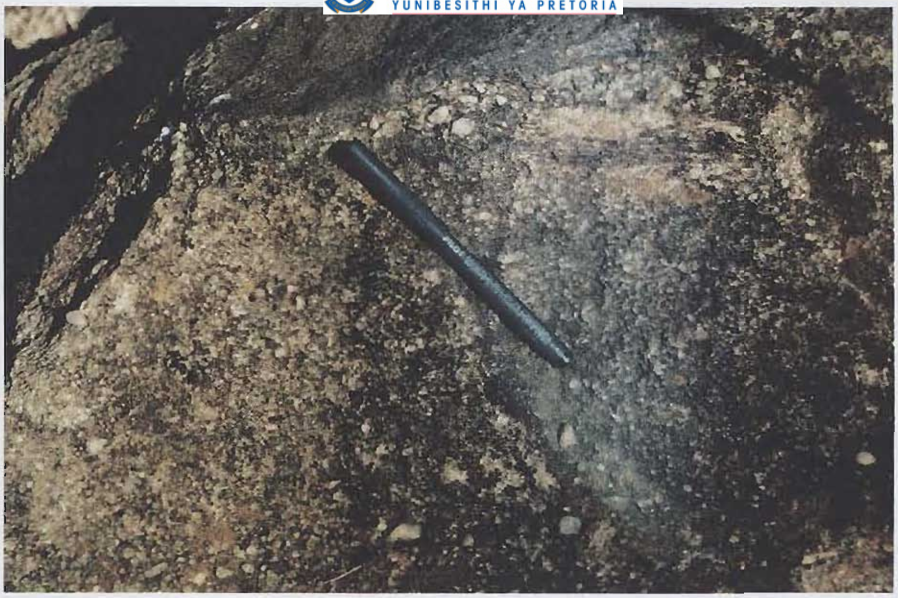


Figure 3.18: Cobbles of foliated gneiss (above and to the right of the pen) in a granulestone matrix in the Blouberg Formation. Recorded at 23°07.47'S; 28°57.42'E. Pen is 15cm long.

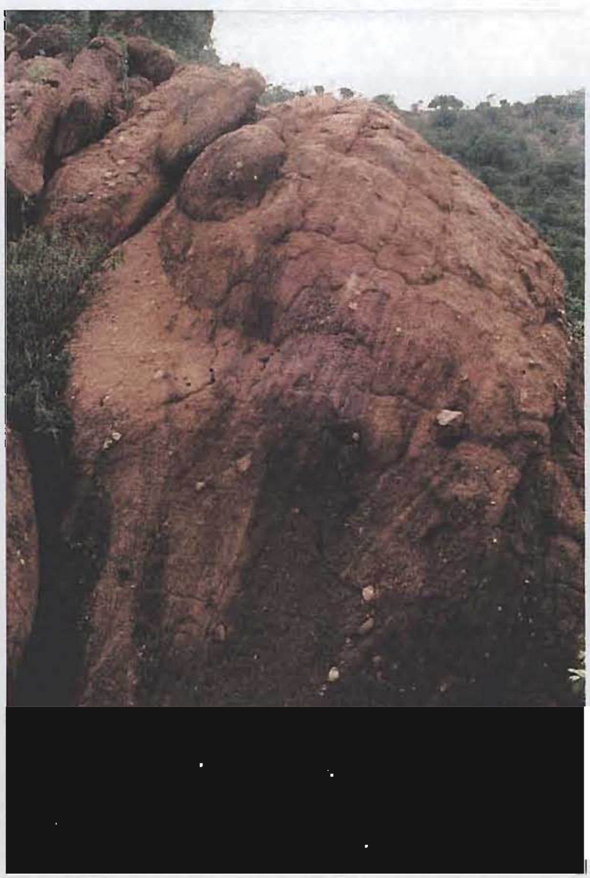


Figure 3.19: Trough and planar cross-bedded sandstone and granulestone, with large (>10cm diameter) quartz cobbles resting on foresets. Recorded at 23°07.71'S; 28°57.08'E.

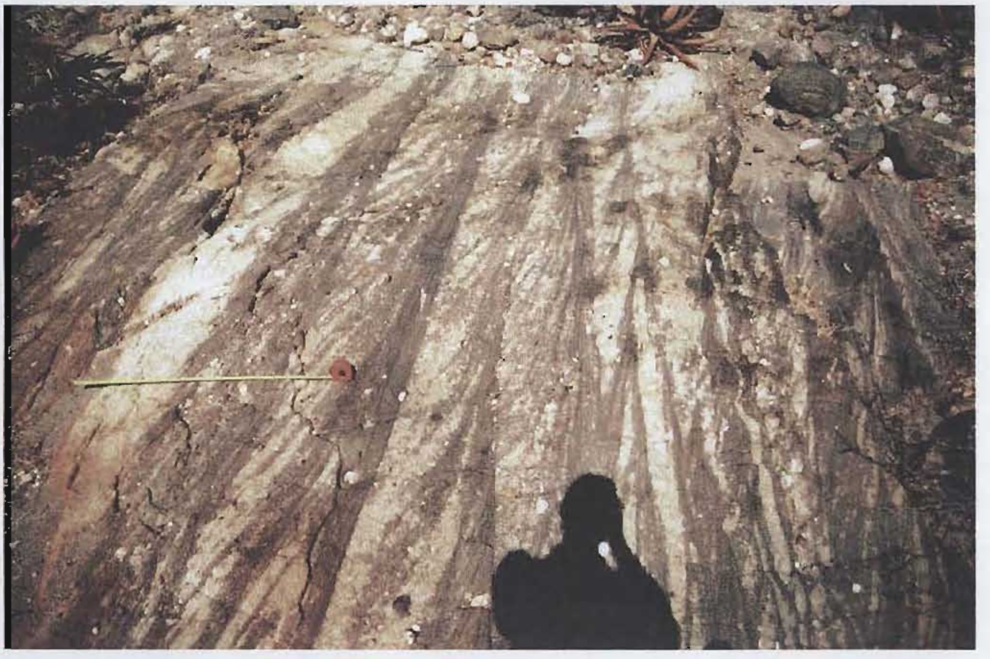


Figure 3.20: Thick (>3m) cosets of cross-bedded sandstone and granulestone in the Blouberg Formation at 23°07.47'S; 28°57.42'E. Cosets are comprised of sets of 30-40cm thickness. Tape measure is 1m long.

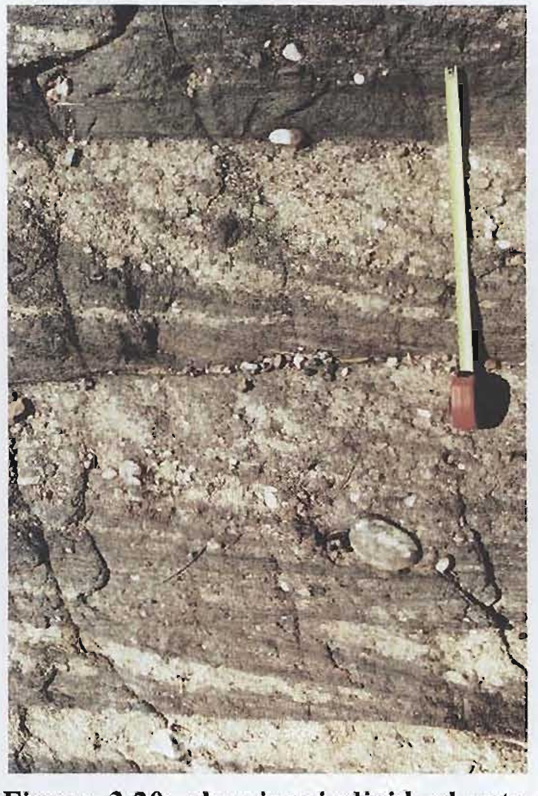


Figure 3.21: Detail of Figure 3.20, showing individual sets with isolated quartz cobbles positioned on foresets. Note fining-upwards cyclicity in each set. Tape measure is 50cm long.

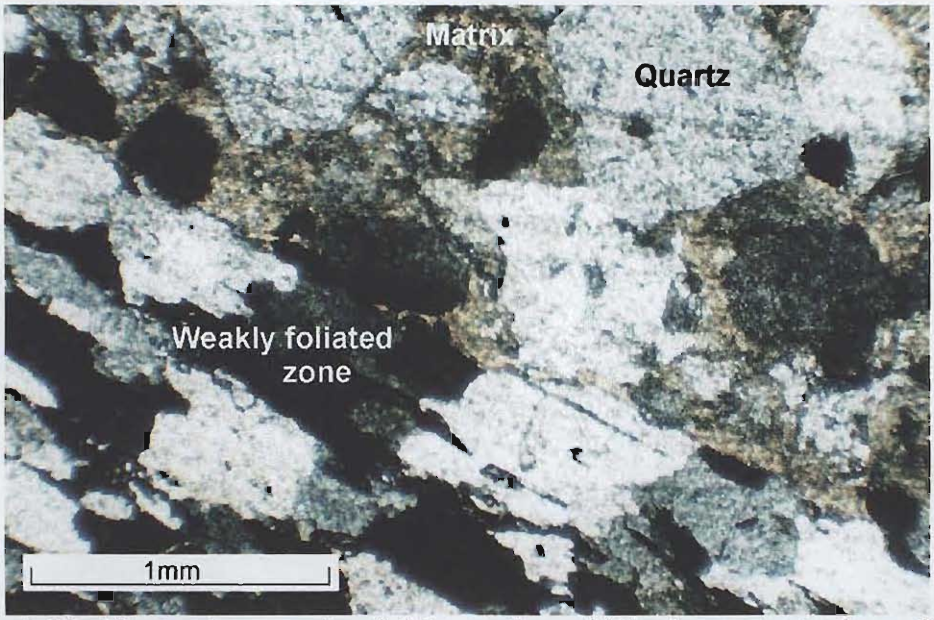


Figure 3.22: Photomicrograph of thin section of Blouberg strata from 23°07.47'S; 28°57.42'E. Sub-rounded quartz grains of low-sphericity have high proportions of interstitial matrix. The lower, left hand side of the photomicrograph shows a weakly developed foliation caused by recrystallisation of quartz grains as a response to stress.

Figure 3.23: The lower half of the photograph shows steeply-dipping trough cross-bedded sandstone in the Blouberg Formation at 23°06.80'S; 28°59.40'E. (Top part of the photograph shows unconformably overlying strata of the Mogalakwena Formation). Hammer is 30cm long.

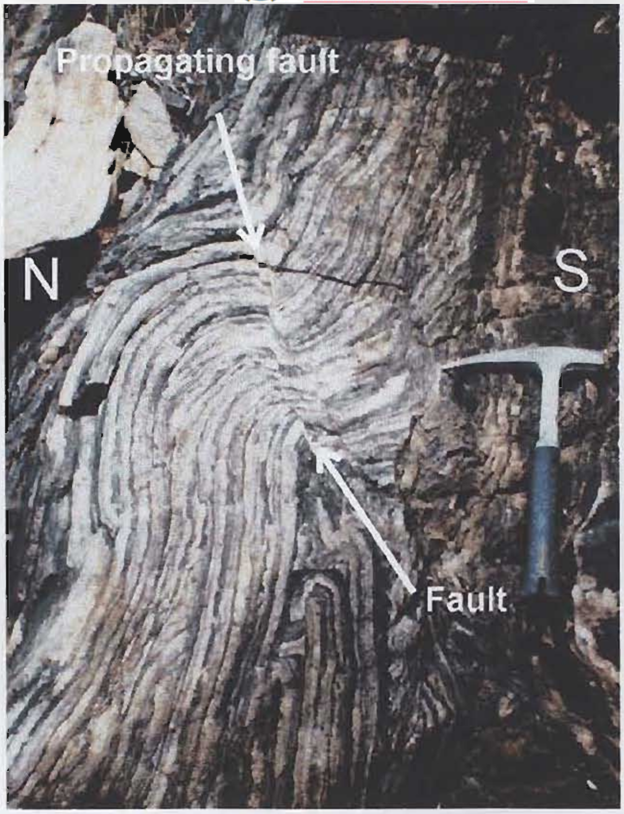


Figure 3.24: Muddy sandstone in the Blouberg Formation at 23°06.80'S; 28°59.40'E. Strata show a fault-propagation fold (fold axis trends 098° and has a plunge of 10° E; Section 7.2). Hammer is 30cm long.

Figure 3.25: Weakly foliated, sub-rounded cobbles of feldspathic basement gneiss in the Blouberg Formation at 23°06.97'S; 28°59.67'E. Pen is 15cm long.

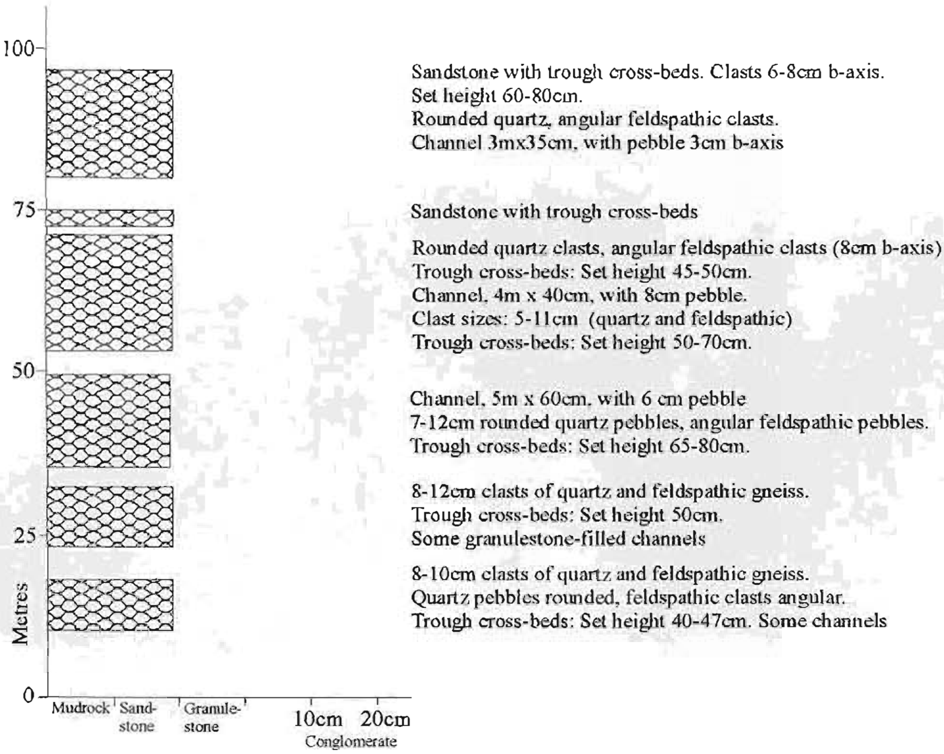


Figure 3.26: Stratigraphic section of the Blouberg Formation in the Dantzig area.

Figure 3.27: Sub-rounded cobbles of highly feldspathic gneiss at 23°06.86'S; 29°02.26'E. c.f. Figure 3.11. Hammer is 30 cm long.

Figure 3.28: Large-scale (<180cm set thickness) trough cross-bedded sets in the Blouberg Formation at 23°06.15'S; 29°01.82'E. Hammer is 30cm long.

Figure 3.29: Vertically-dipping planar cross-bedded granulestone in the Blouberg Formation at 23°06.06'S; 29°02.27'E.

Figure 3.30: Laminated muddy sandstone in the Blouberg Formation at 23°05.76'S; 28°53.47'E. (c.f. Figure 3.24). Hammer is 30cm long.

Figure 3.31: Steeply dipping strata of the Blouberg Formation at 23°05.76'S; 28°53.47'E. A poorly defined, small (c.70cm-wide), pale sand-filled channel form is visible c. 1m above and to the right of the rucksack. Rucksack is 60cm high.

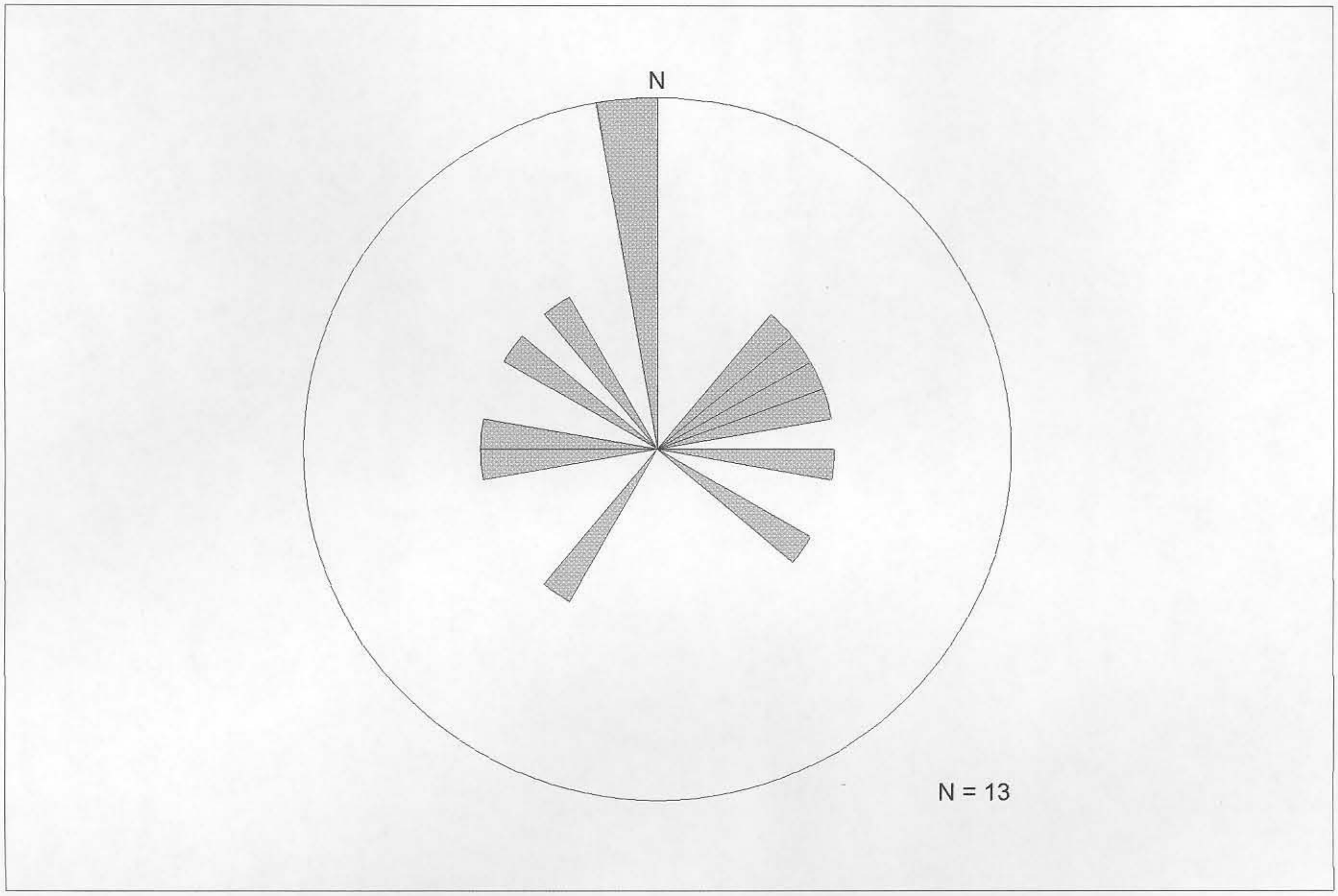


Figure 3.32: Rose diagram showing palaeocurrent directions recorded from steeply-dipping trough cross-beds in the Blouberg Formation (Lower and Upper Members) recorded in the Kranskop area.

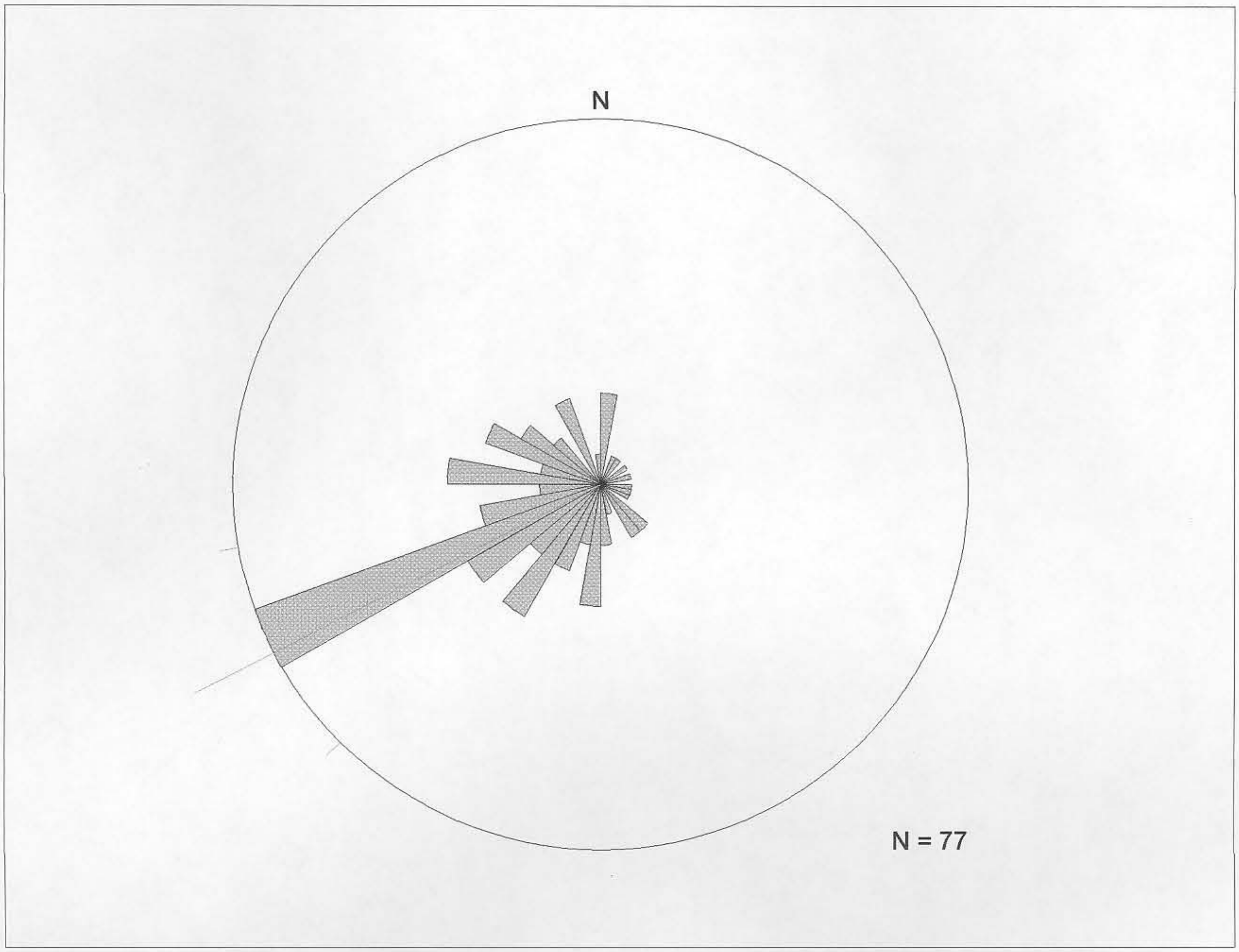


Figure 3.33: Rose diagram showing palaeocurrent directions measured from trough cross-bedding in the Lower Memberof the Blouberg Formation recorded in the Blouberg mountain area. The principal direction (vector mean) is indicated.

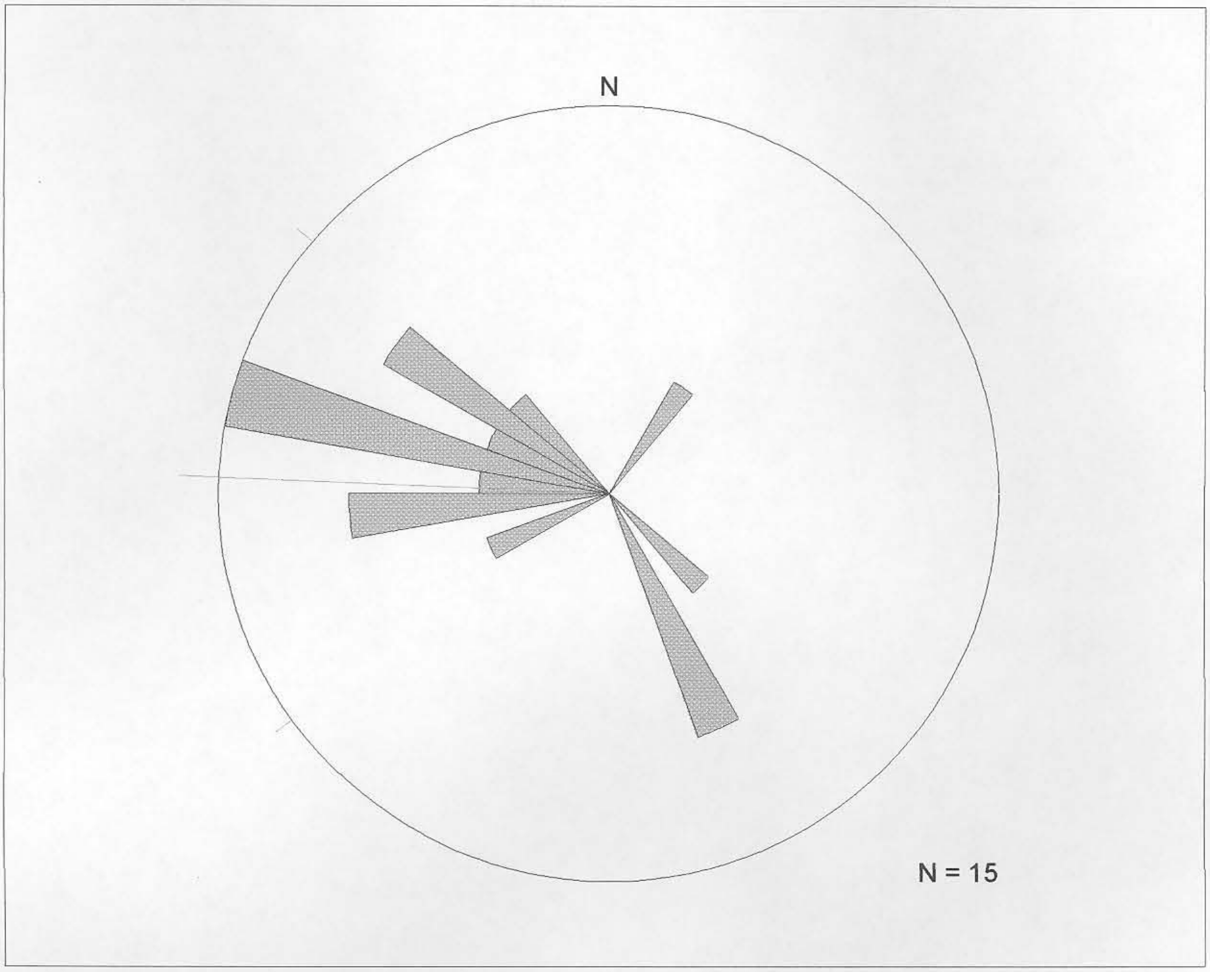


Figure 3.34: Rose diagram showing palaeocurrent directions recorded from trough cross-bedding in the Upper Member of the Blouberg Formation recorded in the Blouberg mountain area. The principal direction (vector mean) is indicated.

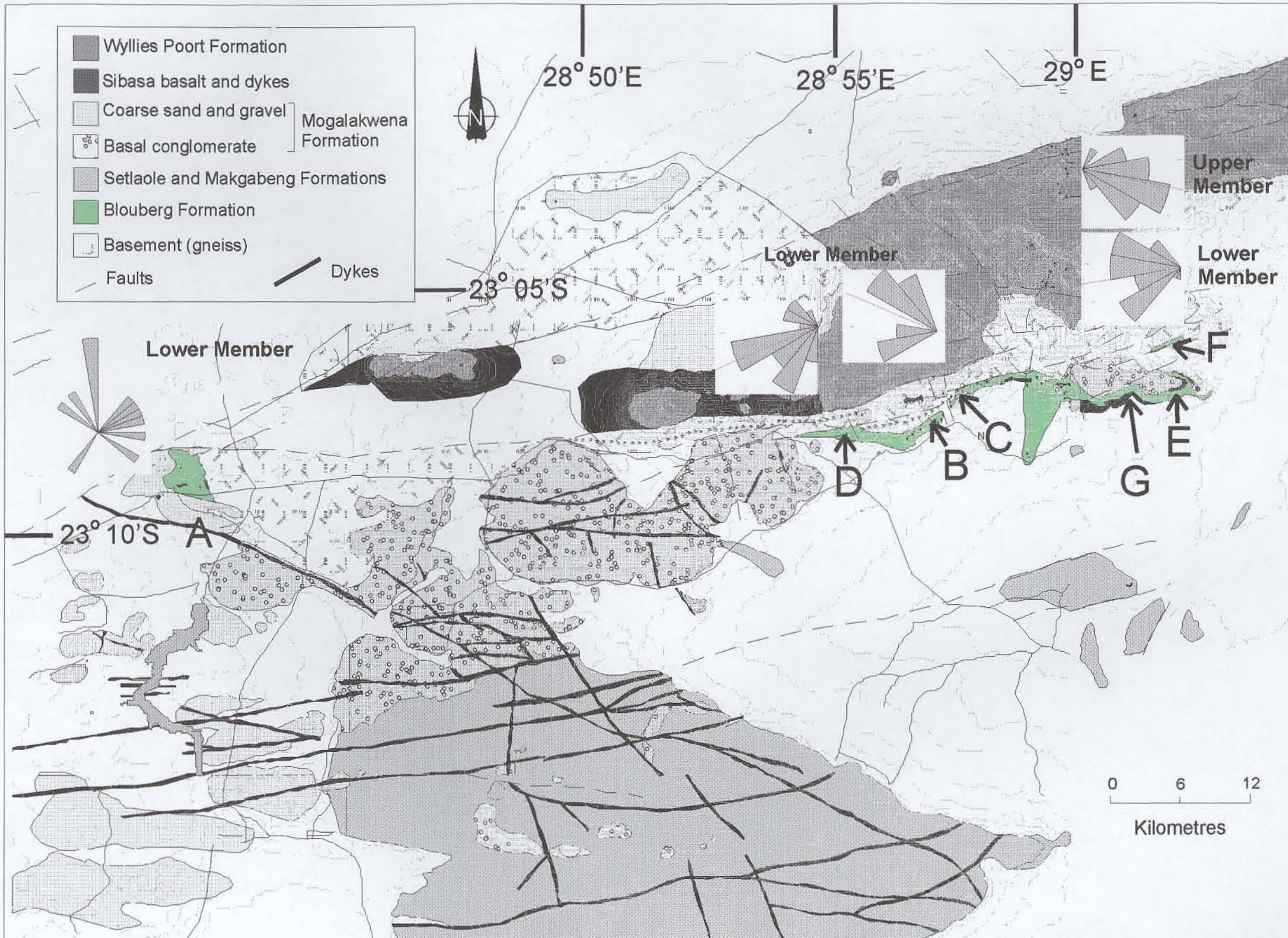


Figure 3.35: Map showing the location of outcrops of the Blouberg Formation, and the variability of palaeocurrent directions across the preserved basin. Letters indicate the location of sites from where palaeohydrological parameters were recorded.

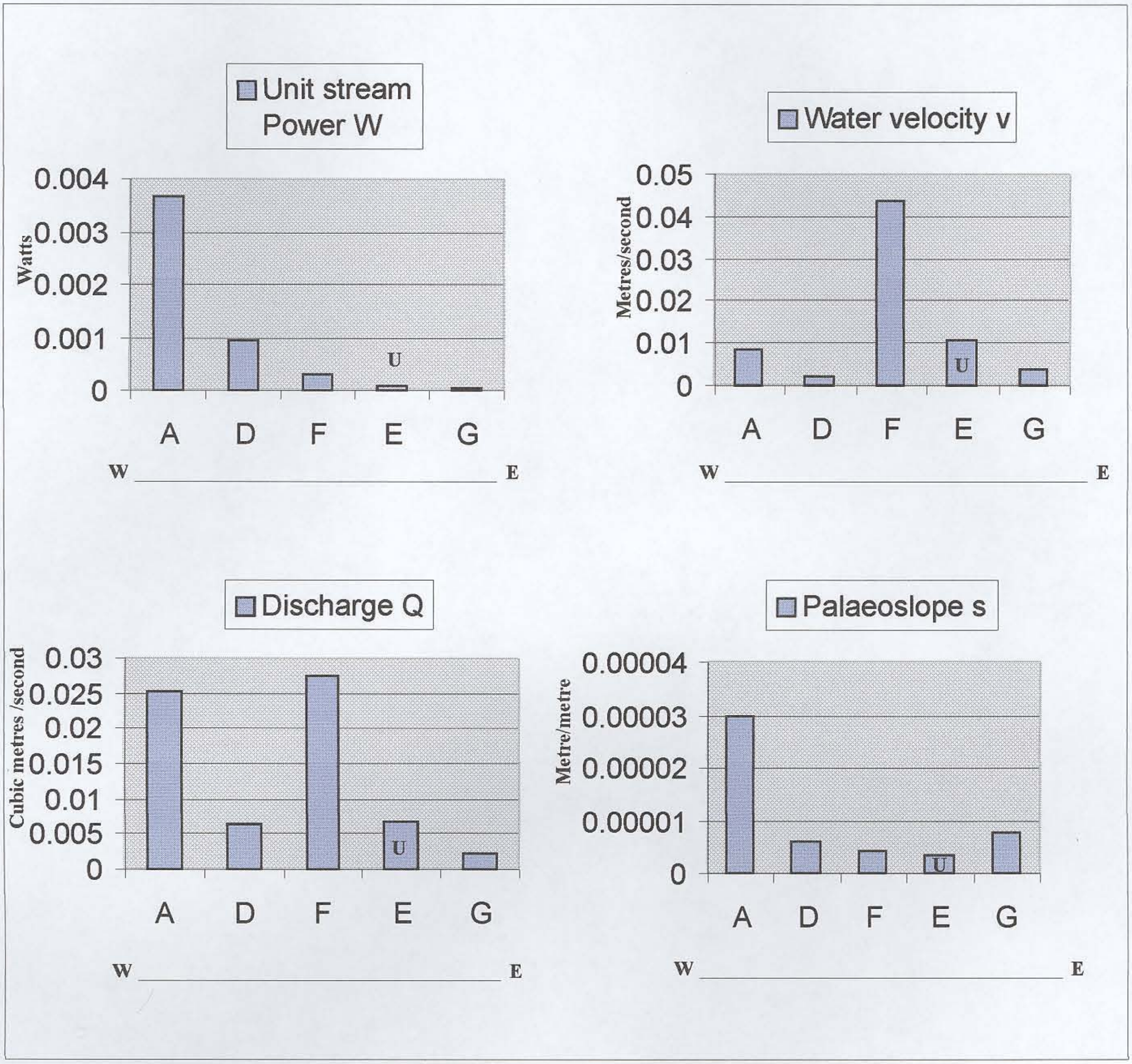
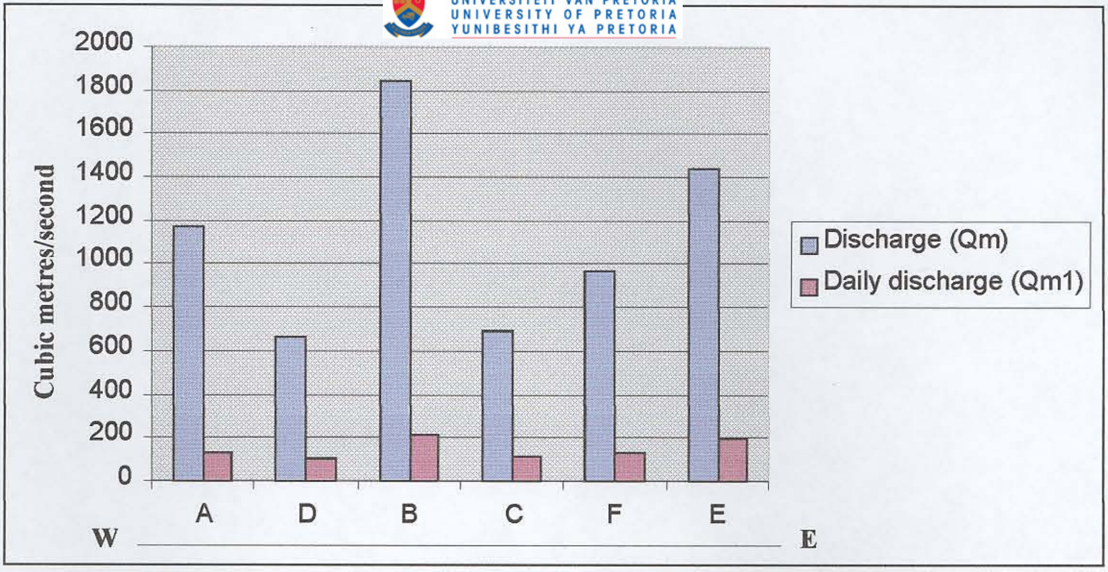
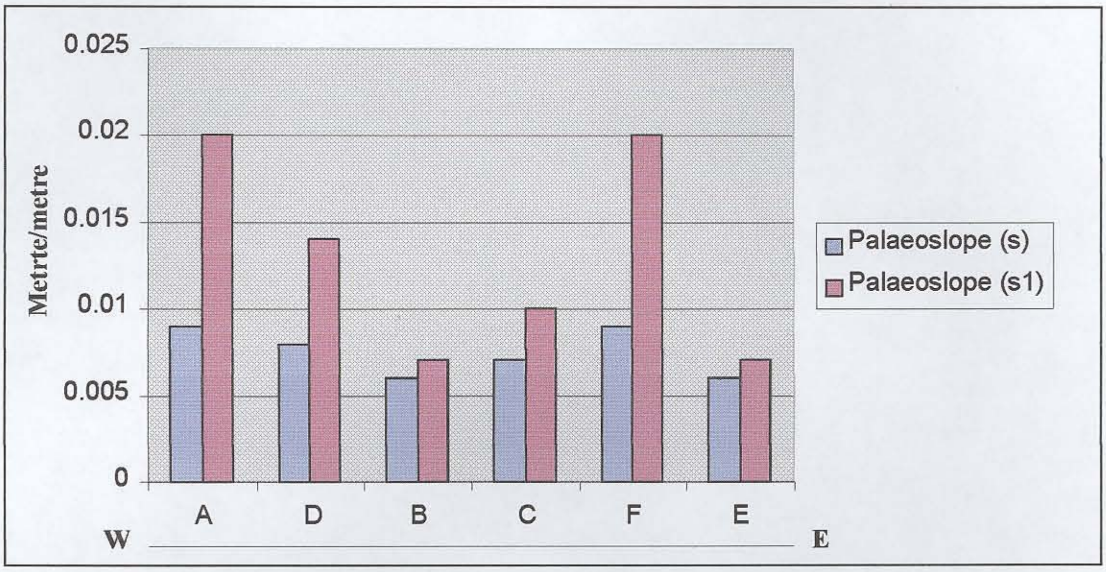


Figure 3.36: Histograms showing variablity in palaeohydrological parameters calculated from clast sizes within channels in the Upper (U) and Lower members of the Blouberg Formation. The location of points A to F are shown in Figure 3.35.





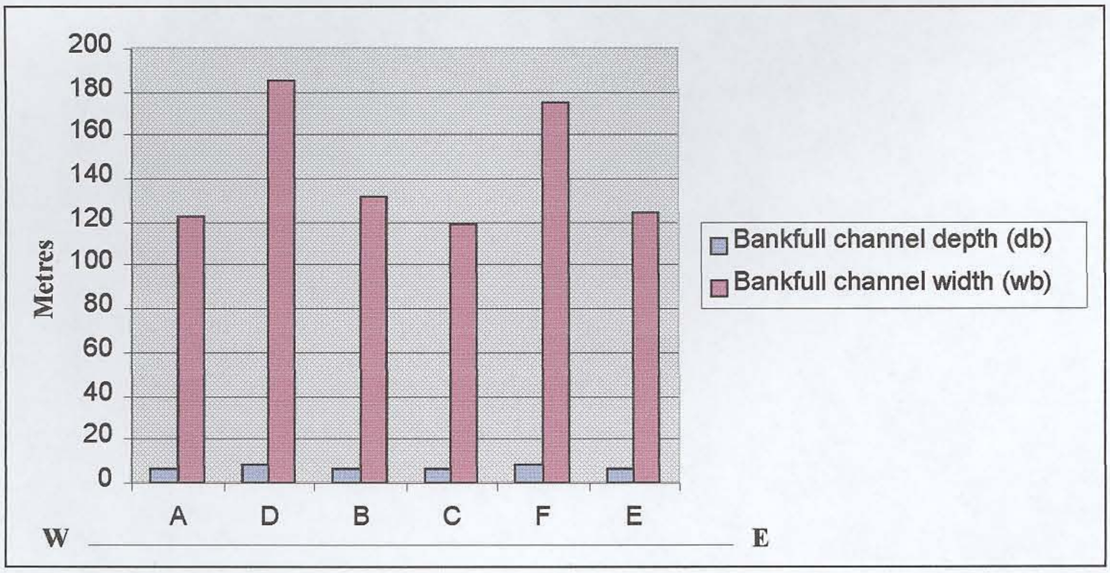


Figure 3.37: Histograms to show variability of calculated palaeohydrological parameters across the Blouberg basin. Location of points A to E is shown in Figure 3.35.

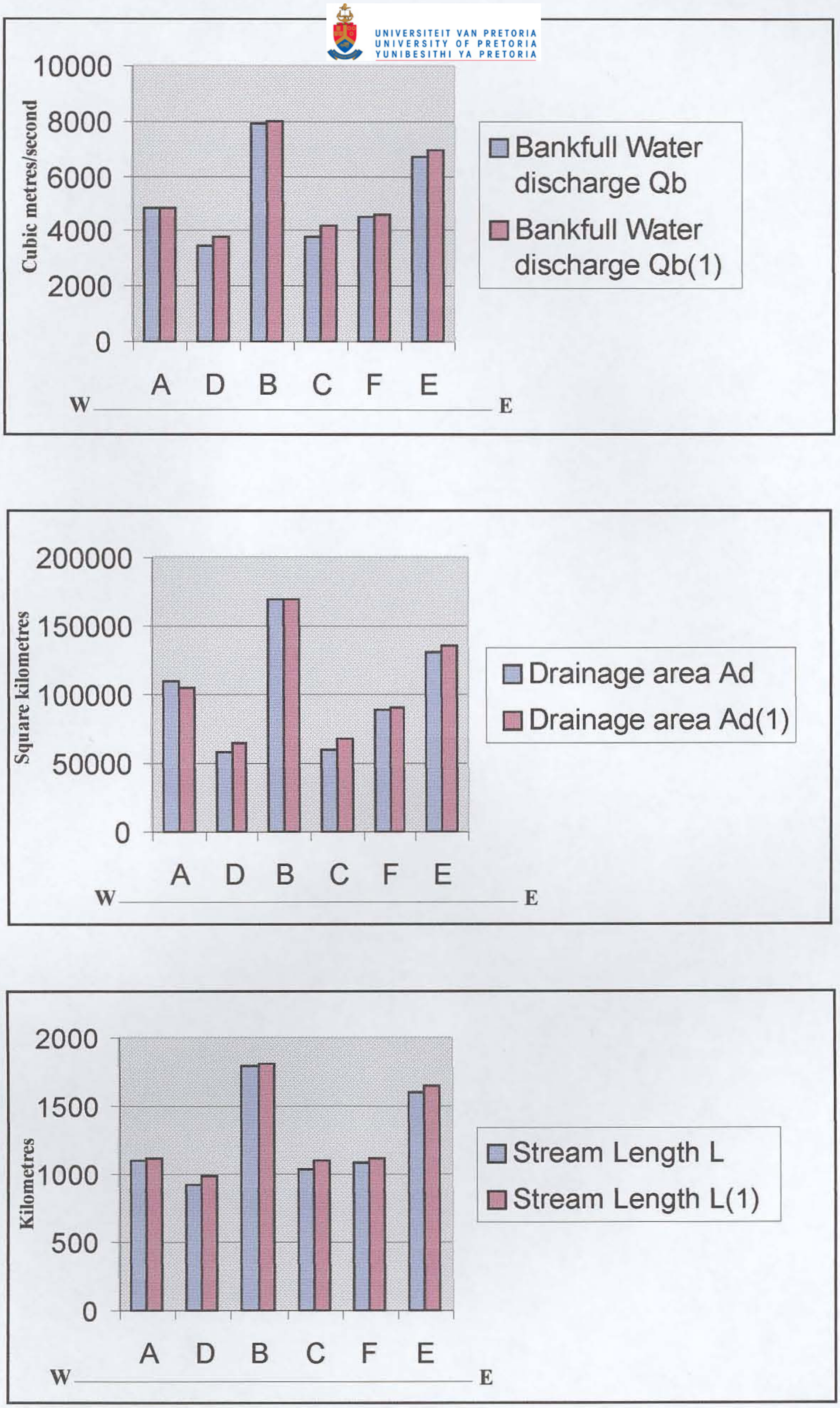


Figure 3.38: Histograms showing the variability of palaeohydrological parameters calculated from set thicknesses in the Lower Member of the Blouberg Formation. See Figure 3.35 for location of points A to E

Element	Symbol	Principal facies assemblage	Geometry and relationships
Channels (Major sandstone sheets)	CH (CHS)-sheet (CHR)-ribbon	Any combination	Finger, lens or sheet; concave-up erosional base; scale and shape highly variable.
Gravel bars and bedforms	GB	Gm, Gp, Gt	Lens, blanket;usually tabular bodies; commonly interbedded with SB
Sandy Bedforms	SB	St, Sp, Sh, Sl, Sr, Se, Ss	Lens, sheet, blanket, wedge, occurs as channel fills, crevasse splays, minor bars
Downstream accretion macroform	DA	St, Sp, Sh, Sl, Sr, Se, Ss	Lens, resting on flat or channelled base.
Lateral accretion macroform	LA	St, Sp, Sh, Sl, Sr, Se, Ss, less commonly Gm, Gt, Gp	Wedge, sheet lobe.
Scour hollows	HO	Gh, Gt, St, Sl	Scoop-shaped hollow with asymmetric fill
Sediment gravity flows	SG	Gmm, Gmg, Gci, Gcm	Lobe, sheet, typically interbedded with GB
Laminated sand sheet	LS	Sh, Sl; minor Sp, Sr	Sheet, blanket
Overbank fines	FF	Fm, Fl	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

Facies Code	Facies	Sedimentary structures	Facies Code	Facies	Sedimentary structures
Gmm	Matrix-supported, massive gravel	Weak grading	Sh	Sand, fine to very coarse, may be pebbley	Horizontal lamination parting or streaming lineation
Gmg	Matrix-supported gravel	Inverse to normal grading	Sl	Sand, fine to very coarse, may be pebbley	Low-angle(<15°) cross-beds
Gci	Clast-supported gravel	Inverse grading	Ss	Sand, fine to very coarse, may be pebbley	Broad, shallow scours
Gcm	Clast-supported massive gravel	-	Sm	Sand, fine to coarse	Massive or faint lamination
Gh	Clast-supported, crudely bedded gravel	Horizontal bedding, imbrication	Fl	Sand, silt, mud	Fine lamination very small ripples
Gt	Gravel, stratified	Trough cross-beds	Fsm	Silt, mud	Massive
Gp	Gravel, stratified	Planar cross-beds	Fm	Mud, silt	Massive desiccation cracks
St	Sand, fine to very coarse may be pebbley	Solitary or grouped trough cross-beds	Fr	Mud, silt	Massive, roots, bioturbation
Sp	Sand, fine to very coarse may be pebbley	Solitary or grouped planar cross-beds	C	Coal, carbon-aceous mud	Plant, mud films
Sr	Sand, fine to very coarse	Ripple cross-lamination	P	Palaeosol carbonate (Calcite, siderite)	Pedogenic features; nodules, filaments

b.

BLOUBERG FORMATION			
Upper Member	Facies Association 4	Gmg; bedded, cross-bedded, massive, matrix supported conglomerate. Angular feldpsathic clasts (pebbles, cobbles, boulders). Laterally extensive sandstone-filled channel-forms or sandstone sheets define top of each fining-up cycle	475m
	Facies Association 3	Gmg; bedded, cross-bedded, massive, matrix supported conglomerate. Angular feldpsathic clasts (pebbles, cobbles, boulders). Arranged in fining-upward cycles (c.100cm). Channel forms with St. at top of each cycle.	250m
Lower Member	Facies Association 2	Sp, St; wedge-shaped sets, <20cm Sp, St; wedge-shaped sets, 20-30cm Planar-bedded sandstone Sandstone and granulestone-filled channels	350m
	Facies Association 1	Sp, St; wedge-shaped sets, 15-50cm medium- to coarse-grained sandstone Gt; Channel fills, 1.5-4m wide, 15-20cm deep. Clasts <7cm. Sub-euhedral feldspars	300m

Stacking patterns within facies association 1 and 2 are comprised predominantly of alternating constituent facies.
Stacking pattens within facies association 3 and 4 are comprised predominantly of fining-upwards cycles.

Table 3.1: Architectural elements, and facies grouping for (a) fluvial deposits (after Miall, 1978; 1985), and (b) for the Blouberg Formation.

Table 3.2: Palaeohydrological parameters calculated from clast size and channel dimensions at locations shown in Figure 3.35 in the Blouberg Formation.

Location	Ch width	Ch depth	dm	Member	v	w	Q	A	S
A	2	0.3	0.15	1	0.00844	0.003674	0.02532	0.3	2.96E-05
D	4.8	0.8	0.05	1	0.0512	0.000576	0.0983	1.92	2.95E-06
	2.2	0.2	0.035	1	0.0435	0.000316	0.00957	0.22	7.41E-06
	5	0.55	0.04	1	0.0462	0.000396	0.06353	1.375	3.18E-06
	4	0.4	0.08	1	0.0634	0.001273	0.05072	0.8	1.02E-05
TotalD	16	1.95	0.205	4	0.2043	0.002561	0.22212	4.315	2.38E-05
AverageD	4	0.4875	0.05125	1	0.051075	0.00064	0.05553	1.07875	5.95E-06
F	3.5	0.36	0.035	1	0.0435	0.000316	0.02741	0.63	4.12E-06
E	6	0.6	0.04	2	0.0462	0.000396	0.08316	1.8	2.92E-06
	5	0.5	0.12	2	0.0762	0.00252	0.09525	1.25	1.35E-06
	4	0.35	0.06	2	0.0556	0.000784	0.03892	0.7	8.22E-06
	4.5	0.4	0.01	1	0.0246	0.00038	0.02214	0.9	7.88E-07
TotalE	19.5	1.85	0.23	7	0.2026	0.00408	0.23947	4.65	1.33E-05
AverageE	4.875	0.4625	0.0575	1.75	0.05065	0.00102	0.0598675	1.1625	3.32E-06
F	4	0.4	0.09	1	0.0669	0.001553	0.05352	0.8	1.18E-05
	4.6	0.2	0.01	1	0.0246	0.00038	0.011316	0.46	1.58E-06
	2.2	0.35	0.07	1	0.06	0.001016	0.0231	0.385	9.87E-06
TotalF	10.8	0.95	0.17	3	0.1515	0.002949	0.087936	1.645	2.33E-05
AverageF	3.6	0.316667	0.056667	1	0.0505	0.000983	0.029312	0.548333	7.76E-06

v= water velocity (meters/second)
w=Unit stream power (Watts)
Q=Discharge (Cubic metres/second)
A= Cross sectional area of channel (square metres)
s= Palaeoslope (metre/metre)

Location		h	dm	w	Qm	db	wb	Qm(1)	s	s(1)	Qb	Qb(1)	Ad	Ad(1)	L	L(1)
South	East	(m)	(m)	(m)	(m3s-1)	(m)	(m)	(m3s-1)	(m m-1)	(m m-1)	(m3s-1)	(m3s-1)	(km2)	(km2)	(km)	(km)
23° 09.12'	28° 41.22'	0.10	1.135124	91.07916	68.30937	3.530208	52.03679	23.24099	0.011894	0.030426	634.9355	825.9283	5457.237	7749.192	244.5185	301.7741
		0.12	1.323068	123.7362	92.80215	3.858272	58.93049	28.75049	0.011112	0.026184	806.351	1025.078	7505.256	10335.76	296.0379	358.7017
		0.19	1.94666	267.8628	200.8971	4.826846	80.63411	49.14858	0.00936	0.017934	1472.764	1766.898	16756.27	21360.69	479.3299	554.4945
		0.20	2.032402	291.9791	218.9843	4.949039	83.50629	52.17994	0.009182	0.017192	1575.194	1877.607	18327.87	23163.61	505.8191	582.119
		0.80	6.515421	3000.664	2250.498	9.726618	215.0486	263.0276	0.005472	0.005489	9694.891	9703.523	206723.8	206969.3	2164.524	2166.065
		0.30	2.857495	577.1697	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		2.00	14.07168	13996.65	10497.49	15.20253	401.8575	766.1734	0.003886	0.002581	32224.16	28735.01	1025437	880133.5	5658.135	5162.466
		0.10	1.135124	91.07916	68.30937	3.530208	52.03679	23.24099	0.011894	0.030426	634.9355	825.9283	5457.237	7749.192	244.5185	301.7741
		0.30	2.857495	577.1697	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		0.05	0.633982	28.41098	21.30824	2.51814	32.42663	10.35156	0.015408	0.053846	255.9323	363.3122	1624.926	2592.428	118.2029	156.4415
		0.30	2.857495	577.1697	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		0.05	0.633982	28.41098	21.30824	2.51814	32.42663	10.35156	0.015408	0.053846	255.9323	363.3122	1624.926	2592.428	118.2029	156.4415
		0.30	2.857495	577.1697	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		0.05	0.633982	28.41098	21.30824	2.51814	32.42663	10.35156	0.015408	0.053846	255.9323	363.3122	1624.926	2592.428	118.2029	156.4415
		0.10	1.135124	91.07916	68.30937	3.530208	52.03679	23.24099	0.011894	0.030426	634.9355	825.9283	5457.237	7749.192	244.5185	301.7741
A		0.20	2.032402	291.9791	218.9843	4.949039	83.50629	52.17994	0.009182	0.017192	1575.194	1877.607	18327.87	23163.61	505.8191	582.119
		0.04	0.525581	19.52596	14.64447	2.258637	27.84678	7.978641	0.016747	0.064708	191.0253	278.9076	1100.157	1822.274	93.54073	126.6182
		0.80	6.515421	3000.664	2250.498	9.726618	215.0486	263.0276	0.005472	0.005489	9694.891	9703.523	206723.8	206969.3	2164.524	2166.065
		0.20	2.032402	291.9791	218.9843	4.949039	83.50629	52.17994	0.009182	0.017192	1575.194	1877.607	18327.87	23163.61	505.8191	582.119
		1.00	7.85922	4366.076	3274.557	10.84414	250.4168	341.2544	0.005035	0.004568	12989.04	12640.06	305330.1	294441.3	2735.204	2676.254
		1.50	11.04982	8630.64	6472.98	13.2136	330.2325	547.7036	0.004327	0.003271	22100.7	20435.4	620213.6	558698.6	4184.589	3930.38
		0.25	2.451583	424.8404	318.6303	5.517652	97.24024	67.69872	0.008448	0.014306	2110.417	2445.819	27070.17	32953.31	639.1793	719.2295
		0.20	2.032402	291.9791	218.9843	4.949039	83.50629	52.17994	0.009182	0.017192	1575.194	1877.607	18327.87	23163.61	505.8191	582.119
		1.00	7.85922	4366.076	3274.557	10.84414	250.4168	341.2544	0.005035	0.004568	12989.04	12640.06	305330.1	294441.3	2735.204	2676.254
		0.30	2.857495	577.1697	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		0.50	4.38948	1361.942	1021.456	7.735258	156.0467	151.995	0.006522	0.008084	5235.676	5560.152	90913.9	98502.88	1322.228	1387.386
		0.15	1.59595	180.0407	135.0305	4.301563	68.62255	37.30114	0.010223	0.021789	1080.335	1335.293	11085.23	14703.99	374.0888	443.1892
		0.80	6.515421	3000.664	2250.498	9.726618	215.0486	263.0276	0.005472	0.005489	9694.891	9703.523	206723.8	206969.3	2164.524	2166.065
		0.10	1.135124	91.07916	68.30937	3.530208	52.03679	23.24099	0.011894	0.030426	634.9355	825.9283	5457.237	7749.192	244.5185	301.7741
		0.15	1.59595	180.0407	135.0305	4.301563	68.62255	37.30114	0.010223	0.021789	1080.335	1335.293	11085.23	14703.99	374.0888	443.1892
		0.80	6.515421	3000.664	2250.498	9.726618	215.0486	263.0276	0.005472	0.005489	9694.891	9703.523	206723.8	206969.3	2164.524	2166.065
		0.14	1.506052	160.3291	120.2468	4.159321	65.46684	34.41599	0.01049	0.023062	986.9182	1230.484	9825.958	13185.64	347.979	415.1344
23° 09.01'	28° 42.01'	0.40	3.63895	936.0188	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		Total	114.7344	51519.75	38639.81	204.5316	4040.599	4331.714	0.300373	0.658085	158963.4	159592.8	3606262	3483592	36169.28	36959.89
		Average	3.476801	1561.204	1170.903	6.197926	122.4424	131.2641	0.009102	0.019942	4817.072	4836.147	109280.7	105563.4	1096.039	1119.997

Table 3.3a: Palaeohydrological parameters calculated from Location A (Figure 3.35) in the Blouberg Formation.

Table 3.3b: Palaeohydrological parameters calculated from locations B, C and D (Figure 3.35) in the Blouberg Formation.

Location South	East	h (m)	dm (m)	w (m)	Qm (m3s-1)	db (m)	wb (m)	Qm(1) (m3s-1)	s (m m-1)	s(1) (m m-1)	Qb (m3s-1)	Qb(1) (m3s-1)	Ad (km2)	Ad(1) (km2)	L (km)	L(1) (km)
23° 07.61'	28° 57.29'	0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		0.60	5.116252	230.2313	1387.706	8.454099	176.7194	188.0268	0.006092	0.006957	6649.167	6900.827	125032.5	131381.7	1600.818	1649.107
		0.85	6.85595	308.5177	2491.89	10.01831	224.1311	282.3076	0.005349	0.005222	10496.78	10426.15	229830.8	227771.2	2306.603	2294.179
B		0.70	5.823844	262.073	1798.097	9.113745	196.3205	225.079	0.005752	0.006127	8138.124	8283.62	163693.9	167607.5	1881.687	1908.553
		0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		1.30	9.797836	440.9026	5089.252	12.3234	299.5112	463.4789	0.004565	0.00368	18320.59	17248.44	482969.1	445656.1	3601.469	3431.847
		Total	38.51073	1732.983	12872.99	60.7239	1298.704	1510.351	0.043023	0.051131	55328.23	55664.3	1186186	1180136	12529.64	12652.39
		Average	5.501533	247.569	1838.998	8.674842	185.5291	215.7644	0.006146	0.007304	7904.033	7952.043	169455.2	168590.9	1789.949	1807.484

Location South	East	h (m)	dm (m)	w (m)	Qm (m3s-1)	db (m)	wb (m)	Qm(1) (m3s-1)	s (m m-1)	s(1) (m m-1)	Qb (m3s-1)	Qb(1) (m3s-1)	Ad (km2)	Ad(1) (km2)	L (km)	L(1) (km)
23° 07.35'	28° 57.53'	0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		0.35	3.252695	146.3713	560.8934	6.500943	122.3367	100.2504	0.007451	0.010844	3280.348	3643.827	48740.86	56071.7	909.6282	989.4054
		0.30	2.857495	128.5873	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
C		0.45	4.017551	180.7898	855.69	7.348062	145.2218	134.4121	0.006783	0.008817	4560.281	4907.642	75623.28	83399.58	1183.917	1255.528
		0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		0.45	4.017551	180.7898	855.69	7.348062	145.2218	134.4121	0.006783	0.008817	4560.281	4907.642	75623.28	83399.58	1183.917	1255.528
		Total	25.06	1,127.80	4,811.19	48.04	924.92	804.28	0.05	0.07	26,804.65	29,299.93	########	########	7,190.38	7,724.07
		Average	3.580306	161.1138	687.3133	6.863116	132.132	114.8972	0.007168	0.00999	3829.236	4185.704	60268.07	67791.86	1027.197	1103.439

Location South	East	h (m)	dm (m)	w (m)	Qm (m3s-1)	db (m)	wb (m)	Qm(1) (m3s-1)	s (m m-1)	s(1) (m m-1)	Qb (m3s-1)	Qb(1) (m3s-1)	Ad (km2)	Ad(1) (km2)	L (km)	L(1) (km)
23° 08.34'	28° 59.045'	0.25	2.451583	110.3213	318.6303	5.517652	97.24024	67.69872	0.008448	0.014306	2110.417	2445.819	27070.17	32953.31	639.1793	719.2295
		0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		0.50	4.38948	197.5266	1021.456	7.735258	156.0467	151.995	0.006522	0.008084	5235.676	5560.152	90913.9	98502.88	1322.228	1387.386
23° 08.02'	28° 55.18'	0.10	1.135124	51.08058	68.30937	3.530208	52.03679	23.24099	0.011894	0.030426	634.9355	825.9283	5457.237	7749.192	244.5185	301.7741
		0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		0.60	5.116252	230.2313	1387.706	8.454099	176.7194	188.0268	0.006092	0.006957	6649.167	6900.827	125032.5	131381.7	1600.818	1649.107
		0.55	4.755507	213.9978	1198.912	8.103066	166.5326	169.8741	0.006294	0.007474	5932.425	6224.852	107393.1	114508.8	1461.214	1518.558
		0.35	3.252695	146.3713	560.8934	6.500943	122.3367	100.2504	0.007451	0.010844	3280.348	3643.827	48740.86	56071.7	909.6282	989.4054
		0.45	4.017551	180.7898	855.69	7.348062	145.2218	134.4121	0.006783	0.008817	4560.281	4907.642	75623.28	83399.58	1183.917	1255.528
		1.00	7.85922	353.6649	3274.557	10.84414	250.4168	341.2544	0.005035	0.004568	12989.04	12640.06	305330.1	294441.3	2735.204	2676.254
		0.06	0.738951	33.25281	28.94845	2.752152	36.72242	12.80549	0.014394	0.046339	325.0272	450.9147	2234.736	3457.742	143.108	185.9532
D		0.30	2.857495	128.5873	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		0.20	2.032402	91.45811	218.9843	4.949039	83.50629	52.17994	0.009182	0.017192	1575.194	1877.607	18327.87	23163.61	505.8191	582.119
		0.23	2.285685	102.8558	276.9659	5.297911	91.86213	61.42246	0.008715	0.015323	1891.906	2215.746	23399.12	28886.39	585.663	664.5749
		0.25	2.451583	110.3213	318.6303	5.517652	97.24024	67.69872	0.008448	0.014306	2110.417	2445.819	27070.17	32953.31	639.1793	719.2295
		0.20	2.032402	91.45811	218.9843	4.949039	83.50629	52.17994	0.009182	0.017192	1575.194	1877.607	18327.87	23163.61	505.8191	582.119
		0.32	3.016748	135.7537	482.4717	6.223116	115.0803	90.29747	0.007704	0.011674	2916.784	3276.781	41674.68	48670.21	828.0402	908.8369
		0.50	4.38948	197.5266	1021.456	7.735258	156.0467	151.995	0.006522	0.008084	5235.676	5560.152	90913.9	98502.88	1322.228	1387.386
		0.30	2.857495	128.5873	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		0.25	2.451583	110.3213	318.6303	5.517652	97.24024	67.69872	0.008448	0.014306	2110.417	2445.819	27070.17	32953.31	639.1793	719.2295
		0.12	1.323068	59.53806	92.80215	3.858272	58.93049	28.75049	0.011112	0.026184	806.351	1025.078	7505.256	10335.76	296.0379	358.7017
		0.30	2.857495	128.5873	432.8772	6.03041	110.1224	83.74733	0.007892	0.012312	2680.173	3035.56	37229.21	43952.65	773.8527	854.9074
		0.45	4.017551	180.7898	855.69	7.348062	145.2218	134.4121	0.006783	0.008817	4560.281	4907.642	75623.28	83399.58	1183.917	1255.528
		Total	73.57	3,310.53	15,222.38	144.15	2,730.29	2,381.74	0.19	0.33	80,355.77	86,875.79	########	########	21,159.96	22,671.45
		Average	3.198576	143.9359	661.8425	6.26735	118.7082	103.5539	0.008124	0.014229	3493.729	3777.208	58804.45	64123.15	919.9984	985.715

Location South	East	h (m)	dm (m)	w (m)	Qm (m3s-1)	db (m)	wb (m)	Qm(1) (m3s-1)	s (m m-1)	s(1) (m m-1)	Qb (m3s-1)	Qb(1) (m3s-1)	Ad (km2)	Ad(1) (km2)	L (km)	L(1) (km)
23° 07.24'	29° 02.92'	0.20	2.032402	91.45811	218.9843	4.949039	83.50629	52.17994	0.009182	0.017192	1575.194	1877.607	18327.87	23163.61	505.8191	582.119
23° 07.13'	29° 01.64'	0.60	5.116252	230.2313	1387.706	8.454099	176.7194	188.0268	0.006092	0.006957	6649.167	6900.827	125032.5	131381.7	1600.818	1649.107
		0.70	5.823844	262.073	1798.097	9.113745	196.3205	225.079	0.005752	0.006127	8138.124	8283.62	163693.9	167607.5	1881.687	1908.553
		0.80	6.515421	293.1939	2250.498	9.726618	215.0486	263.0276	0.005472	0.005489	9694.891	9703.523	206723.8	206969.3	2164.524	2166.065
		0.70	5.823844	262.073	1798.097	9.113745	196.3205	225.079	0.005752	0.006127	8138.124	8283.62	163693.9	167607.5	1881.687	1908.553
		0.75	6.171474	277.7163	2019.164	9.425422	205.7838	243.9477	0.005605	0.005789	8908.437	8989.195	184672.4	186907.9	2022.876	2037.533
		0.60	5.116252	230.2313	1387.706	8.454099	176.7194	188.0268	0.006092	0.006957	6649.167	6900.827	125032.5	131381.7	1600.818	1649.107
		0.70	5.823844	262.073	1798.097	9.113745	196.3205	225.079	0.005752	0.006127	8138.124	8283.62	163693.9	167607.5	1881.687	1908.553
		0.60	5.116252	230.2313	1387.706	8.454099	176.7194	188.0268	0.006092	0.006957	6649.167	6900.827	125032.5	131381.7	1600.818	1649.107
E		0.72	5.963357	268.3511	1885.277	9.239743	200.1308	232.6004	0.005692	0.005987	8444.264	8564.769	171955.4	175235	1938.106	1960.201
		0.50	4.38948	197.5266	1021.456	7.735258	156.0467	151.995	0.006522	0.008084	5235.676	5560.152	90913.9	98502.88	1322.228	1387.386
		0.45	4.017551	180.7898	855.69	7.348062	145.2218	134.4121	0.006783	0.008817	4560.281	4907.642	75623.28	83399.58	1183.917	1255.528
		0.50	4.38948	197.5266	1021.456	7.735258	156.0467	151.995	0.006522	0.008084	5235.676	5560.152	90913.9	98502.88	1322.228	1387.386
		0.65	5.472223	246.25	1587.527	8.790432	186.6398	206.4339	0.005913	0.006513	7384.738	7587.305	143807	149090.5	1740.989	1779.091
		0.70	5.823844	262.073	1798.097	9.113745	196.3205	225.079	0.005752	0.006127	8138.124	8283.62	163693.9	167607.5	1881.687	1908.553
		0.80	6.515421	293.1939	2250.498	9.726618	215.0486	263.0276	0.005472	0.005489	9694.891	9703.523	206723.8	206969.3	2164.524	2166.065
		0.65	5.472223	246.25	1587.527	8.790432	186.6398	206.4339	0.005913	0.006513	7384.738	7587.305	143807	149090.5	1740.989	1779.091
		0.50	4.38948	197.5266	1021.456	7.735258	156.0467	151.995	0.006522	0.008084	5235.676	5560.152	90913.9	98502.88	1322.228	1387.386
		0.47	4.167076	187.5184	920.5694	7.505462	149.5955	141.4081	0.006674	0.008507	4827.78	5167.118	81594.95	89330.11	1239.156	1308.358
		0.40	3.63895	163.7527	702.0141	6.938113	134.0071	117.1527	0.007088	0.009715	3907.855	4268.419	61553.29	69239.84	1046.354	1122.902
		Total	101.78	4,580.04	28,697.62	167.46	3,505.20	3,781.01	0.12	0.15	########	########	########	########	32,043.14	32,900.65
		Average	5.088934	229.002	1434.881	8.373149	175.2601	189.0503	0.006232	0.007482	6729.505	6943.691	129870.2	134974	1602.157	1645.032

Location South	East	h (m)	dm (m)	w (m)	Qm (m3s-1)	db (m)	wb (m)	Qm(1) (m3s-1)	s (m m-1)	s(1) (m m-1)	Qb (m3s-1)	Qb(1) (m3s-1)	Ad (km2)	Ad(1) (km2)	L (km)	L(1) (km)
23° 06.28'	29° 01.83'	0.85	6.85595	308.5177	2491.89	10.01831	224.1311	282.3076	0.005349	0.005222	10496.78	10426.15	229830.8	227771.2	2306.603	2294.179
		0.32	3.016748	135.7537	482.4717	6.223116	115.0803	90.29747	0.007704	0.011674	2916.784	3276.781	41674.68	48670.21	828.0402	908.8369
		0.70	5.823844	262.073	1798.097	9.113745	196.3205	225.079	0.005752	0.006127	8138.124	8283.62	163693.9	167607.5	1881.687	1908.553
F		0.10	1.135124	51.08058	68.30937	3.530208	52.03679	23.24099	0.011894	0.030426	634.9355	825.9283	5457.237	7749.192	244.5185	301.7741
		0.05	0.633982	28.52919	21.30824	2.51814	32.42663	10.35156	0.015408	0.053846	255.9323	363.3122	1624.926	2592.428	118.2029	156.4415
		Total	17.47	785.95	4,862.08	31.40	620.00	631.28	0.05	0.11	22,442.56	23,175.80	########	########	5,379.05	5,569.78
		Average	3.49313	157.1908	972.4153	6.280704	123.9991	126.2553	0.009222	0.021459	4488.511	4635.159	88456.3	90878.12	1075.811	1113.957

h = set thickness of trough cross-beds
dm = mean water depth
w = channel width
Qm = maximum instantaneous water discharge
db = mean bankfull channel depth
wb = bankfull channel width
Qm(1) = average daily discharge (equation11)
s = stream palaeoslope (equation 12)
s(1) = stream palaeoslope (equation 13)
Qb = bankfull water discharge
Qb(1) = bankfull water discharge (using s(1) values)
Ad = drainage area (using Qb values)
Ad(1) = drainage area (using Qb(1) values)
L = principal stream area (using Ad values)
L(1) = principal stream length (using Ad(1) values)

Table 3.3c: Palaeohydrological parameters calculated from locations E and F (Figure 3.35) in the Blouberg Formation.