ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

A PALAEOCURRENT STUDY OF THE DWAAL HEUVEL FORMATION, TRANSVAAL SUPERGROUP

A. BUTTON

INFORMATION CIRCULAR No. 75

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by

A. BUTTON
(Research Fellow, Economic Geology Research Unit)

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ABSTRACT

Measurement of cross-bed foresets in the Dwaal Heuvel Formation, Transvaal Supergroup (2224 ± 21 million years) at 41 localities along the eastern and northeastern outcrop rim of the Transvaal basin indicate that transport of sediment took place down a palaeoslope inclined to the south and south-southwest. Provenance areas were situated north and northeast of the present limits of the basin. The Archaean basement provided some of the detritus; it is possible that material eroded during uplift along the Limpopo tectonic belt may also have contributed to the filling of the Transvaal basin during Dwaal Heuvel times.

The variance in the orientation of foreset azimuths is small, the average within-station variance being 2390. The small variances, together with other evidence, are taken as an indication that deposition of the Dwaal Heuvel took place in a fluvial environment. The Dwaal Heuvel thins down the palaeoslope; in the southern and southwestern portions of the basin, the formation is thinly and sporadically developed. The facies equivalent of the formation in these areas is a suite of shales with beds and lenses of oölitic ironstone. The southwesterly change from an arenaceous facies (Dwaal Heuvel Formation) to deposition of shale with oölitic ironstone is thought to represent a transition from fluvial deposition to deposition in a deltaic situation.

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INTRODUCTION

Palaeoenvironmental reconstructions for the older cratonic sedimentary sequences of the southern African sub-continent are, in general, few and far between. Such studies, in addition to their usefulness in deciphering basin history, are of importance to an understanding of the evolution and behaviour of the earth's early sialic crust. The sedimentary record is, of necessity, a reflection of the development of the crust. In this respect, the Kaapvaal craton is well-endowed, possessing a record of continental sedimentation which extends from around 3200 to about 1800 million years ago (Moodies Group to the Waterberg Supergroup). Intervals in a total period of around 1400 million years of Precambrian crustal history are preserved in the sedimentary basins of the Kaapvaal craton.

During a stratigraphic study of the Transvaal basin in the eastern Transvaal, palaeocurrent features in many of the arenaceous units were investigated. Nowhere in the stratigraphic pile are palaeocurrent indicators better developed than in the Dwaal Heuvel Formation, an arenaceous unit in the Pretoria Group. The orientation of cross-bed foresets was studied at 41 stations around the eastern outcrop rim of the Transvaal basin, some 830 measurements having been made in all. In this paper, an attempt is made to use this information to reconstruct the sedimentary setting of the Transvaal basin during the time-period reflected by Dwaal Heuvel deposition, and to throw light on the behaviour of the cratonic crust at this time.

LOCATION AND GEOLOGICAL SETTING

The Dwaal Heuvel Formation was studied along the eastern outcrop rim of the Transvaal basin, where the formation outcrops more-or-less continuously along an arcuate belt with a strike length of about 350 km. (Figure 1).

The stratigraphic setting of the Dwaal Heuvel Formation is indicated in Figure 2, a schematized stratigraphic section across the eastern portion of the Transvaal basin. In this diagram, the approximate position of the formation in the Pretoria Group is shown. The Dwaal Heuvel is an arenaceous unit in the Pretoria Group, the latter consisting essentially of a cyclically alternating succession of argillaceous and arenaceous sediments with three volcanic horizons. At present, the best estimate of the age of the Pretoria Group suggests that deposition took place at a period dating back some 2224 ± 21 million years ago. This figure represents a Rb-Sr date on the Ongeluk Lava in the Potchefstroom synclinorium (D. Crampton, personal communication).

PREVIOUS WORK

No published accounts of palaeocurrent investigations on the Dwaal Heuvel sediments are found in the literature of the Transvaal basin. Descriptions of the stratigraphy of the unit are presented in most of the explanations to the geological maps covering the eastern outcrop rim of the Transvaal basin. The earliest reference to this unit is that of Molengraaff (1898), who introduced the name and gave a brief description of the unit. He was of the opinion that the Dwaal Heuvel, together with the overlying quartzites, was (broadly speaking) the equivalent of the Daspoort Quartzite developed in the Pretoria area.

Subsequent descriptive accounts are given by Hall (1913, 1918), Visser (1956), Visser and Verwoerd (1960) and Schwellnus and others (1962). The Dwaal Heuvel rests directly on the underlying Ongeluk Lava and is overlain by a shaly formation. The presence of gritty or pebbly phases and of intercalated shales or sandy shales was noted. The rapid lateral variation in the lithology of the unit was recorded. Ripple marks and cross-beds are stated to be common in the formation. Pyrite euhedra and arkosic phases have been reported. Thicknesses are said to vary fairly rapidly along strike; estimates are in the range from 100 to 400 feet (30 to 120 metres).

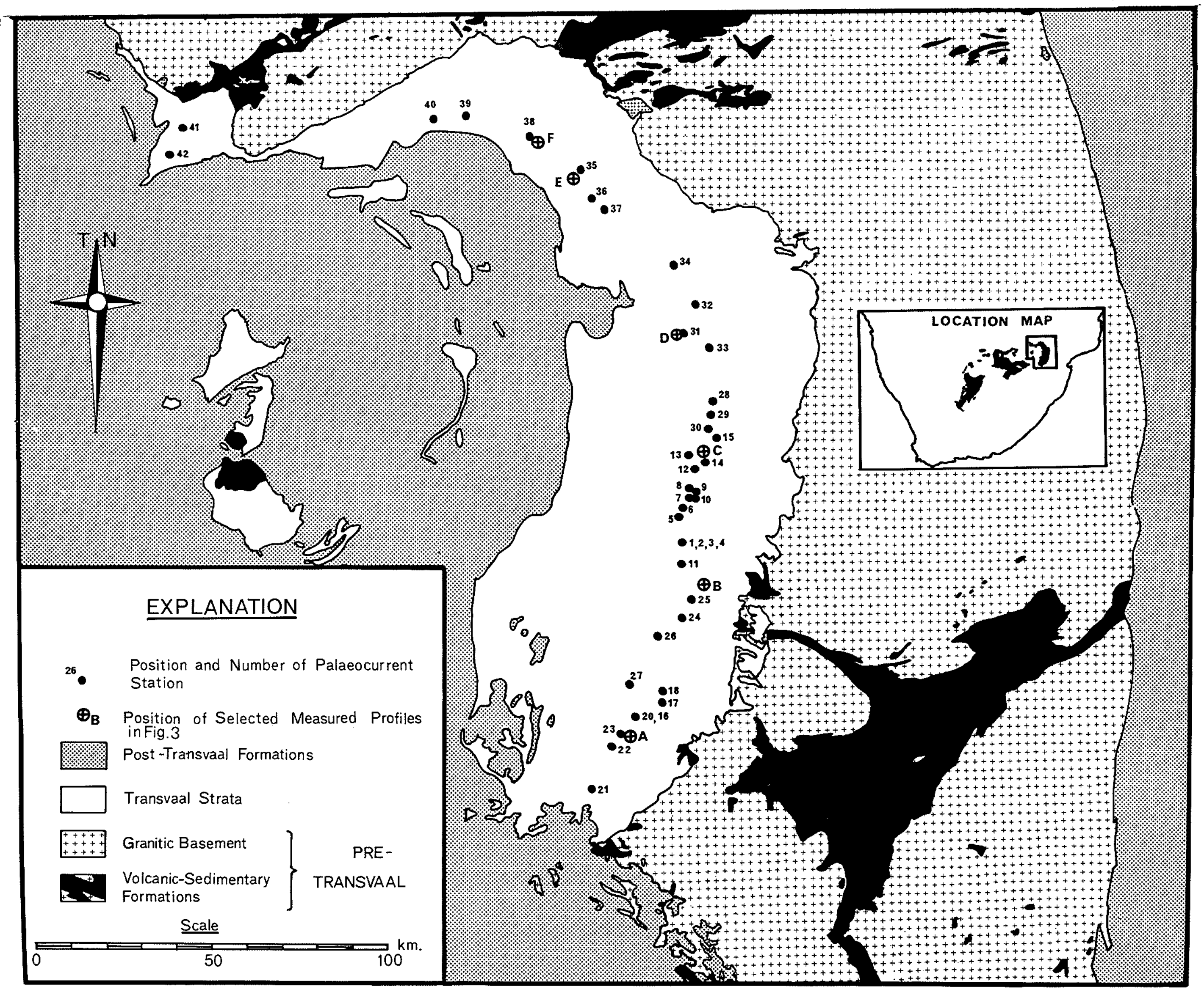

Figure 1 : Map showing locality and regional geology of the area studied. The positions of palaeocurrent stations and selected measured profiles are shown.

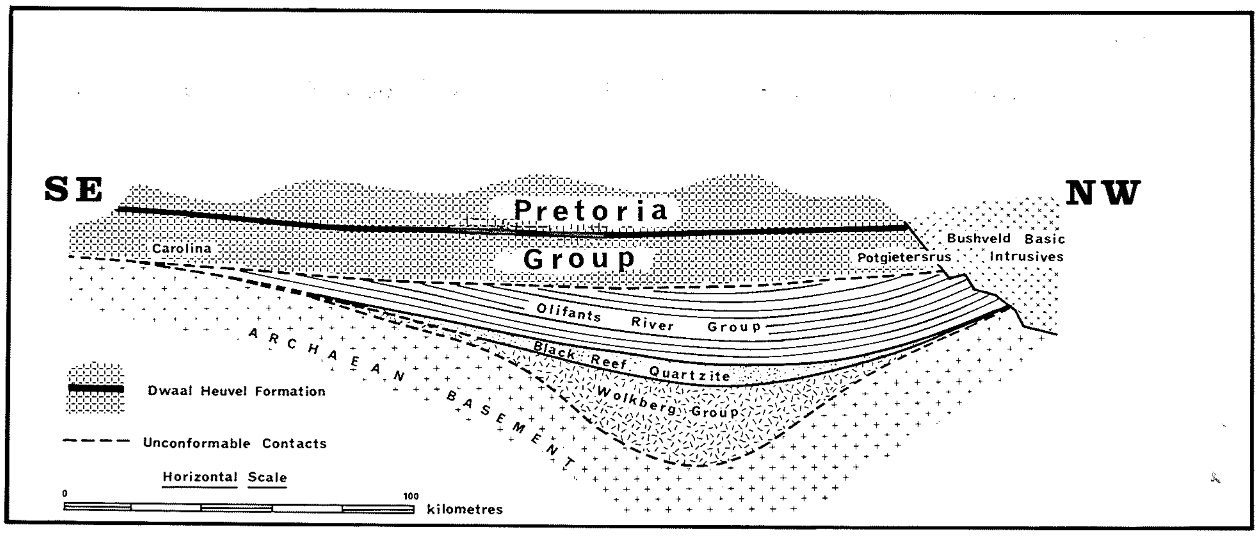

Figure 2 : Schematic diagram showing the stratigraphic setting of the Dwaal Heuvel Formation in the Transvaal Supergroup.

FIELD PROCEDURE

On stratigraphic traverses which crossed the Dwaal Heuvel Formation, the orientation of bedding and foreset bedding was measured using a clinoboard and a compass. The distribution of measurement localities (being limited mainly to stratigraphic profiles) was thus perhaps not quite as regular as would be the case in a study designed purely for palaeocurrent purposes.

At each station, about 5 measurements of bedding dip and strike were made; the average of these values was ultimately used for the untilting of the cross-bed foresets. Initially, an effort was made to measure 25 foresets at each station. Subsequently, since it was found that between 15 and 20 measurements per station gave a good estimate of the mean direction, the number of foresets per station was reduced to this range. Similarly, at the start of the study, stations were chosen fairly close to one another. As work progressed, it became evident that the local variation in the vector mean of foreset azimuths was small. Spacing between stations was increased. On the average, stations were spaced about 10 km apart along strike.

Stratigraphically, all but a few stations were confined to the siliceous quartzites in the uppermost one-third of the Dwaal Heuvel Formation.

TREATMENT OF DATA

The field data collected were tabulated and transferred onto computer punch cards. For each station, the identification, the average inclination and azimuth of bedding, and the azimuths and inclinations of cross-bed foresets were entered. The data were then treated by an IBM 360/50 computer, using a modification of a program documented by van Eeden (1969). In addition to correcting measurements for tilt, this program calculated vectoral means, consistency ratios, standard deviations, and variances of the foreset azimuths at each station. Untilting was done about the strike of bedding as an axis. This method of correction is suitable for the area studied, where strata are not deformed in plunging folds.

The vector mean direction of foresets at each station was plotted on a map, the mean direction being represented by an arrow, the length of which is proportional to the consistency ratio. In order to get an idea of the gross transport direction of sediments, the 41 stations were grouped into four groups (corresponding to large areas along the outcrop). The grouped data were processed to give vectoral statistics for the four areas.

Histograms of variance and initial dip of foresets were constructed for comparison with published data for other sedimentary units.

STRATIGRAPHY OF THE DWAAL HEUVEL FORMATION

The Dwaal Heuvel Formation is developed about 1400 metres up from the base of the Pretoria Group. It rests with a sharp contact on the underlying Ongeluk Lava and is overlain by a shale unit, locally termed the Elands Pass Shale. The basal contact of the Dwaal Heuvel is worthy of detailed description, since it has a bearing on the origin of the unit. The Ongeluk Lava consists of a number of greenish-grey basaltic-andesite flows with minor pyroclastic and sedimentary intercalations. The uppermost portions of the volcanics are consistently altered for a depth of between two and five metres below the basal contact of the Dwaal Heuvel Formation. In this zone of alteration, the normal greenish lavas are missing, their place being taken by buff, cream-coloured or pale green rocks composed largely of a sericitic mica. Similar observations were made on boreholes through this horizon in the Delmas area, by Liebenberg (1961) in the Pretoria area, and by von Backström (1960) in the Rustenburg area. It is probable that these micaceous rocks represent the lithified equivalent of an ancient residual clay soil, indicating that a period of weathering intervened after the volcanics were extruded and before deposition of the Dwaal Heuvel commenced. Subsequently, during basin development, the competent Dwaal Heuvel unit slid out over the sericitic layer described above, producing in it a marked cleavage, shearing, or rodding (Plates 1A and B). This tectonic structure has a dip angle which is usually about 20 to 30 degrees steeper than that of the bedding.

In the area studied, the thickness of the Dwaal Heuvel Formation varies between the limits of 45 and 105 metres. It is thinnest in the south, and increases irregularly in thickness when traced to the north. On account of the variation in detail between neighbouring stratigraphic profiles, it was found impossible to present composite stratigraphic columns for the formation over large areas. To give an indication of the internal stratigraphy of the unit, the details of a few of the best exposed sections in the area are presented in Figure 3.

The Dwaal Heuvel is characterized by cyclical sedimentation with lithological end-members ranging from gritty or pebbly quartzites, on the one hand, to shales, on the others. Lithological types usually grade from one to the other. The number of cycles and their lithological pattern are seldom identical in adjacent measured profiles through the unit.

The shales present in the formation weather with oxide colours; where fresh they are generally shades of greenish-grey. Banding and graded bedding on a centimetre (or thinner) scale were observed. Ripple marks, interference ripples, and ripple cross-lamination are present. Bedding units are often lenticular. The banding observed in the rocks is due to the alternation of lighter-coloured silty layers and darker shaly layers. Micaceous bedding planes are a feature of these shales. A cleavage in the shales, due probably to intrastratal slippage, was noted. True shales tend to be limited to the southern half of the area studied. Farther north, their equivalents tend to be fine-grained, impure quartzites or siltstones.

The fine-grained argillaceous quartzites and siltstones found in the Dwaal Heuvel weather to a variety of colours, being cream-coloured, mauvish, or grey. They are pyritic and micaceous in places, and often exhibit very characteristic centimetre-scale festoon cross-bedding. Foresets and trough boundaries are accentuated by concentrations of black, heavy mineral grains. In the northern half of the area, Bushveld metamorphism, combined with intrastratal movements, have produced from these rocks a suite of muscovite - or rarely fuchsite - bearing phyllites, some of which show very well-developed kind banding.

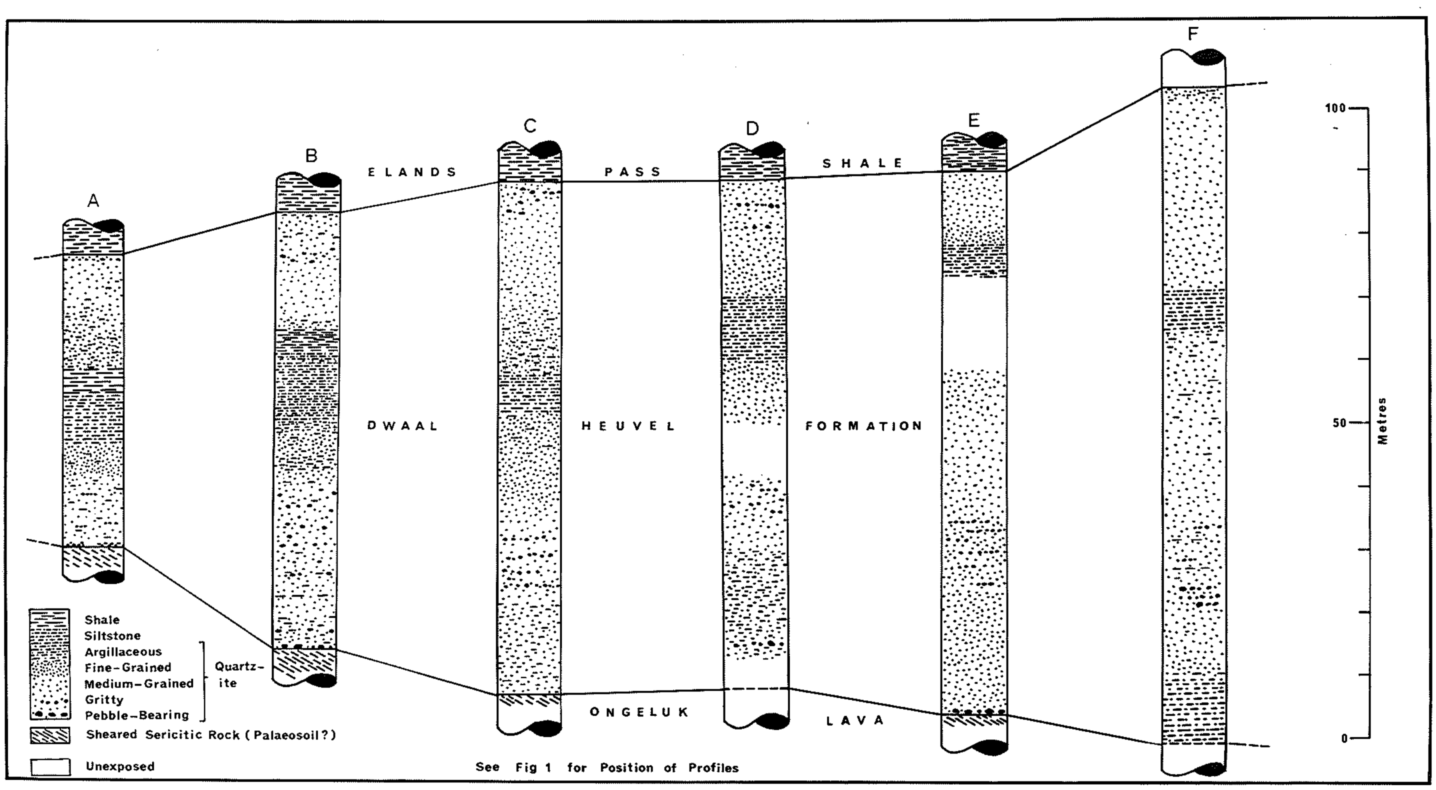

Figure 3 : Selected stratigraphic profiles through the Dwaal Heuvel Formation in the eastern and northeastern Transvaal.

Quartzites come in many guises, and range from impure (argillaceous or, less commonly, felspathic) to very pure types. The impure varieties are shades of green and grey when fresh; they weather to pink, mauve, buff, orange, or maroon rocks. The cleaner quartzites bleach white on surface; they are grey or banded light and dark grey on fresh surfaces. Pyrite euhedra are found in quartzites; they decompose to limonitic cubes, some up to 3 centimetres in size. Shale flakes are found in places, usually adjacent to interbedded shaly units.

The quartzites at the base of the formation vary from pure to impure. The top third or quarter of the formation is almost invariably composed of a clean (sometimes gritty) quartzite. The cross-bed foresets measured in this study were usually found in these upper siliceous quartzites of the formation.

Sedimentary structures abound in the quartzites of the Dwaal Heuvel Formation. Finer quartzites show trough cross-bedding with sets varying between 10 and 30 centimetres. The coarse-grained quartzites (very often the grit-bearing phases) are structured by large-scale planar cross-beds with sets up to and sometimes exceeding a metre in thickness. In the latter type, pre-consolidation crumpling of foresets is not uncommon. Heavy mineral concentrations often accentuate foresets, especially in the northern half of the area, where they are very well-developed. Other sedimentary structures seen in the unit include ripple-marks, mud-cracks (Plate IC), and sand-waves. The latter are particularly common at the top of the formation.

The pebbles and granules found in the formation are composed of chert, vein quartz, and jasper with shale, quartzite, and banded ironstone fragments being very rarely seen. Pebbles are generally small (about 1 centimetre), but some up to 15 centimetres in size have been found in the Potgietersrus area. In the northern portions of the area, the matrix of the pebbly phases is extremely rich in specularite and hematite grains.

The top contact of the Dwaal Heuvel varies from sharp in places to gradational in others. In the Lydenburg area, the Elands Pass shale rests with an abrupt contact on the sand-waved upper surface of the Dwaal Heuvel. Here, intrastratal movement along the contact has localized the conformable auriferous quartz vein known as the "Finsbury Reef".

A few thin diabase sills, intrusive into the formation, were recorded in some profiles. A conformable quartz vein was observed in the Lydenburg area.

The Elands Pass Shale is greenish-grey in colour, and weathers with oxide colours. It is often banded due to the alternation of lighter silty and darker-coloured shaly layers. Bedding planes are micaceous. Limonitic specks after pyrite are common. Lenses of quartzite (up to 50 centimetres thick) are present in the shale, and display sand-waved upper surfaces.

The Elands Pass Shale contains a well-developed set of sedimentary structures which include ripple-marks, interference ripple-marks, mud-cracks (sometimes on rippled surfaces), flute-casts (rare), graded bedding, and lenticular, ripple cross-laminated bedding units. In the Carolina-Lydenburg area, the top of the unit is marked by a persistent zone in which clay-flake rocks are developed.

In the area around Penge, and to the north, the Elands Pass Shale is metamorphosed to a hornfels. In the Potgietersrus region, beds and lenses of ironstone are present in the equivalent of this unit. The Elands Pass is intruded by diabase sills. In addition to the thin sills noted in some profiles, the contact between this formation and the overlying Daspoort Quartzite is intruded by a remarkably persistent sill which has been traced from Carolina to Lydenburg, a distance of about 110 km.

In summary, the stratigraphic setting of the Dwaal Heuvel and the details of its stratigraphy supply important pointers to the origin of the unit. The most important facts are :

(i) The Dwaal Heuvel rests upon a suite of sericitic rocks, interpreted as a residual soil developed on the Ongeluk Lava; the base of the former probably marks a disconformity.

(ii) The internal stratigraphy and pattern of cyclicity of the Dwaal Heuvel vary significantly along strike.

(iii) Sedimentary cycles, in which an upward-fining pattern is prominent, are present in the formation.

(iv) The size and type of cross-bedding sets varies sympathetically with the grain-size in sedimentary cycles.

(v) The formation becomes thicker to the north, the average grain-size increases in this direction, and heavy mineral concentrations become prominent.

The upward-fining cycles (with a sympathetic decrease in the amplitude of structures) are reminiscent of the well-documented class of fluvial cycles (Allen, 1970; Visher, 1972). According to the latter author : "The sequence of specific sedimentary structures in fluvial deposits is still the primary basis for recognizing deposits formed by unidirectional confined flow ...... The amplitude of structures decreases upward with large-scale sand wave or trough cross-bedding near the bottom, overlain by small-scale festoon cross-bedding, followed by either current lamination or ripple cross-bedding".

A fluvial origin for the Dwaal Heuvel is consistent with the evidence of very shallow water sedimentation (mud-cracks). The presence of a probable palaeosoil beneath the unit is also significant; the deposits immediately overlying disconformities are often of a fluvial origin.

GEOMETRY OF CROSS-BED UNITS

The large-scale planar cross-beds found in the Dwaal Heuvel are usually encountered in the coarser quartzites of the unit. On the average, sets are from 50 centimetres to 1 metre thick, although some in excess of the latter figure have been observed. In sections through the sets parallel to the direction of maximum dip of foresets, the latter are straight (Plate ID and IE) or gently curved concave-up (Plate IF). In plan view, the foresets (in the average exposure) are strictly linear, but in larger outcrops they are seen to be curved, being concave in the down-current direction. In some exposures, the foresets could be traced along their strike for distances of up to 20 metres. Cross-bed sets may be grouped (Plate ID) or solitary (Plate IE and IF).

The cross-bed units appear to have erosional lower surfaces, since the downcurrent sets often truncate the foresets of their up-current neighbours. In vertically-grouped sets, the base of the upper set truncates the foresets of the underlying unit (Plate ID). The foresets are lithologically homogeneous, being composed of a medium-grained sand, in places somewhat gritty. They are well-defined individual layers which average about 1 centimetre in thickness. In most outcrops, they can be found as exposed surfaces which can be easily measured (Plate IE). Crumpling of foresets due to soft-sediment deformation was observed in places.

In terms of Allen's (1963) classification of cross-bed types, the solitary units measured in the Dwaal Heuvel are probably of the "beta type" (Plate IE and IF). The grouped sets are identical to the "omikron type" (Plate ID). Both types are common in the sediments of fluvial channels, and are formed either by a train of migrating, large-scale, asymmetrical ripples or by avalanching of sand grains down the slip-off face of solitary banks (Allen, 1963).

PALAEOCURRENT ANALYSIS

The vectoral mean directions of cross-bed foreset azimuths of the Dwaal Heuvel Formation are plotted on the map shown in Figure 4. The consistency of sedimentary transport directions is immediately apparent, being from north to south or from northeast to southwest. The provenance areas which were undergoing uplift and erosion during Dwaal Heuvel times must have been situated to the north and northeast of the present limits of the Transvaal basin.

The consistency in the directions of sedimentary transport is striking, the vector means (with few exceptions) lying in the southwestern quadrant. In addition to the between-station

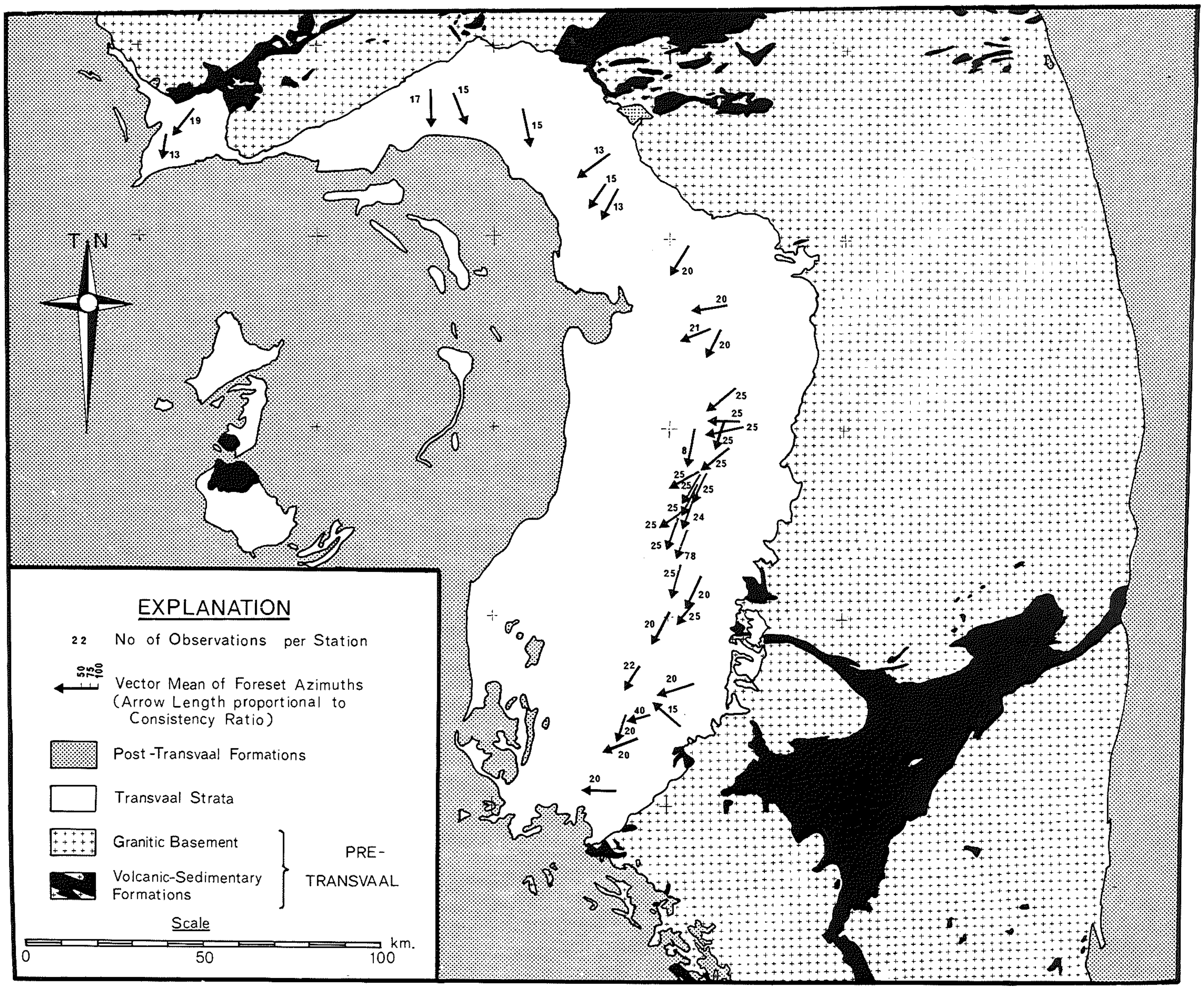

Figure 4 : A palaeocurrent map of the Dwaal Heuvel Formation in the eastern and northeastern Transvaal.

consistency, the within-station consistency of foreset orientation is notable (see Appendix I). The mean within-station consistency ratio for all stations is 71 percent, while the mean standard deviation is 48 degrees, corresponding to a mean variance of 2390. A histogram of the variance values is shown in Figure 5(b). Within-station variances range from 500 to 6500, but 88 percent of the variances fall within the limits of 1000 and 4000.

In order to produce vectoral statistics more directly comparable with those quoted in the literature, it was decided to group stations into four groups corresponding with the four half-degree latitude strips crossing the area. The grouped data were then re-processed to produce the variance and other vector statistics shown in Table I. It is evident that the standard deviations and variances for the grouped data are higher than the mean of these parameters for individual stations, and that consistency ratios are somewhat lower for the grouped data. These differences are to be expected from treating a larger sample from a more extensive area with a resultant wider spread of foreset azimuths. The variance figures, although higher for the grouped data, are of the same order of magnitude, a fact that will be discussed below.

GROUP	LATITUDE LIMITS	NUMBER OF STATIONS	NUMBER OF FORESETS	VECTOR MEAN (Bearing in degrees)	CONSISTENCY RATIO (Percent)	STANDARD DEVIATION (degrees)	VARIANCE (degrees^2)
1	24° -24°30'S	8	120	196	65,2	53,6	2882
2	24°30'-25°S	6	131	237	65,6	50,9	2593
3	25° -25°30'S	17	380	211	68,7	48,7	2375
4	25°30'-26°S	10	202	239	55,4	59,7	3575

Table 1 : Details of statistics of grouped palaeocurrent data, Dwaal Heuvel Formation, eastern and northeastern Transvaal.

SIGNIFICANCE OF VARIANCE MEASUREMENTS

The variance of foreset azimuths at a station is a figure calculated by squaring the standard deviation of individual foreset azimuths from the vector mean. Variance is thus a measure of the directional consistency of foreset azimuths, and, as such, is thought to be related to the environment in which deposition took place. It has been found that the variance for fluvial- and deltaic-deposited sands is commonly low, and in the range from 4000 to 6000; while in marine-deposited sediments, variances are much higher, commonly in the 6000 to 8000 range (Potter and Pettijohn, 1963). The reason for more consistent transport directions in fluvial or fluvio-deltaic systems is that, in these environments, flow of the depositing medium is essentially uni-directional, being down the palaeoslope. River meanders and deflections of the current in the stream bed produce variations in flow direction which are, statistically, spread more-or-less symmetrically on either side of the mean direction of river flow. Conversely, in a marine situation, multidirectional currents (which may include ebb, flood, and longshore currents) are commonly present. In such a situation, foreset azimuths tend to have a wider spread, resulting in higher variance numbers.

In the Dwaal Heuvel, within-station variances which range essentially from 1000 to 3500 suggest a fluvial or fluvio-deltaic depositional environment for the formation. The mean variance of nearly 2400 would, on the basis outlined above, be difficult to reconcile with a marine origin.

The variances for the grouped stations (Table I) are probably more appropriately compared with the variance figures quoted in the literature. The calculated variances are seen to be in the range from 2375 to 3575, figures which are still well within the accepted range for fluvial deposits. The fluvial interpretation of the Dwaal Heuvel Formation from variance statistics is thus good confirmatory evidence for a similar conclusion based on the lithology, sedimentary cycles, and sedimentary structures of the unit.

With reference to Table I, it is seen that the highest variance is for the southermost group of stations. It is logical that variance must be related to palaeoslope gradient, a steeper gradient resulting in a directionally more consistent current. The larger variance in the southern area could reflect a lower gradient, this, in turn, indicating a greater distance from the source area. This interpretation is supported by the geology of the unit in the southern area. It is thinnest here, contains shaly units not found farther north, and is nearly free of pebbly phases.

INITIAL DIP OF FORESETS

The measured dips of foresets in the field were corrected for the tectonic tilt imposed on the strata. The 833 corrected foreset inclination measurements were used to produce the histogram shown in Figure 5(a). Corrected inclinations range from 7 to 37 degrees. The calculated mean inclination is 22,7 degrees, which falls midway in the modal class of 20 to 25 degrees.

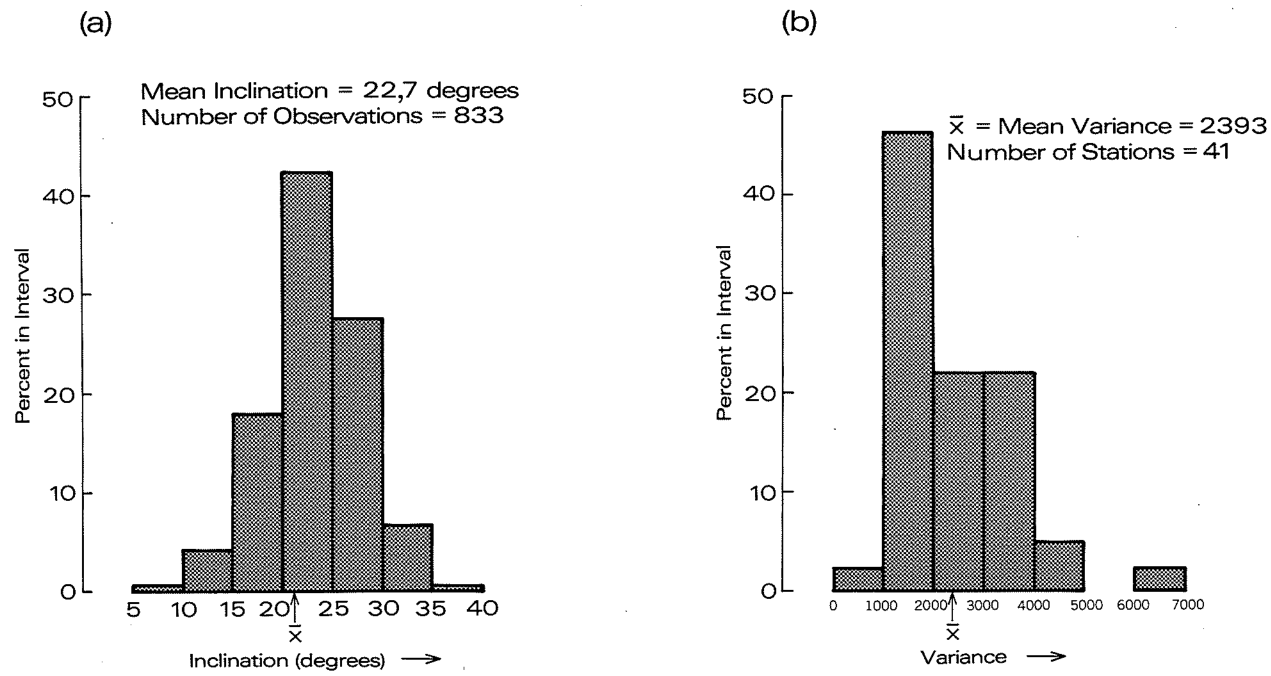

Figure 5 : (a) A histogram of initial dips of 833 foresets, Dwaal Heuvel Formation.
(b) A histogram of the within-station variance for the 41 palaeocurrent stations, Dwaal Heuvel Formation, eastern and northeastern Transvaal.

Potter and Pettijohn (1963), from a study of the literature, indicate that the average inclination of foresets in undeformed beds lies in the range from 18 to 25 degrees. The 22,7 degree average for this study falls well within this range. Inclination of foresets steeper than 34-36 degrees indicates either soft-sediment or tectonic deformation of foresets (Potter and Pettijohn, 1963). In this study, only 0,6 percent of the total population had inclinations steeper than 34 degrees. It is evident that deformational influences have played no significant part in the history of the Dwaal Heuvel cross-bed sets.

REGIONAL ASPECTS

A study of the regional behaviour of the Dwaal Heuvel Formation is particularly valuable because of its stratigraphic setting. It rests with a sharp contact on the underlying Ongeluk Lava, a unit developed through most of the Transvaal basin. The lava acts as a particularly reliable marker, and its top surface probably closely approximates to a time-plane. A study of the sediments immediately above the lava on a basin-wide scale will give an idea of the sedimentary suites which were being deposited more-or-less contemporaneously across the basin.

To this end, a literature survey of the basin in the Transvaal was undertaken to record any possible equivalents of the Dwaal Heuvel Formation in other parts of the basin. The results of this investigation are summarized on the map shown in Figure 6. Where the Dwaal Heuvel Formation is developed, thicknesses were recorded and contoured to produce a tentative isopach map. Elsewhere, the Ongeluk Lava is overlain by finer-grained sediments in which oölitic ironstone beds and magnetic shales are found. Such areas have been indicated with a distinctive ornament on the map.

The equivalent of the Dwaal Heuvel Formation has been recognised in the Marble Hall area, where it has a thickness estimated at 200 feet (67 metres) (de Waal, 1969). In an area east of Thabazimbi, du Preez (1944) records the presence of a robust conglomerate (up to 30 feet thick) and a quartzite which rest directly on the Ongeluk Lava. A thickness estimate of 130 metres for the formation was made from du Preez's map. The situation west of Thabazimbi is unclear. On the existing geological maps of the area (Kynaston and Humphrey, 1920), a quartzite is shown to rest on the lava immediately west of Thabazimbi. Farther west, their mapping shows a thickness of argillaceous sediment between the lava and the quartzite. It is possible that the argillaceous material is portion of a Dwaal Heuvel cycle in a fashion analogous to that portrayed at the base of column F in Figure 3.

Near Delmas, southeast of Pretoria, boreholes drilled in search of Witwatersrand-type gold deposits penetrated the formation in question. The boreholes intersected thicknesses of quartzite up to 12 feet (3,8 metres) thick. These thicknesses increase in a southeasterly direction. In the borehole drilled nearest to Pretoria, shaly rocks were found to rest directly on the lava. Liebenberg (1961) reports that, in an area about 24 km southeast of Pretoria, the "sericitic schists and shales" developed at the top of the Ongeluk Lava are overlain by some 10 feet (3 metres) of a ferruginous and chloritic quartzite. Visser (1969), in describing the "Upper Ongeluk Quartzite" (as the equivalent of the Dwaal Heuvel is known in the Pretoria area) states that the quartzite is sporadically developed, is gritty in places, and reaches thicknesses of up to 4,5 metres southeast of Pretoria. According to this author, the formation is not developed in the vicinity of Pretoria, but is locally up to 0,6 metres thick to the west of the city. In the Rustenburg area, shaly rocks generally rest directly on the lava. In one locality in this region, a thin ferruginous quartzite, pebbly in places, is encountered above the lava (von Backström, 1960). In the extreme west of the Transvaal basin, Boocock (1961) records "a ferruginous rather gritty quartzite, overlying the Ongeluk Volcanics .....". No data on the thickness or lateral persistence were supplied.

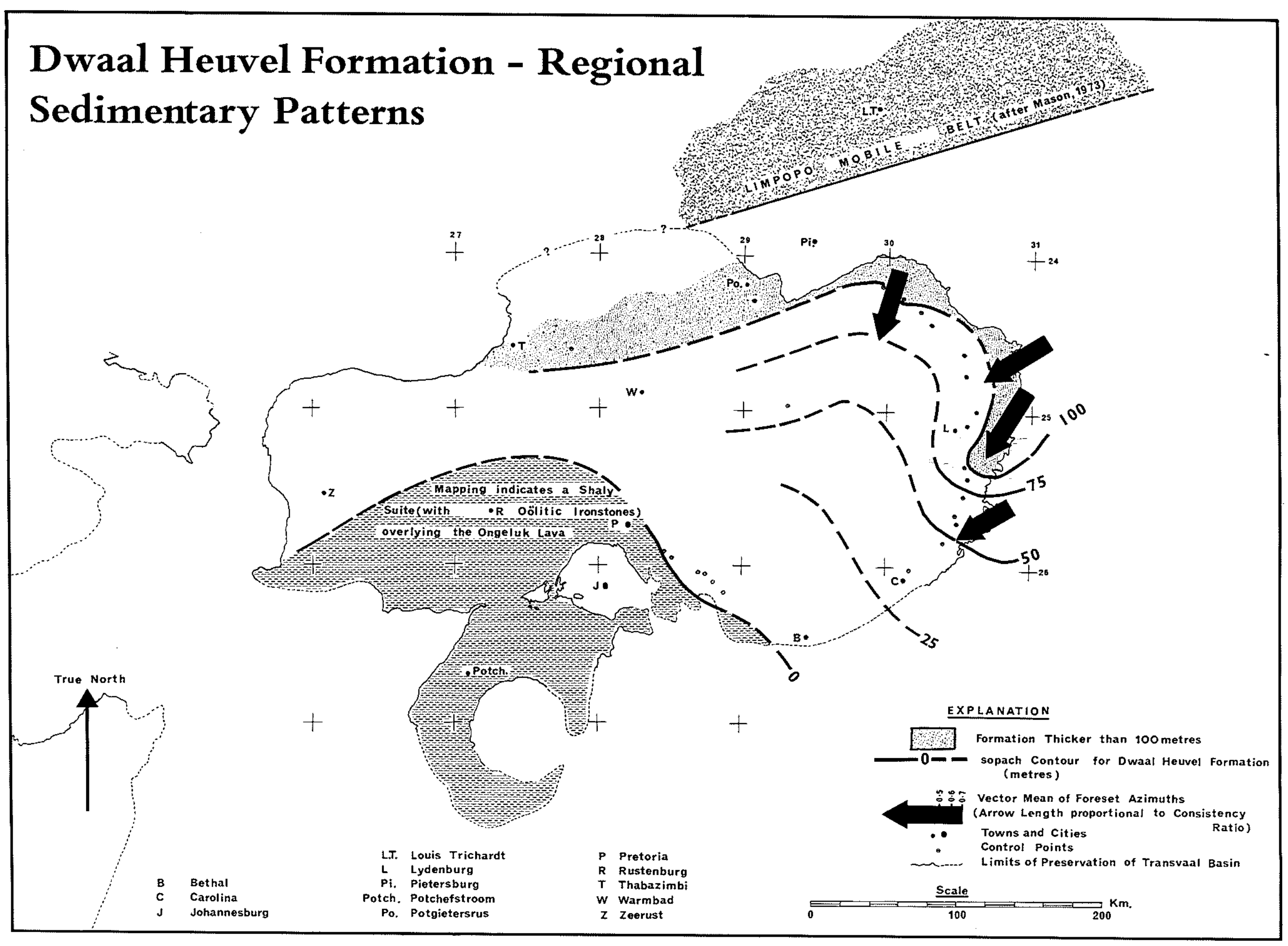

Figure 6 : Map showing the regional patterns of thickness and sedimentation for the Dwaal Heuvel Formation and the approximately isochronous formations developed farther south and southwest.

The descriptions of the geology of the Rustenburg area (von Backström, 1960), the Zeerust area (Humphrey, 1911), the Potchefstroom-Klerksdorp area (Nel and others, 1939), and the Vereeniging area (Nel and Jansen, 1957) indicate that shaly sediments with beds of ironstone are developed above the Ongeluk Volcanics across the southern and western half of the Transvaal basin. The ironstones generally display oölitic textures, being composed of concentric layers of magnetite, hematite, and chamosite (Wagner, 1928). Further west, in the Zeerust area, beds of ferruginous and magnetic shale represent the lateral equivalents of the oölitic iron-rich horizons developed to the east (Hall and Humphrey, 1910).

In summary, there appears to be a zonal pattern of deposition in the sediments immediately above the Ongeluk Volcanics in the Transvaal. The hub of sedimentation was situated in the northern and northeastern sectors of the Transvaal basin, where the Dwaal Heuvel Formation is present, attaining thicknesses of over 100 metres. Available evidence suggests that the formation became thinner down the palaeoslope which was inclined to the south and southwest. In the distal portions of the basin, the Dwaal Heuvel is not developed, its place being taken by shaly sediments with interbedded iron-rich layers.

All available evidence suggests that the Dwaal Heuvel Formation was deposited in a fluvial environment. The shales and oölitic ironstones which represent the southern facies-equivalent of the formation must have been deposited in a more distal setting, possibly in one which approximated to a delta front. The action of agitated waters for the formation of oölites is a well-established prerequisite for their formation. According to Krumbein and Sloss (1963) : ".....oölites are formed in saline waters under agitated conditions along shores or in shallow places where waves break". The model thus envisaged involves a fluvial plane of sedimentation in the eastern and northern portions of the basin in which braided or meandering stream systems were responsible for the deposition of the arenaceous sediments which constitute the Dwaal Heuvel Formation. On encountering the standing water of the Transvaal basin, the streams which entered the water deposited their suspended load of clays and silts to form shales. The oölitic ironstone beds probably formed during periods in which wave action impinged on shallow banks or on a muddy shore-line.

The isopach and facies patterns for the Dwaal Heuvel show a broad parallelism to portions of the Limpopo metamorphic (or mobile) belt (Figure 6). It is tempting to speculate (as has Bahnemann, 1972) that sedimentation in the Transvaal basin might somehow have been linked to the evolution of this structural and metamorphic belt. According to Mason (1973), the major metamorphic episode in the belt (2650 m.y.) predates the Great Dyke System. A major tectono-thermal reactivation took place around 2240 m.y. ago (Mahalapye granite-migmatite complex). A widespread re-setting of Rb-Sr dates at approximately 2000 m.y. terminates the thermal history of the belt.

The metamorphics presently exposed at the surface along the Limpopo belt are inferred to have formed at elevated temperatures and at considerable depths (Bahnemann, 1972). During the interval between the end of the main metamorphic episode and the onset of Waterberg sedimentation (circa 1800 m.y.), the covering over the metamorphics was stripped, so that Waterberg strata were deposited unconformably on the metamorphic rocks. The Transvaal basin is known to have been formed during this timespan. It is possible that uplift of the Limpopo belt and the subsequent de-roofing of the metamorphics played a significant rôle in the evolution of the Transvaal basin.

The situation envisaged is shown schematically in Figure 7. The upwarping of the Limpopo belt could, in part, be of an epeirogenic type, involving broad crustal deformation. It is, however, likely that the uplift took place vertically through the agency of a number of subvertical faults. Existing mapping in the Zoutpansberg region and to the north indicates the presence of an extensive fault system which parallels the northern margin of the Transvaal basin and the southern limit of the Limpopo belt. These faults are known to have been active intermittently from Waterberg to Karroo times. It is possible that they were formed in earlier times. Uplift along the Limpopo belt, facilitated by vertical movements along the fault planes, probably resulted in a sympathetic, but smaller, uplift in the northern portions of the Kaapvaal craton. Direct evidence of the stripping of the craton is available, since jasper pebbles (derived from erosion of Archaean greenstone belts) are present in the Dwaal Heuvel Formation. Conclusive evidence of the contribution of the Limpopo belt to the filling of the Transvaal basin must await a detailed mineralogical study of the Dwaal Heuvel and other arenaceous units of the Transvaal basin.

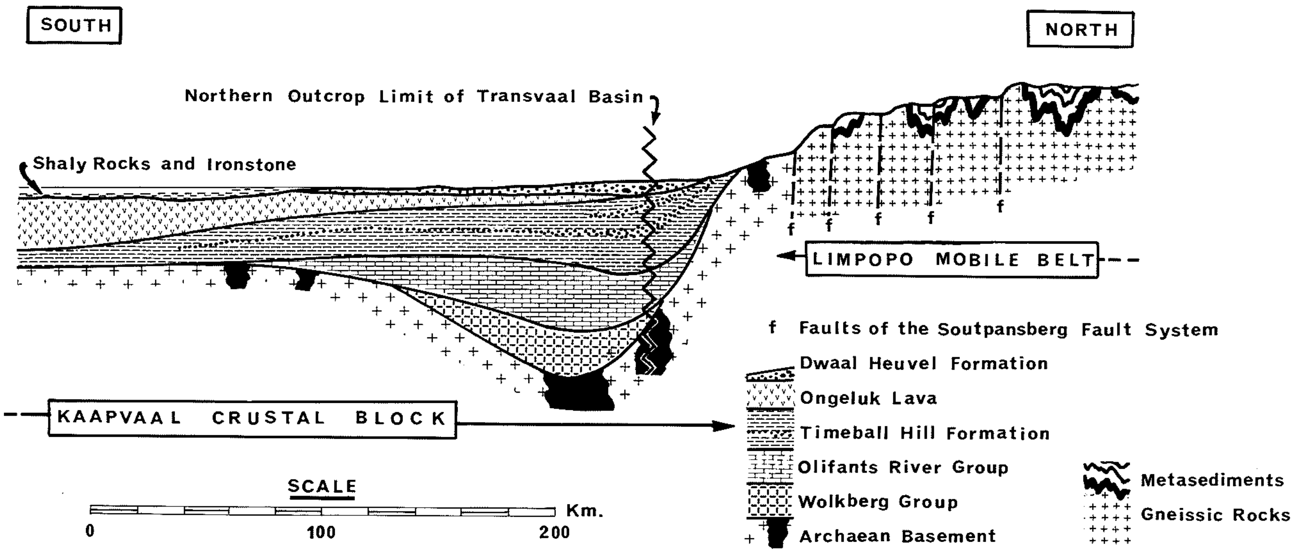

Figure 7 : Schematic cross-section showing the proposed relationship between the Transvaal basin and the Limpopo mobile belt.

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Key to Figures

<u>Figure 1</u> : Map showing locality and regional geology of area studied. The positions of palaeocurrent stations and selected measured profiles are shown.

<u>Figure 2</u> : Schematic diagram showing the stratigraphic setting of the Dwaal Heuvel Formation in the Transvaal Supergroup.

<u>Figure 3</u> : Selected stratigraphic profiles through the Dwaal Heuvel Formation in the eastern and northeastern Transvaal.

<u>Figure 4</u> : A palaeocurrent map of the Dwaal Heuvel Formation in the eastern and northeastern Transvaal.

<u>Figure 5</u> : (a) A histogram of the initial dips of 833 foresets, Dwaal Heuvel Formation

(b) A histogram of the within-station variance for the 41 palaeocurrent stations, Dwaal Heuvel Formation, eastern and northeastern Transvaal.

<u>Figure 6</u> : Map showing the regional patterns of thickness and sedimentation for the Dwaal Heuvel Formation and the approximately isochronous formations developed farther to the south and southwest.

<u>Figure 7</u> : Schematic cross-section showing the proposed relationship between the Transvaal basin and the Limpopo mobile belt.

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Key to Plates

Plate 1

A : A contact of the Dwaal Heuvel Formation and the Ongeluk Lava. The flat-lying basal contact of the quartzite rests on a cleaved sericite-rock with cleavage dipping at about 20 degrees (Penge area).

B : Rodding and cleavage in the sericitic rock immediately below the Dwaal Heuvel Formation (south of the Machadodorp-Nelspruit national road).

C : A mud-cracked shaly surface in the Dwaal Heuvel Formation, Penge area.

D : Grouped planar cross-bed sets of the "omikron" type. Foresets are planar and all dip in approximately the same direction (southeast of Lydenburg).

E : A large-scale planar cross-bed set of the "beta" type (southeast of Lydenburg).

F : A large-scale planar cross-bed of the "beta" type. Foresets are gently curved concave-up (southeast of Lydenburg).

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APPENDIX I

DWAAL HEUVEL FORMATION - PALAEOCURRENT STATISTICS

Station D.H. No.	Number of Foresets Measured	Vectoral Mean (bearing in degrees)	Consistency Ratio (percent)	Standard Deviation (degrees)	Variance (degrees^2)
1	23	184	83,2	34,8	1 215
2	19	178	61,0	56,1	3 152
3	25	214	64,6	52,2	2 734
4	11	232	81,0	37,9	1 441
5	25	199	75,5	42,6	1 822
6	25	235	58,0	59,0	3 490
7	25	207	71,3	46,9	2 205
8	25	210	79,1	40,8	1 666
9	25	205	71,2	47,6	2 273
10	24	200	85,3	32,6	1 067
11	25	195	77,5	41,9	1 758
12	25	240	71,8	47,1	2 219
13	8	189	83,1	39,1	1 532
14	25	229	75,2	42,8	1 835
15	25	198	57,5	58,3	3 410
16	20	253	43,5	67,9	4 615
17	15	311	79,5	40,0	1 601
18	20	251	80,7	37,8	1 433
20	20	251	51,2	66,0	4 363
21	20	269	64,8	54,2	2 943
22	20	246	81,6	36,6	1 345
23	20	198	59,7	57,6	3 318
24	25	218	54,2	60,6	3 680
25	20	204	79,0	40,4	1 632
26	20	207	81,2	40,7	1 657
27	22	210	57,8	59,0	3 484
28	25	231	79,8	38,3	1 468
29	25	269	65,3	52,1	2 723
30	25	256	83,8	35,0	1 230
31	21	241	64,8	52,7	2 782
32	20	259	78,1	41,1	1 697
33	20	205	62,4	56,4	3 188
34	20	208	77,4	43,0	1 849
35	13	233	88,8	29,4	866
36	15	212	59,3	57,2	3 274
37	13	206	75,7	44,2	1 960
38	15	169	69,5	55,9	3 135
39	15	158	73,5	46,3	2 148
40	17	179	82,6	36,3	1 319
41	19	217	73,8	44,9	2 023
42	13	188	48,2	81,0	6 570
TOTAL	833	8 964	2 911,5	1 954,3	98 120
Average	20,3	219	71,0	47,7	2 393

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